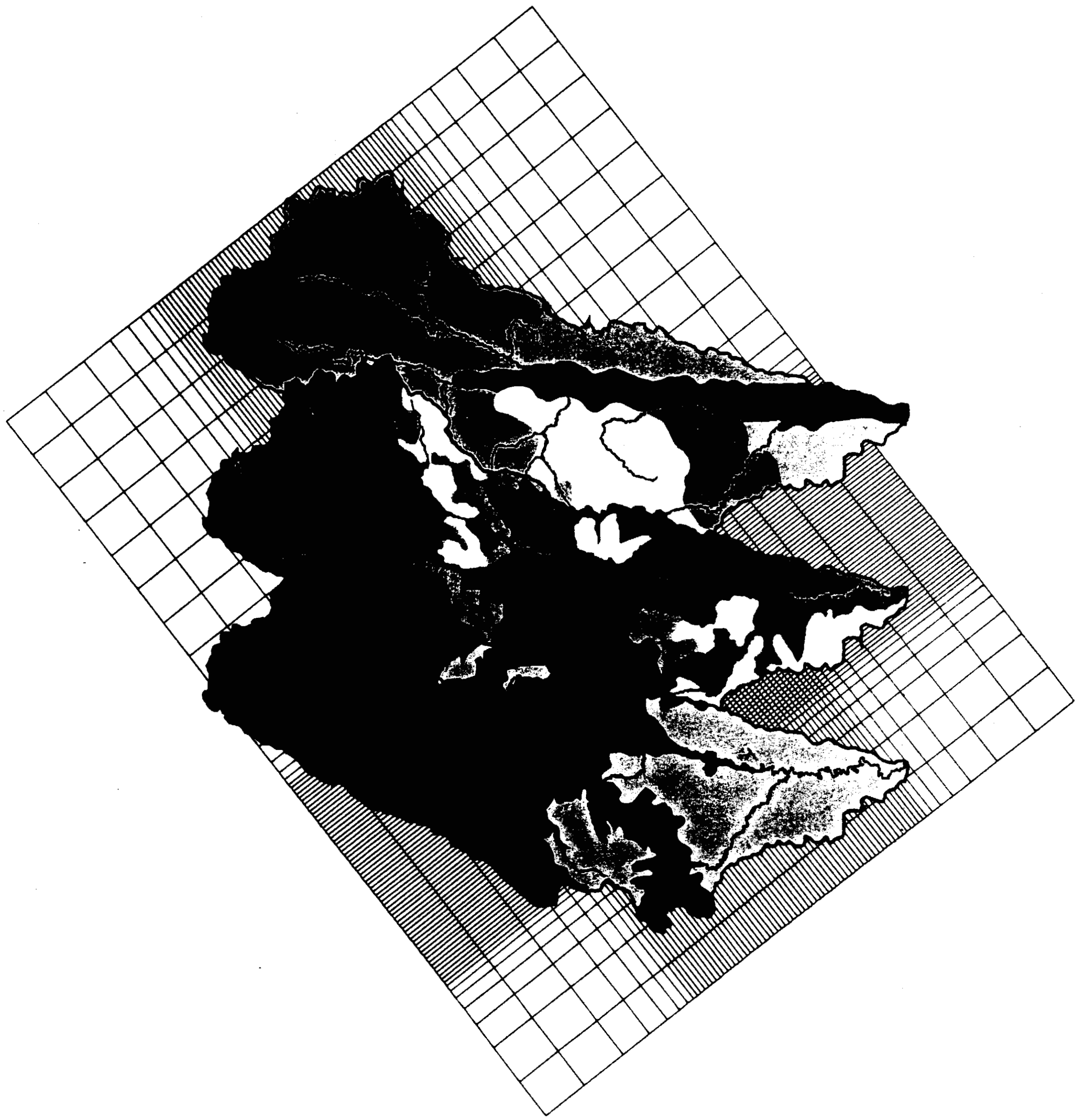
A Study of Techniques to Assess Surface and Groundwater Impacts Associated with Coal Bed Methane and Surface Coal Mining

Little Thunder Creek Drainage, Wyoming



Wyoming Water Resources Center*
University of Wyoming
November, 1997

* This report was prepared by the staff of the Wyoming Initiative Laboratory as part of a cooperative agreement involving the State of Wyoming Department of Environmental Quality, the Wyoming State Engineer's Office, the Wyoming Geological Survey, the Department of the Interior, Bureau of Land Management, the Office of Surface Mining Western Support Center, and the University of Wyoming.

Section 1
Executive Summary

The Need for an Additional Evaluation of Hydrologic Impacts due to Mining and Methane Production

In 1988, the United States Geological Survey (USGS) issued a cumulative hydrologic impact assessment (CHIA) for the eastern Powder River Basin (PRB), which the State of Wyoming used in finding that no material damage was anticipated to the hydrologic balance in the area due to surface coal mining. Wyoming has laws and regulations that address all aspects of surface and groundwater quantity and quality. The state agencies with the authority in this matter are the Department of Environmental Quality/Land Quality Division (DEQ/LQD), Water Quality Division (WQD), and the State Engineer's Office (SEO). The federal Office of Surface Mining (OSM) indicated in 1992 that, given the increase in mining activity in the PRB, the 1988 USGS report had deficiencies and recommended that a new CHIA be initiated. A Cooperative Agreement was entered into in 1993 to accomplish this and to facilitate hydrologic data exchange among the cooperators. The cooperating entities included the DEQ/LQD, the Bureau of Land Management (BLM), the OSM, the SEO, the University of Wyoming (UW), and in 1994, the Wyoming State Geological Survey (WSGS). This report presents results of an analysis of existing and potential surface and groundwater impacts due to coal mining and coal bed methane development on the Little Thunder Creek Drainage located in the south-central portion of the PRB. The report is divided into the following sections:

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Approach

The PRB is located in northeastern Wyoming and contains abundant coal reserves that have been undergoing large-scale mining activity. To assess the best method of conducting a CHIA for the entire PRB, the cooperators decided that one drainage basin would be studied in detail (the Pilot Study Area), which consisted of the Little Thunder Creek Drainage and the areas of groundwater impact in the same vicinity. This region was designated as a cumulative impact area (CIA), which is a watershed or region impacted by two or more mines, and was one of four CIAs delineated in the PRB. The Little Thunder Creek Drainage is affected by three surface coal mines. The pilot study was conducted at the Wyoming Initiative Laboratory of UW, with funding and direction from cooperating agencies.

Groundwater Modeling

Modeling of groundwater flow in the Little Thunder Creek Drainage was undertaken to quantify the impacts from surface coal mining and coal bed methane (CBM) development in the Pilot Study Area, and to work on a method to assess hydrologic impacts from new or expanded development in the Pilot Study Area or other identified CIAs in the PRB. Groundwater flow impacts were expected to the upper Fort Union Formation aquifers and the Wasatch Formation as a result of mining and CBM development. Surface coal mining in the Pilot Study Area has been ongoing since 1976, with small-scale CBM development beginning in the late 1980's north of Gillette in the Powder River Basin. CBM production has become more significant since 1994. Although commercial CBM production has not reached the pilot study area, it is anticipated in the near future. Mining and CBM development are regulated independently, and they have separate environmental compliance requirements. The cumulative impacts from these two industries had not previously been considered.

The USGS Modular Three Dimensional Finite Difference Groundwater Flow Model (MODFLOW) was used to model the groundwater flow system. This model was chosen because its computer code is verified, widely accepted, easily modified, well documented, and thoroughly tested. Hydraulic data were obtained from DEQ/LQD surface mine permits and were input for each modeled aquifer. The modeled aquifers included: the Wyodak Coal; Clinker; Wasatch; and Backfill. Starting ground water levels were developed from time series data in the DEQ Coal Permit and Reclamation (CPR) database. Information on stresses to the aquifers, due to pit inflows at the mines and pumping of CBM wells, was obtained from the mine permits and SEO records, respectively. The mining sequence was simulated as incremental impacts in one-year stress periods from 1975 to the present, and the predictive simulation of impacts was modeled from 1995 to 2021. Two predictive scenarios were investigated: (1) just surface mining from 1995-2021; and (2) surface mining and CBM production from 1995-2005 followed by just surface mining from 2006-2021.

Calibration of the model was evaluated with respect to three quantitative goals. Minimization of Root Mean Square (RMS) error was used as the primary model goal. Absolute error, or the maximum error observed at a single calibration location, was minimized as a secondary criteria to RMS error. Mean error was checked as an estimator of model bias.

Ground Water Modeling Results

Areas with at least five feet of drawdown in the Wyodak Coal Aquifer cover approximately 250 square miles in 2021, considering surface mining development only. Drawdowns of 100 or more feet occur in a much smaller area of less than five square miles, which is largely within the mine permit boundaries. Wasatch Aquifer drawdowns are generally confined to within the mine permit boundaries through 2021.

The 5-foot drawdown contour extends to the west and south model boundaries in 2005, as a result of the 1995 to 2005 CBM pumping. The areal extent of the 5-foot drawdown contour with the added impact of CBM approaches 400 square miles, with a secondary depression of the piezometric surface of greater than 125 feet occurring in the vicinity of CBM production. Recovery from CBM begins almost immediately after the cessation of methane development. CBM impacts are largely undetectable by 2021.

Surface mining impacts also recover following the predicted end-of-mining. In mined areas, a pre-mining dual-aquifer system consisting of the Wyodak Coal Aquifer and the Wasatch Aquifers is replaced by a single Backfill Aquifer. Seventy-five percent of the water level recovery occurs within the first 200 years, with nearly complete recovery taking between 500 and 750 years. The increased length of time for recovery from surface mining impacts is due to replacement of generally confined aquifers, characterized by small storage coefficients, with an unconfined aquifer having much larger storage values.

Surface Water Modeling

For surface water modeling, it was necessary to acquire and analyze data pertaining to soils, vegetation, hydrography, mine permit areas, precipitation, and discharge. This information came from a variety of sources, including the UW Water Resource Center Data System; the Geographic Information System Laboratory; the CPR database; and surface mine permits on file with the DEQ/LQD. The modeling was conducted using HEC-1, which is a rainfall/run-off flood prediction model developed by the Army Corps of Engineers. HEC-1 requires that the watershed be divided into catchments, here called hydrologic response units (HRUs), which should respond to a precipitation event in a uniform manner. Primary output from HEC-1 is a set of hydrographs representing the discharge at the base of each individual component of the system. The model-generated hydrograph for the HRU farthest downstream was compared to observed data to determine model accuracy.

The ephemeral nature of stream flow in the Little Thunder Creek Drainage required the acquisition of hourly precipitation and discharge data for the area. Precipitation data were gathered from gages located on mine sites in the Pilot Study Area, and from National Weather Service Stations located in the vicinity. Discharge data came from one USGS station in the Pilot Study Area that had data of sufficient quality and quantity to be used in model calibration. The Pilot Study Area was divided into thirty-three HRUs based on the analysis of clinker abundance, soils, vegetation, mine permit locations, gaging stations, and hydrography. To determine rainfall distribution through time for each HRU, hourly records from precipitation stations were used. The precipitation records analyzed were for four storms selected between 1978 and 1980. The Natural Resource Conservation Service (NRCS) Run-off Curve Number Method was used to estimate run-off from each HRU.

Certain input parameters, which were not particularly variable for an individual storm, were held constant during calibration. Other parameters, which can be highly variable, were more likely to be altered during calibration. Adjustments to the model were required to reflect the impact of mining present in the Little Thunder Creek Drainage at the time of the observed storms. The storms used in modeling were chosen because they represented a variety of antecedent moisture conditions (AMCs), including dry, intermediate, and wet conditions. The AMCs were used to determine run-off curve numbers within each HRU. AMC, in conjunction with the contributing area of each HRU, was also used to simulate reservoir storage in each HRU.

The goal of the calibration process was to generate a model that matched, as closely as possible, the rainfall/run-off relationships within the Little Thunder Creek Drainage. All calibration was done with values that reflected conditions at the time the given storm occurred. Mining has been ongoing since 1976, so the models were calibrated to reflect the state of the watershed, including mine impacts, at the time of the storm. Adjustments were then made to the model to reflect what would have happened had the mines not been in place. The adjusted, or pre-mining models, were used as a baseline for comparison to post-mining models. For post-mining modeling, the pre-mine models were adjusted to represent the changes in the hydrologic regime that would result from mining. NRCS run-off curve numbers were changed to reflect the post-mining environment. The calibrated models generated peak flows and total volumes within 10% of the observed data for all four storms.

Surface Water Modeling Results

Results of the surface water modeling effort include the possibilities of large and small changes in the response of the post-mining landscape. Change with regard to the magnitude and direction in NRCS run-off curve numbers was incorporated into the model and generated changes of varying magnitudes in response to the four storms. The changes in peak flow, resulting from an increase of 1 NRCS run-off curve number, ranged from 0.0 to 9.9%. Changes in total volume of discharge for the same change ranged from 2.0 to 7.1%. Uncertainty associated with the direction and magnitude of change in the post-mining environment led to additional runs to determine a range of possible outcomes. A decrease of 1 NRCS run-off curve number resulted in changes in peak flow that ranged from 0.0 to -12.0%, and changes in total volume that ranged from -0.2 to -6.7%. Additional runs of the models with positive and negative changes of 2, 3, and 4 NRCS run-off curve numbers were also made. Increasing and decreasing the NRCS run-off curve numbers was believed, by the authors, to represent the most extreme changes that would be represented by mining. Increasing the NRCS run-off curve numbers by 4 generated changes in peak flow between 0.0 and 66.8%, and changes in total volume between 11.0 and 29.7%. Decreasing the NRCS run-off curve numbers by 4 generated changes in peak flow between -0.0 and -18.9%, and changes in total volume between -2.4 and -19.1%.

Conclusions

The groundwater model addressed two concerns indicated by the OSM: 1) States CHIA's were not based on the most recent technical information and 2) The USGS 1988 CHIA was a general assessment that was being applied regionally rather than individually with site specific data. This model also presents one of the first efforts to assess the recharge dynamics of the coal/clinker/overburden boundary. Compilation of BLM, CBM, and mine data for the top and bottom elevations of the coal seam (necessary as model input) has provided valuable information for evaluating the subsurface hydraulics. The complexity of the hydrogeologic setting and the lack of widespread data for verification of model results illustrate the difficulties of trying to extend a model of a Cumulative Impact Area, such as the Little Thunder Creek Drainage, to the PRB as a whole. Although the assumptions used to model the smaller area can be extended from one drainage area to the next, 'extension' of the model assumptions to the PRB as a whole is not considered economically feasible at this time.

The representation of the system, including the assumptions made, for each event simulated is considered to be conceptually correct. The consistency between the models with regard to NRCS run-off curve numbers, reservoir storage, and conveyance loss lend credence to this conclusion. Utilization of the models developed for the Little Thunder Creek Drainage will be most efficient if the pre-mining models are not altered. Post-mining effects can be added to the pre-mining models by determining the areas to be impacted, ascertaining post-mining terrain features, and then altering model input parameters. The model is flexible, allowing a large number of scenarios to be tested if future conditions warrant this.

An addendum was prepared by the LQD to list alternatives to the model conceptualization. Selection of some or all of the options could change the predicted drawdown distributions and rainfall/run-off relationships.

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Section 3
Introduction and Background

Statutory and Regulatory Requirements

The Surface Mining Control and Reclamation Act (SMCRA), United States Public Law 95-87, requires that an "assessment of the probable cumulative impact of all anticipated mining in the area to the hydrologic balance in section 1257(b) [§507(b)(11)] of this title has been made by the regulatory authority and the proposed operations thereof has been designed to prevent material damage to hydrologic balance outside permit area [SMCRA sec..510(b)(3)]." The State of Wyoming, a primacy state under the SMCRA, has designated the Wyoming Department of Environmental Quality/Land Quality Division (WDEQ/LQD) as its regulatory authority.

Wyoming has laws and regulations that address all aspects of surface and groundwater (quantity and quality), within permit areas and off-site, and it is the responsibility of the WDEQ/LQD to satisfy the requirements of these statutes, rules, and regulations. In Chapter 1, Section 2 (bd) of its 1996 Rules and Regulations, the WDEQ/LQD writes: **"Material damage to the hydrologic balance means a significant long-term permanent adverse change to the hydrologic regime."** These regulations define significant long-term or permanent adverse changes to be variations in the surface or groundwater hydrology that are inalterable conditions contrary to: the Wyoming State Constitution; statutes administered by the State Engineer; or water quality standards administered by the Water Quality Division. The WDEQ/LQD, in its "Statement of Material Damage," (Appendix A) lists the Constitutional Articles, Statutes, Interstate Compacts, Supreme Court decrees, state rules and regulations, federal statutes, and federal regulations that apply to the determination and protection of surface and groundwater in the State of Wyoming.

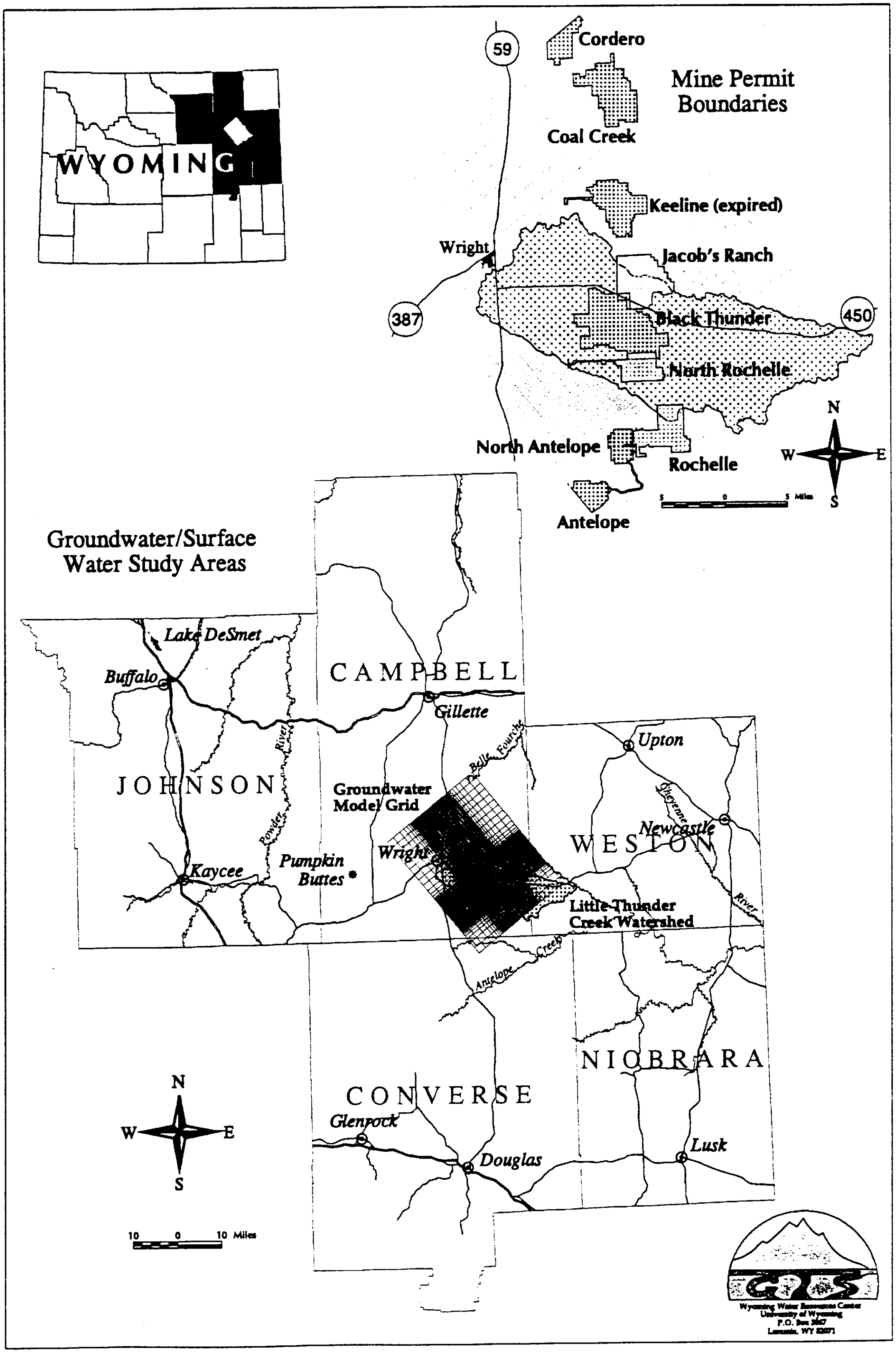
The Powder River Basin

The Powder River Basin (PRB) in Wyoming contains some of the most abundant coal reserves in the world. The eastern and most active portion of the PRB lies primarily in Campbell and Converse Counties, in the northeastern portion of the state (Figure 3-1). These two counties have been undergoing large-scale mining activity. An assessment completed in 1994 indicated that 16 surface coal mines were active in the eastern PRB (Vogler et al., 1995).

Cumulative Hydrologic Impact Assessment by the United States Geological Survey

The United States Geological Survey (USGS) published a report in 1988 titled "Cumulative Potential Hydrologic Impacts of Surface Coal Mining in the Eastern Powder River Structural Basin, Northeastern Wyoming." This cumulative hydrologic impact assessment (CHIA) has been the basis for the State of Wyoming's findings that no material damage to the hydrologic balance of the PRB was anticipated.

Figure 3-1: Counties of northeastern Wyoming lying wholly or partly in the PRB



However, the1988 CHIA recommended the following with regard to future study and monitoring:

1) Recalibration of the ground water models with more current data available from the mines. USGS indicated that they probably overestimated the drawdowns resulting from mining;

2) Additional monitoring of wells west (downdip) of the expected impact from mining;

3) Investigation of the recharge rate and source of recharge water for the spoil aquifers;

4) Studies to determine the suitability of overburden for aquifer restoration, the water quality changes with selective placement of materials, and the long-term changes to water quality;

5) More realistic assessment of the duration of water-level declines to determine if additional mining activities will impact water availability;

6) A study of paired reclaimed and unmined drainages to establish the infiltration rates of each and to extrapolate these findings to larger reclaimed watersheds;

7) Establishment or re-establishment of surface water monitoring stations downstream of the areas to be disturbed to verify rainfall/run-off relationships and to monitor streambed degradation and aggradation; and

Evaluation of the coal mine companies' monitoring network so that: a) a coordinated and efficient monitoring effort is established and maintained; b) quality assurance/quality control (QA/QC) is appropriate; c) a centralized computer file is developed and maintained; and d) the data are available to future cumulative impact analyses.

Office of Surface Mining Finding of Deficiency of 1988 PRB CHIA

A 1992 Office of Surface Mining (OSM) oversite report (Appendix B) pointed out several areas of deficiency in the 1988 CHIA and the WDEQ/LQD's interpretation and use of it. Those deficiencies included:

1a) Lack of a clear statement of the criteria used for determining "material damage";

2a) Application of regional data to areas that the CHIA admitted would vary depending upon the climatic, vegetative, topographic, and geologic conditions present; and

3a) Failure to determine the potential for base flow discharge of poor quality spoils aquifer water to streams in areas where the lack of sufficient overburden, to offset the removal of thick coal beds, could result in the intersection of the post-mine potentiometric and ground surfaces.

OSM's report recommended that the WDEQ/LQD undertake a new CHIA, one of the goals of which would be to address the concerns expressed with the 1988 CHIA, primarily by generating a separate CHIA for each of the three major watersheds in the PRB using site-specific data. It also recommended an expansion of the monitoring data collection as recommended in the 1988 CHIA.

Cooperative Agreement To Complete A CHIA

A Cooperative Agreement was signed in August 1993 for the purpose of facilitating hydrologic data exchange and preparation of CHIAs for the PRB. The signatory parties were the WDEQ/LQD, the OSM, the Bureau of Land Management (BLM), the Wyoming State Engineer (WSE), the University of Wyoming (UW), and in 1994, the Wyoming State Geological Survey (WSGS). The LQD of the WDEQ subsequently contracted with the UW through task orders, prepared in accordance with the cooperative agreement, to complete regionalized CHIAs for the PRB. The BLM has provided a groundwater hydrologist, who works full-time at the facilities provided by the UW, for this effort.

The Wyoming Initiative is an effort to incorporate the software available from the OSM's Technical Information Processing System (TIPS) into an electronic means of permitting and conducting CHIAs. In conjunction with the development of the TIPS Lab associated with the Wyoming Initiative, the UW agreed to implement "full-scale hydrologic assessments for the PRB producing areas" (OSM, 1995). The UW agreed to purchase and maintain the equipment necessary to the development of computer models for the surface and ground water assessments, and to retain a project manager for coordination of the surface water portion of the assessment.

Modeling Based Study Chosen

Decision to Use Pilot Study Approach

The CHIA process for the PRB initially involved delineating the region to be assessed, and then subdividing the region into smaller areas, usually watersheds, for determination of potential impacts. These smaller areas are referred to as cumulative impact areas (CIAs). A CIA is usually a watershed or a region influencing an aquifer that will be impacted by two or more mines. Four CIAs were outlined for the PRB (Figure 3-2), and a variety of approaches to the CHIA were considered. In 1994, it was determined that one drainage basin should be studied in detail in order to determine the most appropriate approach to modeling potential impacts for all CIAs in the PRB. This area, known as the Pilot Study Area, consisted of the Little Thunder Creek Drainage and the areas of groundwater impact in the same vicinity (Figure 3-1). Geographic differences between surface and ground water CIAs are to be expected, as the areas impacting ground water resources often overlap surface water drainage divides (OSM, 1992). The Little Thunder Creek Drainage comprises a significant portion of CIA 2, and it is the only drainage in CIA 2 that is affected by more than one mine.

This report presents results of the Pilot Study Area CHIA. The Little Thunder Creek Drainage in the south-central portion of the PRB is being affected by three surface coal mines. The purpose of this study of the Little Thunder Creek Drainage was to assess the best methods of conducting a CHIA for the entire PRB by conducting a thorough analysis of a single CIA.

Surface Water Model Selection

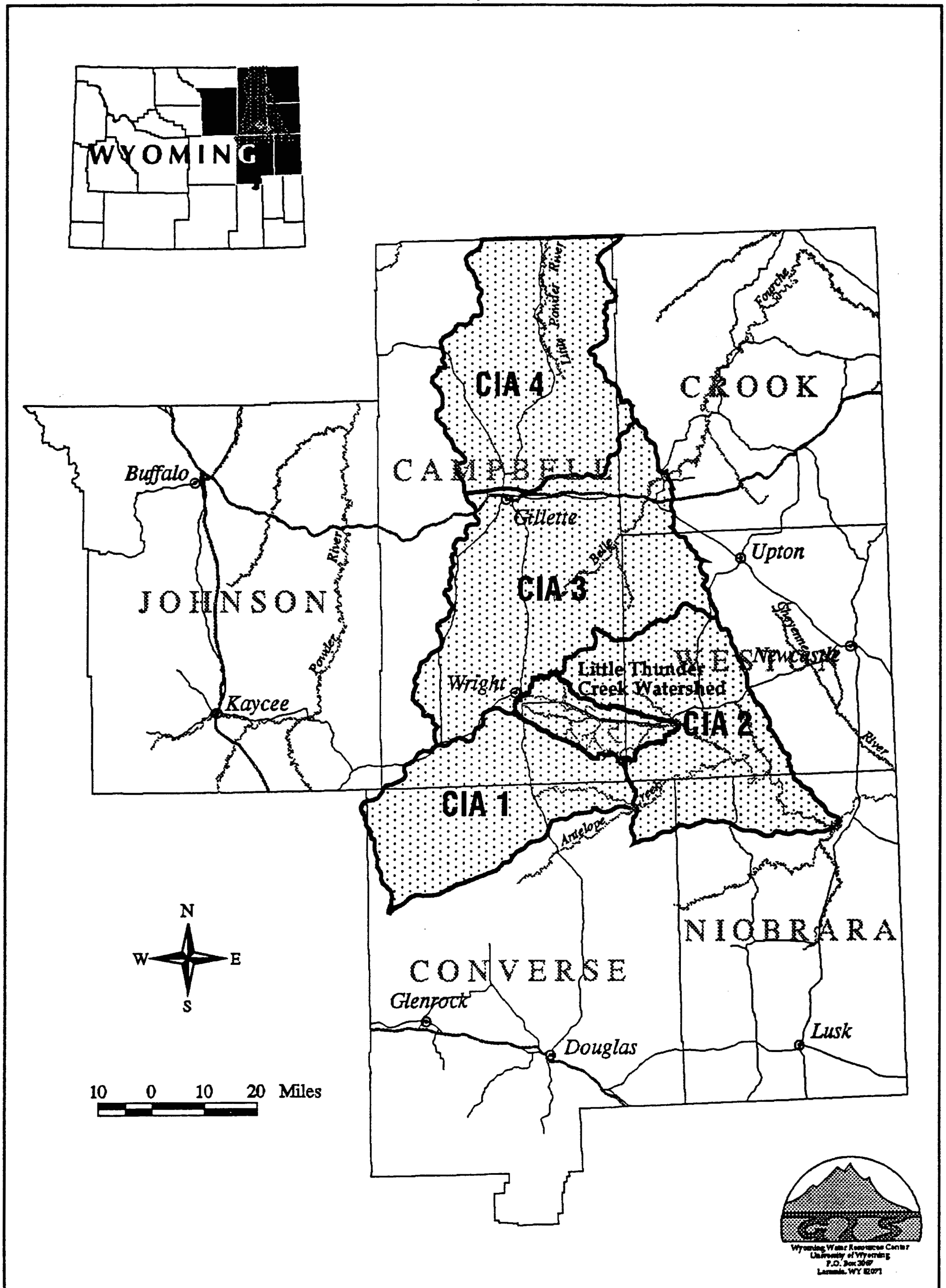
Surface water models can be divided into two general categories: continuous models and event-based models. Continuous models track precipitation and moisture conditions on a continuous basis. The modeler enters the initial hydrologic conditions, and then the model uses inputs, such as precipitation and temperature to predict and track moisture conditions at any given time during the model run period. Event-based models rely upon the modeler to enter the hydrologic conditions present at the beginning of a particular storm event. The model does not track moisture conditions present at the beginning of a particular storm event. The model does not track moisture conditions from moment to moment, but uses the initial conditions entered to predict the response of the area to a given precipitation event.

A literature review of a number of continuous and event-based models was conducted to ascertain the characteristics and capabilities of each. Implementation and testing of a continuous and an event-based model were performed. None of the continuous models available were sufficiently documented or supported by their developers to allow practical application. In addition, the continuous models, while having many desirable features, typically had much more rigorous data input requirements. The Army Corps of Engineers' (ACOE) HEC-1 was chosen as the surface water model for the Little Thunder Creek Drainage CHIA. HEC-1 was run in an operating platform or "front end" called the Watershed Modeling System (WMS) by Boss International, Incorporated.

Groundwater Model Selection

There are a number of numerical groundwater models currently in use. The Modular Three Dimensional Finite Difference Groundwater Flow Model (MODFLOW) (McDonald and Harbaugh, 1983). MODFLOW was selected for this effort because the computer code is verified, widely accepted, easily modified, well documented, and thoroughly tested. MODFLOW was also chosen because the scope of the CHIA effort is to be dynamic, and the modular nature of the model allows for adjustment, modification, and linking with other code. The primary source code for MODFLOW is FORTRAN 77, a portable code that is widely used in engineering and science applications. Future modification of the CHIA modeling effort depends on portable, verified code. MODFLOW was written and it is supported by the USGS. A variety of post-processors, pre-processors, and additional modules are available for use with MODFLOW.

Figure 3-2: CIAs in the PRB and the counties of northeastern Wyoming that make up the PRB



Physical Description of the PRB

Geology

Bedrock and surficial geologic characteristics are important factors of the hydrologic environment of the PRB and the Pilot Study Area in the Little Thunder Creek Drainage. The significant rock units in the Pilot Study Area are the Upper Cretaceous and Tertiary formations, Quaternary sediments, and clinker.

Structure

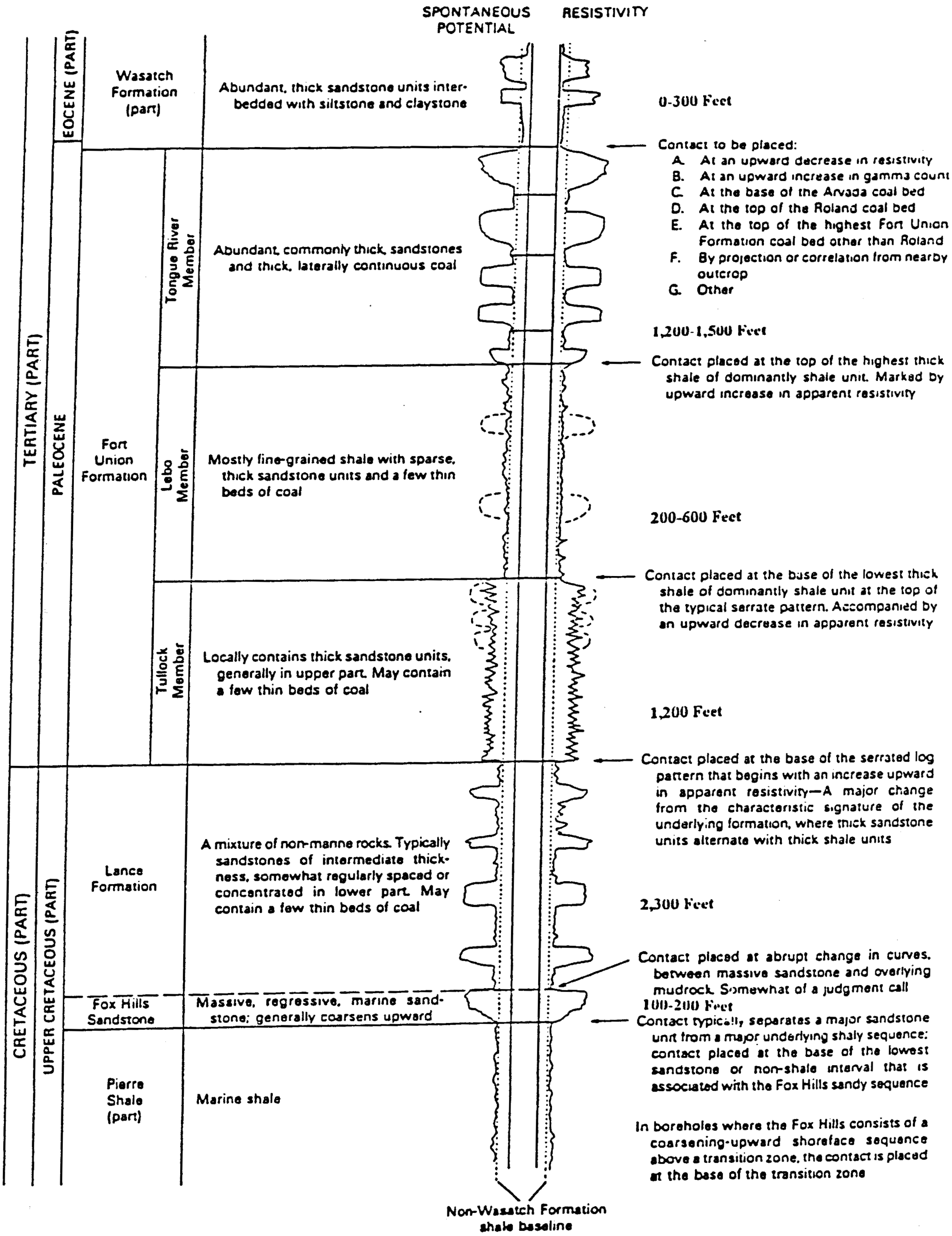
The PRB is a large north-northwest to south-southeast trending asymmetric syncline in northeastern Wyoming and southeastern Montana. It is bounded on the west by the Bighorn Mountains, on the south by the northern part of the Laramie Mountains, on the southwest by the Casper Arch, on the southeast by the Hartville Uplift, on the east by the Black Hills, and on the northeast by the Miles City Arch (Love, 1988). The PRB is about 250 miles (mi.) long by 90 mi. wide, and it contains as much as 23,000 feet (ft.) of sediments in its deepest part (Denson et al., 1989). The basin axis is close to the western part of the PRB, and the west flank of the PRB along the base of the Bighorn Mountains is characterized by steeper dips with minor thrust faulting towards the east. The eastern limb of the PRB is gentle, with slopes of only a few degrees.

Strata in the Pilot Study Area lie on the eastern limb of the PRB. They dip to the west at about one-half of a degree (50 ft./mi.) (Coates and Naeser, 1984). Denson et al. (1980) show the base of the Wyodak Coal to decrease in elevation from 4,600-4,800 ft. along the outcrop near the Black Thunder and Jacobs Ranch Mines, to about 4,000-4,100 ft. near Wyoming Highway 59, at the western edge of the Little Thunder Creek Drainage. Denson et al. (1980) show a number of northwest-trending lineaments and faults crossing the Pilot Study Area. They describe two northwest-trending faults downdropped to the southwest in the vicinity of the Pilot Study Area: Corder Creek Fault, which crosses the North Rochelle Mine area; and the Neil Butte Fault, which crosses south of the Coal Creek Mine. Whether these features are actually faults or rather monoclines that relate to differential compaction along splits in the coal, or nearby channel sandstones, has not been determined. Law (1976) has documented that major structures in the Wyodak Coal northeast of Gillette result from differential compaction along splits. (Denson et al. (1980) also show northwest-trending lineaments along Little Thunder Creek, the North Prong of Little Thunder Creek, and Black Thunder Creek.

Stratigraphy

This discussion will only address the formations deposited above the marine Pierre Shale that represent the last advance of the Western Interior Seaway into what is now Wyoming. The Upper Cretaceous and younger sediments above this, which are discussed in this section, were deposited in a continental environment after the sea retreated to the east. Figure 3-3 is a stratigraphic column that shows typical lithologies and geophysical log characteristics of these formations.

Figure 3-3: Generalized stratigraphic section showing the method of picking stratal boundaries in the PRB



Modified from Seeland, 1992 as presented in Connor, 1992. Not to scale.

Fox Hills Sandstone

The Upper Cretaceous Fox Hills Sandstone marks the last retreat of the Cretaceous seaway to the east. It consists of a shoreline sandstone and shale sequence ranging in thickness from about 100 ft. in the northern part of the PRB, to 200 ft. near the western flank of the Black Hills. The Fox Hills Sandstone consists of two members. The 50-100 ft. thick lower member is comprised of gray to brownish gray, fine-grained, thinly-bedded sandstones, which become finer as they grade downward into gray sandy shale and siltstone, underlain by the dark gray marine Pierre Shale (Robinson et al., 1964). The upper member of the Fox Hills Sandstone is a fine- to medium-grained massive sandstone, 50-100 ft. thick, which pinches out locally or grades laterally into sandstone and shale similar to that of the lower member (Robinson et al., 1964).

Lance Formation

The terrestrial sediments of the Upper Cretaceous Lance Formation overlie and, in places, scour into the Fox Hills Sandstone. The Lance Formation consists of alternating beds of sandstone, bentonitic sandy shale, carbonaceous shale, siltstone, and mudstone. The sandstone is generally fine- to medium-grained, typically cross-bedded, and weathers to light gray or yellowish gray. The thicker beds may contain calcareous concretions. The sandy shale and claystone are medium to dark gray (Robinson et al., 1964). Channel sandstones make up approximately one-third of the Lance Formation; the rest of the Formation is composed of thinner sandstones and finer- grained interfluvial sedimentary rocks (Connor, 1992). Numerous dark carbonaceous shale beds and thin coal beds may be present at some locations, representing ephemeral lake and peat swamp deposits from interfluvial areas (Brown, 1993). The formation predominantly forms grasslands with a few resistant sandstone ridges. Within the PRB, the combined Lance and Fox Hills Sandstone Formations thicken from less than 700 ft. in the north, to more than 3,300 ft. in the south; in the Pilot Study Area, this unit is about 2,300 ft. thick (Connor, 1992; Plate 5). Paleocurrent data indicate the formation was deposited by east-trending rivers before the Bighorn Mountains were uplifted (Connor, 1992).

Fort Union Formation

The Paleocene Fort Union Formation, in the Pilot Study Area, consists of about 3,000 ft. of fluvial, deltaic, and lacustrine sediments, which is subdivided into three members. From oldest to youngest they are: the Tullock Member, the Lebo Shale Member, and the Tongue River Member. The commercially important coal beds occur near the top of the formation. There is disagreement in the literature as to whether the Tongue River Member is present in the Pilot Study Area, or whether the upper coal-bearing member is the Lebo Shale Member.

Tullock Member

The lowest member of the Fort Union Formation, the Tullock Member, overlies the Lance Formation. The base of the Tullock Member is mapped at the base of the lowest coal bed above a thick sequence of massive channel sandstone and shale in the upper Lance Formation, which is at or near the Cretaceous-Tertiary boundary (Robinson et al., 1964). The Tullock Member is composed of fine-grained sandstone, gray sandy or silty shale, carbonaceous shale, discontinuous coal, and rare limestone, most of which are thinly-bedded, and display a sawtooth pattern on resistivity logs. Channel sandstones comprise about one-third of the Tullock Member, while fine-grained overbank deposits form the remaining two-thirds (Brown, 1993). The Tullock Member is lighter in color than the Lance Formation, and it often displays a buff-colored, banded appearance on outcrop (Brown, 1993). The sandstone component of the Tullock Member weathers to light yellow and gray, is friable, and contains some resistant thin layers of calcareous brown-weathering sandstone. The coal is typically lenticular and only a few feet thick (Robinson et al.,1964). The Tullock Member appears to have been deposited by anastomosed east-to northeast-trending rivers. The presence of carbonate clasts in the Tullock Member in the northern part of the PRB indicates erosion of Paleozoic sediments, as the Bighorn Mountains first started to rise (Brown, 1993; Figure 3). Another proposed source of sediment is unroofing of the Lance Formation sediments during initial uplift of the Bighorn Mountains (Whipkey et al., 1991). The Tullock Member is thickest in the southern part of the PRB, over 1,400 ft., but thins to less than 400 ft. in the northern part of the PRB (Brown, 1993). In the Pilot Study Area, the Tullock Member is approximately 1,200 ft. thick (Brown, 1993; Figure 3).

Lebo Shale Member

The Lebo Shale Member of the Fort Union Formation consists of dark gray to olive gray shale, discontinuous lenses of gray fine-grained arkosic sandstone, calcareous to siliceous paleosol horizons, brown carbonaceous shale, and thin coal beds (Brown, 1993). In outcrop, the Lebo Shale Member is represented by rolling grassland interrupted by badlands. The shale and sandstone in these badlands display a somber color and a "popcorn"-weathering texture due to the presence of swelling smectitic clays (Belt et al., 1992; Diemer et al., 1992). The Lebo Shale Member is conformable over the Tullock Member, and in the southeastern part of the PRB, the contact is characterized by a dark gray carbonaceous shale containing many thin coal beds (Brown, 1993).

The origin of the Lebo Shale Member is a subject of debate. Flores (1986) and Whipkey et al. (1991) contend that the clay content of the Lebo Shale Member was governed more by the source of the sediment than by the environment in which the sediment was deposited. They assert that these sediments are mainly derived from reworked Cretaceous shales, such as the Pierre Shale, when the rising Bighorn Mountains and Black Hills shed their several-thousand-foot thick mantle of Cretaceous sediments into the developing PRB. These sediments were deposited by north-south oriented meandering and anastomosed trunk streams that were fed by alluvial fans and tributaries on the PRB margins, with discrete, small to large lakes and backswamps in the low-lying areas between the stream channels. According to this theory, Tongue River Member sediments overlie those of the Lebo Shale Member in the Pilot Study Area, representing unroofing of older Mesozoic and Paleozoic rocks in the Bighorn Mountains and Black Hills. In contrast, Ayers and Kaiser (1984) contend that the shales of the Lebo Shale Member indicate deposition in one large deep lake in the center of the PRB, ringed by deltas from the north, east, and south supplying sediments from the rising Black Hills. In this alternate theory, these deltas of Tongue River Member sediments were deposited at the same time and intertongue with the Lebo Shale Member, but were farther away from the center of the subsiding PRB; the thick coals in the Pilot Study Area were interpreted as interdeltaic deposits elongated parallel to the eastern lake shore. Over time, the deltas prograded westward and eventually filled the lake. This scenario gave rise to the interpretation on several geologic maps (Love and Christiansen, 1985; Denson and Pierson, 1991) that shows the Lebo Shale Member as the uppermost Fort Union Member, directly under the Wasatch Formation in the Pilot Study Area.

The Lebo Shale Member varies from less than 500 ft. thick in the northern part of the PRB, to 1,700 ft. in the southern part (Brown, 1993). Curry (1971) noted that the Lebo Shale Member thickens westward toward the basin axis, and the thickest sections have the lowest sandstone content. Whether the coal bearing unit is called the Lebo Shale Member or the Tongue River Member, the literature generally agrees that the upper Fort Union Formation becomes richer in shale and siltstone, and it takes on more of a drab gray color as one moves south from the

Montana-Wyoming border towards the Pilot Study Area. Two cross sections by Pierce et al. (1990), which traverse the Little Thunder Creek Drainage from northwest to southeast, show the combined Lebo Shale and Tongue River Members to be 1,600-2,000 ft. thick in the Pilot Study Area, while the Lebo Shale Member thickens from less than 200 ft. on the eastern side of the Pilot Study Area, to about 600 ft. on the western side.

Tongue River Member

The Tongue River Member is the uppermost member of the Fort Union Formation, and it consists of thick channel sandstones, fine-grained overbank deposits, and laterally continuous thick coal beds deposited in a fluvial and paludal setting (Flores, 1986; Pierce et al., 1990). Rock units consist of interbedded light gray, very-fine to fine-grained, moderately-sorted friable sandstone, gray siltstone, gray sandy shale, mudstone, thin limestone, and coal. The Tongue River Member tends to be coarser and more conglomeratic on the western margin of the PRB, near the flanks of the Bighorn Uplift (Weaver and Flores, 1987). The Tongue River Member weathers to a yellow-buff color, and it is considerably lighter than the dull gray of the Lebo Shale Member. The presence of carbonate clasts in the sandstones suggest unroofing of Paleozoic strata in the source areas (Whipkey et al., 1991). Belt et al. (1992) report that clays in Tongue River Member sediments are largely non-swelling kaolinite and illite rather than smectite.

Most commercial coal production in the PRB is from the Wyodak Coal in the upper Tongue River Member. Mine plan cross sections, drill hole logs, and published studies all indicate that the coal beds (particularly the Wyodak), are the most continuous lithologic units in the Tongue River Member. The shale, siltstone, and sandstone units are more discontinuous. Several factors control the geometry of the coal beds:

Depositional environment–the location of ancient river channels and peat-forming backswamps in between controls the location of present-day coal beds. The ancient river channels spilled fan-shaped deltas (crevasse splays) of sediments during floods in the backswamps where the peat was forming, which today results in a pattern of thin coal beds merging together like spider legs into the main thick body of the coal deposit (Flores, 1986). Warwick and Stanton (1988) suggest that the Wyodak peat was formed in restricted parts of the floodplain, which were separated by deposits of contemporaneous, anastomosed channels. The channels and associated sediments maintained their position through time because they were confined by thick deposits of raised Wyodak peat;

Differential compaction–a major cause of rolls and splits in coal beds (Law, 1976). As the sediments of the Tongue River Member were buried, the peat compacted up to several times more than the sand, and to a lesser extent, the mud. In the space of a mile or less, a channel sandstone interburden split in a coal bed may increase from zero to 100 ft. thick; and

Structural considerations–may also have had an effect. Basement lineaments could have controlled the course of stream channels and, therefore, the location of the backswamps. Kent (1986) postulated that coal beds on the eastern flank of the PRB formed in elongate north-south "fulcrum" areas that acted as pivots between subsidence along the basin axis to the west, and uplift of the Black Hills to the east; splits in the coal beds occurred east and west of the fulcrum.
The thick Lake DeSmet Coal in the Wasatch Formation formed in a narrow structural trough along the axis of the PRB, east of Buffalo (Obernyer, 1978).

The Tongue River Member is as much as 2,000 ft. thick in the northern and central part of the PRB (Whipkey et al., 1991). According to the cross sections in Pierce et al. (1990), the Tongue River Member is 1,200-1,500 ft. thick in the Pilot Study Area. Although some interpretations, such as

Denson et al. (1989), place the Wasatch Formation/Fort Union Formation contact at the top of the Wyodak Coal, Pierce et al. (1990) show 300-400 ft. of uppermost Tongue River Member sediments above the Wyodak Coal in the Pilot Study Area, and the contact is placed at the top of the Roland/Badger Bed. Flores (1986) observed that Tongue River Member strata above the Wyodak Coal are more thin-bedded, contain more shale and limestone, and indicate deposition in more lake-dominated environments. Observations of highwalls of coal mines in the Pilot Study Area show that the overburden is dominated by shale and siltstone with occasional channel sandstones. Pierce and Johnson (1991) show that Tongue River Member strata below the Wyodak Clinker, east of the Jacobs Ranch Mine, consist of mudrock, carbonaceous shale, coal, ironstone concretions, lenticular channel sandstones, and overband deposits of interbedded sandstone, silstone, and shale. They postulate deposition by north-flowing, low-sinuosity streams across an alluvial plain that contains swamps in interchannel areas.

Wasatch Formation

The Upper Paleocene to Lower Eocene Wasatch Formation consists mainly of alluvial mudstone and sandstone representing overbank floodplain and stream channel deposits. The mudstone makes up about two-thirds of the unit. Minor constituents include coarse conglomerate in alluvial fans along the western edge of the PRB, with carbonaceous shales and thick coal beds deposited in extensive, long-lived, low-lying swamps throughout the PRB (Seeland, 1992). In Wyoming, the Wasatch Formation is second only to the Fort Union Formation in coal deposits, having as many as eight thick, laterally persistent coal beds (Glass and Jones, 1991). Whipkey et al. (1991) consider the sediments in the Wasatch Formation to be largely derived from Precambrian rocks, which had finally been unroofed and exposed in the uplifts adjacent to the PRB. Seeland (1992) interprets the Wasatch Formation to have been deposited by a trunk stream flowing east from the Wind River Basin, across the Casper Arch, then north along the axis of the PRB, while a secondary tributary flowed northwest to join the trunk stream east of Buffalo. The two streams define three depositional systems: 1) a distal mud-rich alluvial plain with a source terrain to the east in the Black Hills (this system includes the Pilot Study Area); 2) a proximal sand-rich alluvial plain-alluvial fan with a source to the south in the Laramie Mountains; and 3) a conglomerate-rich alluvial fan with a source to the west in the Bighorn Mountains.

The contact between the Wasatch Formation and Fort Union Formation has been defined differently in various publications as the top of the Wyodak Coal Seam (Kent, 1986), the top of the Roland Coal Seam (Flores, 1986), a change in heavy mineral assemblages (Denson et al., 1989), and a coquina layer (Olive, 1957). In many areas the mapped contact appears to be arbitrary rather than a consistent time line. Although some studies (Flores, 1986; Seeland, 1992) consider the Wasatch Formation as generally conformable above the Fort Union Formation, Denson et al. (1989) and, Denson and Pierson (1991) show an unconformable relationship along the Wyodak Coal outcrop in the Pilot Study Area; the crop line of the Wyodak Coal marks the Wasatch Formation/Fort Union Formation contact in the north part near the Jacobs Ranch Mine, but the contact rises higher above the top of the coal bed to the south towards the Rochelle Mine. They describe the Wasatch Formation as being coarser-grained, and having two to three times as many heavy minerals as the Fort Union Formation sediments. Glass and Jones (1991) and Kent (1986) show an unconformable contact between the Wasatch Formation and Fort Union Formation in the southern part of the PRB, cutting out progressively older strata towards the east.

The maximum preserved thickness of the Wasatch Formation is about 3,000 ft. along the present structural axis of the PRB, east of Buffalo (Seeland, 1992), and thins toward the basin flanks where the upper parts have been removed by erosion (Fogg et al., 1991). In the Pilot Study Area, the Wasatch Formation varies from zero thickness where it is eroded away east of the coal mines, to a maximum of several hundred feet along the western edge of the Little Thunder Creek Drainage (Pierce et al., 1990).

White River Formation

Isolated buttes capped by the early Oligocene White River Formation occur in the central PRB. Known as the Pumpkin Buttes, they are located about 20 mi. west of Wright, and they contain a 200 ft. thick sequence of very hard, locally conglomeratic sandstone that in places is overlain by a thin layer of blocky, white and pink, tuffaceous, and bentonitic claystone. The conglomerate is derived from Precambrian igneous and metamorphic rocks, and unconformably overlies the Wasatch Formation (Denson and Pierson, 1991).

Alluvium and Other Quaternary Deposits

Quaternary age alluvial deposits of unconsolidated silt, sand, and gravel cover the floodplains of the major streams of the PRB. These deposits can be nearly five miles wide along rivers such as the Belle Fourche, the Little Missouri, and the Little Powder River, including some of their major tributaries (Robinson et al., 1964). The alluvium is generally less than 50 ft. thick, but it can be as thick as 100 ft. in some valleys (Robinson et al., 1964). Quaternary terrace deposits record brief periods of aggradation during nearly continuous erosion of the PRB (Mears et al., 1991). Reheis and Coates (1987) mapped surficial geology at 1:100,000 scale over the Reno Junction quadrangle, which includes the Pilot Study Area. They defined alluvial, lake, eolian, mass-wasting, and residual surficial deposits as well as bedrock units in the Pilot Study Area. The playa lake deposits formed in natural closed depressions in gentle terrain (mainly eolian deflation basins). The eolian sand occurs in dunes and discontinuous sheets, forming gently rolling uplands that mantle parts of the coal permit areas.

Clinker

Clinker, rock that has been baked or melted by the burning of underlying coal beds, covers about 500 square miles (mi.^{2}) of the PRB in northeastern Wyoming (Heffern and Coates, in press, 1996). Range fires and spontaneous combustion ignited the coal (Coates and Naeser, 1984). The clinker in place was produced by the natural burning of some 10-20 billion tons of coal; much more has eroded away over geologic time. As a thick coal bed burns to a thin layer of ash, overlying strata harden and collapse into the void left by the coal. The resulting clinker is more resistant to erosion than the unbaked sediments, and controls the topography of many land forms in the PRB. The overall reddish color of clinker is due to the oxidation of iron; darker "chimneys" of harder rock represent areas of intense heating in reducing conditions. Lithologies in clinker range from hardened shale or sandstone, where heating has not been intense, to porcellanite, paralava, and even glass where temperatures have risen near the melting point. Clinker plays an important role in the storage and flow of water in the PRB (Heffern et al., 1996). The clinker is highly fractured, allowing rainfall and snow melt to rapidly infiltrate.

In the Pilot Study Area, clinker formed by the natural burning of the Wyodak Coal caps a large area of the Rochelle Hills immediately east of the coal mines (Plate 1). The east-facing escarpment of the Rochelle Hills is particularly scenic, with pine trees growing on the clinker rim. About 66 mi.^{2} of clinker occurs east of the Wyodak Coal subcrop line, from the Antelope Coal Mine on the south, to the Coal Creek Mine on the north (Heffern and Oakleaf, personal communication, 1996). The geology appendices of mine permits on file with WDEQ/LQD show that this clinker is commonly 100 ft. thick, and may be as much as 200 ft. thick in places. Coates and Naeser (1984) studied zircon fission-track ages of clinker along the Rochelle Hills escarpment east of the Jacobs Ranch Mine. They found that the clinker was as much as 700,000-years-old on the eastern edge of the escarpment, and became progressively younger towards the west, as erosion caused the escarpment to retreat to the west and expose more coal to burn.

Geomorphology

Coates and Naeser (1984) divide the present landscape of the Pilot Study Area into three main land types. The western part, from the coal mines westward, is gently rolling and punctuated by only a few steep hills, where the clinker of the Felix Coal caps isolated buttes along the northwest border of the drainage. This area is underlain by the Wasatch Formation that contains substantial amounts of fine-grained sandstone, which weathers largely due to fine sand and coarse silt. These products form a mantle of residual soil, sheetwash alluvium, and windblown sand and silt that is sufficiently permeable to absorb most precipitation. Consequently, much of the area has relatively little run-off, resulting in a loosely knit, and poorly integrated drainage network. Wind deflation has created areas of interior drainage now occupied by playas.

The central part of the Pilot Study Area is dominated by three major land forms. The highest parts of the Rochelle Hills are nearly flat to gently rolling uplands, which are underlain mostly by clinker. These areas have little through drainage and minimal surface erosion, because the highly fractured clinker quickly absorbs water. In most places, clinker is underlain by impermeable clay and shale of the Fort Union Formation, which block downward migration of groundwater, and force the development of springs at the base of the clinker. Slopes along the edge of the clinker-capped escarpment are usually steep, and they generally descend to the east. Below the clinker tops are steep slopes of less resistant Fort Union Formation, which are protected by the overlying clinker, and in places, by an armor of clinker fragments. Below the steep slopes the terrain levels off abruptly to pediments that descend to Little Thunder Creek.

In the eastern part of the Pilot Study Area, which is underlain entirely by the Fort Union Formation, the drainage is completely integrated and considerably closer spaced than it is to the west on the Wasatch Formation. The Fort Union Formation, with its higher content of clay, is less permeable than the Wasatch Formation, so more water runs off. Most of the Fort Union Formation is poorly consolidated and weathers to a landscape of low relief.

Geologic History

The rocks of the PRB record the history of the Laramide Orogeny, a compressional mountain and basin building event that created much of the Rocky Mountains. It formed the PRB and the surrounding uplifts, such as the Bighorn Mountains and Black Hills, over a period of 20 million years, from about 70-50 million years ago.

The advent of the orogeny was marked by the eastward retreat of the last cratonic seaway from the area, as recorded by the shoreline sands of the Fox Hills Sandstone (Trimble, 1980), about 69 million years ago in Late Cretaceous time (Lisenbee and DeWitt, 1993). Eastward-flowing rivers then deposited the sandstones and shales of the Lance Formation across a low-lying alluvial plain that occupied the area of the present-day Bighorn Mountains, PRB, and Black Hills (Connor, 1992). These rivers emptied into the Cannonball Sea, which had retreated eastward to the Dakotas. Curry (1971) notes that subsidence was greater to the south, because the Lance Formation is thicker in that direction. At this time, the PRB and nearby uplifts had not yet begun to form.

It appears that the Laramide Orogeny progressed from west to east, so that the Bighorn Mountains began to rise before the Black Hills. The earliest evidence of this is in the Tullock Member of the Fort Union Formation at the Cretaceous-Tertiary boundary, about 66 million years ago (Brown, 1993; Lillegraven, 1993: Figures 4BB and 4CC). The presence of more sand and coal beds in the Paleocene than in the latest Cretaceous rocks indicates that rainfall increased dramatically following this boundary event (Connor, 1992), and plant fossils indicate subtropical conditions (Brown, 1993).

Paleocurrent and rock fragment studies in Tullock Member sandstones indicate that the northern and central Bighorn Mountains first began to rise at this time, blocking the eastward flow of streams, and contributing carbonate and igneous rock fragments (Brown, 1993). However, the streams in the eastern part of the PRB appear to have been flowing east to northeast, indicating that the Black Hills had not yet begun to rise, and the PRB had not developed to any great degree (Brown, 1993; Lisenbee and DeWitt, 1993).

The deposition of the Lebo Shale Member marks the initial uplift of the Black Hills (Lisenbee and DeWitt, 1993; Belt et al., 1992), subsidence of the PRB (Ayers and Kaiser, 1984), and continued uplift of the Bighorn Mountains, at about 65-63 million years ago (Lillegraven, 1993). However, Whipkey et al. (1991) contend that the initial uplift of the Bighorn Mountains commenced in Lebo Shale Member time, in contrast to Brown (1993) and Belt et al. (1992) assertions that uplift commenced in Tullock Member time. Cretaceous shales were stripped from the uplifts and deposited in the PRB. Ayers and Kaiser (1984) assert that sediments were shed westward into a large Lake Lebo in the central and western parts of the PRB. In contrast, Flores (1986) suggests more localized ponding followed by establishment of a northward-flowing river system in Tongue River Member time, which turned eastward in Montana before emptying into the Cannonball Sea in the Dakotas. The Cannonball Sea was connected to the Gulf of Mexico during latest Cretaceous and Paleocene times, then dried up as the Laramide Orogeny progressed (Cherven and Jacob, 1985).

The sediments of the Tongue River Member were deposited in latest Paleocene time, about 62-58 million years ago (Lillegraven, 1993). The abundance of carbonate rock fragments indicates extensive unroofing of Paleozoic strata in the Bighorn Mountains (Whipkey et al., 1991). The presence of widespread coal beds, such as the Wyodak, indicates only moderate sediment influx into a slowly subsiding basin, as well as moist conditions. According to Flores (1986), extensive peat swamps developed on levees and floodplains between sluggish rivers meandering to the north. Uplift along the Cedar Creek Anticline in eastern Montana is postulated by Lisenbee and DeWitt (1993), Belt et al. (1992), and Ayers and Kaiser (1984), to have dammed the rivers draining into the Cannonball Sea, causing a loss of gradient. This led to sluggish drainages and development of widespread swamp and lake deposits during this time.

The Wasatch Formation marks a second pulse of uplift during uppermost Paleocene and lower Eocene times, about 58-54 million years ago (Lisenbee and DeWitt, 1993; Lillegraven, 1993). Increased uplift is suggested by larger grain size of sediments (Seeland, 1992), and the presence of an angular unconformity at the base of the Wasatch Formation, cutting out progressively lower strata in the PRB towards the Black Hills (Kent, 1986). North-flowing streams in the Wyoming part of the PRB carried coarse-grained arkosic sand from Precambrian granite that had been exposed in the Bighorn Mountains, Laramie Mountains, and Hartville Uplift. (Seeland, 1992; Whipkey et al., 1991; Curry, 1971). Northwest-flowing tributaries in the southeast part of the PRB carried finer-grained sedimentary rock and schist fragments from the Black Hills (Seeland, 1992). A last pulse of Laramide igneous activity in the northern Black Hills created Devils Tower, the

Missouri Buttes, and a number of other intrusive bodies from 58-50 million years ago (Lisenbee and DeWitt 1993).

Post-Wasatch Formation erosion and westward tilting of northeastern Wyoming (Love, 1988) removed the topmost sediments in the PRB, and wore down the mountains through late Eocene time. The next record of sedimentation is the White River Formation, which was deposited in the PRB during latest Eocene to early Oligocene time, around 37-32 million years ago (Lillegraven, 1993). The Bighorn Basin and PRB filled with enough sediment to bury much of the Bighorn Mountains. Rivers flowed eastward across the Bighorn Mountains, and deposited reworded volcanic material from the Absaroka Range, and Precambrian igneous and metamorphic rock from the Bighorn Mountains into the central PRB (Love, 1988; Denson et al., 1989). The fossil and paleosol record of these sediments indicate that the climate was drying out and cooling (Lisenbee and DeWitt, 1993). PRB filling continued until early to middle Miocene time. Then there was regional uplift, northward tilting of most of the PRB, and establishment of the north-flowing Powder River and the northeastward-flowing Belle Fourche River. Normal faulting occurred near the southern and southeastern margins of the PRB (Love, 1988).

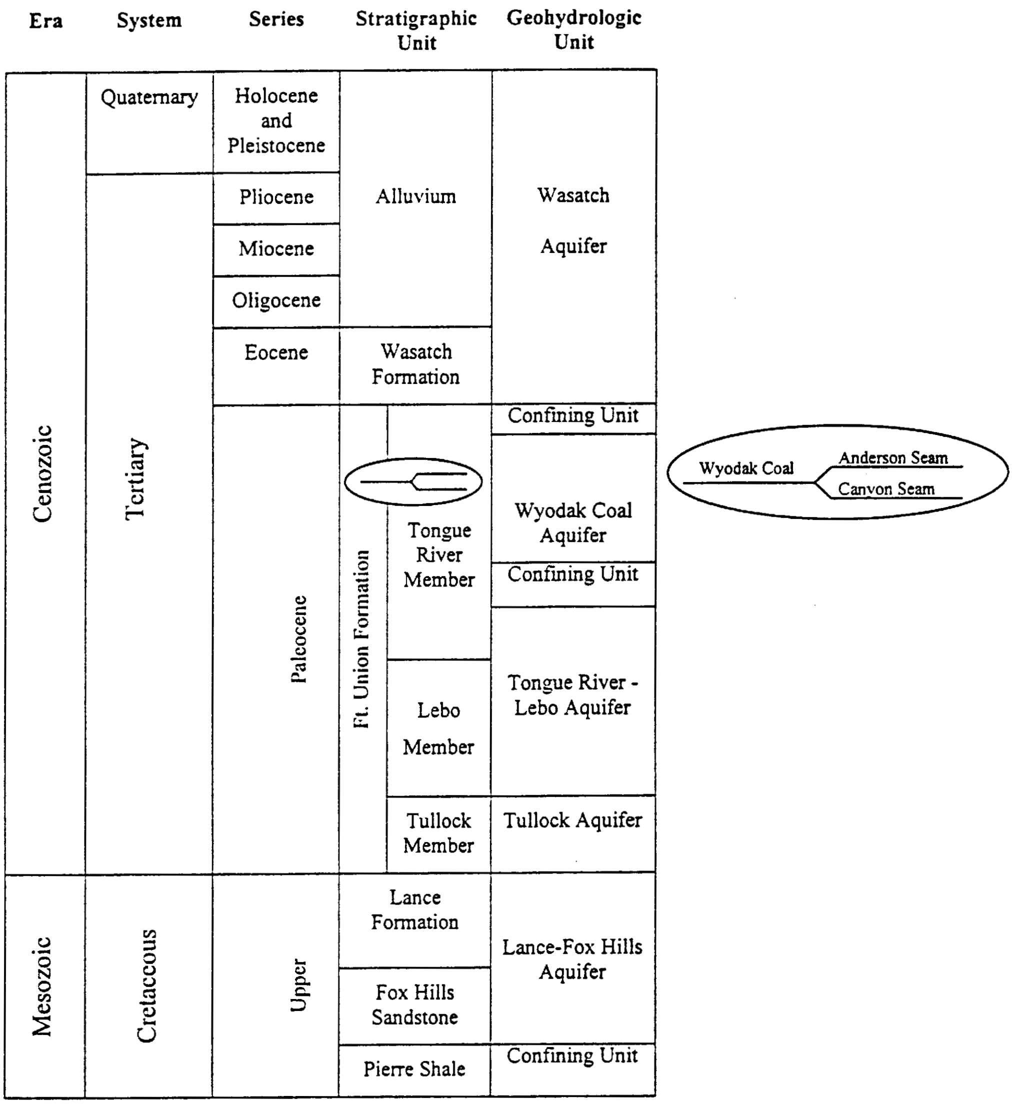
The past ten million years have seen the re-excavation of the PRB and exhumation of the adjacent mountains (Love, 1988). Regional uplift of the Northern Great Plains during the past five million years has stripped much of the post-Laramide debris that had filled the PRB and other intermountain basins (Lisenbee and DeWitt, 1993). Only a small remnant of the White River Formation strata, the Pumpkin Buttes, is left in the PRB. The erosion also exposed buried Paleocene and Eocene coal beds, which commenced to burn and create clinker. These coal fires were ignited periodically by range fires and spontaneous combustion. Clinker formation was not continuous over time in any one place, but it was the result of many intermittent fires separated in space and time. Clinker has been forming in the PRB for at least the past four million years (Heffern and Coates, in press, 1996), and in the southern Rochelle Hills, for at least the past 700,000 years (Coates and Naeser, 1984). During Pleistocene time, the Bighorn Mountains had glaciers, but the PRB was not glaciated. Erosion, with minor periods of aggradation filling valley bottoms, has continued to the present day.

Hydrogeology

The aquifers of importance to the Pilot Study Area within the PRB are those that overlie the relatively impermeable Cretaceous Pierre Shale. Hydrostratigraphic units were delineated by Lewis and Hotchkiss (1981) for the PRB with geophysical logs and drillers logs. They subdivide the sequence above the Pierre Shale into three aquifers and two confining units. These units are as follows: the Fox Hills Sandstone/Lance (lower Hell Creek) Formation Aquifer, the upper Lance (Hell Creek) Formation Confining Layer, the Tullock Aquifer, the Lebo Shale Confining Layer, and the Tongue River Member/Wasatch Formation Aquifer. For the purposes of this Pilot Study Area, it is necessary to further identify several separate aquifers and confining units within the Tongue River Member/Wasatch Formation Aquifer of Lewis and Hotchkiss (1981). These units from the top of the Lebo Shale Confining Layer upward are: the lower and middle Tongue River Member Aquifers; the shale and siltstone confining units that form the floor of the Wyodak Coal; the Wyodak Coal; the low permeability unit that overlies the Wyodak Coal; and the Wasatch Formation Aquifer, consisting of discontinuous sand lenses. These lenses vary from unconfined to confined, with depth and relationship to less permeable materials. This interpretation most directly agrees with the geologic interpretation of Flores (1986) and Whipkey et al. (1991) (Page 3-11, Figure 3-4).

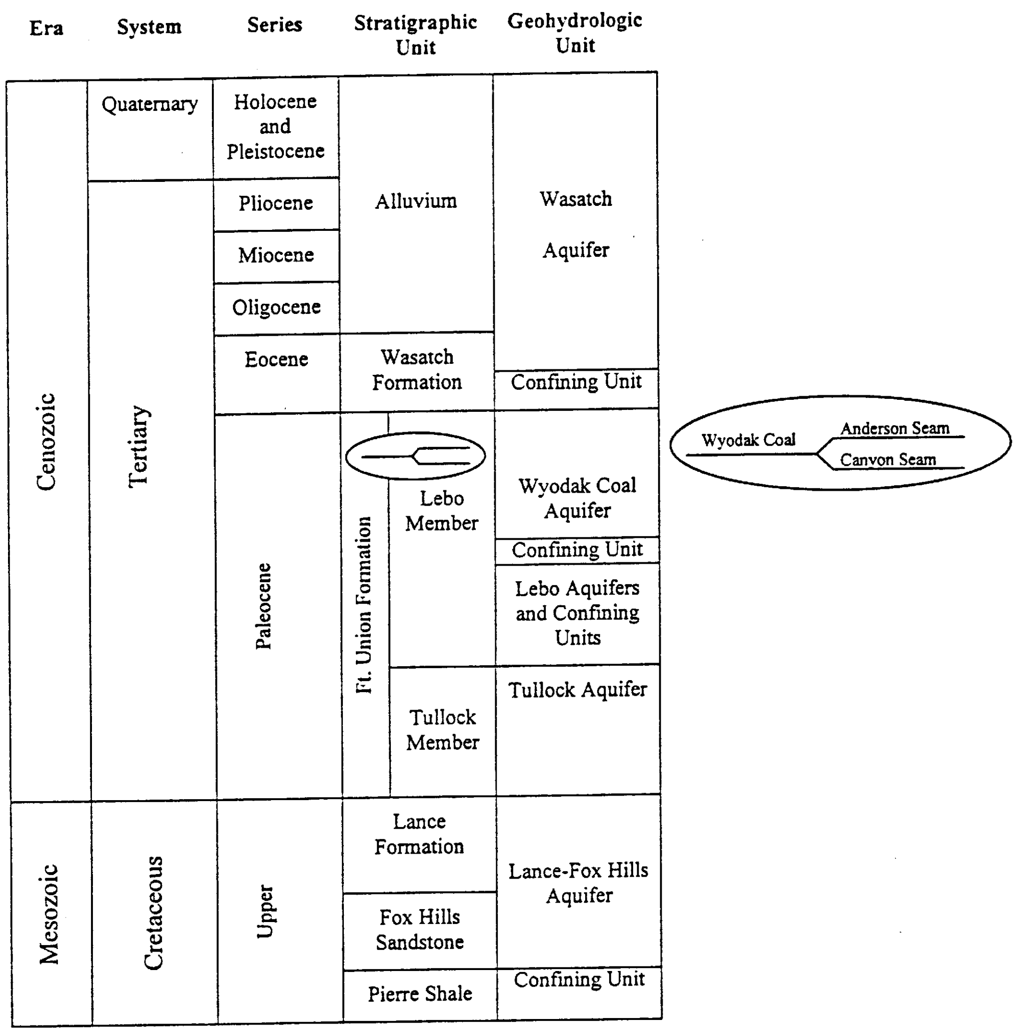
Upper Cretaceous and lower Tertiary aquifers such as the Fox Hills Sandstone/Lance Formation, and Fort Union Formation/Wasatch Formation Aquifers, are the primary source of water supply for domestic, industrial, and municipal users in the area. The productive intervals of these aquifers consist predominantly of sandstones, but they may include coal (Wilson and Cannon, 1989). Most of these wells are for stock or domestic use, and they are less than 500 ft. deep. Quaternary alluvial deposits near streams are generally thick enough to supply domestic or stock wells, but elsewhere, they are too thin (Wilson and Cannon, 1989).

Figure 3-4: Hydrogeologic section showing the hydrogeologic implications of the geologic interpretation of Flores (1986) and Whipkey et al. (1991)



In contrast, the interpretation of Ayers and Kaiser (1984), as presented in Love and Christiansen (1985) and Denson and Pierson (1991), has the Tongue River Member of the Fort Union Formation absent in the Pilot Study Area, with the Lebo Shale Confining Layer directly underlying the Wasatch Formation (Figure 3-5). Given this inconsistency, the low permeability confining unit overlying the Wyodak Coal Aquifer may geologically be part of the either the Wasatch Formation or the Tongue River Member of the Fort Union Formation, while the low permeability confining unit beneath the Wyodak Coal may be part of either the Tongue River Member or Lebo Shale Member of the Fort Union Formation. Lithologic interpretations of drillers logs in the units immediately above and below the Wyodak Coal describe these units as shales, clays, claystones, and occasionally as mudstones. The characterization of the confining layers overlying and underlying the Wyodak Coal is important to the model layering.

Figure 3-5: Hydrogeologic section showing the hydrogeologic implications of the geologic interpretation of Ayers and Kaiser (1984), Love and Christiansen (1985) and Denson and Pierson (1991)



Log Interpretation

Gamma logs are frequently used in the determination of lithology (Bassiouni, 1994). Gamma logs graphically show radioactivity in formations. Highest radioactivity levels in non-radioactive ore producing units are in shales (Bassiouni, 1994). This is due to the accumulation of radioactive ions in clays, and the accumulation of clays in shales.

Gamma logs from the Pilot Study Area (Plate 11, parts B, C, and D) indicate that the Wyodak Coal Aquifer is radioactively dissimilar from overlying and underlying units. Further, the lithologic unit overlying the Wyodak Coal generally is dissimilar from 0-30 ft. over the coal when compared to the remainder of the overlying gamma trace. Gamma counts for the lithologic unit below the coal also show a trend of dissimilar gamma. The logs in the east-west (Plate 11, part D) and north-south cross sections (Plate 11, part B and C) are at different scales. The interpretation for the underlying unit is not as definitive in the east-west cross section.

Examination of the Plate 11 logs show that the coal is the cleanest (least radioactive) formation logged, with gamma counts less than 5 counts per second (cps). Immediately over and under the coal, gamma counts increase to 25-35 cps. The entire gamma trace generally has maximum values of gamma of 35-40 cps, while isolated sands show gamma counts of 10-15 cps. Underlying comparisons are more difficult because logs on the Plate 11, part B and C are logged for only short distances below the coal.

Quantification of the volume of shale in a logged zone of interest is frequently done using gamma ray logs. Initially, a calculation of a *shale index*, I_{shale}, is calculated using the following formula:

$$I_{shale} = \frac{\gamma_{\log} - \gamma_{clean}}{\gamma_{shale} - \gamma_{clean}}$$

where $\gamma_{\log}$ is the average gamma count of a zone of interest;

γ_{clean} is the average gamma count of the cleanest lithologies, always the coal; and

γ_{shale} is the average gamma count in shales.

The shale index is related to volume of shale using several empirical formulas: commonly,

$$V_{shale} = I_{shale}$$

although this may over predict. The Larionov equation (Larionov, 1969) is used for tertiary rocks,

$$V = 0.083(2^{3.7 * I_{shale}} - 1.00)$$

as is the Stieber equation (Stieber, 1970).

$$V_{shale} = \frac{I_{shale}}{(3 - 2 * I_{shale})}$$

Each equation produces similar results with the direct relationship > Stieber > Larionov. Use of these equations is based on the assumptions that the rocks tested are tertiary, that γ_{clean} is representative of a clean formation, that γ_{shale} is representative of shale, and that I_{shale} and V_{shale} can be related using one of the given equations. Selection of an equation depends on the spirit of the calculation.

All three relationships were tested for several of the logs on Plate 11, parts B, C, and D, with results indicating a range of shale volume for the lithology from 0-30 ft. over the coal of 50-75%, compared to 40-85% for the 0-20 ft. underlying the coal.

Fox Hills/Lower Lance Formation Aquifer

The Fox Hills/Lower Lance (Hell Creek) Formation Aquifer consists of the upper Cretaceous Fox Hills Sandstone, and the lower part of the Lance (Hell Creek) Formation. It is confined except near its outcrop, and wells completed in this aquifer produce from 100-200 gallons per minute (gpm). Transmissivities in this aquifer range from 10-250 $ft.^2$/day (Martin et al., 1988). Within the Pilot Study Area, there is 2,000-4,000 ft. of consolidated material between the mined Wyodak Coal and this aquifer, including the Lebo Shale Confining Unit. This aquifer is used by oil companies in water flood operations in the PRB (Martin et al., 1988), and it is one of the secondary aquifers used by the city of Gillette for municipal uses (WSEO, 1995). In the vicinity of the mines, few wells penetrate to the Lance Formation Aquifer, simply because of the availability of sufficient water at shallower depths.

Upper Lance Formation Confining Layer

The mean sand content of the Upper Lance (Hell Creek) Formation Confining Layer is 35%, indicating it will function as a confining layer and retard water movement. Wells screened in the sandy lenses of this unit may produce as much as 4 gpm (Lewis and Hotchkiss, 1981).

Tullock Aquifer

The Tullock Aquifer is composed of the Tullock Member of the Fort Union Formation. The mean sand content of the unit is 53%, with a range of 21-88%, indicating it should act as an aquifer in most of the PRB. Water yields from its coal beds and fine-grained sandstones are generally about 15 gpm, but yields of up to 40 gpm are possible (Lewis and Hotchkiss, 1981). Martin et al. (1988) lists transmissivities in this Aquifer ranging from 200-400 $ft.^2$/day, and possible well yields of 200-300 gpm. Most facility wells for PRB mines are completed in this aquifer, including mines in the Pilot Study Area. The Tullock Aquifer is the lowest water bearing unit in the Fort Union Formation, and it also is used by municipalities as a potable water source. The WSEO (1995) lists the Tullock Aquifer as the lowest of three important subunits of the Fort Union Formation. Lebo Shale Confining Layer

The mean sand fraction of the Lebo Shale Confining Layer is 31%, which means it should act as a confining layer. The confining layer may yield as much as 10 gpm from sand lenses (Lewis and Hotchkiss, 1981). It is primarily a shale unit, with sparse thick sand and thin coal beds. Ayers and Kaiser (1984), Denson and Pierson (1991), Love and Christiansen (1985), and the WSEO (1995) conclude that this is the uppermost unit of the Fort Union Formation, from approximately Gillette south in the PRB. The uppermost contact with the overlying unit is placed as the top of the highest thick shale in a dominantly shale unit (Figure 3-3).

Lower and Mid-Level Tongue River Member Aquifer

Wells screened in the lower part of the Tongue River Member generally produce 10 gpm or less. The mean sand fraction for this unit is 54%, indicating its utility as an aquifer (Lewis and Hotchkiss, 1981). Transmissivity in this aquifer is typically less than 13 $ft.^2$/day, and commonly less than 1.3 $ft.^2$/day (Martin et al., 1988). Martin et al. (1988) puts this unit with the Lebo Shale Confining Layer, and discusses the Tongue River Member/Lebo Shale Aquifer. The WSEO (1995) states that this unit is present only in the northern portion of the PRB. If the Denson and Pierson (1991) interpretation is correct, and the Tongue River Member is present in the Pilot Study Area, then this aquifer remains isolated from the Wyodak Coal by an areally extensive shale unit (Martin et al., 1988; Plate 11).

Wyodak Coal Aquifer

The uppermost bed of the Tongue River Member/Lebo Shale Confining Layer is the Wyodak Coal in the Pilot Study Area. It is confined between an underlying shale unit in the Tongue River Member/Lebo Shale Confining Layer, and the overlying Wasatch Formation. Martin et al. (1988) found the transmissivity in the coal bed to be typically less than 134 $ft.^2$/day.

Wasatch Formation Aquifer

Seeland (1992) describes the Wasatch Formation as overbank floodplain and stream channel deposits with mudstone comprising two-thirds of the unit. Martin et al. (1988) describe the Wasatch Formation Aquifer as discontinuous lenticular sandstones in a siltstone-shale matrix. The Wasatch Formation Aquifer is low yielding aquifer, although it may provide sufficient yields for stock and domestic water where sufficient saturated permeable material is penetrated. Historically, the formation has been used in the Gillette area as a municipal water source, although these wells are now out-of-service in favor of deeper, better quality Fort Union Formation, Lance Formation, and other wells (WSEO, 1995). Martin et al. (1988) lists the Wasatch Formation Aquifer transmissivities as greater than 1.3-13 $ft.^2$/day, with yields ranging from 10-500 gpm, in a north to south gradient. The Martin et al. (1988) study considers the Quaternary alluvial deposits as part of the Wasatch Formation. This may account for some of the wide range of yields reported. The Fort Union Formation/Wasatch Formation contact is placed at an upward decrease in resistivity, or at the top of a selection of Fort Union Coal Beds. The generalized resistivity log presented in Figure 3-3, indicates that the basal unit of the Wasatch Formation is generally more confining than a non-Wasatch Formation shale baseline. In the Pilot Study Area, the Wasatch Formation geophysical logs indicate that the basal unit is areally extensive throughout (Plate 11B-parts 1/3, 2/3, and 3/3).

Site-specific and unit-specific discussions of model parameters in the Little Thunder Creek Drainage Pilot Study Area are included in the Groundwater Model section of this report.

Clinker Aquifer

Clinker plays an important role in the storage and flow of water in the PRB. The highly permeable clinker in the Wyoming portion of the PRB (approximately 500 $mi.^2$), is able to store large amounts of rainfall and snow melt, protect it from evaporation, and discharge this water to springs, streams, and downdip aquifers. Because the transmissivity of the Clinker Aquifer is much higher than that of the coal or overburden, the water ponds against the unaltered coal (Heffern et al., 1996). Western Water Consultants (WWC) (1994) cite a pump test from Koch and Associates (1982), in which the permeability of clinker adjacent to outcrop of the coal was determined to be about 3.74E+04 ft./day, and the storativity about 0.33. Lower (1992) reports clinker transmissivities in the vicinity of the Black Thunder Mine of 3.54E+04 to 2.41+06 $ft.^2$/day; values of 4.55E+02 to 4.01E+06 $ft.^2$/day at the Fort Union Mine, and an average transmissivity of 5.00E+05 $ft.^2$/day at the Dry Fork Mine. Clinker at the North Rochelle Mine is reported to have transmissivities ranging from 5.51E+06 $ft.^2$/day, with a geometric mean hydraulic conductivity of 3.74E+04 ft./day (HKM Associates, 1990).

Surface Features

Cultural Features

The PRB lies predominantly in Converse and Campbell Counties, Wyoming (Figure 3-1). It occupies approximately 71% of Campbell County, and approximately 17% of northern Converse County. Gillette, a city in central Campbell County, is the largest demographically. Campbell County had an estimated population of 32,801 in 1993 (Campbell County Economic Development Corporation (CCEDC), 1995). Wright, Wyoming, 38 mi. south of Gillette, is the only other major population center in the Pilot Study Area. Population estimates for Gillette and Wright in 1994 were 20,892 and 1,357, respectively (CCEDC, 1995). Gillette occupies approximately 23 $mi.^2$ in the middle of Campbell County, on the divide between the Little Powder River and Belle Fourche River Basins. The primary tributary of the Belle Fourche River that is impacted by Gillette is Donkey Creek. The town of Douglas is the major population center in Converse County, but it lies well south of the PRB. The southern portions of the PRB are impacted only by the City of Wright. Wright occupies less than 1 $mi.^2$ near the divide between the Cheyenne and Belle Fourche Rivers, but it lies primarily in the Belle Fourche River Basin.

Major thoroughfares in the PRB are limited to US Highways, Interstate Highways, and Wyoming State Highways. Wyoming Highway 59, the major north-south road in the region, runs from Douglas, Wyoming, in the south to Gillette, and then north to the Wyoming-Montana State line. Interstate Highway 90 is the major east-west road in the region. It runs almost straight east and west through the PRB, and intersects with Wyoming Highway 59 in Gillette. Other major thoroughfares in the region include Wyoming Highway 387 that intersects Highway 59 in Wright, and runs southwest towards Casper, Wyoming. US Highways 14 and 16 run coincidentally through the Pilot Study Area, separating north and west of Gillette. Wyoming Highway 50 runs southeast out of Gillette to a junction with Highway 387 in Pine Tree, Wyoming. Roads within the cities of Gillette and Wright include both asphalt and dirt. Secondary county roads in the area are predominantly gravel or dirt.

Additional linear disturbances include infrastructure built in support of the mineral industries. Rail lines provide transport through the PRB, and they also service the coal mines in the region. Each surface coal mine has a network of rails to expedite the distribution of coal. Two primary rail lines service the PRB, one running east to west, and the other running north to south. The coal mine spurs are tributary to these two lines. Oil and gas production has resulted in the development of a considerable number of pipelines in the region. Numerous major pipelines cross the PRB from north to south, and from east to west (DeBruin, 1996). Feeder pipelines run from wells to the major pipelines throughout the PRB (DeBruin, 1996).

Production of fossil fuels provides the largest part of Campbell County's economic base (BLM, 1995). A 1994 study of the region indicated that 16 mines were operating (Vogler et al., 1995). Mining in Campbell County provided 4,574 jobs in 1992 (BLM, 1995). Coal production from the mines in Campbell County amounted to 213,000,000 tons in 1994 (Vogler et al., 1995). Total production during the life-to-date from those mines is approximately two billion tons (Vogler et al., 1995). The tonnage leased to the mines and expected to be recovered is nearly seven billion tons of coal (Vogler et al., 1995). Mine permit areas range from approximately 900 to 13,000 acres per mine, with an average permit size of 7,345 acres (Vogler et al., 1995). That figure does not include possible future leases and westward expansion of the mines. The permit areas contain considerable amounts of land that will remain relatively undisturbed by mining. Additional mineral industries include construction aggregate, oil, and gas production. The clinker is quarried for use in road building. It is not suitable for concrete aggregate. There were approximately 2,172 oil wells and gas wells in production in Campbell County in 1995 (Wyoming Oil and Gas Conservation Commission (WOGCC), 1996). Total production for the county was approximately 17.4 million barrels of oil, and 20 billion cubic feet (ft.^{3}) of natural gas. Water production from the petroleum wells amounted to approximately 87 million barrels. The water production is from formations underlying the Pierre Shale, and it is well below the strata impacted by coal production. Well depths vary throughout the PRB (WOGCC, 1996).

Agriculture also provides a significant portion of the region's economic base. Agricultural production consists primarily of ranching and dryland farming, which provided 618 jobs in Campbell County during 1992 (BLM, 1995). There is little in the way of irrigated agriculture in Campbell County. Agriculture has resulted in many small disturbances to the surface water drainage, primarily in the form of small reservoirs and stock ponds. Irrigation also provides some withdrawals from the surface water drainage. Spreader dike diversions are a common means of dispersing flow across an alluvial meadow. Over 1,650 water rights were plotted based on records available from the WSEO's Advanced Revelation (AREV) database.

Climate

The PRB is considered to be semiarid with mean annual rainfall ranging between 11 and 16+ inches (in.) (Martner, 1986; Water Resources Data System (WRDS), 1992). Annual precipitation can vary widely from year to year (Apley, 1976; WRDS, 1992). Precipitation tends to increase from the edges of the PRB towards a local mean annual precipitation high in the area of Gillette (Hasfurther, 1994; Toy and Munson, 1978; Schaefer, 1982; WRDS, 1992). Approximately 60-80% of the annual precipitation falls between March and August, most of it in the form of high intensity thunderstorms, which can vary widely in intensity and duration over short distances (Schaefer, 1982). Most of the remaining precipitation (20-40%) comes in the form of snow, which occurs from November through March (Martin et al., 1988; Apley, 1976; Hadley and Schumm, 1961).

The Pilot Study Area is characterized by long, cold winters, and mild summers (Hadley and Schumm, 1961). Temperatures are considered to be northern temperate with average daily minimums between 5 and 40° F in winter, with annual highs between 90 and 100° F in summer. (Schaefer, 1982; Martner, 1986). The annual growing season is approximately 120 days (Martin et al., 1988). National Weather Service (NWS) records indicate the area has substantially greater annual potential evapo-transpiration than precipitation (BLM, 1975).

Vegetation

Campbell County and northern Converse County are range land. While both coniferous and deciduous woodland occur locally, the vegetation is characterized by communities of low-growing shrubs and herbaceous plants that are adapted to the semiarid condition of the region. The region is recognized for supporting sagebrush, grasslands, riparian, and forested communities. The most prominent of these is the big sagebrush (*Artemisia tridentata*) vegetation community. The major understory species associated with big sagebrush are blue grama (*Bouteloua gracilis*), needle and thread (*Stipa comata*), and western wheatgrass (*Agropyron smithii*) (Apley, 1976). The next dominant vegetation community is the Ponderosa Pine (*Pinus ponderosa*), which is found along the Rochelle Hills scoria escarpment (Apley, 1976). Also found within this community are understory shrub species including skunkbush sumac (*Rhus trilobata*), creeping juniper (*Juniperus horizentalis*), and western snowberry (*Symphoricarpos occidentalis*) (BLM, 1975).

The grasslands consist of a variety of species. Some common members include bluebunch wheatgrass (*Agropyron spicatum*), and, blue grama and little bluestem (*Andropogon scoparius*) (BLM, 1975). The remaining riparian communities are associated with streams and playa lakes. Black greasewood (*Sarcobatus vermiculatus*) is found along the larger ephemeral channels and associated floodplains. Plains cottonwood (*Populas sargentii*) is the characteristic species of floodplains along perennial streams. Western wheatgrasses, along with either foxtail barley (*Hordeum jubatum*) or slender spike rush (*Eleocharis acicularis*), are associated with the playa lakes in the area (Apley, 1976).

Soils

To a marked degree, soils of the PRB reflect the character of the bedrock. Soils of the PRB are mostly residual, formed from weathered sedimentary bedrock; mostly sandstone and shale (BLM, 1975). Areas of sandy and medium-textured friable soils are underlain by sandstone and sandy shale, and heavy clay soils are underlain by clayey shale. Soils have developed mostly with short grass vegetative cover, common to the semiarid Great Plains. Due to prevailing climate and vegetative conditions, organic matter is accumulated slowly, and soils have developed with light colored surfaces. Subsoil colors are normally light brown or reddish brown, and substratum colors are often influenced by white, powdery lime carbonate accumulations, caused by low rainfall and insufficient leaching. The soils of the PRB are classified as haplargids–soils with a loamy surface horizon overlying a horizon of clay accumulation, and torriorthents–soils with loamy or clayey textures with weakly developed pedogenic horizons (Apley, 1976).

Surface Water Hydrology

Hydrologically, the PRB falls within three major drainage systems: the Little Powder River, the Belle Fourche River, and the Cheyenne River (Figure 3-2). The Cheyenne River drains the southern section of the Pilot Study Area including CIAs 1 and 2, and the Antelope Creek and Black Thunder Creek Drainages. CIA 3 consists of the headwaters of the Belle Fourche River Drainage. The Belle Fourche River is a tributary of the Cheyenne River, and it flows out of the PRB to the northeast. The lowest point of possible consideration for the CHIA would be the Keyhole Reservoir, which is located below the city of Moorcroft, Wyoming. CIA 4 consists of the Little Powder River Drainage. The Little Powder River flows out of the state to the north, and then into Montana. The state line would mark the farthest point of possible consideration for the CHIA.

The majority of the mapped streams in the area are ephemeral (Lowry et al., 1986; Knutson, 1986; and Martin et al., 1988). There are some reaches of stream channel that intersect ground water and flow at very low rates for part of the year (Knutson, 1986; Martin et al., 1988). All other flow is in direct response to snow melt, rainfall, or stream augmentation. Drainage patterns in the PRB are almost exclusively dendritic (Knutson, 1986).

Section 4
Groundwater Modeling[1]

Introduction

Modeling of groundwater flow in the Little Thunder Creek Drainage was undertaken in response to a need for a cumulative hydrologic impact assessment (CHIA) in the area. The need was established in response to the Office of Surface Mining (OSM) finding of deficiency in the State of Wyoming's coal permitting process with regard to CHIAs for surface coal mining. Additional impacts to groundwater flow in the Powder River Basin (PRB) were determined to be likely from coal bed methane (CBM) development. The primary objectives of the present modeling efforts were:

1) To quantify the likely impacts from surface coal mining and coal bed methane (CBM) development in the Pilot Study Area (CIA 2) in the PRB of Wyoming; and

2) To develop and document a methodology for future development of "dynamic" cumulative assessments that can adequately assess the hydrologic impacts from new or expanded future development, which can be applied to the other identified CIAs in the Wyoming portion of the PRB.

Modeling Objectives

The area chosen for the Pilot Study is located within the Little Thunder Creek Drainage in the PRB of northeastern Wyoming. The drainage is underlain by significant minable coal reserves, currently being developed by three active surface mines; CBM development has also been proposed west of, and structurally downdip from the surface coal mines (Plate 2). Mining and CBM production will alter the groundwater flow regime in the Wasatch and Fort Union Formations. Aquifers below the Wyodak Coal will be affected by mine facilities wells. Surface coal mining and CBM are regulated independently with separate groundwater compliance requirements, and to date, their cumulative impacts have not been considered. Surface mining of coal has been ongoing in the Pilot Study area since 1977, with small-scale CBM interest beginning in the late 1980s. Only since 1994 has CBM development been significant (Zander, 1996). Commodity interest in the Wyodak Coal seam, as a result of its properties (Phase II Clean Air Act compliant coal), has resulted in extensive coal leasing.
The refined groundwater modeling objectives were:

1) Model aquifer stresses to the Wyodak Coal (upper Fort Union Formation) and the Wasatch Formation under two development scenarios:

    - Considering only historic and future surface mining, and
    - Considering both surface mining and CBM development,

2) Predict groundwater flow consequences associated with these development scenarios;

3) Provide a tool for regulatory agencies to assess the likelihood of material damage;

[1] This section is written to conform to American Society for Testing and Materials standard D5718-95.

4) Provide an initial quantification of the recharge dynamics at the coal-clinker interface; and

5) Document a process and provide a model method that is usable and adaptable for use in determining future and additional on-going energy development impacts.

Energy related drawdowns are to be predicted through presently anticipated end-of-mining, with and without CBM development.

Model Function

The United States Geological Survey (USGS) Modular Three Dimensional Finite Difference Groundwater Flow Model (MODFLOW) was used to model the groundwater flow system. Hydraulic data were obtained from surface mine permits, and inputs were developed for each modeled aquifer in a quasi-3-dimensional approach. Stresses were simulated as drains for the surface mining impacts (Appendix C), and as wells for CBM development. Starting heads were developed from time series data in the Wyoming Department of Environmental Quality/Land Quality Division (WDEQ/LQD) Coal Permit and Reclamation (CPR) database. Model calibration was done to pre-mining, or in a few cases, earliest available static water levels. This was assumed to represent steady state conditions.

The mining sequence was simulated as incremental impacts in one year stress periods from 1977 to the present. Predictive simulation of impacts is modeled to the presently anticipated end-of-mining, year 2021, as of 1995. CBM production was simulated in the area using the development scenario proposed in the 1995 National Environmental Policy Act (NEPA) document for the Lighthouse Study (Bureau of Land Management (BLM), 1995). Gas production was assumed to begin in 1996, and to last 10 years in the Lighthouse NEPA document. Mining impacts were modeled with, and without CBM. The resultant output for each layer is history matched against time series data from the CPR database to verify model application. Transient state simulation continues post-mining until steady state conditions reestablish. Steady state is assumed when change in model storage between stress periods approaches zero.

Methods and techniques are documented in this report and its Appendices, and the complete model is presently archived at the Wyoming Initiative Lab at the University of Wyoming (UW). Technology transfer will be provided to cooperating agencies for in-house use and updating.

Conceptual Model

Aquifer System—General Discussion

The stratigraphic column of the PRB shows the Wasatch Formation overlying the Fort Union Formation in the Pilot Study Area. Geologic nomenclatures for the coal beds in the area differ. The Wyodak Coal is also called the Wyodak-Anderson and Roland Coal in various publications and permit to mine applications (PTMAs). For the purposes of this report, the Wyodak Coal is treated as the top unit of the Fort Union Formation.

The dip of the Fort Union Coals is generally 1-2 degrees to the west-northwest, although the Wyodak Coal locally dips 0.5 degree in the Pilot Study Area. Where the Wasatch Formation/Wyodak Coal contact intercepts the land surface, the coal and overburden is eroded to the east. Range fires and spontaneous combustion have ignited the areas of exposed coal at the land surface. The burning of these coal deposits has created a land form composed of permeable material (clinker), formed from the baking and subsequent collapse of the sediments originally above the coal. Through time, many clinker deposits have become saturated as a result of the infiltration of precipitation and snow melt. "Ponding" of water may occur along this interface when the clinker meets the less permeable coal and sediments of the Wasatch Formation and the Fort Union Formation (Heffern et al., 1996). Previous investigations have treated this boundary as a recharge boundary for the coal (Western Water Consultants (WWC), 1994; Lower, 1992).

Groundwater flow is generally to the northwest (downdip) in the PRB (Daddow, 1986). The early time series data (pre-mine) presented in Appendix D, and simulated on Plates 5 and 6, indicate that hydraulic gradients for the coal/clinker/overburden are steep near the cropline with highest potentials in the clinker. Anecdotal support for a continuous system between the coal, clinker, and overburden is presented in several PTMAs. Mining into the clinker can cause mine pit flooding, which has occurred in the Pilot Study Area at the North Rochelle and Jacobs Ranch Mines. Pit inflows increase near the clinker (Gerlach, 1995).

A regional east-to-west hydraulic gradient can be observed, generally decreasing to the west in the simulated steady state potentiometric surfaces. Near cropline flow patterns are more complex, with local flow patterns dominating (Plates 5 and 6). Pre-mine potentiometric surfaces at the Jacobs Ranch and North Rochelle Mines indicate that the hydraulic gradient is greater in this vicinity. Downdip data are sparse, a deficiency of the available data. Water levels from the clinker indicate that they are in dynamic equilibrium with the downdip strata near the coal/clinker/overburden interface, although data are limited. Simulated local flow patterns at the Black Thunder Mine indicate that pre-mining recharge was occurring from both the south and north into the reaches identified by Denson et al. (1980) as the Little Thunder and Black Thunder Lineaments (Plate 7).

The coal/clinker/overburden boundary is modeled in this report as a semi-permeable boundary. A unit of porous material, in this case the Wyodak Coal and the Wasatch Formation, are in contact with another porous material (the clinker), through a semi-pervious boundary (zone of alteration) (Gerlach, 1995; Heffern et al., 1996).

Other geologic boundaries examined in model development included faults and lineaments presented in Denson, et al. (1980). Faults act as impermeable (no-flow) boundaries and lineaments as zones of augmented hydraulic conductivity in the model. Not all the features of Denson et al. (1980) are used in the final model. Where inclusion of lineaments or faults did not improve calibration, they were not used.

Model domain recharge occurs from two sources. Precipitation should provide a minimal source of recharge to the top model layer. Climate and precipitation prohibit infiltration from being a large amount. Recharge is also provided from the clinker contact with the Wyodak Coal Aquifer and the Wasatch sediments on the east side of the model area. Traditionally, recharge through this zone has been adjusted during model calibration (WWC, 1994; Lower, 1992).

Initial values of hydraulic head for the coal, clinker, and overburden were needed model inputs, as were storage coefficients, hydraulic conductivity, vertical leakance, and anisotropy. The Wyodak Coal Aquifer is modeled as an anisotropic medium. Considerable literature indicates that flow in coal aquifers is dominated by fractures associated with various formative processes (Close and Mavor, 1991; LaPointe and Ganow, 1986; Stoner, 1981; Martin et al., 1988).

Model units for this simulation are feet (ft.), and time units are days.

Hydrologic Boundaries

Discontinuities and Wants

The eastern extent of clinker represents an absolute discontinuity in the aquifer system (assuming a continuous coal/clinker/overburden (system). Model boundaries for the Wyodak Coal and Wasatch Formation Aquifers are considered to be at their contact with the clinker in this investigation.

An area where the coal was absent (a "want") was mapped from exploratory drilling near the southwest boundary of the model domain by Martens and Peck Production. Where the coal is verified to be absent, a discontinuous flow system would result, and a no-flow boundary would likely occur (Plate 4).

Lineaments

Denson et al. (1980) mapped lineaments within the Pilot Study Area. These are presented on Plate 8. Although Denson et al. (1980) mapped linear surficial features, the geostatistical methods used to develop the aquifer surfaces used in this model (Appendix E) correlates many of the surficial features of Denson et al. (1980) with sub-surface features (Plate 8). Lineaments are regularly discussed in the PTMAs, generally with regard to augmented groundwater flow (Antelope and North Rochelle Mines PTMAs). CBM operators target coal anticlines as areas of elevated permeability (Peck, personal communication, 1995). Therefore, areas surficially identified as lineaments in Denson et al. (1980), and present in the Wyodak Coal Aquifer structural model, were assigned elevated hydraulic conductivities provided doing so reduced model error. Based on this conceptualization, Porcupine Creek Lineament occurs near the southern boundary of the grid, the Little Thunder Creek and North Prong Lineaments are present in the Black Thunder Mine permit areas, and the Hilight Lineament is a northwest extension of Burning Coal Draw.

Faults

Denson et al. (1980) and Mitchell and Rogers (1993) speculate on the existence of faults within the Pilot Study Area, although faulting is more prevalent on the western axis of the PRB (Glass and Jones, 1991). Faulting will generally result in decreased transmissivity because of aquifer offset. Where Denson et al. (1980) mapped a fault, no-flow conditions were tested along the fault, with model improvement completely determined by reduction in RMS error. The Neil Butte Fault of Denson et al. (1980), was the only fault of Denson et al. (1980) retained in the final model (Plate 8).

Hydraulic Properties

Hydraulic Conductivity from Nine Mines in the Central PRB

The PTMAs of nine mines in the central PRB, including the three mines in the Pilot Study Area, were examined, and all pump tests were extracted. Approximately 20% of the 450 aquifer tests examined were reanalyzed. Aquifer tests were examined for reliability and rated from 0 to 3 (least to most reliable). All data (permit contained and reanalyzed) were committed to the CPR database, provided the well name and location were present in the CPR.

A statistical analysis of the CPR contained tests that were conducted in a single geologic unit (single completion), where hydraulic conductivity could be extracted (occasionally transmissivity was reported without saturated thickness), was conducted. Summary statistics of aquifer hydraulics in the Wyodak Coal, Wasatch, Backfill, and Clinker Aquifers for all tests, permit contained and reanalyzed, regardless of rating were obtained. Results, based on 274 of 450 tests, are summarized in Table 4-1. The complete data set, with frequency histograms, is presented in Appendix F.

Table 4-1: Statistical results for standard and log transformed data of aquifer hydraulic tests conducted in the PRB

Aquifer	N	Mean K (ft./day)	Median K (ft./day)	Mean ln (K)	Variance
Wyodak Coal	166	119	1.47	0.4934	3.822
Clinker	15	10,061	104.26	5.727	16.11
Wasatch Formation	86	3,251	0.401	0.288	11.7
Backfill	7	5.82	0.134	-0.54432	5.37

Discussion

Data were not excluded for any reason. Pump tests and slug tests were treated alike. Some wells were tested multiple times, and reanalysis contributed replicates. The Clinker Aquifer has the highest range (and variance) of all the data sets, although the Wasatch Formation Aquifer data are also highly variable. The low values of hydraulic conductivity for the Clinker Aquifer were derived from slug and injection tests of short duration (Appendix F). Statistical testing of this data is ongoing to determine if significant differences exist between the data by rating code...although it is not complete at the time of this report. Additional work to include the 176 omitted tests is recommended, but it will be time consuming, and some historic data are probably unrecoverable. Finally, the number of tests for the Backfill Aquifer is very small (N = 7). Any additional data would increase the reliability of Backfill Aquifer statistics.

The data, with the possible exception of the Clinker Aquifer, appear to be lognormally distributed. This is born out by the sharply skewed histograms (Appendix F). The Clinker Aquifer appears bimodal. Variances for all data sets are high. The Backfill Aquifer and Wyodak Coal Aquifer data variance is not as elevated as the Clinker and Wasatch Formation Aquifers.

Hydraulic Conductivity at Five Mines in the Pilot Study Area

The "general area" data set was examined, and data for each aquifer within the Pilot Study Area was selected using the following criteria:

1) Data were restricted to mines within the Pilot Study Area (Cordero, Coal Creek, Jacobs Ranch, Black Thunder, and North Rochelle);

2) Data were limited to tested wells in the CPR;

3) Aquifer test ratings assigned in the lab were restricted to only 1, 2, or 3;

4) Only one test was allowed per well using the following selection criteria;

- The highest test was selected at each well,
- Multiple well tests were selected over single well tests,
- Recovery tests were selected over pump tests, and
- If more than a single test remained at a well, test parameters were averaged.

The "quality checked" data were used to choose a "mean" or best initial approximation for the model area. The hydraulic data available for the Wasatch Formation and Clinker Aquifers were significantly reduced, and no Backfill Aquifer hydraulic data satisfied the above criteria. A summary of the quality checked data is presented in Table 4-2. The complete data set is presented in Appendix G.

Table 4-2: Summary statistics of quality checked hydraulic conductivity data within the Pilot Study Area

Aquifer	**Number of tests in the Pilot Study Area**	**Mean (ft./day)**	**Range (ft./day)**	**Mean of log transformed**	**Variance of logs**
Wyodak Coal	38	7.91	0.133-79.40	1.26	1.72
Wasatch Formation	8	0.62	0.133-1.33	-0.789	0.226
Clinker	2	51,000	50,000-52,000	10.84	0.006
Backfill	0	ND	ND	ND	ND

ND - no data.

Discussion

Sample size for all aquifers is restricted when data are subject to location, quality, and replication criteria. The sample size for the Clinker is extremely restricted, although all data indicate that this is a highly permeable aquifer. No adequate testing of the Backfill is present at this time.

Wyodak Coal

Compared to the general area data set, the Wyodak Coal Aquifer remains lognormally distributed, with the mean of the logs at 1.26 compared to 0.493 for the general area data set. This results in an applicable mean value of hydraulic conductivity within the Pilot Study Area of 3.52 ft./day. All deterministic Wyodak Coal Aquifer model calibration/verification adjustments were then made to this initial value of hydraulic conductivity in the Wyodak Coal Aquifer.

Backfill

Two backfill tests were present in the Pilot Study Area, both conducted on the same well. Neither test satisfied quality checking criteria. The backfill data were not used in the model, rather the assumption that backfill hydraulic conductivity would approximate the geometric mean of the undisturbed Wasatch Formation aquifers was simulated. Additional testing will greatly improve knowledge of the backfill hydraulics.

Clinker

The Clinker Aquifer is a difficult aquifer to test, with long duration, high yielding tests a necessity. Two aquifer tests were located within the Pilot Study Area, both at the North Rochelle Mine. The two North Rochelle Mine tests averaged 51,000 ft./day, using only the recovery tests. The pump portion of the tests yielded a mean hydraulic conductivity value of 29,000 ft./day. Both tests were conducted in 25 ft. of saturated clinker, and showed drawdowns of 0.09 ft., after pumping at 1,200 gallons per minute (gpm) for 24 hours. The modeled value Clinker Aquifer hydraulic conductivity more closely follows the pump test values, although 0.01 ft. of water level change accounts for all the variability between the pump and recovery test values.

Wasatch Formation

The variability in the Wasatch Formation Aquifer data for the Pilot Study Area is less than the general area data. This may be a function of reduced sample size, or it may be from general area tests conducted near the zone of alteration, or in a clean Wasatch Formation sand. Within the Pilot Study Area, completion intervals vary widely in the Wasatch Formation wells. At Jacobs Ranch Mine, Wasatch Formation wells are perforated through the entire formation, whereas at Black Thunder Mine, Wasatch Formation wells are perforated only in water bearing zones. This introduces additional uncertainty in aquifer test values. Because of the uncertainty in aquifer test values for the Wasatch aquifers in the Pilot Study Area, the values reported in Martin et al. (1988) for the Wasatch sediments (geometric mean 0.2 ft./day) were tested in the model with sensitivity analysis.

Comparison of Hydraulic Conductivity Values of Martin et al. (1988) to Present Study

Martin et al. (1988) concluded that the geometric mean of hydraulic conductivity for the coal was 0.8 ft./day, based on 357 pump tests in PTMAs. A portion of the permit aquifer testing was reanalyzed. Statistical analysis of the reanalyzed data showed no significant difference between permit contained and reanalyzed data. Martin et al. (1988) reported a geometric mean of hydraulic conductivity values for the Wasatch Formation at 0.2 ft./day, based on 203 tests, without reanalysis.

The examination of permit contained data in the Pilot Study Area for this modeling effort yields higher values for hydraulic conductivity in the coal, considering only the tests rated 1 and above. The mean of the logs of hydraulic conductivity of 3.52 ft./day compared to the reported value of Martin et al. (1988) of 0.8 ft./day. The Wasatch Formation tests in the Pilot Study Area follow closely the values of hydraulic conductivity reported by Martin et al. (1988), with a mean of the logs at 0.45 ft./day compared to 0.2 ft./day, although the number of tests are significantly less than in Martin et al. (1988) for both formations.

Anisotropy in the Wyodak Coal

The Wyodak Coal is considered to be an anisotropic aquifer (Martin et al., 1988; Belle Ayr Mine PTMA). Secondary coal permeability imparted by fracturing is reported to be the major cause of anisotropy in coal aquifers. Vertical fractures in coal are termed cleat (Tremain et al., 1991). LaPointe and Ganow (1986) reported two sets of cleat at the Black Thunder Mine. The more prominent set was oriented northeasterly. The BLM (1992) stated that the general belief in the PRB is that coal permeability may be "increased in the crests of anticlinal structures."

Dobson (1996) studied anisotropy in the Wyodak Coal Aquifer while working on an Abandoned Coal Mine Land Research Program (ACMLRP) grant. His findings suggest that near lineaments, maximum hydraulic conductivity in the coal is oriented along the major axis of the lineaments. His conclusions are based on three close radius, multi-well pump tests conducted within the permit areas of three PRB mines. Dobson (1996) suggested a positive correlation between the orientation of K_{max} and the orientation of faults and lineaments in the PRB. One test was positioned to intentionally intercept the Corder Creek Fault (Denson et al., 1980).

Two additional long duration, long radius pump tests were conducted by the BLM west of Cordero and Coal Creek Mines in 1995 and 1996. Analysis of the Cordero Mine test suggests that K_{max} may be orthogonal to Dobson's (1996) results. This suggests spatial variability of anisotropy, perhaps related to the presence or absence of lineaments. The pump test west of the Coal Creek Mine is complete and awaiting analysis. Results will be published at the completion of the grant.

Based on the literature, the model grid was oriented to be parallel to the axis of structural anisotropy in the Wyodak Coal (Appendix E). This model orientation assumes maximum hydraulic conductivity is either along structure or across structure. Column-to-row anisotropy was investigated with sensitivity analysis, using model root mean square error (RMS) as the test criterion.

Storage Coefficient

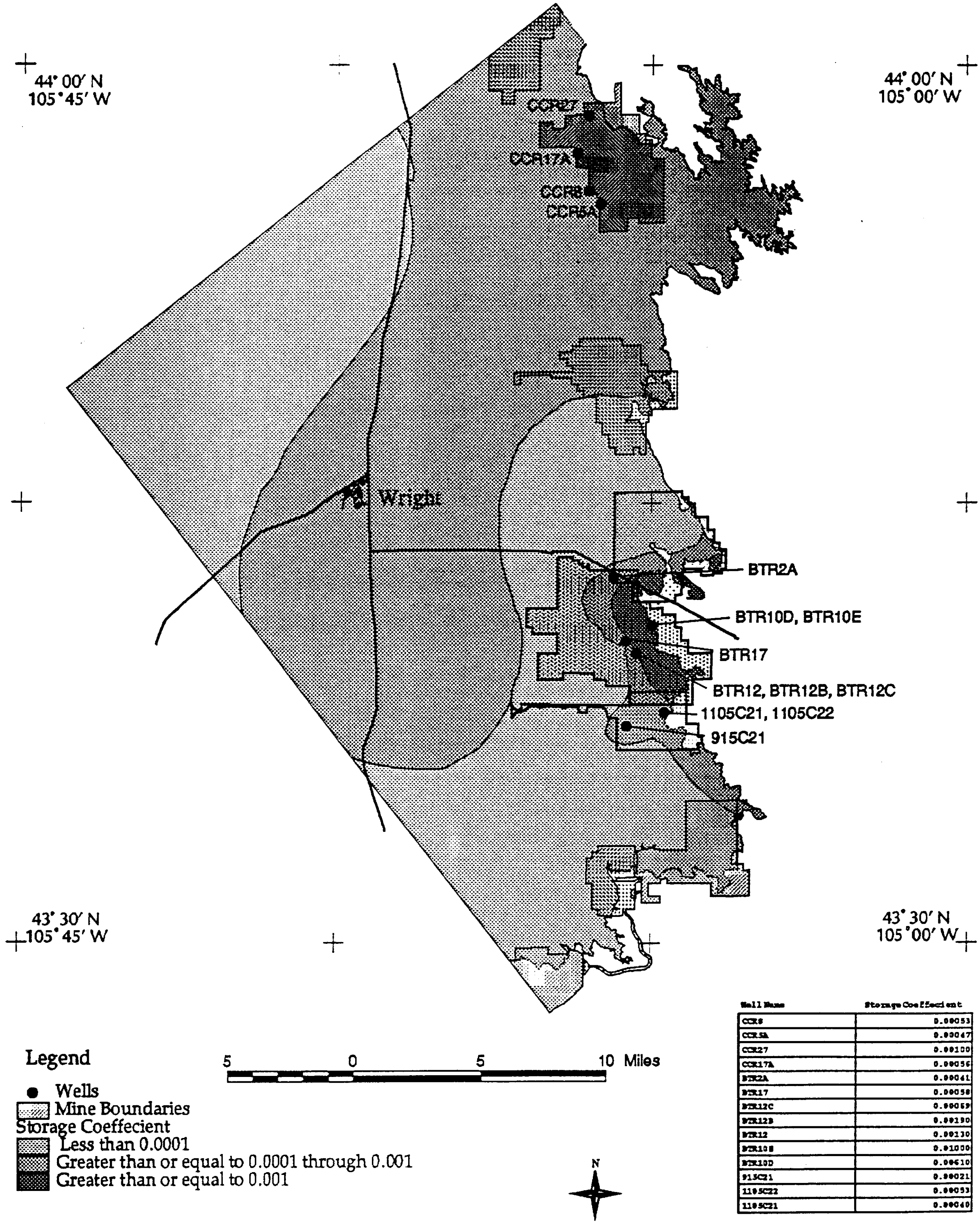
Storage coefficient data in the general area for all aquifers are included in Appendix F. The data source is aquifer tests contained in mine PTMAs. Where storage was extracted from a pump test, the data were committed to the CPR. The data are again spatially clumped near the coal cropline, with far fewer data than for hydraulic conductivity.

There are 25 values of storage coefficient in the Wyodak Coal and 10 values in the Wasatch Formation aquifers in the general area data set. Of these data, 18 values in the Wyodak Coal, and 4 values from pump testing in the Wasatch aquifers are within the Pilot Study Area. No values for the Backfill or Clinker were reported in the complete general area data set from the nine mines (Appendix F).

All four reported values of storage for the Wasatch Formation in the Pilot Study Area were 0.1. This would indicate a single, unconfined value of storage throughout the Pilot Study Area. Since storage is likely to decrease downdip from increasing saturated thickness and increasingly confined conditions, a value of 0.01, reflecting more marginally confined conditions, was used for the Wasatch sediments.

A spline contoured map showing ranges of storage coefficient in the Wyodak Coal Aquifer within the Pilot Study Area is presented in Figure 4-1. In general, storage coefficient declines to the west

Figure 4-1:** Contoured ranges of storage coefficient in the **Wyodak Coal Aquifer



Well Name	Storage Coeffecient
CCR8	0.00053
CCR5A	0.00047
CCR27	0.00100
CCR17A	0.00056
BTR2A	0.00041
BTR17	0.00058
BTR12C	0.00069
BTR12B	0.00190
BTR12	0.00130
BTR10E	0.01000
BTR10D	0.00610
915C21	0.00021
1105C22	0.00053
1105C21	0.00040

as hydraulic head in the aquifer increases, although an area of increasing storage coefficient is located centrally in the Pilot Study Area. This is an anomaly of the contouring method that closely honors the available data. Data at the Coal Creek Mine was included in the storage data set, and these data are significantly west of the three mines in the central Pilot Study Area.

Starting Heads

Starting heads for the model were obtained from the CPR database. Initial groundwater elevation values from wells in the Pilot Study Area were used. The earliest available data were used in all cases. At Jacobs Ranch and Black Thunder Mines, data exist from 1975 and before. North Rochelle Mine elevations from the early 1980s represent the most recent measurements, with the exception of a single BLM monitor well near the western grid boundary. Starting levels were obtained for the Wasatch Formation Aquifer, the Wyodak Coal Aquifer, and the Clinker Aquifer. The groundwater elevations were then gridded. The gridded data, representing the model starting heads, was appended to the ARC/INFO point coverage, and the staring head array was extracted. Initial groundwater elevations for wells completed in the three aquifers is presented in Appendix D.

General Head Boundary Conductance

A valid model solution to head dependent boundary recharge is dependent on reducing the coal/clinker/overburden boundary to a quantifiable recharge/discharge relationship. Recharge/discharge on the boundary is dependent on an appropriate conceptualization and spatial description of hydraulic properties between the clinker and recharged areas.

Given the above, MODFLOW calculates flow to and from constant head nodes, and if specified, will output these values to a binary file by front, right, and lower face flow. Since the general head boundary assumes a constant head portion (clinker), as well as a semi-permeable zone (zone of alteration) and model domain (coal and Wasatch sediments), it is possible to back-calculate values of conductance across the boundary:

$$\text{Conductance} = Q_{(\text{steady state flow constant head})} / (\text{Head}_{(\text{clinker})} - \text{Head}_{(\text{model domain})}$$

where the MODFLOW parameter conductance can be expressed as

$$\text{Conductance} = \text{Transmissivity} * \text{cell width} / \text{Length of Flowpath}_{(\text{clinker-model domain})}$$

Given that T = Kb, and combining the two equations, this becomes a restatement of Darcy's Law

$$Q = K^* (H_2\text{-}H_1) / L_2\text{-}L_1)^*(B^*W)$$

where K is the harmonic mean of hydraulic conductivity between the clinker and model domain (zone of alteration), and (B*W) is the saturated cross-sectional area of the model cell; head and flowpath as stated above. Both flowpath length and cell area are model calculated from user inputs in the model setup. The remaining parameter is the value of harmonic mean of hydraulic conductivity between the boundary cell that contains the zone of alteration and the clinker. This can be derived by assuming the hydraulic conductivity of the altered zone can be approximated as the geometric mean of the hydraulic conductivity in the clinker and model domain.

$$K_{(\text{zone of alteration})} = (K_{(\text{domain})} * K_{(\text{clinker})})^{1/2}$$

It is necessary to reduce this value to accommodate the width of the semi-permeable zone with respect to the model cell. Gerlach (1995) gives the width of the "zone of alteration" as 250 ft. at North Rochelle Mine.

$$K_{(boundary\ cell)} = 250 \text{ ft. /cell dimension} * K_{(zone\ of\ alteration)}$$

For ease of computation, the zone of alteration was assumed to be 33% of the smallest grid cell dimensions (825 x 948 ft.). This value actually ranges between 26.4-30.3%. However, this would assume that the altered zone traverses the minimum distance across a cell. The 33% is a reasonable and probably conservative value of the actual contact, and assumes that the coal/clinker/overburden contact is uniform in each cell of similar size. The actual value of the boundary cell hydraulic conductivity will vary with cell dimension.

Water Budget

The continuity equation for flow in an aquifer can be described as,

INFLOW - OUTFLOW = CHANGE IN STORAGE

For steady state flow,

INFLOW - OUTFLOW = 0

Components of inflow for this model include:

- Recharge, areally applied to the top surface;
- Inflow from the head dependent model nodes (general head boundary) at the interface between the clinker and the unburned coal and overburden; and
- Inflow from constant head nodes on the south and west.

Components of outflow from the model domain include:

- Outflow along the head dependent boundaries at the coal-clinker interface;
- Outflow along the south and west boundaries of the model domain from constant head;
- Outflow from stresses modeled as wells (CBM wells); and
- Outflow from stresses modeled as drains from surface mining (pit discharge).

At a given time t_1, the equation,

$$In_{(rech)}(t_1 - t_0) + In_{(cons\ hd)}(t_1 - t_0) + In_{(gen\ hd)}(t_1 - t_0) - Out_{(gen\ hd)}(t_1 - t_0) - Out_{(cons\ hd)}(t_1 - t_0) - Out_{(drain)}(t_1 - t_0) - Out_{(well)}(t_1 - t_0) = Storage\ (t_1 - t_0)$$

would yield the quantity of water (water balance) taken into or released from storage for the given time increment.

For steady state flow,

$$In_{(rech)} + In_{(cons\ hd)} + In_{(gen\ hd)} - Out_{(gen\ hd)} - Out_{(cons\ hd)} - Out_{(drain)} - Out_{(well)} = 0$$

gives a similar balance.

Model Time Increments

Initial conditions for the model were input into the appropriate MODFLOW modules, and the model was run without pumping or pit inflow stresses for one day. This allows the model to relax the initial heads, solve for flow between cells, and solve the global model steady state mass balance. Model outputs are steady state heads that are inputs in the transient state runs.

Transient state stress periods for 1977-1995 are years. The number of individual time steps within each stress period (year) are user determined, and the length of each time step is calculated using a non-linear equation that relates time step length to the stress period length and the number of time steps within the stress period. The result is that time steps gradually increase in length through the stress period. This helps to reduce model instability when model stresses change at the beginning of each stress period.

Model stress periods for the period from 1996-2005 were months in the CBM simulations. This allowed for additional CBM wells to be added to the model on a monthly basis. From 2006-2021, stress periods were again set to one year.

Computer Code Description

The code for MODFLOW, as used in this investigation, is detailed completely in McDonald and Harbaugh (1983). MODFLOW has been tested through application to groundwater flow problems since 1983, and the code verified to approximate the continuum equations when all discrete space and time intervals are small.

Assumptions

Each of the functional relationships for hydraulic head are refined into a discrete system using spatial grids and time steps to identify small homogeneous cells, or discrete parts of the flow system. Hydraulic parameters are then assigned to individual cells, and between cell flows can be calculated by iterative applications of Darcy's Law. The MODFLOW block-centered approach assigns hydraulic values and initial conditions at a node in the center of the block. The block size is defined by user inputs. The smaller the block, the better the method will become as a system approximation. Numerical techniques are less restrictive than analytical techniques. Heterogeneities and anisotropy can be modeled. Many assumptions are built into the finite difference method, most are related to the extent that the discrete flow system approximates the continuum. Models are improved by spatially decreasing the size of the cells, and temporally by shortening the length of time steps. The extent that the additional subdividing of space and time improves the model must be weighed against the requirements for more data and increased computer time.

Limitations

Limitations of numerical techniques are the need for large, extensive data sets. Frequently, these data sets are quite cumbersome, abstract, and they are difficult to interpret without the knowledge of the application that is imparted by the modeler. All problems are compounded when dealing with large area models. Update and analysis of data sets is difficult; computer central processing unit (CPU) time may be extensive, and numerical models produce non-unique solutions. The fewer simplifying assumptions that are included in the conceptual model, the more complex the final numerical model becomes.

Additional limitations are encountered in a non-rectangular model domain. The finite-difference rectangular grid mesh poorly approximates irregular boundaries in cells that are not adequately refined. In practice, rectangular boundaries seldom occur; this becomes a trade off between analysis, computer time, and acceptability of model results. Alternatively, finite element models are readily adaptable to irregular boundaries, but are less routinely used and accepted.

Computer code for finite differencing methods are tested for reliability by verifying *consistency* (continuum equations are approximated in the limit), *convergence* (the solution approximates the differential equations in the limit...generally provable only in simple case where closed form solutions to the differential equations exist), and *stability* (errors due to round off and approximation do not increase in magnitude with time). For further reference see Bear and Verruijt (1987).

Solution Techniques

Finite difference approximations for groundwater flow state that head, the unknown, which is a function of x, y, z, and t, can be represented for every increment of time t, by assigning initial values of head at systematically defined locations in the model domain. Values of head at all locations (the block centered grid nodes in MODFLOW) are related to the surrounding six nodes (for an interior, intermediate layer cell). The initial conditions (values of head at the starting time) are known or can be approximated, and the solution becomes a system of "n" equations with "n" unknowns (where "n" is the number of cells in the model domain), which must be solved simultaneously using matrix solution techniques.

Head is solved for at all nodes in the model domain (with special applications of image theory for boundary cells), until each node has a new value of head. A user defined criterion for convergence (usually head change between iterations) is tested for, and the process is repeated until the closure criterion is met. A complete discussion of this technique for MODFLOW is available in McDonald and Harbaugh (1983).

Model Effects

The finite difference approximation is best where the cells are the smallest (Plate 1). The assumption is that properties of each cell are homogeneous within the cell. Differential sizing of cells allows an increasing cell size, and reduces input needs in areas remote from stresses. Gradually increasing the size of cells improves the notion of homogeneity between adjoining cells.

Model inputs rely on in-situ data where it is present, and will use statistical techniques, interpolation, and extrapolation elsewhere.

The finite-difference method effects on non-linear boundaries have been discussed. For the present model, this is limited to the eastern coal/clinker/overburden contact. Within the smallest grid cell areas, the approximation of this boundary is best; each cell has a dimension of 825 x 948 ft. Initial inputs for the larger grid cells should be considered to represent more central-tending values

Model Construction

Model Domain

The model domain is presented in Plate 1. The entire model grid covers 790 square miles (mi.^{2}). Model spacing along rows varies from 825-8,250 ft. The dimensions along columns varies from 948-9,475 ft. The smallest grid cells completely enclose the present permit boundaries of the Jacobs Ranch, North Rochelle, and Black Thunder Mines. The smallest grid cells represent 17.95 acres, while the largest grid cells represent 1,794.5 acres. Similarly, the smallest grid cells represent approximately 0.028 mi.^{2}, while the largest grid cells represent 2.8 mi.^{2} (Appendix H).

Where stresses are imposed, it is desirable to minimize the distance between node centers to insure that nodes can be adequately represented in the flow system by a single hydraulic value. It also greatly increases data requirements when dealing with regional models. The multiplier for successive grid cells is 1.47 in the grid transition zones. The multiplier was limited to below 1.5 to insure transitional stability in the model flow system. As cells become larger, the tendency for the previously discussed homogeneity assumptions to be violated and cause model instability is increased. For this model, the grid size increase takes place over six cells. A complete grid size index is presented in Appendix H.

The relationship of grid size to the physical system was also considered. Surface mine disturbance from actual and projected mining occupies at least one grid cell per year (1977), whereas cumulative mining disturbance routinely exceeds 20 cells/year (Appendix C, Plate 2).

The zone of alteration (Gerlach, 1995) is the physical equivalent of the semi-permeable zone between domains in the general head boundary. This would intercept between 25-30% of the smallest grid cells, depending on the boundary orientation. Representation of boundary flow at this level is adequate. Mapped clinker areas were also well delineated by the smallest grid cell size. For areas within the mining areas, it was possible to reasonably describe the irregular boundary at the 825 x 948 ft. resolution. Elevations of geologic surfaces could be determined directly at node centers of the grid, thus eliminating the need for interpolation and extrapolation of geologic surfaces.

Model Layering

A quasi-3-dimensional approach to the model system was chosen to simulate the model domain. The overlying Wasatch Formation was simulated as a single layer, as was the Wyodak Coal Aquifer. The Wyodak Coal Aquifer was considered completely confined by an underlying low permeability zone, and differentially confined by an overlying low permeability zone (Plate 11, parts B, C, D). The underlying hydrogeologic confining unit corresponds to lithologic units in the Lebo Shale and/or Tongue River Formations, while the overlying confining unit corresponds to lithologic units in the Wasatch and/or Tongue River Formations, depending on the geologic interpretation (see pages 3-26 through 3-27).

Vertical leakance was implicitly specified for the confining layer over the coal by assuming vertical hydraulic conductivity in the confining unit to be much less than vertical hydraulic conductivity in the Wyodak Coal Aquifer and sediments that overly the confining unit. Vertical leakance between the two aquifers has not been historically investigated, and quantitative data are not available. This approach allowed an approximation of vertical leakance between the Wyodak Coal Aquifer and the overlying sediments. ACMLRP research, under Borgman et al. (1995) will address this parameter quantitatively.

Data Pre-Processing and Post-Processing Software

Data for the model were handled using a variety of methods and software. Pre-processing and post-processing software is included in Table 4-3, with a brief description of how it was used.

Table 4-3: Data Pre-processing and Post-processing Software

Software	Purpose
The UNIX editor Jot	Creating and editing of data sets in model setup and intermediate steps
Premod (Anderson, 1992)	Initial model setup
Postmod (Williams, 1993)	Reading MODFLOW produced binary output, and writing it as ASCII text
ARC-INFO (1996)	Arc Macro Language Scripts
MODARRRAY (Winkless and Kernodle, 1994)	Extracts a MODFLOW data array from Point, Arc, or Poly coverage
MODELGRID (Winkless and Kernodle, 1993)	Generates a MODFLOW grid in point, line, and arc topology given DELR, DELC, NROW, NCOL, and ANGLE OF ROTATION.
CONTOUR (Oakleaf, 1996)	Extracts and contours ARC INFO point coverages.
MODTOARC (Kern, 1995)	Extracts calibration/validation values from post-processed ASCII data, and computes summary statistics
Quattro-Pro (1993)	Utilized to generate data sets for MODFLOW packages such as DRAIN, WELL, and BOUNDARY. Summary statistics.
Variowin (Pannatier, 1994)	Test variography for geostatistical applications
GEOEAS (1992)	Geostatistical application of Kriging and cross-validation.
Earthvison (1994)	Data development and initial conditions

Hydraulic Parameters

Table 4-4 is a tabular presentation of MODFLOW input parameters, whether input as an array or as a constant, and the method used in calculation of the value.

Table 4-4: Model input parameters

Modeled geo. unit	Parameter	Distributed/ constant	Method/value
Wyodak Coal	Pre-mine hydraulic conductivity	Distributed	Based on mean 3.5 ft./day
	Primary storage coefficient	Distributed	Spline contour
	Thickness	Distributed	Extracted from kriged surfaces
	Anisotropy	constant	2:1 with sensitivity
Wasatch Formation/ Wyodak Coal Confining Layer	Pre-mine hydraulic conductivity	DNA-implicit	Not explicitly input
	Post-mine hydraulic conductivity	DNA-implicit	Not explicitly input
	Pre-mine Vcont	Constant	2.8E-09 ft./day-ft.
	Post-mine Vcont	Distributed	0.02 mined cells; 2.8E-09 ft/day-ft. unmined
Wasatch Formation	Pre-mine hydraulic conductivity	Constant except boundary	Based on 0.2 ft/day with sensitivity
	Post-mine hydraulic conductivity	Constant except boundary	0.2 ft/day with sensitivity
	Primary storage coefficient	Constant	0.01
	Thickness	Distributed	Digital elev. Models-top of Wyodak Coal
Backfill	Hydraulic conductivity	Constant	0.2 ft/day
	Primary storage coefficient	Constant	0.01
	Thickness	Distributed	DEMs - Top of Coal

Vertical Leakance

True three dimensional modeling would require complete data sets for the confining layer overlying the Wyodak Coal, including thickness and hydraulic conductivity; this data intensity is not available for this layer. Quasi-3-dimensional modeling assumes an aquifer relationship, and it does not explicitly specify all data for the confining layer: there is not top surface, bottom surface, etc. Instead, vertical leakance between layers is implicitly modeled. Vertical leakance (Vcont) for both pre- and post-mining is input in MODFLOW as a parameter using the following relationship for quasi-3-dimensional models:

$$\text{Vcont}_{i,j,k+\frac{1}{2}} = \frac{1}{\dfrac{\frac{\Delta z_u}{2}}{K_{z_u}} + \dfrac{\Delta z_c}{K_{z_c}} + \dfrac{\frac{\Delta z_l}{2}}{K_{z_l}}}$$

z_u is the thickness of the upper grid cell (i,j,k);
z_c is the thickness of the semi-confining unit;
z_l is the thickness of the lower grid cell (i,j,k+1);
Kz_u is the vertical hydraulic conductivity of the upper grid cell;
Kz_c is the vertical hydraulic conductivity of the semi confining layer; and
Kz_l is the vertical hydraulic conductivity of the lower grid cell.

Where vertical hydraulic conductivity is much smaller in the confining layer, the equation may be approximated as,

$$\text{Vcont} = Kz_c/\Delta z_c$$

since the calculation is dominated by the confining unit term. Vcont has dimension of ((L/T) /L) or 1/T.

Freeze and Cherry (1979) provide a range of hydraulic conductivity for shale of 10^{-13} to 10^{-9} meter/second (m/sec.). Converting length units to feet, assuming $K_v \approx 0.1 * K_h$, a 10 foot thickness of the confining unit, and converting time units to days, the range of Vcont is 2.8×10^{-9} to 2.8×10^{-5} ft./day-ft. Initially, the minimal value for Vcont was chosen because it was the only value that uniquely represented shale. Hydraulic conductivity values in the range of 10^{-12} to 10^{-9} m/sec. are also representative of marine clay and glacial till. Sensitivity on Vcont between 2.8×10^{-9} and 2.8×10^{-5} ft./day-ft. is discussed on page 4-30.

For the post-mining scenario, where the Backfill Aquifer is present (all mined cells), and the confining layer is absent, $K_{backfill} \approx K_{wasatch} \approx 0.133$ to 1.33 ft./day; $K_v = K_h$ (isotropic) and absence of the confining unit, Vcont will range between 2.7×10^{-2} and 2.7×10^{-3} ft./day-ft., assuming a 50 foot thickness between node centers. The simplified equation for Vcont is still appropriate. A value of 2.0×10^{-2} ft./day-ft. was used in the model.

Model Hydraulic Conductivity Inputs

Model hydraulic conductivity inputs for the Wasatch Formation and the Wyodak Coal Aquifers are presented in Table 4-5. Wasatch Formation aquifer testing was limited to eight tests in the Pilot Study Area (Table 4-2). The data for the these tests indicate low variability in hydraulic conductivity. The reported values of hydraulic conductivity for the Wasatch Formation in Martin et al. (1988) were used in the model, with sensitivity analysis on this input.

Hydraulic conductivity for the Wyodak Coal Aquifer is based on *in-situ* values reported in Table 4-2. Individual values of hydraulic conductivity were adjusted during calibration and verification to minimize root mean square RMS error.

Table 4-5: Comparison of pump test values to the final model hydraulic conductivity inputs values for the aquifers

Aquifer	In-situ Hydraulic Conductivity (ft/day)	N	Model Hydraulic Conductivity (ft/day)	N
Wyodak Coal	3.52	38	3.03 (calibration)	3,897
			2.69 (1996 verification)	3,897
Wasatch Formation	0.45	8	0.2	3,874
Clinker	51,000	2	31, 000	106

Hydraulic conductivity in the coal was changed during the calibration and verification phase from the initial mean value of 3.52 ft./day. The changes were made to calibrate and verify the model to individual groundwater targets. The results of the changes during this phase reduced the mean of the logs of hydraulic conductivity inputs in the Wyodak Coal Aquifer to 3.03 ft./day after calibration, and 2.69 ft./day after verification. All changes were within the mine permit areas, primarily at the North Rochelle and Jacobs Ranch Mines to support observed water levels in the area.

Sources and Sinks

Distributed Sources

Distributed sources are limited to recharge to the top layer. This is included in the modeling scenario to simulate vertical recharge from precipitation and snow melt. Precipitation in the PRB averages 10-16 in./year (Marston, 1990). PRB evapo-transpiration (PET) exceeds precipitation, generating an annual negative water balance.

Nevertheless, recharge from summer convective storms and snow melt in the spring probably occurs, especially on the more permeable surficial materials. There is little quantitative information on precipitation/infiltration dynamics in the PRB. This model assumes that the amount is small, given the PRB water balance (PET>precipitation), and investigates model sensitivity to recharge.

The following method was used to develop the initial value of recharge to the top layer. Assuming a range of precipitation over the PRB of 0.833-1.33 ft./year, yields a daily value of 0.0029 ft./day using the geometric mean of the range (1.05 ft./year). Further, assuming 1% falls on permeable material and 2% of that infiltrates, a value of 6.0×10^{-6} ft./day may provide an initial approximation of vertical recharge from precipitation. This is equivalent to 0.00022 of total PRB precipitation per year. Sensitivity on this parameter is discussed on page 4-30.

Point Sinks

Point sinks for the modeled scenario include the 50 well Lighthouse CBM cluster, and the surface mining pit/drain scenario. CBM development included in this model is limited to the south 50 wells originally proposed in the Lighthouse CBM environmental assessment (Plate 2). Modeled stresses for surface mining are presented (Figure 4-2), and modeled stresses for these wells are included (Figure 4-3).

Stress rates for CBM production have been presented in graphical format in Figure 4-3. Stress rates for CBM were calculated by assuming initial pump rates of 4,813 ft./day (25 gpm), from WSEO's permits, and decaying that pump rate through time, assuming the following relationship.

$$Q_{current} = Q_{initial} * \text{stress period}^{0.2}$$

All pump rates are then calculated for an anticipated life of gas production of 10 years. According to this scenario, assuming eight additional CBM wells come on line per stress period (per month), and allowing an additional well in two of the stress periods, all 50 CBM wells will be on line in six months. This assumes that 50 wells will be the maximum number in production in the model domain, and that the initial pump rate will be approximately 4,813 ft^3/day, and it will decay with time. These appear to be reasonable assumptions based on personal communications with Peck (1995) at the Martens and Peck Operating Company, and the WSEO. Should additional data become available, future modifications will be possible.

Stress rates for the mine pits are presented in Figure 4-2, and they are based on the Theis non-equilibrium well equation, adapted to accommodate "big wells."

$$Q_{pit\ inflow} = Ts/114.6W(u)$$

where,

Q is pit inflow in gpm;
T is aquifer transmissivity in gallons/day-ft, and varies depending on cell value of hydraulic conductivity and the saturated thickness of the Wyodak Coal and Wasatch Formation Aquifers at mined cells;
W(u) is "well function of u" representing the exponential integral;
s is aquifer drawdown in feet measured at the pit face (here assumed to be 60% of the saturated thickness);
t is the time the "well" is discharging (here taken as 365.25 days);
"u" is

$$1.87r^2 S / T t$$

where S is a dimension less storage coefficient, and r is the distance in feet from node center to pit face calculated as,

$$2/\pi \, (L*W)^{1/2}$$

where L and W are the cell length and width, here equal to 825 ft. and 948 ft., respectively.

Figure 4-2: Cumulative mean modeled pit inflow for the North Rochelle, Black Thunder, and Jacobs Ranch Mines

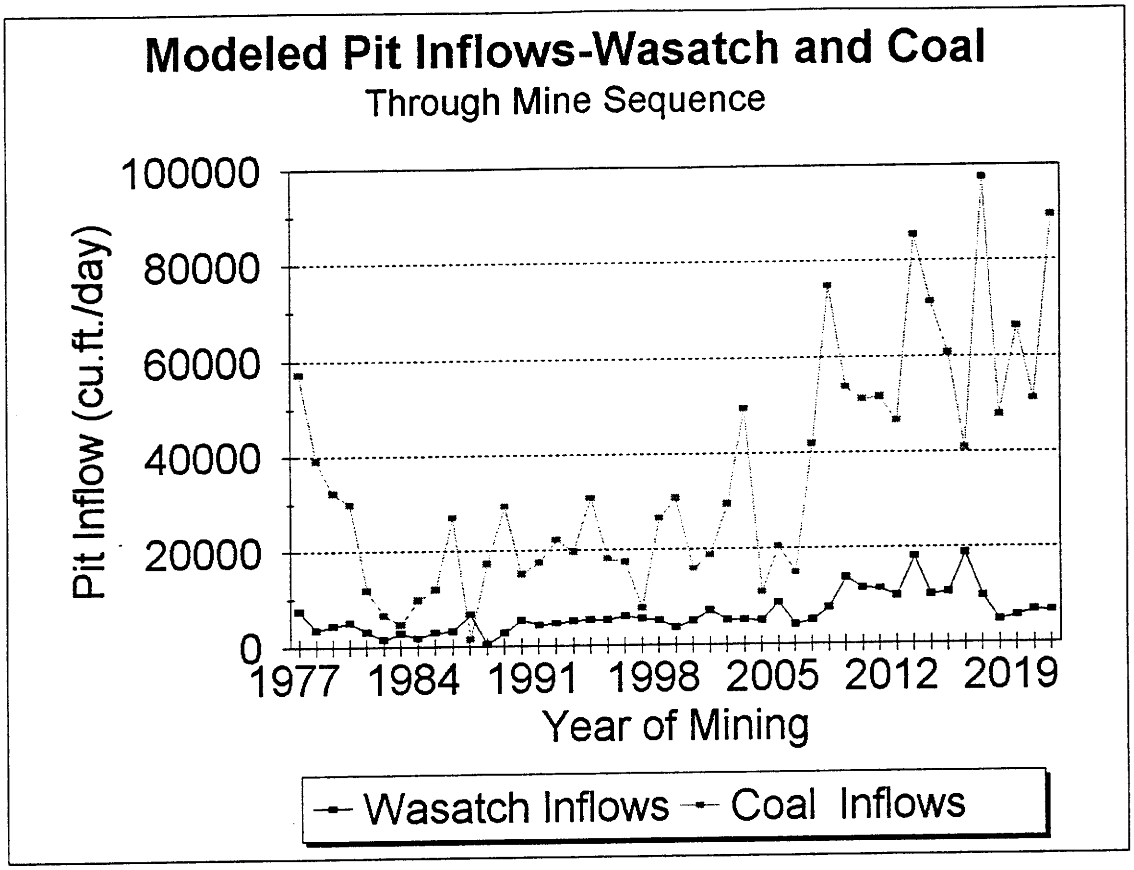
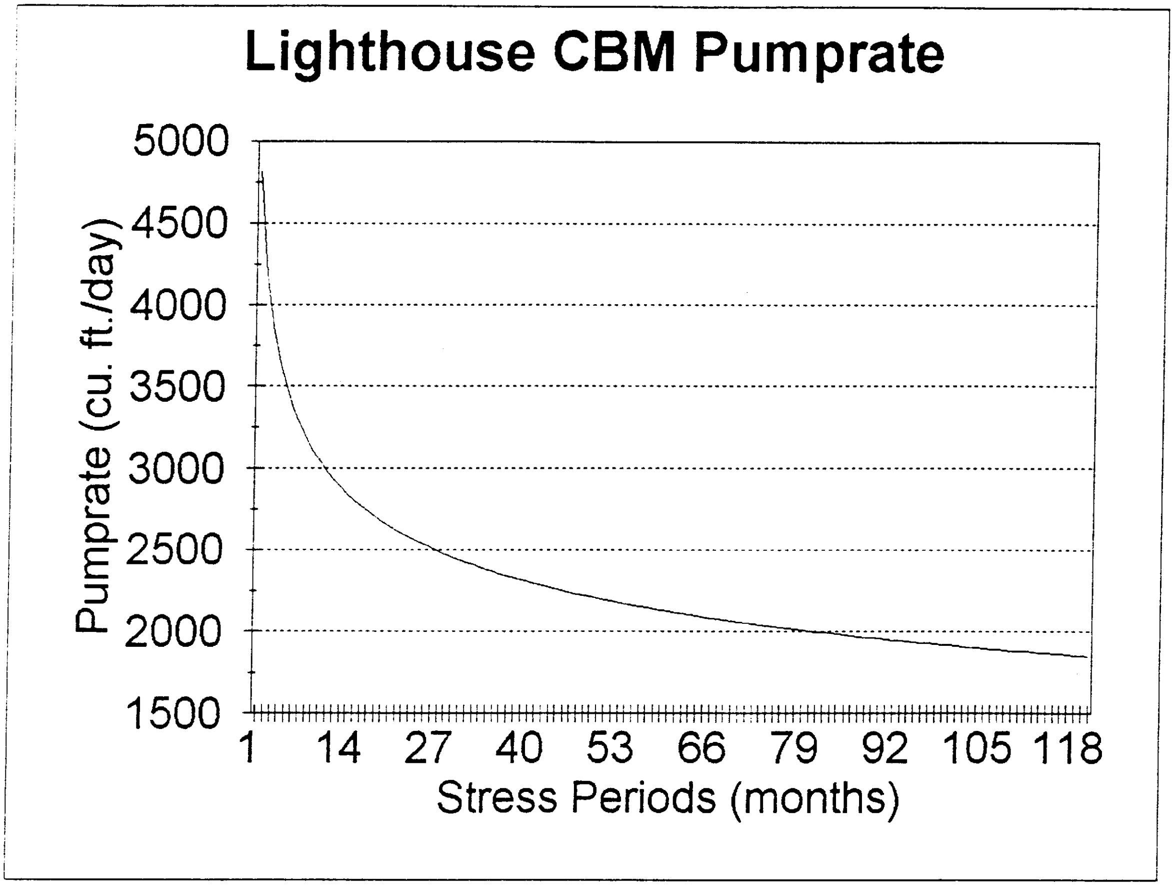


Figure 4-3: Modeled point sink data for CBM production



Knowing Q, it is possible to directly calculate MODFLOW conductance from the relationship

$$\text{Conductance} = Q / (\text{head}_{\text{in cell}} - \text{head}_{\text{out of cell}})$$

where conductance is as previously stated, and it is the needed parameter in the MODFLOW drain package; $\text{head}_{(\text{in cell})}$ is taken as the elevation of the drain (in this application equal to a 60% seepage face), and $\text{head}_{(\text{out of cell})}$ is equal to the steady state head. Appendix C shows the complete calculation for pit inflow.

Boundary Conditions

Boundaries to a flow system seldom are ideal (abrupt) boundaries except at discontinuities. Where flow system boundaries are approximated by idealized boundaries, it is specified that variations occur abruptly, recognizing that this is an approximation of the natural system. Values representative of continuum conditions can then be applied on either side of the boundary. Model boundaries are located on Plates 3 and 4. Designation of individual boundaries are given following their mathematical description below.

1) For the model domain several boundary conditions are present. A constant (specified) head boundary is incorporated at several locations. This is equivalent to specifying that the model domain media is in direct contact with a body of water:

$$hd = constant \qquad on\ W_1, W_2, C_1, C_2$$

This boundary condition, also called an equipotential boundary, is a specialized version of the Dirichlet Boundary (Bear and Verruijt, 1987).

2) For the coal/clinker/overburden interface, a mixed boundary condition is used. This condition states that one porous media is in contact with another porous media (or water body) through a semi-pervious layer. Assuming no change in storage in the semi-pervious layer, flux normal to the boundary can be expressed functionally as:

$$F(\Phi_{model\ domain} - \Phi_{external})*c$$

where c is the ratio of thickness to hydraulic conductivity (K/B) of the semi-pervious layer. For an anisotropic porous media in two dimensions,

$$(K_x\ \partial F/\partial x\ \partial\Phi / \partial x + K_y\ \partial F/\partial y\ \ \partial\Phi /\partial y) + \Phi_{domain}(\partial F/\partial x,\ \partial y)/c = \Phi_{external}(\partial F/\partial x,\ \partial y)/c\ on\ C_3, W_3$$

F is as defined above; Φ is total hydraulic head. This boundary condition relates the state variable to its derivatives, and it is called a general head or mixed boundary.

3) For a limited number of cells in the Wyodak Coal layer, and for internal boundaries modeled as discontinuities, the boundary condition is specified as impermeable:

$$Q_{x,y} = K_{x,y} /x,y\ B = 0 \qquad on\ C_4, C_5, C_6$$

Selection of Calibration Targets and Goals

Coal

Steady state calibration targets for the model in the Wyodak Coal are described as all wells that possessed groundwater head elevation data representing pre-mining conditions. Initially these were conceptualized as 1975 and before. The number of wells that met this criterion were extremely limited (Appendix D). By assuming that negligible impact occurred in the model domain before 1977, the number of wells was significantly increased for both the Wyodak Coal and Wasatch Formation Aquifers. Finally, in the process of verification, it became obvious that calibration targets were needed at the North Rochelle Mine. Targets at the North Rochelle Mine were initially excluded from the calibration due to the relatively late time data (approximately 1980). The need for an assessment of initial conditions of the North Rochelle Mine necessitated the inclusion of these data in the model calibration phase. The Wyodak Coal Aquifer was also calibrated to data *outside* of the smallest grid cell area, which was representative of pre-mining groundwater elevations at the Coal Creek, Rochelle, Keeline, and North Antelope Mines. These data were used only for initial calibration, assuming that the earliest time data represented "baseline" conditions, and that water levels had essentially not been impacted. A single additional coal well, noted in the tables as BLM MON, was used in an attempt to add data west of the mines where the coal potentiometric surface was not monitored. The data for BLM MON are from 1995, and assume no significant impact at this point from 1975-1995.

Wasatch Formation

Calibration targets for the Wasatch Formation were more difficult. Initially, a similar series of wells to the coal wells series was selected and expanded to 1977 and before. Problems arose in the north due to the mapped "full seam" Wyodak Coal line lying to the west of specified Wasatch Formation wells at the Coal Creek Mine (Plate 1). As defined, the full seam line would represent the top of the Wyodak Coal, or alternatively, the top of the Anderson split if a split exists. Since the top of the Wyodak Coal is the eastern most extent of the Wasatch Formation, it would be impossible to have Wasatch Formation wells to the east of this line. Two possible explanations for this are that wells designated as Wasatch Formation wells at the Coal Creek Mine are actually completed in Quaternary deposits. Secondarily, the mapped full seam line as modeled in this area could represent a rider coal that is stratigraphically above the Wyodak Coal. This explanation would affect the geologic model at the Coal Creek Mine, but it should have negligible effect in the Little Thunder Creek Drainage. This issue may be resolved when the Coal Creek Mine area is modeled. For the present model area, Wasatch Formation targets were limited to the smallest grid cell area. This limited the Wasatch Formation validation targets available, but it was used for the above reasons, and because of the lenticular nature of the Wasatch Formation.

Goals

Calibration for the model was evaluated with respect to three quantitative goals. Mean error was checked as an estimator of model bias. Absolute error, or the maximum error observed at a single calibration location, was minimized as a secondary criteria to RMS error. RMS error optimization, given as,

$$RMS = \sqrt{\sum_{i=1}^{n} \frac{(observed - predicted)^2}{n}}$$

was used as the primary model goal.

Numerical Parameters

The strongly implicit procedure (SIP), slice successive over-relaxation (SSOR), and Pre-conditioned Conjugate Gradient (PCG2) solvers were all tested on the model (McDonald and Harbaugh, 1988; Hill, 1990). The SIP solver relies on choice of seed number as a numerical input parameter to improve closure and to minimize model iterations. Closure for SIP was only achieved for simple initial runs. As model complexity was increased with the addition of the general head boundary package and stress packages, the linear system of equations became difficult to converge. The trial and error process to refine model seed is cumbersome and time consuming, requiring multiple runs to evaluate.

SSOR provides a similar, although somewhat more flexible alternative. Acceleration (ACCL) in SSOR can be adjusted in a similar trial and error approach to solve the system of equations. Some success was achieved with the fully complex model, although long runs were susceptible to non-convergence as time steps increased in length.

The PCG2 solver uses Picard iterations to solve the system of equations (Hill, 1990). User specified input parameters include a linear and polynomial preconditioning method, HCLOSE (head change closure) and RCLOSE (residual change closure), and a matrix scaling alternative. Best model solutions were achieved using the polynomial pre-conditioner (POLCG) method for non-linear systems; the modified Cholesky frequently resulted in a non-diagonally dominant matrix. HCLOSE for all runs was set to 0.05 ft., with RCLOSE at 12.5 ft.^{3}/day. RCLOSE and HCLOSE agreement are achieved only with model time units in seconds. Further, the only valid test of RCLOSE is Global Budget Error (GBE) (Hill, personal communication, 1996). GBE for all model runs was less than 0.05% for an individual stress period, with cumulative error less than 0.01%.

Calibration and Verification

Quantitative Analysis

Calibration to observed groundwater elevations was done by iteratively adjusting hydraulic conductivity in the Wyodak Coal Aquifer, within the constraints of the conceptual model and observed hydraulic data. This was not done in the Wasatch Formation due to the scarcity of data, and an observed issue with Wasatch Formation well completion intervals between the Jacobs Ranch and Black Thunder Mines. The model was calibrated to groundwater elevation data from pre-mining conditions, or in some instances to the earliest available data. North Rochelle groundwater elevation data were used in calibration, even though the wells were first measured in late 1979 and 1980. These wells were needed for calibration of the smallest grid cell area south of the Black Thunder Mine. Data from seven mines and one expired lease (Keeline) for the Wyodak Coal Aquifer (Appendix D) were included. The calibration goal for the model was to minimize RMS error. Best achieved RMS error was 3.78 ft. in the Wyodak Coal Aquifer, with mean error of 0.49 ft, and maximum absolute error of 8.5 ft. Table 4-6 summarizes the results of calibration and verification.

Table 4-6: Results of RMS, mean, and maximum absolute error for the Wasatch Formation and Wyodak Coal Aquifers

Run	Wyodak Coal model error (ft.)			Wasatch model error (ft.)		
	RMS	Absolute (row, col.)	Mean	RMS	Absolute (cell)	Mean
Calibration	3.78	8.5 (71,78)	0.49	10.1	20.5 (17,40)	1.38
Verif. 1985	9.60	24.6 (43,39)	-4.32	23.8	37.1 (27, 27)	15.39
Verif. 1995	6.42	14.4 (48,27)	0.54	*	*	*

*Targets are for 1975 (pre-mining), 1985, and 1995. * Indicates that insufficient targets were available to verify the application.*

Calibration for the Wasatch Formation was limited to data from the Jacobs Ranch and Black Thunder Mines. This was done because of the discontinuous nature of the Wasatch Formation sediments. Groundwater elevations observed at targets outside of the smallest grid cell areas were deemed unlikely to represent water bearing units present within this area. Calibration targets for the Wasatch Formation were fewer than for the Wyodak Coal Aquifer. Completion intervals for the Wasatch Formation target wells were examined to address completion in the same water bearing unit, and they were found to vary. Wasatch Formation calibration error was compounded by this completion inconsistency. Individual wells at the Jacobs Ranch Mine are completed throughout the overburden, while Black Thunder Mine wells monitor single water bearing units. Best achieved RMS error in the Wasatch Formation, considering only the Jacobs Ranch Mine targets, was 10.1 ft., with mean error of 1.38 ft., and maximum absolute error of 20.5 ft. Plates 5 and 6 show modeled pre-mine potentiometric surfaces for both units. Individual calibration targets are shown in Appendix I.

Steady State Mass Balance

Table 4-7 shows the global budget for steady state conditions. Wasatch Aquifer hydraulic conductivity array for the coal ranges from 3.03 ft./day in the calibration run, to 2.69 ft./day in the 1995 verification run. The recharge values from the constant head boundary decline with declining coal hydraulic conductivity, as does the flow through the model domain, presented here as the net model from the constant head nodes on the west and south, the expected result.

Table 4-7: Calculated daily budget values for steady state conditions

Run	**Net vertical recharge ($ft.^3$)**	**Net general head boundary recharge(+)/ discharge (-) ($ft.^3$)**	**Net constant head recharge(+)/ discharge (-) ($ft.^3$)**
Calibration	6,866.1	(+) 118,100	(-) 152, 457
1995 Verification	6,866.1	(+) 104, 100	(-) 111, 344

Discussion

Model calibration the Wyodak Coal Aquifer for 1975 shows minimal RMS error and minimal bias. The maximum absolute error of 8.5 ft. occurs at well NA10A, a North Antelope well considerably south of the smallest grid cell area. When RMS error dropped below 10 ft., water level changes became more difficult to achieve at individual targets. Significant reduction in hydraulic conductivity in the coal at both the North Rochelle Mine and the Jacobs Ranch Mine was necessary to duplicate the steep hydraulic gradients.

Calibration in the Wasatch Formation was more problematic. An improved calibration using both the Jacobs Ranch and Black Thunder Mines overburden targets is unlikely given the variability in completion methods between mines for the overburden targets. The Wasatch Formation RMS error, considering only Jacobs Ranch Mine wells, may be improved with deterministic manipulation, although hydraulic data and the aforementioned completion inconsistencies in the Wasatch Formation do not seem to justify this method. Instead, the estimated hydraulic conductivity value of 0.2 ft./day from Martin et al.(1988) was modeled with sensitivity analysis. Using only the Jacobs Ranch Mine targets, RMS error in the Wasatch Formation is 10.1 ft. Considering both the Jacobs Ranch and Black Thunder Mine targets, Wasatch Formation RMS becomes 31.9 ft., mean error is 20.5 ft., and maximum absolute error is 66.38 ft.

The Jacobs Ranch Mine targets calibrate better than those of the Black Thunder Mine, because the model delineates Wasatch Formation water bearing units the way the Jacobs Ranch Mine wells are completed–as a single, marginally confined aquifer of thickness equal to SURFACE ELEVATION - TOP OF COAL. This is not an accurate interpretation of Wasatch Formation lenses, but the additional data needed to delineate individual water bearing units in the Wasatch Formation are significant, and lacking.

Improved calibration for the Wasatch Formation can be qualitatively discussed. Iteratively altering hydraulic conductivity at certain model locations could improve the RMS error for the layer. Altering global vertical recharge (precipitation) may positively affect RMS error, and it could be used to improve calibration for the combined Wasatch Formation data sets, but any comparison would be made suspect by the different completion intervals of the targets.

Sensitivity Analysis

Certain model parameters can be investigated by varying the parameter value, and comparing model response to the variability at targets. This provides insight into the sensitivity of the model to the parameter value.

Anisotropy in the coal

With minimization of RMS error as the model goal, coal anisotropy is best modeled using a 2:1 column to row anisotropy (Table 4-8). This suggests that for the Pilot Study Area, the coal is moderately anisotropic; K_{max} is oriented northeast-southwest, or approximately along model columns. Targets are steady state targets.

Table 4-8: Results of sensitivity analysis of anisotropy in the Wyodak Coal Aquifer

Column to Row anisotropy	**Wyodak Coal Model Error (ft)**		
	RMS	**Absolute (row, col.)**	**Mean**
3:1	4.83	12.30 (11,10)	1.75
2:1	3.78	8.50 (71,78)	0.49
1:1	6.00	18.54 (7,8)	-0.62
1:2	8.43	28.66 (54,61)	-1.66

Boundary

Model RMS error was checked for sensitivity to the Wyodak Coal and Wasatch Formation boundary conditions. Results are presented in Table 4-9. RMS error for groundwater elevations for both the Wasatch Formation and the Wyodak Coal were compared using a constant head and general head boundary. Results indicate that the model is not sensitive to the changing boundary conditions under steady state conditions. Model bias is slightly improved with the general head boundary. This suggests that the general head boundary approximates the constant head boundary for steady state conditions, which was the expected result.

Table 4-9: Results of sensitivity analysis for constant head vs. general head boundary conditions

Boundary	**Wyodak Coal model error (ft.)**			**Wasatch model error (ft.)**		
	RMS	**Absolute (row, col.)**	**Mean**	**RMS**	**Absolute (row, col.)**	**Mean**
General head	3.78	8.5 (71,78)	0.74	10.10	20.50 (17,40)	1.38
Constant head	3.68	8.6 (71,78)	1.07	10.09	20.51 (17,40)	1.49

Wasatch Formation Hydraulic Conductivity Sensitivity

Table 4-10 presents the results of sensitivity analysis on the hydraulic conductivity of the Wasatch Formation sediments. The targets are only the Jacobs Ranch Mine targets. The model is not especially sensitive to change in Wasatch Formation hydraulic conductivity. RMS error increases as hydraulic conductivity increases for values over 0.2ft./day. Maximum absolute error is inversely related to hydraulic conductivity for all values of K. Mean error varies within a small positive range for all values greater than 0.2 ft./day. The mean error indicates that the model narrowly under predicts the initial observed static water levels when global hydraulic conductivity in the Wasatch Formation is 0.2 ft./day or greater, and over predicts for hydraulic conductivity less than 0.2 ft./day. The number of dry cells increases with each of the model runs as hydraulic conductivity increases.

Table 4-10: Sensitivity analysis of global Wasatch Formation K

Global Wasatch Formation K	**Wasatch Formation model error (steady state targets) (ft.)**		
	RMS error	**Maximum absolute (cell)**	**Mean error**
0.04 ft./day	15.42	28.15 (37,31)	- 2.715
0.2 ft./day	10.10	20.5 (17,40)	1.38
1.0 ft/day	10.44	20.03 (17,40)	1.82
2.0 ft/day	11.99	19.55 (17,40)	1.45
3.5 ft/day	13.17	19.08 (17,40)	1.11

The sign reversal of mean error between 0.2 ft./day and 0.04 ft./day suggests that an improved calibration may be possible within this range. The magnitude of RMS error does not support this, however, nor does the inverse relationship of maximum absolute error. In any case, the improvement would likely be small, since the model does not appear particularly sensitive to this parameter.

Recharge Sensitivity

The results of sensitivity analysis on recharge to the top layer is presented in Table 4-11. Vertical leakance is constant at 2.8E-09 ft./day-ft. The Wasatch Formation Aquifer is very sensitive to recharge to the top layer, and the Wyodak Coal Aquifer is insensitive. Reducing the recharge by an order of magnitude results in a single Wasatch Formation Aquifer node drying at row 42, column 56, with all estimators of model error relatively stable. Increasing recharge by one and two orders of magnitude results in large increases in all assessments of model error for the Wasatch Formation Aquifer.

The mean error for the Wasatch Formation Aquifer suggests that the model moderately under predicts water levels when recharge is less than 0.600E-06 ft. The sign reversal in mean error suggests that model bias is optimized as recharge approaches the 0.600E-06 ft. of recharge.

Table 4-11: Results of sensitivity analysis for recharge to the top layer

Recharge (ft.)	Wyodak Coal model error (ft.)				Wasatch Aquifer model error (ft.)			
	RMS	Absolute (row, col.)	Mean	Dry cells (#)	RMS	Absolute (row, col.)	Mean	Dry cells (#)
0.600E-07	3.78	8.50 (71,78)	0.50	0	9.73	20.66 (17, 40)	2.70	1
0.120E-06	3.78	8.50 (71,78)	0.50	0	9.74	20.65 (17, 40)	2.56	0
0.600E-05	3.78	8.50 (71,78)	0.46	0	27.73	63.46 (37, 31)	-10.83	0
0.600E-04	3.78	8.47 (71,78)	0.47	0	172.96	418.84 (37, 31)	-97.04	0

Vertical Leakance Sensitivity

The results of sensitivity analysis for vertical leakance between model layers is presented in Table 4-12. Both model layers are sensitive to variation in vertical leakance, with greater sensitivity in the Wasatch Formation Aquifer. RMS and absolute error for the Wyodak Coal Aquifer increases as vertical leakance increases. Mean error varies within a narrow range. All measures of Wasatch Aquifer error increases as vertical leakance increases. The increase in mean error suggests that as vertical leakance increases, the tendency for the model to under predict water levels in the Wasatch Formation Aquifer increases.

The number of dry cells occurring in the Wasatch Formation Aquifer increases dramatically as vertical leakance increases. This drying occurs in the vicinity of the cropline, for the most part, where gradients are greatest and the cells are minimally saturated. The presence of dry cells does not necessarily invalidate the model, since the areal extent of the Wasatch Formation Aquifer is poorly defined.

The inverse relationship in the Wasatch Formation Aquifer error as vertical leakance is increased compared to increasing recharge to the top layer, suggests that another model solution may be possible by increasing vertical leakance, and minimally increasing recharge to the top layer.

Table 4-12: Results of sensitivity analysis for vertical leakance between model layers

Vcont (ft./day-ft.)	Wyodak Coal model error (ft.)				Wasatch model error (ft.)			
	RMS	Absolute (row, col.)	Mean	Dry cells (#)	RMS	Absolute (row, col.)	Mean	Dry cells (#)
0.280E-07	3.80	8.46 (71,78)	0.41	0	9.67	20.67 (17,40)	2.60	1
0.280E-06	3.96	8.34 (71,78)	0.14	0	12.80	22.28 (17,40)	8.69	28
0.280E-05	4.24	10.58 (25,2)	0.04	0	24.5	35.35 (17,40)	19.39	196
0.280E-04	4.65	14.26 (26,32)	0.184	0	32.21	48.23 (17,40)	24.6	308

Model Verification

The years 1985 and 1995 were selected as dates to verify the model application. These dates represent the approximate onset of increased mining activity in the PRB (1985), and the onset of the proposed CBM production (1995). Similar to calibration, verification targets were selected in the Wyodak Coal and Wasatch Formation Aquifers, and modeled water levels were compared to observed data. Where necessary, individual values of hydraulic conductivity were adjusted to improve the verification, since the location of verification targets differed from calibration targets. The nature of the mining process involves the destruction of targets: there are fewer verification targets than there are calibration targets (1975>1985>1995). Results of error analysis is presented in Table 4-6. A complete target data set is presented in Appendix I.

The number of verification targets is affected by the extent of monitoring data completion in the CPR database. All available database targets at the time of modeling were considered in the verification process. Individual targets were excluded for multiple completion, and location on the eastern boundary only.

Verification Discussion

1985

RMS error increased in the 1985 verification in the Wyodak Coal Aquifer, as did mean error. The negative mean error suggests systematic under prediction of drawdowns in the 1985 verification period. Several possible reasons for this are suggested below.

1) Lack of accuracy in the location of initial pit locations. This error may be several thousands of feet. The result of the pit location inaccuracy may propagate into water level inaccuracies in the modeled data.

2) Cells that are located on the eastern boundary (>50% within the model domain), and that were determined to be "mined" from pit location, were not mined due to violation of the assumptions of the general head boundary.

3) "Block centered" effects of the model process locate predicted groundwater elevations at node centers, while target monitoring wells are seldom at node centers.

4) Wells at the North Rochelle Mine were used during calibration, even though they were not described as "pre-mining" wells in the conceptual model. The time of first observation was 1980-1981 for these wells. They were added to improve the 1985 verification in the south of the Pilot Study Area. The degree that these values reflect pre-mine groundwater elevations will effect model accuracy.

5) Preponderance of "near pit" wells, and the compounding of this with pit (stress) location inaccuracies stated in number 1 above.

6) Number of mined cells is small for the 1975-1985 period.

7) The pit inflows are calculated from simulated inflows, and they are based on a 60% drawdown at the pit face. This is an approximation and may not be appropriate for every stress period.

Numbers 1, 2, and 3 require some additional explanation.

Paper PTMA maps were automated to Geographic Information Systems (GIS) and overlain on the MODFLOW grid to determine the historic mining sequence. Date of mining for the Black Thunder Mine on the paper maps was specified as pre-1992 only for the period from 1977-1992. Exact date of historic mining could not be determined. A similar lack of specific mining year was apparent at the Jacobs Ranch Mine, although reclamation mapping was delineated. Copies of the sequence information was sent to the Jacobs Ranch, Black Thunder, and North Rochelle Mines to allow them to more accurately delineate historic mining sequence. The North Rochelle Mine was the only mine to respond, although it had no historic (pre-1985) mining.

Two methods were devised to assign yearly stress periods to historic mining where the specific year was uncertain. In all cases historic mining was broken subjectively into smaller parcels. Lacking additional information, it was assumed that mining proceeded uniformly throughout the period. A location(s) of the initial box cut was selected, and mining moved in a single direction through the historic mined areas, thus distributing the disturbance systematically and uniformly through the years in question. This was the method employed at the Black Thunder Mine.

The extent of the historic mining was assumed to be one year prior to the reclamation activity for a particular area at the Jacobs Ranch Mine. For example, if reclamation was mapped as occurring in 1978, it was assumed that mining occurred in 1977. This is equivalent to assuming contemporaneous reclamation. Additional historic mining at the Jacobs Ranch Mine was delineated in the same manner as described for the Black Thunder Mine when no reclamation was noted, and the area had been previously mined.

Where cells were located on the coal/clinker/overburden boundary, and the cell was indicated as a mined node, the node was not simulated as mined. This is a result of the assumptions of the general head boundary, which state that no change in storage is allowed in the semi-permeable zone. Recall that the general head boundary in MODFLOW models flow between domains of divergent permeability through a semi-permeable zone. This exclusion of mine impacts may result in local under prediction of drawdowns near these nodes, but it should not be significant in the overall model, since mining of the of zone of alteration would result in prohibitive pit inflow, and it would presumably be avoided. Early mining (1975-1985) is located near the cropline; this timing will disproportionately affect the early drawdown data.

Finally, modeled output is specified at node centers. This is a result of the finite difference method. The smallest grid cells (825 x 948 ft.) have data reported at node centers, and they may have targets located up to 628 ft. distant from the node center, and still be within the cell. This will result in targets not exactly reflecting the results modeled at node center.

The increased RMS error in the 1985 verification simulation is due to a combination of the above data inadequacies, model assumptions, and model limitations. The 1985 mean error indicates these factors bias the model toward under prediction of drawdowns. Finally, the first two sources of variability should decrease with time, and model verification should improve with time (see 1995 below).

1995

The 1995 verification improves the Wyodak Coal Aquifer. The time period from 1985-1995 is characterized by increased mining activity, with fewer previously described uncertainties associated with the 1975-1985 period. In general, mining is progressing downdip (westward), away from the cropline, and fewer coal/clinker/overburden boundary cells are encountered. This results in a more complete areal delineation of surface mining stress. The mining sequence that forms the surface mine stress locations for the period 1985-1995 is much less subjective. Nevertheless, some apportionment of the mapped disturbed areas was done to simulate mining where groups of years were mapped together. This is particularly true for the Black Thunder Mine permit area from 1985-1992.

The increased RMS error that is observed in the 1995 verification when compared to calibration RMS error, may be caused by some or all of the previously mentioned (1985) factors. The 1995 model mean error indicates that the observed under prediction of drawdown is no longer present. The model for 1995 is essentially unbiased. Further, RMS error at coal targets has declined by 33% from 1985 to 1995.
Maximum absolute error in the model domain moves from a south, large grid cell to the Black Thunder Mine permit area for 1985 and 1995. This may be directly attributable to the number of near-pit wells included in the coal targets.

Summary

Verification of the coal targets improves with time as mining moves away from the cropline, the surface mine pit locations are better documented, and the number of mined cells increases. Several complications that are not resolvable in the model process are: the lack of continuity of model targets through time due to the destruction of wells (targets) as the pit advances; the extent to which simulated inflows approximate actual pit inflows; and the disproportionate number of near pit wells. RMS error of the 1995 verification increases 2.5 ft. from calibration RMS values. The mean error from both calibration and 1995 verification indicates that the model is essentially unbiased. Data concerning the 1975-1985 period are previously discussed, and they appear to affect the 1985 verification. These problems appear to be related to historic pit location, and they were not resolved by the mining companies.

Water Budget and Mass Balance

The modeling process produces intermediate output in 1985, 1995, and 2021, with and without CBM production. Table 4-13 summarizes the results. Model recharge from clinker increases as stresses increase. Boundary inflows are conceptually unbounded, so unrealistic inflows can develop. The steady state recharge presented in Table 4-7 indicates recharge ranges from 540-630 gpm
(Plate 7). Average transient state recharges range from 730 gpm from 1977-1985, to 2,400 gpm in the 1996-2021 model period. The mapped surficial clinker in the Pilot Study Area is 66 $mi.^2$ (Plate 1). Assuming uniform permeability, and no other outflows from the clinker, it would require about 0.1 ft. of water over the clinker area to maintain dynamic equilibrium. Judging from this, the recharge values seem plausible. Net declines from the model domain through the south and west constant head boundary can be expected through the active stress periods. Summing cumulative totals will give net change in stored water within the Pilot Study Area plus the cumulative model error.

Table 4-13: Cumulative mass balance and global model water budget through 2021

Date	CBM wells ($ft.^3$)	Pit inflows ($ft.^3$)	Precipitation recharge ($ft.^3$)	Net recharge (+)/discharge (-) ($ft.^3$) boundary	Net constant head recharge (+)/ discharge (-) ($ft.^3$)
1977-1985	-0-	105,790,000	22,571,000	460,500,000	-395,930,000
1986-1995	-0-	1,906,700,000	25,036,000	2,119,500,000	-386,150,000
1996-2021	-0-	3,813,700,000	64,459,000	4,345,000,000	-863,440,000
1996-2021	402,690,000	3,792,000,000	64,459,000	4,385,000,000	-540,030,000
Cumulative	402,690,000	0.58045E+10 to 0.58262E+10	112,070,000	0.6925E+10 to 0.6965E+10	-0.132221E+10 to -0.16455+10

The 1996-2021 time period is modeled with and without CBM production.

Predictive Simulations

Accurate predictive modeling depends on accurate conceptualization of the flow regime. The selected measure of conceptual accuracy is to compare model predicted groundwater elevations to observed groundwater elevations in the Wyodak Coal and Wasatch Formations. Based on this comparison, RMS error of the observed vs. predicted results give a quantifiable estimate of model accuracy.

The model was allowed to run in predictive mode from 1995-2021 (end-of-mining). Two scenarios were investigated: only surface mining from 1995-2021 (Plates 18 and 19); and surface mining and CBM production from 1995-2005 (Plates 14 and 15), followed by only surface from 2006-2021

(Plates 16 and 17). Predictive impacts are modeled for both the Wyodak Coal and the Wasatch Formations. Model inputs are constant during all predictive runs.

No changes were made to inputs during the predictive scenarios, with the exception that model time steps were adjusted during the CBM simulation (1995-2005) to accommodate one month stress periods. One month stress periods were necessary to allow the phased start up of CBM wells. Recall that CBM production was simulated as 50 wells going "on line" over a period of six months. This necessitates the time discretization to be reduced to one month to accommodate the monthly change in the number of wells.

Extent of Predicted Drawdowns

Mining

Drawdowns (1985) for both the Wyodak Coal and Wasatch Aquifers are contained within the mine permit boundaries (Plates 9 and 10). The 5 foot drawdown contour in the coal is approximately 5 mi. west of the mine permit boundaries by 1995 (Plate 12). By 2021, the 5 foot drawdown contour from surface mining only is approximately 3 mi. west of Wyoming Highway 59, and it approaches the south model boundary (Plate 18). The 5 foot drawdown contour in the Wasatch Formation is essentially contained within the permit boundaries through 2021 (Plates 10, 13, and 19).

Mining and CBM

The effect of CBM is seen most in the 2005 scenario. CBM increases the western extent of the 5 foot drawdown contour in the coal to the western model boundary, and to the south to the southern boundary. The contour affects (> 5 ft. of drawdown) the south boundary at five cells. Drawdowns recover rapidly following the cessation of pumping in the modeled scenario (Plates 14, 15, 16, 17).

Summary and Conclusions

This report documents the methods used to deterministically model groundwater stresses related to energy impacts in the Wyodak Coal and Wasatch Formations, and it provides a method for cumulative impact assessment. Some general conclusions that are a result of the study follow. Numbering does not necessarily imply importance.

1) *Data must be assimilated into a single useable format if it is to be used efficiently. The largest single portion of time spent in this project has been in data acquisition, QA/QC, and data development. Geologic and hydrologic data will continue to accumulate in the PRB. The ease with which this work can be updated depends on a commitment to compilation and current electronic storage.*

2) *Data volume will require advanced methods of development and analysis. Calibration and verification (history matching) of time series data limits the utility of simple tools. GIS technology reduces data handling intensity, it is the recommended alternative to locate and analyze spatial data, and it can develop inputs for regional models.*

3) *The distribution of data sampling needs to be addressed. Groundwater elevation and hydraulic data are clumped near the cropline; little additional information may be statistically required to adequately define the potentiometric surfaces in these areas. Additional wells within the current permit areas are problematic, since the life expectancy*

of these wells is short. Downdip water levels, water quality, and aquifer hydraulic data are minimal. Future sampling to the west of the mine permit areas is recommended to determine the adequacy of cumulative predictions, and to assess the need to update this document. Additional attention to sampling of clinker water levels will improve model reliability, and better the assessment of recharge/discharge relationships.

4) *Geologic data on the lenticular Wasatch Formation sand aquifers need to be developed if impacts to this formation are to be accurately modeled. The extent, significance, and importance of these sand lenses should guide the geologic and hydrologic data collection effort.*

5) *Data QA/QC is critical to any modeling effort. The effort to assess data quality for this model effort will be contained in a separate report. Considerable time and effort was spent on QA/QC of aquifer hydraulics, groundwater elevations, geologic contacts, and well completions. This needs to be continued in future CHIAs, or there will be a risk of compromised and flawed results. When additional data are collected in the PRB, attention should be paid to the cumulative need for regional data of high quality in the selection of data collection sites, parameters, and filling data gaps. Special attention should be paid to the need for long-term targets that will not be destroyed.*

6) *A rigorous adherence to standards for groundwater monitoring should be followed to eliminate the variability in groundwater assessments. Databases are needed to warehouse and to evaluate data collected at all levels. A conscientious effort to assess data needs by regulators and permitees will improve the science and reduce monitoring costs.*

7) *Aquifer testing in the Backfill has not been done to the extent necessary to evaluate Backfill hydraulics. This should be a priority.*

Conclusions with Regard to Identified Needs for Additional Study by Martin et al. (1988)

Martin et al. (1988) identified three specific needs for additional study with regard to groundwater flow. These needs can be summarized as:

- The need to re-evaluate the tendency of the 1988 CHIA to over predict impacts;
- The need for down gradient monitoring; and
- Determination of recharge rate and source of recharge for the spoil aquifers.

This report directly addresses two of the three needs. The model results in this report present an unbiased assessment of coal aquifer impacts through 1995. The 1985 bias is toward under predicting of impacts, and it appears to be the result of non-resolvable systemic problems that have been described earlier in this report. The tendency to over predict in Martin et al. (1988) may be the result of superimposing the results of a variety of methods to determine the extent of drawdown. This model uses a single numerical technique, and systematic over prediction is removed. The method to assess recharge in this model is a first effort to assess the recharge dynamics of the coal/clinker/overburden boundary. The goal of the model, reduction in RMS error, is achieved, and it is the only quantifiable verification assessment possible.

The need for down gradient monitoring expressed by Martin et al. (1988) remains a deficiency of monitoring in the PRB. Recent BLM coal and Wasatch Formation monitoring downdip should address some of the down gradient monitoring needs.

Specific Conclusions with Regard to 1992 OSM Oversight Report

The 1992 OSM Report questioned two general areas of the State of Wyoming permitting process:

- The state CHIAs were not based on the most recent technical information; and
- The USGS CHIA (Martin et al., 1988) was a general assessment of PRB impacts, and it was being applied regionally rather than using site-specific data in individual determinations.

This report specifically addresses both of these concerns. Data collection prior to the modeling effort was intensive. Data update was sought for the Pilot Study Area through cooperation of the pilot area mines, the BLM, and other cooperating agencies. PTMA contained data were evaluated and quality checked. Additional funding through the ACMLRP has allowed investigation of technical impact issues such as CIAs from gas and coal development, anisotropy in the Wyodak Coal, and inter-aquifer communication. Utilization of this research is conceptually and physically included in model development The CPR database was updated through December 1995 for the Pilot Study Area mines, and all available data were included in model development, calibration, and verification. The model is site-specific to the Pilot Study Area, and groundwater impacts are best approximated for the three specific mine areas (Black Thunder, North Rochelle, and Jacobs Ranch) within the smallest grid cell areas.

Specific Conclusions with Regard to this CHIA

Modeling of the nature undertaken in this study addresses one of the noted deficiencies of the previous CHIA (Martin et al., 1988). Predictions of the extent of impacts are based on a single predictive documented investigation, conducted using a verified numerical model, rather than relying on superposition of results from a variety of methods and predictive models.

Additional Research Needed

1) Groundwater quality is not addressed in this report. Discussion of the extent of cumulative groundwater quality impacts from energy development is not updated in this report.

2) Improvement and quantification of recharge/discharge relationships is necessary to more accurately assess model vertical precipitation recharge to the system, and to the coal/clinker/overburden recharge boundary. The latter boundary would be improved with additional information on thickness of the zone of alteration after Gerlach (1995), and the lateral extent of the clinker-overburden and clinker-coal boundary. Surficial mapping of the clinker provides an initial assessment of this boundary, but the extent of the subsurface contact would improve quantifiable recharge/discharge dynamics.

3) Groundwater recharge rates may be quantitatively assessed, perhaps using stable isotope ratios. Several radioisotopes are used in hydrogeologic studies. Tritium and radiocarbon (^{14}C) are examples. They have the advantage of being useful in determining groundwater velocities independent of the Darcy Law equation. Darcian assessments require *a priori*

knowledge of hydraulic conductivity, effective porosity, and the hydraulic gradient of the site to quantify recharge rates. Similar procedures may be used to assess vertical leakance (Hebson and Brainard, 1996).

Section 5
Surface Water Modeling

HEC-1/Watershed Modeling System Selection

The Little Thunder Creek Drainage was selected as the Pilot Study Area for conducting a surface water cumulative hydrologic impact assessment (CHIA) in the Powder River Basin (PRB). Little Thunder Creek is a tributary of Black Thunder Creek, and eventually the Cheyenne River. It drains approximately 250 square miles (mi.^{2}) in the southwest section of CIA 2. The Wasatch Formation/Fort Union Formation contact divides the Little Thunder Creek Drainage into three distinct regions. The western headwaters overlie the Wasatch Formation, while the eastern end of the Little Thunder Creek Drainage is underlain by the Fort Union Formation. The clinker escarpment, known as the Rochelle Hills, marks the contact between the two formations. The escarpment creates an area of greater relief and higher drainage density through the middle sections of the drainage network. The Little Thunder Creek Drainage is being impacted by three coal mines located just to the west of the Rochelle Hills.

The surface water modeling for the CHIA Pilot Study Area was conducted using HEC-1, in a platform developed by Boss International, called the Watershed Modeling System (WMS) (Boss International, 1996). HEC-1 is a rainfall/run-off and flood prediction model developed by the United States Army Corps of Engineers (ACOE). HEC-1 tracks rainfall through the entire system, and any water lost to infiltration is eliminated from the model. This aspect of the model makes the possibility of combining the surface and ground water components of the CHIA impractical. It should be noted that HEC-1 was originally designed as a flood prediction program, and as a result, it is designed for large flows and does not always accurately predict small flows. The wide use and acceptance of this model by the hydrology profession, and the relatively small amount of data required to run HEC-1, outweighed these and other limitations of the model. Any model selected would be based upon certain unique assumptions, and it would have such limitations.

HEC-1 is essentially a "front end" for a number of rainfall/run-off and streamflow routing techniques. The model is a means of combining run-off and routing techniques for each section of the watershed that the user believes will respond in a more or less uniform manner. HEC-1 breaks down the hydrologic system into independent components. Each component is then represented by a discrete algorithm within the software (ACOE, 1990). A number of techniques may be used to represent any particular aspect of the hydrologic system. These techniques are generally well known and accepted algorithms that require unique input parameters (ACOE, 1990).

HEC-1 requires that the watershed be divided by the user into discrete catchments, called hydrologic response units (HRUs), which should respond to a precipitation event in a uniform manner. The channels through the HRUs are then represented as another component of the system. HEC-1 also is capable of including reservoir, diversion withdrawals, and return flows as components of the system. Each HRU, channel segment, reservoir, and diversion requires a unique set of descriptive parameters.

The primary output from HEC-1 is a set of hydrographs that represent the discharge at the base of each component of the system. These hydrographs are output in numerical format from HEC-1, and they are then translated into graphical output by the WMS front end. These hydrographs are then compared to observed data to determine the accuracy of the model.

HEC-1 is considered to be a lumped parameter model. This type of model combines a wide range of related variables into a single parameter. Each HEC-1 parameter can represent a large group of related basin or channel characteristics. This aspect of the model means that the input parameters represent a wide range of possible conditions, and they are subject to interpretation based upon the information available, and professional judgment.

Model Implementation

Surface Water Data Acquisition

The acquisition and analysis of appropriate data for the Little Thunder Creek Drainage was the first, and most important step in conducting the CHIA for the Pilot Study Area. Data pertaining to the soils, vegetation, hydrography, mine permit areas, precipitation, and discharge were required. The data were gathered and compiled from a variety of sources available through the University of Wyoming (UW) Wyoming Water Resource Center's (WWRC) Water Resources Data System (WRDS), and the Geographic Information System (GIS) Laboratory. Data were also obtained from the Coal Permitting and Review (CPR) database, and the permit to mine applications (PTMAs) on file with the State of Wyoming Department of Environmental Quality/Land Quality Division (WDEQ/LQD).

Precipitation

The ephemeral nature of stream flow in the Little Thunder Creek Drainage necessitated the acquisition of hourly precipitation and discharge data for the area. Extreme fluctuations in discharge and precipitation make daily values of either variable unacceptable for modeling purposes. Precipitation data were gathered from gages located on mine sites in the Pilot Study Area, as well as from National Weather Service (NWS) stations located in the vicinity. Those stations recording at greater than one hour intervals were disregarded for purposes of determining rainfall patterns, but these values were retained for determining total precipitation and general climatic tendencies in the surrounding areas.

Eighteen precipitation stations were established by the mine companies in the Little Thunder Creek Drainage. Twelve of those stations had adequate data to be used in the Pilot Study Area (Table 5-1). The locations of the 12 stations are presented in Figure 5-1. Consistency in operation varied from station to station, but an adequate distribution of stations was available for the four storms that were selected between 1978 and 1980. The hourly precipitation data from these 12 stations were analyzed, and only those stations with consistent records were used to determine the total precipitation for a given storm. Hourly records for each station were used to establish the rainfall distribution through time for each HRU.

Figure 5-1: Location of precipitation gaging stations in the Little Thunder Creek Drainage

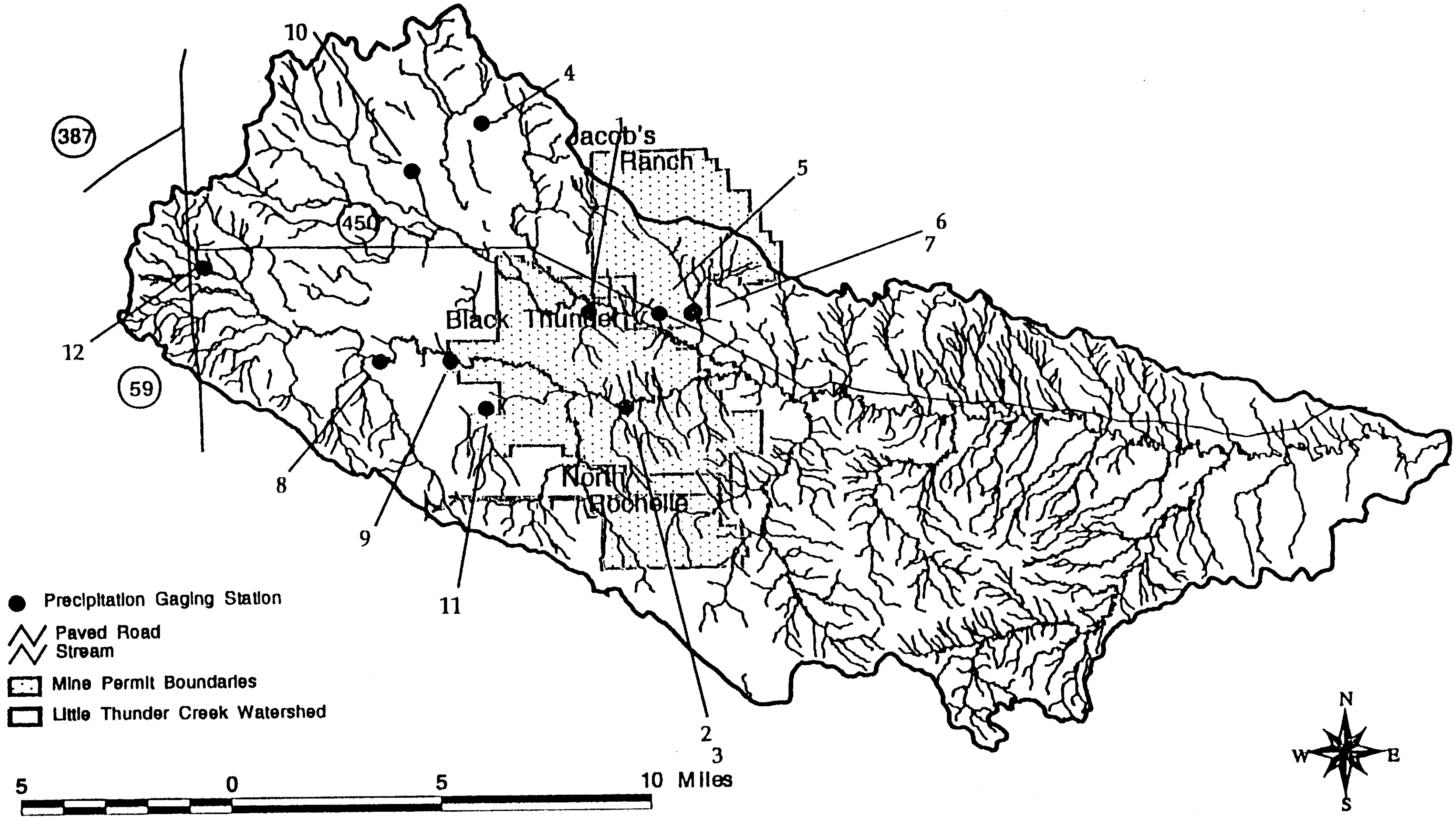


Table 5-1: CHIA identification numbers and NWS precipitation station identification numbers

CHIA station identification number	NWS station number
1	480784
2	480785
3	480787
4	480850
5	484916
6	484917
7	484918
8	485692
9	485693
10	485694
11	487170
12	487691

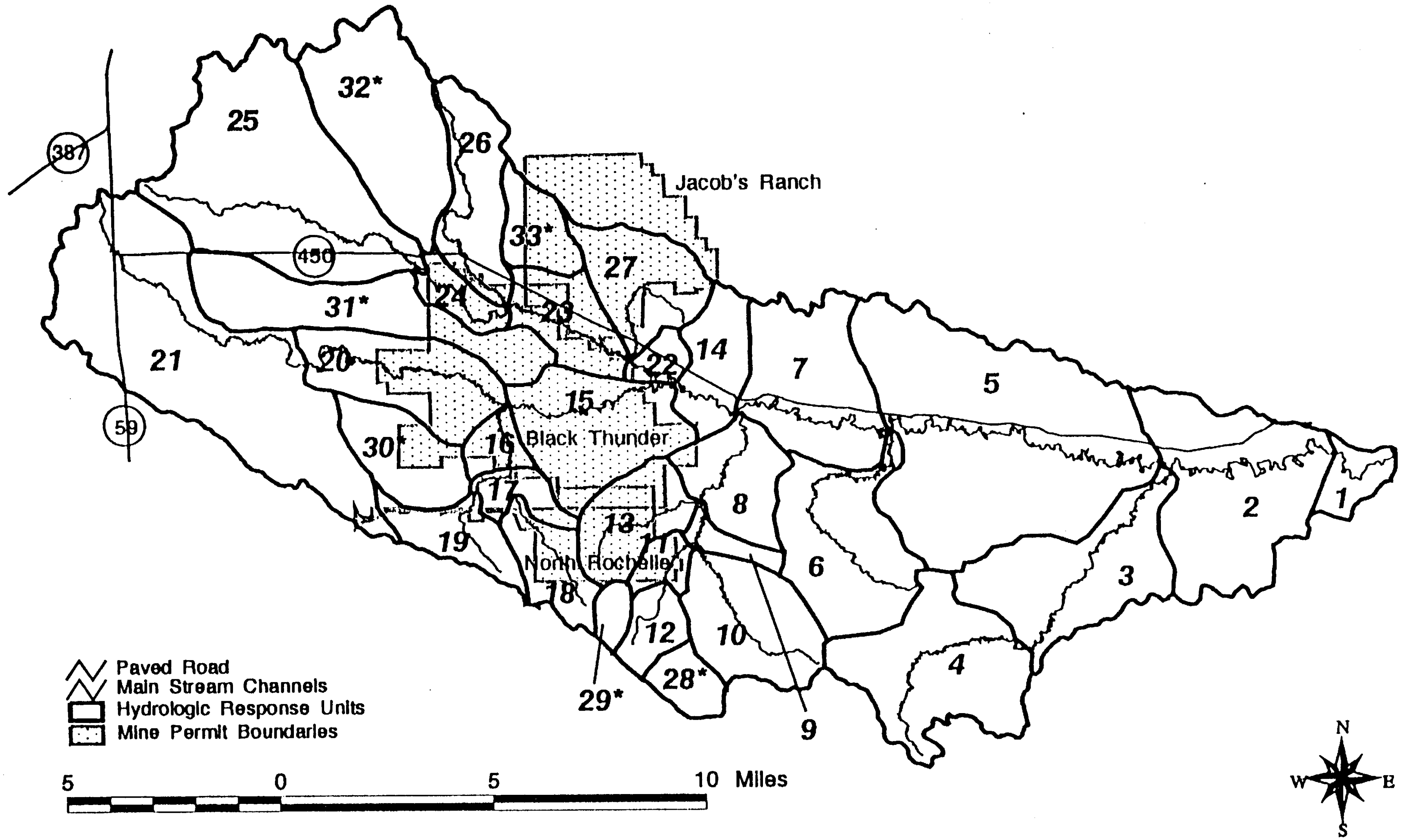
Discharge

The three mines in the Pilot Study Area installed a number of crest gages on their permitted property. One United States Geological Survey (USGS) continuous gage was located on the main channel of the Little Thunder Creek, approximately 12 miles (mi.) east of the mine permits, and approximately 24 river miles downstream. Analysis of the available data indicated that only the USGS station had data of sufficient quality and quantity to be used in model calibration. Crest gages do not provide the hourly discharge readings that are essential to model calibration. The USGS reports discharge measurements in terms of mean daily flows. We were able to obtain the hourly stage measurements for the station, and convert those to discharge using the stage-discharge rating tables for the station. Adjustments were made by the USGS to the recorded stage values on the primary sheets. These primary sheets usually record and explain the types of adjustments made to each stage reading to better reflect the conditions present at the time. The adjustments used for the daily average were applied to the hourly stage in order to determine discharge. If there was any question about the correct adjustment to make, two or more techniques would be used, and the mean daily values compared to that reported by the USGS. The technique that yielded the value closest to the USGS report was used in generating the final records.

HRUs

The Pilot Study Area was divided into 33 HRUs (Figure 5-2), based upon analysis of clinker abundance, soils, vegetation, mine permit locations, gaging stations, and hydrography. Clinker is baked and fused bedrock that results from the burning of subterranean coal (Reheis and Coates, 1987). The resulting rock formation is more resistant to erosion, provides greater topographic relief, and it is more permeable than the surrounding rock formations. Some researchers believe it to be the driving force behind the surface water system (Anderson, 1994). Division of the Little Thunder Creek Drainage into HRUs was largely dependent upon the presence or absence of clinker in the area. After clinker, the presence of stream gaging stations, and the mine permit boundaries were used to choose further divisions of the Pilot Study Area. Soils and vegetation maps were used to ensure that selected HRUs were relatively uniform in ground cover characteristics.

Figure 5-2: Division of Pilot Study Area Into Hydrologic Response Units



National Resource Conservation Service Numbers

The Natural Resource Conservation Service (NRCS) Run-off Curve Number method was used to estimate run-off from each HRU. These numbers express a rainfall/run-off relationship for an area. A curve number of 100 represents complete run-off. Lower numbers represent less run-off from an area. Incorporated in each curve number is an initial abstraction or amount of rainfall required to saturate the top of the soil, and to fill surface storage. A curve number of 50 represents ground that requires large amounts of rain to produce run-off; 75 would represent a curve of intermediate state in which less rainfall was required to produce run-off.

The same ground is represented by different curve numbers depending upon antecedent moisture conditions (AMCs). Wet ground with full surface storage will be represented by a higher curve number. The same ground, with the soil moisture approaching the wilting point, would have a lower curve number. Chow (1964) indicates that for the normal range of AMCs, the difference between dry conditions (AMC I) and wet conditions (AMC III), can be as large as 15 curve numbers. Intermediate conditions (AMC II) would be represented by numbers within that 15 curve number range.

The rainfall/run-off relationship represented by a curve number is entirely cumulative. The expressed relationships do not allow for recovery of the soils during drier periods of the storm. Chow (1964) provides tables that estimate curve numbers for various vegetative communities. Analysis of the tables indicates that the land in the Little Thunder Creek Drainage would have curve numbers between 55 and 80.

Specific curve numbers for each HRU were estimated using tables and graphs found in The Handbook of Hydrology (Chow, 1964). The PTMA for the Black Thunder Coal Mine was also analyzed to obtain estimates of the appropriate range of run-off curve numbers for the area. Curve numbers were estimated using available vegetation (GAP), Wyoming State Soil Geographic Database (STATSGO), and clinker coverages (Heffern et al., 1996; Reheis and Coates, 1987). The information from Chow (1964) was applied to the available surficial geology, soils, and vegetation data using professional judgment.

Unit Hydrograph Method

A number of unit hydrograph methods are available in HEC-1. The authors chose the unit hydrograph method associated with the NRCS run-off curve numbers. This approach assigns a lag-time to each HRU. The lag-time given approximates the time that will elapse between precipitation and run-off. These times were initially estimated from knowledge of the shape and size of each HRU.

The Muskingum-Cunge Routing method was chosen to represent the channel components of the Pilot Study Area. The Muskingum-Cunge method was considered to be more robust with regard to irregular channel shapes and textures (ACOE, 1990). The other method considered was the kinematic wave method. This method requires the same input parameters as Muskingum-Cunge, but it was considered to be overly dependent upon regular channel shapes and conditions. The kinematic wave method is more stable at low flows, and it was used when necessary for areas and times of low flow, or when numerical instability in the Muskingum-Cunge method became too great (ACOE, 1990). The Muskingum-Cunge method requires input of the following parameters: channel length, channel slope, channel shape, channel side slope, and Manning's "n," a measure which represents channel roughness. Greatest channel width was estimated from the width near the gage. Upstream channel widths were estimated for each channel reach relative to the decreasing contributing areas.

Calibration

Calibration is the process by which the initial estimates of parameters for a model are changed to better fit the observed data. Certain input parameters are not particularly variable for an individual storm, and therefore, remained constant throughout the calibration process. Other input parameters are estimates of highly variable characteristics. The more variable the characteristics, the more likely it was that the parameter would be altered during the calibration process. When values for a parameter are estimated with broad confidence intervals, it is more appropriate to adjust those values to reflect the observed data, than it would be to alter parameter values that are more certain.

For example, precipitation was recorded at 5-7 stations within the Pilot Study Area for each storm. The total depth of precipitation at each station, for each storm, was recorded, and a contour map of total precipitation developed. Most HRUs had multiple contour lines, or they were in a large area between contour lines. These areas of multiple readings allowed for a range of acceptable values to be developed. Acceptable values for total precipitation for each HRU were estimated for each storm, and then they were altered as needed during the calibration process. Altering the amount of precipitation that falls on an HRU was one of the most effective means of matching the predicted discharge to the observed discharge data.

It was necessary to make numerous assumptions regarding the application of the surface water model. The lumped nature of the parameters in HEC-1 requires the use of professional judgment with regard to the correct values for certain parameters. Most of the parameters used in the model take into account a variety of conditions that must be balanced against one another in choosing an appropriate value. This section of the report describes the assumptions that were used in modeling the Pilot Study Area.

Certain parameter values were held constant, either throughout the Pilot Study Area, or through time for a particular component of the system. Some parameters were held constant because reliable values for the parameter were available to the authors. Other parameters were held constant because the results were not particularly sensitive to changes in that parameter. The greater the uncertainty or sensitivity associated with a parameter, the more likely it was to serve as a valuable calibration tool.

Muskingum-Cunge parameters that were held constant include: channel shape, channel length, channel slope, channel width, Manning's "n," and channel side slope. Channel length and slope were held constant for each HRU because hard data were available regarding those values. Manning's "n" was held constant at 0.036 because we had estimates of "n" for the region (Jensen, 1994). While Jensen found large variability in the region with regard to Manning's "n," we used the average value found for a particular type of stream (Jensen, 1994). The possibility of using Manning's "n" as a calibration variable was considered, but it actually had little impact on the overall calibration of the model. Channel width also was held constant for each HRU between the storms.

NRCS run-off curve numbers and the methods associated with them allowed for a great deal of flexibility in calibration. The curve numbers represent a run-off pattern that takes into account many geomorphic parameters. Specific curve numbers for each HRU were estimated using tables and graphs found in The Handbook of Hydrology (Chow, 1964), GAP, STATSGO, and clinker coverages (Heffern et al., 1996), as well as personal knowledge of the area. Descriptions of the spatial data bases used in this project are included in Appendix E.

The STATSGO database, available from the NRCS, was the most influential source of information in determining curve numbers. The map indicated that the soils overlying the Wasatch Formation had lower infiltration rates than those in the areas dominated by the clinker. The clinker soils were more coarse, and when combined with the permeable nature of the clinker, they were expected to have a much higher infiltration rate. The authors' initial estimates of the NRCS run-off curve numbers in the clinker dominated units were lower than those numbers eventually used in the calibrated model. The HRUs with large amounts of clinker also contained the greatest amounts of relief. Anderson (1994) found that the channel geometry in the clinker dominated areas was better developed than that of the Wasatch Formation. He concluded that the greater relief provided by the erosion resistant clinker escarpment was providing substantial run-off from the side slopes and alluvial fans of the escarpment. The initial curve numbers of the clinker escarpment were increased before and during the calibration process to achieve a compromise between the highly permeable clinker and the greater relief of the escarpment.

The relationship of each HRU to adjacent or similar HRUs was considered, and the curve numbers assigned with these relationships in mind. It was a priority concern for the authors that the values used reflected not only a calibrated fit, but also the expected relationships between HRUs. HRUs expected to be high in clay soils were assigned curve numbers that were similar to other areas of clay soils, but they also were substantially different from areas with soils of greater infiltration capacities. The values were changed in the process of calibrating the model, and all reasonable attempts were made to stay within ranges that professional judgment deemed appropriate.

Precipitation was another flexible variable. The convective nature of most of the storms that impact the Pilot Study Area results in spatially and temporally inconsistent distributions of rainfall. Precipitation depth and temporal distribution were recorded at 5-7 stations within the Pilot Study Area for each storm. A contour map of total precipitation was developed for each storm using GIS plots of the station locations, and the contouring capabilities of Surfer (Golden Software, Incorporated, 1994). Surfer, a software package developed by Golden Software is able to estimate numerical values between known but scattered data points. Surfer requires an X-Y coordinate for each grid node location along with a corresponding Z value assigned to that node's location. These points were specifically defined to represent known precipitation stations within the Pilot Study Area. The X and Y terms indicate the State Plane Coordinates East and North, respectively, while the Z values reflect the storm totals that each station received for the duration of the storm. Surfer then generates a grid file using these data through manipulation of a user defined numerical estimation technique.

Surfer provides several choices of statistical estimation techniques. The inverse distance to a power technique, and a weighted average interpolator was employed for this project. According to the manual, the power parameter controls how the weighting factors drop off as distance from a grid node increases. For large powers, closer data points are given a higher fraction of the overall weight; for smaller powers, the weights are more evenly distributed among the data points. A default power of two was chosen for this task. Inverse distance was also selected for its time efficient manner of gridding. Additionally, it proves particularly effective, and it is considered adequate when dealing with less than 500 data points that are distributed unevenly in space (Golden Software, Incorporated, 1994).

Once gridding was completed, the contour map output was produced providing an estimation of storm totals at locations where data were insufficient or unknown. Surfer was used to generate contour plots of precipitation for each storm (Figures 5-3 through 5-6). Most HRUs had multiple contour lines, or they were in a large area between contour lines. These areas of multiple readings allowed for a range of acceptable values to be developed. Acceptable values for total precipitation for each HRU were estimated for each storm, and then they were altered as needed during the calibration process. Table 5-2 presents the range of precipitation values, the starting points that were used for calibration, and the storm total values that were eventually used in the model. Exceeding the minimum or maximum estimates for a given HRU was an option available during the calibration process. If too much, or not enough, water was available to approximate the observed hydrograph, the limits that appear in Table 5-2 were exceeded to produce an accurate calibration. Altering the amount of water that falls on an HRU was one of the most effective means of matching the predicted discharge to the observed discharge data.

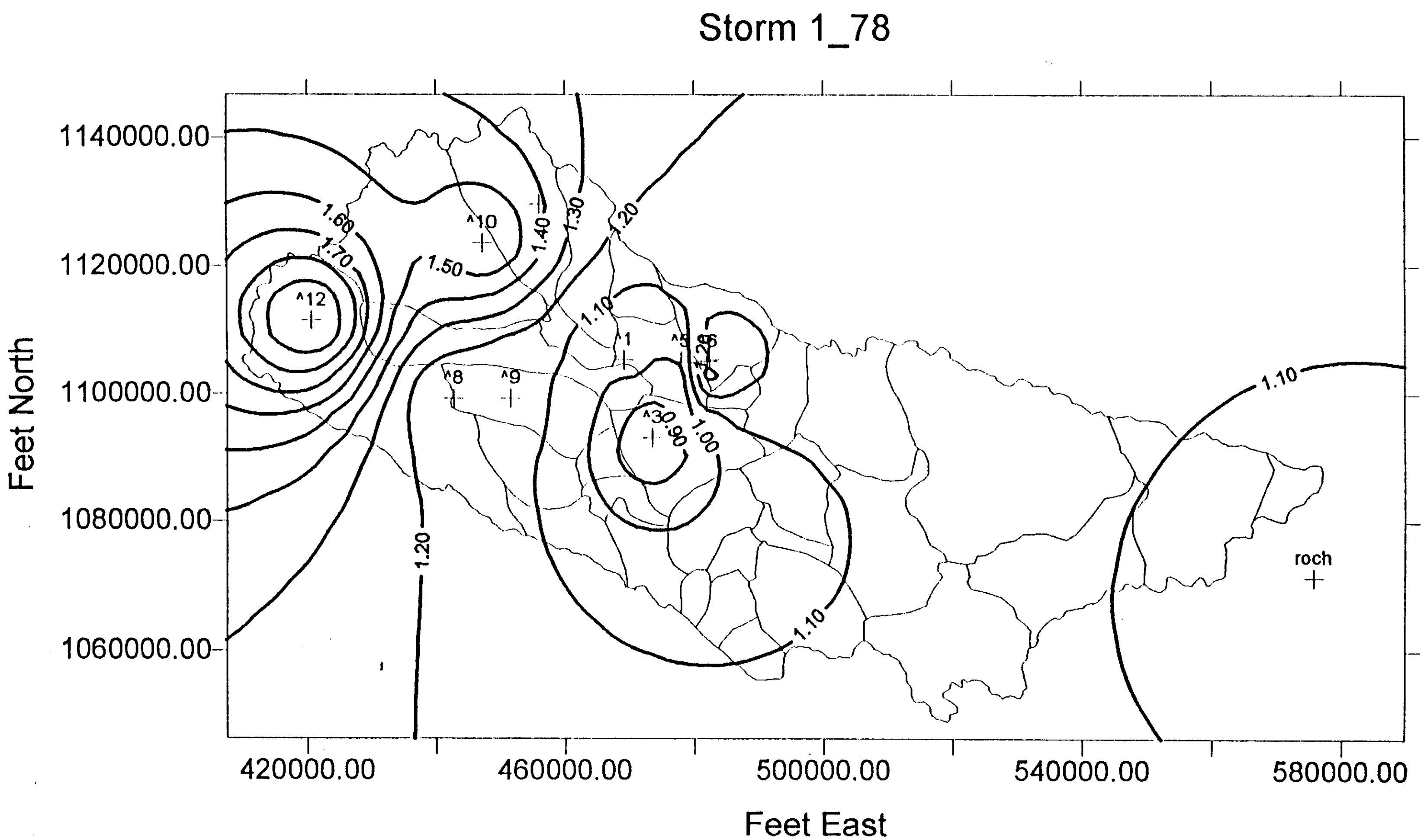
The time series data associated with each precipitation station also were used. The gage pattern associated with each HRU was changed between storms as our available stations changed. The choice of the appropriate gage was made based upon proximity of the gage to the HRU. Situations arose that required a decision between two gages approximately the same distance away. Professional judgment was used to determine which station would be used. Such availability of multiple stations also allowed us to change precipitation patterns for an HRU if it was felt to be necessary. The distribution pattern associated with a particular gage was never altered from the raw data.

Drainage basin characteristics were also used in calibrating models. The drainage areas of each HRU remained constant throughout the calibration process associated with each storm. However, a procedure was developed to account for small reservoir storage and AMC by adjusting effective contributing area. This procedure is explained below.

Two values associated with the shape of a hydrograph produced by an HRU were regularly used to calibrate the model. Input parameters for each HRU included a recession point and a recession constant. The recession point is the point of inflection in the hydrograph, and it occurs at the amount of discharge at which the HRU's run-off hydrograph begins an exponential decay. The recession constant is the exponential slope value that controls the rate of decay. Recession constants were calculated for some observed hydrographs. This was of limited usefulness, however, because a single recession constant for the "overall flow" is probably not appropriate for all the point sources from which the flow originates. Recession constants for individual HRUs were unknown and given a relatively wide range of acceptable values.

The delay between rainfall on an HRU and initiation of discharge is referred to as "lag-time." Lag-time also became an important calibration tool for the model. These times were initially estimated from knowledge of the shape and size of each HRU. Increasing or decreasing the lag-time allowed storm peaks to be slowed or moved up in time to better fit the observed data.
Certain adjustments to the model were required to reflect the impacts of mining present in the Little Thunder Creek Drainage at the time of the observed storms used for model calibration. Five of the 27 contributing HRUs were estimated to have been impacted by mining activities during the time period of the calibration storms. The presence of sediment retention ponds on these areas indicated that only large precipitation events capable of exceeding the storage capacity of the ponds would produce run-off. Contributing areas for these mined HRUs were reduced 90% to account for those values. The diversions built by the mines around their property were not accounted for, and stream flow was modeled as it would have been without the diversions. The contributing areas of all the HRUs were returned to their actual values, antecedent storage reductions not withstanding, when generating the "pre-mining" model.

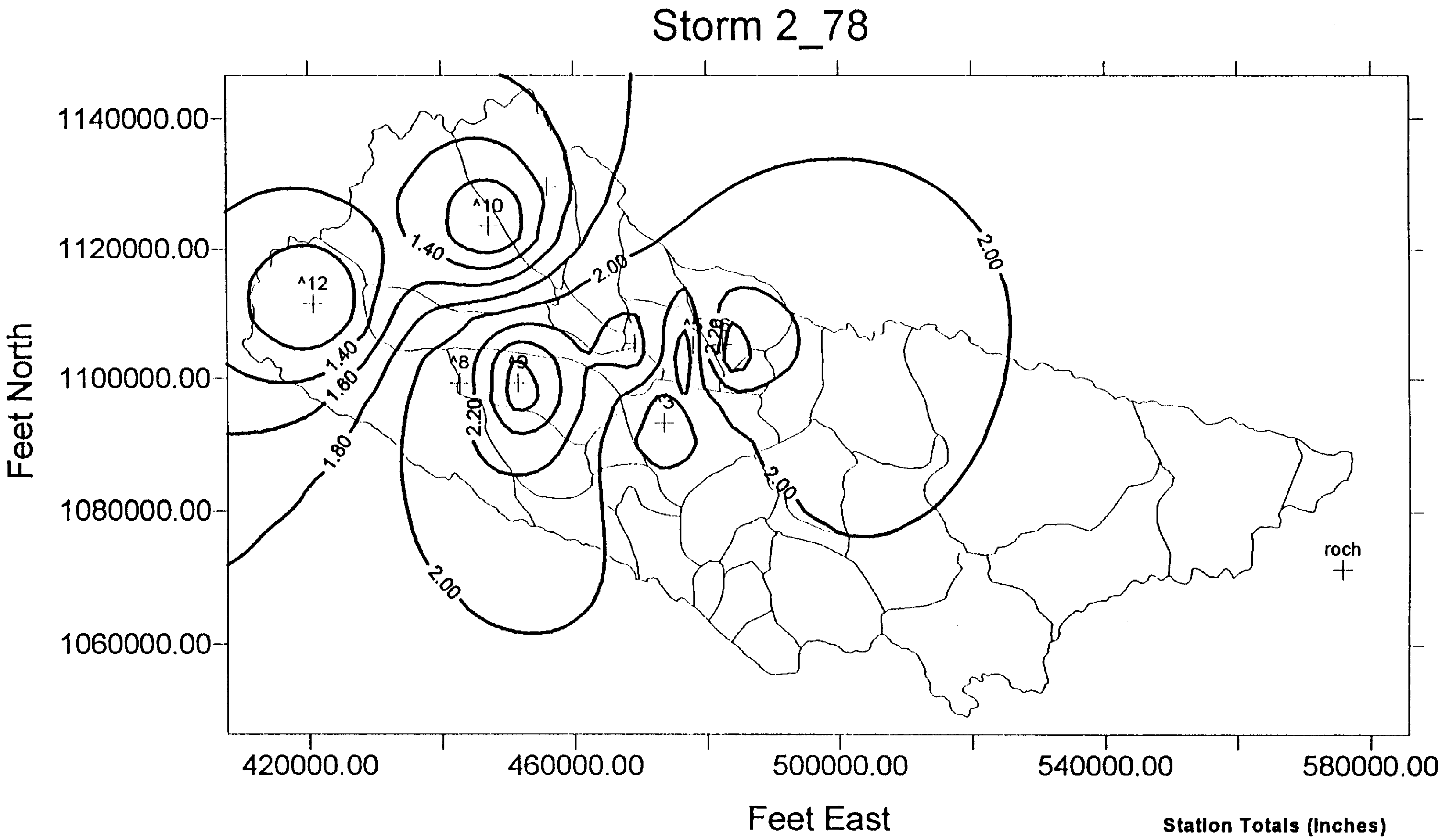
Figure 5-3: Contours of total precipitation for Storm 1_78



Station Totals (Inches)

^1	1.00	^8	1.11
^3	0.77	^9	1.12
^5	0.86	^10	1.61
^6	1.46	^12	2.02
		roch	1.05

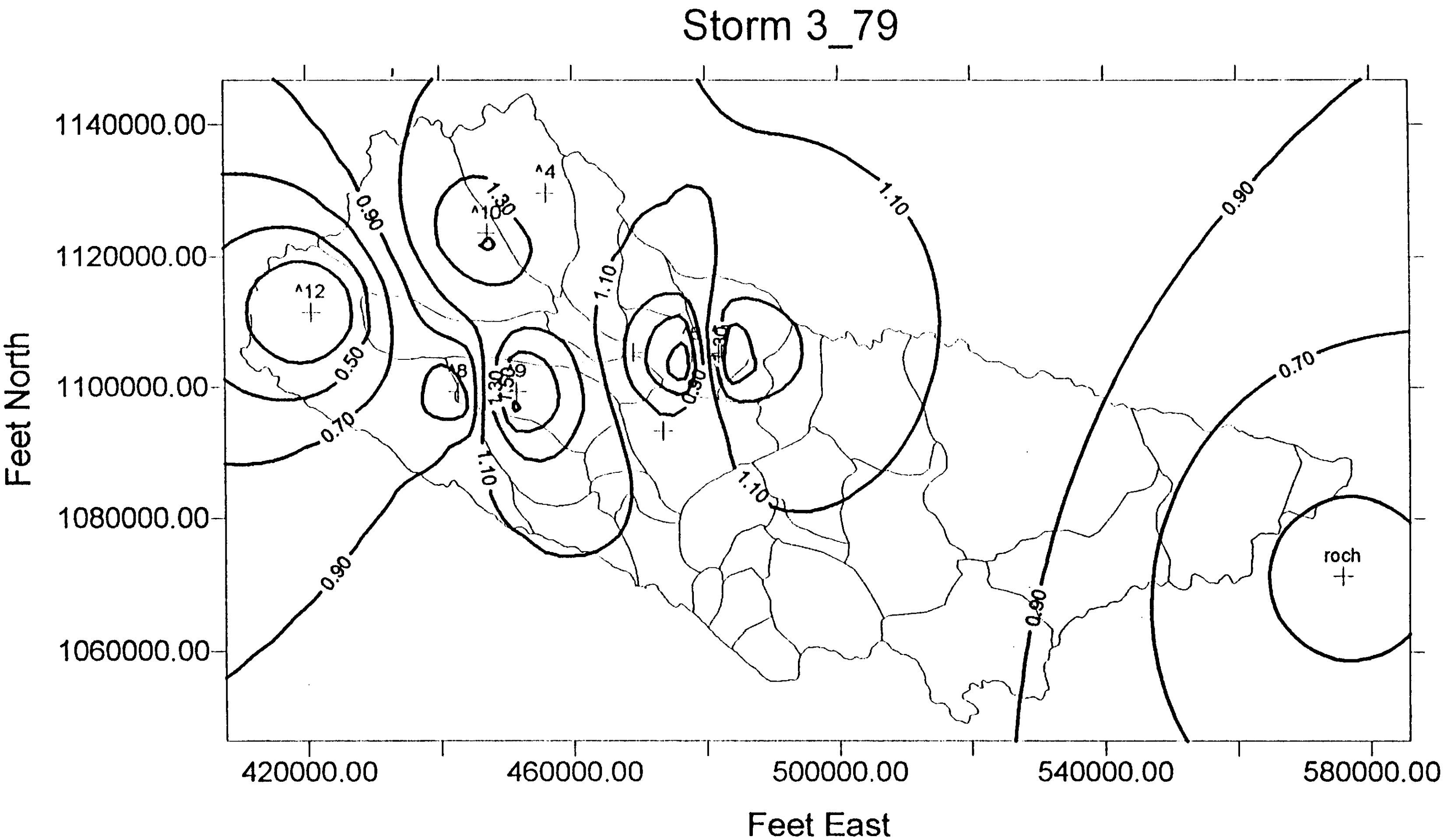
Figure 5-4: Contours of total precipitation for Storm 2_78



Station Totals (Inches)

^1	2.35	^8	2.05
^3	1.64	^9	2.81
^5	1.34	^10	0.98
^6	2.85	^12	0.98
		roch	1.84

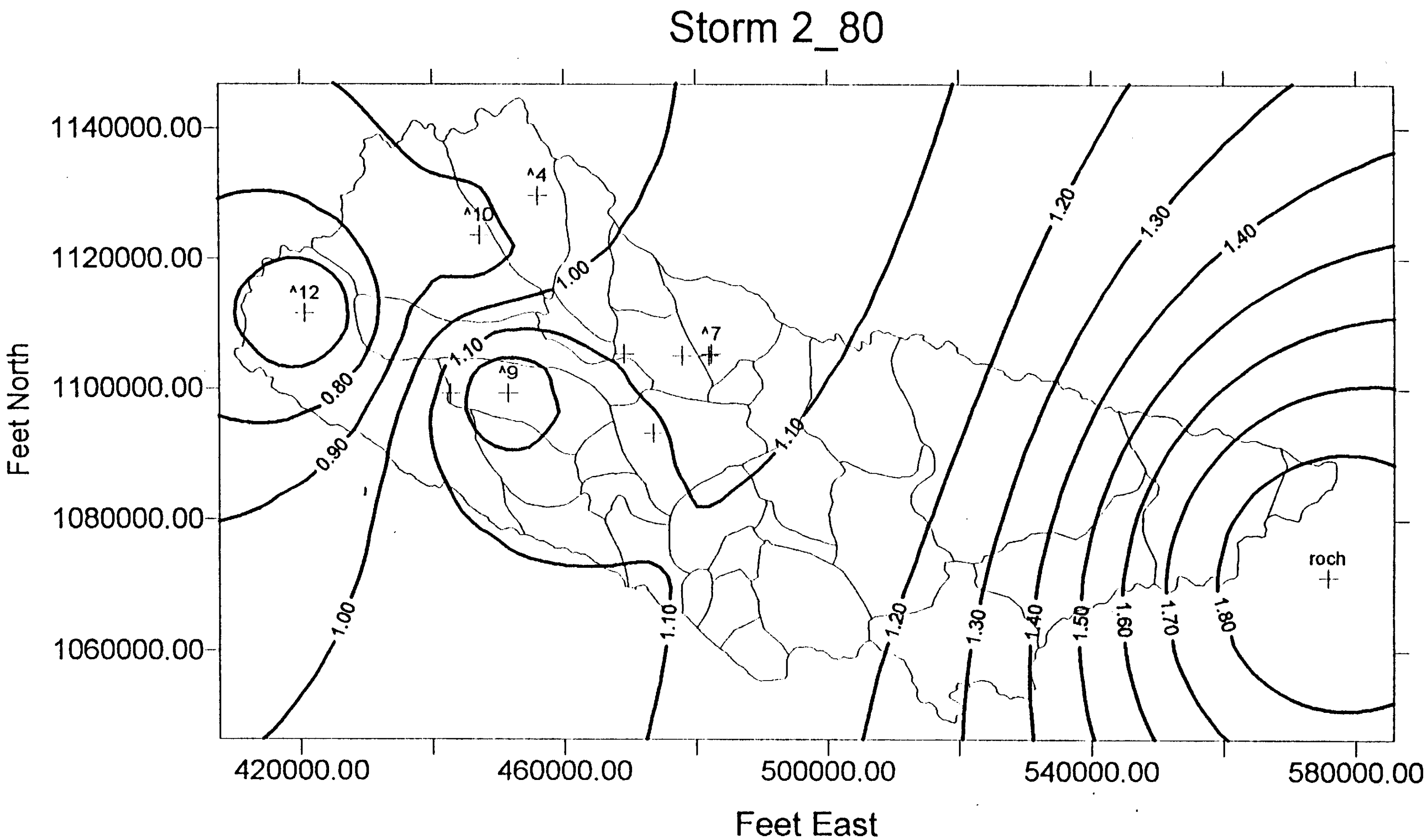
Figure 5-5: Contours of total precipitation contours for Storm 3_79



Station Totals (Inches)

^4	1.08	^9	1.86
^5	0.00	^10	1.55
^7	2.05	^12	0.06
^8	0.50	roch	0.46

Figure 5-6: Contours for total precipitation for Storm 2_80



Station Totals (Inches)

^4	0.99	^10	0.84
^7	1.10	^12	0.63
^9	1.27	roch	1.89

Table 5-2: Initial estimates of total precipitation for each HRU, initial maximum value, initial minimum value, and final calibrated value (all precipitation values are in inches)

	1_78				2_78				3_79				2_80			
HRU	**Start**	**Max**	**Min**	**Actual**	**Start**	**Max**	**Min**	**Actual**	**Start**	**Max**	**Min**	**Actual**	**Start**	**Max**	**Min**	**Actual**
1	1	1.05	0.95	1	1.85	1.9	1.84	1.5	0.15	0.5	0.4	0.5	1.8	1.9	1.75	1.8
2	1.05	1.1	1	1.15	1.9	1.85	1.95	1.2	0.85	0.7	0.45	1.22	1.75	1.85	1.6	1.42
3	1.1	1.13	1.05	1.13	1.9	1.95	1.85	1.46	0.8	0.9	0.7	1.1	1.55	1.7	1.4	1.4
4	1.1	1.15	1	1.1	1.95	2	1.9	1.39	1	1.05	0.9	1.25	1.3	1.4	1.2	1.25
5	1.1	1.15	1	1.05	1.95	2	1.9	1.56	1	1.1	0.85	1.1	1.25	1.35	1.1	1.29
6	1.1	1.15	1	1.1	2	2.05	1.95	1.38	1.1	1.15	1.05	1.2	1.2	1.25	1.15	1.2
7	1.05	1.1	0.95	1	2.05	2.1	2	1.38	1.2	1.25	1.1	1.2	1.15	1.2	1.1	1.08
8	1.1	1.15	1.05	1.1	2	2.05	1.95	1.77	1.15	1.2	1.1	1.2	1.15	1.18	1.12	1.15
9	1.05	1.08	1.03	1.05	1.95	2	1.9	1.65	1.13	1.18	1.1	1.2	1.15	1.2	1.1	1.15
10	1.1	1.15	1.05	1.1	1.9	2	1.85	1.5	1.1	1.15	1.05	1.2	1.18	1.15	1.2	1.18
11	1.05	1.08	1.03	1.05	1.9	1.95	1.85	1.7	1.15	1.18	1.12	1.2	1.15	1.2	1.1	1.15
12	1.05	1.09	1.04	1.05	1.95	2	1.9	1.7	1.15	1.18	1.12	1.2	1.15	1.2	1.1	1.1
13	1	1.05	0.95	1	1.95	2	1.9	1.2	1.15	1.18	1.12	1.2	1.13	1.15	1.1	1.05
14	1.05	1.1	1	1.05	2.15	2.25	2.05	1.8	1.3	1.35	1.25	1.3	1.1	1.15	1.05	1.05
15	0.9	1.05	0.8	0.9	1.8	1.9	1.7	1.8	1.15	1.05	1.2	1.15	1.1	1.15	1.05	1.01
16	0.95	1	0.9	0.95	1.95	2	1.9	1.9	1.25	1.3	1.2	1.3	1.15	1.2	1.1	1.15
17	0.95	1	0.9	0.95	1.95	2	1.9	1.9	1.2	1.25	1.15	1.25	1.15	1.2	1.1	1.15
18	1.05	1.1	1	1.05	1.95	2	1.9	1.9	1.2	1.25	1.15	1.25	1.13	1.1	1.2	1.13
19	1.1	1.15	1	1.1	2.05	2.15	1.95	1.93	1.3	1.4	1.2	1.4	1.13	1.1	1.2	1.13
20	1.1	1.2	1	1.1	2.5	2.2	2.3	2.15	1.7	1.85	1.6	1.85	1.2	1.25	1.15	1.2
21	1.8	2	1.6	1.8	1.5	1.8	1.2	1.42	0.9	1.2	0.6	1.2	0.85	1.1	0.7	0.85
22	1.05	1.1	1	1.05	2.2	2.25	2.1	1.6	1.3	1.4	1.2	1.25	1.08	1.1	1.05	1.05
23	1.05	1.1	1	1.05	2.1	2.15	2.05	1.6	1.4	1.55	1.3	1.3	1.08	1.1	1.05	1
24	1.1	1.2	1.05	1.1	2.15	2.2	2.1	1.6	1.3	1.4	1.2	1.35	1.1	1.15	1.05	1
25	1.6	1.7	1.4	1.45	1.45	1.6	1.3	1.45	1	1.3	0.8	1.2	0.9	1	0.8	0.93
26	1.4	1.5	1.3	1.4	1.85	1.95	1.7	1.6	1.25	1.3	1.2	1.4	1	1.05	0.95	0.95
27	1.05	1.1	1	1.05	2.15	2.25	2.05	1.8	1.15	1.3	1	1.2	1.05	1.08	1.02	1

Storm Selection

There are four years during which hourly precipitation and hourly discharge are available for the Pilot Study Area, 1978 through 1981. However, this period represents a time of active mining at the Black Thunder and Jacobs Ranch Mines. The data from 1978 though 1981 are being used to represent pre-mining conditions. We assume the more obvious hydrologic impacts of active mining were accounted for in our methodology.

Precipitation and discharge data were arranged into time series formats so that a direct comparison of the two could be made at each time stamp. The hourly records were then compared to determine which rainfall/run-off events were most likely to provide consistent, well distributed, and accurate data. The events chosen were then prepared for entry into HEC-1. The four selected storms were chosen to represent a variety of AMCs (Chow, 1964). AMC I was represented by a storm in early July 1978. AMC III was represented by a storm in May 1980, and two storms (1978 and 1979), were chosen to represent AMC II. The four storms and the precipitation stations that recorded them are listed in Table 5-3. It should be noted that the storms selected do not correspond to the three AMCs listed in Chow (1964). The authors do not believe that the four selected storms encompass the full range of AMCs as defined by Chow (1964). We have retained the notation, however, and future references to AMC I, AMC II, and AMC III should be considered as statements of relative AMCs, not conditions indicated by the same notations from Chow (1964).

Table 5-3: Recording and daily precipitation stations used to model four storms

	Station storm totals (in.)											
Storms	1	3	4	5	6	7	8	9	10	11	12	Roch
1_78	1.00	0.77		0.86	1.46		1.11	1.12	1.61		2.02	1.05
2_78	2.35	1.64		1.34	2.85		2.05	2.81	0.98		0.98	1.84
3_79			1.08	5.00		2.05	0.50	1.86	1.55		0.06	0.46
2_80			0.99			1.10		1.27	0.84		0.63	1.89

These values represent the total rainfall for a station during a study storm.

AMCs

AMCs were selected for each storm by analyzing the daily precipitation and temperature values for the Rochelle Station. Precipitation for the thirty days prior to the first hourly precipitation of each storm were totaled and compared to one another. These values, along with temperature data from the same 30 day period, were then used to establish the relationship between the storms with regard to AMCs (Table 5-4). AMCs were then used to determine curve numbers within each catchment or HRU. The clinker dominated HRUs were expected to change less than the soils overlying the Wasatch Formation in response to changes in AMCs. This relationship was carefully considered when calibrating the models from different AMCs.

Table 5-4: Temperature and precipitation levels for storms 1_78, 2_78, 3_79, and 2_80 (data from the Rochelle Station, taken 30 days prior to the four storms selected)

Storm	Total precipitation (in.)	Average maximum temperature °F*	Average minimum temperature °F
1_78	0.64	83.7	50.4
2_78	1.07	86.3	52.7
3_79	1.50	78.5	42.7
2_80	2.78	78.0	43.6

**Degrees Fahrenheit (° F).*

AMC, in conjunction with contributing area, was also used to simulate reservoir storage in each HRU. The number of reservoirs present in the Little Thunder Creek Drainage (as represented by water rights), was too great for each reservoir to be modeled separately. It was decided that contributing area would be adjusted to reflect the impact of reservoir storage on an HRU. The locations of water rights were plotted for each HRU. Visual analysis of these plots generated approximations of the proportion of contributing area impacted by reservoir storage. The percentage of the HRU that was impacted was estimated. A formula, developed by the authors and explained below, for the three relative AMCs used in this study was applied to each HRU. The contributing area was reduced by the percentage of the area impacted by the reservoirs. During AMC I, the reservoirs were assumed to be 20% full, and the amount of impacted area reduced by 20%. In AMC II, 50% capacity was assumed, and the impacted area was reduced by 50%. In AMC III, 70% capacity was assumed, and the impacted area was reduced by 70%. Contributing area was thus reduced more for dry conditions than for wet. This method was developed to represent storage in the Little Thunder Creek Drainage considering AMCs, practicality, and accuracy. It is assumed that by never reducing the impact to absolute zero, and never increasing it to its maximum, the contributing area changes would reflect the effect of many small reservoirs reaching overflow at different times.

Process

Calibration of the model to a particular storm was largely an iterative process. The baseline estimates of each parameter were entered into the model. The output from the model was compared to the observed data. Peaks that appear in the model output can be traced up the watershed using WMS's graphical capability, and their point of origin can be identified. Altering the basin parameters for the HRU of origin would allow the peaks and valleys of the predicted data to be matched to the peaks of the observed data. NRCS run-off curve numbers were usually the first parameters to be changed. After curve numbers were optimized, total precipitation was altered to add or subtract water from a particular HRU. Other parameters, such as lag-time, the recession point, and the recession constant were used to shape the hydrograph once the total volume was approximately correct. The adjustments to the model would be used to generate new hydrographs. Each series of new hydrographs was compared to the previous set, and additional adjustments were made to generate a better fit between the predicted and observed values, with the process continuing. A single calibration could require between 100 and 250 iterations of the process.

The goal of the calibration process was to generate a model that matched, as closely as possible, the rainfall/run-off relationships within the Little Thunder Creek Drainage, without entering parameter values that were outside the range of feasibility. A variety of parameter inputs can be used to generate the same hydrograph at the mouth of the stream. It is entirely possible to achieve a well matched hydrograph for the wrong reasons. Therefore, professional judgment becomes one of the most important factors in calibrating a model. During the calibration process, each parameter that was altered was bracketed by values believed by the authors to represent the minimum and maximum acceptable values for that parameter. All possible attempts were made to remain within those limits. There were times, however, when calibration was impossible without exceeding the maximum, or dropping below the minimum. Analysis of the available discharge and precipitation parameters often led us to distrust the original estimates for a parameter, and to make changes to the input parameters that did not fit between the anticipated maximums and minimums. Judgment also was critical in maintaining what the authors' believed to be the appropriate relationship between components of the system. Efforts were made to maintain similar values for a parameter in areas with similar characteristics.

Four storms were calibrated to help insure that the models represented a variety of conditions, and that the model adequately reflected the appropriate relationships between HRUs. AMCs for the four storms were estimated, and curve numbers established for the driest and wettest storms. The remaining two storms were calibrated by keeping them between the two outside values with regard to NRCS run-off curve numbers. It was anticipated that any substantial errors in our assumptions or methods would be revealed in the process of attempting to calibrate the intermediate storms.

An arbitrary standard of accuracy was established for the models. Pre-mining models were established with the goal of being within 15% of the observed data with regard to peak discharge and total volume. The time of the peaks had a more lenient goal wherein we sought to be within 20% of the observed value. The worst fit model that the authors were willing to accept was within 20% of peak and total discharge, and within 25% with regard to timing of the peak. It was, of course, desirable to have models that were closer to the observed values, with values of plus or minus 5-10% being preferred.

Post-Mining Estimates

All calibration was done with values that the author believes reflect conditions at the time the given storm occurred. The mines had been in operation since 1976, so the models were calibrated to reflect the state of the watershed, including mine impacts, at the time of the storm. Adjustments were then made to the model to reflect what would have happened had the mines not been in place. This portion of the calibration process is highly speculative. The adjusted or pre-mining models were used as a baseline for comparison to post-mining models. For post-mine modeling, the pre-mine models were adjusted to represent the changes in the hydrologic regime that would result from mining. Both the adjustments to the calibrated model to reflect pre-mining conditions, and the adjustments to the pre-mining model to reflect post-mining conditions are speculative. Professional judgment with regard to the impacts on curve number and contributing area is the foundation of those adjustments.

NRCS run-off curve numbers were changed to reflect the post-mining environment. The NRCS run-off curve numbers that were used for each HRU in the final calibration of each storm are presented in Table 5-5. A general lowering of the ground surface and reduction in overall slope is expected in the post-mining environment. The infiltration rates of the post-mining soils are expected to decrease in the short-term, primarily due to compaction and reduced vegetative rooting, and then slowly return towards a pre-mining level (Martin et al., 1988). These impacts tend to move the NRCS curve numbers in opposite directions. The types of changes to be made were at times contradictory with regard to the direction of change in NRCS run-off curve numbers. The authors decided that based upon expected changes in infiltration, slope, and cover, the overall changes in the NRCS run-off curve numbers would be small and positive.

Table 5-5: NRCS run-off curve numbers for HRUs used to calibrate HEC-1 models

Storms	Storm 1_78	Storm 2_78	Storm 3_79	Storm 2_80
HRU number	Curve number	Curve number	Curve number	Curve number
1	64	67	68	69
2	67	67	69	70
3	67	68	71	72
4	65	66	67	67
5	67	68	71	72
6	65	64	65	64
7	66	66	65	67
8	64	64	67	68
9	64	64	65	66
10	63	63	65	65
11	63	63	70	71
12	64	64	70	71
13	66	67	70	71
14	64	66	69	70
15	65	66	69	70
16	65	66	70	72
17	65	66	70	72
18	65	66	70	72
19	65	66	70	72
20	65	66	69	72
21	63	67	71	72
22	66	67	70	71
23	67	67	65	70
24	66	65	69	70
25	63	64	71	72
26	63	64	68	71
27	64	65	69	70

Uncertainty exists, however, as to the direction or extent of the changes that led to additional runs of the models. The first model represents our prediction regarding the most likely post- mining condition, and it has an increase of one curve number in the impacted HRUs. The second model predicts a decrease of one curve number in the affected areas. This bracketing operation creates a type of confidence interval for expected impacts. Similar, but more widespread brackets were modeled for changes of two and three curve numbers in each direction. A worst case scenario model was generated using a change of four curve numbers in both directions. It was not expected that any greater alterations in run-off would occur. This bracketing approach allows for analysis of predicted impacts, greatest probable impacts, and worst case scenario impacts on the hydrographs generated by a given storm.

Other parameters also were changed between the pre- and post-mining models. The largest single difference was the new channel lengths that were to exist in the post-mining environment. The new channel lengths and slopes, while not representing great change, were easily documented alterations to the system. Lag-times were increased by 10% in the post-mining models. The authors felt this would reflect the topographic changes in the post-mining environment. The new values are included in the post-mining models.

Results

Results for the Pilot Study Area are presented in two sections. The first section outlines the input parameters used for each HRU in each storm, the resultant hydrographs, and how they compared to the observed values. These calibration results are presented for comparison to the goals determined for the model. The calibrated storms are adjusted to reflect the authors' opinion as to how the Little Thunder Creek Drainage would have reacted to a storm without the presence of mining in the watershed. Included in this section is an analysis of the four storms that were modeled, and the accompanying rainfall distributions.

The second section of the results presents the possible impacts of mining and reclamation on the watershed. These changes reflect the changes in topography and storage that are planned for the post-mining landscape. The primary changes introduced are those in channel length, small changes in topography, and an estimated change in the NRCS run-off curve numbers for the impacted HRUs.

HRUs

The 33 HRUs identified for the Little Thunder Creek Drainage include six that are non-contributing areas. These non-contributing areas are large enclosed playas or dry lakes. They have a unique drainage area that happens to fall entirely within the Little Thunder Creek Drainage. It is highly improbable that any of these playas would fill to the point of overflow, and contribute to discharge in Little Thunder Creek. Therefore, they were removed from the model.

Twenty-seven HRUs were identified that actively contributed to run-off. The areas and the amount of storage, as indicated from water rights data provided by the Wyoming State Engineer's Office (WSEO), are presented in Table 5-6. Table 5-7 presents the amount of the HRU believed to be impacted by storage, and the contributing areas associated with AMC I, II, and III. As was seen in Table 5-5, the magnitude of the changes between AMCs varied from one HRU to the next. The HRUs that experience smaller changes between varying AMCS are generally those dominated by clinker (i.e., HRUs 4, 6, 7, 9, and 10). HRUs with large clinker components, which also had large areas of non-clinker overlying the Fort Union Formation (i.e., HRUs 3 and 5), exhibit changes in run-off curve number that are generally larger than the HRUs with more clinker, but generally smaller than those exhibited on the Wasatch Formation.

Lag-times for each HRU showed considerable consistency throughout the four storms and four AMCs. The fact that lag-time was relatively unknown resulted in it being used liberally in the calibration process. The consistency between the lag-times is considered to be a positive sign by the authors. The lag-times for each calibrated model are presented in Table 5-8.

Channel Routes

HEC-1 only routes flow through an HRU when flow enters from an upstream source. The model otherwise considers run-off from an HRU to be overland flow. A HRU with no flow entering from an upstream HRU is not considered to have a routing component, and as a result, it has no flow routing parameters. The hydrographs for each storm are presented in Figures 5-7 through 5-10. It was anticipated that the hydrographs would be consistent in their response to precipitation, but each storm represented a unique temporal distribution of rainfall. A few characteristics did seem consistent from storm to storm. The most obvious being a sharp spike early in the hydrograph, and a small dip in the receding tail of the hydrograph. Modeling efforts have indicated that at least part of the early spike is usually associated with HRU 2, the HRU immediately above the gage.

Reservoirs

The model developed for Little Thunder Creek includes only two reservoirs. There are actually many smaller reservoirs throughout the Little Thunder Creek Drainage. The presence of smaller reservoirs in an HRU was modeled using an adjustment to contributing area and AMCs as was explained above. The two reservoirs included in the model are large reservoirs on the main channel that were deemed to be large enough to model explicitly. Little Thunder Reservoir is on the main channel of Little Thunder Creek above the areas to be mined; Reno Reservoir is on the main channel of Little Thunder Creek, and it has been mined through. Reno Reservoir will be replaced as part of the reclamation plan. Input parameters for both reservoirs are listed in Table 5-9. These reservoirs are both present in the post-mining models. It was felt that with the exception of storm 2_78, the reservoir removed by mining (Reno Reservoir) would adequately represent the terrain features that are to replace it (Pronghorn Lake and Reservoir 26-SR-1), because the reservoir(s) will not overflow during most run-off events. Detailed information on the post-mining features was not available at the time of the model runs.

Table 5-6: The number of storage water rights contained in HRUs, and total storage allowed

HRU number	Number of water rights	Total acre-feet (ac.-ft.)
1	0	0
2	2	3.3
3	5	43.49
4	2	9.69
5	7	31.22
6	4	36.93
7	2	14.87
8	8	49.7
9	0	0
10	6	127.96
11	1	19.52
12	0	0
13	2	171.42
14	1	7.66
15	6	24.71
16	2	18.37
17	1	0
18	4	34.93
19	5	11.62
20	4	1688.9
21	12	19.73
22	2	1.95
23	15	182.23
24	3	27.93
25	7	295.74
26	6	19.09

Table 5-7: Percentage of HRUs impacted by surface water storage, actual contributing areas, and effective contributing areas associated with AMCs

HRU number	% Impacted	Effective contributing area (mi.^{2})			
		Actual	AMC I	AMC II	AMC III
1	0	2.17	2.17	2.17	2.17
2	0	15	15	15	15
3	10	11.4	10.49	10.83	11.06
4	5	12.12	11.64	11.82	11.94
5	5	29.16	27.99	28.43	28.72
6	20	11.01	9.25	9.91	10.35
7	5	10.37	9.96	10.11	10.21
8	25	5.49	4.39	4.8	5.08
9	5	1.38	1.32	1.35	1.36
10	30	8.03	6.1	6.83	7.31
11	20	1.54	1.29	1.39	1.45
12	0	2.39	2.39	2.39	2.39
13	50	5.2	3.12	3.9	4.42
14	5	4.56	4.38	4.45	4.49
15	0	9.5	9.5	9.5	9.5
16	5	1.72	1.65	1.68	1.69
17	0	2.07	2.07	2.07	2.07
18	80	3.87	1.39	2.32	2.94
19	20	3.84	3.23	3.46	3.61
20	5	8.03	7.07	7.43	7.67
21	5	25.11	24.11	24.48	24.73
22	20	1.35	1.13	1.21	1.27
23	15	4.7	4.14	4.35	4.49
24	5	2.06	1.98	2.01	2.03
25	60	20.83	10.83	14.58	17.08
26	20	6.56	5.51	5.9	6.17
27	80	6.28	6.26	3.77	4.77

Table 5-8: Lag-times for each HRU used to calibrate HEC-1 models for selected storms

Storms	Storm 1_78	Storm 2_78	Storm 3_79	Storm 2_80
HRU number	Lag-time	Lag-time	Lag-time	Lag-time
1	*	*	*	*
2	2.1	2.3	1.6	1.0
3	2.5	2.4	3.35	1.45
4	1.5	2.0	2.1	1.8
5	2.5	3.7	4.6	2.75
6	1.5	1.2	1.9	1.2
7	2.0	1.8	2.0	1.9
8	2.8	2.0	2.8	2.0
9	2.5	1.0	2.5	0.8
10	2.9	2.0	2.9	1.8
11	2.5	1.7	2.5	1.7
12	2.4	1.5	2.4	1.5
13	2.5	1.8	2.7	1.8
14	2.7	2.0	3.0	2.2
15	3.1	2.8	3.1	2.8
16	2.5	2.2	2.5	2.5
17	2.0	1.8	2.0	2.0
18	2.6	2.05	2.6	2.6
19	2.3	2.15	2.3	2.3
20	3.5	3.0	3.5	3.5
21	3.2	3.2	3.2	3.2
22	2.0	2.0	2.1	1.8
23	3.1	2.5	4.1	2.0
24	2.5	1.5	2.5	1.5
25	2.7	2.5	3.5	2.5
26	3.3	2.5	3.0	2.2
27	2.8	1.9	2.8	2.2

* *Lag-times not pertinent.*

Figure 5-7: Hydrograph of observed discharge, Storm 1_78

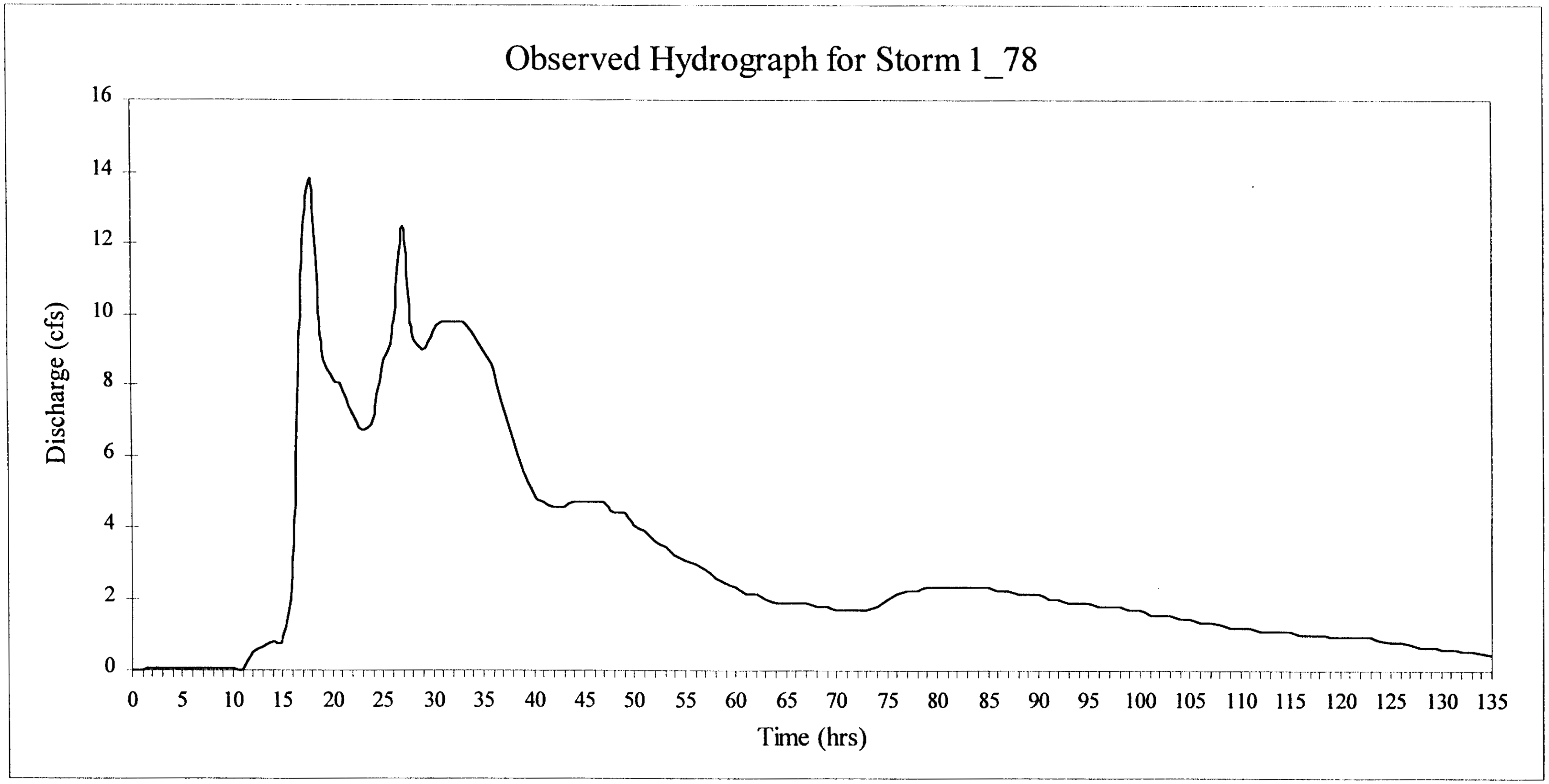


Figure 5-8: Hydrograph of observed discharge, Storm 2_78

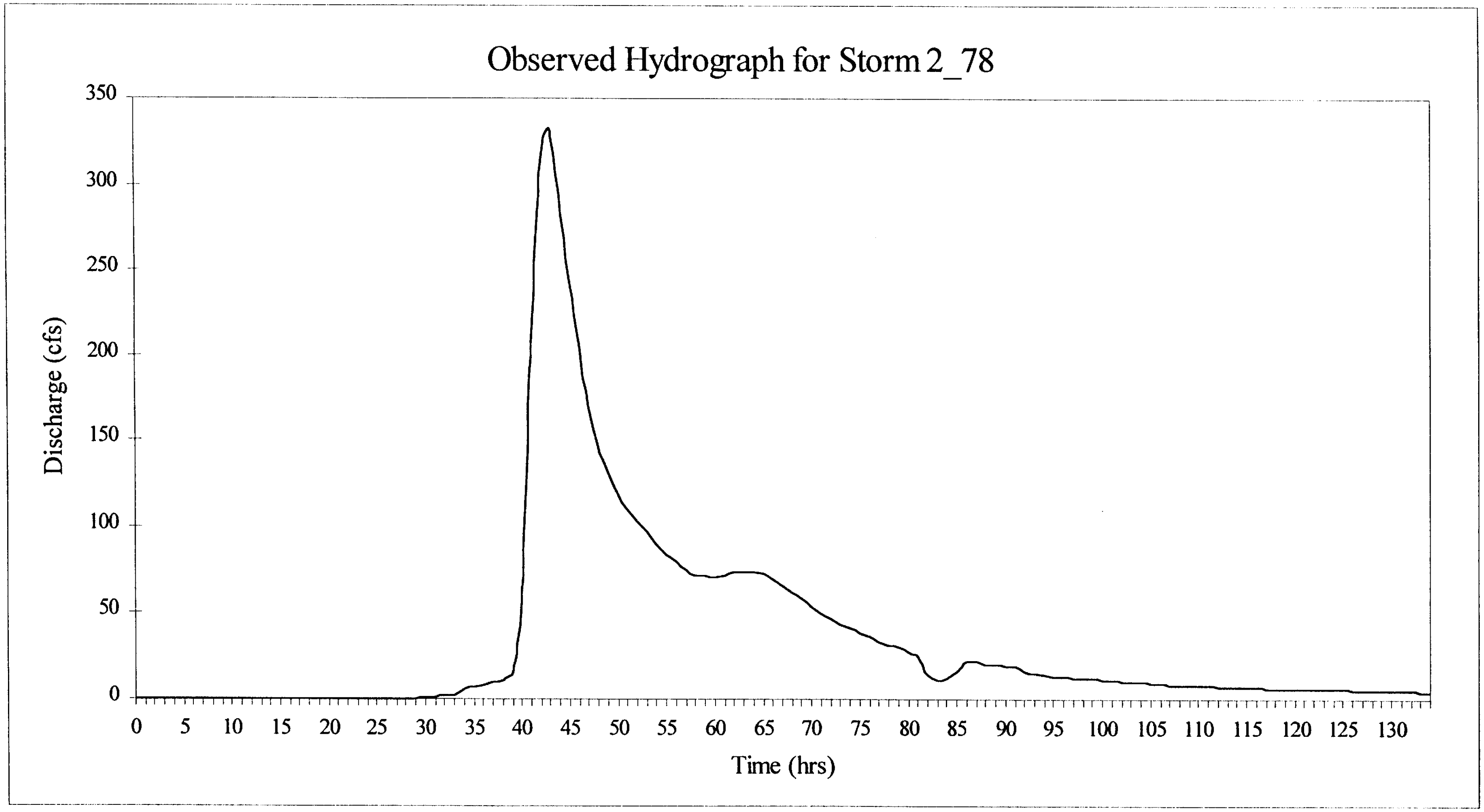


Figure 5-9: Hydrograph of observed discharge, Storm 3-79

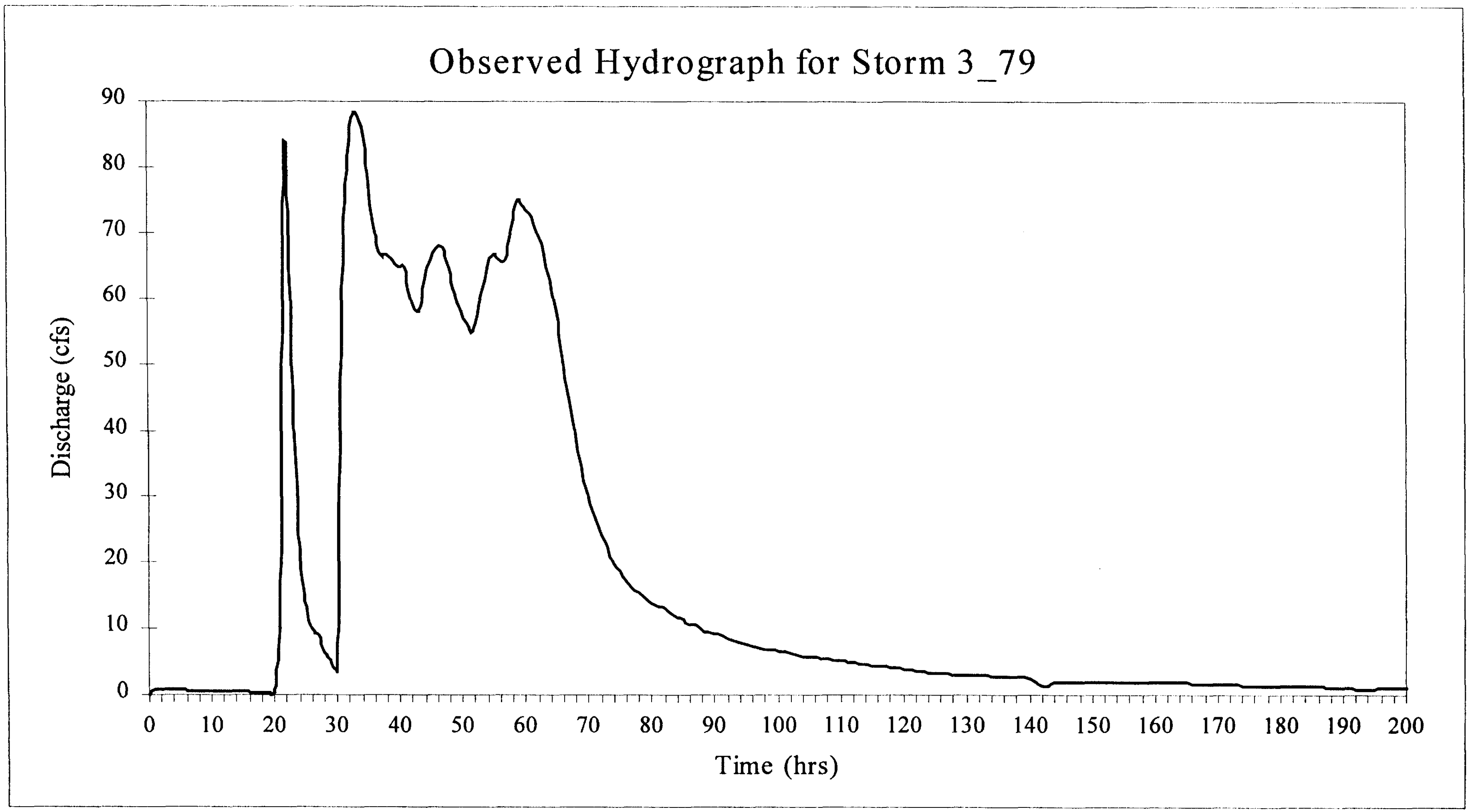


Figure 5-10: Hydrograph of observed discharge, Storm 2_80

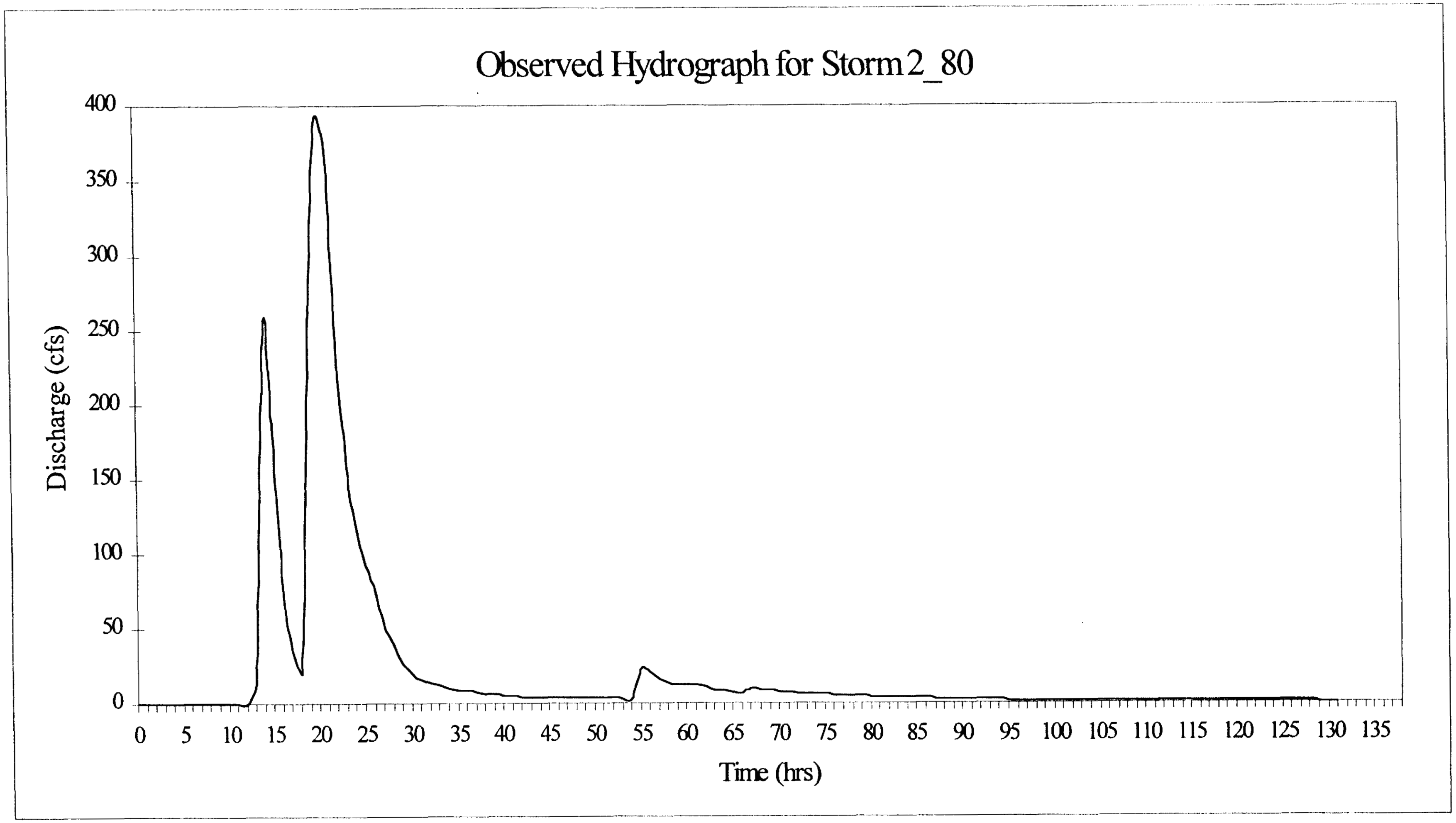


Table 5-9: Reservoir characteristics for the Little Thunder and Reno Reservoirs

Little Thunder Reservoir Information

Storage Depth (ft.)	Cumulative Storage (ac.-ft.)*	Notes
0	0	Storage/elevation relationship from reservoir permit
2	4.9	
4	14.6	
6	33.6	
8	68.8	
10	122.4	
12	197	Size of spillway crest height, water right
13	236	Begin extrapolated storage values
14	282	
15	333	Dam crest 6 ft. above spillway crest

Starting elevation for 2_78 storm: 11.22 ft. (0.0 in all others)
Estimated spillway width: 128 ft.
Discharge coefficient in weir spillway flow equation: 3.2
Exponent of head in weir spillway flow equation: 1.5

Reno Reservoir Information

Storage Depth (ft.)	Cumulative Storage (ac.-ft.)*	Notes
0	0	Storage/Elevation relationship from reservoir permit
5	3	
10	20.6	
15	72.4	
20	195.75	
25	425.45	Size of spillway crest height, water right
26	478	Begin extrapolated storage values
27	536	
28	598	
29	665	Dam crest 5 ft. above spillway crest

Starting elevation for 2_78 storm: 22.41 ft. (0.0 in all others)
Estimated spillway width: 150 ft.
Discharge coefficient in weir spillway flow equation: 3.2
Exponent of head in weir spillway flow equation: 1.5

**HEC-1 uses linear interpolation for storage at intermediate depths.*

Storm 1_78

The storm labeled 1_78 started on July 6, 1978, at 11:00 AM. It is a small flow event during one of the wettest years on record. After a large event in May, the month of June was relatively dry. Flow from the event in May, however, continued well into June. The dry weather and relatively high temperatures of June 1978 indicated to the authors that 1_78 would be a good representative of AMC I. The small reservoirs were treated as they would be for dry conditions, and contributing areas were adjusted accordingly.

The observed hydrograph for storm 1_78, and the hydrograph predicted by the calibration effort are presented in Figure 5-11. The pre-mining predicted hydrograph for this model is effectively identical to the calibrated model. Peak flow and total volume fall well within operating targets. The actual values for observed and predicted peak flows and volumes are presented in Table 5-10. Little, if any, run-off is generated from the HRUs that the mines have eliminated from contribution. The predicted hydrograph is presented with hydrographs that represent an increase and decrease of one NRCS run-off curve number for each of the impacted HRUs (Figure 5-12). The pre-mining hydrograph also is compared to hydrographs that represent increases and decreases of 2, 3, and 4 NRCS run-off curve numbers for the impacted areas (Figures 5-13 through 5-15). Pre-mining hydrograph values for peak flow and total volume as well as post-mining values that were produced by each change are presented in Table 5-11.

Table 5-10: Predicted and observed peak flows, total volumes, and percentage difference from predicted and observed responses for Storm 1_78

Storm 1_78	Peak 1 (cfs*)	Peak 2 (cfs)	Peak 3 (cfs)	Total volume (ac.-ft.)
Predicted	13.9	12.4	9.2	30.99
Observed	13.8	12.5	9.8	33.62
% Difference	0.7%	0.8%	6.1%	8.49%

**cubic ft./second (CFS).*

Figure 5-11: Hydrographs of observed and predicted discharge, Storm 1_78

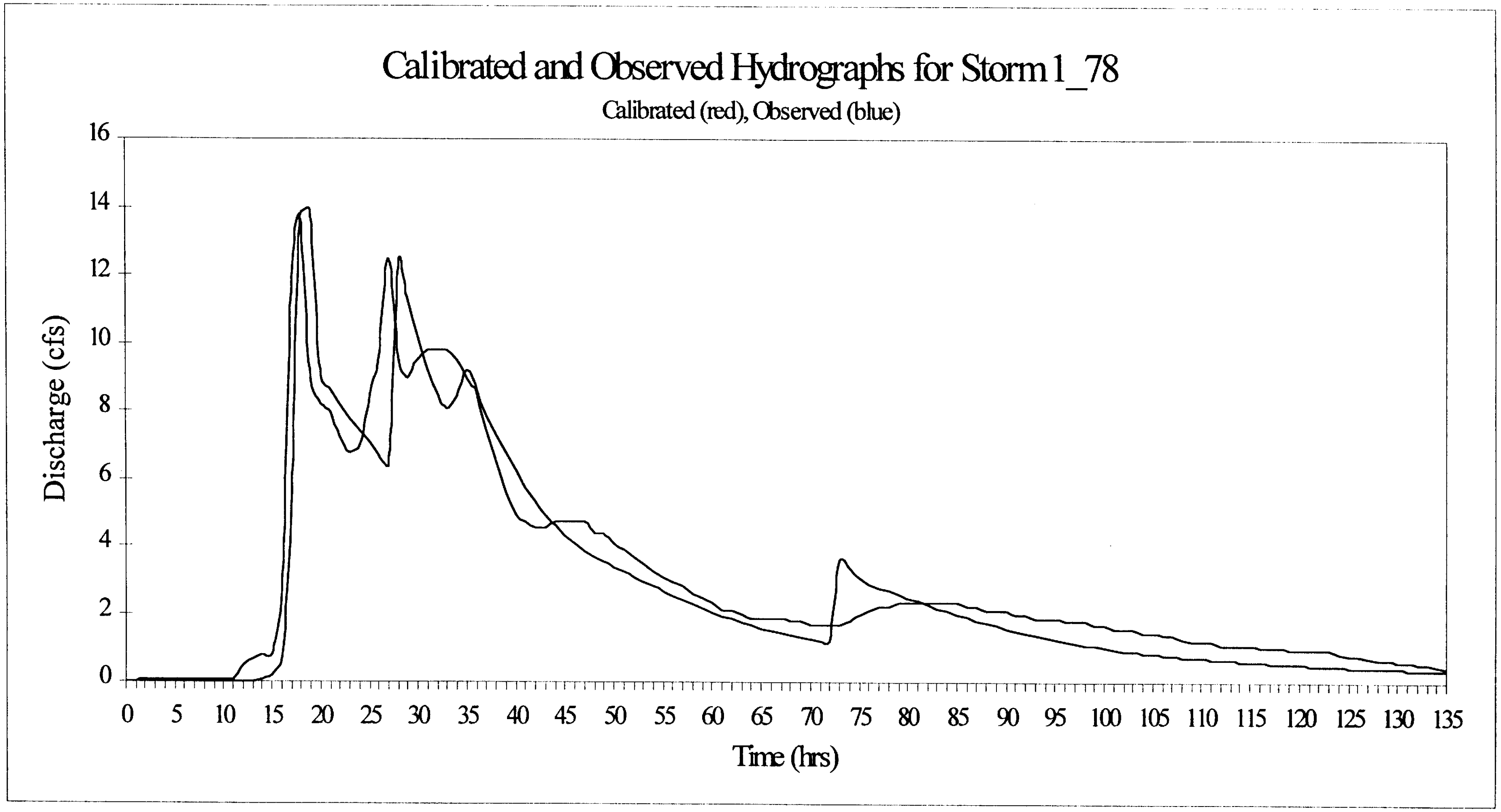


Figure 5-12: Estimated pre-mining and post-mining hydrographs Storm, 1-78: post-mining models represent an increase and decrease of one NRCS run-off curve number

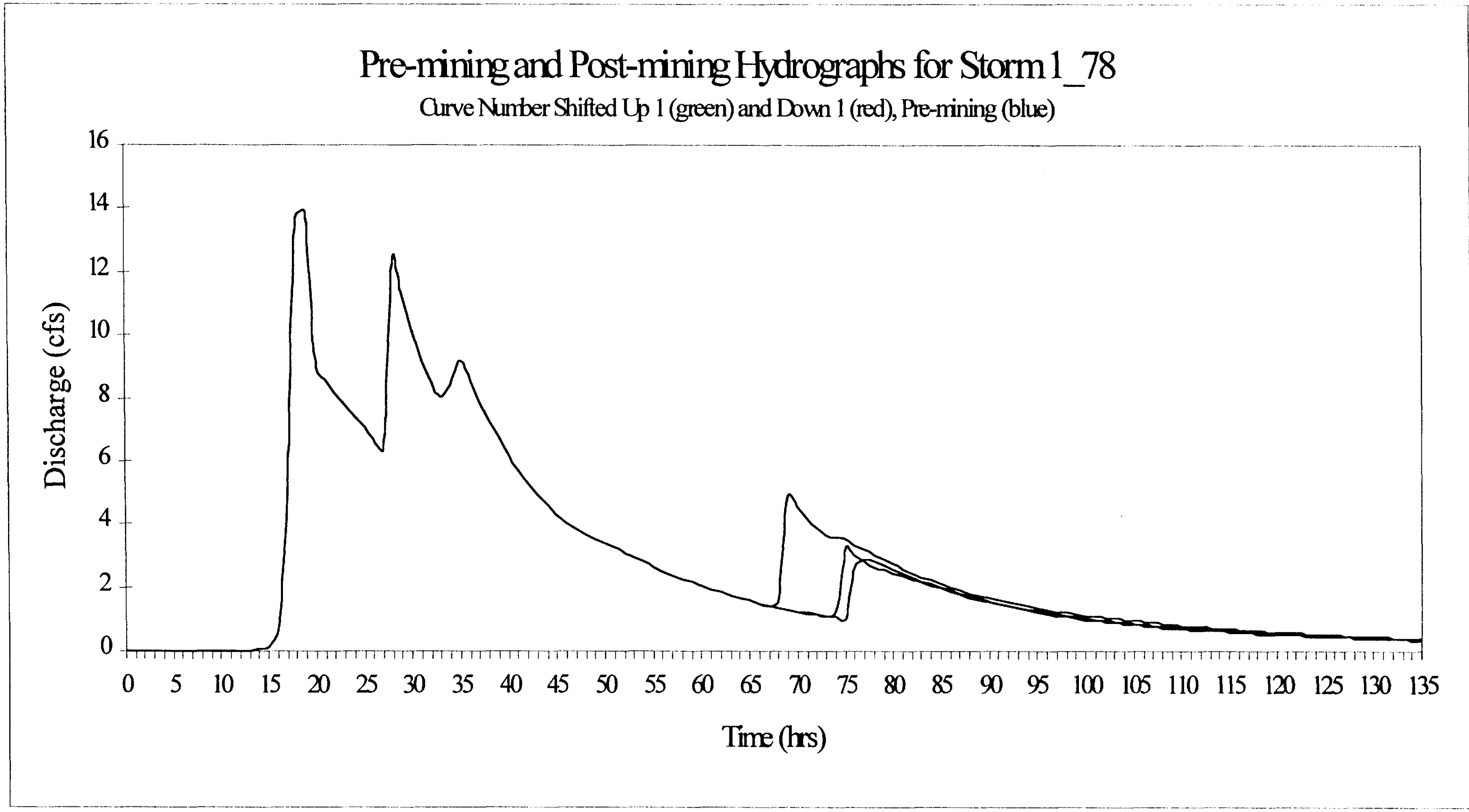


Figure 5-13: Estimated pre-mining and post-mining hydrographs, Storm 1-78: post-mining models represent an increase and decrease of two NRCS run-off curve numbers

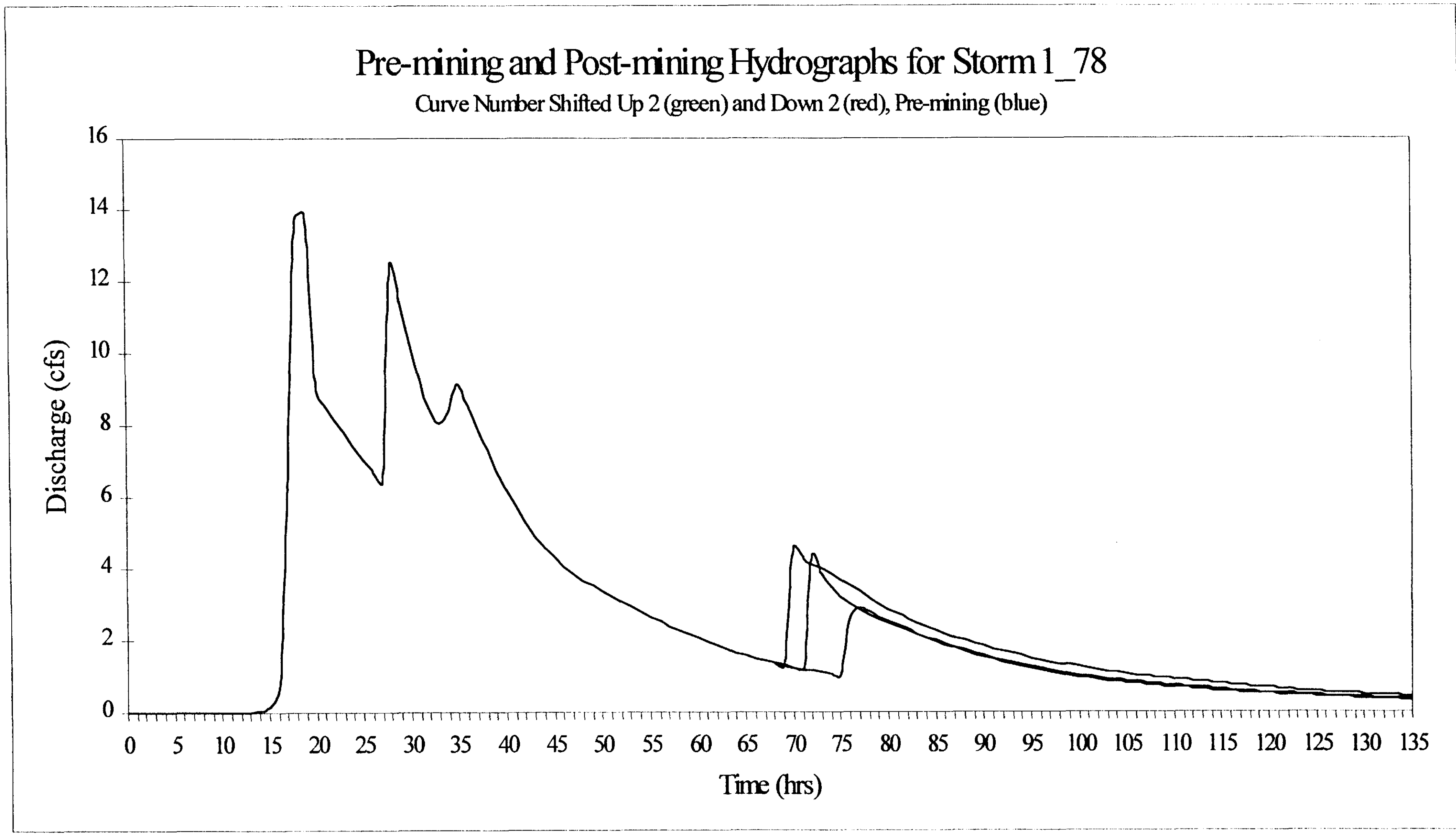


Figure 5-14: Estimated pre-mining and post-mining hydrographs, Storm 1-78: post-mining models represent an increase and decrease of three NRCS run-off curve numbers

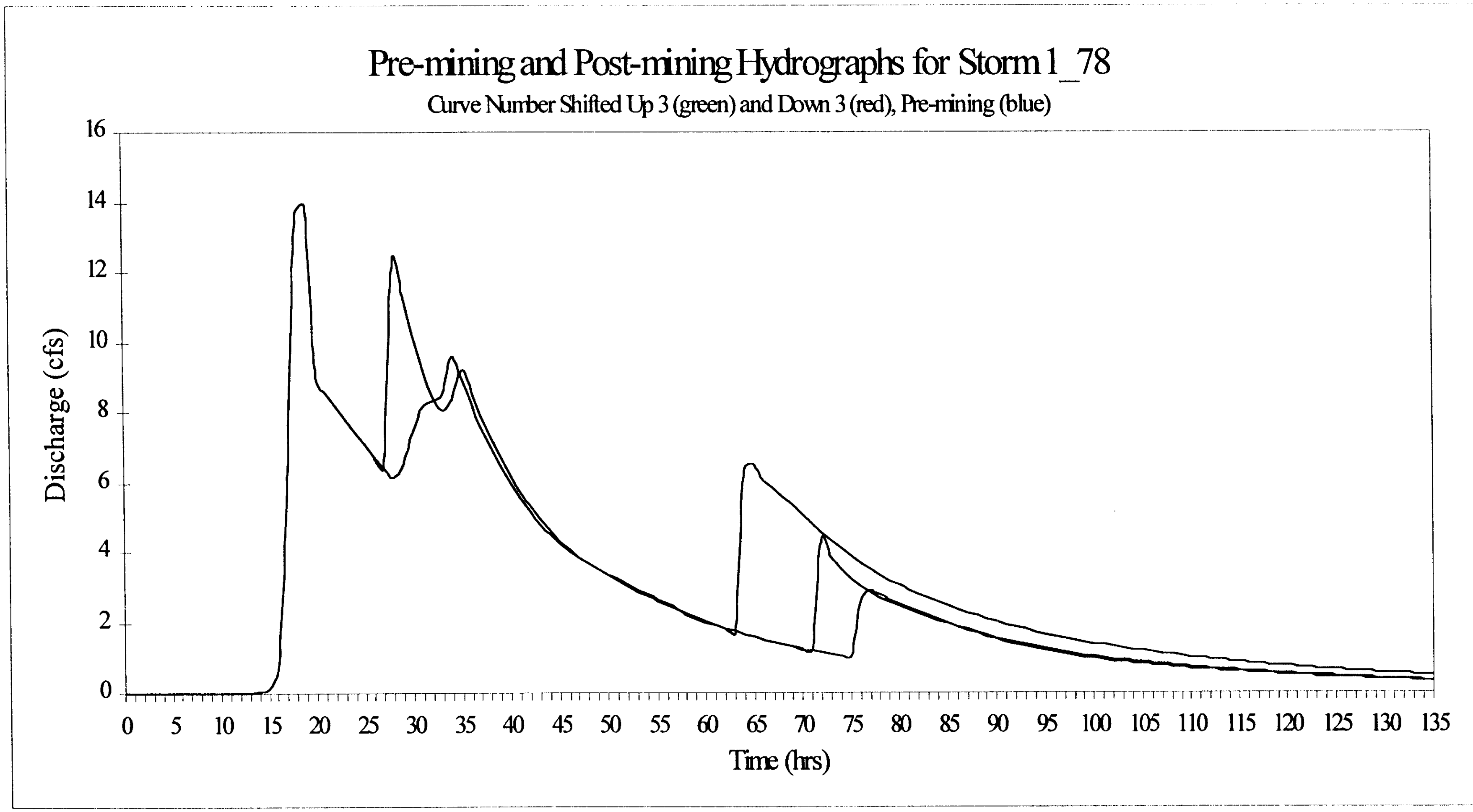


Figure 5-15: Estimated pre-mining and post-mining hydrographs, Storm 1-78: post-mining models represent an increase and decrease of four NRCS run-off curve numbers

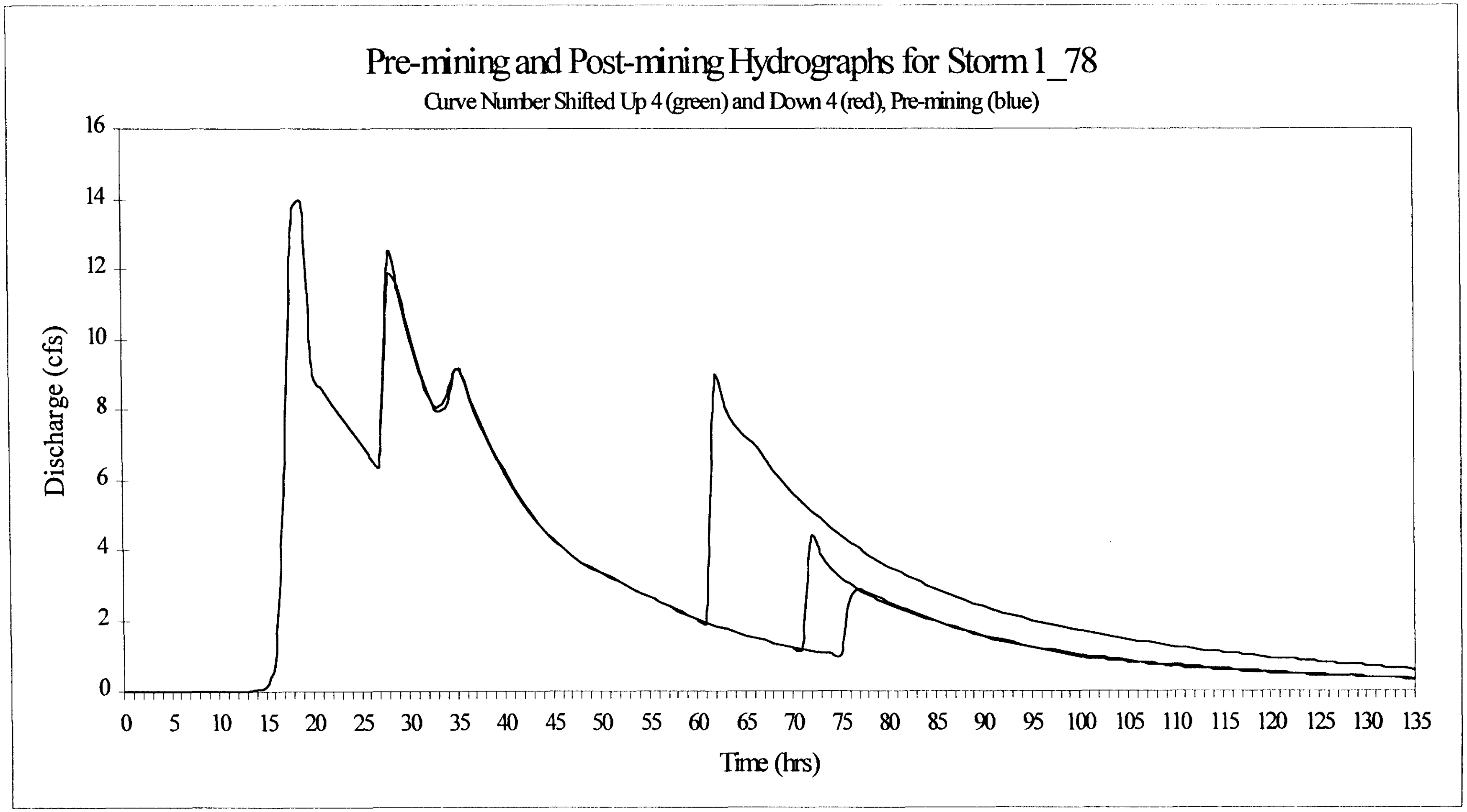


Table 5-11: Comparison of pre- and post-mining peak flows and total volumes, with percentage differences for Storm 1_78

Storm 1_78	Peak (cfs)	Total volume (ac-ft.)
Pre-mine*	13.9	30.48
Post-mine**	13.9	30.96
% Difference	0%	1.57%
+1***	13.9	32.64
% Difference	0%	7.09%
-1***	13.9	30.54
% Difference	0%	0.20%
+2	13.9	33.06
% Difference	0%	8.46%
-2	13.9	31.20
% Difference	0%	2.36%
+3	13.9	34.82
% Difference	0%	14.24%
-3	13.9	31.20
% Difference	0%	2.36%
+4	13.9	39.52
% Difference	0%	29.66%
-4	13.9	31.20
% Difference	0%	2.36%

**Pre-mining indicates the model developed from the calibrated model to reflect conditions that existed prior to mining.*

***Post-mining indicates the model developed from the pre-mining model to reflect changes resulting from mining activity.*

****+1/-1, +2/-2 etc., indicates the models developed for post-mining conditions including a uniform increase/decrease of 1, 2, 3, or 4 NRCS run-off curve numbers.*

Storm 2_78

The storm labeled 2_78 started on July 21, 1978, at midnight. It is a large event that follows storm 1_78 by 15 days. The dry weather and relatively high temperatures of June 1978 continued in the inter-storm period. The small reservoirs were treated as they would have been for intermediate conditions, and contributing areas were adjusted to AMC II values. During the calibration process, it became evident that some water was flowing out of the reservoirs on the main channel. In order to match the observed flow, the starting conditions for the reservoirs became part of the calibration process, and they were altered accordingly. The available storage of the larger reservoirs was adjusted downward from those expected of the other storms, to reflect the storage from the 100 year event in May, and the storm of 15 days earlier. The calibration process resulted in a general lowering of the NRCS run-off curve numbers from original estimates. The recovery to dry conditions after storm 1_78 was more rapid than we had expected. The NRCS run-off curve numbers are just slightly higher than those used for storm 1_78. The precipitation values generally fell outside the expected ranges, with most HRUs receiving less rain than originally anticipated. The observed hydrograph is presented in Figure 5-16, along with the hydrograph that represents our calibration.

The pre-mining predicted hydrograph was generated by calibrating the model without HRUs 15, 22, 23, and 27 contributing (Figure 5-16). The pre-mining predicted model includes the four impacted basins. Peak flow and total volume comparisons for the calibration model fall well within our operating standards; observed and predicted values for our calibrated model are presented in Table 5-12. The pre-mining hydrograph is presented with hydrographs that represent an increase and decrease of one NRCS run-off curve number for each of the impacted HRUs (Figure 5-17). The pre-mining hydrograph is compared to hydrographs that represent increases and decreases of 2, 3, and 4 NRCS run-off curve numbers for the impacted areas (Figures 5-18 through 5-20). Pre-mining hydrograph values for peak flow and total volume as well as post-mining values that were produced by each change are presented in Table 5-13.

Table 5-12: Predicted and observed peaks, total volumes, and percentage difference from predicted and observed responses for Storm 2_78

Storm 2_78	**Peak 1 (cfs)**	**Peak 2 (cfs)**	**Peak 3 (cfs)**	**Total volume (ac-ft.)**
Predicted	327.5	82.3		407.95
Observed	332.6	74.1		392.41
% Difference	1.5%	11.1%		3.81%

Blanks in Peak 3 indicate the storm produced only two peaks.

Figure 5-16: Hydrographs of observed and predicted discharge, Storm 2_78

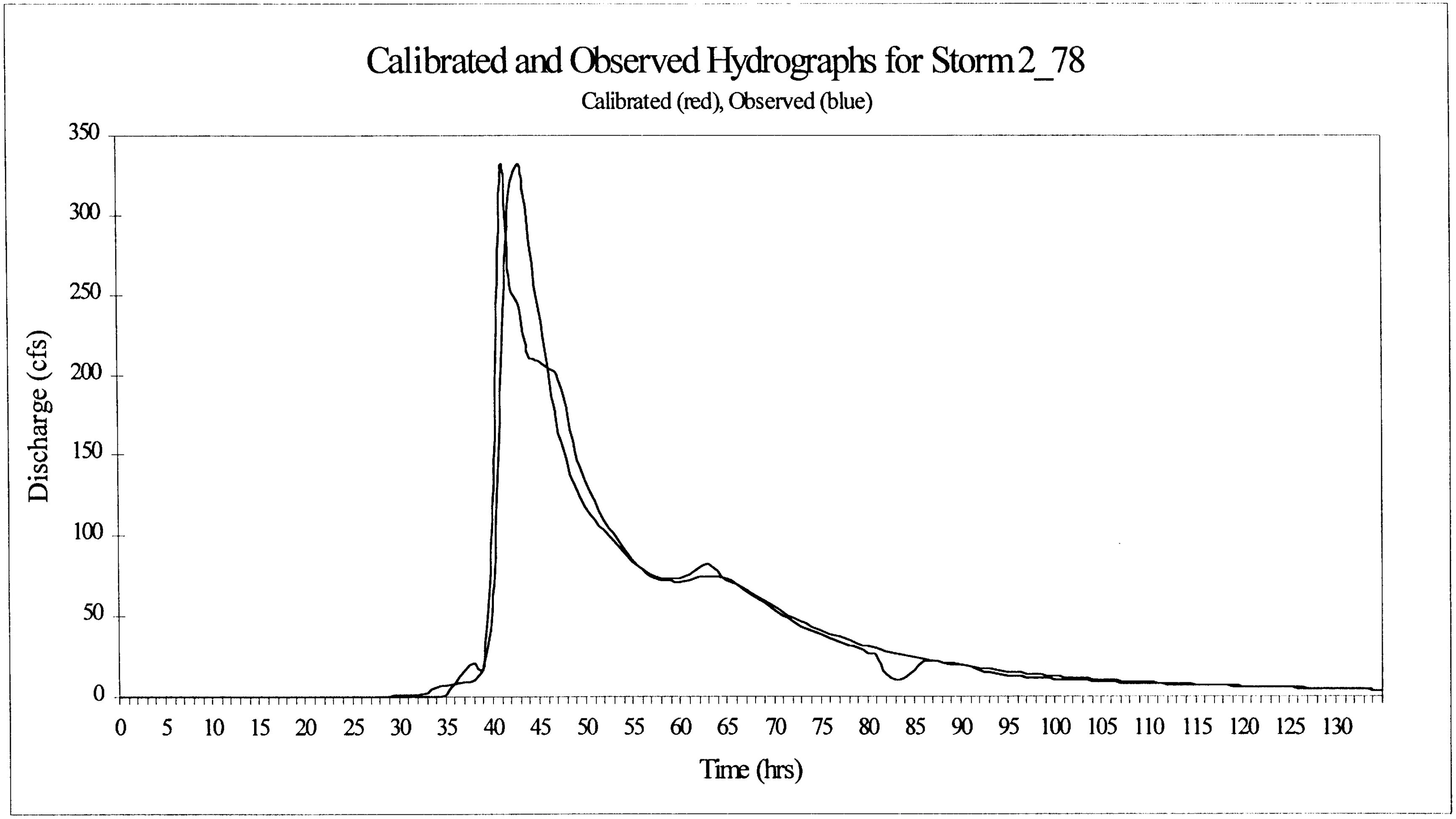


Figure 5-17: Estimated pre-mining and post-mining hydrographs, Storm 2_78: post-mining model represents and increase and decrease of one NRCS run-off curve number

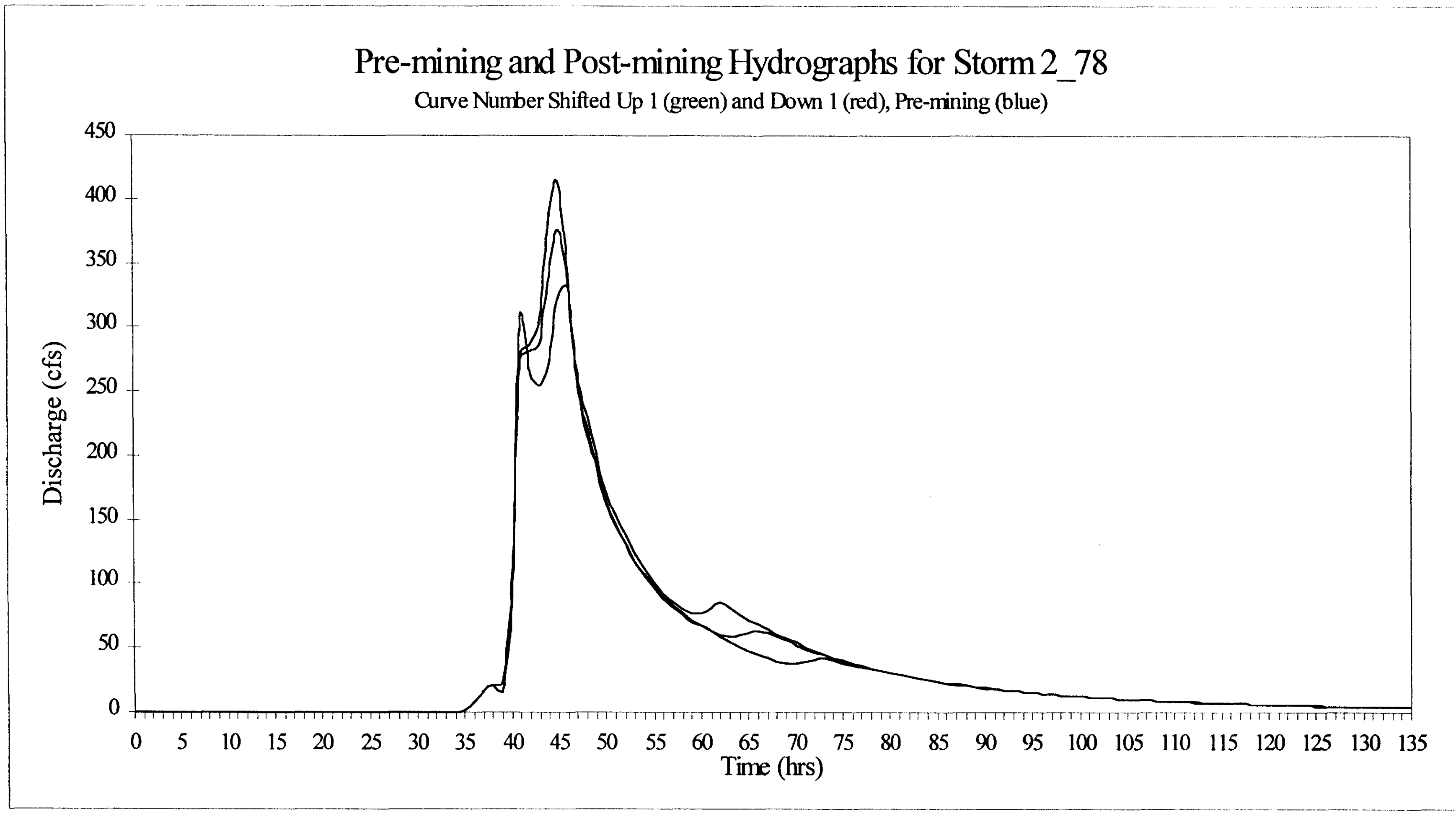


Figure 5-18: Estimated pre-mining and post-mining hydrographs, Storm 2_78: post-mining models represent an increase and decrease of two NRCS run-off curve numbers

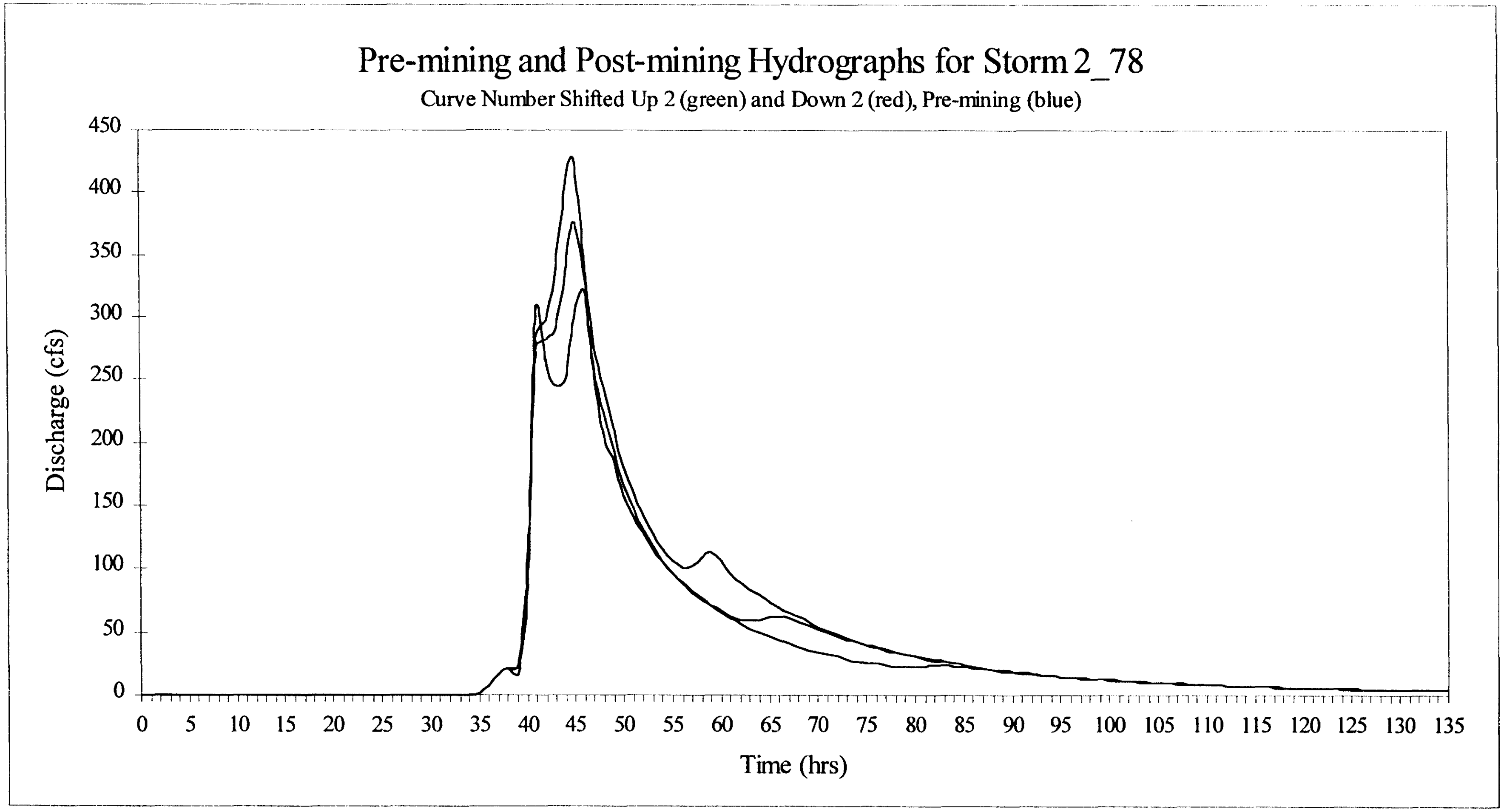


Figure 5-19: Estimated pre-mining and post-mining hydrographs, Storm 2_78: post-mining models represent an increase and decrease of three NRCS run-off curve numbers

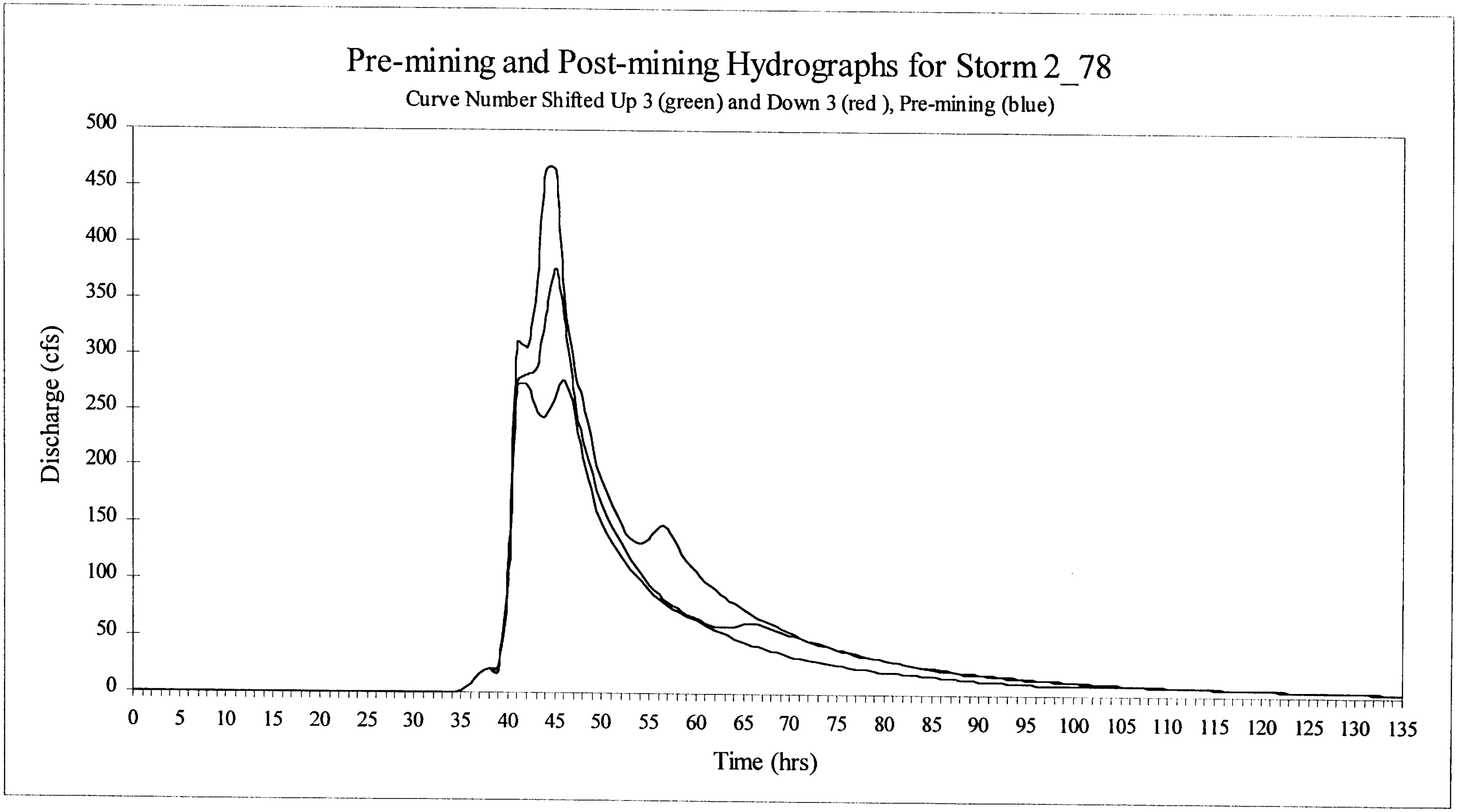


Figure 5-20: Estimated pre-mining and post-mining hydrographs, Storm 2_78: post-mining models represent an increase and decrease of four NRCS run-off curve numbers

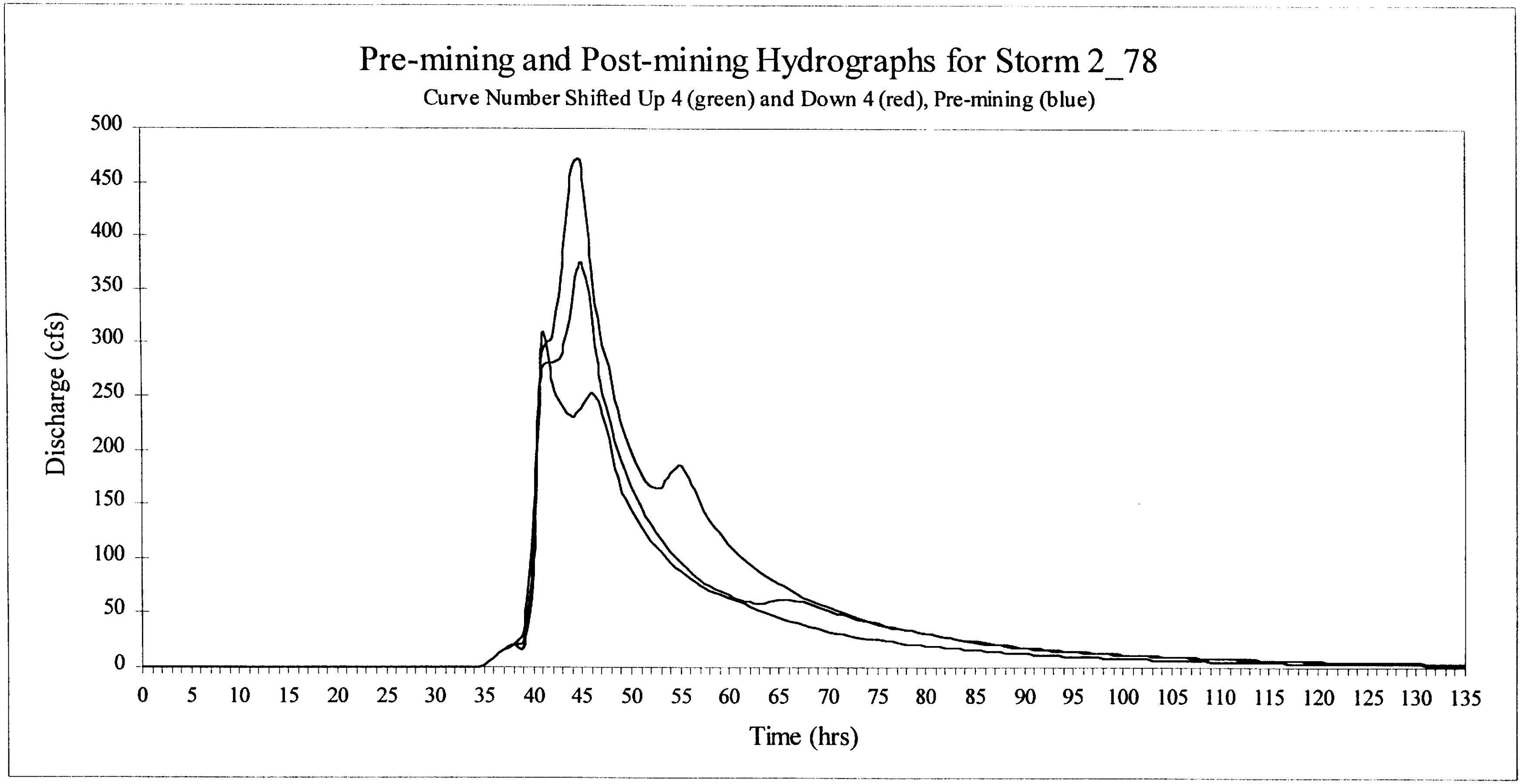


Table 5-13: Comparison of pre- and post-mining peak flows and total volumes, with percentage differences for Storm 2_78

Storm 2_78	Peak (cfs)	Total volume (ac-ft.)
Pre-mine*	376.9	453.84
Post-mine**	376.6	454.88
% Difference	0.1%	0.23%
+1***	414.3	480.37
% Difference	9.9%	5.85%
-1***	331.7	429.42
% Difference	12.0%	5.38%
+2	426.9	506.26
% Difference	13.3%	11.55%
-2	321.6	407.63
% Difference	14.7%	10.18%
+3	465.6	538.33
% Difference	23.5%	18.61%
-3	276.3	382.90
% Difference	26.7%	15.63%
+4	470.3	562.80
% Difference	24.8%	24.0%
-4	305.5	367.21
% Difference	18.9%	19.09%

**Pre-mining indicates the model developed from the calibrated model to reflect conditions that existed prior to mining.*

***Post-mining indicates the model developed from the pre-mining model to reflect changes resulting from mining activity.*

****+1/-1, +2/-2 etc., indicates the models developed for post-mining conditions including a uniform increase/decrease of 1, 2, 3, or 4 NRCS run-off curve numbers.*

Storm 3-79

The storm labeled 3_79 started on June 25, 1979, at midnight. It was a medium sized event of longer duration. The nature of the hydrograph is unlike the other three storms. Flows do not exhibit the flashy tendencies usually associated with ephemeral systems. Flows peak, decline, and then peak again. The unusual aspect is that after the second peak, flows become unusually consistent for nearly two days. After the two days the hydrograph drops off sharply into the familiar long recession tail. Analysis of the precipitation pattern for the area indicates that a second storm occurred in the Pilot Study Area approximately two days after the initial precipitation. The last two peaks in the observed hydrograph could coincide with the run-off from that event. With that in mind, the storm was calibrated using only the peaks that occurred earlier than the last two. The comparison of the total volumes for the calibrated and observed hydrographs was cut off after 51 hours when the two hydrographs begin to permanently diverge. This storm does bear some resemblance with the hydrograph produced by storm 1_78; they both include multiple peaks with more gentle summits than those of 2_78 and 2_80.

The year 1979 was dry, especially when compared with 1978. The storm labeled 3_79 was just the third major flow event recorded by the USGS in that water year. The one month period prior to the storm was fairly wet, however. A storm two or three days prior to the event, and recorded at the Rochelle Station, deposited substantial amounts of rain in the area. The relatively wet month preceding the storm suggested that a wet AMC II would be appropriate for this storm. The calibration procedures later indicated that AMC III contributing areas and high AMC II curve numbers were more appropriate.

Storm total values also changed substantially from our initial estimates. The low storm total at the Rochelle Station lowered the storm totals for lower HRUs. During the calibration process, it was decided that the low storm totals in the lower Little Thunder Creek Drainage would prevent any calibration. It was decided to ignore the low values of the Rochelle Station, and move the storm totals higher, to be more consistent with the other recording stations in the Pilot Study Area.

Further analysis of the 30 days preceding the storm revealed that it may indeed have been wetter than the 30 days prior to storm 2_80. The initial calibrations of the four storms were done with the idea that 2_80 was the wetter of the two storms. The end calibration almost brought the contributing areas and NRCS run-off curve numbers up to the level of 2_80. This inconsistency is a concern, but it is not believed to be a fatal flaw to the modeling process. The timing of the rain in the 30 days prior to the studied storm is probably as important as the amount.

The small reservoirs were treated as they would be for AMC III, and contributing areas were adjusted to AMC III values. The available storage of the larger reservoirs was adjusted upward to reflect the depleted storage of a dry year in the PRB. The previous storms during the month were probably enough to reduce the storage capacity of the small reservoirs throughout the PRB. It is doubtful, however, that the ability of the larger reservoirs to handle a storm of this magnitude, without overflowing, was seriously compromised.

The observed hydrograph and the hydrograph that represents our calibration are presented in Figure 5-21. The pre-mining predicted hydrograph was generated by calibrating the model without HRUs 15, 22, 23, and 27 contributing. The pre-mining predicted model includes the four impacted basins. Peak flow and total volume comparisons for the calibration model fall well within our operating standards. The actual values for the observed and predicted hydrographs through 51 hours are presented in Table 5-14. The pre-mining hydrograph of the full storm is presented with hydrographs representing an increase and decrease of one NRCS run-off curve number for each of the impacted HRUs (Figure 5-22). The pre-mining hydrograph also is compared to hydrographs representing increases and decreases of 2, 3, and 4 NRCS run-off curve numbers for the impacted areas (Figures 5-23 through 5-25). Pre-mining hydrograph values for peak flow and total volume, as well as post-mining values produced by each change, are presented in Table 5-15.

Table 5-14: Predicted and observed peak flows, total volumes, and percentage difference from predicted and observed responses for Storm 3_79

Storm 3_79	**Peak 1 (cfs)**	**Peak 2 (cfs)**	**Peak 3 (cfs)**	**Total volume (ac.-ft.)**	**Total volume 51 hours (ac.-ft.)**
Predicted	74.9	95.7	74.2	184.74	129.9
Observed	82.8	88.5	67.9	280.87	135.7
% Difference	9.5%	8.1%	9.3%	52.04%	4.3%

Total volume through 51 hours is presented to demonstrate the theorized impact of a second storm in the area.

Figure 5-21: Hydrographs of observed and predicted discharge, Storm 3_79

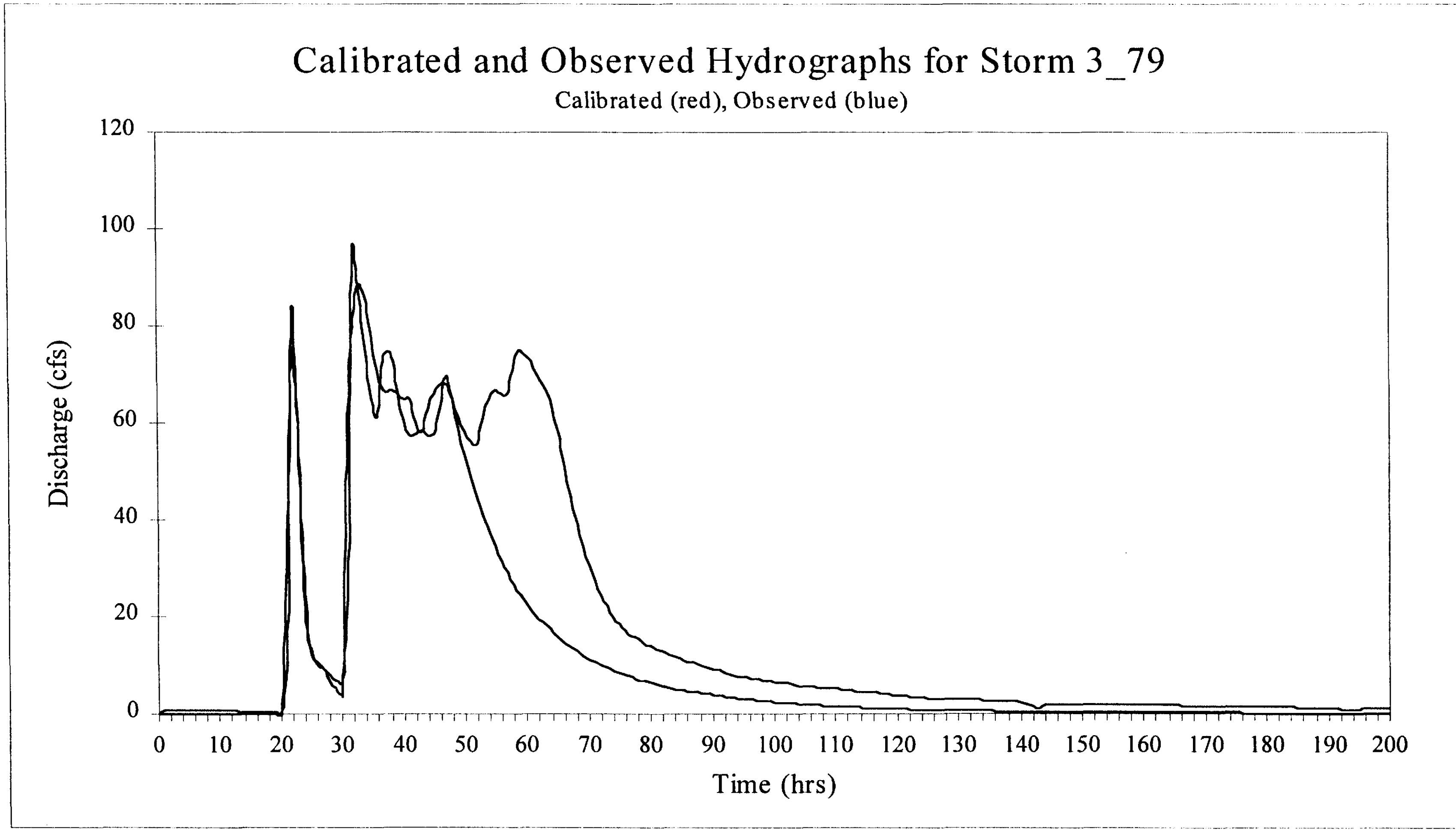


Figure 5-22: Estimated pre-mining and post-mining hydrographs, Storm 3-79: post-mining models represent an increase and decrease of one NRCS run-off curve number

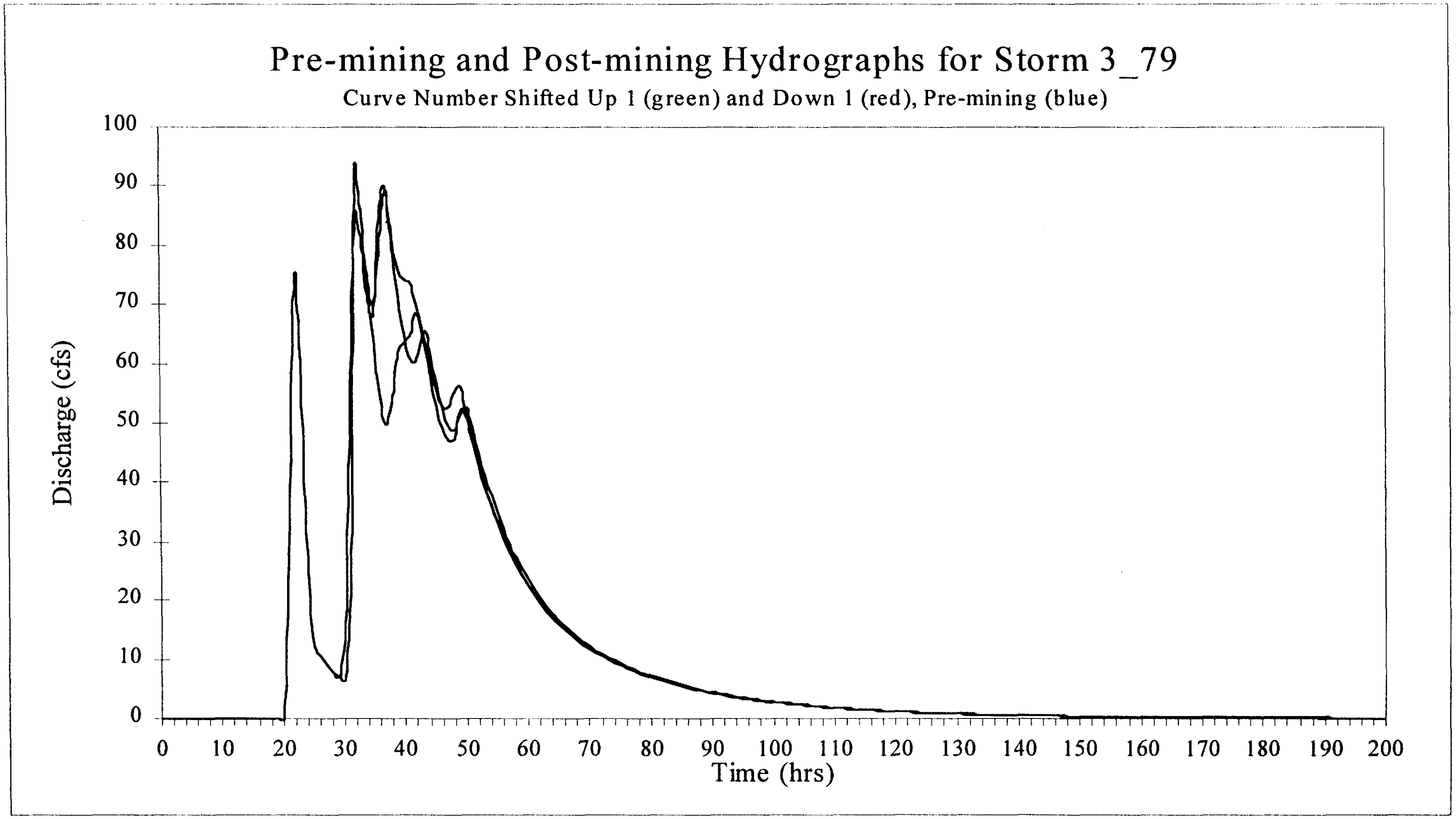


Figure 5-23: Estimated pre-mining and post-mining hydrographs, Storm 3_79: post-mining models represent an increase and decrease of two NRCS run-off curve numbers

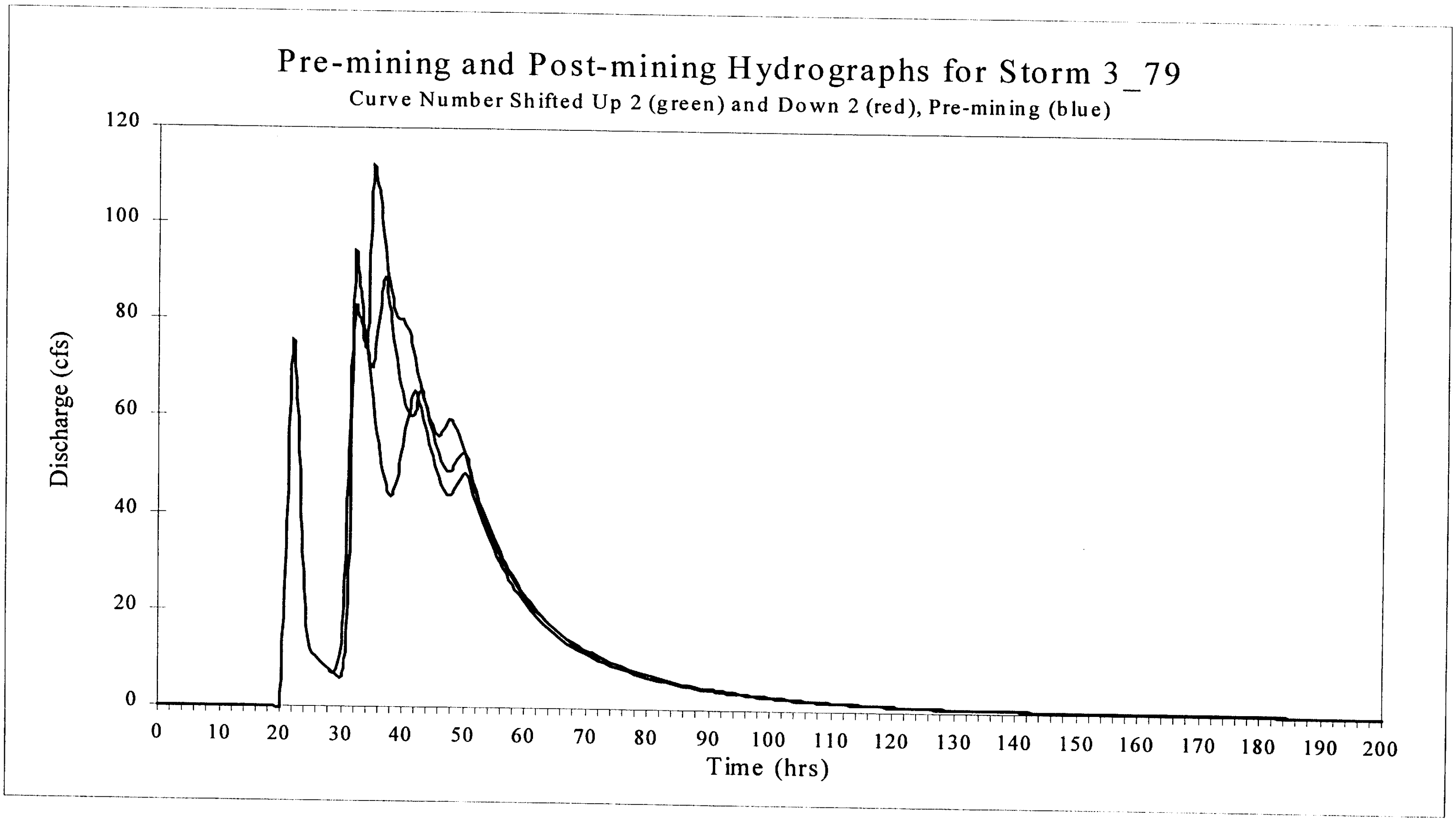


Figure 5-24: Estimated pre-mining and post-mining hydrographs, Storm 3-79: post-mining models represent an increase and decrease of three NRCS run-off curve numbers

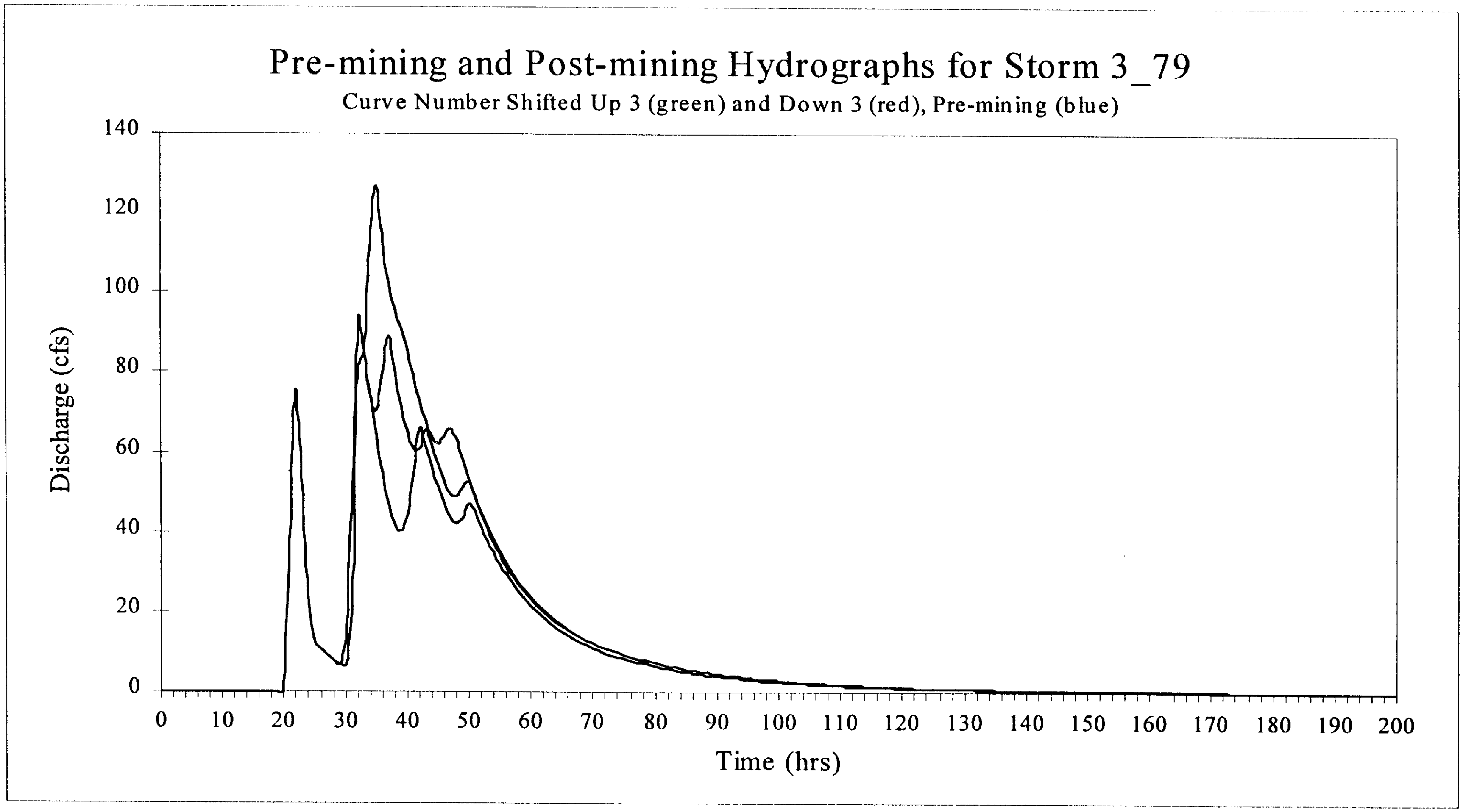


Figure 5-25: Estimated pre-mining and post-mining hydrographs, Storm 3_79: post-mining models represent an increase and decrease of four NRCS run-off curve numbers

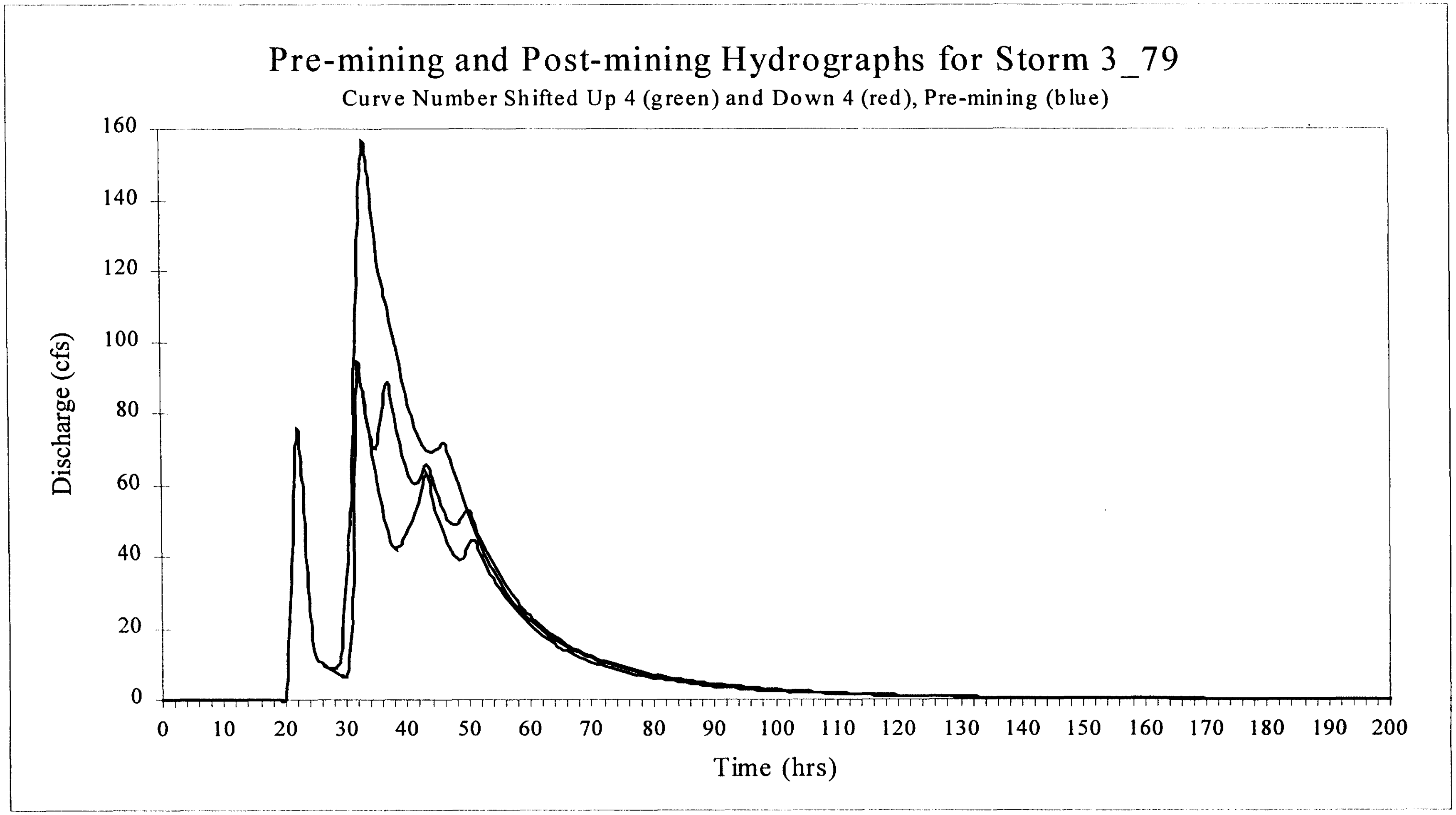


Table 5-15: Comparison of pre- and post-mining peak flows and total volumes, with percentage differences for Storm 3_79

Storm 3_79	Peak (cfs)	Total volume (ac.-ft.)
Pre-mine*	93.2	189.43
Post-mine**	93.2	183.09
% Difference	0%	3.35%
+1***	90.1	193.27
% Difference	3.2%	2.03%
-1***	93.2	176.81
% Difference	0%	6.66%
+2	111.3	203.63
% Difference	19.4%	7.5%
-2	93.2	170.29
% Difference	0%	10.10%
+3	127.0	214.32
% Difference	36.3%	13.14%
-3	93.2	165.89
% Difference	0%	12.43%
+4	155.5	229.47
% Difference	66.8%	21.14%
-4	93.2	162.17
% Difference	0%	14.39%

**Pre-mining indicates the model developed from the calibrated model to reflect conditions that existed prior to mining.*

***Post-mining indicates the model developed from the pre-mining model to reflect changes resulting from mining activity.*

****+1/-1, +2/-2 etc., indicates the models developed for post-mining conditions including a uniform increase/decrease of 1, 2, 3, or 4 NRCS run-off curve numbers.*

Storm 2_80

The storm labeled 2_80 started on June 24, 1980, at 10:00 AM. It was a large flow event, with a duration and hydrograph that is more common to ephemeral systems, than that displayed by Storm 3_79. The hydrograph exhibits the large peaks associated with ephemeral systems that are impacted by largely convective weather patterns. Flows peak, decline, and then peak again. The single large peak is followed by the familiar long recession tail.

The year 1980 was intermediate with regard to precipitation. Storm 2_80 was just the second major flow event recorded by the USGS in that water year, and it was an earlier storm than the other three storms used in the study. The one month period prior to the storm was fairly wet, and substantially colder than the other three storms. A storm shortly prior to the event, and recorded at the Rochelle Station, deposited substantial amounts of rain in the area. The relatively wet month preceding the storm suggested that AMC III would be appropriate for this storm. The calibration procedures later indicated that this was a valid analysis. The wet, cold month prior to the storm also suggested that most of the smaller reservoirs would be full, and they would have experienced little in the way of evaporative depletion.

The small reservoirs were treated as they would be for wet conditions, and contributing areas were adjusted to AMC III values. The available storage of the larger reservoirs was adjusted downward to reflect the wet spring conditions associated with this storm. The previous storms during the month were probably enough to reduce the storage capacity of the small reservoirs throughout the PRB. It is doubtful, however, that the ability of the larger reservoirs to handle a storm of this magnitude, without overflowing, was seriously compromised.

The observed hydrograph and the hydrograph representing the calibration are presented in Figure 5-26. The pre-mining predicted hydrograph was generated by calibrating the model without HRUs 15, 22, 23, and 27 contributing. The pre-mining predicted model includes the four impacted basins. Peak flow and total volume comparisons for the calibration model fall well within our operating standards; actual values for the observed flow and the calibrated model are presented in Table 5-16.

The pre-mining hydrograph is presented with hydrographs representing an increase and decrease of one NRCS run-off curve number for each of the impacted HRUs (Figure 5-27). The pre-mining hydrograph also is compared to hydrographs representing increases and decreases of 2, 3, and 4 NRCS run-off curve numbers for the impacted areas (Figures 5-28 through 5-30). Pre-mining hydrograph values for peak flow and total volume, as well as post-mining values produced by each change, are presented in Table 5-17.

Table 5-16: Predicted and observed peak flows, total volumes, and percentage difference from predicted and observed responses for Storm 2_80

Storm 2_80	Peak 1 (cfs)	Peak 2 (cfs)	Peak 3 (cfs)	Total Volume (ac.-ft.)
Predicted	247.7	387.2		242.70
Observed	253.4	392.8		240.66
% Difference	2.2%	1.4%		0.84%

Blanks in Peak 3 indicate the storm produced only two peaks.

Figure 5-26: Hydrographs of observed and predicted discharge, Storm 2_80

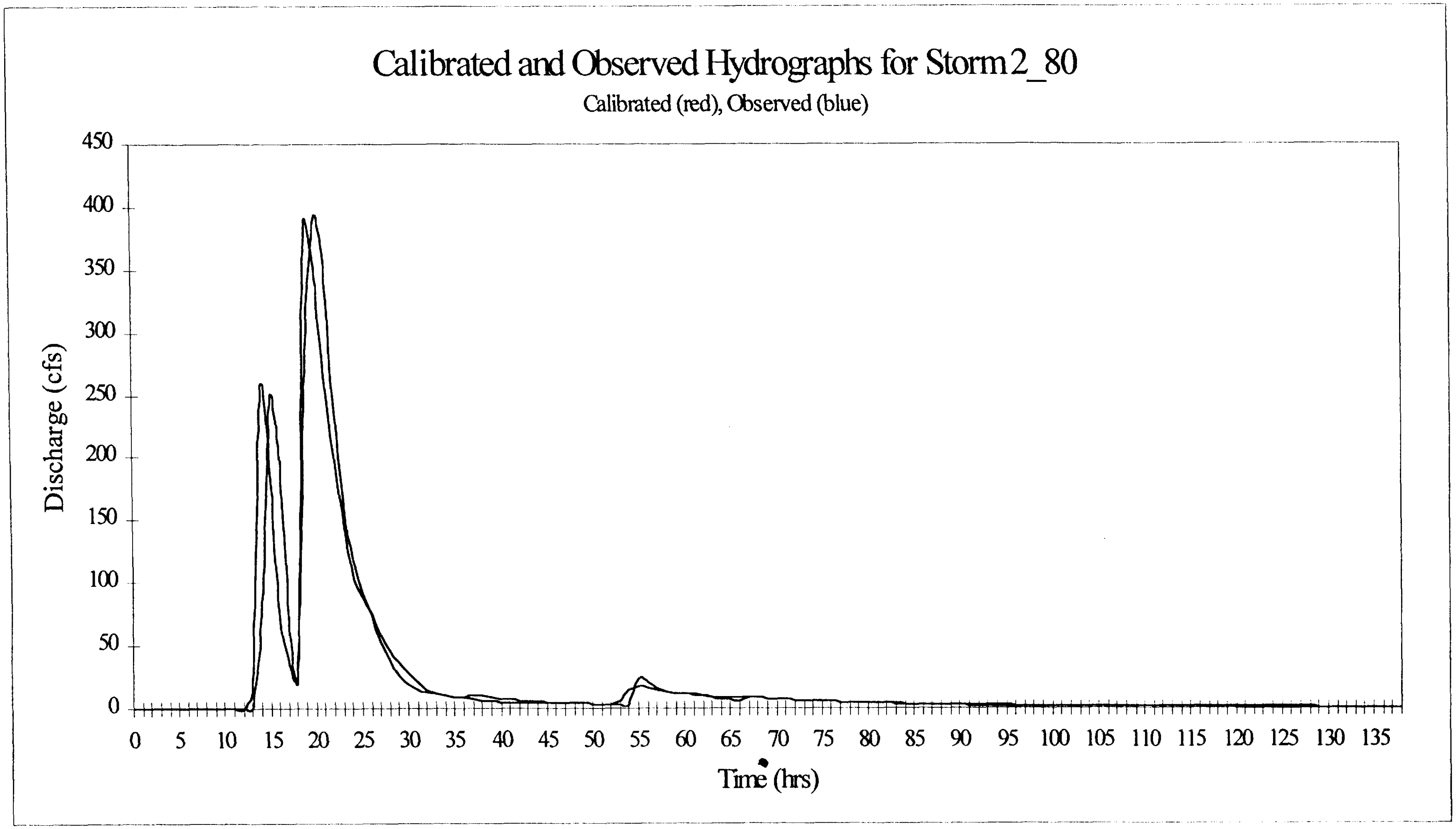


Figure 5-27: Estimated pre-mining and post-mining hydrographs Storm, 2_80: post-mining models represent an increase and decrease of one NRCS run-off curve number

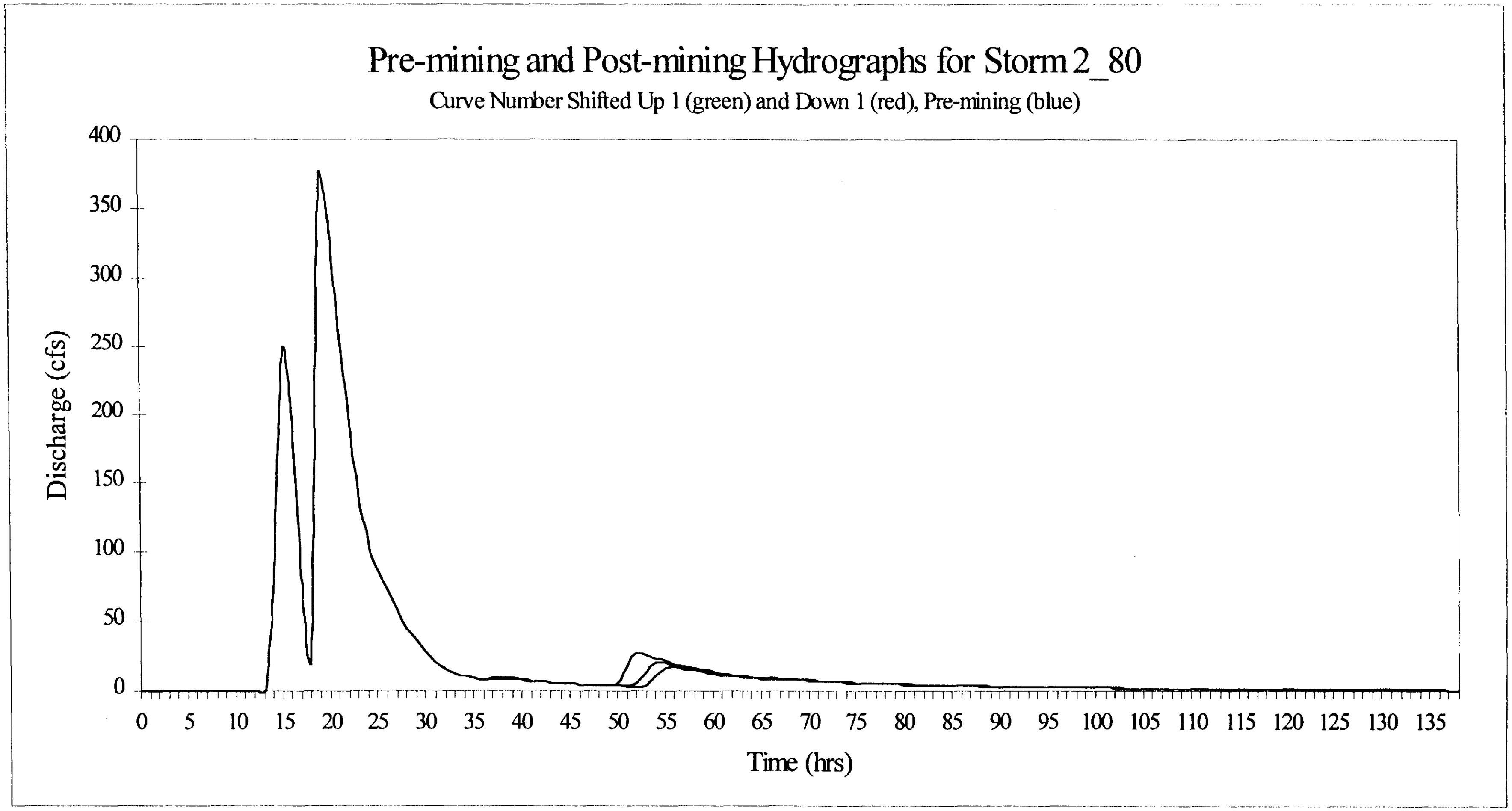


Figure 5-28: Estimated pre-mining and post-mining hydrographs, Storm 2_80: post-mining models represent an increase and decrease of two NRCS run-off curve numbers

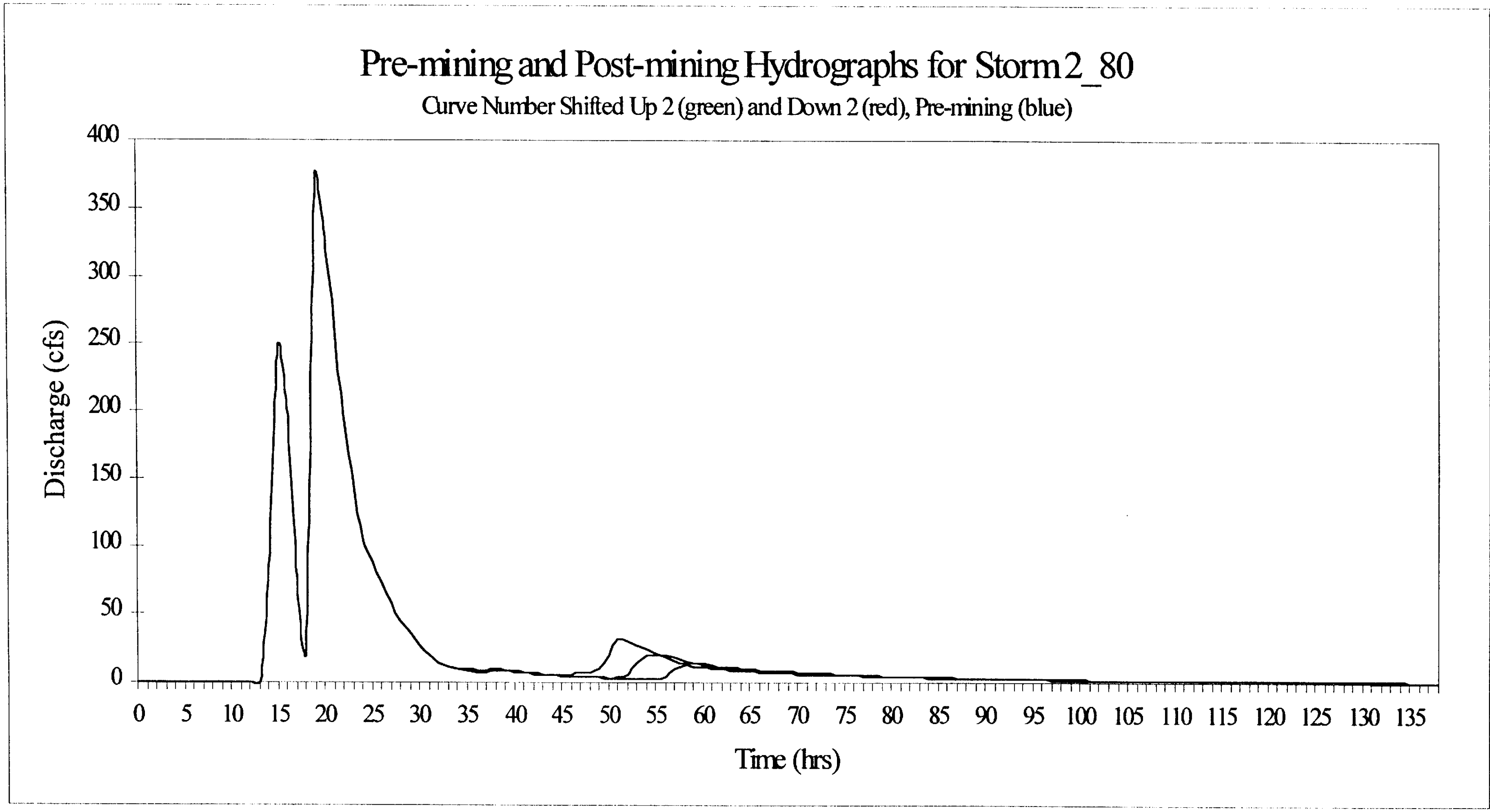


Figure 5-29: Estimated pre-mining and post-mining hydrographs, Storm 2_80: post-mining models represent an increase and decrease of three NRCS run-off curve numbers

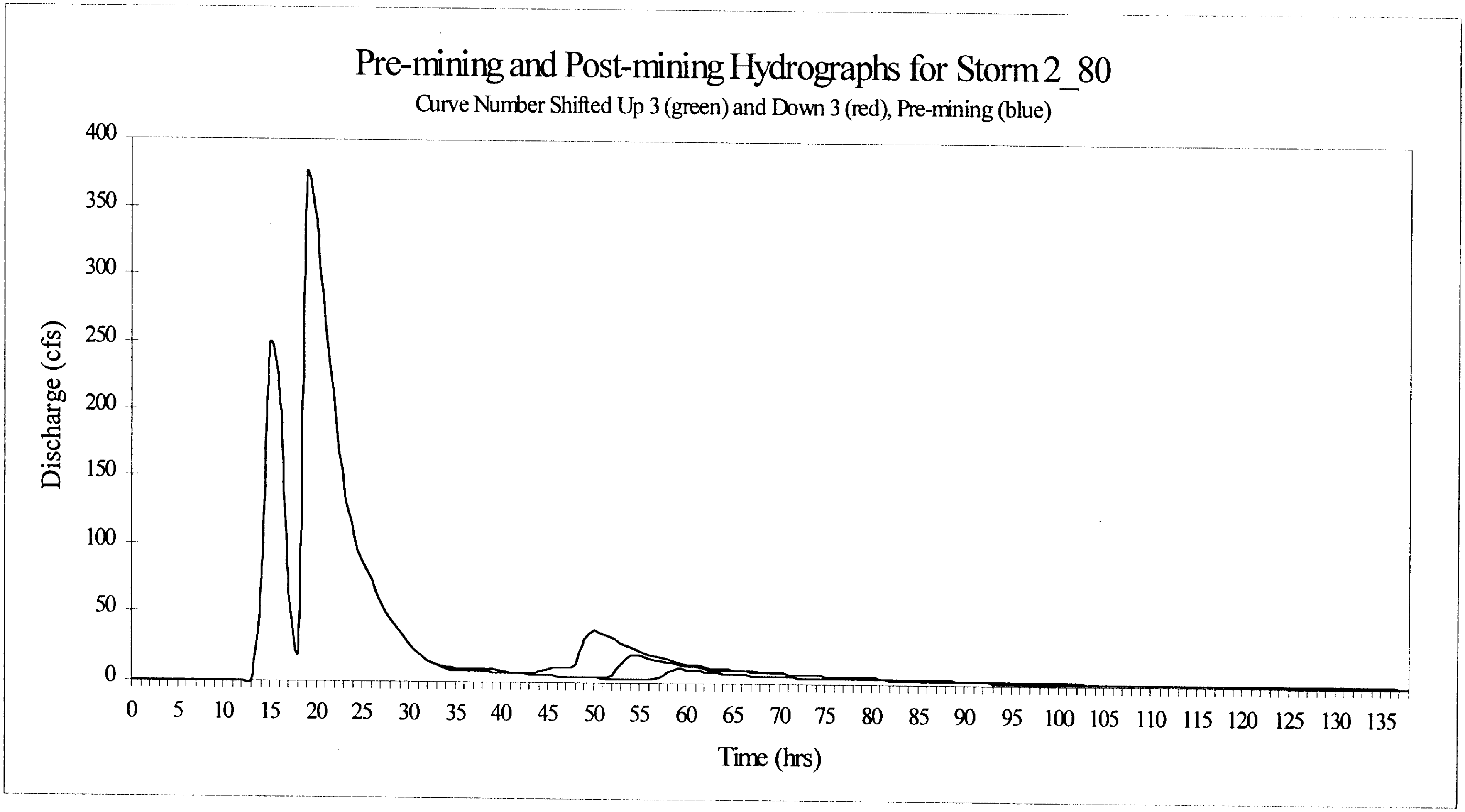


Figure 5-30: Estimated pre-mining and post-mining hydrographs, Storm 2_80: post-mining models represent an increase and decrease of four NRCS run-off curve numbers

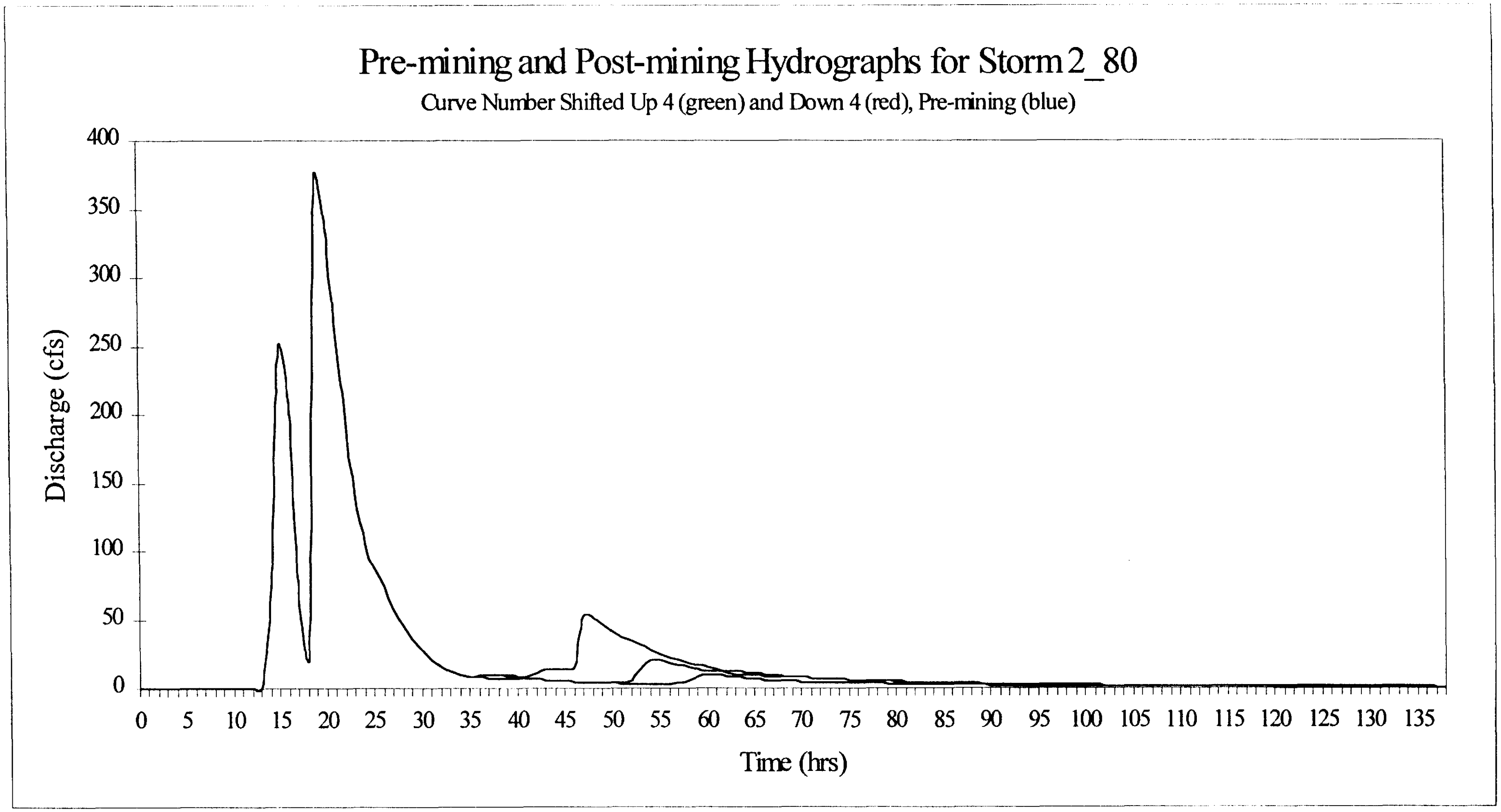


Table 5-17: Comparison of pre- and post-mining peak flows and total volumes, with percentage differences for Storm 2_80

Storm 2_80	**Peak (cfs)**	**Total volume (ac.-ft.)**
Pre-mine*	372.4	242.65
Post-mine**	372.4	242.59
% Difference	0%	0.02%
+1***	2372.4	247.57
% Difference	0%	2.03%
-1***	372.4	239.25
% Difference	0%	1.40%
+2	372.4	252.13
% Difference	0%	3.91%
-2	372.4	233.44
% Difference	0%	3.80%
+3	372.4	258.54
% Difference	0%	6.55%
-3	372.4	229.39
% Difference	0%	5.46%
+4	372.4	269.31
% Difference	0%	10.99%
-4	372.4	227.33
% Difference	0%	6.31%

**Pre-mining indicates the model developed from the calibrated model to reflect conditions that existed prior to mining.*

***Post-mining indicates the model developed from the pre-mining model to reflect changes resulting from mining activity.*

***+*1/-1, +2/-2 etc., indicates the models developed for post-mining conditions including a uniform increase/decrease of 1, 2, 3, or 4 NRCS run-off curve numbers.*

Discussion

The current implementation of HEC-1 for this modeling project is somewhat unique in its approach. In most modeling situations, the model is developed with known or closely estimated parameters, which are applied to the model. Predictions regarding real or hypothetical events are based upon that model. The unusual aspect of this approach is that the model was calibrated, not to predict an unknown, but to reflect observed data. Only after the calibration was acceptable, were models altered to predict the unknown. Whenever possible, input parameters believed to reflect actual conditions within the watershed, were used in the model. If, however, those parameters provided results that could not be reconciled to the observed discharge data, the input parameters were changed accordingly.

The NRCS run-off curve numbers and the total precipitation for a storm were the "sledgehammers" of the calibration effort. Using those two aspects of an HRU, the total volume of output and the peak flows were approximated. At a certain point, finer adjustments to the model were made. These finer adjustments usually reflected changes in timing, hydrograph shape, or, to a smaller extent, the peak flow. The parameters discussed in the methods section were the primary tools with which the finer adjustments were made during the calibration process. Lag-time, recession point, recession constant, and other parameters were used to fine tune the calibrations.

The modeling process documented above was an inherently intuitive process. Alterations in NRCS run-off curve number and precipitation storm totals, as well as lag-time and conveyance loss, were made based upon interpretation of the WMS output from each model run. It would be well out of the realm of feasibility to assume or assert that these models represent the only possible calibrations. What they represent is the authors' professional analyses, with regard to calibration, for four storms in the Little Thunder Creek Drainage Basin. It was anticipated that in the process of calibrating these storms and analyzing them relative to one another, that the authors would be able to identify any conceptual errors within the algorithms or assumptions used to calibrate and eventually model the Little Thunder Creek Drainage.

Utilization of the models developed for the Little Thunder Creek Drainage will be most efficient if the pre-mine models are not altered. Attempting to recreate the models developed here will simply be redundant, and probably unsuccessful. Models developed by others, will likely be different from those developed here, and in some cases, substantially different. It is expected, however, that these models are "conceptually correct," and that the underlying assumptions used in modeling are fundamentally sound. The consistency between the models with regard to NRCS run-off curve numbers, reservoir storage, and conveyance loss lend credence to the idea that the fundamental assumptions of the models are correct.

Post-mining impacts can be added to the pre-mining models by determining the areas to be impacted, ascertaining post-mining terrain features such as topography or channel lengths, and then altering those values in the model. NRCS run-off curve number changes are largely a function of professional judgment with regard to the direction and amount of change. Nothing about the model is dependent upon a standardized change in NRCS run-off curve numbers. To the contrary, the authors have provided a wide range of changes based upon the simplest possible assertions. The uniform change in curve numbers for the entire impacted area is the simplest model that was developed. The flexibility of the model is such that a large number of scenarios can be put into place if future conditions warrant.

The decision to calibrate four storms of varying intensities and magnitudes was primarily based upon the nature of HEC-1. Replicating the AMCs between two storms closely enough to allow validation of one storm by the other would be virtually impossible. Even if such a match were possible, matching only one storm to the model would neither confirm nor deny the validity of the model, regardless of the output. A larger sample size would be required to test the validity of the model. The limited number of storms available makes acquisition of an adequate sample unreasonable at best, and impossible at worst.

The primary strength of doing four storms was that it facilitated the detection of conceptual errors in the model. At times, the observed discharge data and the watershed data input simply could not be reconciled. These discrepancies were believed to be the product of erroneous data at sometimes, while at others, they were believed to be conceptual problems with the model algorithms. The cause of the discrepancies became more or less irrelevant, because the only way of resolving the problems was to alter the input data. If only one storm had been calibrated, the correctness of the model would be dubious. The calibration of four models, having varying conditions, allowed the authors to develop models that were not only correct with regard to the observed discharge data for a given storm, but also correct in the model's underlying concepts. By recreating four different hydrographs, the models have, in a sense, been validated relative to one another. The underlying concepts used in the driest and wettest models were confirmed during the calibration process of the intermediate storms.

The alteration of parameter inputs from the expected ranges was not an anticipated outcome of the modeling effort. It was, however, necessary to the completion of the calibration process. This was one of the secondary influences of calibrating four storms. After modeling 200 or 300 calibration runs, it became obvious to the modeler what was required to make the input data fit the observed data. Sometimes this meant going beyond what was initially believed to be a reasonable value. This process also resulted in the conclusion that the initial estimates of reasonable maximum and minimum precipitation values did not account for the tremendous variability in precipitation. Eastwood (1994) established that variability of point precipitation data can vary greatly within relatively small areas. That concept was not well applied to the precipitation contour maps until the calibration process revealed that the estimates for precipitation were well outside the limits of the initial minimums and maximums.

This project was designed and conducted with the intent of creating a tool for use by the WSEO and the WDEQ. The goal was to develop a model that could be used at the present time (1997), and in the future to assess what impact surface mining will have on the surface water hydrology of the Little Thunder Creek Drainage.

All comparisons of pre-mining to post-mining run-off are made at the location of the USGS stream gaging station, approximately 24 river miles below the nearest mining impact. This location was chosen because it represents the only known source of data. Predicted hydrographs for areas between the mines and the gaging station are available from the HEC-1 models, but there are no observed hydrographs above the gage with which to calibrate the models. It is the opinion of the authors that the distance from the point of calibration (e.g., the gaging station), is inversely proportional to the confidence level associated with the model. The difference in confidence levels between the predicted hydrographs at the gaging station location, and the areas upstream is unknown. It is believed that impacts to discharge in areas closer to the mines will be greater than those observed farther away. The predicted hydrographs for the areas between the mines and the gaging station may be valuable tools in the decision making process, but there is greater uncertainty associated with these predicted hydrographs. This greater uncertainty should be taken into account when analyzing the hydrographs.

Conducting a quantitative analysis of the hydrologic regime of the PRB is greatly complicated by the lack of consistent and reliable data collection within the area. Hourly data is critical to the development of a calibrated surface water model. The comments in the 1988 CHIA that address data quantity and quality remain pertinent today. A coordinated and consistent collection of hourly precipitation and discharge data would provide a more comprehensive and more efficient monitoring system. The variable climate of the PRB will, however, require substantial periods of record to reflect the types of conditions that occur within the area.

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Section 7
Appendices

Appendix A: Statement of Material Damage

Appendix B: 1992 Wyoming Hydrology Oversight Report - PHC/CHIA

Appendix C: Pit Inflows

Appendix D: Calibration Wells - Time Series Graphs

Appendix E: Databases

Appendix F: Pump Test Data and Aquifer Hydraulic Parameters

Appendix G: QA/QC'd Hydraulic Values in Coal Aquifer

Appendix H: MODFLOW Setup

Appendix I: Calibration of Model Using Early Time Data

Appendix A: Statement of Material Damage

STATEMENT OF MATERIAL DAMAGE

1. The Department of Environmental Quality has undertaken a cooperative effort to update the process of conducting Cumulative Hydrological Impact Assessments (CHIA's) for coal mining regions within Wyoming. After the CHIA for a particular mine and surrounding area is completed, the State Regulatory Agency must make a determination whether the hydrology of the area will suffer **material damage** as a result of mining activities as described at W.S. 35-11-406(n)(iii) for areas outside the permit and as described at W.S. 35-11-406(n)(v)(B) for alluvial valley floors.

2. Before beginning an extensive effort to develop an updated CHIA process, a detailed examination of what is meant by material damage was conducted. Our conclusion was that the definition of Material Damage as given in Chapter I.2(bd) of the LQD Regulations is full and complete. This definition is reprinted below as Figure 1:

> **"Material damage to the hydrologic balance" means a significant long-term or permanent adverse change to the hydrologic regime.**

Figure 1: DEQ/LQD Regulations Chapter I.2(bd), January 11, 1996

3. The OSM released a draft paper titled "OSM Hydrology Oversight Guideline Document" in mid 1993. The section heading and instructions excerpted from that document are reproduced below as Figures 2 & 3. These statements provide insight to the OSM position on how to define material damage.

> 3.0 THE CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT
>
> 3.3 Material Damage and Environmental Considerations
>
> THE RA SHOULD ESTABLISH CRITERIA FOR "DEFINING" OR DETERMINING MATERIAL DAMAGE
>
> In order to determine whether a proposed operation has been designed to prevent off-site material damage, the RA must establish a working definition of "material damage" that is consistent with existing laws, standards, regulations, and water-resource concerns

Figure 2: Excerpt from the OSM draft oversight document

Under Section 3 of this document, the following statement is made:

Material-damage criteria for both ground-water and surface-water quality should be related to existing standards, where possible.

Figure 3: Excerpt from OSM draft oversight document

4. Unlike most states, Wyoming has laws and regulations that address all aspects of surface and groundwater, quantity and quality, within the permit area as well as offsite. With the regulations and statutes in place, what is needed is to clarify what is meant by the phrase "Significant Longterm or Permanent Adverse Changes". We believe:

   "Significant Longterm or Permanent Adverse Changes" are those changes to the surface or groundwater hydrology that are inalterable conditions contrary to the Wyoming State Constitution or of statutes administered by the State Engineer or water quality standards administered by the Water Quality Division.

5. Applicable sections of the Wyoming State Constitution and specific State and Federal statutes and regulations have been identified that support this clarification. These cites are listed here.

   A. Wyoming State Constitution:

      1) Article 1

      2) Article 2

   B. Statutes administered by the State Engineer control water quantities:

      1) WS 41-3-101

      2) WS 41-3-102

      3) WS 41-2-111

      4) WS 41-3-504

      5) WS 41-3-604

      6) WS 41-3-901

C. Statutes administered by the State Engineer control water quantities (continued)

7) WS 41-3-916

8) WS 41-3-919

9) WS 41-3-933

D. Interstate Compacts incorporated into Wyoming State Statutes: Various Interstate Compacts relating to the allocation of surface water flows from Wyoming have been incorporated into Wyoming Satutes. These compacts are identified by the river they are associated with and are as follows:

1) Colorado River Compact: WS-41-12-301

2) Upper Colorado River Basin Compact : WS-41-12-401

3) Bear River Compact: WS-41-12-101

4) Snake River Compact: WS-41-12-501

5) Yellowstone River Compact: WS-41-12-601

6) Belle Fourche River Compact: WS-41-12-201

7) Niobrara River Compact: WS-41-12-701

E. U.S. Supreme Court Decrees regulating use of water in or tributary to the North Platte River: On October 8, 1945 the U.S. Supreme Court issued a decree enjoining the States of Colorado and Wyoming from diverting or permitting the diversion of water from the North Platte River beyond narrowly defined limits. Legal actions and resulting court decrees affecting the North Platte River basin continue to the present. There is a separate decree for the Laramie River as a tributary to the North Platte.

F. Statutes and rules and regulations administered by the Water Quality Division address surface and groundwater qualities:

1) WS 35-11-103

2) WS 35-11-301

3) Chapter I "Quality Standards for Wyoming Surface Waters" addresses the regulation of surface waters of the state.

4) Chapter VIII "Quality Standards for Wyoming Groundwaters" addresses the regulation of groundwaters of the state.

5) Chapter VI "Salinity Standards for the Colorado River Basin."

G. U.S. Public Law 95-87, Surface Mining and Reclamation Act & Regulations:

1) Section 510(a)

2) Section 510(b)(3)

3) 30CFR §780.21

6. Existing federal regulations and the state regulations address mitigation of less than long-term or permanent adverse changes to the hydrologic regime.

A. 30CFR §780 (e) & (h)

B. WS 35-11-415(b)(xii)

Dennis Hemmer
Department of Environmental Quality

Gordon Fassett
State Engineer

Appendix B: 1992 Wyoming Hydrology Oversight Report - PHC/CHIA

United States Department of the Interior
OFFICE OF SURFACE MINING
Reclamation and Enforcement
Brooks Towers
1020 15th Street
Denver, Colorado 80202

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TAKE PRIDE IN AMERICA

May 28, 1992

MEMORANDUM

TO: Director, Casper Field Office

FROM: Chief, Technical Assistance Division

Subject: 1992 Wyoming Hydrology Oversight Report - PHC/CHIA

Attached is a copy of the draft PHC/CHIA oversight report for the state of Wyoming.

If you have questions regarding the subject evaluation please call Phil Reinholtz, Hydrologist, Hydrology Support Section, at FTS 564-2788.

Paul Hutzenater, acting
Russell F. Price

Attachment

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OFFICE OF SURFACE MINING
ALBUQUERQUE FIELD OFFICE

WYOMING

OVERSIGHT MEETING AGENDA

June 22, 1992

1. Review Findings of the WSC/Denver Hydrology Oversight Report (Scheduled for 10:00 a.m. arrival of WSC representatives)

2. Status Update of Condition "c" Award of Attorney Fees

3. Inspections

    a. Frequency
    b. Annual Report Process
    c. Annual Report Inspections

4. Enforcement

    a. Appropriateness of Remedial Measures and Abatement Periods
    b. Timeliness of Issuance and Termination
    c. Show Cause Orders and Hearings

5. Civil Penalties

    a. Procedures
    b. Documentation of Actions

6. Administrative/Judicial Review

7. Program Amendments

    a. Status
    b. Schedule
    c. Removal of Disapproved Rules from Approved Program

8. Enforcement Criteria for Water Violations

9. Status Update on Rochelle Coal Revision (Approximate original contour/playa

10. Other Issues as Necessary

FINDINGS SUMMARY

State: Wyoming - 1992 Oversight

Program Element: **Permitting Actions**

Subelement Reviewed: **Baseline Data; PHC/CHIA; Monitoring Plans**

Summary of Findings: Baseline data, PHC's, and hydrologic monitoring plans in the reviewed permit applications are adequate. However, CHIA documents are deficient in that in some instances hydrologic impact projections are not based on the most recent available technical information. In addition, assessments of the hydrologic impacts of mine sites in the Powder River Basin are based on technical data that may not be site specific.

Status of Problems: See detailed Oversight evaluation report for status of problems and proposed corrective actions.

0636H **FY 1992 Permit Oversight Evaluation Report**

STATE:

Wyoming

SUBJECT EVALUATED:

Baseline Data, PHC's, CHIA's, and Monitoring Plans

SUMMARY OF FINDINGS AND CONCLUSIONS:

Baseline data, PHC's, and hydrologic monitoring plans in the reviewed permit applications are adequate. However, CHIA documents are deficient in that in some instances hydrologic impact projections are not based on the most recent available technical information. In addition, assessments of the hydrologic impacts of mine sites in the Powder River Basin are based on technical data that may not be site specific.

OSM REVIEWER:

Don Minges, Hydrologist, Denver, CO (303) 844-2618
Philip Reinholtz, Hydrologist, Denver, CO (303) 844-2788

STATE PERSONNEL CONTACTED:

Greg Smith
Chris West
Steve Ingle

REVIEW DATES:

April 13-17, 1992

STATE PROGRAM STANDARDS:

II 2., (a),(i),(F) paragraphs (I),(G),(H) & (I); II, 3., (a),(v),(A),(I); II, 3., (a),(vi),(B) paragraphs (I),(III), & (IV); II, 3., (vi), (c), (VII) & (VIII); II, 3., (a),(vi), paragraphs (H), & (I) & (J).

II, 1.,(c); II, 2.(a),(i) paragraphs (A),(F),(G),(H),(I); II, 2.,(ii) paragraphs (A),(D),(E),(F); II, 3.,(a)(v),(A) paragraphs (I),(II),(III), II;3.,(a),(vi), paragraphs (A),(B),(C),(H),(I),(J),(K); ii, 3.,(b),(i)(B) paragraphs (I),(III),(IV); II, 3., (b) (ii); II,3.,(b) paragraphs (ix),(x),(xi),(xiii); III, 2.; IV, 3., (a),(viii); IV, 3., (c)(iii); IV, 3., (e),(f),(g),(h), and (i); IV, 3., (o),(ii); IV, 3., (t); V,3., VIII, II, 3.,(b),(x); IV, 3.,(t).

BACKGROUND:

The hydrology issues reviewed for FY 1991 WY oversight included baseline data, mining and reclamation plans, PHC's, CHIA's, and monitoring plans. None of these topics had been reviewed in recent years. An issue tracking approach was used for the review to verify that issues raised by the DEQ were satisfactorily resolved.

The DEQ appropriately raised and tracked to satisfactory resolution many mining and reclamation plan issues. However, issues concerning the adequacy of both ground- and surface-water baseline data as well as spoils aquifer quality and its potential impact to ground- and surface-water uses including AVF's were not satisfactorily resolved. Because of their importance to protecting the hydrologic balance, these issues constituted programmatic deficiencies.

REVIEW METHODOLOGY:

Permit revisions reviewed:

#379-T3, Kemmerer Mine; #235-T4, Skull Point Mine; #500-T4, Buckskin Mine; #233-T4, Black Thunder Mine.

Documents reviewed:

The permit application, as well as review and response and conditions volumes, and correspondence files were reviewed.

Review method:

A standard document review was done for three of the four permit revisions. However, the Black Thunder Mine revision T4 was so unclear as to which documents related to that revision that an issue-tracking approach was used for that review.

FINDINGS AND CONCLUSIONS:

Baseline Hydrologic Data:

Skull Point

The Skull Point Mine revision provided a description of the surface-water system, and synthesized permit-area basin peak flow and volume characteristics using three different estimation techniques. However, results from two regression techniques were discounted as overestimating peaks and volumes as compared to the SCS TR-55 curve number technique. Data collection networks provided good areal coverage, and also provided full-suite water quality analyses which were compared to pertinent water-use criteria. Water rights within and downstream of the permit area were adequately documented. In addition, permit-area aquifer systems were described and existing wells in the permit and adjacent area were identified. Aquifer characteristics were defined for overburden, coal, and the Lazeart sandstone aquifers. The Lazeart SS aquifer was appropriately identified as an important, regional water source that would be affected by mining-related drawdowns. Upgradient and downgradient sampling points, and full-suite water quality analyses were provided for permit-area aquifers.

Kemmerer

Surface-water information includes regional data for Little Muddy Creek, Twin Creek, Carter Creek, Sheep Creek, and Chicken Creek. Most of the data is for the 1975-1980 time period. Information from sediment pond discharges is provided from 1979 to the present. Thirty-five surface-water rights present within three miles of the mine are described in Appendix D6-N. Premine streamflows were estimated with surface-water modeling. Ground-water baseline information was provided for eight stratigraphic zones (42 wells). Data was presented for the 1/85-12/86 period. Data from 1981 were available for the area south of the mining complex. Ground water in the Lazeart sandstone and #1 coal is suitable for livestock and marginal for irrigation. Ground-water rights are described and only three rights are not associated with testing/monitoring at the mine. No appropriated springs were identified. Surface- and ground-water baseline information provided adequate coverage and data. However, "premine" water quality data is lacking because mining activity has occurred in the area for several decades.

Buckskin

Surface-water baseline information was provided for eight original water monitoring sites. Data from six sites were available for the time period 4/79 to 12/81. Full suite analyses were conducted during the time period 1982-1988. Surface-water rights and water use were well documented. Surface-water monitoring at the mine has been decreased from the eight original sites to two sites, one on Rawhide Creek above the mine and one below the mine. Ground-water baseline data included information from ten different stratigraphic zones and the spoil aquifer. Twenty-three additional wells were installed in 1988. Completion and location information was adequate. Chemical parameters included a majority of those recommended by Guideline #8. Potentiometric maps were provided for the overburden, Anderson coal, and the Canyon coal (based on 1977-1982 data). Aquifer zones were summarized for water quality and compared against appropriate standards. Ground-water rights were identified and alternate water supplies from the deeper Fort Union formation were described.

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Geologic Descriptions:

Skull Point
Overburden descriptions were based on core samples obtained within the revision area. The applicant provided comparisons of overburden constituents concentrations to DEQ criteria for several parameters including selenium, boron, and SAR. In addition, acid-base accounting indicated that several overburden strata in the revision area had negative (acid producing) potential.

Kemmerer
Baseline geologic information included information from 40 drill/core holes. Seventeen cross-sections perpendicular to strike and four parallel to strike were provided. Geochemical analyses included parameters recommended by Guideline #1. Analysis and sampling methodologies were described well. Overall it was found that the overall weighted average of undesirable strata was 15-17 percent. Most of this material is sandstone associated with the 1,2,3, and 4 coal seams. Organic sulfur is a major component of the sulfur forms, comprising from 20-80 percent of total sulfur. Leaching tests were carried forward from the previous permit. Issues regarding regraded spoil sampling, sulfate forms, acid/base accounting, and chemical data from several cores were resolved during the application review.

Buckskin
The geologic description submitted for the renewal/revision included additional information from four sampling points (two core, two rotary chip). Isopach and structure maps were provided for appropriate stratigraphic intervals and the coal seams. Cross-sections provided good overall coverage. In addition, narratives describing stratigraphic and structural relationships were included with the cross-sections. Geochemical analyses were completed in accordance with WDEQ guidelines and summaries of the results were provided. Stratigraphic intervals were identified if suitability criteria for particular chemical parameters were exceeded. The acid/base account information indicated that excess acid producing potential was one of the more problematic geochemical characteristics. Issues regarding regraded spoil sampling, forwarding of previous baseline data, and information regarding sulfate were resolved during the application review.

PHC's:

Skull Point
The Skull Point mine revision compared baseline surface-water information to various use criteria to demonstrate no impacts to identified uses. Similarly for ground water, the applicant compared baseline information to appropriate use criteria to indicate no impacts. Because of the potential

acid production from several overburden strata, the applicant performed a leach test to more accurately predict potential acid production in spoils material. In addition, selective handling and isolation of potentially acid material by neutral material was proposed to mitigate acid production. Finally, leach test results showed that no major ions or metals were significantly higher than baseline concentrations.

For drawdowns, a model study had been performed for the original application. Based on operational data those predictions were determined to overestimate pit inflows and drawdowns and therefore were modified for the current revision.

Kemmerer

Streams draining the Kemmerer site include Little Muddy Creek and Twin Creeks. Surface-water quality impacts to Little Muddy Creek are expected to be minor. The BLM reservoir which collects runoff from the southern part of the Kemmerer mine acts as a buffer zone. Water quantity impacts are expected to be minimal since sediment ponds are designed to release storm runoff. Pit water at the Kemmerer mine is minimal because of the relatively long time the operation has been active. An analysis of the impacts of pit dewatering to surface-water flow showed that in a worst case scenario (including impacts of the Skull Point Mine) an increase of two cfs would occur in Little Muddy Creek. An analysis of flood peaks and water volumes following reclamation in the mined watersheds was conducted and showed that postmine flows should approximate premining conditions. Quality of discharge from the sediment ponds must meet effluent standards and should not degrade the downstream sections of the streams. A simple mass balance was performed that showed that the TDS of the drainage from the mine would have to have the concentration of seawater to raise the TDS above the concentration of 2000 mg/l.

The major impact to ground water resulting from the mine operation is the drawdown in the Lazeart sandstone. Maximum drawdown was calculated to be 300 feet in the vicinity of the highwall. Projections for drawdown were provided through the year 2030 and the overlapping effect of the Skull Point mine were included. A qualitative discussion on the return of the potentiometric head to the Lazeart was included in the PHC. Impacts of pits 1-UD, 2-UD, and the Skull Point Mine pit were discussed. Some permanent local drawdown in the Lazeart sandstone is expected because of upward leakage into the reclaimed pit areas and permanent impoundment. Information on impacts to water rights was also provided. The PHC discussion regarding impacts to ground-water quality was qualitative. Selective handling and isolation of potentially toxic and acid materials to avoid contamination of surface drainage or alluvial aquifers is discussed in Appendix D5.

PHC determinations for both ground- and surface-water impacts for the Kemmerer mine renewal were adequate.

Buckskin

Ground-water modeling was used to predict drawdown during the permit term and for the life of mine. The drawdown analyses were conducted considering the impacts of the Buckskin mine alone and also in conjunction with seven additional mining operations. The extent of the five foot drawdown in the surrounding area was discussed. During the T-4 permit term there are approximately 10 wells predicted to be impacted by the mining operations. Twenty wells may be affected during the life-of-mine period. Long-term potentiometric surface recovery was also investigated. Analytical testing conducted to predict the spoils aquifer water quality included saturated paste and shake extraction tests. In addition, spoils aquifer monitoring data available from other mine sites were summarized and used in the analysis of the potential impact of the Buckskin mining and reclamation operations on ground-water quality.

One issue raised in the 1991 oversight report was the apparent lack of information provided by Triton regarding postmine spoils aquifer quality and possible discharge of poor quality water to Rawhide Creek. To address these issues in the T-4 renewal, Triton submitted geochemical data from four additional drill holes. In addition, ground-water modeling to predict postmine potentiometric surfaces in the reconstructed AVF and spoils/Canyon coal aquifer was performed. This effort did not indicate a problem with intersection of the potentiometric surface and reclaimed ground surface.

Pre and postmine surface-water quantity for Rawhide Creek and Spring Draw were evaluated using SCS precipitation/runoff modeling techniques. Postmine peak discharges were found to be similar to premine conditions. Low-flow analyses were also conducted. During mining, water inflow into the pits and dewatering wells provide additional volume to the stream systems. Surface-water quality during mining is improved by the addition of water lower in TDS (ground water). Alluvial valley floors (AVF's) are present in parts of the Rawhide Creek and Spring Draw drainages. Specific plans have been provided to reconstruct the AVF's. A salt loading analysis (TDS) to demonstrate resultant water quality in the constructed AVF's was provided.

PHC determinations for both ground- and surface-water impacts for the Buckskin mine revision were adequate.

CHIA's:

Skull Point

The Skull Point mine revision appropriately incorporated the

P&M Kemmerer mine, situated immediately north of the Skull Point mine, into the cumulative impact area. The surface-water assessment focused primarily on seep flows in the north area of the mine which would be affected by mining drawdowns. Because seepage contributions to surface flows were minor their interruption was considered insignificant to the surface-water regime. However, although a final pit impoundment proposed at the south permit boundary of the Kemmerer mine was acknowledged to have an effect on the spoils aquifer resaturation rate, impoundment interception of runoff previously tributary to streamflow was not addressed in the cumulative surface-water assessment.

For ground-water quality impacts, projections were based on overburden leach test results which showed that, after initial flushing, constituent concentrations were not significantly higher than baseline levels. Available information on backfill (spoils) wells in annual reports were also reviewed to confirm that conclusion.

For drawdown impacts to the Lazeart sandstone aquifer, combined effects from both Skull Point and Kemmerer mines pumping were assessed using the Skull Point ground-water model. Results indicated drawdowns of less than 5 feet one mile from mine pits. Water level recovery to within 100 feet of the premining level was projected to occur upon completion of reclamation with complete recovery within 60 to 200 years. Impacts to shallower, more discontinuous aquifers, were expected to be insignificant primarily because no existing uses in those aquifers were identified within 2 miles of the permit boundaries.

Although based on reasonable assumptions and information, drawdown projections contained in the Skull Point mine revision application are brought into question by information contained in the Kemmerer mine revision application. That application contains a Lazeart aquifer drawdown projection for the year 1996 which appears to exceed counterpart projections contained in the Skull Point mine application. Because the two mines are immediately adjacent, CHIA analyses must necessarily consider the most current information available for each mine in assessing cumulative impacts in order to safeguard existing uses.

Although material damage criteria, per se, were not established, impact projections were discussed within the context of livestock and wildlife habitat uses in the cumulative impact area. Impacts were shown not to exceed those criteria.

Kemmerer

The Kemmerer T3 decision document references the T1 Decision Document TEA for information on hydrologic impacts. The proposed changes of this revision/renewal are stated not to have altered the findings of the previous T1 CHIA.

The T1 CHIA assessed the impacts of the Kemmerer, Skull Point, and two proposed mining operations. The majority of present and proposed disturbance is located in the North Fork Little Muddy Creek basin. However, Twin Creek and Ham's Fork will also be impacted. Impacts to surface water are qualitatively discussed, including slightly reduced runoff during mining, increased suspended solids, slightly increased runoff after reclamation, and loss of streamflow due to permanent impoundments storage.

Impacts to ground water discussed in the CHIA included drawdown and water quality degradation. The discussion in the CHIA (Section 3) was qualitative in nature. In Decision Document Section 2, quantitative assessment of projected ground-water quality was provided. Best and worst-case estimates of spoils aquifer quality were presented. In the worst case, water quality does not meet the livestock watering standards. However, reasons were provided on why ground-water quality should be suitable for anticipated uses.

The CHIA prepared for the T1 permit and referenced by the T3 decision document addresses ground-water and surface-water quality and quantity impacts by the present and anticipated mining operations. The assessments are largely qualitative in nature. As pointed out in the discussion of the Skull Point CHIA, the most recent information regarding the ground-water drawdown was apparently not utilized in analysis of impacts. With the use of the hydrologic data collected since the T1 document was written, a more refined and quantitative assessment of the cumulative hydrologic impacts of the Kemmerer/Skull Point mining operations should be possible.

Buckskin

The Buckskin T-4 decision document references the Cumulative Hydrologic Impact Assessment prepared by the U.S. Geological Survey (USGS)(1988). The addendum to the T-4 findings document (dated May 21, 1991) includes on page 18 a summary of the impacts to the surface-and ground-water systems and a reference to the USGS CHIA. Probable hydrologic impacts noted were changes to the aquifer physical properties, ground-water level reductions, spoil-aquifer water quality, surface-water quality, surface-water flow, and ground-water/surface-water interactions. It is stated in the addendum that the premining class of use for the ground water will be preserved, and qualitative reference is made to information included in the permit application. Drawdowns in the aquifer are stated to be within projections for the Buckskin mine contained in the CHIA. Surface-water cumulative impacts are also qualitatively described. Disturbance is substantially increased in the T-4 mine plan from the previous T-3 application (1467 acres to 3253 acres).

The CHIA prepared by the USGS for the Powder River Basin was reviewed to determine the projected ground- and surface-water impacts in the Buckskin Mine area. Although the CHIA document does evaluate the impacts of coal mining operations to the surface- and ground-water, the scope of the CHIA is generally broad-based. The surface-water quantity analysis centered on an evaluation of the change in average runoff within mined and reclaimed watersheds. The runoff study was accomplished through a review of available infiltration rate data. Infiltration rates of reclaimed soils were found to be about 29 percent less than that of natural soils. One mine, Black Thunder, was utilized in a sensitivity analysis study of the infiltration rate change resulting from mining. It was determined that changes in quantity and quality could not be detected at the streamflow gaging station at the mouth of the basin. In addition runoff analyses were conducted for two watersheds of the little Powder River (204 and 1235 square miles). Increase in runoff was 0.6 and 3.6% respectively after mining. Although the study does suggest that surface-water quantity will not be significantly impacted, reliance on the infiltration rate alone to determine impact to surface-water quantity has obvious drawbacks. Changes to slope, aspect, watershed size, etc. resulting from mining may have a significant impact on surface-water quantity. In the CHIA document the USGS recommended specific monitoring and research to refine the CHIA analysis including establishment of paired watershed monitoring sites, reestablishment of streamflow gaging stations to verify precipitation/runoff relations, collection of streamflow data (before, during, and after mining operations), and monitoring of erosion or aggradation in major stream channels.

Surface-water quality (dissolved constituents) evaluation in the USGS CHIA is limited to a reference to a study by Bloyd and others (1986) in which a computer model of the Belle Fourche River Basin was utilized to determine the change in TDS and sulfate caused by mining. In this section it is acknowledged (page 112) that "Impacts of surface mining on streamflow quality in other basins will depend on climate, geologic and soil characteristics, vegetation, and streamflow, and those impacts may, therefore, be different in other basins than in Belle Fourche."
Evaluation of sediment yield was limited to development of a relationship of total sediment load to peak discharge at Coal Creek near Piney (Belle Fourche basin).

Evaluation of ground-water impacts due to mining included drawdown and water quality. The extent of the five foot drawdown in the Wyodak aquifer is the focus of the quantity aspect of mining impacts to ground water. North of Gillette this drawdown is expected to extend for as much as 15 miles. Quality and quantity of alternative ground-water supplies were discussed. Drawdown estimates are updated annually in

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the report generated by the Gillette Area Ground water Monitoring Organization. This information should be periodically incorporated into the CHIA evaluations for new permitting actions. Ground-water quality impacts expected in the spoil aquifers were discussed and two studies are referenced, one at the Cordero mine and one at the Dave Johnson mine. However, the results were qualified with the statement, "Conclusions drawn from the following site-specific studies may not apply to all mine sites in the study area because of differences in overburden quality, hydrologic conditions, methods of mining, and so forth" (page 62). This finding is also reiterated in the conclusion section of the CHIA. It was recommended in the CHIA that additional information regarding ground-water be collected, including more realistic assessment of the duration of water level declines, spoils resaturation time frames, additional monitoring of the Wyodak coal aquifer downgradient from mining operations (school section wells already located from north of Gillette to northwest of Antelope mine were suggested), additional geochemistry studies regarding selective placement of overburden, and additional information on the source or sources of ground water. In addition, OSM recommends that the potential for the establishment of baseflow discharge of poor quality spoils aquifer water to streams must be assessed in mine areas where the lack of sufficient overburden to offset the removal of thick coal seams could result in the intersection of the postmine potentiometric and ground surfaces.

The assessment of "material damage" to the hydrologic balance in the USGS CHIA included general findings regarding ground-water quantity, alternate sources of water, ground-water quality (TDS), surface-water quantity (infiltration rate), stability of postmining topography. One important aspect of a material damage finding is a discussion of criteria utilized during the evaluation. The USGS CHIA does not provide such information clearly.

The USGS CHIA provides an important assessment of the impacts to surface and ground water in the Powder River Basin. However, because of the differences in climate, geology, hydrology, soils, etc. from one major drainage basin to another, the assessment of material damage in one area to another must be approached with caution because of the lack of basin specific data utilized in the various analyses included in the USGS CHIA. For this reason, it is strongly recommended that the DEQ begin to formulate plans to address the data concerns and recommendations described by the USGS in the CHIA. Preparation of separate CHIA documents for each main subwatershed of the Powder River Basin should be the goal of this effort. This would result in CHIAs for the Little Powder River basin, Belle Fourche River basin, and Cheyenne River. This would especially be applicable to evaluation of surface-water cumulative impacts. Ground-water cumulative impact areas (CIAs) may tend to overlap from one surface-water basin to another, but differences between geographic areas in recharge, geologic overburden disturbed by mining, and other important factors also dictates that smaller ground-water CIA areas are needed to adequately evaluate the impacts of surface mining on the hydrologic balance.

Monitoring Plans:

Skull Point
Both surface- and ground-water monitoring plans for the Skull Point mine incorporated adequate areal coverage and sampling frequency to measure mining impacts to the hydrologic balance. For surface-water sites, sampling is event-oriented measuring high spring-season and storm runoffs. Although water quality sampling is done only for the largest permit area basin, that basin encompasses most mining disturbance in the revision area. In addition, full-suite analyses are performed on the quarterly samples to routinely track all constituent concentrations. The ground-water monitoring network includes 18 wells completed in the various aquifers plus three spoils aquifer wells. Quarterly monitoring includes water level and full-suite analyses. Both surface- and ground-water monitoring plans comply with DEQ regulations.

Finally, no AVF's were identified in or adjacent to the Skull Point mine permit or revision areas.

Kemmerer
Surface-water monitoring at the Kemmerer mine is centered on the monitoring of discharges from seven sediment ponds. This includes NPDES monitoring and additional semi-annual monitoring of the discharges. The semi-annual monitoring includes the chemical parameters recommended by Guideline #8, Appendix 2.

Ground-water is monitored at a total of 37 wells. Quarterly water level and semi-annual quality analyses are conducted at 11 wells. Another 26 wells located north of the 1UD pit are monitored for water level. Areal coverage of the well sites is adequate. Parameters monitored are those recommended by Guideline #8. No AVF's were identified in or adjacent to the Kemmerer mine permit or revision areas.

Buckskin
Surface water is monitored at the Buckskin Mine on Rawhide Creek at one upgradient and one downgradient site from the mine area. Monitoring is quarterly and chemical parameters include those recommended by Guideline #8. Ground water in six different stratigraphic intervals is monitored at the Buckskin mine. This results in seventy-seven different monitoring points within these intervals mine-wide. Analyses

include parameters recommended by Guideline #8. Procedures for sampling the wells and maintenance plans are provided in the permit application. Sediment accumulation in ponds is determined at five year intervals (minimum). Adequate areal coverage and sampling frequency to measure mining impacts to the hydrologic balance are included in the monitoring plans.

Black Thunder Mine Issue Tracking:

As indicated under the Review Methodology section, the Black Thunder mine revision was very unclear as to which documents, sections, etc. related to the revision. Although an entire PAP may have to be reviewed to gain a hydrologic perspective of a permit area, revision documentation should reflect the most current information on the mining operation including appropriate revisions in the mining and operation plans, PHC, CHIA, etc., based on monitoring data. Unless it is clear what is the most current information, review assessments and conclusions may be based on out-dated information. The apparent confusion in the PAP was confirmed by a DEQ decision document condition requesting clarification of the PAP and providing suggestions for reformatting the entire document.

The major issues for the Black Thunder mine renewal include:

1. A proposed large (3700 ac. ft.) permanent impoundment (Thunder Lake);
2. Selenium monitoring;
3. Ground-water monitoring; and
4. Alluvial valley floor (AVF) protection

Concerning issue number 1., the DEQ appropriately questioned the Thunder Lake proposal based on rule IV, 3., (h) demonstrations including: 1) suitability of stored water quantity and quality for its intended uses; 2) downstream impacts; and 3) slope stability. The size of the proposed impoundment and its effects on an immediately downstream impoundment that was constructed to replace a pre-existing impoundment prompted the DEQ to consider the necessity for either an EA or possibly even an EIS to address its impacts. In addition, the stability of proposed steep slopes during the 20-year fill period was questioned.

Although the DEQ appeared to appropriately condition its approval of Thunder Lake, the Powder River Basin Resource Council successfully challenged the proposal in court at which time the DEQ required all reference to the proposal be deleted from the revision application.

Concerning issue 2., selenium contamination of both spoils aquifers and downgradient wetlands is a significant issue in Wyoming coal areas. The DEQ appropriately required extensive core drilling and overburden sampling to define the extent of selenium occurrence, and also required a special study at mine to help define resulting spoil aquifer concentrations of selenium. Disposal requirements for overburden with elevated selenium concentrations were as follows: 1) above postmining potentiometric surfaces; 2) beneath root zones; and 3) isolation with an adequate layer of non-toxic material beneath permanent impoundments and recreated stream channels (10 ft and 6 ft, respectively, under major and minor channels).

In all of these respects the DEQ adequately addressed the occurrence and mitigation of potential selenium contamination at the Black Thunder mine.

With respect to issue 3., the DEQ required use of monitoring data to update potentiometric surface maps for the Wyodak coal and overburden aquifers, and for recalibration of the ground-water drawdown model. In addition, periodic reverification of the model was provided for throughout the 5-year renewal term. Ground-water monitoring networks provided good areal coverage for alluvial, overburden, coal, and spoils aquifers with spoils wells sampled quarterly for water level and full-suite analyses to track selenium concentrations in particular. Overall, ground-water monitoring was adequate to track mining impacts and, in addition, to provide information for updating impact projections.

Concerning issue 4., AVF's exist immediately east of the permit boundary within alluvium of the North Prong Little Thunder Creek, and Little Thunder Creek. Because potentiometric surfaces are well below the land surface, with gradients away from AVF's, there is no potential for spoils aquifer impacts. In addition, with deletion of the proposed Thunder Lake from the renewal application, remaining impacts on surface supplies to downstream AVF's are considered minimal. Mining impacts to adjacent AVF's therefore were adequately addressed by the DEQ.

EFFECTS OF DEFICIENCIES:

Concerning CHIA drawdown projections for the important Lazeart sandstone aquifer (Skull Point and Kemmerer mines), the most current information available should be incorporated into the analysis, and projections modified if warranted. Otherwise, existing ground-water uses previously considered to be unaffected could require remediation to safeguard their yield.

The USGS Powder River Basin CHIA provides an important assessment of the hydrologic impacts of mining in the basin. However, predictions of the cumulative hydrologic impacts in each major river basin could be significantly improved if additional data collection and analyses recommended by the USGS is obtained.

Concerning the Black Thunder mine application package, confusion within the various documents as to which sections, exhibits, appendices, etc. constitute the updated renewal information did not allow a satisfactory review of that information. Clear identification of the most current information is necessary for the DEQ and other reviewers to make informed decisions about the validity and adequacy of hydrologic projections, special handling plans, proposed mining and operation plan modifications, etc.

CORRECTIVE ACTION:

Although the DEQ appropriately considered cumulative impacts from the adjoining Kemmerer mine in the Skull Point mine CHIA, periodic updating of impact projections based on the most current information for mines within the CIA should be done when permit renewals or revisions warrant as a safeguard for existing water uses. In addition, adoption of a more formal CHIA procedure by the DEQ may aid in a more consistent consideration of all possible ground- and surface-water impacts within CIA's. Such a procedure could include application of specific material damage criteria for impacts based on the DEQ material damage definition as significant long-term or permanent adverse changes in the hydrologic balance.

The DEQ should begin to formulate an action plan that would result in more regionalized CHIA's for the subwatersheds within the Powder River Basin. This long-term project would result in the preparation of CHIAs for the Little Powder River basin, Belle Fourche River basin, and Cheyenne River basin. The use of the Oracle data base as described below would be a key component of the effort.

The DEQ has already acknowledged and addressed by a permit condition the apparent confusion in the Black Thunder mine application package.

NOTE: The DEQ staff was questioned about use of their new Oracle data base in permitting decisions and analyses such as PHCs and CHIAs. They indicated that the data base has not yet been successfully used primarily because it is not user-friendly and because of turnover in the DEQ staff. Effective use of the data base apparently requires fairly extensive training and experience. For these reasons the DEQ has recently received approval for a contract with the Water Resources Division of the U.S. Geological Survey to develop a user-friendly interface for the data base. The DEQ felt this to be a prudent investment considering the funds, both state and federal, expended so far to develop the data base. Full implementation of the data base should expedite review of applications and renewals as well as conducting and updating CHIA's as discussed above.

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The DEQ should begin to formulate an action plan that would result in more regionalized CHIA's for the subwatersheds within the Powder River Basin. This long-term project would result in the preparation of CHIAs for the Little Powder River basin, Belle Fourche River basin, and Cheyenne River basin. The use of the Oracle data base as described below would be a key component of the effort.

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WSC REVIEWER: Philip N Reinholtz DATE: 5/28/92
Philip N. Reinholtz, Hydrologist
Hydrology Support Section

WSC REVIEWER: Don Minges DATE: 5/29/92
Don Minges, Hydrologist
Hydrology Support Section

WSC SUPERVISOR: Lynn Shown DATE: 5/28/92
Lynn Shown, Chief
Hydrology Support Section

CFO PROJECT LEADER:____________________ DATE: ________

CFO DIRECTOR:____________________ DATE: ________

Appendix C: Pit Inflows

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1999"	31	29	4602.073	4542.106	0.1	4628.492	0.000453	268.51	5.9967	16372.2	0.0164002	3.549	6.88106	1324.535	21.219015
"1999"	31	30	4610.204	4549.069	0.1	4628.009	0.0024957	1479.3	6.1135	16691.1	0.0886271	1.928	11.2766	2170.635	39.823787
"2000"	31	27	4596.926	4536.07	0.1	4630.107	4.65E-05	27.562	6.0856	16614.9	0.0016589	5.826	4.75165	914.646	13.118815
"1999"	31	28	4597.966	4538.205	0.1	4629.235	0.000165	97.801	5.9761	16315.9	0.0059942	4.546	5.75999	1108.74	16.511334
"1998"	43	55	4633.588	4561.501	0.1	4653.67	0.0014193	841.26	7.2087	19681.2	0.0427446	2.616	11.3898	2192.421	34.604006
"2001"	43	56	4635.898	4563.652	0.1	4663.826	0.0003443	204.08	7.2246	19724.6	0.0103463	4.004	8.39386	1615.734	22.66051
"1996"	43	53	4626.48	4557.425	0.1	4633.73	0.0012939	766.94	6.9055	18853.4	0.0406789	2.664	8.23682	1585.505	32.555998
"1997"	43	54	4630.326	4559.738	0.1	4643.969	1E-05	5.9273	7.0588	19271.9	0.0003076	7.51	3.43532	661.266	11.804869
"1992"	30	35	4638.916	4575.805	0.1	4637.551	1E-05	5.9273	6.1746	16857.9	0.0003516	7.376	2.02422	389.641	10.513461
"1993"	30	36	4644.235	4581.073	0.1	4636.022	1E-05	5.9273	5.4949	15002.2	0.0003951	7.26	1.62884	313.535	9.506388
"1997"	30	31	4620.531	4559.802	0.1	4637.52	0.0001064	63.067	6.0729	16580.2	0.0038037	4.998	4.23685	815.55	15.259335
"1992"	30	34	4634.866	4573.039	0.1	4638.234	0.0003519	208.58	6.1827	16880	0.0123568	3.829	4.26513	820.996	20.281989
"1984"	30	39	4661.54	4601.657	0.1	4629.236	1E-05	5.9273	2.7579	7529.62	0.0007872	6.571	0.45334	87.263	5.2715641
"2000"	31	26	4593.608	4532.539	0.1	4631.063	0.0003613	214.15	6.1069	16673.1	0.0128443	3.79	7.79218	1499.916	20.235348
"1991"	30	37	4651.923	4590.298	0.1	4633.742	1E-05	5.9273	4.3444	11861.1	0.0004997	7.025	1.0522	202.538	7.7672289
"1991"	30	38	4657.725	4597.178	0.1	4631.176	1E-05	5.9273	3.3998	9282.13	0.0006386	6.78	0.66767	128.521	6.2980917
"2001"	43	57	4638.867	4566.813	0.1	4675.23	2.81E-05	16.656	7.2054	19672.2	0.0008467	6.498	5.76095	1108.926	13.926929
"1998"	44	54	4621.631	4551.271	0.1	4643.962	0.0002924	173.31	7.036	19209.7	0.0090223	4.14	7.16046	1378.317	21.345866
"2001"	44	55	4624.786	4552.683	0.1	4652.216	0.0021142	1253.2	7.2103	19685.6	0.0636585	2.237	14.8718	2862.668	40.480201
"1984"	31	39	4652.99	4592.489	0.1	4623.578	1E-05	5.9273	3.1089	8487.92	0.0006983	6.69	0.56576	108.904	5.8361504
"1997"	44	53	4619.177	4551.259	0.1	4634.923	0.001677	994.01	6.7918	18543	0.0536058	2.4	10.436	2008.833	35.543546
"2001"	44	58	4634.703	4562.076	0.1	4683.114	1E-05	5.9273	7.2627	19828.6	0.0002989	7.538	5.78447	1113.453	12.099996
"2001"	44	59	4637.764	4564.856	0.1	4700.477	1E-05	5.9273	7.2908	19905.3	0.0002978	7.542	6.7169	1292.935	12.140595
"2001"	44	56	4628.733	4555.696	0.1	4660.868	1E-05	5.9273	7.3037	19940.6	0.0002972	7.544	4.79983	923.92	12.159227
"2001"	44	57	4632.042	4559.238	0.1	4670.772	0.0001164	68.994	7.2804	19876.9	0.0034711	5.09	7.6946	1481.134	17.965638
"1997"	31	31	4615.816	4554.359	0.1	4627.816	0.0008495	503.53	6.1457	16779	0.0300093	2.958	6.62738	1275.704	26.092226
"1997"	31	32	4619.768	4557.807	0.1	4627.906	0.0003482	206.39	6.1961	16916.6	0.0122004	3.841	4.77106	918.382	20.259366
"2001"	43	58	4641.643	4569.634	0.1	4688.939	0.0003053	180.96	7.2009	19659.9	0.0092046	4.12	10.3244	1987.35	21.951273
"2001"	43	59	4644.818	4572.398	0.1	4706.931	0.0019279	1142.7	7.242	19772.1	0.057795	2.328	21.4305	4125.162	39.062654
"1991"	31	37	4645.056	4582.994	0.1	4625.322	1E-05	5.9273	4.2328	11556.4	0.0005129	6.999	1.00255	192.98	7.5958279
"1984"	31	38	4649.655	4588.765	0.1	4624.247	1E-05	5.9273	3.5482	9687.3	0.0006119	6.822	0.72268	139.109	6.5318647
"1993"	31	35	4632.167	4568.524	0.1	4627.838	1.23E-05	7.2906	5.9314	16193.9	0.0004502	7.129	1.93264	372.015	10.449419
"1991"	31	36	4639.539	4576.358	0.1	4626.888	1E-05	5.9273	5.053	13795.7	0.0004296	7.176	1.39348	268.23	8.8439782
"1997"	30	30	4615.787	4555.105	0.1	4637.856	0.0001777	105.33	6.0682	16567.4	0.0063576	4.487	5.16172	993.58	16.984367
"2002"	29	21	4591.736	4530.754	0.1	4660.647	0.0038985	2310.8	6.0982	16649.3	0.1387905	1.521	27.6002	5312.76	50.339351
"2002"	29	22	4592.875	4532.327	0.1	4660.486	0.0034487	2044.2	6.0548	16530.8	0.1236572	1.624	25.2865	4867.395	46.81181
"2001"	42	58	4647.96	4577.18	0.1	4691.911	0.0003305	195.9	7.078	19324.4	0.0101374	4.024	9.92067	1909.631	22.089245
"2001"	42	59	4649.715	4578.808	0.1	4708.671	0.0019176	1136.6	7.0907	19359	0.0587128	2.313	20.305	3908.519	38.493376
"2001"	29	25	4602.292	4539.796	0.1	4657.608	0.0042573	2523.4	6.2496	17062.7	0.1478924	1.465	25.8365	4973.261	53.563677
"2000"	29	26	4604.108	4541.655	0.1	4655.716	0.0052639	3120.1	6.2453	17050.9	0.1829862	1.281	28.3447	5456.081	61.226901
"2001"	29	23	4595.879	4534.94	0.1	4659.956	1E-05	5.9273	6.0939	16637.6	0.0003563	7.363	5.43664	1046.499	10.394586

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2001"	29	24	4599.523	4537.551	0.1	4659.003	1E-05	5.9273	6.1972	16919.6	0.0003503	7.38	5.29822	1019.854	10.54672
"1986"	26	34	4685	4628	0.1	4658	0.00046	272.66	3	8190.6	0.033289	2.858	1.23343	237.423	13.185349
"1995"	42	53	4630.71	4560.161	0.1	4633.687	1E-05	5.9273	7.0549	19261.3	0.0003077	7.509	2.7782	534.776	11.799215
"1985"	26	32	4685	4628	0.1	4658	0.00014	82.982	3	8190.6	0.0101314	4.025	0.87569	168.562	9.3611467
"1985"	26	33	4685	4628	0.1	4658	0.00026	154.11	3	8190.6	0.0188155	3.414	1.0323	198.707	11.035231
"2001"	42	56	4640.257	4569.103	0.1	4665.99	0.0018513	1097.3	7.1154	19426.5	0.0564861	2.35	13.5219	2602.829	38.024975
"2001"	42	57	4643.832	4572.888	0.1	4678.214	0.0015858	939.95	7.0944	19369.1	0.0485285	2.495	14.2825	2749.23	35.715122
"1996"	42	54	4635.687	4564.39	0.1	4644.181	0.001341	794.85	7.1297	19465.5	0.040834	2.66	8.96886	1726.416	33.659234
"1997"	42	55	4638.012	4566.776	0.1	4654.733	2.83E-05	16.774	7.1236	19448.9	0.0008625	6.479	4.26707	821.368	13.808122
"2000"	29	27	4609.177	4546.651	0.1	4653.42	0.0005916	350.66	6.2526	17070.8	0.0205415	3.328	10.0253	1929.772	23.594635
"2001"	30	23	4587.44	4527.982	0.1	4646.698	0.0034194	2026.8	5.9458	16233.2	0.1248543	1.616	22.8008	4388.931	46.21502
"2000"	30	25	4593.127	4532.377	0.1	4644.795	0.0053711	3183.6	6.075	16586	0.1919468	1.241	28.1624	5420.974	61.496932
"1991"	29	37	4663.064	4602.475	0.1	4642.183	1E-05	5.9273	3.9708	10841.1	0.0005467	6.935	0.8904	171.394	7.1912841
"1984"	29	39	4671.714	4612.435	0.1	4635.073	1E-05	5.9273	2.2638	6180.63	0.000959	6.373	0.3149	60.616	4.4610441
"2000"	30	28	4601.748	4542.105	0.1	4640.272	5.64E-05	33.43	5.9643	16283.7	0.002053	5.613	5.15353	992.002	13.344651
"1999"	30	29	4608.014	4548.338	0.1	4638.854	7.33E-05	43.447	5.9676	16292.7	0.0026667	5.352	4.85	933.577	14.002945
"2000"	30	26	4596.647	4535.611	0.1	4643.394	3.62E-05	21.457	6.1036	16664	0.0012876	6.079	5.4635	1051.669	12.610069
"2000"	30	27	4599.135	4538.63	0.1	4641.825	3.75E-05	22.227	6.0505	16519.1	0.0013456	6.035	5.16909	994.999	12.591422
"1997"	29	30	4625.368	4563.877	0.1	4647.261	8.51E-05	50.441	6.1491	16788.3	0.0030046	5.233	4.50848	867.837	14.756841
"1992"	29	31	4631.213	4570.944	0.1	4646.944	5.62E-05	33.312	6.0269	16454.6	0.0020244	5.627	3.62758	698.274	13.451249
"1996"	29	28	4614.789	4552.45	0.1	4650.948	1.49E-05	8.8317	6.2339	17019.8	0.0005189	6.987	4.28387	824.603	11.205457
"1996"	29	29	4620.086	4558.22	0.1	4648.771	0.0010536	624.5	6.1866	16890.7	0.0369733	2.756	9.64138	1855.87	28.192399
"1992"	29	35	4650.676	4589.393	0.1	4647.773	1E-05	5.9273	5.838	15938.9	0.0003719	7.32	1.82339	350.984	10.016427
"1991"	29	36	4656.446	4594.948	0.1	4645.465	1E-05	5.9273	5.0517	13792.2	0.0004298	7.175	1.39281	268.102	8.8420198
"1992"	29	32	4636.61	4577.343	0.1	4647.854	0.0016809	996.32	5.9267	16181.1	0.0615734	2.268	7.98136	1536.333	32.812642
"1989"	29	33	4640	4570	0.1	4634	0.00075	444.55	6.4	17473.3	0.0254416	3.119	5.14299	989.975	25.771144
"2006"	16	27	4737.658	4678.546	0.1	4740.281	7.27E-05	43.092	5.9112	16138.8	0.0026701	5.351	2.7464	528.654	13.873904
"2007"	16	26	4735.744	4679.395	0.1	4735.397	2.29E-05	13.574	5.6002	15289.7	0.0008878	6.45	1.90407	366.515	10.903789
"2007"	16	25	4732.915	4678.943	0.1	4729.077	0.0001454	86.183	5.0134	13687.6	0.0062965	4.497	2.18891	421.344	14.002117
"2006"	16	28	4738.656	4676.417	0.1	4745.763	0.0009329	552.96	6.2239	16992.5	0.0325414	2.88	6.27086	1207.079	27.145676
"2000"	16	31	4746.104	4686.312	0.1	4765.511	0.00264	1564.8	5.9792	16324.4	0.0958572	1.856	11.6256	2237.809	40.464892
"2006"	16	30	4743.905	4684.066	0.1	4758.92	0.0016935	1003.8	5.9839	16337.2	0.0614419	2.271	8.75895	1686.01	33.099863
"2006"	16	29	4741.306	4680.379	0.1	4752.458	0.0010437	618.63	6.0927	16634.3	0.0371903	2.75	6.89803	1327.803	27.821542
"2006"	15	27	4747.288	4684.311	0.2	4767.413	3.14E-05	18.612	12.5954	34388	0.0005412	6.945	6.85519	1319.556	22.777503
"2006"	15	26	4745.263	4683.555	0.2	4762.442	0.0002001	118.61	12.3416	33695	0.00352	5.076	8.60263	1655.921	30.5387
"2007"	15	25	4742.41	4685.054	0.2	4753.102	0.000634	375.79	11.4712	31318.7	0.011999	3.858	8.75471	1685.194	37.347389
"2006"	15	28	4750.452	4687.868	0.2	4773.756	0.0034748	2059.6	12.5168	34173.4	0.0602699	2.289	21.7225	4181.359	68.685678
"2006"	15	31	4759.369	4696.286	0.2	4787.069	0.0025871	1533.5	12.6166	34445.8	0.0445179	2.577	20.944	4031.503	61.480356
"2006"	15	30	4757.248	4693.721	0.2	4784.882	6.73E-05	39.891	12.7054	34688.3	0.00115	6.192	8.80594	1695.054	25.770765
"2006"	15	29	4754.564	4690.618	0.2	4781.484	0.0013019	771.68	12.7892	34917.1	0.0221003	3.257	16.7351	3221.347	49.322772
"2006"	45	59	4632.209	4559.616	0.25	4691.357	0.0026712	1583.3	18.1482	49548.4	0.0319548	2.897	41.9912	8082.882	78.672043

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2001"	45	58	4627.648	4555.033	0.25	4676.742	0.0042158	2498.8	18.1537	49563.4	0.0504171	2.458	44.6635	8597.283	92.746081
"2001"	45	57	4626.172	4553.583	0.25	4666.527	2.4E-05	14.226	18.1472	49545.6	0.0002871	7.579	13.1141	2524.34	30.073444
"1984"	28	38	4681.253	4622.85	0.25	4642.664	1E-05	5.9273	4.9535	13524	0.0004383	7.156	0.53714	103.395	8.6939139
"1991"	28	35	4665.574	4607.192	0.25	4655.976	1E-05	5.9273	12.196	33297.5	0.000178	8.057	2.89208	556.696	19.012095
"1991"	28	36	4671.326	4612.763	0.25	4653.078	1E-05	5.9273	10.0788	27517	0.0002154	7.866	2.02297	389.401	16.092346
"1986"	28	37	4677.022	4618.39	0.25	4648.799	1E-05	5.9273	7.60225	20755.7	0.0002856	7.584	1.19374	229.783	12.589416
"2001"	45	56	4621.97	4549.243	0.25	4658.2	0.0022623	1340.9	18.1817	49639.8	0.0270134	3.061	30.9684	5961.114	74.611395
"1999"	32	29	4606.647	4544.144	0.25	4621.212	7.54E-05	44.692	15.6257	42661.4	0.0010476	6.285	8.44904	1626.356	31.2245
"1999"	32	30	4610.42	4547.491	0.25	4621.039	0.0004964	294.23	15.7323	42952.2	0.0068502	4.413	11.2564	2166.754	44.773055
"1998"	32	31	4615.927	4551.877	0.25	4621.002	0.0001356	80.374	16.0125	43717.3	0.0018385	5.723	7.94437	1529.212	35.137367
"1999"	32	28	4602.688	4540.269	0.25	4621.542	0.0024879	1474.7	15.6047	42604.1	0.0346131	2.82	20.3379	3914.839	69.503168
"2001"	45	55	4615.324	4542.458	0.25	4650.96	0.0003348	198.45	18.2165	49734.7	0.0039901	4.951	19.0587	3668.609	46.213044
"2001"	45	54	4612.012	4540.955	0.25	4644.197	0.0018505	1096.9	17.7642	48500	0.0226155	3.234	26.8246	5163.463	68.987239
"1998"	45	53	4609.84	4538.896	0.25	4636.909	1E-05	5.9273	17.736	48422.8	0.0001224	8.431	9.56138	1840.47	26.420397
"1990"	28	34	4655	4598	0.25	4650	0.00083	491.97	13	35492.6	0.0138611	3.715	7.12593	1371.67	43.947667
"2002"	28	23	4607.822	4543.937	0.25	4669.15	1E-05	5.9273	15.9713	43604.7	0.0001359	8.326	12.4773	2401.763	24.090976
"2001"	28	24	4610.271	4545.636	0.25	4668.174	3.74E-05	22.168	16.1587	44116.6	0.0005025	7.019	14.5275	2796.396	28.912442
"2001"	28	25	4614.051	4549.369	0.25	4666.61	0.0034241	2029.6	16.1705	44148.7	0.0459713	2.547	37.8689	7289.389	79.751116
"2002"	28	22	4604.875	4541.489	0.25	4669.6	0.0039733	2355.1	15.8465	43264.1	0.0544355	2.385	44.5575	8576.881	83.437331
"2009"	28	19	4595.866	4532.998	0.25	4667.214	0.0035674	2114.5	15.717	42910.6	0.0492772	2.48	45.114	8683.995	79.590232
"2003"	28	20	4598.25	4535.182	0.25	4668.839	1E-05	5.9273	15.767	43047.1	0.0001377	8.313	13.4226	2583.713	23.819703
"2003"	28	21	4601.414	4538.27	0.25	4669.524	1.04E-05	6.1644	15.786	43098.9	0.000143	8.275	13.1975	2540.388	23.957949
"1995"	28	26	4619.055	4554.461	0.25	4664.337	0.0023082	1368.1	16.1485	44088.6	0.0310317	2.926	30.2764	5827.9	69.32263
"1992"	28	31	4646.277	4588.25	0.25	4653.08	0.0001973	116.95	14.5068	39606.3	0.0029527	5.251	7.50514	1444.664	34.698753
"1992"	28	32	4651.37	4594.059	0.25	4654.951	0.0001103	65.378	14.3277	39117.6	0.0016713	5.819	6.10226	1174.623	30.926169
"1992"	28	33	4655.421	4597.821	0.25	4656.809	0.0001427	84.583	14.4	39314.9	0.0021514	5.567	6.0697	1168.357	32.489398
"1992"	28	30	4640.17	4579.352	0.25	4653.279	0.0013997	829.65	15.2045	41511.3	0.019986	3.355	14.6711	2824.04	56.915644
"1996"	28	27	4623.271	4557.982	0.25	4661.383	1.78E-05	10.551	16.3222	44563	0.0002368	7.771	10.5947	2039.38	26.377969
"1996"	28	28	4628.243	4562.832	0.25	4658.035	0.0033945	2012	16.3528	44646.3	0.045066	2.566	28.7216	5528.629	80.050893
"1996"	28	29	4633.686	4569.259	0.25	4655.185	1E-05	5.9273	16.1067	43974.6	0.0001348	8.335	7.58765	1460.547	24.270741
"1991"	32	36	4637.51	4573.504	0.25	4620.237	1E-05	5.9273	11.6833	31897.6	0.0001858	8.014	2.66823	513.608	18.310379
"1991"	32	35	4629.604	4565.325	0.25	4621.035	1E-05	5.9273	13.9275	38024.9	0.0001559	8.189	3.71043	714.221	21.359394
"1984"	32	37	4642.883	4579.884	0.25	4618.822	1E-05	5.9273	9.7345	26577.1	0.000223	7.831	1.8955	364.866	15.611654
"1984"	32	38	4641.479	4579.815	0.25	4619.367	1E-05	5.9273	9.888	26996.2	0.0002196	7.847	1.95186	375.713	15.826218
"1998"	32	33	4623.345	4558.001	0.25	4621.219	1E-05	5.9273	15.8045	43149.4	0.0001374	8.316	4.7053	905.723	23.869535
"1998"	32	32	4620.936	4555.989	0.25	4621.099	3.67E-05	21.753	16.2368	44329.6	0.0004907	7.043	5.88826	1133.43	28.954252
"1998"	33	31	4605	4552.199	0.5	4618.108	3.63E-05	21.516	26.4005	72078.6	0.0002985	7.54	10.2362	1970.36	43.976306
"1998"	33	30	4614.484	4549.375	0.5	4618.08	0.0007324	434.12	32.5545	88880.3	0.0048843	4.749	19.0865	3673.962	86.087543
"1999"	33	29	4611.798	4547.139	0.5	4618.149	0.0003776	223.82	32.3295	88266	0.0025357	5.403	17.6334	3394.254	75.155708
"1998"	33	32	4625.278	4556.807	0.5	4618.206	1E-05	5.9273	30.6995	83815.8	7.07E-05	8.98	8.22055	1582.374	42.937557
"1998"	33	33	4627.779	4559.34	0.5	4618.268	1E-05	5.9273	29.464	80442.6	7.37E-05	8.939	7.60699	1464.27	41.398902

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1984"	33	36	4637.083	4571.69	0.5	4617.374	1E-05	5.9273	22.842	62363.2	9.5E-05	8.684	4.70592	905.843	33.035303
"1998"	34	31	4618.155	4550.801	0.75	4616.491	1E-05	5.9273	49.2675	134510	4.41E-05	9.453	13.4083	2580.968	65.459517
"1994"	23	32	4708.808	4651.202	0.75	4684.714	1E-05	5.9273	25.134	68620.8	8.64E-05	8.78	3.7571	723.205	35.954255
"1998"	34	32	4623.38	4554.42	0.75	4616.567	1E-05	5.9273	46.6102	127255	4.66E-05	9.397	12.0718	2323.695	62.294317
"2001"	18	29	4729.404	4677.34	1	4724.208	1E-05	5.9273	46.868	127959	4.63E-05	9.403	9.14887	1761.066	62.602062
"2001"	18	30	4728.178	4676.151	1	4732.849	0.0001305	77.352	52.027	142044	0.0005446	6.939	17.5629	3380.69	94.16868
"2005"	18	28	4728.77	4677.708	1	4717.471	1E-05	5.9273	39.763	108561	5.46E-05	9.238	6.70244	1290.153	54.056932
"2005"	18	26	4723.273	4675.664	1	4708.196	1E-05	5.9273	32.532	88818.9	6.67E-05	9.038	4.58601	882.761	45.208692
"2005"	18	27	4725.275	4677.115	1	4712.049	1E-05	5.9273	34.934	95376.8	6.21E-05	9.109	5.24687	1009.971	48.167039
"2005"	19	27	4724.892	4675.267	1	4701.723	1E-05	5.9273	26.456	72230.2	8.21E-05	8.831	3.10393	597.475	37.625714
"2005"	17	29	4731.593	4675.668	1	4730.753	2.36E-05	13.988	55.085	150393	9.3E-05	8.706	13.65	2627.495	79.469045
"2000"	17	30	4731.09	4676.317	1	4739.381	0.0011722	694.8	54.773	149541	0.0046462	4.799	30.658	5901.349	143.34137
"2001"	19	30	4730.358	4677.532	1	4722.599	1E-05	5.9273	45.067	123042	4.82E-05	9.364	8.49465	1635.135	60.448349
"2002"	19	28	4728.76	4678.81	1	4706.514	1E-05	5.9273	27.704	75637.5	7.84E-05	8.877	3.386	651.771	39.196048
"2001"	19	29	4730.813	4679.608	1	4713.399	1E-05	5.9273	33.791	92256.2	6.42E-05	9.076	4.92714	948.425	46.761835
"1994"	23	31	4705.597	4647.985	1	4678.996	1E-05	5.9273	31.011	84666.2	7E-05	8.99	4.1894	806.418	43.324529
"1982"	24	37	4717.197	4661.137	1	4680.245	1E-05	5.9273	19.108	52168.7	0.0001136	8.506	1.68111	323.597	28.214871
"1982"	24	36	4714.068	4657.622	1	4678.033	1E-05	5.9273	20.411	55726.1	0.0001064	8.572	1.90344	366.393	29.906955
"1981"	24	38	4663.427	4638.427	1	4687.284	0.0019621	1163	25	68255	0.017039	3.512	18.055	3475.408	89.40819
"1982"	25	39	4681.131	4662.186	1	4673.245	1E-05	5.9273	11.059	30193.3	0.0001963	7.959	0.6018	115.841	17.451593
"1981"	24	39	4725.515	4669.763	1	4685.294	1E-05	5.9273	15.531	42402.7	0.0001398	8.298	1.13835	219.122	23.505805
"2007"	24	23	4663.225	4600.308	1	4676.538	0.0015258	904.39	62.917	171776	0.0052649	4.675	44.8579	8634.691	169.03612
"1993"	23	33	4712.473	4655.202	1	4687.208	1E-05	5.9273	32.006	87382.8	6.78E-05	9.021	4.44693	855.99	44.558089
"2004"	19	26	4723.082	4673.994	1	4699.245	1E-05	5.9273	25.251	68940.3	8.6E-05	8.784	2.84262	547.176	36.102528
"1993"	23	34	4715.952	4658.673	1	4689.365	1E-05	5.9273	30.692	83795.3	7.07E-05	8.979	4.10838	790.822	42.928236
"2007"	24	22	4653.983	4590.442	1	4676.611	0.0008974	531.92	63.541	173480	0.0030662	5.213	48.3319	9303.415	153.07993
"1993"	23	35	4718.489	4661.081	1	4693.255	1E-05	5.9273	32.174	87841.5	6.75E-05	9.027	4.49113	864.498	44.765998
"2007"	17	26	4727.433	4676.951	1	4714.476	1E-05	5.9273	37.525	102451	5.79E-05	9.18	6.00686	1156.261	51.336309
"2005"	17	28	4731.798	4676.294	1	4724.299	1E-05	5.9273	48.005	131063	4.52E-05	9.427	9.57374	1842.85	63.957727
"2005"	17	27	4729.609	4676.475	1	4718.925	2.06E-05	12.21	42.45	115897	0.0001054	8.581	8.22398	1583.035	62.130124
"2002"	38	39	4593.287	4521.567	2	4617.903	0.0005707	338.27	143.44	391620	0.0008638	6.478	97.7714	18820.02	278.10303
"2002"	38	38	4586.815	4512.593	2	4617.129	0.0012119	718.33	148.444	405282	0.0017724	5.76	125.903	24235.05	323.67496
"1994"	23	30	4701.875	4644.573	2	4677.697	1E-05	5.9273	66.248	180870	3.28E-05	9.749	8.81523	1696.843	85.347024
"2002"	38	40	4599.895	4530.574	2	4618.632	0.000268	158.85	138.642	378520	0.0004197	7.199	75.8324	14596.98	241.86507
"1992"	40	47	4609.95	4540.334	3.5	4620.283	1E-05	5.9273	243.656	665230	8.91E-06	11.05	74.9804	14432.97	276.90905
"1992"	40	48	4618.227	4550.064	3.5	4620.64	7.79E-05	46.174	238.57	651345	7.09E-05	8.977	75.1255	14460.9	333.76434
"1992"	40	46	4604.075	4534.322	3.5	4619.966	0.0002078	123.17	244.135	666539	0.0001848	8.019	114.739	22086.13	382.3513
"2006"	49	42	4573.648	4487.554	3.5	4616.148	0.0029	1718.9	301.329	822688	0.0020894	5.596	330.94	63702.68	676.31435
"1992"	40	45	4607.468	4539.838	3.5	4619.718	0.0012271	727.34	236.705	646252	0.0011255	6.213	131.358	25285.03	478.45381
"2005"	49	63	4612.817	4550.672	3.5	4696.709	0.0006032	357.54	217.508	593839	0.0006021	6.839	251.569	48424.49	399.46471
"2010"	49	61	4603.705	4542.803	3.5	4686.682	0.0018297	1084.5	213.157	581961	0.0018636	5.71	291.22	56056.97	468.85257

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2010"	49	60	4601.543	4540.877	3.5	4680.383	0.0027286	1617.3	212.331	579706	0.0027899	5.307	300.924	57924.96	502.4637
"2010"	50	62	4599.033	4541.406	3.5	4686.488	0.0006895	408.69	201.695	550666	0.0007422	6.629	242.328	46645.76	382.1044
"2005"	49	62	4608.756	4547.034	3.5	4692.128	0.0024935	1478	216.027	589797	0.0025059	5.414	313.56	60357.2	501.10021
"2005"	50	63	4603.818	4545.564	3.5	4690.867	0.0016889	1001.1	203.889	556658	0.0017983	5.745	282.586	54394.95	445.69163
"2006"	49	41	4566.326	4485.179	3.5	4615.26	1E-05	5.9273	284.014	775416	7.64E-06	11.2	161.517	31090.42	318.36019
"1992"	39	53	4631.353	4561.369	3.5	4632.283	4.91E-05	29.103	244.944	668746	4.35E-05	9.465	72.4971	13954.96	325.01664
"1981"	39	43	4612.754	4545.042	3.5	4619.418	0.000534	316.52	236.992	647036	0.0004892	7.046	103.821	19984.52	422.42932
"2010"	49	66	4627.741	4564.17	3.5	4705.899	0.0011058	655.44	222.498	607465	0.001079	6.256	269.996	51971.49	446.70821
"2006"	49	40	4563.125	4483.726	3.5	4614.435	1E-05	5.9273	277.897	758713	7.81E-06	11.18	160.498	30894.32	312.10895
"1992"	39	52	4630.5	4561.414	3.5	4623.362	1E-05	5.9273	216.818	591957	1E-05	10.93	48.1056	9259.844	249.03813
"1986"	40	43	4609.955	4543.068	3.5	4619.096	0.0006069	359.73	234.104	639152	0.0005628	6.906	109.023	20985.82	425.75111
"1992"	40	44	4609.46	4542.768	3.5	4619.454	0.0006673	395.53	233.422	637289	0.0006206	6.808	111.913	21542.07	430.60413
"2005"	49	64	4614.723	4552.83	3.5	4700.47	0.0023454	1390.2	216.626	591431	0.0023506	5.478	317.159	61049.98	496.63249
"2006"	50	41	4571.356	4480.363	3.5	4614.822	0.0001755	104.02	318.475	869502	0.0001196	8.454	241.12	46413.17	473.13173
"2005"	49	65	4620.971	4558.508	3.5	4703.476	0.0005116	303.24	218.62	596878	0.000508	7.008	244.297	47024.78	391.7856
"1998"	40	57	4656.341	4586.539	3.5	4678.869	0.0006685	396.24	244.307	667007	0.0005941	6.852	149.896	28853.42	447.80624
"2001"	40	58	4660.655	4591.273	3.5	4692.017	0.0004381	259.68	242.837	662994	0.0003917	7.268	159.174	30639.38	419.6142
"1992"	38	47	4617.963	4551.312	3.5	4618.761	5.09E-05	30.17	233.278	636897	4.74E-05	9.38	66.2082	12744.41	312.33583
"2006"	50	45	4601.329	4494.499	3.5	4619.009	0.0023895	1416.3	373.905	1020835	0.0013874	6.004	332.384	63980.54	782.08169
"2006"	50	44	4602.227	4489.787	3.5	4617.783	0.0018486	1095.7	393.54	1074443	0.0010198	6.312	337.851	65032.97	783.05376
"2001"	40	59	4662.728	4594.092	3.5	4705.967	0.0057126	3386	240.226	655865	0.0051627	4.694	281.983	54278.86	642.72177
"2010"	49	59	4599.311	4537.367	3.5	4673.491	0.0014954	886.37	216.804	591918	0.0014975	5.928	265.786	51161.22	459.30949
"2001"	49	46	4598.628	4497.569	3.5	4620.759	0.0027043	1602.9	353.706	965689	0.0016599	5.825	328.008	63138.25	762.56909
"2001"	40	62	4676.389	4606.116	3.5	4746.726	0.0029455	1745.9	245.956	671508	0.0026	5.378	335.844	64646.62	574.42183
"2001"	40	60	4667.481	4598.363	3.5	4720.533	0.0048629	2882.4	241.913	660471	0.0043642	4.861	307.005	59095.47	624.96882
"2001"	40	61	4672.357	4602.454	3.5	4733.941	1E-05	5.9273	244.661	667972	8.87E-06	11.06	149.542	28785.26	277.94717
"2006"	49	43	4583.164	4490.152	3.5	4617.112	0.0005167	306.26	325.542	888795	0.0003446	7.396	257.851	49633.77	552.78768
"2001"	49	44	4589.646	4491.409	3.5	4618.174	0.0005334	316.16	343.83	938723	0.0003368	7.419	264.586	50930.15	582.04366
"1995"	40	55	4639.004	4568.701	3.5	4654.532	0.0003653	216.53	246.06	671794	0.0003223	7.463	124.191	23905.45	414.08364
"1993"	40	53	4629.976	4559.174	3.5	4633.163	0.0001503	89.088	247.807	676563	0.0001317	8.358	88.3768	17011.65	372.36869
"1994"	40	54	4633.925	4563.269	3.5	4643.574	1E-05	5.9273	247.296	675168	8.78E-06	11.07	75.911	14612.11	280.66922
"2001"	49	45	4595.028	4494.193	3.5	4619.377	0.0030647	1816.5	352.923	963549	0.0018853	5.698	343.004	66024.79	777.85014
"2010"	50	61	4592.158	4535.131	3.5	4681.364	0.0015136	897.16	199.595	544933	0.0016464	5.834	275.627	53055.38	429.71141
"2015"	50	60	4588.904	4529.583	3.5	4675.696	0.0014433	855.49	207.624	566854	0.0015092	5.92	280.133	53922.75	440.43923
"1992"	38	48	4616.728	4551.142	3.5	4618.729	8.25E-05	48.9	229.551	626720	7.8E-05	8.881	69.7623	13428.55	324.61379
"1996"	40	56	4649.023	4579.027	3.5	4666.318	0.0023182	1374.1	244.986	668861	0.0020543	5.613	168.924	32516.24	548.20196
"1992"	38	49	4620.855	4555.632	3.5	4619.562	1E-05	5.9273	223.755	610896	9.7E-06	10.97	51.0859	9833.53	256.2679
"2010"	49	67	4633.425	4569.347	3.5	4707.969	0.0027931	1655.6	224.273	612310	0.0027038	5.339	309.821	59637.5	527.61496
"2006"	50	43	4594.162	4486.129	3.5	4616.707	0.0033369	1977.9	378.116	1032331	0.0019159	5.682	379.453	73040.95	835.739
"2016"	51	33	4511.637	4429.989	3.5	4608.472	0.0005941	352.14	285.768	780204	0.0004513	7.127	381.665	73466.65	503.61949
"1992"	39	48	4615.217	4547.607	3.5	4619.949	0.000917	543.54	236.635	646061	0.0008413	6.504	107.568	20705.74	456.93284

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1992"	39	46	4610.779	4541.528	3.5	4619.571	0.0004574	271.12	242.379	661742	0.0004097	7.223	110.259	21223.67	421.43014
"1992"	39	47	4609.524	4540.92	3.5	4619.621	0.0014508	859.94	240.114	655559	0.0013118	6.06	132.556	25515.8	497.59534
"1998"	38	59	4681.696	4611.398	3.5	4703.459	0.0016728	991.52	246.043	671747	0.001476	5.943	172.796	33261.41	519.99183
"2015"	50	69	4627.166	4566.063	3.5	4705.772	0.0025232	1495.6	213.861	583882	0.0025614	5.393	298.376	57434.36	498.08616
"1993"	38	55	4647.871	4575.666	3.5	4651.864	1E-05	5.9273	252.717	689969	8.59E-06	11.09	70.3918	13549.71	286.26137
"1994"	38	56	4658.979	4587.23	3.5	4664.092	0.0001616	95.785	251.122	685612	0.0001397	8.299	95.1239	18310.4	380.04088
"1997"	38	58	4676.462	4606.405	3.5	4689.468	2.05E-05	12.151	245.2	669444	1.82E-05	10.34	85.1948	16399.15	297.83932
"1995"	38	57	4668.631	4597.833	3.5	4677.146	0.0015041	891.53	247.793	676524	0.0013178	6.056	136.19	26215.24	513.89828
"1992"	39	45	4611.976	4542.42	3.5	4619.615	0.0001191	70.594	243.446	664656	0.0001062	8.573	91.5113	17615	356.6461
"2009"	39	44	4614.369	4546.092	3.5	4619.603	3.22E-05	19.086	238.97	652435	2.93E-05	9.862	73.0675	14064.75	304.31896
"1998"	39	58	4670.646	4601.099	3.5	4691.099	0.0002261	134.02	243.414	664570	0.0002017	7.932	124.55	23974.66	385.41992
"2001"	38	60	4690.752	4619.679	3.5	4722.481	0.0006901	409.04	248.756	679152	0.0006023	6.838	176.589	33991.67	456.87682
"2011"	51	36	4542.837	4441.188	3.5	4610.37	0.0030211	1790.7	355.772	971327	0.0018436	5.721	521.698	100421.7	781.06902
"2011"	51	37	4546.825	4450.87	3.5	4611.108	0.0026166	1550.9	335.842	916917	0.0016915	5.807	460.019	88549.03	726.40297
"1997"	39	57	4666.412	4596.413	3.5	4678.085	1.02E-05	6.0459	244.997	668889	9.04E-06	11.04	77.7651	14969.01	278.79366
"2016"	51	35	4535.716	4436.368	3.5	4609.693	1E-05	5.9273	347.718	949340	6.24E-06	11.41	265.793	51162.42	382.85252
"2016"	51	34	4524.508	4432.833	3.5	4609.106	0.0019915	1180.4	320.863	876019	0.0013475	6.034	484.564	93273.73	667.89056
"1993"	39	54	4634.318	4563.235	3.5	4642.576	0.0009733	576.91	248.791	679248	0.0008493	6.495	127.285	24501.04	481.10619
"1995"	39	56	4654.762	4584.099	3.5	4665.418	0.0007111	421.49	247.32	675234	0.0006242	6.802	125.901	24234.73	456.62782
"1994"	39	55	4643.976	4572.945	3.5	4653.51	0.0006239	369.81	248.608	678751	0.0005448	6.938	121.97	23477.95	450.01291
"1993"	38	54	4641.096	4569.601	3.5	4641.104	1.56E-05	9.2466	250.232	683185	1.35E-05	10.63	65.9038	12685.82	295.56386
"2011"	50	39	4561.344	4475.79	3.5	4613.155	1E-05	5.9273	299.439	817528	7.25E-06	11.26	179.075	34470.08	334.07313
"2006"	50	40	4564.4	4478.723	3.5	4613.968	0.0055553	3292.8	299.869	818704	0.004022	4.943	399.843	76965.7	761.95187
"2011"	50	38	4553.836	4468.305	3.5	4612.39	1E-05	5.9273	299.358	817309	7.25E-06	11.26	190.711	36709.95	333.9913
"2011"	50	36	4530.247	4447.417	3.5	4610.977	0.0018643	1105	289.905	791499	0.0013961	5.998	411.453	79200.57	607.01331
"2011"	50	37	4542.527	4457.205	3.5	4611.65	2.09E-05	12.388	298.627	815311	1.52E-05	10.52	222.978	42921.06	356.60468
"2001"	39	61	4689.357	4618.306	3.5	4736.339	0.0059204	3509.2	248.679	678942	0.0051686	4.693	309.933	59658.92	665.49839
"2015"	49	69	4639.463	4577.389	3.5	4711.482	0.0001537	91.103	217.259	593161	0.0001536	8.204	188.858	36353.24	332.58994
"2010"	49	68	4637.964	4573.976	3.5	4709.771	0.0037259	2208.5	223.958	611450	0.0036118	5.05	318.992	61402.77	556.99064
"2015"	49	70	4639.896	4580.262	3.5	4713.021	0.0019993	1185	208.719	569845	0.0020796	5.6	264.915	50993.46	468.06462
"2001"	39	60	4682.36	4612.053	3.5	4721.281	0.000174	103.14	246.074	671833	0.0001535	8.205	158.771	30561.87	376.67945
"2006"	50	42	4583.609	4483.06	3.5	4615.73	0.0013893	823.48	351.921	960816	0.0008571	6.486	327.43	63027.08	681.48938
"2001"	39	59	4674.471	4604.796	3.5	4705.295	0.0026736	1584.7	243.862	665793	0.0023802	5.466	211.507	40712.94	560.35484
"2010"	50	67	4618.415	4557.39	3.5	4702.311	0.0009105	539.68	213.587	583137	0.0009255	6.409	262.141	50459.61	418.56019
"2020"	50	29	4482.634	4390.804	3.5	4606.891	0.0001938	114.87	321.405	877500	0.0001309	8.364	449.855	86592.59	482.62293
"2015"	50	68	4624.702	4562.885	3.5	4704.143	0.0029244	1733.4	216.36	590705	0.0029344	5.257	313.041	60257.28	516.90178
"1992"	38	53	4637.057	4567.206	3.5	4629.981	1E-05	5.9273	219.712	599859	9.88E-06	10.95	49.3387	9497.212	252.05707
"2011"	51	38	4558.838	4464.137	3.5	4611.893	7.02E-05	41.61	331.454	904934	4.6E-05	9.41	252.607	48624.4	442.37817
"2020"	50	30	4488.717	4405.533	3.5	4607.303	0.0002271	134.61	291.144	794881	0.0001693	8.107	394.985	76030.69	451.06492
"2010"	50	65	4608	4548.491	3.5	4697.599	0.0007187	426	208.282	568650	0.0007491	6.62	257.317	49530.9	395.13962
"2005"	50	64	4606.277	4547.69	3.5	4694.536	0.0003253	192.82	205.055	559840	0.0003444	7.397	223.304	42983.84	348.17

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2010"	50	66	4612.39	4552.057	3.5	4700.155	0.0013808	818.44	211.166	576524	0.0014196	5.982	285.643	54983.38	443.37762
"2020"	50	31	4494.569	4417.179	3.5	4607.832	0.0002929	173.61	270.865	739516	0.0002348	7.78	362.902	69855.07	437.26217
"2011"	50	35	4522.531	4441.553	3.5	4610.288	0.0011481	680.52	283.423	773801	0.0008794	6.46	390.448	75157.27	551.0314
"2000"	46	62	4638.8	4568.096	3.5	4710.559	1E-05	5.9273	247.464	675626	8.77E-06	11.07	166.652	32078.77	280.84266
"1995"	46	63	4641.691	4570.779	3.5	4715.715	0.0036102	2139.9	248.192	677614	0.003158	5.184	364.293	70122.82	601.32441
"2005"	46	61	4637.321	4565.856	3.5	4704.401	1E-05	5.9273	250.128	682898	8.68E-06	11.08	162.059	31194.83	283.59108
"2006"	46	59	4628.793	4556.836	3.5	4683.62	1E-05	5.9273	251.849	687600	8.62E-06	11.08	145.34	27976.54	285.36671
"2005"	46	60	4633.977	4561.634	3.5	4696.761	0.0033666	1995.5	253.2	691288	0.0028866	5.273	332.797	64060.11	603.0393
"1995"	46	64	4645.657	4573.882	3.5	4719.621	0.0033919	2010.5	251.213	685860	0.0029313	5.258	364.948	70248.82	600.04836
"2020"	47	25	4461.559	4375.342	3.5	4608.074	0.0002013	119.32	301.76	823864	0.0001448	8.263	472.55	90961.16	458.66334
"2020"	47	26	4470.214	4384.566	3.5	4608.286	0.0001696	100.53	299.768	818427	0.0001228	8.428	439.862	84669.12	446.73133
"2005"	46	72	4693.979	4630.068	3.5	4731.797	0.0013073	774.88	223.689	610714	0.0012688	6.094	182.486	35126.82	461.02701
"1995"	46	65	4652.034	4580.589	3.5	4722.275	1E-05	5.9273	250.057	682707	8.68E-06	11.08	166.658	32080.02	283.51888
"2000"	46	71	4692.072	4626.218	3.5	4731.501	1.12E-05	6.6386	230.489	629281	1.05E-05	10.88	109.133	21006.92	266.01021
"2006"	44	60	4642.049	4569.497	3.5	4714.484	1E-05	5.9273	253.932	693285	8.55E-06	11.09	173.276	33353.99	287.51276
"1996"	44	52	4615.121	4547.483	3.5	4628.867	1.1E-05	6.5201	236.733	646328	1.01E-05	10.93	76.8256	14788.16	272.09762
"2006"	44	61	4645.374	4573.84	3.5	4719.032	1E-05	5.9273	250.369	683557	8.67E-06	11.08	171.966	33101.77	283.84016
"2000"	44	63	4651.096	4580.382	3.5	4731.675	0.0011617	688.58	247.499	675722	0.001019	6.313	314.779	60591.8	492.40603
"2000"	44	62	4647.953	4577.278	3.5	4725.312	0.0028766	1705.1	247.363	675349	0.0025247	5.407	357.623	68838.93	574.57737
"1992"	44	51	4607.279	4537.827	3.5	4627.488	0.0023704	1405	243.082	663662	0.0021171	5.583	175.866	33852.54	546.86517
"1993"	44	47	4584.152	4515.031	3.5	4621.675	0.0005825	345.27	241.924	660500	0.0005227	6.98	178.714	34400.66	435.31594
"2006"	46	58	4625.762	4554.091	3.5	4673.241	0.0006345	376.09	250.848	684867	0.0005491	6.93	213.759	41146.52	454.58342
"1993"	44	48	4584.247	4514.889	3.5	4622.922	0.0039253	2326.7	242.753	662764	0.0035105	5.078	250.511	48220.78	600.36387
"1992"	44	50	4598.093	4528.027	3.5	4625.861	0.0030701	1819.7	245.231	669530	0.0027179	5.333	209.504	40327.5	577.48313
"1993"	44	49	4589.038	4519.327	3.5	4624.298	0.004009	2376.3	243.988	666137	0.0035672	5.062	242.503	46679.38	605.32258
"2000"	43	63	4654.975	4584.136	3.5	4741.256	0.0006621	392.45	247.936	676916	0.0005798	6.876	303.088	58341.34	452.8495
"2000"	43	62	4650.951	4580.134	3.5	4732.781	0.0024135	1430.6	247.86	676706	0.002114	5.584	360.175	69330.12	557.4693
"2001"	47	44	4563.167	4488.489	3.5	4618.73	2.08E-05	12.329	261.373	713601	1.73E-05	10.39	164.82	31726.17	315.97693
"2001"	47	42	4558.985	4486.841	3.5	4616.873	1E-05	5.9273	252.504	689386	8.6E-06	11.09	150.401	28950.68	286.04134
"2001"	47	43	4558.59	4486.563	3.5	4617.745	1E-05	5.9273	252.095	688268	8.61E-06	11.09	151.955	29249.91	285.61926
"2006"	43	61	4648.069	4576.589	3.5	4725.043	0.0026838	1590.8	250.18	683041	0.002329	5.487	356.682	68657.71	572.59626
"1992"	43	50	4613.815	4545.14	3.5	4624.732	0.0014958	886.61	240.362	656238	0.001351	6.031	135.586	26098.95	500.54449
"1991"	43	49	4607.095	4538.651	3.5	4623.33	0.0005141	304.72	239.554	654030	0.0004659	7.095	126.284	24308.41	424.06456
"1992"	43	51	4621.525	4553.524	3.5	4626.201	0.0007235	428.84	238.003	649797	0.00066	6.747	104.711	20155.82	443.0505
"2006"	43	60	4646.468	4573.817	3.5	4719.817	1E-05	5.9273	254.278	694231	8.54E-06	11.09	174.948	33675.72	287.86969
"1995"	43	52	4623.061	4554.725	3.5	4627.527	0.0001136	67.334	239.176	652998	0.0001031	8.603	82.5106	15882.46	349.18571
"2011"	47	30	4498.154	4422.318	3.5	4609.594	0.0002574	152.57	265.426	724666	0.0002105	7.889	344.656	66342.74	422.56747
"2011"	47	31	4507.666	4431.492	3.5	4610.013	0.000259	153.52	266.609	727896	0.0002109	7.887	326.654	62877.54	424.54499
"2016"	47	29	4491.171	4414.667	3.5	4609.195	0.0002244	133.01	267.764	731049	0.0001819	8.035	356.569	68636.01	418.5466
"2016"	47	27	4480.437	4397.908	3.5	4608.534	0.0001949	115.52	288.851	788622	0.0001465	8.251	405.823	78116.91	439.65055
"2016"	47	28	4485.611	4406.966	3.5	4608.835	0.0002004	118.78	275.257	751508	0.0001581	8.175	374.49	72085.66	422.85547

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2011"	47	32	4516.384	4440.326	3.5	4610.452	0.0004249	251.85	266.203	726787	0.0003465	7.391	328.436	63220.64	452.37073
"2006"	47	36	4542.758	4468.997	3.5	4612.555	0.0019284	1143	258.163	704838	0.0016217	5.849	328.596	63251.4	554.37275
"2006"	47	41	4559.324	4488.32	3.5	4616.041	0.0010011	593.38	248.514	678493	0.0008746	6.465	249.174	47963.59	482.74557
"2011"	47	35	4536.193	4462.331	3.5	4611.951	0.0034172	2025.5	258.517	705803	0.0028698	5.279	383.79	73875.71	615.01976
"2011"	47	33	4523.573	4447.986	3.5	4610.916	0.002058	1219.8	264.555	722287	0.0016889	5.808	394.501	75937.48	572.06013
"2011"	47	34	4529.216	4454.674	3.5	4611.429	0.0026133	1549	260.897	712301	0.0021746	5.556	389.07	74892.06	589.77203
"2000"	44	64	4653.667	4582.716	3.5	4736.337	0.0015221	902.2	248.329	677986	0.0013307	6.046	335.744	64627.46	515.83719
"1997"	45	52	4603.025	4531.529	3.5	4630.857	0.0002244	133.01	250.236	683194	0.0001947	7.967	145	27911.05	394.47149
"1995"	45	51	4594.116	4521.483	3.5	4628.905	2.68E-05	15.885	254.215	694059	2.29E-05	10.11	128.65	24763.77	315.87427
"2006"	45	60	4637.24	4565.084	3.5	4706.688	0.0007313	433.46	252.546	689501	0.0006287	6.795	273.484	52642.88	466.7627
"2000"	45	62	4643.789	4573.364	3.5	4717.789	0.0002612	154.82	246.488	672960	0.0002301	7.8	239.783	46155.87	396.87711
"2000"	45	61	4641.098	4569.824	3.5	4711.917	0.0033676	1996.1	249.459	681073	0.0029308	5.258	351.718	67702.24	595.839
"1994"	45	50	4584.546	4511.643	3.5	4626.925	1.53E-05	9.0688	255.161	696639	1.3E-05	10.67	134.398	25870.31	300.28547
"1993"	45	46	4572.964	4502.78	3.5	4620.899	1E-05	5.9273	245.644	670657	8.84E-06	11.06	130.545	25128.57	278.96325
"1993"	45	45	4573.831	4501.957	3.5	4619.882	1.02E-05	6.0459	251.559	686806	8.8E-06	11.06	132.349	25475.83	285.57749
"1995"	45	47	4572.011	4503.188	3.5	4622.092	1E-05	5.9273	240.881	657652	9.01E-06	11.04	130.134	25049.43	274.03885
"1992"	45	49	4577.241	4506.118	3.5	4625.115	0.001549	918.14	248.93	679630	0.0013509	6.031	243.937	46955.42	518.38036
"1994"	45	48	4571.871	4503.167	3.5	4623.507	0.0001548	91.755	240.464	656515	0.0001398	8.299	175.626	33806.22	363.92859
"2020"	46	24	4463.631	4381.16	3.5	4608.822	0.0001487	88.139	288.649	788068	0.0001118	8.521	430.414	82850.43	425.43031
"2020"	46	23	4455.286	4376.189	3.5	4608.7	0.000145	85.946	276.839	755827	0.0001137	8.505	426.78	82150.79	408.82048
"2020"	46	25	4471.659	4387.226	3.5	4608.968	0.0003854	228.44	295.516	806816	0.0002831	7.593	477.518	91917.42	488.8243
"2016"	46	27	4486.587	4406.827	3.5	4609.37	0.0002062	122.22	279.16	762163	0.0001604	8.161	380.981	73335.1	429.60993
"2016"	46	26	4480.23	4397.393	3.5	4609.147	0.000183	108.47	289.929	791566	0.000137	8.318	406.357	78219.59	437.75197
"2016"	46	28	4491.343	4414.418	3.5	4609.643	0.0002217	131.41	269.238	735072	0.0001788	8.052	358.902	69085.01	419.93054
"1995"	45	64	4649.37	4578.181	3.5	4727.193	0.0032394	1920.1	249.162	680261	0.0028226	5.296	370.163	71252.64	590.91291
"2000"	45	63	4646.701	4575.835	3.5	4723.216	0.002327	1379.3	248.031	677174	0.0020368	5.621	342.822	65989.83	554.17188
"2011"	46	31	4512.966	4438.206	3.5	4610.72	0.0009776	579.45	261.66	714384	0.0008111	6.541	372.376	71678.58	502.43528
"2011"	46	29	4497.309	4422.103	3.5	4609.971	0.000247	146.4	263.221	718646	0.0002037	7.922	342.204	65870.76	417.31695
"2011"	46	30	4504.629	4429.698	3.5	4610.334	0.0007225	428.25	262.258	716018	0.0005981	6.845	376.767	72523.85	481.18629
"1995"	46	50	4583.438	4507.138	3.5	4627.818	0.0010295	610.22	267.05	729100	0.0008369	6.509	241.426	46472.14	515.25173
"1997"	46	51	4585.066	4507.869	3.5	4630.282	1.04E-05	6.1644	270.19	737671	8.36E-06	11.12	145.228	27954.88	305.29169
"1994"	46	49	4577.57	4503.962	3.5	4625.749	0.0024007	1423	257.628	703376	0.0020231	5.628	275.91	53109.96	574.92201
"1996"	46	47	4559.095	4492.063	3.5	4622.371	2.06E-05	12.21	234.612	640538	1.91E-05	10.29	154.009	29645.27	286.33597
"1995"	46	48	4566.187	4496.929	3.5	4623.95	1E-05	5.9273	242.403	661809	8.96E-06	11.05	142.259	27383.38	275.61363
"1998"	46	52	4597.398	4521.07	3.5	4633.489	1E-05	5.9273	267.148	729367	8.13E-06	11.14	128.139	24665.4	301.09928
"2001"	46	56	4619.043	4546.885	3.5	4657.016	0.0017714	1050	252.553	689520	0.0015227	5.912	226.614	43620.97	536.55908
"2001"	46	57	4624.073	4552.1	3.5	4664.542	0.0034345	2035.7	251.905	687752	0.00296	5.248	262.069	50445.7	602.81549
"2001"	46	55	4612.047	4539.018	3.5	4650.375	2.74E-05	16.241	255.601	697843	2.33E-05	10.09	135.809	26141.86	318.12215
"2001"	46	53	4605.671	4529.98	3.5	4638.906	0.0030137	1786.3	264.919	723280	0.0024697	5.429	250.504	48219.53	612.86835
"2001"	46	54	4608.878	4533.578	3.5	4644.419	0.0046001	2726.6	263.55	719544	0.0037894	5.002	277.596	53434.45	661.72188
"2006"	46	35	4537.118	4463.988	3.5	4612.577	0.0003434	203.54	255.955	698808	0.0002913	7.564	263.564	50733.38	424.97108

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2006"	46	36	4539.953	4467.307	3.5	4613.129	1E-05	5.9273	254.261	694183	8.54E-06	11.09	174.674	33622.93	287.85167
"2006"	46	34	4533.57	4460.043	3.5	4612.067	0.0018851	1117.4	257.345	702602	0.0015903	5.868	350.966	67557.38	550.77762
"2011"	46	32	4520.991	4446.836	3.5	4611.135	0.0012651	749.87	259.542	708603	0.0010582	6.275	363.476	69965.58	519.47034
"2011"	46	33	4527.852	4454.111	3.5	4611.582	0.0003591	212.85	258.094	704647	0.0003021	7.528	286.379	55125.09	430.59226
"2006"	46	37	4542.002	4469.783	3.5	4613.691	1E-05	5.9273	252.767	690103	8.59E-06	11.09	171.145	32943.79	286.31187
"1993"	46	45	4567.575	4495.041	3.5	4619.894	0.000833	493.75	253.869	693113	0.0007124	6.67	238.077	45827.43	477.99366
"1996"	46	46	4566.104	4494.882	3.5	4621.029	0.0034494	2044.6	249.277	680576	0.0030042	5.234	303.608	58441.49	598.20943
"1998"	46	44	4561.982	4491.433	3.5	4618.893	1E-05	5.9273	246.921	674145	8.79E-06	11.06	144.556	27825.56	280.28257
"2006"	46	38	4544.734	4473.317	3.5	4614.333	0.0012771	756.98	249.96	682439	0.0011092	6.228	294.575	56702.67	504.06651
"2001"	46	43	4554.716	4485.295	3.5	4617.964	1E-05	5.9273	242.974	663366	8.94E-06	11.05	150.577	28984.54	276.20352
"1991"	43	48	4601.359	4533.161	3.5	4622.241	0.0005376	318.65	238.693	651680	0.000489	7.046	136.64	26301.88	425.43517
"2010"	48	67	4649.275	4581.725	3.5	4713.541	1E-05	5.9273	236.425	645488	9.18E-06	11.02	146.735	28245.09	269.42567
"2006"	41	62	4661.275	4591.477	3.5	4743.719	0.0027591	1635.4	244.293	666969	0.002452	5.436	364.664	70194.16	564.40511
"1995"	48	66	4644.526	4576.925	3.5	4711.496	1E-05	5.9273	236.603	645975	9.18E-06	11.02	150.668	29002.03	269.61063
"1995"	48	64	4629.037	4562.781	3.5	4706.516	0.0030703	1819.9	231.896	633122	0.0028744	5.278	336.222	64719.38	551.85711
"1995"	48	65	4636.388	4569.689	3.5	4709.429	1E-05	5.9273	233.446	637356	9.3E-06	11.01	156.493	30123.31	266.33781
"2001"	41	61	4656.469	4587.167	3.5	4731.857	7.62E-05	45.166	242.557	662229	6.82E-05	9.016	205.397	39536.92	337.88742
"2001"	41	57	4648.213	4578.111	3.5	4679.258	0.0032501	1926.4	245.357	669874	0.0028758	5.277	221.859	42705.63	583.94461
"1998"	41	56	4642.862	4572.63	3.5	4666.779	7.11E-05	42.143	245.812	671116	6.28E-05	9.098	116.484	22421.96	339.31309
"2001"	41	58	4653.17	4583.393	3.5	4692.41	0.0009118	540.45	244.22	666768	0.0008106	6.541	197.643	38044.33	468.89607
"2001"	41	60	4655.533	4586.265	3.5	4720.481	0.004086	2421.9	242.438	661904	0.003659	5.037	334.604	64407.98	604.49802
"2001"	41	59	4655.464	4586.046	3.5	4706.298	0.0033583	1990.6	242.963	663338	0.0030008	5.235	280.182	53932.31	582.93398
"1998"	48	47	4589.209	4498.817	3.5	4622.475	8.19E-05	48.545	316.372	863759	5.62E-05	9.209	196.199	37766.41	431.45196
"2006"	48	57	4608.373	4540.351	3.5	4661.87	0.0003462	205.2	238.077	649998	0.0003157	7.484	195.826	37694.49	399.53974
"2001"	48	46	4586.501	4496.648	3.5	4620.966	1.04E-05	6.1644	314.486	858608	7.18E-06	11.27	161.007	30992.26	350.55459
"2001"	48	44	4576.154	4490.82	3.5	4618.49	1.21E-05	7.1721	298.669	815426	8.8E-06	11.06	164.806	31723.51	339.03244
"2001"	48	45	4582.396	4493.932	3.5	4619.648	0.0002011	119.2	309.624	845335	0.000141	8.29	220.217	42389.55	469.10023
"2010"	48	58	4611.857	4545.708	3.5	4669.279	0.0034423	2040.4	231.522	632100	0.0032279	5.162	284.294	54723.67	563.30778
"2005"	48	62	4621.772	4555.104	3.5	4697.9	0.0015315	907.77	233.338	637059	0.0014249	5.978	295.868	56951.69	490.23851
"2005"	48	63	4624.772	4558.232	3.5	4702.666	0.0006805	403.35	232.89	635836	0.0006344	6.786	263.904	50798.94	431.00638
"2005"	48	61	4618.048	4552.039	3.5	4692.139	0.000957	567.24	231.032	630762	0.0008993	6.438	266.325	51264.97	450.72816
"2010"	48	59	4614.243	4548.565	3.5	4677.232	1E-05	5.9273	229.873	627599	9.44E-06	10.99	139.758	26901.96	262.62884
"2005"	48	60	4615.538	4549.858	3.5	4685.229	1E-05	5.9273	229.88	627618	9.44E-06	10.99	148.911	28663.85	262.63611
"2020"	49	28	4474.339	4382.303	3.5	4607.242	0.0002902	172.01	322.126	879468	0.0001956	7.962	496.751	95619.69	508.09215
"2020"	49	29	4481.123	4397.904	3.5	4607.619	0.0002223	131.76	291.266	795216	0.0001657	8.128	412.642	79429.5	450.04558
"2005"	48	71	4653.878	4595.814	3.5	4719.468	0.0007373	437.02	203.224	554842	0.0007876	6.57	202.76	39029.18	388.48446
"1992"	41	44	4606.352	4542.793	3.5	4619.362	0.0011074	656.39	222.457	607351	0.0010807	6.254	118.744	22857.1	446.7405
"1992"	41	43	4603.169	4538.375	3.5	4618.851	1.76E-05	10.432	226.779	619152	1.68E-05	10.41	77.5466	14926.95	273.49555
"2016"	49	30	4487.067	4411.721	3.5	4608.062	0.0002738	162.29	263.711	719984	0.0002254	7.821	365.799	70412.65	423.50017
"2006"	49	38	4554.68	4477.777	3.5	4612.928	1E-05	5.9273	269.161	734862	8.07E-06	11.15	164.47	31658.77	303.16336
"2006"	49	39	4560.154	4482.815	3.5	4613.645	1E-05	5.9273	270.687	739028	8.02E-06	11.16	158.199	30451.75	304.72764

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2011"	49	37	4544.693	4466.657	3.5	4612.196	1E-05	5.9273	273.126	745689	7.95E-06	11.17	182.537	35136.47	307.22686
"2016"	49	31	4496.019	4421.715	3.5	4608.562	0.0002466	146.17	260.064	710027	0.0002059	7.911	337.129	64893.97	412.85604
"2016"	49	32	4505.191	4430.118	3.5	4609.067	0.0003577	212.02	262.755	717375	0.0002956	7.55	338.29	65117.35	437.10424
"1993"	41	52	4627.932	4557.352	3.5	4627.109	4.13E-05	24.48	244.15	666577	3.67E-05	9.635	69.2254	13325.2	318.25506
"1992"	41	51	4626.251	4556.779	3.5	4623.549	1.6E-05	9.4837	233.695	638034	1.49E-05	10.54	57.9808	11160.73	278.48426
"1994"	41	53	4631.356	4560.479	3.5	4634.591	5.26E-05	31.178	248.069	677279	4.6E-05	9.409	78.7491	15158.42	331.12911
"1996"	41	55	4639.482	4569.004	3.5	4655.065	1E-05	5.9273	246.673	673467	8.8E-06	11.06	84.2173	16210.99	280.02597
"1995"	41	54	4635.155	4564.349	3.5	4644.264	0.000546	323.63	247.821	676601	0.0004783	7.068	118.064	22726.04	440.32887
"1992"	41	50	4626.475	4558.181	3.5	4622.226	1E-05	5.9273	224.158	611995	9.69E-06	10.97	51.2615	9867.323	256.68682
"1992"	41	46	4605.532	4539.161	3.5	4620.316	0.0015497	918.56	232.299	634221	0.0014483	5.962	138.882	26733.47	489.3853
"1992"	41	45	4604.809	4540.67	3.5	4619.833	0.0002194	130.05	224.487	612893	0.0002122	7.881	99.4802	19148.94	357.74335
"2005"	48	70	4654.094	4593.481	3.5	4719.322	0.0003075	182.27	212.146	579200	0.0003147	7.487	187.896	36168.01	355.86855
"2010"	48	68	4651.797	4586.093	3.5	4715.301	0.0001715	101.65	229.964	627848	0.0001619	8.151	189.526	36481.95	354.31702
"2015"	48	69	4653.837	4590.714	3.5	4717.248	1E-05	5.9273	220.931	603184	9.83E-06	10.95	133.345	25667.53	253.32645
"2001"	48	43	4569.725	4489.149	3.5	4617.458	0.0010026	594.27	282.016	769960	0.0007718	6.59	268.356	51655.87	537.44469
"2005"	47	62	4631.941	4562.242	3.5	4703.943	1E-05	5.9273	243.946	666023	8.9E-06	11.05	163.977	31563.93	277.20931
"1995"	47	63	4634.441	4564.83	3.5	4708.925	0.0024065	1426.4	243.638	665182	0.0021444	5.57	331.907	63888.81	549.37684
"2005"	47	61	4630.579	4560.037	3.5	4697.9	0.0025577	1516	246.897	674078	0.002249	5.522	319.969	61590.86	561.51761
"2005"	47	59	4623.507	4554.037	3.5	4680.725	1E-05	5.9273	243.145	663834	8.93E-06	11.05	142.055	27344.09	276.38082
"2005"	47	60	4627.93	4557.67	3.5	4690.409	0.0026544	1573.3	245.91	671383	0.0023434	5.481	306.401	58979.11	563.45849
"1995"	47	64	4639.503	4569.824	3.5	4712.824	0.0024706	1464.4	243.877	665832	0.0021994	5.545	330.523	63622.38	552.41846
"2005"	47	72	4674.706	4614.943	3.5	4725.431	1E-05	5.9273	209.17	571077	1.04E-05	10.9	108.463	20878.07	241.04576
"2020"	48	26	4457.398	4366.373	3.5	4607.444	0.0004608	273.13	318.588	869808	0.000314	7.489	568.26	109384.3	534.26988
"2005"	47	71	4672.736	4611.192	3.5	4724.833	1E-05	5.9273	215.404	588096	1.01E-05	10.93	114.535	22046.91	247.56214
"1995"	47	65	4647.738	4577.406	3.5	4715.512	1.04E-05	6.1644	246.162	672071	9.17E-06	11.02	160.31	30858.01	280.49282
"1995"	47	66	4656.956	4586.175	3.5	4716.814	1E-05	5.9273	247.733	676362	8.76E-06	11.07	149.497	28776.69	281.12086
"1985"	43	44	4582.89	4517.154	3.5	4619.253	0.002952	1749.7	230.076	628153	0.0027855	5.309	214.428	41275.22	544.2953
"1993"	43	43	4577.549	4511.45	3.5	4618.494	9.23E-05	54.709	231.347	631622	8.66E-05	8.777	138.675	26693.55	331.046
"1997"	47	47	4569.512	4493.664	3.5	4622.499	2.85E-05	16.893	265.468	724781	2.33E-05	10.09	169.151	32559.94	330.45069
"2001"	47	45	4570.535	4492.524	3.5	4619.82	1E-05	5.9273	273.038	745450	7.95E-06	11.16	153.38	29524.14	307.13725
"1997"	47	46	4571.202	4493.405	3.5	4621.057	0.0003149	186.65	272.29	743405	0.0002511	7.713	222.44	42817.5	443.38943
"1996"	47	48	4574.868	4499.38	3.5	4624.179	0.0051693	3064	264.208	721341	0.0042477	4.888	333.737	64241.09	678.80499
"2006"	47	57	4622.03	4551.604	3.5	4663.487	0.0051647	3061.3	246.491	672970	0.0045489	4.82	279.412	53784.1	642.24956
"2006"	47	58	4621.311	4551.849	3.5	4671.624	1E-05	5.9273	243.117	663758	8.93E-06	11.05	132.116	25430.99	276.35187
"2001"	47	56	4616.931	4544.925	3.5	4656.303	0.0013678	810.74	252.021	688068	0.0011783	6.168	220.234	42392.92	513.19494
"1998"	47	51	4594.323	4513.389	3.5	4631.112	0.0036508	2163.9	283.269	773381	0.002798	5.304	297.495	57264.75	670.69895
"2001"	47	52	4599.91	4519.345	3.5	4634.553	0.0020724	1228.4	281.977	769855	0.0015956	5.865	260.409	50126.11	603.83858
"1992"	42	46	4602.803	4537.895	3.5	4620.589	0.0009202	545.43	227.178	620241	0.0008794	6.46	130.219	25065.78	441.67529
"1984"	42	45	4601.356	4539.276	3.5	4619.932	0.0022722	1346.8	217.28	593218	0.0022703	5.513	143.608	27643.16	495.00258
"2011"	48	34	4522.441	4448.37	3.5	4610.79	0.0007139	423.15	259.248	707800	0.0005978	6.846	328.242	63183.33	475.63368
"1992"	42	51	4624.765	4555.576	3.5	4625.012	4.33E-05	25.665	242.162	661149	3.88E-05	9.579	68.9045	13263.43	317.49131

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1992"	42	50	4625.537	4557.543	3.5	4623.521	0.0002398	142.14	230.923	630466	0.0002254	7.82	76.2964	14686.29	370.85348
"1984"	42	44	4595.914	4532.89	3.5	4619.299	1E-05	5.9273	220.584	602238	9.84E-06	10.95	80.4562	15487.01	252.96539
"2006"	48	41	4565.021	4489.663	3.5	4615.671	0.0024765	1467.9	263.753	720098	0.0020385	5.62	293.635	56521.88	589.38375
"2006"	48	42	4565.936	4489.234	3.5	4616.529	1E-05	5.9273	268.457	732941	8.09E-06	11.15	151.857	29230.91	302.44197
"2006"	48	40	4561.755	4488.054	3.5	4614.897	0.0050462	2991	257.954	704265	0.004247	4.889	335.329	64547.46	662.71638
"1993"	42	43	4591.547	4527.109	3.5	4618.656	0.0016942	1004.2	225.533	615750	0.0016309	5.843	165.702	31895.91	484.77023
"2006"	48	39	4558.458	4486.249	3.5	4614.119	1E-05	5.9273	252.731	690008	8.59E-06	11.09	147.269	28347.81	286.2758
"2016"	48	30	4492.186	4416.825	3.5	4608.839	0.0002307	136.74	263.763	720127	0.0001899	7.992	348.689	67119.22	414.49786
"2016"	48	31	4501.842	4426.283	3.5	4609.298	0.0003112	184.46	264.456	722019	0.0002555	7.695	342.719	65969.89	431.60613
"2016"	48	29	4483.166	4407.307	3.5	4608.403	0.0002315	137.22	265.507	724886	0.0001893	7.995	370.11	71242.49	417.07391
"2020"	48	27	4469.89	4381.959	3.5	4607.709	0.0004826	286.05	307.759	840242	0.0003404	7.408	516.743	99467.9	521.73723
"2020"	48	28	4478.127	4396.198	3.5	4608.022	0.0001675	99.283	286.752	782889	0.0001268	8.396	399.16	76834.24	428.95859
"2011"	48	32	4511.499	4435.256	3.5	4609.763	0.0003421	202.77	266.85	728555	0.0002783	7.61	329.613	63447.21	440.41407
"2001"	42	60	4650.151	4579.333	3.5	4722.256	1E-05	5.9273	247.863	676716	8.76E-06	11.07	167.502	32242.41	281.25453
"1993"	42	52	4626.749	4557.031	3.5	4626.841	2.6E-05	15.411	244.013	666204	2.31E-05	10.1	66.1279	12728.96	303.51716
"2006"	42	61	4649.488	4578.992	3.5	4729.453	0.0004506	267.09	246.736	673639	0.0003965	7.256	271.358	52233.64	427.06836
"2011"	48	33	4518.283	4442.296	3.5	4610.229	0.0004289	254.22	265.955	726109	0.0003501	7.38	323.496	62269.76	452.5792
"2006"	42	62	4652.439	4582.387	3.5	4739.812	0.0004568	270.76	245.182	669396	0.0004045	7.236	286.187	55088.17	425.55012
"2009"	20	21	4700.487	4645.607	3.5	4688.217	1E-05	5.9273	149.135	407168	1.46E-05	10.56	23.5661	4536.23	177.36706
"2009"	20	20	4695.18	4640.544	3.5	4686.035	1E-05	5.9273	159.218	434698	1.36E-05	10.63	26.6952	5138.55	188.19349
"2004"	20	23	4706.709	4653.878	3.5	4691.623	1E-05	5.9273	132.107	360680	1.64E-05	10.44	18.7067	3600.854	158.94085
"2009"	20	22	4703.354	4649.33	3.5	4690.194	1E-05	5.9273	143.024	390484	1.52E-05	10.52	21.7605	4188.686	170.77582
"2009"	20	19	4691.188	4636.467	3.5	4683.988	1E-05	5.9273	166.324	454096	1.31E-05	10.67	29.0116	5584.446	195.78706
"1992"	19	37	4736.035	4678.756	3.5	4744.254	0.0003976	235.67	200.476	547341	0.0004306	7.174	77.6808	14952.78	350.98755
"1993"	19	36	4731.796	4673.792	3.5	4744.636	1.4E-05	8.2982	203.014	554269	1.5E-05	10.53	59.9403	11537.92	242.08865
"2009"	20	18	4688.51	4633.375	3.5	4682.247	7.47E-05	44.277	171.052	467006	9.48E-05	8.687	37.6887	7254.699	247.31402
"1992"	19	38	4741.394	4686.486	3.5	4744.123	8.44E-05	50.027	192.178	524684	9.53E-05	8.681	51.5474	9922.351	278.03915
"2004"	20	24	4712.25	4660.426	3.5	4692.286	1E-05	5.9273	111.51	304445	1.95E-05	10.27	13.5481	2607.881	136.37395
"1996"	20	31	4731.835	4676.101	3.5	4721.867	4.68E-05	27.74	160.181	437326	6.34E-05	9.088	31.5889	6080.543	221.35477
"2001"	20	30	4731.874	4677.194	3.5	4711.685	1E-05	5.9273	120.718	329586	1.8E-05	10.35	15.7564	3032.949	146.50378
"1996"	20	33	4732.155	4675.23	3.5	4731.327	1.21E-05	7.1721	196.34	536046	1.34E-05	10.64	40.5216	7800.01	231.65678
"1996"	20	32	4730.892	4674.958	3.5	4727.582	1E-05	5.9273	184.184	502859	1.18E-05	10.77	35.24	6783.354	214.75837
"2002"	20	29	4728.281	4675.02	3.5	4703.004	1E-05	5.9273	97.944	267407	2.22E-05	10.14	10.5859	2037.682	121.31543
"2004"	20	26	4720.959	4669.443	3.5	4691.12	1E-05	5.9273	75.8695	207139	2.86E-05	9.884	6.51606	1254.276	96.401421
"2004"	20	25	4718.326	4667.141	3.5	4692.229	1E-05	5.9273	87.808	239733	2.47E-05	10.03	8.60092	1655.591	109.94527
"2002"	20	28	4725.102	4672.592	3.5	4696.662	1E-05	5.9273	84.245	230006	2.58E-05	9.989	7.94991	1530.278	105.92142
"2002"	20	27	4722.181	4670.065	3.5	4692.817	1E-05	5.9273	79.632	217411	2.73E-05	9.933	7.14339	1375.031	100.6891
"2015"	53	66	4592.932	4533.473	3.5	4683.644	0.0002811	166.62	208.106	568172	0.0002933	7.558	227.156	43725.32	345.83579
"1988"	18	43	4790.481	4750.94	3.5	4765.125	1E-05	5.9273	49.6475	135548	4.37E-05	9.46	2.91534	561.173	65.910834
"2009"	19	20	4704.836	4653.655	3.5	4690.119	1E-05	5.9273	127.624	348439	1.7E-05	10.4	17.5164	3371.74	154.05621
"2009"	19	19	4700.906	4649.735	3.5	4687.341	1E-05	5.9273	131.621	359352	1.65E-05	10.44	18.5757	3575.645	158.41152

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1979"	18	42	4777.608	4736.078	3.5	4759.072	1E-05	5.9273	80.479	219724	2.7E-05	9.943	7.2884	1402.943	101.6518
"1992"	18	39	4744.369	4695.252	3.5	4751.822	0.0002904	172.13	171.909	469347	0.0003667	7.334	56.4905	10873.85	294.39112
"1992"	18	38	4743.937	4691.418	3.5	4753.319	0.0013979	828.58	183.817	501856	0.001651	5.831	84.1448	16197.04	395.93437
"1988"	18	41	4763.687	4720.176	3.5	4753.454	1E-05	5.9273	116.473	317995	1.86E-05	10.31	14.7185	2833.173	141.84214
"2020"	54	35	4573.271	4408.097	3.5	4608.235	0.0033914	2010.2	578.109	1578353	0.0012736	6.09	830.689	159899.3	1192.2324
"2009"	19	21	4706.989	4655.964	3.5	4693.073	1E-05	5.9273	129.882	354602	1.67E-05	10.42	18.1111	3486.203	156.5175
"1997"	19	33	4732.329	4676.983	3.5	4740.864	0.0004571	270.94	193.711	528870	0.0005123	7	75.3978	14513.32	347.55862
"1997"	19	32	4730.694	4677.024	3.5	4737.133	0.0001553	92.051	187.845	512854	0.0001795	8.048	58.865	11330.93	293.12837
"1992"	19	35	4731.848	4673.585	3.5	4744.437	0.0012587	746.07	203.92	556744	0.0013401	6.039	104.791	20171.15	424.08233
"1997"	19	34	4732.967	4675.706	3.5	4743.283	0.0016124	955.72	200.413	547169	0.0017467	5.775	101.196	19479.3	435.88595
"2001"	19	31	4730.319	4676.671	3.5	4732.119	7.54E-05	44.692	187.768	512644	8.72E-05	8.77	47.4957	9142.447	268.88549
"2009"	19	23	4713.105	4663.89	3.5	4698.127	1E-05	5.9273	119.83	327159	1.81E-05	10.34	15.5363	2990.579	145.52883
"2009"	19	22	4709.245	4658.923	3.5	4695.807	1E-05	5.9273	129.094	352452	1.68E-05	10.42	17.9026	3446.067	155.65933
"2004"	19	25	4722.294	4673.548	3.5	4699.761	1E-05	5.9273	91.7455	250484	2.37E-05	10.07	9.3487	1799.531	114.37527
"2004"	19	24	4719.042	4670.664	3.5	4699.532	1E-05	5.9273	101.038	275854	2.15E-05	10.17	11.2308	2161.823	124.76505
"2010"	22	17	4655.563	4594.772	3.5	4676.017	0.0026136	1549.2	212.769	580901	0.0026668	5.352	147.711	28432.95	499.26617
"1992"	21	37	4735.873	4678.356	3.5	4722.938	1E-05	5.9273	156.037	426012	1.39E-05	10.61	25.6878	4944.638	184.78402
"2010"	22	19	4664.065	4603.504	3.5	4678.603	3.34E-05	19.797	211.963	578703	3.42E-05	9.706	72.5182	13959.02	274.28039
"2010"	22	18	4659.343	4598.603	3.5	4677.241	1E-05	5.9273	212.59	580413	1.02E-05	10.91	69.0849	13298.15	244.62239
"1994"	21	36	4734.066	4676.005	3.5	4725.313	3.78E-05	22.405	172.578	471172	4.76E-05	9.377	35.541	6841.287	231.1585
"1993"	21	33	4728.162	4670.417	3.5	4722.319	0.0001679	99.52	181.657	495960	0.0002007	7.937	46.5216	8954.944	287.45392
"1996"	21	32	4727.647	4670.624	3.5	4718.387	1E-05	5.9273	167.17	456409	1.3E-05	10.67	29.2939	5638.784	196.69046
"1992"	21	35	4732.979	4674.354	3.5	4725.881	1E-05	5.9273	180.345	492377	1.2E-05	10.75	33.8523	6516.234	210.69358
"1993"	21	34	4730.613	4671.941	3.5	4724.777	1E-05	5.9273	184.926	504885	1.17E-05	10.78	35.5113	6835.567	215.54309
"2010"	22	20	4669.465	4609.545	3.5	4679.991	0.00077	456.4	209.72	572578	0.0007971	6.558	97.0121	18673.86	401.63105
"2003"	22	27	4702.844	4646.458	3.5	4681.928	1E-05	5.9273	124.145	338941	1.75E-05	10.38	16.6186	3198.917	150.25581
"2003"	22	26	4697.598	4641.366	3.5	4681.098	1E-05	5.9273	139.062	379667	1.56E-05	10.49	20.6267	3970.437	166.4897
"1995"	22	29	4708.909	4652.667	3.5	4686.599	1E-05	5.9273	118.762	324244	1.83E-05	10.33	15.2739	2940.077	144.3573
"2003"	22	28	4706.472	4650.274	3.5	4682.884	1E-05	5.9273	114.135	311611	1.9E-05	10.29	14.1614	2725.931	139.26872
"2006"	22	25	4692.795	4636.306	3.5	4681.576	1E-05	5.9273	158.445	432587	1.37E-05	10.62	26.4485	5091.078	187.3651
"2007"	22	22	4677.7	4619.03	3.5	4682.448	0.0010913	646.85	205.345	560633	0.0011538	6.189	86.5211	16654.46	416.72962
"2009"	22	21	4673.179	4613.959	3.5	4681.315	0.0005936	351.85	207.27	565889	0.0006218	6.806	86.7964	16707.43	382.46094
"2006"	22	24	4688.739	4631.323	3.5	4682.282	1E-05	5.9273	178.356	486949	1.22E-05	10.74	33.1443	6379.943	208.58611
"2006"	22	23	4683.394	4625.171	3.5	4682.795	1.78E-05	10.551	201.684	550638	1.92E-05	10.29	44.2507	8517.81	246.27143
"2009"	21	19	4679.734	4621.896	3.5	4681.176	0.0002139	126.79	202.433	552683	0.0002294	7.803	61.2039	11781.15	325.82352
"2010"	21	18	4675.898	4617.771	3.5	4679.699	0.0001009	59.807	203.445	555444	0.0001077	8.559	60.0039	11550.16	298.52017
"2009"	21	21	4687.562	4630.302	3.5	4684.361	1E-05	5.9273	189.207	516572	1.15E-05	10.8	37.0955	7140.513	220.06495
"2009"	21	20	4683.349	4625.691	3.5	4682.776	2.12E-05	12.566	199.798	545487	2.3E-05	10.1	44.2186	8511.639	248.41663
"1986"	20	38	4742.213	4684.688	3.5	4732.263	1E-05	5.9273	166.512	454612	1.3E-05	10.67	29.0745	5596.549	195.98868
"1992"	20	35	4734.854	4675.827	3.5	4735.022	0.0001863	110.43	206.595	564044	0.0001958	7.962	60.2694	11601.26	325.90312
"1992"	20	34	4736.034	4677.174	3.5	4733.801	1E-05	5.9273	198.195	541111	1.1E-05	10.84	40.5294	7801.497	229.53233

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1993"	20	37	4737.539	4679.739	3.5	4734.038	1E-05	5.9273	190.046	518865	1.14E-05	10.8	37.4103	7201.101	220.9513
"1993"	20	36	4734.79	4676.54	3.5	4735.042	0.0003693	218.9	203.875	556620	0.0003933	7.264	64.4851	12412.74	352.48529
"2006"	21	22	4692.325	4635.573	3.5	4685.738	1.73E-05	10.254	175.577	479362	2.14E-05	10.18	33.8992	6525.261	216.7138
"2002"	21	29	4719.878	4664.655	3.5	4695.529	1E-05	5.9273	108.059	295023	2.01E-05	10.24	12.7616	2456.481	132.55925
"2002"	21	28	4717.3	4662.625	3.5	4690.146	1E-05	5.9273	96.3235	262982	2.25E-05	10.12	10.2554	1974.06	119.50487
"1996"	21	31	4728.269	4671.187	3.5	4712.103	1E-05	5.9273	143.206	390981	1.52E-05	10.52	21.8133	4198.845	170.97246
"1995"	21	30	4724.398	4667.913	3.5	4703.358	1E-05	5.9273	124.058	338702	1.75E-05	10.38	16.5963	3194.626	150.1601
"2002"	21	27	4716.114	4661.363	3.5	4687.259	1E-05	5.9273	90.636	247454	2.4E-05	10.06	9.13499	1758.394	113.12873
"2004"	21	24	4701.714	4646.655	3.5	4686.571	1E-05	5.9273	139.706	381425	1.55E-05	10.49	20.809	4005.533	167.18709
"2006"	21	23	4697.428	4641.226	3.5	4686.502	1E-05	5.9273	158.466	432644	1.37E-05	10.62	26.4552	5092.364	187.38759
"2003"	21	26	4710.999	4656.759	3.5	4685.898	1E-05	5.9273	101.987	278444	2.13E-05	10.18	11.4322	2200.581	125.8207
"2003"	21	25	4706.014	4651.715	3.5	4686.174	1E-05	5.9273	120.606	329280	1.8E-05	10.35	15.7286	3027.596	146.38098
"1999"	15	37	4778.407	4733.249	3.5	4789.17	0.0007743	458.95	158.053	431516	0.0010636	6.27	62.2888	11989.98	316.59483
"1999"	15	36	4774.404	4725.691	3.5	4790.218	0.0018386	1089.8	170.496	465487	0.0023412	5.482	91.4302	17599.41	390.59167
"1990"	15	41	4790	4765.096	3.5	4797.124	0.0011213	664.63	87.164	237975	0.0027929	5.306	23.659	4554.129	206.30728
"1990"	15	40	4793.843	4759.089	3.5	4789.387	1E-05	5.9273	106.043	289519	2.05E-05	10.22	12.3125	2370.037	130.32589
"1999"	15	35	4771.829	4721.517	3.5	4790.265	6.99E-05	41.432	176.092	480766	8.62E-05	8.782	63.6369	12249.47	251.83399
"1999"	15	32	4763.298	4705.751	3.5	4787.97	0.0035632	2112	201.414	549902	0.0038407	4.989	156.007	30029.72	507.07114
"2007"	15	24	4739.736	4686.112	3.5	4737.073	2.35E-05	13.929	178.364	486968	2.86E-05	9.885	36.0118	6931.917	226.62348
"1999"	15	34	4769.67	4718.865	3.5	4789.603	0.00112	663.86	177.818	485477	0.0013674	6.019	97.216	18713.12	371.03806
"1999"	15	33	4767.159	4713.993	3.5	4788.671	1.43E-05	8.4761	186.081	508038	1.67E-05	10.42	62.2337	11979.37	224.20179
"1989"	15	42	4801.732	4769.445	3.5	4803.14	5.1E-05	30.229	113.005	308525	9.8E-05	8.654	17.7119	3409.357	164.0074
"1998"	16	34	4751.794	4696.583	3.5	4776.527	0.0008115	481	193.239	527580	0.0009117	6.424	113.603	21867.39	377.80022
"2000"	16	33	4749.192	4691.072	3.5	4775.248	0.002283	1353.2	203.42	555377	0.0024366	5.442	148.641	28611.89	469.4294
"1998"	16	36	4759.048	4706.207	3.5	4777.085	1.77E-05	10.491	184.943	504933	2.08E-05	10.2	58.8419	11326.48	227.62295
"1998"	16	35	4754.781	4700.792	3.5	4777.21	0.0029815	1767.2	188.961	515903	0.0034255	5.103	132.51	25506.82	465.09211
"2000"	16	32	4747.535	4686.825	3.5	4773.636	9.72E-05	57.614	212.485	580127	9.93E-05	8.64	100.367	19319.72	308.86879
"2008"	16	22	4727.25	4679.182	3.5	4716.086	1E-05	5.9273	129.164	352644	1.68E-05	10.42	17.9211	3449.625	155.73563
"2016"	54	38	4537.518	4425.198	3.5	4610.491	0.0014106	836.11	393.12	1073296	0.000779	6.581	547.275	105345	750.23243
"2007"	16	24	4730.354	4679.333	3.5	4725.626	1E-05	5.9273	162.026	442362	1.34E-05	10.64	27.5993	5312.594	191.19685
"2008"	16	23	4729.148	4679.591	3.5	4721.651	2.77E-05	16.419	147.21	401913	4.09E-05	9.528	25.4481	4898.501	194.03649
"2006"	14	28	4761.223	4701.357	3.5	4783.234	0.0024046	1425.3	209.531	572062	0.0024915	5.42	146.171	28136.53	485.51566
"2006"	14	27	4757.75	4698.062	3.5	4776.094	4.3E-05	25.487	208.908	570361	4.47E-05	9.439	78.2374	15059.92	277.97795
"2016"	55	39	4580.089	4425.19	3.5	4610.853	4.46E-05	26.436	542.147	1480168	1.79E-05	10.36	422.702	81365.82	657.50808
"2016"	55	40	4606.812	4433.115	3.5	4611.688	0.0012651	749.87	607.94	1659796	0.0004518	7.126	607.52	116941.6	1071.539
"2006"	14	26	4754.381	4694.461	3.5	4772.876	0.0020552	1218.2	209.72	572578	0.0021275	5.578	133.621	25720.78	472.22717
"2020"	56	38	4592.886	4415.769	3.5	4609.57	1.01E-05	5.9866	619.91	1692477	3.54E-06	11.97	415.446	79969.14	650.15931
"2020"	56	39	4601.756	4421.815	3.5	4610.375	0.0002677	158.67	629.794	1719462	9.23E-05	8.714	549.994	105868.3	907.75617
"2006"	14	25	4751.39	4692.872	3.5	4767.984	1E-05	5.9273	204.813	559180	1.06E-05	10.88	63.5445	12231.69	236.48103
"2006"	14	24	4748.58	4694.212	3.5	4750.462	0.0005493	325.59	190.288	519524	0.0006267	6.798	63.0337	12133.36	351.53417
"2020"	55	38	4562.733	4418.504	3.5	4610.003	0.0001741	103.19	504.802	1378209	7.49E-05	8.923	494.117	95112.49	710.55572

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1989"	14	42	4809.73	4776.961	3.5	4817.421	0.0003059	181.32	114.691	313131	0.000579	6.877	29.7724	5730.884	209.44352
"1989"	14	41	4806.921	4773.086	3.5	4810.161	0.000245	145.22	118.423	323317	0.0004492	7.131	25.5154	4911.463	208.55794
"2007"	15	23	4737.532	4686.184	3.5	4730.17	1E-05	5.9273	153.951	420317	1.41E-05	10.59	25.0373	4819.431	182.54537
"2016"	54	39	4575.563	4435.822	3.5	4611.35	0.0005796	343.55	489.094	1335323	0.0002573	7.688	496.728	95615.21	798.95408
"1999"	14	38	4797.663	4761.158	3.5	4793.305	1E-05	5.9273	112.514	307187	1.93E-05	10.28	13.7813	2652.76	137.48238
"2015"	54	61	4555.319	4493.372	3.5	4663.532	0.0003414	202.36	216.815	591947	0.0003419	7.404	277.864	53486.02	367.76701
"2020"	55	37	4555.585	4412.454	3.5	4609.195	1E-05	5.9273	500.959	1367717	4.33E-06	11.77	387.447	74579.62	534.46859
"2011"	54	40	4608.863	4441.587	3.5	4612.167	8.31E-05	49.256	585.466	1598439	3.08E-05	9.81	403.819	77731.14	749.5219
"2011"	54	41	4624	4446.776	3.5	4612.996	1E-05	5.9273	581.77	1588348	3.73E-06	11.92	317.669	61148.1	612.89938
"2020"	54	36	4545.588	4412.78	3.5	4608.868	1E-05	5.9273	464.828	1269073	4.67E-06	11.7	370.82	71379.18	499.09492
"1988"	17	43	4799.12	4763.957	3.5	4780.216	1E-05	5.9273	56.9065	155366	3.82E-05	9.597	3.7757	726.785	74.473502
"2009"	18	21	4712.121	4664.49	3.5	4698.561	1E-05	5.9273	119.248	325572	1.82E-05	10.34	15.3932	2963.042	144.89132
"2009"	18	20	4709.944	4662.002	3.5	4694.768	1E-05	5.9273	114.681	313102	1.89E-05	10.3	14.2906	2750.799	139.87011
"1988"	17	42	4791.774	4756.181	3.5	4773.979	1E-05	5.9273	62.293	170072	3.49E-05	9.687	4.48208	862.755	80.761746
"1992"	17	39	4757.601	4711.596	3.5	4761.628	0.0001405	83.279	161.018	439610	0.0001894	7.994	41.5817	8004.06	252.96002
"1992"	17	38	4751.814	4700.769	3.5	4763.227	1E-05	5.9273	178.658	487771	1.22E-05	10.74	45.6419	8785.601	208.90532
"1988"	17	41	4777.938	4740.437	3.5	4766.036	1E-05	5.9273	89.5965	244616	2.42E-05	10.05	8.9369	1720.263	111.95961
"1992"	17	40	4765.904	4724.985	3.5	4758.659	1E-05	5.9273	117.859	321779	1.84E-05	10.32	15.0537	2897.678	143.36558
"2009"	18	22	4714.383	4667.607	3.5	4702.301	1.07E-05	6.3422	121.429	331525	1.91E-05	10.29	16.0382	3087.188	148.25119
"1997"	18	34	4732.149	4675.289	3.5	4753.548	0.0031475	1865.6	199.01	543337	0.0034336	5.1	141.385	27215.18	490.05139
"1997"	18	33	4732.014	4676.808	3.5	4751.333	0.0004189	248.3	193.221	527532	0.0004707	7.085	93.3556	17970.01	342.53494
"1992"	18	37	4739.674	4684.555	3.5	4754.208	0.0011713	694.27	192.916	526701	0.0013181	6.056	98.9881	19054.23	400.1067
"1998"	18	35	4730.526	4672.928	3.5	4754.55	0.0001225	72.61	201.593	550389	0.0001319	8.356	92.2473	17756.69	302.99298
"2000"	18	32	4731.533	4677.313	3.5	4747.26	3.35E-05	19.857	189.77	518110	3.83E-05	9.592	62.3165	11995.31	248.46987
"2008"	18	24	4720.476	4672.503	3.5	4707.367	1E-05	5.9273	122.024	333150	1.78E-05	10.36	16.0823	3095.685	147.93437
"2008"	18	23	4716.782	4670.16	3.5	4705.543	1E-05	5.9273	123.84	338109	1.75E-05	10.37	16.5411	3183.997	149.92274
"2001"	18	31	4728.257	4675.638	3.5	4740.818	0.0012984	769.6	184.166	502811	0.0015306	5.906	89.8177	17289	391.6094
"2005"	18	25	4722.717	4674.405	3.5	4706.699	1E-05	5.9273	113.029	308592	1.92E-05	10.28	13.9014	2675.889	138.04977
"2020"	54	37	4514.148	4414.972	3.5	4609.633	0.0005151	305.32	347.116	947696	0.0003222	7.464	470.491	90564.89	584.1108
"1989"	16	43	4801.426	4768.659	3.5	4795.196	1E-05	5.9273	92.8795	253580	2.34E-05	10.09	9.56956	1842.046	115.64797
"2008"	17	22	4720.092	4673.718	3.5	4709.231	1E-05	5.9273	124.295	339352	1.75E-05	10.38	16.657	3206.303	150.4204
"2008"	17	21	4717.179	4672.145	3.5	4704.407	1E-05	5.9273	112.917	308286	1.92E-05	10.28	13.8752	2670.846	137.92628
"1989"	16	42	4796.947	4764.175	3.5	4790.075	1.35E-05	8.0019	90.65	247493	3.23E-05	9.762	9.41856	1812.98	116.62257
"1992"	16	39	4773.55	4731.622	3.5	4772.949	1.47E-05	8.7132	144.644	394908	2.21E-05	10.14	23.077	4442.083	179.07801
"1992"	16	38	4766.823	4719.801	3.5	4773.769	0.000731	433.29	164.577	449328	0.0009643	6.368	59.3105	11416.69	324.595
"1989"	16	41	4791.779	4758.965	3.5	4782.296	1E-05	5.9273	81.6585	222944	2.66E-05	9.958	7.49264	1442.257	102.99091
"1990"	16	40	4782.411	4745.499	3.5	4774.956	1E-05	5.9273	103.1	281482	2.11E-05	10.19	11.6706	2246.478	127.05834
"2008"	17	23	4722.265	4674.335	3.5	4713.331	1E-05	5.9273	136.486	372634	1.59E-05	10.47	19.9051	3831.531	163.6974
"1998"	17	35	4740.652	4684.604	3.5	4765.41	0.0038034	2254.4	196.168	535578	0.0042093	4.897	152.648	29383.19	503.066
"1998"	17	34	4734.895	4677.607	3.5	4764.578	0.000136	80.612	200.508	547427	0.0001473	8.246	101.66	19568.5	305.37948
"1992"	17	37	4748.727	4694.968	3.5	4764.682	0.0020044	1188.1	188.157	513705	0.0023128	5.494	107.76	20742.65	430.09477

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1998"	17	36	4745.25	4690.371	3.5	4765.433	0.0001179	69.883	192.076	524407	0.0001333	8.346	79.7786	15356.58	289.03846
"2000"	17	33	4736.848	4679.252	3.5	4762.696	5.16E-05	30.585	201.586	550370	5.56E-05	9.221	86.1969	16592.05	274.57655
"2007"	17	25	4725.366	4676.111	3.5	4711.708	1E-05	5.9273	124.589	340154	1.74E-05	10.38	16.7321	3220.756	150.74188
"2008"	17	24	4723.621	4674.412	3.5	4715.387	1E-05	5.9273	143.412	391545	1.51E-05	10.52	21.8733	4210.386	171.19555
"2000"	17	32	4737.393	4680.475	3.5	4758.529	0.001019	603.99	199.213	543891	0.0011105	6.227	115.449	22222.71	401.80587
"2000"	17	31	4734.695	4679.284	3.5	4747.318	1E-05	5.9273	193.939	529491	1.12E-05	10.82	53.6491	10326.92	225.05388
"1995"	22	30	4712.824	4655.952	3.5	4694.025	1E-05	5.9273	133.255	363814	1.63E-05	10.45	19.0175	3660.674	160.18925
"2002"	36	37	4592.394	4523.313	3.5	4617.148	0.0010972	650.35	241.784	660117	0.0009852	6.346	164.622	31688.15	478.47864
"2019"	36	36	4595.968	4525.403	3.5	4616.523	0.0003365	199.45	246.977	674298	0.0002958	7.549	134.307	25852.76	410.90208
"1998"	36	39	4595.205	4526.668	3.5	4619.14	0.0023646	1401.6	239.88	654919	0.0021401	5.572	182.813	35189.69	540.70547
"2002"	36	38	4594.442	4526.534	3.5	4618.107	3.09E-05	18.315	237.678	648908	2.82E-05	9.898	100.95	19431.82	301.57986
"2015"	52	60	4570.447	4508.853	3.5	4667.258	0.0004968	294.47	215.579	588574	0.0005003	7.024	267.988	51585.09	385.49132
"2007"	35	39	4600.073	4537.85	3.5	4619.953	0.0008263	489.77	217.78	594584	0.0008237	6.525	124.634	23990.86	419.16569
"2015"	52	62	4579.882	4522.203	3.5	4675.969	0.0007491	444.02	201.876	551163	0.0008056	6.548	263.017	50628.07	387.23544
"2015"	52	61	4574.076	4514.523	3.5	4671.757	0.0008296	491.73	208.435	569071	0.0008641	6.477	280.208	53937.21	404.1399
"1994"	35	40	4603.673	4538.608	3.5	4620.523	4.93E-05	29.222	227.727	621742	4.7E-05	9.388	88.4864	17032.75	304.6485
"1998"	36	40	4595.577	4525.067	3.5	4619.881	0.0002425	143.74	246.785	673772	0.0002133	7.876	136.235	26223.86	393.54817
"2011"	52	38	4559.996	4459.249	3.5	4611.431	1.15E-05	6.8164	352.615	962708	7.08E-06	11.28	228.263	43938.38	392.57252
"2011"	52	39	4580.915	4473.237	3.5	4612.248	0.0002772	164.31	376.873	1028939	0.0001597	8.165	289.029	55635.14	579.68374
"2016"	52	36	4552.017	4434.439	3.5	4609.834	1E-05	5.9273	411.523	1123540	5.28E-06	11.58	297.869	57336.72	446.50984
"2011"	52	37	4548.785	4444.194	3.5	4610.606	0.0012577	745.48	366.068	999440	0.0007459	6.624	449.327	86490.91	694.02996
"2011"	52	40	4593.057	4469.142	3.5	4613.058	1E-05	5.9273	433.702	1184095	5.01E-06	11.63	229.698	44214.52	468.45057
"2006"	52	43	4614.772	4475.376	3.5	4615.81	6.29E-05	37.283	487.886	1332026	2.8E-05	9.906	272.191	52394.05	618.53517
"1997"	36	41	4604.776	4535.544	3.5	4620.587	0.00013	77.055	242.312	661560	0.0001165	8.481	106.953	20587.4	358.84533
"2011"	52	41	4603.933	4468.083	3.5	4613.909	0.000443	262.58	475.475	1298142	0.0002023	7.929	358.086	68928.05	753.15101
"2011"	52	42	4613.494	4470.21	3.5	4614.821	7.79E-05	46.174	501.494	1369179	3.37E-05	9.72	293.976	56587.47	647.97717
"1995"	27	25	4630.598	4564.995	3.5	4669.525	0.0003694	218.96	229.611	626883	0.0003493	7.383	158.924	30591.2	390.60488
"2002"	27	24	4625.322	4559.375	3.5	4671.123	1.04E-05	6.1644	230.815	630170	9.78E-06	10.96	117.371	22592.71	264.55
"1995"	27	27	4639.367	4572.708	3.5	4663.874	0.0003637	215.58	233.307	636973	0.0003384	7.414	132.48	25501.07	395.2057
"1995"	27	26	4635.376	4569.637	3.5	4667.128	0.0009444	559.78	230.087	628182	0.0008911	6.447	165.852	31924.88	448.24764
"2002"	27	23	4620.443	4553.953	3.5	4672.048	8.55E-05	50.679	232.715	635358	7.98E-05	8.859	156.877	30197.17	329.9063
"2009"	27	20	4609.591	4544.069	3.5	4671.694	1E-05	5.9273	229.327	626109	9.47E-06	10.99	138.122	26587.05	262.06173
"2009"	27	19	4605.88	4540.305	3.5	4670.242	1E-05	5.9273	229.512	626615	9.46E-06	10.99	141.345	27207.6	262.25442
"2003"	27	22	4617.645	4551.726	3.5	4672.473	0.0026314	1559.7	230.717	629902	0.0024761	5.426	261.919	50416.88	533.99784
"2003"	27	21	4613.744	4548.125	3.5	4672.383	0.0011751	696.52	229.666	627035	0.0011108	6.227	235.96	45419.99	463.25019
"1996"	27	28	4643.396	4576.828	3.5	4659.976	0.0021484	1273.4	232.988	636104	0.0020019	5.638	152.441	29343.27	518.96849
"1990"	27	35	4670	4612	3.5	4653	0.00085	503.82	143.5	391784	0.001286	6.08	37.8947	7294.347	296.40946
"1990"	27	34	4670	4612	3.5	4653	0.00065	385.28	143.5	391784	0.0009834	6.348	36.2951	6986.451	283.89794
"1986"	27	37	4689.411	4632.547	3.5	4651.317	1E-05	5.9273	65.695	179360	3.3E-05	9.74	4.95779	954.325	84.707429
"1986"	27	36	4680	4629.836	3.5	4656.1	1E-05	5.9273	91.924	250971	2.36E-05	10.08	9.3833	1806.192	114.5757
"1987"	27	33	4670	4612	3.5	4653	0.00045	266.73	143.5	391784	0.0006808	6.716	34.3094	6604.215	268.36559

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1993"	27	30	4656.107	4596.241	3.5	4654.496	1E-05	5.9273	203.893	556667	1.06E-05	10.87	42.7814	8235.001	235.51573
"1993"	27	29	4649.692	4586.173	3.5	4656.727	0.0002374	140.71	222.317	606969	0.0002318	7.793	84.0687	16182.38	358.31085
"1992"	27	32	4666.802	4612.023	3.5	4657.25	1E-05	5.9273	158.294	432176	1.37E-05	10.62	26.4007	5081.865	187.20388
"1992"	27	31	4662.279	4606.225	3.5	4654.29	1E-05	5.9273	168.227	459295	1.29E-05	10.68	29.648	5706.946	197.81731
"2010"	51	63	4597.94	4542.378	3.5	4685.199	0.0018742	1110.9	194.467	530934	0.0020923	5.594	273.62	52669.09	436.57907
"2010"	51	64	4600.517	4543.125	3.5	4688.769	0.0015883	941.44	200.872	548421	0.0017166	5.792	277.725	53459.34	435.57711
"2015"	51	61	4584.598	4526.243	3.5	4676.346	0.0011855	702.68	204.242	557623	0.0012601	6.101	276.999	53319.52	420.4761
"2010"	51	62	4591.03	4534.641	3.5	4681.025	0.0010875	644.6	197.362	538836	0.0011963	6.153	259.267	49906.22	402.87946
"2010"	51	65	4602.428	4543.91	3.5	4691.83	0.0003688	218.6	204.813	559180	0.0003909	7.27	228.952	44070.98	353.81756
"2015"	51	68	4616.746	4554.986	3.5	4698.558	0.0021948	1300.9	216.16	590160	0.0022044	5.542	302.599	58247.26	489.83661
"1995"	37	57	4668.605	4597.377	3.5	4676.814	0.0007739	458.72	249.298	680633	0.000674	6.726	123.254	23725.09	465.52208
"2010"	51	66	4603.682	4544.751	3.5	4694.429	0.0004107	243.44	206.258	563127	0.0004323	7.17	236.792	45580.06	361.31102
"2015"	51	67	4609.097	4548.681	3.5	4696.663	0.0009144	541.99	211.456	577317	0.0009388	6.395	267.238	51440.62	415.30922
"2006"	51	44	4607.618	4485.941	3.5	4617.342	0.0003292	195.13	425.87	1162709	0.0001678	8.116	283.36	54544.02	659.05825
"1982"	38	44	4618.496	4549.851	3.5	4619.862	3E-05	17.782	240.258	655951	2.71E-05	9.938	67.1436	12924.47	303.61511
"2002"	38	43	4616.843	4548.235	3.5	4619.863	9.98E-05	59.155	240.128	655597	9.02E-05	8.736	79.2719	15259.04	345.21925
"1992"	38	46	4619.251	4551.871	3.5	4619.104	1E-05	5.9273	235.316	642458	9.23E-06	11.02	56.2427	10826.16	268.27581
"1993"	38	45	4620.425	4552.602	3.5	4619.549	1.02E-05	6.0459	234.315	639725	9.45E-06	10.99	55.8873	10757.75	267.71944
"2011"	51	39	4567.651	4472.931	3.5	4612.687	1E-05	5.9273	331.52	905116	6.55E-06	11.36	194.054	37353.49	366.55075
"2006"	51	42	4595.815	4478.076	3.5	4615.281	0.0027315	1619	412.086	1125079	0.0014391	5.968	406.113	78172.77	867.21364
"2006"	51	43	4606.855	4481.038	3.5	4616.265	0.0006503	385.45	440.36	1202270	0.0003206	7.468	326.742	62894.6	740.53464
"2011"	51	40	4574.446	4475.752	3.5	4613.504	0.000567	336.08	345.429	943090	0.0003564	7.363	300.939	57927.74	589.2328
"2006"	51	41	4584.945	4475.606	3.5	4614.365	7.3E-05	43.269	382.686	1044811	4.14E-05	9.515	249.456	48017.84	505.14118
"2002"	37	39	4592.152	4519.754	3.5	4618.557	0.0003116	184.7	253.393	691814	0.000267	7.651	150.972	29060.69	415.92854
"2002"	37	38	4590.852	4518.522	3.5	4617.689	0.0009507	563.51	253.155	691164	0.0008153	6.536	177.572	34180.9	486.48626
"2002"	37	41	4606.985	4537.537	3.5	4619.838	0.0009194	544.96	243.068	663624	0.0008212	6.528	132.498	25504.6	467.61569
"2002"	37	40	4598.58	4527.976	3.5	4619.287	0.0028634	1697.2	247.114	674671	0.0025156	5.411	188.016	36191.13	573.6198
"2002"	37	37	4587.582	4514.884	3.5	4616.844	3.74E-05	22.168	254.443	694680	3.19E-05	9.775	123.819	23833.94	326.90638
"2019"	37	34	4587.653	4516.116	3.5	4615.405	0.0001096	64.963	250.38	683586	9.5E-05	8.684	132.999	25601	362.10682
"2016"	52	35	4554.294	4429.485	3.5	4609.14	1E-05	5.9273	436.832	1192637	4.97E-06	11.63	317.917	61195.82	471.53874
"2006"	37	36	4583.441	4510.229	3.5	4616.261	2.34E-05	13.87	256.242	699592	1.98E-05	10.25	125.213	24102.25	313.93219
"2007"	37	35	4585.394	4512.574	3.5	4615.81	1E-05	5.9273	254.87	695846	8.52E-06	11.1	111.104	21386.44	288.47892
"1998"	37	42	4616.977	4547.797	3.5	4620.369	9.64E-05	57.139	242.13	661063	8.64E-05	8.779	80.8291	15558.79	346.39397
"2020"	52	32	4530.984	4422.288	3.5	4607.324	0.0019562	1159.5	380.436	1038666	0.0011163	6.222	564.976	108752.1	767.9719
"1992"	37	48	4624.416	4562.286	3.5	4616.757	1.09E-05	6.4608	190.648	520509	1.24E-05	10.72	37.9392	7302.915	223.3677
"1993"	37	56	4659.842	4587.611	3.5	4662.29	0.0009089	538.73	252.808	690218	0.0007805	6.579	114.837	22104.9	482.60386
"1993"	37	55	4652.667	4579.698	3.5	4649.155	1E-05	5.9273	243.099	663710	8.93E-06	11.05	59.8484	11520.21	276.33378
"2020"	52	33	4537.801	4423.589	3.5	4607.912	0.0025195	1493.4	399.742	1091376	0.0013684	6.018	601.044	115694.9	834.20356
"1997"	37	44	4620.325	4551.775	3.5	4620.325	3.64E-05	21.575	239.925	655043	3.29E-05	9.744	66.1038	12724.32	309.25498
"1998"	37	43	4619.034	4549.883	3.5	4620.501	6.51E-05	38.587	242.028	660786	5.84E-05	9.171	73.9948	14243.26	331.44402
"2020"	52	34	4545.147	4425.609	3.5	4608.519	3.62E-05	21.457	418.383	1142269	1.88E-05	10.31	357.989	68909.3	509.89405

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1993"	37	45	4624.246	4556.953	3.5	4619.567	1E-05	5.9273	219.149	598321	9.91E-06	10.95	49.0975	9450.776	251.4696
"2010"	24	16	4623.086	4559.267	3.5	4669.718	0.0051266	3038.7	223.367	609835	0.0049828	4.73	261.786	50391.26	593.15552
"2011"	24	15	4618.135	4556.011	3.5	4668.714	0.0016196	959.99	217.434	593638	0.0016171	5.852	213.077	41015.1	466.68726
"2010"	24	18	4628.218	4562.295	3.5	4672.481	1E-05	5.9273	230.73	629940	9.41E-06	11	114.787	22095.44	263.51928
"2010"	24	17	4625.852	4560.737	3.5	4671.012	0.0014679	870.07	227.902	622219	0.0013983	5.997	208.939	40218.6	477.31604
"1981"	23	38	4699.645	4671.705	3.5	4697.498	9.17E-05	54.354	90.2755	246470	0.0002205	7.842	11.6275	2238.175	144.57118
"1995"	23	29	4698.494	4640.757	3.5	4675.461	1E-05	5.9273	121.464	331621	1.79E-05	10.35	15.9421	3068.699	147.32087
"1995"	23	28	4695.442	4637.117	3.5	4675.072	1E-05	5.9273	132.842	362687	1.63E-05	10.44	18.9054	3639.099	159.74024
"1985"	23	37	4724.568	4667.916	3.5	4703.864	1E-05	5.9273	125.818	343508	1.73E-05	10.39	17.0476	3281.483	152.08449
"1984"	23	36	4721.354	4664.34	3.5	4705.312	1E-05	5.9273	143.402	391516	1.51E-05	10.52	21.8702	4209.799	171.18421
"2005"	24	27	4681.803	4620.885	3.5	4669.96	2.93E-05	17.367	171.762	468946	3.7E-05	9.626	34.2917	6600.809	224.09197
"2005"	24	26	4676.525	4615.491	3.5	4672.678	2.97E-05	17.604	200.154	546462	3.22E-05	9.766	45.9006	8835.41	257.40613
"1994"	24	29	4689.364	4629.91	3.5	4663.534	1E-05	5.9273	117.684	321301	1.84E-05	10.32	15.0111	2889.495	143.17332
"1994"	24	28	4686.202	4625.769	3.5	4667.608	1E-05	5.9273	146.436	399801	1.48E-05	10.54	22.7603	4381.13	174.45938
"2005"	24	25	4672.963	4611.426	3.5	4674.469	0.0003622	214.69	215.379	588029	0.0003651	7.338	73.6147	14170.08	368.60661
"2008"	24	20	4641.655	4575.596	3.5	4675.003	0.0002988	177.11	231.207	631240	0.0002806	7.602	144.886	27889.2	381.99059
"2010"	24	19	4634.504	4567.928	3.5	4673.869	1E-05	5.9273	233.016	636180	9.32E-06	11.01	109.594	21095.73	265.89124
"2007"	24	24	4670.091	4607.718	3.5	4675.682	0.0002253	133.54	218.306	596018	0.0002241	7.827	78.3115	15074.19	350.31333
"2007"	24	21	4646.829	4581.871	3.5	4675.797	1E-05	5.9273	227.353	620719	9.55E-06	10.98	91.809	17672.32	260.01048
"2003"	23	27	4691.331	4655	3.5	4675.749	1E-05	5.9273	72.6215	198271	2.99E-05	9.841	5.99663	1154.292	92.684704
"1985"	22	37	4731.483	4674.354	3.5	4712.346	1E-05	5.9273	132.972	363040	1.63E-05	10.45	18.9405	3645.857	159.88104
"1994"	22	36	4728.288	4670.812	3.5	4715.387	1E-05	5.9273	156.012	425945	1.39E-05	10.61	25.6801	4943.158	184.75774
"2010"	23	17	4638.662	4575.359	3.5	4673.538	0.0027243	1614.8	221.56	604904	0.0026695	5.351	196.89	37899.44	519.99292
"2010"	23	16	4636.523	4574.4	3.5	4672.437	0.0008199	485.98	217.431	593629	0.0008187	6.531	159.026	30610.84	418.09722
"1993"	22	35	4725.792	4668.013	3.5	4716.999	1E-05	5.9273	171.451	468096	1.27E-05	10.7	30.7405	5917.234	201.25016
"1993"	22	32	4719.086	4661.861	3.5	4709.881	1E-05	5.9273	168.07	458865	1.29E-05	10.68	29.5951	5696.764	197.64944
"1995"	22	31	4716.376	4659.199	3.5	4703	1E-05	5.9273	153.304	418549	1.42E-05	10.59	24.837	4780.879	181.84996
"1993"	22	34	4723.456	4665.735	3.5	4716.079	9.04E-05	53.583	176.204	481072	0.0001114	8.525	40.7488	7843.741	259.57629
"1993"	22	33	4721.211	4663.917	3.5	4713.574	1E-05	5.9273	173.799	474507	1.25E-05	10.71	31.5483	6072.729	203.74778
"2006"	23	24	4677.66	4618.066	3.5	4678.893	1.1E-05	6.5201	208.579	569462	1.14E-05	10.8	46.6258	8975.006	242.54827
"2007"	23	23	4671.554	4611.287	3.5	4680.151	0.0004513	267.5	210.934	575893	0.0004645	7.098	86.8167	16711.35	373.24099
"2005"	23	26	4685.533	4627.394	3.5	4676.696	1E-05	5.9273	172.557	471115	1.26E-05	10.71	31.1197	5990.222	202.42674
"2005"	23	25	4681.108	4622.646	3.5	4677.785	1E-05	5.9273	192.987	526892	1.12E-05	10.82	38.5219	7415.088	224.05101
"2007"	23	22	4662.812	4602.325	3.5	4679.999	0.0021446	1271.2	211.705	577996	0.0021993	5.545	133.279	25654.86	479.54061
"2010"	23	19	4647.557	4584.232	3.5	4676.143	0.0007818	463.4	221.637	605115	0.0007658	6.598	145.979	28099.42	421.87892
"2010"	23	18	4641.542	4578.018	3.5	4674.819	0.003626	2149.2	222.334	607016	0.0035407	5.07	204.354	39336.01	550.78888
"2007"	23	21	4658.392	4596.932	3.5	4678.568	6.2E-05	36.749	215.11	587293	6.26E-05	9.102	88.0058	16940.24	296.81744
"2010"	23	20	4654.089	4591.439	3.5	4677.393	0.001234	731.43	219.275	598665	0.0012218	6.131	142.14	27360.56	449.14985
"1994"	24	30	4692.612	4633.795	3.5	4660.073	1E-05	5.9273	91.973	251105	2.36E-05	10.08	9.39281	1808.022	114.63071
"2011"	53	38	4541.89	4443.554	3.5	4610.974	1E-05	5.9273	344.176	939669	6.31E-06	11.4	252.48	48599.8	379.29307
"2008"	26	21	4625.443	4557.586	3.5	4673.138	1E-05	5.9273	237.499	648421	9.14E-06	11.03	124.302	23926.9	270.53884

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2016"	53	36	4540.165	4422.478	3.5	4609.328	1E-05	5.9273	411.904	1124582	5.27E-06	11.58	324.623	62486.77	446.888
"2016"	53	37	4531.672	4430.52	3.5	4610.122	0.0015204	901.19	354.032	966578	0.0009324	6.402	502.264	96680.86	694.58514
"2008"	26	20	4621.18	4553.469	3.5	4672.549	0.0042699	2530.9	236.989	647026	0.0039116	4.97	286.294	55108.72	598.81684
"2011"	26	17	4607.948	4541.264	3.5	4666.951	1E-05	5.9273	233.394	637212	9.3E-06	11.01	137.022	26375.29	266.28335
"1994"	25	28	4675.023	4613.02	3.5	4661.665	1E-05	5.9273	170.257	464837	1.28E-05	10.69	30.3338	5838.951	199.97979
"2009"	26	19	4617.011	4549.466	3.5	4671.297	0.0009065	537.31	236.408	645440	0.0008325	6.515	224.569	43227.31	455.75459
"2009"	26	18	4611.971	4545.031	3.5	4669.39	1E-05	5.9273	234.29	639659	9.27E-06	11.01	135.513	26084.97	267.21261
"2015"	52	63	4587.125	4529.936	3.5	4679.836	0.0006735	399.21	200.162	546481	0.0007305	6.645	249.73	48070.51	378.29644
"2010"	52	64	4594.808	4537.492	3.5	4683.297	0.0009161	543	200.606	547695	0.0009914	6.34	253.769	48848.01	397.38485
"2009"	27	18	4602.669	4537.462	3.5	4667.754	1E-05	5.9273	228.224	623099	9.51E-06	10.99	141.305	27199.85	260.91626
"1986"	26	35	4692.782	4637.777	3.5	4661.244	1E-05	5.9273	82.1345	224244	2.64E-05	9.964	7.57582	1458.27	103.53083
"2010"	52	65	4597.723	4539.252	3.5	4686.299	0.0011279	668.54	204.648	558731	0.0011965	6.152	268.48	51679.74	417.76948
"2020"	53	34	4573.764	4413.923	3.5	4608.049	1E-05	5.9273	559.444	1527393	3.88E-06	11.88	400.082	77011.86	591.31926
"2020"	53	35	4568.129	4418.349	3.5	4608.648	5.63E-05	33.371	524.23	1431253	2.33E-05	10.09	442.198	85118.74	652.57677
"2015"	52	66	4599.927	4540.467	3.5	4688.917	0.0013346	791.06	208.11	568182	0.0013923	6.001	282.185	54317.87	435.54738
"2015"	52	67	4604.847	4543.849	3.5	4691.203	0.0009275	549.76	213.493	582879	0.0009432	6.39	268.131	51612.48	419.61401
"1994"	25	27	4670.141	4607.003	3.5	4666.347	1E-05	5.9273	207.704	567073	1.05E-05	10.89	44.3204	8531.231	239.5104
"2011"	53	40	4609.596	4457.307	3.5	4612.621	2.29E-05	13.574	533.011	1455228	9.33E-06	11.01	298.411	57441.11	608.2735
"2011"	53	41	4624.655	4456.354	3.5	4613.455	1E-05	5.9273	549.853	1501210	3.95E-06	11.86	285.119	54882.6	582.02979
"2008"	25	22	4643.707	4577.632	3.5	4673.846	0.000611	362.16	231.263	631393	0.0005736	6.887	152.95	29441.43	421.73898
"2011"	53	39	4577.655	4452.933	3.5	4611.817	0.0011049	654.91	436.527	1191806	0.0005495	6.93	448.14	86262.47	791.1435
"2011"	53	42	4625.318	4461.049	3.5	4614.362	1E-05	5.9273	536.596	1465013	4.05E-06	11.84	272.095	52375.61	569.16678
"2015"	53	62	4567.144	4507.686	3.5	4671.314	0.0004118	244.09	208.103	568163	0.0004296	7.176	264.709	50953.77	364.22584
"2015"	53	65	4589.11	4530.042	3.5	4681.038	0.0003096	183.51	206.738	564436	0.0003251	7.454	230.561	44380.73	348.31497
"2015"	53	60	4558.339	4496.557	3.5	4663.469	0.0004612	273.37	216.237	590370	0.000463	7.101	282.637	54404.76	382.45511
"2015"	53	61	4561.756	4501.224	3.5	4667.5	0.0002571	152.39	211.862	578426	0.0002635	7.665	256.306	49336.34	347.15708
"2004"	25	23	4652.438	4587.22	3.5	4673.504	0.0007501	444.61	228.263	623204	0.0007134	6.669	134.484	25886.77	429.8779
"2004"	25	25	4662.746	4598.508	3.5	4671.74	0.0004717	279.59	224.833	613839	0.0004555	7.117	98.0135	18866.61	396.73886
"2005"	25	26	4665.808	4602.184	3.5	4669.547	0.0010873	644.48	222.684	607972	0.00106	6.273	97.11	18692.7	445.8202
"2004"	25	24	4659.483	4594.65	3.5	4673.11	0.0015612	925.37	226.916	619525	0.0014937	5.931	131.175	25249.8	480.52698
"2016"	50	32	4501.515	4425.675	5	4608.41	0.0002882	170.83	379.2	1035292	0.000165	8.133	463.813	89279.44	585.61215
"2011"	49	33	4511.345	4436.406	5	4609.593	0.0002856	169.28	374.695	1022992	0.0001655	8.13	430.827	82929.83	578.86051
"2011"	49	34	4514.2	4441.309	5	4610.177	0.0006326	374.96	364.455	995035	0.0003768	7.307	454.844	87552.84	626.43859
"2011"	48	35	4528.784	4455.674	5	4611.374	0.001202	712.46	365.55	998025	0.0007139	6.668	452.468	87095.59	688.4897
"2011"	48	36	4537.964	4464.365	5	4612.001	0.0005545	328.67	367.995	1004700	0.0003271	7.448	381.161	73369.69	620.51626
"2006"	47	38	4549.746	4477.608	5	4613.833	0.0019172	1136.4	360.69	984756	0.001154	6.188	408.46	78624.44	732.00857
"2006"	47	37	4545.574	4472.354	5	4613.172	1E-05	5.9273	366.1	999526	5.93E-06	11.46	232.589	44771.14	401.27966
"2020"	51	31	4505.385	4413.594	5	4607.195	0.0006303	373.6	458.955	1253039	0.0002982	7.541	623.217	119963.1	764.37789
"2001"	46	40	4553.324	4484.276	5	4615.667	1E-05	5.9273	345.24	942574	6.29E-06	11.4	205.13	39485.39	380.36262
"2006"	46	39	4550.4	4480.329	5	4614.987	1E-05	5.9273	350.355	956539	6.2E-06	11.41	213.626	41120.86	385.50064
"1992"	41	47	4612.703	4545.028	5	4620.829	0.0002718	161.1	338.375	923831	0.0001744	8.077	133.248	25648.88	526.14309

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"1992"	41	48	4625.123	4557.897	5	4621.277	1E-05	5.9273	316.9	865200	6.85E-06	11.31	69.5231	13382.5	351.78267
"1992"	41	42	4599.815	4534.682	5	4618.353	0.0001649	97.742	325.665	889131	0.0001099	8.539	143.437	27610.1	479.01816
"1993"	41	40	4594.854	4528.301	5	4617.287	0.0004434	262.82	332.765	908515	0.0002893	7.571	178.908	34438.06	552.00107
"1993"	41	41	4596.34	4530.964	5	4617.852	0.0013414	795.09	326.88	892448	0.0008909	6.447	201.006	38691.67	636.79629
"2011"	42	27	4534.243	4465.835	5	4611.78	0.0001657	98.216	342.04	933838	0.0001052	8.583	308.449	59373.42	500.51229
"2011"	42	28	4539.088	4471.462	5	4611.943	0.0008096	479.88	338.13	923163	0.0005198	6.985	358.38	68984.54	607.94213
"2011"	42	26	4528.542	4460	5	4611.689	0.0022995	1363	342.71	935667	0.0014567	5.956	466.741	89843.03	722.68851
"1992"	41	49	4628.613	4561.555	5	4621.672	1E-05	5.9273	300.585	820657	7.22E-06	11.26	62.8424	12096.54	335.23793
"2011"	42	25	4522.327	4454.393	5	4611.627	0.0016876	1000.3	339.67	927367	0.0010786	6.256	460.923	88723.06	681.91797
"2019"	41	33	4531.582	4457.646	5	4613.834	0.0001031	61.111	369.68	1009300	6.05E-05	9.135	334.44	64376.36	508.26102
"1990"	41	34	4539.902	4466.433	5	4614.226	0.0020153	1194.5	367.345	1002925	0.001191	6.157	461.106	88758.32	749.3389
"2019"	41	32	4523.954	4450.855	5	4613.475	0.0005467	324.05	365.495	997874	0.0003247	7.456	426.783	82151.55	615.69338
"2019"	41	30	4539.475	4470.595	5	4612.859	0.0028769	1705.2	344.4	940281	0.0018135	5.737	449.468	86518.07	753.9433
"2019"	41	31	4529.065	4459.049	5	4613.146	0.0012091	716.67	350.08	955788	0.0007498	6.619	435.272	83785.57	664.24341
"1989"	41	38	4578.373	4508.483	5	4616.148	0.0008413	498.67	349.45	954068	0.0005227	6.98	260.473	50138.43	628.78781
"1993"	41	39	4591.318	4522.969	5	4616.709	0.0014713	872.09	341.745	933032	0.0009347	6.399	231.46	44553.75	670.74015
"1989"	41	37	4565.599	4494.658	5	4615.617	0.0006095	361.27	354.705	968416	0.0003731	7.317	292.943	56388.68	608.84011
"1990"	41	35	4546.812	4474.694	5	4614.653	0.0037542	2225.2	360.59	984483	0.0022603	5.517	473.985	91237.41	820.8305
"1990"	41	36	4554.783	4483.418	5	4615.117	4.04E-05	23.946	356.825	974204	2.46E-05	10.04	239.374	46077.16	446.52379
"1994"	42	42	4588.981	4524.658	5	4618.076	0.0018825	1115.8	321.615	878073	0.0012708	6.092	233.236	44895.67	663.02263
"2020"	43	20	4478.625	4409.056	5	4611.097	0.0002121	125.72	347.845	949686	0.0001324	8.353	473.538	91151.23	523.02412
"1996"	42	41	4587.637	4524.168	5	4617.534	0.0003698	219.19	317.345	866415	0.000253	7.705	182.741	35175.76	517.26515
"1996"	42	39	4575.636	4508.032	5	4616.381	0.0042818	2538	338.02	922862	0.0027501	5.322	337.088	64886.1	797.74172
"1996"	42	40	4582.822	4516.898	5	4616.958	0.0007707	456.82	329.62	899929	0.0005076	7.009	226.194	43540.05	590.63433
"2011"	43	27	4518.402	4447.243	5	4611.225	0.0008122	481.42	355.795	971392	0.0004956	7.033	447.479	86135.22	635.3649
"2011"	43	28	4521.091	4450.478	5	4611.42	0.0014321	848.85	353.065	963938	0.0008806	6.459	473.474	91139.04	686.56984
"2011"	43	26	4512.623	4441.508	5	4611.088	0.0003943	233.71	355.575	970791	0.0002407	7.755	422.386	81305.12	575.87331
"2011"	43	24	4495.497	4426.796	5	4610.987	0.0002662	157.79	343.505	937837	0.0001682	8.113	433.076	83362.84	531.75899
"2011"	43	25	4505.609	4435.128	5	4611.003	0.000578	342.6	352.405	962136	0.0003561	7.363	461.323	88799.97	601.06886
"2006"	42	32	4516.449	4445.435	5	4613.068	0.0004178	247.64	355.07	969412	0.0002555	7.695	419.294	80709.99	579.4865
"2006"	42	33	4522.682	4452.048	5	4613.447	0.0005582	330.86	353.17	964225	0.0003431	7.401	414.73	79831.43	599.36101
"2019"	42	31	4516.559	4444.98	5	4612.721	0.0010308	610.99	357.895	977125	0.0006253	6.801	477.832	91977.92	660.94881
"2006"	42	29	4534.432	4465.529	5	4612.155	0.0004003	237.27	344.515	940595	0.0002523	7.708	347.345	66860.43	561.3407
"2006"	42	30	4526.432	4456.063	5	4612.415	0.0004025	238.57	351.845	960607	0.0002484	7.724	381.195	73376.28	572.12839
"1989"	42	37	4554.479	4485.546	5	4615.284	6.34E-05	37.579	344.665	941004	3.99E-05	9.551	240.637	46320.3	453.22177
"2001"	42	38	4566.348	4498.135	5	4615.822	7.42E-05	43.981	341.065	931176	4.72E-05	9.383	214.475	41284.27	456.50781
"1990"	42	36	4546.867	4477.146	5	4614.775	1E-05	5.9273	348.605	951761	6.23E-06	11.41	218.856	42127.68	383.74344
"2001"	42	34	4531.408	4460.986	5	4613.858	0.0003041	180.25	352.11	961331	0.0001875	8.005	358.037	68918.52	552.45778
"2001"	42	35	4539.366	4469.356	5	4614.3	0.0030451	1804.9	350.05	955707	0.0018886	5.697	469.023	90282.31	771.75652
"2006"	41	29	4548.012	4480.526	5	4612.624	0.0035814	2122.8	337.43	921251	0.0023043	5.498	421.025	81043.05	770.79504
"2019"	39	32	4561.839	4487.503	5	4614.176	1E-05	5.9273	371.68	1014761	5.84E-06	11.47	204.971	39454.78	406.85874

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2019"	39	33	4559.934	4483.117	5	4614.498	1E-05	5.9273	384.085	1048629	5.65E-06	11.51	219.303	42213.57	419.23823
"2019"	39	31	4565.355	4494.559	5	4613.899	0.0032534	1928.4	353.98	966436	0.0019954	5.642	372.761	71752.68	788.01482
"2019"	39	28	4561.389	4492.915	5	4613.224	0.0005135	304.37	342.37	934739	0.0003256	7.453	278.608	53629.32	576.94791
"2019"	39	30	4565.84	4496.938	5	4613.646	1E-05	5.9273	344.51	940581	6.3E-06	11.4	175.881	33855.26	379.62884
"1978"	39	37	4579.454	4503.502	5	4616.198	4.19E-05	24.835	379.76	1036821	2.4E-05	10.06	202.774	39032.04	474.00394
"1979"	39	38	4586.44	4512.812	5	4616.731	0.0008614	510.58	368.14	1005096	0.000508	7.008	255.319	49146.39	659.72627
"2022"	39	36	4573.054	4497.133	5	4615.709	2.08E-05	12.329	379.605	1036398	1.19E-05	10.76	203.075	39089.97	442.99629
"2022"	39	34	4559.219	4481.187	5	4614.854	4.98E-05	29.518	390.16	1065215	2.77E-05	9.916	263.106	50645.33	494.14039
"2022"	39	35	4565.588	4489.167	5	4615.259	0.0001778	105.39	382.105	1043223	0.000101	8.623	276.28	53181.05	556.52795
"2006"	38	34	4573.301	4498.42	5	4615.123	0.0005364	317.94	374.405	1022201	0.000311	7.499	282.713	54419.37	627.07831
"2006"	38	35	4573.557	4497.579	5	4615.521	0.0009745	577.62	379.89	1037176	0.0005569	6.916	313.872	60417.18	689.82841
"2019"	38	33	4574.667	4501.389	5	4614.791	1.79E-05	10.61	366.39	1000318	1.06E-05	10.88	184.887	35588.91	423.06485
"2019"	38	29	4571.379	4503.14	5	4613.753	0.0020787	1232.1	341.195	931531	0.0013227	6.052	306.579	59013.31	708.0354
"2019"	38	32	4576.533	4504.985	5	4614.475	1E-05	5.9273	357.74	976702	6.07E-06	11.44	165.133	31786.47	392.90843
"2002"	38	42	4614.016	4546.051	5	4619.608	9.21E-05	54.591	339.825	927790	5.88E-05	9.164	112.242	21605.46	465.75534
"2019"	39	27	4560.729	4492.576	5	4613.137	0.0025564	1515.3	340.765	930357	0.0016287	5.844	355.07	68347.34	732.28748
"2002"	38	41	4607.846	4539.933	5	4619.214	0.0010375	614.96	339.565	927080	0.0006633	6.742	171.333	32979.87	632.58702
"1977"	38	36	4578.796	4503.672	5	4615.967	0.00432	2560.6	375.62	1025518	0.0024969	5.418	372.168	71638.7	870.71653
"1977"	38	37	4583.113	4508.589	5	4616.451	0.0001907	113.03	372.62	1017327	0.0001111	8.528	222.601	42848.51	548.76974
"2009"	40	38	4586.937	4514.503	5	4616.453	0.0028984	1718	362.17	988797	0.0017374	5.78	298.466	57451.67	786.97503
"2009"	40	39	4595.194	4525.536	5	4617.033	4.92E-05	29.162	348.29	950901	3.07E-05	9.815	147.384	28370	445.66874
"1992"	40	37	4574.135	4500.355	5	4615.922	0.0003591	212.85	368.9	1007171	0.0002113	7.885	262.783	50583.02	587.58319
"1991"	40	35	4556.563	4481.451	5	4614.972	0.0004094	242.66	375.56	1025354	0.0002367	7.772	326.37	62822.95	606.90206
"1992"	40	36	4563.824	4489.589	5	4615.428	0.005169	3063.8	371.175	1013382	0.0030234	5.227	445.61	85775.47	891.81979
"2006"	41	27	4549.274	4482.414	5	4612.302	0.0037378	2215.5	334.3	912706	0.0024274	5.446	413.246	79545.77	770.92808
"2006"	41	28	4548.904	4481.729	5	4612.449	0.0007211	427.42	335.875	917006	0.0004661	7.094	320.914	61772.68	594.60793
"1992"	40	42	4606.244	4539.933	5	4618.684	0.0012861	762.31	331.555	905211	0.0008421	6.503	173.795	33453.83	640.31673
"2009"	40	40	4599.99	4532.786	5	4617.631	0.0004899	290.38	336.02	917402	0.0003165	7.481	169.928	32709.37	564.10376
"2009"	40	41	4602.074	4535.78	5	4618.213	0.000347	205.68	331.47	904979	0.0002273	7.812	154.85	29807	532.87762
"1981"	39	42	4609.608	4542.575	5	4619.093	0.0015533	920.69	335.165	915067	0.0010061	6.325	171.904	33089.71	665.48045
"2019"	40	29	4556.424	4488.811	5	4613.053	0.0001346	79.782	338.065	922985	8.64E-05	8.779	244.302	47025.68	483.64177
"1980"	39	41	4605.379	4539.128	5	4618.648	0.0001165	69.053	331.255	904392	7.64E-05	8.903	128.76	24784.93	467.29585
"1979"	39	39	4593.74	4523.042	5	4617.351	0.0015851	939.54	353.49	965098	0.0009735	6.358	239.601	46120.89	698.2299
"1980"	39	40	4600.284	4532.501	5	4617.995	0.0006753	400.27	338.915	925306	0.0004326	7.169	180.145	34676.11	593.74643
"2019"	40	33	4543.26	4465.326	5	4614.183	1E-05	5.9273	389.67	1063877	5.57E-06	11.52	259.808	50010.41	424.80141
"1991"	40	34	4550.016	4472.712	5	4614.556	0.0031839	1887.2	386.52	1055277	0.0017883	5.751	486.589	93663.52	844.09619
"2019"	40	32	4544.526	4470.364	5	4613.843	1E-05	5.9273	370.81	1012385	5.85E-06	11.47	240.139	46224.3	405.98932
"2019"	40	30	4555.469	4487.329	5	4613.272	0.0041172	2440.4	340.7	930179	0.0026236	5.369	408.777	78685.51	797.03162
"2019"	40	31	4548.754	4477.938	5	4613.54	1.85E-05	10.966	354.08	966709	1.13E-05	10.81	229.354	44148.33	411.39027
"2001"	44	39	4554.999	4485.263	5	4615.712	1E-05	5.9273	348.68	951966	6.23E-06	11.41	204.566	39376.82	383.81876
"2001"	44	40	4558.171	4489.269	5	4616.328	1E-05	5.9273	344.51	940581	6.3E-06	11.4	196.302	37786.24	379.62884

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2001"	44	38	4549.771	4479.966	5	4615.128	1E-05	5.9273	349.025	952908	6.22E-06	11.41	214.105	41212.99	384.16523
"2006"	44	36	4539.027	4468.791	5	4614.022	0.0032263	1912.3	351.18	958792	0.0019945	5.642	475.879	91601.97	781.72307
"2001"	44	37	4544.5	4474.527	5	4614.561	1E-05	5.9273	349.865	955201	6.21E-06	11.41	224.189	43154.05	385.00869
"1993"	44	44	4573.186	4503.962	5	4619.154	0.0031641	1875.5	346.12	944977	0.0019847	5.647	350.058	67382.74	769.78501
"2020"	45	22	4452.553	4380.034	5	4609.516	0.0001171	69.409	362.595	989957	7.01E-05	8.988	527.864	101608.6	506.65495
"1993"	44	43	4565.986	4497.897	5	4618.364	1E-05	5.9273	340.445	929483	6.38E-06	11.39	181.958	35025.02	375.54056
"1994"	44	41	4560.95	4493.225	5	4616.974	1E-05	5.9273	338.625	924514	6.41E-06	11.38	187.727	36135.58	373.70888
"1994"	44	42	4562.87	4495.437	5	4617.647	0.0017729	1050.9	337.165	920528	0.0011416	6.199	338.083	65077.68	683.07433
"2011"	44	29	4507.484	4435.059	5	4611.152	0.0002879	170.65	362.125	988674	0.0001726	8.087	429.975	82765.86	562.35607
"2011"	44	30	4510.937	4438.173	5	4611.461	0.0005369	318.24	363.82	993301	0.0003204	7.469	458.403	88238.07	611.7648
"2011"	44	28	4507.201	4434.841	5	4610.883	0.0003233	191.63	361.8	987786	0.000194	7.971	435.812	83889.52	570.08772
"2011"	44	26	4498.561	4422.869	5	4610.483	0.0002455	145.52	378.46	1033271	0.0001408	8.291	468.779	90235.17	573.30426
"2011"	44	27	4503.83	4430.446	5	4610.656	0.0002738	162.29	366.92	1001765	0.000162	8.151	443.251	85321.44	565.37313
"2006"	44	34	4529.921	4459.572	5	4613.037	0.0021043	1247.3	351.745	960334	0.0012988	6.07	473.988	91237.93	727.74133
"2006"	44	35	4532.876	4462.565	5	4613.514	0.0015282	905.81	351.555	959815	0.0009437	6.389	441.099	84907.17	691.03453
"2006"	44	33	4528.366	4458.078	5	4612.593	0.0014938	885.42	351.44	959501	0.0009228	6.412	452.204	87044.66	688.39302
"2006"	44	31	4520.076	4447.907	5	4611.805	0.0010268	608.62	360.845	985179	0.0006178	6.813	466.814	89857.09	665.21424
"2006"	44	32	4525.636	4454.512	5	4612.182	0.0011872	703.69	355.62	970914	0.0007248	6.653	450.823	86778.95	671.31139
"2006"	45	36	4538.186	4466.73	5	4613.624	0.0033744	2000.1	357.28	975446	0.0020505	5.615	491.406	94590.72	799.21188
"2006"	45	37	4540.317	4469.263	5	4614.177	1E-05	5.9273	355.27	969958	6.11E-06	11.43	236.371	45499.06	390.43217
"2006"	45	35	4535.5	4463.65	5	4613.096	0.0031771	1883.2	359.25	980824	0.00192	5.68	498.292	95916.19	794.33516
"2006"	45	33	4531.791	4460.023	5	4612.141	0.0007788	461.62	358.84	979705	0.0004712	7.084	408.058	78547.08	636.23504
"2006"	45	34	4532.945	4461.086	5	4612.602	0.0030018	1779.3	359.295	980947	0.0018138	5.737	501.869	96604.81	786.57242
"2001"	45	41	4550.343	4481.865	5	4616.691	0.0012078	715.9	342.39	934793	0.0007658	6.598	363.886	70044.36	651.73181
"2001"	45	42	4552.438	4484.281	5	4617.427	1E-05	5.9273	340.785	930411	6.37E-06	11.39	206.838	39814.26	375.88265
"2001"	45	40	4552.401	4483.148	5	4616.006	1E-05	5.9273	346.265	945373	6.27E-06	11.4	208.43	40120.75	381.39271
"2006"	45	38	4545.601	4474.743	5	4614.768	0.0003793	224.82	354.29	967283	0.0002324	7.79	331.531	63816.34	571.20267
"2001"	45	39	4550.644	4480.425	5	4615.363	1.02E-05	6.0459	351.095	958560	6.31E-06	11.4	214.853	41357.15	386.91461
"2016"	45	26	4488.022	4408.372	5	4609.879	0.0002212	131.11	398.25	1087302	0.0001206	8.446	522.113	100501.6	592.19875
"2011"	45	27	4493.781	4417.147	5	4610.077	0.0002484	147.23	383.17	1046131	0.0001407	8.292	489.475	94219.02	580.39538
"2016"	45	25	4479.844	4398.226	5	4609.728	0.0001733	102.72	408.09	1114167	9.22E-05	8.714	546.678	105230.1	588.13932
"2020"	45	23	4460.144	4385.27	5	4609.563	0.0003642	215.87	374.37	1022105	0.0002112	7.886	602.211	115919.6	596.24917
"2016"	45	24	4468.862	4390.231	5	4609.625	0.0001568	92.94	393.155	1073392	8.66E-05	8.777	549.472	105767.8	562.56329
"2011"	45	31	4517.452	4444.471	5	4611.319	0.0003312	196.31	364.905	996264	0.000197	7.955	412.143	79333.49	576.10733
"2011"	45	32	4527.02	4455.009	5	4611.714	0.0021809	1292.7	360.055	983022	0.001315	6.058	496.168	95507.4	746.45762
"2011"	45	30	4508.711	4435.348	5	4610.958	0.0007768	460.43	366.815	1001478	0.0004598	7.108	492.666	94833.31	648.12952
"2011"	45	28	4497.454	4423.623	5	4610.327	0.0002691	159.5	369.155	1007867	0.0001583	8.174	463.291	89178.82	567.18975
"2011"	45	29	4501.356	4428.354	5	4610.625	0.0002723	161.4	365.01	996550	0.000162	8.151	447.4	86119.97	562.41115
"2016"	44	25	4490.671	4415.621	5	4610.363	0.0002505	148.48	375.25	1024508	0.0001449	8.262	488.307	93994.29	570.41454
"2001"	43	38	4554.112	4485.49	5	4615.479	0.0006118	362.63	343.11	936759	0.0003871	7.28	315.439	60718.88	591.92991
"2001"	43	37	4548.738	4479.98	5	4614.93	1E-05	5.9273	343.79	938615	6.31E-06	11.4	211.58	40727.06	378.905

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2001"	43	36	4542.136	4472.62	5	4614.409	0.0004795	284.22	347.58	948963	0.0002995	7.536	343.117	66046.54	579.23161
"2001"	43	39	4562.726	4494.452	5	4616.049	0.0001067	63.245	341.37	932008	6.79E-05	9.021	232.886	44828.31	475.26891
"1994"	43	42	4575.718	4510.004	5	4617.841	1E-05	5.9273	328.57	897062	6.61E-06	11.35	154.091	29660.94	363.57512
"1995"	43	41	4574.043	4508.292	5	4617.245	0.004722	2798.9	328.755	897567	0.0031183	5.196	341.308	65698.39	794.58242
"1996"	43	40	4570.514	4503.614	5	4616.64	0.0041212	2442.8	334.5	913252	0.0026748	5.349	352.09	67773.73	785.34856
"2006"	43	30	4515.826	4443.63	5	4611.948	0.0008808	522.08	360.98	985548	0.0005297	6.966	471.601	90778.5	650.78509
"2006"	43	31	4516.087	4444.03	5	4612.274	0.0002739	162.35	360.285	983650	0.000165	8.132	403.165	77605.2	556.41997
"2006"	43	32	4520.203	4449.209	5	4612.635	0.0005461	323.69	354.97	969139	0.000334	7.427	421.203	81077.38	600.22673
"2011"	43	29	4520.466	4449.512	5	4611.662	0.0007024	416.33	354.77	968593	0.0004298	7.175	431.694	83096.76	620.97096
"2006"	43	35	4534.283	4464.678	5	4613.917	0.0002376	140.83	348.025	950178	0.0001482	8.24	334.673	64421.22	530.47108
"2006"	43	34	4525.2	4456.207	5	4613.457	0.0017711	1049.8	344.965	941823	0.0011146	6.223	469.1	90297.02	696.19713
"2006"	43	33	4523.047	4453.232	5	4613.03	0.0009018	534.53	349.075	953045	0.0005609	6.909	434.86	83706.14	634.52019
"1986"	43	45	4589.266	4523.199	5	4619.997	0.0021074	1249.1	330.335	901881	0.001385	6.006	252.619	48626.66	690.74883
"2016"	44	23	4465.546	4396.438	5	4610.311	0.0001433	84.938	345.54	943393	9E-05	8.738	480.666	92523.37	496.64145
"2020"	44	21	4462.036	4392.193	5	4610.31	0.0002842	168.45	349.215	953427	0.0001767	8.064	537.548	103472.7	543.87883
"1986"	43	46	4593.415	4526.616	5	4620.71	2.47E-05	14.64	333.995	911873	1.61E-05	10.46	140.387	27023.05	400.94065
"2016"	44	24	4479.666	4406.83	5	4610.303	0.0001898	112.5	364.18	994284	0.0001131	8.51	486.98	93738.86	537.48559
"2020"	44	22	4464.7	4394.946	5	4610.314	0.0001705	101.06	348.77	952212	0.0001061	8.574	497.749	95811.78	510.90033
"2019"	36	34	4604.013	4535.094	7.5	4615.703	0.0006887	408.21	516.892	1411220	0.0002893	7.571	236.355	45495.98	857.43023
"2019"	35	37	4603.129	4539.455	7.5	4617.228	0.0009616	569.97	477.555	1303821	0.0004372	7.158	227.746	43838.92	837.85834
"2011"	25	16	4612.625	4546.667	7.5	4667.607	1E-05	5.9273	494.685	1350589	4.39E-06	11.76	259.632	49976.56	528.34104
"2011"	25	15	4609.169	4545.324	7.5	4666.458	0.0026669	1580.8	478.838	1307322	0.0012092	6.142	486.46	93638.76	979.16677
"1993"	26	28	4660.123	4596.068	7.5	4659.824	2.42E-05	14.344	478.17	1305500	1.1E-05	10.84	110.124	21197.68	553.93239
"2019"	39	29	4563.574	4495.25	7.5	4613.417	0.0055678	3300.2	512.43	1399036	0.0023589	5.475	554.954	106823	1175.5496
"2016"	43	23	4489.578	4420.687	7.5	4610.962	0.0002378	140.95	516.683	1410647	9.99E-05	8.634	635.572	122341.2	751.58188
"2016"	43	22	4486.579	4416.802	7.5	4610.997	0.0002087	123.7	523.328	1428789	8.66E-05	8.777	647.112	124562.6	748.81984
"2020"	43	21	4484.097	4413.925	7.5	4611.029	0.0002104	124.71	526.29	1436877	8.68E-05	8.775	661.728	127376	753.27059
"2001"	46	42	4552.111	4482.864	7.5	4617.114	2.49E-05	14.759	519.353	1417936	1.04E-05	10.9	331.501	63810.55	598.65259
"2020"	51	32	4510.905	4422.842	7.5	4607.816	0.0006866	406.97	660.473	1803222	0.0002257	7.819	825.589	158917.7	1060.8393
"2019"	36	35	4601.112	4531.078	7.5	4616.044	0.0001333	79.011	525.255	1434051	5.51E-05	9.229	211.559	40723.05	714.77444
"2001"	46	41	4552.523	4484.008	7.5	4616.431	0.0012472	739.26	513.863	1402947	0.0005269	6.972	505.221	97250.02	925.70116
"1994"	26	27	4655.642	4590.56	7.5	4664.44	0.0003677	217.95	488.115	1332652	0.0001635	8.141	187.24	36041.77	752.99192
"2019"	38	30	4573.617	4504.573	7.5	4613.963	0.0026509	1571.3	517.83	1413779	0.0011114	6.226	443.915	85449.18	1044.5805
"2008"	25	20	4632.002	4562.546	7.5	4673.484	0.0001805	106.99	520.92	1422216	7.52E-05	8.918	317.043	61027.65	733.62796
"2008"	25	19	4625.958	4558.111	7.5	4672.368	1E-05	5.9273	508.852	1389269	4.27E-06	11.79	245.469	47250.25	542.17055
"2019"	38	31	4575.954	4505.508	7.5	4614.183	0.0024384	1445.3	528.345	1442488	0.001002	6.33	438.568	84420.01	1048.3555
"2003"	26	23	4637.12	4570.762	7.5	4672.565	0.0002109	125.01	497.685	1358780	9.2E-05	8.717	280.471	53987.79	717.08923
"2004"	26	24	4642.403	4576.702	7.5	4671.732	0.0023738	1407	492.758	1345327	0.0010459	6.287	351.718	67702.23	984.40432
"2008"	25	21	4637.005	4569.243	7.5	4674.069	0.0001218	72.195	508.215	1387529	5.2E-05	9.287	277.621	53439.2	687.32342
"2003"	26	22	4630.751	4563.236	7.5	4672.989	0.0014205	841.98	506.363	1382471	0.000609	6.827	400.589	77109.43	931.52811
"2011"	25	17	4616.252	4549.249	7.5	4669.096	0.0042838	2539.1	502.523	1371987	0.0018507	5.717	533.845	102759.7	1103.9946

Coal Aquifer Pit Inflow

SEQNCE	ROW	COL	TPCOAL-1	BTCOAL-1	K FT/DAY	COAL_SSHD	COAL STORAGE	1.87* R^2 S (FT)	TRANS FT^2 / DAY	Tt FT	U FT	W(u)	Q GPM	Q FT^3/DA	CONDCT FT^2/DAY
"2019"	37	32	4589.138	4520.163	7.5	4614.746	1.06E-05	6.283	517.313	1412367	4.45E-06	11.75	192.584	37070.44	553.14506
"1998"	45	43	4560.04	4491.03	7.5	4618.233	6.96E-05	41.254	517.575	1413083	2.92E-05	9.864	341.096	65657.62	658.97793
"1987"	45	44	4567.171	4496.922	7.5	4618.972	0.0003104	183.98	526.868	1438454	0.0001279	8.387	385.215	74150.01	788.9569
"2004"	26	25	4647.686	4582.169	7.5	4670.185	0.0032116	1903.6	491.377	1341559	0.001419	5.982	331.388	63788.85	1031.6501
"2010"	25	18	4620.669	4553.672	7.5	4670.831	0.0008861	525.22	502.478	1371864	0.0003829	7.291	406.464	78240.21	865.5528
"2019"	37	33	4588.74	4518.83	7.5	4615.034	0.0001859	110.19	524.325	1431512	7.7E-05	8.895	262.552	50538.62	740.32948
"1995"	26	26	4652.56	4586.822	7.5	4667.815	0.0018078	1071.5	493.035	1346084	0.000796	6.559	268.348	51654.27	944.01107
"1992"	40	49	4623.561	4555.724	7.5	4620.863	1E-05	5.9273	488.543	1333819	4.44E-06	11.75	106.095	20422.14	522.33564
"2011"	41	25	4538.485	4470.886	7.5	4612.157	0.0032234	1910.6	506.992	1384191	0.0013803	6.01	629.01	121078.2	1059.5493
"2011"	41	26	4545.141	4478.19	7.5	4612.186	0.0018854	1117.5	502.133	1370922	0.0008152	6.536	537.651	103492.5	964.92024
"1993"	44	45	4580.121	4510.593	7.5	4619.984	0.0018766	1112.3	521.46	1423690	0.0007813	6.578	422.103	81250.64	995.59995
"2011"	50	34	4513.008	4437.579	7.5	4609.62	0.0003445	204.2	565.718	1544522	0.0001322	8.354	627.058	120702.4	850.48744
"2016"	50	33	4508.616	4432.36	7.5	4609.081	0.0004636	274.79	571.92	1561456	0.000176	8.068	676.526	130224.5	890.28892
"1993"	44	46	4584.604	4514.614	7.5	4620.729	0.0017131	1015.4	524.925	1433150	0.0007085	6.676	400.927	77174.49	987.54713
"2006"	47	40	4559.435	4490.535	7.5	4615.252	9.42E-05	55.835	516.75	1410831	3.96E-05	9.56	342.775	65980.72	678.8654
"2011"	42	24	4518.271	4449.631	7.5	4611.583	0.0009479	561.85	514.8	1405507	0.0003997	7.248	623.527	120022.7	892.06162
"2006"	47	39	4554.588	4484.062	7.5	4614.604	1.56E-05	9.2466	528.945	1444126	6.4E-06	11.38	310.41	59750.86	583.68039
"2011"	49	35	4519.319	4447.504	7.5	4610.888	0.0008671	513.96	538.613	1470520	0.0003495	7.382	641.275	123439.1	916.34981
"1992"	43	47	4596.541	4528.641	7.5	4621.393	1E-05	5.9273	509.25	1390354	4.26E-06	11.79	184.947	35600.53	542.55814
"2020"	44	20	4453.385	4385.31	7.5	4610.287	0.0001309	77.589	510.562	1393938	5.57E-05	9.219	714.807	137593.3	695.54952
"2011"	49	36	4532.906	4456.566	7.5	4611.48	0.002238	1326.5	572.55	1563176	0.0008486	6.496	715.581	137742.2	1107.0423
"2006"	40	27	4556.024	4488.65	7.5	4612.737	1E-05	5.9273	505.305	1379584	4.3E-06	11.78	271.952	52348.13	538.7105
"2019"	40	28	4555.76	4488.124	7.5	4612.855	0.0018614	1103.3	507.27	1384949	0.0007966	6.559	493.094	94915.75	971.37845
"2006"	48	38	4553.87	4480.314	7.5	4613.358	0.0039164	2321.4	551.67	1506169	0.0015412	5.899	632.459	121742	1174.4403
"2006"	48	37	4549.235	4474.751	7.5	4612.742	1E-05	5.9273	558.63	1525172	3.89E-06	11.88	332.056	63917.43	590.53173
"1992"	42	47	4608.402	4541.686	7.5	4621.206	0.0007314	433.52	500.37	1366110	0.0003173	7.479	230.726	44412.42	840.30124
"1992"	42	48	4617.795	4550.835	7.5	4621.767	0.0001202	71.246	502.2	1371106	5.2E-05	9.288	155.808	29991.56	679.09226
"1992"	42	49	4623.85	4556.653	7.5	4622.442	1E-05	5.9273	493.417	1347128	4.4E-06	11.76	108.131	20814.15	527.10231
"1992"	40	51	4625.851	4556.247	10	4621.485	1E-05	5.9273	652.38	1781128	3.33E-06	12.04	138.48	26656.09	680.74637
"1992"	40	52	4628.414	4558.316	10	4625.463	1E-05	5.9273	671.47	1833247	3.23E-06	12.06	146.353	28171.44	698.99142
"1992"	40	50	4624.885	4556.216	10	4621.028	1E-05	5.9273	648.12	1769497	3.35E-06	12.03	136.752	26323.43	676.66945

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2020"	45	22	4	4452.553	4664.923	4537.5	0.2	0.01	212.37	42.474	115962.5	5927.3	0.05111	2.445215	144.4666	27808.041
"2020"	44	20	7	4453.385	4664.671	4537.9	0.2	0.01	211.29	42.2572	115370.6	5927.3	0.05138	2.440336	143.2815	27579.91
"2020"	46	23	1	4455.286	4664.348	4538.9	0.2	0.01	209.06	41.8124	114156.2	5927.3	0.05192	2.430252	140.8631	27114.398
"2020"	48	26	1	4457.398	4664.288	4540.2	0.2	0.01	206.89	41.378	112970.2	5927.3	0.05247	2.420304	138.5183	26663.069
"2020"	45	23	4	4460.144	4665.755	4542.4	0.2	0.01	205.61	41.1222	112271.8	5927.3	0.05279	2.414399	137.1456	26398.827
"2020"	47	25	1	4461.559	4664.676	4542.8	0.2	0.01	203.12	40.6234	110910	5927.3	0.05344	2.402784	134.4857	25886.828
"2020"	44	21	1	4462.036	4665.558	4543.4	0.2	0.01	203.52	40.7044	111131.2	5927.3	0.05334	2.40468	134.9161	25969.678
"2020"	46	24	1	4463.631	4665.17	4544.2	0.2	0.01	201.54	40.3078	110048.4	5927.3	0.05386	2.395365	132.8143	25565.109
"2020"	44	22	4	4464.7	4666.409	4545.4	0.2	0.01	201.71	40.3418	110141.2	5927.3	0.05382	2.396167	132.9939	25599.685
"2016"	44	23	4	4465.546	4667.204	4546.2	0.2	0.01	201.66	40.3316	110113.3	5927.3	0.05383	2.395926	132.94	25589.31
"2016"	45	24	4	4468.862	4666.542	4547.9	0.2	0.01	197.68	39.536	107941.2	5927.3	0.05491	2.376984	128.7649	24785.648
"2020"	48	27	1	4469.89	4665.169	4548	0.2	0.01	195.28	39.0558	106630.1	5927.3	0.05559	2.365375	126.2727	24305.928
"2020"	47	26	1	4470.214	4665.513	4548.3	0.2	0.01	195.3	39.0598	106641.1	5927.3	0.05558	2.365472	126.2933	24309.907
"2020"	46	25	1	4471.659	4665.977	4549.4	0.2	0.01	194.32	38.8636	106105.4	5927.3	0.05586	2.36069	125.281	24115.051
"2020"	49	28	1	4474.339	4664.937	4550.6	0.2	0.01	190.6	38.1196	104074.1	5927.3	0.05695	2.342345	121.4742	23382.279
"2020"	48	28	1	4478.127	4666.054	4553.3	0.2	0.01	187.93	37.5854	102615.7	5927.3	0.05776	2.328962	118.772	22862.145
"2020"	43	20	7	4478.625	4666.332	4553.7	0.2	0.01	187.71	37.5414	102495.5	5927.3	0.05783	2.327852	118.5506	22819.528
"2016"	44	24	4	4479.666	4667.965	4555	0.2	0.01	188.3	37.6598	102818.8	5927.3	0.05765	2.330837	119.1468	22934.285
"2016"	45	25	4	4479.844	4667.313	4554.8	0.2	0.01	187.47	37.4938	102365.6	5927.3	0.0579	2.326649	118.3113	22773.462
"2016"	46	26	1	4480.23	4666.777	4554.8	0.2	0.01	186.55	37.3094	101862.1	5927.3	0.05819	2.321977	117.3862	22595.384
"2016"	47	27	1	4480.437	4666.354	4554.8	0.2	0.01	185.92	37.1834	101518.1	5927.3	0.05839	2.318772	116.7558	22474.048
"2020"	49	29	1	4481.123	4665.861	4555	0.2	0.01	184.74	36.9476	100874.3	5927.3	0.05876	2.312745	115.5801	22247.733
"2020"	50	29	1	4482.634	4664.778	4555.5	0.2	0.01	182.14	36.4288	99457.91	5927.3	0.0596	2.299357	113.0112	21753.267
"2016"	48	29	1	4483.166	4666.922	4556.7	0.2	0.01	183.76	36.7512	100338.1	5927.3	0.05907	2.307698	114.6047	22059.984
"2020"	43	21	7	4484.097	4667.202	4557.3	0.2	0.01	183.11	36.621	99982.65	5927.3	0.05928	2.304338	113.96	21935.895
"2016"	47	28	1	4485.611	4667.187	4558.2	0.2	0.01	181.58	36.3152	99147.76	5927.3	0.05978	2.296401	112.4521	21645.632
"2016"	43	22	7	4486.579	4668.019	4559.2	0.2	0.01	181.44	36.288	99073.5	5927.3	0.05983	2.295692	112.3184	21619.894
"2016"	46	27	1	4486.587	4667.57	4559	0.2	0.01	180.98	36.1966	98823.96	5927.3	0.05998	2.293306	111.8695	21533.505
"2016"	49	30	1	4487.067	4666.771	4558.9	0.2	0.01	179.7	35.9408	98125.57	5927.3	0.06041	2.286597	110.6176	21292.516
"2016"	45	26	4	4488.022	4668.071	4560	0.2	0.01	180.05	36.0098	98313.96	5927.3	0.06029	2.288411	110.9547	21357.406
"2020"	50	30	1	4488.717	4665.745	4559.5	0.2	0.01	177.03	35.4056	96664.37	5927.3	0.06132	2.272412	108.0177	20792.076
"2016"	43	23	7	4489.578	4668.781	4561.3	0.2	0.01	179.2	35.8406	97852.01	5927.3	0.06057	2.283956	110.1288	21198.436
"2016"	44	25	4	4490.671	4668.705	4561.9	0.2	0.01	178.03	35.6068	97213.69	5927.3	0.06097	2.277768	108.992	20979.609
"2016"	47	29	1	4491.171	4667.996	4561.9	0.2	0.01	176.82	35.365	96553.52	5927.3	0.06139	2.271328	107.8216	20754.321
"2016"	46	28	1	4491.343	4668.343	4562.1	0.2	0.01	177	35.4	96649.08	5927.3	0.06133	2.272263	107.9907	20786.867
"2016"	48	30	1	4492.186	4667.775	4562.4	0.2	0.01	175.59	35.1178	95878.62	5927.3	0.06182	2.264701	106.6306	20525.081
"2011"	45	27	4	4493.781	4668.809	4563.8	0.2	0.01	175.03	35.0056	95572.29	5927.3	0.06202	2.261678	106.092	20421.393
"2020"	50	31	1	4494.569	4666.712	4563.4	0.2	0.01	172.14	34.4286	93996.96	5927.3	0.06306	2.245987	103.3403	19891.73
"2011"	43	24	1	4495.497	4669.516	4565.1	0.2	0.01	174.02	34.8038	95021.33	5927.3	0.06238	2.256218	105.1261	20235.47
"2016"	49	31	1	4496.019	4667.678	4564.7	0.2	0.01	171.66	34.3318	93732.68	5927.3	0.06324	2.24333	102.8817	19803.456
"2011"	46	29	1	4497.309	4669.088	4566	0.2	0.01	171.78	34.3558	93798.21	5927.3	0.06319	2.24399	102.9953	19825.326
"2011"	45	28	4	4497.454	4669.516	4566.3	0.2	0.01	172.06	34.4124	93952.73	5927.3	0.06309	2.245543	103.2635	19876.945

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2011"	47	30	1	4498.154	4668.789	4566.4	0.2	0.01	170.63	34.127	93173.54	5927.3	0.06362	2.237686	101.9143	19617.25
"2011"	44	26	4	4498.561	4669.414	4566.9	0.2	0.01	170.85	34.1706	93292.57	5927.3	0.06353	2.23889	102.12	19656.829
"2011"	45	29	4	4501.356	4670.192	4568.9	0.2	0.01	168.84	33.7672	92191.21	5927.3	0.06429	2.227692	100.2243	19291.945
"2016"	50	32	7	4501.515	4667.681	4568	0.2	0.01	166.17	33.2332	90733.28	5927.3	0.06533	2.212672	97.73846	18813.445
"2016"	48	31	1	4501.842	4668.627	4568.6	0.2	0.01	166.79	33.357	91071.28	5927.3	0.06508	2.216174	98.31239	18923.92
"2011"	44	27	4	4503.83	4670.087	4570.3	0.2	0.01	166.26	33.2514	90782.97	5927.3	0.06529	2.213188	97.82274	18829.669
"2011"	46	30	1	4504.629	4669.812	4570.7	0.2	0.01	165.18	33.0366	90196.53	5927.3	0.06572	2.207085	96.82999	18638.576
"2016"	49	32	1	4505.191	4668.594	4570.6	0.2	0.01	163.4	32.6806	89224.57	5927.3	0.06643	2.196887	95.19421	18323.708
"2020"	51	31	7	4505.385	4665.677	4569.5	0.2	0.01	160.29	32.0584	87525.84	5927.3	0.06772	2.17881	92.36398	17778.923
"2011"	43	25	4	4505.609	4670.209	4571.4	0.2	0.01	164.6	32.92	89878.18	5927.3	0.06595	2.203756	96.29291	18535.195
"2011"	44	28	4	4507.201	4670.719	4572.6	0.2	0.01	163.52	32.7036	89287.37	5927.3	0.06638	2.197549	95.29953	18343.981
"2011"	44	29	4	4507.484	4671.313	4573	0.2	0.01	163.83	32.7658	89457.19	5927.3	0.06626	2.199337	95.58461	18398.855
"2011"	47	31	1	4507.666	4669.578	4572.4	0.2	0.01	161.91	32.3824	88410.43	5927.3	0.06704	2.188264	93.83321	18061.732
"2016"	50	33	7	4508.616	4668.652	4572.6	0.2	0.01	160.04	32.0072	87386.06	5927.3	0.06783	2.177307	92.13271	17734.407
"2011"	45	30	4	4508.711	4670.839	4573.6	0.2	0.01	162.13	32.4256	88528.37	5927.3	0.06695	2.189518	94.02985	18099.584
"2020"	51	32	7	4510.905	4666.71	4573.2	0.2	0.01	155.81	31.161	85075.76	5927.3	0.06967	2.152145	88.34651	17005.611
"2011"	44	30	4	4510.937	4671.87	4575.3	0.2	0.01	160.93	32.1866	87875.86	5927.3	0.06745	2.182561	92.94413	17890.596
"2011"	49	33	7	4511.345	4669.519	4574.6	0.2	0.01	158.17	31.6348	86369.33	5927.3	0.06863	2.166312	90.45808	17412.063
"2011"	48	32	1	4511.499	4669.487	4574.7	0.2	0.01	157.99	31.5976	86267.77	5927.3	0.06871	2.165207	90.29152	17380.002
"2016"	51	33	1	4511.637	4667.731	4574.1	0.2	0.01	156.09	31.2188	85233.57	5927.3	0.06954	2.153884	88.60296	17054.975
"2011"	43	26	4	4512.623	4670.853	4575.9	0.2	0.01	158.23	31.646	86399.91	5927.3	0.0686	2.166645	90.50826	17421.72
"2011"	46	31	1	4512.966	4670.525	4576	0.2	0.01	157.56	31.5118	86033.52	5927.3	0.0689	2.162654	89.90786	17306.152
"2011"	50	34	7	4513.008	4669.626	4575.7	0.2	0.01	156.62	31.3236	85519.69	5927.3	0.06931	2.15703	89.06876	17144.635
"2020"	54	37	1	4514.148	4668.464	4575.9	0.2	0.01	154.32	30.8632	84262.71	5927.3	0.07034	2.143137	87.03025	16752.247
"2011"	49	34	7	4514.2	4670.442	4576.7	0.2	0.01	156.24	31.2484	85314.38	5927.3	0.06948	2.154774	88.73442	17080.278
"2006"	43	30	4	4515.826	4672.906	4578.7	0.2	0.01	157.08	31.416	85771.96	5927.3	0.06911	2.159795	89.48031	17223.853
"2006"	43	31	4	4516.087	4673.305	4579	0.2	0.01	157.22	31.4436	85847.32	5927.3	0.06904	2.160619	89.6034	17247.546
"2011"	47	32	1	4516.384	4670.369	4578	0.2	0.01	153.98	30.797	84081.97	5927.3	0.07049	2.141123	86.7388	16696.146
"2006"	42	32	4	4516.449	4674.355	4579.6	0.2	0.01	157.91	31.5812	86222.99	5927.3	0.06874	2.16472	90.21814	17365.876
"2019"	42	31	4	4516.559	4674.209	4579.6	0.2	0.01	157.65	31.53	86083.21	5927.3	0.06886	2.163196	89.98919	17321.806
"2011"	45	31	4	4517.452	4671.463	4579.1	0.2	0.01	154.01	30.8022	84096.17	5927.3	0.07048	2.141282	86.76168	16700.55
"2011"	42	24	7	4518.271	4671.258	4579.5	0.2	0.01	152.99	30.5974	83537.02	5927.3	0.07095	2.135027	85.86257	16527.483
"2011"	48	33	1	4518.283	4670.353	4579.1	0.2	0.01	152.07	30.414	83036.3	5927.3	0.07138	2.129393	85.06082	16373.156
"2011"	43	27	4	4518.402	4671.444	4579.6	0.2	0.01	153.04	30.6084	83567.05	5927.3	0.07093	2.135364	85.91076	16536.759
"2011"	49	35	7	4519.319	4671.366	4580.1	0.2	0.01	152.05	30.4094	83023.74	5927.3	0.07139	2.129251	85.04075	16369.293
"2006"	44	31	4	4520.076	4672.394	4581	0.2	0.01	152.32	30.4636	83171.72	5927.3	0.07127	2.13092	85.27733	16414.832
"2006"	43	32	4	4520.203	4673.642	4581.6	0.2	0.01	153.44	30.6878	83783.83	5927.3	0.07075	2.137793	86.25895	16603.781
"2011"	43	29	4	4520.466	4672.471	4581.3	0.2	0.01	152	30.401	83000.81	5927.3	0.07141	2.128992	85.00411	16362.24
"2011"	46	32	1	4520.991	4671.233	4581.1	0.2	0.01	150.24	30.0484	82038.14	5927.3	0.07225	2.118065	83.47217	16067.361
"2011"	43	28	4	4521.091	4671.983	4581.4	0.2	0.01	150.89	30.1784	82393.07	5927.3	0.07194	2.122107	84.03559	16175.813
"2011"	42	25	1	4522.327	4671.882	4582.1	0.2	0.01	149.55	29.911	81663.01	5927.3	0.07258	2.113774	82.87844	15953.074
"2011"	48	34	1	4522.441	4671.22	4582	0.2	0.01	148.78	29.7558	81239.29	5927.3	0.07296	2.108905	82.20997	15824.402

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2011"	50	35	1	4522.531	4670.598	4581.8	0.2	0.01	148.07	29.6134	80850.5	5927.3	0.07331	2.104417	81.59867	15706.734
"2006"	42	33	4	4522.682	4674.452	4583.4	0.2	0.01	151.77	30.354	82872.49	5927.3	0.07152	2.127542	84.79922	16322.802
"2006"	43	33	4	4523.047	4673.932	4583.4	0.2	0.01	150.89	30.177	82389.25	5927.3	0.07194	2.122064	84.02952	16174.643
"2011"	47	33	1	4523.573	4671.165	4582.6	0.2	0.01	147.59	29.5184	80591.14	5927.3	0.07355	2.101411	81.19193	15628.443
"2019"	41	32	4	4523.954	4675.061	4584.4	0.2	0.01	151.11	30.2214	82510.47	5927.3	0.07184	2.123441	84.22231	16211.754
"2016"	51	34	1	4524.508	4668.743	4582.2	0.2	0.01	144.24	28.847	78758.08	5927.3	0.07526	2.079906	78.3422	15079.904
"2006"	43	34	4	4525.2	4674.203	4584.8	0.2	0.01	149	29.8006	81361.6	5927.3	0.07285	2.110313	82.40269	15861.499
"2006"	44	32	4	4525.636	4672.886	4584.5	0.2	0.01	147.25	29.45	80404.39	5927.3	0.07372	2.099241	80.89962	15572.177
"2006"	42	30	4	4526.432	4673.996	4585.5	0.2	0.01	147.56	29.5128	80575.85	5927.3	0.07356	2.101233	81.16798	15623.833
"2011"	45	32	4	4527.02	4672.076	4585	0.2	0.01	145.06	29.0112	79206.38	5927.3	0.07483	2.085209	79.03512	15213.283
"2011"	46	33	1	4527.852	4671.945	4585.5	0.2	0.01	144.09	28.8186	78680.54	5927.3	0.07533	2.078987	78.22261	15056.886
"2006"	44	33	4	4528.366	4673.348	4586.4	0.2	0.01	144.98	28.9964	79165.97	5927.3	0.07487	2.084732	78.97255	15201.24
"2011"	42	26	4	4528.542	4672.438	4586.1	0.2	0.01	143.9	28.7792	78572.97	5927.3	0.07544	2.077709	78.05684	15024.977
"2011"	48	35	7	4528.784	4672.098	4586.1	0.2	0.01	143.31	28.6628	78255.18	5927.3	0.07574	2.073925	77.56798	14930.878
"2019"	41	31	4	4529.065	4675.13	4587.5	0.2	0.01	146.07	29.213	79757.33	5927.3	0.07432	2.091687	79.89028	15377.89
"2011"	47	34	1	4529.216	4671.966	4586.3	0.2	0.01	142.75	28.55	77947.21	5927.3	0.07604	2.070244	77.09549	14839.929
"2006"	44	34	4	4529.921	4673.794	4587.5	0.2	0.01	143.87	28.7746	78560.41	5927.3	0.07545	2.07756	78.0375	15021.254
"2011"	50	36	1	4530.247	4671.572	4586.8	0.2	0.01	141.32	28.265	77169.1	5927.3	0.07681	2.060882	75.90721	14611.199
"2020"	52	32	1	4530.984	4665.583	4584.8	0.2	0.01	134.6	26.9198	73496.44	5927.3	0.08065	2.01547	70.40535	13552.159
"2001"	42	34	4	4531.408	4674.524	4588.7	0.2	0.01	143.12	28.6232	78147.06	5927.3	0.07585	2.072634	77.40197	14898.922
"2019"	41	33	4	4531.582	4674.936	4588.9	0.2	0.01	143.35	28.6708	78277.02	5927.3	0.07572	2.074185	77.60154	14937.337
"2016"	53	37	1	4531.672	4669.591	4586.8	0.2	0.01	137.92	27.5838	75309.29	5927.3	0.07871	2.038144	73.09901	14070.655
"2006"	45	33	4	4531.791	4672.682	4588.1	0.2	0.01	140.89	28.1782	76932.12	5927.3	0.07705	2.058014	75.54687	14541.838
"2006"	44	35	4	4532.876	4674.248	4589.4	0.2	0.01	141.37	28.2744	77194.77	5927.3	0.07678	2.061193	75.94627	14618.719
"2011"	49	36	7	4532.906	4672.316	4588.7	0.2	0.01	139.41	27.882	76123.44	5927.3	0.07786	2.048162	74.32275	14306.211
"2006"	45	34	4	4532.945	4673.281	4589.1	0.2	0.01	140.34	28.0672	76629.07	5927.3	0.07735	2.054333	75.08713	14453.345
"2006"	46	34	1	4533.57	4672.664	4589.2	0.2	0.01	139.09	27.8188	75950.89	5927.3	0.07804	2.046047	74.06267	14256.148
"2011"	42	27	4	4534.243	4672.933	4589.7	0.2	0.01	138.69	27.738	75730.29	5927.3	0.07827	2.043337	73.73073	14192.253
"2006"	43	35	4	4534.283	4674.484	4590.4	0.2	0.01	140.2	28.0402	76555.35	5927.3	0.07743	2.053436	74.97549	14431.854
"2006"	42	29	4	4534.432	4673.711	4590.1	0.2	0.01	139.28	27.8558	76051.91	5927.3	0.07794	2.047286	74.21489	14285.448
"2006"	45	35	4	4535.5	4673.887	4590.9	0.2	0.01	138.39	27.6774	75564.84	5927.3	0.07844	2.0413	73.48219	14144.412
"2016"	51	35	1	4535.716	4669.751	4589.3	0.2	0.01	134.03	26.807	73188.47	5927.3	0.08099	2.011566	69.95205	13464.904
"2011"	47	35	1	4536.193	4672.788	4590.8	0.2	0.01	136.59	27.319	74586.33	5927.3	0.07947	2.029163	72.01961	13862.885
"2006"	46	35	1	4537.118	4673.397	4591.6	0.2	0.01	136.28	27.2558	74413.79	5927.3	0.07965	2.027008	71.76301	13813.492
"2016"	54	38	1	4537.518	4669.374	4590.3	0.2	0.01	131.86	26.3712	71998.65	5927.3	0.08233	1.996338	68.21249	13130.061
"2020"	52	33	1	4537.801	4666.681	4589.4	0.2	0.01	128.88	25.776	70373.64	5927.3	0.08423	1.975158	65.86695	12678.573
"2011"	48	36	7	4537.964	4673.017	4592	0.2	0.01	135.05	27.0106	73744.34	5927.3	0.08038	2.018601	70.77115	13622.571
"2006"	45	36	4	4538.186	4674.524	4592.7	0.2	0.01	136.34	27.2676	74446	5927.3	0.07962	2.027411	71.81089	13822.708
"2011"	41	25	7	4538.485	4673.753	4592.6	0.2	0.01	135.27	27.0536	73861.74	5927.3	0.08025	2.02008	70.94466	13655.97
"2006"	44	36	4	4539.027	4674.739	4593.3	0.2	0.01	135.71	27.1424	74104.18	5927.3	0.07999	2.023129	71.30356	13725.054
"2011"	42	28	4	4539.088	4673.361	4592.8	0.2	0.01	134.27	26.8546	73318.43	5927.3	0.08084	2.013215	70.14318	13501.695
"2001"	42	35	4	4539.366	4674.601	4593.5	0.2	0.01	135.23	27.047	73843.72	5927.3	0.08027	2.019853	70.91802	13650.842

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2019"	41	30	4	4539.475	4675.145	4593.7	0.2	0.01	135.67	27.134	74081.25	5927.3	0.08001	2.022841	71.26958	13718.513
"1990"	41	34	4	4539.902	4674.772	4593.9	0.2	0.01	134.87	26.974	73644.41	5927.3	0.08049	2.01734	70.6236	13594.17
"2006"	46	36	1	4539.953	4674.16	4593.6	0.2	0.01	134.21	26.8414	73282.39	5927.3	0.08088	2.012758	70.09016	13491.488
"2016"	53	36	1	4540.165	4668.705	4591.6	0.2	0.01	128.54	25.708	70187.98	5927.3	0.08445	1.972709	65.60121	12627.421
"2006"	45	37	4	4540.317	4675.21	4594.3	0.2	0.01	134.89	26.9786	73656.97	5927.3	0.08047	2.017498	70.64214	13597.739
"2011"	53	38	1	4541.89	4670.518	4593.3	0.2	0.01	128.63	25.7256	70236.03	5927.3	0.08439	1.973343	65.66994	12640.652
"2006"	46	37	1	4542.002	4674.965	4595.2	0.2	0.01	132.96	26.5926	72603.12	5927.3	0.08164	2.004103	69.0939	13299.722
"2001"	43	36	4	4542.136	4674.806	4595.2	0.2	0.01	132.67	26.534	72443.13	5927.3	0.08182	2.002054	68.86014	13254.726
"2011"	50	37	1	4542.527	4672.581	4594.5	0.2	0.01	130.05	26.0108	71014.69	5927.3	0.08347	1.983567	66.78805	12855.874
"2006"	47	36	1	4542.758	4673.648	4595.1	0.2	0.01	130.89	26.178	71471.18	5927.3	0.08293	1.989512	67.4473	12982.77
"2011"	51	36	1	4542.837	4670.738	4594	0.2	0.01	127.9	25.5802	69839.06	5927.3	0.08487	1.96809	65.10301	12531.525
"2019"	40	33	4	4543.26	4675.427	4596.1	0.2	0.01	132.17	26.4334	72168.47	5927.3	0.08213	1.998526	68.45963	13177.632
"2001"	44	37	4	4544.5	4675.291	4596.8	0.2	0.01	130.79	26.1582	71417.12	5927.3	0.083	1.98881	67.36908	12967.715
"2019"	40	32	4	4544.526	4675.824	4597	0.2	0.01	131.3	26.2596	71693.96	5927.3	0.08268	1.992401	67.77003	13044.894
"2011"	49	37	1	4544.693	4673.328	4596.1	0.2	0.01	128.64	25.727	70239.86	5927.3	0.08439	1.973394	65.67541	12641.704
"2006"	46	38	1	4544.734	4675.825	4597.2	0.2	0.01	131.09	26.2182	71580.93	5927.3	0.08281	1.990936	67.60621	13013.359
"2011"	41	26	7	4545.141	4674.211	4596.8	0.2	0.01	129.07	25.814	70477.38	5927.3	0.0841	1.976523	66.01565	12707.196
"2020"	52	34	1	4545.147	4667.762	4594.2	0.2	0.01	122.61	24.523	66952.69	5927.3	0.08853	1.92904	61.04416	11750.247
"2006"	47	37	7	4545.574	4674.556	4597.2	0.2	0.01	128.98	25.7964	70429.33	5927.3	0.08416	1.975891	65.94676	12693.935
"2020"	54	36	1	4545.588	4667.492	4594.3	0.2	0.01	121.9	24.3808	66564.46	5927.3	0.08905	1.923669	60.50675	11646.801
"2006"	45	38	4	4545.601	4675.966	4597.7	0.2	0.01	130.37	26.073	71184.5	5927.3	0.08327	1.985783	67.03297	12903.019
"1990"	41	35	4	4546.812	4674.589	4597.9	0.2	0.01	127.78	25.5554	69771.35	5927.3	0.08495	1.967192	65.00652	12512.952
"2011"	51	37	1	4546.825	4671.725	4596.8	0.2	0.01	124.9	24.98	68200.4	5927.3	0.08691	1.946109	62.78502	12085.339
"1990"	42	36	4	4546.867	4674.711	4598	0.2	0.01	127.84	25.5688	69807.94	5927.3	0.08491	1.967677	65.05865	12522.986
"2006"	41	29	4	4548.012	4675.061	4598.8	0.2	0.01	127.05	25.4098	69373.84	5927.3	0.08544	1.961899	64.44128	12404.149
"2001"	43	37	4	4548.738	4675.194	4599.3	0.2	0.01	126.46	25.2912	69050.03	5927.3	0.08584	1.957567	63.98241	12315.822
"2019"	40	31	4	4548.754	4676.143	4599.7	0.2	0.01	127.39	25.4778	69559.49	5927.3	0.08521	1.964374	64.705	12454.913
"2011"	52	37	1	4548.785	4670.706	4597.6	0.2	0.01	121.92	24.3842	66573.74	5927.3	0.08903	1.923798	60.51957	11649.27
"2006"	41	28	4	4548.904	4674.881	4599.3	0.2	0.01	125.98	25.1954	68788.48	5927.3	0.08617	1.954053	63.61277	12244.672
"2006"	48	37	7	4549.235	4673.995	4599.1	0.2	0.01	124.76	24.952	68123.95	5927.3	0.08701	1.945071	62.67775	12064.693
"2006"	41	27	1	4549.274	4674.593	4599.4	0.2	0.01	125.32	25.0638	68429.19	5927.3	0.08662	1.949207	63.1065	12147.221
"2006"	47	38	7	4549.746	4675.509	4600.1	0.2	0.01	125.76	25.1526	68671.63	5927.3	0.08631	1.95248	63.44793	12212.942
"2001"	44	38	4	4549.771	4675.925	4600.2	0.2	0.01	126.15	25.2308	68885.13	5927.3	0.08605	1.955353	63.74925	12270.943
"1991"	40	34	4	4550.016	4674.951	4600	0.2	0.01	124.94	24.987	68219.51	5927.3	0.08689	1.946368	62.81184	12090.503
"2001"	45	41	4	4550.343	4678.769	4601.7	0.2	0.01	128.43	25.6852	70125.73	5927.3	0.08452	1.971886	65.51221	12610.29
"2006"	46	39	7	4550.4	4676.76	4600.9	0.2	0.01	126.36	25.272	68997.61	5927.3	0.08591	1.956863	63.90825	12301.548
"2001"	45	39	4	4550.644	4676.815	4601.1	0.2	0.01	126.17	25.2342	68894.41	5927.3	0.08603	1.955478	63.76237	12273.467
"2016"	52	36	1	4552.017	4669.769	4599.1	0.2	0.01	117.75	23.5504	64297.3	5927.3	0.09219	1.891711	57.40902	11050.526
"2001"	46	42	7	4552.111	4680.001	4603.3	0.2	0.01	127.89	25.578	69833.06	5927.3	0.08488	1.968011	65.09445	12529.877
"2001"	45	40	4	4552.401	4677.754	4602.5	0.2	0.01	125.35	25.0706	68447.75	5927.3	0.0866	1.949458	63.13262	12152.248
"2001"	45	42	7	4552.438	4679.857	4603.4	0.2	0.01	127.42	25.4838	69575.87	5927.3	0.08519	1.964592	64.72829	12459.396
"2001"	46	41	7	4552.523	4678.859	4603.1	0.2	0.01	126.34	25.2672	68984.51	5927.3	0.08592	1.956688	63.88972	12297.981

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2001"	46	40	7	4553.324	4677.776	4603.1	0.2	0.01	124.45	24.8904	67955.77	5927.3	0.08722	1.942785	62.44206	12019.324
"2011"	50	38	1	4553.836	4673.678	4601.8	0.2	0.01	119.84	23.9684	65438.53	5927.3	0.09058	1.907926	58.95965	11349.003
"2006"	48	38	7	4553.87	4675.032	4602.3	0.2	0.01	121.16	24.2324	66159.3	5927.3	0.08959	1.918032	59.94806	11539.261
"2001"	43	38	4	4554.112	4675.675	4602.7	0.2	0.01	121.56	24.3126	66378.26	5927.3	0.0893	1.921083	60.24972	11597.326
"2016"	52	35	1	4554.294	4668.8	4600.1	0.2	0.01	114.51	22.9012	62524.86	5927.3	0.0948	1.865992	55.03577	10593.705
"1989"	42	37	4	4554.479	4674.89	4602.6	0.2	0.01	120.41	24.0822	65749.22	5927.3	0.09015	1.912295	59.38485	11430.85
"2006"	47	39	7	4554.588	4676.524	4603.4	0.2	0.01	121.94	24.3872	66581.93	5927.3	0.08902	1.923911	60.53089	11651.448
"2006"	49	38	1	4554.68	4674.413	4602.6	0.2	0.01	119.73	23.9466	65379.01	5927.3	0.09066	1.907087	58.87834	11333.353
"2001"	46	43	1	4554.716	4681.218	4605.3	0.2	0.01	126.5	25.3004	69075.15	5927.3	0.08581	1.957903	64.01795	12322.664
"1990"	41	36	4	4554.783	4674.427	4602.6	0.2	0.01	119.64	23.9288	65330.41	5927.3	0.09073	1.906401	58.81199	11320.581
"2001"	44	39	4	4554.999	4676.663	4603.7	0.2	0.01	121.66	24.3328	66433.41	5927.3	0.08922	1.921849	60.3258	11611.97
"2015"	54	61	1	4555.319	4696.138	4611.6	0.2	0.01	140.82	28.1638	76892.81	5927.3	0.07709	2.057537	75.48716	14530.345
"2019"	40	30	4	4555.469	4676.39	4603.8	0.2	0.01	120.92	24.1842	66027.7	5927.3	0.08977	1.916195	59.76708	11504.424
"2020"	55	37	1	4555.585	4667.129	4600.2	0.2	0.01	111.54	22.3088	60907.49	5927.3	0.09732	1.841929	52.90757	10184.054
"2019"	40	28	7	4555.76	4676.525	4604.1	0.2	0.01	120.76	24.153	65942.52	5927.3	0.08989	1.915004	59.65005	11481.897
"2006"	40	27	7	4556.024	4676.404	4604.2	0.2	0.01	120.38	24.076	65732.3	5927.3	0.09017	1.912057	59.36165	11426.384
"2019"	40	29	1	4556.424	4676.524	4604.5	0.2	0.01	120.1	24.02	65579.4	5927.3	0.09038	1.909909	59.15229	11386.084
"1991"	40	35	4	4556.563	4674.431	4603.7	0.2	0.01	117.87	23.5736	64360.64	5927.3	0.0921	1.892618	57.49462	11067.003
"2001"	44	40	4	4558.171	4677.51	4605.9	0.2	0.01	119.34	23.8678	65163.87	5927.3	0.09096	1.904047	58.58485	11276.858
"2015"	53	60	1	4558.339	4696.527	4613.6	0.2	0.01	138.19	27.6376	75456.18	5927.3	0.07855	2.039959	73.31915	14113.03
"2006"	48	39	1	4558.458	4676.118	4605.5	0.2	0.01	117.66	23.532	64247.07	5927.3	0.09226	1.890991	57.34116	11037.465
"2001"	47	43	1	4558.59	4681.187	4607.6	0.2	0.01	122.6	24.5194	66942.87	5927.3	0.08854	1.928905	61.03053	11747.623
"2011"	51	38	1	4558.838	4672.795	4604.4	0.2	0.01	113.96	22.7914	62225.08	5927.3	0.09526	1.861575	54.63861	10517.257
"2001"	47	42	1	4558.985	4679.942	4607.4	0.2	0.01	120.96	24.1914	66047.36	5927.3	0.08974	1.91647	59.7941	11509.625
"1996"	46	47	1	4559.095	4687.066	4610.3	0.2	0.01	127.97	25.5942	69877.28	5927.3	0.08482	1.968597	65.15751	12542.015
"2022"	39	34	4	4559.219	4675.08	4605.6	0.2	0.01	115.86	23.1722	63264.74	5927.3	0.09369	1.876808	56.02125	10783.398
"2006"	47	41	1	4559.324	4678.75	4607.1	0.2	0.01	119.43	23.8852	65211.37	5927.3	0.09089	1.904719	58.6496	11289.323
"2006"	47	40	7	4559.435	4677.608	4606.7	0.2	0.01	118.17	23.6346	64527.18	5927.3	0.09186	1.894998	57.71995	11110.377
"2019"	39	33	4	4559.934	4675.956	4606.3	0.2	0.01	116.02	23.2044	63352.65	5927.3	0.09356	1.878086	56.13884	10806.033
"2011"	52	38	1	4559.996	4671.705	4604.7	0.2	0.01	111.71	22.3418	60997.58	5927.3	0.09717	1.843285	53.02518	10206.692
"1998"	45	43	7	4560.04	4681.049	4608.4	0.2	0.01	121.01	24.2018	66075.75	5927.3	0.0897	1.916866	59.83314	11517.139
"2006"	49	39	1	4560.154	4675.56	4606.3	0.2	0.01	115.41	23.0812	63016.29	5927.3	0.09406	1.873189	55.6895	10719.541
"2019"	39	27	7	4560.729	4678.328	4607.8	0.2	0.01	117.6	23.5198	64213.76	5927.3	0.09231	1.890513	57.2962	11028.809
"1994"	44	41	4	4560.95	4678.459	4608	0.2	0.01	117.51	23.5018	64164.61	5927.3	0.09238	1.889808	57.22987	11016.043
"2011"	50	39	1	4561.344	4674.863	4606.8	0.2	0.01	113.52	22.7038	61985.91	5927.3	0.09562	1.858038	54.32263	10456.435
"2019"	39	28	7	4561.389	4678.285	4608.1	0.2	0.01	116.9	23.3792	63829.89	5927.3	0.09286	1.884992	56.77902	10929.26
"2006"	48	40	1	4561.755	4677.256	4608	0.2	0.01	115.5	23.1002	63068.17	5927.3	0.09398	1.873946	55.7587	10732.86
"2015"	53	61	1	4561.756	4697.812	4616.2	0.2	0.01	136.06	27.2112	74292.02	5927.3	0.07978	2.025484	71.58216	13778.68
"2019"	39	32	4	4561.839	4676.686	4607.8	0.2	0.01	114.85	22.9694	62711.06	5927.3	0.09452	1.868725	55.28307	10641.308
"1998"	46	44	1	4561.982	4682.544	4610.2	0.2	0.01	120.56	24.1124	65831.67	5927.3	0.09004	1.913451	59.49791	11452.613
"2001"	43	39	4	4562.726	4676.273	4608.1	0.2	0.01	113.55	22.7094	62001.2	5927.3	0.0956	1.858264	54.34281	10460.319
"2020"	55	38	1	4562.733	4668.184	4604.9	0.2	0.01	105.45	21.0902	57580.46	5927.3	0.10294	1.790524	48.64291	9363.1594

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"1994"	44	42	4	4562.87	4679.508	4609.5	0.2	0.01	116.64	23.3276	63689.01	5927.3	0.09307	1.882959	56.58972	10892.822
"2006"	49	40	1	4563.125	4676.746	4608.6	0.2	0.01	113.62	22.7242	62041.61	5927.3	0.09554	1.858863	54.39615	10470.586
"2001"	47	44	1	4563.167	4682.506	4610.9	0.2	0.01	119.34	23.8678	65163.87	5927.3	0.09096	1.904047	58.58485	11276.858
"2019"	39	29	7	4563.574	4678.141	4609.4	0.2	0.01	114.57	22.9134	62558.16	5927.3	0.09475	1.866481	55.07997	10602.214
"1992"	40	36	4	4563.824	4673.906	4607.9	0.2	0.01	110.08	22.0164	60109.18	5927.3	0.09861	1.829834	51.87035	9984.401
"2006"	50	40	1	4564.4	4676.095	4609.1	0.2	0.01	111.7	22.339	60989.94	5927.3	0.09719	1.84317	53.0152	10204.77
"2006"	48	41	1	4565.021	4678.445	4610.4	0.2	0.01	113.42	22.6848	61934.04	5927.3	0.0957	1.857269	54.2542	10443.263
"2019"	39	31	4	4565.355	4677.307	4610.1	0.2	0.01	111.95	22.3904	61130.27	5927.3	0.09696	1.845278	53.19859	10240.071
"2022"	39	35	4	4565.588	4674.105	4609	0.2	0.01	108.52	21.7034	59254.62	5927.3	0.10003	1.816722	50.76978	9772.5546
"1989"	41	37	1	4565.599	4674.328	4609.1	0.2	0.01	108.73	21.7458	59370.38	5927.3	0.09984	1.818508	50.91828	9801.1385
"2019"	39	30	1	4565.84	4677.814	4610.6	0.2	0.01	111.97	22.3948	61142.28	5927.3	0.09694	1.845458	53.2143	10243.096
"2006"	48	42	1	4565.936	4679.678	4611.4	0.2	0.01	113.74	22.7484	62107.68	5927.3	0.09544	1.85984	54.48341	10487.383
"1993"	44	43	7	4565.986	4680.666	4611.9	0.2	0.01	114.68	22.936	62619.87	5927.3	0.09466	1.867387	55.1619	10617.984
"1996"	46	46	1	4566.104	4685.537	4613.9	0.2	0.01	119.43	23.8866	65215.2	5927.3	0.09089	1.904773	58.65481	11290.326
"1995"	46	48	1	4566.187	4688.603	4615.2	0.2	0.01	122.42	24.4832	66844.03	5927.3	0.08867	1.92754	60.89354	11721.254
"2006"	49	41	1	4566.326	4677.968	4611	0.2	0.01	111.64	22.3284	60961	5927.3	0.09723	1.842734	52.97741	10197.497
"2001"	42	38	4	4566.348	4675.173	4609.9	0.2	0.01	108.82	21.765	59422.8	5927.3	0.09975	1.819316	50.98558	9814.0938
"2015"	53	62	1	4567.144	4699.143	4619.9	0.2	0.01	132	26.3998	72076.73	5927.3	0.08224	1.997345	68.32608	13151.925
"1987"	45	44	1	4567.171	4682.378	4613.3	0.2	0.01	115.21	23.0414	62907.63	5927.3	0.09422	1.871602	55.54467	10691.662
"1993"	46	45	1	4567.575	4684.001	4614.1	0.2	0.01	116.43	23.2852	63573.25	5927.3	0.09324	1.881284	56.43438	10862.92
"2011"	51	39	1	4567.651	4674.006	4610.2	0.2	0.01	106.36	21.271	58074.08	5927.3	0.10206	1.79832	49.26597	9483.0907
"2020"	53	35	1	4568.129	4667.708	4608	0.2	0.01	99.579	19.9158	54374.12	5927.3	0.10901	1.73834	44.67855	8600.0687
"1997"	47	47	1	4569.512	4686.87	4616.5	0.2	0.01	117.36	23.4716	64082.16	5927.3	0.0925	1.888624	57.11867	10994.639
"2001"	48	43	1	4569.725	4680.957	4614.2	0.2	0.01	111.23	22.2464	60737.12	5927.3	0.09759	1.83936	52.68549	10141.305
"2015"	52	60	1	4570.447	4698.126	4621.5	0.2	0.01	127.68	25.5358	69717.84	5927.3	0.08502	1.966481	64.93031	12498.282
"1996"	43	40	4	4570.514	4677.007	4613.1	0.2	0.01	106.49	21.2986	58149.44	5927.3	0.10193	1.799505	49.36138	9501.456
"2001"	47	45	1	4570.535	4683.923	4615.9	0.2	0.01	113.39	22.6776	61914.38	5927.3	0.09573	1.856977	54.22828	10438.274
"1997"	47	46	1	4571.202	4685.4	4616.9	0.2	0.01	114.2	22.8396	62356.68	5927.3	0.09506	1.863516	54.81281	10550.787
"2006"	50	41	1	4571.356	4677.359	4613.8	0.2	0.01	106	21.2006	57881.88	5927.3	0.1024	1.795292	49.02296	9436.3143
"2019"	38	29	7	4571.379	4679.976	4614.8	0.2	0.01	108.6	21.7194	59298.31	5927.3	0.09996	1.817397	50.82579	9783.3368
"1994"	45	48	1	4571.871	4688.802	4618.6	0.2	0.01	116.93	23.3862	63849	5927.3	0.09283	1.885268	56.80472	10934.207
"1995"	45	47	1	4572.011	4687.121	4618.1	0.2	0.01	115.11	23.022	62854.66	5927.3	0.0943	1.870828	55.47413	10678.085
"1993"	45	46	1	4572.964	4685.471	4618	0.2	0.01	112.51	22.5014	61433.32	5927.3	0.09648	1.849816	53.59556	10316.482
"2022"	39	36	4	4573.054	4673.104	4613.1	0.2	0.01	100.05	20.01	54631.3	5927.3	0.1085	1.742628	44.99122	8660.2537
"1993"	44	44	7	4573.186	4681.964	4616.7	0.2	0.01	108.78	21.7556	59397.14	5927.3	0.09979	1.818921	50.95262	9807.7502
"2020"	54	35	1	4573.271	4666.332	4610.5	0.2	0.01	93.061	18.6122	50815.03	5927.3	0.11665	1.677025	40.44774	7785.6894
"2006"	38	34	4	4573.301	4675.192	4614.1	0.2	0.01	101.89	20.3782	55636.56	5927.3	0.10654	1.759214	46.22227	8897.2162
"2006"	38	35	4	4573.557	4673.633	4613.6	0.2	0.01	100.08	20.0152	54645.5	5927.3	0.10847	1.742864	45.00851	8663.5813
"2019"	38	30	7	4573.617	4679.468	4616	0.2	0.01	105.85	21.1702	57798.88	5927.3	0.10255	1.793981	48.91819	9416.146
"2006"	49	42	1	4573.648	4679.237	4615.9	0.2	0.01	105.59	21.1178	57655.82	5927.3	0.10281	1.791718	48.73781	9381.4253
"2020"	53	34	1	4573.764	4666.568	4610.9	0.2	0.01	92.804	18.5608	50674.7	5927.3	0.11697	1.674528	40.28461	7754.2902
"1993"	45	45	1	4573.831	4683.867	4617.8	0.2	0.01	110.04	22.0072	60084.06	5927.3	0.09865	1.829451	51.83786	9978.1466

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"1995"	43	41	4	4574.043	4677.874	4615.6	0.2	0.01	103.83	20.7662	56695.88	5927.3	0.10455	1.776398	47.53485	9149.8705
"2015"	52	61	1	4574.076	4699.465	4624.2	0.2	0.01	125.39	25.0778	68467.41	5927.3	0.08657	1.949724	63.16028	12157.572
"1992"	40	37	4	4574.135	4673.43	4613.9	0.2	0.01	99.295	19.859	54219.04	5927.3	0.10932	1.735745	44.49047	8563.8654
"2011"	51	40	1	4574.446	4675.3	4614.8	0.2	0.01	100.85	20.1708	55070.32	5927.3	0.10763	1.749905	45.5271	8763.4038
"2019"	38	33	1	4574.667	4676.565	4615.4	0.2	0.01	101.9	20.3796	55640.38	5927.3	0.10653	1.759276	46.22698	8898.1224
"1996"	47	48	1	4574.868	4688.337	4620.3	0.2	0.01	113.47	22.6938	61958.61	5927.3	0.09567	1.857633	54.28661	10449.502
"2016"	54	39	1	4575.563	4670.394	4613.5	0.2	0.01	94.831	18.9662	51781.52	5927.3	0.11447	1.694051	41.57884	8003.4117
"1996"	42	39	4	4575.636	4675.594	4615.6	0.2	0.01	99.958	19.9916	54581.07	5927.3	0.1086	1.741792	44.93007	8648.4838
"1994"	43	42	4	4575.718	4678.867	4617	0.2	0.01	103.15	20.6298	56323.48	5927.3	0.10524	1.77039	47.07163	9060.7066
"2019"	38	31	7	4575.954	4678.648	4617	0.2	0.01	102.69	20.5388	56075.03	5927.3	0.1057	1.766362	46.76367	9001.4278
"2001"	48	44	1	4576.154	4682.29	4618.6	0.2	0.01	106.14	21.2272	57954.5	5927.3	0.10228	1.796437	49.11472	9453.9767
"2019"	38	32	1	4576.533	4677.719	4617	0.2	0.01	101.19	20.2372	55251.6	5927.3	0.10728	1.752895	45.74917	8806.1502
"1992"	45	49	1	4577.241	4690.522	4622.6	0.2	0.01	113.28	22.6562	61855.96	5927.3	0.09582	1.85611	54.15127	10423.449
"1993"	43	43	1	4577.549	4679.992	4618.5	0.2	0.01	102.44	20.4886	55937.98	5927.3	0.10596	1.764133	46.59415	8968.7979
"1994"	46	49	1	4577.57	4690.211	4622.6	0.2	0.01	112.64	22.5282	61506.49	5927.3	0.09637	1.850908	53.69159	10334.967
"2011"	53	39	1	4577.655	4671.613	4615.2	0.2	0.01	93.958	18.7916	51304.83	5927.3	0.11553	1.68569	41.01929	7895.7058
"1989"	41	38	4	4578.373	4674.336	4616.8	0.2	0.01	95.963	19.1926	52399.64	5927.3	0.11312	1.70479	42.30921	8143.999
"1977"	38	36	4	4578.796	4671.967	4616.1	0.2	0.01	93.171	18.6342	50875.09	5927.3	0.11651	1.678091	40.51764	7799.1453
"1978"	39	37	4	4579.454	4672.122	4616.5	0.2	0.01	92.668	18.5336	50600.43	5927.3	0.11714	1.673204	40.19841	7737.6962
"2015"	52	62	1	4579.882	4700.874	4628.3	0.2	0.01	120.99	24.1984	66066.47	5927.3	0.08972	1.916737	59.82037	11514.682
"2016"	55	39	1	4580.089	4669.222	4615.7	0.2	0.01	89.133	17.8266	48670.18	5927.3	0.12179	1.638168	37.98542	7311.723
"1993"	44	45	7	4580.121	4683.46	4621.5	0.2	0.01	103.34	20.6678	56427.23	5927.3	0.10504	1.772068	47.20048	9085.5095
"2011"	52	39	1	4580.915	4672.906	4617.7	0.2	0.01	91.991	18.3982	50230.77	5927.3	0.118	1.666589	39.77044	7655.3187
"2001"	48	45	1	4582.396	4683.677	4622.9	0.2	0.01	101.28	20.2562	55303.48	5927.3	0.10718	1.753749	45.8128	8818.3982
"1996"	42	40	4	4582.822	4676.166	4620.2	0.2	0.01	93.344	18.6688	50969.56	5927.3	0.11629	1.679767	40.62769	7820.3279
"1985"	43	44	1	4582.89	4681.271	4622.2	0.2	0.01	98.381	19.6762	53719.96	5927.3	0.11034	1.727349	43.88747	8447.7951
"1977"	38	37	4	4583.113	4670.326	4618	0.2	0.01	87.213	17.4426	47621.79	5927.3	0.12447	1.61861	36.80598	7084.6966
"2006"	49	43	1	4583.164	4680.56	4622.1	0.2	0.01	97.396	19.4792	53182.11	5927.3	0.11145	1.718221	43.24157	8323.4667
"1995"	46	50	1	4583.438	4691.859	4626.8	0.2	0.01	108.42	21.6842	59202.2	5927.3	0.10012	1.815912	50.7026	9759.6227
"2006"	37	36	1	4583.441	4670.427	4618.2	0.2	0.01	86.986	17.3972	47497.84	5927.3	0.12479	1.616272	36.66759	7058.0582
"2006"	50	42	1	4583.609	4678.674	4621.6	0.2	0.01	95.065	19.013	51909.29	5927.3	0.11419	1.696281	41.72937	8032.3872
"1993"	44	47	1	4584.152	4686.974	4625.3	0.2	0.01	102.82	20.5644	56144.92	5927.3	0.10557	1.767497	46.85022	9018.0873
"1993"	44	48	1	4584.247	4688.869	4626.1	0.2	0.01	104.62	20.9244	57127.8	5927.3	0.10376	1.78332	48.07452	9253.7513
"1994"	45	50	1	4584.546	4692.279	4627.6	0.2	0.01	107.73	21.5466	58826.53	5927.3	0.10076	1.810088	50.22223	9667.158
"2015"	51	61	1	4584.598	4701.104	4631.2	0.2	0.01	116.51	23.3012	63616.94	5927.3	0.09317	1.881917	56.49298	10874.199
"1993"	44	46	7	4584.604	4685.157	4624.8	0.2	0.01	100.55	20.1106	54905.96	5927.3	0.10795	1.747187	45.32616	8724.7256
"2006"	51	41	1	4584.945	4676.639	4621.6	0.2	0.01	91.694	18.3388	50068.59	5927.3	0.11838	1.663673	39.58332	7619.2988
"1997"	46	51	1	4585.066	4693.479	4628.4	0.2	0.01	108.41	21.6826	59197.83	5927.3	0.10013	1.815845	50.697	9758.5454
"2007"	37	35	1	4585.394	4673.013	4620.4	0.2	0.01	87.619	17.5238	47843.48	5927.3	0.12389	1.622778	37.05406	7132.4476
"1979"	39	38	4	4586.44	4671.256	4620.4	0.2	0.01	84.816	16.9632	46312.93	5927.3	0.12798	1.593644	35.35594	6805.582
"2001"	48	46	1	4586.501	4685.104	4625.9	0.2	0.01	98.603	19.7206	53841.18	5927.3	0.11009	1.729395	44.03361	8475.9251
"2002"	38	38	2	4586.815	4668.851	4619.6	0.2	0.01	82.036	16.4072	44794.94	5927.3	0.13232	1.563887	33.70558	6487.9075

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2009"	40	38	4	4586.937	4673.055	4621.4	0.2	0.01	86.118	17.2236	47023.87	5927.3	0.12605	1.607282	36.14048	6956.5953
"2015"	52	63	1	4587.125	4702.371	4633.2	0.2	0.01	115.25	23.0492	62928.93	5927.3	0.09419	1.871913	55.57304	10697.123
"2001"	30	23	2	4587.44	4703.34	4633.8	0.2	0.01	115.9	23.18	63286.04	5927.3	0.09366	1.877118	56.04973	10788.879
"2002"	37	37	1	4587.582	4667.866	4619.7	0.2	0.01	80.284	16.0568	43838.28	5927.3	0.13521	1.544669	32.68291	6291.0559
"1996"	42	41	4	4587.637	4676.907	4623.3	0.2	0.01	89.27	17.854	48744.99	5927.3	0.1216	1.639549	38.07018	7328.0393
"2019"	37	34	1	4587.653	4675.424	4622.8	0.2	0.01	87.771	17.5542	47926.48	5927.3	0.12368	1.624334	37.14711	7150.3601
"2019"	37	33	7	4588.74	4677.45	4624.2	0.2	0.01	88.71	17.742	48439.21	5927.3	0.12237	1.633892	37.72421	7261.4432
"2015"	50	60	1	4588.904	4701.198	4633.8	0.2	0.01	112.29	22.4588	61317.02	5927.3	0.09667	1.848077	53.44306	10287.128
"1994"	42	42	4	4588.981	4677.822	4624.5	0.2	0.01	88.841	17.7682	48510.74	5927.3	0.12219	1.635218	37.80502	7276.9986
"1993"	44	49	1	4589.038	4690.783	4629.7	0.2	0.01	101.75	20.349	55556.84	5927.3	0.10669	1.757908	46.12413	8878.3243
"2015"	53	65	1	4589.11	4703.538	4634.9	0.2	0.01	114.43	22.8856	62482.27	5927.3	0.09486	1.865365	54.97927	10582.829
"2019"	37	32	7	4589.138	4679.076	4625.1	0.2	0.01	89.938	17.9876	49109.75	5927.3	0.1207	1.646255	38.48465	7407.819
"1998"	48	47	1	4589.209	4686.537	4628.1	0.2	0.01	97.328	19.4656	53144.98	5927.3	0.11153	1.717588	43.19713	8314.9127
"1986"	43	45	7	4589.266	4682.735	4626.7	0.2	0.01	93.469	18.6938	51037.81	5927.3	0.11614	1.680975	40.70728	7835.6485
"2001"	49	44	1	4589.646	4681.921	4626.6	0.2	0.01	92.275	18.455	50385.84	5927.3	0.11764	1.669369	39.94973	7689.83
"2002"	37	38	1	4590.852	4665.591	4620.7	0.2	0.01	74.739	14.9478	40810.48	5927.3	0.14524	1.481305	29.53577	5685.2706
"2010"	51	62	1	4591.03	4702.607	4635.7	0.2	0.01	111.58	22.3154	60925.51	5927.3	0.09729	1.8422	52.93109	10188.58
"1993"	41	39	4	4591.318	4674.499	4624.6	0.2	0.01	83.181	16.6362	45420.15	5927.3	0.1305	1.57625	34.38122	6617.96
"1993"	42	43	1	4591.547	4678.903	4626.5	0.2	0.01	87.356	17.4712	47699.87	5927.3	0.12426	1.62008	36.89328	7101.4996
"2002"	29	21	2	4591.736	4705.529	4637.3	0.2	0.01	113.79	22.7586	62135.53	5927.3	0.09539	1.860252	54.52021	10494.466
"2002"	37	39	1	4592.152	4663.734	4620.8	0.2	0.01	71.582	14.3164	39086.64	5927.3	0.15165	1.443368	27.80538	5352.1917
"2010"	50	61	1	4592.158	4702.676	4636.4	0.2	0.01	110.52	22.1036	60347.25	5927.3	0.09822	1.833456	52.17876	10043.765
"2002"	36	37	1	4592.394	4664.323	4621.2	0.2	0.01	71.929	14.3858	39276.11	5927.3	0.15091	1.447608	27.99338	5388.3791
"2002"	29	22	2	4592.875	4706.035	4638.1	0.2	0.01	113.16	22.632	61789.89	5927.3	0.09593	1.855129	54.06423	10406.696
"2020"	56	38	1	4592.886	4666.641	4622.4	0.2	0.01	73.755	14.751	40273.18	5927.3	0.14718	1.469632	28.99162	5580.5282
"2015"	53	66	1	4592.932	4705.102	4637.8	0.2	0.01	112.17	22.434	61249.31	5927.3	0.09677	1.847063	53.35437	10270.056
"2011"	52	40	1	4593.057	4674.298	4625.6	0.2	0.01	81.241	16.2482	44360.84	5927.3	0.13362	1.555212	33.23985	6398.2605
"2000"	30	25	2	4593.127	4703.834	4637.4	0.2	0.01	110.71	22.1414	60450.45	5927.3	0.09805	1.835022	52.31269	10069.545
"2002"	38	39	2	4593.287	4667.648	4623	0.2	0.01	74.361	14.8722	40604.08	5927.3	0.14598	1.476837	29.32622	5644.9353
"1986"	43	46	7	4593.415	4684.436	4629.8	0.2	0.01	91.021	18.2042	49701.11	5927.3	0.11926	1.657033	39.16068	7537.9467
"2000"	31	26	2	4593.608	4700.84	4636.5	0.2	0.01	107.23	21.4464	58552.96	5927.3	0.10123	1.805826	49.87365	9600.0619
"1979"	39	39	4	4593.74	4670.618	4624.5	0.2	0.01	76.878	15.3756	41978.46	5927.3	0.1412	1.506223	30.73358	5915.8348
"1995"	45	51	1	4594.116	4694.069	4634.1	0.2	0.01	99.953	19.9906	54578.34	5927.3	0.1086	1.741746	44.92675	8647.8443
"2006"	50	43	1	4594.162	4680.043	4628.5	0.2	0.01	85.881	17.1762	46894.46	5927.3	0.1264	1.604814	35.99712	6929.0011
"1998"	47	51	1	4594.323	4692.878	4633.7	0.2	0.01	98.555	19.711	53814.97	5927.3	0.11014	1.728953	44.00199	8469.8395
"2002"	36	38	1	4594.442	4661.062	4621.1	0.2	0.01	66.62	13.324	36377.18	5927.3	0.16294	1.380724	25.17681	4846.2245
"2010"	52	64	1	4594.808	4703.97	4638.5	0.2	0.01	109.16	21.8324	59606.82	5927.3	0.09944	1.822147	51.22215	9859.6303
"1993"	41	40	4	4594.854	4674.858	4626.9	0.2	0.01	80.004	16.0008	43685.38	5927.3	0.13568	1.541564	32.52072	6259.8369
"2001"	49	45	1	4595.028	4683.29	4630.3	0.2	0.01	88.262	17.6524	48194.58	5927.3	0.12299	1.629343	37.4484	7208.3537
"2009"	40	39	4	4595.194	4672.861	4626.3	0.2	0.01	77.667	15.5334	42409.29	5927.3	0.13976	1.515261	31.18056	6001.8732
"1998"	36	39	1	4595.205	4658.55	4620.5	0.2	0.01	63.345	12.669	34588.9	5927.3	0.17136	1.337181	23.50351	4524.136
"1998"	36	40	1	4595.577	4656.473	4619.9	0.2	0.01	60.896	12.1792	33251.65	5927.3	0.17826	1.303387	22.28447	4289.4852

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2006"	51	42	1	4595.815	4678.015	4628.7	0.2	0.01	82.2	16.44	44884.49	5927.3	0.13206	1.565667	33.802	6506.4672
"2009"	28	19	2	4595.866	4707.438	4640.5	0.2	0.01	111.57	22.3144	60922.77	5927.3	0.09729	1.842159	52.92752	10187.894
"2001"	29	23	2	4595.879	4706.456	4640.1	0.2	0.01	110.58	22.1154	60379.47	5927.3	0.09817	1.833945	52.22055	10051.81
"1984"	42	44	1	4595.914	4680.157	4629.6	0.2	0.01	84.243	16.8486	46000.05	5927.3	0.12885	1.587583	35.01302	6739.5726
"2019"	36	36	1	4595.968	4668.294	4624.9	0.2	0.01	72.326	14.4652	39492.89	5927.3	0.15009	1.452437	28.20913	5429.9092
"1993"	41	41	4	4596.34	4675.429	4628	0.2	0.01	79.089	15.8178	43185.76	5927.3	0.13725	1.531347	31.99313	6158.2824
"1992"	43	47	7	4596.541	4686.545	4632.5	0.2	0.01	90.004	18.0008	49145.78	5927.3	0.12061	1.646915	38.5257	7415.7215
"2000"	30	26	2	4596.647	4703.923	4639.6	0.2	0.01	107.28	21.4552	58576.99	5927.3	0.10119	1.806201	49.90423	9605.9466
"2000"	31	27	2	4596.926	4700.737	4638.5	0.2	0.01	103.81	20.7622	56684.96	5927.3	0.10457	1.776222	47.52124	9147.2504
"1998"	46	52	1	4597.398	4695.1	4636.5	0.2	0.01	97.702	19.5404	53349.2	5927.3	0.1111	1.721066	43.44178	8362.0062
"2010"	52	65	1	4597.723	4705.625	4640.9	0.2	0.01	107.9	21.5804	58918.81	5927.3	0.1006	1.811522	50.34004	9689.8362
"2010"	51	63	1	4597.94	4704.231	4640.5	0.2	0.01	106.29	21.2582	58039.14	5927.3	0.10213	1.79777	49.22175	9474.5785
"1999"	31	28	2	4597.966	4700.441	4639	0.2	0.01	102.47	20.495	55955.45	5927.3	0.10593	1.764418	46.61575	8972.9551
"1992"	44	50	1	4598.093	4692.712	4635.9	0.2	0.01	94.619	18.9238	51665.76	5927.3	0.11472	1.692027	41.44266	7977.199
"2003"	28	20	2	4598.25	4708.14	4642.2	0.2	0.01	109.89	21.978	60004.34	5927.3	0.09878	1.828235	51.73479	9958.3066
"2002"	37	40	1	4598.58	4662.278	4624.1	0.2	0.01	63.698	12.7396	34781.66	5927.3	0.17042	1.341963	23.6815	4558.3969
"2001"	49	46	1	4598.628	4684.654	4633	0.2	0.01	86.026	17.2052	46973.64	5927.3	0.12618	1.606325	36.0848	6945.878
"2010"	50	62	1	4599.033	4704.272	4641.1	0.2	0.01	105.24	21.0478	57464.7	5927.3	0.10315	1.788686	48.49729	9335.1283
"2000"	30	27	2	4599.135	4703.838	4641	0.2	0.01	104.7	20.9406	57172.03	5927.3	0.10368	1.784026	48.12993	9264.4172
"2010"	49	59	1	4599.311	4701.193	4640.1	0.2	0.01	101.88	20.3764	55631.65	5927.3	0.10655	1.759133	46.21622	8896.0511
"2001"	29	24	2	4599.523	4706.799	4642.4	0.2	0.01	107.28	21.4552	58576.99	5927.3	0.10119	1.806201	49.90423	9605.9466
"1992"	41	42	4	4599.815	4676.233	4630.4	0.2	0.01	76.418	15.2836	41727.28	5927.3	0.14205	1.500916	30.47427	5865.9192
"2002"	38	40	2	4599.895	4666.842	4626.7	0.2	0.01	66.947	13.3894	36555.74	5927.3	0.16214	1.384972	25.34658	4878.9036
"2001"	47	52	1	4599.91	4694.346	4637.7	0.2	0.01	94.436	18.8872	51565.83	5927.3	0.11495	1.690277	41.32526	7954.6015
"2015"	52	66	1	4599.927	4707.267	4642.9	0.2	0.01	107.34	21.468	58611.93	5927.3	0.10113	1.806746	49.94871	9614.5088
"2009"	40	40	4	4599.99	4672.935	4629.2	0.2	0.01	72.945	14.589	39830.89	5927.3	0.14881	1.459922	28.54695	5494.9356
"2007"	35	39	1	4600.073	4651.349	4620.6	0.2	0.01	51.276	10.2552	27998.75	5927.3	0.2117	1.159383	17.76231	3419.0249
"1980"	39	40	4	4600.284	4670.314	4628.3	0.2	0.01	70.03	14.006	38239.18	5927.3	0.15501	1.424184	26.9712	5191.6222
"2010"	51	64	1	4600.517	4705.956	4642.7	0.2	0.01	105.44	21.0878	57573.91	5927.3	0.10295	1.79042	48.63467	9361.5718
"2019"	36	35	7	4601.112	4672.371	4629.6	0.2	0.01	71.259	14.2518	38910.26	5927.3	0.15233	1.439405	27.63087	5318.6013
"2006"	50	45	1	4601.329	4682.779	4633.9	0.2	0.01	81.45	16.29	44474.96	5927.3	0.13327	1.5575	33.36202	6421.7762
"1984"	42	45	1	4601.356	4681.604	4633.5	0.2	0.01	80.248	16.0496	43818.62	5927.3	0.13527	1.544271	32.66204	6287.0383
"1991"	43	48	1	4601.359	4688.78	4636.3	0.2	0.01	87.421	17.4842	47735.36	5927.3	0.12417	1.620747	36.93299	7109.143
"2003"	28	21	2	4601.414	4708.762	4644.4	0.2	0.01	107.35	21.4696	58616.3	5927.3	0.10112	1.806814	49.95427	9615.5794
"2010"	49	60	1	4601.543	4702.622	4642	0.2	0.01	101.08	20.2158	55193.18	5927.3	0.10739	1.751932	45.67755	8792.3638
"2000"	30	28	2	4601.748	4703.556	4642.5	0.2	0.01	101.81	20.3616	55591.24	5927.3	0.10662	1.758472	46.16647	8886.4742
"2020"	56	39	1	4601.756	4667.839	4628.2	0.2	0.01	66.083	13.2166	36083.96	5927.3	0.16426	1.373709	24.89907	4792.7629
"1999"	31	29	2	4602.073	4699.917	4641.2	0.2	0.01	97.844	19.5688	53426.74	5927.3	0.11094	1.722383	43.53483	8379.9164
"2009"	40	41	4	4602.074	4673.306	4630.6	0.2	0.01	71.232	14.2464	38895.52	5927.3	0.15239	1.439073	27.61631	5315.7975
"2006"	50	44	1	4602.227	4681.432	4633.9	0.2	0.01	79.205	15.841	43249.1	5927.3	0.13705	1.532648	32.05981	6171.1176
"2001"	29	25	2	4602.292	4707.042	4644.2	0.2	0.01	104.75	20.95	57197.69	5927.3	0.10363	1.784436	48.1621	9270.6084
"2010"	51	65	1	4602.428	4707.705	4644.5	0.2	0.01	105.28	21.0554	57485.45	5927.3	0.10311	1.789016	48.52338	9340.1501

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2009"	27	18	1	4602.669	4709.991	4645.6	0.2	0.01	107.32	21.4644	58602.1	5927.3	0.10115	1.806593	49.9362	9612.1004
"1999"	32	28	2	4602.688	4697.374	4640.6	0.2	0.01	94.686	18.9372	51702.34	5927.3	0.11464	1.692667	41.48567	7985.4792
"1992"	42	46	1	4602.803	4683.341	4635	0.2	0.01	80.538	16.1076	43976.97	5927.3	0.13478	1.547478	32.83034	6319.4336
"1997"	45	52	1	4603.025	4695.892	4640.2	0.2	0.01	92.867	18.5734	50709.1	5927.3	0.11689	1.675141	40.32458	7761.9822
"2019"	35	37	7	4603.129	4658.574	4625.3	0.2	0.01	55.445	11.089	30275.19	5927.3	0.19578	1.224088	19.67027	3786.2832
"1992"	41	43	1	4603.169	4677.262	4632.8	0.2	0.01	74.093	14.8186	40457.74	5927.3	0.14651	1.473657	29.17804	5616.4125
"1994"	35	40	1	4603.673	4648.866	4621.8	0.2	0.01	45.193	9.0386	24677.19	5927.3	0.24019	1.058524	15.11263	2908.9935
"2010"	51	66	1	4603.682	4709.437	4646	0.2	0.01	105.76	21.151	57746.46	5927.3	0.10264	1.793152	48.85206	9403.4175
"2010"	49	61	1	4603.705	4704.149	4643.9	0.2	0.01	100.44	20.0888	54846.44	5927.3	0.10807	1.746201	45.25349	8710.7372
"2005"	50	63	1	4603.818	4706.013	4644.7	0.2	0.01	102.19	20.439	55802.56	5927.3	0.10622	1.761926	46.42692	8936.6077
"2011"	52	41	1	4603.933	4675.759	4632.7	0.2	0.01	71.826	14.3652	39219.87	5927.3	0.15113	1.446351	27.93752	5377.6267
"2019"	36	34	7	4604.013	4676.176	4632.9	0.2	0.01	72.163	14.4326	39403.88	5927.3	0.15042	1.450457	28.12046	5412.8413
"1992"	40	46	1	4604.075	4679.37	4634.2	0.2	0.01	75.295	15.059	41114.08	5927.3	0.14417	1.487841	29.84516	5744.8236
"2000"	29	26	2	4604.108	4707.175	4645.3	0.2	0.01	103.07	20.6134	56278.7	5927.3	0.10532	1.769666	47.01606	9050.0111
"1997"	36	41	1	4604.776	4654.382	4624.6	0.2	0.01	49.606	9.9212	27086.86	5927.3	0.21883	1.132443	17.01963	3276.0685
"1992"	41	45	1	4604.809	4679.923	4634.9	0.2	0.01	75.114	15.0228	41015.25	5927.3	0.14452	1.485718	29.74429	5725.4075
"2015"	52	67	1	4604.847	4708.889	4646.5	0.2	0.01	104.04	20.8084	56811.09	5927.3	0.10433	1.778249	47.67855	9177.5318
"2002"	28	22	2	4604.875	4709.306	4646.6	0.2	0.01	104.43	20.8862	57023.5	5927.3	0.10395	1.781653	47.94397	9228.6217
"1998"	33	31	2	4605	4691.72	4639.7	0.2	0.01	86.72	17.344	47352.59	5927.3	0.12517	1.613526	36.50571	7026.8979
"1980"	39	41	4	4605.379	4670.404	4631.4	0.2	0.01	65.025	13.005	35506.25	5927.3	0.16694	1.359746	24.35573	4688.1767
"1992"	41	46	1	4605.532	4681.634	4636	0.2	0.01	76.102	15.2204	41554.74	5927.3	0.14264	1.497254	30.29667	5831.7346
"2001"	46	53	1	4605.671	4696.745	4642.1	0.2	0.01	91.074	18.2148	49730.05	5927.3	0.11919	1.657558	39.19389	7544.3398
"2009"	27	19	1	4605.88	4710.809	4647.9	0.2	0.01	104.93	20.9858	57295.43	5927.3	0.10345	1.785994	48.28468	9294.2039
"1992"	40	42	4	4606.244	4673.97	4633.3	0.2	0.01	67.726	13.5452	36981.11	5927.3	0.16028	1.395023	25.75299	4957.1329
"2005"	50	64	1	4606.277	4707.853	4646.9	0.2	0.01	101.58	20.3152	55464.56	5927.3	0.10687	1.756395	46.01063	8856.4777
"1992"	41	44	1	4606.352	4678.495	4635.2	0.2	0.01	72.143	14.4286	39392.96	5927.3	0.15047	1.450214	28.10959	5410.7486
"1999"	32	29	2	4606.647	4696.832	4642.7	0.2	0.01	90.185	18.037	49244.62	5927.3	0.12036	1.648724	38.63839	7437.4119
"2016"	55	40	1	4606.812	4670.413	4632.3	0.2	0.01	63.601	12.7202	34728.69	5927.3	0.17068	1.340651	23.63254	4548.9714
"2006"	51	43	1	4606.855	4679.426	4635.9	0.2	0.01	72.571	14.5142	39626.67	5927.3	0.14958	1.455406	28.34264	5455.6069
"2002"	37	41	1	4606.985	4661.24	4628.7	0.2	0.01	54.255	10.851	29625.4	5927.3	0.20008	1.205987	19.11767	3679.9153
"1991"	43	49	1	4607.095	4690.917	4640.6	0.2	0.01	83.822	16.7644	45770.16	5927.3	0.1295	1.583106	34.76197	6691.2492
"1992"	44	51	1	4607.279	4694.728	4642.3	0.2	0.01	87.449	17.4898	47750.65	5927.3	0.12413	1.621035	36.9501	7112.4366
"1992"	40	45	1	4607.468	4677.665	4635.5	0.2	0.01	70.197	14.0394	38330.37	5927.3	0.15464	1.426266	27.06043	5208.7991
"2006"	51	44	1	4607.618	4680.822	4636.9	0.2	0.01	73.204	14.6408	39972.31	5927.3	0.14829	1.463037	28.68882	5522.2424
"2002"	28	23	2	4607.822	4709.788	4648.6	0.2	0.01	101.97	20.3932	55677.51	5927.3	0.10646	1.759883	46.27273	8906.9276
"2002"	38	41	4	4607.846	4666.486	4631.3	0.2	0.01	58.64	11.728	32019.79	5927.3	0.18511	1.271271	21.18595	4078.0343
"2011"	26	17	1	4607.948	4712.56	4649.8	0.2	0.01	104.61	20.9224	57122.34	5927.3	0.10377	1.783233	48.06768	9252.4349
"2010"	50	65	1	4608	4709.733	4648.7	0.2	0.01	101.73	20.3466	55550.29	5927.3	0.1067	1.757801	46.11606	8876.7723
"1999"	30	29	2	4608.014	4703.069	4646	0.2	0.01	95.055	19.011	51903.83	5927.3	0.1142	1.696186	41.72293	8031.148
"2006"	48	57	1	4608.373	4699.908	4645	0.2	0.01	91.535	18.307	49981.77	5927.3	0.11859	1.662108	39.48329	7600.0452
"1992"	42	47	7	4608.402	4685.576	4639.3	0.2	0.01	77.174	15.4348	42140.09	5927.3	0.14066	1.509623	30.90095	5948.0503
"2005"	49	62	1	4608.756	4705.822	4647.6	0.2	0.01	97.066	19.4132	53001.92	5927.3	0.11183	1.715144	43.02609	8281.9897

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2011"	54	40	1	4608.863	4671.681	4634	0.2	0.01	62.818	12.5636	34301.14	5927.3	0.1728	1.33	23.23886	4473.1926
"2001"	46	54	1	4608.878	4698.329	4644.7	0.2	0.01	89.451	17.8902	48843.82	5927.3	0.12135	1.64137	38.1823	7349.6198
"2015"	51	67	1	4609.097	4711.15	4649.9	0.2	0.01	102.05	20.4106	55725.02	5927.3	0.10637	1.76066	46.33128	8918.1985
"2011"	25	15	7	4609.169	4713.933	4651.1	0.2	0.01	104.76	20.9528	57205.33	5927.3	0.10361	1.784558	48.17168	9272.4529
"2000"	29	27	2	4609.177	4707.164	4648.4	0.2	0.01	97.987	19.5974	53504.82	5927.3	0.11078	1.723708	43.62862	8397.9693
"1992"	40	44	1	4609.46	4676.174	4636.1	0.2	0.01	66.714	13.3428	36428.51	5927.3	0.16271	1.381947	25.22556	4855.6088
"1992"	39	47	1	4609.524	4678.547	4637.1	0.2	0.01	69.023	13.8046	37689.32	5927.3	0.15727	1.411541	26.43579	5088.563
"2009"	27	20	1	4609.591	4711.559	4650.4	0.2	0.01	101.97	20.3936	55678.61	5927.3	0.10646	1.759901	46.27407	8907.1866
"2011"	53	40	1	4609.596	4673.005	4635	0.2	0.01	63.409	12.6818	34623.85	5927.3	0.17119	1.338049	23.53574	4530.3394
"1981"	39	42	4	4609.608	4670.873	4634.1	0.2	0.01	61.265	12.253	33453.14	5927.3	0.17718	1.308549	22.46638	4324.5006
"1998"	45	53	2	4609.84	4697.712	4645	0.2	0.01	87.872	17.5744	47981.63	5927.3	0.12353	1.625366	37.209	7162.2732
"1992"	40	47	1	4609.95	4681.571	4638.6	0.2	0.01	71.621	14.3242	39107.93	5927.3	0.15156	1.443845	27.82648	5356.2536
"1986"	40	43	1	4609.955	4674.931	4635.9	0.2	0.01	64.976	12.9952	35479.5	5927.3	0.16706	1.359095	24.33069	4683.3569
"1999"	31	30	2	4610.204	4699.129	4645.8	0.2	0.01	88.925	17.785	48556.61	5927.3	0.12207	1.636067	37.85688	7286.9806
"2001"	28	24	2	4610.271	4710.19	4650.2	0.2	0.01	99.919	19.9838	54559.77	5927.3	0.10864	1.741437	44.90416	8643.4964
"1999"	32	30	2	4610.42	4696.009	4644.7	0.2	0.01	85.589	17.1178	46735.02	5927.3	0.12683	1.601764	35.82083	6895.0677
"1992"	39	46	1	4610.779	4676.414	4637	0.2	0.01	65.635	13.127	35839.34	5927.3	0.16539	1.367819	24.66837	4748.3564
"1999"	33	29	2	4611.798	4693.651	4644.5	0.2	0.01	81.853	16.3706	44695.01	5927.3	0.13262	1.561897	33.59813	6467.2244
"2010"	48	58	1	4611.857	4701.206	4647.6	0.2	0.01	89.349	17.8698	48788.13	5927.3	0.12149	1.640344	38.1191	7337.4551
"2009"	26	18	1	4611.971	4713.517	4652.6	0.2	0.01	101.55	20.3092	55448.18	5927.3	0.1069	1.756126	45.9905	8852.602
"1992"	39	45	1	4611.976	4674.564	4637	0.2	0.01	62.588	12.5176	34175.55	5927.3	0.17344	1.326851	23.12375	4451.0363
"2001"	45	54	2	4612.012	4699.441	4647	0.2	0.01	87.429	17.4858	47739.73	5927.3	0.12416	1.62083	36.93787	7110.0839
"2001"	46	55	1	4612.047	4699.807	4647.2	0.2	0.01	87.76	17.552	47920.47	5927.3	0.12369	1.624221	37.14038	7149.0632
"2010"	50	66	1	4612.39	4711.629	4652.1	0.2	0.01	99.239	19.8478	54188.46	5927.3	0.10938	1.735233	44.45342	8556.7344
"2011"	25	16	7	4612.625	4715.074	4653.6	0.2	0.01	102.45	20.4898	55941.25	5927.3	0.10596	1.764187	46.5982	8969.5773
"1992"	41	47	7	4612.703	4683.939	4641.2	0.2	0.01	71.236	14.2472	38897.71	5927.3	0.15238	1.439122	27.61846	5316.2128
"1981"	39	43	1	4612.754	4671.714	4636.3	0.2	0.01	58.96	11.792	32194.52	5927.3	0.18411	1.275886	21.34035	4107.7526
"2005"	49	63	1	4612.817	4707.67	4650.8	0.2	0.01	94.853	18.9706	51793.53	5927.3	0.11444	1.694261	41.59298	8006.134
"1996"	36	42	3	4612.962	4652.466	4628.8	0.2	0.01	39.504	7.9008	21570.76	5927.3	0.27478	0.958716	12.74941	2454.1046
"2011"	52	42	1	4613.494	4677.225	4639	0.2	0.01	63.731	12.7462	34799.68	5927.3	0.17033	1.342409	23.69817	4561.6054
"2003"	27	21	1	4613.744	4712.242	4653.1	0.2	0.01	98.498	19.6996	53783.85	5927.3	0.11021	1.728428	43.96446	8462.6154
"1992"	43	50	1	4613.815	4693.159	4645.6	0.2	0.01	79.344	15.8688	43325	5927.3	0.13681	1.534205	32.13979	6186.5128
"2002"	38	42	4	4614.016	4666.637	4635.1	0.2	0.01	52.621	10.5242	28733.17	5927.3	0.20629	1.180655	18.36934	3535.87
"2001"	28	25	2	4614.051	4710.51	4652.6	0.2	0.01	96.459	19.2918	52670.47	5927.3	0.11254	1.70946	42.63094	8205.9285
"2010"	48	59	1	4614.243	4702.554	4649.6	0.2	0.01	88.311	17.6622	48221.34	5927.3	0.12292	1.629841	37.47852	7214.1522
"2009"	39	44	1	4614.369	4672.958	4637.8	0.2	0.01	58.589	11.7178	31991.94	5927.3	0.18528	1.270534	21.16139	4073.3063
"1998"	33	30	2	4614.484	4692.812	4645.8	0.2	0.01	78.328	15.6656	42770.22	5927.3	0.13859	1.52277	31.55716	6074.3634
"2005"	49	64	1	4614.723	4709.664	4652.7	0.2	0.01	94.941	18.9882	51841.58	5927.3	0.11434	1.6951	41.64957	8017.0271
"2006"	52	43	1	4614.772	4678.659	4640.3	0.2	0.01	63.887	12.7774	34884.86	5927.3	0.16991	1.344514	23.77704	4576.7858
"1996"	29	28	2	4614.789	4706.969	4651.7	0.2	0.01	92.18	18.436	50333.97	5927.3	0.11776	1.66844	39.88972	7678.2784
"1996"	44	52	1	4615.121	4696.785	4647.8	0.2	0.01	81.664	16.3328	44591.81	5927.3	0.13292	1.559837	33.48731	6445.8929
"1992"	39	48	1	4615.217	4681.909	4641.9	0.2	0.01	66.692	13.3384	36416.5	5927.3	0.16276	1.381661	25.21415	4853.4118

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2001"	45	55	2	4615.324	4701.036	4649.6	0.2	0.01	85.712	17.1424	46802.18	5927.3	0.12665	1.60305	35.89505	6909.3529
"2005"	48	60	1	4615.538	4703.972	4650.9	0.2	0.01	88.434	17.6868	48288.5	5927.3	0.12275	1.631092	37.55419	7228.7165
"1997"	30	30	2	4615.787	4702.339	4650.4	0.2	0.01	86.552	17.3104	47260.85	5927.3	0.12542	1.611788	36.40363	7007.2481
"1997"	31	31	2	4615.816	4698.083	4648.7	0.2	0.01	82.267	16.4534	44921.07	5927.3	0.13195	1.566394	33.84143	6514.0561
"1998"	32	31	2	4615.927	4694.919	4647.5	0.2	0.01	78.992	15.7984	43132.79	5927.3	0.13742	1.530258	31.93742	6147.5583
"2011"	25	17	7	4616.252	4716.177	4656.2	0.2	0.01	99.925	19.985	54563.05	5927.3	0.10863	1.741492	44.90815	8644.2636
"1995"	36	43	3	4616.677	4651.896	4630.8	0.2	0.01	35.219	7.0438	19230.98	5927.3	0.30822	0.884123	10.98853	2115.1559
"1992"	38	48	1	4616.728	4677.501	4641	0.2	0.01	60.773	12.1546	33184.49	5927.3	0.17862	1.301661	22.22397	4277.8403
"2015"	51	68	1	4616.746	4712.854	4655.2	0.2	0.01	96.108	19.2216	52478.81	5927.3	0.11295	1.706158	42.40315	8162.0827
"2002"	38	43	1	4616.843	4667.255	4637	0.2	0.01	50.412	10.0824	27526.97	5927.3	0.21533	1.145519	17.37657	3344.7741
"2001"	47	56	1	4616.931	4699.932	4650.1	0.2	0.01	83.001	16.6002	45321.87	5927.3	0.13078	1.574317	34.27463	6597.4418
"1998"	37	42	1	4616.977	4660.711	4634.5	0.2	0.01	43.734	8.7468	23880.51	5927.3	0.24821	1.033294	14.49815	2790.7145
"2009"	26	19	1	4617.011	4714.409	4656	0.2	0.01	97.398	19.4796	53183.2	5927.3	0.11145	1.71824	43.24287	8323.7183
"2003"	27	22	1	4617.645	4712.853	4655.7	0.2	0.01	95.208	19.0416	51987.38	5927.3	0.11401	1.697641	41.82147	8050.1165
"1992"	42	48	1	4617.795	4688.252	4646	0.2	0.01	70.457	14.0914	38472.34	5927.3	0.15407	1.429499	27.19962	5235.5901
"1992"	38	47	1	4617.963	4674.713	4640.7	0.2	0.01	56.75	11.35	30987.77	5927.3	0.19128	1.243606	20.28369	3904.3601
"2005"	48	61	1	4618.048	4705.505	4653	0.2	0.01	87.457	17.4914	47755.02	5927.3	0.12412	1.621117	36.95499	7113.3778
"2011"	24	15	1	4618.135	4717.534	4657.9	0.2	0.01	99.399	19.8798	54275.83	5927.3	0.10921	1.736696	44.55931	8577.1154
"1998"	34	31	2	4618.155	4688.522	4646.3	0.2	0.01	70.367	14.0734	38423.2	5927.3	0.15426	1.428381	27.1514	5226.3096
"1992"	40	48	1	4618.227	4685.271	4645	0.2	0.01	67.044	13.4088	36608.71	5927.3	0.16191	1.386229	25.39704	4888.6155
"2010"	50	67	1	4618.415	4713.498	4656.4	0.2	0.01	95.083	19.0166	51919.12	5927.3	0.11416	1.696452	41.74096	8034.618
"1982"	38	44	1	4618.496	4668.412	4638.5	0.2	0.01	49.916	9.9832	27256.13	5927.3	0.21747	1.137488	17.15658	3302.4302
"1995"	36	44	3	4618.683	4652.558	4632.2	0.2	0.01	33.875	6.775	18497.11	5927.3	0.32045	0.862224	10.42406	2006.5021
"1998"	37	43	1	4619.034	4660.925	4635.8	0.2	0.01	41.891	8.3782	22874.16	5927.3	0.25913	1.000987	13.73129	2643.103
"2001"	46	56	1	4619.043	4701.215	4651.9	0.2	0.01	82.172	16.4344	44869.2	5927.3	0.1321	1.565363	33.78553	6503.2969
"1995"	28	26	2	4619.055	4710.759	4655.7	0.2	0.01	91.704	18.3408	50074.05	5927.3	0.11837	1.663771	39.58961	7620.5104
"1997"	44	53	2	4619.177	4698.796	4651	0.2	0.01	79.619	15.9238	43475.16	5927.3	0.13634	1.537278	32.29828	6217.0195
"1992"	38	46	1	4619.251	4672.3	4640.5	0.2	0.01	53.049	10.6098	28966.88	5927.3	0.20462	1.187344	18.56419	3573.377
"1992"	39	49	3	4619.728	4687.316	4646.8	0.2	0.01	67.588	13.5176	36905.75	5927.3	0.16061	1.39325	25.6808	4943.2357
"1997"	31	32	2	4619.768	4696.765	4650.6	0.2	0.01	76.997	15.3994	42043.44	5927.3	0.14098	1.507591	30.80082	5928.7773
"1996"	29	29	2	4620.086	4706.55	4654.7	0.2	0.01	86.464	17.2928	47212.8	5927.3	0.12554	1.610876	36.3502	6996.9648
"1997"	37	44	1	4620.325	4661.894	4637	0.2	0.01	41.569	8.3138	22698.34	5927.3	0.26113	0.995304	13.59821	2617.4878
"1993"	38	45	1	4620.425	4670.146	4640.3	0.2	0.01	49.721	9.9442	27149.65	5927.3	0.21832	1.134317	17.07039	3285.8386
"2002"	27	23	1	4620.443	4713.398	4657.6	0.2	0.01	92.955	18.591	50757.15	5927.3	0.11678	1.675996	40.38042	7772.7322
"1997"	30	31	2	4620.531	4701.309	4652.8	0.2	0.01	80.778	16.1556	44108.02	5927.3	0.13438	1.550125	32.9699	6346.2975
"2010"	25	18	7	4620.669	4717.236	4659.3	0.2	0.01	96.567	19.3134	52729.44	5927.3	0.11241	1.710473	42.70113	8219.4397
"1992"	38	49	1	4620.855	4682.993	4645.7	0.2	0.01	62.138	12.4276	33929.83	5927.3	0.17469	1.320661	22.89925	4407.8228
"1998"	32	32	2	4620.936	4693.706	4650	0.2	0.01	72.77	14.554	39735.33	5927.3	0.14917	1.457811	28.45127	5476.5181
"2005"	49	65	1	4620.971	4711.795	4657.3	0.2	0.01	90.824	18.1648	49593.54	5927.3	0.11952	1.655081	39.03733	7514.2041
"2008"	26	20	1	4621.18	4715.242	4658.8	0.2	0.01	94.062	18.8124	51361.61	5927.3	0.1154	1.686689	41.08578	7908.504
"2006"	47	58	1	4621.311	4702.557	4653.8	0.2	0.01	81.246	16.2492	44363.57	5927.3	0.13361	1.555267	33.24277	6398.8226
"1992"	43	51	1	4621.525	4695.491	4651.1	0.2	0.01	73.966	14.7932	40388.39	5927.3	0.14676	1.472147	29.10794	5602.9178

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"1998"	44	54	2	4621.631	4700.682	4653.3	0.2	0.01	79.051	15.8102	43165.01	5927.3	0.13732	1.530921	31.9713	6154.0802
"2005"	48	62	1	4621.772	4707.222	4656	0.2	0.01	85.45	17.09	46659.12	5927.3	0.12703	1.600308	35.73705	6878.9396
"2001"	45	56	2	4621.97	4702.528	4654.2	0.2	0.01	80.558	16.1116	43987.89	5927.3	0.13475	1.547699	32.84196	6321.6704
"2006"	47	57	1	4622.03	4701.252	4653.7	0.2	0.01	79.222	15.8444	43258.38	5927.3	0.13702	1.532839	32.06959	6172.9996
"1995"	43	52	1	4623.061	4697.814	4653	0.2	0.01	74.753	14.9506	40818.13	5927.3	0.14521	1.48147	29.54354	5686.7668
"2010"	24	16	1	4623.086	4718.761	4661.4	0.2	0.01	95.675	19.135	52242.38	5927.3	0.11346	1.702069	42.12287	8108.132
"1996"	28	27	2	4623.271	4710.907	4658.3	0.2	0.01	87.636	17.5272	47852.76	5927.3	0.12387	1.622952	37.06446	7134.45
"1998"	32	33	2	4623.345	4691.405	4650.6	0.2	0.01	68.06	13.612	37163.48	5927.3	0.15949	1.399302	25.92809	4990.8373
"1998"	34	32	2	4623.38	4686.891	4648.8	0.2	0.01	63.511	12.7022	34679.55	5927.3	0.17092	1.339432	23.58714	4540.2336
"2005"	47	59	1	4623.507	4703.85	4655.6	0.2	0.01	80.343	16.0686	43870.49	5927.3	0.13511	1.545323	32.71713	6297.6427
"1992"	40	49	7	4623.561	4689.558	4650	0.2	0.01	65.997	13.1994	36037	5927.3	0.16448	1.372581	24.85471	4784.2247
"1992"	42	49	1	4623.85	4690.926	4650.7	0.2	0.01	67.076	13.4152	36626.18	5927.3	0.16183	1.386643	25.41369	4891.8213
"1993"	36	45	3	4623.854	4653.743	4635.8	0.2	0.01	29.889	5.9778	16320.59	5927.3	0.36318	0.809985	8.638618	1662.8271
"2011"	54	41	1	4624	4673.219	4643.7	0.2	0.01	49.219	9.8438	26875.54	5927.3	0.22055	1.126117	16.84923	3243.2692
"2001"	46	57	1	4624.073	4702.573	4655.5	0.2	0.01	78.5	15.7	42864.14	5927.3	0.13828	1.524715	31.65547	6093.2874
"1992"	39	50	3	4624.152	4691.915	4651.3	0.2	0.01	67.763	13.5526	37001.31	5927.3	0.16019	1.395498	25.77237	4960.8618
"1993"	37	45	1	4624.246	4663.572	4640	0.2	0.01	39.326	7.8652	21473.57	5927.3	0.27603	0.95556	12.67651	2440.0717
"1992"	37	48	1	4624.416	4673.391	4644	0.2	0.01	48.975	9.795	26742.31	5927.3	0.22165	1.122113	16.74213	3222.6522
"2011"	53	41	1	4624.655	4674.604	4644.6	0.2	0.01	49.949	9.9898	27274.15	5927.3	0.21732	1.138024	17.17119	3305.2411
"2015"	50	68	1	4624.702	4715.266	4660.9	0.2	0.01	90.564	18.1128	49451.57	5927.3	0.11986	1.652499	38.8748	7482.9177
"1992"	42	51	1	4624.765	4696.261	4653.4	0.2	0.01	71.496	14.2992	39039.68	5927.3	0.15183	1.442314	27.75887	5343.2392
"2005"	48	63	1	4624.772	4709.171	4658.5	0.2	0.01	84.399	16.8798	46085.23	5927.3	0.12862	1.589237	35.10624	6757.5164
"2001"	44	55	2	4624.786	4702.418	4655.8	0.2	0.01	77.632	15.5264	42390.18	5927.3	0.13983	1.514861	31.16068	5998.0452
"1992"	40	50	2	4624.885	4693.279	4652.2	0.2	0.01	68.394	13.6788	37345.86	5927.3	0.15871	1.403564	26.1037	5024.6397
"1992"	41	48	1	4625.123	4687.121	4649.9	0.2	0.01	61.998	12.3996	33853.39	5927.3	0.17509	1.318728	22.8296	4394.4152
"1998"	33	32	2	4625.278	4690.222	4651.3	0.2	0.01	64.944	12.9888	35462.02	5927.3	0.16715	1.358669	24.31434	4680.2104
"2011"	53	42	1	4625.318	4676.18	4645.7	0.2	0.01	50.862	10.1724	27772.69	5927.3	0.21342	1.152759	17.57707	3383.3682
"2002"	27	24	1	4625.322	4713.901	4660.8	0.2	0.01	88.579	17.7158	48367.68	5927.3	0.12255	1.632564	37.64347	7245.902
"1997"	29	30	2	4625.368	4705.867	4657.6	0.2	0.01	80.499	16.0998	43955.67	5927.3	0.13485	1.547048	32.80768	6315.0729
"2008"	26	21	1	4625.443	4716.02	4661.7	0.2	0.01	90.577	18.1154	49458.67	5927.3	0.11984	1.652629	38.88292	7484.4807
"1992"	42	50	1	4625.537	4693.6	4652.8	0.2	0.01	68.063	13.6126	37165.12	5927.3	0.15949	1.399341	25.92967	4991.1405
"2006"	46	58	1	4625.762	4703.844	4657	0.2	0.01	78.082	15.6164	42635.9	5927.3	0.13902	1.519982	31.41678	6047.3416
"1992"	40	51	2	4625.851	4697.084	4654.3	0.2	0.01	71.233	14.2466	38896.07	5927.3	0.15239	1.439086	27.61685	5315.9013
"2010"	24	17	1	4625.852	4719.962	4663.5	0.2	0.01	94.11	18.822	51387.82	5927.3	0.11534	1.687151	41.11648	7914.4139
"2008"	25	19	7	4625.958	4718.231	4662.9	0.2	0.01	92.273	18.4546	50384.75	5927.3	0.11764	1.66935	39.94847	7689.5867
"2001"	45	57	2	4626.172	4703.903	4657.3	0.2	0.01	77.731	15.5462	42444.24	5927.3	0.13965	1.51599	31.21694	6008.8755
"1992"	41	51	1	4626.251	4696.833	4654.5	0.2	0.01	70.582	14.1164	38540.6	5927.3	0.15379	1.431049	27.26664	5248.4913
"1992"	37	47	3	4626.357	4669.454	4643.6	0.2	0.01	43.097	8.6194	23532.69	5927.3	0.25188	1.022177	14.23201	2739.4866
"1992"	41	50	1	4626.475	4693.793	4653.4	0.2	0.01	67.318	13.4636	36758.32	5927.3	0.16125	1.389771	25.53979	4916.0939
"1996"	43	53	2	4626.48	4700.031	4655.9	0.2	0.01	73.551	14.7102	40161.79	5927.3	0.14759	1.467195	28.87935	5558.9181
"1993"	42	52	1	4626.749	4698.867	4655.6	0.2	0.01	72.118	14.4236	39379.31	5927.3	0.15052	1.44991	28.096	5408.1333
"2015"	50	69	1	4627.166	4716.856	4663	0.2	0.01	89.69	17.938	48974.33	5927.3	0.12103	1.643771	38.33055	7378.1571

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2001"	45	58	2	4627.648	4705.113	4658.6	0.2	0.01	77.465	15.493	42298.99	5927.3	0.14013	1.512954	31.06586	5979.7948
"2010"	49	66	1	4627.741	4714.037	4662.3	0.2	0.01	86.296	17.2592	47121.07	5927.3	0.12579	1.609133	36.24831	6977.3509
"1998"	33	33	2	4627.779	4687.983	4651.9	0.2	0.01	60.204	12.0408	32873.79	5927.3	0.18031	1.293638	21.94502	4224.1452
"1993"	37	46	3	4627.874	4665.921	4643.1	0.2	0.01	38.047	7.6094	20775.18	5927.3	0.28531	0.932941	12.15303	2339.3087
"2005"	47	60	1	4627.93	4705.2	4658.8	0.2	0.01	77.27	15.454	42192.51	5927.3	0.14048	1.510723	30.95531	5958.5147
"1993"	41	52	1	4627.932	4699.889	4656.7	0.2	0.01	71.957	14.3914	39291.4	5927.3	0.15086	1.447949	28.00857	5391.3037
"2010"	24	18	1	4628.218	4721.123	4665.4	0.2	0.01	92.905	18.581	50729.85	5927.3	0.11684	1.67551	40.34869	7766.6235
"1996"	28	28	2	4628.243	4710.888	4661.3	0.2	0.01	82.645	16.529	45127.48	5927.3	0.13135	1.570482	34.06422	6556.9418
"1992"	39	51	3	4628.317	4696.737	4655.7	0.2	0.01	68.42	13.684	37360.06	5927.3	0.15865	1.403895	26.11739	5027.2751
"1992"	40	52	2	4628.414	4700.806	4657.4	0.2	0.01	72.392	14.4784	39528.93	5927.3	0.14995	1.453238	28.24507	5436.8267
"1992"	41	49	1	4628.613	4690.568	4653.4	0.2	0.01	61.955	12.391	33829.91	5927.3	0.17521	1.318134	22.80822	4390.3007
"2001"	44	56	2	4628.733	4703.997	4658.8	0.2	0.01	75.264	15.0528	41097.15	5927.3	0.14423	1.487478	29.82787	5741.4962
"2006"	46	59	1	4628.793	4705.049	4659.3	0.2	0.01	76.256	15.2512	41638.83	5927.3	0.14235	1.49904	30.38316	5848.3835
"1995"	48	64	1	4629.037	4711.398	4662	0.2	0.01	82.361	16.4722	44972.4	5927.3	0.1318	1.567412	33.89677	6524.7095
"1991"	32	35	2	4629.604	4684.594	4651.6	0.2	0.01	54.99	10.998	30026.74	5927.3	0.1974	1.217202	19.45822	3745.4667
"1993"	40	53	1	4629.976	4704.402	4659.7	0.2	0.01	74.426	14.8852	40639.57	5927.3	0.14585	1.477607	29.36221	5651.8625
"1997"	43	54	2	4630.326	4702.122	4659	0.2	0.01	71.796	14.3592	39203.49	5927.3	0.15119	1.445985	27.92126	5374.4966
"1992"	39	52	1	4630.5	4701.605	4658.9	0.2	0.01	71.105	14.221	38826.17	5927.3	0.15266	1.43751	27.54784	5302.618
"2005"	47	61	1	4630.579	4706.677	4661	0.2	0.01	76.098	15.2196	41552.55	5927.3	0.14265	1.497207	30.29443	5831.3025
"1995"	27	25	1	4630.598	4714.383	4664.1	0.2	0.01	83.785	16.757	45749.96	5927.3	0.12956	1.582711	34.73994	6687.0094
"1995"	42	53	2	4630.71	4701.394	4659	0.2	0.01	70.684	14.1368	38596.29	5927.3	0.15357	1.432312	27.32139	5259.0289
"2003"	26	22	7	4630.751	4716.734	4665.1	0.2	0.01	85.983	17.1966	46950.16	5927.3	0.12625	1.605877	36.05879	6940.8713
"1992"	29	31	2	4631.213	4704.882	4660.7	0.2	0.01	73.669	14.7338	40226.22	5927.3	0.14735	1.468606	28.94427	5571.4137
"1992"	39	53	1	4631.353	4706.107	4661.3	0.2	0.01	74.754	14.9508	40818.67	5927.3	0.14521	1.481482	29.5441	5686.8737
"1994"	41	53	1	4631.356	4702.862	4660	0.2	0.01	71.506	14.3012	39045.14	5927.3	0.15181	1.442437	27.76428	5344.2799
"2005"	47	62	1	4631.941	4708.355	4662.5	0.2	0.01	76.414	15.2828	41725.1	5927.3	0.14206	1.500869	30.47201	5865.486
"2008"	25	20	7	4632.002	4719.186	4666.9	0.2	0.01	87.184	17.4368	47605.95	5927.3	0.12451	1.618312	36.78829	7081.291
"2001"	44	57	2	4632.042	4705.369	4661.4	0.2	0.01	73.327	14.6654	40039.48	5927.3	0.14804	1.464513	28.75629	5535.2308
"1993"	31	35	2	4632.167	4689.16	4655	0.2	0.01	56.993	11.3986	31120.46	5927.3	0.19046	1.247203	20.39878	3926.5127
"2006"	45	59	2	4632.209	4706.176	4661.8	0.2	0.01	73.967	14.7934	40388.94	5927.3	0.14676	1.472159	29.10849	5603.024
"2010"	49	67	1	4633.425	4716.224	4666.5	0.2	0.01	82.799	16.5598	45211.57	5927.3	0.1311	1.572143	34.15517	6574.4484
"1998"	43	55	2	4633.588	4704.046	4661.8	0.2	0.01	70.458	14.0916	38472.89	5927.3	0.15406	1.429511	27.20015	5235.6932
"1996"	28	29	2	4633.686	4710.592	4664.4	0.2	0.01	76.906	15.3812	41993.75	5927.3	0.14115	1.506545	30.7494	5918.879
"1994"	40	54	1	4633.925	4707.695	4663.4	0.2	0.01	73.77	14.754	40281.37	5927.3	0.14715	1.469811	28.99988	5582.1186
"2005"	46	60	1	4633.977	4706.254	4662.9	0.2	0.01	72.277	14.4554	39466.13	5927.3	0.15019	1.451842	28.18246	5424.7759
"1993"	39	54	1	4634.318	4710.085	4664.6	0.2	0.01	75.767	15.1534	41371.81	5927.3	0.14327	1.493357	30.10889	5795.5883
"1992"	38	52	3	4634.425	4702.464	4661.6	0.2	0.01	68.039	13.6078	37152.02	5927.3	0.15954	1.399034	25.91707	4988.7153
"1995"	47	63	1	4634.441	4710.338	4664.8	0.2	0.01	75.897	15.1794	41442.8	5927.3	0.14302	1.494871	30.1817	5809.6038
"2010"	24	19	1	4634.504	4722.247	4669.6	0.2	0.01	87.743	17.5486	47911.19	5927.3	0.12371	1.624047	37.12996	7147.059
"2001"	44	58	2	4634.703	4706.499	4663.4	0.2	0.01	71.796	14.3592	39203.49	5927.3	0.15119	1.445985	27.92126	5374.4966
"1992"	30	34	2	4634.866	4696.015	4659.3	0.2	0.01	61.149	12.2298	33389.8	5927.3	0.17752	1.306929	22.40913	4313.48
"1995"	41	54	1	4635.155	4705.641	4663.3	0.2	0.01	70.486	14.0972	38488.18	5927.3	0.154	1.429858	27.21516	5238.5819

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"1995"	27	26	1	4635.376	4714.84	4667.2	0.2	0.01	79.464	15.8928	43390.52	5927.3	0.1366	1.535547	32.20891	6199.8169
"1996"	42	54	2	4635.687	4703.79	4662.9	0.2	0.01	68.103	13.6206	37186.96	5927.3	0.15939	1.399852	25.95067	4995.1836
"2001"	43	56	2	4635.898	4705.734	4663.8	0.2	0.01	69.836	13.9672	38133.25	5927.3	0.15544	1.421761	26.86769	5171.6987
"1995"	48	65	1	4636.388	4713.985	4667.4	0.2	0.01	77.597	15.5194	42371.07	5927.3	0.13989	1.514462	31.1408	5994.2183
"2010"	23	16	1	4636.523	4722.727	4671	0.2	0.01	86.204	17.2408	47070.83	5927.3	0.12592	1.608177	36.19256	6966.62
"1992"	29	32	2	4636.61	4703.583	4663.4	0.2	0.01	66.973	13.3946	36569.94	5927.3	0.16208	1.385309	25.3601	4881.506
"2008"	25	21	7	4637.005	4720.114	4670.2	0.2	0.01	83.109	16.6218	45380.84	5927.3	0.13061	1.575477	34.33857	6609.7495
"1992"	38	53	1	4637.057	4708.204	4665.5	0.2	0.01	71.147	14.2294	38849.11	5927.3	0.15257	1.438028	27.57047	5306.975
"1984"	33	36	2	4637.083	4671.154	4650.7	0.2	0.01	34.071	6.8142	18604.13	5927.3	0.3186	0.865336	10.50711	2022.4884
"2003"	26	23	7	4637.12	4717.4	4669.2	0.2	0.01	80.28	16.056	43836.09	5927.3	0.13522	1.544625	32.68059	6290.6095
"2006"	45	60	1	4637.24	4707.134	4665.2	0.2	0.01	69.894	13.9788	38164.92	5927.3	0.15531	1.422486	26.89862	5177.6518
"2005"	46	61	1	4637.321	4707.534	4665.4	0.2	0.01	70.213	14.0426	38339.11	5927.3	0.1546	1.426465	27.06899	5210.4461
"1991"	32	36	2	4637.51	4679.027	4654.1	0.2	0.01	41.517	8.3034	22669.94	5927.3	0.26146	0.994385	13.57674	2613.3554
"2001"	44	59	2	4637.764	4707.377	4665.6	0.2	0.01	69.613	13.9226	38011.48	5927.3	0.15593	1.418968	26.74893	5148.8376
"2010"	49	68	1	4637.964	4718.072	4670	0.2	0.01	80.108	16.0216	43742.17	5927.3	0.13551	1.542718	32.58092	6271.4247
"1997"	42	55	2	4638.012	4705.956	4665.2	0.2	0.01	67.944	13.5888	37100.14	5927.3	0.15977	1.397818	25.86722	4979.1205
"2010"	23	17	1	4638.662	4724.011	4672.8	0.2	0.01	85.349	17.0698	46603.97	5927.3	0.12718	1.59925	35.67622	6867.2307
"2000"	46	62	1	4638.8	4708.989	4666.9	0.2	0.01	70.189	14.0378	38326	5927.3	0.15466	1.426166	27.05616	5207.9757
"2001"	43	57	2	4638.867	4707.124	4666.2	0.2	0.01	68.257	13.6514	37271.05	5927.3	0.15903	1.401818	26.03161	5010.7628
"1992"	30	35	2	4638.916	4693.443	4660.7	0.2	0.01	54.527	10.9054	29773.92	5927.3	0.19908	1.21015	19.24341	3704.1188
"1995"	40	55	1	4639.004	4710.598	4667.6	0.2	0.01	71.594	14.3188	39093.19	5927.3	0.15162	1.443515	27.81187	5353.4414
"1995"	27	27	1	4639.367	4715.243	4669.7	0.2	0.01	75.876	15.1752	41431.33	5927.3	0.14306	1.494627	30.16993	5807.3388
"2015"	49	69	1	4639.463	4719.46	4671.5	0.2	0.01	79.997	15.9994	43681.56	5927.3	0.13569	1.541486	32.51667	6259.0573
"1996"	41	55	1	4639.482	4708.116	4666.9	0.2	0.01	68.634	13.7268	37476.91	5927.3	0.15816	1.406615	26.2302	5048.9892
"1995"	47	64	1	4639.503	4712.828	4668.8	0.2	0.01	73.325	14.665	40038.38	5927.3	0.14804	1.464489	28.75519	5535.0195
"1991"	31	36	2	4639.539	4685.388	4657.9	0.2	0.01	45.849	9.1698	25035.39	5927.3	0.23676	1.06975	15.39132	2962.6387
"2015"	49	70	1	4639.896	4720.502	4672.1	0.2	0.01	80.606	16.1212	44014.1	5927.3	0.13467	1.548229	32.86985	6327.0401
"1990"	29	33	1	4640	4700	4664	0.2	0.01	60	12	32762.4	5927.3	0.18092	1.290747	21.84537	4204.9642
"1992"	28	30	2	4640.17	4709.957	4668.1	0.2	0.01	69.787	13.9574	38106.49	5927.3	0.15555	1.421148	26.84158	5166.6717
"2001"	42	56	2	4640.257	4707.794	4667.3	0.2	0.01	67.537	13.5074	36877.9	5927.3	0.16073	1.392594	25.65414	4938.104
"1993"	38	54	1	4641.096	4713.12	4669.9	0.2	0.01	72.024	14.4048	39327.98	5927.3	0.15072	1.448766	28.04494	5398.3046
"2000"	45	61	1	4641.098	4708.038	4667.9	0.2	0.01	66.94	13.388	36551.92	5927.3	0.16216	1.384881	25.34294	4878.2031
"1984"	32	38	2	4641.479	4664.911	4650.9	0.2	0.01	23.432	4.6864	12794.81	5927.3	0.46326	0.875473	4.912176	945.53324
"2010"	23	18	1	4641.542	4725.268	4675	0.2	0.01	83.726	16.7452	45717.75	5927.3	0.12965	1.582082	34.70483	6680.251
"2001"	43	58	2	4641.643	4708.185	4668.3	0.2	0.01	66.542	13.3084	36334.59	5927.3	0.16313	1.379708	25.13639	4838.4433
"2008"	24	20	1	4641.655	4723.376	4674.3	0.2	0.01	81.721	16.3442	44622.93	5927.3	0.13283	1.560459	33.52071	6452.323
"1995"	46	63	1	4641.691	4710.819	4669.3	0.2	0.01	69.128	13.8256	37746.65	5927.3	0.15703	1.412867	26.4914	5099.2675
"2006"	44	60	1	4642.049	4707.998	4668.4	0.2	0.01	65.949	13.1898	36010.79	5927.3	0.1646	1.371951	24.82997	4779.4621
"2004"	26	24	7	4642.403	4718.079	4672.7	0.2	0.01	75.676	15.1352	41322.12	5927.3	0.14344	1.492296	30.05796	5785.7861
"1998"	41	56	1	4642.862	4710.216	4669.8	0.2	0.01	67.354	13.4708	36777.98	5927.3	0.16116	1.390236	25.55857	4919.7091
"1984"	32	37	2	4642.883	4671.4	4654.3	0.2	0.01	28.517	5.7034	15571.42	5927.3	0.38065	0.800551	7.956401	1531.5087
"1996"	27	28	1	4643.396	4715.513	4672.2	0.2	0.01	72.117	14.4234	39378.77	5927.3	0.15052	1.449898	28.09546	5408.0287

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2008"	25	22	1	4643.707	4721.01	4674.6	0.2	0.01	77.303	15.4606	42210.53	5927.3	0.14042	1.511101	30.97401	5962.1137
"2000"	45	62	1	4643.789	4708.989	4669.9	0.2	0.01	65.2	13.04	35601.81	5927.3	0.16649	1.362069	24.44525	4705.4078
"2001"	42	57	2	4643.832	4709.274	4670	0.2	0.01	65.442	13.0884	35733.95	5927.3	0.16587	1.365272	24.56927	4729.2804
"1994"	39	55	1	4643.976	4713.613	4671.8	0.2	0.01	69.637	13.9274	38024.59	5927.3	0.15588	1.419269	26.7617	5151.2959
"1993"	30	36	2	4644.235	4690.604	4662.8	0.2	0.01	46.369	9.2738	25319.33	5927.3	0.2341	1.078592	15.61336	3005.3795
"1995"	48	66	1	4644.526	4716.924	4673.5	0.2	0.01	72.398	14.4796	39532.2	5927.3	0.14994	1.453311	28.24834	5437.4558
"2001"	43	59	2	4644.818	4708.868	4670.4	0.2	0.01	64.05	12.81	34973.86	5927.3	0.16948	1.34671	23.85956	4592.6705
"1991"	31	37	2	4645.056	4681.037	4659.4	0.2	0.01	35.981	7.1962	19647.07	5927.3	0.30169	0.897007	11.30443	2175.9631
"2006"	44	61	1	4645.374	4708.344	4670.6	0.2	0.01	62.97	12.594	34384.14	5927.3	0.17239	1.332076	23.31506	4487.8607
"1995"	46	64	1	4645.657	4713.37	4672.7	0.2	0.01	67.713	13.5426	36974.01	5927.3	0.16031	1.394856	25.74619	4955.823
"1992"	28	31	2	4646.277	4709.026	4671.4	0.2	0.01	62.749	12.5498	34263.46	5927.3	0.17299	1.329056	23.2043	4466.5408
"2006"	43	60	1	4646.468	4709.097	4671.5	0.2	0.01	62.629	12.5258	34197.94	5927.3	0.17332	1.327413	23.14425	4454.9825
"2000"	45	63	1	4646.701	4710.209	4672.1	0.2	0.01	63.508	12.7016	34677.91	5927.3	0.17092	1.339392	23.58563	4539.9424
"2007"	24	21	1	4646.829	4724.507	4677.9	0.2	0.01	77.678	15.5356	42415.3	5927.3	0.13974	1.515386	31.18682	6003.0764
"1992"	37	54	3	4647.168	4717.087	4675.1	0.2	0.01	69.919	13.9838	38178.57	5927.3	0.15525	1.422798	26.91196	5180.2186
"2010"	23	19	1	4647.557	4726.545	4679.2	0.2	0.01	78.988	15.7976	43130.61	5927.3	0.13743	1.530213	31.93512	6147.1162
"2004"	26	25	7	4647.686	4718.81	4676.1	0.2	0.01	71.124	14.2248	38836.55	5927.3	0.15262	1.437744	27.55808	5304.5888
"1995"	47	65	1	4647.738	4716.1	4675.1	0.2	0.01	68.362	13.6724	37328.39	5927.3	0.15879	1.403156	26.08685	5021.3969
"1993"	38	55	1	4647.871	4717.354	4675.7	0.2	0.01	69.483	13.8966	37940.5	5927.3	0.15623	1.417336	26.67979	5135.5306
"2000"	44	62	1	4647.953	4708.45	4672.2	0.2	0.01	60.497	12.0994	33033.78	5927.3	0.17943	1.297777	22.08848	4251.759
"2001"	42	58	2	4647.96	4710.336	4672.9	0.2	0.01	62.376	12.4752	34059.79	5927.3	0.17403	1.323939	23.01787	4430.6556
"2006"	43	61	1	4648.069	4708.785	4672.4	0.2	0.01	60.716	12.1432	33153.36	5927.3	0.17878	1.30086	22.19596	4272.4484
"2001"	41	57	1	4648.213	4711.918	4673.7	0.2	0.01	63.705	12.741	34785.48	5927.3	0.1704	1.342058	23.68504	4559.0774
"1996"	40	56	1	4649.023	4713.141	4674.7	0.2	0.01	64.118	12.8236	35010.99	5927.3	0.1693	1.347624	23.89402	4599.3042
"2010"	48	67	1	4649.275	4719.809	4677.5	0.2	0.01	70.534	14.1068	38514.39	5927.3	0.1539	1.430454	27.2409	5243.5356
"1995"	45	64	1	4649.37	4712.084	4674.5	0.2	0.01	62.714	12.5428	34244.35	5927.3	0.17309	1.328577	23.18678	4463.1683
"2006"	42	61	1	4649.488	4709.834	4673.6	0.2	0.01	60.346	12.0692	32951.33	5927.3	0.17988	1.295646	22.0145	4237.5185
"1984"	31	38	2	4649.655	4676.898	4660.6	0.2	0.01	27.243	5.4486	14875.77	5927.3	0.39845	0.798965	7.275788	1400.4993
"1993"	27	29	1	4649.692	4715.487	4676	0.2	0.01	65.795	13.159	35926.7	5927.3	0.16498	1.369927	24.75066	4764.1955
"2001"	42	59	2	4649.715	4710.874	4674.2	0.2	0.01	61.159	12.2318	33395.26	5927.3	0.17749	1.307069	22.41406	4314.4296
"2001"	42	60	1	4650.151	4710.745	4674.4	0.2	0.01	60.594	12.1188	33086.75	5927.3	0.17914	1.299144	22.13606	4260.9175
"1992"	29	35	2	4650.676	4697.791	4669.5	0.2	0.01	47.115	9.423	25726.67	5927.3	0.2304	1.091188	15.93372	3067.0433
"2000"	43	62	1	4650.951	4707.81	4673.7	0.2	0.01	56.859	11.3718	31047.29	5927.3	0.19091	1.245221	20.33528	3914.2904
"2000"	44	63	1	4651.096	4708.433	4674	0.2	0.01	57.337	11.4674	31308.3	5927.3	0.18932	1.252274	20.56216	3957.9619
"1992"	28	32	2	4651.37	4707.813	4673.9	0.2	0.01	56.443	11.2886	30820.14	5927.3	0.19232	1.239046	20.13868	3876.4477
"2010"	48	68	1	4651.797	4721.785	4679.8	0.2	0.01	69.988	13.9976	38216.25	5927.3	0.1551	1.42366	26.94878	5187.306
"1991"	30	37	2	4651.923	4687.486	4666.1	0.2	0.01	35.563	7.1126	19418.82	5927.3	0.30524	0.889906	11.13143	2142.6628
"1995"	46	65	1	4652.034	4717.227	4678.1	0.2	0.01	65.193	13.0386	35597.99	5927.3	0.16651	1.361976	24.44166	4704.718
"1995"	45	65	3	4652.17	4715.251	4677.4	0.2	0.01	63.081	12.6162	34444.75	5927.3	0.17208	1.33359	23.37077	4498.5852
"2004"	25	23	1	4652.438	4721.89	4680.2	0.2	0.01	69.452	13.8904	37923.57	5927.3	0.1563	1.416947	26.66332	5132.3596
"2006"	42	62	1	4652.439	4707.86	4674.6	0.2	0.01	55.421	11.0842	30262.08	5927.3	0.19587	1.223726	19.65906	3784.1257
"1995"	26	26	7	4652.56	4719.567	4679.4	0.2	0.01	67.007	13.4014	36588.5	5927.3	0.162	1.38575	25.37779	4884.91

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"1993"	37	55	1	4652.667	4721.632	4680.3	0.2	0.01	68.965	13.793	37657.65	5927.3	0.1574	1.410808	26.40509	5082.6541
"1984"	31	39	2	4652.99	4674.135	4661.4	0.2	0.01	21.145	4.229	11546.02	5927.3	0.51336	1.048972	3.338488	642.61776
"2001"	41	58	1	4653.17	4713.122	4677.2	0.2	0.01	59.952	11.9904	32736.19	5927.3	0.18106	1.290066	21.82195	4200.4564
"2000"	44	64	1	4653.667	4708.576	4675.6	0.2	0.01	54.909	10.9818	29982.51	5927.3	0.19769	1.215971	19.42057	3738.2195
"2015"	48	69	1	4653.837	4722.752	4681.4	0.2	0.01	68.915	13.783	37630.35	5927.3	0.15751	1.410176	26.37864	5077.5626
"2005"	48	71	1	4653.878	4723.157	4681.6	0.2	0.01	69.279	13.8558	37829.11	5927.3	0.15669	1.41477	26.57147	5114.6786
"2007"	24	22	2	4653.983	4725.639	4682.6	0.2	0.01	71.656	14.3312	39127.04	5927.3	0.15149	1.444274	27.84543	5359.9001
"2010"	23	20	1	4654.089	4727.857	4683.6	0.2	0.01	73.768	14.7536	40280.28	5927.3	0.14715	1.469787	28.99878	5581.9066
"2005"	48	70	1	4654.094	4722.97	4681.6	0.2	0.01	68.876	13.7752	37609.05	5927.3	0.1576	1.409682	26.35802	5073.5928
"1995"	39	56	1	4654.762	4716.835	4679.6	0.2	0.01	62.073	12.4146	33894.34	5927.3	0.17488	1.319764	22.8669	4401.5957
"2000"	43	63	1	4654.975	4705.981	4675.4	0.2	0.01	51.006	10.2012	27851.32	5927.3	0.21282	1.155067	17.64141	3395.7541
"1990"	28	34	1	4655	4707	4675.8	0.2	0.01	52	10.4	28394.08	5927.3	0.20875	1.170881	18.08807	3481.7296
"1992"	28	33	2	4655.421	4706.31	4675.8	0.2	0.01	50.889	10.1778	27787.43	5927.3	0.21331	1.153192	17.58913	3385.6892
"2001"	41	59	1	4655.464	4713.646	4678.7	0.2	0.01	58.182	11.6364	31769.7	5927.3	0.18657	1.264632	20.9658	4035.6579
"2001"	41	60	1	4655.533	4713.31	4678.6	0.2	0.01	57.777	11.5554	31548.55	5927.3	0.18788	1.258726	20.77193	3998.3401
"2010"	22	17	1	4655.563	4728.528	4684.7	0.2	0.01	72.965	14.593	39841.81	5927.3	0.14877	1.460162	28.5579	5497.0422
"1994"	26	27	7	4655.642	4720.344	4681.5	0.2	0.01	64.702	12.9404	35329.88	5927.3	0.16777	1.355446	24.19087	4656.4442
"1995"	44	65	3	4655.945	4709.385	4677.3	0.2	0.01	53.44	10.688	29180.38	5927.3	0.20313	1.193422	18.74292	3607.7798
"1993"	27	30	1	4656.107	4714.872	4679.6	0.2	0.01	58.765	11.753	32088.04	5927.3	0.18472	1.273076	21.24621	4089.6322
"1998"	40	57	1	4656.341	4715.276	4679.9	0.2	0.01	58.935	11.787	32180.87	5927.3	0.18419	1.275526	21.32827	4105.4276
"1991"	29	36	2	4656.446	4695.394	4672	0.2	0.01	38.948	7.7896	21267.17	5927.3	0.27871	0.948862	12.52176	2410.2849
"2001"	41	61	1	4656.469	4712.043	4678.7	0.2	0.01	55.574	11.1148	30345.63	5927.3	0.19533	1.226033	19.73056	3797.8884
"1992"	36	55	3	4656.611	4725.867	4684.3	0.2	0.01	69.256	13.8512	37816.55	5927.3	0.15674	1.414481	26.55926	5112.33
"1995"	47	66	1	4656.956	4720.359	4682.3	0.2	0.01	63.403	12.6806	34620.57	5927.3	0.17121	1.337968	23.53272	4529.7577
"1991"	30	38	2	4657.725	4684.337	4668.4	0.2	0.01	26.612	5.3224	14531.22	5927.3	0.4079	0.801679	6.919154	1331.8515
"2007"	23	21	1	4658.392	4729.18	4686.7	0.2	0.01	70.788	14.1576	38653.08	5927.3	0.15335	1.433599	27.37725	5269.7823
"2015"	43	64	3	4658.9	4703.119	4676.6	0.2	0.01	44.219	8.8438	24145.34	5927.3	0.24549	1.041719	14.70163	2829.8814
"1994"	38	56	1	4658.979	4721.36	4683.9	0.2	0.01	62.381	12.4762	34062.52	5927.3	0.17401	1.324008	23.02037	4431.1358
"2010"	22	18	1	4659.343	4729.899	4687.6	0.2	0.01	70.556	14.1112	38526.4	5927.3	0.15385	1.430727	27.25269	5245.8067
"2015"	42	63	3	4659.367	4703.945	4677.2	0.2	0.01	44.578	8.9156	24341.37	5927.3	0.24351	1.047931	14.85274	2858.9683
"2004"	25	24	1	4659.483	4722.815	4684.8	0.2	0.01	63.332	12.6664	34581.81	5927.3	0.1714	1.337004	23.49697	4522.8763
"1993"	37	56	1	4659.842	4726.25	4686.4	0.2	0.01	66.408	13.2816	36261.42	5927.3	0.16346	1.37796	25.067	4825.0883
"1993"	26	28	7	4660.123	4721.147	4684.5	0.2	0.01	61.024	12.2048	33321.54	5927.3	0.17788	1.305181	22.3475	4301.6178
"2001"	40	58	1	4660.655	4716.829	4683.1	0.2	0.01	56.174	11.2348	30673.25	5927.3	0.19324	1.235034	20.01198	3852.0585
"2006"	41	62	1	4661.275	4709.68	4680.6	0.2	0.01	48.405	9.681	26431.07	5927.3	0.22426	1.11271	16.49288	3174.676
"1995"	46	66	3	4661.337	4723.47	4686.2	0.2	0.01	62.133	12.4266	33927.1	5927.3	0.17471	1.320592	22.89676	4407.3437
"1984"	30	39	2	4661.54	4681.168	4669.4	0.2	0.01	19.628	3.9256	10717.67	5927.3	0.55304	1.280964	2.355665	453.43632
"1992"	27	31	1	4662.279	4713.996	4683	0.2	0.01	51.717	10.3434	28239.55	5927.3	0.20989	1.1664	17.96046	3457.1663
"1993"	36	56	3	4662.463	4731.497	4690.1	0.2	0.01	69.034	13.8068	37695.33	5927.3	0.15724	1.41168	26.44161	5089.6839
"2001"	40	59	1	4662.728	4717.521	4684.6	0.2	0.01	54.793	10.9586	29919.17	5927.3	0.19811	1.214207	19.3667	3727.8508
"2004"	25	25	1	4662.746	4723.824	4687.2	0.2	0.01	61.078	12.2156	33351.03	5927.3	0.17773	1.305936	22.37412	4306.7406
"2007"	23	22	1	4662.812	4730.527	4689.9	0.2	0.01	67.715	13.543	36975.1	5927.3	0.16031	1.394882	25.74724	4956.0245

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"1991"	29	37	2	4663.064	4692.944	4675	0.2	0.01	29.88	5.976	16315.68	5927.3	0.36329	0.809903	8.63429	1661.994
"1995"	47	67	3	4663.117	4725.086	4687.9	0.2	0.01	61.969	12.3938	33837.55	5927.3	0.17517	1.318327	22.81518	4391.6401
"2007"	24	23	2	4663.225	4726.783	4688.6	0.2	0.01	63.558	12.7116	34705.21	5927.3	0.17079	1.340069	23.61085	4544.7958
"1981"	24	38	2	4663.427	4726.879	4688.8	0.2	0.01	63.452	12.6904	34647.33	5927.3	0.17108	1.338633	23.55741	4534.5093
"2010"	22	19	1	4664.065	4731.33	4691	0.2	0.01	67.265	13.453	36729.38	5927.3	0.16138	1.389087	25.51215	4910.7736
"1991"	28	35	2	4665.574	4702.489	4680.3	0.2	0.01	36.915	7.383	20157.07	5927.3	0.29406	0.913114	11.68905	2249.9972
"2015"	47	68	3	4665.575	4727.279	4690.3	0.2	0.01	61.704	12.3408	33692.85	5927.3	0.17592	1.314657	22.68362	4366.3158
"2005"	25	26	1	4665.808	4724.878	4689.4	0.2	0.01	59.07	11.814	32254.58	5927.3	0.18377	1.277467	21.39353	4117.9892
"1993"	26	29	3	4665.999	4721.808	4688.3	0.2	0.01	55.809	11.1618	30473.95	5927.3	0.1945	1.229567	19.84059	3819.0673
"1997"	39	57	1	4666.412	4719.7	4687.7	0.2	0.01	53.288	10.6576	29097.38	5927.3	0.20371	1.191063	18.67336	3594.3901
"1992"	27	32	1	4666.802	4712.889	4685.2	0.2	0.01	46.087	9.2174	25165.35	5927.3	0.23554	1.073803	15.49282	2982.1766
"2001"	40	60	1	4667.481	4717.174	4687.4	0.2	0.01	49.693	9.9386	27134.37	5927.3	0.21844	1.133861	17.05802	3283.4588
"2000"	47	69	3	4667.803	4727.446	4691.7	0.2	0.01	59.643	11.9286	32567.46	5927.3	0.182	1.285669	21.67145	4171.4863
"2006"	41	63	3	4667.973	4705.526	4683	0.2	0.01	37.553	7.5106	20505.44	5927.3	0.28906	0.924257	11.95073	2300.3686
"1995"	37	57	1	4668.605	4731.378	4693.7	0.2	0.01	62.773	12.5546	34276.57	5927.3	0.17293	1.329385	23.21632	4468.854
"1995"	38	57	1	4668.631	4725.219	4691.3	0.2	0.01	56.588	11.3176	30899.31	5927.3	0.19183	1.241202	20.20712	3889.6207
"2010"	22	20	1	4669.465	4732.813	4694.8	0.2	0.01	63.348	12.6696	34590.54	5927.3	0.17136	1.337221	23.50502	4524.4267
"1999"	36	57	3	4669.788	4738.88	4697.4	0.2	0.01	69.092	13.8184	37727	5927.3	0.15711	1.412413	26.47233	5095.5963
"1990"	27	33	1	4670	4715	4688	0.2	0.01	45	9	24571.8	5927.3	0.24122	1.055207	15.03093	2893.2673
"1990"	27	34	1	4670	4715	4688	0.2	0.01	45	9	24571.8	5927.3	0.24122	1.055207	15.03093	2893.2673
"2007"	24	24	1	4670.091	4727.988	4693.2	0.2	0.01	57.897	11.5794	31614.08	5927.3	0.18749	1.260479	20.8293	4009.3821
"1994"	25	27	1	4670.141	4726.078	4692.5	0.2	0.01	55.937	11.1874	30543.84	5927.3	0.19406	1.231487	19.90062	3830.6235
"2000"	47	70	3	4670.552	4725.799	4692.7	0.2	0.01	55.247	11.0494	30167.07	5927.3	0.19648	1.221097	19.57788	3768.499
"1998"	39	58	1	4670.646	4721.88	4691.1	0.2	0.01	51.234	10.2468	27975.81	5927.3	0.21187	1.158713	17.74348	3415.4009
"1991"	28	36	2	4671.326	4700.335	4682.9	0.2	0.01	29.009	5.8018	15840.07	5927.3	0.3742	0.803165	8.206523	1579.6542
"2007"	23	23	1	4671.554	4731.941	4695.7	0.2	0.01	60.387	12.0774	32973.72	5927.3	0.17976	1.296225	22.03457	4241.3831
"1984"	29	39	2	4671.714	4688.391	4678.4	0.2	0.01	16.677	3.3354	9106.309	5927.3	0.6509	2.358036	0.923812	177.82243
"1993"	26	30	3	4672.22	4720.773	4691.6	0.2	0.01	48.553	9.7106	26511.88	5927.3	0.22357	1.115158	16.55747	3187.108
"2001"	40	61	1	4672.357	4715.768	4689.7	0.2	0.01	43.411	8.6822	23704.14	5927.3	0.25005	1.027664	14.36305	2764.7092
"2005"	47	71	1	4672.736	4724.644	4693.5	0.2	0.01	51.908	10.3816	28343.84	5927.3	0.20912	1.169426	18.04655	3473.7369
"2005"	24	25	1	4672.963	4729.215	4695.5	0.2	0.01	56.252	11.2504	30715.84	5927.3	0.19297	1.236199	20.04868	3859.1239
"2009"	22	21	1	4673.179	4734.3	4697.6	0.2	0.01	61.121	12.2242	33374.51	5927.3	0.1776	1.306538	22.39532	4310.8217
"2001"	39	59	1	4674.471	4722.945	4693.9	0.2	0.01	48.474	9.6948	26468.74	5927.3	0.22394	1.113852	16.52298	3180.4699
"2005"	47	72	1	4674.706	4724.053	4694.4	0.2	0.01	49.347	9.8694	26945.44	5927.3	0.21997	1.128213	16.90552	3254.1041
"1994"	25	28	1	4675.023	4727.794	4696.1	0.2	0.01	52.771	10.5542	28815.08	5927.3	0.2057	1.183004	18.43753	3548.997
"1993"	26	31	3	4675.727	4719.833	4693.4	0.2	0.01	44.106	8.8212	24083.64	5927.3	0.24611	1.03976	14.65415	2820.7429
"2010"	21	18	1	4675.898	4735.187	4699.6	0.2	0.01	59.289	11.8578	32374.17	5927.3	0.18309	1.280609	21.49957	4138.4014
"2001"	40	62	1	4676.389	4713.249	4691.1	0.2	0.01	36.86	7.372	20127.03	5927.3	0.2945	0.912158	11.66646	2245.6487
"1996"	37	58	3	4676.455	4736.311	4700.4	0.2	0.01	59.856	11.9712	32683.77	5927.3	0.18135	1.288702	21.77515	4191.4469
"1997"	38	58	1	4676.462	4728.391	4697.2	0.2	0.01	51.929	10.3858	28355.31	5927.3	0.20904	1.169758	18.05602	3475.5607
"2005"	24	26	1	4676.525	4730.435	4698.1	0.2	0.01	53.91	10.782	29437.02	5927.3	0.20136	1.200685	18.95867	3649.3089
"1986"	28	37	2	4677.022	4698.333	4685.5	0.2	0.01	21.311	4.2622	11636.66	5927.3	0.50937	1.030628	3.451467	664.36481

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2006"	23	24	1	4677.66	4733.379	4699.9	0.2	0.01	55.719	11.1438	30424.8	5927.3	0.19482	1.228215	19.79842	3810.9505
"2007"	22	22	1	4677.7	4735.847	4701	0.2	0.01	58.147	11.6294	31750.59	5927.3	0.18668	1.264122	20.94902	4032.4272
"2009"	21	19	1	4679.734	4736.785	4702.6	0.2	0.01	57.051	11.4102	31152.13	5927.3	0.19027	1.24806	20.42629	3931.8078
"1986"	27	36	1	4680	4704.996	4690	0.2	0.01	24.996	4.9992	13648.82	5927.3	0.43427	0.823647	5.94153	1143.671
"2006"	40	63	3	4680.019	4709.282	4691.7	0.2	0.01	29.263	5.8526	15978.77	5927.3	0.37095	0.804871	8.333163	1604.0308
"2005"	23	25	1	4681.108	4734.788	4702.6	0.2	0.01	53.68	10.736	29311.43	5927.3	0.20222	1.197136	18.85296	3628.9622
"1982"	25	39	2	4681.131	4712.872	4693.8	0.2	0.01	31.741	6.3482	17331.86	5927.3	0.34199	0.830987	9.496099	1827.8816
"1984"	28	38	2	4681.253	4696.711	4687.4	0.2	0.01	15.458	3.0916	8440.686	5927.3	0.70223	3.317299	0.564183	108.5983
"1998"	38	59	1	4681.696	4729.994	4701	0.2	0.01	48.298	9.6596	26372.64	5927.3	0.22475	1.110938	16.44625	3165.6989
"2005"	24	27	1	4681.803	4731.739	4701.8	0.2	0.01	49.936	9.9872	27267.05	5927.3	0.21738	1.137813	17.16543	3304.1337
"2001"	39	60	1	4682.36	4722.862	4698.6	0.2	0.01	40.502	8.1004	22115.71	5927.3	0.26801	0.976417	13.15879	2532.9036
"2009"	21	20	1	4683.349	4738.41	4705.4	0.2	0.01	55.061	11.0122	30065.51	5927.3	0.19715	1.218279	19.49125	3751.8239
"2006"	22	23	1	4683.394	4737.463	4705	0.2	0.01	54.069	10.8138	29523.84	5927.3	0.20076	1.203132	19.03188	3663.4016
"1997"	37	59	3	4683.545	4738.142	4705.4	0.2	0.01	54.597	10.9194	29812.15	5927.3	0.19882	1.211219	19.27583	3710.358
"1985"	26	33	1	4685	4724	4700.6	0.2	0.01	39	7.8	21295.56	5927.3	0.27834	0.949783	12.54305	2414.3818
"1986"	26	34	1	4685	4724	4700.6	0.2	0.01	39	7.8	21295.56	5927.3	0.27834	0.949783	12.54305	2414.3818
"1985"	26	32	1	4685	4724	4700.6	0.2	0.01	39	7.8	21295.56	5927.3	0.27834	0.949783	12.54305	2414.3818
"2005"	23	26	1	4685.533	4736.189	4705.8	0.2	0.01	50.656	10.1312	27660.2	5927.3	0.21429	1.14945	17.48517	3365.6797
"1994"	24	28	1	4686.202	4733.16	4705	0.2	0.01	46.958	9.3916	25640.95	5927.3	0.23117	1.088546	15.86612	3054.0312
"2000"	46	70	3	4686.549	4728.271	4703.2	0.2	0.01	41.722	8.3444	22781.88	5927.3	0.26018	0.998005	13.66141	2629.6533
"2009"	21	21	1	4687.562	4740.078	4708.6	0.2	0.01	52.516	10.5032	28675.84	5927.3	0.2067	1.179008	18.32166	3526.6926
"2009"	20	18	1	4688.51	4741.085	4709.5	0.2	0.01	52.575	10.515	28708.05	5927.3	0.20647	1.179934	18.34844	3531.8482
"2006"	22	24	1	4688.739	4739.091	4708.9	0.2	0.01	50.352	10.0704	27494.21	5927.3	0.21558	1.14455	17.3499	3339.641
"2001"	39	61	1	4689.357	4721.564	4702.2	0.2	0.01	32.207	6.4414	17586.31	5927.3	0.33704	0.837308	9.703165	1867.7393
"1994"	24	29	1	4689.364	4734.417	4707.4	0.2	0.01	45.053	9.0106	24600.74	5927.3	0.24094	1.056118	15.05335	2897.5834
"1986"	27	37	1	4689.411	4703.75	4695.1	0.2	0.01	14.339	2.8678	7829.668	5927.3	0.75703	4.749538	0.339066	65.26607
"2001"	38	60	1	4690.752	4730.343	4706.6	0.2	0.01	39.591	7.9182	21618.27	5927.3	0.27418	0.960259	12.78506	2460.9651
"2001"	37	60	3	4690.881	4738.496	4709.9	0.2	0.01	47.615	9.523	25999.69	5927.3	0.22798	1.099569	16.14965	3108.6082
"2009"	20	19	1	4691.188	4742.788	4711.8	0.2	0.01	51.6	10.32	28175.66	5927.3	0.21037	1.164542	17.90781	3447.0311
"2003"	23	27	1	4691.331	4737.629	4709.9	0.2	0.01	46.298	9.2596	25280.56	5927.3	0.23446	1.077388	15.58299	2999.5322
"2000"	46	71	1	4692.072	4725.445	4705.4	0.2	0.01	33.373	6.6746	18222.99	5927.3	0.32527	0.854408	10.20994	1965.2878
"2006"	21	22	1	4692.325	4741.835	4712.1	0.2	0.01	49.51	9.902	27034.44	5927.3	0.21925	1.130877	16.9773	3267.9208
"1994"	24	30	1	4692.612	4733.96	4709.2	0.2	0.01	41.348	8.2696	22577.66	5927.3	0.26253	0.991398	13.50701	2599.9329
"1986"	26	35	1	4692.782	4714.38	4701.4	0.2	0.01	21.598	4.3196	11793.37	5927.3	0.5026	1.001491	3.648197	702.23272
"2006"	22	25	1	4692.795	4740.699	4712	0.2	0.01	47.904	9.5808	26157.5	5927.3	0.2266	1.104391	16.27492	3132.7206
"2001"	39	62	3	4692.931	4718.958	4703.3	0.2	0.01	26.027	5.2054	14211.78	5927.3	0.41707	0.806829	6.576051	1265.8086
"2005"	46	72	1	4693.979	4723.69	4705.9	0.2	0.01	29.711	5.9422	16223.39	5927.3	0.36536	0.808407	8.552684	1646.2859
"2009"	20	20	1	4695.18	4744.547	4714.9	0.2	0.01	49.367	9.8734	26956.36	5927.3	0.21989	1.12854	16.91432	3255.7982
"1995"	23	28	1	4695.442	4739.05	4712.9	0.2	0.01	43.608	8.7216	23811.71	5927.3	0.24892	1.0311	14.44541	2780.5627
"1994"	24	31	3	4695.985	4733.572	4711	0.2	0.01	37.587	7.5174	20524.01	5927.3	0.2888	0.924854	11.96466	2303.05
"2006"	21	23	1	4697.428	4743.628	4715.9	0.2	0.01	46.2	9.24	25227.05	5927.3	0.23496	1.075724	15.54109	2991.4673
"2003"	22	26	1	4697.598	4742.328	4715.5	0.2	0.01	44.73	8.946	24424.37	5927.3	0.24268	1.050555	14.91685	2871.3089

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2000"	45	70	3	4697.945	4722.724	4707.9	0.2	0.01	24.779	4.9558	13530.33	5927.3	0.43808	0.828699	5.803221	1117.0482
"1995"	23	29	1	4698.494	4740.222	4715.2	0.2	0.01	41.728	8.3456	22785.16	5927.3	0.26014	0.998111	13.66389	2630.1306
"1981"	23	38	1	4699.645	4740.267	4715.9	0.2	0.01	40.622	8.1244	22181.24	5927.3	0.26722	0.978544	13.2081	2542.3963
"2001"	38	61	3	4699.739	4729.342	4711.6	0.2	0.01	29.603	5.9206	16164.42	5927.3	0.36669	0.807497	8.500196	1636.1826
"2001"	38	62	3	4699.963	4725.099	4710	0.2	0.01	25.136	5.0272	13725.26	5927.3	0.43185	0.820692	6.029903	1160.6818
"2009"	20	21	1	4700.487	4746.446	4718.9	0.2	0.01	45.959	9.1918	25095.45	5927.3	0.23619	1.071624	15.43821	2971.6638
"2009"	19	19	1	4700.906	4749.035	4720.2	0.2	0.01	48.129	9.6258	26280.36	5927.3	0.22554	1.108134	16.37268	3151.5384
"2004"	21	24	1	4701.714	4745.449	4719.2	0.2	0.01	43.735	8.747	23881.06	5927.3	0.2482	1.033312	14.49857	2790.7951
"1994"	23	30	2	4701.875	4740.887	4717.5	0.2	0.01	39.012	7.8024	21302.11	5927.3	0.27825	0.949995	12.54796	2415.3272
"2003"	22	27	1	4702.844	4743.986	4719.3	0.2	0.01	41.142	8.2284	22465.18	5927.3	0.26384	0.987754	13.42209	2583.5873
"2009"	20	22	1	4703.354	4748.396	4721.4	0.2	0.01	45.042	9.0084	24594.73	5927.3	0.241	1.055929	15.04869	2896.6874
"2009"	19	20	1	4704.836	4750.958	4723.3	0.2	0.01	46.122	9.2244	25184.46	5927.3	0.23536	1.074398	15.50777	2985.0533
"1994"	23	31	2	4705.597	4741.436	4719.9	0.2	0.01	35.839	7.1678	19569.53	5927.3	0.30289	0.894586	11.24573	2164.6644
"2000"	45	71	3	4705.799	4723.437	4712.9	0.2	0.01	17.638	3.5276	9631.054	5927.3	0.61544	1.869332	1.303498	250.90733
"2003"	21	25	1	4706.014	4747.271	4722.5	0.2	0.01	41.257	8.2514	22527.97	5927.3	0.26311	0.989788	13.46949	2592.7102
"2003"	22	28	1	4706.472	4745.612	4722.1	0.2	0.01	39.14	7.828	21372.01	5927.3	0.27734	0.952263	12.60036	2425.4128
"2004"	20	23	1	4706.709	4750.362	4724.2	0.2	0.01	43.653	8.7306	23836.28	5927.3	0.24867	1.031884	14.46424	2784.1872
"2009"	19	21	1	4706.989	4752.972	4725.4	0.2	0.01	45.983	9.1966	25108.56	5927.3	0.23607	1.072033	15.44844	2973.6341
"1994"	23	32	2	4708.808	4742.01	4722.1	0.2	0.01	33.202	6.6404	18129.62	5927.3	0.32694	0.851802	10.1365	1951.1516
"2005"	45	72	3	4708.846	4723.596	4714.7	0.2	0.01	14.75	2.95	8054.09	5927.3	0.73594	4.141964	0.411411	79.191532
"1995"	22	29	1	4708.909	4747.021	4724.2	0.2	0.01	38.112	7.6224	20810.68	5927.3	0.28482	0.934087	12.17964	2344.4301
"2009"	19	22	1	4709.245	4755.003	4727.5	0.2	0.01	45.758	9.1516	24985.7	5927.3	0.23723	1.068197	15.35257	2955.1791
"2009"	18	20	1	4709.944	4757.179	4728.8	0.2	0.01	47.235	9.447	25792.2	5927.3	0.22981	1.093204	15.98545	3077.0014
"2003"	21	26	1	4710.999	4749.192	4726.3	0.2	0.01	38.193	7.6386	20854.91	5927.3	0.28422	0.935515	12.21279	2350.8115
"2009"	18	21	1	4712.121	4759.146	4730.9	0.2	0.01	47.025	9.405	25677.53	5927.3	0.23084	1.089674	15.89495	3059.5818
"2004"	20	24	1	4712.25	4752.361	4728.3	0.2	0.01	40.111	8.0222	21902.21	5927.3	0.27063	0.969483	12.99825	2502.0025
"1993"	23	33	2	4712.473	4742.747	4724.6	0.2	0.01	30.274	6.0548	16530.81	5927.3	0.35856	0.813698	8.822148	1698.1544
"1995"	22	30	1	4712.824	4748.244	4727	0.2	0.01	35.42	7.084	19340.74	5927.3	0.30647	0.887495	11.07209	2131.2404
"2009"	19	23	1	4713.105	4757.093	4730.7	0.2	0.01	43.988	8.7976	24019.21	5927.3	0.24677	1.037711	14.60462	2811.2085
"1982"	24	36	3	4714.068	4733.971	4722	0.2	0.01	19.903	3.9806	10867.83	5927.3	0.5454	1.228742	2.525078	486.04627
"2009"	18	22	1	4714.383	4761.187	4733.1	0.2	0.01	46.804	9.3608	25556.86	5927.3	0.23193	1.08595	15.7999	3041.2858
"1993"	23	34	2	4715.952	4743.501	4727	0.2	0.01	27.549	5.5098	15042.86	5927.3	0.39403	0.798563	7.443907	1432.86
"2002"	21	27	1	4716.114	4751.148	4730.1	0.2	0.01	35.034	7.0068	19129.97	5927.3	0.30984	0.881039	10.91145	2100.3194
"1995"	22	31	1	4716.376	4749.418	4729.6	0.2	0.01	33.042	6.6084	18042.25	5927.3	0.32852	0.849391	10.06754	1937.8762
"2008"	18	23	1	4716.782	4763.353	4735.4	0.2	0.01	46.571	9.3142	25429.63	5927.3	0.23309	1.082013	15.6999	3022.0358
"2008"	17	21	1	4717.179	4764.83	4736.2	0.2	0.01	47.651	9.5302	26019.35	5927.3	0.2278	1.100171	16.16524	3111.6083
"1982"	24	37	3	4717.197	4731.855	4723.1	0.2	0.01	14.658	2.9316	8003.854	5927.3	0.74056	4.268654	0.394236	75.885622
"2002"	21	28	1	4717.3	4752.912	4731.5	0.2	0.01	35.612	7.1224	19445.58	5927.3	0.30482	0.890734	11.15174	2146.573
"2004"	20	25	1	4718.326	4754.472	4732.8	0.2	0.01	36.146	7.2292	19737.16	5927.3	0.30031	0.899831	11.37255	2189.0756
"1993"	23	35	2	4718.489	4744.313	4728.8	0.2	0.01	25.824	5.1648	14100.94	5927.3	0.42035	0.809297	6.454125	1242.3393
"2004"	19	24	1	4719.042	4759.299	4735.1	0.2	0.01	40.257	8.0514	21981.93	5927.3	0.26965	0.972073	13.05817	2513.5361
"1993"	22	32	1	4719.086	4750.65	4731.7	0.2	0.01	31.564	6.3128	17235.21	5927.3	0.34391	0.828678	9.416656	1812.5898

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2002"	21	29	1	4719.878	4754.539	4733.7	0.2	0.01	34.661	6.9322	18926.29	5927.3	0.31318	0.874882	10.7555	2070.3011
"2008"	17	22	1	4720.092	4766.893	4738.8	0.2	0.01	46.801	9.3602	25555.22	5927.3	0.23194	1.085899	15.79861	3041.0377
"2008"	18	24	1	4720.476	4765.605	4738.5	0.2	0.01	45.129	9.0258	24642.24	5927.3	0.24053	1.057425	15.08552	2903.7758
"2004"	20	26	1	4720.959	4756.643	4735.2	0.2	0.01	35.684	7.1368	19484.89	5927.3	0.3042	0.891954	11.18158	2152.3153
"1993"	22	33	1	4721.211	4751.833	4733.5	0.2	0.01	30.622	6.1244	16720.84	5927.3	0.35449	0.817382	8.985458	1729.5896
"1984"	23	36	1	4721.354	4744.832	4730.7	0.2	0.01	23.478	4.6956	12819.93	5927.3	0.46235	0.873363	4.943398	951.54292
"2002"	20	27	1	4722.181	4758.664	4736.8	0.2	0.01	36.483	7.2966	19921.18	5927.3	0.29754	0.905628	11.51143	2215.8084
"2008"	17	23	1	4722.265	4769.067	4741	0.2	0.01	46.802	9.3604	25555.76	5927.3	0.23194	1.085916	15.79904	3041.1204
"2004"	19	25	1	4722.294	4761.566	4738	0.2	0.01	39.272	7.8544	21444.08	5927.3	0.27641	0.954603	12.6544	2435.8155
"2005"	18	25	1	4722.717	4767.808	4740.8	0.2	0.01	45.091	9.0182	24621.49	5927.3	0.24074	1.056772	15.06943	2900.6791
"2004"	19	26	2	4723.082	4763.706	4739.3	0.2	0.01	40.624	8.1248	22182.33	5927.3	0.26721	0.97858	13.20892	2542.5545
"2005"	18	26	2	4723.273	4769.816	4741.9	0.2	0.01	46.543	9.3086	25414.34	5927.3	0.23323	1.081539	15.68789	3019.7252
"1993"	22	34	1	4723.456	4752.851	4735.2	0.2	0.01	29.395	5.879	16050.85	5927.3	0.36928	0.805845	8.39834	1616.5767
"2008"	17	24	1	4723.621	4771.254	4742.7	0.2	0.01	47.633	9.5266	26009.52	5927.3	0.22789	1.09987	16.15744	3110.1081
"1995"	21	30	1	4724.398	4756.122	4737.1	0.2	0.01	31.724	6.3448	17322.57	5927.3	0.34217	0.830763	9.488489	1826.4167
"1985"	23	37	1	4724.568	4745.291	4732.9	0.2	0.01	20.723	4.1446	11315.59	5927.3	0.52382	1.10105	3.054897	588.0299
"2005"	19	27	2	4724.892	4765.62	4741.2	0.2	0.01	40.728	8.1456	22239.12	5927.3	0.26653	0.980423	13.25168	2550.7853
"2002"	20	28	1	4725.102	4760.451	4739.2	0.2	0.01	35.349	7.0698	19301.97	5927.3	0.30708	0.886301	11.04259	2125.5628
"2005"	18	27	2	4725.275	4771.659	4743.8	0.2	0.01	46.384	9.2768	25327.52	5927.3	0.23403	1.078846	15.61978	3006.6153
"2007"	17	25	1	4725.366	4773.382	4744.6	0.2	0.01	48.016	9.6032	26218.66	5927.3	0.22607	1.106255	16.32356	3142.0827
"1981"	24	39	2	4725.515	4725.998	4725.7	0.2	0.01	0.483	0.0966	263.7373	5927.3	22.4743	1.36E+08	1.34E-11	2.584E-09
"1993"	22	35	1	4725.792	4753.648	4736.9	0.2	0.01	27.856	5.5712	15210.49	5927.3	0.38969	0.798688	7.60954	1464.7425
"2008"	16	22	1	4727.25	4772.307	4745.3	0.2	0.01	45.057	9.0114	24602.92	5927.3	0.24092	1.056187	15.05504	2897.9092
"2007"	17	26	2	4727.433	4775.301	4746.6	0.2	0.01	47.868	9.5736	26137.84	5927.3	0.22677	1.103792	16.2593	3129.7135
"1996"	21	32	1	4727.647	4759.242	4740.3	0.2	0.01	31.595	6.319	17252.13	5927.3	0.34357	0.829078	9.430603	1815.2744
"1993"	21	33	1	4728.162	4760.514	4741.1	0.2	0.01	32.352	6.4704	17665.49	5927.3	0.33553	0.839341	9.767019	1880.0303
"2001"	18	30	2	4728.178	4776.582	4747.5	0.2	0.01	48.404	9.6808	26430.52	5927.3	0.22426	1.112694	16.49245	3174.5921
"2001"	18	31	1	4728.257	4777.828	4748.1	0.2	0.01	49.571	9.9142	27067.75	5927.3	0.21898	1.131873	17.00419	3273.0971
"1996"	21	31	1	4728.269	4757.735	4740.1	0.2	0.01	29.466	5.8932	16089.61	5927.3	0.36839	0.806393	8.433224	1623.2913
"2002"	20	29	1	4728.281	4762.248	4741.9	0.2	0.01	33.967	6.7934	18547.34	5927.3	0.31958	0.863681	10.46308	2014.0128
"1994"	22	36	1	4728.288	4753.951	4738.6	0.2	0.01	25.663	5.1326	14013.02	5927.3	0.42299	0.811529	6.35637	1223.5226
"2002"	19	28	2	4728.76	4767.451	4744.2	0.2	0.01	38.691	7.7382	21126.83	5927.3	0.28056	0.944313	12.41659	2390.0396
"2005"	18	28	2	4728.77	4773.458	4746.6	0.2	0.01	44.688	8.9376	24401.44	5927.3	0.24291	1.049831	14.89913	2867.8975
"2008"	16	23	1	4729.148	4774.524	4747.3	0.2	0.01	45.376	9.0752	24777.11	5927.3	0.23923	1.061663	15.19021	2923.9285
"2001"	18	29	2	4729.404	4775.132	4747.7	0.2	0.01	45.728	9.1456	24969.32	5927.3	0.23738	1.067685	15.3398	2952.7211
"2005"	17	27	2	4729.609	4777.095	4748.6	0.2	0.01	47.486	9.4972	25929.26	5927.3	0.2286	1.097412	16.09384	3097.8661
"2001"	19	31	1	4730.319	4772.428	4747.2	0.2	0.01	42.109	8.4218	22993.2	5927.3	0.25779	1.004829	13.82152	2660.4717
"2007"	16	24	1	4730.354	4776.606	4748.9	0.2	0.01	46.252	9.2504	25255.44	5927.3	0.23469	1.076607	15.56332	2995.7458
"2001"	19	30	2	4730.358	4771.006	4746.6	0.2	0.01	40.648	8.1296	22195.43	5927.3	0.26705	0.979005	13.21879	2544.4536
"1998"	18	35	1	4730.526	4782.371	4751.3	0.2	0.01	51.845	10.369	28309.44	5927.3	0.20938	1.168429	18.01813	3468.2678
"1993"	21	34	1	4730.613	4761.617	4743	0.2	0.01	31.004	6.2008	16929.42	5927.3	0.35012	0.821746	9.162124	1763.5956
"1997"	19	32	1	4730.694	4773.647	4747.9	0.2	0.01	42.953	8.5906	23454.06	5927.3	0.25272	1.019656	14.17202	2727.9381

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"2001"	19	29	2	4730.813	4769.287	4746.2	0.2	0.01	38.474	7.6948	21008.34	5927.3	0.28214	0.940476	12.32779	2372.9468
"1996"	20	32	1	4730.892	4767.125	4745.4	0.2	0.01	36.233	7.2466	19784.67	5927.3	0.29959	0.901324	11.40844	2195.9829
"2000"	17	30	2	4731.09	4781.519	4751.3	0.2	0.01	50.429	10.0858	27536.25	5927.3	0.21526	1.145793	17.38412	3346.229
"1985"	22	37	1	4731.483	4752.932	4740.1	0.2	0.01	21.449	4.2898	11712.01	5927.3	0.50609	1.016225	3.545868	682.5357
"2000"	18	32	1	4731.533	4779.028	4750.5	0.2	0.01	47.495	9.499	25934.17	5927.3	0.22855	1.097562	16.09774	3098.6151
"2005"	17	29	2	4731.593	4780.245	4751.1	0.2	0.01	48.652	9.7304	26565.94	5927.3	0.22312	1.116793	16.60072	3195.4338
"1993"	19	36	1	4731.796	4778.364	4750.4	0.2	0.01	46.568	9.3136	25427.99	5927.3	0.2331	1.081963	15.69861	3021.7882
"2005"	17	28	2	4731.798	4778.782	4750.6	0.2	0.01	46.984	9.3968	25655.14	5927.3	0.23104	1.088984	15.8773	3056.1848
"1996"	20	31	1	4731.835	4765.76	4745.4	0.2	0.01	33.925	6.785	18524.41	5927.3	0.31997	0.863015	10.44527	2010.5855
"1992"	19	35	1	4731.848	4777.27	4750	0.2	0.01	45.422	9.0844	24802.23	5927.3	0.23898	1.062451	15.20974	2927.6862
"2001"	20	30	1	4731.874	4764.079	4744.8	0.2	0.01	32.205	6.441	17585.22	5927.3	0.33706	0.83728	9.702283	1867.5694
"1997"	18	33	1	4732.014	4780.218	4751.3	0.2	0.01	48.204	9.6408	26321.31	5927.3	0.22519	1.109379	16.40531	3157.8199
"1997"	18	34	1	4732.149	4781.36	4751.8	0.2	0.01	49.211	9.8422	26871.17	5927.3	0.22058	1.125986	16.84572	3242.5925
"1996"	20	33	1	4732.155	4768.354	4746.6	0.2	0.01	36.199	7.2398	19766.1	5927.3	0.29987	0.90074	11.39442	2193.284
"1997"	19	33	1	4732.329	4774.885	4749.4	0.2	0.01	42.556	8.5112	23237.28	5927.3	0.25508	1.012692	14.00691	2696.1576
"2007"	16	25	2	4732.915	4778.865	4751.3	0.2	0.01	45.95	9.19	25090.54	5927.3	0.23624	1.071471	15.43437	2970.9251
"1997"	19	34	1	4732.967	4776.147	4750.2	0.2	0.01	43.18	8.636	23578.01	5927.3	0.25139	1.023628	14.26662	2746.1483
"1992"	21	35	1	4732.979	4762.665	4744.9	0.2	0.01	29.686	5.9372	16209.74	5927.3	0.36566	0.808194	8.540558	1643.9518
"1994"	21	36	1	4734.066	4763.259	4745.7	0.2	0.01	29.193	5.8386	15940.55	5927.3	0.37184	0.804378	8.298424	1597.3441
"2000"	17	31	1	4734.695	4782.724	4753.9	0.2	0.01	48.029	9.6058	26225.76	5927.3	0.22601	1.106472	16.3292	3143.1701
"1993"	20	36	1	4734.79	4771.72	4749.6	0.2	0.01	36.93	7.386	20165.26	5927.3	0.29394	0.913375	11.69521	2251.1829
"1992"	20	35	1	4734.854	4770.784	4749.2	0.2	0.01	35.93	7.186	19619.22	5927.3	0.30212	0.896137	11.28336	2171.9066
"1998"	17	34	1	4734.895	4786.01	4755.3	0.2	0.01	51.115	10.223	27910.83	5927.3	0.21237	1.156812	17.69018	3405.1412
"2007"	16	26	2	4735.744	4780.835	4753.8	0.2	0.01	45.091	9.0182	24621.49	5927.3	0.24074	1.056772	15.06943	2900.6791
"1992"	21	37	1	4735.873	4763.001	4746.7	0.2	0.01	27.128	5.4256	14812.97	5927.3	0.40014	0.799263	7.211805	1388.1832
"1992"	20	34	1	4736.034	4769.609	4749.5	0.2	0.01	33.575	6.715	18333.29	5927.3	0.32331	0.857525	10.29636	1981.9212
"1992"	19	37	1	4736.035	4779.697	4753.5	0.2	0.01	43.662	8.7324	23841.2	5927.3	0.24862	1.032041	14.46801	2784.9123
"2000"	17	33	1	4736.848	4785.003	4756.1	0.2	0.01	48.155	9.631	26294.56	5927.3	0.22542	1.108565	16.38399	3153.7155
"2000"	17	32	1	4737.393	4783.91	4756	0.2	0.01	46.517	9.3034	25400.14	5927.3	0.23336	1.081099	15.67675	3017.5802
"2007"	15	23	1	4737.532	4780.142	4754.6	0.2	0.01	42.61	8.522	23266.76	5927.3	0.25475	1.01364	14.02935	2700.4755
"1993"	20	37	1	4737.539	4772.466	4751.5	0.2	0.01	34.927	6.9854	19071.54	5927.3	0.31079	0.879264	10.86679	2091.7231
"2006"	16	27	2	4737.658	4782.562	4755.6	0.2	0.01	44.904	8.9808	24519.38	5927.3	0.24174	1.053554	14.99034	2885.4543
"2006"	16	28	2	4738.656	4784.064	4756.8	0.2	0.01	45.408	9.0816	24794.58	5927.3	0.23906	1.062211	15.20379	2926.5424
"1992"	18	37	1	4739.674	4784.854	4757.7	0.2	0.01	45.18	9.036	24670.09	5927.3	0.24026	1.058301	15.10712	2907.9335
"2007"	15	24	1	4739.736	4781.757	4756.5	0.2	0.01	42.021	8.4042	22945.15	5927.3	0.25833	1.003279	13.78508	2653.4578
"1998"	17	35	1	4740.652	4787.032	4759.2	0.2	0.01	46.38	9.276	25325.34	5927.3	0.23405	1.078779	15.61807	3006.2858
"2006"	16	29	2	4741.306	4785.369	4758.9	0.2	0.01	44.063	8.8126	24060.16	5927.3	0.24635	1.039013	14.6361	2817.2675
"1992"	19	38	1	4741.394	4781.787	4757.6	0.2	0.01	40.393	8.0786	22056.19	5927.3	0.26874	0.974484	13.11401	2524.2849
"1986"	20	38	1	4742.213	4773.159	4754.6	0.2	0.01	30.946	6.1892	16897.75	5927.3	0.35078	0.821063	9.135467	1758.4644
"2007"	15	25	2	4742.41	4784.851	4759.4	0.2	0.01	42.441	8.4882	23174.48	5927.3	0.25577	1.010671	13.95917	2686.9672
"2006"	16	30	2	4743.905	4786.631	4761	0.2	0.01	42.726	8.5452	23330.11	5927.3	0.25406	1.015676	14.07756	2709.7561
"1992"	18	38	1	4743.937	4786.686	4761	0.2	0.01	42.749	8.5498	23342.66	5927.3	0.25393	1.01608	14.08712	2711.5971

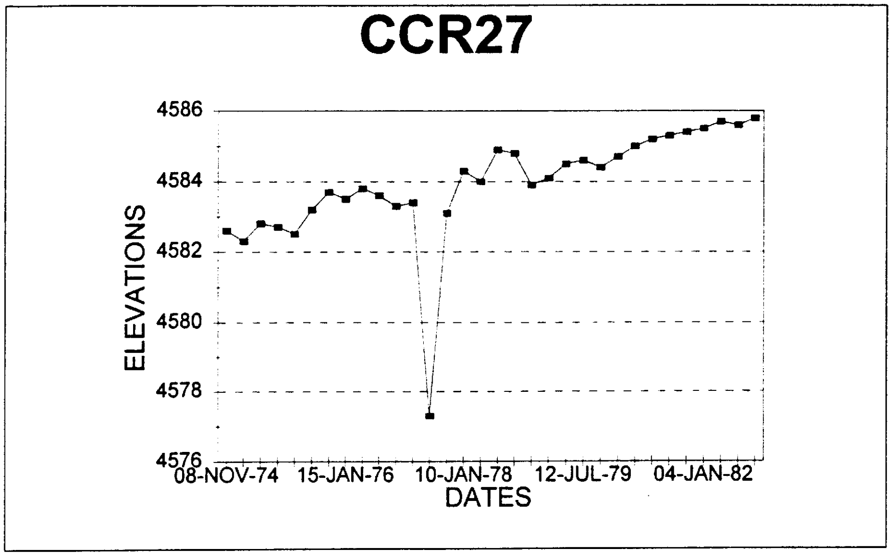
Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"1992"	18	39	1	4744.369	4788.818	4762.1	0.2	0.01	44.449	8.8898	24270.93	5927.3	0.24421	1.045702	14.79839	2848.5069
"1998"	17	36	1	4745.25	4788.162	4762.4	0.2	0.01	42.912	8.5824	23431.67	5927.3	0.25296	1.018937	14.15495	2724.6521
"2006"	15	26	2	4745.263	4786.849	4761.9	0.2	0.01	41.586	8.3172	22707.62	5927.3	0.26103	0.995604	13.60523	2618.839
"2000"	16	31	2	4746.104	4787.872	4762.8	0.2	0.01	41.768	8.3536	22807	5927.3	0.25989	0.998817	13.68043	2633.3129
"2006"	15	27	2	4747.288	4788.395	4763.7	0.2	0.01	41.107	8.2214	22446.07	5927.3	0.26407	0.987134	13.40768	2580.8118
"2000"	16	32	1	4747.535	4788.977	4764.1	0.2	0.01	41.442	8.2884	22628.99	5927.3	0.26193	0.99306	13.54579	2607.3972
"2006"	14	24	1	4748.58	4790.575	4765.4	0.2	0.01	41.995	8.399	22930.95	5927.3	0.25849	1.002821	13.77432	2651.3862
"1992"	17	37	1	4748.727	4789.478	4765	0.2	0.01	40.751	8.1502	22251.68	5927.3	0.26638	0.98083	13.26114	2552.6061
"2000"	16	33	1	4749.192	4789.972	4765.5	0.2	0.01	40.78	8.156	22267.51	5927.3	0.26619	0.981344	13.27307	2554.9021
"1987"	18	40	3	4749.466	4790.065	4765.7	0.2	0.01	40.599	8.1198	22168.68	5927.3	0.26737	0.978136	13.19865	2540.5765
"2006"	15	28	2	4750.452	4789.774	4766.2	0.2	0.01	39.322	7.8644	21471.38	5927.3	0.27606	0.955489	12.67487	2439.7564
"2006"	14	25	1	4751.39	4792.517	4767.8	0.2	0.01	41.127	8.2254	22456.99	5927.3	0.26394	0.987488	13.41591	2582.3978
"1998"	16	34	1	4751.794	4790.999	4767.5	0.2	0.01	39.205	7.841	21407.5	5927.3	0.27688	0.953415	12.62697	2430.5351
"1992"	17	38	1	4751.814	4790.953	4767.5	0.2	0.01	39.139	7.8278	21371.46	5927.3	0.27735	0.952246	12.59995	2425.334
"2006"	14	26	1	4754.381	4793.581	4770.1	0.2	0.01	39.2	7.84	21404.77	5927.3	0.27692	0.953327	12.62492	2430.1411
"2006"	15	29	2	4754.564	4791.105	4769.2	0.2	0.01	36.541	7.3082	19952.85	5927.3	0.29707	0.90663	11.5353	2220.4034
"1998"	16	35	1	4754.781	4792.184	4769.7	0.2	0.01	37.403	7.4806	20423.53	5927.3	0.29022	0.921629	11.88926	2288.5358
"2006"	15	30	2	4757.248	4792.479	4771.3	0.2	0.01	35.231	7.0462	19237.54	5927.3	0.30811	0.884324	10.99352	2116.1172
"1992"	17	39	1	4757.601	4792.573	4771.6	0.2	0.01	34.972	6.9944	19096.11	5927.3	0.31039	0.88001	10.88558	2095.3398
"2006"	14	27	1	4757.75	4794.766	4772.6	0.2	0.01	37.016	7.4032	20212.22	5927.3	0.29325	0.914871	11.73052	2257.9796
"1998"	16	36	1	4759.048	4793.373	4772.8	0.2	0.01	34.325	6.865	18742.82	5927.3	0.31624	0.869415	10.61432	2043.1262
"2006"	15	31	2	4759.369	4793.795	4773.1	0.2	0.01	34.426	6.8852	18797.97	5927.3	0.31532	0.87105	10.65684	2051.3093
"2006"	14	28	1	4761.223	4796.086	4775.2	0.2	0.01	34.863	6.9726	19036.59	5927.3	0.31136	0.878206	10.84005	2086.5759
"1999"	15	32	1	4763.298	4794.96	4776	0.2	0.01	31.662	6.3324	17288.72	5927.3	0.34284	0.82995	9.460698	1821.0673
"1988"	18	41	3	4763.687	4791.539	4774.8	0.2	0.01	27.852	5.5704	15208.31	5927.3	0.38974	0.798683	7.607401	1464.3307
"2006"	14	29	3	4765.767	4797.54	4778.5	0.2	0.01	31.773	6.3546	17349.33	5927.3	0.34165	0.83141	9.510413	1830.637
"1992"	17	40	1	4765.904	4794.307	4777.3	0.2	0.01	28.403	5.6806	15509.17	5927.3	0.38218	0.800087	7.897493	1520.1697
"2006"	13	27	3	4765.98	4801.212	4780.1	0.2	0.01	35.232	7.0464	19238.08	5927.3	0.3081	0.88434	10.99394	2116.1973
"1992"	16	38	1	4766.823	4795.774	4778.4	0.2	0.01	28.951	5.7902	15808.4	5927.3	0.37495	0.802808	8.177374	1574.0433
"1999"	15	33	1	4767.159	4796.033	4778.7	0.2	0.01	28.874	5.7748	15766.36	5927.3	0.37595	0.802353	8.138539	1566.5682
"1999"	15	34	1	4769.67	4797.284	4780.7	0.2	0.01	27.614	5.5228	15078.35	5927.3	0.3931	0.798547	7.479226	1439.6585
"2006"	13	28	3	4770.369	4802.618	4783.3	0.2	0.01	32.249	6.4498	17609.24	5927.3	0.3366	0.837894	9.721688	1871.3047
"1999"	15	35	1	4771.829	4798.687	4782.6	0.2	0.01	26.858	5.3716	14665.54	5927.3	0.40417	0.800298	7.05982	1358.928
"1992"	16	39	1	4773.55	4797.584	4783.2	0.2	0.01	24.034	4.8068	13123.53	5927.3	0.45166	0.850948	5.316762	1023.4109
"1988"	19	43	3	4773.809	4791	4780.7	0.2	0.01	17.191	3.4382	9386.974	5927.3	0.63144	2.07415	1.11599	214.81435
"1999"	15	36	1	4774.404	4799.89	4784.6	0.2	0.01	25.486	5.0972	13916.38	5927.3	0.42592	0.814278	6.247825	1202.6291
"1999"	14	32	3	4776.02	4802.234	4786.5	0.2	0.01	26.214	5.2428	14313.89	5927.3	0.4141	0.804878	6.687056	1287.1756
"1979"	18	42	1	4777.608	4794.298	4784.3	0.2	0.01	16.69	3.338	9113.408	5927.3	0.6504	2.350128	0.928366	178.69905
"1988"	17	41	7	4777.938	4796.819	4785.5	0.2	0.01	18.881	3.7762	10309.78	5927.3	0.57492	1.452729	1.922045	369.96986
"1999"	15	37	1	4778.407	4800.771	4787.4	0.2	0.01	22.364	4.4728	12211.64	5927.3	0.48538	0.937659	4.177844	804.18339
"1990"	16	40	3	4782.411	4800	4789.4	0.2	0.01	17.589	3.5178	9604.298	5927.3	0.61715	1.890107	1.282018	246.77259
"1999"	14	33	3	4783.826	4804.019	4791.9	0.2	0.01	20.193	4.0386	11026.19	5927.3	0.53757	1.179111	2.708602	521.37232

Wasatch Formation Pit Inflow

SEQNCE	ROW	COL	IBOUND	TPCOAL-1	WAS_SSHD	DRAIN ELEV	K FT/DAY	WASATCH STORAGE	THICK FT	TRANS FT^2 / DAY	Tt ft	1.87* R^2 S (FT)	U FT	W(u)	Q GPM	Q FT^3 /DAY
"1999"	14	34	3	4786.674	4805.634	4794.3	0.2	0.01	18.96	3.792	10352.92	5927.3	0.57253	1.432239	1.965891	378.40978
"1999"	14	35	3	4786.917	4807.241	4795	0.2	0.01	20.324	4.0648	11097.72	5927.3	0.5341	1.158373	2.792982	537.61443
"1999"	14	36	3	4789.631	4808.748	4797.3	0.2	0.01	19.117	3.8234	10438.65	5927.3	0.56782	1.393256	2.054503	395.4665
"1990"	15	41	1	4790	4809.997	4798	0.2	0.01	19.997	3.9994	10919.16	5927.3	0.54284	1.21207	2.584045	497.3968
"1988"	18	43	1	4790.481	4799.391	4794	0.2	0.01	8.91	1.782	4865.216	5927.3	1.21831	53.77343	0.011563	2.2258134
"1988"	17	42	1	4791.774	4801.458	4795.6	0.2	0.01	9.684	1.9368	5287.851	5927.3	1.12093	34.98979	0.020993	4.0408177
"1989"	16	41	1	4791.779	4803.874	4796.6	0.2	0.01	12.095	2.419	6604.354	5927.3	0.89749	11.15094	0.102754	19.778856
"1988"	18	44	1	4792.245	4805.644	4797.6	0.2	0.01	13.399	2.6798	7316.39	5927.3	0.81014	6.641619	0.211723	40.754153
"1990"	15	40	4	4793.843	4806.911	4799.1	0.2	0.01	13.068	2.6136	7135.651	5927.3	0.83066	7.530196	0.177627	34.191095
"1999"	14	37	3	4794.005	4809.256	4800.1	0.2	0.01	15.251	3.0502	8327.656	5927.3	0.71176	3.533404	0.515587	99.244031
"1989"	16	42	1	4796.947	4808.496	4801.6	0.2	0.01	11.549	2.3098	6306.216	5927.3	0.93992	14.12504	0.07396	14.236399
"1999"	14	38	1	4797.663	4808.658	4802.1	0.2	0.01	10.995	2.199	6003.71	5927.3	0.98728	18.18388	0.052072	10.023165
"1988"	17	43	1	4799.12	4807.804	4802.6	0.2	0.01	8.684	1.7368	4741.811	5927.3	1.25001	61.39014	0.009621	1.8520048
"1989"	16	43	1	4801.426	4813.268	4806.2	0.2	0.01	11.842	2.3684	6466.206	5927.3	0.91666	12.42339	0.088411	17.018104
"1989"	15	42	1	4801.732	4813.4	4806.4	0.2	0.01	11.668	2.3336	6371.195	5927.3	0.93033	13.4018	0.079566	15.315486
"1988"	17	44	1	4802.116	4814.023	4806.9	0.2	0.01	11.907	2.3814	6501.698	5927.3	0.91166	12.0803	0.091923	17.694089
"1989"	16	44	3	4804.733	4817.845	4810	0.2	0.01	13.112	2.6224	7159.676	5927.3	0.82788	7.403855	0.181877	35.009109
"1990"	15	43	1	4805.278	4816.734	4809.9	0.2	0.01	11.456	2.2912	6255.434	5927.3	0.94755	14.72336	0.069816	13.438791
"1989"	14	41	1	4806.921	4816.109	4810.6	0.2	0.01	9.188	1.8376	5017.016	5927.3	1.18144	45.89297	0.014408	2.7733002
"1989"	14	42	1	4809.73	4819.052	4813.5	0.2	0.01	9.322	1.8644	5090.185	5927.3	1.16446	42.58995	0.015981	3.076183
"1989"	14	43	3	4812.015	4821.258	4815.7	0.2	0.01	9.243	1.8486	5047.048	5927.3	1.17441	44.50155	0.015037	2.8943552

Appendix D: Calibration Wells - Time Series Graphs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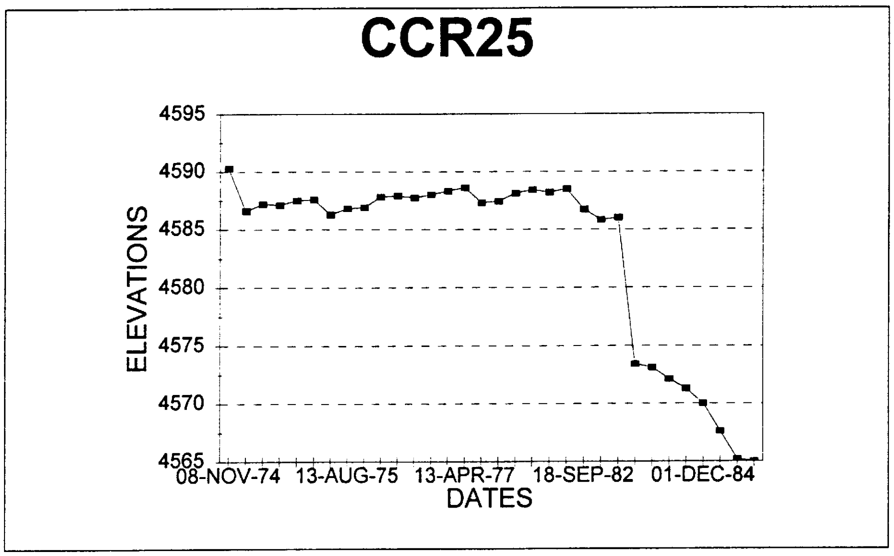
15-JAN-76
10-JAN-78
12-JUL-79
04-JAN-82
DATES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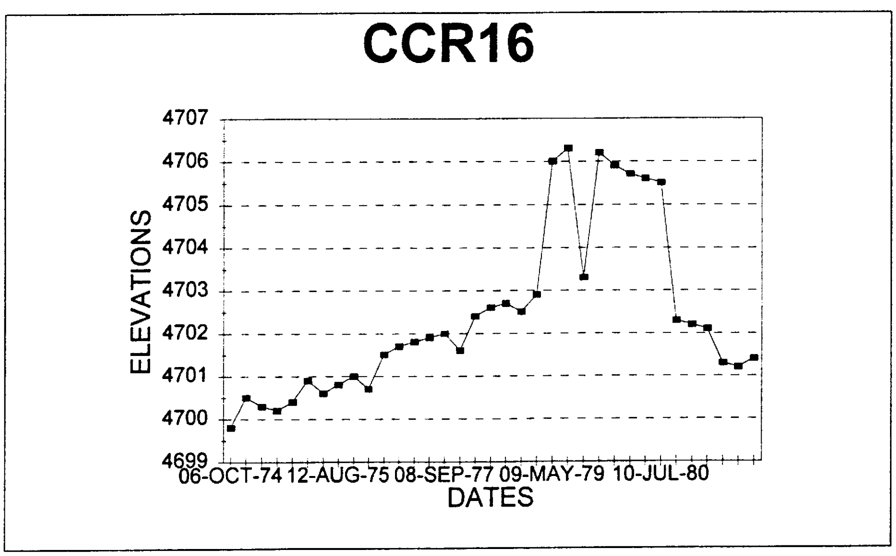
13-AUG-75
13-APR-77
18-SEP-82
01-DEC-84
DATES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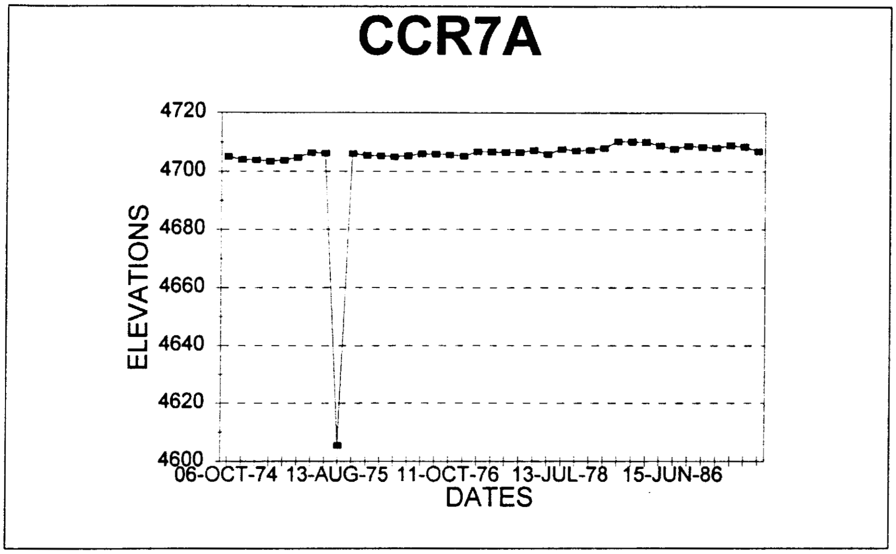
10-JUL-80
DATES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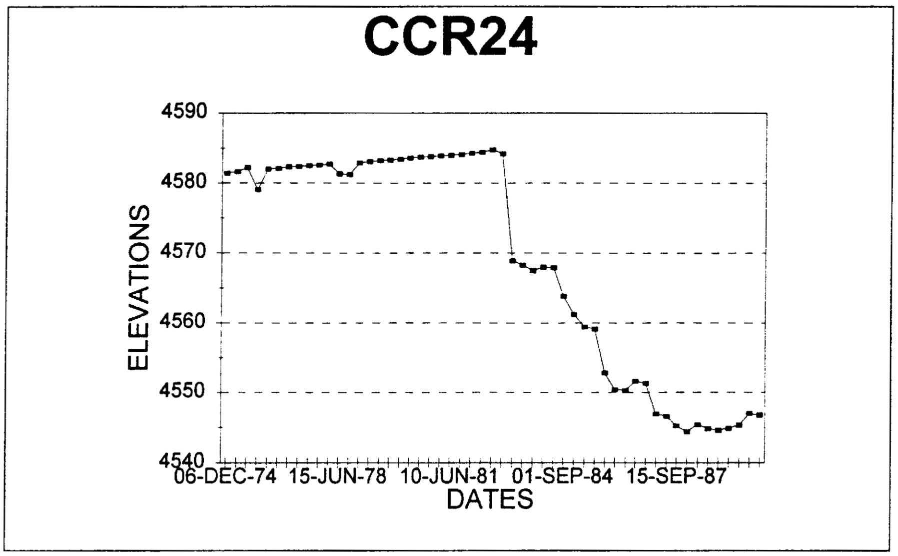
DATES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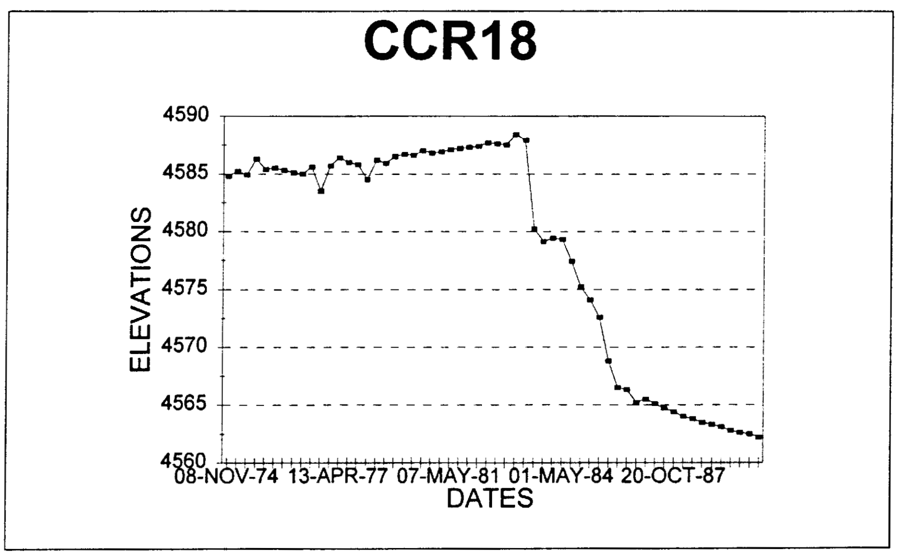
DATES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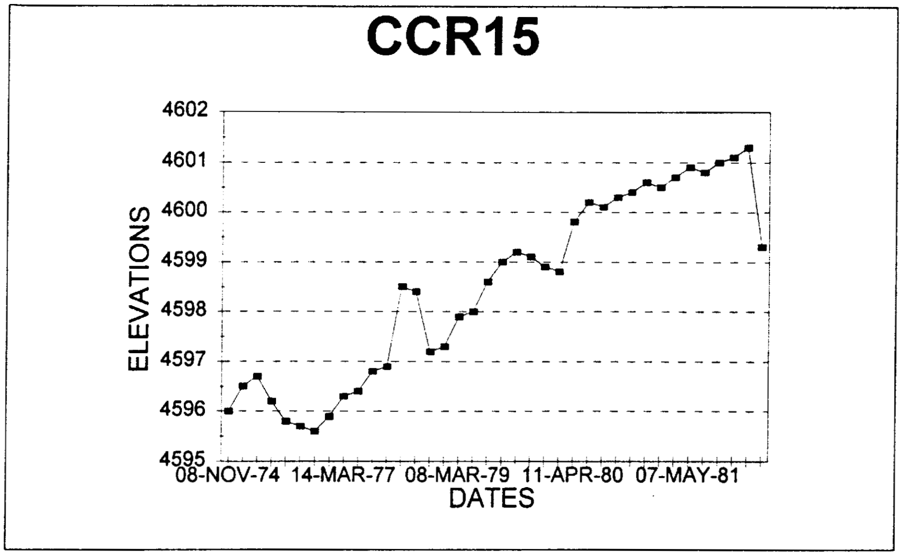
DATES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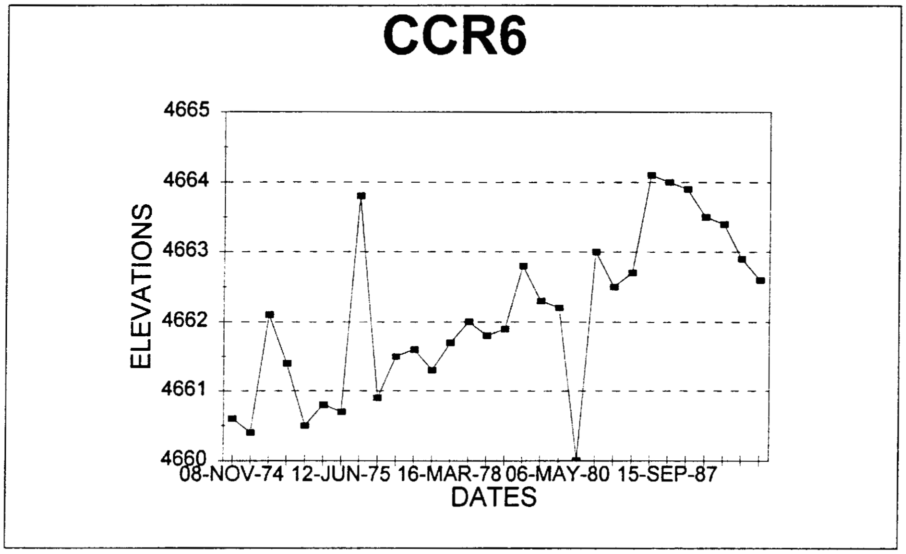
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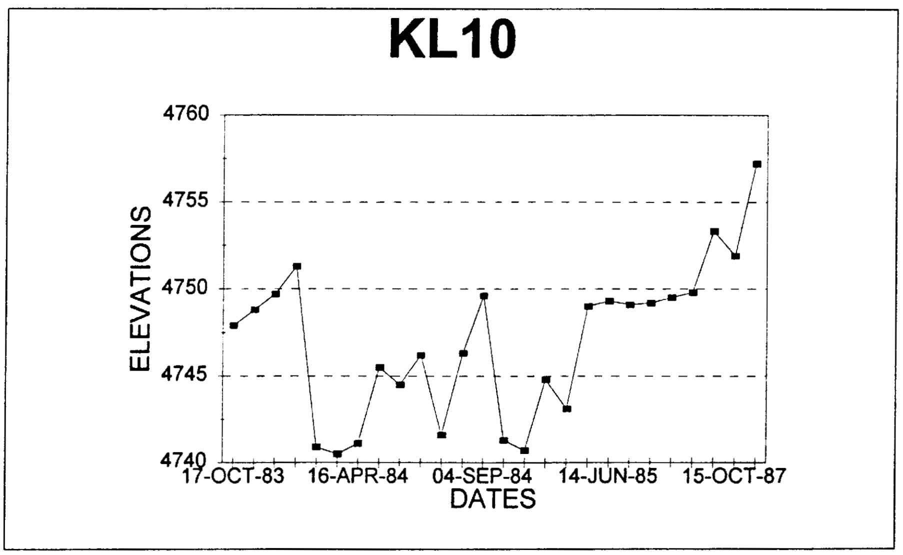
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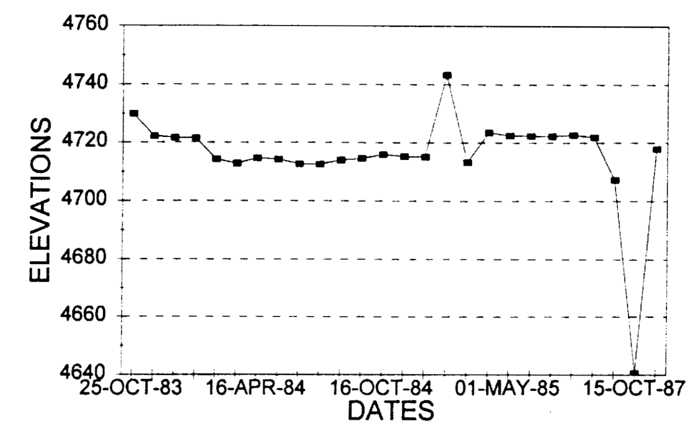
DATES

KL8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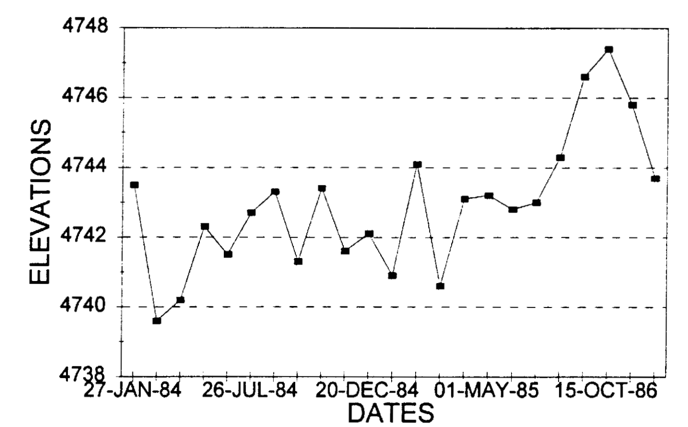
16-OCT-84
01-MAY-85
15-OCT-87
DATES

KL4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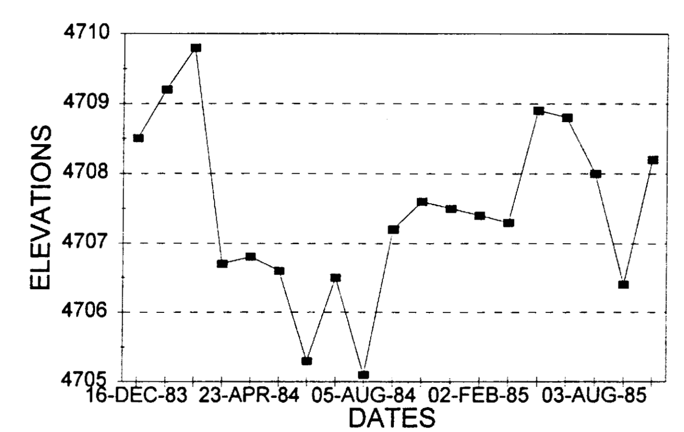
DATES

KL9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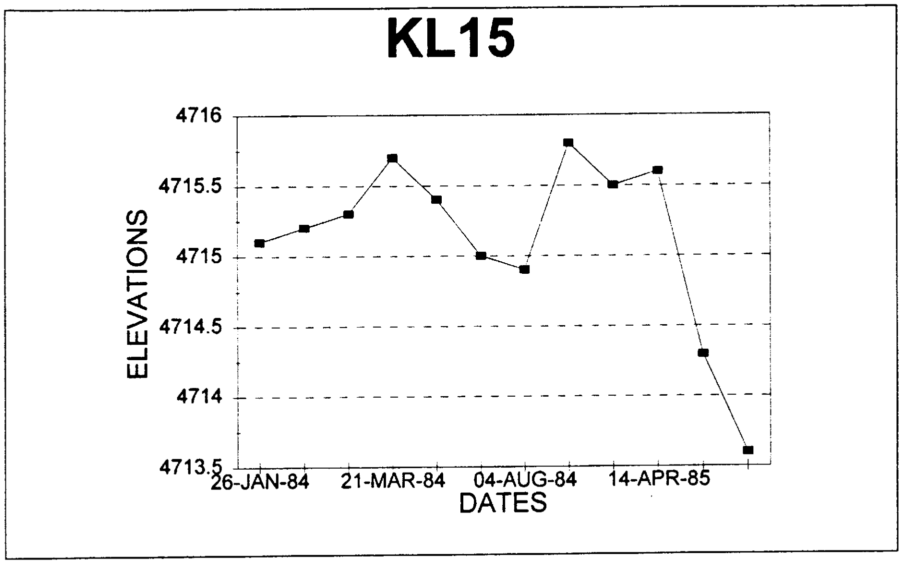
DATES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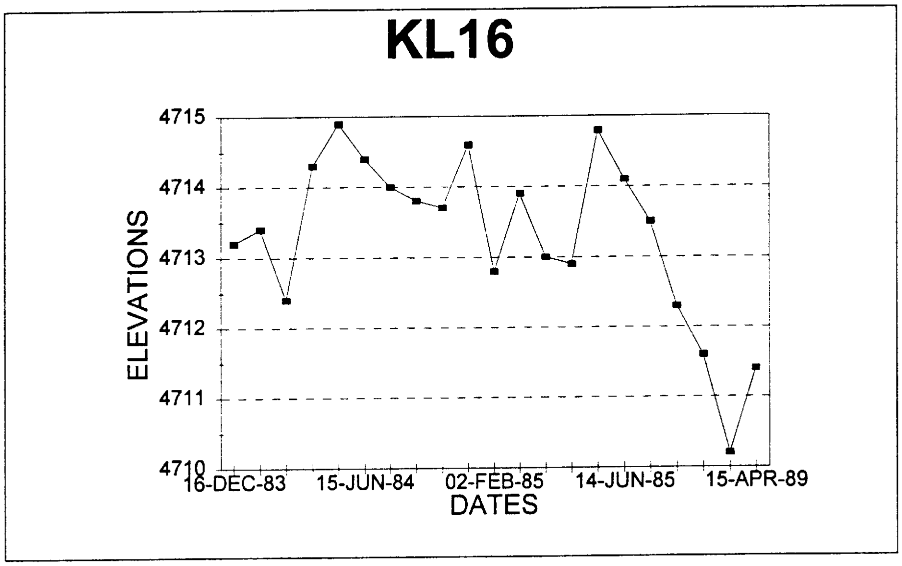
14-APR-85
DATES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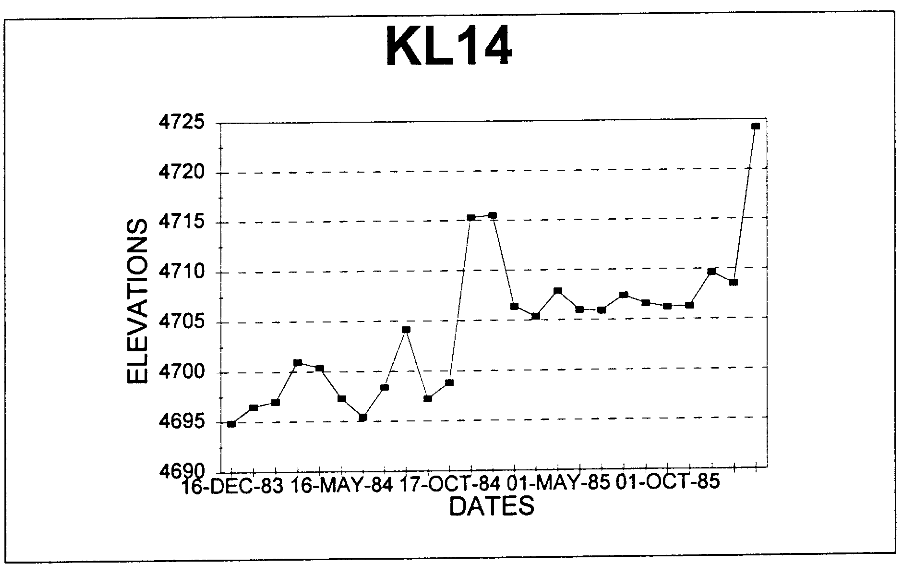
DATES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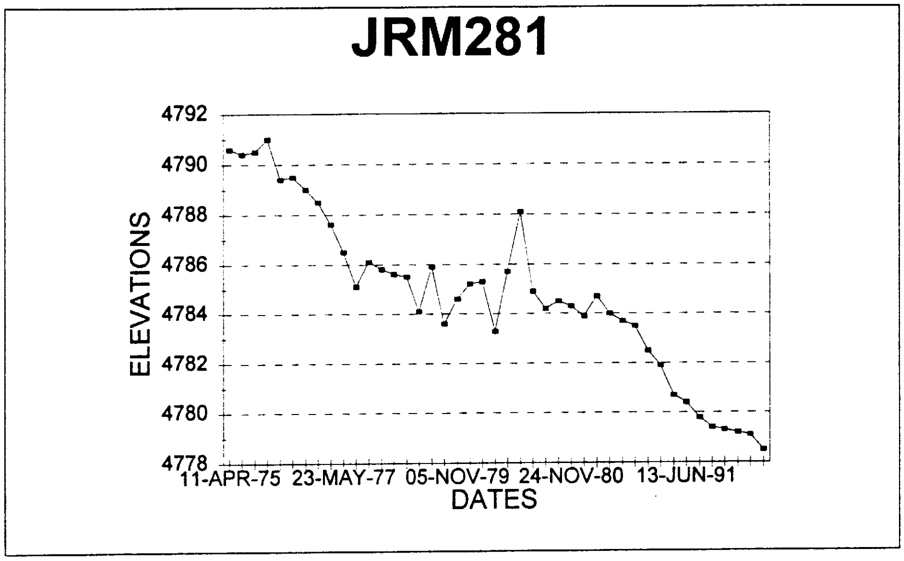
DATES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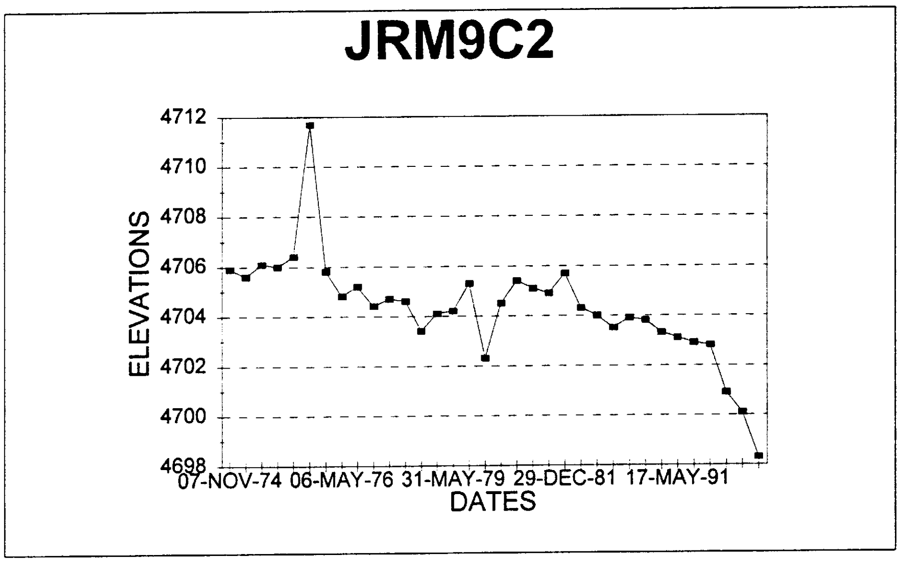
DATES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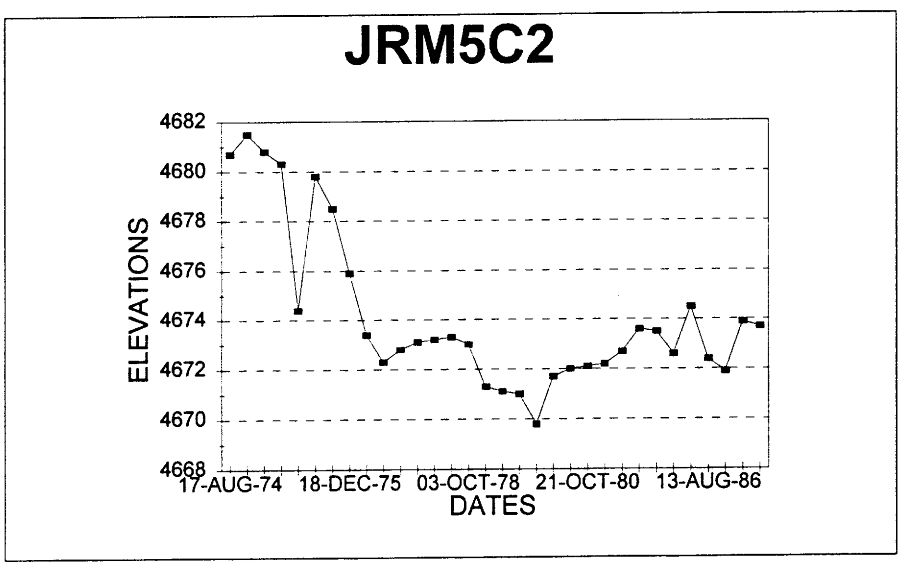
DATES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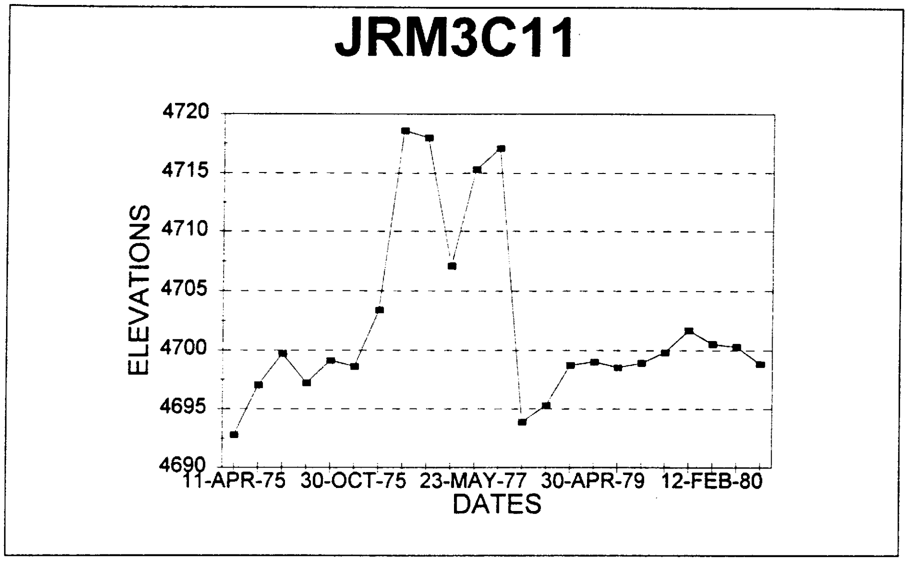
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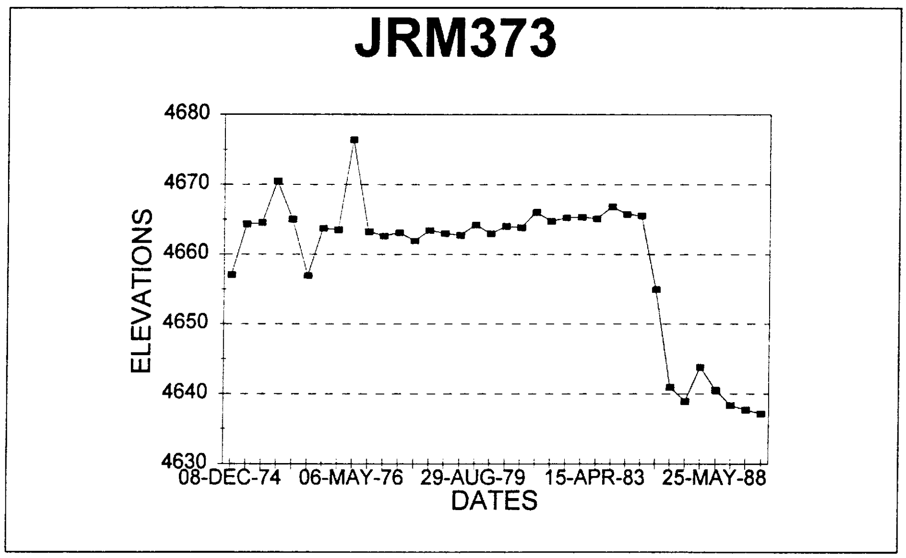
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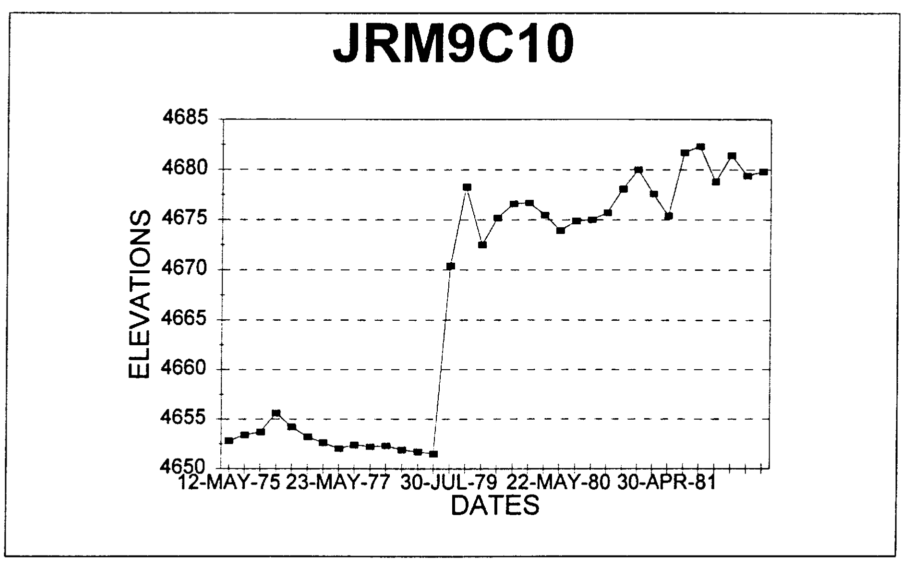
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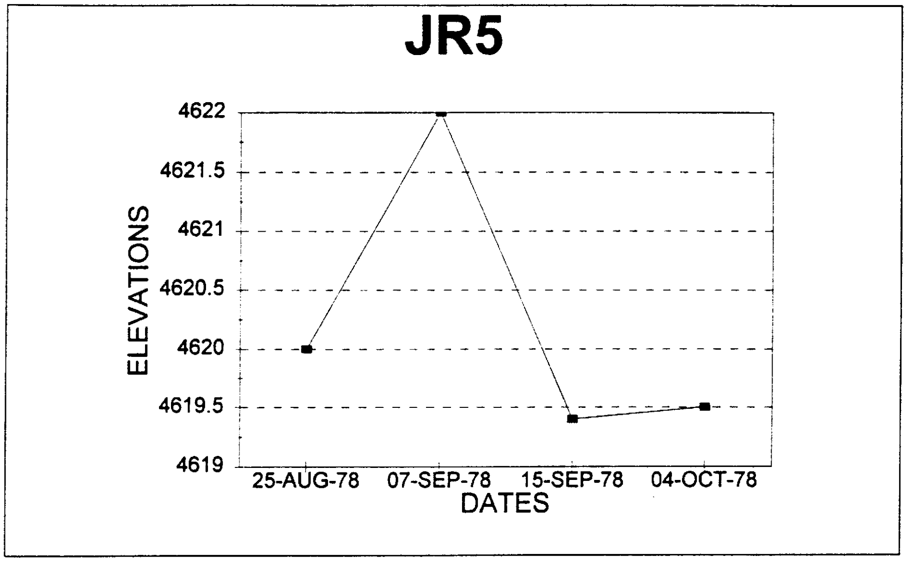
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04-OCT-78
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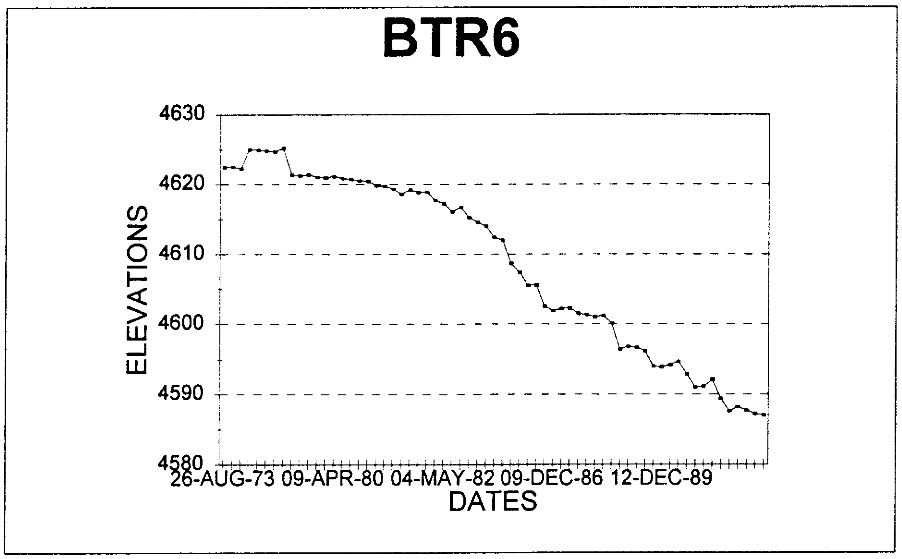
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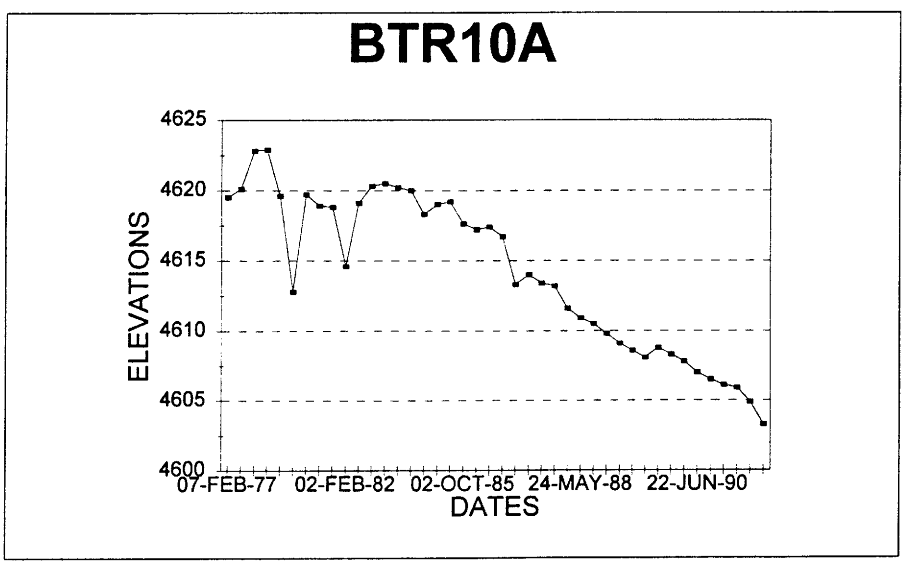
DATES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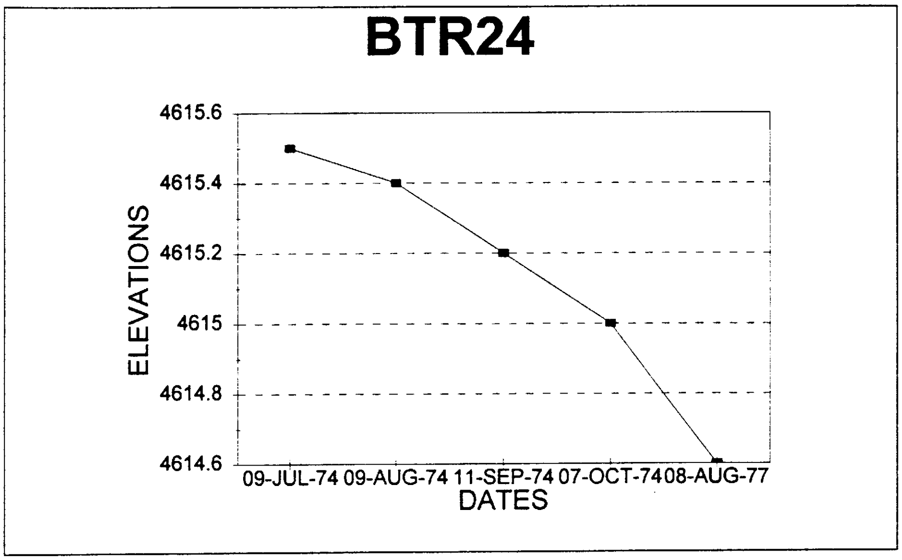
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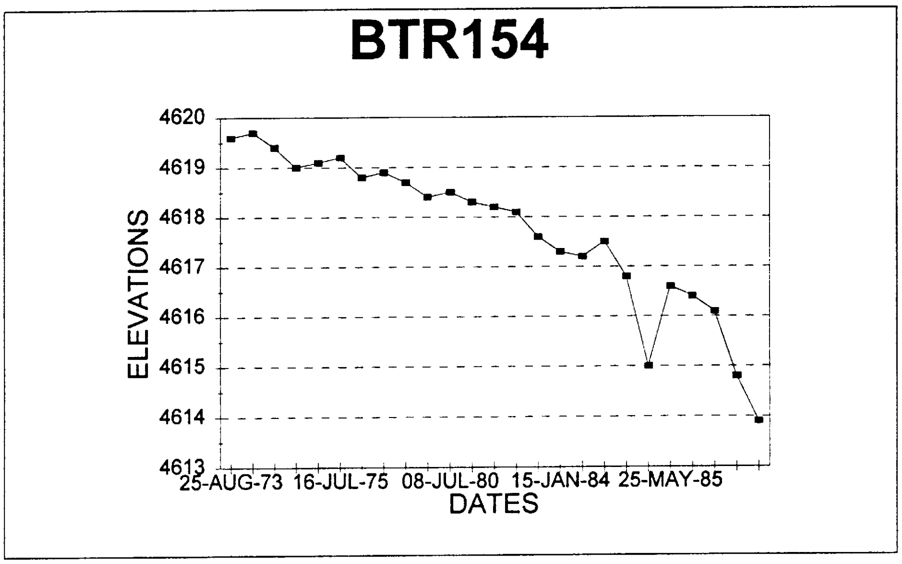
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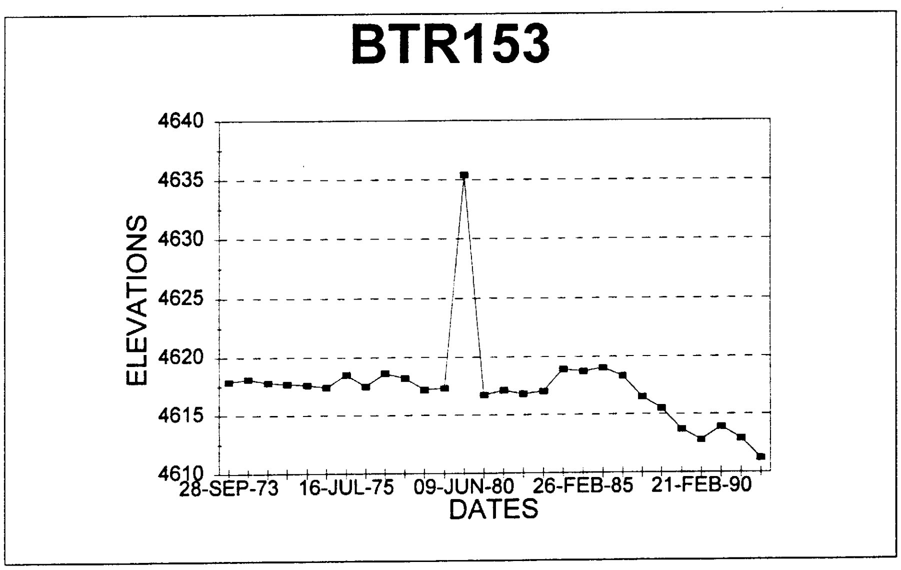
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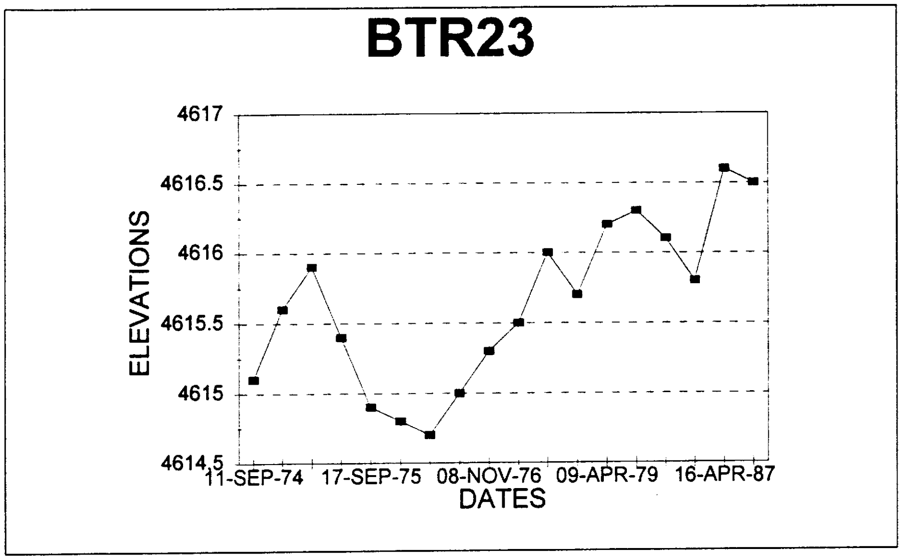
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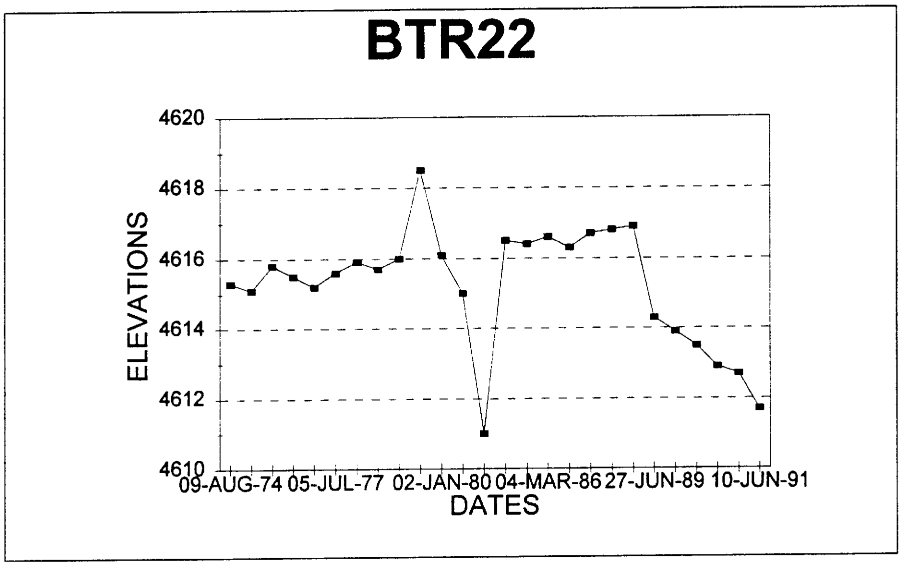
DATES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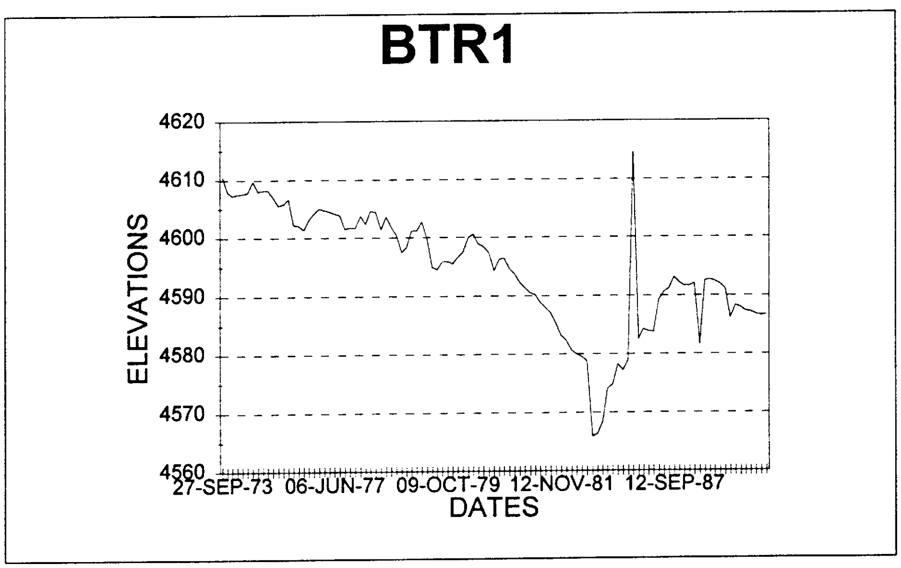
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12-NOV-81
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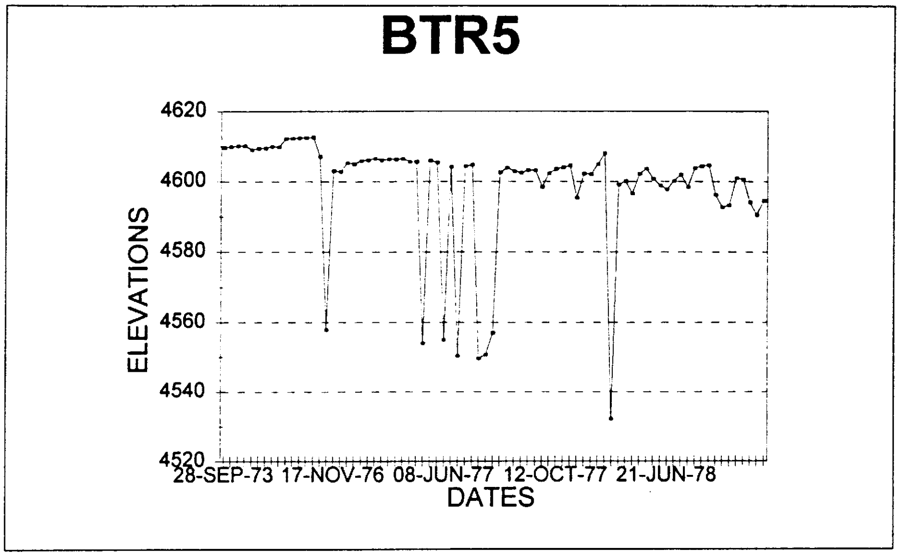
DATES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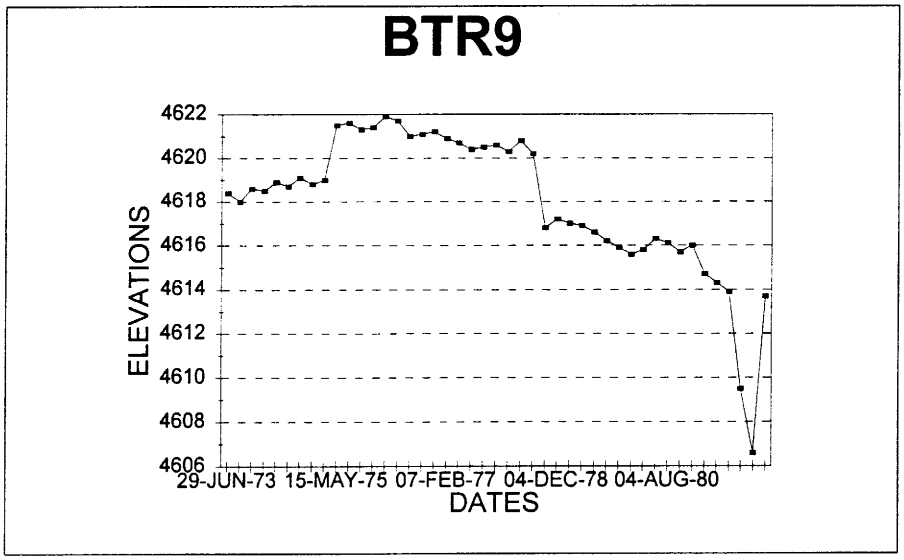
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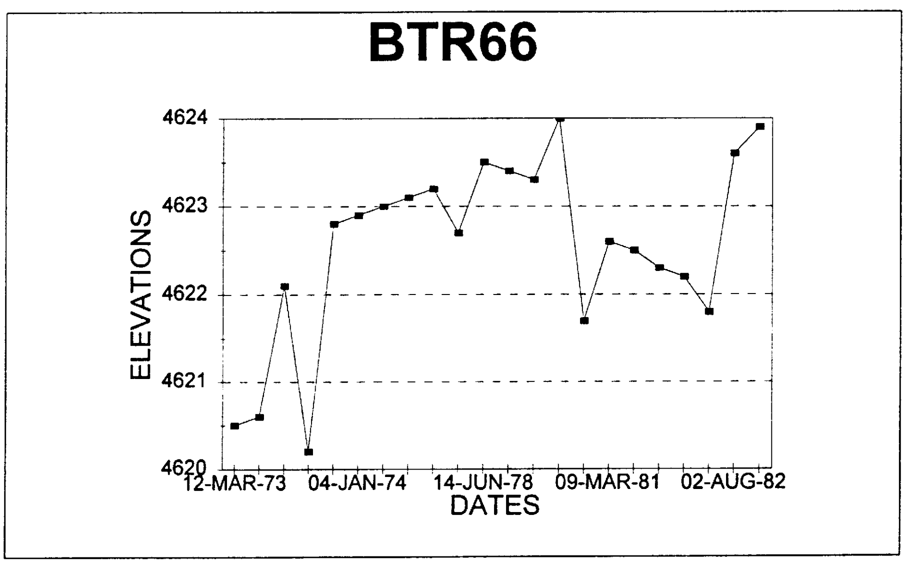
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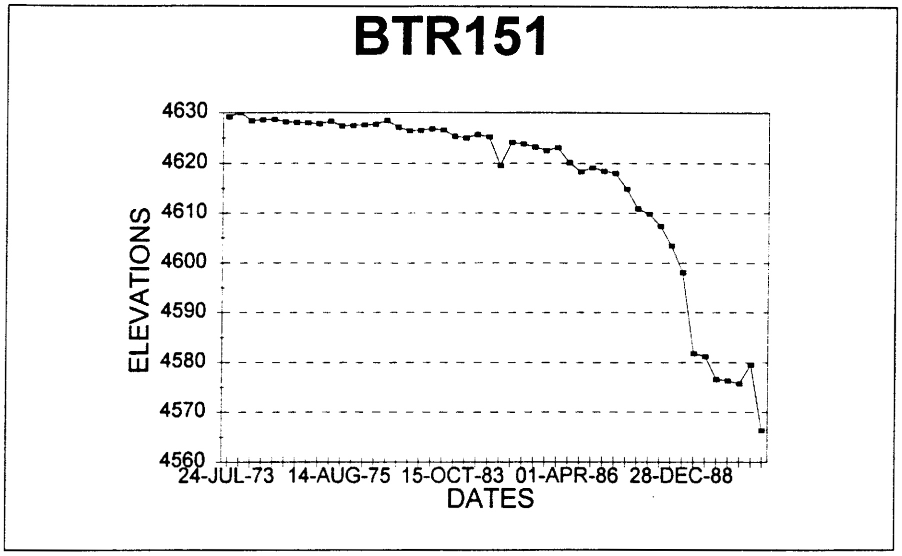
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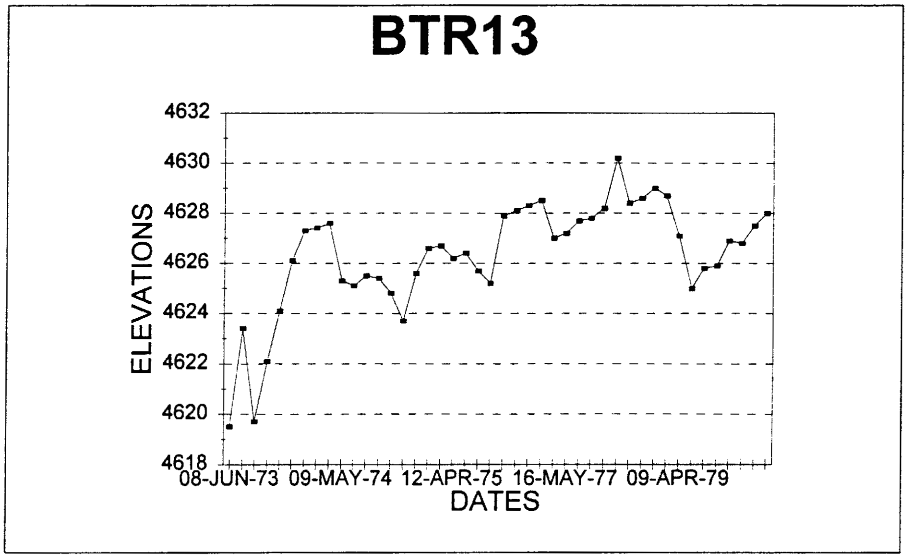
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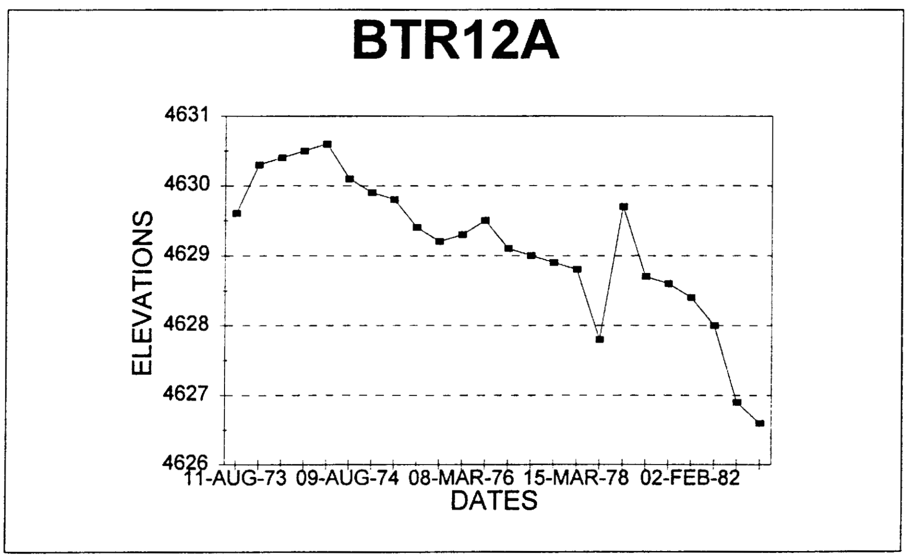
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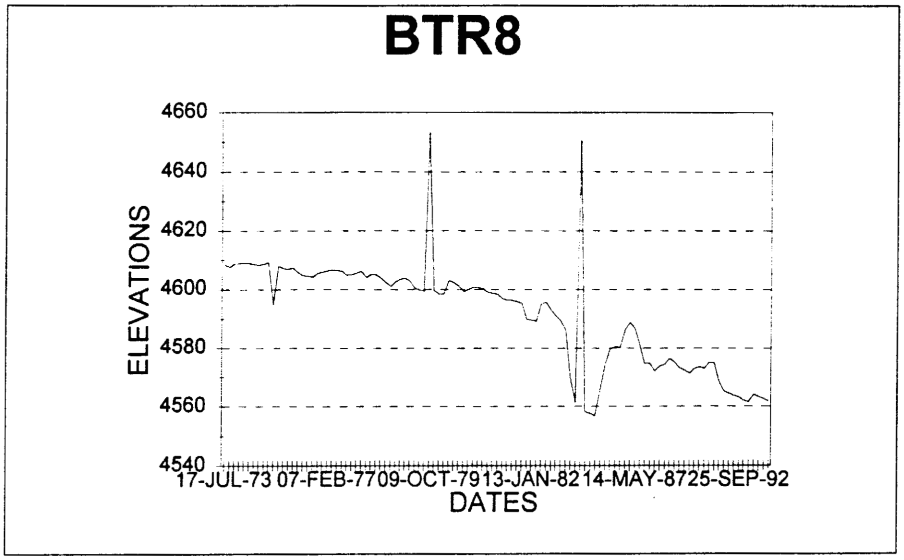
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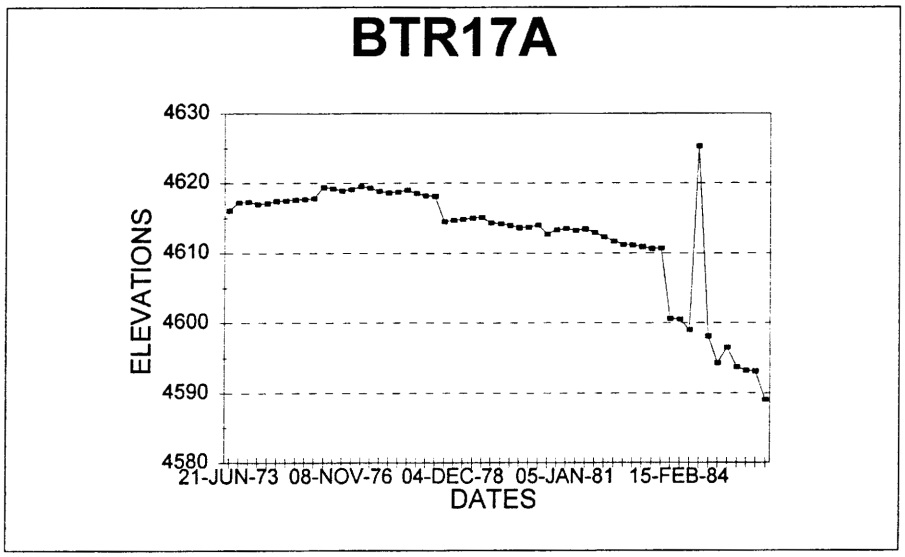
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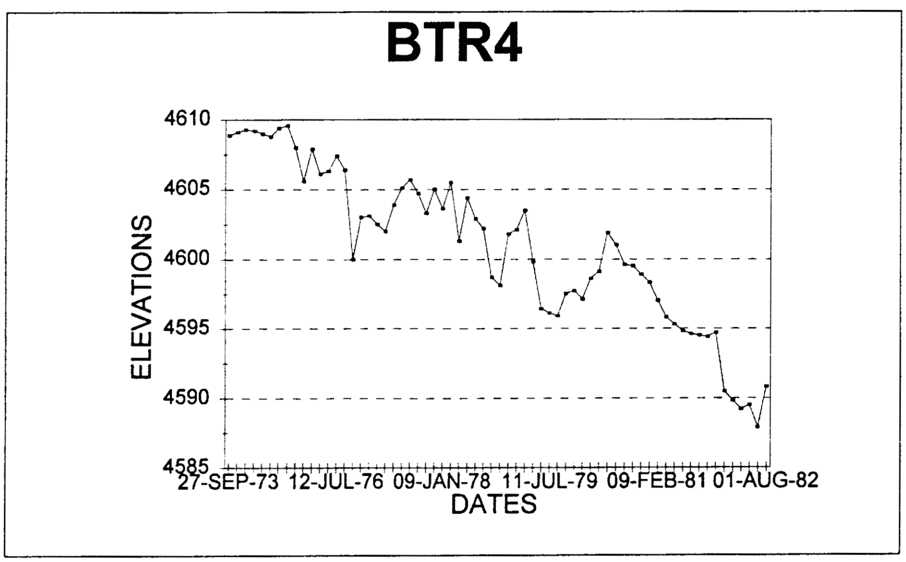
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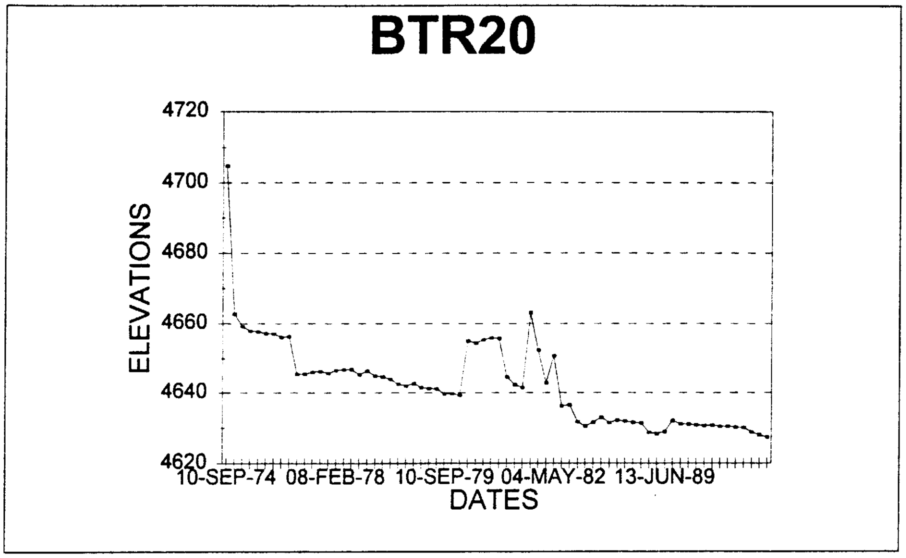
DATES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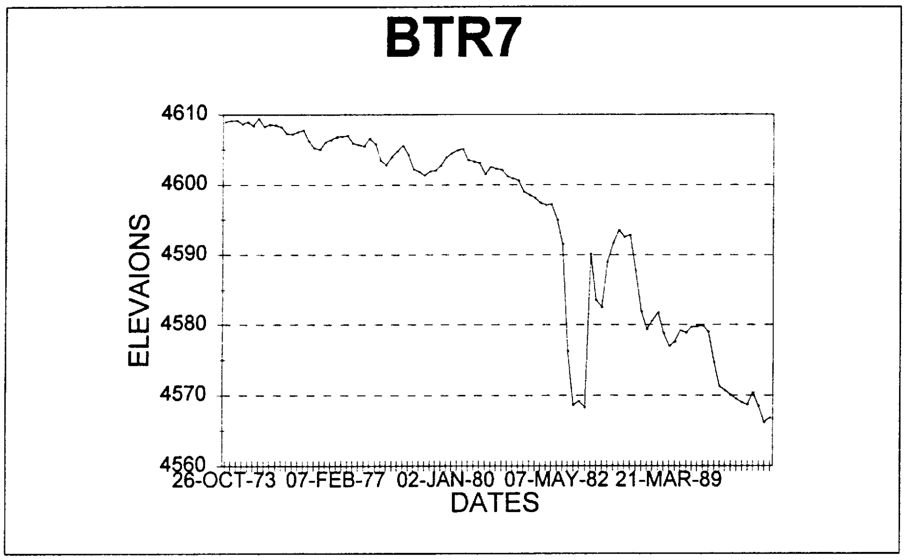
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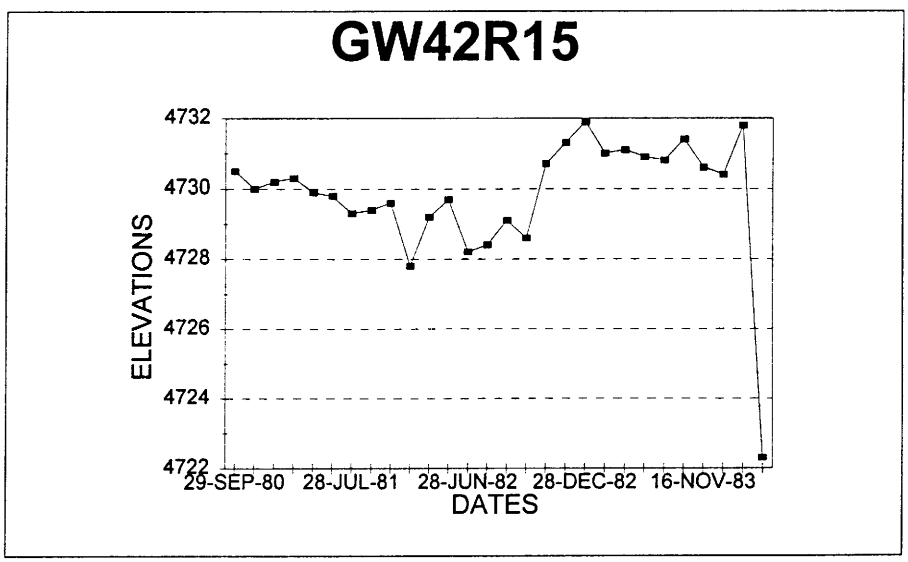
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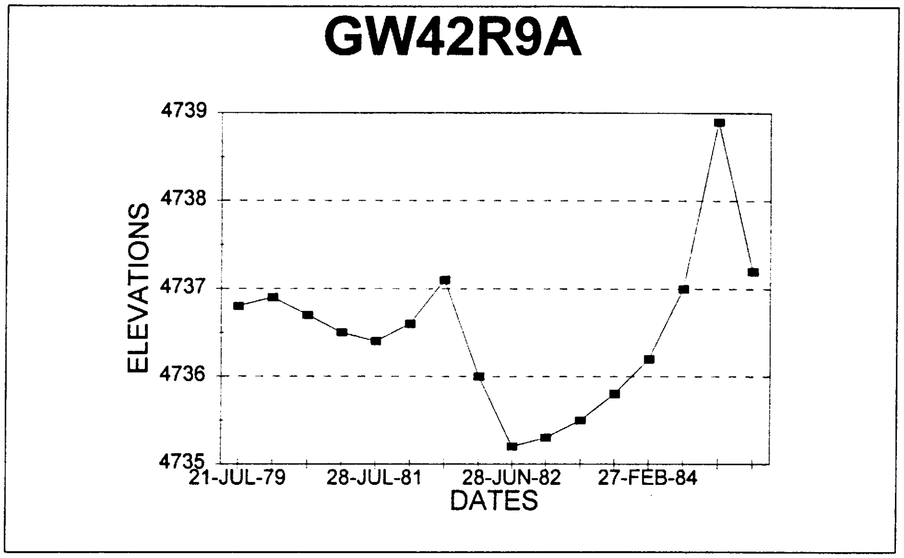
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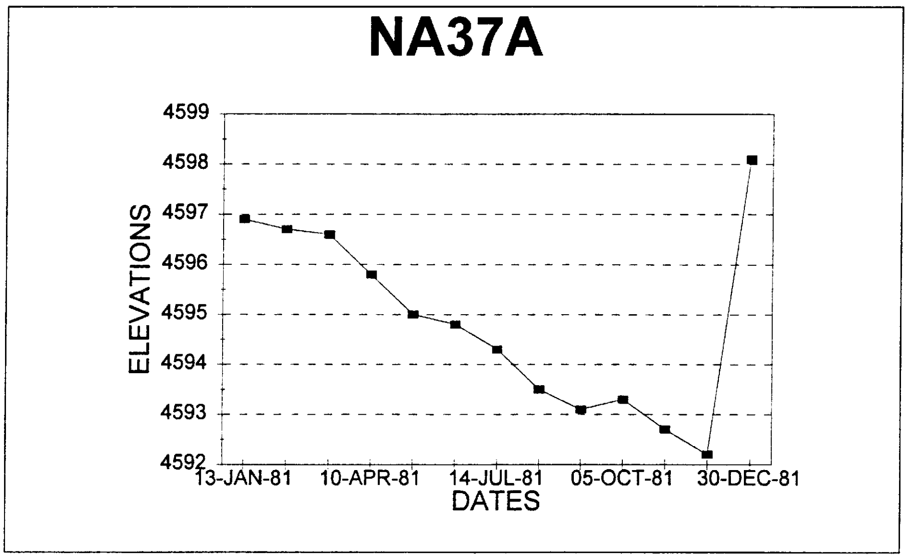
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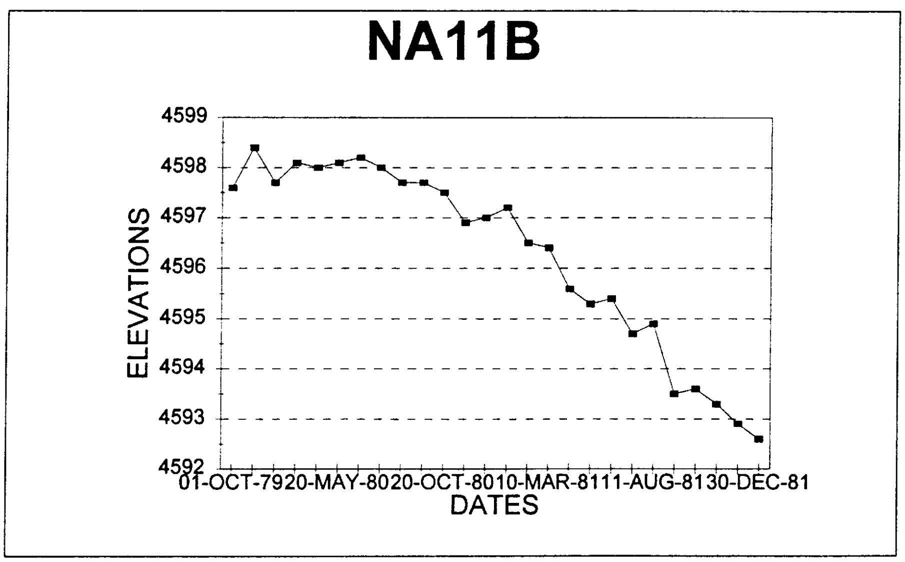
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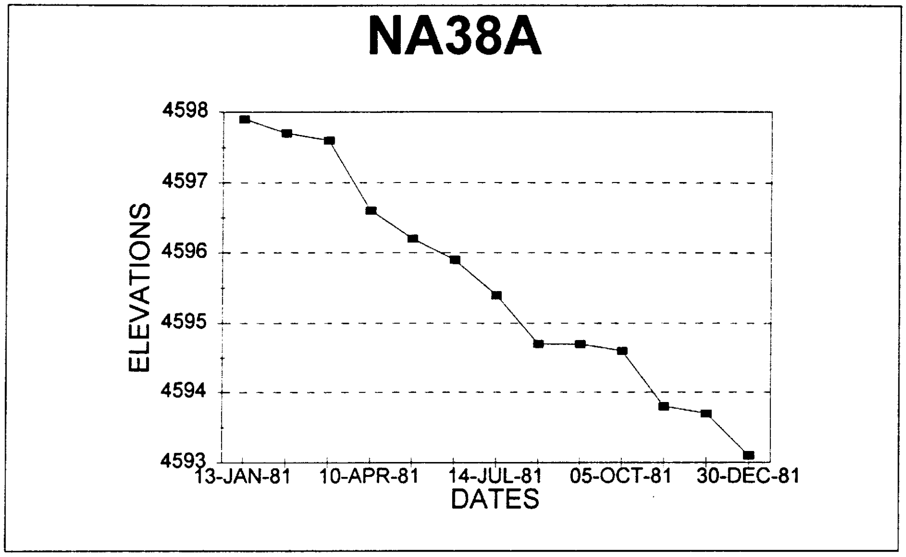
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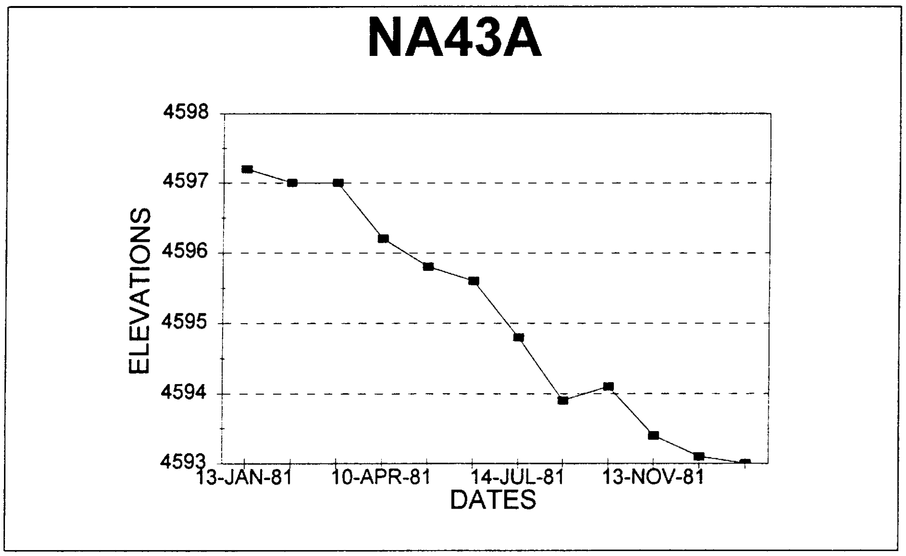
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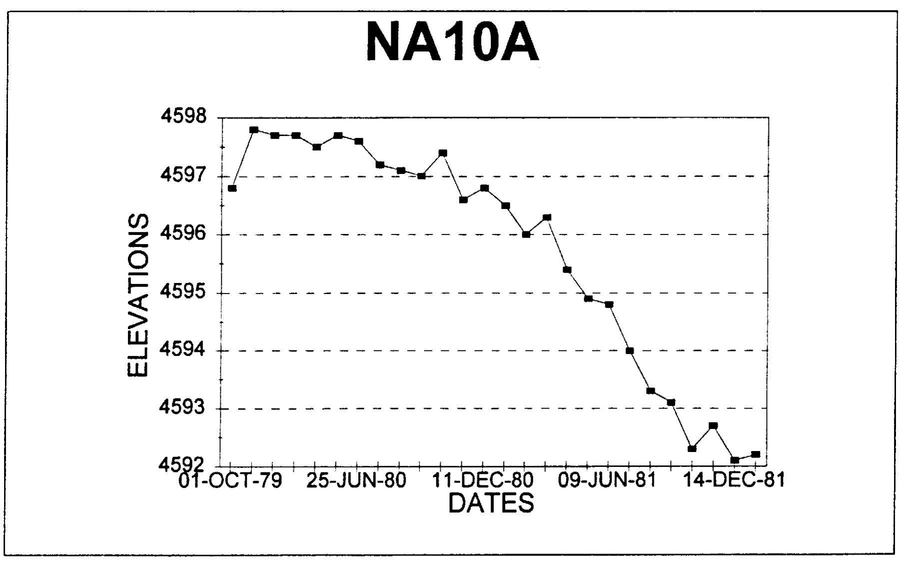
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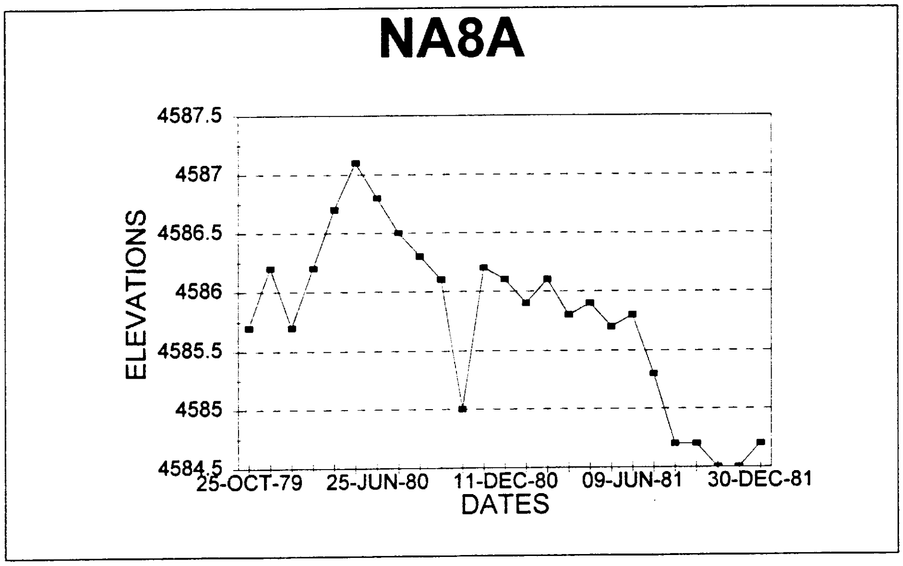
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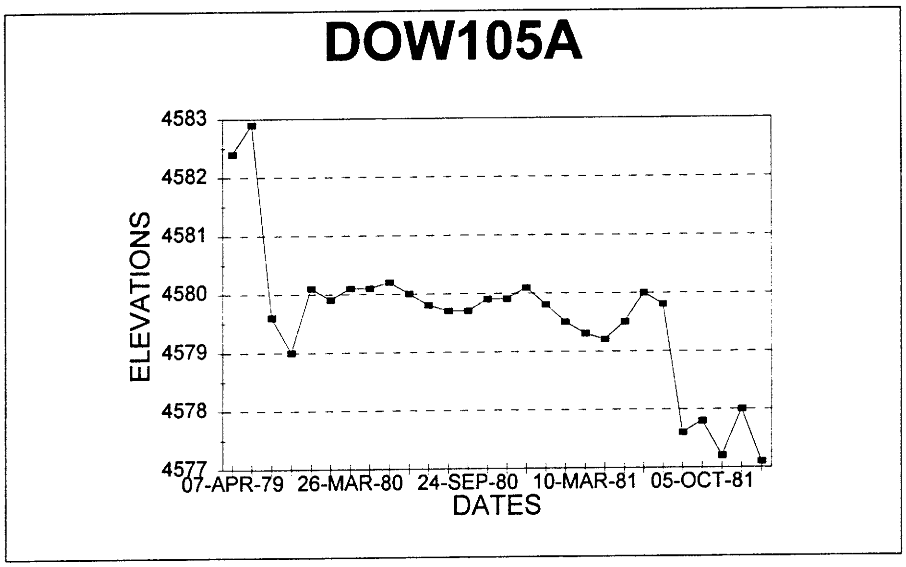
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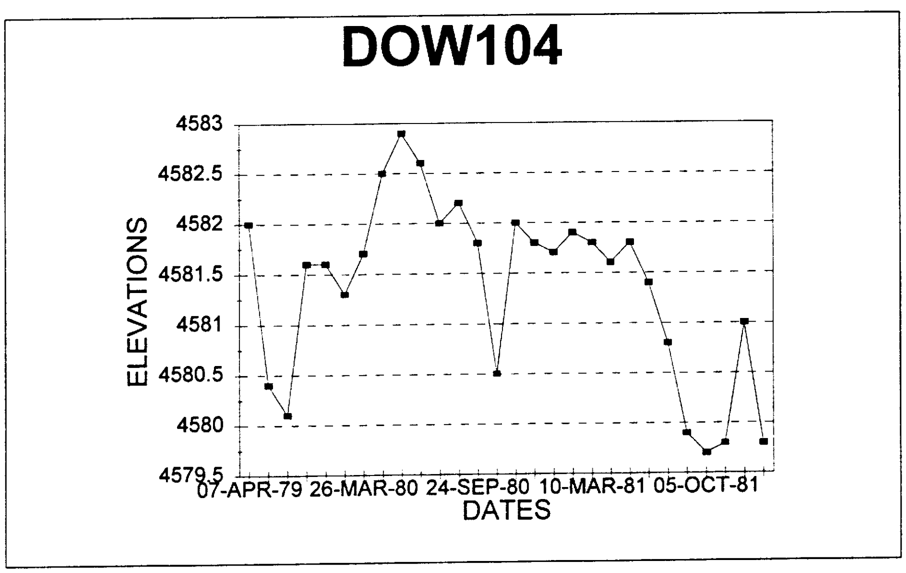
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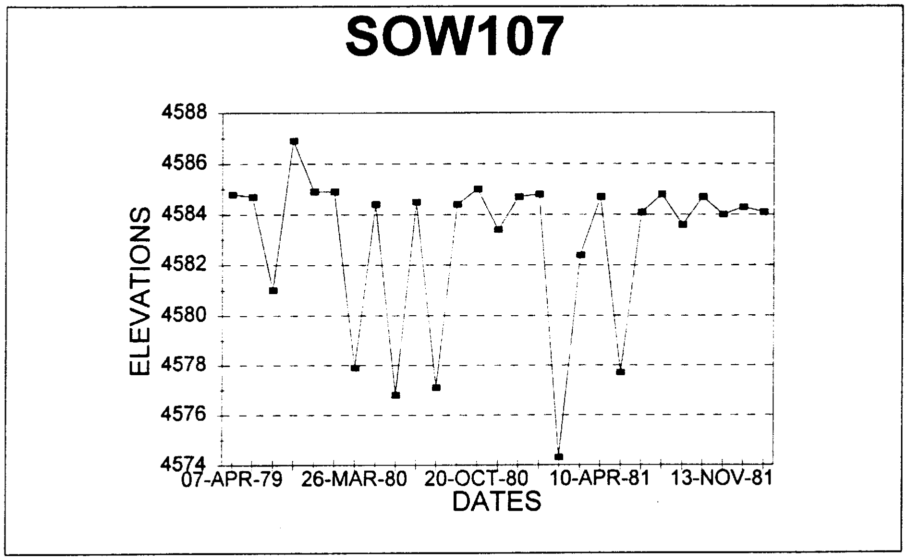
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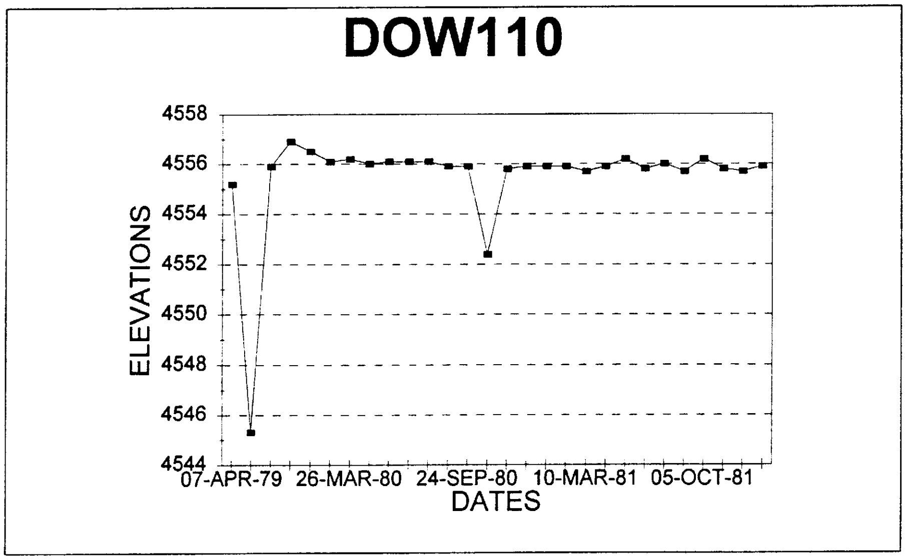
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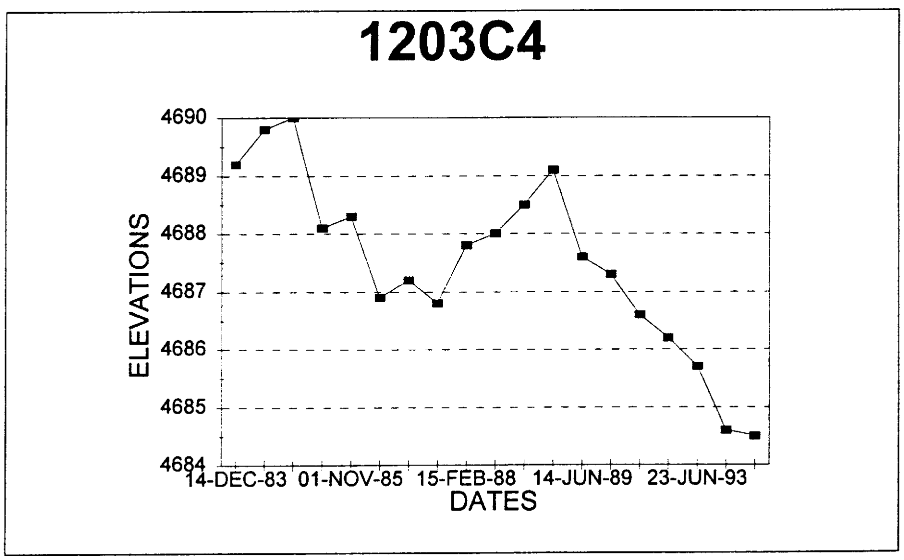
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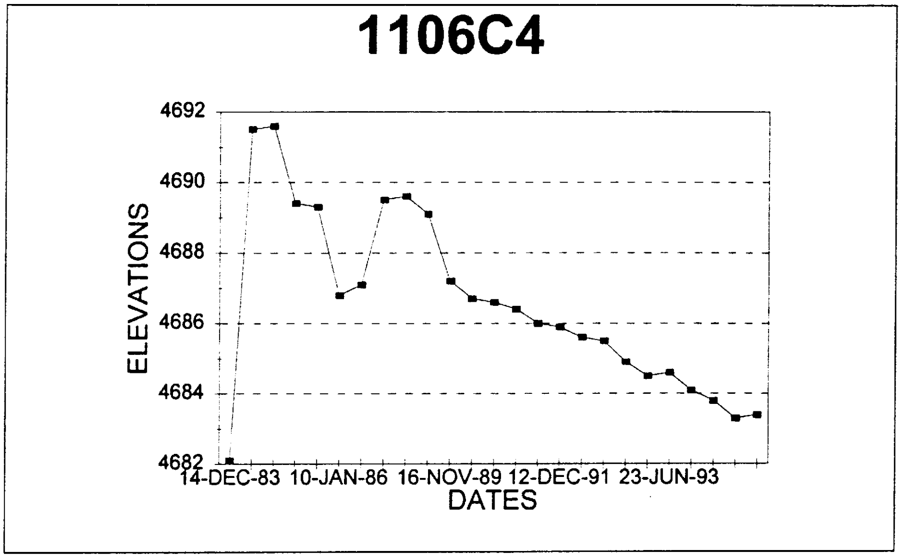
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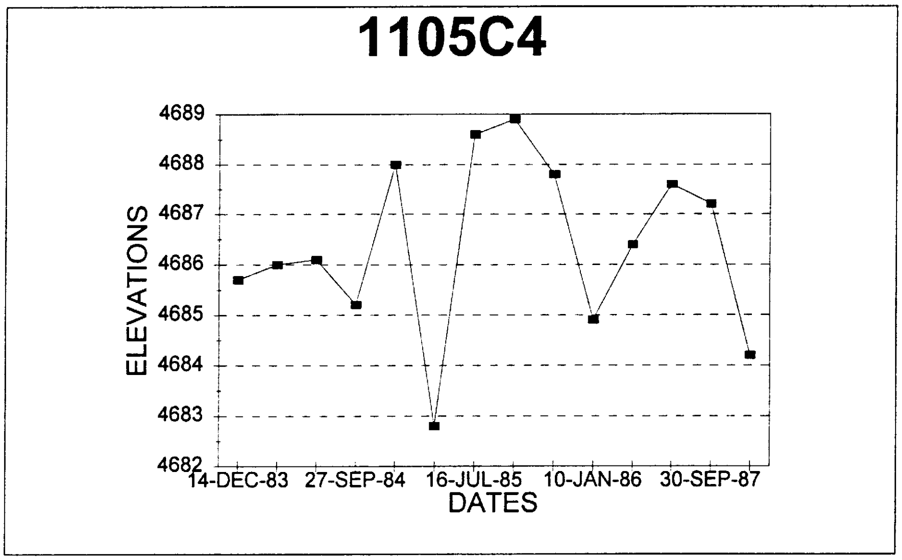
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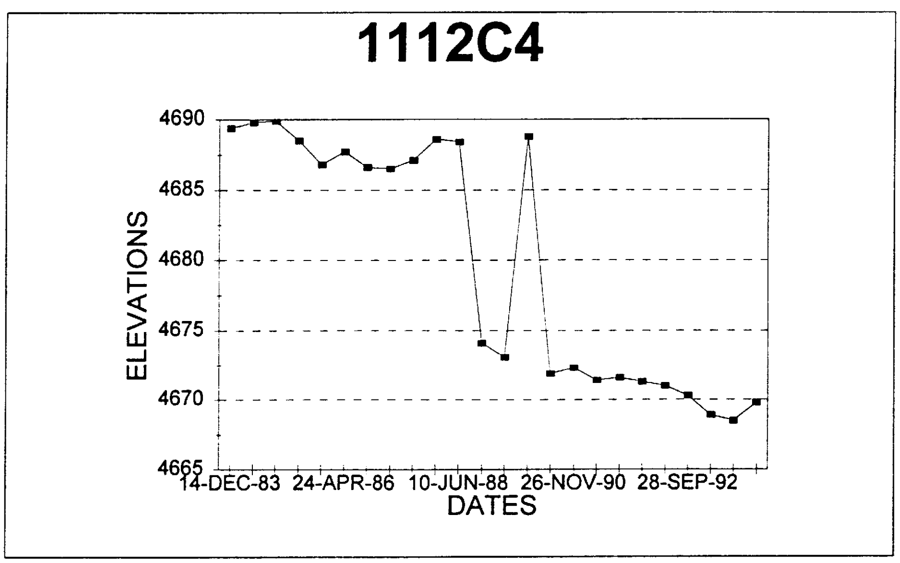
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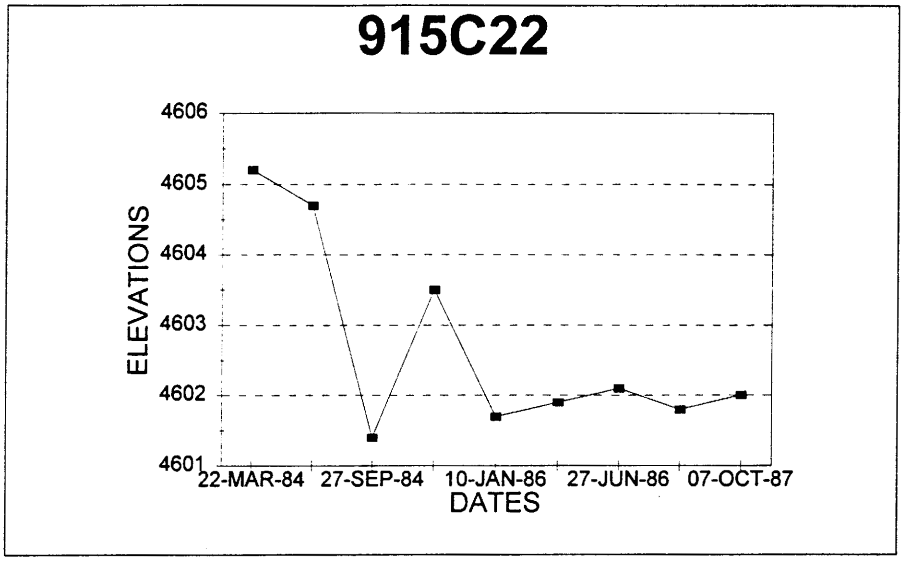
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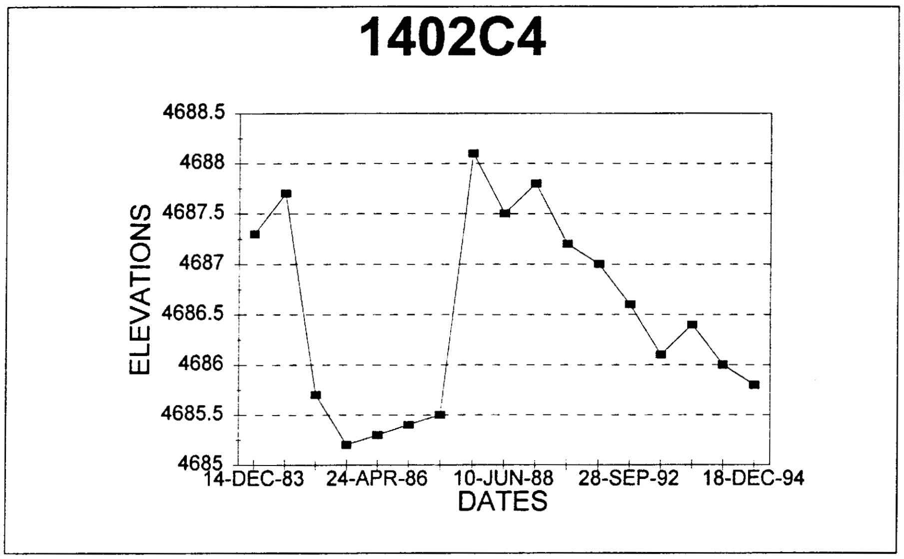
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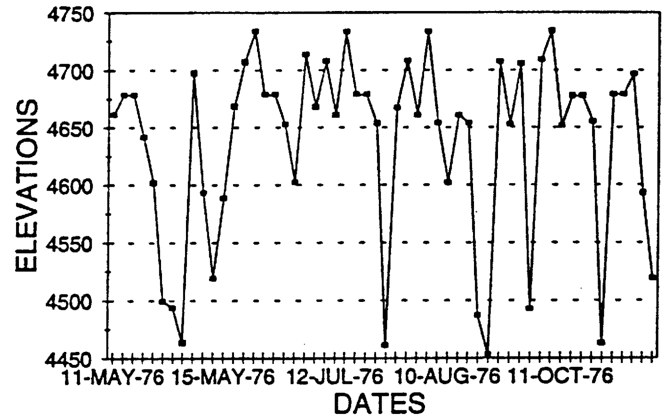

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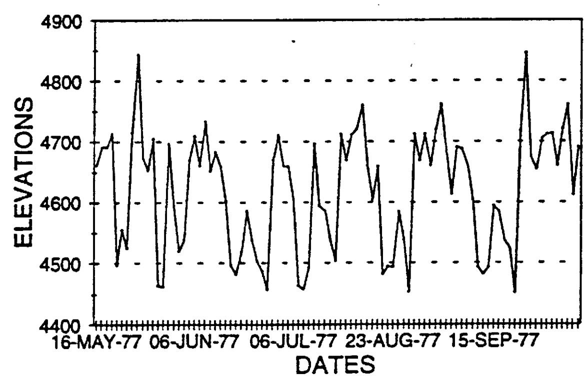

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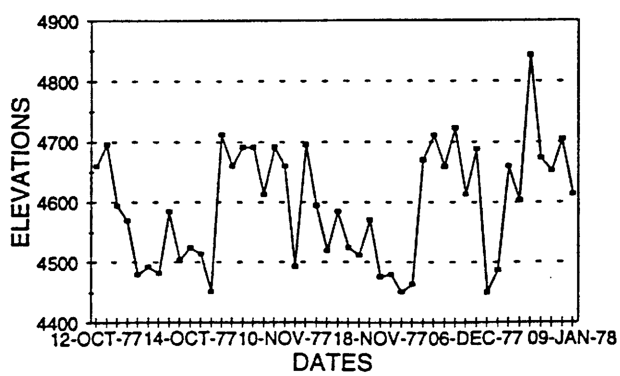

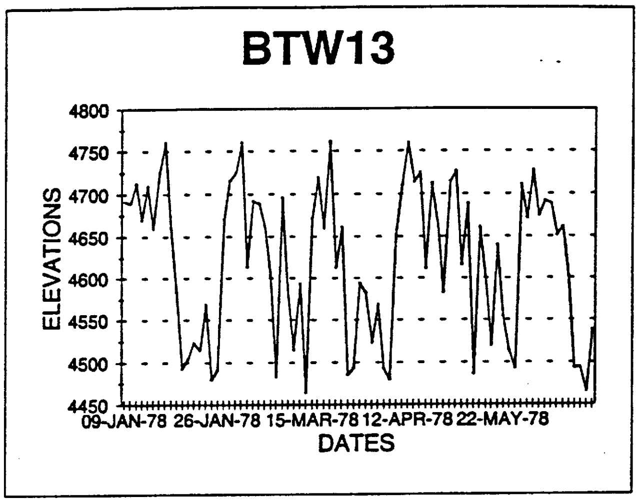
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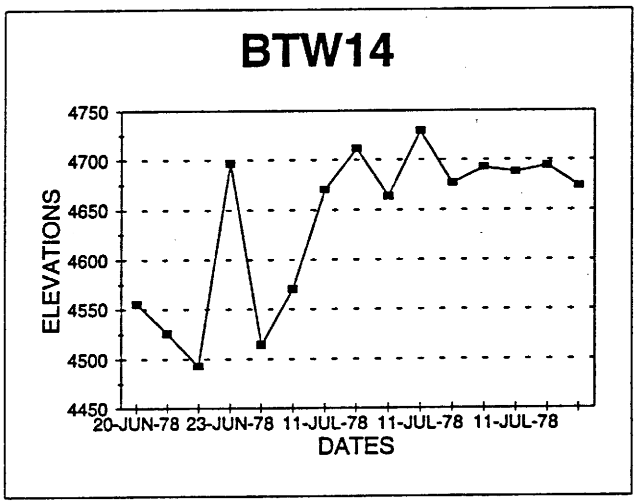
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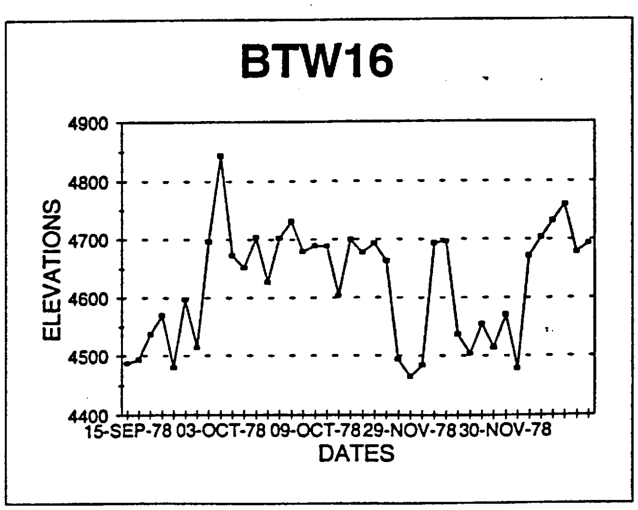
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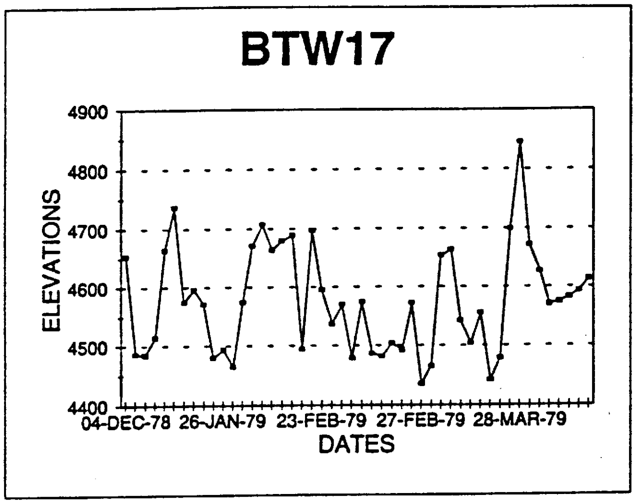
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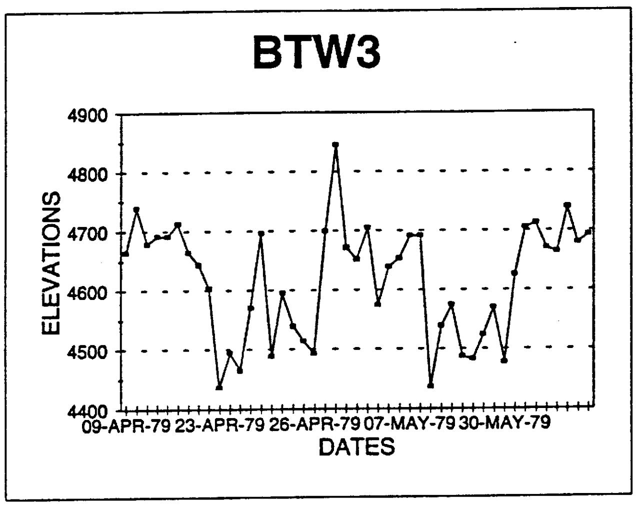
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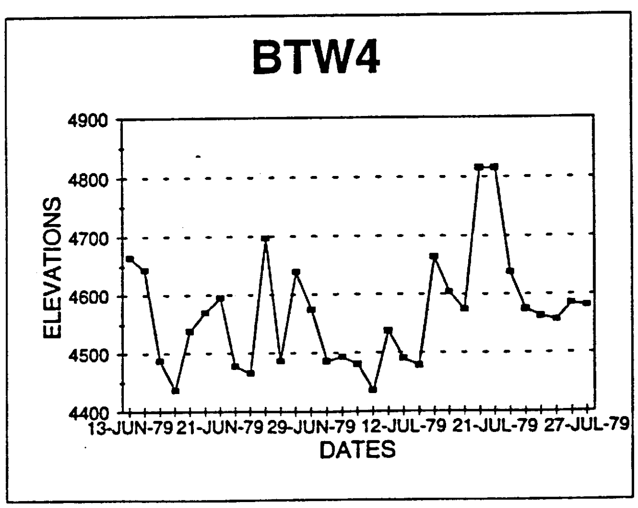
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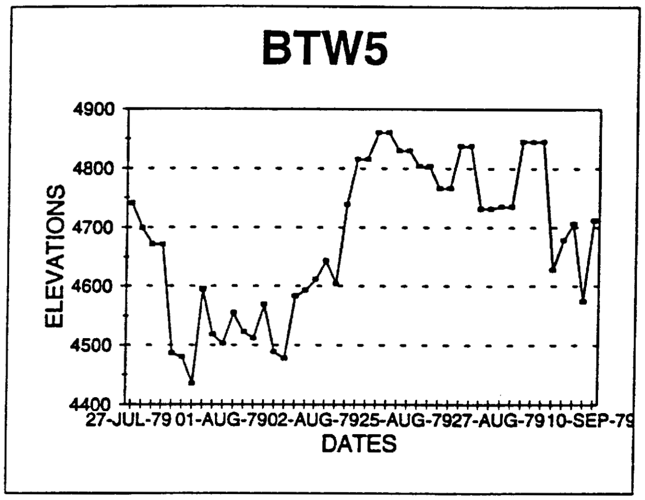
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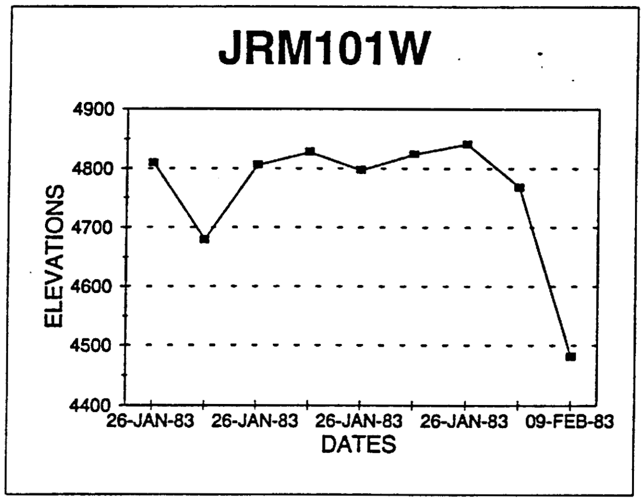
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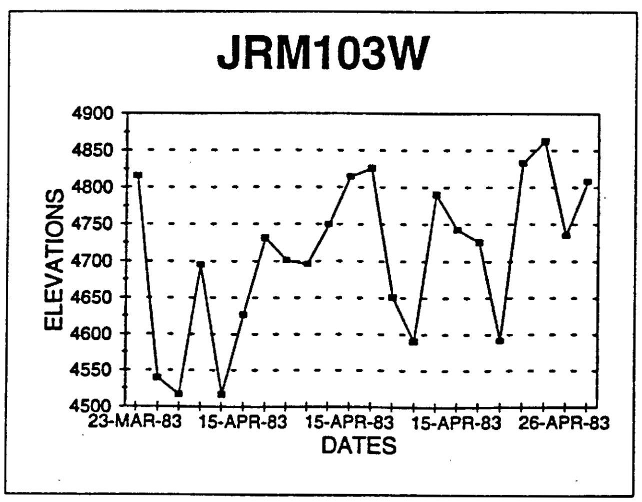
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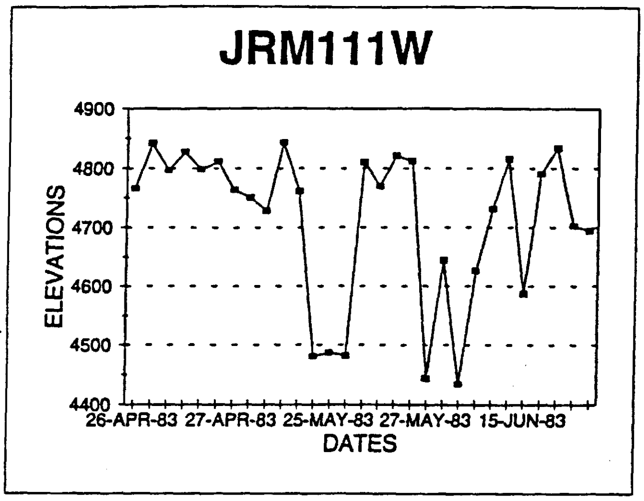
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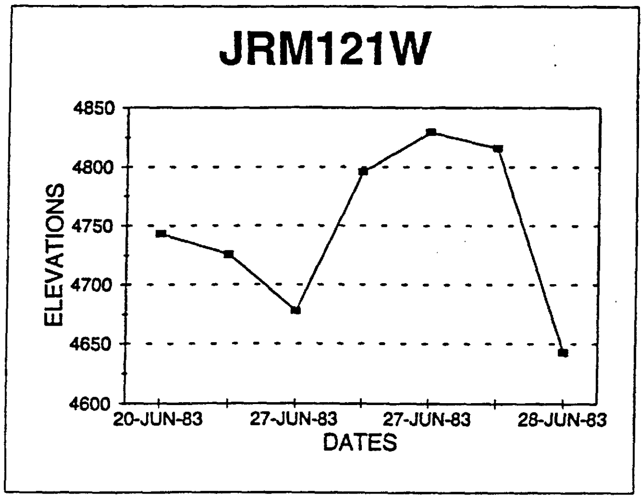
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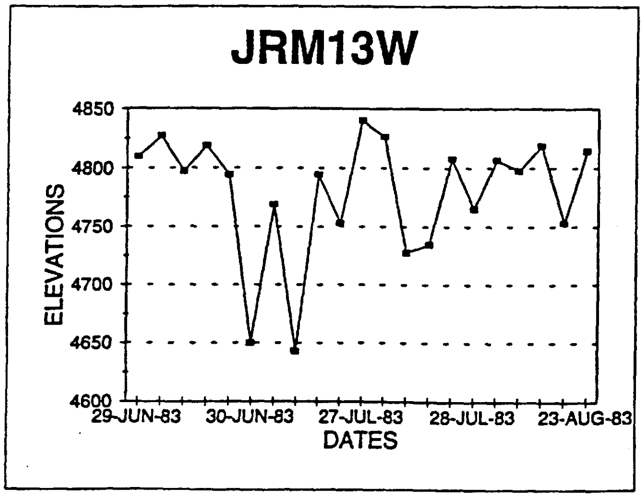
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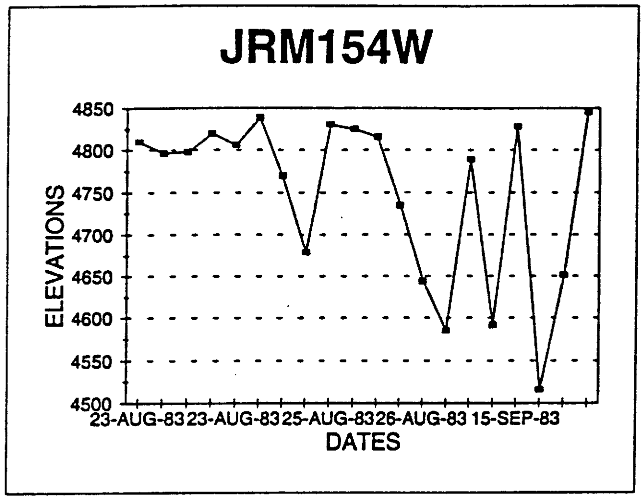
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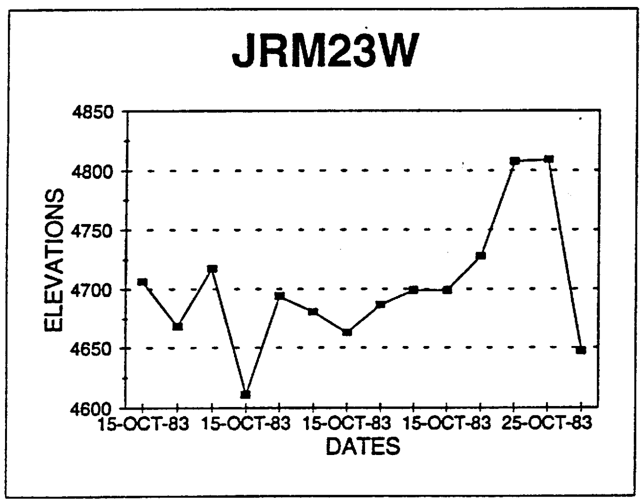
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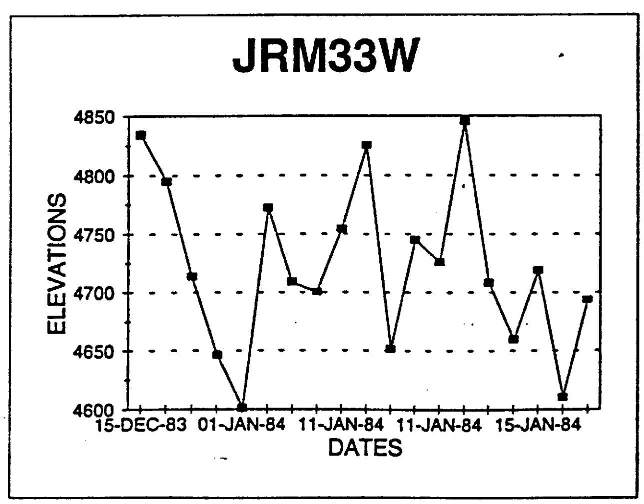
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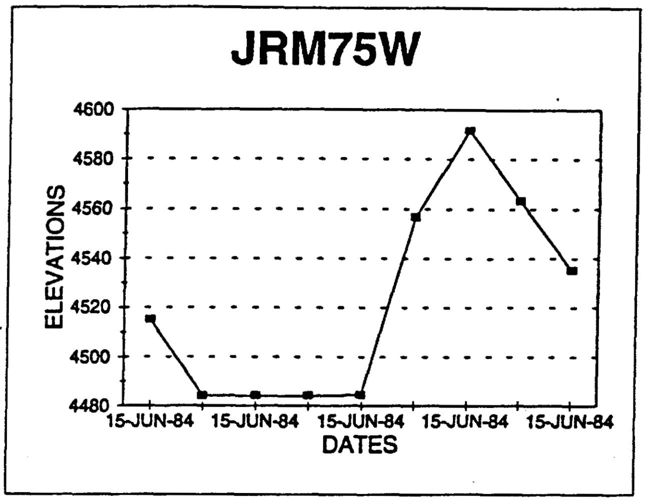
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DATES

Appendix E: Databases

Appendix E: DATA BASES

Hydrology Data (CPR Database)

A Wyoming database for mining related hydrology data was built beginning in 1987. The Office of Surface Mining (OSM) and the Wyoming Department of Environmental Quality/Land Quality Division (WDEQ/LQD) contracted with the Western Research Institute (WRI) to design and populate a database using the Oracle Relational Database Management System (RDBMS). This development occurred from 1987 to 1992, and the product is referred to as the Coal Permit and Reclamation (CPR) database. Work continues on the development and updating of the CPR database. The purpose of this section is to document the work that has been done to date, and to propose methods for continuing the development and updating processes.

CPR Design

The CPR is conceptually organized in four layers. The top layer contains the names of the mines and their description, the second layer identifies the sample stations. Third layer consists of the type of sample station, which may be a well, water body, spring, stream station, or precipitation station, and the fourth layer is the data collected at each sample station - aquifer test, ground water elevations, water quality data from both surface and groundwater sources, surface flow data, and precipitation measurements. Structured Query Language (SQL) used by the Oracle RDBMS allows rapid selection and output of data based on either simple or elaborate criteria. For example it is easy to query the data from an area defined by coordinates, restricted to certain dates, taken from wells completed only in a certain aquifer, or from a water quality parameter exceeding a specified limit. The CPR is currently resident on a server at the Western Regional Service Center of the OSM located in Denver, Colorado. Access to the data is restricted to the data base administrator, WDEQ/LQD staff, and designated individuals working at the Wyoming Water Resources Center (WWRC). Remote access is achieved using the Internet, and wide area networks operated by the OSM, the State of Wyoming, and the University of Wyoming (UW).

Data Acquisition

The data in the CPR comes primarily from Wyoming coal mine permits. Mine companies are required to collect extensive data on all aspects of hydrology within, and adjacent to permit areas. In 1988 and 1989 contract labor was used to input data from the permit files, which were located at the WDEQ/LQD offices in Cheyenne, Wyoming. Due to personnel turnover and other priorities, no further data were input until 1994. At that time, an organized effort to obtain data in digital format was begun. Most companies have cooperated by submitting data in electronic ASCII text files. In 1995, an effort was initiated to establish common data exchange formats. The use of electronic data transfer eliminates keystroke errors and facilitates programming to conduct error trapping.

Data Quality

Poor data quality is a major risk in using database information. Good quality data facilitate meaningful statistical analysis, and before using database information, reliability of the must be known. Svanks (1984) and Cooke and Dobing (1984) suggest that defect rates in stored data may average around 5% and may exceed 45%. These statistics reflect data defects that have slipped through verification and control procedures.

The CPR Database

As in every database, keystroke and measurement errors are present in this database. Because it is an integrated database, CPR may also have data compatibility errors. Both graphical displays and constraint based error checking procedures have been applied to determine errors in the CPR database. As expected, graphical displays were effective in detecting keystroke errors. Although the number of constraints used in data checking have been limited, the results are promising.

The CPR has a wide number of data elements. Creating and analyzing graphical displays is not advisable for every data element in the database. In this case, constraint based error checking seems to be a plausible solution. However, finding effective constrains on the range of values of the data elements, and logical constraints for relationships between data elements is not an easy task. The potential seasonal characteristics of hydrologic data must be considered in the analysis data errors.

The problems faced in the CPR database are primarily problems of data integration from different sources, and keystroke errors. Mining companies either take their own samples, or they contract with consultants to do the sampling. In either case, independent laboratories analyze the water quality samples. Although regulations promulgated by the regulatory agencies for sampling and analysis procedures are generally unambiguous, individual mines may negotiate alternate methodologies in their mining permits. A strict standardization of measurement techniques would help in overcoming data incompatibility. The precision and the accuracy of the measurements also needs to be addressed. Precision and accuracy of electronic measuring instruments are not only subject to change based on time of usage, but also based on the specific laboratory doing the analysis. In the event that the precision and the accuracy of the same kind of electronic instruments differ, the need for equipment calibration to a uniform sample is apparent.

Keystroke errors are a result of hand data entry. Some of the initial data were entered from ten-key by trained office technicians that lacked hydrologic experience. The resulting data entry errors were due to the technicians' unfamiliarity with geospatial and hydrologic data.

Methodology For Verification Of CPR Data Quality

Because of the nature of the problems encountered in the CPR database, it was suggested that graphical displays and constraint based error checking be used to verify data quality. This was implemented with success. Graphical displays are useful in identifying key stroke errors, while integrity constraints are helpful in detecting measurement errors. Identifying constraints that define the relationships among data elements, and validity checks for each data element, is crucial to data validation in the CPR. The step-by-step process is described below.

- Define integrity constraints for validity checks for each data element and relationships among data elements. Examples include:

  a) Easting must be between 350,000 and 450,000.
  b) Ground water elevation must be less than top of casing elevation.

- Decide what percentage (sample size) of the database will be checked.

- Define suitable quality measures to be used in summarizing the constraint based error checking results (such as percent defective).

- Create a unique table (output) for records that violate a particular constraint.

- Analyze output tables, diagnose causes, summarize results, and propose remedial actions.

Results

The proposed methodology was applied to the data for the cumulative hydrologic impact assessment (CHIA) in the Pilot Study Area. Data from Thunder Basin, Jacobs Ranch, and North Rochelle mines were represented in the data set. The graphical displays were helpful in identifying key stroke errors. However, the information provided by these displays is limited, and the time required for the preparation is extensive. Definition of proper constraints is very critical and time consuming. The number of data errors detected using the data constraints indicate that constraint based error checking is worth using in data quality assurance (QA). After potential errors are defined, a resolution of each error must occur. Resolutions may range from research to determine the proper value for each potential error, to simply discarding all suspect data. Previously, corrective actions have been cumbersome because of the database ownership provisions.

Conclusions

Constrained error checking to validate internal consistency in the CPR is recommended, as is the use of exploratory statistical techniques that can aid in the initial examination of data. Data editing methodologies such as integrity analysis, were used, with overall promising results.

Comments and Suggestions

Although data quality problems have been discussed in the literature, statistical considerations are very limited. Constraint based error checking is the main method used today in database error checking. Even though it is very effective in various applications, it cannot be used in cases where relationships between data elements are not possible to address.

It is interesting that the literature does not discuss classical statistical quality control techniques in relation to data quality. Similarities exist between database quality and product manufacturing quality, such as conformity to specification, lowered defect rates and improved client (researcher) satisfaction. Tools developed by modifying statistical quality control techniques may be effective and easy to implement in data error checking.

Employing pattern recognition principles in data quality is another possibility that may be effective. Fuzzy logic and complexity concepts should be analyzed for possible uses in data checking.

Some of the original data input to the CPR was ten-key entered as part of the WRI task order. These data contain random errors, and keystroke errors are encountered regularly when working with CPR data. As previously discussed, data QA/quality control (QC) for the CPR is proceeding, and corrections are being made. The focus of QA/QC efforts has been on graphical displays to detect keystroke errors, and systematic integrity analysis to detect errors that violate data constraints. These efforts have been largely confined to the Pilot Study Area.

Geographic Data (Geographic Information Systems Database)

Introduction

A CHIA can be very demanding in terms of management and analysis of hydrologic data. One critical component of a CHIA is the use of a geographic information system (GIS) for support, management, manipulation, pre-analysis, and display of data associated with the chosen groundwater and surface water models. This section discusses the methodology behind the utilization of GIS technology in the CHIA modeling process.

Background

GIS

A GIS is a computer-based system that captures, stores, edits, manipulates, analyzes, synthesizes, and displays geographically referenced information (Burrough, 1985). There are five major components of any GIS software: data input and verification, data storage and management, data output and presentation, data transformation, and interaction with the user. All of these components focus on data that can be described as digitally automated, spatially-referenced features representing physical characteristics of the earth.

Within a GIS, features can be developed and displayed in a manner that coincides with the user's needs. This provides the user with the flexibility to examine any spatially-referenced feature in a variety of ways for an assortment of purposes. This flexibility can be illustrated by the diverse questions that can be answered in using such a system (e.g., where is it, what is at, what changes have occurred, what if, etc.). A GIS, therefore, is not limited to just questions pertaining to location of a feature. It can also provide answers to questions of condition, trends, patterns, modeling, proximity, boundary operations, and logical operations relating to that feature.

GIS - Hydrology and Mine Land Reclamation

GIS and Hydrologic Modeling

The use of computers in hydrologic analysis has become increasingly widespread among hydrologists and modelers alike. Because hydrology is linked in so many ways to processes at the earth's surface, the connection to such sophisticated computer-based technologies GIS is a predictable step in the evolution of hydrologic analysis (DeVantier, et. al., 1993).

Simply defined, a geographic information system, or GIS, is a computer-based information technology which stores, analyzes, and displays both spatial and non-spatial data (Parker, 1988; Maguire, 1991). In the last 20 years, GIS technology has been increasingly applied to a wide range of water-resource-related studies (Males and Grayman, 1992). Specifically, "...hydrologic applications of GIS have ranged from synthesis and characterization of hydrologic tendencies to prediction of response to hydrologic events," (DeVantier, et. al., 1993, page 247).

Maidment (1993) provides the following interpretation of the relationship between GIS technology and hydrologic modeling:

> GIS provides representations of the spatial features of the Earth, while hydrologic modeling is concerned with the flow of water and its constituents over the land surface and in the subsurface environment... Hydrologic modeling has been successful in dealing with time variation, ...but spatial disaggregation of ...study area[s] has [traditionally] been relatively simple. In many cases, hydrologic models assume uniform spatial properties or allow for small numbers of spatial subunits within which properties are uniform. GIS offers the potential to increase the degree of definition of spatial subunits, in number and in descriptive detail... (Maidment, 1993, page 147).

GIS-hydrologic model integration may be grouped into four categories: 1) hydrologic assessment; 2) hydrologic parameter determination; 3) hydrologic modeling inside GIS and linking GIS; and 4) hydrologic models. Of these categories, hydrologic parameter determination and GIS-hydrologic model linking are currently the primary focus of ongoing research nationwide (Maidment, 1993). Relative to GIS-model linking, numerous examples may be identified in the current literature which illustrate the development of applications linking GIS to both surface-water (Yoon, Padmanabhan and Woodbury 1993; Sasowsky, Connors and Gardner 1991) and ground-water hydrology models (Hinaman, 1993; El-Kadi, et.al., 1994).

The advantage of integrating GIS into the hydrologic modeling process, is in its ability to relate different data sets through the common denominator of location. GIS links data sets and analyzes them as a unit within one integrated system, making it an excellent tool for managing the modeling process, analyzing the results, and updating and archiving spatially-referenced data sets (Richards, Roaza, and Roaza, 1993).

GIS and Mining Applications

The use of GIS in the management of mining activities and mine reclamation is a new and growing application of the technology. Specific examples of recent work related to coal mine reclamation include development of GIS-based statistical methods for conducting coal availability studies (Watson and Bryant 1993), spatial predictive modeling of mine subsidence risk (Hao and Chugh 1993), and restoration of polluted streams and watersheds stemming from acid mine drainage associated with abandoned coal mines (United States Environmental Protection Agency (USEPA) and OSM, 1995). GIS has also been incorporated into the Office of Surface Mining's Technical Information Processing System (OSM 1991), which is utilized in many state Regulatory Authority offices for tracking permit compliance, etc.

GIS and Wyoming's CHIA Modeling Process

A logical merging of technologic applications can be realized when incorporating GIS into the CHIA process. This paper outlines the utilization of GIS in the modeling process developed for conducting CHIAs in the PRB of northeastern Wyoming. The following sections focus on the methods applied in the use of GIS to develop, manipulate, and display model inputs and outputs.

Methods

The GIS utilized in this study was ARC/INFO GIS®, a relational, arc-node vector/raster-based system running in a UNIX® operating system environment. Application development was carried out using ARC/INFO's Arc Macro Language (AML). This language is an interpreted language modeled after Prime Computer, Incorporated's, Command Procedure Language (CPL), and it provides programming capabilities and a set of tools for tailoring the user interface of ARC/INFO applications. These specific products were selected based on compatibility with other cooperating parties and pre-existing expertise with the software[1].

Surface water modeling was performed using HEC-1 and generally required data layer overlays and querying of the GIS database. HEC-1 is a lumped parameter, rainfall/run-off and flood prediction model developed by the United States Army Corps of Engineers (ACOE, 1990). Groundwater modeling employed the United States Geological Survey's (USGS) Modular Three Dimensional Finite Difference Groundwater Flow Model (MODFLOW) (McDonald and Harbaugh, 1988) and directly used manipulated GIS data layers as inputs in the modeling process.

Pilot Study Area and Needs Assessment

All hydrologic models require certain data inputs, and regardless of what is being modeled, there are certain factors that must be considered before gathering these inputs. First, a Pilot Study Area must be defined, and then an assessment of data needs specific to the models has to be completed. Once these items have been examined, actual data development can occur.

Pilot Study Area

Due to modeling efforts being directed towards both groundwater and surface water, two separate Cumulative Impact Assessment (CIA) Pilot Study Areas were developed for the Little Thunder Creek Drainage CHIA. The differentiating boundaries related to the hydrologic regimes for surface water being defined by watersheds, and groundwater being bounded by geological lineaments, faults, and folds. Both modeling regions were, however, in reference to the Little Thunder Creek Drainage, with three coal mines being the focus of each model: Jacobs Ranch, Black Thunder, and North Rochelle.

For the surface water modeling, the 250 square mile (mi.^{2}) Little Thunder Creek Drainage established the Pilot Study Area in question. This drainage is located in southeast corner of Campbell County, and it makes up a headwaters portion of the Cheyenne River Drainage Basin (Figure 3-1, page 3-2). On the groundwater modeling side, a refined grid centered on mining activities and angling north-northwest constituted the two-dimensional spatial extent of the study area. This grid covered 790 mi.^{2}, and not only included the three mines, but also a portion of the coal bed methane (CBM) wells found in the region.

[1] The remainder of the test will make reference to ARC/INFO GIS specific commands and functions in *ITALIC CAPITALS.*

Needs Assessment

Once the Pilot Study Area had been defined, it was necessary to determine what spatially referenced data were required. Through careful collaboration among modelers and GIS analysts involved with the CHIA process, 18 GIS data layers were initially identified for development. These layers could be classified by feature type (point, line, or polygon), spatial application (groundwater aquifer system or surface hydrology watershed, or both), and functionality (modeling or cartographic reference). Table 7-1 provides a brief outline of the type of data layers developed, feature type, spatial extent, and use of each.

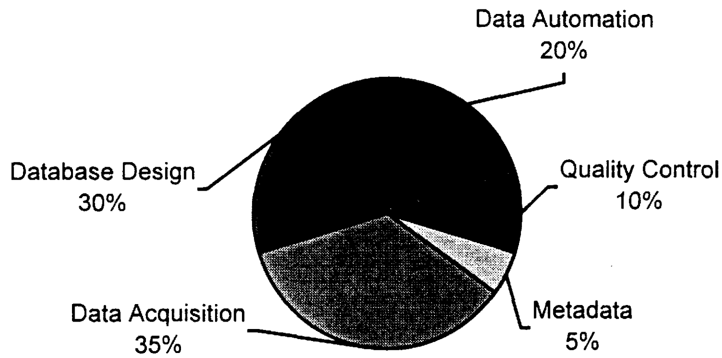
Table 7-1: GIS data layers for the CHIA

Data Layer	Scale	Spatial Extent	Use
Surface Water Flow Stations	Point	surface water	modeling
Climate Stations	Point	surface water	modeling
Surficial Hydrography	Line/Polygon	surface water	modeling
Vegetation	Polygon	surface water	modeling
Soils	Polygon	surface water	modeling
Surficial Geology	Polygon	surface water	modeling
Bedrock Geology	Polygon	both	modeling
Coal Faults and Folds	Line	groundwater	modeling
Coal Isopach	Point/Polygon	groundwater	modeling
Coal Burnline	Line	groundwater	modeling
Clinker	Polygon	both	modeling
Monitoring Wells	Point	groundwater	modeling
Mining Sequence	Polygon	both	modeling
Surface Water Rights	Polygon/Point	surface water	modeling
Ground Water Rights	Point	groundwater	modeling
Digital Elevation Models	Point/Polygon	both	modeling
Public Land Survey System	Polygon	both	cartographic
Transportation	Line	both	cartographic

GIS Development

Once a Pilot Study Area has been defined and an initial data requirements list established, the next objective was to develop the GIS layers. Five steps were identified for development and manipulation of each GIS data layer required in the modeling process: 1) data acquisition; 2) data automation; 3) database design and construction; 4) QC; and 5) metadata. For the CHIA Pilot Study Area, data acquisition required the most time, followed closely by database design and construction (Figure 7-1). When looking strictly at work performed at theWWRC GIS Lab in support of the CHIA, database design and construction, and data automation become the majority of duties. This was due to data acquisition tasks being distributed among all cooperating parties.

Figure 7-1: GIS data layer development, percentage of time required per step



Data Acquisition

Data for the CHIA Pilot Study fell into two categories: 1) data previously developed by the WWRC GIS Lab and therefore in a pre-existing GIS format; or 2) required data only available from an outside secondary source. An assortment of state and federal agencies provided data in a variety of scales and formats. Some of the more common forms were paper and mylar maps, AutoCad data exchange files, or database and ASCII files. Additionally, some mining operations provided large scale, mine-specific data that were incorporated into the modeling process.

Data Layer Automation and Management

This is the process of converting data from its existing format to a digital, spatially referenced GIS layer, while maintaining each data layer in the same projection and units. Different techniques were employed creating the 18 different GIS data layers, which depended directly on the original format of the data. Hard copy maps were either digitized or scanned. AutoCad files and dBase tables were directly converted into ARC/INFO through the *DXFTOARC* and *DBASINFO* command respectively. ASCII text files were manipulated and formatted by AWK scripts allowing for the *GENERATE* command to be applied. These techniques were the most common methods of data automation throughout the study. Many additional steps accompany these commands, and by no means were these the only methods applied (see Data Layer Descriptions below).

Once the data had been converted into a GIS data layer, all the layers had to be projected into a common coordinate system, allowing for data compatibility in the modeling process. For this CHIA, all the data layers were projected to a state plane coordinate system in reference to the Wyoming , East Zone. This coordinate system uses a Lambert projection and measures units in feet, consistent with the units employed in the surface and groundwater models (inches, feet, cubic feet/second, acre-feet, etc.).

Database Design and Construction

Creating a sound structure in which modelers can access and use the data layers is essential, even with only 18 layers. First, the layers were divided by application-dependent areal extent for groundwater and surface water. Then each layer was placed under a thematic directory. For example, both monitoring and groundwater stock wells were placed under a wells sub-directory of the groundwater directory. This allowed for a logical and systematic approach to organizing the data.

In addition to the overall data structure, each individual data layer can have numerous attribute fields associated with each depicted feature. These attributes can be either directly tied to the data layer, or indirectly through relational files. For ease by use of modelers, most data layers, with a few exceptions, did not use a relational database structure.

Quality Control

With any modeling, a degree of data QA is necessary to provide defensible results. For the GIS data layers, both spatial feature completeness and location were examined, as well as the accuracy of associate attributes. This was accomplished, in many cases, by producing a map of the data layer and comparing it to the original. This allowed for missing and/or mislabeled features to be identified and corrected. In cases where there were not comparable maps, the source data were directly compared with its GIS counterpart. Spatial accuracy of all the data layers followed the U.S. National Map Accuracy Standards (U.S. Bureau of the Budget, 1941).

Metadata

Metadata describe the content, quality, condition, and other characteristics of data (Federal Geographic Data Committee, 1995). For each GIS data layer that had not been previously developed, metadata were completed. This allows for people, other than the creator, to understand and have reference to all the different aspects related to the data layer (i.e. data quality, type of features, spatial reference, attribute naming conventions, etc.). This is an essential component of any GIS data layer deliverable, and it accompanies the data during distribution.

Data Layer Descriptions

As previously mentioned, 18 data layers were identified as modeling needs for the CHIA process. The following summarizes each data layer in respect to description, automation techniques, scale, and source. These are just brief descriptions, extensive definitions can be found in other sections of the report or in the metadata. Table 7-2 lists the data layers, and also displays the scale, source, and major conversion techniques employed for each layer.

Table 7-2: GIS data layers - scale, source, and automation method

Data Layer	Scale	Source	Conversion Technique
Surface Water Flow Stations	NA	WRDS	*DBASEINFO*
Climate Stations	NA	WRDS	*DBASEINFO*
Surficial Hydrography	1:24,000	7.5 minute USGS quadrangles	Digitizing
Vegetation	1:100,000	Wyoming GAP Project	Pre-existing
Soils	1:250,000	STATSGO	Pre-existing
Surficial Geology	1:100,000	WWRC	Pre-existing
Bedrock Geology	1:500,000	WWRC	Pre-existing
Coal Faults and Folds	1:62,500	USGS (Denson, 1980)	Digitizing
Coal Isopach	NA	WDEQ/LQD CPR database	ASCII to ARC/INFO with *GENERATE*
Coal Burnline	1:24,000	BLM (Heffern, 1996)	Digitizing
Clinker	1:24,000	BLM (Heffern, 1996)	Digitizing
Monitoring Wells	NA	WDEQ/LQD CPR database	ASCII to ARC/INFO with *GENERATE*
Mining Sequence	1:2,000	WDEQ/LQD mining permits	Digitizing
Surface Water Rights	1:24,000	WSEO	Digitizing
Ground Water Rights	NA	WSEO AREV database	*DBASE INFO*
Digital Elevation Models	30 meter resolution	USGS	*DEMLATTICE*
Public Land Survey System	1:100,000	WWRC	Pre-existing
Transportation	1:100,000	TIGER	Pre-existing

NA - not available

Surface Water Flow

This data layer contains points showing the location of stream flow and surface water quality stations in the Pilot Study Area. Each point has a station identification number that can be related to the database describing time series of flows, and water quality measurements. Data were acquired from the Water Resource Data System (WRDS) and the WDEQ/LQD CPR database. These values were then imported into a usable dBase format and locational data fields were used to generate an ARC/INFO point coverage.

Climatologic Data

This data layer depicts precipitation stations through individual point features. Each station is linked to its unique identification number that can be tied to its respected time series of precipitation information. The data values were acquired from the WRDS and developed into an ARC/INFO coverage through the exact methods applied to the flow data.

Surficial Hydrography

This data layer displays the stream network for the Pilot Study Area, and the accompanying lakes and reservoirs. A directional line coverage (all arcs go downstream) depicts stream channels with a polygon coverage containing all reservoirs. Additionally, all channels have hydraulic connectivity through reservoir regions. Water regime attributes (perennial or intermittent) tied to the associated features replicated the USGS 7.5 minute quadrangle naming conventions. These features were digitized off paper 1:24,000 USGS quadrangles.

Land Cover/Vegetation

This layer contains land cover polygons linked to attribute fields describing primary and secondary land cover. Both land cover fields have associated polygon percentages describing the breakdown of land cover found within the polygon. The land cover layer was acquired from the Wyoming Gap project in ARC/INFO format and was constructed from Landsat Thematic Mapping (TM) imagery using a manual polygon digitizing technique. Photo-interpretation was then performed for land cover attributing. This coverage is completed statewide at a 1:100,000 scale with a land cover minimum mapping unit of 100 hectares (Merrill, et al, 1996).

Soils

This layer contains soil polygons attributed by a general soil profile identification describing that feature. Additionally, relational tables linked by profile identification have a wide assortment of physical characteristics (i.e. texture, permeability, holding capacity, rooting depth, etc.) associated with each soil (Lytle, et al, 1993). The Wyoming State Soil Geographic Data Base (STATSGO), previously developed in a GIS format by the Natural Resources Conservation Service (1991), served as the primary source. This digital data set is statewide at a 1:250,000 scale.

Surficial Geology

This layer contains surficial geology polygons linked to an attribute table comprised of the associated geology for each feature. Data were digitally developed at the WWRC GIS Laboratory through scanning of the original mylar surficial geology maps produced by the Wyoming Geological Survey (WSGS) (Arneson and Case , 1996). Photo-interpretation of surface geology was the primary source for creation of the mylar maps. The digital coverage presently maintained by WWRC is statewide at a 1:500,000 scale.

Bedrock Geology

This layer contains bedrock geology polygons linked to an attribute table comprised of the associate geology for each feature. Data were digitally developed at the WWRC GIS Laboratory through the scanning of the original mylar bedrock geology map produced by Love and

Christianson of the USGS. The digital coverage presently maintained by WWRC is statewide at a 1:500,000 scale.

Coal Faults/Folds

This layer defines faults, lineaments, and folds found in the Wyodak Coal in the Pilot Study Area, and it is linked to an attribute table distinguishing among the three. The data layer was developed from digitizing a paper copy of Denson's Coal Structure Contour Map (Denson, 1980). These digital data are specific to the PRB at a scale of 1:62,500.

Coal Isopach

This layer contains polygons describing the thickness of the coal seam. The coal isopach coverage was digitally created from geologic drill hole data found in the Pilot Study Area. Through generating the x and y locations of these drill holes, a point coverage was created in which coal thickness was produced by subtracting the top of coal elevation with the bottom of coal elevation for each individual point. These point data were then converted to polygons through kriging in order to expand the extent of the data.

Clinker

This layer contains clinker polygons linked to an attribute table naming clinker regions by the associated coal seam that was burned. Also, an additional layer was created using arcs to depict the actual burn line found within the region. Data from this layer were developed by Ed Heffern, geologist for the Mineral Program Operations branch of the Burau of Land Management (BLM) in Cheyenne. Through analysis of 1:24,000 surficial geologic maps by USGS, fine tuned photo-interpretation of color IR photos, and mine permit records, clinker regions were mapped onto 1:24,000 quadrangles. These paper maps were then converted to ARC/INFO through digitizing these delineations.

Well Data

This data layer is made up of point locations depicting monitoring well locations. Associated with the points are related attributes of formation monitored, groundwater elevation (monthly), and groundwater quality (monthly). Data points and attributes were obtained from the WDEQ/LQD's CPR database and they were converted into an ARC/INFO coverage by using the *GENERATE* command to create point features from the locational data. Water elevations and water quality data were developed in separate data files and related to each point with a unique identifier.

Mining Sequence

This layer contains mining sequence polygons linked to an attribute table showing the year that the area was mined or going to be mined. This directly relates to the area in which backfill/spoil will be present for a given year. Data for this layer were obtained from mining permits located in Cheyenne at WDEQ/LQD. Within each mine permit is a proposed mining sequence map which was automated through digitizing.

Surface Water Rights

This data layer contains surface water right polygons linked to an attribute table containing permit number, type of water right (ditch, enlargement, stock reservoir, and reservoir), acre/feet or cubic feet per second depending on type, priority date, and the associated drainage location of the right. The data layer was developed from surface water permits found at the State Engineers Office (WSEO). All surface water rights for the Pilot Study Area were transferred from the permits and hand drawn onto 7.5 minute quadrangles. The water rights were then digitized off of 1:24,000 USGS quadrangles to produce the ARC/INFO coverage.

Groundwater Rights

This data layer contains groundwater right points (wells) linked to an attribute table containing permit number, yield, priority date, and static water level. Well data were obtain from the WSEO's Advance Revelation (AREV) database. By using the accompanying locational data, a point coverage was generated.

Digital Elevation Models (DEMs).

Digital Elevation Models (DEMs) consist of a sample array of elevations for ground positions that are usually at regularly spaced intervals (USGS, 1987). DEMs are developed by the USGS and tiled by either 7.5 minute or 1 degree blocks. For use in this CHIA, the 7.5 minute DEMs were chosen, in which the spacing of the elevations along and between each point is 30 meters.

DEMs allow for surfaces to be emulated in a raster format, which can be converted to vector data layers with respect to slope, contours, and aspect. In order to produce ARC/INFO raster and vector data layers a routine of commands were employed. First it was necessary to convert each DEM into ARC/INFO's raster format, grid. These grids were then merged together to encompass the whole Pilot Study Area. Finally, additional commands were used to convert the Pilot-Study-Area-wide grid to vector formatted slope, aspect, and elevation coverages.

Public Land Survey System (PLSS)

This layer contains the Public Land Survey System (PLSS) lines, with the polygons linked to an attribute table listing township, range, and section. The PLSS layer was developed by digitizing the associated linework from 1:100,000 BLM quadrangle maps. Currently, this layer is completed for the entire state and managed by the WWRC GIS Laboratory.

Transportation

This layer contains transportation linework linked to a relational attribute table distinguishing between road types and rail lines. This data layer was previously developed digitally by the U.S. Bureau of Census in a digital line graph (DLG) format. The Topological Integrate Geographic Encodes & Reference (TIGER) data have been produced for several different years and for this project the 1990 data proved to be adequate. TIGER data set were converted to ARC/INFO coverages through a series of ARC commands, and then they were related through unique identifiers to an accompanying data description set. Currently WWRC GIS Laboratory maintains Wyoming TIGER data layers, tiled by counties, which have a scale of 1:100,000.

Model Integration

For this CHIA, GIS model integration involved modifying and querying data layers for model input, which aid in spatially displaying model outputs. Future work will be directed at producing a seamless GIS connection for each model used in the assessment.

Model Input

The main focus surrounding the use of GIS data in the surface water modeling effort was limited to developing hydrological response units (HRUs) and then querying data with reference to these units. Hydrography, slope, aspect, land cover, soils, surficial geology, and clinker data layers were all used in determining the boundaries of the HRUs. The goal during creation was to maximize homogeneity in respect to these data layers, while maintaining a catchment identity. This required a multitude of overlays and several modifications before a final layer could be produced.

The HRU data layer provided the framework in which parameter estimation and/or calculations was structured. For example, each HRU had an associated attribute relating to the sum acre-feet of surface water rights for that particular unit. Additionally percentage breakdown of land cover, soils, surface geology, and clinker could be found within the attributes of this layer. All of these attributes were determined by overlaying the HRU layer with the necessary data layer, and then applying specific calculations.

GIS played a significant role in the CHIA groundwater modeling. The fully refined cells set the data structure in which all other data layers had to be transformed before modeling could occur. This grid was developed by MODELGRID (Winkless and Kernodel, 1993), an Arc Macro Language (AML) program designed to produce a vector based grid, with both polygon (cells) and point (cell centroids) attribute data.

The most common data manipulation involved placing vector data layers and the associated attributes into this pre-defined, irregularly shaped grid. For example, it was necessary to determine which grid cells have 50% or more of their total area designated as clinker, and then differentiating those cells from the others. Other data layers such as burn line, coal faults and folds, mining sequence, and monitoring wells, all had to incorporated into the grid, with each having its own set of stipulations. These processes required extensive Arc Macro Language (AML) programming for testing and attributing each of the 5,994 grid cells based on specific criteria. Once all model input data layers had been placed within the grid, the MODARRAY (Winkless and Kernodel, 1994) AML was used to export the data from an ARC/INFO coverage to an ASCII array format specific to MODFLOW.

Additional data manipulation was required in converting spot groundwater elevations into contours. This first involved kriging the data points into order to interpolate the values throughout the region. Due to ARC/INFO's limited kriging models, all kriging was performed using an external statistical package, which produced a surface that could be imported back into ARC/INFO coverage. The krigged coverage was then transformed back into the refined grid through an AML that used a weighted average method to determine each cell's approximate groundwater elevation.

Model Output

In addition to parameter estimation, GIS played a significant role in displaying MODFLOW modeling outputs. Through the use of spatial contour mapping, visual comparisons could be made between years and aquifers in relation to coal mining effects on groundwater.

Groundwater drawdown outputs produced by MODFLOW were placed back into the previously discussed refined grid. This was accomplished through the use of AWK scripts for ASCII array manipulation, and importing this file into INFO with the cell identifier and accompanying drawdown output. Once within INFO, the table was joined to the refined grid data layer. The centroids for each cell then provided spot elevations from which a Triangular Irregular Network (TIN) was created. With an elevation TIN, the command *TINCONTOUR* was applied to produce drawdown contours for the specific MODFLOW modeled year. This process was repeated for five different years and two different aquifers.

Ongoing Research

GIS proved to be a critical tool for completing the CHIA modeling process in an accurate and efficient manner. Building on initial methodologies, it is anticipated that the role of GIS will continue to expand in future CHIA efforts, given the enormous data management tasks associated with each of the three areas (CIAs) delineated in the PRB.

While certain, specific data management and analysis issues are currently being addressed by the ongoing CHIA development effort at the UW, a broader need still exists for the development of computer application tools capable of: 1) managing large quantities of spatial and non-spatial digital hydrologic data; and 2) providing an efficient means for utilizing such information in an integrated hydrologic impact analysis/modeling environment. The utilization of GIS systems can greatly enhance complex spatial problem solving. However, such systems often do not adequately support decision making because they are lacking in analytical modeling capabilities when not linked to existing models. One response to this shortcoming is the development of a spatial decision support system (SDSS) specifically designed to support a decision research process for addressing complex spatial problems. An SDSS provides a framework for integrating database management systems with analytical models, graphical and tabular display, and reporting capabilities, in combination with the knowledge of decision makers (Densham, 1991).

Supported by funding from the Wyoming Abandoned Coal Mine Land Research Program (ACMLRP), research is currently underway at the UW to develop an integrated, modular spatial decision support system (SDSS) for assessing the hydrologic impacts of coal mining and land reclamation activities in the PRB. Components of the system will include existing surface water and groundwater models (HEC-1; MODFLOW), a GIS (ARC/INFO GIS), and a relational database management system (ORACLE RDBMS). The overall goal in developing the system will be to provide resource managers with a dynamic evaluation and decision making tool. Applications will include model input generation/manipulation, model execution, and transfer of model-generated results into a spatially referenced format.

By integrating the surface and groundwater models chosen for the CHIA, the SDSS will provide regulatory authorities with: 1) a user-friendly, integrated modeling software application, providing hydrologists and resource managers with the ability to pose "what if..." type questions concerning hydrological conditions without having to be GIS experts or database managers; and 2) an adaptable methodology for conducting dynamic CHIAs in any foreseeable application area of

Wyoming. In addition, the SDSS will provide a set of application tools for use by mine permit applicants in completing probable hydrologic consequence (PHC) determinations, as well as contributing to the advancement of electronic permitting methods (format compatibility, data transfer, etc.), thus making the permitting process more efficient and cost-effective for all parties involved.

Geologic Data (Geologic Database)

Data Sources

Geologic data is intensively used in groundwater model investigations. The surfaces that form aquifer tops, bottoms and confining layers are inputs in the MODFLOW block centered flow file. Development of this data for a region involves data assimilation from a variety of sources. The sources used in the pilot study were the United States Department of Interior (USDI), Bureau of Land Management Coal-Sys database; public data, primarily from USGS, Montana Bureau of Mines, the BLM downdip exploration from coal bed methane developmental drilling (Martens and Peck Operating Company), and proprietary data from the three surface coal mines in the Little Thunder Creek Drainage. These data were used with permission. The combined data set contained downhole structure elevations for each of the geologic contacts of interest. For this model, data were initially gathered for all coal beds and partings. Wasatch formation picks were only available on holes that were completely logged...a small subset of the total data set, generally confined to the public data set. This is attributable to the tendency of energy companies to not log economically unimportant lithologies.

The public data set consists of data from geologic drilling that is generally available to the public. The data comes from exploration in the PRB by federal agencies, private companies, and agencies that have released ownership rights. These data reside primarily in the USDI Coal-Sys database. Martens and Peck Operating Company did exploratory drilling prior to development of the Lighthouse coal bed methane project. These data were provided on hardcopy map, with downhole depths to coal noted. The map was automated in the TIPS/CHIA Laboratory, and the data were converted to digital format. The surface coal mines (Black Thunder, North Rochelle and Jacobs Ranch) provided data on the coal elevations within their permit area on quarter mile centers. This greatly improved the data spacing near the cropline.

Work continues to the present on the completion and expansion of this data set to accommodate future needs. Data from the coal permits have been input for a large area of the PRB. Funding for this work has been primarily provided by the ACMLRP (Borgman, et al 1994). The database is currently warehoused in STRATIFACT (GRG Incorporated, 1992).

Data Quality

Data received in the manner described have shortcomings. For example, it is not clear that a depth logged for the top of an aquifer represents the same geologic unit between data sets. The top of coal elevation could represent the top of the Wyodak Coal, top of the main split of the Wyodak Coal, or even the top of a less prominent coal seam. The normal procedure is to correlate the geologic data using the complete logs. For this data set, the complete logs were not present in most holes, consequently a combination of regression and cross-validation of kriged data was utilized.

Data Modeling

Summary

The combined data from 527 locations were used to construct a model of the top of Coal A. Coal A was taken to be the top of the Wyodak Coal, Coal B the bottom of the first split of the Wyodak Coal, Coal C as the top of the second split, and Coal D as the bottom of the second split of the Wyodak Coal in the Pilot Study Area. The coal A,B,C,D nomenclatures are used because the data provided were not uniformly named, or were unnamed. The following process was used to check the correlation of the combined data. The number of logged intercepts decreased with depth; successive layers had 90, 91, and 454 picks for the bottom of Coal A, top of Coal B, and bottom of Coal B, respectively.

The variograms of the raw data sets were investigated to detect if any large-scale trends could be anticipated. The variograms increased well beyond the sample variance of the top of coal elevations without achieving any obvious sill ("flattening" of the variogram). This is an indicator that the data may contain some form of non-stationarity (i.e., large-scale trend). Since the Wyodak Coal is considered to have a strong regional trend in dip, this was expected. A model for the coal surfaces was adopted of the form,

$$Z = \beta_0 + \beta_1 x + \beta_2 y + r(x,y)$$

$$= T(x,y) + r(x,y).$$

where Z, x, and y represent top elevation of coal structure, easting and northing respectively. The error or residual term, r(x,y) was assumed to be adequately modeled by a mean zero Gaussian (normal) stationary random function. The existence of spatial auto-correlations was then investigated in the residual process to find out if predictions of coal elevation could be improved through incorporation of this spatial correlation structure. Under this modeling framework, the coal elevations can be viewed as a sum of large-scale linear trend, and small scale spatially correlated fluctuations about this trend.

Kriging Analysis of Geologic Structure in the Pilot Study Area

The large-scale linear trend was estimated in Quattro-Pro, with $R^2 = 0.89$, 0.69, 0.75 and 0.88 for the coal surfaces. The smaller R^2 values are felt to be due to decreased sample size where the coal was not significantly split or the split was not logged. All three regression coefficients were significantly different from zero at the p=0.05 level. The estimated large-scale trend is,

$$T_{est} = 1374.4 + .0074x - 0.0002y \text{ (Top of Coal A)}$$

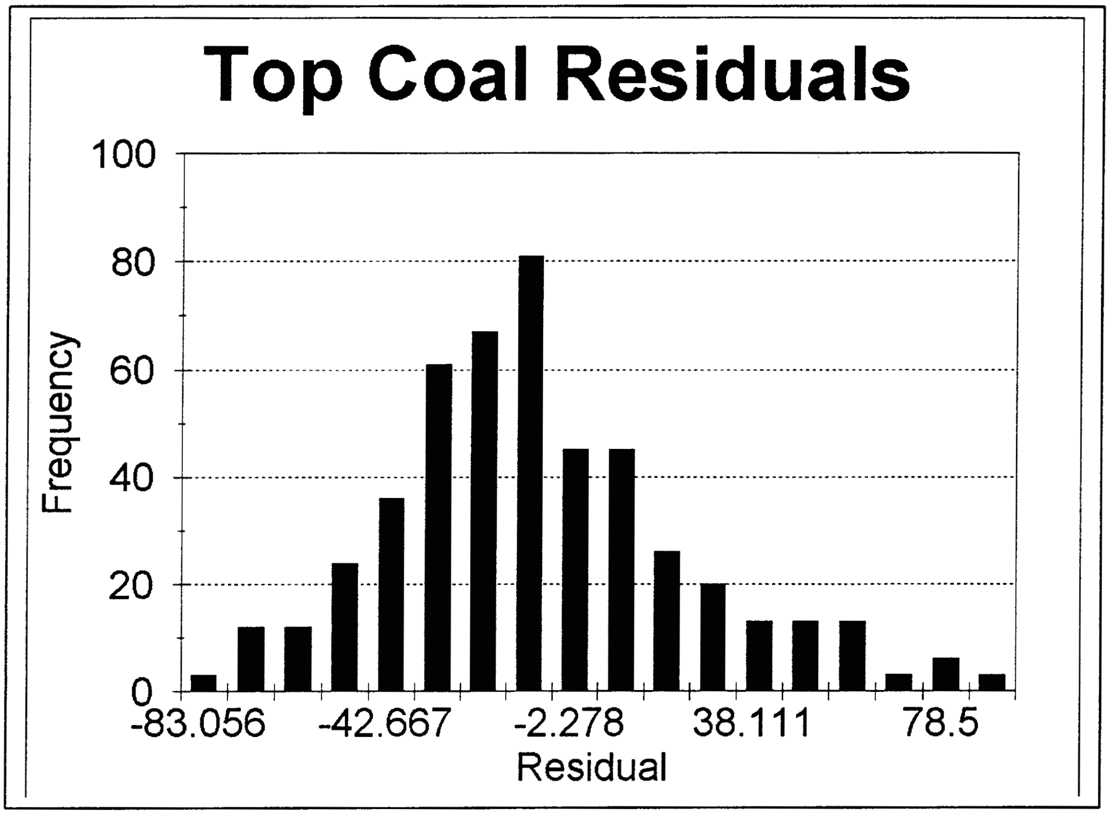
$$T_{est} = 2535.455 + .006611x - 0.00096y \text{ (Bottom of Coal A)}$$

$$T_{est} = 2447.051 + .007387x - 0.0012y \text{ (Top of Coal B)}$$

$$T_{est} = 710.2268 + .008171x - 0.000014y \text{ (Bottom of Coal B)}$$

A histogram of the residuals from the top of Coal A within the MODFLOW grid can be seen in Figure 7-2. As expected, the residual process was nearly symmetric about zero for all modeled surfaces. This suggests that the mean zero Gaussian assumption for the residuals is probably reasonable.

Figure 7-2: Frequency histogram of the top of coal residuals from geologic data analysis



The spatial auto-correlation structure was investigated in VARIO-WIN using directional sample variograms to detect any anisotropy present in the covariance structure. An anisotropic spherical model was fit by inspection with angle of anisotropy oriented 38 degrees West of North. The major range of the spherical model was estimated to be 70,000 ft., and the minor axis was 20,000 ft. for the top of layer A. The sill was estimated, from the sample variance of the data to be 4,848 ft. These parameters for the anisotropic spherical variograms were used to construct kriged estimates of the residuals, and the error of interpolation on 2,500 by 2,500 foot grid spacing throughout the Pilot Study Area. Final estimates of the top of coal elevation were obtained by adding the predicted residuals to the estimated large-scale trend at each location on the grid

$$Z_{est} = T(x,y) + r(x,y).$$

A complete comparison of the kriging parameters for all surfaces is presented in Table 7-3.

Table 7-3: Kriging model parameters for the four geologic surfaces. Major and minor angles of anisotropy are measured counterclockwise from horizontal x axis

Structure residuals	Model	Anistropic ratio	Sill	Nugget	Major angle	Minor angle
Top Coal A	Spherical	3.5:1	4,828	800	128	38
Bot Coal A	Spherical	1.5:1	5,125	2,100	128	38
Top Coal B	Spherical	2.8:1	4,900	2,100	128	38
Bot Coal B	Spherical	5:1	6,000	1,200	128	38

The kriging algorithm also provides estimates of the interpolation standard errors. These errors ranged from 5.7 ft. to 94.5 ft. Near known data, standard errors were generally less than 40 ft. Large areas in the southwest of the Pilot Study Area also had low standard error. Larger standard errors were generally associated with areas of low data availability. The interpolated model for the top of Coal A (Wyodak) can be seen in Plate 8.

Two issues are apparent with the method. The first is that insufficient data exist to model the Wasatch Formation water bearing lenses. The total number of geology logs with Wasatch lithologic picks was approximately 35 of 527 points. The second is that kriged surfaces generated in the manner discussed can intersect, which is a function of small sample size. This in turn is a function of the significance of the top coal split and of the tendency of the Wyodak Coal to be a single seam in much of the Pilot Study Area. Due to this uncertainty, the Wyodak Coal was modeled as a single seam having thickness (TOP COAL A - BOTTOM COAL B).

Appendix F: Pump Test Data and Aquifer Hydraulic Parameters

PUMP TEST DATA AND AQUIFER HYRAULIC PARAMETERS

MINE NAME	WELL NAME (PMP)	WELL NAME (OBS)	DATE	TESTING COMPAN	TEST TYPE	TEST DURATION	DISCHGE RATE	BAILED Q	INJCTD Q	WTR LVL LVL CHG	TRNS G/D-FT	HY CND GAL/D-FT^2	HY CND FT/DAY	STORAGE	ANYSIS MTHD	WHO ANLZD	RATING
BELLE AYR	WRRI10	WRRI10	07/22/82	WESTERN	PUMP	750	7			104	25				JACOB S	PERMIT	0
BELLE AYR	WRRI10	WRRI10	07/22/82	WESTERN	RECOVERY	90	7			104	24				JACOB S	PERMIT	0
BELLE AYR	BAS17F	BAS17F	10/27/76		SLUG BAILED						256				JACOB S	PERMIT	0
BELLE AYR	WRRI10	WRRI10	11/21/75	WESTERN	PUMP	585	7			104	3542			0.0038	JACOB S	PERMIT	0
BELLE AYR	N3	N3	06/05/74		PUMP	30	1				1353			0.01	JACOB S	PERMIT	0
BELLE AYR	WRRI10	WRRI10	07/22/82	WESTERN	PUMP	750	7			104	148	2	0.267344		JACOB S	PERMIT	2
BELLE AYR	WRRI10	WRRI10	07/22/82	WESTERN	RECOVERY	90	7			104	140	2	0.267344		JACOB S	PERMIT	1
BELLE AYR	WRRI10	WRRI10	07/22/82	WESTERN	PUMP	750	7			104	21				THEIS M	PERMIT	0
BELLE AYR	WRRI10	WRRI10	07/22/82	WESTERN	PUMP	750	7			104	21			9E-05	JACOB S	PERMIT	0
BELLE AYR	BAS15B	BAS15B	10/06/76		SLUG BAILED						5			0.04	JACOB S	PERMIT	0
BELLE AYR	BAS14B	BAS14B	10/06/76		SLUG BAILED						5			4E-05	JACOB S	PERMIT	0
BELLE AYR	BAS13B	BAS13B	10/06/76		SLUG BAILED	3					1000				JACOB S	PERMIT	0
BELLE AYR	BAS13C	BAS13C	10/06/76		SLUG BAILED						100			4E-05	JACOB S	PERMIT	0
BLACK THUNDER	BTR2	BTR2A	05/06/74	THUNDER	PUMP	2000	16				7950	126	16.84267	0.00041	JACOB S	PERMIT	3
BLACK THUNDER	BTR2	BTR2	09/18/73	THUNDER	PUMP	240	21			8	3300	77	10.29274		JACOB S	REANA	2
BLACK THUNDER	BTR5	BTR5	05/17/76	THUNDER	RECOVERY	240	36			27	5300	77	10.29274		JACOB S	REANA	3
BLACK THUNDER	BTR11	BTR11	05/24/73	THUNDER	RECOVERY	35	20			28	5300	76	10.15907		JACOB S	REANA	1
BLACK THUNDER	BTR5	BTR5	04/17/73	THUNDER	PUMP	7530	24			30	1670				SPECIFI	PERMIT	1
BLACK THUNDER	BTR5	BTR5	04/17/73	THUNDER	PUMP	7530	24			30	1900				JACOB S	REANA	1
BLACK THUNDER	BTR4	BTR4	04/30/74	THUNDER	RECOVERY	1000	23			34	6000				JACOB S	REANA	2
BLACK THUNDER	BTR8	BTR8	07/10/73	THUNDER	PUMP	300	17			23	7900	110	14.70392		JACOB S	REANA	2
BLACK THUNDER	BTR1	BTR1	09/09/73	THUNDER	RECOVERY	40	7			27	5300	84	11.22845		JACOB S	REANA	2
BLACK THUNDER	BTR2	BTR2	09/18/73	THUNDER	PUMP	240	21			8	5600	81	10.82743		SPECIFI	PERMIT	1
BLACK THUNDER	BTR8	BTR8	07/10/73	THUNDER	RECOVERY	47	17			23	7500	110	14.70392		JACOB S	REANA	3
BLACK THUNDER	BTR14	BTR14	05/12/73	THUNDER	PUMP	30	2			75	80	1	0.133672		SPECIFI	PERMIT	0
BLACK THUNDER	BTR2	BTR2	09/18/73	THUNDER	RECOVERY	110	21			8	7900	110	14.70392		JACOB S	REANA	2
BLACK THUNDER	BTW17	BTW17	07/01/82	THUNDER	SLUG INJECTION	640			40		73				JACOB S	PERMIT	0
BLACK THUNDER	BTR10A	BTR10A	06/24/73	THUNDER	RECOVERY	180	50			15	24000	680	90.89694		JACOB S	REANA	2
BLACK THUNDER	BTR10A	BTR10A	06/23/73	THUNDER	RECOVERY	120	23			4	22000	650	86.88678		JACOB S	REANA	2
BLACK THUNDER	BTFU17	BTFU17	05/18/76	THUNDER	PUMP	3000	52			10	9852				JACOB S	PERMIT	1
BLACK THUNDER	BTFU17	BTFU17	05/20/76	THUNDER	RECOVERY	240	52			10	10000				JACOB S	REANA	2
BLACK THUNDER	BTFU17	BTFU17	05/18/76	THUNDER	PUMP	3000	52			10	10000				JACOB S	REANA	2
BLACK THUNDER	BTFU17	BTFU17	05/20/76	THUNDER	RECOVERY	240	52			10	10000				JACOB S	PERMIT	1
BLACK THUNDER	BTR10A	BTR10D	08/09/73	THUNDER	PUMP	400	50			1	22780	633	84.61436	0.0061	CHOW M	PERMIT	2
BLACK THUNDER	BTR10A	BTR10E	08/09/73	THUNDER	PUMP	400	50			1	20000	555	74.18794	0.01	CHOW M	PERMIT	2
BLACK THUNDER	BTR10A	BTR10A	06/23/73	THUNDER	RECOVERY	180	23			4	12000	340	45.44847		SPECIFI	PERMIT	1
BLACK THUNDER	BTR10A	BTR10A	06/24/73	THUNDER	RECOVERY	120	50			15	8000	240	32.08127		SPECIFI	PERMIT	1
BLACK THUNDER	BTW13	BTW13	07/02/82	THUNDER	SLUG INJECTION	1610			40		55	3	0.401016		JACOB S	PERMIT	0
BLACK THUNDER	BTW5	BTW5	07/01/82	THUNDER	SLUG INJECTION	785			40		23	1	0.133672		JACOB S	PERMIT	0
BLACK THUNDER	BTW16	BTW16	07/01/82	THUNDER	SLUG INJECTION	1050			40		44	1	0.133672		JACOB S	PERMIT	0
BLACK THUNDER	BTW3	BTW3	07/02/82	THUNDER	SLUG INJECTION	880			40		31	2	0.267344		JACOB S	PERMIT	0
BLACK THUNDER	BTR5	BTR5	04/17/73	THUNDER	PUMP	7530	24			30	4570	66	8.82235		JACOB S	REANA	2
BLACK THUNDER	BTR27	BTR27	08/17/77	THUNDER	PUMP	420	11			28	780	13	1.737736		SPECIFI	PERMIT	1
BLACK THUNDER	BTR13	BTR13	08/16/73	THUNDER	PUMP	18	4			46	280	5	0.66836		SPECIFI	PERMIT	0
BLACK THUNDER	BTR17A	BTR17	06/20/73	THUNDER	PUMP	300	12			6	321	5	0.66836	0.00058	CHOW M	PERMIT	1
BLACK THUNDER	BTR17A	BTR17A	06/20/73	THUNDER	PUMP	240	13			45	780	12	1.604064		SPECIFI	PERMIT	1
BLACK THUNDER	BTR12A	BTR12	06/08/73	THUNDER	PUMP	200	5				798	14	1.871408	0.0013	CHOW M	PERMIT	2
BLACK THUNDER	BTR151	BTR151	08/10/73	THUNDER	PUMP	12	23			73	1040	15	2.00508		SPECIFI	PERMIT	0
BLACK THUNDER	BTR15B	BTR15B	08/16/73	THUNDER	PUMP	40	2			24	220	5	0.66836		SPECIFI	PERMIT	0
BLACK THUNDER	BTR12A	BTR12B	06/08/73	THUNDER	PUMP	200	5			2	782	13	1.737736	0.0019	CHOW M	PERMIT	2
BLACK THUNDER	BTR28	BTR28	08/14/77	THUNDER	PUMP	240	13			57	420	5	0.66836		SPECIFI	PERMIT	1
BLACK THUNDER	BTR17A	BTR17A	06/20/73	THUNDER	RECOVERY	300	13			45	520	7	0.935704		JACOB S	REANA	2
BLACK THUNDER	BTR9	BTR9	06/26/73	THUNDER	PUMP	125	5			54	360	7	0.935704		SPECIFI	PERMIT	1
BLACK THUNDER	BTR1	BTR1	09/09/73	THUNDER	PUMP	200	7			27	500	8	1.069376		SPECIFI	PERMIT	1
BLACK THUNDER	BTR154	BTR154	08/26/73	THUNDER	PUMP	102	4			38	360	8	1.069376		SPECIFI	PERMIT	0
BLACK THUNDER	BT66	BT66	07/05/73	THUNDER	PUMP	12	6			53	380	6	0.802032		SPECIFI	PERMIT	0
BLACK THUNDER	BTR6	BTR6	08/26/73	THUNDER	RECOVERY	40	15			54	770	11	1.470392		JACOB S	REANA	2
BLACK THUNDER	BTR6	BTR6	08/26/73	THUNDER	PUMP		15			54	720	10	1.33672		SPECIFI	PERMIT	1
BLACK THUNDER	BTR26	BTR26	08/26/77	THUNDER	PUMP	240	10			35	620	11	1.470392		SPECIFI	PERMIT	1

PUMP TEST DATA AND AQUIFER HYRAULIC PARAMETERS

MINE NAME	WELL NAME (PMP)	WELL NAME (OBS)	DATE	TESTING COMPAN	TEST TYPE	TEST DURATION	DISCHGE RATE	BAILED Q	INJCTD Q	WTR LVL LVL CHG	TRNS G/D-FT	HY CND GAL/D-FT^2	HY CND FT/DAY	STORAGE	ANYSIS MTHD	WHO ANLZD	RATING
BLACK THUNDER	BTR3A	BTR3A	08/24/77	THUNDER	PUMP	300	9			24	940	16	2.138752		SPECIFI	PERMIT	1
BLACK THUNDER	BTR28	BTR28	08/14/77	THUNDER	RECOVERY	120	13			57	3400	43	5.747895		JACOB S	REANA	3
BLACK THUNDER	BTR7	BTR7	09/25/73	THUNDER	PUMP	320	20			20	3900	55	7.351958		JACOB S	REANA	2
BLACK THUNDER	BTR27	BTR27	08/17/77	THUNDER	PUMP	420	11			28	2560	42	5.614223		JACOB S	REANA	2
BLACK THUNDER	BTR3A	BTR3A	08/24/77	THUNDER	RECOVERY	120	9			24	2600	43	5.747895		JACOB S	REANA	1
BLACK THUNDER	BTR7	BTR7	09/25/73	THUNDER	RECOVERY	110	20			20	4200	59	7.886646		JACOB S	REANA	3
BLACK THUNDER	BTR11	BTR11	05/24/73	THUNDER	PUMP	40	20			28	4400	63	8.421334		JACOB S	REANA	1
BLACK THUNDER	BTR4	BTR4	04/30/74	THUNDER	PUMP	3810	23			34	3000	56	7.48563		JACOB S	REANA	1
BLACK THUNDER	BTR26	BTR26	08/26/77	THUNDER	RECOVERY	120	10			35	3300	58	7.752974		JACOB S	REANA	2
BLACK THUNDER	BTR7	BTR7	09/25/73	THUNDER	PUMP	320	20			20	2000	28	3.742815		SPECIFI	PERMIT	1
BLACK THUNDER	BTR153	BTR153	08/11/73	THUNDER	PUMP	45	6			40	120	3	0.401016		SPECIFI	PERMIT	0
BLACK THUNDER	BTR8	BTR8	07/10/73	THUNDER	PUMP	300	17			23	1480	21	2.807111		SPECIFI	PERMIT	1
BLACK THUNDER	BTR12B	BTR12C	06/12/73	THUNDER	PUMP	300	13			8	1090	18	2.406095	0.00069	CHOW M	PERMIT	1
BLACK THUNDER	BTR11	BTR11	05/24/73	THUNDER	PUMP	40	20			28	1420	20	2.673439		SPECIFI	PERMIT	1
BLACK THUNDER	BTR26	BTR26	08/26/77	THUNDER	PUMP	240	10			35	1300	23	3.074455		JACOB S	REANA	1
BLACK THUNDER	BTR4	BTR4	04/30/74	THUNDER	PUMP	3810	23			34	1380	26	3.475471		SPECIFI	PERMIT	1
BLACK THUNDER	BTR9	BTR9	06/26/73	THUNDER	RECOVERY	150	5			54	1200	22	2.940783		JACOB S	REANA	1
BLACK THUNDER	BTR3A	BTR3A	08/24/77	THUNDER	PUMP	300	9			24	1300	22	2.940783		JACOB S	REANA	1
BLACK THUNDER	BTW16	BTW16	07/01/82	THUNDER	SLUG BAILED	1300		40			14				COOPER	PERMIT	1
BLACK THUNDER	BTW16	BTW16	07/01/82	THUNDER	SLUG INJECTION	1520			40		12				COOPER	PERMIT	1
BLACK THUNDER	BTW13	BTW13	07/01/82	THUNDER	SLUG INJECTION	1210			40		15	1	0.133672	0.1	COOPER	PERMIT	1
BLACK THUNDER	BTW3	BTW3	07/01/82	THUNDER	SLUG INJECTION	970			40		19	1	0.133672	0.1	COOPER	PERMIT	1
BLACK THUNDER	BTW17	BTW17	07/01/82	THUNDER	SLUG INJECTION	46			40		390				COOPER	PERMIT	1
BLACK THUNDER	ECH6	ECH6	08/17/76	THUNDER	PUMP	240	14			25	3600	44	5.881567		JACOB S	REANA	2
BLACK THUNDER	ECH6	ECH6	08/17/76	THUNDER	RECOVERY	120	14			25	5300	65	8.688678		JACOB S	REANA	2
BLACK THUNDER	BTW17	BTW17	07/01/82	THUNDER	SLUG BAILED	70		40			257			0.1	COOPER	PERMIT	1
BLACK THUNDER	W17	W17	08/14/77	THUNDER	RECOVERY	120	6			35	590				JACOB S	REANA	2
BLACK THUNDER	W17	W17	08/14/77	THUNDER	PUMP	240	6			35	140				JACOB S	REANA	1
BLACK THUNDER	ECH6	ECH6	08/17/76	THUNDER	PUMP	240	14			25	1510	19	2.539767		JACOB S	REANA	1
BLACK THUNDER	ECH6	ECH6	08/17/76	THUNDER	PUMP	240	14			25	1120	14	1.871408		SPECIFI	PERMIT	0
BLACK THUNDER	W17	W17	08/14/77	THUNDER	PUMP	240	6			35	343				JACOB S	PERMIT	1
BLACK THUNDER	ECH7	ECH7	08/16/76	THUNDER	PUMP	240	30			34	1760	30	4.010159		SPECIFI	PERMIT	1
BLACK THUNDER	BTW5	BTW5	07/01/82	THUNDER	SLUG BAILED	90		40			200	10	1.33672	0.1	COOPER	PERMIT	1
BLACK THUNDER	BTW5	BTW5	07/01/82	THUNDER	SLUG INJECTION	93			40		193	10	1.33672	0.1	COOPER	PERMIT	1
BLACK THUNDER	ECH7	ECH7	08/16/76	THUNDER	PUMP	240	30			34	2000	34	4.544847		JACOB S	REANA	1
BLACK THUNDER	ECH7	ECH7	08/16/76	THUNDER	RECOVERY	120	30			34	16000	270	36.09143		JACOB S	REANA	1
CABALLO	CA726O	CA726O	01/01/85	CARTER	SLUG INJECTION						19				JACOB S	PERMIT	0
CABALLO	CA350C	CA350C	01/01/85	CARTER	AIR LIFT RECOVERY						3520	48	6.416255		JACOB S	PERMIT	0
CABALLO	CA797CL	CA797CL	01/01/85	CARTER	SLUG INJECTION						2				JACOB S	PERMIT	0
CABALLO	CA796CL	CA796CL	01/01/85	CARTER	SLUG INJECTION						1				JACOB S	PERMIT	0
CABALLO	CA725O	CA725O	01/01/85	CARTER	PUMP	27	2				8				PAPADO	PERMIT	0
CABALLO	CA359C	CA359C	01/01/85	CARTER	AIR LIFT RECOVERY						1540	39	5.213207		JACOB S	PERMIT	0
CABALLO	CA727C	CA727C	01/01/85	CARTER	PUMP	240	2				122	2	0.267344		JACOB S	REANA	2
CABALLO	CA727O	CA727O	01/01/85	CARTER	RECOVERY	150	2				86				JACOB S	PERMIT	1
CABALLO	CA727O	CA727O	01/01/85	CARTER	PUMP	150	2				131	1	0.133672		JACOB S	PERMIT	1
CABALLO	CA344C	CA344C	01/01/85	CARTER	AIR LIFT RECOVERY						4400	67	8.956022		JACOB S	PERMIT	0
CABALLO	CA360UC	CA360UC	01/01/85	CARTER	AIR LIFT RECOVERY						18	1	0.133672		JACOB S	PERMIT	0
CABALLO	CA794O	CA794O	01/01/85	CARTER	SLUG INJECTION						13				JACOB S	PERMIT	0
CABALLO	CA357CL	CA357CL	01/01/85	CARTER	AIR LIFT RECOVERY						11550	385	51.46371		JACOB S	PERMIT	0
CABALLO	CA356CL	CA356CL	01/01/85	CARTER	AIR LIFT RECOVERY						1006	123	16.44165		JACOB S	PERMIT	0
CABALLO	CA795CL	CA795CL	01/01/85	CARTER	SLUG BAILED						1500	60	8.020318		JACOB S	PERMIT	0
CABALLO	CA795CL	CA795CL	01/01/85	CARTER	SLUG INJECTION						21	1	0.133672		JACOB S	PERMIT	0
CABALLO	CA727C	CA727C	01/01/85	CARTER	PUMP	240	2				76	1	0.133672		NEUMAN	PERMIT	1
CABALLO	CA727C	CA727C	01/01/85	CARTER	PUMP	240	2				69	1	0.133672		JACOB S	PERMIT	1
CABALLO	CA759B	CA759B	01/01/85	CARTER	PUMP	60	0				22	2	0.267344		NEUMAN	PERMIT	0
CABALLO	CA728S	CA728S	01/01/85	CARTER	PUMP	45	5				825	11	1.470392		JACOB S	REANA	2
CABALLO	CA727C	CA727C	01/01/85	CARTER	RECOVERY	240	2				391	5	0.66836		JACOB S	PERMIT	3
CABALLO	CA728S	CA728S	01/01/85	CARTER	RECOVERY	45	5				880	12	1.604064		JACOB S	REANA	3
CABALLO	CA677A	CA677C	01/27/82	CARTER	PUMP	3240	40				3200	78	10.42641	0.00027	JACOB S	PERMIT	2

PUMP TEST DATA AND AQUIFER HYRAULIC PARAMETERS

MINE NAME	WELL NAME (PMP)	WELL NAME (OBS)	DATE	TESTING COMPAN	TEST TYPE	TEST DURATION	DISCHGE RATE	BAILED Q	INJCTD Q	WTR LVL LVL CHG	TRNS G/D-FT	HY CND GAL/D-FT^2	HY CND FT/DAY	STORAGE	ANYSIS MTHD	WHO ANLZD	RATING
CABALLO	CA347C	CA347C	01/01/85	CARTER	AIR LIFT RECOVERY						792	10	1.33672		JACOB S	PERMIT	0
CABALLO	CA728S	CA728S	01/01/85	CARTER	PUMP	45	5				630	9	1.203048		NEUMAN	PERMIT	1
CABALLO	CA355C	CA355C	01/01/85	CARTER	AIR LIFT RECOVERY						557	9	1.203048		JACOB S	PERMIT	0
CABALLO	CA728S	CA728S	01/01/85	CARTER	PUMP	45	5				541	8	1.069376		JACOB S	PERMIT	1
CABALLO	CA760B	CA760B	01/01/85	CARTER	PUMP	480	0				11				JACOB S	PERMIT	0
CABALLO	CA760B	CA760B	01/01/85	CARTER	RECOVERY	480	0				27	1	0.133672		JACOB S	PERMIT	0
CABALLO	CA724B	CA724B	01/01/85	CARTER	PUMP	80	0				10	1	0.133672		NEUMAN	PERMIT	0
CABALLO	CA724B	CA724B	01/01/85	CARTER	PUMP	80	0				9	1	0.133672		JACOB S	PERMIT	0
CABALLO	CA348UC	CA348UC	01/01/85	CARTER	AIR LIFT RECOVERY						132	3	0.401016		JACOB S	PERMIT	0
CABALLO	CA761B	CA761B	01/01/85	CARTER	PUMP	36	0				6	1	0.133672		NEUMAN	PERMIT	0
CABALLO	CA677A	CA677A	01/27/82	CARTER	RECOVERY	3240	40				2200	57	7.619302		JACOB S	PERMIT	2
CABALLO	CA677A	CA677B	01/27/82	CARTER	PUMP	3240	40				3200	61	8.15399	0.00013	JACOB S	PERMIT	2
CABALLO	CA760B	CA760B	01/01/85	CARTER	PUMP	480	0				11				NEUMAN	PERMIT	0
CABALLO	CA728S	CA728S	01/01/85	CARTER	RECOVERY	45	5				299	4	0.534688		JACOB S	PERMIT	1
CABALLO	CA725O	CA725O	01/01/85	CARTER	SLUG INJECTION						1				JACOB S	PERMIT	0
CABALLO	CA799O	CA799O	01/01/85	CARTER	SLUG BAILED						161	266	35.55674		JACOB S	PERMIT	0
CABALLO	CA798O	CA798O	01/01/85	CARTER	SLUG BAILED						249	4	0.534688		JACOB S	PERMIT	0
CABALLO	CA348LC	CA348LC	01/01/85	CARTER	AIR LIFT RECOVERY						180	6	0.802032		JACOB S	PERMIT	0
CABALLO	CA726O	CA726O	01/01/85	CARTER	PUMP	51	2				11				JACOB S	PERMIT	0
CABALLO	CA361LC	CA361LC	01/01/85	CARTER	AIR LIFT RECOVERY						12				JACOB S	PERMIT	0
CABALLO	CA360LC	CA360LC	01/01/85	CARTER	AIR LIFT RECOVERY						2				JACOB S	PERMIT	0
CABALLO	CA728O	CA728O	01/01/85	CARTER	RECOVERY	49	3				3				JACOB S	PERMIT	0
CABALLO	CA726O	CA726O	01/01/85	CARTER	SLUG BAILED						39	1	0.133672		JACOB S	PERMIT	0
CABALLO	CA727O	CA727O	01/01/85	CARTER	PUMP	150	2				1	1	0.133672		NEUMAN	PERMIT	0
CABALLO	CA799O	CA799O	01/01/85	CARTER	SLUG INJECTION						156	3	0.401016		JACOB S	PERMIT	0
CABALLO	CA726O	CA726O	01/01/85	CARTER	PUMP		2				0	1	0.133672		NEUMAN	PERMIT	0
CABALLO	CA728O	CA728O	01/01/85	CARTER	PUMP	49	3				6				NEUMAN	PERMIT	0
CABALLO	CA347O	CA347O	01/01/85	CARTER	AIR LIFT RECOVERY						20	1	0.133672		JACOB S	PERMIT	0
CABALLO	CA798O	CA798O	01/01/85	CARTER	SLUG INJECTION						266	4	0.534688		JACOBS	PERMIT	0
CABALLO	DWW2	CA307CL	01/01/85	CARTER	PUMP	3000	2100				6.2E+06	230000	30744.55		JACOB S	PERMIT	1
CABALLO	CA725O	CA725O	01/01/85	CARTER	PUMP	27	2				5				JACOB S	PERMIT	0
CABALLO	CA649B	CA649B	03/30/82	CARTER	RECOVERY	15	0				3				JACOB S	PERMIT	0
CABALLO	DWW2	CA358CL	01/01/85	CARTER	PUMP	3000	2100				6.2E+06	230000	30744.55		JACOB S	PERMIT	1
CABALLO	CA350O	CA350O	01/01/85	CARTER	AIR LIFT RECOVERY						4				JACOB S	PERMIT	0
CABALLO	CA726O	CA726O	01/01/85	CARTER	RECOVERY	51	2				20				JACOB S	PERMIT	0
CABALLO	DWW2	CA356CL	01/01/85	CARTER	PUMP	3000	2100				6.2E+06	230000	30744.55		JACOB S	PERMIT	1
CABALLO	CA728O	CA728O	01/01/85	CARTER	PUMP	49	3				6				JACOB S	PERMIT	0
CABALLO	DWW2	CA357CL	01/01/85	CARTER	PUMP	3000	2100				6.2E+06	230000	30744.55		JACOB S	PERMIT	1
CABALLO ROJO	M791C	M791C	11/07/78	E.D. APPO	PUMP	2885	11			15	1040	15	2.00508		JACOB S	PERMIT	2
CABALLO ROJO	CR8241C	CR8241C	08/22/82	E.D. APPO	PUMP	250	21			12	1400	19	2.539767		THEIS M	PERMIT	1
CABALLO ROJO	CR82162CC	CR82162CC	09/24/82	E.D. APPO	SLUG BAILED	44			5		1260	18	2.406095		VARIABL	PERMIT	0
CABALLO ROJO	CR821620	CR821620	08/23/82	E.D. APPO	RECOVERY	130	5			3	3200	240	32.08127		JACOB S	PERMIT	3
CABALLO ROJO	CR82810	CR82810	09/08/82	E.D. APPO	RECOVERY	44	2			6	500	26	3.475471		JACOB S	REANA	2
CABALLO ROJO	CR8242A	CR8242A	09/12/82	E.D. APPO	RECOVERY	64	30			11	5710	97	12.96618		JACOB S	PERMIT	2
CABALLO ROJO	CR82520	CR82520	08/28/82	E.D. APPO	PUMP	295	1			23	19	1	0.133672		JACOB S	REANA	2
CABALLO ROJO	O76414	O76413	11/08/78	E.D. APPO	PUMP	75	7			0	1360	24	3.208127	0.021	THEIS M	PERMIT	2
CABALLO ROJO	O76414	O7513	11/08/78	E.D. APPO	PUMP	75	7			1	870	15	2.00508	0.0023	JACOB S	PERMIT	2
CABALLO ROJO	CR8241A	CR8241A	08/21/82	E.D. APPO	RECOVERY	35	4			7	1700	95	12.69884		JACOB S	REANA	3
CABALLO ROJO	CR8241A	CR8241A	08/21/82	E.D. APPO	PUMP	130	4			7	1700	95	12.69884		JACOB S	REANA	3
CABALLO ROJO	CR821620	CR821620	08/23/82	E.D. APPO	PUMP	311	5			3	3300	250	33.41799		JACOB S	PERMIT	2
CABALLO ROJO	CR8242A	CR8242A	09/12/82	E.D. APPO	PUMP	246	30			11	4820	82	10.9611		JACOB S	PERMIT	1
CABALLO ROJO	O76414	O7513	08/31/76	E.D. APPO	PUMP	390	0			1	729	13	1.737736		DUPUIT	PERMIT	1
CABALLO ROJO	CR82810	CR82810	09/08/82	E.D. APPO	PUMP	221	2			6	149	8	1.069376		JACOB S	PERMIT	1
CABALLO ROJO	O756	O756	08/25/76	E.D. APPO	SLUG INJECTION	45					76	1	0.133672		VARIABL	PERMIT	0
CABALLO ROJO	CR8281C	CR8281C	09/09/82	E.D. APPO	RECOVERY	70	23			25	4600	61	8.15399		JACOB S	PERMIT	2
CABALLO ROJO	CR821610	CR821610	09/13/82	E.D. APPO	PUMP	85	1			25	10	1	0.133672		THEIS M	PERMIT	0
CABALLO ROJO	C76414	C76413	11/07/78	E.D.APPO	PUMP	243	7			0	10100	142	18.98142	0.0005	JACOB S	PERMIT	2
CABALLO ROJO	CR821610	CR821610	09/13/82	E.D. APPO	PUMP	85	1			25	9				JACOB S	PERMIT	0
CABALLO ROJO	O7513	O7513	08/23/76	E.D. APPO	SLUG INJECTION	45					6				VARIABL	PERMIT	0

PUMP TEST DATA AND AQUIFER HYRAULIC PARAMETERS

MINE NAME	WELL NAME (PMP)	WELL NAME (OBS)	DATE	TESTING COMPAN	TEST TYPE	TEST DURATION	DISCHGE RATE	BAILED Q	INJCTD Q	WTR LVL LVL CHG	TRNS G/D-FT	HY CND GAL/D-FT^2	HY CND FT/DAY	STORAGE	ANYSIS MTHD	WHO ANLZD	RATING
CABALLO ROJO	O76413	O76413	08/25/76	E.D. APPO	SLUG INJECTION	60					40	1	0.133672		VARIABL	PERMIT	0
CABALLO ROJO	CR8252C	CR8252C	08/27/82	E.D. APPO	RECOVERY	70	21			15	10000	150	20.0508		JACOB S	REANA	2
CABALLO ROJO	CR8241A	CR8241A	08/21/82	E.D. APPO	PUMP	130	4			7	258	14	1.871408		JACOB S	PERMIT	0
CABALLO ROJO	O793	O793	09/14/79	E.D. APPO	SLUG BAILED	1561		8			170	21	2.807111		JACOB S	PERMIT	0
CABALLO ROJO	O792	O792	09/14/79	E.D. APPO	SLUG BAILED	1731		9			50	5	0.66836		JACOB S	PERMIT	0
CABALLO ROJO	CR8241A	CR8241A	08/21/82	E.D. APPO	RECOVERY	35	4			7	209	12	1.604064		JACOB S	PERMIT	0
CABALLO ROJO	C76414	C7513	11/07/78	E.D. APPO	PUMP	243	7			1	8300	117	15.63962	0.0007	JACOB S	PERMIT	2
CABALLO ROJO	CR8281C	CR8281C	09/09/82	E.D. APPO	PUMP	446	23			25	4950	65	8.688678		JACOB S	PERMIT	1
CABALLO ROJO	CR8241A	CR8241A	08/21/82	E.D. APPO	PUMP	130	4			7	84	5	0.66836		BOLTON	PERMIT	0
CABALLO ROJO	O8123	O8123	05/15/81	E.D. APPO	SLUG BAILED	72		0			18	3	0.401016		JACOB S	PERMIT	0
CABALLO ROJO	CR8231C	CR8231C	09/10/82	E.D. APPO	PUMP	250	17			10	2250	54	7.218286		JACOB S	PERMIT	2
CABALLO ROJO	M791O	M791O	09/15/79	E.D. APPO	PUMP	42	4			18	62	3	0.401016		JACOB S	PERMIT	1
CABALLO ROJO	CR8252C	CR8252C	08/27/82	E.D. APPO	RECOVERY	70	21			15	1530	23	3.074455		JACOB S	PERMIT	1
CABALLO ROJO	CR82520	CR82520	08/28/82	E.D. APPO	RECOVERY	100	1			23	7				JACOB S	PERMIT	1
CABALLO ROJO	O76414	O76413	08/31/76	E.D. APPO	PUMP	390	0			0	89	2	0.267344		DUPUIT	PERMIT	1
CABALLO ROJO	O76414	O76414	08/31/76	E.D. APPO	PUMP	390	0			2	384	7	0.935704		DUPUIT	PERMIT	1
CABALLO ROJO	CR82810	CR82810	09/08/82	E.D. APPO	RECOVERY	44	2			6	136	7	0.935704		JACOB S	PERMIT	1
CABALLO ROJO	O76414	O7513	11/08/78	E.D. APPO	PUMP	75	7			1	360	6	0.802032	0.0032	THEIS M	PERMIT	1
CABALLO ROJO	CR8241C	CR8241C	08/22/82	E.D. APPO	PUMP	250	21			12	1600	22	2.940783		JACOB S	PERMIT	2
CABALLO ROJO	CR821610	CR821610	08/25/82	E.D. APPO	PUMP	100	1			23	7				JACOB S	PERMIT	0
CABALLO ROJO	CR821610	CR821610	08/25/82	E.D. APPO	RECOVERY	130	1			23	7				JACOB S	PERMIT	0
CABALLO ROJO	M791C	M793C	11/07/78	E.D. APPO	PUMP	2885	11			2	3600	51	6.81727	0.0003	THEIS M	PERMIT	2
CABALLO ROJO	CR8241C	CR8241C	08/22/82	E.D. APPO	RECOVERY	58	21			12	3720	51	6.81727		JACOB S	PERMIT	1
CABALLO ROJO	CR82520	CR82520	08/28/82	E.D. APPO	PUMP	295	1			23	8				JACOB S	PERMIT	1
CABALLO ROJO	CR8231C	CR8231C	09/10/82	E.D. APPO	PUMP	250	17			10	1270	30	4.010159		THEIS M	PERMIT	1
CABALLO ROJO	M791C	M794C	11/07/78	E.D. APPO	PUMP	2885	11			3	3000	43	5.747895	0.0005	THEIS M	PERMIT	2
CABALLO ROJO	CR821610	CR821610	08/25/82	E.D. APPO	PUMP	100	1			23	6				JACOB S	PERMIT	0
CABALLO ROJO	CR82113C	CR82113C	08/17/82	E.D. APPO	PUMP	287	1			9	20	1	0.133672		BOLTON	PERMIT	1
CABALLO ROJO	CR82113C	CR82113C	08/17/82	E.D. APPO	RECOVERY	38	1			9	24	1	0.133672		JACOB S	PERMIT	1
CABALLO ROJO	CR8221C	CR8221C	08/19/82	E.D. APPO	PUMP	228	1			15	39	1	0.133672		JACOB S	PERMIT	1
CABALLO ROJO	CR82113C	CR82113C	08/17/82	E.D. APPO	PUMP	287	1			9	33	1	0.133672		JACOB S	PERMIT	1
CABALLO ROJO	C8124	C8124	05/16/81	E.D. APPO	SLUG INJECTION	32			9		89	3	0.401016		JACOB S	PERMIT	0
CABALLO ROJO	C8126	C8126	05/16/81	E.D. APPO	SLUG INJECTION	40			11		130	4	0.534688		JACOB S	PERMIT	0
CABALLO ROJO	CR82113C	CR82113C	08/17/82	E.D. APPO	PUMP	287	1			9	20	1	0.133672		JACOB S	REANA	2
CABALLO ROJO	CR8221C	CR8221C	08/19/82	E.D. APPO	RECOVERY	56	1			15	52	1	0.133672		JACOB S	PERMIT	2
CABALLO ROJO	C8111	C8111	05/15/81	E.D. APPO	SLUG INJECTION	29			15		3800	250	33.41799		JACOB S	PERMIT	0
CABALLO ROJO	CR82124KK	CR82124KK	08/26/82	E.D. APPO	PUMP	430	40			3	3920	780	104.2641		BOULTO	PERMIT	1
CABALLO ROJO	C8122	C8122	05/15/81	E.D. APPO	SLUG INJECTION	46			11		1800	86	11.49579		JACOB S	PERMIT	0
CABALLO ROJO	C8121	C8121	05/15/81	E.D. APPO	SLUG INJECTION	43			10		830	92	12.29782		JACOB S	PERMIT	0
CABALLO ROJO	CR8216KK	CR8216KK	09/22/82	E.D. APPO	PUMP	360	92			0	1.7E+06	130000	17377.36		JACOB S	PERMIT	3
CABALLO ROJO	CR8221C	CR8221C	08/19/82	E.D. APPO	PUMP	228	1			15	31	1	0.133672		BOLTON	PERMIT	1
CABALLO ROJO	CR82124KK	CR82124KK	08/26/82	E.D. APPO	PUMP	430	40			3	11000	2200	294.0783		JACOB S	PERMIT	2
CABALLO ROJO	CR8216KK	CR8216KK	09/22/82	E.D. APPO	RECOVERY	20	92			0	970000	75000	10025.4		JACOB S	PERMIT	2
CABALLO ROJO	C7513	C7513	10/19/76	E.D.APPO	SLUG INJECTION	148			30		500	7	0.935704		VARIABL	PERMIT	0
COAL CREEK	CCR17	CCR17A	05/17/75	ATLANTIC	PUMP	240	44			3	8328	245	32.74963	0.00056	THEIS M	PERMIT	2
COAL CREEK	CCR8A	CCR8A	05/15/75	ATLANTIC	RECOVERY	240	19			30	4762	144	19.24876		JACOB S	PERMIT	2
COAL CREEK	CCR17	CCR17	05/17/75	ATLANTIC	RECOVERY	240	44			12	11000	313	41.83933		JACOB S	PERMIT	2
COAL CREEK	CCR2A	CCR2A	10/03/74	ATLANTIC	RECOVERY	80	1				44				JACOB S	PERMIT	0
COAL CREEK	CCFU171	CCFU171	12/06/82	GROUND	PUMP	1440	300				776	4	0.534688		JACOB S	PERMIT	1
COAL CREEK	CCR5	CCR5	06/11/75	ATLANTIC	RECOVERY	240	16			23	2000	63	8.421334		JACOB S	PERMIT	2
COAL CREEK	CCR27A	CCR27	06/13/75	ATLANTIC	PUMP	300	4			4	421	11	1.470392	0.001	THEIS M	PERMIT	2
COAL CREEK	CCR5	CCR5A	06/11/75	ATLANTIC	PUMP	240	16			4	1900	55	7.351958	0.00047	THEIS M	PERMIT	2
COAL CREEK	CCR8A	CCR8	05/15/75	ATLANTIC	PUMP	240	19			3	4250	122	16.30798	0.00053	THEIS M	PERMIT	2
COAL CREEK	CCR10	CCR10	07/01/75	ATLANTIC	RECOVERY	60	13			54	2842	114	15.2386		JACOB S	PERMIT	2
COAL CREEK	CCR21	CCR21	07/07/75	ATLANTIC	RECOVERY	150	16			18	2353	65	8.688678		JACOB S	PERMIT	2
COAL CREEK	CCA6C	CCA6C	06/23/79	ATLANTIC	SLUG BAILED	60					6	4	0.534688	0.1	COOPER	PERMIT	0
COAL CREEK	CCA6B	CCA6B	06/24/79	ATLANTIC	SLUG BAILED	60					15	6	0.802032	0.1	COOPER	PERMIT	0
COAL CREEK	CCA15B	CCA15B	06/27/79	ATLANTIC	SLUG BAILED	80					9	2	0.267344	0.1	COOPER	PERMIT	0
COAL CREEK	164670	164670	03/08/79	ATLANTIC	PUMP	1440	215			216	1720				JACOB S	PERMIT	2

PUMP TEST DATA AND AQUIFER HYRAULIC PARAMETERS

MINE NAME	WELL NAME (PMP)	WELL NAME (OBS)	DATE	TESTING COMPAN	TEST TYPE	TEST DURATION	DISCHGE RATE	BAILED Q	INJCTD Q	WTR LVL LVL CHG	TRNS G/D-FT	HY CND GAL/D-FT^2	HY CND FT/DAY	STORAGE	ANYSIS MTHD	WHO ANLZD	RATING
COAL CREEK	CCA3	CCA3	07/10/79	ATLANTIC	SLUG BAILED	30					420			1E-05	COOPER	PERMIT	0
COAL CREEK	CCA9A	CCA9A	06/25/79	ATLANTIC	SLUG BAILED	70					41	7	0.935704	0.01	COOPER	PERMIT	0
COAL CREEK	CCFU171	CCFU171	06/01/79	CONSULT	PUMP	2880	275				1100	5	0.66836		JACOB S	PERMIT	2
COAL CREEK	CCFU171	CCFU171	12/05/82	GROUND	PUMP	1440	300				954	4	0.534688		JACOB S	PERMIT	2
COAL CREEK	CCA1B	CCA1B	07/06/79	ATLANTIC	SLUG BAILED	50					67	17	2.272423	0.0001	COOPER	PERMIT	0
COAL CREEK	CCA12C	CCA12C	06/26/79	ATLANTIC	SLUG BAILED	60					18	8	1.069376	0.01	COOPER	PERMIT	0
COAL CREEK	CCA15C	CCA15C	06/27/79	ATLANTIC	SLUG BAILED	155					24	8	1.069376	0.001	COOPER	PERMIT	0
COAL CREEK	CCR9	CCR9	07/15/75	ATLANTIC	RECOVERY	180	15			64	815	22	2.940783		JACOB S	PERMIT	2
CORDERO	MC226P	MC226P	12/14/81	CORDER	PUMP	70	15			31	157	3	0.401016		JACOB S	PERMIT	0
CORDERO	MC2712P	MC2712P	12/15/81	CORDER	RECOVERY	35	30			53	202	3	0.401016		THEIS M	PERMIT	1
CORDERO	MC226P	MC226P	12/14/81	CORDER	RECOVERY	40	15			31	930	15	2.00508		JACOB S	REANA	2
CORDERO	MC2712P	MC2712P	12/15/81	CORDER	PUMP	150	30			53	666	8	1.069376		JACOB S	PERMIT	3
CORDERO	MC274P	MC274P	12/14/81	CORDER	PUMP	120	9			47	480	8	1.069376		JACOB S	REANA	3
CORDERO	MC156P	MC156P	12/14/81	CORDER	PUMP	150	22			59	135	3	0.401016		THEIS M	PERMIT	0
CORDERO	MC352P	MC352P	12/11/81	CORDER	RECOVERY	80	15			38	150	3	0.401016		THEIS M	PERMIT	1
CORDERO	MS347P	MS347P	12/12/81	CORDER	PUMP	76	35			81	307				JACOB S	PERMIT	0
CORDERO	MS227O	MS227O	12/11/81	CORDER	RECOVERY	40	0			119	1				THEIS M	PERMIT	0
CORDERO	MS268O	MS268O	12/11/81	CORDER	RECOVERY	50	0			21	7				THEIS M	PERMIT	0
CORDERO	MS343P	MS343P	12/11/81	CORDER	RECOVERY	195	16			57	410	4	0.534688		JACOB S	REANA	3
CORDERO	MS343P	MS343P	12/11/81	CORDER	PUMP	160	16			57	480	5	0.66836		JACOB S	REANA	2
CORDERO	MC38P	MC38P	12/15/81	CORDER	PUMP	110	30			29	823	14	1.871408		JACOB S	PERMIT	0
CORDERO	MC267P	MC267P	12/11/81	CORDER	PUMP	120	11			41	426	9	1.203048		JACOB S	PERMIT	1
CORDERO	MS37P	MS37P	12/12/81	CORDER	PUMP	110	3			135	67	2	0.267344		JACOB S	PERMIT	0
CORDERO	MC222P	MC222P	12/15/81	CORDER	PUMP	65	19			97	187	3	0.401016		JACOB S	PERMIT	0
CORDERO	MC15XP	MC15XP	12/15/81	CORDER	PUMP	100	11			105	15				THEIS M	PERMIT	0
CORDERO	MS266O	MS266O	12/13/81	CORDER	RECOVERY	70	1			124	7				THEIS M	PERMIT	0
CORDERO	MS244P	MS244P	12/10/81	CORDER	RECOVERY	70	3			51	15				THEIS M	PERMIT	0
CORDERO	MS37P	MS37P	12/12/81	CORDER	RECOVERY	150	3			135	67	2	0.267344		THEIS M	PERMIT	0
CORDERO	MC226P	MC226P	12/14/81	CORDER	RECOVERY	40	15			31	150	3	0.401016		THEIS M	PERMIT	0
CORDERO	MC352P	MC352P	12/11/81	CORDER	RECOVERY	25	15			38	550	9	1.203048		JACOB S	REANA	3
CORDERO	MC267P	MC267P	12/11/81	CORDER	RECOVERY	30	11			41	440	9	1.203048		JACOB S	REANA	2
CORDERO	MS244P	MS244P	12/10/81	CORDER	PUMP	50	3			51	15				JACOB S	PERMIT	0
CORDERO	MC222P	MC222P	12/15/81	CORDER	RECOVERY	20	19			97	187	3	0.401016		THEIS M	PERMIT	0
CORDERO	MC134P	MC134P	12/11/81	CORDER	RECOVERY	60	0			29	8				THEIS M	PERMIT	0
CORDERO	MC38P	MC38P	12/15/81	CORDER	RECOVERY	60	30			29	299	5	0.66836		THEIS M	PERMIT	0
CORDERO	MS223O	MS223O	12/10/81	CORDER	RECOVERY	50	0			37	2				THEIS M	PERMIT	0
CORDERO	MS34O	MS34O	12/12/81	CORDER	RECOVERY	30	2			10	45	2	0.267344		THEIS M	PERMIT	0
CORDERO	MS158P	MS158P	12/14/81	CORDER	RECOVERY	25	20			59	97	2	0.267344		THEIS M	PERMIT	0
CORDERO	MS343P	MS343P	12/11/81	CORDER	RECOVERY	195	16			57	165	2	0.267344		THEIS M	PERMIT	0
CORDERO	MS158P	MS158P	12/14/81	CORDER	PUMP	120	20			59	82	2	0.267344		THEIS M	PERMIT	0
CORDERO	MS2711O	MS2711O	12/11/81	CORDER	RECOVERY	40	0			13	127	2	0.267344		THEIS M	PERMIT	0
CORDERO	MS343P	MS343P	12/11/81	CORDER	PUMP	160	16			57	157	2	0.267344		JACOB S	PERMIT	0
CORDERO	MS155P	MS155P	12/14/81	CORDER	PUMP	25	8			63	30	2	0.267344		THEIS M	PERMIT	0
CORDERO	MS343P	MS343P	12/11/81	CORDER	PUMP	160	16			57	247	3	0.401016		JACOB S	PERMIT	1
CORDERO	MS158P	MS158P	12/14/81	CORDER	PUMP	120	20			59	150	3	0.401016		JACOB S	PERMIT	1
CORDERO	MS347P	MS347P	12/12/81	CORDER	RECOVERY	75	35			81	471				THEIS M	PERMIT	1
CORDERO	MS346O	MS346O	12/12/81	CORDER	RECOVERY	30	3			7	217	7	0.935704		THEIS M	PERMIT	0
CORDERO	MS155P	MS155P	12/14/81	CORDER	PUMP	25	8			63	45	2	0.267344		JACOB S	PERMIT	0
CORDERO	MS310P	MS310P	12/12/81	CORDER	RECOVERY	60	7			40	97	3	0.401016		THEIS M	PERMIT	0
CORDERO	MS310P	MS310P	12/12/81	CORDER	PUMP	110	7			40	140	4	0.534688		JACOB S	PERMIT	0
CORDERO	MS271O	MS271O	12/11/81	CORDER	RECOVERY	60	0			70	7				THEIS M	PERMIT	0
CORDERO	MS343P	MS343P	12/11/81	CORDER	PUMP	160	16			57	120	1	0.133672		THEIS M	PERMIT	0
CORDERO	MS32P	MS32P	12/11/81	CORDER	PUMP	93	10			96	30	1	0.133672		THEIS M	PERMIT	0
CORDERO	MS33P	MS33P	12/11/81	CORDER	RECOVERY	490	3			55	15				THEIS M	PERMIT	0
CORDERO	MS344O	MS344O	12/11/81	CORDER	RECOVERY	35	0			22	3				THEIS M	PERMIT	0
CORDERO	MS33P	MS33P	12/11/81	CORDER	PUMP	110	3			55	15				JACOB S	PERMIT	0
CORDERO	MS347P	MS347P	12/12/81	CORDER	PUMP	76	35			81	135				THEIS M	PERMIT	0
CORDERO	MS32P	MS32P	12/11/81	CORDER	PUMP	93	10			96	30	1	0.133672		JACOB S	PERMIT	0
CORDERO	MS24O	MS24O	12/12/81	CORDER	RECOVERY	35	1			18	30	1	0.133672		THEIS M	PERMIT	0

PUMP TEST DATA AND AQUIFER HYRAULIC PARAMETERS

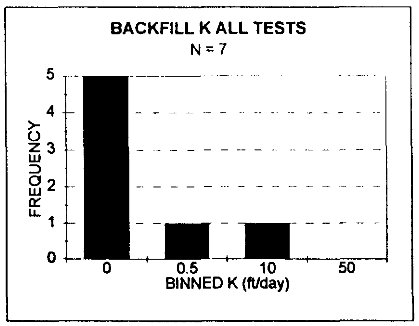
MINE NAME	WELL NAME (PMP)	WELL NAME (OBS)	DATE	TESTING COMPAN	TEST TYPE	TEST DURATION	DISCHGE RATE	BAILED Q	INJCTD Q	WTR LVL LVL CHG	TRNS G/D-FT	HY CND GAL/D-FT^2	HY CND FT/DAY	STORAGE	ANYSIS MTHD	WHO ANLZD	RATING
CORDERO	MS155P	MS155P	12/14/81	CORDER	RECOVERY	90	8			63	30	2	0.267344		THEIS M	PERMIT	0
CORDERO	MS32P	MS32P	12/11/81	CORDER	RECOVERY	110	10			96	22	1	0.133672		THEIS M	PERMIT	0
CORDERO	MS310P	MS310P	12/12/81	CORDER	PUMP	110	7			40	45	1	0.133672		JACOB S	PERMIT	0
CORDERO	MS33P	MS33P	12/11/81	CORDER	PUMP	110	3			55	69	1	0.133672		JACOB S	PERMIT	0
CORDERO	MS133O	MS133O	12/09/81	CORDER	RECOVERY	60	0			15	15	1	0.133672		THEIS M	PERMIT	0
CORDERO	MS273P	MS273P	12/14/81	CORDER	RECOVERY	50	6			78	22				THEIS M	PERMIT	0
CORDERO	MC352P	MC352P	12/11/81	CORDER	PUMP	25	15			38	350	6	0.802032		JACOB S	REANA	2
CORDERO	MC23P	MC23P	12/13/81	CORDER	PUMP	130	10			71	67	1	0.133672		JACOB S	PERMIT	0
CORDERO	MC226P	MC226P	12/14/81	CORDER	PUMP	70	15			31	67	1	0.133672		THEIS M	PERMIT	0
CORDERO	MC345P	MC345P	12/15/81	CORDER	PUMP	110	30			74	292	5	0.66836		JACOB S	PERMIT	1
CORDERO	MC2712P	MC2712P	12/15/81	CORDER	PUMP	150	30			53	389	5	0.66836		JACOB S	PERMIT	1
CORDERO	MC274P	MC274P	12/14/81	CORDER	PUMP	120	9			47	97	2	0.267344		THEIS M	PERMIT	1
CORDERO	MC36P	MC36P	12/12/81	CORDER	PUMP	100	7			98	30	1	0.133672		JACOB S	PERMIT	0
CORDERO	MS273P	MS273P	12/14/81	CORDER	PUMP	67	6			78	37	1	0.133672		JACOB S	PERMIT	0
CORDERO	MC156P	MC156P	12/14/81	CORDER	RECOVERY	30	22			59	1300	22	2.940783		JACOB S	REANA	1
CORDERO	MC23P	MC23P	12/13/81	CORDER	PUMP	130	10			71	52	1	0.133672		THEIS M	PERMIT	0
CORDERO	MC15XP	MC15XP	12/15/81	CORDER	PUMP	100	11			105	30	1	0.133672		JACOB S	PERMIT	0
CORDERO	MC23P	MC23P	12/13/81	CORDER	RECOVERY	35	10			71	30	1	0.133672		THEIS M	PERMIT	0
CORDERO	MC267P	MC267P	12/11/81	CORDER	RECOVERY	30	11			41	90	2	0.267344		THEIS M	PERMIT	1
CORDERO	MC345P	MC345P	12/15/81	CORDER	RECOVERY	40	30			74	142	2	0.267344		THEIS M	PERMIT	0
CORDERO	MC156P	MC156P	12/14/81	CORDER	RECOVERY	30	22			59	127	2	0.267344		THEIS M	PERMIT	0
CORDERO	MC38P	MC38P	12/15/81	CORDER	PUMP	110	30			29	1705	28	3.742815		JACOB S	PERMIT	2
CORDERO	MC267P	MC267P	12/11/81	CORDER	PUMP	120	11			41	112	2	0.267344		JACOB S	PERMIT	1
CORDERO	MC156P	MC156P	12/14/81	CORDER	PUMP	150	22			59	2300	38	5.079535		JACOB S	REANA	3
CORDERO	MC274P	MC274P	12/14/81	CORDER	PUMP	120	9			47	127	2	0.267344		JACOB S	PERMIT	1
CORDERO	MC274P	MC274P	12/14/81	CORDER	RECOVERY	35	9			47	45	1	0.133672		THEIS M	PERMIT	1
CORDERO	MC267P	MC267P	12/11/81	CORDER	PUMP	120	11			41	530	11	1.470392		JACOB S	REANA	3
CORDERO	MC156P	MC156P	12/14/81	CORDER	PUMP	150	22			59	292	5	0.66836		JACOB S	PERMIT	0
CORDERO	MC38P	MC38P	12/15/81	CORDER	RECOVERY	60	30			29	2588	43	5.747895		THEIS M	PERMIT	3
CORDERO	MC352P	MC352P	12/11/81	CORDER	PUMP	80	15			38	284	5	0.66836		JACOB S	PERMIT	1
CORDERO	MC36P	MC36P	12/12/81	CORDER	PUMP	100	7			98	22				THEIS M	PERMIT	0
CORDERO	MC36P	MC36P	12/12/81	CORDER	RECOVERY	70	7			98	15				THEIS M	PERMIT	0
CORDERO	MS37P	MS37P	12/12/81	CORDER	RECOVERY	150	3			135					THEIS M	PERMIT	0
CORDERO	MC15XP	MC15XP	12/15/81	CORDER	RECOVERY	25	11			105	22				THEIS M	PERMIT	0
CORDERO	MC269P	MC269P	12/11/81	CORDER	PUMP	110	2			38	22	1	0.133672		JACOB S	PERMIT	0
CORDERO	MC269P	MC269P	12/11/81	CORDER	RECOVERY	60	2			38	15	1	0.133672		THEIS M	PERMIT	0
CORDERO	MC269P	MC269P	12/11/81	CORDER	PUMP	110	2			38	60	3	0.401016		JACOB S	PERMIT	0
CORDERO	MS37P	MS37P	12/12/81	CORDER	PUMP	110	3			135	8				JACOB S	PERMIT	0
JACOBS RANCH	FACILITYWELL19	FACILITYWELL19	02/16/89		RECOVERY	1440	428			300	2825	7	0.935704		JACOB S	PERMIT	2
JACOBS RANCH	FACILITYWELL18	FACILITYWELL18	05/21/86		RECOVERY	1440	420			278	2218	6	0.802032		JACOB S	PERMIT	2
JACOBS RANCH	JR281	JR281	12/01/74	HERSHEY	PUMP	46	2				121	32	4.277503		JACOB S	PERMIT	0
JACOBS RANCH	FACILITYWELL16	FACILITYWELL16	08/13/81	KERR-MC	RECOVERY	1260	275			182	2792	13	1.737736		JACOB S	PERMIT	2
JACOBS RANCH	JRM103W	JRM103W	06/15/82	KERR-MC	SLUG INJECTION	100					1				PAPADO	PERMIT	0
JACOBS RANCH	JRM102W	JRM102W	06/15/82	KERR-MC	SLUG BAILED	60					30	1	0.133672		PAPADO	PERMIT	0
JACOBS RANCH	JRM32W	JRM32W	05/25/82	KERR-MC	SLUG INJECTION	70					7				FERRIS	PERMIT	0
JACOBS RANCH	JRM33W	JRM33W	05/25/82	KERR-MC	SLUG INJECTION	30					14				FERRIS	PERMIT	0
JACOBS RANCH	FACILITYWELL3	FACILITYWELL3	07/08/75	J.L.HAMIL	RECOVERY	44	60			151	233	4	0.534688		JACOB S	PERMIT	2
JACOBS RANCH	FACILITYWELL17	FACILITYWELL17	08/16/81	KERR-MC	RECOVERY	1410	345			371	1339	5	0.66836		JACOB S	PERMIT	2
JACOBS RANCH	JR281	JR281	06/16/82	HERSHEY	SLUG BAILED	46					32	1	0.133672		COOPER	PERMIT	0
JACOBS RANCH	JR102C	JR102C	06/16/82	KERR-MC	SLUG BAILED	17					90	3	0.401016		BOUER A	PERMIT	0
JACOBS RANCH	JRM111R	JRM111R	05/26/82	KERR-MC	SLUG INJECTION	10					911	61	8.15399		PAPADO	PERMIT	0
JACOBS RANCH	JRM111R	JRM111R	05/26/82	KERR-MC	SLUG INJECTION	10					3576	238	31.81393		FERRIS	PERMIT	0
JACOBS RANCH	FACILITYWELL17	FACILITYWELL17	08/25/81	KERR-MC	PUMP	1545	345			371	1719	6	0.802032		HANTUS	PERMIT	1
JACOBS RANCH	FACILITYWELL19	FACILITYWELL19	02/15/89		PUMP	1440	428			300	2511	6	0.802032		JACOB S	PERMIT	1
JACOBS RANCH	JR373	JR373	12/05/74	HERSHEY	RECOVERY	1060	5			75	26				JACOB S	PERMIT	1
JACOBS RANCH	FACILITYWELL18	FACILITYWELL18	05/20/86		PUMP	1440	420			278	2218	6	0.802032		JACOB S	PERMIT	1
JACOBS RANCH	FACILITYWELL3	FACILITYWELL3	07/08/75	J.L.HAMIL	RECOVERY	44	60			151	337	6	0.802032		JACOB S	PERMIT	1
JACOBS RANCH	FACILITYWELL3	FACILITYWELL3	07/08/75	J.L.HAMIL	PUMP	68	60			151	352	6	0.802032		JACOB S	PERMIT	1
JACOBS RANCH	JR12C	JR12C	11/01/81	KERR-MC	SLUG BAILED	120					2				BOLTON	PERMIT	0

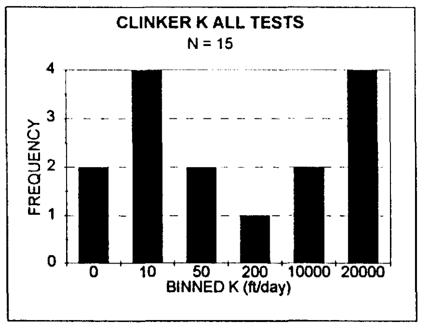
PUMP TEST DATA AND AQUIFER HYRAULIC PARAMETERS

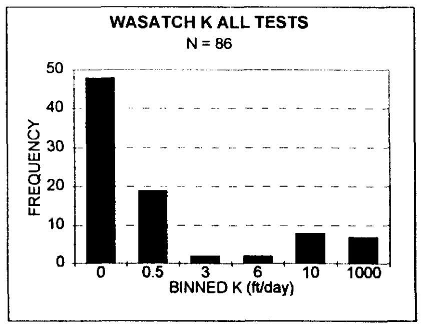
MINE NAME	WELL NAME (PMP)	WELL NAME (OBS)	DATE	TESTING COMPAN	TEST TYPE	TEST DURATION	DISCHGE RATE	BAILED Q	INJCTD Q	WTR LVL LVL CHG	TRNS G/D-FT	HY CND GAL/D-FT^2	HY CND FT/DAY	STORAGE	ANYSIS MTHD	WHO ANLZD	RATING
JACOBS RANCH	JR33C	JR33C	05/01/82	KERR-MC	SLUG INJECTION	100					10				FERRIS	PERMIT	0
JACOBS RANCH	JR23C	JR23C	06/11/82	KERR-MC	SLUG BAILED	100					2				BOUER A	PERMIT	0
JACOBS RANCH	JR5C11	JR11C11	03/01/77	KERR-MC	PUMP	4000	1			4	78	3	0.401016	0.00083	HANTUS	PERMIT	1
JACOBS RANCH	FACILITYWELL16	FACILITYWELL16	08/12/81	KERR-MC	PUMP	1575	275			182	2521	12	1.604064		HANTUS	PERMIT	1
JACOBS RANCH	FACILITYWELL16	FACILITYWELL16	08/12/81	KERR-MC	PUMP	1575	275			182	2689	12	1.604064		JACOB S	PERMIT	1
JACOBS RANCH	JR5C11	JR11C11	03/01/77	KERR-MC	PUMP	4000	1			4	75	3	0.401016	0.00069	JACOB S	PERMIT	2
JACOBS RANCH	FACILITYWELL17	FACILITYWELL17	08/25/81	KERR-MC	PUMP	1545	345			371	1859	7	0.935704		JACOB S	PERMIT	1
JACOBS RANCH	JR373	JR373	12/05/74	HERSHEY	PUMP	1060	5			75	220	3	0.401016		JACOB S	PERMIT	1
NORTH ROCHELLE	WSW1	215O42	10/21/81		PUMP	1450	1197			0	5.1E+06	210000	28071.11		JACOB S	PERMIT	1
NORTH ROCHELLE	WSW1	215O42	10/21/81		RECOVERY	3014	1182			0	9.5E+06	380000	50795.35		JACOB S	PERMIT	1
NORTH ROCHELLE	WSW2	1109O42	10/23/81		PUMP	1440	1199			0	7.4E+06	290000	38764.87		JACOB S	PERMIT	1
NORTH ROCHELLE	WSW1	215O41	10/21/81		PUMP	1450	1197			0	4.7E+06	190000	25397.67		JACOB S	PERMIT	1
NORTH ROCHELLE	115C4	115C22	07/17/80		PUMP	2849	1			4	51	1	0.133672	0.0004	THEIS M	PERMIT	2
NORTH ROCHELLE	1012U4	1012U4	08/16/80		PUMP	165	0			70	0				JACOB S	PERMIT	0
NORTH ROCHELLE	1012U4	1012U4	08/16/80		PUMP	165	0			70	1				JACOB S	PERMIT	0
NORTH ROCHELLE	316U4	316U4	06/22/80		PUMP	62	0			36	1				JACOB S	PERMIT	0
NORTH ROCHELLE	1106U4	1106U4	07/27/80		PUMP	1440	0			61	4				JACOB S	PERMIT	0
NORTH ROCHELLE	WSW1	215O41	10/21/81		RECOVERY	3014	1182			0	9.5E+06	380000	50795.35		JACOB S	PERMIT	1
NORTH ROCHELLE	1010O4	1010O4	05/26/80		PUMP	93	1			67	18	2	0.267344		JACOB S	PERMIT	0
NORTH ROCHELLE	1010O4	1010O4	05/26/80		RECOVERY	101	1			67	19	2	0.267344		JACOB S	PERMIT	0
NORTH ROCHELLE	1306O4	1306O4	07/21/80		RECOVERY	235	1			88	6	2	0.267344		JACOB S	PERMIT	0
NORTH ROCHELLE	WSW2	1109O41	10/23/81		RECOVERY	2860	1151			0	9.7E+06	390000	52132.07		JACOB S	PERMIT	1
NORTH ROCHELLE	WSW2	1109O41	10/23/81		PUMP	1440	1199			0	6.3E+06	250000	33417.99		JACOB S	PERMIT	0
NORTH ROCHELLE	1404O4	1404O4	05/25/80		RECOVERY	196	3			60	15	2	0.267344		JACOB S	PERMIT	0
NORTH ROCHELLE	1010O4	1010O4	05/26/80		PUMP	93	1			67	4	1	0.133672		JACOB S	PERMIT	0
NORTH ROCHELLE	1306O4	1306O4	07/21/80		PUMP	92	1			88	1				JACOB S	PERMIT	0
NORTH ROCHELLE	1404O4	1404O4	05/25/80		PUMP	30	3			60	19	1	0.133672		JACOB S	PERMIT	0
NORTH ROCHELLE	1010O4	1010O4	05/26/80		RECOVERY	101	1			67	5	1	0.133672		JACOB S	PERMIT	0
NORTH ROCHELLE	910O42	910O42	11/13/80				0			32	39	1	0.133672		JACOB S	PERMIT	0
NORTH ROCHELLE	1503C4	1503C4	06/03/80		PUMP	60	0			33	5				JACOB S	PERMIT	0
NORTH ROCHELLE	103C4	103C4	08/16/80		RECOVERY	110	1			10	320	8	1.069376		JACOB S	PERMIT	1
NORTH ROCHELLE	1402C4	1402C4	05/25/80		RECOVERY	100	2			35	12				JACOB S	PERMIT	0
NORTH ROCHELLE	915C4	915C4	07/05/80		PUMP	2866	3			4	4700	78	10.42641		JACOB S	REANA	2
NORTH ROCHELLE	114C4	114C4	07/16/80		PUMP	200	1			23	38	1	0.133672		JACOB S	PERMIT	0
NORTH ROCHELLE	1106U4	1106U4	07/27/80		RECOVERY	1260	0			61	12	1	0.133672		JACOB S	PERMIT	1
NORTH ROCHELLE	114C4	114C4	07/16/80		RECOVERY	35	1			23	9				JACOB S	PERMIT	0
NORTH ROCHELLE	1112C4	1112C4	06/19/80		PUMP	180	1			34	7				JACOB S	PERMIT	1
NORTH ROCHELLE	115C4	115C22	07/17/80		PUMP	2849	1			4	132	2	0.267344	0.00051	JACOB S	PERMIT	2
NORTH ROCHELLE	115C4	115C4	07/17/80		PUMP	2849	1			21	211	4	0.534688		JACOB S	PERMIT	2
NORTH ROCHELLE	115C4	115C22	07/17/80		PUMP	2849	1			4	132	2	0.267344	0.0007	JACOB S	REANA	2
NORTH ROCHELLE	115C4	115C4	07/17/80		RECOVERY	500	1			21	88	2	0.267344		JACOB S	PERMIT	2
NORTH ROCHELLE	1112C4	1112C4	06/19/80		RECOVERY	100	1			34	10				JACOB S	PERMIT	1
NORTH ROCHELLE	116C4	116C4	06/20/80		RECOVERY	100	4			23	642	16	2.138752		JACOB S	PERMIT	1
NORTH ROCHELLE	316U4	316U4	06/21/80		PUMP	21	1			36	6				JACOB S	PERMIT	0
NORTH ROCHELLE	1106U4	1106U4	07/27/80		RECOVERY	1260	0			61	1				JACOB S	PERMIT	0
NORTH ROCHELLE	1012U4	1012U4	08/16/80		RECOVERY	1361	0			70	7	1	0.133672		JACOB S	PERMIT	0
NORTH ROCHELLE	115C4	115C21	07/17/80		RECOVERY	4471	1			5	50	1	0.133672		JACOB S	PERMIT	2
NORTH ROCHELLE	115C4	115C21	07/17/80		PUMP	2849	1			5	71	1	0.133672	0.0003	JACOB S	PERMIT	2
NORTH ROCHELLE	115C4	115C21	07/17/80		PUMP	2849	1			5	51	1	0.133672	0.0004	THEIS M	PERMIT	2
NORTH ROCHELLE	115C4	115C22	07/17/80		RECOVERY	4471	1			4	70	1	0.133672	0.00027	JACOB S	PERMIT	2
NORTH ROCHELLE	316U4	316U4	06/22/80		RECOVERY	100	0			36	92	2	0.267344		JACOB S	PERMIT	0
NORTH ROCHELLE	915C4	915C21	07/05/80		PUMP	2866	3			1	1400	23	3.074455	0.00029	THEIS M	PERMIT	2
NORTH ROCHELLE	1408U4	1408U4	06/19/80		PUMP	130	1			38	11				JACOB S	PERMIT	1
NORTH ROCHELLE	1402C4	1402C4	05/25/80		PUMP	80	2			35	29	1	0.133672		JACOB S	PERMIT	0
NORTH ROCHELLE	915C4	915C4	07/05/80		PUMP	2866	3			4	1500	24	3.208127		JACOB S	PERMIT	2
NORTH ROCHELLE	1203C4	1203C4	10/11/81		PUMP	1441	25			1	170000	85000	11362.12		JACOB S	PERMIT	1
NORTH ROCHELLE	1203C4	1203C4	10/11/81		RECOVERY	2084	25			1	110000	55000	7351.958		JACOB S	PERMIT	2
ROCKY BUTTE	813612	813612C	08/01/81	TEXAS EN	PUMP										SPECIFI	PERMIT	0
ROCKY BUTTE	81311U	81311U	08/03/81	TEXAS EN	PUMP	70	4			6	594	11	1.470392		SPECIFI	PERMIT	0

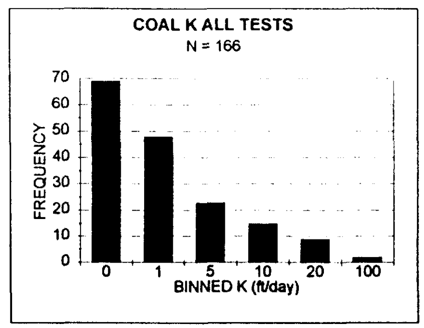
PUMP TEST DATA AND AQUIFER HYRAULIC PARAMETERS

MINE NAME	WELL NAME (PMP)	WELL NAME (OBS)	DATE	TESTING COMPAN	TEST TYPE	TEST DURATION	DISCHGE RATE	BAILED Q	INJCTD Q	WTR LVL LVL CHG	TRNS G/D-FT	HY CND GAL/D-FT^2	HY CND FT/DAY	STORAGE	ANYSIS MTHD	WHO ANLZD	RATING
ROCKY BUTTE	8113	8113C	07/23/81	TEXAS EN	PUMP	25	17			26	422	6	0.802032		SPECIFI	PERMIT	0
ROCKY BUTTE	81361U	81361U	07/29/81	TEXAS EN	PUMP	95	2			12	123	1	0.133672		SPECIFI	PERMIT	0
ROCKY BUTTE	81364	81364C	07/31/81	TEXAS EN	PUMP	80	2			14	110	1	0.133672		SPECIFI	PERMIT	0
ROCKY BUTTE	MW319U	MW319U	07/30/81	TEXAS EN	PUMP	110	2			13	2	2	0.267344		SPECIFI	PERMIT	0
ROCKY BUTTE	8162	8162C	07/31/81	TEXAS EN	PUMP	90	1			26	21	1	0.133672		SPECIFI	PERMIT	0
ROCKY BUTTE	81351U	81351U	08/03/81	TEXAS EN	PUMP	40	3			29	41	1	0.133672		SPECIFI	PERMIT	0
ROCKY BUTTE	8112U	8112U	07/29/81	TEXAS EN	PUMP	55	1			28	19				SPECIFI	PERMIT	0
ROCKY BUTTE	813610L	813610L	08/06/81	TEXAS EN	PUMP	40	1			36	4				JACOB S	PERMIT	0
ROCKY BUTTE	81364	81364C	07/31/81	TEXAS EN	PUMP	80	2			14	80	1	0.133672		JACOB S	PERMIT	0
ROCKY BUTTE	MW317	MW317C	07/30/81	TEXAS EN	PUMP	15	1			14	21	1	0.133672		SPECIFI	PERMIT	0
ROCKY BUTTE	8162	8162C	07/31/81	TEXAS EN	PUMP	90	1			26	24	1	0.133672		JACOB S	PERMIT	0
ROCKY BUTTE	9105CC50V	9105CC50V	09/29/91	WESTERN	RECOVERY	935	2			37	54	1	0.133672		THEIS M	PERMIT	2
ROCKY BUTTE	81365U	81368UO	07/27/81	TEXAS EN	PUMP	80	7			15	230	2	0.267344	3E-05	THEIS M	PERMIT	2
ROCKY BUTTE	81365U	81365U	07/27/81	TEXAS EN	PUMP	80	7			22	290	3	0.401016		JACOB S	PERMIT	2
ROCKY BUTTE	9132DD5	9132DD5C	11/16/91	WESTERN	PUMP	485	18			7	4100	60	8.020318		JACOB S	PERMIT	1
ROCKY BUTTE	MW317U	MW317U	08/07/81	TEXAS EN	PUMP	92	33			2	11600	120	16.04064		JACOB S	PERMIT	1
ROCKY BUTTE	9106BA50V	9106BA50V	09/27/91	WESTERN	PUMP	690	1			22	70	1	0.133672		JACOB S	REANA	2
ROCKY BUTTE	9133BA50V	9133BA50V	10/01/91	WESTERN	PUMP	710	19			30	713	6	0.802032		JACOB S	PERMIT	2
ROCKY BUTTE	81365U	81368UO	07/27/81	TEXAS EN	PUMP	80	7			15	288	3	0.401016	0.0001	JACOB S	PERMIT	3
ROCKY BUTTE	81365U	81365U	07/27/81	TEXAS EN	RECOVERY	80	7			22	332	3	0.401016		JACOB S	PERMIT	3
ROCKY BUTTE	81311U	81311U	08/03/81	TEXAS EN	PUMP	70	4			6	704	13	1.737736		JACOB S	PERMIT	3
ROCKY BUTTE	9131AD5	9131AD5C	10/11/91	WESTERN	PUMP	480	20			23	6000	80	10.69376		JACOB S	REANA	2
ROCKY BUTTE	9105CC50V	9105CC50V	09/29/91	WESTERN	PUMP	935	2			37	74	1	0.133672		JACOB S	PERMIT	3
ROCKY BUTTE	81365U	81368UO	07/27/81	TEXAS EN	RECOVERY	80	7			15	319	3	0.401016		JACOB S	PERMIT	3
ROCKY BUTTE	81351U	81351U	08/03/81	TEXAS EN	RECOVERY	40	3			29	19				JACOB S	PERMIT	1
ROCKY BUTTE	9106BA50V	9106BA50V	09/27/91	WESTERN	PUMP	690	1			22	30				JACOB S	PERMIT	1
ROCKY BUTTE	9103AA50V	9103AA50V	10/09/91	WESTERN	RECOVERY	615	1			51	32				THEIS M	PERMIT	1
ROCKY BUTTE	MW317U	MW317U	08/07/81	TEXAS EN	PUMP	92	33			2	28000	289	38.6312		SPECIFI	PERMIT	0
ROCKY BUTTE	8112U	8112U	07/29/81	TEXAS EN	PUMP	55	1			28	20				JACOB S	PERMIT	1
ROCKY BUTTE	9103AA50V	9103AA50V	10/09/91	WESTERN	PUMP	615	1			51	35				JACOB S	PERMIT	1
ROCKY BUTTE	813612	813612C	08/01/81	TEXAS ENERGY SERVICES INC						38	27				JACOB S	PERMIT	1
ROCKY BUTTE	9133BA50V	9133BA50V	10/01/91	WESTERN	RECOVERY	710	19			30	659	6	0.802032		THEIS M	PERMIT	1
ROCKY BUTTE	9131AD5	9131AD5C	10/11/91	WESTERN	RECOVERY	480	20			23	1700	22	2.940783		THEIS M	PERMIT	1
ROCKY BUTTE	9131AD5	9131AD5C	10/11/91	WESTERN	PUMP	480	20			23	2400	31	4.143831		JACOB S	PERMIT	1
ROCKY BUTTE	81351U	81351U	08/03/81	TEXAS EN	PUMP	40	3			29	36	1	0.133672		JACOB S	PERMIT	1
ROCKY BUTTE	81361U	81361U	07/29/81	TEXAS EN	PUMP	95	2			12	104	1	0.133672		JACOB S	PERMIT	1
ROCKY BUTTE	81361U	81361U	07/29/81	TEXAS EN	RECOVERY	95	2			12	114	1	0.133672		JACOB S	PERMIT	1









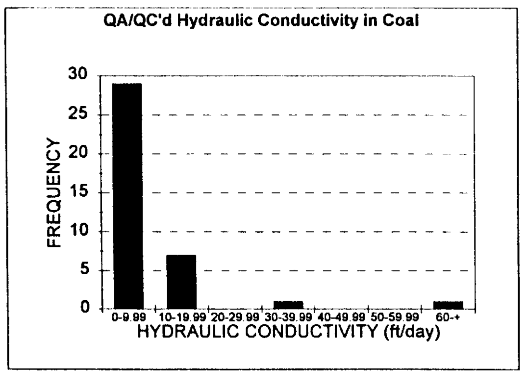
Appendix G: QA/QC'd Hydraulic Values in Coal Aquifer

QA/QC'D HYDRAULIC VALUES IN COAL AQUIFER

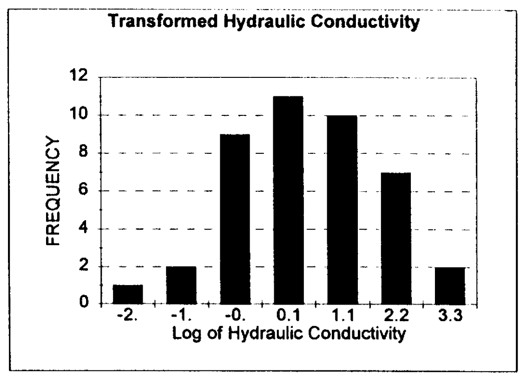
Tests Rated 1, 2, or 3 Within the Pilot Study Area

MINE NAME	WELL NAME	K (GA/D-FT)	MEAN K (MULT TESTS) (GA/D-FT)	K (FT/DY)	LOG K	NORTHING	EASTIN	FORMATION	RATING	OBS WELL	TEST_TYPE	SWT/MULTI	
NORTH ROCHEL	1003C4	8	8	1.06937575	0.06708	1081610	476691	COAL	1	1003C4	RECOVERY	SWT	*
NORTH ROCHEL	1105C4	1	1	0.13367197	-2.01237	1080400	480787	COAL	2	1105C22	RECOVERY	MULTI	*
NORTH ROCHEL	1106C4	16	16	2.1387515	0.76022	1080431	481546	COAL	1	1106C4	RECOVERY	SWT	*
NORTH ROCHEL	915C4	23	23	3.07445529	1.12313	1077577	472577	COAL	2	915C21	PUMP	MULTI	*
BLACK THUNDE	BTR1	84	84	11.2284454	2.41845	1108351	465816	COAL	2	BTR1	RECOVERY	SWT	*
BLACK THUNDE	BTR10A	555	594	79.4011496	4.37451	1098111	478093	COAL	2	BTR10E	PUMP	MULTI	*
BLACK THUNDE	BTR11	76	76	10.1590696	2.31837	1092688	469615	COAL	1	BTR11	RECOVERY	SWT	*
BLACK THUNDE	BTR12A	14	13.5	1.80457158	0.59032	1092433	474799	COAL	2	BTR12	PUMP	MULTI	*
BLACK THUNDE	BTR12B	18	18	2.40609544	0.87801	1092445	474821	COAL	1	BTR12C	PUMP	MULTI	*
BLACK THUNDE	BTR17A	7	7	0.93570378	-0.06646	1094949	472390	COAL	2	BTR17A	RECOVERY	SWT	*
BLACK THUNDE	BTR2	126	126	16.8426681	2.82392	1108391	469663	COAL	3	BTR2A	PUMP	MULTI	*
BLACK THUNDE	BTR26	58	58	7.7529742	2.04808	1113795	469802	COAL	2	BTR26	RECOVERY	SWT	*
BLACK THUNDE	BTR27	42	42	5.6142227	1.7253	1113649	459031	COAL	2	BTR27	PUMP	SWT	*
BLACK THUNDE	BTR28	43	43	5.74789467	1.74883	1103119	458967	COAL	3	BTR28	RECOVERY	SWT	*
BLACK THUNDE	BTR3A	43	43	5.74789467	1.74883	1109216	474318	COAL	1	BTR3A	RECOVERY	SWT	*
BLACK THUNDE	BTR4	26	41	5.48055073	1.70121	1102996	464377	COAL	1	BTR4	PUMP	SWT	*
BLACK THUNDE	BTR5	77	77	10.2927416	2.33144	1103009	469819	COAL	3	BTR5	RECOVERY	SWT	*
BLACK THUNDE	BTR6	11	11	1.47039166	0.38553	1102633	474865	COAL	2	BTR6	RECOVERY	SWT	*
BLACK THUNDE	BTR7	59	59	7.88664617	2.06517	1097766	464610	COAL	3	BTR7	RECOVERY	SWT	*
BLACK THUNDE	BTR8	110	110	14.7039166	2.68811	1097868	469564	COAL	3	BTR8	RECOVERY	SWT	*
BLACK THUNDE	BTR9	22	22	2.94078332	1.07868	1097809	474840	COAL	1	BTR9	RECOVERY	SWT	*
COAL CREEK	CCR10	114	114	15.2386045	2.72383	1188715	475015	COAL	2	CCR10	RECOVERY	SWT	*
COAL CREEK	CCR17	245	245	32.7496324	3.48889	1196612	461802	COAL	2	CCR17A	PUMP	MULTI	*
COAL CREEK	CCR21	65	65	8.68867798	2.16202	1199280	464360	COAL	2	CCR21	RECOVERY	SWT	*
COAL CREEK	CCR27A	11	11	1.47039166	0.38553	1204430	464384	COAL	2	CCR27	PUMP	MULTI	*
COAL CREEK	CCR5	55	55	7.35195829	1.99497	1185923	466919	COAL	2	CCR5A	PUMP	MULTI	*
COAL CREEK	CCR8A	122	122	16.3079802	2.79165	1188699	464379	COAL	2	CCR8	PUMP	MULTI	*
COAL CREEK	CCR9	22	22	2.94078332	1.07868	1188731	469647	COAL	2	CCR9	RECOVERY	SWT	*
JACOBS RANCH	JR5C11	3	3	0.40101591	-0.91375	1109067	482956	COAL	2	JR11C11	PUMP	SWT	*
JACOBS RANCH	JRM373	3	3	0.40101591	-0.91375	1119000	476474	COAL	1	JRM373	PUMP	SWT	*
CORDERO	MC156P	38	38	5.07953482	1.62522	1229796	448454	COAL	3	MC156P	PUMP	SWT	*
CORDERO	MC226P	15	15	2.00507953	0.69568	1232664	445087	COAL	2	MC226P	RECOVERY	SWT	*
CORDERO	MC267P	11	11	1.47039166	0.38553	1237701	437923	COAL	3	MC267P	PUMP	SWT	*
CORDERO	MC2712P	8	8	1.06937575	0.06708	1228858	435569	COAL	3	MC2712P	PUMP	SWT	*
CORDERO	MC274P	8	8	1.06937575	0.06708	1231454	439122	COAL	3	MC274P	PUMP	SWT	*
CORDERO	MC345P	5	5	0.66835984	-0.40293	1231114	434161	COAL	1	MC345P	PUMP	SWT	*
CORDERO	MC352P	9	9	1.20304772	0.18486	1234210	432883	COAL	3	MC352P	RECOVERY	SWT	*
CORDERO	MC38P	43	43	5.74789467	1.74883	1229216	425249	COAL	3	MC38P	RECOVERY	SWT	*
NORTH ROCHEL	1105C4	1	....	....	....	1080400	480787	COAL	2	1105C21	RECOVERY	MULTI	
BLACK THUNDE	BTR10A	633	....	....	....	1098111	478093	COAL	2	BTR10D	PUMP	MULTI	
BLACK THUNDE	BTR12A	13	....	....	....	1092433	474799	COAL	2	BTR12B	PUMP	MULTI	
BLACK THUNDE	BTR4	56	....	....	....	1102996	464377	COAL	1	BTR4	PUMP	SWT	

SUM	47.9658
MEAN	1.26226
VARIANCE	1.7208



0-9.99	0
10-19.99	9.99
20-29.99	19.99
30-39.99	29.99
40-49.99	39.99
50-59.99	49.99
60-+	59.99



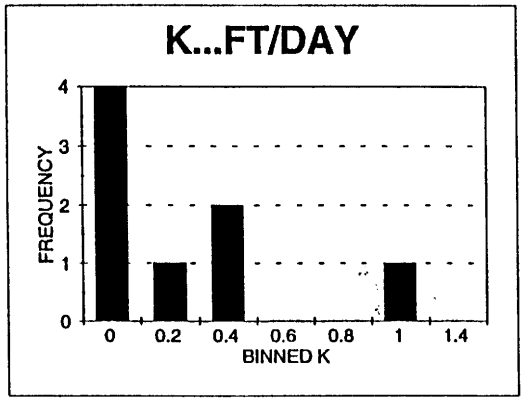
QA/QC'D HYDRAULIC VALUES IN WASATCH AQUIFER

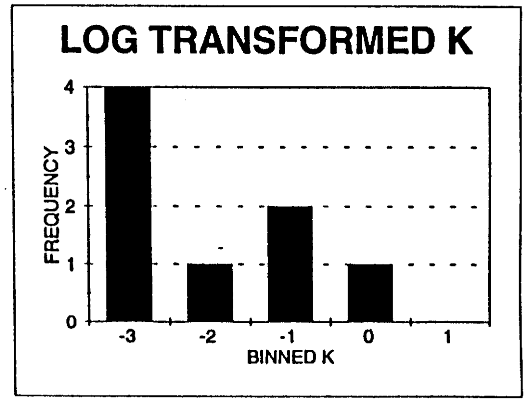
Tests Rated 1, 2, or 3 Within the Pilot Study Area

MINE NAME	WELL NAME (PMP)	WELL NAME (OBS)	DATE	TESTING COMPAN	TEST TYPE	TRNS G/D-FT	HY CND GAL/D-FT	HY CND FT/DAY	LOG OF K	STORAGI	ANYSIS MTHD	WHO ANLZD	RATING
CORDERO	MS32P	MS32P	12/11/81	CORDER(	PUMP	30	1	0.13367196899	-2.01237		THEIS ME	PERMIT	1
CORDERO	MS343P	MS343P	12/11/81	CORDER(	PUMP	120	1	0.13367196899	-2.01237		THEIS ME	PERMIT	1
NORTH ROCHELL	101004	101004	05/26/80		PUMP	18	2	0.26734393798	-1.31922		JACOB S'	PERMIT	1
BLACK THUNDER	BTW5	BTW5	07/01/82	THUNDEI	SLUG BAILED	200	10	1.33671968988	0.290219	0.1	COOPER:	PERMIT	1
BLACK THUNDER	BTW13	BTW13	07/01/82	THUNDEI	SLUG INJECTION	15	1	0.13367196899	-2.01237	0.1	COOPER:	PERMIT	1
BLACK THUNDER	BTW3	BTW3	07/01/82	THUNDEI	SLUG INJECTION	19	1	0.13367196899	-2.01237	0.1	COOPER:	PERMIT	1
CORDERO	MS158P	MS158P	12/14/81	CORDER(	PUMP	150	3	0.40101590696	-0.91375		JACOB S'	PERMIT	1
CORDERO	MS343P	MS343P	12/11/81	CORDER(	RECOVERY	410	4	0.53468787595	-0.62607		JACOB S'	REANALY	3

Bin	Frequency
0	4
0.2	1
0.4	2
0.6	0
0.8	0
1	1
1.4	0

Bin	Frequency
-3	4
-2	1
-1	2
0	1
1	0





Appendix H: MODFLOW Setup

MODFLOW SETUP....INDIVIDUAL MODFLOW INPUTS...NOTATION LIKE 5*N INDICATES THAT THE DIMENSION N IS REPEATED 5 TIMES

```
74 81                (NROW, NCOL)
308.                 (ANGLE OF ROTATION)
457000. 1227500.     (STATE PLANE N, E OF MODFLOW 1,1)
2*9475.              (DELR)
6455
4398
2996
2041
1391
60*948
1391
2041
2996
4398
6455
2*9475
END
9*8250               (DELC)
5620
3829
2609
1778
1211
60*825
1211
1778
2609
3829
5620
2*8250
END
```

Appendix I: Calibration of Model Using Early Time Data

Calibration of Model for Coal Aquifer Using 1975 Data

Row	Col.	Well	Surface Elev.	Well Depth	Screened Interval Top	Screened Interval Bottom	Ground Water Elevation Observed	Ground Water Elevation Predicted
1	3	CCR27	4652.2	137	101	137	4582.4	*
1	4	CCR25	4642.1	100	60	100	4589.7	*
1	5	CCR16	4745.9	101	71	101	4699.8	*
1	6	CCR7A					4705	*
2	3	CCR24	4625.4	160	119	160	4582.8	4584
2	4	CCR18	4734.8	205	165	205	4584.7	4590
2	5	CCR15	4697.7	155	135	155	4596.1	4600
2	6	CCR6	4763.1	160	132	160	4661	4659
6	9	KL10	4813.6	163.5	120	163.5	4747.9	4749
7	8	KL8	4862.65	182.8	140	182.8	4729.8	4736
7	9	KL4	4846.7	188.3	110	170	4743.5	4744
9	9	KL9	4847.45	178	125	163	4709.2	4712
9	10	KL15	4729.3	64.4	15	45	4715.1	*
11	10	KL16	4731.4	53.4	15	30	4713.2	4708
15	9	KL14	4829.4	171.5	100	151.5	4694.9	4690
15	32	JRM281	4877.4	160	88	160	4790.6	4789
19	28	JRM9C2	4854.8	200	100	200	4705	4704
23	31	JRM5C2	4820.9	195	95	195	4681	4678
23	34	JRM3C11	4804.8	160	60	160	4691.1	4688
24	24	JRM373	4810.5	240	160	240	4670.5	4671
25	2	BLMMON					4606	4601
26	32	JRM9C10	4800.6	170	70	170	4653	4656
33	40	JR5	4632	39.5	17	37	4620	*
36	39	BTR6	4752.1	226	156	226	4622	4619
36	46	BTR10A	4716.2	142	72	142	4619.4	*
36	49	BTR24	4628.5	40	30	40	4615.5	*
37	47	BTR154	4679.1	118	47	117	4619.3	4619
37	48	BTR153	4651.8	86	26	86	4618	4617
37	50	BTR23	4632.6	47	27	47	4615.2	*
37	51	BTR22	4657.4	80.5	60.5	80.5	4615.4	*
39	27	BTR1	4678.6	196	126	196	4610.6	4610
39	35	BTR5	4672.3	185	115	185	4609.7	4613
39	43	BTR9	4731.2	180	100	180	4625.9	4619
39	48	BTR66	4649.8	97	24	88	4621.3	4620
39	67	1203C4	4690.2	30	13.5	15.5	4689.2	*
40	48	BTR151	4648.4	108	37	107	4627.9	4620
40	53	BTR13	4759.9	211	131	211	4627	4631
42	49	BTR12A	4682.6	118	38	118	4630	4622
43	39	BTR8	4757.5	260	180	260	4608.5	4613
43	44	BTR17A	4692	154	84	154	4616.9	4617
44	31	BTR4	4706.9	246	176	246	4608.5	*
44	61	BTR20	4821.4	260	180	260	4662	4665
44	65	1106C4	4767.5	280	155	195	4691	*
45	65	1105C4	4779.6	280	138	198	4685.7	4690
45	70	1402C4	4842.2	300	155	215	4687	4690
46	66	1112C4	4815.9	197	155	195	4689.4	4690
47	36	BTR7	4712.2	260	190	260	4609	4608
47	52	BTR14	4743.9	220	150	220	4638.1	*
48	57	BTR19	4816.3	280	200	280	4654.2	*
53	80	GW42R17	4965.07	200	138	200	4777.1	*
54	61	915C22	4835.2	350	290	350	4604.7	*

Calibration of Model for Coal Aquifer Using Premine Data

Row	Col.	Well	Surface Elev.	Well Depth	Screened Interval Top	Screened Interval Bottom	Ground Water Elevation Observed	Ground Water Elevation Predicted
58	80	GW42R15	4919.63	192.5	130	192.5	4730.5	4732
63	81	GW42R9A	4742.96	24.7	5.6	24.7	4736.8	*
70	77	NA37A	4765.9	303	238	298	4596.9	4597
70	79	NA11B	4705.6	189	129	189	4597.6	4598
71	76	NA38A	4703.7	282.5	203	273	4597.9	4593
71	77	NA43A	4681.5	228	153.5	223.5	4597.2	4592
71	78	NA10A	4645.1	180	113	173	4596.8	4588
71	79	NA8A	4705.8	202	142	202	4585.7	*
72	78	DOW105A					4582.4	4583
72	79	DOW104					4582	4581
72	80	SOW107	4781.6	265	150	230	4584.8	*
73	80	DOW110					4555.2	*

* = well is located in cell greater than 50% clinker or inactive

Calibration of Model for Wasatch Aquifer Using Premine Data

Row	Col.	Well	Surface Elev.	Well Depth	Screened Interval Top	Screened Interval Bottom	Ground Water Elevation Observed	Ground Water Elevation Predicted
47	52	BTW10A					4709.4	4678.0
44	55	BTW11A					4721.2	4692.0
43	44	BTW12					4662.2	4660.0
48	57	BTW13					4730.3	4686.0
40	56	BTW14					4762.5	4712.0
42	17	BTW16					4691.1	4625.0
48	27	BTW17					4687.5	4627.0
44	31	BTW3					4669.2	4638.0
39	35	BTW4					4650.7	4646.0
47	36	BTW5					4687.3	4641.0
26	32	JRM101W					4730.9	4726.0
29	34	JRM103W					4680.5	4697.0
23	33	JRM111W					4743.3	4738.0
17	40	JRM121W					4814.3	4794.0
14	38	JRM13W					4823.5	4821.0
37	31	JRM154W					4648.2	4653.0
20	31	JRM23W					4762.9	4767.0
24	27	JRM33W					4727.3	4727.0
17	44	JRM75W					4833	4829.0

Section 8
Addendum

Land Quality Division Review of the Pilot Study
August 1997

Table of Contents

1.0 INTRODUCTION

The purpose of this addendum is to discuss alternatives to the assumptions and simplifications used to represent the geohydrologic conditions in the Pilot Study Area as a mathematical model (i.e., the model conceptualization). The model operation is also discussed.

2.0 ALTERNATIVES IN THE MODEL CONCEPTUALIZATION

LQD believes there are three major aspects of the model conceptualization that may warrant alternative approaches. The first aspect is the incorporation of an aerially extensive, essentially impermeable shale layer between the overburden and coal throughout the model area. The second and third aspects relate to recharge and vertical conductivity, both of which are also impacted by incorporation of the shale layer. There are also possible alternatives to other input parameters including hydraulic conductivities, storage coefficients, and vertical leakance.

2.1 Shale Layer above the Coal

The model includes a 10-foot thick shale layer above the coal as well as a shale layer below the coal. An alternative supported by the data suggests that such a layer is not as laterally extensive nor as impervious as conceptualized in the model. Including this layer in the model 'isolates' the coal, thus impacting other aspects of the model.

The shale layer between the "Wyodak Coal Aquifer" and the "Wasatch Formation Aquifer" was assigned a thickness of ten feet and a vertical permeability of 10^{-13} meters/second (10^{-11} centimeters/second (cm/sec)), throughout the model area. For comparison, the U.S. Environmental Protection Agency generally requires a permeability of 10^{-7} cm/sec or less for the secondary containment barriers underlying facilities for storage or disposal of waste material (see, e.g., design criteria for landfills - 40 C.F.R. §264.301, July 1, 1994). Therefore, the assigned permeability is exceptionally low. Although the presence of shale (or claystone) is noted on lithologic logs for mines in the Pilot Study Area, no definitive regional shale layer is noted, e.g. the material is usually noted as sandy shale or something similar. Similarly, LQD does not believe the geophysical logs indicate a regional shale layer is present, in part because only gamma logs were used and the scale (sensitivity) of the geophysical logs varied considerably.

By including the laterally extensive, practically impermeable shale layers above and below the Wyodak Coal, only limited evaluation of "inter-aquifer communication" could be done. This evaluation indicates the Wyodak Coal Aquifer is insensitive to vertical recharge.

V_{cont} (vertical conductance) is a model parameter which allows the 'quasi-three dimensional' representation of the model layers, i.e., it allows for representation of a leaky interlayer as a single input array rather than an entirely separate layer. The term V_{cont} must be carefully defined, as it is **not** the vertical hydraulic conductivity. V_{cont} takes into account the vertical hydraulic conductivity (K_v), along with the thickness of the confining layer (i.e., the "shale layer" at the base of the overburden) and the cell size. The vertical hydraulic conductivity assigned to the 'shale layer' between the overburden and coal was extremely low. Therefore, the calculated value of V_{cont}, which depends on the vertical hydraulic conductivity, was also extremely low. The 'simplified' form of the V_{cont} equation was used. The simplified equation can only be used in some cases. Alternatively, the 'long' equation could have been used since the hydraulic conductivity of the confining layer is larger than the vertical hydraulic conductivity of the over- and underlying layers.

Sensitivity analyses were performed using the pre-mining V_{cont} values; however, the range of values in the sensitivity analyses was based on the initial values. Therefore, the entire range may have been too low. Also, post-mining V_{cont} sensitivity analyses could have been performed because the rate of recovery is dependent in part on vertical movement of water in the backfill. Some literature is available, such as *Hydraulic Characteristics of Aquifers and Confining Units into the Fort Union Formation, by T.S. Reed (USGS),* describing vertical hydraulic conductivity in the Fort Union Formation, which could be consulted.

2.2 Recharge

LQD believes the distribution of recharge across the top layer of the model should have included a more representative distribution of recharge from precipitation and recharge along alluvial channels.

2.2.1 Recharge from Precipitation

The amount of recharge in the model was derived by assuming that: (a) 1% of the precipitation falls on permeable materials in the top layer; and (b) 2% of the precipitation that falls on the permeable materials (i.e., 2% of (a)) infiltrates. This calculated amount was then distributed uniformly over the top layer of the model, with no differentiation between areas with permeable and impermeable materials. As an alternative, the model could take into account the type of surface material; for example, a clinker surface, sandy overburden area, or alluvium which would allow more infiltration than a clay surface. Infiltration data on the soils in the PRB should be taken into consideration in at least a qualitative way. This could add additional complexity to the model. However, the special properties of several areas, such as the 'clinker' cells and those cells that represent the lineaments, are already differentiated in the input arrays. Therefore, at a minimum, recharge could be increased in those cells. In addition, reference is made to a "Soils" layer in the GIS database discussed in the Appendices. Information from this database should be helpful.

2.2.2 Recharge along Alluvial Channels

Recharge to (or discharge from) alluvial channels and impoundments was not included as a source/sink term. Many of the drainages follow preferential northwest-southeast trending paths rather than forming a typical dendritic drainage pattern. If these drainages follow "zones of augmented hydraulic conductivity", there could be a significant contribution to recharge from runoff. For example, the Hilight Lineament (which was apparently assigned an "elevated hydraulic conductivity") is noted as a northwest extension of a drainage feature, specifically Burning Coal Draw.

2.3 Other Input Parameters

2.3.1 Boundaries

The eastern boundaries of the Wasatch Aquifer and the Wyodak Coal Aquifer, along the coal outcrop and areas of clinker, are the most difficult to represent in a mathematical model. In this model, the option of 'General Head Boundaries' was chosen as the best modeling option. Although this approach would not be LQD's method of choice, it can be workable if used with caution and if it is clear exactly how the option was used. For example, it seems that the coal/clinker boundary cells were assigned as Constant Head Boundaries during the steady-state calibration to establish the rates of flow through the coal/clinker boundary. These flow rates were apparently then used to calculate the conductance across the boundary cells, which were changed from Constant to General Head Boundaries during the transient runs. However, LQD is not sure that this was the approach used.

The model setup also apparently set the clinker nodes as constant head sources of ground water. (In other words, the clinker cannot 'dry up', even if the drawdowns due to the mines indicate that at least the clinker nodes adjacent to the mines should be dry.) The clinker should only be simulated as a constant head if the clinker body is large enough and the length of time is short enough that significant drawdown does not occur in the clinker. An alternative is to simulate the clinker nodes as flux nodes, which allows the water level in the node to rise or fall.

2.3.2 Hydraulic Conductivities

The distribution of the input coal permeabilities reflects numerous linear features, such as faults and lineaments. In one instance a feature may have been treated as a 'no-flow' area, but in another instance, the feature may have been given a very high permeability. The text differentiates between treatment of lineaments and faults (lineaments were treated as high conductivity nodes and faults were reportedly treated as low conductivity nodes), even though a lineament may be a fault or one of many possible structural (or non-structural) features. Prior to making a determination of how to treat a fault or lineament in the model inputs, the character of the feature should be investigated using all of the information available.

The selection of linear features in the model was based in part on the lineaments mapped by Denson et al (1980) were described in their report as "Topographic Lineament[s] Representing Linear Stream Course or Aligned Topographic Features". However, the lineaments were only modeled in the coal aquifer, even though it is likely these lineaments affect the overburden aquifer too, based on their topographic expression. LQD's efforts to correlate the permeability distributions in the coal, based on the electronic files provided to LQD, with the lineament and fault information in the model report leads to several alternate possibilities:

a) In general, the lineaments extend across the entire area covered by the model, but they are only assigned increased (or decreased) permeabilities in certain portions of the model. For example, according to Denson et al (1980), the North Prong Little Thunder Creek (NPLTC) Lineament extends northwest to its intersection with the EMS Ranch Lineament which continues to the northwest. However, in the model, only the NPLTC Lineament was highlighted by increased permeabilities of 5 to 7.5 feet/day (about Row 35, Column 37 to Row 62, Column 15). At least one mine in the model area reports significantly different drawdowns and pit inflows on opposite sides of linear features through that mine, so these linear features are significant to ground water flow.

b) In the Denson report, lineaments are distinguished from faults, and in some cases, lineaments change to faults. It is not clear how these differences or changes were represented in the model. A feature which acts as a no-flow barrier at one location and as a conduit at another would impact ground water flow directions.

c) For the backfill, the model uses a conductivity of 0.2 feet/day (the same value as for "undisturbed Wasatch Formation aquifers" from Martin et al (1988) was used. However, other backfill tests in the PRB indicate a conductivity of 5.8 feet/day. The higher conductivity would result in a faster rate of recovery of the backfill aquifer after mining.

2.3.3 Anisotropy

The model uses global anisotropy. However, the input hydraulic conductivities can reflect anisotropy on a much smaller scale, although this is laborious, and much more difficult to check in sensitivity analyses. The direction of the global coal anisotropy determined using the sensitivity analyses (i.e., 2:1 column to row anisotropy) could have been compared with the directions of coal anisotropy determined by aquifer testing, particularly as those directions were orthogonal.

2.3.4 Storage Coefficients

The Wasatch storage coefficient was input as a constant value of 0.01. However, based on the discussion of the available storage coefficient data, a more representative approximation could have been to use the measured values of 0.1 along the outcrop and 'grade' the values to 0.01 in the 'downdip' cells. Alternately (or additionally), the sensitivity of the model to the Wasatch Formation storage value could have been evaluated.

2.3.5 Inflow from Beneath the Coal

At least one mine in the PRB, although not in this drainage area, has found that inflow from the material beneath the coal is important. This issue warrants further consideration.

3.0 MODEL OPERATION

LQD has comments on two aspects of the model operation. First, the calibration process could have been more representative of actual conditions. Second, the predictive simulations could have been expanded.

3.1 The Calibration Process

Based on the electronic files provided to LQD in July 1997, the steady-state calibration run was apparently for a 1-day time period. LQD reran the model for a 10,000-day period, which resulted in changes to the steady-state heads, indicating that a steady-state condition had not been achieved at the end of one day. The steady-state run could have been repeated for a longer time period and the input parameters adjusted to achieve convergence.

The first available data point in select wells was reportedly used as the calibration target, even though some of these points may not be representative because of problems associated with well development, construction, or similar factors. In addition, even though drawdown is determined at node centers, extrapolation could have been completed to 'correct' the drawdown at a target well for its distance from the node center. (Some versions of MODFLOW will automatically make this correction, or it can be done by contouring the output heads and comparing the contours with the well.)

The magnitude of the Root Mean Squared (RMS) error was apparently used as the basis for the decision to include or exclude a particular lineament or fault. Because the RMS error combines positive and negative variations across the model area, the model results could actually be better (or worse) in the immediate vicinity of faults or lineaments than would be indicated by the RMS error. In addition, this approach incorporates large portions of the model area where no data is available, which would dilute local problems, even though there could be an improvement in local areas where data is available.

3.2 Predictive Simulations

For the 'during mining' simulations, LQD believes more complete pit sequences could have been developed on the basis of available information. None of the "predictive simulations" show the rate of recovery after mining is complete, i.e., none of the predictive simulations discussed in the text extend beyond the year 2021.

4.0 SUMMARY

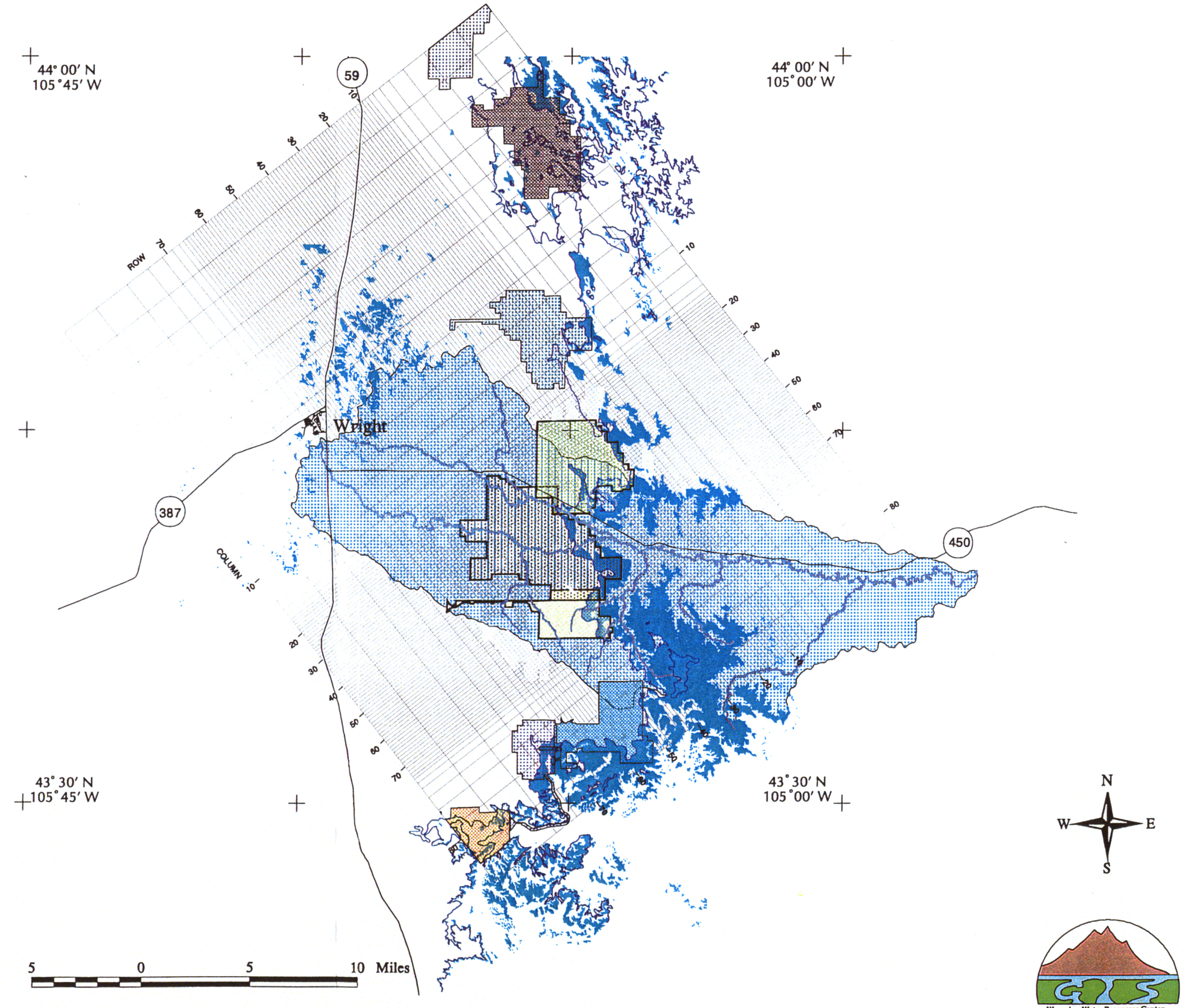
LQD's comparison of the results of the Pilot Study Model with the results of the models generated by the individual coal companies and the results of the 1988 USGS CHIA show both some similarities and some discrepancies. There is some agreement on the extent of the western 5-foot drawdown contour predicted by the mines for 1995 or the late 1990s. However, the drawdowns predicted by the Pilot Study Model seem to extend several miles farther north and south than the mines' predictions. The reasons for the differences in the predicted extent of the 5-foot drawdown could have been explained. Several of the factors noted in this addendum, such as 'isolation' of the coal layer from the overburden by including an impermeable layer above the coal, would contribute to more extensive drawdown. Incorporation of these factors into the model would require recalibration and reverification of the model. Some aspects of the model set-up, such as the evaluation of the recharge/discharge relationship of the clinker with the coal, will be helpful to LQD in reviewing the individual mine models.

LQD is required to look at cumulative impacts due to mining, not the cumulative impacts of all the water users. This report indicates an overlap in the drawdown from coal mining and coal bed methane development. The calibration of any groundwater model is difficult to impossible since it is questionable if the impacts of the coal bed methane industry can be differentiated in some way from the mining impacts. Without being able to differentiate the two impacts by field measurements (such as regular water level measurements coordinated with CBM pumping schedules and mine development), it will not be possible to calibrate any model over time.

Section 9
Plates

Plate 1

Model Setup



Legend

- Coal Crop Line, Wyodak & Anderson Coal
- State Highway
- Stream
- Clinker Region
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area
- Groundwater Model Grid
- Little Thunder Creek Watershed

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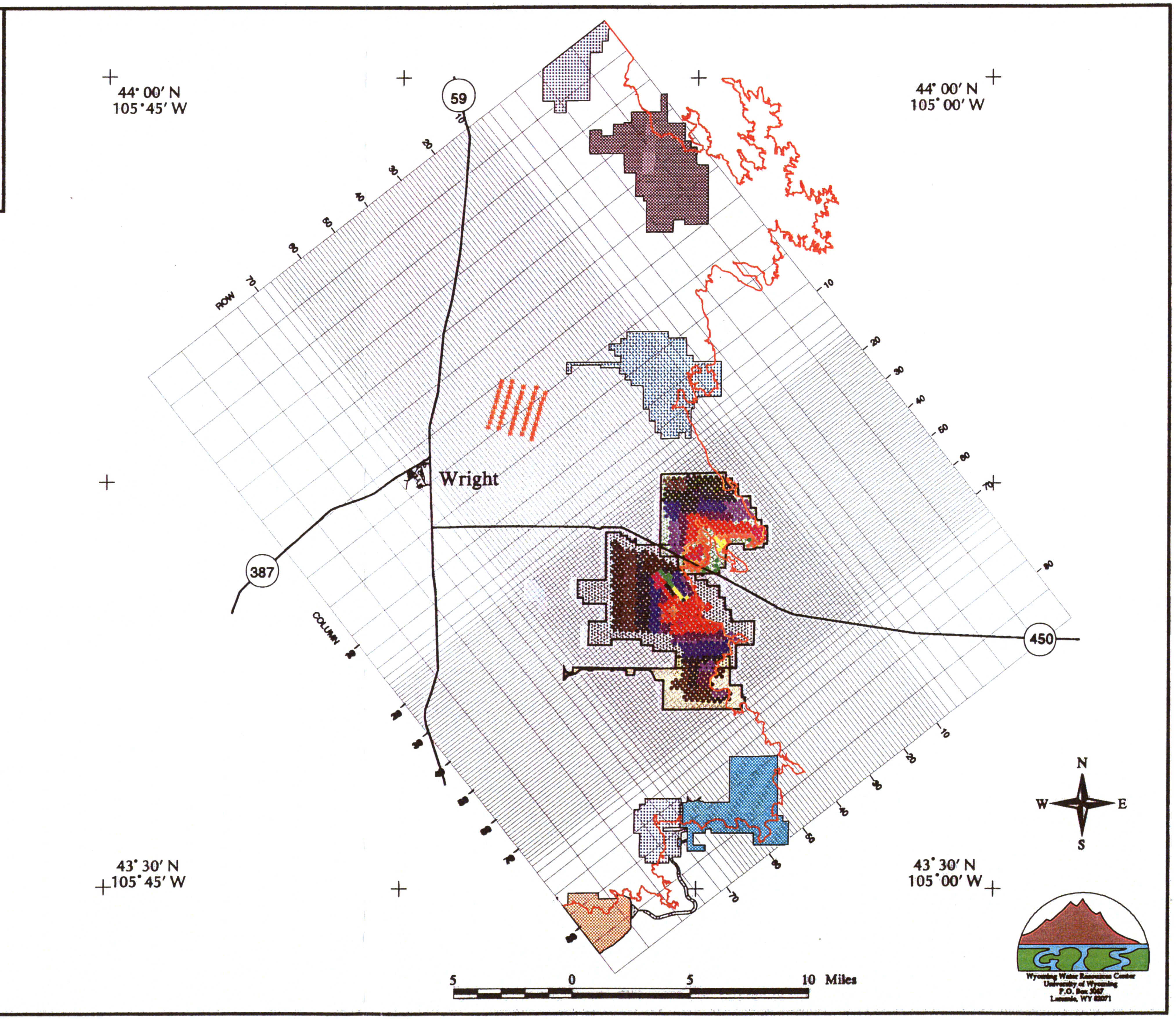
Plate 2

Hydrologic Stress Locations



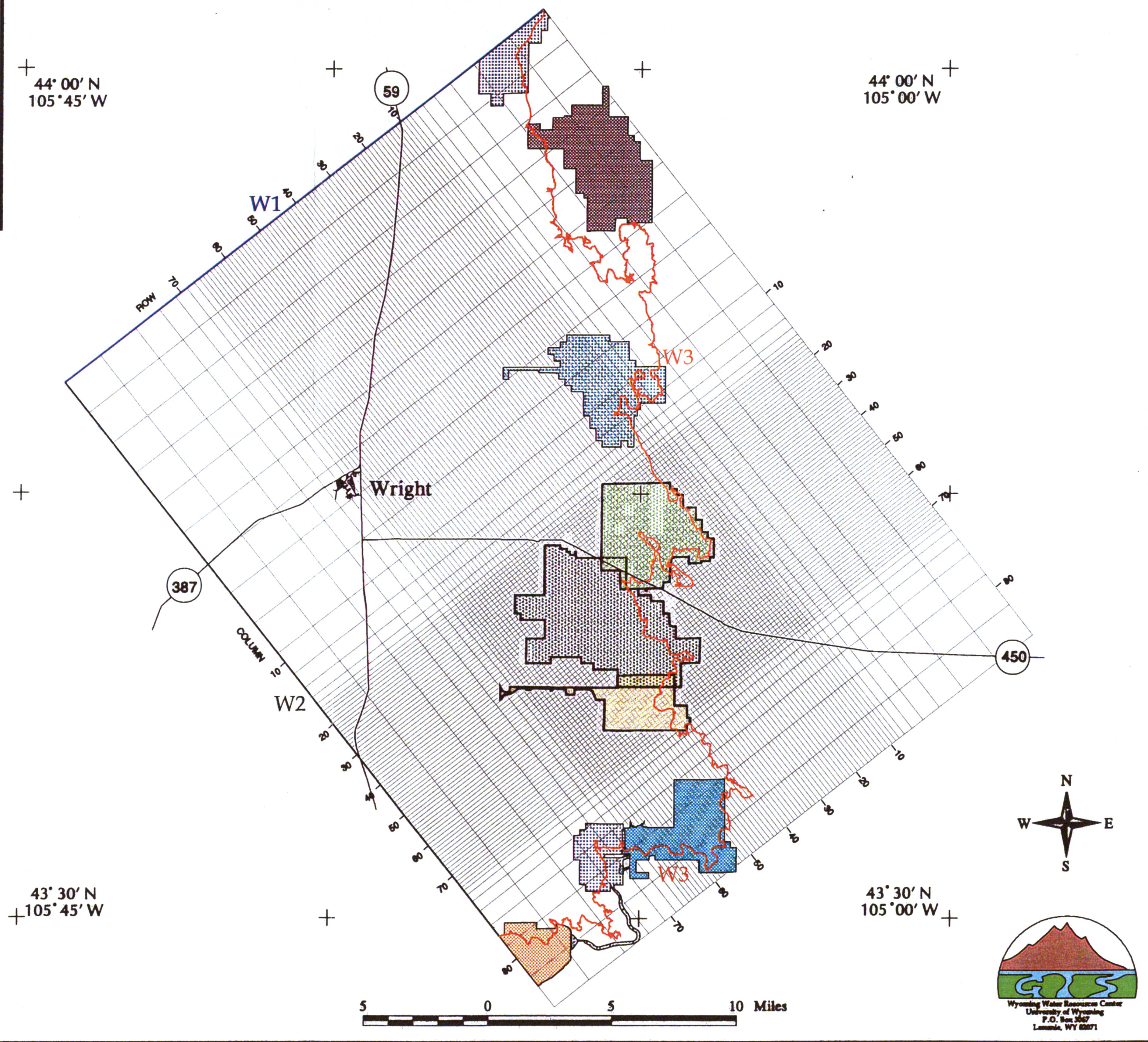
Legend

Coal Mining Sequence

- 1977 - 1979
- 1980 - 1982
- 1983 - 1985
- 1986 - 1988
- 1989 - 1991
- 1992 - 1994
- 1995 - 1997
- 1998 - 2000
- 2001 - 2003
- 2004 - 2006
- 2007 - 2009
- 2010 - 2015
- 2016 - 2020
- Lighthouse (Coal Bed Methane) Well
- State Highway
- Coal Full-Seam Line
- Groundwater Model Grid
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Plate 3

MODFLOW Boundary Conditions for Wasatch Aquifer



Legend

- W1 - Constant Head Boundary
- W2 - Constant Head Boundary
- W3 - General Head Boundary
- State Highway
- Groundwater Model Grid
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Plate 4

MODFLOW Boundary Conditions for Wyodak Coal Aquifer

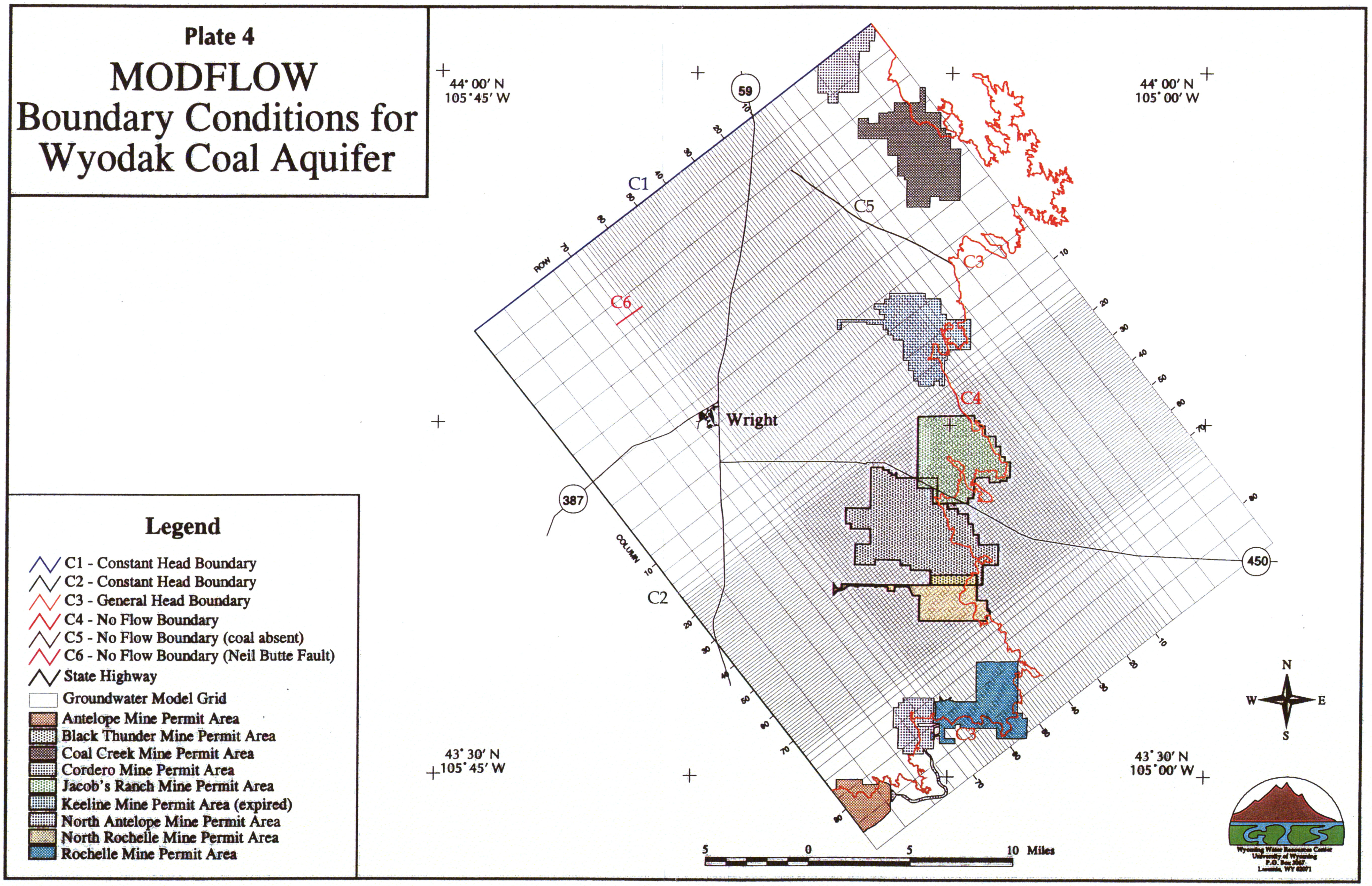
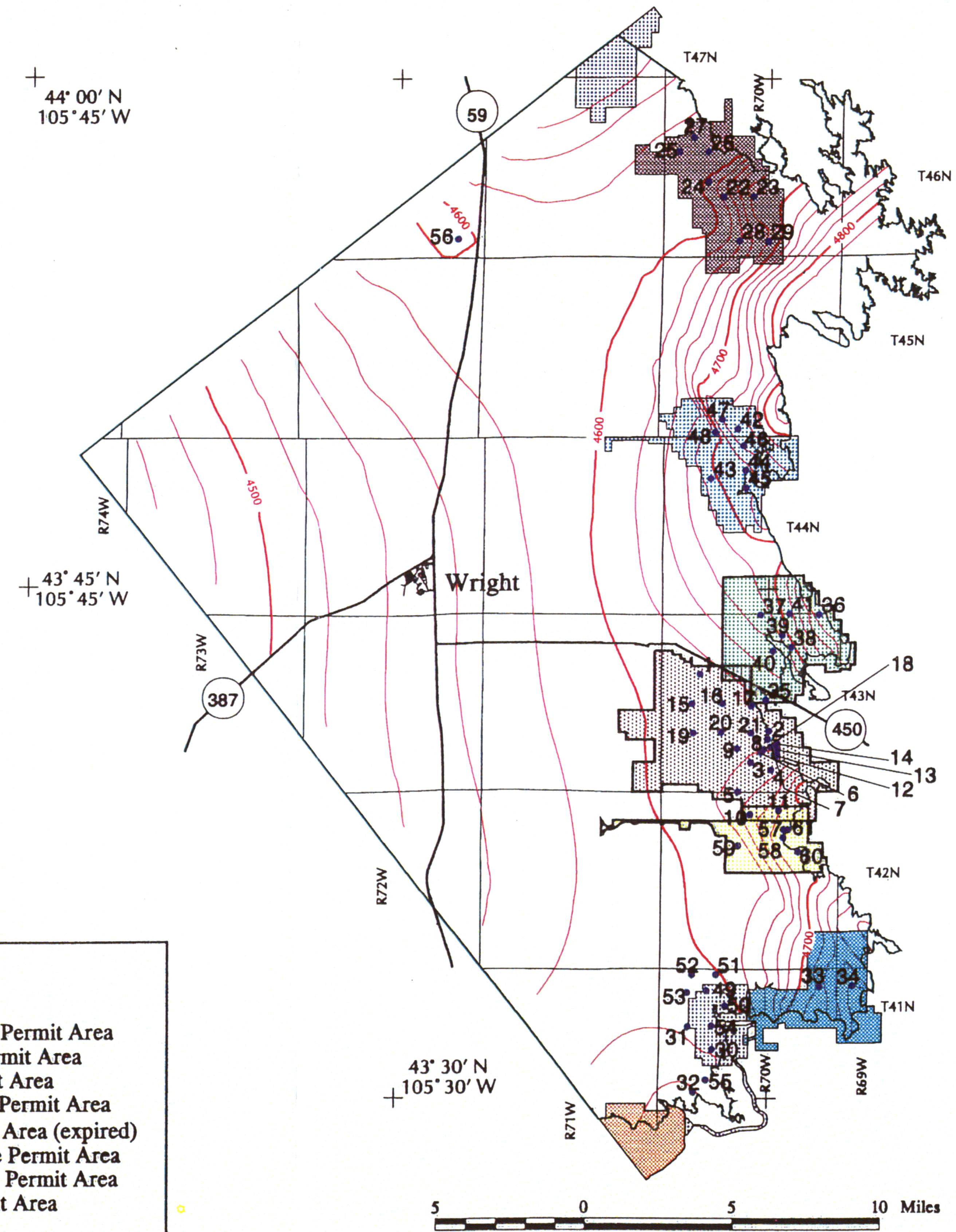


Plate 5

Premine Potentiometric Surface in Wyodak Coal from Calibrated Model with Calibration Wells

Well #	Well Name	Head (ft)
1	BTR1	4607.7
2	BTR10A	4619.4
3	BTR12A	4630.0
4	BTR13	4620.4
5	BTR14	4638.1
6	BTR151	4627.9
7	BTR153	4618.0
8	BTR154	4619.3
9	BTR17A	4616.9
10	BTR19	4650.5
11	BTR20	4717.0
12	BTR22	4615.4
13	BTR23	4615.2
14	BTR24	4615.5
15	BTR4	4608.5
16	BTR5	4609.6
17	BTR6	4622.0
18	BTR66	4621.3
19	BTR7	4608.8
20	BTR8	4608.5
21	BTR9	4625.9

Well #	Well Name	Head (ft)
22	CCR15	4596.1
23	CCR16	4699.8
24	CCR18	4584.7
25	CCR24	4582.8
26	CCR25	4589.7
27	CCR27	4582.4
28	CCR6	4661.0
29	CCR7A	4705.0
30	DOW104	4582.0
31	DOW105A	4582.4
32	DOW110	4555.2
33	GW42R15	4730.5
34	GW42R17	4777.1
35	JR5	4620.0
36	JRM281	4790.6
37	JRM373	4657.0
38	JRM3C11	4691.1
39	JRM5C2	4681.0
40	JRM9C10	4653.0
41	JRM9C2	4705.0
42	KL10	4747.9



Well #	Well Name	Head (ft)
43	KL14	4694.9
44	KL15	4715.1
45	KL16	4713.2
46	KL4	4743.5
47	KL8	4729.8
48	KL9	4709.2
49	NA10A	4596.8
50	NA11B	4597.6
51	NA37A	4596.9
52	NA38A	4597.9
53	NA43A	4597.2
54	NA8A	4585.7
55	SOW107	4584.8
56	BLM	4612.0
57	1105C4	4685.7
58	1112C4	4689.4
59	915C22	4604.7
60	1402C4	4687.0
61	1106C4	4691.0

44° 00′ N
105° 00′ W

Legend

- Potentiometric Surface Contours (Contour Interval 20 feet)
- Model Domain Boundary
- State Highway
- Calibration Well
- Public Land Survey System
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

N
W E
S

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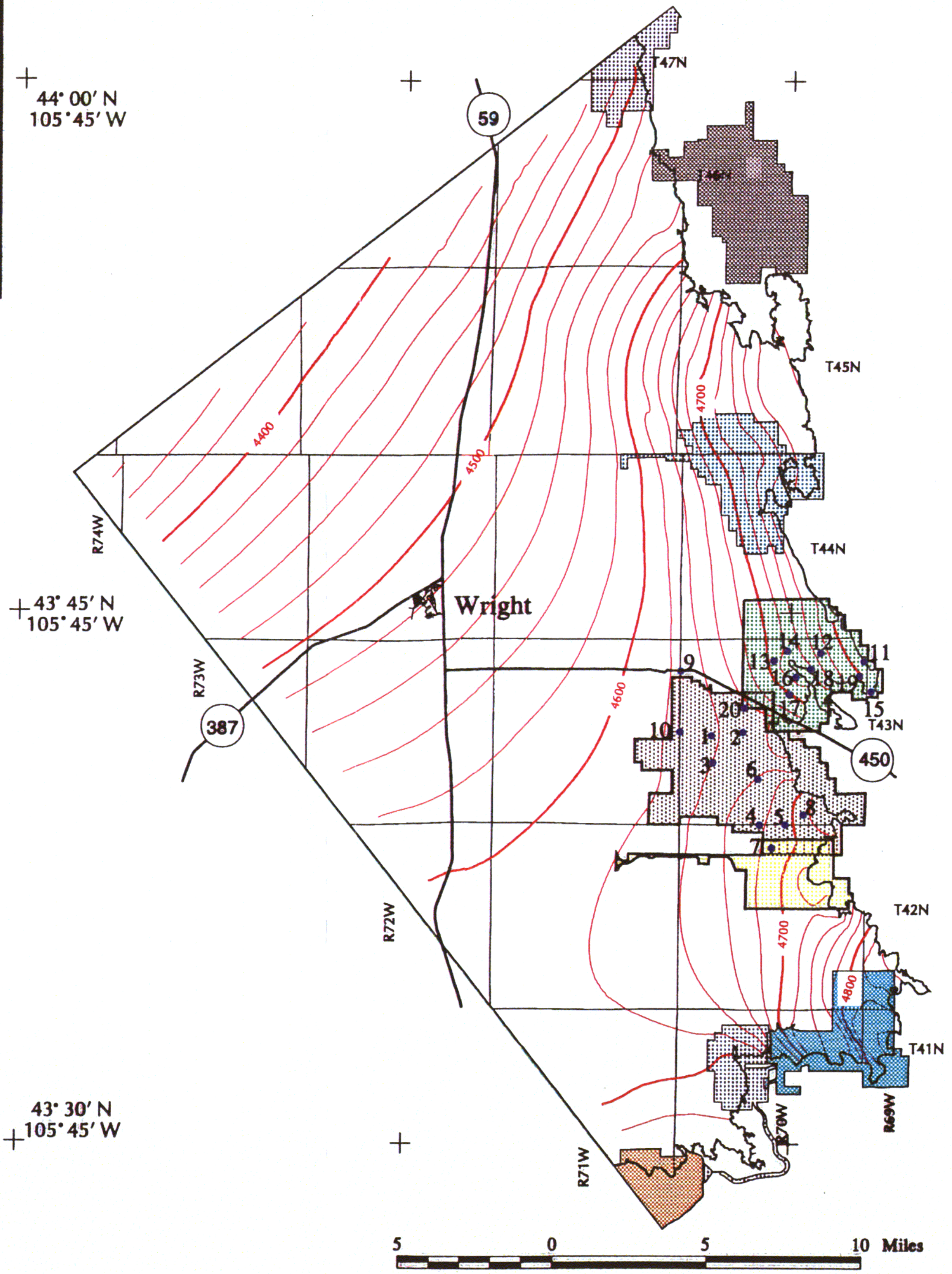
Laramie, WY 82071

Plate 6
Premine Potentiometric Surface in Wasatch from Calibrated Model with Calibration Wells



Well #	Well Name	Head (ft)
1	BTW3	4669.2
2	BTW4	4650.7
3	BTW5	4687.5
4	BTW10A	4709.4
5	BTW11A	4721.2
6	BTW12	4662.2
7	BTW13	4730.3
8	BTW14	4762.5
9	BTW16	4691.1
10	BTW17	4687.5
11	JRM13W	4823.5
12	JRM23W	4762.9
13	JRM32W	4741.2
14	JRM33W	4727.3
15	JRM75W	4833.0
16	JRM101W	4730.9
17	JRM103W	4680.5
18	JRM111W	4743.3
19	JRM121W	4814.3
20	JRM154W	4648.2

N
W
E
S

Legend

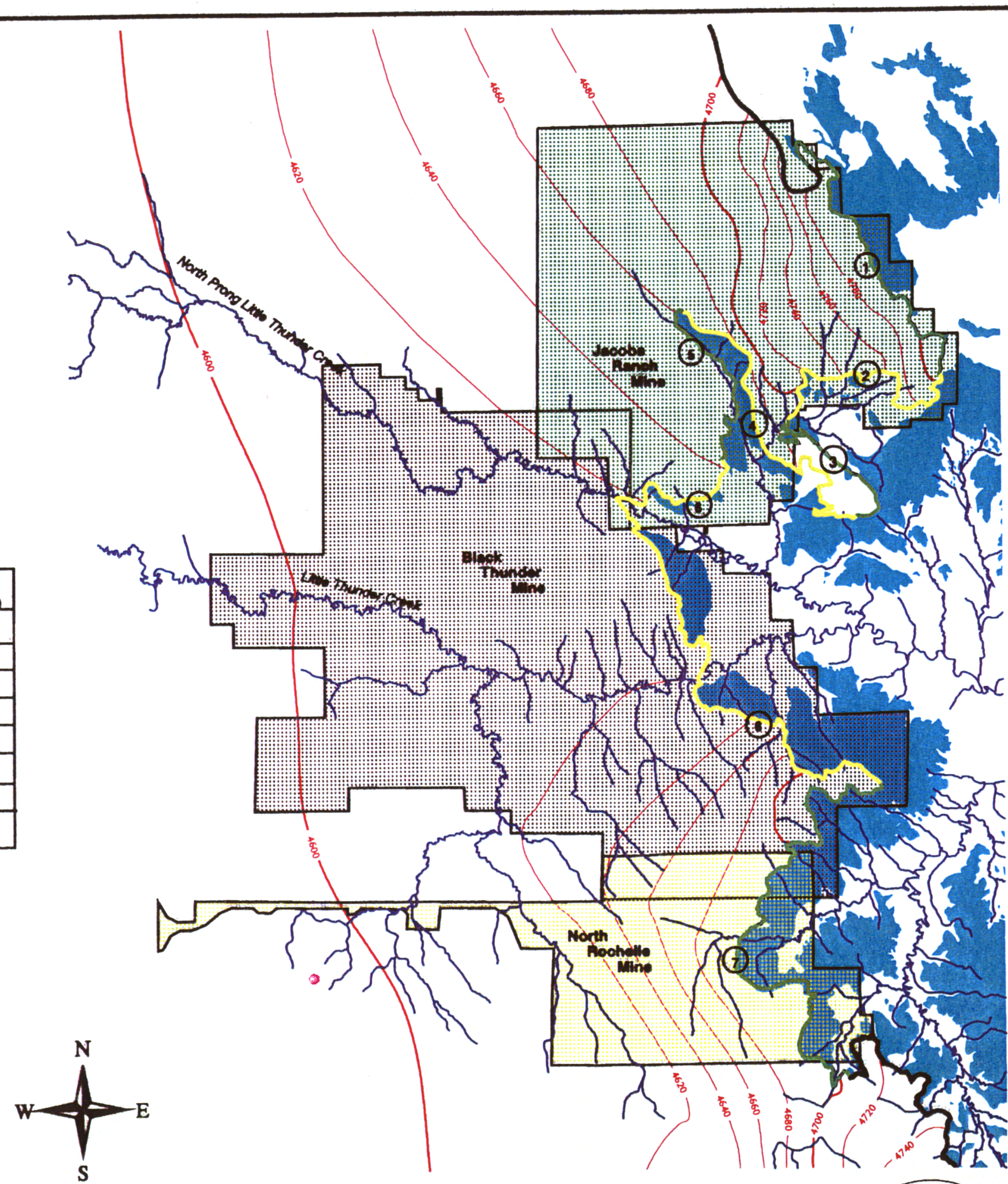
- Potentiometric Surface Contours (Contour Interval 20 feet)
- Model Domain Boundary
- State Highway
- Calibration Well
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area
- Public Land Survey System

Plate 7

MODFLOW Simulated Premining Recharge/Discharge to Wyodak Coal Aquifer

Steady State Recharge/Discharge Along Full Seam Coal Line, Premine data

Segment	Length(ft)	Recharge (ft³/day)	Discharge (ft³/day)
1	20,643	114,300	
2	16,267		78,800
3	12,699	1,700	
4	23,228		83,800
5	12,030	127,300	
6	40,432		159,900
7	35,647	177,300	
Net	160,946	420,600	322,500



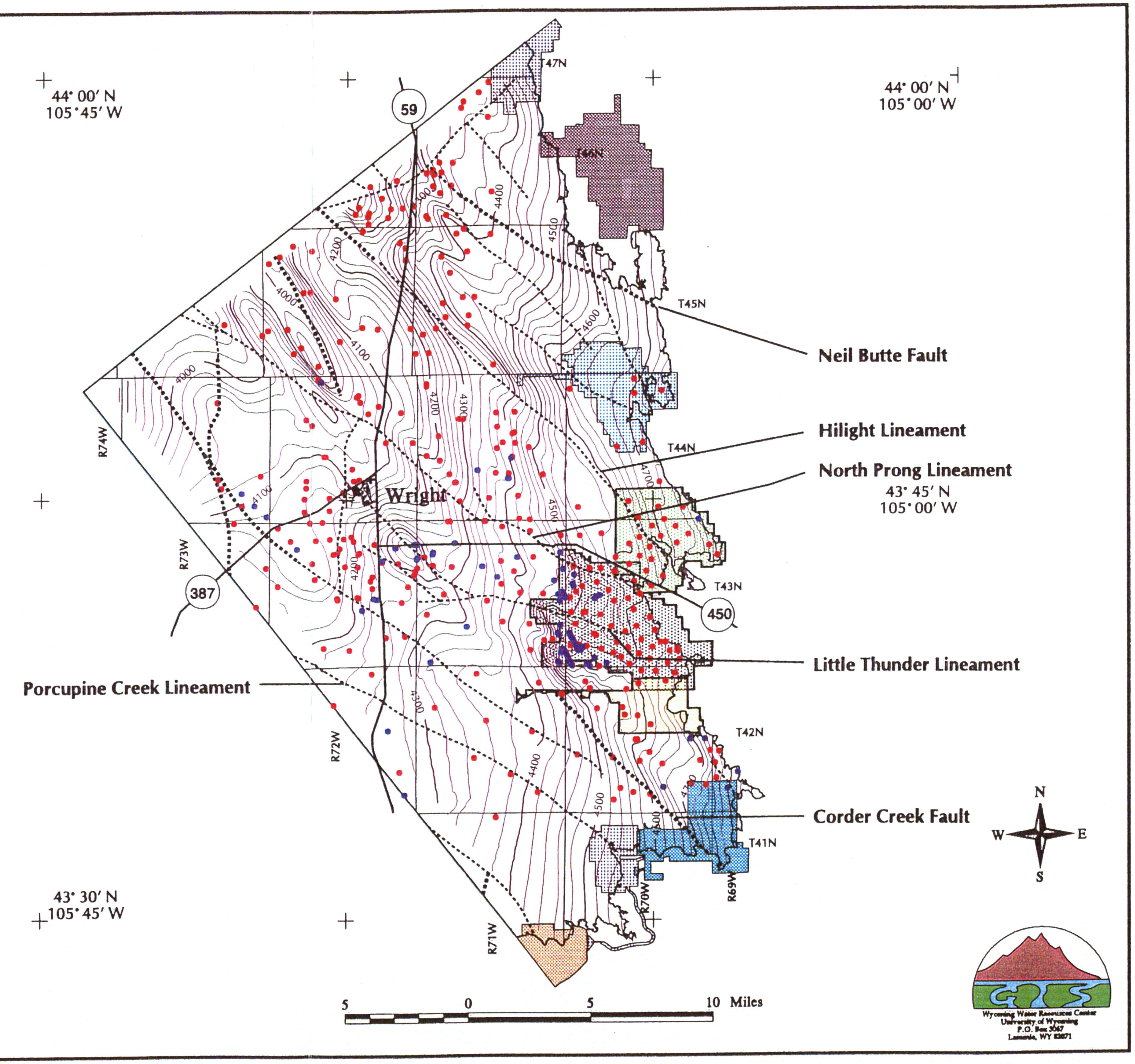
5 0 5 Miles

Legend

Full Seam Line, Wyodak Coal
- Discharging Boundary
- Recharging Boundary
- Not Evaluated
- Stream Channels
- Premine Potentiometric Surface
- Mapped Clinker
- North Rochelle Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Black Thunder Mine Permit Area

Plate 8

Top of Wyodak Coal Contours from Kriged Data



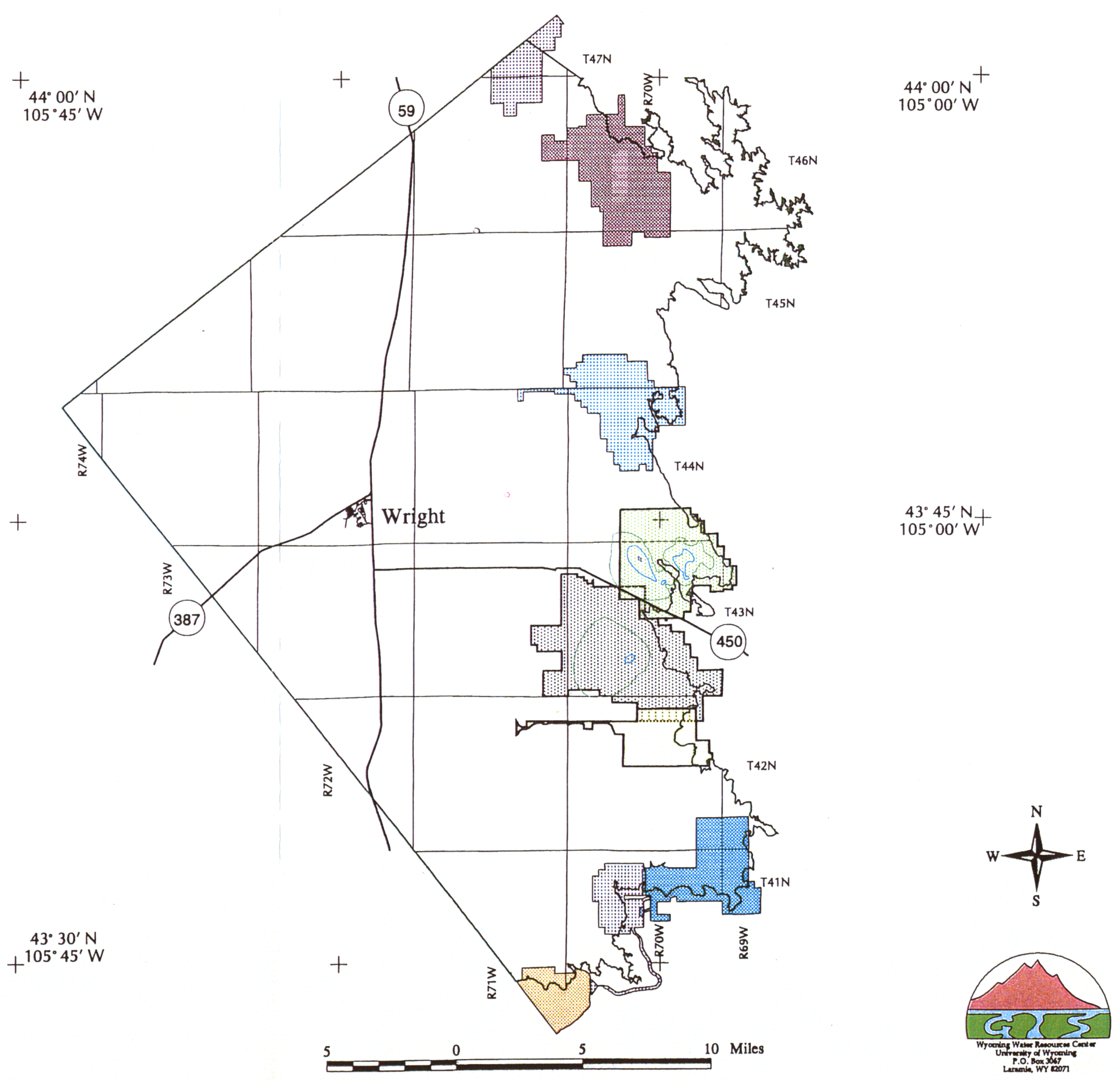
Legend

- Contours (Contour Interval 20 feet)
- Fault *
- Lineament *
- Model Domain Boundary
- State Highway
- Geologic Structure Data Point
- Geologic Structure Data Point with High Residual
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area
- Public Land Survey System

* Data from Denson, et al (1980)

Plate 9

Modeled Drawdown in Wyodak Coal 1985



Legend

- State Highway
- Model Domain Boundary

Drawdown Contours (feet)

- 5
- 20
- 35

- Public Land Survey System
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Plate 10

Modeled Drawdown in Wasatch Aquifer 1985

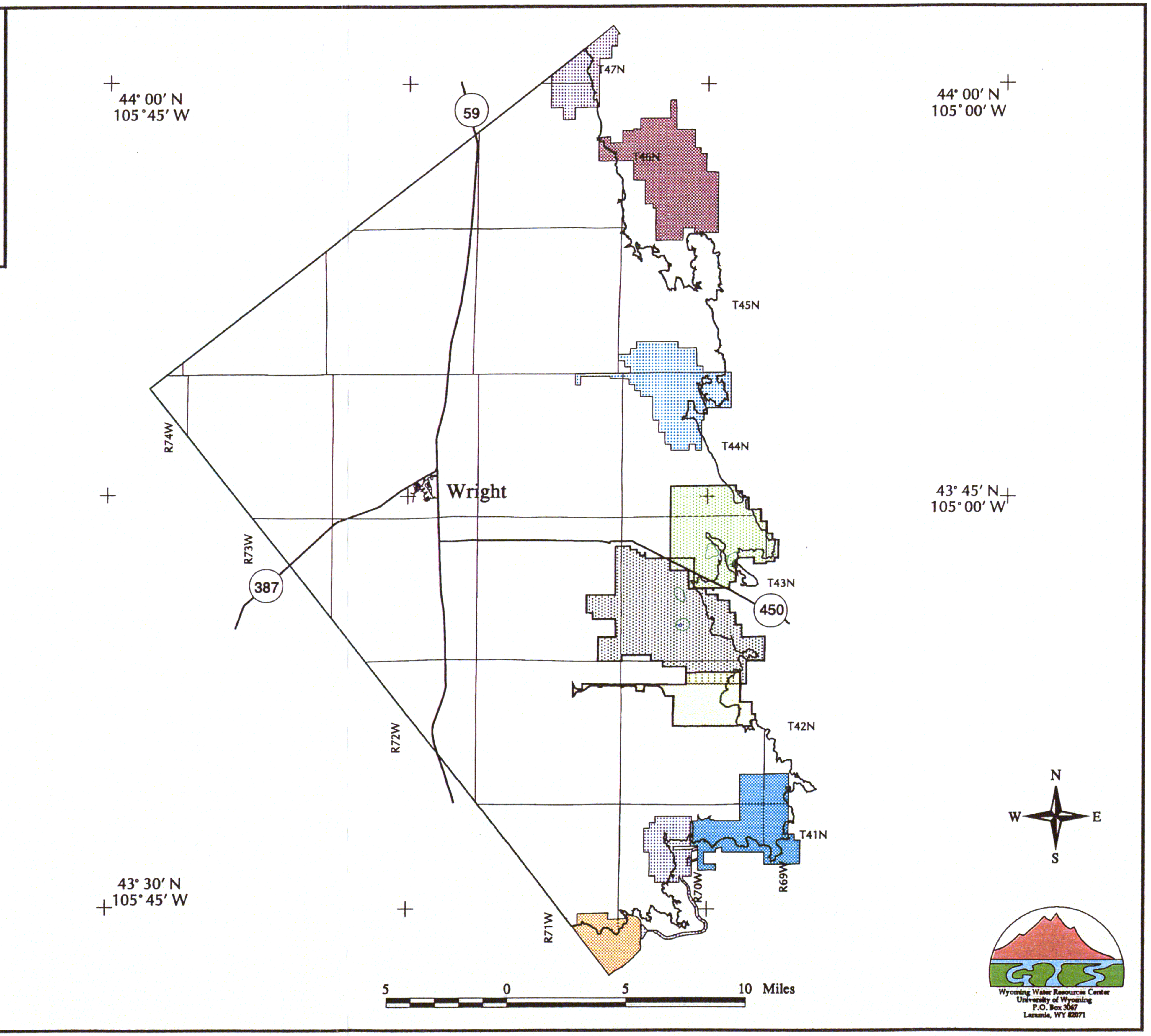


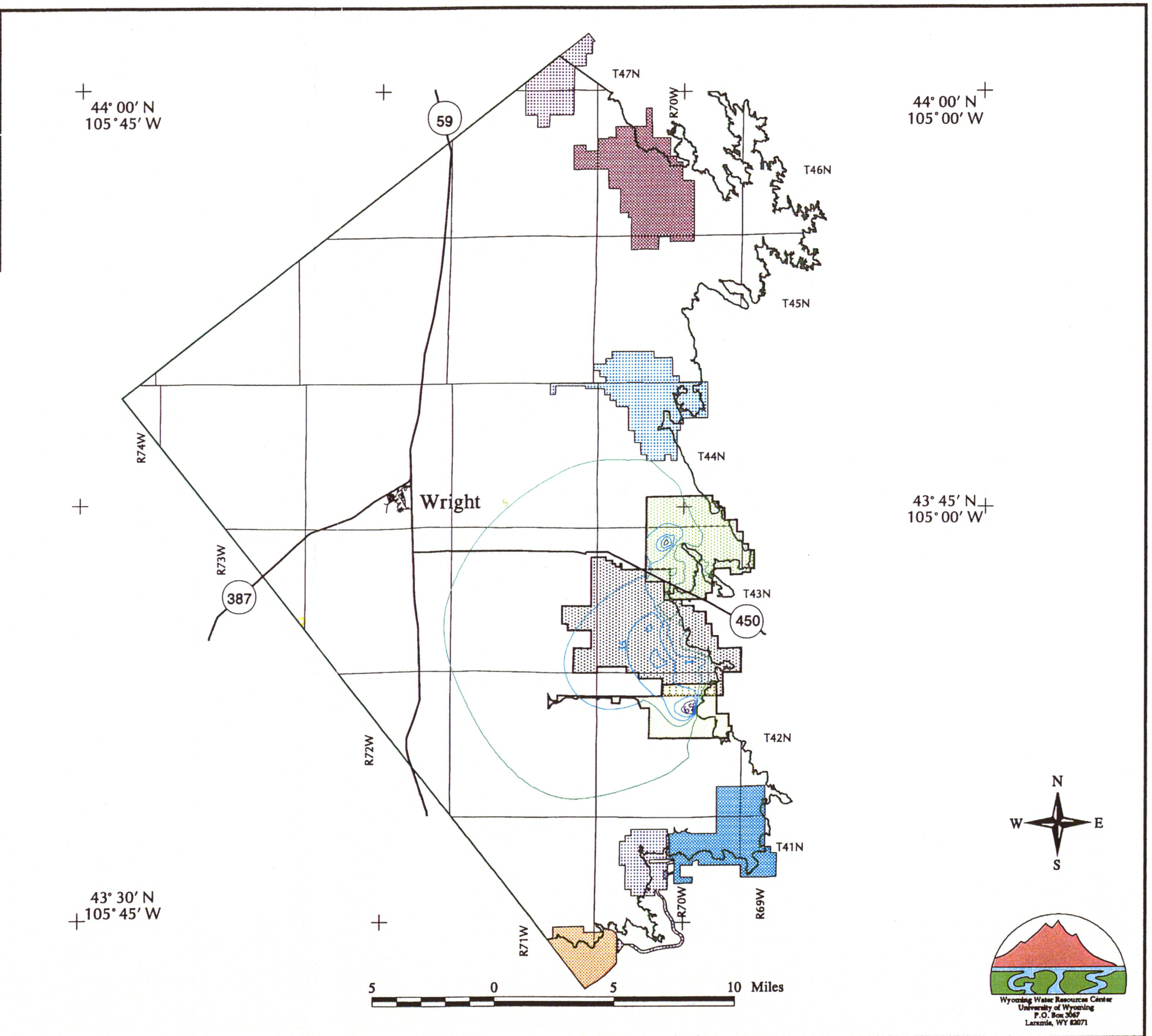
Plate 11
Well Logs

This plate shows geologic cross sections of the study area based on gamma curves from oil well logs (E - W cross section) and BLM coal exploration test borings (N - S cross section). Coal correlations were completed using a natural gamma curve.

Due to its size and cost of reproduction, this plate is not included in this report, but is available for review at the Casper District Office of the Bureau of Land Management, 1701 East E Street, Casper, WY 826001, Ph: 307-261-7600

Plate 12

Modeled Drawdown in Wyodak Coal 1995



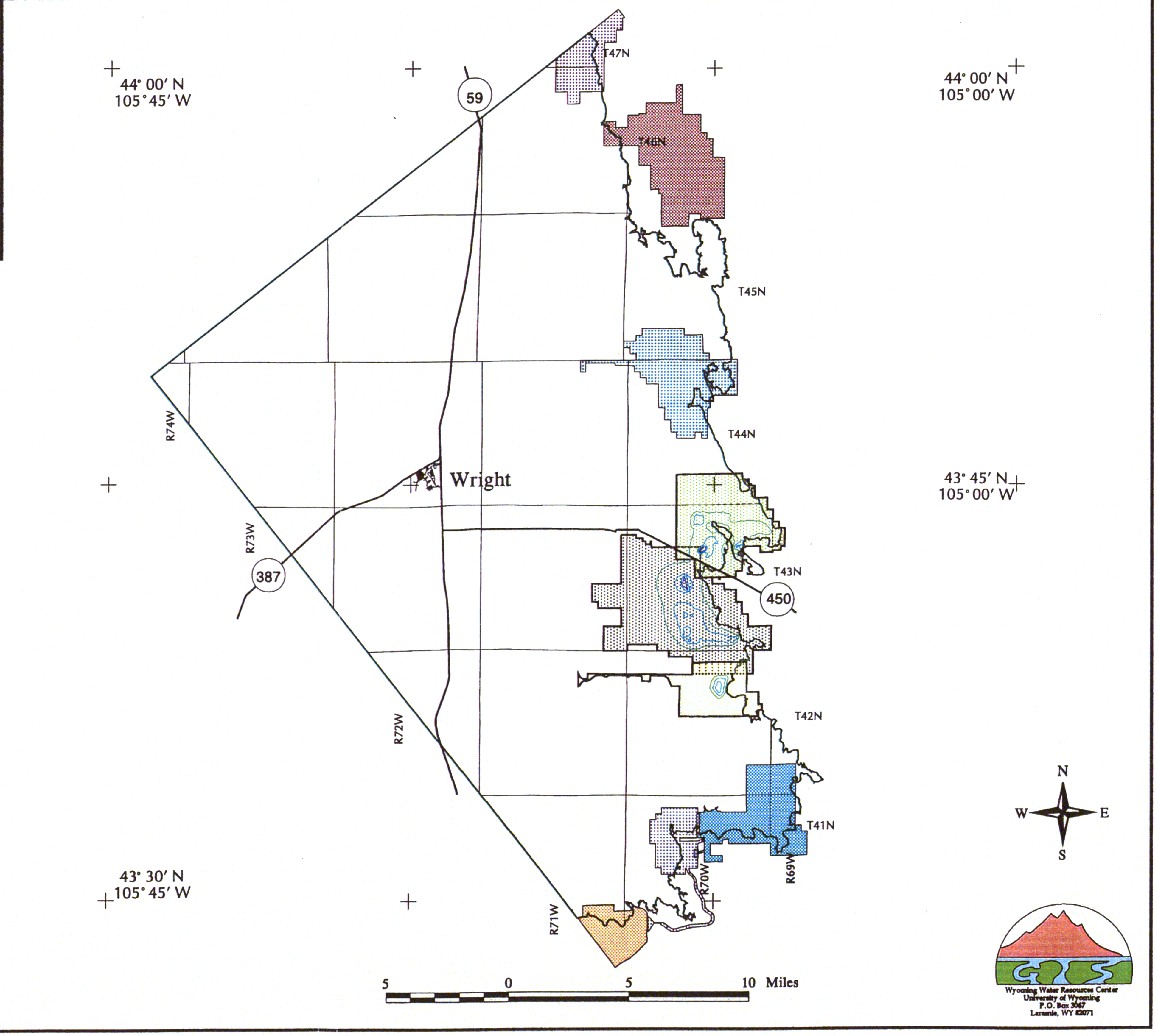
Legend

Drawdown Contours (feet)
- 5
- 20
- 35
- 50
- 65

State Highway
Model Domain Boundary
Public Land Survey System
Antelope Mine Permit Area
Black Thunder Mine Permit Area
Coal Creek Mine Permit Area
Cordero Mine Permit Area
Jacob's Ranch Mine Permit Area
Keeline Mine Permit Area (expired)
North Antelope Mine Permit Area
North Rochelle Mine Permit Area
Rochelle Mine Permit Area

Plate 13

Modeled Drawdown in Wasatch Aquifer 1995



Legend

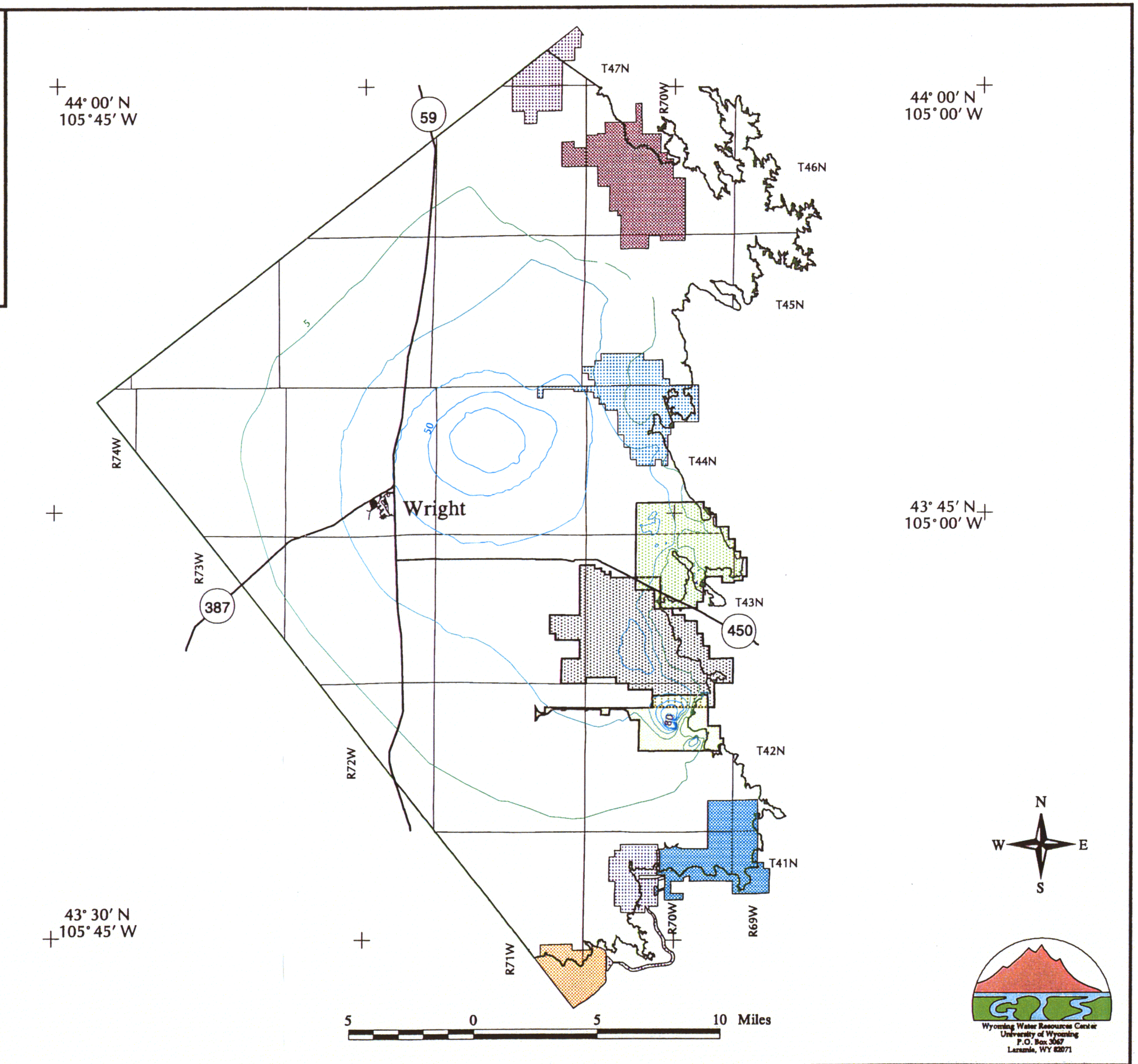
Drawdown Contours (feet)

- 5
- 20
- 35
- 50

- State Highway
- Model Domain Boundary
- Public Land Survey System
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Plate 14

Modeled Drawdown (with Coal Bed Methane) in Wyodak Coal 2005



Legend

Drawdown Contours (feet)
- 5
- 20
- 35
- 50
- 65
- 80
- 115

- State Highway
- Model Domain Boundary
- Public Land Survey System
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Plate 15

Modeled Drawdown in Wasatch Aquifer (with Coal Bed Methane) 2005

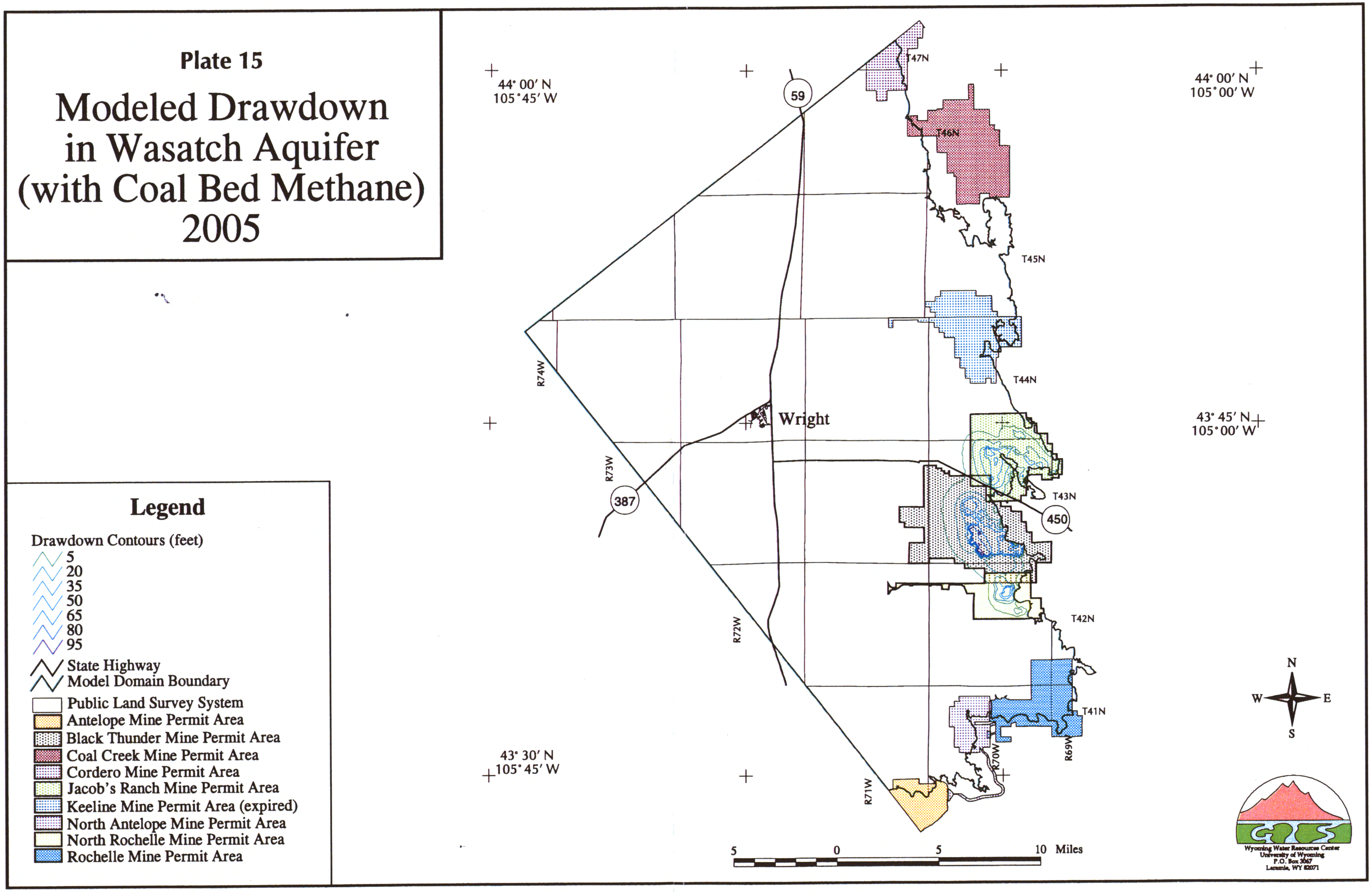


Plate 16

Modeled Drawdown (with Coal Bed Methane) in Wyodak Coal 2021

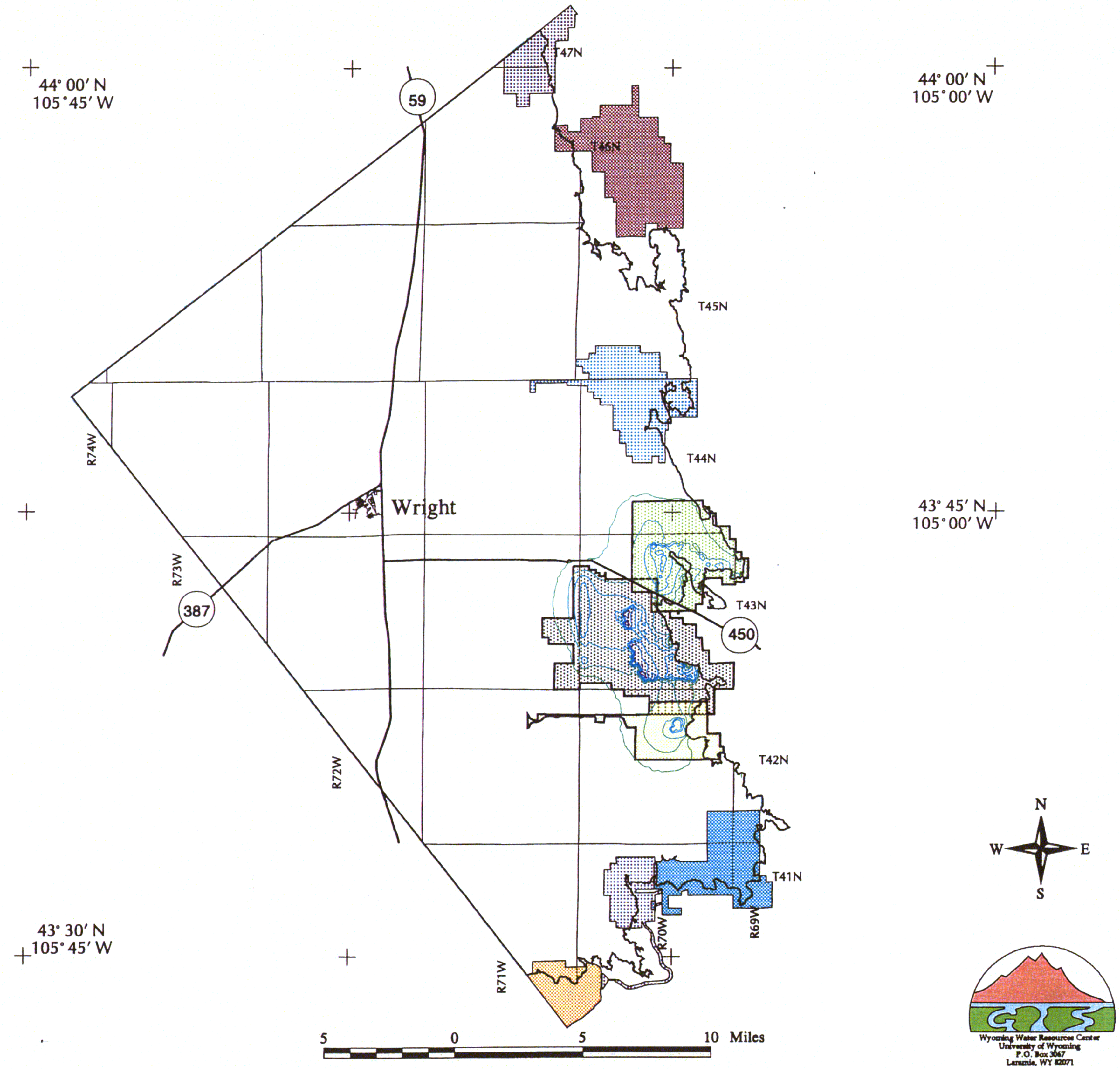
Legend

Drawdown Contours (feet)
- 5
- 20
- 35
- 50
- 65
- 80
- 95
- 110

State Highway
Model Domain Boundary
Public Land Survey System
Antelope Mine Permit Area
Black Thunder Mine Permit Area
Coal Creek Mine Permit Area
Cordero Mine Permit Area
Jacob's Ranch Mine Permit Area
Keeline Mine Permit Area (expired)
North Antelope Mine Permit Area
North Rochelle Mine Permit Area
Rochelle Mine Permit Area

Plate 17

Modeled Drawdown in Wasatch Aquifer (with Coal Bed Methane) 2021



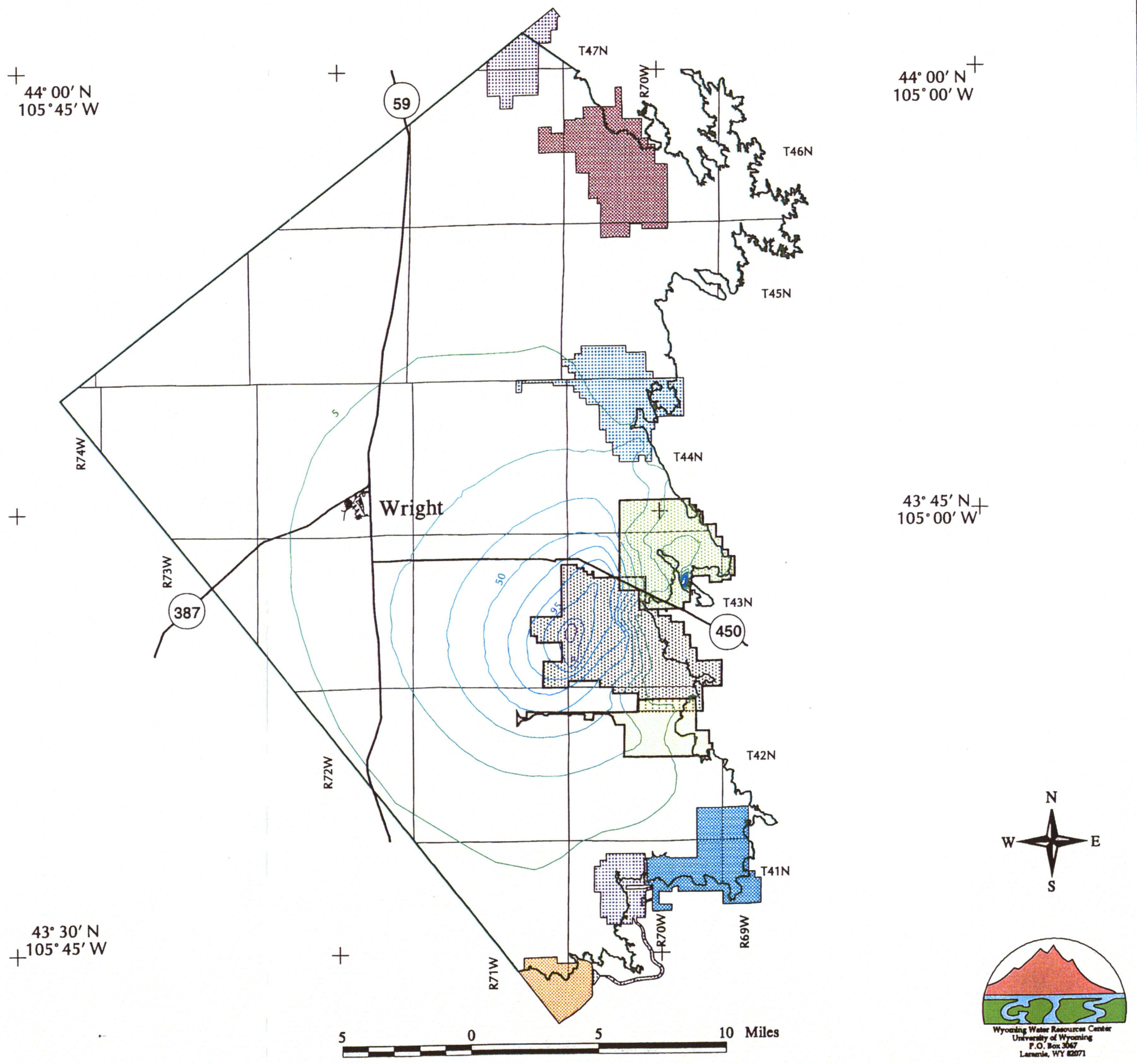
Legend

Drawdown Contours (feet)
- 5
- 20
- 35
- 50
- 65
- 80
- 95

State Highway
Model Domain Boundary
Public Land Survey System
Antelope Mine Permit Area
Black Thunder Mine Permit Area
Coal Creek Mine Permit Area
Cordero Mine Permit Area
Jacob's Ranch Mine Permit Area
Keeline Mine Permit Area (expired)
North Antelope Mine Permit Area
North Rochelle Mine Permit Area
Rochelle Mine Permit Area

Plate 18

Modeled Drawdown in Wyodak Coal 2021



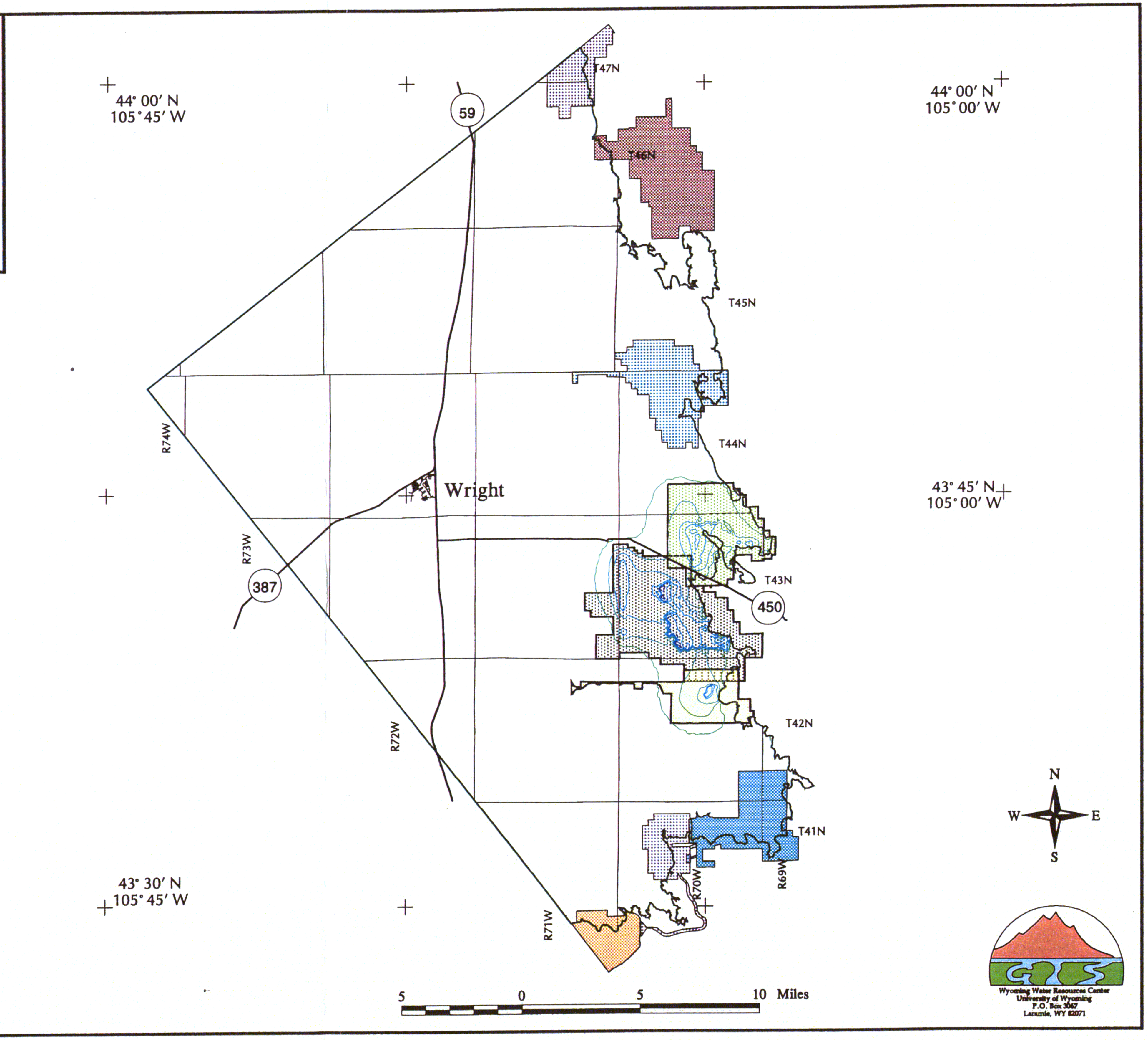
Legend

Drawdown Contours (feet)
- 5
- 20
- 35
- 50
- 65
- 80
- 95
- 110
- 125

- State Highway
- Model Domain Boundary
- Public Land Survey System
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Plate 19

Modeled Drawdown in Wasatch Aquifer 2021



Legend

Drawdown Contours (feet)

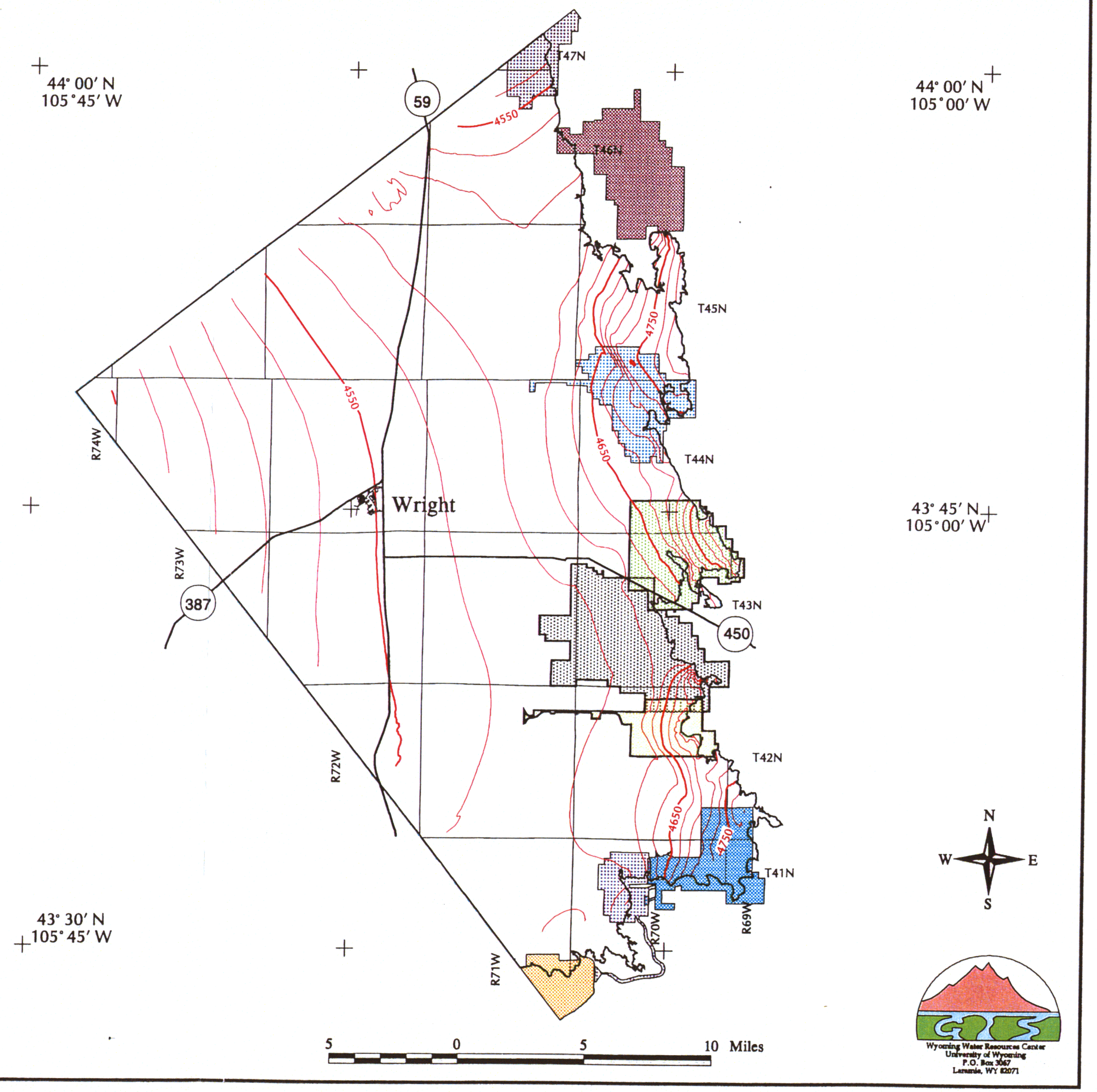
- 5
- 20
- 35
- 50
- 65
- 80
- 95

State Highway
Model Domain Boundary

Public Land Survey System
Antelope Mine Permit Area
Black Thunder Mine Permit Area
Coal Creek Mine Permit Area
Cordero Mine Permit Area
Jacob's Ranch Mine Permit Area
Keeline Mine Permit Area (expired)
North Antelope Mine Permit Area
North Rochelle Mine Permit Area
Rochelle Mine Permit Area

Plate 20

Modeled Potentiometric Surface for Wyodak Coal Year 3021

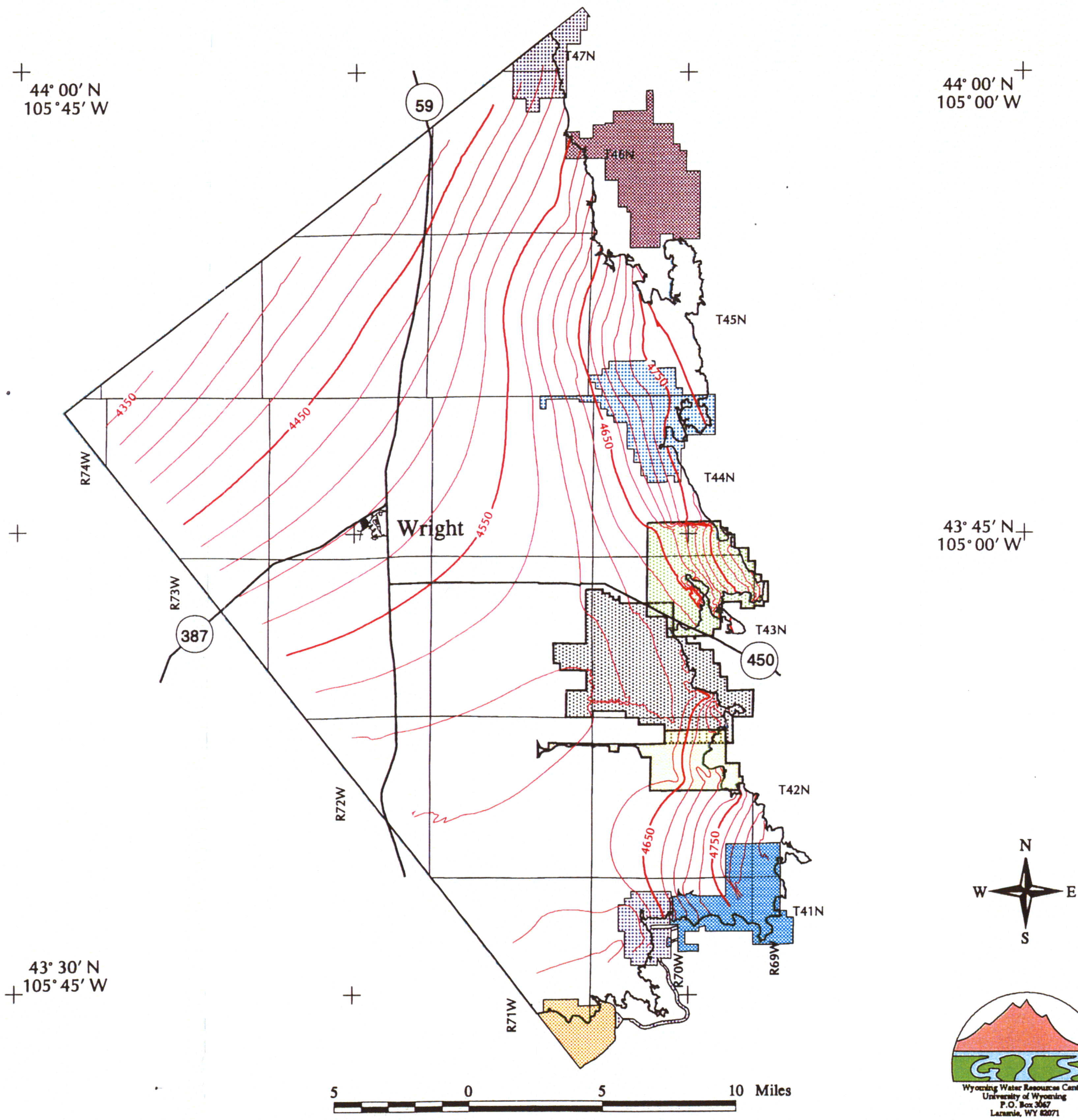


Legend

- Potentiometric Surface Contours (Contour Interval 20 feet)
- Model Domain Boundary
- State Highway
- Public Land Survey System
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Plate 21

Modeled Potentiometric Surface for Wasatch Aquifer - Year 3021



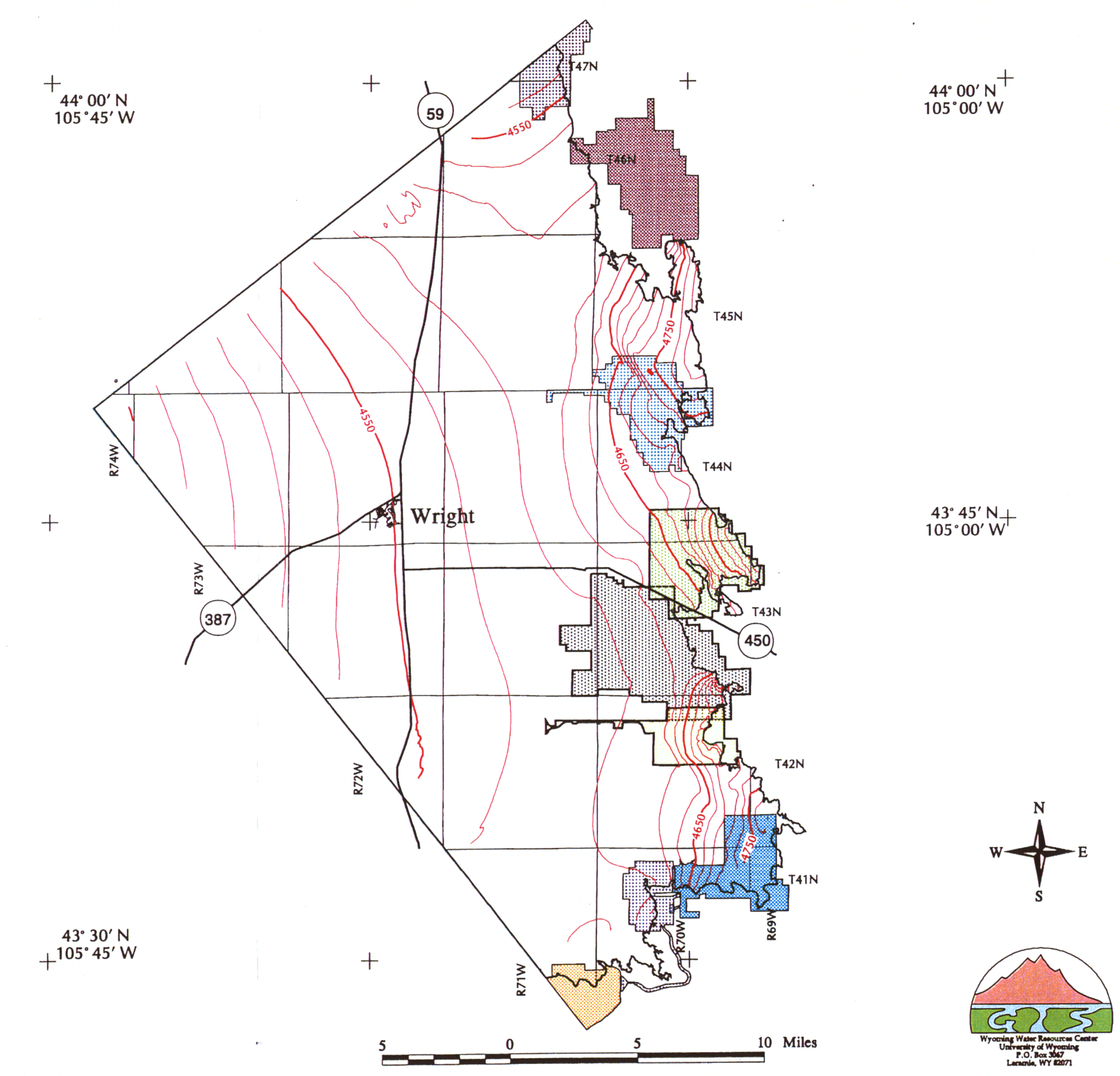
Legend

- Potentiometric Surface Contours (Contour Interval 20 feet)
- Model Domain Boundary
- State Highway
- Public Land Survey System
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Wyoming Water Resources Center
University of Wyoming
P.O. Box 3067
Laramie, WY 82071

Plate 22

Modeled Potentiometric Surface for Wyodak Coal Year 4021

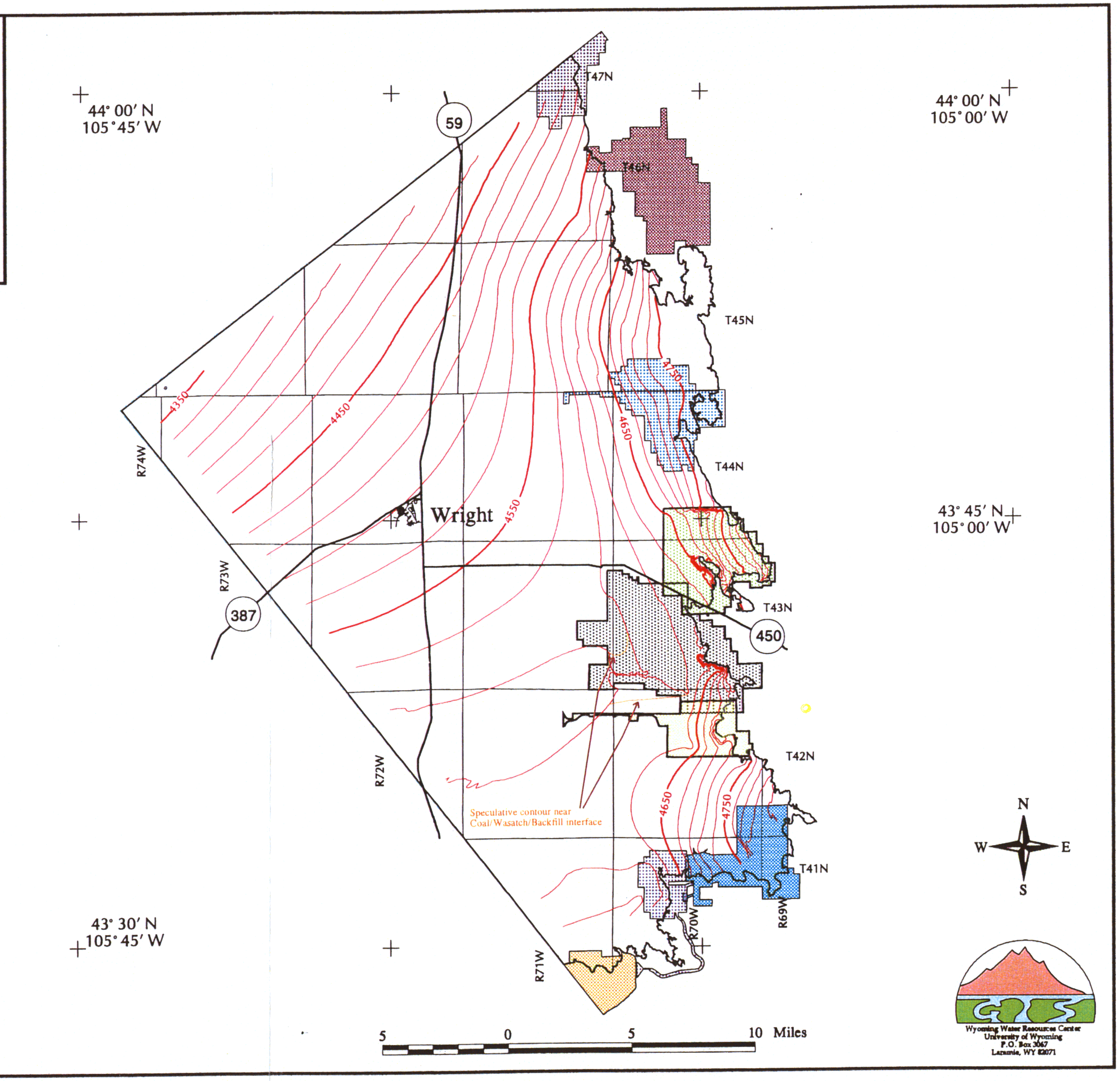


Legend

- Potentiometric Surface Contours (Contour Interval 20 feet)
- Model Domain Boundary
- State Highway
- Public Land Survey System
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Plate 23

Modeled Potentiometric Surface for Wasatch Aquifer - Year 4021

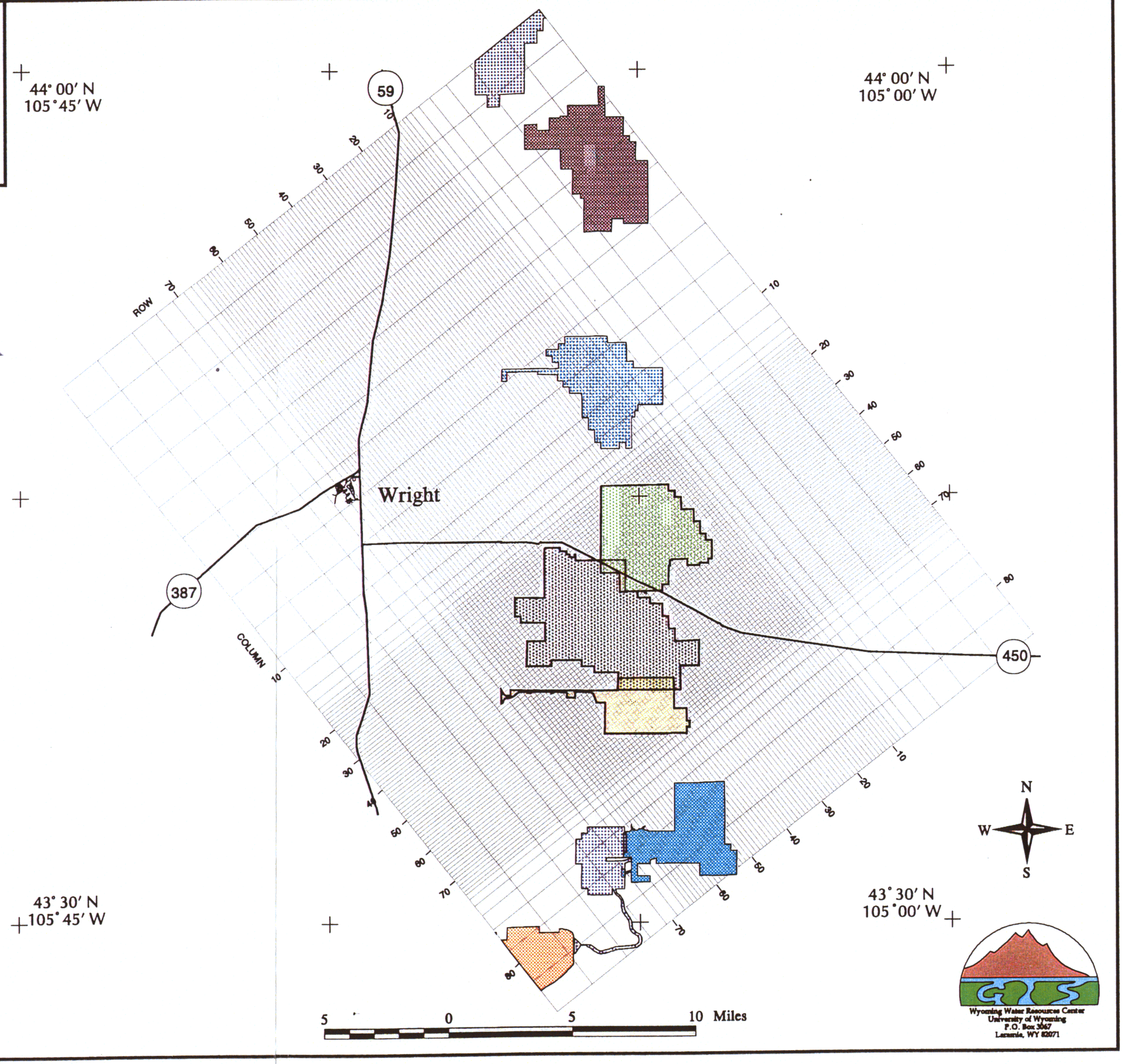


Legend

- Potentiometric Surface Contours (Contour Interval 20 feet)
- Model Domain Boundary
- State Highway
- Public Land Survey System
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Plate 24

Hydraulic Conductivity in the Wyodak Coal Aquifer

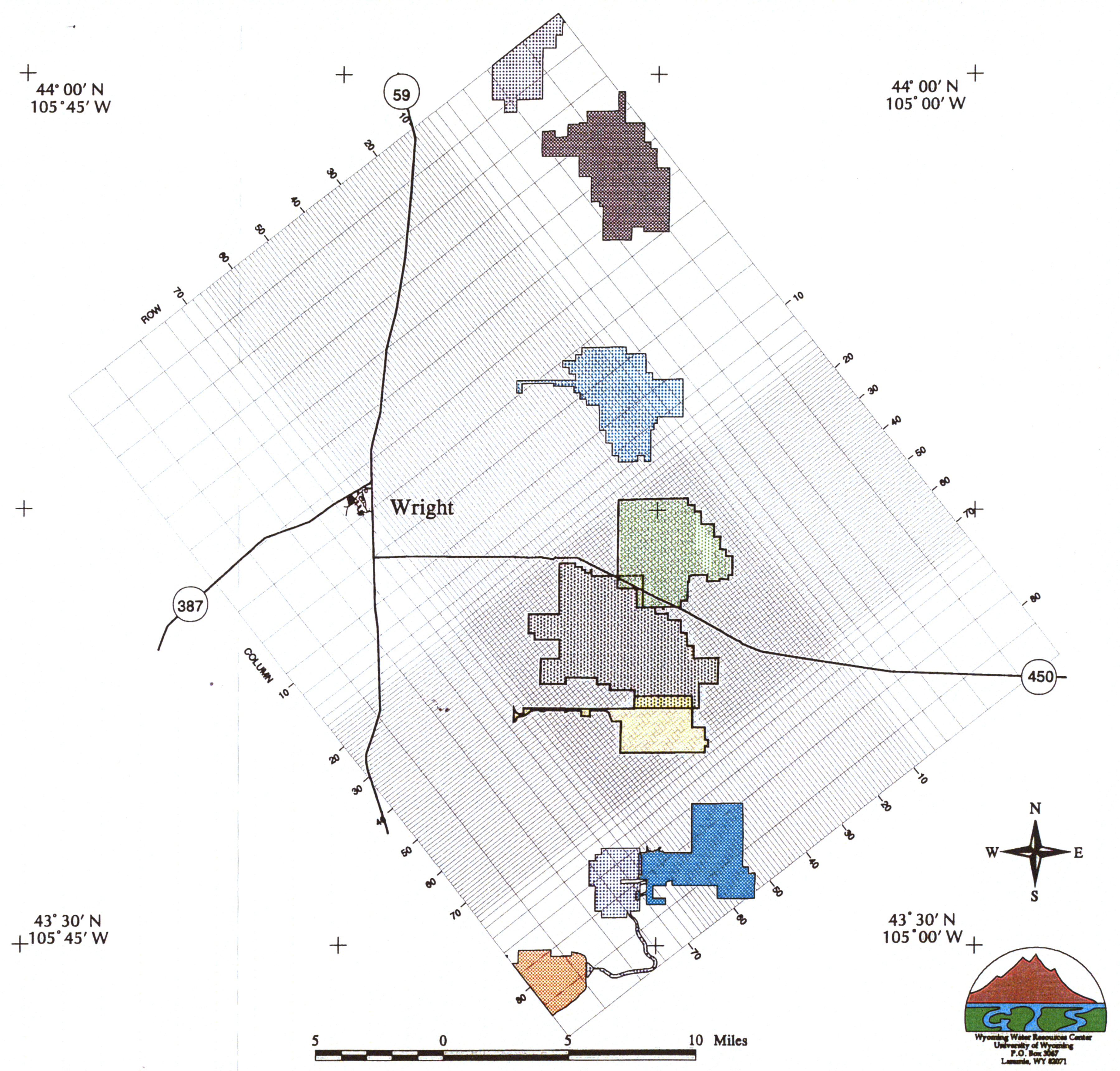


Legend

- State Highway
- Groundwater Model Grid
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area

Plate 25

Hydraulic Conductivity in the Wasatch Aquifer



Legend

- State Highway
- Groundwater Model Grid
- Antelope Mine Permit Area
- Black Thunder Mine Permit Area
- Coal Creek Mine Permit Area
- Cordero Mine Permit Area
- Jacob's Ranch Mine Permit Area
- Keeline Mine Permit Area (expired)
- North Antelope Mine Permit Area
- North Rochelle Mine Permit Area
- Rochelle Mine Permit Area