PHOENIX – Web-Based Application for Accessing Hanford Tank Monitoring Data-16157

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ABSTRACT

Data volume, complexity, and access issues pose severe challenges for analysts, regulators, and stakeholders interested in evaluating scientific data to support decision making at the Department of Energy's (DOE) Hanford Site. Pacific Northwest National Laboratory (PNNL) has developed a suite of web applications known collectively as PHOENIX (PNNL-Hanford Online ENvironmental Information eXchange) to address data access, transparency, and integration challenges through intuitive query, visualization, and analysis tools that are accessible via desktop computer or mobile device by simply accessing the application webpage (http://phoenix.pnnl.gov). Beginning in 2013, DOE's Office of River Protection (ORP) has worked with PNNL to develop a PHOENIX Tank Farm application to provide access to, and visualization of, in-tank monitoring data that had only been available to the public as text downloads for almost two decades. The Tank Farm application's user-friendly web-interface allows the public, stakeholders, regulators, and program managers to quickly and easily visualize in-tank and ex-tank data, facilitating data transparency and high-level decisions related to tank operations and management.

INTRODUCTION

The Hanford Site is home to 177 underground storage tanks, grouped into 18 tank farms, which contain about 211,983 cubic meters of radioactive and chemically hazardous wastes, comprised of a variety of waste forms including sludges, salts, and liquids. The physical and chemical properties of the waste vary widely. There are 149 aging single-shell tanks (SSTs), first constructed in the mid-1940s, and 28 double-shell tanks (DSTs) of newer construction, with tank capacities ranging in size from 208 to over 3,785 cubic meters. Approximately 63 of the SSTs are assumed to have leaked up to one million gallons into the environment, and in 2013 a small leak from the inner shell of one DST was detected. DOE has minimized the risk of waste leaking from the SSTs by removing pumpable liquids and transferring those liquids to the DSTs. Nevertheless, more than 9,464 cubic meters of liquid remains in the SSTs although most tanks have less than 151 cubic meters of liquid remaining. Ultimately, the Waste Treatment and Immobilization Plant (WTP) will immobilize the waste stored in the DSTs and SSTs for permanent disposition. In the interim, the underground tanks will continue to be monitored for evidence of leakage to the environment.

In-tank conditions are monitored through a variety of methods including measuring surface levels, interstitial liquid levels (ILLs), and waste temperatures. External drywells in and around the tank farms are used to look for gamma signatures indicative of a potential leak. Additionally, both the chemical composition of each tank's waste inventory and waste transfer data are stored in the Tank Waste Information Network System (TWINS). While much of this data is publically available, it is scattered among many locations and in formats that make dissemination and evaluation challenging. In-tank monitoring data (surface level, ILL, and waste temperature measurements) along with best-basis inventory (BBI) estimates of waste composition have been available to the public through TWINS as text downloads for almost two decades, which limited data usefulness and understanding; accessing, disseminating, and interpreting these complex data sets can be challenging for non-technical users. Limited gamma signature data in the form of geophysical logs (GPLs) are available in the Hanford Environmental Information System (HEIS), while other GPL data is housed in hard-to-access contractor databases and reporting documents. Waste transfer information is published in a monthly Waste Tank Summary Report that is publically accessible, yet is not presented in a manner that is easy to understand.

The office responsible for the management and cleanup of the tank waste, DOE ORP, has partnered with PNNL to develop a Tank Farms application within the PHOENIX family of web applications which seeks to address data access, transparency, and integration challenges related to tank waste monitoring to provide effective decision support and stakeholder engagement. The following sections provide a background on PHOENIX, along with a detailed discussion of the Tank Farms application and how it is being used to support decision making and facilitate communication between regulators and stakeholders at Hanford.

BACKGROUND ON PHOENIX

PHOENIX is a family of spatially enabled web applications providing quick access to decades of valuable scientific data and insight through intuitive query, visualization, and analysis tools. PHOENIX realizes broad, public accessibility by relying only on ubiquitous web browsers, eliminating the need for specialized software. It accommodates a wide range of users with intuitive interfaces that require little or no training to quickly obtain and visualize data. PHOENIX currently hosts many map-based Explorers and Dashboards, which are customized to address different applications at Hanford. The PHOENIX family of web applications is located in a Web Application Gallery available at http://phoenix.pnnl.gov. All PHOENIX applications are accessible on almost any web browser, including Internet Explorer®[a] 9.0 and greater, Chrome™[b], Firefox®[c], and Safari®[d].

PHOENIX applications provide access to a wide range of geospatial and environmental monitoring data at the Hanford Site. Users can access geographic information system (GIS) information related to historic aerial imagery dating back to 1943, waste sites, facilities, land topography, soil classification, surface geology, groundwater plume extents, and locations of groundwater wells and soil sampling locations. Users can also access and visualize monitoring data, including environmental data (e.g., groundwater, soil, hydraulic head, GPL) and tank waste data (e.g., surface level, ILL, temperature, transfer data, inventory estimates). Atmospheric data such as air temperature and wind speed and direction are also provided via connections to local Hanford Meteorological Stations (HMS) and National Oceanic and Atmospheric Administration (NOAA) weather stations.

PHOENIX TANK FARMS APPLICATION

The PHOENIX Tank Farms application provides a centralized, publically available portal for users to access volumes of tank waste-related data that have only been available as text downloads for the last 20 years. Currently, the principal uses for the PHOENIX Tank Farm application include visualization of:

- Basic information about SSTs and DSTs including leak status
- Historical and current in-tank sensor data: surface level, ILL, and temperature measurements
- Atmospheric temperature and barometric pressure
- Tank/farm waste volume by phase (sludge, supernate, saltcake)
- Tank-specific inventory of risk driving constituents
- Drywell gamma logging results for selected tank farms
- Tank volume and waste transfer history
- Groundwater contaminant trends in the vicinity of the tank farms
- Multiple Hanford site GIS layers: facilities, waste sites, wells, etc.

The user-friendly web interface attracts a wide-range of users ranging in technical ability. Users of the PHOENIX Tank Farms application (and other PHOENIX applications, as well) include:

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- Regulators representing federal and state agencies, such as DOE, US Environmental Protection Agency, and Washington State Department of Ecology
- Analysts and researchers working for DOE, contractors, universities, PNNL, and other national laboratories
- Stakeholders, including local Native American Tribes, Hanford Advisory Board (a DOE Site-Specific Advisory Board established in accordance with the Federal Advisory Committee Act) and Hanford Natural Resource Trustee Council
- General public

The following paragraphs summarize how the PHOENIX Tank Farms application is used to investigate and evaluate in-tank and atmospheric monitoring data, leak detection, and groundwater monitoring at Hanford.

In-Tank and Atmospheric Monitoring

The PHOENIX Tank Farms application is used to access and visualize in-tank sensor data (including surface level, ILL, and waste temperature data) and tank waste transfer information, along with atmospheric monitoring data (Fig. **1**).

A series of tank risers that extend out the top of the tanks above the ground surface are used to monitor liquid levels, collect samples, pump out tank contents, and permit chemical additions. Several different gauges may be used to monitor the surface level (in inches) of a tank, which is plotted over time in the Tank Farms application. Each different gauge's surface level measurements are represented by a different color on the chart. Users can also access information related to work order numbers and descriptions associated with gauge inspection, calibration, or flushing. These work order numbers can be used to correlate small increases or decreases in waste surface level with either the addition or removal of the gauge from the tank.

Interstitial liquid is the liquid in a waste matrix contained within the pore spaces of salts and sludge, some of which can gravity drain and the rest of which cannot drain due to capillary action. The level of this liquid is called the interstitial liquid level (ILL) and is plotted in the Tank Farms application within a specific tank over time. Changes in the ILLs are used for leak detection and intrusion monitoring; however, depending on the waste phases present in a tank, ILL measurements may or may not be measured and presented.

Certain risers out of the top of the tank house thermocouple probes which are used to monitor in-tank temperature. The temperature in some of the DSTs has elevated over time causing the water in the waste to evaporate. Evaporation causes the waste level to slowly decline, mimicking a slow leak. Monitoring the in-tank temperature provides the necessary data to calculate evaporation rates and compare those with the observed surface decrease to determine if a leak is truly occurring.

In-tank temperature data can also be correlated with atmospheric conditions, which are also provided in the Tank Farms application. As discussed in [1], barometric pressure changes and ambient air temperatures affect gases within the waste, causing the waste to expand and contract. Contraction of the waste causes the surface level to decrease and expansion of the waste causes the surface level to increase, both of which phenomena can be viewed in the Tank Farms application by correlating surface level changes to trends in both barometric pressure and ambient air temperature.

Much of the work at Hanford’s tank farms requires transferring waste between tanks, particularly when retrieving waste from SSTs and transferring that waste to newer DSTs. Volume transfer data allows the contractor to maintain an inventory of the tank wastes. Since waste volume and surface level are directly correlated, waste transfer volumes are presented in the Tank Farms application to show that dramatic changes in the surface level are tied to the addition or removal of liquid in a tank and not to a leak or intrusion event. Information is provided for source transfers (either a tank-to-tank volume transfer or transfer from a tank to an evaporator), generator transfers (water, chemical, or non-tank waste added to the tank), and volume adjustments (used to adjust records to match measurements).

Fig. 1. PHOENIX Tank Farms application used to visualize in-tank sensor and atmospheric monitoring data.

As discussed in [2], the best-basis inventory (BBI) contains inventory estimates for chemical and radionuclide components in the 177 underground storage tanks. BBI estimates have been available to the public as text downloads via TWINS, where inventories are presented on both a tank-by-tank and global (total) basis. The tank-by-tank best-basis waste inventories include 25 chemical and 46 radionuclide components. The global waste inventories include five chemicals in addition to the chemicals and radionuclides reported in the tank-by-tank inventories. The best-basis global inventories are independent estimates of the total amount of a chemical or radionuclide component in all tanks. The standard analytes account for approximately 99 weight percent (wt%) of the chemical inventory (not including percent water and hydroxide) and the radionuclides account for over 99 percent of the activity (Curies), in terms of short and long-term risk. Information used to establish global inventories originated from key historical records, from various chemical flowsheets used in reprocessing of irradiated Hanford Site reactor fuels, and from calculations of radionuclide isotope generation and decay. Tank-by-tank inventories are most often based on sample analysis results.

The Tank Farms application visualizes waste volume estimates and BBI data for individual tanks and for each tank farm (Fig. **2**). Users can visualize waste volumes by phase (sludge, saltcake, supernatant) and can also visualize waste inventories by phase for top risk-driving contaminants at the Site, including Iodine-129, Technetium-99, Strontium-90, Cesium-137, and Plutonium-239.

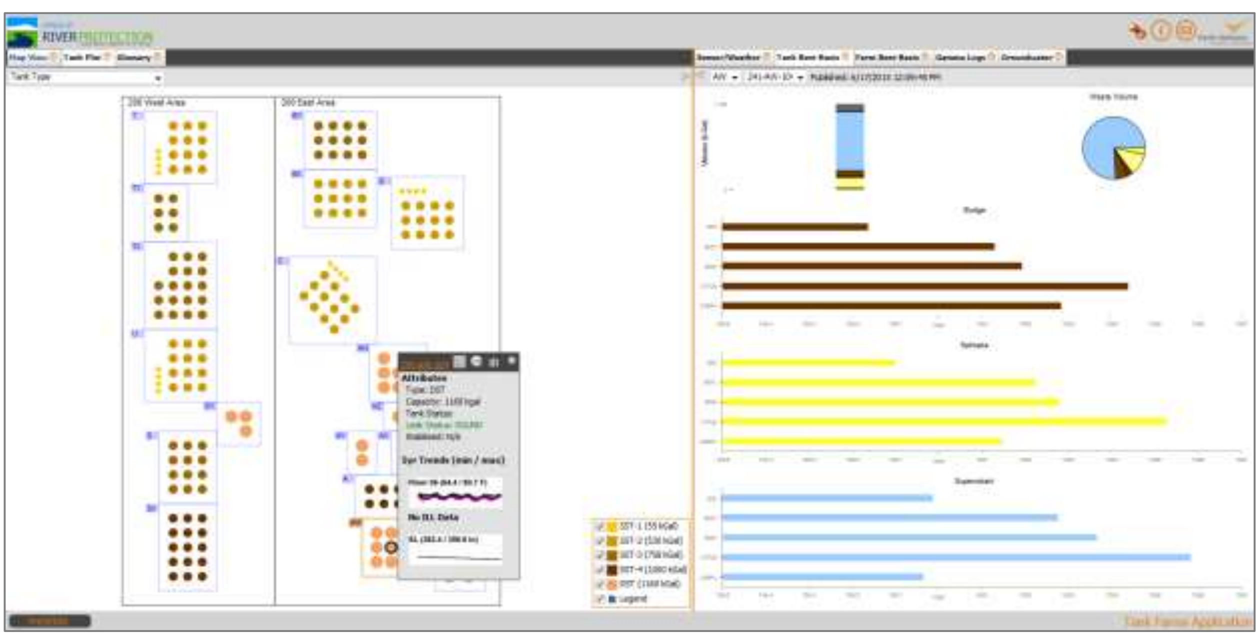

Fig. 2. PHOENIX Tank Farms application used to visualize best-basis inventory estimates of waste composition.

Leak Detection

The primary ex-tank monitoring method in the SST farms is drywell logging in the form of geophysical logging the over 700 drywells in and around the SST farms. Drywells, or vadose wells, are vertical boreholes with 15.24- or 20.32-cm diameter carbon steel casings, positioned radially around SSTs. They are called drywells because they do not penetrate the water table, instead they are drilled 15.24 and 76.20 meters below ground surface (bgs) and are normally monitored down to between 15.24 and 45.72 meters bgs. Gamma probes are used to obtain radiation profiles (gamma logs) within drywells and is a valuable leak monitoring method.

While drywell logging is not considered a reliable method for detecting new releases to the environment from the SSTs, it is a valuable tool for monitoring past releases. Drywell logging may also be a good tool for providing supporting information when in-tank monitoring indicates a new release may have occurred. Drywell logging can be used to track migration of past releases and drywell logging data will be an important part of closure planning for tank farms.

The Tank Farms application plots gamma logging results (total gamma and constituent concentrations) to show how radioactivity varies with depth in the drywell at different time periods. Users can view either total gamma in counts per second (counts/s) (Fig. **3**) or isotope-specific logs in picocuries per gram (pCi/g) (Fig. **4**).

When evaluating the isotope-specific logs in a drywell, 50^{th} and 90^{th} percentile background concentrations for the specific isotope are provided for context (Fig. **4**). There is a certain amount of background radiation that occurs from natural sources (e.g., radon or naturally-occurring Uranium deposits) or from human activities (e.g., Chernobyl). These values represent the amount of background radiation expected from the selected radionuclide. These values were obtained from a study of background radiation in the subsurface at the Hanford Site [3]. 50^{th} percentile means 50 percent of the background samples were at or below that level of radioactivity, and 90^{th} percentile means 90 percent of the background samples were at or below that level of radioactivity. Therefore, any value over the 90^{th} percentile line on the charts is likely not from natural background.

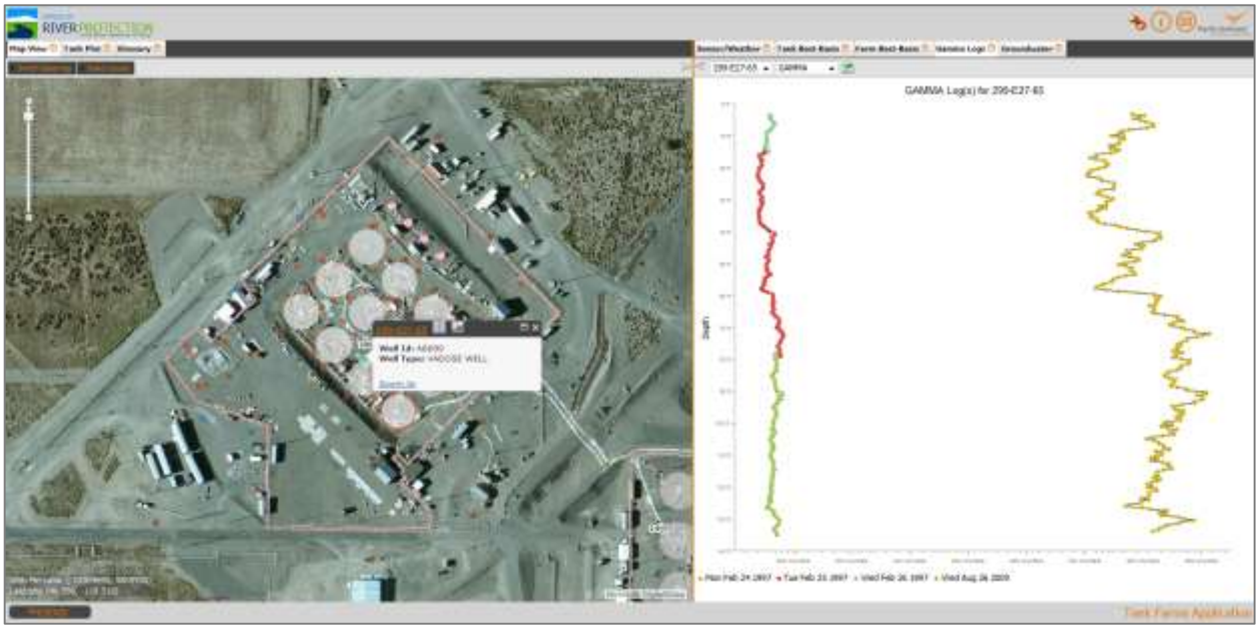

Fig. 3. PHOENIX Tank Farms application used to visualize gamma signature data measured in dry/vadose wells in the vicinity of tanks.

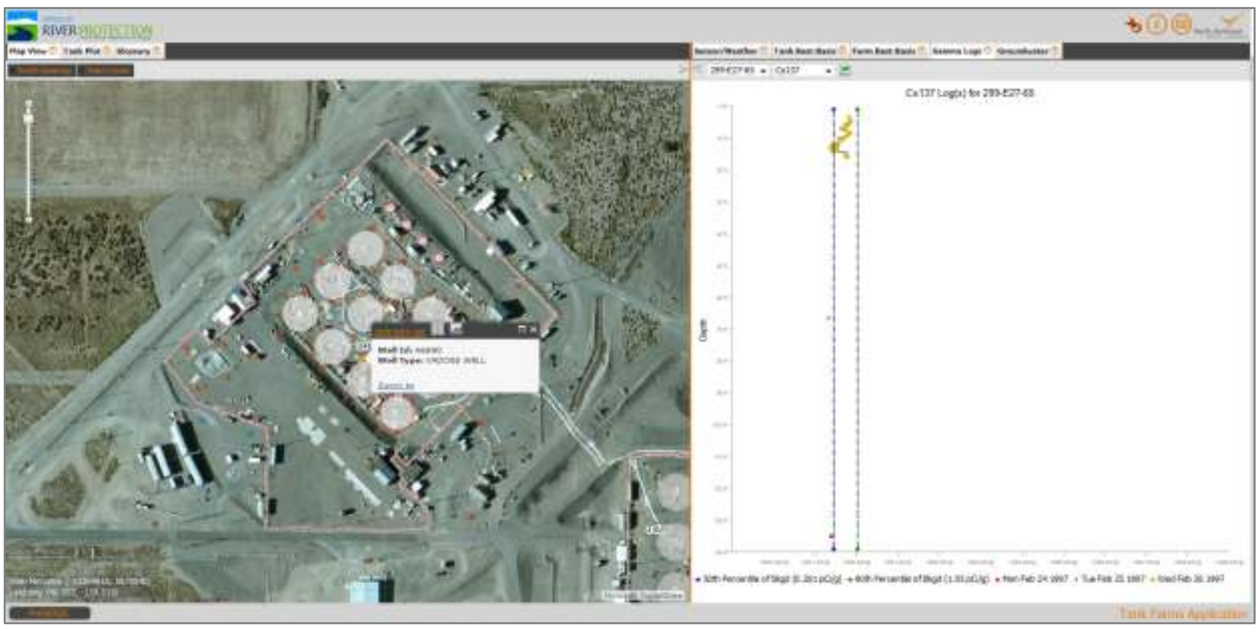

Fig. 4. PHOENIX Tank Farms application used to visualize constituent concentrations measured in dry/vadose wells in the vicinity of tanks.

Groundwater Monitoring

DOE operates an extensive groundwater monitoring program on the Hanford Site, collecting thousands of samples from hundreds of wells each year. This monitoring tracks movement of existing groundwater contamination plumes and measures the effectiveness of remedial actions. The most recent groundwater monitoring results for the Site can be found in [4].

The Tank Farms application provides access to the monitoring data collected in the groundwater wells in the vicinity of the tank farms (Fig. **5**). Only results for ten key contaminants have been identified as the top contaminants of potential concern (COPCs) in the Hanford groundwater monitoring report. Groundwater monitoring results are plotted in the Tank Farms application over time for a specific well respective to the associated drinking water standard (DWS).

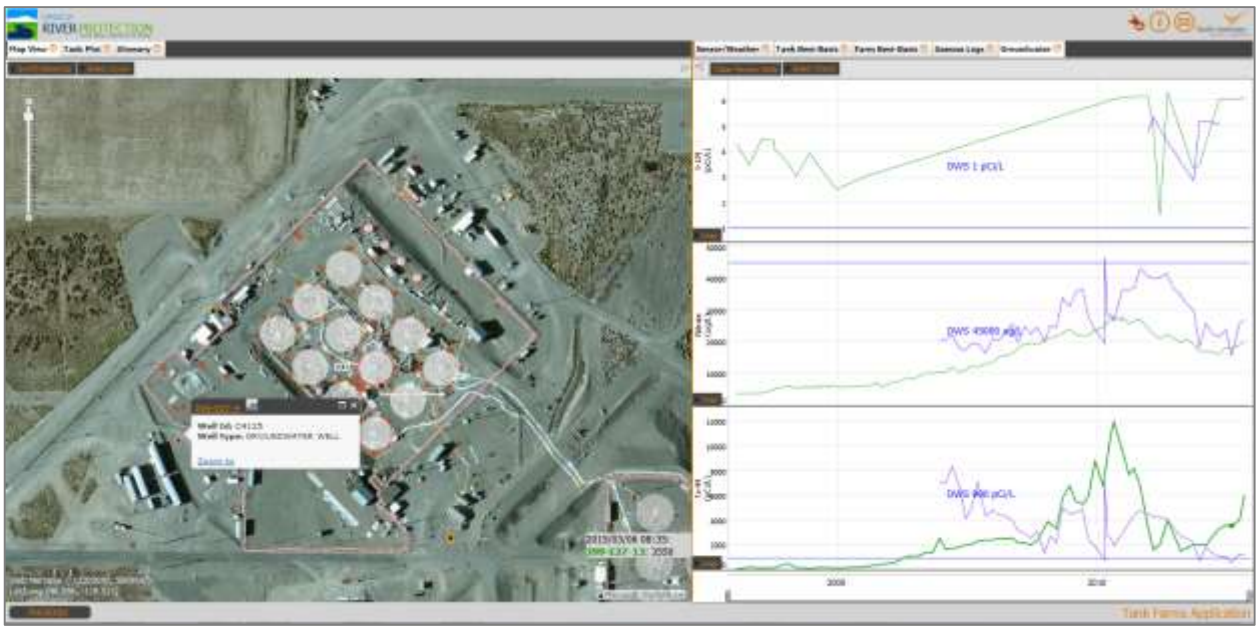

Fig. 5. PHOENIX Tank Farms application used to visualize groundwater monitoring data in the vicinity of tanks.

CONCLUSION

The PHOENIX family of web applications is a set of intuitive query, visualization, and analysis tools providing quick access to decades of valuable scientific data collected at the DOE Hanford Site. PHOENIX applications provide open and transparent access to a vast amount of environmental and tank monitoring data, along with other pertinent Site information related to facilities, waste sites, and geological and topographic information. These tools are currently being used by analysts, regulators, and stakeholders to understand and address complex Site issues related to cleanup, management, and operations. Specifically, the Tank Farms application provides access to tank-related monitoring data that has been available to the public for many years only as text downloads which made data visualization, integration, dissemination, and evaluation challenging. For the first time, data related to in-tank monitoring, atmospheric monitoring, leak detection, and groundwater monitoring can be accessed through one centralized, easy-to-use portal, allowing users to visualize relevant information in meaningful, insightful ways. By providing open and transparent access to decades of tank-related data, DOE is succeeding in regaining public trust and engaging community members in important discussions that will impact the region for generations to come.

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