NYE COUNTY NUCLEAR WASTE REPOSITORY PROJECT OFFICE

WORK PLAN 4

TITLE: **Aquifer Testing Plan for Nye County's Independent Scientific Investigations Program**	**Revision: 1** **Date: 02-14-02** **Page: 1 of 11**

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1.0 INTRODUCTION

This work plan describes aquifer-testing activities that may be conducted as part of Nye County's Independent Scientific Investigations Program (ISIP), including the third phase of Nye County's Early Warning Drilling Program (EWDP) and future ISIP drilling and characterization efforts in the region between Yucca Mountain and populated areas in Amargosa Valley. The main goal of the ISIP has been, and will continue to be, the independent evaluation of selected site characterization, repository design, and performance issues of the U.S. Department of Energy's Yucca Mountain Project that potentially affect human health, safety, and the environment in Nye County.

This work plan is a working document that is intended to outline the activities that are needed to achieve the goals of the ISIP. Specific details of the program will be changed on the basis of technical needs and budgetary constraints.

2.0 PURPOSE

The purpose of this work plan is to ensure that ISIP aquifer tests are selected and conducted in a technically defensible manner. Appropriate testing strategies will be identified for different borehole or well conditions. In addition, specific Nye County Quality Assurance (QA) Technical Procedures, which provide detailed instructions for different aquifer tests, will be referenced where applicable.

3.0 BACKGROUND

The ISIP is part of the Nye County Nuclear Waste Repository Project Office's (NWRPO's) ongoing oversight investigations related to the proposed construction and operation of a high-level radioactive waste repository at Yucca Mountain.

Basic geologic and hydrologic data are lacking for a large area near Yucca Mountain. Past studies conducted by the U.S. Department of Energy have concentrated on characterizing the conditions in the immediate vicinity of the proposed repository site. The data collected to date indicate that there is significant spatial variability in aquifer properties near and downgradient of Yucca Mountain. Quantitative hydrologic data are needed to define the conditions in these areas to identify and evaluate the risk associated with long-term waste disposal at a repository at Yucca Mountain.

ISIP site characterization activities, including borehole drilling, well construction, and aquifer testing, are designed to meet the need for additional data in these areas. In addition, these activities are designed to facilitate the establishment of a monitoring system downgradient from the Yucca Mountain site to ensure protection for the environment and the residents of Nye County.

4.0 SCOPE OF WORK

This work plan is a general description of the procedures that will be used during aquifer testing of boreholes and wells as part of Nye County's ISIP characterization activities. Because of the large uncertainty in the geology and hydrology of the drill sites, it is not possible to provide detailed specifications of the hydraulic testing. It is, however, possible to describe the types of

aquifer tests that could be conducted for different types of well completions. General categories of wells and applicable tests are summarized below. Nye County Quality Assurance Program (QAP) technical procedures applicable to different test types are given in parentheses. These technical procedures provide more detailed instructions for testing. Testing instructions specific to individual boreholes (test plans) will be generated prior to conducting tests and will not be described further herein.

1. **Open-hole testing before the installation of well casing and well screen**–Open-hole testing will be conducted in boreholes that penetrate stable formations that will not partially or fully collapse during testing. Three types of tests are envisioned:

    a. Pumping/injection tests of packed-off zones. Monitoring may be in the same well and/or in separate observation wells (TP-10.0, *Pumping/Injection Tests in Packed-Off Zones in Unscreened Open Boreholes or in Multiple Screen Boreholes with or without Observation Wells*).

    b. Conventional pumping tests where monitoring may be in the pumping well and/or in separate observation wells (TP-9.5, *Variable Scale Pumping Tests in Unscreened Open Boreholes or in Screened Boreholes with and without Observation Wells*).

    c. Pump-spinner tests (TP-9.0, *Pump-Spinner Tests in Unscreened Open Boreholes and Screened Boreholes*).

2. **Testing in cased/screened boreholes without zonal isolation equipment (e.g., Westbay® casing, packers, and sampling ports)** -The same types of well tests conducted in open boreholes are applicable to cased/screen boreholes. In addition, slug tests may be conducted when it is not possible to stress the aquifer or zones within the aquifer by pumping. The four types of tests applicable are:

    a. Pumping/injection tests of packed-off zones. Monitoring may be in the same well and/or in separate observation wells (TP-10.0, *Pumping/Injection Tests in Packed-Off Zones in Unscreened Open Boreholes or in Multiple Screen Boreholes with or without Observation Wells*).

    b. Conventional pumping tests where monitoring may be in the pumping well and/or in separate observation wells (TP-9.5, *Variable Scale Pumping Tests in Unscreened Open Boreholes or in Screened Boreholes with and without Observation Wells*).

    c. Pump-spinner tests (TP-9.0, *Pump-Spinner Tests in Unscreened Open Boreholes and Screened Boreholes*).

    d. Slug tests (TP-9.6, *Slug Testing in Low to Moderate Permeability Formations*).

3. **Testing of the boreholes completed with multiple well screen(s) and zonal isolation equipment with pumping ports associated with each well screen**–In general, these tests will be applicable to boreholes containing Westbay® zonal

isolation equipment, including casing, packers, and sampling ports. In future ISIP investigations, other types of zonal isolation equipment may be installed in boreholes.

a. Pumping tests of individual pumping ports (TP-10.1, *Pump Testing of Individual Zonal Isolation Pumping Ports in Multiple Screen Wells*).

b. Slug tests (TP-9.6, *Slug Testing in Low to Moderate Permeability Formations*).

Key personnel involved in directing and implementing these tests include the On-Site Geotechnical Representative, the Principal Investigator, and the onsite NWRPO Scientist/Engineer. The responsibilities of these individuals are summarized in Section 4.5.

4.1 TYPES OF PLANNED INVESTIGATIONS

4.1.1 Open-Hole Testing

Open-hole testing (holes without well casing and well screen) will be conducted only in boreholes that penetrate stable formations that will not collapse during testing. The necessity of this testing will be determined by the Principal Investigator and the On-Site Geotechnical Representative and will only be performed if borehole conditions and budgetary constraints allow.

Pumping/Injection Test of Packed-Off Zones in Open Boreholes–Testing conducted according to NWRPO QA Technical Procedure TP-10.0, *Pumping/Injection Tests in Packed-Off Zones in Unscreened Open Boreholes or in Multiple Screen Boreholes with or without Observation Wells.*

If possible, these tests will be conducted after geophysical and geological logging is completed. These logs will be evaluated to estimate the depths of the intervals in each borehole that are of interest. The criteria for selection of test intervals will depend on the relative significance of each producing zone, and budgetary and time constraints. The geologic logs will be used to divide the saturated zone into a series of conceptual hydrogeologic units. The geophysical logs will be used to further subdivide these hydrogeologic units based on their porosity and productivity. These evaluations will be qualitative, and procedures for selection of intervals may vary from borehole to borehole.

The selected intervals of interest in each borehole will be tested using a guarded packer system. This test will require good borehole conditions and competent packer seats. In general, the packers should be set in a portion of the borehole that is nearly in gauge and that is in a competent section of the borehole. Packers should not be set in sections of the borehole that may be eroded during testing, and should provide an effective seal between the test interval and the rest of the borehole above or below the test interval. The determination of the seal effectiveness will be made using a short-term pulse test. In this pulse test, the pressure in the center zone will be perturbed. Pressure perturbation may be accomplished by pumping a small amount of water from, or injecting a small amount of water into, the test interval. (Water may be injected using a small amount of air injection, as long as the volume of air injected is small enough to ensure that air does not enter the formation.)

The contractor responsible for the packer testing should have a complete QA-technical program that covers lowering and raising, packers, integrity and maintenance, decontamination, and assembly and disassembly of the packer system. This QA procedure should be compliant with Nye County's NWRPO QAP. At a minimum, the pressure and temperature measurements should be done with transducers placed downhole and recorded with a datalogger that is able to transfer the data to a personal computer in an acceptable format. A flow meter should be installed at the ground-surface facility. The accuracy of the flow meter should be cross-checked with the timed filling of known-volume vessels. Pressure and temperature gauges should be selected to cover the anticipated range. In addition, surface facilities should include measurements of barometric pressure and surface temperature. The test zone pressure-transducer sensitivity should be no larger than 0.1 psi. All zones should have temperature probes sensitive to 0.1ºC. Packer lengths should be no less than 2 m. The flow-metering device should be equipped with reducing valves to enable relatively accurate regulation of the flow rate. The objective is to obtain a stabilized pressure and flow rate in the test zone before completion of the test. The packer/pump system should be equipped with a downhole solenoid or check valve to allow for rapid shut off of flow.

Hydraulic heads in zones both above and below the packers may be monitored. In addition, heads may be monitored in one or more observation wells.

After completion of the packer seal test, the packers will be allowed to come to equilibrium for approximately 1 hr. The pump will be turned on for a pre-determined flow rate specified by the on-site NWRPO Scientist/Engineer. Pressure, temperature, and flow rates at all downhole zones and at the surface facility will be monitored at a rate specified by the on-site NWRPO Scientist/Engineer. If feasible, the test will be run for at least 4 hr. at an approximately constant flow rate. Shorter testing times may be necessary if there are budget or schedule constraints. Once an approximately steady flow and pressure are established, the flow solenoid or check valve will be closed and the pressure and temperature in all locations recorded. The length of the shut-in pressure test will be at least 1 hr. or until the pressure and temperature have reached steady-state conditions. The recovery test may be terminated after 4 hr., if full recovery is not achieved. This is to minimize the drilling-rig standby time.

Conventional Pump Testing of Open Boreholes–The detailed specifications for this test are given in NWRPO QA Technical Procedure TP-9.5, *Variable Scale Pumping Tests in Unscreened Open Boreholes or in Screened Boreholes with and without Observation Wells.*

This is a conventional aquifer test where pumping is continued to form a cone of depression or drawdown in the aquifer. The degree to which the aquifer is stressed is dependent on the pumping time interval and the pumping rate.

This test will be performed in boreholes in which isolation of intervals with packers does not seem practical due to borehole conditions and in which it is not desirable to set casing. This test will not be conducted when there is a substantial perceived risk of sticking or damaging the submersible pump or other downhole equipment in the open borehole.

The procedure will be to lower a submersible pump with a check or solenoid flow valve capable of pumping an appropriate rate (typically 100 to 200 gpm) to a sufficient depth below the water table where risk of drawdown below the pump is low or manageable. A flow-metering device

with the specifications described above will be used to record the test. In addition, a pressure transducer will be lowered downhole to measure water-level changes in the borehole. Water level changes may also be monitored in nearby observation wells. The downhole transducer ranges should be selected to match the anticipated drawdown and setting depth. Once the water level has reached its initial conditions after installation of the pump, the pumping test will begin and run, if possible, for 4 hr. Shorter testing times may be necessary if there are budget or schedule constraints. The pumping rate may be stepped up or down as deemed necessary by the on-site NWRPO Scientist/Engineer. The amount and timing of any step changes in rate should be documented in the field Scientific Notebook by the on-site NWRPO Scientist/Engineer. After completion of pumping, recovery measurements will be recorded for at least 1 hr. or for up to 4 hr. until the water level approaches its initial conditions. The test results will be plotted at the site by the NWRPO Scientist/Engineer to ensure that sufficient time has been given for the test.

Pump-Spinner Testing in Open Boreholes–The detailed specifications for this test are given in NWRPO QA Technical Procedure TP-9.0, *Pump-Spinner Tests in Unscreened Open Boreholes and Screened Boreholes.* These tests will provide preliminary information on production rates and relative hydraulic heads in different test intervals.

The first type of test to be conducted will be a static spinner log. Static logs are simply spinner logs conducted prior to pumping. Static logs are useful to estimate flow rates between different depth intervals.

Upon completion of static spinner logs, with the spinner logging tool still in the hole, an appropriately sized submersible pump with an appropriate downhole shut-off valve will then be run in the hole and set to as high a position in the well as is feasible. The setting depth will be dictated by the water table depth and anticipated drawdown. A pressure transducer will be attached to the tubing just above the submersible pump to monitor changes in the water level. The pump will then be started with the rate determined by the on-site NWRPO Scientist/Engineer. Once a stabilized rate has been obtained, a series of spinner logging runs will be made to determine each zone's contribution to the total flow. This pumping portion of the test will typically last from 1 to 4 hr. Following completion of the logging runs, the well will be shut in and the recovery will be monitored for a period of time (usually overnight) determined by the NWRPO Scientist/Engineer. The results obtained from the spinner logs before and during the pump test will be used to allocate the hydraulic properties to the individual screened intervals. As with the prior tests, care should be taken to accurately measure and record in the scientific notebook the surface flow rate with appropriate meters and timed volume checks.

Due to the wide variability in the completions and hydraulic properties, this test design may be modified by the NWRPO Scientist/Engineer in consultation with the Principal Investigator and/or the NWRPO On-Site Geotechnical Representative. Typical variations may include, but are not limited to, setting the pump deeper, leaving the spinner logging tool in the hole for the conventional pump tests described above, a 48-hr. pump test to monitor changes in contribution during the test, or allocation of production based on fluid temperature or geochemistry. Many of the EWDP boreholes have been drilled with multiple wells on the same location. In this case, it is desirable to instrument these holes with pressure transducers.

4.1.2 Testing of Cased/Screened Boreholes without Zonal Isolation Equipment

The same types of tests conducted in open boreholes (Section 4.1.1) may also be conducted in cased/screened boreholes. The same NWRPO QA Technical Procedures also apply. The only restriction is that pumping/injection tests in packed-off zones are limited to multiple screen wells. It is not possible to pack off depth intervals with a single well screen.

In addition, slug tests may be conducted in small diameter boreholes (e.g., piezometers) where permeabilities are expected to be low to moderate and where it is not possible to pump water at rates that will yield useful drawdown data. Slug tests are briefly described below.

Slug Testing–The detailed specifications for this test are given in QA Technical Procedure TP-9.6, *Slug Testing in Low to Moderate Permeability Formations.* In this test, two approaches may be used to rapidly increase or decrease the water level in a well screen and produce a sudden (pulse) change in water level. The subsequent water level recovery will be used to obtain hydraulic properties of the formations. This method may be useful in low to moderate permeability zones. For high permeability zones, this method is not expected to produce meaningful results. The methods used to create a rapid decrease or increase in the water level are air injection or insertion of a rod into the water within the casing. Prior to testing, a pressure transducer must be installed at a depth below the water level in the casing that will significantly exceed the depth to which the rod will be inserted or the depth to which the water level will be depressed by air injection.

For the air injection method, a wellhead cap equipped with a pressure gauge must be installed. A source of pressurized gas is then used to rapidly increase the gas pressure above the water. Generally, each 4.3 psig of increase in air pressure will depress the water table by 10 ft. After the desired pressure (and water level depression) is reached, the gas pressure will be released quickly. The water-level response will then be recorded with the downhole transducers.

For the rod method, a solid rod with a density greater than water and slightly smaller in diameter than the well will be dropped into the water to cause a rapid increase in water level. The length of the rod may be varied to increase or decrease the water level increase. The water-level response will then be recorded with the downhole transducers.

4.1.3 Testing of Cased/Screened Boreholes Completed with Zonal Isolation Equipment

In general, these tests will be limited to multiple screened boreholes containing zonal isolation equipment with pumping ports (e.g., Westbay® casing, packers, and sampling ports).

Pumping Test of Individual Pumping Ports–Detailed testing specifications are described in NWRPO QA Technical Procedure TP-10.1, *Pump Testing of Individual Zonal Isolation Pumping Ports in Multiple Screen Wells.* Before implementing these tests, a detailed Test Plan will be developed. These tests may be necessary for the zones that could not be tested prior to completion with the zonal isolation equipment. They may also be run as part of the groundwater purging and sampling of the pumping ports for water chemistry analyses. The procedures will be similar to the pumping tests in the open boreholes, except that, because of the space limitations within the completion, the pump used may not be able to produce more than 10 gpm. Larger pumping rates may be used if appropriate pumps are identified. In this test, one or more

pressure transducers should be attached to the tubing above the pump to record the water level changes during pumping. If possible, the adjacent intervals should be equipped with transducers to monitor for vertical interference. The test should be run for a period of time specified by the NWRPO Scientist/Engineer and will be influenced by the length of the test interval, hydraulic properties, test flow rate, and water disposal limitations. Optimum test time periods consist of 4 hr. of pumping, followed by 1 hr. of recovery. Shorter test time periods may be necessary if pumping is associated with groundwater sampling activities and/or there are budget or schedule constraints.

Slug Testing of Individual Pumping Ports–The detailed specifications for this test are given in NWRPO QA Technical Procedure TP-9.6, *Slug Testing in Low to Moderate Permeability Formations.* In this test, two approaches may be used to increase or decrease the water level in the zonal isolation equipment tubing and produce a sudden (pulse) change in water level. The subsequent water level recovery will be used to obtain hydraulic properties of the formations. This method may be useful in low to moderate permeability zones. For large permeability zones, this method is not expected to produce meaningful results. The methods used to create a decrease or increase in the water level are air injection or insertion of a rod into the tubing. Because of the strings of MOSDAX™ transducers installed inside the tubing on most of the EWDP completions, the latter method does not seem to be practical. Therefore, the method described here is limited to air injection. If field conditions and observations prove the latter method to be practical, it may be used in place of air injection.

In the air injection method, the zone to be tested will be exposed by sliding the sleeve open. Prior to opening the sleeve, the tubing will be tested to ensure that no other screen is open. The open and close tool will be removed and the tubing will be pressure-tested to ensure that the selected screen is open and can communicate with the formation. The MOSDAX™ assembly will then be replaced in pre-selected positions. The wellhead cap will be installed. The wellhead cap will need to be equipped with a pressure gauge up to 50 psi gauge pressure. A nitrogen tank outlet with two separate pressure regulators (0 to 1,000 psi, and 0 to 100 psi) connected in series will be attached to the inlet to the zonal isolation equipment tubing. The tubing will then be pressurized slowly to a pre-calculated water-level decline desired. Generally, each 4.3 psig increase of air pressure will depress the water table by 10 ft. The amount of pressure may vary, depending on the transmissivity and the confined nature of the formation. After the desired pressure is reached, the shut-in valve will be closed and the pressure gauge and transducers downhole will be monitored to ensure near-equilibrium conditions. Once a near-equilibrium condition is reached, the relief valve will be opened to relieve the pressure quickly. The water-level response will then be recorded with the downhole transducers. If the formation has low permeability and testing is deemed necessary, the pulse may be induced by applying a sudden pulse of air and shutting the inlet valve. The response can then be analyzed to obtain approximate hydraulic parameters.

4.2 EXTENT OF INVESTIGATIONS

The three categories of aquifer tests described in the preceding section cover a wide range of test conditions. Testing of open boreholes will be performed in limited cases when borehole conditions warrant it. It is possible to conduct nearly all types of aquifer tests discussed above in cased/screened boreholes. Larger scale conventional aquifer pump tests will yield properties

over a larger area, but require much more lead-time and resources. Testing with the zonal isolation equipment will yield valid results for lower permeability intervals or to help evaluate the completion efficiency (e.g., leakage in annular seals between screens). Slug or pulse tests will be performed only if pumping is not practical. The Principal Investigator and/or the On-Site Geotechnical Representative will be responsible for selecting the preferred type of test.

4.3 LOCATION OF INVESTIGATIONS

These aquifer test activities will be carried out throughout Amargosa Valley and in the vicinity of the Yucca Mountain site.

4.4 SCHEDULE

The testing schedule will be determined by the Principal Investigator and/or the On-Site Geotechnical Representative. For new boreholes drilled as part of the ISIP, open-hole tests will be completed as soon as possible after the borehole is cleaned by the drillers. The pump-spinner tests will be performed as soon after initial development as is feasible. The zonal-isolation-equipped boreholes will be tested following installation of the tools and instruments. These tests will be attempted during the time that the zonal isolation equipment crew is available on the site. However, once the field staff is trained with the operation of the zonal isolation equipment and instruments, the test may be run at any time, except during regional pumping tests.

4.5 RESPONSIBILITIES OF INVESTIGATORS

The Nye County On-Site Geotechnical Representative will designate a Principal Investigator to oversee all aquifer-testing activities and an on-site NWRPO Scientist/Engineer to direct aquifer test activities in the field. The Principal Investigator will provide detailed instructions to the on-site NWRPO Scientist/Engineer as required. The on-site NWRPO Scientist/Engineer will carry out these instructions and supply the Principal Investigator with data for analysis and interpretation.

Due to the uncertainties involved in the sequence and types of tests, the Principal Investigator will be primarily responsible for deciding when and where it is most appropriate to conduct a particular test outlined in this work plan. The Principal Investigator will be responsible for all variations that will affect the technical outcome of the testing and may override the specifications and requirements stated in this work plan, provided he has obtained approval from the NWRPO On-Site Geotechnical Representative.

4.6 EQUIPMENT AND CALIBRATION REQUIREMENTS

The equipment used for this investigation includes, but is not limited to, the Westbay® downhole instrument assembly, the MOSDAX™ assembly, and the flow-measuring and water and gas sampling apparatus. Equipment calibrations specified in QA Technical Procedures will be up to date.

4.7 NUMBER AND TYPES OF TESTS PERFORMED

The number and types of tests will be selected by the Principal Investigator and/or the On-Site Geotechnical Representative.

5.0 MANAGEMENT

The Project QA Officer shall be responsible for the coordination of the internal review of this work plan. The Project QA Officer is also responsible for ensuring the proper training of NWRPO personnel and verifying compliance with the requirements of this plan. The Principal Investigator shall be responsible for the preparation and modification of this work plan, as well as the oversight of the performance of the plan.

To ensure that the work involved will be quality controlled and accomplished in accordance with the scope and objectives of the ISIP, the following procedures will be implemented prior to conducting tests. All individuals performing the aquifer tests described in the above sections shall be trained in procedures specifically applicable to the instrumentation used before conducting work, and shall document that they have read and understood the QA Technical Procedures listed below:

- TP-9.0, *Pump-Spinner Tests in Unscreened Open Boreholes and Screened Boreholes*
- TP-9.5, *Variable Scale Pumping Tests in Unscreened Open Boreholes or in Screened Boreholes with and without Observation Wells*
- TP-9.6, *Slug Testing in Low to Moderate Permeability Formations*
- TP-10.0, *Pumping/Injection Tests in Packed-Off Zones in Unscreened Open Boreholes or in Multiple Screen Boreholes with or without Observation Wells*
- TP-10.1, *Pump Testing of Individual Zonal Isolation Pumping Ports in Multiple Screen Wells.*