# Summary of PNNL Transportation Activities for FY12 to Support the UFD Program

1. Integration of Transportation Gap Analysis with the Storage Gap Analysis

For this task, the Features, Events, and Processes (FEPs) for Transportation that were identified and documented in the FY11 mid-year and year-end reports were further evaluated to understand the differences between the transportation gaps and the storage gaps. The transportation gaps report was modified to facilitate consolidation of the transportation FEPs with the storage FEPs. The list of SSCs and the associated degradation mechanisms [known as features, events, and processes (FEPs)] were based on the list of used nuclear fuel (UNF) storage system SSCs and degradation mechanisms developed in *Gap Analysis to Support Extended Storage of Used Nuclear Fuel* (Revision 0). For each SSC, the impacts of the degradation of the SSC were evaluated for the following six transportation safety functional areas:

- Containment
- Criticality Control
- Shielding
- Heat Transfer
- Structural Integrity
- Operations Support.

Sections were prepared for the integrated gap analysis that covered the following SSCs:

- Fuel
- Cladding
- Assembly Hardware
- Fuel Baskets
- Neutron Poisons
- Neutron Shielding
- Containers (bolted direct-load metal casks and welded metal canisters)
- Overpacks and Storage Modules
- Concrete Storage Pad

A Stress Profile gap analysis was also performed for the vibration associated with the normal conditions of transport. For UNF, the primary concern is the effects of this vibration on the UNF cladding.

Potential degradation mechanisms (FEPs) for the SSCs included mechanical, thermal, radiation and chemical stressors, such as fuel fragmentation, embrittlement of cladding by hydrogen, oxidation of cladding, metal fatigue, corrosion, etc. The degradation mechanisms were evaluated for influence by high burnup, additional data needs, importance of research and development (R&D), and the importance to transportation. These categories were used to identify the most significant transportation degradation mechanisms. In general, the Transportation Importance assigned in the Transportation Gap Analysis mirrored the importance assigned by the UFD Storage Task. However, there were a few differences as noted in Table 1 below.

Table 1 – Summary of Storage and Transportation Importance Differences

| Stressor | Degradation Mechanism | Importance | | Comments |
|---|---|---|---|---|
| | | Storage | Trans | |
| **Neutron Poisons** | | | | |
| Thermal | Thermal aging affects | *Med* | *HIGH* | Aging effects on poisons could affect structural properties to the extent that they would not survive the loads of transportation hypothetical accident conditions and compromise the ability to prevent a nuclear criticality. For storage moderator control is the primary mechanism for criticality control. |
| **Bolted Direct-Load Casks** | | | | |
| Thermal and Mechanical | Thermo mechanical fatigue of seals and bolts | *Med* | Low | Failure of seals and bolts due to thermomechical fatigue is important for storage relicensing. It is expected that bolts and seals would be inspected prior to transportation to assure their integrity. However, if issues are found with seals that could mean having to replace the seals in an enclosing facility, for example a reactor fuel pool facility. |

In addition to the comparison of storage and transportation gaps the following discussions were prepared as contributions to the storage and transportation gap analysis report.

- Transportation Regulation History including a summary of historical shipment
- Used Nuclear Fuel Transportation Casks including key functional and performance requirements of UNF transportation casks. It also described modern UNF shipping casks for both legal weight truck and rail/intermodal transportation.
- Regulations and Regulatory Guidance Governing Transportation of UNF

- Application of NRC Regulations in the Design and use of Used Nuclear Fuel Transportation Casks
- Current Issues Surrounding the Application of NRC Regulations in the Design and use of UNF Transportation Casks

## 2. Orphan Site Task

A report is in progress that will be completed in October 2012 that analyzes capabilities, conditions, and requirements for transporting UNF stored at each of the orphan sites. Specifically, the report will present the following discussions:

- Site Inventory
- Site Conditions
- Near-Site Transportation Infrastructure and Experience
- Actions Necessary to Remove Used Nuclear from Orphan Sites
- Conclusions

Figures 1 and 2 illustrate the type of used nuclear fuel inventory information that has been developed for the Orphan Sites using the 2002 RW-859 database. Table 1 lists detailed assembly-type level information for the Orphan Sites. Additional information that will be included in this section includes the types of canisters and storage systems; the number of assemblies per canister; the condition of each fuel assembly (undamaged, intact, failed); whether the canisters, as loaded, are transportable; and, if transportable, the name of the transportation cask and associated current NRC 10 CFR 71 Certificate of Compliance. All information may not be available for all sites. The section will also describe any unique considerations associated with the storage and transportation system used at the site.

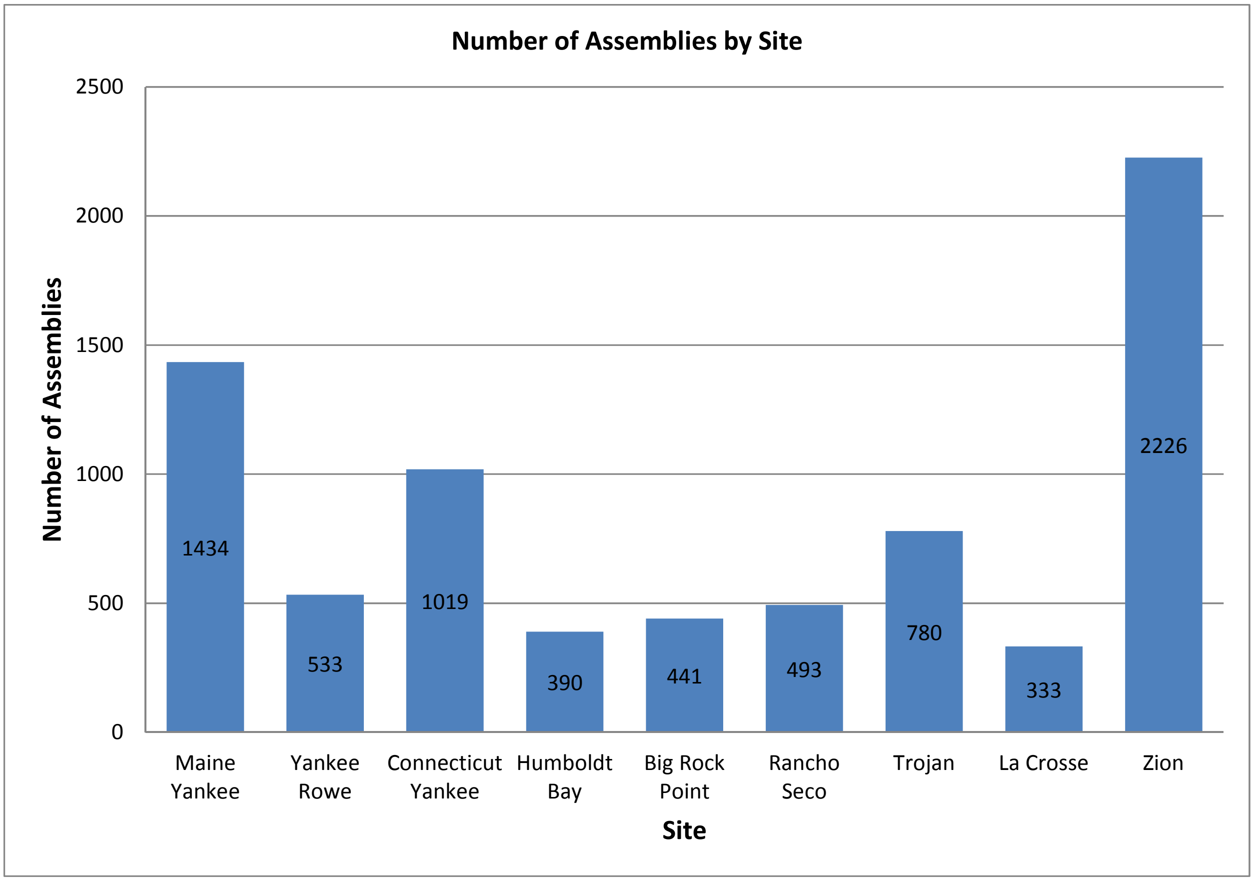

Figure 1. Number of Assemblies by Site for the Nine Orphan Sites

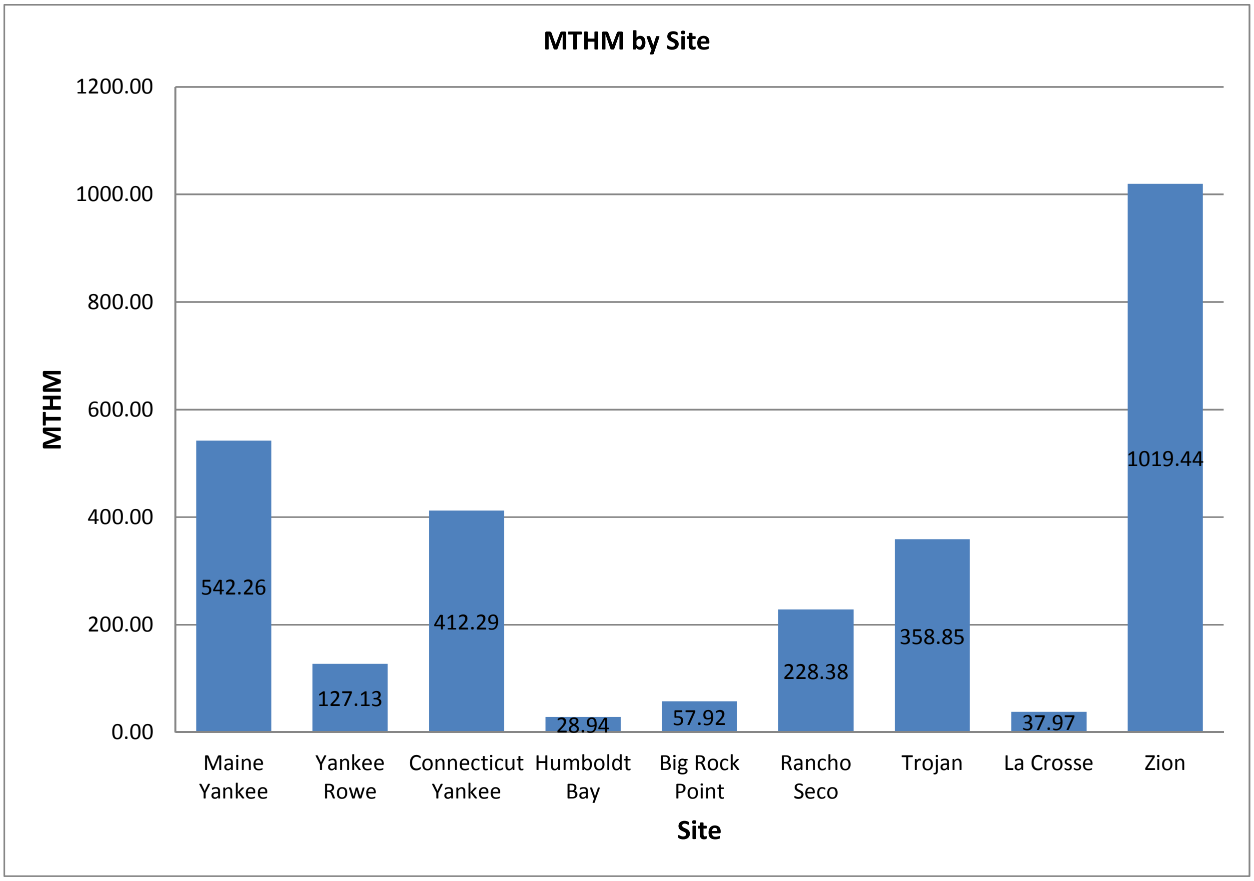


Figure 2. Metric Tons of Heavy Metal by Site for the Nine Orphan Sites

Table 1. Assembly-Type Information for the Nine Orphan Sites

| Site | Assembly Class | Array Size | Manufacturer Code | Version | Assembly Code | Length (in.) | Width (in.) | Clad Material | Number of Assemblies | MTHM | Maximum Burnup (GWd/MTHM) | Maximum Enrichment (wt. percent) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maine Yankee | CE 14 x 14 | 14 x 14 | ANF | ANF | C1414A | 157.0 | 8.10 | Zircaloy-4 | 288 | 106.96 | 47.08 | 3.31 |
| | CE 14 x 14 | 14 x 14 | CE | CE | C1414C | 157.0 | 8.10 | Zircaloy-4 | 1078 | 408.80 | 49.24 | 3.92 |
| | CE 14 x 14 | 14 x 14 | WE | WE | C1414W | 157.0 | 8.10 | Zircaloy-4 | 68 | 26.50 | 10.85 | 3.76 |
| Yankee Rowe | Yankee Rowe | 15 x 16 | ANF | ANF | XYR16A | 111.8 | 7.62 | Zircaloy-4 | 228 | 53.25 | 35.09 | 4.02 |
| | Yankee Rowe | 15 x 16 | CE | CE | XYR16C | 111.8 | 7.62 | Zircaloy-4 | 156 | 35.69 | 36.00 | 3.92 |
| | Yankee Rowe | 15 x 16 | UNC | UNC | XYR16U | 111.8 | 7.62 | Zircaloy-4 | 73 | 17.42 | 31.99 | 4.02 |
| | Yankee Rowe | 17 x 18 | WE | WE | XYR18W | 111.8 | 7.62 | St. Steel 348H | 76 | 20.77 | 31.76 | 4.94 |
| Connecticut Yankee | Haddam Neck | 15 x 15 | B&W | B&W SS | XHN15B | 137.1 | 8.42 | St. Steel 304 | 627 | 257.01 | 37.83 | 4.02 |
| | Haddam Neck | 15 x 15 | B&W | B&W Zir. | XHN15BZ | 137.1 | 8.42 | Zircaloy-4 | 104 | 37.85 | 42.96 | 3.91 |
| | Haddam Neck | 15 x 15 | GA | Gulf Zir. | XHN15HZ | 137.1 | 8.42 | Zircaloy-4 | 2 | 0.73 | 18.55 | 3.26 |
| | Haddam Neck | 15 x 15 | NU | NUM SS | XHN15MS | 137.1 | 8.42 | St. Steel 304 | 2 | 0.81 | 28.32 | 3.66 |
| | Haddam Neck | 15 x 15 | NU | NUM Zir. | XHN15MZ | 137.1 | 8.42 | Zircaloy-4 | 2 | 0.74 | 25.64 | 2.95 |
| | Haddam Neck | 15 x 15 | WE | WE | XHN15W | 137.1 | 8.42 | St. Steel 304 | 229 | 94.75 | 35.20 | 4.00 |
| | Haddam Neck | 15 x 15 | WE | WE Zir. | XHN15WZ | 137.1 | 8.42 | Not Available | 53 | 20.40 | 19.38 | 4.60 |
| Humboldt Bay | Humboldt Bay | 6 x 6 | ANF | 6 X 6 ANF | XHB06A | 95.0 | 4.67 | Zircaloy-2 | 126 | 8.79 | 22.38 | 2.41 |
| | Humboldt Bay | 6 x 6 | GE | GE | XHB06G | 95.0 | 4.67 | Zircaloy-2 | 176 | 13.44 | 22.88 | 2.52 |
| | Humboldt Bay | 7 x 7 | GE | GE Type II | XHB07G2 | 95.0 | 4.67 | Zircaloy-2 | 88 | 6.72 | 20.77 | 2.31 |
| Big Rock Point | Big Rock Point | 9 x 9 | ANF | ANF | XBR09A | 84.0 | 9.52 | Zircaloy-2 | 4 | 0.51 | 22.81 | 3.52 |
| | Big Rock Point | 9 x 9 | GE | GE | XBR09G | 84.0 | 9.52 | Zircaloy-2 | 70 | 9.62 | 22.08 | 3.54 |
| | Big Rock Point | 11 x 11 | ANF | ANF | XBR11A | 84.0 | 9.52 | Zircaloy-2 | 359 | 46.76 | 34.21 | 3.82 |
| | Big Rock Point | 11 x 11 | NFS | NFS | XBR11N | 84.0 | 9.52 | Zircaloy-2 | 8 | 1.03 | 21.85 | 3.51 |
| Rancho Seco | B&W 15 x 15 | 15 x 15 | B&W | B&W Mark B4 | B1515B4 | 165.7 | 8.54 | Zircaloy-4 | 437 | 202.49 | 38.19 | 3.22 |
| | B&W 15 x 15 | 15 x 15 | B&W | B&W Mark B4Z | B1515BZ | 165.7 | 8.54 | Zircaloy-4 | 56 | 25.90 | 10.00 | 3.06 |
| Trojan | WE 17 x 17 | 17 x 17 | B&W | B&W Mark B | W1717B | 159.8 | 8.44 | Zircaloy-4 | 48 | 21.61 | 18.00 | 3.60 |
| | WE 17 x 17 | 17 x 17 | WE | WE LOPAR | W1717WL | 159.8 | 8.44 | Zircaloy-4 | 732 | 337.24 | 42.07 | 3.46 |
| La Crosse | La Crosse | 10 x 10 | ANF | ANF | XLC10A | 102.5 | 5.62 | St. Steel 348H | 178 | 19.34 | 20.13 | 3.71 |
| | La Crosse | 10 x 10 | AC | AC | XLC10L | 102.5 | 5.62 | St. Steel 348H | 155 | 18.62 | 21.53 | 3.94 |
| Zion | WE 15 x 15 | 15 x 15 | WE | LOPAR | W1515WL | 159.8 | 8.44 | Zircaloy-4 | 1112 | 506.47 | 55.39 | 3.31 |
| | WE 15 x 15 | 15 x 15 | WE | OFA | W1515WO | 159.8 | 8.44 | Zircaloy-4 | 920 | 423.56 | 48.32 | 3.64 |
| | WE 15 x 15 | 15 x 15 | WE | WE Vantage 5 | W1515WV5 | 159.8 | 8.44 | Not Available | 194 | 89.41 | 37.27 | 3.74 |
| Total | | | | | | | | | 7649 | 2813.17 | | |

The Site Conditions section of the report will describe the infrastructure that is available at each site, such as electrical power, container and cask handling equipment, cranes, staging and parking areas, onsite roads, etc.

The Near-Site Transportation Infrastructure and Experience section will describe the transportation interfaces for rail, barge, and heavy haul trucks. In addition, it will describe site experience with moving heavy loads from the site as part of major equipment removal during the decommissioning and decontamination of the reactor facilities at the site. This major equipment would include reactor pressure vessels, steam generators, and pressurizers.

As part of this task, Maine Yankee, Connecticut Yankee, and Yankee Rowe were visited during the week of August 27-August 31, 2012. Other Orphan Sites will be visited in FY2013. For sites not visited, information from Facility Interface Data Sheets, Services Planning Documents, Near-Site Transportation Infrastructure Reports, and Facility Interface Capability Assessment Cask-Handling Assessments will be used to establish a baseline, augmented by information from site managers and web resources.

The section entitled Actions Necessary to Remove Used Nuclear from Orphan Sites will contain a top-level outline of the plan that will be necessary to remove the used nuclear fuel from the Orphan Sites. Included will be a preliminary schedule for these actions.

The conclusions section will discuss the overall conclusions for the FY 2012 orphan sites study including items such as shipping considerations and hurdles for each site

3. Evaluation of Issues Associated with Canister Stabilization

The following report was issued on August 28$^{th}$, 2012 -
*A Preliminary Evaluation of Using Fill Materials to Stabilize Used Nuclear Fuel During Storage and Transportation* – **FCRD-UFD-2012-000243** (PNNL-21664).

The objective of the research described in this report was to conduct a preliminary evaluation of potential fill materials that could be used to fill void spaces in and around used nuclear fuel contained in dry storage canisters in order to stabilize the geometry and mechanical structure of the used nuclear fuel during extended storage and subsequent transportation. The use of fill material to stabilize used nuclear fuel is not considered to be a primary option for safely transporting used nuclear fuel after extended storage. However, the evaluation of potential fill materials, such as those described in this report, might provide the U.S. Department of Energy Used Fuel Disposition Campaign with an option that would allow continued safe storage and transportation if other options such as showing that the fuel remains intact or canning of used nuclear fuel do not prove to be feasible.

As a first step in evaluating fill materials, previous work done in this area was summarized. This involved studies done by the Spent Fuel Stabilizer Materials Program, Allied-General Nuclear Services, the Canadian Nuclear Fuel Waste Management Program, the U.S. Department of Energy, Spain, Sweden, and the Department of Energy’s Yucca Mountain Project. A wide variety of potential fill materials were evaluated in these studies, ranging from molten metal to particulates and beads to liquids and gases. The common element in the studies was that they were focused on the use of fill materials in waste packages for disposal, not in storage canisters or transportation casks. In addition, very few studies involved actual experiments that measured some physical property of the fill material to be used as a stabilizing material, and no studies were found that analyzed the performance of transportation casks containing fill material during the normal conditions of transport specified in 10 CFR 71.71 or under hypothetical accident conditions specified in 10 CFR 71.73. In addition, most studies did not address issues that would be associated with production-scale emplacement of fill material in canisters, as opposed to laboratory- or experimental-scale use of fill material. It is noteworthy that Sweden abandoned its plan to use fill materials to stabilize waste packages due to the complexity of emplacing the fill material.

As part of the evaluation of fill materials, conceptual descriptions of how canisters might be filled were developed with different concepts for liquids, particles, and foams. The requirements for fill materials were also developed. Elements of the requirements included criticality avoidance, heat transfer or thermodynamic properties, homogeneity and rheological properties, retrievability, material availability and cost, weight and radiation shielding, and operational considerations.

Potential fill materials were grouped into 5 categories and their properties, advantages, disadvantages, and requirements for future testing were discussed. The categories were molten materials, which included molten metals and paraffin; particulates and beads; resins; foams; and grout. Based on this analysis, further development of fill materials to stabilize used nuclear fuel during storage and transportation is not recommended unless options such as showing that the fuel remains intact or canning of used nuclear fuel do not prove to be feasible.