NYE COUNTY NUCLEAR WASTE REPOSITORY PROJECT OFFICE

WORK PLAN

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Surface Geophysical Surveys	DATE: 8-20-07
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WP-12.0	**None**

APPROVAL

8/20/07

Project Manager — Date

CONCURRENCE

Kathy Gilmore for OSGR 8/20/07

On-Site Geotechnical Representative — Date

8/20/07

Principal Investigator — Date

Quality Assurance Officer — Date 8-20-07

QUALITY ASSURANCE RECORD

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1.0 INTRODUCTION

This work plan (WP) has been prepared in accordance with the provisions of the Nye County Nuclear Waste Repository Project Office (NWRPO) quality administrative procedure (QAP) QAP-5.2, *Preparation of Work Plans, Test Plans, and Technical Procedures*. All NWRPO technical procedures (TPs), test plans (TPNs), WPs, and other quality assurance (QA) documents referenced herein are the most current versions of those documents.

2.0 PURPOSE

The purpose of this WP is to ensure that: NWRPO surface geophysical surveys are conducted and documented in a technically defensible manner consistent with the NWRPO QA program, in full compliance with regulatory requirements; and that these surveys support, to the maximum extent possible, all NWRPO Independent Scientific Investigations Program (ISIP) objectives and tasks.

3.0 BACKGROUND

The primary mission of the NWRPO is to protect the health, welfare, and safety of the population of Nye County. One of the tools the NWRPO uses to carry out this mission is independent characterization of the geologic, hydrologic, and hydrogeologic properties of the area between the proposed high level nuclear waste repository at Yucca Mountain and the potential receptor population in Amargosa Valley through its ISIP and Early Warning Drilling Program (EWDP).

The characterization of this area is important because the results of Department of Energy (DOE) Yucca Mountain Project (YMP) models have indicated that releases may occur from the repository at Yucca Mountain during the life of the repository. Characterization of this area allows Nye County to better evaluate methods of protecting its citizens in the event of a release from the repository. In addition, this characterization provides Nye County (and other interested parties) with independent data that will assist in evaluation of the YMP License Application, Site Scale Model, and Performance Confirmation analysis.

The ISIP has, historically, relied upon drilling and geologic sampling data from its EWDP as one of the primary means of characterization of this area (Figure 1). Drilling and geologic sampling, while valuable, are relatively expensive methods of obtaining point geologic data (e.g., data at one specific location). Some airborne and ground-based geophysical studies have been used to help plan borehole locations.

Several other activities have been utilized to provide additional information, including borehole geophysical logging, aquifer and tracer testing, water sampling, water level monitoring, and to a limited extent, surface and airborne geophysical surveys.

Surface geophysical methods provide a means to collect data to "fill in the gaps" between boreholes, as well as increase the understanding of the geologic, hydrologic, and hydrogeologic properties (e.g., to identify and image faults that may be barriers or conduits to groundwater movement) of the subsurface in the areas these surveys are conducted. These surveys also help refine drilling targets and objectives, and focus on smaller, more specific areas than airborne

surveys, thus increasing the effectiveness of boreholes in filling in subsurface geologic data gaps. These surveys also allow specific data gaps to be targeted over larger areas than a single borehole.

This WP describes all geophysical activities that will be conducted to fill data gaps within the region, such as: collection of technically defensible geophysical data; types of surveys that may be used to detect various geophysical targets, including the bedrock/alluvium interface, depth to water table, faults, and other objectives, as defined by the Principal Investigator (PI).

4.0 SCOPE OF WORK

Items specifically addressed in this WP include: methods and procedures for survey preparation, general methods for thorough documentation of survey parameters and results during the survey, and types of surveys. Several other ISIP field activities and procedures not specifically addressed by this WP, including geophysical logging, borehole drilling and well construction, aquifer and tracer testing, geophysical logging, health and safety, and environmental compliance are only described briefly and referenced in this WP.

4.1 Health, Safety, and Environmental Compliance

4.1.1 Health and Safety

NWRPO health and safety information, responsibilities, and procedures are described in detail in Health and Safety Plan HSP-1.0, *Independent Scientific Investigations Program Health and Safety Plan for General Field Activities*. NWRPO personnel will adhere to the provisions of HSP-1.0 when conducting the activities described in this WP.

4.1.2 Permitting and Environmental Compliance

No land-disturbing activities (e.g., building of roads for access, or the use of explosives as a seismic source) will take place until the necessary right-of-way grants have been approved and all necessary permits, permissions, and waivers have been obtained from the proper regulatory agency or landowner.

The NWRPO will obtain right-of-way grants (if necessary) from the BLM for the construction of roads, or access across undisturbed desert by motor vehicle (e.g., all-terrain vehicles). In addition, the NWRPO will obtain the necessary permits and permissions from the DOE for activities conducted on the Nevada Test Site.

Processes to ensure compliance with applicable federal and state of Nevada requirements for the handling of hazardous, nonhazardous, and universal wastes are described in Environmental Management Procedure EP-1.0, *Waste Management*. Wastes generated during the activities described in this WP will be handled and disposed of by NWRPO personnel in accordance with EP-1.0.

4.2 Types of Surface Geophysical Surveys

A brief overview of several typical surface geophysical survey types is given in the following subsections, as well as examples of typical applications of each survey type. This overview is not considered comprehensive, nor does it describe the use of specific equipment. These details are presented in the appropriate TPNs.

Surface methods not described in this WP may be employed, and new "cutting edge" techniques and applications are constantly being developed by the geophysical community.

4.2.1 Gravity Methods

Gravity methods, both absolute and relative, consist of making measurements of the earth's gravitational field at the earth's surface. Variations in the densities of subsurface materials will alter the local gravitational field, producing differences which are analyzed after data have been collected and corrected (Burger, 1992). These variations are often very small, on the order of hundredths of milliGals for standard surveys, and on the order of tenths of microGals for microgravity surveys.

Standard corrections that are applied to gravity data collected during surveys are: drift, latitude, elevation (free-air and Bougeur), and terrain. Note that these corrections generally require that the gravity measurement stations have very precisely surveyed locations (x,y, and z locations). One of the easiest ways to collect this survey information is with the use of a global positioning system (GPS). For further processing information, the user is referred to Burger (1992), or Telford, et. al. (1990).

Several examples of types of gravity surveys and their purposes are listed below:

1. 2D and 3D Profiles – typically used to map the depth to bedrock, where bedrock is denser than the overlying materials.
2. Microgravity surveys – used during pumping tests to map the extent of the cone of depression around the pumping well (i.e., the difference in mass between saturated and unsaturated geologic materials).

4.2.2 Magnetic Methods

Similar to gravity methods, magnetic surveys measure the earth's total magnetic field. Variations in the magnetic properties (e.g., ferrous mineral content) of subsurface media will cause changes to the earth's total magnetic field at a given location. These measurements typically have accuracies of tenths to hundredths of nanoteslas.

Several types of magnetometers are in use today: fluxgate, proton precession, and optically pumped magnetometers, as well as gradiometers, which measure the total-field vertical gradient (Telford et. al., 1990).

Standard corrections applied to magnetic measurements are: instrument drift, diurnal, elevation, and horizontal position (Burger, 1992). While positioning requirements are not as severe as in

gravity surveys, measurement positions must still be known with a fair degree of accuracy. Many magnetometers available today have real-time GPS built in to the instruments, fully integrating position and magnetic measurements.

One additional consideration is that the operator(s) of the magnetometer must remove as much magnetically susceptible material (e.g., metal belt buckles, watches, etc.) from their person as possible, as well as avoid metal fences, well casings, and other large metal objects to avoid introducing an artificial influence on the magnetic measurements.

Examples of typical applications of magnetic surveys are listed below:

1. Detection of voids, where sufficient magnetic susceptibility contrast exists between the void and the surrounding material.
2. Detection of shallow magnetic (e.g., alluvial) anomalies.
3. Aeromagnetic mapping of fault blocks and/or volcanic anomalies in the Nevada Test Site, Yucca Mountain area, and Amargosa Desert (Ponce, 1999, Kelley, 2005, and Blakely, et. al., 2000, respectively).

4.2.3 Seismic Methods

Seismic reflection and refraction surveys involve the measurement of travel times of acoustic waves through subsurface media. In general, refraction techniques are used for shallower targets (usually less than 1,000 feet deep), and reflection techniques are used for deeper targets.

Both reflection and refraction techniques use similar equipment: seismograph, geophones, and a source. The sources available vary in cost and utility, but they can be classified into 3 categories:

1. Small, multi-frequency sources (i.e., sledgehammer and plate, weight drop,
2. Larger, multi-frequency sources (i.e., explosives).
3. Frequency sweep vibrator sources (i.e., vibroseis).

Care must be taken when choosing a source. Higher frequencies provide more subsurface detail, but attenuate faster than lower frequencies. Lower frequencies provide less subsurface detail, but are able (generally) to travel much deeper into the subsurface.

Seismic processing can be quite involved, and generally requires multiple corrections to be made to the raw data, including data reduction, convolution, correlation, frequency filtering, velocity analysis, common-midpoint stacking, apparent-velocity (apparent-dip) filtering, the p-τ transform, relative-amplitude processing, and migration (Telford, et. al., 1990). A thorough treatment to seismic processing is given in Yilmaz (1987).

Some typical uses for surface seismic surveys are:

1. Refraction to locate a shallow water table.

2. Refraction for engineering studies (modulus of elasticity, velocity field measurements, etc.).
3. Reflection to image stratigraphy.
4. Reflection for the detection of faults, folds, and related structures.

4.2.4 Electromagnetic Methods

Electromagnetic methods rely upon the use of inductive coupling to produce geophysical responses based on the electromagnetic properties of subsurface materials. For example, in a frequency-domain electromagnetic (FDEM) survey, an electrical current is passed through the transmitter coil, which produces a secondary magnetic field. This magnetic field is transmitted into subsurface materials, which induces an electrical current in those materials. A secondary magnetic field is then generated in the subsurface, which creates an electrical current in the receiver coil; this current is recorded by the instrument. Through various equations, the changes in the electrical and magnetic fields can be related to the properties of subsurface materials.

In the past, FDEM surveys were primarily used, due to the limitations of equipment. Advances in technology since the 1970s (Telford, et. al., 1990) have allowed more precise electronics to be used in the construction of geophysical equipment. As a result, the use of time-domain electromagnetics (TDEM) has recently become much more common.

Generally, the equipment used for both FDEM and TDEM surveys consist of: a transmitter coil, receiver coil, receiver unit (which records the transmitted and received signals), and power source. Power sources range in size from 12-volt direct-current (DC) batteries to 120-volt DC generators, depending on the requirements of the survey.

Some of the types and uses for surface electromagnetic surveys are as follows:

1. FDEM may be used to detect layers with differing electromagnetic properties.
2. Transient electromagnetics (TEM) may be used to map the resistivity of subsurface media; may also be used to detect the water table.

4.2.5 Electrical Resistivity Methods

During electrical resistivity surveys, current (usually direct-current) is injected into the earth through a set current electrodes, and the potential difference is measured between another set of electrodes (Burger, 1992). Given the current and potential, the apparent resistivity of the media being measured can be calculated. The apparent resistivity will depend on the electrical properties of the media being measured, and can be affected by many parameters (e.g., fracture orientation relative to survey orientation, dip of subsurface stratigraphy, etc.), and must be taken into consideration when planning the survey.

Equipment used for surface resistivity usually consists of: a transmitter, a receiver, current and potential electrodes, and a power source. As with electromagnetics, the power source can range from 12-volt DC batteries to a 120-volt DC generator, depending on the survey size and objectives.

Several electrode arrays are commonly used in surface resistivity surveys. These include Wenner, Schlumberger, and dipole-dipole arrays. Typical applications for surface resistivity studies include:

1. Determining the location of the shallow water table.
2. Determining the depth to bedrock (usually only in shallow surveys).
3. Determining the location of faults.

4.3 Planning and Documentation of Surface Geophysical Surveys

Due to the cost and scheduling of geophysical surveys (e.g., equipment rentals, contractor scheduling, etc.) it is extremely important that surveys are thoroughly researched and planned well in advance of the anticipated start dates. Thorough, technically defensible documentation compliant with NWRPO QA procedures is also required. The following sections outline general planning considerations for geophysical surveys, as well as the requirements for proper documentation of those surveys.

4.3.1 Planning Considerations

Geophysical surveys shall be planned based on the needs of the ISIP. Whenever possible, surveys will "tie" to at least one existing EWDP well, where stratigraphic control is present. Before scheduling a survey, the PI will research the objective, determine the most appropriate geophysical method(s) to accomplish the survey, and research the available geophysical equipment to accomplish the survey (these steps are critical to writing a comprehensive TPN). Consideration should also be given to geophysical methods that may be used to validate or corroborate the primary method.

A GPS will be used whenever possible to survey the locations of gravity meter, magnetic measurement, electromagnetic measurement, seismic, and resistivity stations to increase the accuracy and representativeness of the raw data and any processed/interpreted results.

Anticipated processing and interpretation methods/steps will be considered and, if possible, extra time taken to experiment with the equipment, test data, and processing steps before beginning the actual survey. These steps will increase survey effectiveness and productivity, as well as aid in increasing the quality of data collected in the field. While processing requirements have been described generally in this WP, specific requirements will be addressed in the TPN for each survey.

4.3.2 Documentation Process

All surveys performed under this WP will be documented in applicable scientific notebooks in accordance with QAP-3.2, *Documentation of Technical Investigations*. In addition, personnel will record measurements, parameters, and applicable notes on the appropriate forms, as described in appropriate TPNs. All scientific notebooks, notes, and completed forms will be returned to the QARC in a timely manner (i.e., within 2 days of completion). These processes will ensure that data are collected in a traceable, technically defensible manner, in compliance with the requirements of the NWRPO QA program.

5.0 MANAGEMENT

The project QA Officer (or designee) is responsible for the coordination of the internal review of this WP, ensuring proper training of NWRPO personnel, and verifying compliance with the requirements of this WP. The PIs are responsible for the preparation and modification of this WP, as well as oversight of its performance.

To ensure that the work involved will be quality controlled and accomplished in accordance with the scope and objectives of the ISIP, specific training and documentation will be accomplished before conducting the activities described in this WP. Calibration documentation, if required, shall be submitted to the QARC in accordance with QAP-12.1, *Control of Measurement and Test* Equipment. All individuals working under this WP will be trained in the QA procedures listed below and will document that they have read and understood these procedures:

EP-1.0, *Waste Management.*

HSP-1.0, *Independent Scientific Investigations Program Health and Safety Plan for General Field Activities.*

QAP-3.2, *Documentation of Technical Investigations.*

QAP-12.1, *Control of Measurement and Test Equipment.*

TP-9.8, *GPS Planning, Setup, Data Collection, and Post-Processing for the Trimble PRO/XRS.*

6.0 REFERENCES

Blakely, R.J., V.E. Langenheim, D.A. Ponce, and G.L. Dixon, 2000, Aeromagnetic survey of the Amargosa Desert, Nevada and California: A tool for understanding near-surface geology and hydrology: USGS Open-file Report 00-1888.

Burger, H.R., 1992, Exploration geophysics of the shallow subsurface: Prentice-Hall, Inc.

EP-1.0, *Waste Management*, Environmental Management Procedure: Nye County Nuclear Waste Repository Project Office. Pahrump, NV.

HSP-1.0, *Independent Scientific Investigations Program Health and Safety Plan for General Field Activities*, Health and Safety Plan: Nye County Nuclear Waste Repository Project Office. Pahrump, NV.

Kelley, R.E., 2005, 1999 and 2004 Aeromagnetic surveys, named magnetic anomalies, existing and proposed borehole locations, map number m201425: Los Alamos National Laboratory.

Ponce, D.A., 1999, Digital aeromagnetic map of the Nevada Test Site and vicinity, Nye, Lincoln, and Clark Counties, Nevada, and Inyo County, California: USGS Open-file Report 99-554-B.

QAP-3.2, *Documentation of Technical Investigations*, Quality Assurance Procedure: Nye County Nuclear Waste Repository Project Office. Pahrump, NV.

_QAP-5.2, *Preparation of Work Plans, Test Plans, and Technical Procedures.*

_QAP-12.1, *Control of Measurement and Test Equipment.*

Telford, W.M., L.P. Geldart, and R.E. Sheriff, 1990, Applied geophysics, second edition: Cambridge University Press.

TP-9.8, *GPS Planning, Setup, Data Collection, and Post-Processing for the Trimble PRO/XRS*, Technical Procedure: Nye County Nuclear Waste Repository Project Office.

Yilmaz, O., 1987, Seismic data processing: Society of Exploration Geophysicists.

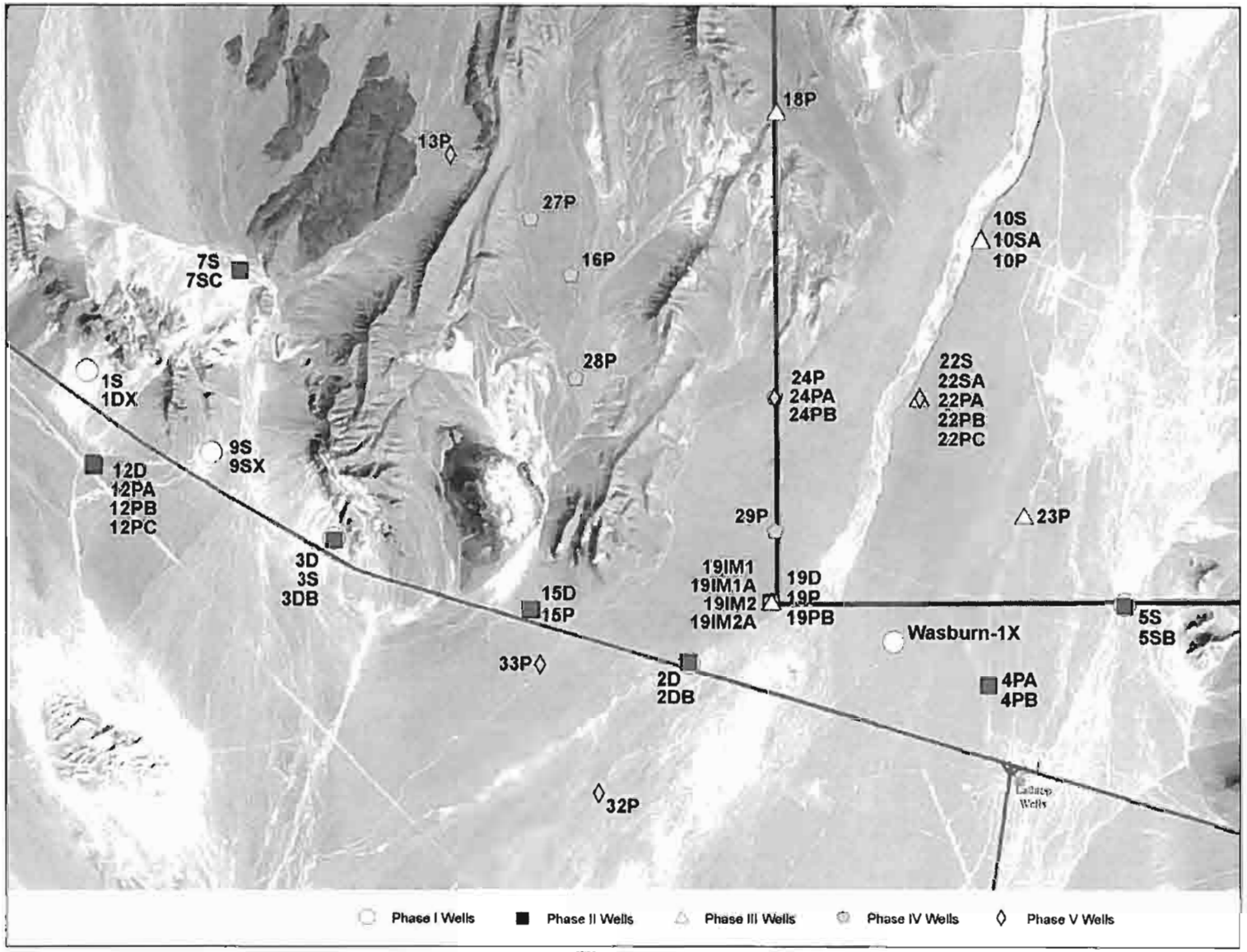

Figure 1
Map showing EWDP well locations.