**NYE COUNTY NUCLEAR WASTE
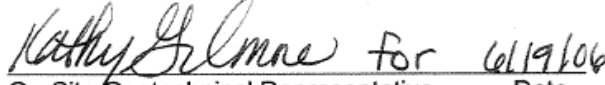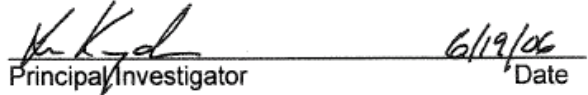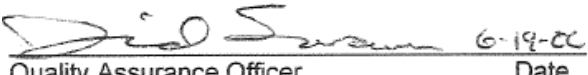REPOSITORY PROJECT OFFICE**

TEST PLAN

TITLE: **Thermal Logging in Early Warning Drilling Program Wells Using Sensornet Equipment**	Revision: **0**
	Date: **6-19-06**
	Page: **1 of 10**

TEST PLAN NUMBER: **TPN-6.1**	SUPERSEDES: **None**

APPROVAL	CONCURRENCE
~~Did Swzru~~ 6-19-a ――――――――――――――― Director Date	~~Kathy Gilmore~~ for 6/19/06 On-Site Geotechnical Representative Date ~~K Kd~~ 6/19/06 Principal Investigator Date ~~Did Swzru~~ 6-19-06 Quality Assurance Officer Date

1.0   INTRODUCTION

This test plan (TPN) provides detailed instructions for the collection of temperature data in Nye County Nuclear Waste Repository Project Office (NWRPO) Early Warning Drilling Program (EWDP) wells using the Sensornet Sentinel Distributed Temperature Sensor (DTS) data acquisition system starting in June 2006.

The work described in this TPN will be conducted in conjunction with Lawrence Berkeley National Laboratory (LBL) in support of planned Office of Science and Technology International (OSTI) tracer testing in the lower Fortymile Wash area. NWRPO work plan WP-6.0, *Early Warning Drilling Program Geophysical Logging Work Plan*, provides the background, purpose, and general objectives of geophysical data collection in EWDP boreholes and wells. In addition to the requirements of this TPN, data shall be collected in accordance with applicable OSTI and LBL documents.

2.0   BACKGROUND AND PURPOSE

While conducting geophysical logging activities in borehole NC-EWDP-24PB, drilled in the spring of 2006, it became apparent that several intervals within the Crater Flat tuff group had significant groundwater movement through them. Nye County believes that these features and others similar to them could act as potential groundwater flow pathways from the proposed high-level nuclear waste repository at Yucca Mountain to residents in Amargosa Valley.

The collection of temperature data in new boreholes and existing wells using the DTS method described in this TPN will aid in identifying preferential flow pathways and improving estimates of flow and transport properties. These data will also support and complement those obtained from future single- and cross-hole tracer tests planned in conjunction with OSTI.

3.0   SCOPE OF WORK

3.1   Responsibilities

The Principle Investigator (PI) is responsible for supervising the data collection activities described in this TPN. NWRPO personnel, including staff and contract geologists and technicians, are responsible for conducting the activities described in this TPN.

The Field Safety Supervisor (FSS) is responsible for monitoring the health and safety of workers relative to the guidelines established in the NWRPO Health and Safety Plan for General Field Activities (HASP).

The Site Supervisor is responsible for ensuring the completion of work in a safe manner according to the guidelines established in this TPN.

Nye County Field Personnel, as assigned by the PI, FSS or Site Supervisor are responsible for the completion of the activities described in this TPN.

3.2   Well Locations

Figure 1 shows the locations of existing EWDP wells. Temperature logging work may be conducted within existing wells, in new boreholes, and/or in conjunction with aquifer pump tests, single- and cross-hole tracer tests and other activities at the discretion of the PI.

3.3   Equipment Requirements

The equipment required for DTS temperature logging shall be used according to manufacturer's specifications or methods detailed in this TPN and is listed in Table 1.

Table 1
DTS Logging Equipment

Item (In Alphabetical Order)	Amount
Control Panel for heater wire (240 volts at 33 amps)	1
Electric wireline winch	1
Fiber optic cable, 2-fiber, 50/125, indoor/outdoor with E2000 connector	1350 feet
Field Trailer, air conditioned	1
Generator (25 kilowatt [KW] minimum), 240 Volts	1
Heater wire (14-AWG 2-conductor)	1350 feet
Polyvinyl chloride (PVC) pipe ¾-inch (in.) diameter	12 inches
PVC Tape, 10-mil	1 roll
3M™ Scotchcast™ electrical insulating resin	2
Sensornet Sentinel DTS temperature logger, associated software and monitor	1

3.4 Safety

NWRPO personnel shall adhere to the safety practices described in the HASP. Hazard Analysis worksheets will be completed by the Field Safety Supervisor (FSS) prior to commencement of work to determine what hazards are present and the control measures or personal protective equipment (PPE) necessary to mitigate them. All personnel shall wear appropriate PPE at all times and stop work if life-threatening or otherwise unsafe conditions develop or are observed. Work shall resume only when actions have been taken to correct unsafe conditions and all on-site personnel have been briefed.

It should noted that the Sentinel DTS is a Class 1M laser product, and care should be taken to avoid looking directly into or magnifying the laser while it is energized. Users should refer to the *Sentinel DTS Quick Start Guide SEN2-QSG 1.0* or the HASP for further safety warnings and precautions.

4.0 INSTRUMENTATION AND DATA COLLECTION

The Sensornet Sentinel DTS comprises a temperature-logging hardware interface built into a personal computer with the proprietary Windows based software package *Sentinel DTS v3.1*. This system is capable of collecting and stacking distributed temperature data along the length of a fiber optic cable at user-defined intervals.

4.1 Cable Preparation

The downhole end of the heater wire should be prepared as follows:

1. Split the two conductor wires apart approximately 2-inches (in.) at the end of the wire;

2. Strip 1-in. insulation from the end of each wire;

3. Twist the two wires together and solder the connection;

4. Place the wires inside a 6-in. long section of ¾-in. outside diameter (O.D.) PVC pipe; and

5. Mix and pour Scotchcast™ electrical insulation resin into the pipe, around the wires and let set up overnight.

Once the resin has set, the heater wire is ready to be installed.

The downhole end of the fiber optic cable should be prepared in a similar manner:

1. Fold the end of the fiber optic cable over approximately 1-in. from the end of the cable and secure with 10-mil PVC tape, if necessary;

2. Place the folded end of the fiber optic cable inside a 6-in. long section of ¾-in. O.D. PVC pipe; and

3. Mix and pour Scotchcast™ electrical insulation resin into the pipe, around the cable and let set up overnight.

Once the resin has set, the fiber optic cable is ready to be installed.

4.2   Cable Installation and Removal

4.2.1 Cable Installation

Heater wire and fiber optic temperature sensing cables may be installed at the time a well is completed or in an existing well. If installation takes place at the time a well is completed, cables should be secured to the outside of the well casing using PVC tape at regular intervals (e.g., every 10 to 20 feet [ft]). Care should be taken to ensure that the fiber optic cable is not crushed or kinked during installation. Centralizers should be used on the well casing to help protect the cables.

When installing cables in an existing well, it is preferable to use an electric winch cable as a support member due to the weight of the heater wire and fiber optic cables (approximately 0.07 lbs [pounds]/ft together). The procedure for installing cables using a winch is as follows:

1. Set up a tripod and sheave block over the well to be instrumented and position spools on spool stands so each cable will feed into the well without interference;

2. Install a coupler and end cap on the cable head, if using the Westbay/Mount Sopris (or similar) "sampler" winch;

3. Run the winch cable over the sheave block and position the cable head at the top of the well casing;

4. Tape the resin-sealed cable ends immediately above the cable head;

5. Begin lowering the winch cable, heater wire and fiber optic cable into the well, stopping to "zero" the depth counter on the winch when the resin-sealed pipes are at ground level;

6. Continue lowering the cables into the well, taping the heater wire and fiber optic cables to the winch cable every 10 ft; and ensuring the cables feed into the well without snagging, pinching or kinking;

7. When the bottoms of the cables reach the desired depth, clamp the winch cable at the top of the well and power down the winch. For data collection procedures, see section 4.3;

8. Run the remaining lengths of heater wire and fiber optic cable inside PVC pipe to the control panel and/or office trailer, if present. Ensure that all lengths of cable at ground surface are protected from local fauna;

9. Plug the heater wire into its control panel, and wire the control panel into the generator. Plug the E2000 connector on the end of the fiber optic cable into the Sentinel DTS; and

10. Allow the cables to equilibrate to in situ temperatures (allow approximately 2 hours) before any data are collected.

4.2.2 Cable Removal

After data collection is complete, ensure that the system is de-energized and all power cables are disconnected from the heater wire and its control panel. Disconnect the fiber optic cable from the Sentinel DTS. Remove the heater wire and fiber optic cables from the well according to the following instructions:

1. Power up the winch and use it to pull the support cable up until the clamp is off the top of the well. Remove the clamp.

2. Continue winching in the support cable until the first piece of tape passes the top of the well. Remove the tape, being careful not to crush or pinch the fiber optic cable, and reel the heater wire and fiber optic cables onto their respective spools.

3. Repeat step 2 until the resin-sealed ends of the wires have reached the top of the well casing. Remove them from the winch cable and secure the reels for transport, if necessary.

4.3   Data Collection

Data collection shall comprise three separate phases: background, heating and cooling data. A description of the Sentinel DTS configuration and each phase can be found in the sections below.

4.3.1   Sentinel DTS System Setup and Startup

Once cables are installed in the well, they should be allowed to equilibrate to in situ temperatures before any data are collected (allow approximately 2 hours). While the cables are equilibrating, the set the Sentinel DTS up in the field trailer (e.g., attach the keyboard, monitor and power cords). Temperatures in the field trailer should be kept below 85 °Fahrenheit (F) to prevent the Sentinel DTS from overheating. If a field trailer is not available, an insulated box of sufficient size may be used if ambient temperatures are less than 85 °F.

The procedure for powering up the Sentinel DTS and collecting data is as follows:

1. Turn the master power switch (located on the back of the Sentinel DTS) to the "On" position. Press the green "On/Standby" switch on the front of the unit. The Sentinel DTS should begin its boot sequence. Turn the monitor on;

2. After the Sentinel DTS has booted into the Windows® 2000 operating system, the Sensornet DTS v3.1 software should start automatically. If it does not, double-click on the Sensornet DTS v3.1.exe shortcut on the desktop to start the program. It may take several minutes for the hardware and software to initialize;

3. If the appropriate configuration file exists, load it and go to step 8. Otherwise, when the Sensornet DTS main menu window appears, click on the "Edit Configuration" button. The Choose Configuration Setup window appears. Select "Go straight to editor" and click the "OK" button;

4. The Edit Configuration window appears. Change the repetition time to 900 seconds (sec.) under the "repetitions" tab. Ensure that the "continuous" checkbox is selected. The repetition time may be changed at the discretion of the PI;

5. Under the "installation details" tab, fill in the installation and notes fields with the name of the well and zone to be instrumented and other pertinent notes, respectively;

6. Under the "range" tab, set the range field to the total length of the fiber optic cable (e.g., the length in the well plus the length at the surface) in the well or borehole. All other values may be left at their defaults (for more detail, the user is referred to the Sensornet *Sentinel DTS Quick Start Guide SEN2-QSG1.0*);

7. Click on the "Save" button at the bottom of the window. Note the name and path of the configuration file for future reference. Click the "OK" button to return to the main menu;

8. On the main menu, select the "Start Measurement" button to begin collecting data. After the laser stabilizes, data collection will begin; and

9. After data have been collected for the length of time determined by the PI, press the "Stop After Current Repetition" button. Note the filename and path where the software writes the data.

4.3.2   Background Data

Background data are used to help identify temperature conditions in the well or borehole prior to disturbance by heating and cooling.

After the fiber optic cable has equilibrated to in situ temperatures, collect one cycle (15 minutes or 900 sec.) of background data following the instructions in section 4.3.1, adding a note in the configuration file identifying the file as background data.

4.3.3   Heating and Cooling Data

Heating and cooling data help identify zones in the well or borehole where groundwater may be moving. These zones appear as anomalous highs or lows in the temperature data. Heating data should be collected as follows:

1. Start data collection as detailed in section 4.3.1. After one cycle (15 minutes or 900 sec.) or longer as directed by the PI, turn the heater wire control switch to the "On" position. Note that the power output of the control panel is about 8000 watts;

2. Heating data should be collected for a minimum of 24 hours, at the discretion of the PI;

3. After 24 hours of data have been collected, turn the heater wire control switch to the "Off" position. Collect cooling data for the same length of time as heating data were collected; and

4. After collection of heating and cooling data is complete, stop logging according to section 4.3.1.

4.4   Temperature Drift Determination

Upon receipt of a new fiber optic cable, efforts shall be made to determine whether temperature drift occurs along the length of the cable. Temperature drift determination should be conducted at two different temperatures, as follows:

1. Connect the new fiber optic cable and a reference temperature sensor (calibrated to National Institute of Standards and Technology traceable standards) to the Sentinel DTS;

2. Place the fiber optic cable and reference sensor in a temperature controlled bath (use ice to hold the temperature at approximately 32 °F) and allow them to equilibrate for 15 minutes;

3. Collect data for several cycles according to section 4.3.1, identifying the data and reference temperature in the configuration file;

4. Stop data collection and transfer the fiber optic cable and reference sensor to a second bath at room temperature (approximately 78 °F) and allow them to equilibrate for 15 minutes;

5. Collect data for several cycles according to section 4.3.1, identifying the data and reference temperature in the configuration file;

6. Stop data collection and remove the fiber optic cable and reference sensor from the bath. Transfer the data files to a computer with spreadsheet software; and

7. Open the data files collected for each temperature and combine them in a spreadsheet. Graph the data and determine whether any temperature drift (e.g., deviation from the reference temperature) occurs along the length of the cable.

Any observed temperature drift should be taken into account when data collected in wells or boreholes is analyzed. Temperature drift data shall be submitted to the NWRPO Quality Assurance Records Center (QARC), in accordance with Quality Assurance Procedure 12.1, Rev. 2, along with any field data collected using that cable.

4.5   Data Processing

Data are recorded by the Sentinel DTS in document description format (.ddf). The location of these files on the hard drive can be noted at the time of data collection. The name of each data file will contain a well and zone designation, an eight-digit date, three-digit configuration file designation and five-digit sequential file identification number. For example, the filename *32P deep 20060608 002 00003.ddf* represents the third sequential data file, collected according to the second configuration file in the deep piezometer tube at well NC-EWDP-32P on June 8, 2006.

After a complete set of heating and cooling data has been collected (e.g., for a 48-hour period), transfer the files to a computer with spreadsheet software. The temperature data should be combined into one spreadsheet for heating and one for cooling data, along with length information.

Extraneous (e.g., negative length) data should be removed from the data set at this time. Data may be graphed to aid in determining zones where flow may be occurring.

5.0   RECORDS

Data collected as part of this TPN are recorded electronically by the Sensornet Sentinel DTS and documented manually in the appropriate scientific notebook. Data will be submitted, along with metadata describing their collection and limitations, to the NWRPO QARC for archival. Records in the QARC are available upon request.

6.0   REFERENCES

Sensornet Sentinel DTS Quick Start Guide, *Sentinel DTS Quick Start Guide SEN2-QSG1.0.*

Applicable NWRPO Plans and Procedures

Independent Scientific Investigations Program Health and Safety Program, *Site Specific Health and Safety Plan for General Field Activities.*

Quality Administrative Procedure QAP-5.2, *Preparation of Work Plans and Technical
    Procedures.*

Quality Administrative Procedure QAP-12.1, *Control of Measuring and Test Equipment.*
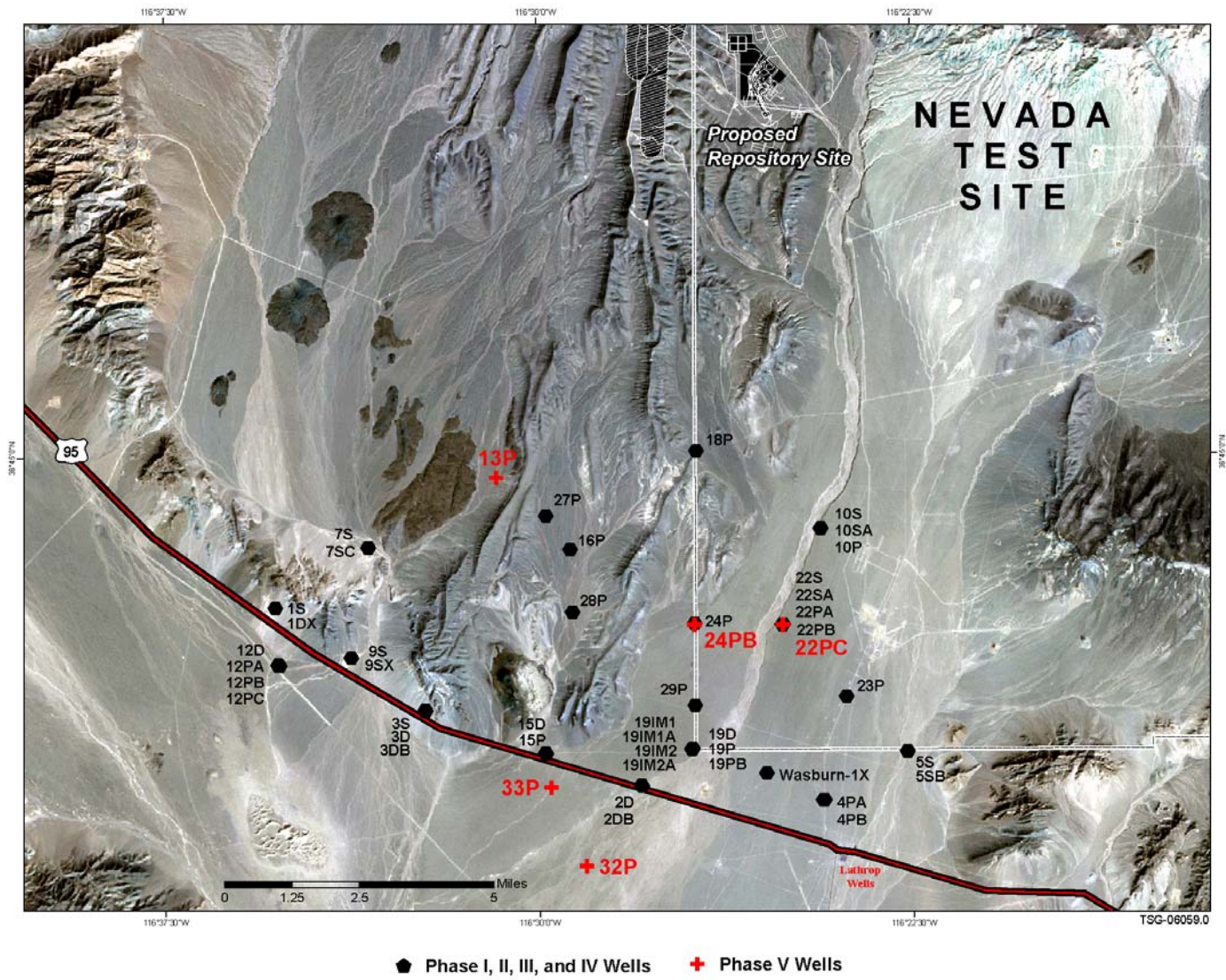
Work Plan 6, *Early Warning Drilling Program Geophysical Logging Work Plan*

Figure 1
EWDP Well Location