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Challenges for Deep Vadose Zone Remediation at the Hanford Site

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ABSTRACT

The "deep vadose zone" is defined as the region below the practical depth of surface remedy influence (e.g., excavation or barrier). At the Hanford Site, this region of the Central Plateau poses unique challenges for characterization and remediation. Currently, deep vadose zone characterization efforts and remedy selection are spread over multiple waste site Operable Units and tank farm Waste Management Areas. A particular challenge for this effort is the situation in which past leaks from single-shell tanks have become commingled with discharges from nearby liquid disposal sites. In addition, tests of potentially viable remediation technologies will be initiated in the next few years.

The Hanford Site is working with all affected parties, including the Washington State Department of Ecology, the Environmental Protection Agency, DOE-RL, DOE-ORP, and multiple contractor organizations to develop remediation approaches. This effort addresses the complex and challenging technical and is evaluating the best strategy or combination of strategies for focusing technical investigations, including treatability studies to facilitate deep vadose zone remediation at the Hanford Site.

INTRODUCTION

The Central Plateau of the Hanford Site is an area of approximately 200 square kilometers (75 square miles). Nearly all of the 800 waste sites (including solid waste sites) are within the 200 Areas, which cover 16 square kilometers (6 square miles) near the center of the plateau. Approximately 900 facilities are in the 200 Areas, whose mission during Hanford operations (1943 to 1989) was to process irradiated materials produced in reactors near the Columbia River and extract plutonium. The byproducts of this activity were effluents contaminated in various degrees with chemicals and radionuclides. The most concentrated wastes were stored in the 177 underground tanks, but due to capacity and worker safety concerns some of the wastes were discharged into engineered surface structures and allowed to percolate through the vadose zone using cribs or specific retention trenches. In addition to direct discharges to the soil, there have been unintentional releases from the underground tanks due to leaks, overfills, and unplanned release from pipeline and valve systems.

Chemical and radioactive constituents from past discharges are bound up in the shallow soils (vadose zone) and can be addressed by conventional surface remedies (i.e., remove, treat and dispose, stabilization, capping, etc.) However, in many cases, the more mobile constituents

migrated deeper in the vadose zone and cannot be addressed by conventional surface based remediation methods.

For purposes of this discussion deep vadose zone contamination is defined as the inventory of chemicals and radionuclides from past discharges that is not mitigated by surface remedy implementation and that poses a potential continuing impact to groundwater quality. Figure 1 provides a diagram that illustrates this concept for the Central Plateau at the Hanford Site.

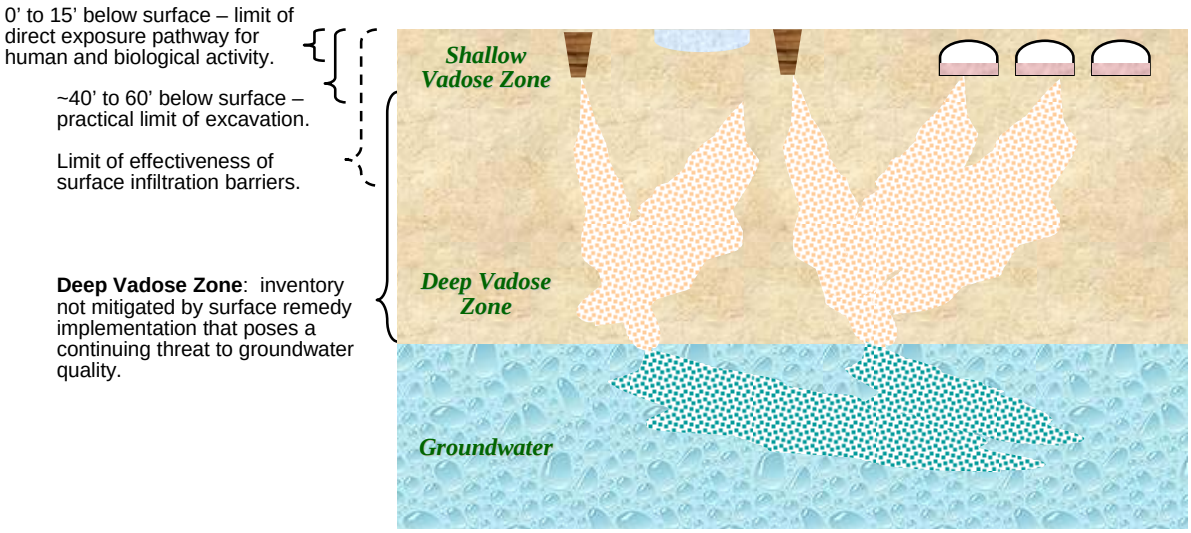

Fig. 1. Deep vadose zone terminology.

Making cleanup decisions for the deep vadose zone problem at the Hanford Site is further complicated by the following factors:

- Additional information is needed regarding the nature and extent of deep vadose zone contamination and the potential fate and transport into the groundwater.
- Readily available or proven methods are not available for remediating deep vadose zone contamination that may reside at depths of 200 feet or more below the surface, beyond the reach of traditional removal or containment approaches.
- There are emerging uranium and technetium-99 plumes entering Hanford's groundwater [1] that appear to result from deep vadose zone sources that will complicate remedy selection and remediation of Hanford's groundwater plumes.
- Deep vadose zone contamination from multiple sources, operable units and areas under different regulatory authority is often commingled in the subsurface.

CHALLANGES

This paper describes the ongoing process to develop an approach for conducting deep vadose zone investigations and remediation for the Central Plateau of the Hanford Site under these complex and challenging conditions. The following sections of this paper are organized around the following steps conducted in cooperation with DOE-RL, DOE-ORP, EPA and Ecology and associated contractor organizations.

- Step 1: Clarify the nature of the problem and challenges with the current situation.
- Step 2: Define criteria to evaluate the relative merits of alternative strategies.
- Step 3: Define alternatives for investigation and remediation for the deep vadose zone.

Step 1: Clarify the Nature of the Problem and Challenges with the Current Situation

This section describes the challenges that must be addressed by a successful strategy for investigating and selecting remedies for Hanford's deep vadose zone contamination.

On the Central Plateau the waste sites are grouped into 26 CERCLA operable units and the single-shell tank (SST) farms are grouped into seven RCRA waste management areas (WMAs). The groundwater that underlies the waste sites and tank farms is divided into four CERCLA operable units, two in 200 West Area and two in the 200 East Area of the Central Plateau. Theses areas are shown in Fig. 2. The Central Plateau source operable units are currently based on waste site process chemistry similarities, rather than geographical proximity.

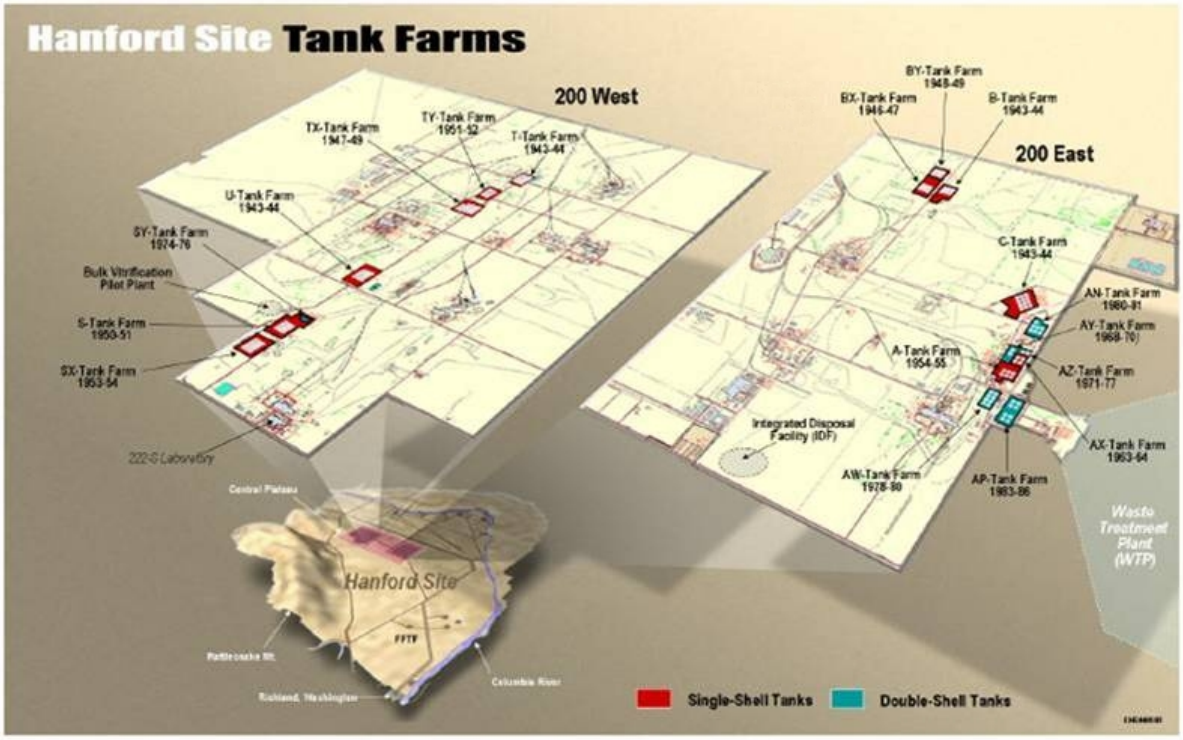

Fig. 2. Location of 200 East and 200 West Areas of the Hanford Site.

Waste sites that involve cribs and trenches or otherwise received large volume liquid discharges have, in some cases, resulted in remaining deep vadose zone contamination. For WMAs, the deep vadose issues are associated with past unintentional releases from the SSTs with sufficient mass and volume. Current studies indicate [2] that even relatively small volume releases from tanks may have migrated deep into the vadose zone if there is an additional hydraulic driver from nearby water discharges or surface flooding from snow melt. The surfaces of WMAs consist of coarse gravel and result in a much high recharge rate than is observed elsewhere on the Hanford Site. These sites generally have a shallow contamination component for which a remedy is

available and a deep component for which a remedy is currently not available. Some of these sites have a shallow and deep component unique to that location and some are commingled at depth with contaminants from other sites. In many cases the cribs and trenches with deep vadose contamination are adjacent to WMAs with similar releases and there are commingled or multiple adjacent sources of deep vadose zone contamination that are or may potentially impact groundwater. The schedule for remedy selection between waste site groupings and between waste sites and WMAs currently differs by a few years to over a decade.

For operable units with waste sites that have both a shallow and deep vadose zone component, remedy decisions can usually be developed for the near surface cleanup. However the decision process becomes difficult if there is deep vadose zone contamination for which there currently is no remedy. This difficulty is further compounded if there are multiple commingled sources from waste sites and tank farms under different regulatory authority, lead agency and different time frames for remedy selection.

There are several distinct categories of deep vadose zone problems and these should each be addressed in a focused manner – a single investigation and remediation approach may not be suited to each category of problem. The two principal deep vadose zone contaminants of concern are technetium-99 and uranium. Other contaminants such as iodine-129 and nitrate are also prevalent in the deep vadose zone and groundwater, but these generally move with the other plumes. There is also a large carbon tetrachloride plume in the groundwater but this problem is being successfully addressed through a combination of soil vapor extraction and groundwater extraction and treatment. Critical regions of interest for deep vadose investigations include:

- **Laterally extensive subsurface plumes of mobile contaminants**. The BC cribs and trenches are the primary example of this situation. These waste sites received more than 20 million gallons of tank waste and have an estimated inventory of approximately 400 Curies of technetium-99, which is the mobile contaminant of concern at this location. Initial characterization efforts indicate that the Tc-99 inventory is located mostly at a depth in the vadose zone of between 100’ and 150’ below ground surface (bgs) and is spread across an area of nearly 35 acres. The contaminants have not reached groundwater (340 feet bgs) but potentially could eventually reach groundwater in the area.
- **Commingled tank farm and non-tank farm plumes.** There are several locations on the Site where tank farms and their associated engineered disposal structures have both resulted in deep vadose zone contamination and even groundwater contamination. These include the areas around the B-BX-BY WMA, the S-SX WMA and T WMA. The commingling of the plumes makes source identification difficult. The principal contaminants of concern in these areas are Tc-99 and uranium.
- **Deep vadose zone plumes from processing facilities**. Hanford’s five processing canyons have liquid disposal sites associated with them – several of which have resulted in existing groundwater plumes and these disposal sites may have residual deep vadose zone inventories that have the potential to continue to release contaminants to the groundwater.
- **Tank farm plumes without associated waste sites**. WMA C is an example of this situation. Recent investigations indicate an emerging groundwater plume of Tc-99 and

investigations are underway to determine the precise source and nature of the continuing threat to groundwater.

- **Other isolated sites**. Waste site investigations are underway on the Central Plateau and it is likely that additional deep vadose threats will be identified once surface remedies are selected. Hanford's deep vadose zone strategy will need to recognize that ongoing remedial investigations will likely identify new areas that pose a threat to groundwater that is not fully addressed by traditional surface remedies.

Step 2: Define Criteria to Evaluate the Relative Merits of Alternative Strategies

Based on the analysis of the current situation and the numerous challenges that face the Hanford Site relative to deep vadose zone investigation and remediation, the Deep Vadose Zone Workgroup, through a collaborative process, identified several criteria that could be used to evaluate alternative strategies for addressing the deep vadose zone. These criteria reflect essential attributes that would be desired in a preferred solution to these challenges. The criteria include:

- **Project-like focus for the deep vadose zone**. While there are several distinct categories of deep vadose zone problems, there are many individual waste sites, operable units, and tank farm waste management units that must address the problems. A centralized "project-like" effort would provide a more efficient approach to these challenges and provide clear requirements for deep vadose zone treatability testing which is expected to start within the next two years.
- **Integrated, consistent investigations and decision making**. In areas with commingled deep vadose zone plumes, it would be preferable to have a single investigation effort conducted to evaluate the future threats to groundwater. Separate investigations, in time and approach, for groundwater, waste sites and tank farms are not likely to yield complete and consistent remedy decisions.
- **Enable joint or concurrent decisions (for adjacent or commingled areas).** Remedy selection decisions that provide protection of groundwater should be made concurrently, rather than staggered in time as would result from the current approach.
- **Allow surface, groundwater and deep vadose zone remediation to proceed on reasonable schedules**. Surface remedy decisions should not be delayed because of uncertainties in the deep vadose zone. Removal decisions and capping decisions for near-surface waste sites should be able to proceed, and, more complete remedies for the deep vadose zone should be able to occur once sufficient understanding of the threat and potential remedies is gained.

Step 3: Define Alternatives for Investigation and Remediation for the Deep Vadose Zone

To address the challenges identified above and the criteria or objectives defined in the previous section, the Deep Vadose Zone Workgroup defined a series of options for restructuring the investigation and remediation for the deep vadose zone of the Central Plateau. These options differ in the approach used to conduct investigations and to make remedy selections. The options also differ in the boundaries of the deep vadose zone relative to other operable units

(groundwater and waste sites) and tank farm waste management areas. The specific options evaluated by the Workgroup include:

1. **Status Quo.** Maintain separate assessment and remediation approach for each waste unit, source operable unit and tank farm area. This option maintains the current approach of using separate, and potentially overlapping, processes for the deep vadose zone depending upon whether the contaminant plumes originate from tank farms or from non-tank farm waste sites.
2. **Transfer problematic deep vadose sites to an existing operable unit.** This option would address waste sites and past tank farm releases with deep vadose zone issues within and existing operable unit.
3. **Merge waste sites adjacent to tank farms with SST waste management areas.** This option would address waste sites that threaten groundwater as part of the adjacent tank farm investigation and remediation process.
4. **Use the existing groundwater operable units to include the overlying deep vadose zone.** This option would simply use the four existing groundwater operable units on the Central Plateau to include those deep vadose zone contaminated areas. Investigation and remediation for these areas would be completed through the existing process for each groundwater operable unit.
5. **Create new deep vadose zone operable unit(s) for the Central Plateau.** This option would create new deep vadose zone operable units that would be defined by the contaminant plumes that pose a potential impact to groundwater.
6. **Use a combination of the above approaches, as appropriate, for each type of vadose zone problem.** This option would acknowledge that there are a variety of distinct deep vadose zone problems on the Central Plateau, and that no one solution is best for all situations.

OBSERVATIONS AND CONCLUSIONS

Hanford's two DOE offices, Richland Operations and the Office of River Protection, are engaging the Site's regulators, EPA and the Washington State Department of Ecology, in a collaborative process to resolve one of Hanford's most challenging technical issues – investigation and remedy selection for the deep vadose zone. While this process has not reached its conclusion, several important findings are apparent.

- All parties agree that the current approach of addressing this problem is not likely to be successful and an alternative is needed.
- An essential initial step is to develop and then implement a deep vadose zone treatability test plan that logically organizes the testing of candidate technologies for application to the variety of Hanford's deep vadose zone problems. This plan is currently under development.
- The deep vadose zone needs to be addressed through a "project-like" focused and high priority effort. Currently, there is a very diffuse focus to this problem. There are roughly 30 to 50 waste sites, multiple operable units and seven tank farm WMAs that may have to address deep vadose zone issues. No single waste site or investigation can adequately take on this Plateau-wide problem.

- Investigations of regions with commingled plumes from tank farms and non-tank farm sources need to be integrated or closely coordinated.

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