DOE-FIU SCIENCE & TECHNOLOGY WORKFORCE DEVELOPMENT PROGRAM

STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

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Logic Model for the Deep Vadose Zone Program at the Hanford Site

Principal Investigators:

Melina Idarraga (DOE Fellow)
Florida International University

Kurt Gerdes, Mentor
DOE-HQ Environmental Management

Acknowledgements:

Skip Chamberlain
Dawn Wellman

Florida International University Collaborator and Program Director:

Leonel Lagos, Ph.D., PMP®

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ABSTRACT

The deep vadose zone at the Hanford Site has unique remediation challenges. It is of major concern as a conduit and ongoing source of groundwater contamination and exposure to human or ecological receptors to the groundwater path. This subsurface environment consists of complex layers of sediments contaminated with radionuclides, metals, organics and sometimes a complex mixture of both hazardous chemicals and radionuclides. The main objective of the research and development (R&D) plan is to identify scientific and technical knowledge gaps; define research priorities; and prioritize near-term, mid-term and long-term research goals. The first step to this research and development plan for the Hanford Site deep vadose zone is to create a logic model that will include four critical areas of the process: understand, predict, control, and monitor. This logic model will show the linkage between the Office of Science and the Office of Groundwater and Soil Remediation (EM-32); it will also demonstrate the important role that the applied site operators or national laboratories and applied contractors play on the progress of the remediation of the deep vadose zone at the Hanford Site. The expected outcomes are to update biogeochemical and conceptual models for contaminants, to provide scientific information to support CERCLA, to effectively treat low permeability zones and to establish a basis for early warning monitoring. The impact of the deep vadose zone program at the Hanford Site is expected to contribute to the $10 billion life-cycle cost savings associated with the Office of Technology Innovation and Development across the DOE complex.

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1. INTRODUCTION

The mission of the Office of Technology Innovation and Development (EM-30) within the United States Department of Energy (DOE) Environmental Management (EM) is to transform science and innovation into practical solutions for environmental clean-up. The EM-30 office is planning on achieving this goal through leadership in integration, collaboration, and communication to accelerate environmental clean-up and reduce costs. The Office of Groundwater and Soil Remediation (EM-32) has the specific task of protecting the water resources of the different regions of the DOE complex. There are three main field research programs under the EM-32 office: the Deep Vadose Zone/Groundwater Applied Research Center at Hanford, the Biogeochemical Process for Applied Subsurface Science Center at Savannah River, and the Mercury Remediation and Characterization Program Center at Oak Ridge.

This report will focus on the Deep Vadose Zone/Groundwater Applied Research Center at the Hanford Site; specifically, a logic model will be developed to understand the needs and opportunities of the Deep Vadose Zone Program and to integrate the contributions of the Office of Science, the national laboratories, and the private contractors and universities to the development and application of new remediation technologies to support the unique challenges at the Hanford Site deep vadose zone (Figure 1).

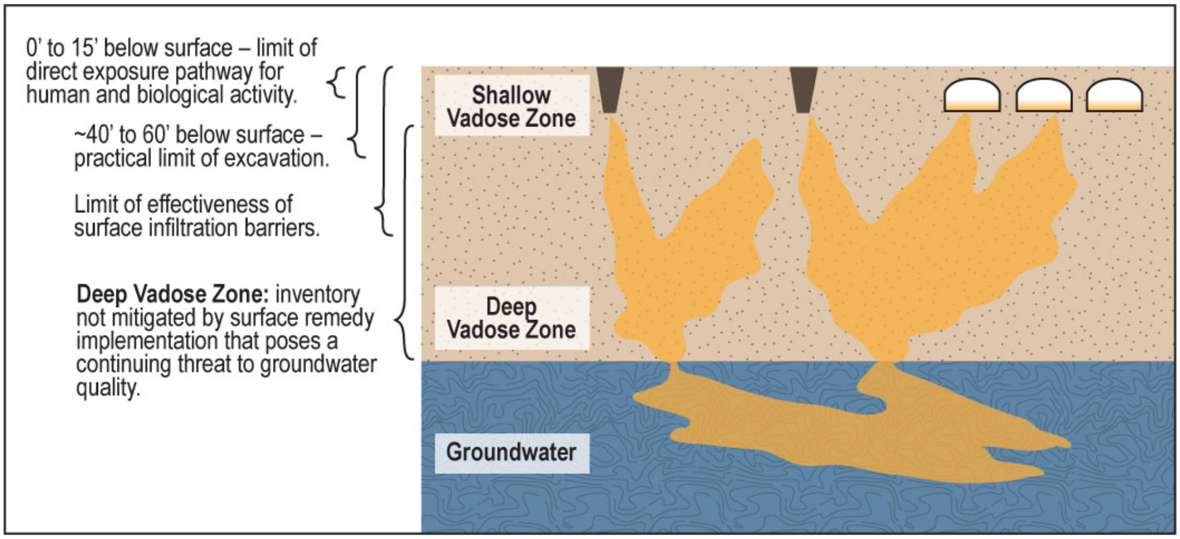

Figure 1. Hanford Site subsurface contamination.

This logic model on the needs and opportunities for the deep vadose zone at the Hanford site was developed based on three important documents:

> **Multi-Scale Mass Transfer Processes Controlling Natural Attenuation and Engineered Remediation: An Integrated Field-Scale Subsurface Research Challenge Focused on Hanford's 300 Area Uranium Plume.** A proposal to the Office of Biological and Environmental Research by the Pacific Northwest National Laboratory.

> **Role of Microenvironments and Transition Zones in Subsurface Reactive Contaminant Transport.** A Pacific Northwest National Laboratory Subsurface Science Focus Area for the Office of Biological and Environmental Remediation Science Program.
>
> **Scientific Opportunities to Reduce Risk in Groundwater and Soil Remediation.** Prepared in conjunction by national laboratories and the DOE-EM Office of Groundwater and Soil and the DOE-SC Office of Biological and Environmental Research.

These three documents were essential in understanding the needs and opportunities of the Deep Vadose Zone Program and to develop a logic model to establish a basis for science and technology needs to accelerate and complete groundwater and soil remediation. After reviewing these three documents, I can conclude that one of the main problems with applying the adequate technologies to resolve the Hanford's Site deep vadose zone challenges is the heterogeneity of the subsurface; Figure 2 illustrates how the subsurface is composed of different materials such as silts, sands, and rock formations.

Figure 2. Hanford Sites' subsurface soil.

2. EXECUTIVE SUMMARY

The described research work is supported by the Department of Energy (DOE)-Florida International University (FIU) Science & Technology Workforce Initiative, an innovative program developed by the U.S. DOE Office of Environmental Management and FIU's Applied Research Center (ARC) in creating a pipeline of minority students for DOE's future workforce. A DOE Fellow intern (Ms. Melina Idarraga) was sent to the Department of Energy Head Quarters office (DOE-HQ) in the Office of Groundwater and Soil Remediation (EM-32) in Germantown, MD, for a 10-week internship in the summer of 2010 (June 1 – August 6, 2010). There, the DOE Fellow was mentored by Mr. Kurt Gerdes and Mr. Skip Chamberlain. This internship was coordinated by the Applied Research Center at FIU and the DOE-HQ Office of Environmental Management (EM) with the help of Junita Turner, the summer internship coordinator for EM.

This research aims to develop a logic model based on the needs and opportunities of the deep vadose zone at the Hanford Site. This is an extremely important subject matter due to researchers and scientists not fully understanding the contaminant behavior in the subsurface. Moreover, the site and contaminant source characteristics may limit the usefulness of baseline subsurface remediation technologies. The logic model developed in this report will approach the different challenges and will link the science and the technology to better understand the undergoing processes of the contaminants in the subsurface.

3. RESEARCH DESCRIPTION

3.1 Components of a Logic Model

A logic model is a commonly-used tool to present the understanding and the relationship among the resources you have to operate a program within an organization, the activities planned, and the changes or results expected to be achieved (Taylor-Powell 2008). It serves as the basis for program planning and evaluation and has the following components: problem statement and goals, resources and activities, outcomes, and assumptions and external factors (W.K. Kellogg Foundation 2004). The full understanding of these main components is essential to develop a logic model for the Deep Vadose Zone Program (Figure 3).

3.1.1 Problem Statement and Goals

The problem statement is the first step to create a logic model for a program; it frames a particular challenge or goals. The problem statement will briefly explain what the needs are and why there is a need for change. The goals should describe the overall purpose of the program and serve as the basis of the logic model; every component or element that follows should reflect and relate to the goals of the program.

3.1.2 Resources and Activities

It is important to identify the available resources for the program to determine the extent to which you will be able to implement the program and achieve the intended goals and outcomes. In this particular logic model, the resources are one of the main components, since there is an extensive list of resources. The activities may be general or specific to a task with even a time outline. Sometimes general descriptions of the activities help people who are not familiar with the program to have a better understanding.

3.1.3 Outcomes

Outcomes in a logic model are the intended or unintended changes that occur as a result of the program activities. Sometimes the outcomes are not as expected but they will still be useful in figuring out what needs to be done differently or in determining the strongest elements of the program.

3.1.4 Assumptions and External Factors

The assumptions are conditions that are necessary to the program success and that are believed to be true. The external factors are very important to take into account because those are factors that you do not have control over but that will affect the expected outcomes of the program.

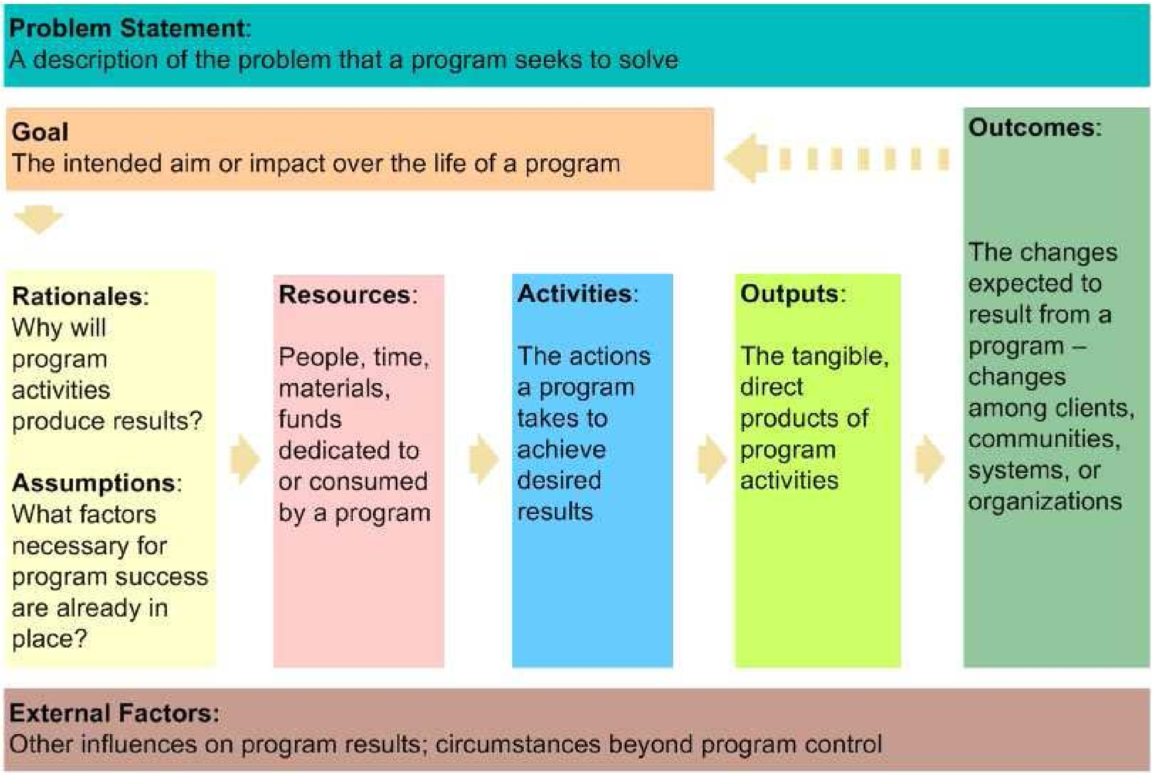

Figure 3. Schematic of Logic Model components.

3.2 Literature Research

In order to complete the logic model for the deep vadose zone at the Hanford Site, the following documents were reviewed extensively. These pieces of literatures describe the needs of the subsurface of the Hanford Site and the opportunities that will be provided if the Office of Science, the Groundwater and Soil Remediation Office, the sites and the private contractors work together towards the same goal; therefore, it is very important to establish the resources, priorities and initiatives.

3.2.1 Multi-Scale Mass Transfer Processes Controlling Natural Attenuation and Engineered Remediation

This proposal focuses on multi-scale mass transfer processes in the vadose zone and saturated zone, their influence on field-scale U (VI) biogeochemistry and transport and their implications to natural attenuation and remediation. This information will help to understand the Deep Vadose Zone Program from a science point of view.

Characterization

- Hydrology: Unique aspects of the site are the hydrologic and geochemical conditions imposed by the boundary condition of the Columbia River on the east.

- Geochemistry: This research has sought to identify the mineral association and molecular speciation of sorbed U (VI), quantify adsorption/precipitation and desorption/dissolution rates for contaminant U (VI), and develop a surface complexation model for U (VI) on 300 Area sediments. The overall goal of this research has been to develop better conceptual and numeric models of microscopic U (VI)-sediment interactions for improved predictions of future plume behavior.

  - Molecular speciation measurements by X-ray absorption and cryogenic laser induced fluorescence spectroscopy (CLIFS) have shown that the chemical speciation of U(VI) changes from precipitated forms in the upper vadose zone near the historic source term to adsorption complexes in the deeper vadose zone and aquifer sediments

- Microbiology: These sediments were used in anaerobic microcosm and microbial enrichment experiments to assess the feasibility of stimulating the *in situ* subsurface microbiota to reduce Fe (III) and 99Tc (IV) O4. The Tc- and Fe-reducing enrichment cultures included *Sporomusa*, *Acetonema*, and *Paenibacillus* species, as determined by 16S rDNA sequencing. These enrichment cultures rapidly reduced Tc as did a *Paenibacillus* SP-C isolate that also reduced Fe(III) as hydrous ferric oxide.
  - A glycerol polylactate-based hydrogen release compound (HRC®) was injected into aquifer sediments at Hanford's 100H Area to stimulate in situ reduction of chromate.

Experimental Programs (Remedial Technologies)

- Vadose Zone Infiltration: Will solubilize sediment-bound U (VI) in response to contact time, as desorption/dissolution extent is controlled by mass transfer from intraparticle domains and export from fine-textured zones with higher U (VI) sorptivity. Resupply of contaminant U(VI) to groundwater occurs as the water table rises into the capillary fringe and lower vadose zone, capturing U(VI) that was mobilized by infiltrating meteoric water or released locally by mass-transfer controlled desorption.

- Mass Transfer Limitation: Macroscopic in-situ mass transfer rates for sorbed U (VI) will decrease with transport distance as a result of heterogeneity in sorption site concentration, and plume intersection with finer-textured sediment zones.

- Shoreline Microbial Mediation: U (VI) concentration is mediated by microbial redox metabolism coupled with adsorption/desorption processes, and the diversity, abundance, and activity of subsurface microorganisms decay with distance from the groundwater-river interface. The U (VI) concentration may thus be driven by biogeochemical processes influenced by variations in nutrient/energy source addition, water composition, and temperature at the nutrient-rich, near-shore environment.

- Polyphosphate and Microbiology: Hydrolyzed P will stimulate microbial growth and activity by providing a limiting nutrient, leading to changes in carbonate chemistry, pH, and U (VI) solid-liquid distribution. Kinetic effects related to polyphosphate hydrolysis, mass transfer controlled adsorption/desorption (of U and P), and diffusive transport into less permeable zones will control the rates of microbial evolution and U (VI) precipitation. Enhanced microbial activity and P assimilation will compete with U (VI) precipitation, decreasing the formation and long-term stability of uranyl-phosphate precipitates.

3.2.2 Role of Microenvironments and Transition Zones in Subsurface Reactive Contaminant Transport

This scientific focus area focuses on reactive transport of: technetium (Tc), uranium (U), and plutonium (Pu) contaminants at the Hanford Site in the primary areas as well as the associated, enabling scientific areas.

PRIMARY AREAS:

Molecular Scale Studies

- Molecular scale research will be performed to advance understanding of the mechanical and kinetics that underline the reactivity and transport of U, Tc, and Pu at the Hanford Site. Research will focus on key issues at mineral and bacteria interfaces that control biogeochemical behavior of contaminants at different scales: sub-pore, sub-cellular, microbial cell.

- Characterization and monitoring of the molecular structure, chemical composition, and oxidation states of Hanford contaminant species and their mineral or microbial associations will be executed through a range of bulk and surface spectroscopic techniques with high spatial, temporal and/or energetic resolution available in the EMSL and at DOE user facilities.

- Identification of the proteins interfacing with Hanford mineral surfaces will be developed through biological methods: molecular biology and genomics techniques, isolation and purification of biomolecules, electrochemical, spectroscopic, and structural characterization of biomolecules.

- Molecular modeling such as *ab initio* calculations and molecular dynamics simulations will be provided to support molecular and microscopic studies.

Pore Scale Research

Pore scale research includes biotic and mineralogic microenvironments at the sub-and pore scale with emphasis on kinetic reactions, biogeochemical speciation, and coupling with microscopic transport.

- Oxidation/reduction and precipitation/dissolution reactions involving the target polyvalent contaminants will be investigated in various types of mineral and biotic Hanford-relevant microenvironments.

- PNNL topics of expertise: microscale controls on uranium transport, speciation, and reactivity, biogeochemical processes controlling technetium solubility, and heterogeneous electron transfer reactions of Tc.

Reactive Transport Experiments

Reactive transport experiments include laboratory- and meso- scale (through collaboration) reactive transport experiments of microenvironments and transition zones.

- Explore how diffusion-controlled, microscopic reaction and transport processes couple with advection to regulate contaminant transport in heterogeneous porous media.

- Investigate the effect of microenvironments and transition zones on geophysical response, and to determine the relationship of this response to the determination of effective reactive transport properties and kinetics parameters of different type that can be extrapolated to the field.

- Characterization of mass transfer processes in terms of fundamental properties controlling apparent diffusivity: Traditional and stop-flow column breakthrough studies of nonreactive and reactive tracers of different molecular diffusivities and charge and direct diffusivity measurements grains using X-ray, Nuclear Magnetic Resonance (NMR), and other spectroscopic techniques.

- Biogeochemical processes: Precipitation and dissolution in restricted physical domains (both redox and non-redox driven) as commonly observed for U in Hanford sediments and hypothesized for Tc and development of pH and redox zonation at reaction zones and physical discontinuities.

In-situ Field Experiments

In-situ field experimentation is de-emphasized, but not ignored_in the Scientific Focus Area (SFA) because it is the primary focus of the associated PNNL Hanford Integrated Field-Scale Challenge (IFC).

- The SFA and IFC will jointly install two highly instrumented, multiple-level monitoring well clusters above, within, and below two well defined groundwater transition zones.

- SFA/IFC field research will target biogeochemical and microbiologic processes, and uranium and other solute fluxes that occur within and across the various types of transition zones that are present at the IFC.

ASSOCIATED, ENABLING SCIENTIFIC AREAS:

Microbial Ecology

- Develop a conceptual model for microbial ecology in Hanford’s unconfined aquifer with specific emphasis on implications to long-term contaminant fate and transport.

- Apply high-efficiency cultivation dependent approaches with subsurface materials to address ecological questions of organism and community functional redundancy and to produce isolated microbes or consortia that affect U, Tc, or Pu biogeochemical behavior.

- Experimental approaches will include the exposure of either natural microbial communities or model metal-reducing isolates (identified from census efforts) to zones that transition between terminal electron acceptors imposed in cm-scale laboratory column experiments. For natural microbial communities molecular analysis of phylogenetic or functional gene markers will be use. For model organisms for which genomic and /or proteomic information was determined, a higher degree of functional specificity can be address via transcriptome and proteome analysis.

Reactive Transport Modeling

- Ab-initio and molecular dynamics approaches will be used in support of molecular scale studies of electron transfer processes and bio-molecule interactions with mineral surfaces and target contaminants, and microscopic studies of intragrain diffusive processes of different sorts. Grid-based computational fluid dynamics (CFD) model and particle-based smoothed particle hydrodynamics (SPH) model will be used.

- In-silico microbial metabolic models will be linked to geochemical reaction and transport models to represent the interplay between microbial function (at individual and community levels) and variations in the local geochemical environment. Continuum biogeochemical reactive transport models such as STOM will be applied to macroscopic and mesoscopic laboratory transport experiments with quantified heterogeneities, and to field experiments at the Hanford IFC and other locations with their inherent in-situ complexities.

3.2.3 Scientific Opportunities to Reduce Risk in Groundwater and Soil Remediation

This particular document was useful to the development of the logic model because it emphasizes the technical risk and uncertainty for the groundwater and soil remediation program with regards to the deep vadose zone situation at the Hanford Site.

Risks and Uncertainties

- Improve sampling and characterization technologies and strategies for multiple contaminants in the Hanford Site vadose zone.

- Advance predictive capabilities that incorporate chemical reactions, complex geologic features, and multiphase transport for radionuclides to provide and improve technical basis for selecting and implementing remedies.

- Enhance remediation methods that reduce costs, increase effectiveness, and reduce risk to human health and the environment by employing cost-effective technologies.

- Enhance long-term performance evaluation and monitoring by developing and employing cost-effective long-term strategies and technologies to monitor and verify the cleanup performance.

After reviewing extensively and understanding the issues and different technologies that have been successfully applied in the efforts to remediate and contain the different contaminants in the deep vadose zone, a logic model has been created to illustrate the Hanford Site Deep Vadose Zone Program or Plan to execute in order to obtain the desired outcomes. Along with the identification of the needs and opportunities of the program and the resources and activities to be taken, a Work Breakdown Structure (WBS) was created to focus each of the activities under a goal and specific authority.

The first digit of the WBS will represent the office or operator in charge of the activity:

70 – Office of Science
32 – Office of Groundwater and Soil Remediation
1 – Applied Site Operators (Direct)
2 – Applied Contractors (Indirect)

The second digit will remain constant throughout the logic model, since it represents the Research Program:

1 – Deep Vadose Zone Research Program

The third digit will be represented by the needs and opportunities as follows:

1 – Understand
2 – Predict
3 – Control
4 – Monitor

The fourth or last digit will be the item or action implemented by a particular office or laboratory.

1 – First item or action
2 – Second item or action, etc.

This work breakdown structure will help organized the logic model in a way that when other research programs are added or included it will be easy to keep track of which office or contractor is in charge of performing a certain activity.

4. RESULTS AND ANALYSIS

As stated above, there are four main components to this logic model based on the needs and opportunities of the deep vadose zone program at the Hanford Site. These components are to understand the needs, predict the mobilization of the contaminants, control the contamination plumes, and monitor the implemented technologies.

4.1 Understand

Understanding biogeochemical and hydrogeologic processes active in the deep vadose zone and how they affect contaminant movement is necessary to understand and set reasonable, attainable, and verifiable remediation goals for the deep vadose zone.

4.1.1 Office of Science (Subsurface and Biogeochemical Research Program)

The following are the activities the basic science will expand to understand the needs of the Hanford Site subsurface:

70.1.1.1 Investigate redox chemistry of ^{99}Tc in 200 A sediments.

70.1.1.2 Evaluate biogeochemistry of (300 A) microbial isolates toward ^{99}Tc and U under microaeophilic conditions.

70.1.1.3 Characterize intragrain microsocopic transport processes of U and ^{99}Tc in different Hanford sediment facies.

4.1.2 Office of Groundwater and Soil Remediation (EM-32)

The following are the activities that will be developed by the applied research to understand the needs of the Hanford Site subsurface:

32.1.1.1 Geochemical and hydrodynamic characterization of field site.

32.1.1.2 Characterize effects of geochemical and hydrodynamic heterogeneities on Tc transport in remedial strategies.

4.1.3 Applied Site Operators (Direct)

The following is the contribution of national laboratories to the understanding of the needs of the Hanford Site subsurface:

1.1.1.1 Perform geochemical and hydrodynamic characterization of field site.

4.1.4 Applied Contractor (Indirect)

The following is the expected involvement of the private contractors or universities that support the deep vadose zone program:

2.1.1.1 Conduct characterization of sites to meet remedial investigation goals and provide baseline characterization information to be used in conjunction with basic and applied research data.

4.2 Predict

Advances in existing conceptual models and numerical approaches are needed to support predictions of the subsurface environment and to the impact of remedial actions to accurately depict contaminant fate and transport in the deep vadose zone.

4.2.1 Office of Science (Subsurface and Biogeochemical Research Program)

The following is the activity the basic science will expand to predict the needs of the Hanford Site subsurface:

70.1.2.1 Develop sufficient understanding of deep vadose zone contamination and processes affecting fate and transport to develop predictive models for ^{99}Tc and U.

4.2.2 Office of Groundwater and Soil Remediation (EM-32)

The following are the activities that will be developed by the applied research to predict the needs of the Hanford Site subsurface:

32.1.2.1 Develop numerical model to simulate foam transport and remedial delivery and implementation for in situ stabilization of U and Tc.

32.1.2.2 Develop an advanced computing platform (ASCEM).

4.2.3 Applied Site Operators (Direct)

The following is the contribution of national laboratories to the prediction of the needs of the Hanford Site subsurface:

1.1.2.1 Develop baseline conceptual and numerical model consistent with needs for evaluating impact to groundwater.

4.2.4 Applied Contractor (Indirect)

The following is the expected involvement of the private contractors or universities that support the deep vadose zone program:

2.1.2.1 Develop and apply numerical model to support design of deep vadose zone treatability tests.

2.1.2.2 Develop conceptual models and apply numerical models use in CERCLA and RCRA efforts.

4.3 Control

Current baseline approaches (i.e., pump and treat) address the symptom of minimizing plume migration but do not prevent contaminant flux from vadose zone to groundwater and surface water.

4.3.1 Office of Science (Subsurface and Biogeochemical Research Program)

The following are the activities the basic science will expand the opportunities to control the Hanford Site subsurface:

70.1.3.1 Develop sufficient understanding of deep vadose zone contamination and processes to provide underlying technical basis for in-situ remediation approaches or natural attenuation.

70.1.3.2 Biogeochemical processes controlling technetium solubility.

70.1.3.3 Heterogeneous electron transfer reaction of ^{99}Tc.

4.3.2 Office of Groundwater and Soil Remediation (EM-32)

The following is the activity that will be developed by the applied research to control the Hanford Site subsurface contamination:

32.1.3.1 Evaluate the physical and chemical processes influencing the efficacy of foam-based delivery of remedial amendments to deep vadose zone environments to remediate metals and radionuclides.

4.3.3 Applied Site Operators (Direct)

The following is the contribution of national laboratories to the prediction of the needs of the Hanford Site subsurface:

1.1.3.1 Provide support and input to field testing of technologies developed through EM-32 (e.g., foam).

4.3.4 Applied Contractor (Indirect)

The following is the expected involvement of the private contractors or universities that support the deep vadose zone program:

2.1.3.1 Identify source-control alternatives that provide an appropriate range of remedial options and sufficient information to support the comparison of alternatives against one another.

2.1.3.2 Implement deep vadose zone treatability test plan to evaluate specific remediation technologies for ^{99}Tc and U within the Central Plateau, including desiccation and reactive gas field tests, other potential technology field tests, and studies of soil flushing, in situ grouting, surface barriers, and pore water extraction.

4.4 Monitor

Less expensive and more efficient techniques are needed to image and characterize subsurface vadose zone and contaminant plumes to evaluate the short to long-term performance of in situ cleanup techniques and containment systems and detect the early warnings of remediation failure.

4.4.1 Office of Science (Subsurface and Biogeochemical Research Program)

The following is the activity the basic science will expand to monitor the needs of the Hanford Site subsurface:

70.1.4.1 Develop sufficient understanding of deep vadose zone contamination and processes to provide cost effective and reliable long-term monitoring.

4.4.2 Office of Groundwater and Soil Remediation (EM-32)

The following is the activity that will be developed by the applied research to monitor the needs of the Hanford Site subsurface:

32.1.4.1 Develop advanced geophysical and natural marker monitoring capabilities to provide effective and appropriate monitoring of plume behavior and remedial emplacement and performance within the deep vadose zone.

4.4.3 Applied Site Operators (Direct)

The following is the contribution of national laboratories to the monitor the needs of the Hanford Site subsurface:

1.1.4.1 Perform monitoring through routine environmental sampling.

4.4.4 Applied Contractor (Indirect)

The following is the expected involvement of the private contractors or universities that support the deep vadose zone program:

2.1.4.1 Collect monitoring data through existing programs as baseline information for use in evaluating potential alternative methods.

The assumptions and external factors taken into account for the logic model to be successful are:

- Technology Innovation & Development (EM-30) budget remain essentially constant at $35M/year (FY2010 through 2014).
- Groundwater and Soil Remediation (EM-32) budget remains constant at approximately $10M/year.
- Funding is available at the start of each fiscal year.
- Groundwater and Soil Remediation federal staffing levels remain relatively stable.
- Ability exists to leverage the resources of other DOE offices, government agencies, and industry programs to address DOE needs.
- Maintain expertise and resources necessary to address EM’s long-term needs – field test facilities and information archives to develop detailed conceptual understanding and site models to guide remedial actions and support DOE’s long-term stewardship planning.

5. CONCLUSION

In conclusion, the logic model created to improve the deep vadose zone applied research program is a series of activities expected to be performed by different offices and laboratories, all of them working towards the same goal and needs to contribute to the $10 billion cost cost savings associated with groundwater and soil remediation across the DOE complex.

This impact will be achieved after the following outcomes:

- An updated biogeochemical conceptual model for Tc contamination and long-term behavior;
- An understanding of the role of multi-scale reactive facies, microenvironments and biogeochemical processes defined in remediation strategy;
- Scientific and technology information to support CERCLA fate and transport assessments of long-term performance for remedial alternatives;
- Advanced remedial strategies to effectively treat low permeability zones and mitigate the flux of contaminants (Tc, U) from vadose zone environments to groundwater, and meet long-term plume remediation goals; and
- Capabilities to accurately refine subsurface DVZ remedial performance through monitoring and accurately evaluating both predictive tools and remedial action impacts on subsurface system; establish basis for early warning monitoring “thresholds” of unexpected or unacceptable DVZ behavior such changes in moisture flow and contaminant movement.

This internship in the DOE-HQ office helped me understand the DOE-EM mission from an administrative point of view of the resources that are available to help with the challenging environmental cleanup that DOE-EM faces with the support of national laboratories and private contractors.

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