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Sandia National Laboratories

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Albuquerque, New Mexico 87185-0101
Livermore, California 94551-0969

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to: WIPP Records Center

from: Dale Bowman

subject: Milestone HYDRO-21-01: Milestone report that reviews progress made on the WIPP Integrated Hydrology Program Plan in FY2020

This Milestone Report documents the progress made on the work scope included in the 2016 Five-Year Projection Plan by Thomas et al. (2016) for the Waste Isolation Pilot Plant (WIPP) Integrated Hydrology Program and other completed work tasks through the end of FY2020. The Integrated Hydrology Program supports the strategic objectives of the WIPP groundwater monitoring program (DOE, 2003) including demonstrating regulatory compliance, improving efficiency and effectiveness of the program, and addressing concerns that arise from day-to-day operation of the site. Table 1 outlines the roles and responsibilities shared by Sandia National Laboratories (SNL) and Regulatory Environmental Services (RES). The WIPP Integrated Hydrology Program includes the United States Department of Energy Carlsbad Field Office (DOE CBFO), SNL as the WIPP Scientific Advisor, and the WIPP Management and Operations Contractor (Nuclear Waste Partnership [NWP] including RES).

The most recent plan for the Integrated Hydrology Program was published in March 2016 (Thomas et al., 2016). The program plan was written by SNL, as the Scientific Advisor, at the request of the DOE CBFO Hydrology Program Manager to provide a basis, review, and five-year projection of the program. Six investigative activity areas were identified to address knowledge or capability gaps in the groundwater monitoring system: 1) implementation of hydrology database linked to remote telemetry system, 2) expansion of the long-term high frequency monitoring network, 3) hydraulic testing, 4) depth-specific groundwater quality sampling and analysis, 5) Culebra-based performance assessment model conversion, and 6) analysis of transient forcings on the Culebra. Additional activities discussed in the program plan conducted as part of the Integrated Hydrology Program are recurring and are expected to continue. These activities include groundwater-level monitoring, groundwater-quality sampling, pressure-head/barometric air pressure/rainfall measurements, replacement of select deteriorating steel-cased wells, well plugging and abandonment activities, generation of the annual potentiometric surface map/compliance monitoring parameter assessment/observed water-level fluctuations reporting, and Culebra flow and radionuclide solute transport modeling. This memo does not focus on recurring activities, but instead focuses on the progress made in the six investigative activity areas and additional work areas that appeared by circumstance.

WIPP: 4.4.2.3.1: TD: RECERT: QA-L: 575046

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Table 1. Roles and responsibilities matrix for the WIPP Integrated Hydrology Program

Program Component	Responsible Agency
Plan Development and Maintenance	
Statements of Work	RES
Compliance Monitoring plan	RES
Long-term monitoring and well-based testing plans	SNL
Specific procedures and data/modeling analysis plans	SNL
Well-Related Contracting and Permitting	
Procurement for drilling, plugging, and abandonment	RES
Procurement for well-based testing support	RES
Procurement for well-based testing and analyses	SNL
Archaeological, New Mexico Office of the State Engineer, and Bureau of Land Management permits	RES
Drilling. Maintenance, Plugging and Abandonment Activities	
Site preparation and drilling	RES
Well completion and development	RES
Basic data reports	RES
Well maintenance	RES
Well plugging and abandonment	RES
Compliance and Long-Term Monitoring	
Monthly and annual Culebra groundwater-level and groundwater-quality measurements, respectively	RES
Semi-annual Culebra groundwater surface elevation report	RES
Annual Culebra groundwater report	RES
Quarterly and semi-annual shallow groundwater-level and groundwater-quality measurements, respectively	RES
Semi-annual discharge monitoring report for Discharge Permit DP-831 (for which RES contributes shallow groundwater-level and groundwater-quality data)	RES
Continuous Culebra, Magenta, and shallow groundwater pressure head, barometric air pressure, and rainfall measurements	SNL
Annual Culebra groundwater-level fluctuation report	SNL
Annual Culebra pressure-density calculations	SNL
Hydrological Field Studies and Data Analyses	
Well-based testing (e.g., pumping tests, slug tests and associated water quality sampling)	SNL
Well-based testing field support	RES
Well-based testing analyses (e.g., estimates of transmissivity)	SNL
Well-based test analysis reports	SNL
Compliance Recertification Application; Appendix HYDRO Hydrological Investigations section (i.e., a summary of SNL monitoring data and analyses)	SNL
Investigative activities (e.g., analysis of depth-specific groundwater quality)	SNL
Conceptual and Numerical Modeling	
Annual Culebra potentiometric surface generation	SNL
Annual Culebra potentiometric surface analysis report	SNL
Annual compliance monitoring parameter assessment	SNL
Performance Assessment (i.e., Culebra flow and solute transport modeling) for Compliance Recertification Application	SNL
Investigative activities (e.g., use of numerical models to analyze transient forcings on the Culebra)	SNL

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1.0 Implementation of Hydrology Database Linked to Remote Telemetry System

1.1 Hydrology Database

In the 2016 Five-Year Projection Plan, SNL proposed the implementation of an online hydrology database. A commercial database was proposed to maintain continuous professional support. SNL has begun implementation of this database with the ultimate goal of linking the new hydrology database to a remote telemetry system to provide near-real time data.

SNL purchased the commercial database software ESdat (Earth Science Data Manager) produced by EarthScience Information Systems (EScIS, 2020) for the new hydrology database. Well location, construction, and water quality have been imported into the ESDat database. However, a working evaluation of the software revealed that the advertised customization of the data needed to import the volumes of pressure data that exist was inadequate. In response, SNL is developing customized scripts to import the pressure data and is also evaluating the potential of using an alternate database program. Additionally, work is ongoing to qualify and format hydrology data for database entry. Efforts in both facets are ongoing.

1.2 Remote Telemetry System

Remote telemetry will provide major benefits to our well-monitoring network, used to record high-frequency long-term groundwater pressure data, for the Integrated Hydrology Program. SNL has implemented telemetry systems at eighteen locations in the monitoring network over three deployment phases. Figure 1 displays both the wells with telemetry systems by deployment phase and the land-withdrawal boundary (LWB).

Phase 1 locations (green) were implemented as an initial proof of concept using the Port-A-Camp (PAC) as a repeater station to the base computer in the SNL Carlsbad office. Wells H-9bR and C-2737 were added to test long- and short-range capabilities, respectively. Telemetry was also added for one of the two barometric transducers at the PAC. Phase 2 locations (blue) were SNL's first large-scale deployment introducing telemetry systems to wells H-4bR, SNL-10, SNL-12, SNL-13, WQSP-1, WQSP-2, and WQSP-3. Additionally, SNL established a repeater station midway, geographically, between the monitoring network and the base computer utilizing a communications tower owned by the U.S. Department of Homeland Security / U.S. Customs and Border Protection. Phase 3 locations (yellow) include AEC-7R, SNL-1, SNL-3, SNL-5, SNL-6, and SNL-18. These locations now provide transducer data in near-real time. Additional systems are presently being built and will be integrated into the monitoring network throughout calendar year 2021. The next wells to be equipped with telemetry systems include wells IMC-461, SNL-2, and SNL-8. A more complete description of the telemetry system progress is contained in milestone HYDRO-20-03 (Bowman, et al., 2020).

A fully implemented telemetry system will decrease SNL response time for data inquiries from the DOE CBFO. The system will also provide improved continuity of the well-pressure datasets. An alarm system, currently under development, will activate if pressure transducer issues interrupt data collection, and the system is being designed to detect anthropomorphic changes to aquifer water levels. These alarms will minimize loss of data that may currently go unnoticed between monitoring downloads. The telemetry system may also allow for higher frequency data acquisition during episodic/targeted events such as intense precipitation or during a pumping test.

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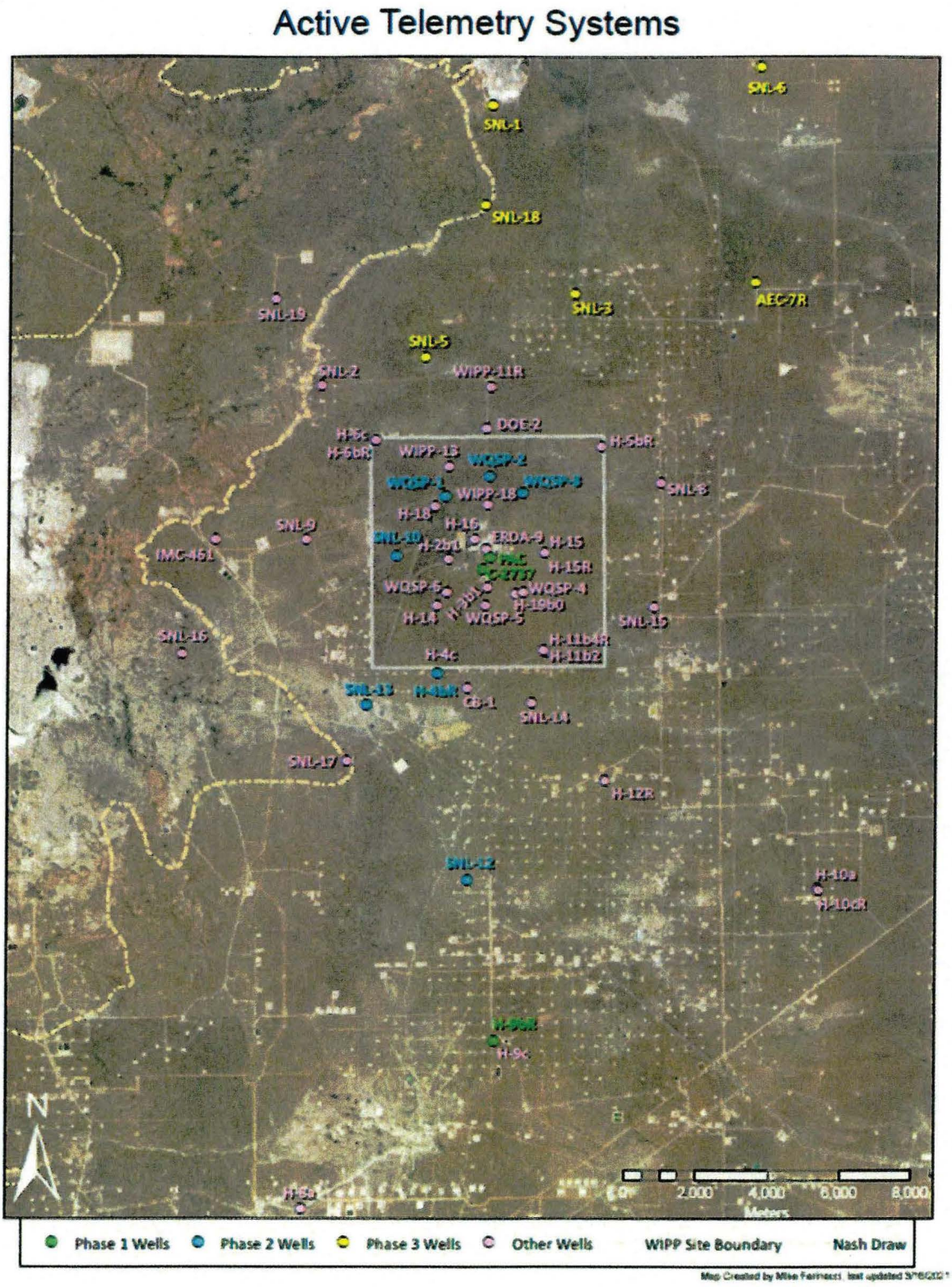

Figure 1. Well pad locations with telemetry deployments for the WIPP groundwater monitoring network (excluding the shallow subsurface wells).

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2.0 Expansion of the Long-Term High-frequency Monitoring Network

2.1 Incorporation of Existing Culebra Wells

SNL identified an opportunity to expand the WIPP monitoring network by instrumenting the existing compliance wells. Six wells completed in the Culebra (WQSP 1-6) were not equipped with pressure transducers prior to CY2019. Although originally designed for regulatory groundwater-quality sampling purposes, the incorporation of fiberglass-cased wells WQSP 1-6 into the long-term monitoring program would significantly expand the Culebra network (>15%) without the cost of drilling and developing new wells (Thomas et al., 2016). Wells WQSP 1-6, located within the LWB, are shown in Figure 1.

Wells WQSP 1-3 were integrated into the high-frequency monitoring network between March 2018 and March 2019. The WQSP well equipment (transducers, cables) was designated exclusive to each well, and was decontaminated to RES' requested standards prior to installation. SNL has successfully installed transducers and monitored the pressures in wells WQSP-1, WQSP-2, and WQSP-3 throughout CY 2020, with no adverse effects on the wells. We have discussed similarly instrumenting wells WQSP-4, WQSP-5, and WQSP-6 with RES, and the plan is to proceed as budget becomes available for augmented surface casings. Presently, SNL has purchased all required cable and transducers for the three proposed monitoring wells.

3.0 Hydraulic Testing

3.1 Optimize Well Network

The 2016 Five-Year Projection Plan identified three wells for replacement and six wells to be plugged and abandoned (P&A'd) as prioritized by previous network optimization studies and other practical constraints. The wells scheduled for replacement were H-5b, WIPP-11, and WIPP-19. Wells H-5b and WIPP-11 were plugged and replaced with wells H-5bR and WIPP-11R in September 2019. Development for well H-5bR began in October 2020 and is presently in progress. WIPP-11R development activities are in the planning phase.

Wells H-2b2, H-3b2, H-7b1, H-17, and WIPP-19 were plugged during CY2020. Wells ERDA-9 and WIPP-13 are scheduled for plugging and abandonment in CY2021. As of December 2019, a Modification to the Hazardous Waste Facility Permit to include the plugging of these wells had been submitted to the New Mexico Environmental Department (DOE & NWP, 2019).

3.2 New Culebra Wells Near Nash Draw

SNL proposed a multi-year effort to drill, core, complete, develop, and test up to three new Culebra wells to assess the flow system in Nash Draw, which is the northwestern-most boundary condition of the Culebra performance assessment flow model (see Figure 2). Due to the dip of the Culebra, wells in or near Nash Draw would be shallower and therefore less expensive to drill and complete than Culebra wells at or east of the WIPP surface infrastructure. This activity has not yet taken place.

Locations for Nash Draw wells, with respect to optimizing the complete WIPP monitoring well network, are described in the Analysis for the Optimization of the Culebra Monitoring Network for New Well Locations (Bowman et al., 2021). It is important to note that the potential locations described in this analysis report may not be the best locations with respect to Nash Draw investigation.

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To best site these wells with respect to Nash Draw investigation, SNL is developing a test plan to study the water balance in sub-basins in Nash Draw (Hayes, 2019). Interdisciplinary approaches, including a large-scale passive tracer experiment coupled with geophysical observation in the Nash Draw area, would provide data that could be used to inform a relevant, process-based understanding. Monitoring rainfall, soil infiltration, and discharge into preferential flow pathways would improve understanding of recharge to the Culebra, which can then be used to improve the Performance Assessment hydrology model.

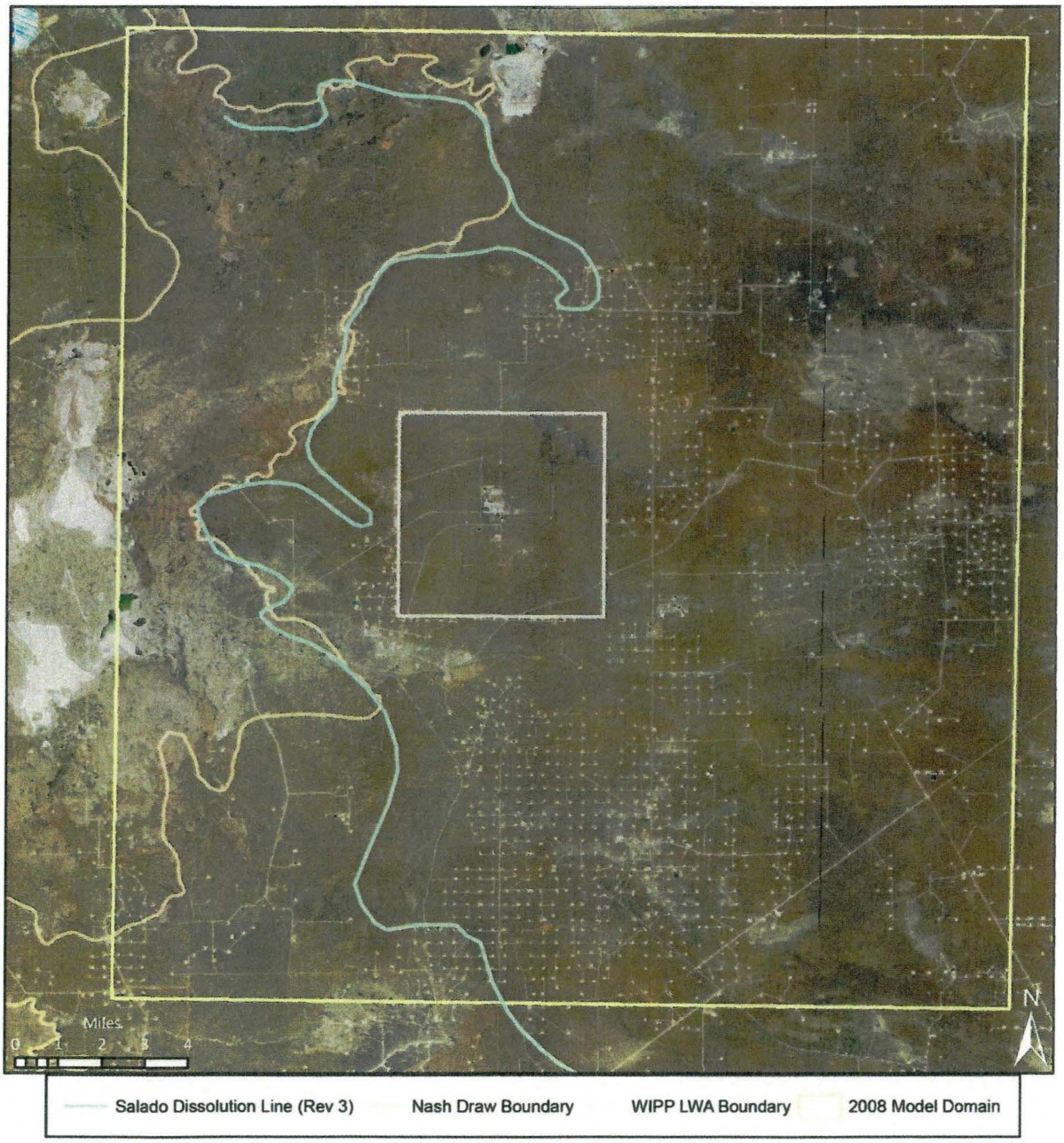

Figure 2. Map of Salado Dissolution, the Nash Draw, and WIPP Land Withdrawal boundaries.

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3.3 Explore recent advances in well testing

Currently, SNL primarily employs traditional single- and multi-pad pumping and slug tests to estimate effective parameters (e.g., transmissivity and storativity). In an effort to reduce water disposal costs associated with traditional tests, SNL will continue to employ alternative methods where appropriate, including the use of pulse and slug tests, and possibly pneumatic sinusoidal pressure pulses applied to the wellhead.

To assess the validity of the pneumatic sinusoidal method, well IMC-461 was tested using five variations of a pneumatic sinusoid, three pneumatic (pressure) slug tests, and three pneumatic pulses designed to mimic pumping tests (Bowman, 2016). The log-average of estimated transmissivities for the pneumatic tests was a factor of 1.1 difference from previous slug test transmissivity estimate. The evaluation of all three pneumatic tests established pneumatic sinusoidal testing as a reasonable alternative to pumping tests. The pneumatic sinusoidal method also inherently affects a wider portion of the aquifer tested than a traditional solid slug test, so it is potentially more representative of the local aquifer. A discussion on the value of re-evaluating more slug tests using this method is warranted and in progress.

4.0 Depth specific Groundwater Quality Testing and Analysis

4.1 Design of a Downhole Borehole Tool

The density in undisturbed Culebra wells is known to stratify with time. Presently, SNL calculates the fluid density for the mid-formation water of the Culebra annually (Johnson, 2015). In the 2016 Five-Year Projection Plan, SNL proposed to design and employ a downhole borehole tool that can measure the pressure gradient, pH, conductivity, turbidity, salinity, and temperature over the full length of the water column within a well to assess the representativeness of the current mid-formation measurement assumption. Per our efforts detailed in Vento and Bowman (2019) and the 2019 Summary Report (Hayes, 2020), the instrument accuracy required to measure the necessary density changes over signal noise disqualified our original prototype tool. The density measurements made by Vento and Bowman were based on weight measurements of water samples taken from downhole increments in well H-6bR. These measurements showed a trend, but the measurement approach allowed for an excess of potential human error.

In 2020, SNL expanded its study of well water density stratification. A combination of incremental downhole water quality sampling and water quality profiling using a multi-parameter sonde was performed. Wells H-6bR, H-11b4R, and H-19b0 were progressively measured, with respect to depth, using a multi-parameter sonde for water quality (conductivity, temperature and pH). The three wells were also sampled at various depths for water quality analyses and comparison. The milestone report associated with this task is presently in progress.

4.2 Depth-Specific Water Quality Sampling

Historically, water quality samples were collected from produced water resulting from pumping tests or purges at the end of each well's development and testing. The 2016 Five-Year Projection Plan proposed collecting discrete water samples for water chemistry analyses. With the depth-specific groundwater-quality measurements proposed in that plan and an understanding of any composition and density stratification discussed in the previous section, SNL would be in a position to better understand the spatio-temporal characteristics of the fluid chemistry within the wellbore and more rigorously examine the existing protocol used to calculate equivalent freshwater heads.

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Beginning in 2017, SNL has employed a depth-specific "snap" sampler to obtain discrete-depth water quality samples annually for a select set of 28 Culebra monitoring wells. The Milestone report, *WIPP Water Qualities Collected from 2017 to 2018* (Bowman, 2019), details the results of water quality analyses from CY2017 and CY2018 and compares them to the results of historical post-pumping test water quality samples. SNL has continued sampling those Culebra wells on an annual basis through CY2020. A milestone report scheduled for FY2021 will summarize the evaluation of the accuracy of the discrete depth "snap" sampling method, with respect to collecting water quality samples after completion of long-term pumping tests.

5.0 Culebra-Based Performance Assessment Model Conversion

5.1 Replacement of MODFLOW-2000 and SECOTP2D with PFLOTRAN

The Culebra flow model implementations are being modernized for Compliance Recertification Application purposes. The current hydrologic modeling employed for Culebra-based Performance Assessment is conducted with the U.S. Geological Survey MODFLOW-2000 finite difference flow model (Harbaugh et.al, 2000) which simulates confined two-dimensional flow. Currently, 600 realizations of steady-state flow simulations are performed using MODFLOW-2000 on a 100 × 100 m, two-dimensional mesh (full and partial potash mining scenarios for three replicates of 100 sampled vectors of random input parameters). Transmissivity fields are developed by optimizing hydrologic field parameters to available head data using the PEST code (Doherty, 2019).

Radionuclide transport in the Culebra is simulated using the SNL-developed SECOTP2D (Gilkey, 2013) dual porosity, finite volume solute transport model on a smaller flow domain with finer discretization (50 × 50 m cells) nested within the larger MODFLOW domain. SECOTP2D simulates transport of a unit release of each of five radionuclides from a release point at the center of the WIPP disposal panels (the Culebra well C-2737 location) to the edge of the WIPP LWB (Kuhlman, 2010), for each realization of the transmissivity fields.

The 2016 Five-Year Projection Plan included the goal to replace MODFLOW and SECOTP2D with PFLOTRAN (Lichtner et al, 2017). We have ceased pursuing this avenue for modernizing the Culebra flow code, as PFLOTRAN development and software quality assurance is focused on Salado flow and transport modeling. Because the need for modernizing the Culebra flow model implementation is on-going, the Hydrology/PA teams will explore other modern codes as replacements for MODFLOW and PEST.

6.0 Analysis of Transient Forcings on the Culebra

6.1 Examine Steady-State Assumption for the Culebra

Fluid pressure responses measured throughout the Culebra, as a part of the compliance and long-term monitoring programs, reflect natural and anthropogenic forcings on the aquifer. Initial scoping studies conducted by Hillesheim et al. (2007) indicate distinct and sometimes abrupt increases in Culebra groundwater pressure head are possible soon after rainfall events (e.g., > 60 mm within 48 hrs). These observations challenge the previous assumption that Culebra fluid pressures would not respond to local rainfall events (DOE, 1996). Additionally, pumping at a commercial well (Mills Ranch), beginning in 2013 and continuing intermittently until summer 2018 created a significant pumping depression across

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much of the Culebra near the WIPP site. Monitoring data have shown other possible commercial pumping events in the Culebra unrelated to the Mills Ranch well.

The 2016 Five-Year Projection Plan proposed re-examining the steady-state conceptual model for the Culebra flow field. The work performed for this activity can be split into two categories: research into the modeled response of Mills Ranch pumping and investigations into Nash Draw. The Mills Ranch pumping event paper by Thomas et al. in 2017 suggested that improved characterization of Culebra storage characteristics would be beneficial for future modeling efforts. Their paper also reinforced that the high-frequency data collection method adopted by SNL is valuable for addressing the impacts of anthropogenic effects on water level data.

An in-depth Nash Draw research project is presently in the planning phase. SNL's objective is to quantify the natural forcings and attempt to replicate observed groundwater pressure heads in response to rainfall and subsequent recharge events in Nash Draw, with one-dimensional simulations of variably-saturated flow combined with data from a hydrological study of Nash Draw. The SNL hydrology team has had discussions regarding the potential equipment needed and the field efforts that will be required to adequately monitor the precipitation and hydrology of the area. A Test Plan for Nash Draw investigations is currently in development.

7.0 Geologic Core Processing

In CY2020, SNL worked in conjunction with Los Alamos National Laboratory to preserve and package salt cores drilled from underground Map Units 3 and 4. Seventy-four 2 ft to 3 ft salt cores were wrapped in industrial-grade plastic and placed in capped PVC tubes with silicon sealant to better preserve the water content of the cores. Eighteen of these cores were successfully shipped to research partners in Germany, with an additional four cores delivered to SNL rock mechanics researchers in Albuquerque, NM. The remaining core is being stored in Carlsbad, NM for future use.

8.0 Culebra Release Point Reassessment

An Analysis Report reassessing the release pathways from the waste panels, including the additional panels, was completed in CY2020 (Kushnereit, et al. 2020). Potential pathways were characterized for the full expanse of the proposed additional panels for both full and partial potash mining scenarios (Figure 3) using Culebra transmissivity fields reported by Kuhlman (2010). Model results showed that a minor fraction of flow paths could be markedly different from flow paths originating at the release point used in Performance Assessment calculations since PABC-2009. Summary analysis showed that for most release points, it was uncommon for a released particle to reach the LWB after 10,000 years, particles originating at some release points inside mining-affected areas in the full-mining scenario could reach the LWB prior to 10,000 years.

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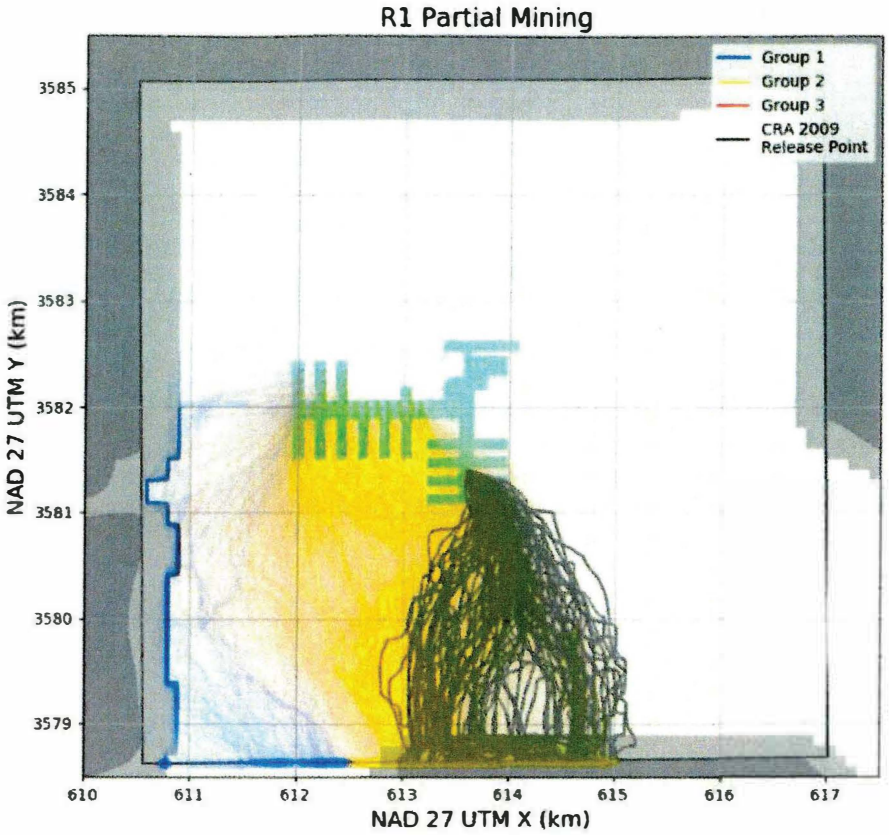

Figure 3. One of the partial mining scenarios illustrating potential released particle flow paths for existing and proposed additional panels.

9.0 Summary

The Integrated Hydrology Program continues to support the strategic objectives of the WIPP groundwater monitoring program which include:

- Demonstrating regulatory compliance (for example: employing groundwater sampling and analysis to maintain a scientifically defensible groundwater database);
- Improving efficiency and effectiveness of the program (for example: implementing a radio telemetry system); and
- Addressing concerns that arise from day-to-day operation of the site (for example: evaluating paths forward for areas with aging wells).

Since the most recent plan for the Integrated Hydrology Program was published in March 2016, work has begun on generating a new program plan, one that extends some of the work described in the 2016 plan and adds additional activities to improve our conceptual model and monitoring practices.

A brief summary of FY2020 activities and their current status are listed below:

- Construction and assessment of the remote telemetry system continues, with new systems added each month.

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- A database structure to house monitoring network data is being developed and data formatting for data entry is in progress.

- The remaining three WQSP wells are intended to be integrated into the monitoring well network in CY2021.

- Five monitoring wells were P&A'd in CY2020, and two wells remain to P&A'd in CY2021. Two monitoring wells were replaced in CY2020, H-5bR which is presently being developed and WIPP-11R which is also planned for development in CY2021.

- Density sampling of three wells was performed to continue investigation of an alternative method for water density analysis, and four years of discrete-depth water quality sampling has been completed. Both the density and discrete-depth sampling investigations will be reported in an upcoming milestone.

- Geologic salt core was successfully preserved and distributed to several research partners for rock mechanic experiments.

- An assessment of Culebra travel times at different release points related to the proposed additional panels was completed.

- Model software to complete updates of the Culebra flow and transport model is under evaluation.

- Investigation of the transient forcings of the Culebra, including the hydrology of Nash Draw, to test the assumption of steady state in the Culebra, is in the planning phase.

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