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WP 02-1
Revision 7

WIPP Groundwater Monitoring Program Plan

Cognizant Organization: Environmental Monitoring and Hydrology

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ABBREVIATIONS AND ACRONYMS

AR/VR	Approval Request/Variation Request
Bell Canyon	Bell Canyon Formation
bgs	below ground surface
Castile	Castile Formation
CBFO	Carlsbad Field Office
CCA	Compliance Certification Application
CFR	*Code of Federal Regulations*
cm	centimeter(s)
Culebra	Culebra Member of the Rustler Formation
CofC	chain of custody
°C	degree(s) Celsius
%C	percent completeness
DI	deionized
DMP	Detection Monitoring Program
DMW	Detection Monitoring Well
DOE	U.S. Department of Energy
DQO	data quality objectives
Eh	oxygen reduction potential
EPA	U.S. Environmental Protection Agency
EM&H	Environmental Monitoring and Hydrology
FEIS	Final Environmental Impact Statement
ft	foot (feet)
ft^2	square foot (square feet)
g/cm^3	gram per cubic centimeter
GMP	Groundwater Monitoring Program
GWSP	Groundwater Surveillance Program
HWDU	hazardous waste disposal unit(s)
HWFP	Hazardous Waste Facility Permit
km	kilometer(s)
km^2	square kilometer(s)
$lb/in.^2$	pound(s) per square inch
LCS	laboratory control samples
LD	limit of detection
LWA	Land Withdrawal Act

m	meter(s)
M&DC	monitoring and data collection
m^2	square meter(s)
mg/L	milligram(s) per liter
mi	mile(s)
mi^2	square mile(s)
MPa	megapascal(s)
mV	millivolt(s)
NIST	National Institute for Standards and Technology
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
P&A	plugging and abandonment
pH	measure of acidity/alkalinity
PRS	Project Records Services
QA	quality assurance
QAPD	Quality Assurance Program Description
QC	quality control
RCRA	Resource Conservation and Recovery Act
RFA	request for analysis
RIDS	Records Inventory and Disposition Schedule
RPD	relative percent difference
Rustler	Rustler Formation
%R	percent recovery
Salado	Salado Formation
SAP	Sampling and Analysis Plan
SC	specific conductance
SOP	standard operating procedure
STLB	sample tracking logbook
SVOC	semivolatile organic compound
TDS	total dissolved solids
TOC	total organic carbon
TOX	total organic halogens
TRU	transuranic
TSDF	treatment, storage, and disposal facilities
TSS	total suspended solids
VOC	volatile organic compound
WTS	Washington TRU Solutions LLC
WIPP	Waste Isolation Pilot Plant

WLMP	WIPP Groundwater Level Monitoring Program
WQSP	Water Quality Sampling Program
µg/L	microgram(s) per liter
µm	micrometers

1.0 INTRODUCTION

This is the implementing document for the Waste Isolation Pilot Plant (WIPP) Groundwater Monitoring Program (GMP). The GMP ensures compliance with the WIPP Hazardous Waste Facility Permit (HWFP) mandated by 20.4 NMAC (New Mexico Administrative Code), "Hazardous Waste," (incorporating applicable sections of Title 40 *Code of Federal Regulations* [CFR] Part 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," and 40 CFR Part 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities"). The GMP also ensures compliance with the WIPP Compliance Recertification Application (CRA) (U.S. Department of Energy [DOE], 1996b) mandated by 40 CFR Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," and 40 CFR Part 194, "Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance With the 40 CFR Part 191, "Disposal Regulations" (61 *Federal Register* 5224), DOE Orders 450.1, Chg. 3, *Environmental Protection Program*; and 5400.5, *Radiation Protection of the Public and the Environment*, which were the driving documents for the previous groundwater surveillance program now become secondary to the above-mentioned regulatory drivers. The intent of the Orders and subsequent documents required by these Orders continues to be implemented and carried out by the current GMP. The hierarchy of GMP governing documents is outlined in Figure 1.

WIPP is a geologic repository for the disposal of transuranic (TRU) waste. The disposal horizon is located 2,150 feet (ft) (655 meters [m]) below the land surface in the bedded salt of the Salado Formation (hereinafter referred to as the Salado). At WIPP, water-bearing units occur both above and below the disposal horizon. Groundwater monitoring of the uppermost aquifer below the facility is not proposed at WIPP because that water-bearing unit (the Bell Canyon Formation) is not considered a credible pathway for a release from the repository. This is because the repository horizon and water-bearing sandstones of the Bell Canyon Formation are separated by over 2,000 ft (610 m) of very low-permeability evaporite sediments. No natural credible pathway has been established for contaminant transport to aquifers below the repository horizon, as there is no hydrologic communication between the repository and underlying aquifers. The U.S. Environmental Protection Agency (EPA) concluded in 1990 that natural vertical communication does not exist based on their review of numerous studies (EPA, 1990). Furthermore, drilling boreholes for groundwater monitoring through the Salado and the Castile Formation (hereinafter referred to as the Castile) into the Bell Canyon aquifer would compromise the isolation properties of the repository medium.

Two types of waste are to be disposed of at WIPP: TRU waste and TRU mixed waste. Disposal of TRU waste is subject to regulation under 40 CFR Part 191 and 40 CFR Part 194.

Disposal of TRU mixed waste in the WIPP facility is subject to regulation under 20.4.1.500 NMAC, "Adoption of 40 CFR Part 264." As required by 20.4.1.500 NMAC (incorporating 40 CFR §264.601), WIPP intends to demonstrate that the environmental performance standards for all regulatory requirements will be met.

Groundwater monitoring at WIPP in the past has focused on the Culebra Member of the Rustler Formation (hereinafter referred to as the Culebra) because it represents the most significant hydrologic contaminant migration pathway to the accessible environment. The Culebra is the most significant water-bearing unit lying above the repository. Modeling of groundwater movement in the Culebra, based on the concept of a groundwater basin, is discussed in detail in Appendix D6, Section D6-2a(1), of the WIPP Resource Conservation and Recovery Act (RCRA) Part B Permit Application (DOE, 1997b). Groundwater modeling is also discussed in chapter seven of the CRA.

The WIPP site is located in Eddy County in southeastern New Mexico (Figure 2) within the Pecos Valley section of the southern Great Plains physiographic province (Powers et al., 1978). The site is 26 miles (mi) (42 kilometers [km]) east of Carlsbad, New Mexico, in an area known as Los Medaños (the dunes). Los Medaños is a relatively flat, sparsely inhabited plateau with little water and limited land uses.

The WIPP site (Figure 2) consists of 16 sections of federal land in Township 22 south, Range 31 east. The 16 sections of federal land were withdrawn from the application of public land laws by the WIPP Land Withdrawal Act (LWA) (Public Law 102-579). The WIPP LWA transferred the responsibility for the administration of the 16 sections from the Department of Interior, Bureau of Land Management, to the DOE. This law specified that mining and drilling for purposes other than support of the WIPP Project are prohibited within this 16-section area, with the exception of Section 31. Oil and gas drilling activities are restricted in Section 31 from the surface down to 6,000 ft.

This GMP addresses requirements for sample collection, groundwater surface elevation monitoring, groundwater flow direction, data management, and reporting of groundwater monitoring data. It also identifies analytical parameters selected to assess groundwater quality, and establishes personnel responsibilities for the WIPP groundwater detection monitoring program (DMP). Because quality assurance (QA) is an integral component of the groundwater sampling, analysis, and reporting process, QA/QC (quality control) elements and associated data acceptance criteria are included in this plan.

Instructions for performing field activities that will be conducted in conjunction with this sampling and analysis plan are provided in field operating procedures. Procedures are required for each aspect of the groundwater sampling process, including groundwater surface elevation measurement, groundwater flow direction, sampling equipment installation and operation, field water-quality measurements, and sample collection. These procedures prescribe proper field sampling techniques. Samples will be collected by trained personnel under the supervision and direction of qualified engineers, scientists, or other technical personnel.

2.0 GEOLOGIC AND HYDROLOGIC CHARACTERISTICS

2.1 Geology

The WIPP site is situated within the Delaware Basin, which is part of the larger Permian Basin, located in the south-central region of North America. During the Permian period, which came to a close about 245 million years ago, ancient seas covered the basin. Their later evaporation resulted in the deposition of a thick sequence of evaporites. Appendix D6 of the WIPP RCRA Part B Permit Application (DOE, 1997b) presents a detailed discussion of the regional geologic history. Three major evaporite-bearing formations were deposited in the Delaware Basin (see Figure 3):

- The Castile, which formed through evaporation of the Permian Sea, consists of interbedded anhydrites and halite. Its upper boundary is at a depth of about 2,825 ft (861 m) below ground surface (bgs), and its thickness at the WIPP facility is 1,250 ft (381 m).

- The repository is located in the Salado, which overlies the Castile and resulted from prolonged desiccation that produced predominantly halite, with some carbonates, anhydrites, and clay seams. Its upper boundary is at a depth of about 850 ft (259 m) bgs, and it is about 2,000 ft (610 m) thick in the repository area.

- The Rustler Formation (hereinafter referred to as the Rustler) was deposited in a lagoonal environment during a major freshening of the basin and consists of carbonates, anhydrites, and halites. Its beds consist of clay and anhydrite and contain small amounts of brine. The Rustler's upper boundary is about 500 ft (152 m) bgs, and it ranges up to 350 ft (107 m) in thickness in the area.

These evaporite-bearing formations lie between two other formations significant to the geology and hydrology of the WIPP site. The Dewey Lake overlying the Rustler is dominated by nonmarine sediments and consists almost entirely of mudstone, claystone, siltstone, and interbedded sandstone. This formation forms a 500-ft (152-m) thick barrier of fine-grained sediments that retard the downward percolation of water into the evaporite units below. The Bell Canyon Formation (hereinafter referred to as the Bell Canyon), the first water-bearing unit below the repository, is confined by the thick evaporite sequences of the Castile above. It consists of 1,200 ft (366 m) of interbedded sandstone, shale, and siltstone.

The Salado was selected to host the WIPP repository for several reasons. First, it is regionally extensive, underlying an area of more than 36,000 square mi (mi^2) (93,240 square kilometers [km^2]). Second, its permeability is extremely low. Third, salt behaves mechanically in a plastic manner under pressure (the pressure at the disposal horizon is more than 2,000 pounds per square inch [lb/in.^{2}] or 13.8 megapascals [MPa]) and eventually moves to fill any opening (referred to as creep). Fourth, any fluid remaining in small fractures or openings is saturated with salt, is incapable of further salt dissolution, and has probably remained in place for millions of years. Finally, the

Salado lies between the Rustler and the Castile, which contain very low permeability layers that help confine and isolate waste within, and keep water outside, the WIPP facility.

Further discussions of site geology can be found in Appendix D6 of the RCRA Part B Permit Application and Appendix GCR of the CCA.

2.2 Groundwater Hydrology

The general hydrogeology of the area surrounding the WIPP facility is described in this section starting with the first geologic unit below the Salado. Relevant hydrological parameters for the various rock units above the Salado at WIPP are summarized in Table 1.

2.2.1 The Castile

The Castile is a basin-filling evaporite sequence of sediments surrounded by the Capitan Reef. The Castile represents a major regional groundwater aquitard that effectively prevents upward migration of water from the underlying Bell Canyon. Fluid present in the Castile is very restricted because evaporites do not readily maintain pore space, solution channels, or open fractures at depth. Drill-stem tests conducted in the Castile during construction of the WIPP facility found its permeability to be lower than detection limits; however, the hydraulic conductivity has been conservatively estimated to be less than 10^{-8} ft (3×10^{-9} m) per day.

2.2.2 The Salado

The Salado is an evaporite sequence that filled the remainder of the Delaware Basin and lapped extensively over the Capitan Reef and the back-reef sediments beyond. The Salado consists of approximately 2,000 ft (610 m) of bedded halite, with interbeds or seams of anhydrite, clay, and polyhalite. It acts hydrologically as a regional confining bed. The porosity of the Salado is very low, and interconnected pores are probably nonexistent in halite at the depth of the disposal horizon. Fluids associated with the Salado occur mainly as very small fluid inclusions in the halite crystals, and also occur between crystal boundaries (interstitial fluid) of the massive crystalline salt formation; fluids also occur in clay seams and anhydrite beds. Permeabilities measured from the surface in the area of the WIPP facility range from 0.01 to 25 microdarcies. The most reliable value, 0.3 microdarcy, was obtained from well DOE-2. The results of permeability testing at the disposal horizon are within the range of 0.001 to 0.01 microdarcy. As a comparison, the permeability of the Salado is roughly a thousand times less than that of a lower clay liner required of surface impoundments and landfills, assuming similar thicknesses.

2.2.3 The Rustler

The Rustler has been the subject of extensive characterization activities because it contains the most transmissive hydrologic units overlying the Salado, specifically, the

Culebra. Within the Rustler, five members have been identified. Of these, the Culebra is the most transmissive and has been the focus of most of the Rustler hydrologic studies.

The Culebra is the first continuous water-bearing zone above the Salado and is up to 30 ft (9 m) thick. Water in the Culebra is usually present in fractures and is confined by overlying gypsum or anhydrite and underlying clay and anhydrite beds. The hydraulic gradient within the Culebra in the area of the WIPP facility is approximately 20 ft per mi (3.8 m per km) and becomes much flatter south and southwest of the site. Culebra transmissivities in the Nash Draw range up to 1,250 square ft (ft^2) (116 square m [m^2]) per day; closer to the WIPP facility, they are as low as 0.007 to 74 ft^2 (0.00065 to 7.0 m^2) per day. The Culebra is hydrologically confined.

The two primary types of field tests being used to characterize the flow and transport characteristics of the Culebra are hydraulic tests and tracer tests.

The hydraulic tests consist of pump, injection, and slug testing of wells across the study area (e.g., Beauheim, 1987a). The most detailed hydraulic test data exist for the WIPP hydropads (e.g., H-19). The hydropads generally comprise a network of three or more wells located within a few tens of meters of each other. Long-term pumping tests have been conducted at hydropads H-3, H-11, and H-19 and at well WIPP-13 (Beauheim, 1987b, 1987c). These pumping tests provided transient pressure data both at the hydropad and over a much larger area. Tests often included use of automated data-acquisition systems, providing high-resolution (in both space and time) data sets. In addition to long-term pumping tests, slug tests and short-term pumping tests have been conducted at individual wells to provide pressure data that can be used to interpret the transmissivity at that well (Beauheim, 1987a). (Additional short-term pumping tests have been conducted in the Water Quality Sampling Program (WQSP) wells [Stensrud, 1995]). Detailed cross-hole hydraulic testing has recently been conducted at the H-19 hydropad (Kloska et al., 1995).

The hydraulic tests are designed to yield pressure data for estimation of hydrologic characteristics such as transmissivity, permeability, and storativity. The pressure data from long-term pumping tests and the interpreted transmissivity values for individual wells are used for input to flow modeling. Some of the hydraulic test data and interpretations are also important for the interpretation of transport characteristics. For instance, the permeability values interpreted from the hydraulic tests at a given hydropad are needed for interpretations of tracer test data at that hydropad.

There is strong evidence that the permeability of the Culebra varies spatially and varies sufficiently that it cannot be characterized with a uniform value or range over the region of interest to WIPP. The transmissivity of the Culebra varies spatially over six orders of magnitude from east to west in the vicinity of WIPP. Over the site, Culebra transmissivity varies over three to four orders of magnitude. Transmissivities have been calculated at 1×10^{-3} ft^2 per day (1×10^{-9} m^2 per second) at well P-18 east of the WIPP site to 1×10^{3} ft^2 per day (1×10^{-3} m^2 per second) at well H-7 in Nash Draw.

Transmissivity variations in the Culebra are believed to be controlled by the relative abundance of open fractures rather than by primary (i.e., depositional) features of the unit. Lateral variations in depositional environments were small within the mapped region, and primary features of the Culebra show little map-scale spatial variability, according to Holt and Powers (1988). Direct measurements of the density of open fractures are not available from core samples because of incomplete recovery and fracturing during drilling, but observation of the relatively unfractured exposures in the WIPP shafts suggests that the density of open fractures in the Culebra decreases to the east. Qualitative correlations have been noted between transmissivity and several geologic features possibly related to open-fracture density, including (1) the distribution of overburden above the Culebra, (2) the distribution of halite in other members of the Rustler, (3) the dissolution of halite in the upper portion of the Salado, and (4) the distribution of gypsum fillings in fractures in the Culebra.

Measured matrix porosities of the Culebra vary from 0.03 to 0.30. Fracture porosity values have not been measured directly, but interpreted values from tracer tests at the H-3, H-6, and H-11 hydropads vary from 5×10^{-4} to 3×10^{-3}. Data are insufficient to determine whether the average porosity of the matrix and fractures varies significantly on a regional scale.

Geochemical and radioisotope characteristics of the Culebra have been studied. There is considerable variation in groundwater geochemistry in the Culebra. The variation has been described in terms of different hydrogeochemical facies that can be mapped in the Culebra. A halite-rich hydrogeochemical facies exists in the region of the WIPP site and to the east, approximately corresponding to the regions in which halite exists in units above and below the Culebra, and in which a large portion of the Culebra fractures are gypsum filled. An anhydrite-rich hydrogeochemical facies exists west and south of the WIPP site, where there is relatively less halite in adjacent strata and where there are fewer gypsum-filled fractures. Radiogenic isotopic signatures suggest that the age of the groundwater in the Culebra is on the order of 10,000 years or more (see, for example, Lambert, 1987; Lambert and Carter, 1987; and Lambert and Harvey, 1987).

The radiogenic ages of the Culebra groundwater and the geochemical differences provide information potentially relevant to the groundwater flow directions and groundwater interaction with other units and are important constraints on conceptual models of groundwater flow. Previous conceptual models of the Culebra (see for example, Chapman, 1986; Chapman, 1988; LaVenue et al., 1990) have not been able to consistently relate the hydrogeochemical facies, radiogenic ages, and flow constraints (i.e., transmissivity, boundary conditions, etc.) in the Culebra. However, new conceptual models have been developed for groundwater flow that could explain observed geochemical facies and groundwater flow patterns. The new conceptualization, referred to as the groundwater basin model, offers a three dimensional approach to treatment of Supra-Salado rock units, and assumes vertical leakage (albeit very slow) between rock units of the Rustler exists (where hydraulic head is present).

Flow in the Culebra is considered transient. This differs from previous interpretations, wherein no-flow was assumed between Rustler units. The model assumes that the groundwater system is dynamic and is responding to the drying of climate that has occurred since the late Pleistocene period. The model assumes that recharge rates during the late Pleistocene period were sufficient to maintain the water table near land surface, but has since dropped significantly. Therefore, the impact of local topography on groundwater flow was greater during wetter periods, with discharge from the Rustler to the west; flow is dominated by more regional topographic effects during drier times, with flow to a more southerly direction.

Four hydrogeochemical facies within the Culebra in the WIPP area (DOE, 1997a) have been identified:

- Zone A - saline (2-3 molal) NaCl brines, Mg/Ca ratio of 1.2 to 2;
- Zone B - dilute (<0.1 molal) CaSO4 - rich groundwater;
- Zone C - variable composition (0.3-1.6 molal); Mg/Ca ratio 0.3 to 1.2; and
- Zone D - high salinities (3-7 molal); K/Na weight ratios (0.2).

Facies A groundwater flow is slow, has not changed over the last 14,000 years, and probably recharged more than 600,000 years ago. Vertical leakage occurs to Facies A, and both lateral and vertical groundwater flow rates are extremely low. Facies B occurs in an area with greater vertical fracturing in the Culebra and, therefore, exhibits more vertical infiltration and more rapid lateral flow in the Culebra. Flow in Facies B is currently to the south (it may mix with Facies C water to the southeast), but was more toward the west during wetter climates; vertical infiltration from the Dewey Lake to the Culebra Facies B is assumed to have occurred during wetter climates in an area south of the WIPP site. Facies C water was not diluted to create Facies B water. Facies C occurs "in between" Facies A and B, and groundwater flow entered the Culebra prior to the climate change (to drier conditions) 14,000 years ago. Facies C groundwater flow is to the south at WIPP, where it is theorized that it joins with a small amount of Facies A solute being transported from the east. Groundwater flow rate in Facies C is faster than in Facies A but slower than in Facies B, and the proposed recharge area from the Dewey Lake to the Culebra was to the northeast of the WIPP site. Facies C groundwater infiltrated into the Dewey Lake and then interacted with anhydrite and halite along its path to the Culebra, wherein it mixed with smaller amounts of Facies A water. The conclusion can be drawn that the presence of anhydrite within Rustler units does not preclude slow downward infiltration (DOE, 1997a).

Previously, some believed the geochemistry of Culebra groundwater was inconsistent with flow directions. This was based on the premise that Facies C water must transform to Facies B water (e.g., become "fresher"), which is inconsistent with the observed flow direction. It is now believed that the observed geochemistry and flow directions can be explained with different recharge areas and Culebra travel paths (DOE, 1997a).

Head distribution in the Culebra is consistent with groundwater basin modeling results indicating that the generalized groundwater flow direction in the Culebra is currently north to south. However, the fractured nature of the Culebra, coupled with variable fluid densities, can cause localized flow patterns to differ from general flow patterns.

Groundwater levels in the Culebra in the WIPP region have been measured for several decades. Water-level rises have been observed in the WIPP region and are possibly related to recovery from impacts caused by shaft installation or response to potash effluent discharge, or are unexplained, as discussed below. The extent of water-level rise observed at a particular well depends on several factors, but the proximity of the observation point to the potential cause of the water-level rise appears to be a primary factor.

In the vicinity of the WIPP site, water-level rises are believed to be caused by recovery from drainage into the shafts. Drainage into shafts has been reduced by a number of grouting programs over the years, most recently in 1993 around the Air Intake Shaft. Northwest of the site, in and near Nash Draw, water levels appear to fluctuate in response to effluent discharge from potash mines. Correlation of water-level fluctuation with potash mine discharge, however, cannot be proven definitively because sufficient data on the timing and volumes of discharge are not available. Water-level rises in the vicinity of the H-9 hydropad, about 6.5 mi (10.5 km) south of the site, are thought to be caused by neither WIPP activities nor potash mining discharge. They remain unexplained. WIPP continues to monitor groundwater levels throughout the region.

Inferences about vertical flow directions in the Culebra have been made from well data collected. Beauheim (1987a) reported flow directions towards the Culebra from both the underlying unnamed lower member of the Rustler and the overlying Magenta member of the Rustler over the WIPP site, indicating that the Culebra acts as a drain for the units around it. This is consistent with results of groundwater basin modeling. Recent simulations to enhance the conceptual understanding of the geohydrology of the Rustler can be found in Corbet and Knupp (1996).

Use of water from the Culebra in the WIPP area is quite limited because of its varying yields and high salinity. The Culebra is not used for water supply in the immediate WIPP site vicinity. Its nearest use is approximately 7 mi (11 km) southwest of the WIPP facility, where salinity is low enough to allow its use for livestock watering. However, the Culebra has been identified as a potential aquifer in the CCA (DOE, 1996b). Because of this, the Culebra will be the focus of future groundwater monitoring at WIPP as it is also the most transmissive continuous water-bearing zone at WIPP and is the most likely pathway for contaminant migration.

Appendix D6 of the WIPP RCRA Part B Permit Application (DOE, 1997b) and appendix Hydro of the CCA provide more detailed discussions of the local and regional hydrogeology.

3.0 GENERAL REGULATORY REQUIREMENTS

| DOE O 450.1 contains the following policy statement:

| *DOE O 450.1 requires implementation of sound stewardship practices*
| *that are protective of air, water, land, and cultural and ecological*
| *resources impacted by DOE operations and by which DOE meets or*

> *exceeds compliance with applicable environmental, public health, and resource protection laws, regulations, and DOE requirements in a cost-effective way. This objective is to be accomplished by implementing environmental management systems at DOE facilities as part of ISMSs established pursuant to DOE P 450.4, Safety Management System Policy, dated 10-15-96. DOE O 450.1 requires DOE elements to ensure that the ISMS includes an EMS that (1) provides for the systematic planning, integrated execution, and evaluation of programs for public health and environmental protection, pollution presventi9on, and compliance with applicable environmental protection requirements; (2) includes policies, procedures, and training to identify activities with significant environmental impacts; to manage, control, and mitigate the impacts of these activities; and to assess performance and implement corrective actions where needed; and (3) includes measurable environmental goals, objectives, and targets that are reviewed annually and updated when appropriate.*

DOE Order 5400.5 states the following:

> *Regulatory Requirements. DOE facilities and operations, in some instances, are subject to the regulatory requirements of the NRC and the EPA, e.g., 10 CFR Parts 60 and 72 and 40 CFR Parts 61, 191, and 192. It is Departmental policy that DOE facilities and operations will comply fully with the requirements of those and other applicable regulatory requirements. In addition, these same DOE facilities and operations shall comply with all applicable requirements in this Order unless they are duplicative or conflict with any of the other Federal regulatory requirements.*

Earlier groundwater programs such as the WQSP and the WIPP Groundwater Surveillance Program (GWSP) were structured to meet the requirements of DOE Orders. The current GMP is structured to be inclusive of the DOE Orders mentioned above and meet the requirements of more stringent regulatory drivers.

Because geologic repositories such as the WIPP facility are defined under the Resource Conservation and Recovery Act (RCRA) as land disposal facilities and as miscellaneous units, the groundwater monitoring requirements of 20.4.1.500 NMAC (incorporating 40 CFR §§264.600 through 264.603) shall be addressed. Title 20.4.1.500 NMAC (incorporating 40 CFR §§264.90 through 264.101) applies to miscellaneous unit treatment, storage, and disposal facilities (TSDF) only if groundwater monitoring is needed to satisfy 20.4.1.500 NMAC (incorporating 40 CFR §§264.601 through 264.603) environmental performance standards.

The New Mexico Environment Department (NMED) has concluded that groundwater monitoring in accordance with 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subpart F) at WIPP is necessary to meet the requirements of 20.4.1.500 NMAC (incorporating 40 CFR §§264.601 through 264.603).

The DOE has demonstrated that the WIPP facility can be operated and closed in a manner that complies with federal standards found in 40 CFR Part 191.

In 1992, the U.S. Congress passed the WIPP LWA which, among other things, mandated that the EPA certify the DOE's compliance with 40 CFR Part 191, Subparts B and C. The EPA issued the criteria that it intends to use for certification as 40 CFR Part 194. This application, titled "Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant," was the DOE submittal to the EPA, requesting certification which was granted in 1997.

4.0 WIPP GROUNDWATER DETECTION MONITORING PROGRAM OVERVIEW

4.1 Scope

The HWFP groundwater DMP was established to define and protect groundwater resources at WIPP. One of the objectives of the WIPP DMP is to establish, by means of groundwater sampling and analysis, an accurate and representative groundwater database that is scientifically defensible and demonstrates regulatory compliance. In addition, the DMP will be used to determine background or existing conditions of groundwater quality and quantity, including groundwater surface elevation and direction of flow, around the WIPP facility area.

The WIPP CCA specifically states:

> *The DOE has addressed the need for monitoring the disposal system during both the preclosure period and the postclosure period in its application for a hazardous waste facility operating permit (see Appendix MON). In its Pre-Closure and Post-Closure (Long-Term) Monitoring Plan (Appendix MON), the DOE incorporates three monitoring programs that will be used to ensure compliance with the hazardous waste regulations of RCRA as implemented by the NMED. These programs include (1) a confirmatory volatile organic compound (VOC) monitoring program to demonstrate that the numerical predictions of VOC releases are reasonable, (2) a groundwater monitoring program to verify knowledge regarding the characteristics of groundwater flow, including periodic testing for releases from the repository, and (3) a geomechanical monitoring program to support decisions regarding operations and maintenance of underground openings. Only the groundwater program is expected to extend into the 30-year RCRA postclosure period. The EPA has established, as a certification criterion, that the monitoring programs in this application must be complementary with the RCRA programs that the DOE will be required to implement.*

This plan governs all groundwater sampling events conducted to meet the requirements of 20.4.1.500 NMAC (incorporating 40 CFR §§264.90 through 264.101), as well as 40 CFR Part 191 and 40 CFR Part 194 requirements of the CCA. It also ensures that all such data are gathered in accordance with these and other applicable requirements.

The groundwater quality data generated by monitoring activities will provide a comprehensive background database against which future analytical results can be compared during the DMP.

Groundwater monitoring at WIPP historically has been conducted by several programs, including the WIPP Site Characterization Program, the WIPP WQSP and, recently, the GWSP. Groundwater quality and groundwater surface elevation data have been collected by these programs for over 12 years at WIPP. Data from the WQSP wells will be used to continually define changes in the area's potentiometric surface and groundwater flow directions to meet the requirements of the CCA. New monitoring wells included in the WIPP GWSP (WQSP wells 1-6a) were constructed to the specifications provided in the *RCRA Groundwater Monitoring Technical Enforcement Guidance Document* (EPA, 1986) and constitute the HWFP groundwater monitoring network specified in the DMP as required by 20.4.1.500 NMAC (incorporating 40 CFR §§264.90 through 264.101). These wells were used to establish background groundwater quality and groundwater surface elevations and flow directions in accordance with 20.4.1.500 NMAC (incorporating 40 CFR §§264.97[f] and [g] and 264.98[e]). Justification for the locations of these wells (3 upgradient and 4 downgradient) is presented below.

4.2 Current WIPP DMP

WQSP wells 1 through 6a constitute the HWFP DMP for WIPP (Figure 4) during detection monitoring as required by 20.4.1.500 NMAC (incorporating 40 CFR §§264.90 through 264.101). This monitoring plan is a continuation of the current WIPP GWSP, and these wells will serve as the monitoring locations during background water-quality characterization and the HWFP DMP (Figure 4).

Wells WQSP-1, WQSP-2, and WQSP-3 were located directly upgradient of the WIPP shaft area. The locations of the three upgradient wells were selected to be representative of the flow vectors of groundwater moving downgradient onto the WIPP site. Figure 34 of Davies, 1989, shows the simulation of direction and magnitude of groundwater flow. The upgradient wells were located based on the flow vectors resulting from this model simulation. The original WQSP observation wells, as well as those in the HWFP DMP, have been and will continue to be used as piezometer wells to support collection of groundwater surface elevation and groundwater flow modeling data to demonstrate regulatory compliance (40 CFR Part 191). Well location surveys for each of the seven wells were performed by survey personnel using the State Plane Coordinates-North American Datum Model 27 method. Results of the surveys are on file with the New Mexico Office of the State Engineer (State Engineer's Office) along with the associated extraction permits for each well.

WQSP-4, WQSP-5, and WQSP-6 were located downgradient of the WIPP shaft area in concert with the flow vectors shown by this model simulation. WQSP-6a was installed in the Dewey Lake Formation at the WQSP-6 location to assess groundwater conditions at this location. All three Culebra downgradient wells (WQSP-4, 5, and 6) were sited based on the greatest velocity magnitude of groundwater flow leaving the shaft area as shown on Figure 34 of Davies, 1989, and upgradient of the WIPP Land Withdrawal Area boundary. WQSP-4 was also specifically located to monitor the zone of higher transmissivity around wells DOE-1 and H-11, which may represent faster flow path away from the WIPP shaft area to the Land Withdrawal Area boundary (DOE, 1996b).

The Culebra has been selected for the focus of the DMP due to it being regionally extensive and exhibiting the most significant transmissivity of the water-bearing units at WIPP. The Culebra has been extensively studied during all past hydrologic characterization programs and found to be the most likely hydrologic pathway to the accessible environment or compliance point for any potential contamination.

The compliance point is defined in 20.4.1.500 NMAC (incorporating 40 CFR §264.95) as the vertical plane immediately downgradient of the hazardous waste management unit area (i.e., at the downgradient footprint of the WIPP repository). HWFP Module V specifies the point of compliance as "the vertical surface located at the hydraulically downgradient limit of the underground HWDUs [hazardous waste disposal units] that extends to the Culebra Member of the Rustler Formation." The HWFP groundwater monitoring network was not installed immediately downgradient of this plane. However, because the underground HWDUs at WIPP are Subpart X units, and due to the relatively unique containment and transport aspects of the site, monitoring at these locations will allow for detection of releases prior to release of these contaminants to the general public at the Land Withdrawal Area boundary.

The DMP wells were located to intercept flow vectors downgradient away from the WIPP shafts area based on density corrected potentiometric surfaces. The selected well placement locations are downgradient of the general flow direction from the shaft area. Transport modeling of contaminant migration throughout the Culebra to the Land Withdrawal Area boundary suggests that travel times could be on the order of thousands of years if, under worst case conditions, hazardous constituents could migrate from the sealed repository. If contaminants were to migrate from the disposal facility, they would be detected by the DMP wells located midway between the shafts and Land Withdrawal Area such that samples from wells could detect these contaminants long before they could reach the Land Withdrawal Area boundary.

Potentiometric surfaces and groundwater flow directions defined prior to large-scale pumping in the WIPP area and the excavation of WIPP shafts suggests that flow was generally to the south-southeast from the waste disposal and shaft areas (Mercer, 1983; Davies, 1989). Potentiometric surface maps (December 1998) of the Culebra adjusted for density differences show very similar characteristics (Figure 4). WQSP-4, WQSP-5, and WQSP-6 have been located downgradient of the waste emplacement areas according to adjusted potentiometric surfaces.

Potentiometric surfaces that have not been corrected for density differences and that contain transient relics of previous pumping-drawdown events do not reflect accurate natural groundwater flow directions and should not be used to assess the adequacy of groundwater monitoring locations.

4.2.1 DMP Well Construction Specification

a. WQSP-1

WQSP-1 was drilled between September 13 and 16, 1994, to a total depth of 737 ft (225 m) bgs. The borehole was drilled through the Culebra and extends 15 ft (5 m) into the Los Medaños Member of the Rustler. The well was drilled to a depth of 693 ft (211 m) bgs using compressed air as the drilling fluid. The interval from 693 to 737 ft (211 to 225 m) bgs (the total depth) was drilled using air mist with a foaming agent as the drilling fluid. WQSP-1 was drilled to 695.6 ft (212 m) bgs using a 9⅞-in. drill bit and was cored from 695.6 to 737 ft (212 to 225 m) bgs using a 5¼-in. core bit to cut 4-in. diameter core. After coring, WQSP-1 was reamed to 9⅞ in. in diameter to total depth. WQSP-1 was cased from the surface to 737 ft (224.6 m) bgs with 5-in. blank fiberglass casing with in-line 5-in. diameter fiberglass 0.02-in. slotted screen across the Culebra interval from 702 to 727 ft (214 to 222 m) bgs. The annulus between the borehole wall and the casing/screen is packed with sand from 640 to 651 ft (195 to 198 m) bgs and with 8/16 Brady gravel from 651 to 737 ft (198 to 225 m) bgs. Based on core log results, the Culebra is located from 699 to 722 ft (213 to 220 m) bgs (see Figure 6).

b. WQSP-2

WQSP-2 was drilled between September 6 and 12, 1994, to a total depth of 846 ft (257.9 m) bgs. The borehole was drilled through the Culebra and extends 12.3 ft (3.7 m) into the Los Medaños Member of the Rustler. The well was drilled to a depth of 800 ft (244 m) bgs with a 9⅞-in. drill bit using compressed air as the drilling fluid. The interval from 800 to 846 ft (244 to 258 m) bgs (the total depth) was drilled with a 5¼-in. core bit to cut 4-in. diameter core using air mist with a foaming agent as the drilling fluid. After coring, WQSP-2 was reamed to 9⅞ in. in diameter to total depth. WQSP-2 was cased from the surface to 846 ft (258 m) bgs with 5-in. blank fiberglass casing with in-line 5-in. diameter fiberglass 0.02-in. slotted screen across the Culebra interval from 811 to 836 ft (247 to 255 m) bgs. The annulus between the borehole wall and the casing/screen is packed with sand from 790 to 793 ft (241 to 242 m) bgs and with 8/16 Brady gravel from 793 to 846 ft (242 to 258 m) bgs. Based on core log results, the Culebra is located from 810.1 to 833.7 ft (247 to 254 m) bgs (see Figure 7).

c. WQSP-3

WQSP-3 was drilled between October 21 and 26, 1994, to a total depth of 880 ft (268 m) bgs. The borehole was drilled through the Culebra and extends 10 ft (3.1 m) into the Los Medaños Member of the Rustler. The well was drilled to a depth of 880 ft (268 m) bgs using compressed air as the drilling fluid. The borehole was cleaned using air mist with a foaming agent. WQSP-3 was drilled to 833 ft (254 m) bgs using a 9⅞-in. drill bit and was cored from 833 to 879 ft (254 to 268 m) bgs using a 5¼-in. core bit to cut 4-in. diameter core. After coring, WQSP-3 was reamed to 9⅞ in. in diameter to total depth of 880 ft (268 m) bgs. WQSP-3 was cased from the surface to 880 ft (268 m) bgs with 5-in. blank fiberglass casing with in-line 5-in. diameter fiberglass 0.02-in. slotted screen across the Culebra interval from 844 to 869 ft (257 to 265 m) bgs. The annulus between the borehole wall and the casing/screen is packed with sand from 827 to 830 ft (252 to 253 m) bgs and with 8/16 Brady gravel from 830 to 880 ft (253 to 268 m) bgs. Based on core log results, the Culebra is located from 844 to 870 ft (257 to 265 m) bgs (see Figure 8).

d. WQSP-4

WQSP-4 was drilled between October 5 and 10, 1994, to a total depth of 800 ft (244 m) bgs. The borehole was drilled through the Culebra and extends 9.2 ft (2.8 m) into the Los Medaños Member of the Rustler. The well was drilled to a depth of 740 ft (226 m) bgs with a 9⅞-in. drill bit using compressed air as the drilling fluid. The interval from 740.5 to 798 ft (225.7 to 243 m) bgs was cored with a 5¼-in. core bit to cut 4-in. diameter core using air mist with a foaming agent as the drilling fluid. After coring, WQSP-4 was reamed to 9⅞ in. in diameter to total depth of 800 ft (244 m) bgs. WQSP-4 was cased from the surface to 800 ft (244 m) bgs with 5-in. blank fiberglass casing with in-line 5-in. diameter fiberglass 0.02-in. slotted screen across the Culebra interval from 764 to 789 ft (233 to 241 m) bgs. The annulus between the borehole wall and the casing/screen is packed with sand from 752 to 755 ft (229 to 230 m) bgs and with 8/16 Brady gravel from 755 to 800 ft (230 to 244 m) bgs. Based on core log results, the Culebra is located from 766 to 790.8 ft (233 to 241 m) bgs (see Figure 9).

e. WQSP-5

WQSP-5 was drilled between October 12 and 19, 1994, to a total depth of 681 ft (208 m) bgs. The borehole was drilled through the Culebra and extends into the Los Medaños Member of the Rustler. The well was drilled to a depth of 676 ft (206 m) bgs using compressed air as the drilling fluid. The borehole was cleaned using air mist with a foaming agent. WQSP-5 was drilled to 648 ft (198 m) bgs using a 9⅞-in. drill bit and was cored from 648 to 676 ft (198 to 206 m) bgs using a 5¼-in. core bit to cut 4-in. diameter core. After coring, WQSP-5 was reamed to 9⅞ in. in diameter to total depth of 681 ft (208 m) bgs. WQSP-5 was cased from the surface to 681 ft (208 m) bgs with 5-in. blank fiberglass casing with in-line 5-in. diameter fiberglass 0.02-in. slotted screen across the Culebra interval from 646 to 671 ft (197 to 205 m) bgs. The annulus between the borehole wall and the casing/screen is packed with sand from 623 to 626 ft (190 to 191 m) bgs and with 8/16 Brady gravel from 626 to 681 ft (191 to 208 m) bgs. Based on core log results, the Culebra is located from 648 to 674.4 ft (198 to 205.6 m) bgs (see Figure 10).

f. WQSP-6

WQSP-6 was drilled between September 26 and October 3, 1994, to a total depth of 616.6 ft (187.9 m) bgs. The borehole was drilled through the Culebra and extends 9.7 ft (3 m) into the Los Medaños Member of the Rustler. The well was drilled to a depth of 367 ft (112 m) bgs using compressed air as the drilling fluid. The interval from 367 to 616 ft (112 to 188 m) bgs (the total depth) was drilled using brine as the drilling fluid. WQSP-6 was drilled to 568 ft (173 m) ft bgs using a 9⅞-in. drill bit and was cored from

568 to 616 ft (173 to 188 m) bgs using a 5¼-in. core bit to cut 4-in. diameter core. After coring, WQSP-6 was reamed to 9⅞ in. in diameter to total depth of 616.6 ft (188 m) bgs. WQSP-6 was cased from the surface to 616.6 ft (188 m) bgs with 5-in. blank fiberglass casing with in-line 5-in. diameter fiberglass 0.02-in. slotted screen across the Culebra interval from 581 to 606 ft (177 to 185 m) bgs. The annulus between the borehole wall and the casing/screen is packed with sand from 567 to 570 ft (173 to 173.7 m) bgs and with 8/16 Brady gravel from 570 to 616.6 ft (174 to 188 m) bgs. Based on core log results, the Culebra is located from 582 to 606.9 ft (177 to 185 m) bgs (see Figure 11).

g. WQSP-6A

WQSP-6A was drilled between October 31 and November 1, 1994, to a total depth of 225 ft (69 m) bgs. It is located approximately 100 ft immediately west of WQSP-6. The borehole was drilled through a water-producing zone in the Dewey Lake Redbeds that had been previously encountered while drilling well WQSP-6. The well was drilled to a depth of 225 ft (69 m) bgs using compressed air as the drilling fluid. The borehole was cleaned using air mist with a foaming agent. WQSP-6A was drilled to 160 ft (49 m) bgs using a 9⅞-in. drill bit and was cored from 160 to 220 ft (49 to 67 m) bgs using a 5¼-in. core bit to cut 4-in. diameter core. After coring, WQSP-6A was reamed to 9⅞ in. in diameter to total depth of 225 ft (69 m) bgs. WQSP-6A was cased from the surface to 225 ft (69 m) bgs with 5-in. blank fiberglass casing with in-line 5-in. diameter fiberglass 0.02-in. slotted screen from 190 to 215 ft (58 to 66 m) bgs. The annulus between the borehole wall and the casing/screen is packed with sand from 172 to 175 ft (52 to 53 m) bgs and with 8/16 Brady gravel from 175 to 225 ft (53 to 69 m) bgs (see Figure 12).

4.3 Well Plugging and Abandonment

The main purposes of the plugging and abandonment (P&A) program is to reduce Carlsbad Field Office (CBFO) liability and potential environmental damage by preventing disturbances to the existing hydrologic conditions in the subsurface domain in the vicinity of WIPP. The objectives of the P&A program include:

- Eliminate physical hazards
- Prevent groundwater contamination
- Conserve aquifer yield and hydrostatic head
- Prevent intermixing of formation waters
- Comply with state and federal regulations

At the present time, the WIPP area-wide groundwater-monitoring network contains more than 70 accessible wells, the majority of which are completed in the Culebra. Most of these wells are in reasonably good operating condition. Wells are selected for P&A based on health and safety factors, condition of the well (i.e., casing, annular seal, and production interval), geographic location, and the ability of the well to yield useful data.

The State Engineer's Office has regulatory authority over the plugging and abandoning of groundwater production and monitoring wells in the state. The state of New Mexico has several groundwater basins, with each basin having its own district office providing oversight of groundwater issues. The WIPP area is under the jurisdiction of the Roswell, New Mexico, branch of the State Engineer's Office. The Roswell office will be the regulatory body to approve the WIPP plans for well P&A.

A proposal may be made to plug and abandon a Detection Monitoring Well (DMW) by submitting a permit modification request to the Secretary in compliance with 20.4.1.900 NMAC (incorporating 40 CFR §270.42). The DMW must be plugged and abandoned in a manner which eliminates physical hazards, prevents groundwater contamination, conserves hydrostatic head, and prevents intermixing of subsurface water. A report will be submitted to the NMED which summarizes and certifies DMW plugging and abandoning methods within ninety calendar days from the date a DMW is removed from the DMP.

5.0 MONITORING PROGRAM DESCRIPTION

The WIPP DMP has been designed to meet the groundwater monitoring requirements of 20.4.1.500 NMAC (incorporating 40 CFR §§264.90 through 264.101) and the CCA. The following sections of the monitoring plan specify the components of the DMP.

5.1 Monitoring Frequency

The seven HWFP monitoring wells have been sampled on a semiannual basis since their installation in 1994 to establish background groundwater quality in accordance with 20.4.1.500 NMAC (incorporating 40 CFR §§264.97 and 264.98). This has included at least two full rounds of 20.4.1.500 NMAC (incorporating 40 CFR Part 264) Appendix IX analysis for samples from each of the proposed HWFP detection monitoring wells. In addition, groundwater samples were collected from the DMP wells (from March 1997 until waste emplacement) at a frequency of four sample replicates collected semiannually from each well for the indicator parameters of pH (measure of acidity), specific conductance (SC), total organic carbon (TOC), and total organic halogen (TOX) to further establish background groundwater quality until detection monitoring in accordance with 20.4.1.500 NMAC (incorporating 40 CFR §264.98) becomes applicable. A total of four rounds of Appendix IX analysis were initially conducted for samples from each well for use in background groundwater quality determinations. The background data were extended in 2000 to include ten rounds of sampling.

Detection monitoring started with the emplacement of waste and will continue through the postclosure phase as required by 20.4.1.500 NMAC (incorporating 40 CFR §264.90[c]). During detection monitoring, one sample and one sample duplicate will be collected semiannually from each well in the HWFP detection monitoring network. As shown in Table 2, the DMP will continue to collect groundwater quality samples for all seven wells on a semiannual basis during the life of the DMP. 20.4.1.500 NMAC (incorporating 40 CFR §264.97[g][2]) provides that an alternate sampling frequency to that provided in 20.4.1.500 NMAC (incorporating

40 CFR §264.98) may be proposed. Given the nature and rate of groundwater flow in the area surrounding WIPP, collecting and analyzing one sample semiannually will be protective of human health and the environment because any hazardous constituent leaving the underground disposal facility will not have the potential to migrate beyond the groundwater monitoring network in a one-year time frame. Groundwater flow characteristics are presented in detail in Appendices D6 and E1 of the RCRA Part B Permit Application (DOE, 1997b) and Appendix Hydro of the CCA (DOE, 1996b).

Groundwater surface elevations will be monitored in each of the seven DMP wells on a monthly basis. The groundwater surface elevation in each DMP well will also be measured prior to each sampling event. Groundwater surface elevation measurements in the other existing WQSP well sites will also be monitored on a monthly basis to supplement the area water-level database and to help define regional changes in groundwater flow directions and gradients. The characteristics of the HWFP DMP (frequency, location) will be evaluated if significant changes are observed in the groundwater flow direction or gradient. If any change occurs which could affect the ability of the DMP to fulfill the requirements of 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subpart F), the proper notifications and actions will be taken to comply with applicable permit requirements (Table 5).

5.2 Analytical Parameters

The analytes of interest measured to establish background groundwater quality prior to emplacement of waste include all indicator parameters and all other parameters listed in 20.4.1.500 NMAC (incorporating 40 CFR Part 264) Appendix IX. Field measurements of pH, SC, temperature, chloride, Eh (oxygen reduction potential), total iron, and alkalinity are also measured during background sampling.

The DMP was initiated upon waste emplacement, and the semiannual samples will be analyzed for the parameters listed in Table 3. Parameters to be analyzed by the contract laboratory such as specific conductance, total dissolved solids, total suspended solids, density, pH, TOC, and TOX were included as indicator parameters because of their universal commonality to groundwater. Parameters such as chloride, alkalinity, calcium, magnesium, and potassium were included as matrix-specific general indicator parameters. Calcium, magnesium, potassium, chloride, and iron may be deleted during detection monitoring, with prior approval of the NMED. Organic and inorganic compounds on the right hand side of Table 3 were chosen because they will occur in the waste to be disposed at the WIPP facility. Additional parameters may be identified through the tentatively identified compound process resulting from a library search performed by the contracted Laboratory. If compounds are identified, these will be added to the DMP list, unless omission of these compounds is justified, and this omission is approved by the NMED.

5.3 Groundwater Surface Elevation Measurement, Sample Collection and Laboratory Analysis

Groundwater surface elevations will be measured in each well prior to groundwater sample collection. Groundwater will be extracted using serial and final sampling methods. Serial samples will be collected until groundwater field indicator parameters stabilize, after which the final sample for complete analysis will be collected. Final samples will then be analyzed for the DMP analytical suite.

5.3.1 Groundwater Surface Elevation Monitoring Methodology

The WIPP groundwater level monitoring program (WLMP) is a subprogram of the DMP. The QA activities of the WLMP are in strict accordance with the WTS Quality Assurance Program Description (QAPD) (WP 13-1), and the QA implementing procedures specific to groundwater surface elevation monitoring. Groundwater surface elevation monitoring is in progress now and will continue through the postclosure care period. This section of the plan addresses the activities of the WLMP during the preoperational and operational phases of WIPP.

Collection of groundwater surface elevation data is required by 20.4.1.500 NMAC (incorporating 40 CFR §264.97[f]) and 40 CFR Part 191. These data also provide:

- Data collection as required by the Environmental Monitoring Plan.
- A means to fulfill commitments made in the Final Environmental Impact Statement (FEIS).
- A means to comply with future groundwater inventory and monitoring regulations.
- Input for making land use decisions (i.e., designing long-term active and passive institutional controls for the site).
- Assistance in understanding any changes to readings from the water-pressure transducers installed in each of the shafts to monitor water conditions behind the liners.
- An understanding of whether or not the horizontal and vertical gradients of flow are changing over time.

The objective of the WLMP is to extend the documented record of groundwater surface elevation fluctuations in the Culebra and Magenta Members of the Rustler in the vicinity of the WIPP facility and to meet the requirements of 20.4.1.500 NMAC (incorporating 40 CFR §264.97[f]) and 40 CFR Part 191, and 40 CFR §194.42. Groundwater surface elevation data will be collected from each well of the HWFP DMP. Groundwater surface elevation data will also be collected from other Culebra wells, as well as monitoring wells completed in other water-bearing zones overlying and underlying the WIPP repository horizon when access to those zones is possible (Figure 5). This includes, but is not limited to, the Bell Canyon, the Forty-niner, the contact zone between the Rustler and Salado, and the Dewey Lake.

Groundwater surface elevation measurements will be taken monthly in at least one accessible completed interval at each available well pad. At well pads with two or more wells completed in the same interval, quarterly measurements will be taken in the redundant wells. Groundwater surface elevation measurements will be taken monthly at each of the seven DMP wells, as well as prior to each sampling event. If a cumulative groundwater surface elevation change of more than two feet is detected in any DMP well over the course of one year which is not attributable to site tests or natural stabilization of the site hydrologic system, notification will be made to the NMED in writing and discuss the origin of the changes in the report specified in Permit Module V. Abnormal, unexplained changes in groundwater surface elevation may indicate changes in site recharge/discharge that could affect the assumptions regarding DMP well placement and constitute new information as specified in 20.4.1.900 NMAC (incorporating 40 CFR §270.41[a][2]).

Groundwater surface elevation monitoring will continue through the postclosure care period. The frequency of monitoring may be temporarily increased to effectively document naturally occurring or artificial perturbations that may be imposed on the hydrologic systems at any point in time. This will be conducted in selected key wells by increasing the frequency of the manual groundwater surface elevation measurements or by monitoring water pressures with the aid of electronic pressure transducers and remote data-logging systems. Such additional data will be included in the reports specified in Section V.J.2 of the HWFP.

Interpretation of groundwater surface elevation measurements and corresponding fluctuations over time is complicated at WIPP by spatial variation in fluid density both vertically in well bores and areally from well to well. To monitor the hydraulic gradients of the hydrologic flow systems at WIPP accurately, actual groundwater surface elevation measurements will be monitored at the frequencies specified in Table 2, and the densities of the fluids in the well bores will be measured annually. When both of these parameters are known, equivalent freshwater heads can be calculated. The concept of freshwater head is discussed in Lusczynski (1961).

A discussion explaining the calculation of freshwater heads from mid-formation depth at WIPP can be found in Haug, et al. (1987). Freshwater heads are useful in identifying hydraulic gradients in aquifers of variable density such as those existing at the WIPP site. Freshwater head at a given point is defined as the height of a column of freshwater that will balance the existing pressure at that point (Lusczynski, 1961).

Measured groundwater surface elevation data can be converted to equivalent freshwater head from knowledge of the density of the borehole fluid, using the following formula.

$$p=\rho gh$$

where

p = freshwater head (pressure)
ρ = average specific gravity of the borehole fluid (unitless)
g = freshwater density (mass/volume)
h = fluid column height above the datum (length)

If the freshwater density is assumed to be 1.000 gram per cubic centimeter (g/cm^3), then the equivalent freshwater head is equal to the fluid column height times the average borehole fluid density (expressed as specific gravity).

Groundwater surface elevation data will be used to determine the direction and rate of flow in the Culebra at least annually. The results of the determination of direction and flow rate will be presented annually in the Site Environmental Report.

5.3.2 Field Methods and Data Collection Requirements

To obtain an accurate groundwater surface elevation measurement, a calibrated water-level measuring device will be lowered into a test well and the depth to water recorded from a known reference point. When using an electrical conductance probe, the depth to water will be determined by reading the appropriate measurement markings on the embossed measuring tape when the alarm is activated at the surface. WIPP procedures specify the methods to be used in obtaining groundwater-level measurements.

5.3.3 Groundwater Surface Elevation Records and Document Control

All incoming data will be processed in a timely manner to assure data integrity. The data management process for groundwater surface elevation measurements will begin with completion of the field data sheets. Date, time, tape measurement, equipment identification number, calibration due date, initial of the field personnel, and equipment/ comments will be recorded on the field data sheets. If, for some unexpected reason, a measurement is not possible (i.e., a test is under way that blocks entry to the well bore), then a notation as to why the measurement was not taken will be recorded in the comment column. Personnel will also use the comment column to report any security observations (i.e., well lock missing).

Data recorded on the field data sheets and submitted by field personnel will be subject to guidelines outlined in WIPP environmental procedures. These procedures specify the processes for administering and managing such data. The data will be entered onto a computerized work sheet. The work sheet will calculate groundwater surface elevation in both feet and meters relative to the top of the casing and also relative to mean sea level. The work sheet will also adjust groundwater surface elevations to equivalent freshwater heads.

A check print will be made of the work sheet printout. The check print will be used to verify that data taken in the field was properly reported on the database printout. A minimum of 10 percent of the spreadsheet calculations will be randomly verified on the check print to ensure that calculations are being performed correctly. If errors are found, the work sheet will be corrected. The data contained on the computerized work sheet will be translated into a database file. A printout will be made of the database file. The data each month will then be compiled into report format and transmitted to the appropriate agencies as requested by the CBFO. Groundwater surface elevation data and equivalent freshwater heads for all Culebra wells will be transmitted to the NMED one month after data are collected.

A computerized database file will be maintained for all groundwater surface elevation data. Monthly and quarterly data will be appended into a yearly file. Upon verification that the yearly database is free of errors, it will be appended into the project database file. A printed copy of the current project database (through December of the preceding year) will be kept in the Environmental Monitoring and Hydrology (EM&H) fire-resistant storage area (operating record).

5.4 Groundwater Sampling

5.4.1 Groundwater Pumping and Sampling Systems

The water-bearing units at WIPP are highly variable in their ability to yield water to monitoring wells. The Culebra, the most transmissive hydrologic unit in the WIPP area, exhibits transmissivities that range many orders of magnitude across the site area and is the primary focus of the DMP.

The groundwater pumping and sampling systems used to collect a groundwater sample from the seven DMP wells will provide continuous and adequate production of water so that a representative groundwater sample can be obtained. The wells used for groundwater quality sampling vary in yield, depth, and pumping lift. These factors affect the duration of pumping as well as the equipment required at each well.

The type of pumping and sampling system to be used in a well depends primarily on the aquifer characteristics of the Culebra and well construction. The DMP wells will be individually equipped with dedicated submersible pumping assemblies. Each well has a specific type of submersible pump, matched to the ability of the well to yield water during pumping. The down hole submersible pumps will be controlled by a variable electronic flow controller to match the production capacity of the formation at each well. The electronic flow controller allows personnel collecting samples to control the rate of discharge during well purging to minimize the potential for loss of volatiles from the sample. As recommended in *RCRA Groundwater Monitoring Technical Enforcement Guidance Document* (EPA, 1986), the wells will be purged a minimum of three well bore volumes at a rate that will minimize the agitation of recharge water. This will be accomplished by monitoring formation pressure and matching the rate of discharge from the well as nearly as possible to the rate of recharge to the well. WIPP procedures specify the methods used for controlling flow rates and monitoring formation pressure. Well purging requirements will be used in conjunction with serial sampling to determine when the groundwater chemistry stabilizes and is therefore representative of undisturbed groundwater.

The DMP wells will be cased and screened through the production interval with materials that do not yield contamination to the aquifer or allow the production interval to collapse under stress (high epoxy fiberglass). An electric, submersible pump installation without the use of a packer will be used in this instance. The largest amount of discharge from the submersible pump will take place from a discharge pipe. In addition to this main discharge pipe, a dedicated sample line, running parallel to the discharge pipe, will also be used. Flow through the pipe will be regulated on the surface by a flow control valve and/or variable speed drive controller. Cumulative flow will be measured using a totalizing flow meter. Flow from the discharge pipe will be routed to a discharge tank for disposal.

The dedicated sampling line will be used to collect the water sample that will undergo analysis. By using a dedicated sample line, the water will not be contaminated by the metal discharge pipe. The sample line will branch from the main discharge pipe a few inches above the pump. Flow from the sample line will be routed into the sample collection area. Flow through the sample collection line will be regulated by a flow-control valve. The sample line will be insulated at the surface to minimize temperature fluctuations.

5.4.2 Pressure Monitoring Systems

The DMP wells do not require the installation of a packer because sample biases due to well construction deficiencies are not present. However, pressures will be monitored using down hole automatic air line bubblers in the formation to maintain the water level above the pump intake. Pressure transducers may be used in line with bubblers to provide continual electronic monitoring through data acquisition systems. WIPP procedures provide instructions for monitoring formation pressure using automatic airline bubblers in conjunction with pressure transducers and data acquisition systems. The mobile field laboratory provides a work place for conducting field sampling and analyses. The laboratory will be positioned near the wellhead, will be climate controlled, and will contain the necessary equipment, reagents, glassware, and deionized water for conducting the various field analyses.

5.4.3 Sampling Overview

Two types of water samples will be collected: serial samples and final samples. Serial samples will be taken at regular intervals and analyzed in the mobile field laboratory for various physical and chemical parameters (called field indicator parameters). The serial sample data will be used to determine whether the sample is representative of undisturbed groundwater as a direct function of the stabilization of field indicator parameters and the volume of the water being pumped from the well. Interpretation of the serial sampling data will enable the Team Leader to determine when conditions representative of undisturbed groundwater are attained in the pumped groundwater.

Final samples will be collected when the serially sampled field indicator parameters have stabilized and are, therefore, representative of undisturbed groundwater.

a. Serial Samples

Serial sampling is the collection of sequential samples for the purpose of determining when the groundwater chemistry stabilizes and is therefore representative of undisturbed groundwater. A serial sample is considered representative of undisturbed groundwater when the majority of field indicator parameter measurements have stabilized within ±5 percent of the average of analytical results for the field indicator parameter from the background groundwater quality for each DMP well. Nonstabilization of one or two field indicator parameters attributable to matrix interferences, instrument drift, or other unforeseen reasons will not preclude the collection of final samples, provided the volume of purged water exceeds three well bore volumes. Final samples collected when field indicator parameters were not stabilized will be reported in the operating record, and an explanation of why the sample was collected when field indicator parameters were not stabilized will be provided.

Serial samples will be collected and analyzed to detect and monitor the chemical variation of the groundwater as a function of the volume of water pumped. Once serial sampling begins, the frequency at which serial samples are collected and analyzed will be left to the discretion of the Team Leader, but will be performed a minimum of three times during a sampling round.

The appropriate field methods to identify stabilization of the following field indicator parameters: chloride, divalent cations (hardness), alkalinity, total iron, pH, Eh, temperature, SC, and specific gravity will be used. Protocols for collection of serial samples are specified in WIPP procedures.

The three field indicator parameters of temperature, Eh, and pH will be determined by either an "in-line" technique, using a self-contained flow cell, or an "off-line" technique, in which the samples will be collected from a sample line at atmospheric pressure. The iron, divalent cation, chloride, alkalinity, specific conductance, and specific gravity samples will be collected from the nylon sample line at atmospheric pressure. Because of the lack of sophisticated weights and measures equipment available for field density assessments, field density evaluations will be expressed in terms of specific gravity, which is a unitless measure. Density is expressed as unit weight per unit volume.

New polyethylene containers will be used to collect the serial samples from the sample line. Serial sampling water collected for solute and specific conductance determinations will be filtered through a 0.45 micrometers (µm) membrane filter using a stainless-steel, in-line filter holder. Filtered water will be used to rinse the sample bottle prior to serial sample collection. Unfiltered groundwater will be used when determining temperature, pH, Eh, and specific gravity. Sample bottles will be properly identified and labeled.

The filtered sample collected for solute analyses will be immediately analyzed for iron and alkalinity because these two solution parameters are extremely sensitive to changes in the ambient water-sample pressure and temperature. A sample and duplicate of filtered water will be collected and analyzed for solute parameters (alkalinity, chloride, divalent cations, and iron). Temperature, pH, and Eh, when not measured in a flow cell, will be measured at the approximate time of serial sample collection. These samples will be collected from the unfiltered sample line.

Samples to be analyzed for chloride and divalent cations (after preservation with nitric acid and stored at four degrees Celsius (4°C) may be stored for one week prior to analysis with confidence that the analytical results will not be altered.

Upon completion of the collection of the last serial sample suite, the serial sample bottles accrued throughout the duration of the pumping of the well will be discarded. No serial sample bottles will be reused for sampling purposes of any sort. However, serial samples may be stored for a period of time depending upon the need.

During the first two years of DMP well serial sampling, the first sample will be analyzed as soon as possible after the pump is turned on and daily thereafter for a period of four days or until the field indicator parameters (chloride, divalent cations, alkalinity, and iron) stabilize. Eh, pH, and SC will be continually monitored by using a flow cell with ion-specific electrodes and a real-time readout. When detection monitoring begins, the serial sampling process may be modified and the decision to collect final samples would then be based on the number of well bore volumes purged and results of the analysis of chloride, temperature, specific gravity, pH, Eh, and SC. Removal of serial sampling from the DMP will be accomplished through a permit modification and a modification to this plan.

b. Final Samples

The final sample will be collected once the measured field indicator parameters have stabilized. A serial sample will also be collected and analyzed for each day of final sampling to ensure that samples collected for laboratory analysis are still representative of stable conditions. Sample preservation, handling, and transportation methods will maintain the integrity and representativeness of the final samples.

Prior to collecting the final samples, the collection team shall consider the analyses to be performed so that proper shipping or storage containers can be assembled. Table 4 presents the sample containers, volumes, and holding times for laboratory samples collected as part of the DMP.

The monitoring system will use dedicated pumping systems and sample collection lines from the sampled formation to the well head. Nondedicated sample collection lines from the well head to the sample collection area will be discarded after each use.

Sample integrity will be ensured through appropriate decontamination procedures. Laboratory glassware will be washed after each use with a solution of nonphosphorus detergent and deionized (DI) water and rinsed in DI water. Sample containers will be new, certified clean containers that will be discarded after one use. Groundwater surface elevation measurement devices will be rinsed with fresh water after each use. Nondedicated sample collection manifold assemblies will be rinsed with two gallons of fresh water, then rinsed with five gallons of 5 percent nitric acid solution and rinsed with five gallons of DI water after each use. The exposed ends will be capped off during storage. Prior to the next use of the sampling manifold, it will be rinsed a second time with DI water and a blank rinsate sample will be collected to verify decontamination.

Water samples will be collected at atmospheric pressure using either the filtered or unfiltered sampling lines branching from the main sample line. Detailed protocols, in the form of procedures, assure that final samples will be collected in a consistent and repeatable fashion.

Final samples will be collected in the appropriate type of container for the specific analysis to be performed. The samples will be collected in new and unused glass and plastic containers. For each parameter analyzed, a sufficient volume of sample will be collected to satisfy the volume requirements of the analytical laboratory (as specified by laboratory standard operating procedures [SOPs]). This includes an additional volume of sample water necessary for maintaining QC standards. All final samples will be treated, handled, and preserved as required for the specific type of analysis to be performed. Details about sample containers, preservation, and volumes required for individual types of analyses are found in the applicable procedures generated, approved, and maintained by the contract analytical laboratory.

Before the final sample is taken, all plastic and glass containers will be rinsed with the pumped groundwater, either filtered or unfiltered, dependent upon analysis protocol. When the rinsing procedure is completed, the final sample will be collected.

Final samples will be sent to contract laboratories and analyzed for general chemistry, radionuclides, metals, and selected VOCs that are specific to the waste anticipated to arrive at WIPP. Table 3 presents the specific analytes for the DMP.

WIPP did not accept TRU mixed waste for disposal prior to issuance of the HWFP, and previous WQSP sample analyses have shown that requested hazardous constituents have not been introduced to the groundwater in the vicinity of WIPP by other activities. Appendix D18, Attachment A, of the RCRA Part B Permit Application (DOE, 1997b) presented analytical data obtained from WQSP wells 1-6 which indicated that, for the Appendix IX parameters analyzed for, none of the anticipated waste constituents presented on Table 3 were present in sampled groundwater at WIPP.

Duplicates of the final sample will be provided to WIPP oversight agencies as requested by the CBFO or the NMED.

Resulting wastes are disposed of in accordance with the WTS Hazardous and Universal Waste Management Plan, WP 02-RC.01.

5.4.4 Sample Preservation, Tracking, Packaging, and Transportation

Many of the chemical constituents measured by the DMP are not chemically stable and require preservation and special handling techniques. Samples requiring acidification will be treated with either high purity hydrochloric acid, nitric acid, or sulfuric acid (ULTREX or equivalent), depending upon the standard method of treatment required for the particular parameter suite or as requested by contract laboratory SOPs (see Table 4).

The contract laboratory receiving the samples will use procedures that prescribe the type and amount of preservative, the container material type, and the required sample volumes that shall be collected. This information will be recorded on the Final Sample Checklist for use by field personnel when final samples are being collected. EPA *RCRA Groundwater Monitoring Technical Enforcement Guidance Document*, Table 4-1 (EPA, 1986), will be followed if laboratory SOPs do not specify sample container, volume, or preservation requirements.

The sample tracking system at WIPP will use uniquely numbered chain-of-custody (CofC) forms and request for analysis (RFA) forms. The primary consideration for storage or transportation is that samples shall be analyzed within the prescribed holding times for the parameters of interest. WIPP procedures provide instructions to ensure proper sample tracking protocol.

Insulated shipping containers packaged with crushed ice or reusable ice packs will be used to keep the samples cool during transport to the contract laboratory. Holding times for specific analytical parameters require samples to be shipped by express air freight. The coolers will be packaged to meet Department of Transportation and International Air Transportation Association commercial carrier regulations.

5.4.5 Sample Documentation and Custody

To ensure the integrity of samples from the time of collection through reporting date, sample collection, handling, and custody shall be documented. Sample custody and documentation for hydrology sampling and analysis activities are detailed in WIPP procedures. These procedures will be strictly followed throughout the course of each sample collection and analysis event.

Standardized forms used to document samples will include sample identification numbers, sample labels, custody tape, the sample tracking log books, and the RFA and CofC forms. The forms are briefly defined in the following subsections.

All sample documentation will be completed for each sample and reviewed by the Team Leader or their designee for completeness and accuracy.

a. Sample Numbers and Labels

A unique sample identification number will be assigned to each sample sent to the laboratory for analysis. The Team Leader will assign the numbers prior to sample collection. The sample identification numbers will be used to track the sample from the time of collection through data reporting. Every sample container sent to the laboratory for analysis will be identified with a label affixed to it. Sample label information will be completed in permanent, indelible ink and will contain the following information: sample identification number with sample matrix type; sample location; analysis requested; time and date of collection; preservative(s), if any; and the sampler's name or initials.

b. Custody Seals

Custody seals will be used to detect unauthorized sample tampering from collection through analysis. The custody seals will be adhesive-backed strips that are destroyed when removed or when the container is opened. The seal will be dated, initialed, and affixed to the sample container in such a manner that it is necessary to break the seal to open the container. Seals will be affixed to sample containers in the field immediately after collection. Upon receipt at the laboratory, the laboratory custodian will inspect the seal for integrity; a broken seal will invalidate the sample.

c. Sample Tracking Logbook

A sample tracking logbook (STLB) form will be completed for each sample collected. The STLB will include the following information: CofC number; RFA number; date sample(s) were sent to the lab; laboratory name; acknowledgment of receipt or comments; well name; and round number. Sample codes will indicate the well location; the geologic formation from which the water was collected, the sampling round number; and the sample number. The code is broken down as follows:

WQ6[1]C[2]R2[3]N1[4]

[1] Well identification (e.g., WQSP-6 in this case)
[2] Geologic formation (e.g., the Culebra in this case)
[3] Sample round number (Round 2)
[4] Sample number (N1)

To distinguish duplicate samples from other samples, a "D" is added as the last digit to signify a duplicate. STLB information will be completed in the field by the sampling team and checked by the Team Leader. When samples are shipped, the STLB will remain in the custody of EM&H for sample tracking purposes.

d. Request for Analysis and Chain of Custody

RFA and CofC forms will be completed during or immediately following sample collection and will accompany the sample through analysis and disposal. The RFA and CofC forms will be signed and dated each time the sample custody is transferred. A sample will be considered to be in a person's custody if: the sample is in his or her physical possession; the sample is in his or her unobstructed view; and/or the sample is placed, by the last person in possession of it, in a secured area with restricted access. During shipment, the carrier's air bill number serves as custody verification. Upon receipt of the samples at the laboratory, the laboratory sample custodian acknowledges possession of the samples by signing and dating the RFA and CofC forms. The completed original (top page) of the RFA and CofC forms will be returned to the Team Leader with the laboratory analytical report and becomes part of the permanent record of the sampling event. The RFA and CofC forms also contain specific instructions to the laboratory for sample analysis, potential hazards, and disposal instructions.

5.5 Laboratory Analysis

Analysis of samples will be performed by a commercial laboratory. Methods will be specified in procurement documents and will be selected to be consistent with EPA-recommended procedures in *Test Methods for Evaluating Solid Waste* (SW 846, EPA, 1996). Additional detail on analytical techniques and methods will be given in laboratory SOPs. Table 3 presents the analytical parameters for the WIPP DMP.

WTS has established criteria for laboratory selection, including the stipulation that the laboratory follow the procedures specified in SW 846 and that the laboratory follow EPA protocols. The selected laboratory shall demonstrate, through laboratory SOPs, that it will follow appropriate EPA SW 846 requirements and the requirements specified by the EPA protocols. The laboratory shall also provide documentation to the WIPP describing the sensitivity of laboratory instrumentation. This documentation will be retained in the facility operating record and will be available for review upon request by an authorized agency. Instrumentation sensitivity needs to be considered because of regulatory requirements governing constituent concentrations in groundwater and the complexity of brines associated with the WIPP repository.

Once the initial qualification criteria, as specified above, have been met, a laboratory will be selected based upon competitive bid. The selected laboratory will perform analytical work for the DMP for a predetermined period of time, as specified in the contract between WTS and the selected laboratory. As this period of performance comes to an end, a new laboratory selection/competitive bid process will be initiated. The same or a different laboratory may be selected for the new contract period. The SOPs for the laboratory currently under contract will be maintained in a file in the operating record. An initial set of SOPs will be provided to the NMED for information purposes along with any SOP updates on an annual basis.

Data validation will be performed by EM&H. Data validation results are documented on an Approval/Variation Request (AR/VR) form. If no discrepancies are found in the data, the AR/VR form will be signed and the approved box will be checked. If however, discrepancies are found, the AR/VR form will be signed and the disapproved or approved-on-condition box will be checked and the form will be returned to the team leader accompanied by an attached report discussing the data validation results, any anomalies, and resolutions. Copies of the data validation report will be distributed to the EM&H manager, the QA manager, the Team Leader, and the Contract Administrator. Copies of the data validation report will be kept on file in the EM&H records for review upon request by the NMED.

6.0 CALIBRATION

6.1 Sampling Equipment Calibration Requirements

The equipment used to collect data for the WQSP and the DMP will be calibrated in accordance with maintenance administrative procedures. EM&H will be responsible for calibrating needed equipment on schedule, in accordance with written procedures. EM&H will also be responsible for maintaining current calibration records for each piece of equipment.

6.2 Groundwater Surface Elevation Monitoring Equipment Calibration Requirements

The equipment used in taking groundwater surface elevation measurements will be maintained in accordance with WIPP procedures. EM&H will be responsible for calibrating the needed equipment on schedule in accordance with written procedures. EM&H will also be responsible for maintaining current calibration records for each piece of equipment.

7.0 STATISTICAL ANALYSIS OF LABORATORY DATA

As required by 20.4.1.500 NMAC (incorporating 40 CFR §§264.97 and 264.98), data collected to establish background groundwater quality and as part of the DMP will be evaluated using appropriate statistical techniques. The following specifies the statistical analysis to be performed by the DMP. Statistical analysis of DMP data will conform to EPA guidance *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (EPA, 1989), *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance* (EPA, 1992), and DOE/EH-0173T, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*.

7.1 Temporal and Spatial Analysis

Environmental parameters vary with space and time. The effect of one or both of these two factors on the expected value of a point measurement will be statistically evaluated through spatial analysis and time series analysis. These methods often require extensive sampling efforts that may exceed the practical limits of the DMP sampling procedures.

Spatial analysis may have limited use during the operational period, although the effect of spatial auto-correlation on the interpretation of the data will be considered for each parameter. Spatial variability will be accounted for by the use of predetermined key sampling locations. Data analysis will be performed on a location-specific basis, or data from different locations will be combined only when the data are statistically homogeneous. Statistical homogeneity will be determined by evaluating mean values and variances from the residuals from the individual well data.

Time series analysis plays a more important role in data analysis for the DMP. Parameters will be reported as time series, either in tabular form or as time plots. For key time series parameters, these plots will be in the form of control charts on which control levels will be identified based on preoperational database, fixed standards, control location databases, or other standards for comparison. Where significant seasonal changes in the expected value of the parameter are identified in the preoperational database or in the control locations, corrections in the control levels which reflect the seasonal change will be made and documented.

7.2 Distributions and Descriptive Statistics

For data sets which include more than ten data points that are homogeneous in space and time (including seasonal homogeneity) and have less than 10 percent missing data, a test for conformance to the normal distribution will be performed. The test for normality of the data will be performed in accordance with the methodologies presented in *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance* (EPA, 1992). Examples of tests performed on the data are the Shapiro-Wilk Test or the Kolmogorov-Smirnov Test. At the 95 percent confidence level, there is only a one-in-twenty chance of falsely identifying the distribution as normal when it really is not.

If normality is not met, the data will be log-transformed (or transformed using a suitable mathematical transformation [e.g., square root]) and retested for normality. If the transformed data fit a normal distribution, the original data will be accepted as having lognormal or an otherwise mathematically transformed normal distribution. If normality is still not found, two courses may be taken. One will be to continue to test the fit to standard families of distributions, such as the gamma, beta, and Weibull, with proper modifications to subsequent analyses based on these results. The other course will be to use nonparametric methods of data analysis. Nonradiological data sets with greater than 15 percent nondetect are automatically treated as nonparameteric distributions.

For data sets smaller than ten, but homogeneous and complete, the lognormal distribution will be assumed. Data sets with more than 10 percent missing data will be analyzed using nonparametric methods. Nonhomogeneous data sets will be subdivided into homogeneous sets and each of these analyzed individually.

Descriptive statistics will be calculated for each homogeneous data set. At a minimum, these include a central value and a range of variation. The central value is the arithmetic mean of the untransformed data if the data are not censored at either end. If the data are censored, either a trimmed mean or the median will be used as the central value (which may be within the censored range). If the data set is greater than ten and is uncensored, the standard deviation will be calculated and used as a basis for the reported range in variation. If these criteria are not met, the range between the 0.25 and 0.75 cartelist will be used. Radiological normally distributed data with a small number of extreme or less than detectable values, the arithmetic mean is the estimator of central tendency. When data set contains large extreme values, the median, which is less sensitive to extreme values than the mean, will be used to summarize the data. All of the actual values, including those that are negative will be included in the statistical analysis for radiological data. Radiological data will also be transformed to approximate a normal distribution before the central values are calculated. Most often a log transformation will normalize environmental data.

7.3 Data Anomalies

Data anomalies include data points reported as being below the limit of detection (LD) or otherwise censored over a specific range of values, missing data points occurring randomly in the data set, and outliers that cannot be ascribed to a known source of variation.

Whenever possible, sample values that are reported below detection limits will be incorporated into the database as sample values measured at one-half the detection limit for statistical analysis. When values are not available, alternative methods of analysis, as specified in previous sections, will be used. In particular, the use of nonparametric statistics will be required.

Missing data points comprising less than 10 percent of the data set do not significantly affect data analyses. Results based on data in which more than 10 percent is missing will be identified as such at the time of reporting. Consideration of the potential effect of missing data shall be made when the majority of the data are missing from a discrete time span.

Formal testing for outliers will only be done in accordance with EPA guidance. The methodologies specified in Section 8.2 of the *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (EPA, 1989) will be used to check for outliers.

If an outside source of variation is not identified to account for outliers in a data set, it will be included in the data set and all subsequent analyses. If the inclusion of such outliers is found to affect the final results of the analyses significantly, both results (with and without outliers) will be reported. Radiological outliers will be tested with respect to the mean or median of the entire data set for outliers. Trend analyses on radiochemical data will be performed by comparing the results for the current year with the results of last several years to identify changes or inconsistencies in the results. Radiological data will also be plotted in time series for historical comparison. Data points falling outside ± 3 standard deviations could be considered outliers. Time plot and other yearly or seasonal trends in the data should be considered to reject/accept outliers.

8.0 COMPARISONS AND REPORTING

Prior to waste receipt, measurements will have been made of each background groundwater quality parameter and constituent specified in Table 3 at every DMP groundwater monitoring well during each of the four background sampling events. If any background groundwater quality parameter or constituent has not been measured prior to waste receipt, measurements will be made for those parameters or constituents in hydraulically upgradient DMP groundwater monitoring wells for a sequence of four sampling events. Following completion of the four sampling events, the arithmetic mean and variance shall then be calculated by the field supervisor or designee for each well. These measurements will then serve as a background value against which statistical values for subsequent sampling events during detection monitoring will be compared. Statistical analysis and comparison will be accomplished within sixty days after the final sample is taken, using one of the five statistical tests specified in 20.4.1.500 NMAC (incorporating 40 CFR §264.98[h]), which may include Cochran's Approximation to the Behrens-Fisher students' t-test at the 0.01 level of significance (described in Appendix IV to 20.4.1.500 NMAC (incorporating 40 CFR Part 264). If the comparisons show a significant increase at any monitoring site (as defined in 20.4.1.500 NMAC (incorporating 40 CFR §264.98[f]), the well shall be resampled and an analysis performed as soon as possible, in accordance with 20.4.1.500 NMAC (incorporating 40 CFR §264.98[g][2]) (HWFP Requirement V.J.3.b). The results of the statistical comparison will be reported annually in the Site Environmental Report, and will be reported to the NMED as stated in Module V, Section V.J.3 of the WIPP HWFP and as required under 20.4.1.500 NMAC (incorporating 40 CFR §264.98[g]).

8.1 Reporting

8.1.1 Laboratory Data Reports

Laboratory data will be provided in electronic and hard copy reports. Laboratory data reports will be forwarded to the Team Leader and the NMED and will contain the following information for each analytical report:

- A brief narrative summarizing laboratory analyses performed, date of issue, deviations from the analytical method, technical problems affecting data quality, laboratory quality checks, corrective actions (if any), and the project manager's signature approving issuance of the data report.
- Header information for each analytical data summary sheet, including sample number and corresponding laboratory identification number; sample matrix; date of collection, receipt, preparation and analysis; and analyst's name.
- Analytical parameter, analytical result, reporting units, reporting limit, analytical method used.
- Results of QC sample analyses for all concurrently analyzed QC samples.

8.1.2 Statistical Analysis and Reporting of Results

Analytical results from semiannual groundwater sampling activities will be compared and interpreted by the Team Leader through generation of statistical analyses as specified in Section L-4e of the HWFP. The Team Leader will perform statistical analyses; the results will be included in the Site Environmental Report in summary form, and will also be provided to the NMED as specified in Permit Module V (HWFP Section V.J.2).

8.1.3 Site Environmental Report

Data collected from the DMP will be reported to the NMED as specified in Permit Module V, and to the Hydrology manager and the NMED in the Site Environmental Report. The Site Environmental Report will include all applicable information that may affect the comparison of background groundwater quality and groundwater surface elevation data through time. This information will include, but is not limited to:

- Well configuration changes that may have occurred from the time of the last measurement (i.e., plug installation and removal, packer removal and reinstallation, or both; and the type and quantity of fluids that may have been introduced into the test wells).

- Any pumping activities that may have taken place since publication of the last annual report (i.e., groundwater quality sampling, hydraulic testing, and shaft installation or grouting activities).

The DMP data used in generating the Site Environmental Report will be maintained as part of the WIPP operating record and will be provided to the NMED for review as specified in the HWFP.

9.0 RECORDS MANAGEMENT

Records generated during groundwater sampling and groundwater surface elevation monitoring events will be maintained in accordance with the WTS Records Management Program (WP15-PR) in the EM&H project files (operating record). Project records will include, but are not limited to:

- Sampling and Analysis Plans (SAPs)
- SOPs
- STLBs
- RFA and CofC forms
- Contract Analytical Laboratory Data Reports
- Variance Logs and Nonconformance Reports
- Corrective Action Reports.

These and all raw analytical records generated in conjunction with groundwater sampling and groundwater surface elevation monitoring will be stored in fire-resistant cabinets according to the Records Management Program (WP 15-PR) and the EM&H Records Inventory and Disposition Schedule (RIDS) and will be made available for inspection upon request. The following records will be transmitted to the Project Records Services (PRS) for long-term storage in accordance with the RIDS:

- Instrument maintenance and calibration records
- QC sample data
- Control charts and calculation
- Sample tracking and control documentation
- Raw analytical results

10.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

10.1 Environmental Monitoring and Hydrology Manager

The EM&H manager will be responsible for the overall design and implementation of the DMP. The EM&H manager will develop and approve specific procedures all DMP activities, and will review and approve programmatic reports. The EM&H manager will provide oversight of appropriate levels of cooperation and consultation between EM&H and the state of New Mexico regarding groundwater monitoring and will revise the QA section of the DMP, if necessary, and submit revisions as permit modifications as specified in 20.4.1.900 NMAC (incorporating 40 CFR §270.42).

The EM&H manager and staff will be responsible for achieving and maintaining quality in the DMP. All DMP data will be reviewed and approved by the EM&H manager, or designee, prior to release.

The EM&H manager will establish minimum qualification criteria and training requirements for all DMP personnel. The EM&H manager will assure that position descriptions for assigned DMP personnel are adequately prepared. The EM&H manager and/or Team Leader will assure that training is performed on an individual basis to maintain an acceptable level of proficiency by all new or temporary DMP staff and by all permanent GWSP staff. The EM&H manager will assure that documents detailing all staff training are current and properly filed. Copies of training records will be on file in the WTS Technical Training Section.

The EM&H manager will appoint a DMP Team Leader and field team, and assign the responsibilities specified below.

10.2 Team Leader

The Team Leader will coordinate and oversee field sampling activities, ensuring that sampling and associated procedures will be followed and that QA/QC and safety guidelines will be met. The Team Leader will direct the DMP per written approved procedures, and initiate the review of programmatic plans and procedures. The Team Leader will review and evaluate sample data, prepare and review programmatic reports, and assure that appropriate samples will be collected and analyzed. The Team Leader will assure that adequate technical support is provided to the QA Department, when required during audits of vendor facilities. Any nonconformances or project changes will be immediately communicated to the Team Leader.

10.3 Field Team

The field team members will consist of one or more scientists, engineers, or technicians, who will be responsible for sample collection, handling, shipping, preparation and maintenance of appropriate data sheets, and completion of sample tracking documentation under the direction of the Team Leader, in accordance with the DMP and associated field procedures. The field team will inspect, maintain, and ensure proper calibration of equipment prior to use at each site, while ensuring that site health and safety requirements are met at all times. The field team will communicate any nonconformances, malfunctions, or project changes to the Team Leader immediately.

10.4 Industrial Safety Manager

The Industrial Safety manager will be responsible for ensuring that the necessary requirements for the health and safety of personnel associated with sampling and analysis activities are met. The cognizant manager will be responsible for ensuring that field team members operate in a safe manner and personnel have appropriate training. The Industrial Safety manager will ensure that periodic health and safety assessments are conducted and that the cognizant manager will initiate corrective actions where deficiencies are identified.

10.5 Analytical Laboratory Manager

Sample collection containers supplied by the laboratory will be certified as clean by either the laboratory or their supplier. WIPP will supply containers for radiological samples. The analytical laboratory will be responsible for performing analyses in accordance with the DMP and regulatory requirements. The laboratory will maintain documentation of sample handling and custody, analytical results, and internal QC data. Additionally, the laboratory will analyze QC samples in accordance with this plan and its own internal QC program for indicators of analytical accuracy and precision. Data generated outside laboratory acceptance limits will trigger an investigation and, if appropriate, corrective action, as directed by the EM&H manager. The laboratory will report the results of the environmental sample and QC sample analyses and any necessary corrective actions that were performed. In the event that more than one analytical laboratory is used (e.g., for different analyses), each one will have the responsibilities specified above.

10.6 Quality Assurance Manager

The QA manager will provide independent oversight of the DMP, via the assigned cognizant QA engineer, to verify that quality objectives are defined and achieved. The QA manager will ensure objective, independent assessments of the DMP quality performance and the quality performance of the contract analytical laboratory. The QA manager has been delegated authority on behalf of the WTS General Manager, and will have access to work areas, identify quality problems, initiate or recommend corrective actions, verify implementation of corrective actions, and ensure that work will be controlled or stopped until adequate disposition of an unsatisfactory condition has been implemented.

11.0 QUALITY ASSURANCE REQUIREMENTS

Specific QA requirements for WIPP are defined in the WTS QAPD Requirements specific to the DMP are presented in this section.

11.1 QA Program Overview

The QA program was developed to ensure that integrity and quality are maintained for all samples collected and that equipment and records are maintained in accordance with EPA guidance. The QA program identifies data quality objectives (DQOs), processes for assuring sample quality, and processes for generating and maintaining quality records.

11.1.1 Data Quality Objectives

Data Quality Objectives (DQOs) are qualitative and quantitative statements that specify the quality of data required to support project decisions. DQOs will be established to ensure that the data collected will be of a sufficient and known quality for their intended uses. The overall DQO for this project will be to collect accurate and defensible data of known quality that will be sufficient to assess the concentrations of constituents in the groundwater underlying the WIPP area. The data generated thus far by the DMP has been used to establish background groundwater quality. For the purpose of the DMP, DQOs for measurement data will be specified in terms of accuracy, precision, completeness, representativeness, and comparability. Measurements of data quality in terms of accuracy and precision will be derived from the analysis of QC samples generated in the field and laboratory. Appropriate QC procedures will be used so that known and acceptable levels of accuracy and precision will be maintained for each data set. This section defines the acceptance criteria for each QC analysis performed. The following subsections define each DQO.

a. Accuracy

Accuracy is the closeness of agreement between a measurement and an accepted reference value. When applied to a set of observed values, accuracy is a combination of a random component and a common systematic error (bias) component. Measurements for accuracy will include analysis of calibration standards, laboratory control samples, matrix spike samples, and surrogate spike samples. The bias component of accuracy is expressed as percent recovery (%R). Percent recovery is expressed as follows:

$$\%R = \frac{(measured\ sample\ concentration)}{true\ concentration}\ x\,100$$

1. Accuracy Objectives for Field Measurements

Field measurements will include pH, SC, temperature, Eh, and static groundwater surface elevation. Field measurement accuracy will be determined using calibration check standards. Thermometers used for field measurements will be calibrated to the National Institute for Standards and Technology (NIST) traceable standard on an annual basis to assure accuracy. Accuracy of groundwater surface elevation measurements will be checked before each measurement period by verifying calibration of the device within the specified schedule. The QAPD, Section 2.4.4, Monitoring, Measuring, Test and Data Collection Equipment, outlines the basic requirements for field equipment use and calibration. WP10-AD.01, Metrology Program, contains instructions that outline protocols for maintaining current calibration of groundwater surface elevation measurement instrumentation.

2. Accuracy Objectives for Laboratory Measurements

Analytical system accuracy will be quantified using the following laboratory accuracy QC checks: calibration standards, laboratory control samples (LCSs), laboratory blanks, matrix and surrogate spike samples. Single LCSs and matrix spike and surrogate spike sample analyses will be expressed as %R. Laboratory analytical accuracy is parameter dependent and will be prescribed in the laboratory SOP.

b. Precision

Precision is the agreement among a set of replicate measurements without assumption or knowledge of the true value. Precision data will be derived from duplicate field and laboratory measurements. Precision will be expressed as relative percent difference (RPD), which is calculated as follows:

$$RPD = \frac{|(measured\ value\ sample\ 1 - measured\ value\ sample\ 2)|}{average\ of\ \ measured\ samples\ 1+2}\ x\ 100$$

1. Precision Objectives for Field Measurements

Precision of field measurements of water-quality parameters will meet or exceed required reporting levels. SC, pH, temperature, and optionally Eh will be measured during well purging and after sampling. SC measurements will be precise to ±10% pH to 0.10 standard unit, and temperature to 0.10°C, Eh to 10 millivolts (mV).

c. Precision Objectives for Laboratory Measurements

Precision of laboratory analyses will be assessed by performing the same analyses twice on LCSs with each analytical batch assessed at a minimum frequency of one in twenty groundwater samples for nonradiological parameters and 1 in 10 for radiological parameters. The laboratory will determine analytical precision control limits by performing replicate analyses of control samples. Precision measurements will be expressed as RPD. Laboratory analytical precision is also parameter dependent and will be prescribed in laboratory SOPs.

d. Contamination

In addition to measurements of precision and bias, QC checks for contamination will be performed. QC samples including trip blanks, field blanks, and method blanks will be analyzed to assess and document contamination attributable to sample collection equipment, sample handling and shipping, and laboratory reagents and glassware. Trip blanks will be used to assess VOC sample contamination during shipment and handling and will be collected and analyzed at a frequency of one sample per sample shipment. Field blanks will be used to assess field sample collection methods and will be collected and analyzed at a minimum frequency of one sample per 20 samples (5 percent of the samples collected). Method blanks will be used to assess contamination resulting from the analytical process and will be analyzed at a minimum frequency of one sample per 20 samples, or 5 percent of the samples collected. Evaluation of sample blanks will be performed following the *National Functional Guidelines for Organic Data Review* (EPA, 1991) and *Functional Guidelines for Evaluating Inorganics Analyses* (EPA, 1988). Only method blanks will be analyzed via wet chemistry methods. The criteria for evaluating method blanks will be established as follows: if method blank results exceed reporting limits, that value will become the detection limit for the sample batch. Detection of analytes of interest in blank samples may be used to disqualify some samples, which requires resampling and additional analyses on a case-by-case basis.

e. Completeness

Completeness is a measure of the amount of usable valid data resulting from a data collection activity, given the sample design and analysis. Completeness may be affected by unexpected conditions that may occur during the data collection process. Occurrences that reduce the amount of data collected include sample container breakage in the laboratory and data generated while the laboratory was operating outside prescribed QC limits. All attempts will be made to minimize data loss and to recover lost data whenever possible. The completeness objective for noncritical measurements (i.e., field measurements) will be 90 percent and 100 percent for critical measurements (i.e., compliance data). If the completeness objective is not met, the EM&H manager will determine the need for resampling on a case-by-case basis. Numerical expression of the completeness (%C) of data is as follows:

$$\%C = \frac{number\ of\ accepted\ samples}{total\ number\ of\ samples\ collected}\ x\ 100$$

f. Representativeness

Representativeness is the degree to which sample analyses accurately and precisely represent the media they are intended to represent. Data representativeness for the DMP will be accomplished through implementing approved sampling procedures and the use of validated analytical methods. Sampling procedures will be designed to minimize factors affecting the integrity of the samples. Groundwater samples will only be collected after well purging criteria have been met. The analytical methods selected will be those that will most accurately and precisely represent the true concentration of analytes of interest.

g. Comparability

Comparability is the extent to which one data set can be compared to another. Comparability will be achieved through reporting data in consistent units and collection and analysis of samples using consistent methodology. Aqueous samples will consistently be reported in units of measures dictated by the analytical method. Units of measure include:

- Milligrams per liter (mg/L) for alkalinity, inorganic compounds, and metals
- Micrograms per liter (µg/L) for VOCs.

Groundwater surface elevation measurements will be expressed as equivalent freshwater elevation in feet above mean sea level.

11.2 Design Control

The groundwater monitoring system was designed and will be maintained to meet specifications established in 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subpart F, and §§264.601 through 264.603).

11.3 Instructions, Procedures, and Drawings

Provisions and responsibilities for the preparation and use of instructions and procedures at WIPP are outlined in Section 1.4, Documents; Section 2.1.2, Implementing Procedures; and Section 4, Sample Control, and Quality Assurance Requirements, of the QAPD. Any activities performed for groundwater monitoring that may affect groundwater will be performed in accordance with documented and approved procedures which comply with the Permit and the requirements of 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subpart F).

Technical procedures, as specified elsewhere in the DMP, have been developed for each quality-affecting function performed for groundwater monitoring. The technical procedures unique to the DMP will be controlled by Site Environmental Compliance. The procedures are sufficiently detailed and include, when applicable, quantitative or qualitative acceptance criteria.

Procedures were prepared in accordance with requirements in Section 1.4, Documents; Section 2.1.2, Implementing Procedures; and Section 4, Sample Control, and Quality Assurance Requirements, of the QAPD.

11.4 Document Control

Document controls will ensure that the latest approved versions of procedures will be used in performing groundwater monitoring functions and that obsolete materials will be removed from work areas.

11.5 Control of Work Processes

Process control requirements, defined in the QAPD Section 2.1, Work Processes; and Section 4, Sample Control and Quality Assurance Requirements, are met, and will continue to be met, for the DMP.

11.6 Inspection and Surveillance

Inspection and surveillance activities will be conducted as outlined in Section 2.4, Inspection and Testing; and Section 3.2, Independent Assessment, of the QAPD. The QA Department will be responsible for performing the applicable inspections and surveillance on the scope of work. EM&H personnel will be responsible for performance checks as defined in applicable procedures and determined by WTS metrology laboratory personnel. Performance checks for the DMP will determine the acceptability of purchased items and assess degradation that occurs during use.

11.7 Control of Monitoring and Data Collection Equipment

QAPD Section 2.4.4, Monitoring, Measuring, Testing, and Data Collection Equipment, outlines the basic requirements for control and calibrating monitoring and data collection (M&DC). M&DC equipment shall be properly controlled, calibrated, and maintained according to WIPP procedures to ensure continued accuracy of groundwater monitoring data. Results of calibrations, maintenance, and repair will be documented. Calibration records will identify the reference standard and the relationship to national standards or nationally accepted measurement systems. Records will be maintained to track uses of M&DC equipment. If M&DC equipment is found to be out of tolerance, the equipment will be tagged and will not be used until corrections are made.

11.8 Control of Nonconforming Conditions

Section 1.3, Quality Improvement; and Section 4.4, Disposition of Nonconforming Samples, of the QAPD specify the system used at WIPP for ensuring that appropriate measures are established to control nonconforming conditions. Nonconforming conditions connected to the DMP will be identified in and controlled by documented procedures. Equipment that does not conform to specified requirements will be controlled to prevent use. The disposition of defective items will be documented on records traceable to the affected items. Prior to final disposition, faulty items will be tagged and segregated. Repaired equipment will be subject to the original acceptance inspections and tests prior to use.

11.9 Corrective Action

Requirements for the development and implementation of a system to determine, document, and initiate appropriate corrective actions after encountering conditions adverse to quality at WIPP are outlined in Section 1.3, Quality Improvement, of the QAPD. Conditions adverse to acceptable quality will be documented and reported in accordance with corrective action procedures and corrected as soon as practical. Immediate action will be taken to control work performed under conditions adverse to acceptable quality and its results to prevent quality degradation.

11.10 Quality Assurance Records

Section 1.5, Records, of the QAPD outlines the policy that will be used at WIPP regarding identification, preparation, collection, storage, maintenance, disposition, and permanent storage of QA records.

Records to be generated in the DMP will be specified by procedure. QA and RCRA operating records will be identified. This will be the basis for the labeling of records as "QA" or "RCRA operating" on the EM&H RIDS.

QA records will document the results of the DMP implementing procedures and will be sufficient to demonstrate that all quality-related aspects are valid. The records will be identifiable, legible, and retrievable.

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Table 1 - Hydrological Parameters for Rock Units above the Salado at WIPP							
Unit		Hydraulic Conductivity	Storage Coefficient	Transmissivity	Permeability	Thickness	Hydraulic Gradient
Santa Rosa		2×10^{-8} to 2×10^{-6} m/s (1) (2)	Specific capacity 0.029 to 0.041 ℓ/s/m	6×10^{-7} to 6×10^{-5} m^2/s (3)	10^{-10} m^2	0 to 91 m	0.001 (5)
Dewey Lake		10^{-8} m/s	Specific storage 1×10^{-5} (1/m) (2)	2.8×10^{-6} to 2.8×10^{-4} m^2/s (4)	5.01×10^{-17} m^2	152 m	0.001 (5)
Rustler	Forty-niner	1×10^{-13} to 1×10^{-11} m/s (anhydrite) 1×10^{-9} m/s (mudstone) (2)	Specific storage 1×10^{-5} (1/m) (2)	8×10^{-8} to 8×10^{-9} m^2/s	0 m^2	13 to 23 m	NA (6)
	Magenta	$1 \times 10^{-8.5}$ to $1 \times 10^{-6.5}$ m/s (2)	Specific storage 1×10^{-5} (1/m) (2)	4×10^{-4} to 1×10^{-9} m^2/s	6.31×10^{-14} m^2	7 to 8.5 m	3 to 6
	Tamarisk	1×10^{-13} to 1×10^{-11} m/s (anhydrite) 1×10^{-9} m/s (mudstone) (2)	Specific storage 1×10^{-5} (1/m) (2)	$<2.7 \times 10^{-11}$ m^2/s	0 m^2	26 to 56 m	NA (6)
	Culebra	$1 \times 10^{-7.5}$ to $1 \times 10^{-5.5}$ m/s (2)	Specific storage 1×10^{-5} (1/m) (2)	1×10^{-3} to 1×10^{-9} m^2/s	2.1×10^{-14} m^2	4 to 11.6 m	0.003 to 0.007 (5)
	Los Medraños	6×10^{-15} to 1×10^{-13} m/s 1.5×10^{-11} to 1.2×10^{-11} m/s (basal interval)	Specific storage 1×10^{-5} (1/m) (2)	2.9×10^{-10} to 2.2×10^{-13} m^2/s 2.9×10^{-10} to 2.4×10^{-10} m^2/s (basal interval)	0 m^2	29 to 38 m	NA (6)

Matrix characteristics relevant to fluid flow include values used in this table such as permeability, hydraulic conductivity, gradient, etc.

Table Notes:

(1) The Santa Rosa Formation is not present in the western portion of the WIPP site. It was combined with the Dewey Lake Red Beds in three-dimensional regional groundwater flow modeling (Corbet and Knupp, 1996), and the range of values entered here are those used in that study for the Dewey Lake/Triassic hydrostratigraphic unit.

(2) Values or ranges of values given for these entries are the values used in three-dimensional regional groundwater flow modeling (Corbet and Knupp, 1996). Values are estimated based on literature values for similar rock types, adjusted to be consistent with site-specific data where available. Ranges of values include spatial variation over the WIPP site and differences in values used in different simulations to test model sensitivity to the parameter.

(3) The range of values given here for transmissivity of the Santa Rosa is estimated for the center of the site. Transmissivity is the product of the thickness of the productive interval times its hydraulic conductivity. Thickness of the Santa Rosa is estimated to be 30 meters at the center of the WIPP site, and the range of derived transmissivities are based on the range of hydraulic conductivity values used by Corbet and Knupp (1996) for the combined Dewey Lake/Triassic unit.

(4) The range of values given here by transmissivity of the Dewey Lake is estimated for the center of the site. Transmissivity is the product of the thickness of the productive interval times its hydraulic conductivity. Thickness of the Dewey Lake is estimated to be 140 meters at the center of the WIPP site, and the range of derived transmissivities are based on the range of hydraulic conductivity values used by Corbet and Knupp (1996) for the combined Dewey Lake/Triassic unit.

(5) Hydraulic gradient is a dimensionless term describing change in the elevation of hydraulic head divided by change in horizontal distance. Values given in these entries are determined from potentiometric surfaces. The range of values given for the Culebra reflects the highest and lowest gradients observed within the WIPP site boundary. Values for the Dewey Lake and Santa Rosa are assumed to be the same as the gradient determined from the water table. Note that the Santa Rosa Formation is absent or above the water table in most of the controlled area, and that the concept of a horizontal hydraulic gradient is not meaningful for these regions.

(6) Flow in units of very low hydraulic conductivity is slow, and primarily vertical. The concept of a horizontal hydraulic gradient is not applicable.

Sources: Beauheim, 1986; Domenico and Schwartz, 1990; Domski, Upton, and Beauheim, 1996; Earlough, 1977.

Table 2 - WIPP Groundwater Detection Monitoring Program Sample Collection and Groundwater Surface Elevation Measurement Frequency

Installation	Frequency
Groundwater Quality Sampling	
DMP monitoring wells	Semiannually
All other WIPP surveillance wells	On special request only
Groundwater Surface Elevation Monitoring	
DMP monitoring wells	Monthly and prior to sampling events
All other WIPP surveillance well sites	Monthly
Redundant wells at all other WIPP surveillance well sites	Quarterly

Table 3 - Analytical Parameter List for the WIPP GMP

Background Ground-Water Quality

Indicator Parameters
pH, SC, TOC, TOX, TDS, TSS, Density

Parameters Listed in
20.4.1.500 NMAC (incorporating 40 CFR 264) Appendix IX, + Calcium, Magnesium, Potassium

Field Analysis
pH, SC, temperature, chloride, Eh, alkalinity, total fe, Specific gravity

Operational Parameters

Chemical Analysis

Alkalinity	Chloride
Nitrate (as N)	Sulfate
Total Organic Carbon (TOC)	
Total Organic Halogens (TOX)	

Physical Analysis

Total Dissolved Solids (TDS)	pH
Total Suspended Solids (TSS)	Density

Inorganic Metals

Antimony	Arsenic	Barium
Beryllium	Cadmium	Chromium
Lead	Mercury	Nickel
Selenium	Silver	Thallium
Vanadium	Calcium	Iron
Magnesium	Potassium	Sodium

Volatile Organic Compounds (VOCs)

1,1-dichloroethylene	Carbon Tetrachloride
Methylene Chloride	Chloroform
1,1,2,2-tetrachloroethane	1,1,1-trichloroethane
Chlorobenzene	1,2-dichloroethane
Toluene	1,1-dichloroethane
Vinyl Chloride	Xylenes (Total)
Methyl Ethyl Ketone	Tetrachloroethylene
cis-1,2-dichloroethylene	
trans-1,2 dichloroethylene	Trichloroethylene
Trichlorofluoromethane	1,1,2-trichloroethane

Semivolatile Organic Compounds (SVOCs)

Cresols (Total)	1,2-dichlorobenzene
2,4-dinitrophenol	Hexachloroethane
Pyridine	Nitrobenzene
1,4-dichlorobenzene	2,4-dinitrotoluene
Hexachlorobenzene	Pentachlorophenol

Radionuclides of Interest
K^{40}, Cs^{137}, Co^{60}, U^{234}, U^{235}, U^{238}, Pu^{238},$Pu^{239+240}$,Am^{241}

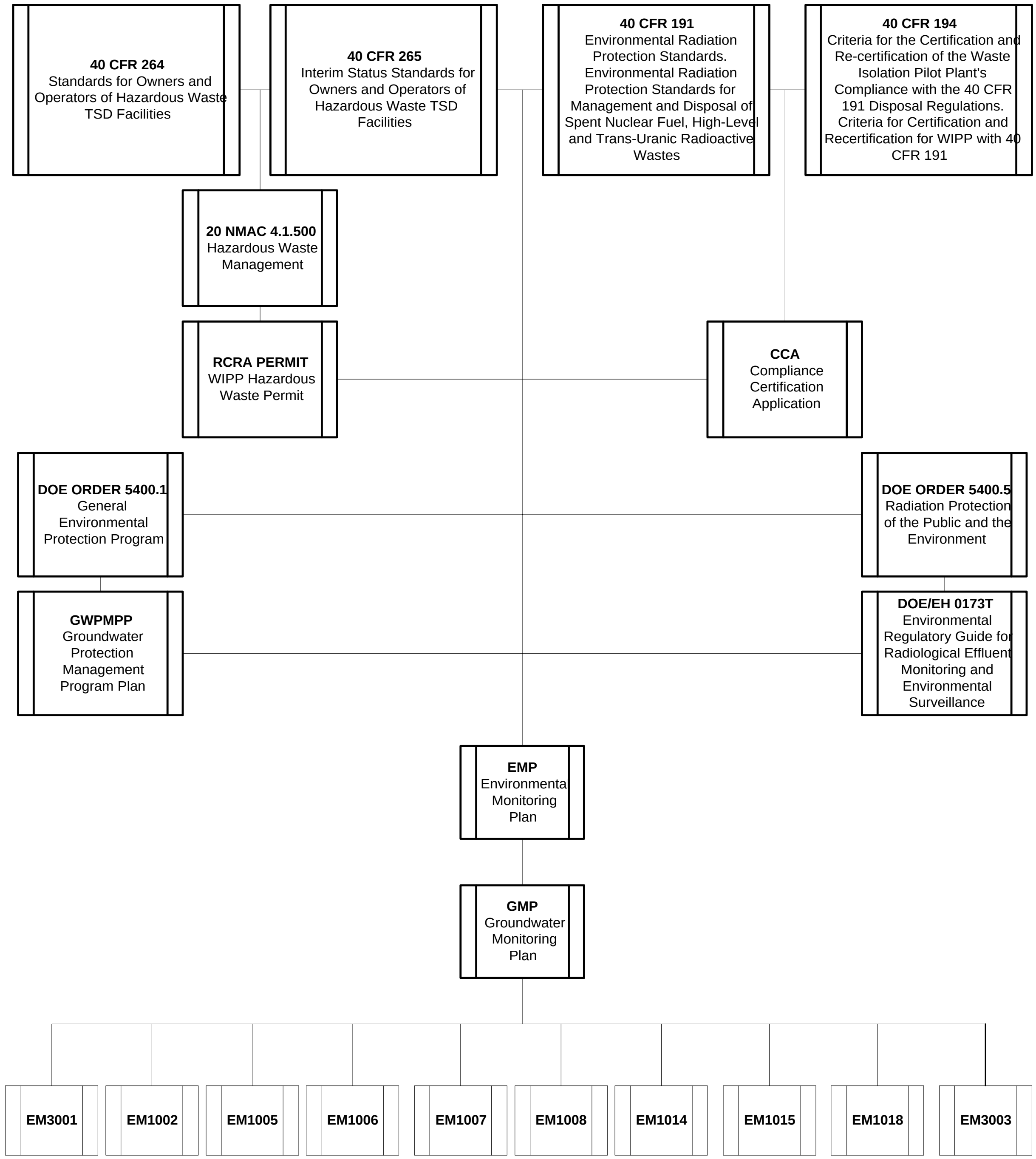
Table 4 - RCRA Permit Stipulations Requiring Actions, Reporting, or Notifications

Permit Stipulation	Action, Report or Notification Due date	Permit §
Determination of statistically significant contamination of parameters or constituents in table V.D.	Seven calendar days from determination.	V.J.3.a., V.J.4.a., L-4e(4)
If the Permittees determine, pursuant to permit condition V.I, that there is a statistically significant difference for parameters or constituents specified in Table V.D at any DMW at the Compliance point, they may demonstrate that a source other than a regulated unit caused the increase or that the detection is an artifact caused by an error in sampling, analysis, statistical evaluation, or natural variation in the groundwater.	Submittal of modification request-the permittees shall, within 90 calendar days, submit to the Secretary an application for a permit modification to make any appropriate changes to the DMP, as required by 20.4.1.500 NMAC.	V.J.4.c
Changes that occur that could affect the DMP's ability to fulfill the requirements of 20.4.1.500 NMAC.	Permit modification request. No time specified.	L-4a
Groundwater Flow results Report-Direction and Rate of flow in the Culebra.	Twelve months after permit issuance and annually thereafter.	V.J.2.c.,V.H
Background Water quality data report.	Prior to waste receipt.	V.F.3, L-4e(4)
For those parameters and constituents listed in Table V.D which the Permittees have not met the requirements of Permit Condition V.F1. For establishing background water quality at the time the Permit is approved, the Permittees shall collect additional background water quality data.	The permittees shall submit the background water quality data to the secretary within three months of complying with the permit condition V.F.1.	V.F.4.c
Groundwater Surface Elevation Results Report.	Thirty days after data are collected.	V.J.2b., L-4c(1)ii
DMP Statistical Comparison Report.	Annually in the Site Environmental Report.	L-4e(4)
The Permittees shall determine the groundwater flow rate and direction in the Culebra Member of the Rustler Formation at least annually.	Determine groundwater flow rate and direction annually.	V.H
For those parameters and constituents listed in Table V.D which the permittees have not met the requirements of Permit condition V.F.1 for establishing background groundwater quality at the time the Permit is approved, the permittees shall collect additional background groundwater quality data to comply with the following conditions.	The permittees shall collect background groundwater quality data only from hydraulically upgradient DMWs.	V.F.4.a-b
Evidence that a source other than a regulated unit caused groundwater contamination, or that contamination resulted from error in sampling, analysis, or evaluation.	Ninety calendar days from determination.	V.J.4.b
DMW plugging and abandoning Reports.	Ninety days after date DMW is removed from the DMP.	V. C.3
The Permittees shall collect one (1) DMP sample and (1) DMP sample duplicate semiannually from each DMW using the procedure specified in Permit Attachment L section, L-4c, as required by 20.4.1.500 NMAC (incorporating 40 CFR §§264.97[g][2], 264.98[d], and 264.601[a]).	Collect one sample and one duplicate sample semiannually.	V.E.1
DMP Data Evaluation Results Report.	Biannually.	V.J.2.a
Cumulative groundwater surface elevation changes more than 2 feet in any DMW during one year which is not attributable to site tests or natural stabilization.	Notification in writing (time not specified) Report in the Site Environmental Report.	L-4c(1), V.J.2.c

Table 4 - RCRA Permit Stipulations Requiring Actions, Reporting, or Notifications

Permit Stipulation	Action, Report or Notification Due date	Permit §
The permittees shall immediately, but no later than one (1) month, sample the groundwater in all DMWs specified in table V.C.1 for which there was statistically significant evidence of contamination. The remaining DMWs shall be sampled within two (2) months after statistically significant evidence of contamination is found in any DMW. All DMWs shall be sampled to determine the concentration of all substances identified in 20.4.1.500 NMAC (incorporating 40 CFR 264 appendix IX), as required by 20.4.1.500 NMAC (incorporating 40 CFR §264.98[g][2]).	Contaminated well within 1 month All other DMWs within 2 months.	V.J.3.b
Permittees may resample within one (1) month and repeat the analysis for those compounds detected. If the results of the second analysis confirm the initial analysis, these substances shall form the basis for compliance monitoring specified in permit condition V.J.3.d. If the permittees do not resample, the substances found during the initial analysis specified in condition V.J.3.b shall form the basis for compliance monitoring specified in permit condition V.J.3.d.	Resample within (1) month.	V.J.3.c
If the permittees determine, pursuant to Permit Condition V.I ... that there is statistically significant evidence of contamination for any parameter or constituent specified in Table V.D, the permittees shall comply with the following: ... The permittees shall within ninety (90) calendar days, submit to the secretary an application for a permit modification to establish a compliance monitoring program . . .	Submit an application for permit modification accompanied by a compliance monitoring program plan with in 90 days.	V.J.3.d
If the Permittees determine, pursuant to Permit Condition V.I ... that there is statistically significant evidence of contamination for any parameter or constituent specified in table V.D, the Permittees shall comply with the following: (i) All data necessary to justify an alternate concentration limit proposed in compliance with permit condition V.J.3.d.iv. (ii) An engineering feasibility plan for corrective action required by 20.4.1.500 NMAC (incorporating 40 CFR §264.100), if necessary.	Submit plan for corrective action within 180 calendar days accompanied by an engineering feasibility study if necessary.	V.J.3.e
The Permittees shall submit a report to the Secretary which summarizes and certifies DMW plugging and abandoning methods . . .	Ninety (90) calendar days from the date the DMW is removed from the DMP.	V.C.3
If the permittees determine, pursuant to Permit condition V.I that there is significant evidence of contamination for any parameter or constituents specified in Table V.d. . .	Submittal of compliance monitoring program within 90 calendar days with an application for a permit modification to establish a compliance monitoring program.	V.J.3.d
Releases have caused, or are expected to cause, concentrations of radionuclides or estimated doses due to radionuclides in underground sources of drinking water in the accessible environment to exceed the limits established pursuant to Part 191, Subpart C, or this Chapter.	Report to EPA, within 24 hours, in writing.	40 CFR 194.4(b)iic 40 CFR 194.4(b)iii

Note: Notifications to the NMED as specified in this table will be transmitted by the Site Environmental Compliance HWFP Compliance Team.



EM3001 - Administrative Processes for Environmental Monitoring
EM1002 - Electric Submersible Pump Monitoring System Installation and Operation
EM1005 - Groundwater Serial Sample Analysis
EM1006 - Final Sample and Serial Sample Collection
EM1007 - Cation and Anion Analysis
EM1008 - ONAN 35 DGBB Generator Set Operation
EM1014 - Groundwater Level Measurement
EM1015 - Water Quality Monitoring Using the YSI Model 3560 Monitoring System
EM1018 - ONAN 25DKAF Generator Set Operation
EM3003 - Data Validation and Verification of RCRA Constituents

Figure 1 - Hierarchy of Documents Governing the GMP

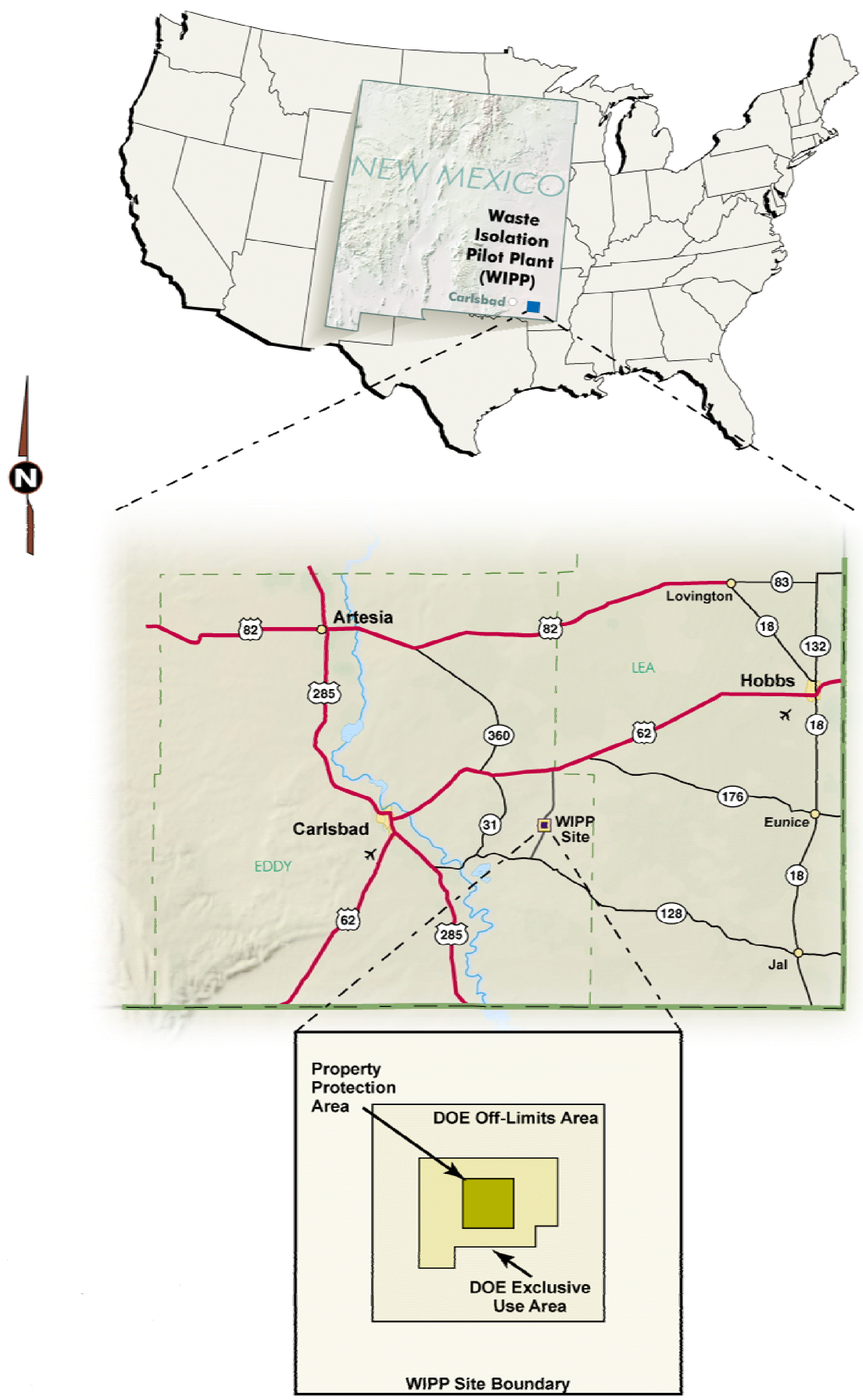


Figure 2 - WIPP Facility Location

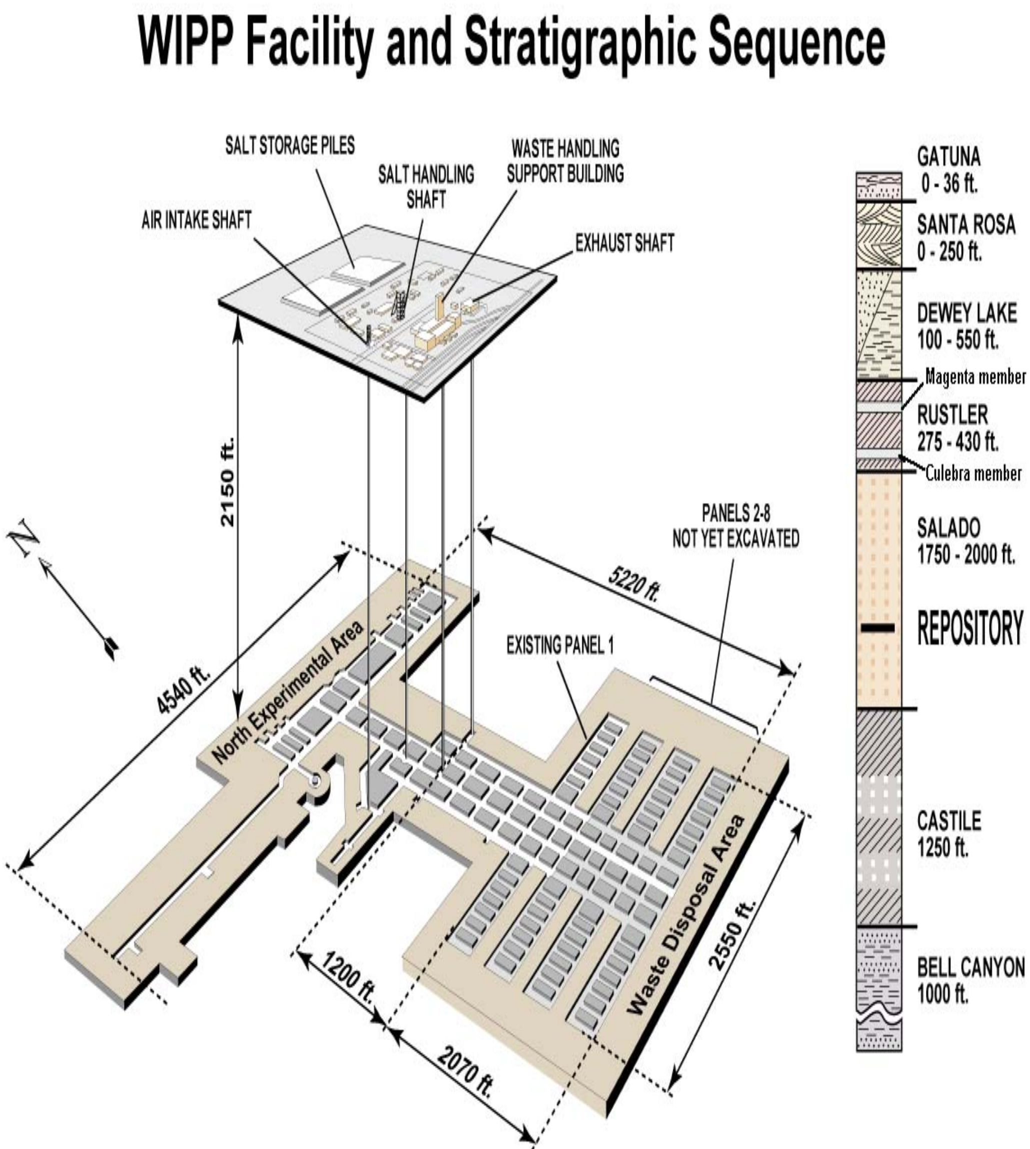


Figure 3 - Site Geologic Column

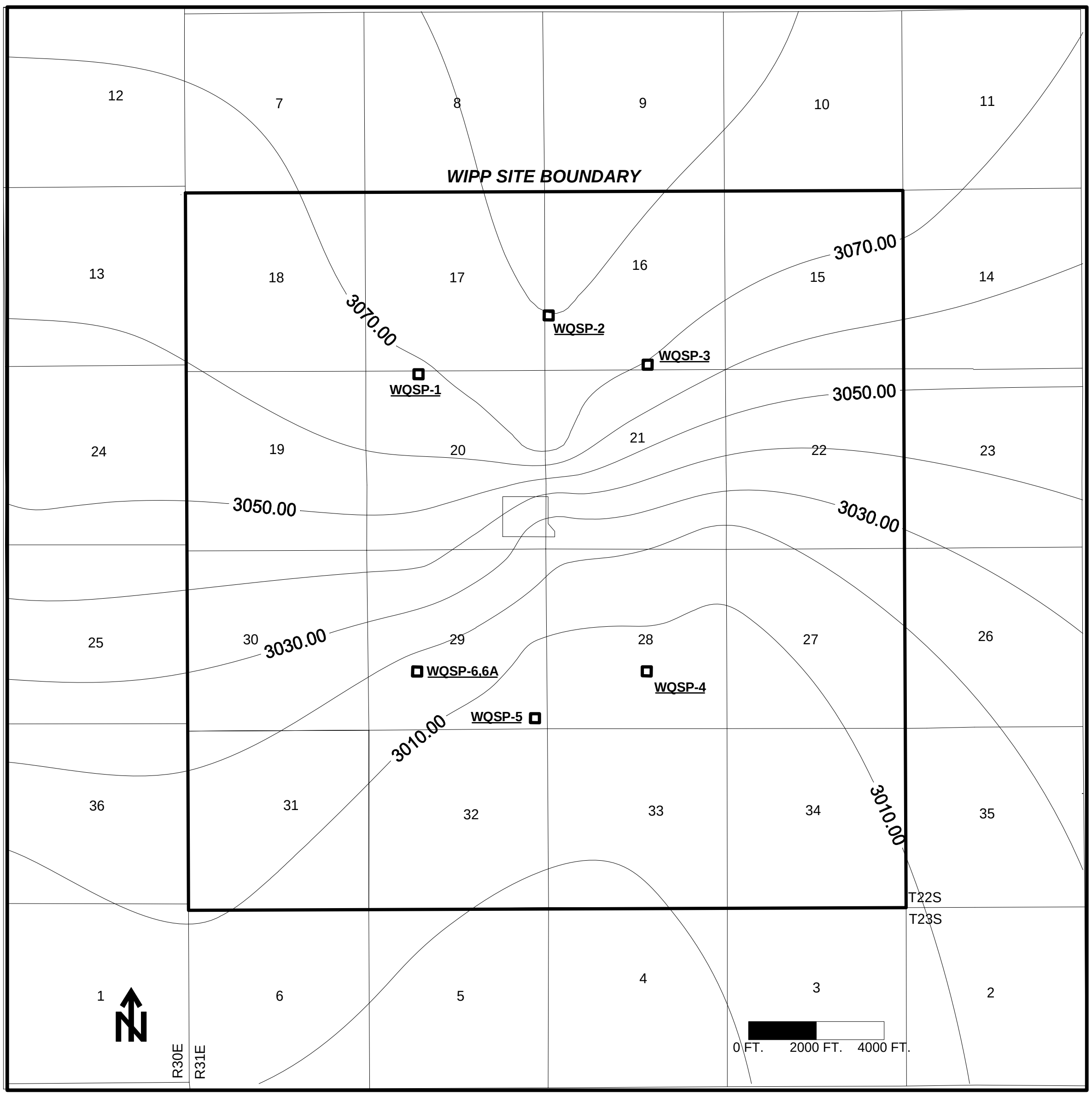


Figure 4 - WIPP DMW Configuration with Potentiometric Surfaces in Relationship to the WIPP Site

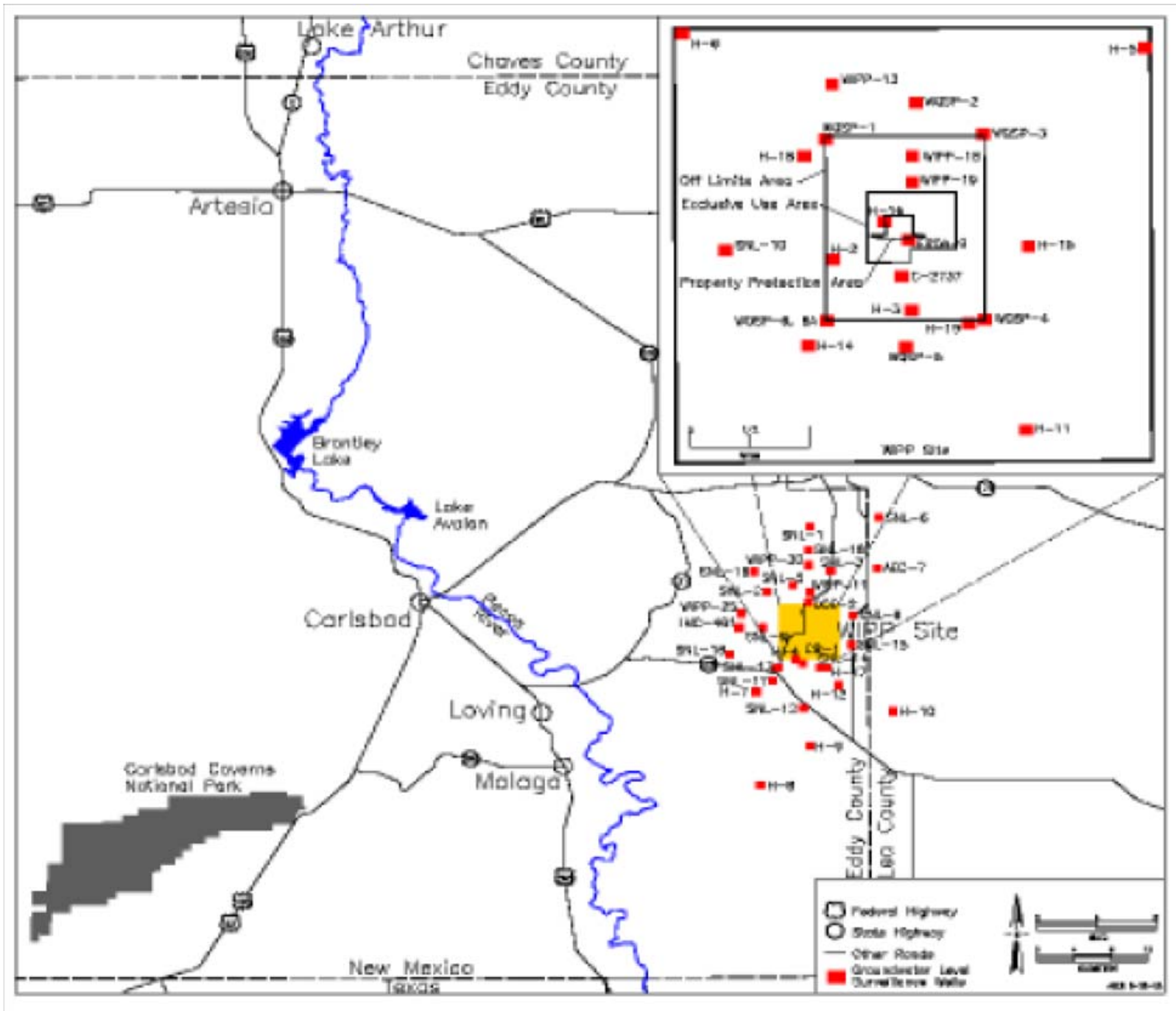


Figure 5 - WLMP Program Wells

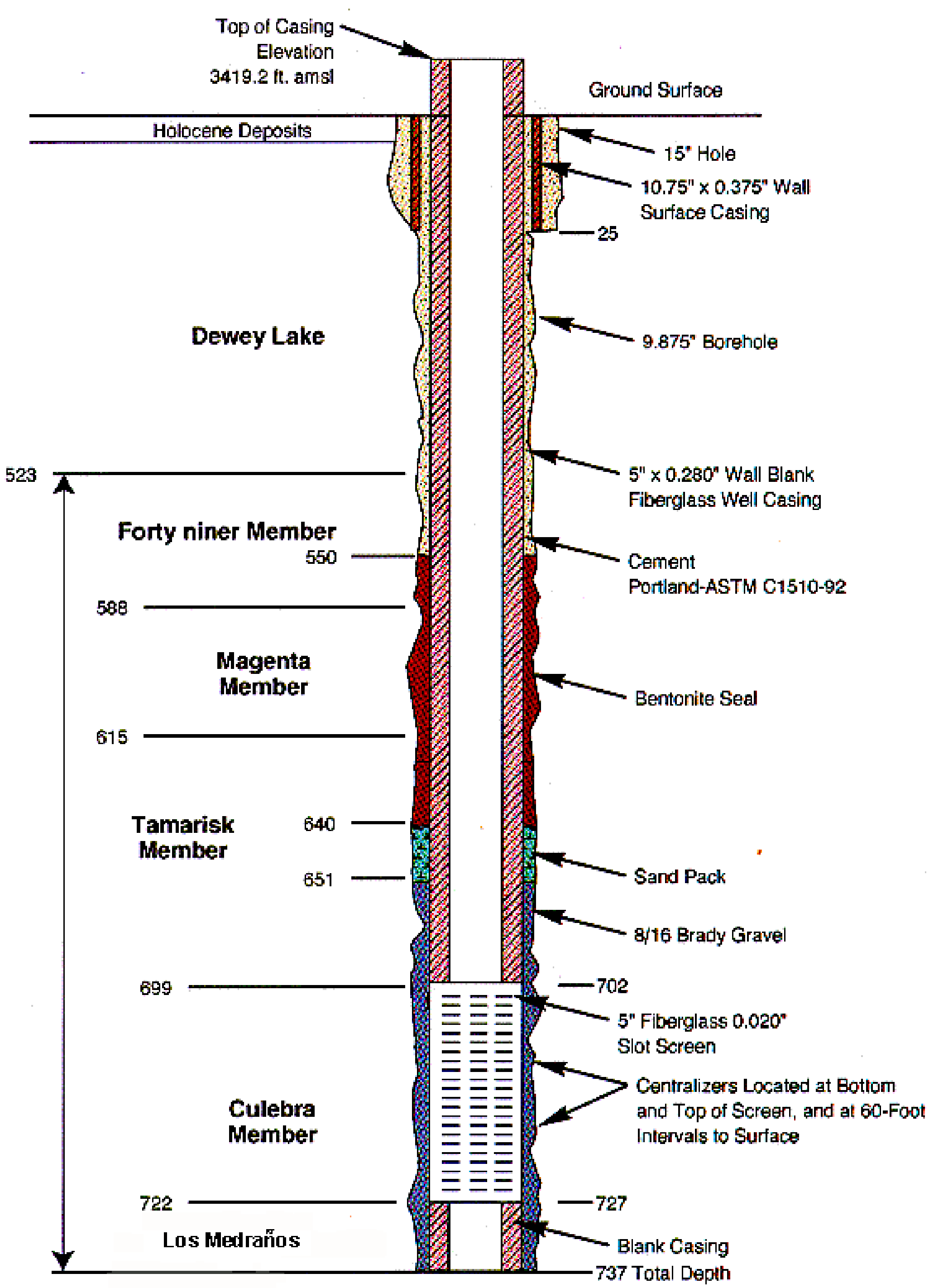


Figure 6 - As-Built Configuration of Well WQSP-1

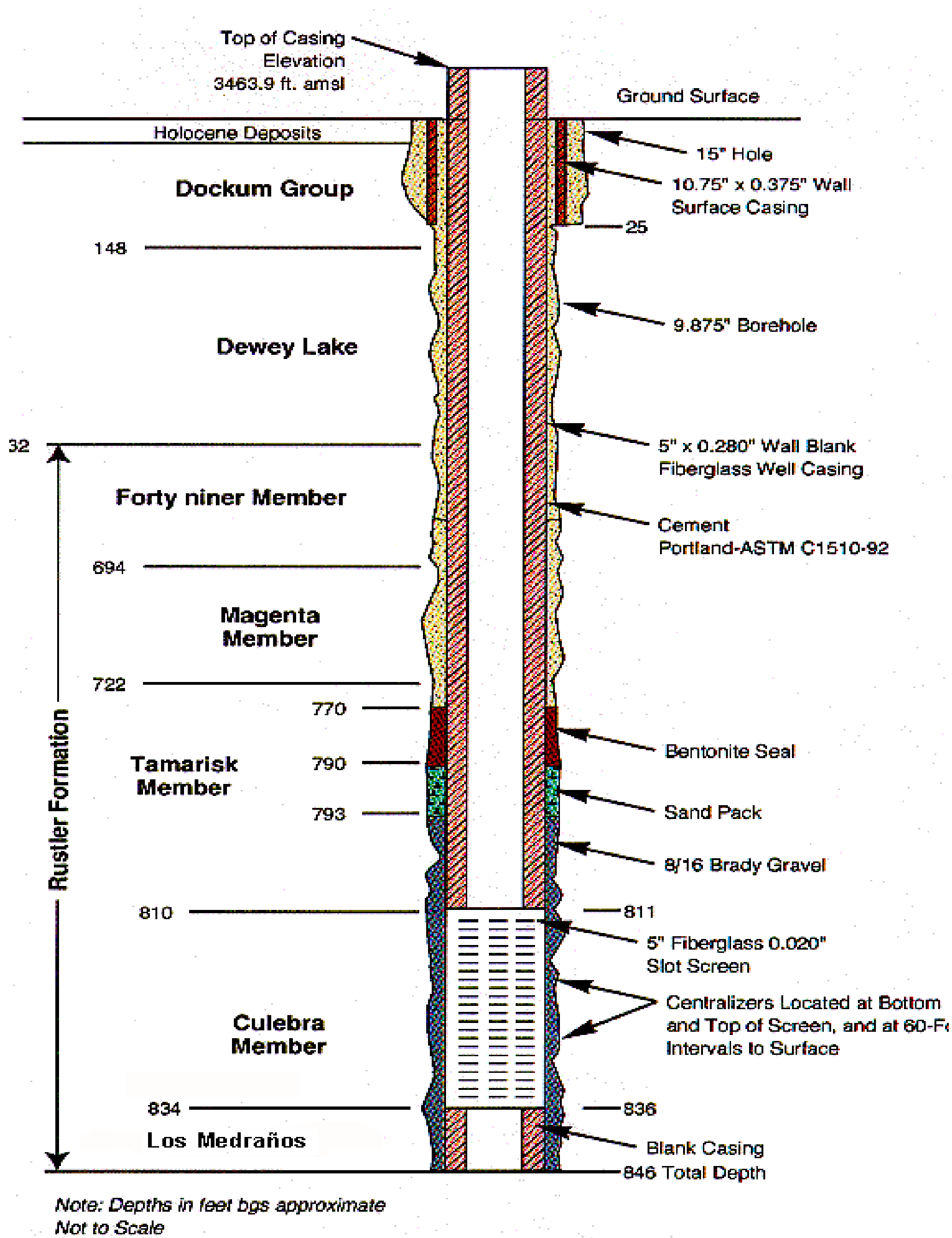


Figure 7 - As-Built Configuration of Well WQSP-2

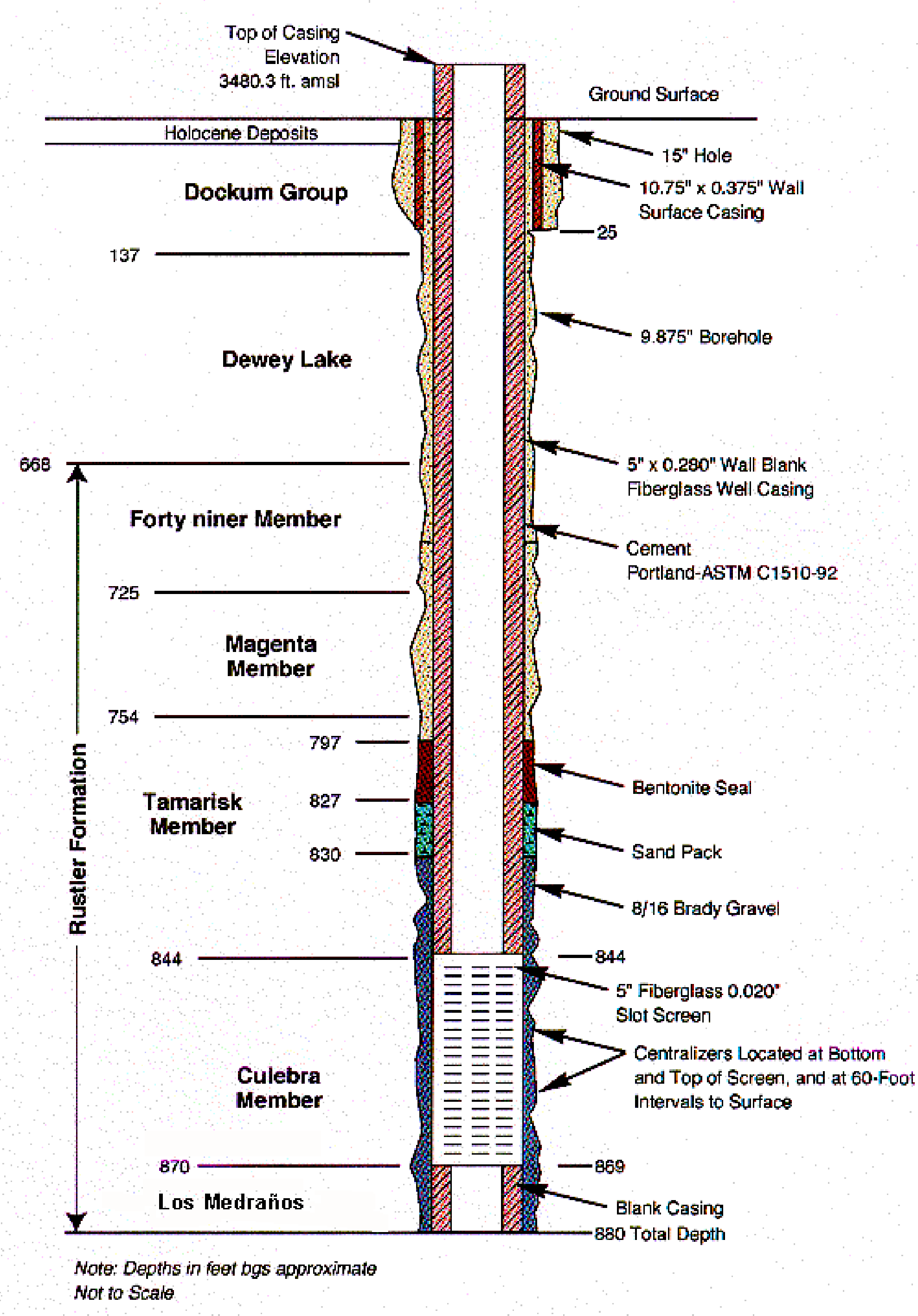


Figure 8 - As-Built Configuration of Well WQSP-3

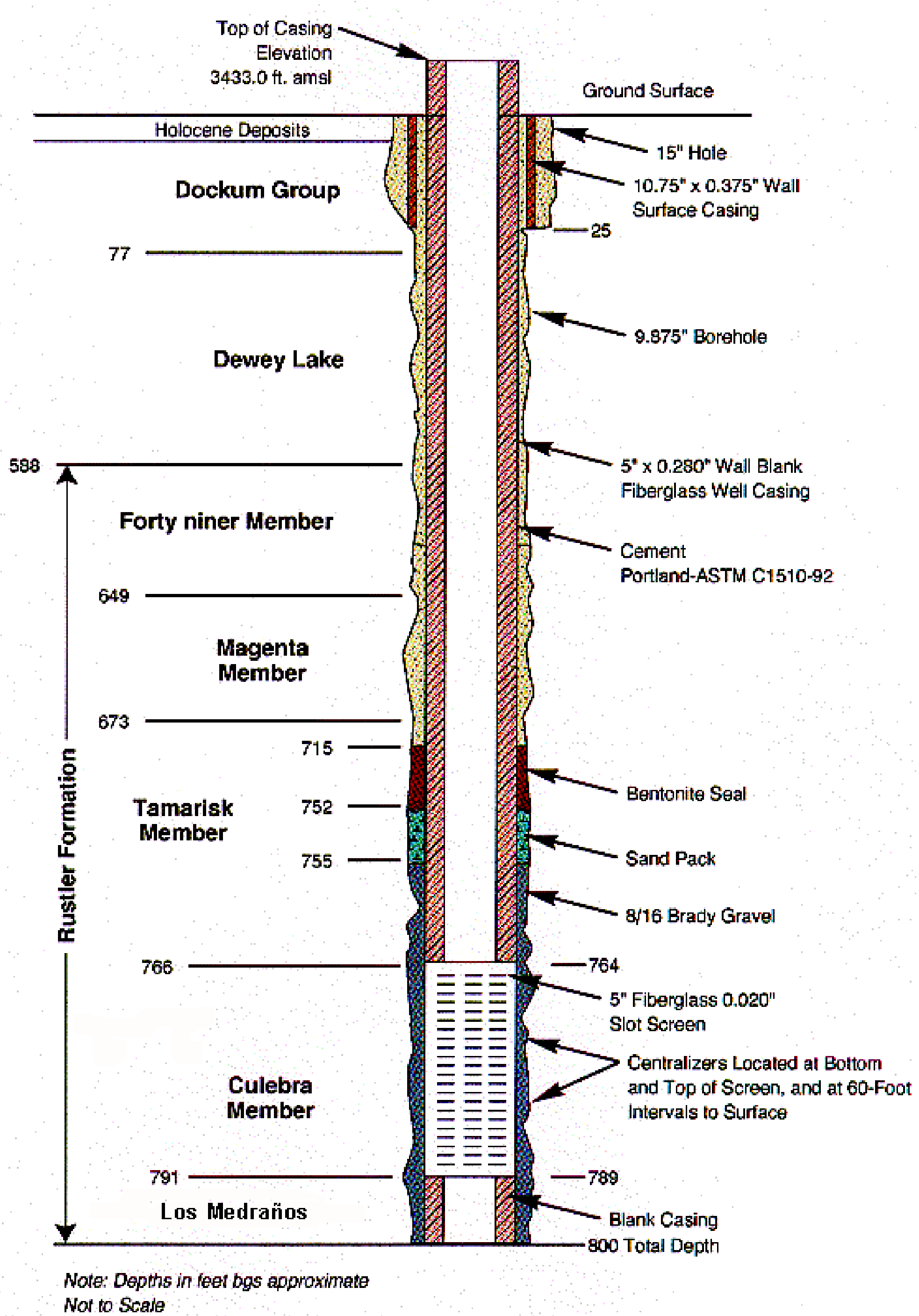


Figure 9 - As-Built Configuration of Well WQSP-4

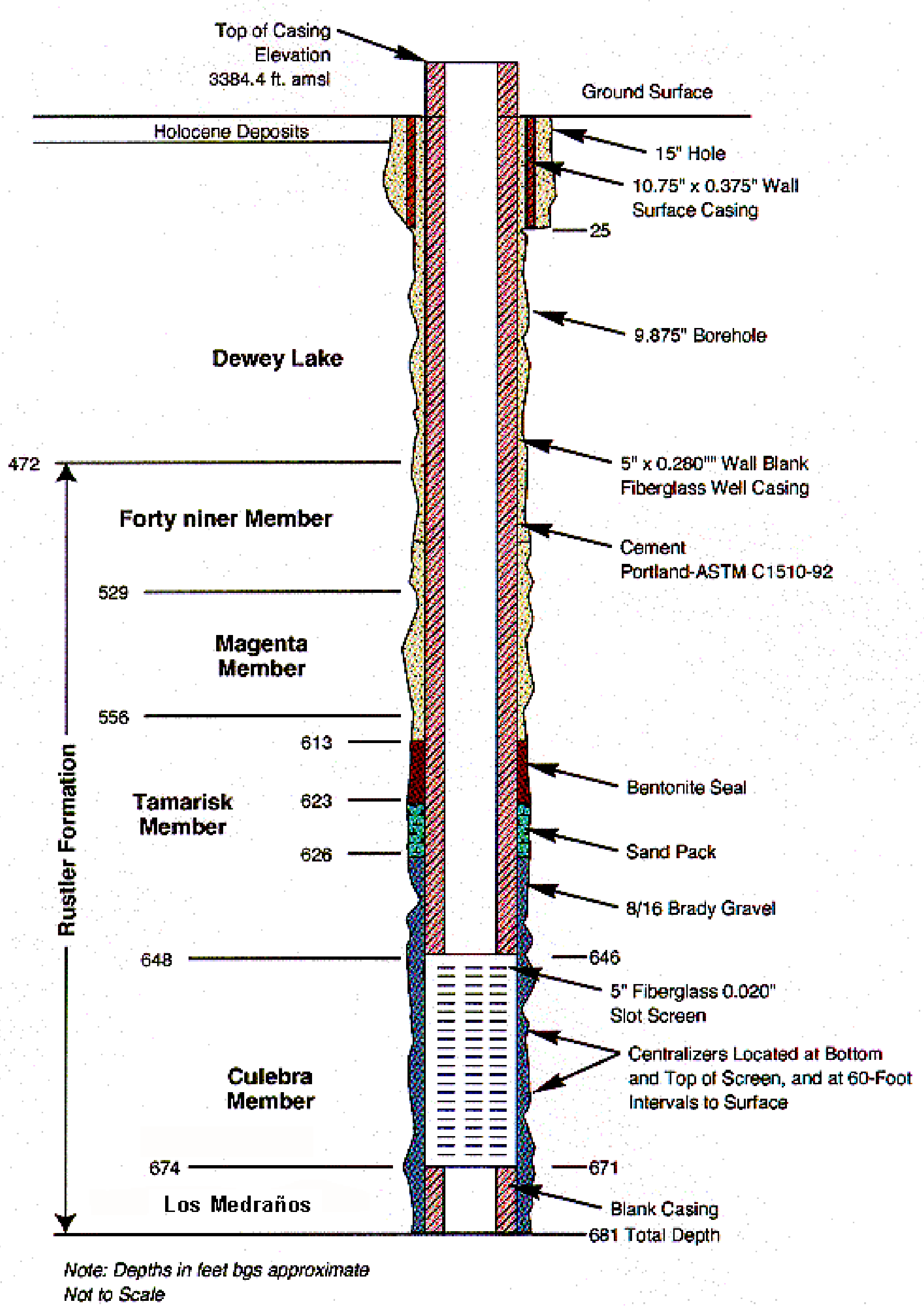


Figure 10 - As-Built Configuration of Well WQSP-5

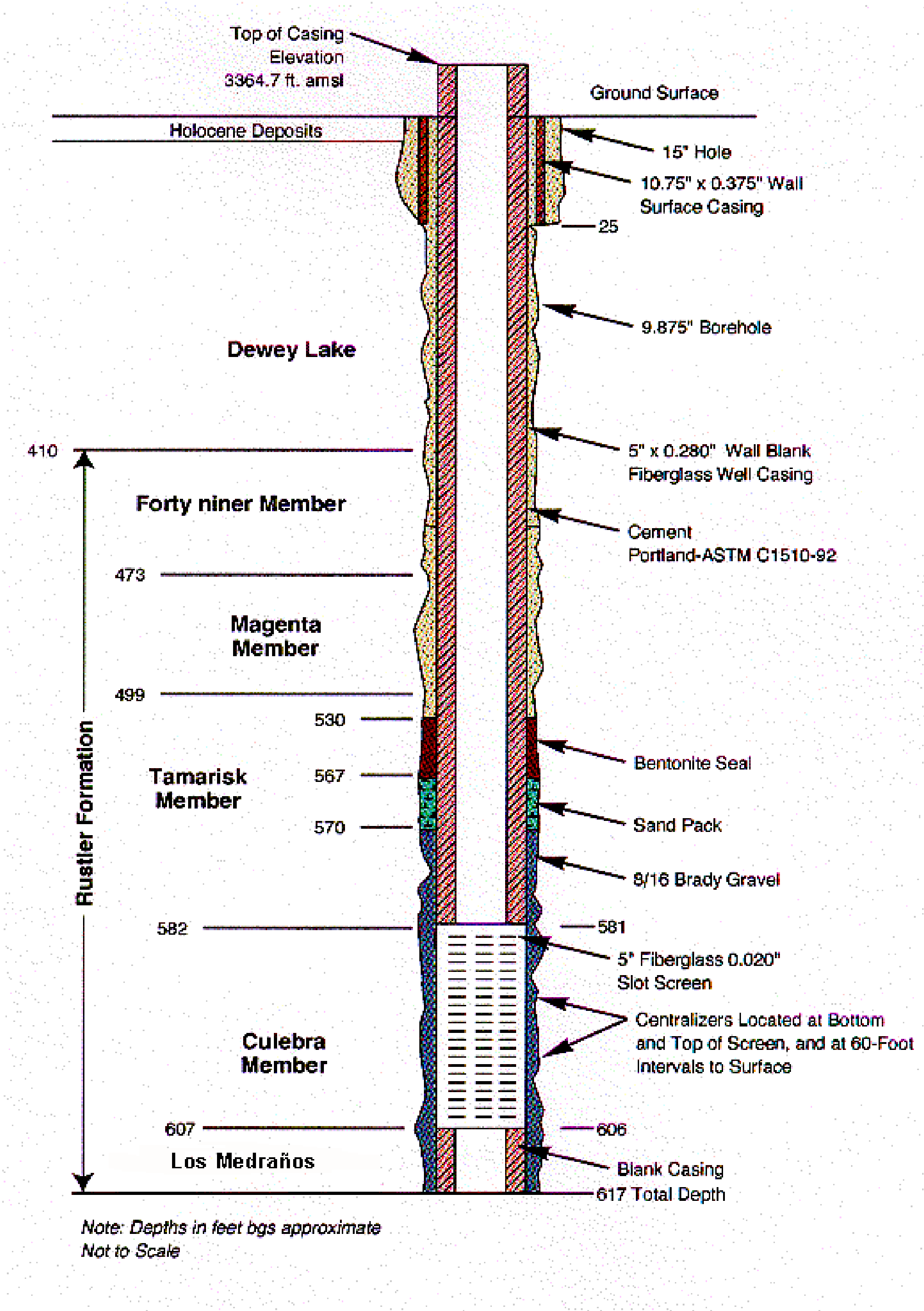


Figure 11 - As-Built Configuration of Well WQSP-6

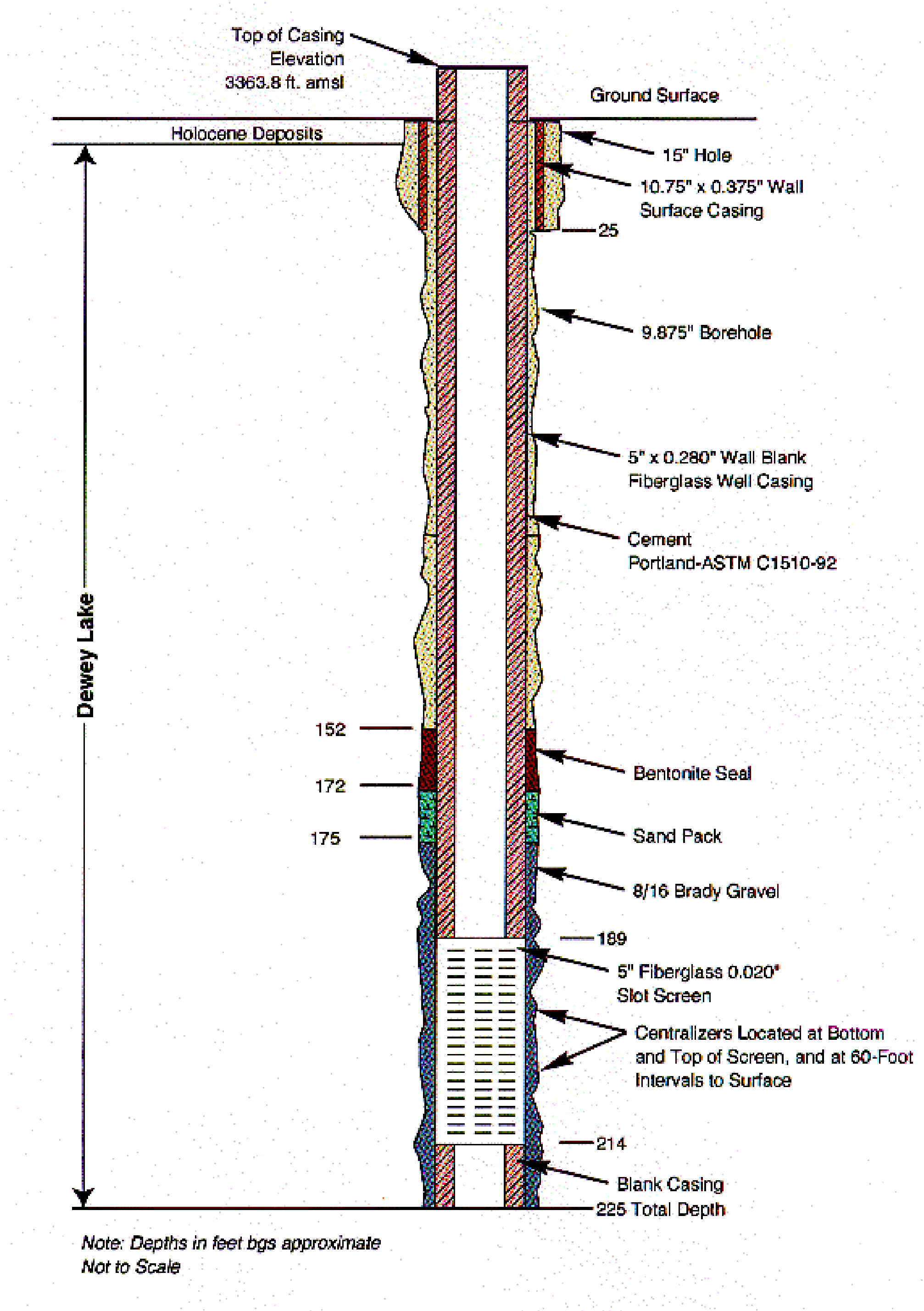


Figure 12 - As-Built Configuration of Well WQSP-6A