100-N Proposed Plan & RI/FS Report

- Submitted to Ecology June 2012
- TPA Milestone M-015-75
- TPA “Primary Document”
- 45 day review (30 day extension)
N Reactor Operational History

- Reactor constructed from 1958-1963
- Full Production started January 1964
- Operated continuously until January 1987
- Placed in Cold Standby February 1988
- Shutdown order issued September 1991
100-NR-1 / NR-2 Operable Unit

- 234 facilities
- 136 waste sites
- 4 RCRA designated TSD facilities *
- Sr-90 GW plume unique to this operable unit
- Petroleum spills (80,000 gal 1966 largest spill)
- No persistent chromium plume in groundwater

* RCRA TSD’s: 1301-N & 1325N LWDF’s, 1324-N Surface Impoundment & 1324 NA Percolation Pond
100-N Reactor Closed Loop Cooling

- De-ionized water used for reactor coolant
- Non-radioactive secondary cooling water disposed directly to the river
- 1% of primary cooling water replaced on a continuous basis with secondary cooling water
- Primary coolant passed through N reactor the equivalent of 100 times instead of once in the other single-pass reactors
- Primary coolant discharged to soil column (Feed and Bleed)
Liquid Waste Disposal Practices

- Primary coolant disposed to 1301 Crib and trench from 1963 to 1983
- 1325-N Crib built as replacement in 1983
- 1325-N Crib expanded with the addition of a 2700 ft. trench in 1985
- Ion Exchange regenerate solution from river water treatment disposed to 1324-N/NA pond
- Most of the Sr-90 inventory sent to trenches was from fuel storage basin overflow
- All liquid discharges cease January 1992
100 N Area Environmental Issues

- Strontium-90 concentrations at N Springs reaches 5,000 pCi/liter in 1985
- Strontium-90 groundwater plume concentrations peaked in excess of 45,000 pCi/liter beneath 1325-N in late 1989
- Persistent Strontium-90 GW plume; max concentration ~ 1,000X MCL of 8 pCi/L
- Large petroleum spill
100-N Sr-90 Inventory

- The estimated Sr-90 inventory released to 116-N-1 and 116-N-3 is ~3,000 Ci
  - Approximately 56% (1,672 Ci) has decayed through 2010
  - Approximately 17% (500 Ci) was removed during remediation of 116-N-1 and 116-N-3
  - Approximately 0.06% (1.8 Ci) was removed during the pump and treat operation

- **825 Ci (27%) are estimated to remain in the vadose zone and groundwater**
  - Approximately 90% (742 Ci) remain in the vadose zone
  - Approximately 10% (83 Ci) remain in the aquifer (0.8 Ci estimated to be in the groundwater and 82 Ci in the saturated sediment)

- Sr-90 has a half-life of 29.1 years and a $K_d$ of 15 mL/g

**Estimate of Sr-90 Inventory**

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<th>Fifth Column</th>
<th>Sixth Column</th>
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<tr>
<td>Original Mass (Ci)</td>
<td>2997</td>
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<tr>
<td>2010 Decayed (Ci)</td>
<td>1325</td>
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<tr>
<td>Removed from waste site for disposal (Ci)</td>
<td>500</td>
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<tr>
<td>Remaining (Ci)</td>
<td>825</td>
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</table>
There is No Persistent Chromium Plume from 100-N Operations

• New alloys and materials reduced need for corrosion inhibitors by 100X compared to other 100 Area reactors

• Sodium dichromate only used in primary (recirculation) cooling loop; discontinued in 1972

• 54K lbs chromium discharged to 1301-N; flushed by 21 BILLION GALLONS of water; 10 yrs of chromium-free discharge
1966 Fuel Oil Spill

- ~80,000 gal of Diesel spilled in 166-N Tank Farm *
- Interception Trench collected & burned oil through 1967
- ROD for Interim Action requires sorbing free product in wells; Amendment requires bioventing contaminated soils

* Multiple spills of diesel & #6 Fuel oil reported – this is the largest
Remediation Under 1999 IROD

- Nearly all of the structures have been demolished
- Estimated 6 of 136 waste sites will remain when ROD will be signed
- P&T for Sr-90 tested & abandoned
- Permeable Reactive Barrier partially constructed (900 ft)– active test
- Jet Injection of apatite in VZ portion of barrier successfully tested
- Phytoextraction tested in laboratory & cold field test completed
- Bioremediation of petroleum products in VZ initiated
- Reactor in Interim Safe Storage (EE/CA)
100-N Area Current Sr-90 and Nitrate GW Plume Extent, 2011

[Map showing the 100-N Area with highlighted regions for Sr-90 and Nitrate plumes]
NR-2 OU Commingled Strontium-90 and Nitrate Groundwater Plumes, 2011
100-N Area Current Tritium GW Plume Extent, 2011

Tritium has dropped below the 20,000 pCi/L DWS and continues a rapid decline; Recent occurrence >DWS in aquifer tubes near reactor due to RTD activities.
Major GW Plumes in 100-NR-2
Groundwater

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Water Quality Standard</th>
<th>Maximum Concentration</th>
<th>Plume Area</th>
<th>Shoreline Impact</th>
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<tr>
<td>Strontium-90</td>
<td>8 pCi/L</td>
<td>13,500</td>
<td>0.57 km²</td>
<td>640</td>
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<tr>
<td>Nitrate</td>
<td>45 mg/L</td>
<td>394</td>
<td>0.57 km²</td>
<td>150</td>
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<tr>
<td>Tritium</td>
<td>20,000 pCi/L</td>
<td>16,500</td>
<td>0</td>
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**Remediation**

Groundwater (interim action):

- Pump-and-treat: 1995-2006, 1.8 Ci strontium-90 removed
- Apatite sequestration barrier: 2006-2011

Final record of decision anticipated in 2013
100-N Area GW TPH-Diesel Range Plume Extent, 2010 - 2011

TPH-DR Cleanup Levels in GW = 500 µg/L
(WAC 173-340-720, Table 720-1)
100-N Area - Sr-90
Conceptual Site Model

Bank Storage and Zone of Interaction

Former Liquid Waste Disposal sites

Vadose Zone

Residual Sr-90 Extent

Hanford fm

Abandoned Paleo-channel

Response to Stage Changes

Unconfined Aquifer

More Transmissive

Very Low Transmissivity

RUM

~River Water Intrusion Limit

36:1 Vertical Exaggeration

High Stage

Low Stage

N-Springs

Rearranged Springs
Current Extent of Sr-90 Beneath LWDF’s
Columbia Rivershore-Apatite Barrier and Sr-90 Conceptual Model, 100-N Area
Phytoextraction is considered but not recommended

- Willows
- Columbia River
- Rip Rap Apatite Barrier
- Groundwater Flow
- 90Sr Contaminated Riparian Zone
- 100-N Bluff
- Apatite injection
- Infiltration
- Apatite
- Barrier

Phytoextraction is considered but not recommended.
Alternatives – Common Elements

<table>
<thead>
<tr>
<th>100-NR-1</th>
<th>100-NR-2</th>
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<tr>
<td>• RTD</td>
<td>• Apatite PRB</td>
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<tr>
<td>– Consistent with IROD; some new soil PRGs</td>
<td>– Expand to 2,500 feet</td>
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<td>– Dispose to ERDF</td>
<td>– Vadose zone jet injections along</td>
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<tr>
<td>– Backfill, grade, and re-vegetate</td>
<td>contaminated vadose zone</td>
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<tr>
<td>• Bioventing for TPH</td>
<td>(1,000 feet)</td>
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<tr>
<td>• ICs</td>
<td>– Additional round of injections within</td>
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<td>5 years of completion</td>
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- P&T Decommissioning
- ICs
- TI Waiver
- Maintaining shoreline rip-rap
## Components of Remedial Alternatives

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Remedial Alternative 2: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing for TPH-D in Vadose Zone, MNA for TPH-D in Groundwater, Groundwater Monitoring, and ICs

- **Estimated capital cost:** $42.6 million
- **Estimated O&M cost:** $80.1 million
- **Estimated present value (discounted):** $91.3 million
- **Estimated time to achieve RAOs at river boundary:** 110 years for strontium-90, 39 years for nitrate, and 0 years for TPH-D
- **Estimated time to achieve RAOs at upland area:** 225 years for strontium-90, 50 years for nitrate, and 32 years for TPH-D
Remedial Alternative 3 (Preferred Alternative): RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs

- **Estimated capital cost:** $45.8 million
- **Estimated O&M cost:** $81.1 million
- **Estimated present value (discounted):** $93.8 million
- **Estimated time to achieve RAOs at river boundary:** 110 years for strontium-90, 39 years for nitrate, and 0 years for TPH-D
- **Estimated time to achieve RAOs at upland area:** 225 years for strontium90, 50 years for nitrate, and 3 years for TPH-D
Alternative 4: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs

- **Estimated capital cost:** $56.1 million
- **Estimated O&M cost:** $86.8 million
- **Estimated present value (discounted):** $109.3 million
- **Estimated time to achieve RAOs at river boundary:** 110 years for strontium-90, 10 years for nitrate, and 0 years for TPH-D
- **Estimated time to achieve RAOs at upland area:** 225 years for strontium-90, 20 years for nitrate, and 3 years for TPH-D
Alternative 5: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, Apatite Treatment and TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Treatment of Sr-90 highest concentrations in GW under cribs, Groundwater Monitoring, and ICs

- **Estimated capital cost:** $222.4 million
- **Estimated O&M cost:** $94.6 million
- **Estimated present value (discounted):** $284.9 million
- **Estimated time to achieve RAOs at river boundary:** 110 years for strontium-90, 10 years for nitrate, and 0 years for TPH-D
- **Estimated time to achieve RAOs at upland area:** 161 years for strontium-90, 20 years for nitrate, and 3 years for TPH-D
Backup Slides
Summary of Remedial Alternatives

What technologies are unique in each Alternative?

- Alternative 1: No Action
- Alternative 2: MNA for TPH-D in Groundwater
- Alternative 3 (Preferred Alternative): Biosparging for TPH-D
- Alternative 4: Biosparging for TPH-D, In Situ Biological Treatment for Nitrate
- Alternative 5: Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Upland injection of apatite in source areas
100-N Operations and Remediation Timeline

Figure gwf11112. Nitrate Trends in Wells 199-N-2 and 199-N-67 near the 116-N-1 LWDF

- 199-N-2 Nitrate (ug/L)
- 199-N-67 Nitrate (ug/L)
- 116-N-1 in use
- 116-N-3 in use
- N Reactor Defueling Completed
- Pump and Treat Operations
- N-1 Remediation
- N-3 Remediation
- Period of elevated River Stage observed in upriver well 699-72-92

Replicate data averaged. The nitrate DWS (10 mg/L NO$_3$-N) is shown expressed as nitrate ion (45 mg/L NO$_3$).
TPA Milestones

- M-016-00 Complete remedial actions for all non-tank farm operable units Sept 2024
  - M-016-110-T03 DOE shall take actions necessary to contain the Sr-90 plume at the 100-NR-2 Operable Unit such that the default ambient water quality standard (8 pCi/L) for Sr-90 is achieved in the hyporheic zone and river water column Dec 2016
100-N Mulberries  1990
Field Remediation Status under IROD

- 87 waste sites closed/47 waste sites in closure verification/21 Remaining source sites under WCH contract/Complete by Fall 2013

- Direct Costs
  - 68% complete/SPI 0.81/CPI 1.34/CSPI 1.08
  - BAC $37.7M/ EAC $28.1M/ VAC $9.6M

- Anticipate 6 sites requiring remediation post ROD

- Reactor in Interim Safe Storage under EE/CA
GW Decision History

• 1991 - EE/CA (meet DCG of 1,000pCi/L); recommended slurry wall over P&T; no action taken
• 1993 - TPA SEC agreement to reduce Sr-90 flux to river; non-time-critical ERA
• 1994 - EE/CA evaluated no action, P&T, slurry wall, hydraulic control
• 1994 - Independent Review recommends vertical barrier (sheet pile) to increase GW travel time; advises that P&T would not be effective
• 1994 - Ecology issues Action Memorandum to install P&T system augmented with sheet pile barrier
• 1996 – Workshop presenting clinoptilolite permeable reactive barrier; strong negative stakeholder response
• 1997 RFI/CMS/1999 ROD for Interim Action; P&T, remove free product petroleum, assess alternative GW remedial technologies
• 1998-2001 – ITRD Process
• Groundwater Modeling
  Models fate and transport of $^{90}\text{Sr}$ in groundwater
• Bank Stability
  Stability study of 100-N Area Columbia River bank
• Clinoptilolite Treatment Wall
  Permeable barrier for $^{90}\text{Sr}$ adsorption
• Natural Attenuation
  Natural process that leads to reduction of contaminants (EPA requires monitoring $\sim$250 yrs)
• Sheet pile/Cryobarrier
  Controls contaminant flux to river
• Soil Flushing
  Lixiviant removes exchangeable $^{90}\text{Sr}$
• Soil Stabilization
  Immobilize $^{90}\text{Sr}$ in stable, insoluble $\text{PO}_4$ minerals
• Phytoremediation
  Uptake of $^{90}\text{Sr}$ by plants
ACTION MEMORANDUM; N-SPRINGS
EXPEDITED RESPONSE ACTION (ERA)
CLEANUP PLAN
September 24, 1994

- Ecology and EPA direction to DOE to perform an ERA
- 50 gpm pump-and-treat system
  - Operational by September 1995
  - Continuous operation
  - Design Requirements
    - Meet Sr-90 draft DWS
    - 90% reduction of Sr-90 minimum in treatment effluent
    - Design to evaluate commercially-available Sr-90 treatment technologies
    - Ease of expansion
    - Discharge treated water upgradient to aid Sr-90 recovery

- P&T System enhanced by a 3,000 ft. grouted hinge sheet pile wall
  - Initiate construction February 1995, Complete June 1995
  - Terminated after constructability test
  - The intent of the wall was to reduce the inflow of river water and increase the capture zone inland.
Record of Decision for Interim Action
September 1999

• 100-NR-01 Source & 100-NR-02 Groundwater combined ROD
• Groundwater provisions include
  – Remove and treat Sr-90 contaminated groundwater through extraction and treatment with ion exchange and discharge treated groundwater upgradient into the aquifer
  – Maintain approved groundwater monitoring networks
  – Evaluate technologies for Sr-90 removal and submit information to Ecology
  – Remove free-floating petroleum hydrocarbons from monitoring wells
  – Remove petroleum-contaminated solid waste, if needed, and dispose to ERDF
  – Conduct an evaluation of aquatic and riparian receptor impacts at the groundwater/river interface within 5-years. Evaluation will include a literature search and evaluation of existing data. Lab tests and studies may be required.
  – 5-Year review and maintain institutional controls
• ROD Amended to discontinue P&T and initiate permeable reactive barrier (apatite); 171 wells drilled with ARRA funds, 900 ft of barrier installed in GW, jet injection successfully demonstrated for VZ, completion of barrier has been funding-limited
IROD Requirement: Remove and treat Sr-90 contaminated groundwater through extraction and treatment with ion exchange and discharge treated groundwater upgradient into the aquifer

- The P&T system did:
  - Create a hydraulic sink to reduce flux to the river
  - Provide sufficient data to support Proposed Plan
  - Remove ~1.8 Ci Sr-90 at a cost exceeding $20M; Whereas, ~320 curies were “removed” by radioactive decay during same period (15 curies in the groundwater)

- The P&T system did not:
  - Significantly impact the Sr-90 source, groundwater plume and Sr-90 concentrations between the pumping zone and the river
Justification for VZ Component of Apatite Barrier

- Jet injection of phosphate solutions/bone char intended to emplace apatite in PRZ
- Apatite was not emplaced in PRZ during previous construction
- High river stage will cause GW to “overtop” existing barrier
- VZ/GW combination has been an integral component of the design from inception; VZ component is included in IROD Amendment
- Concentrations of Sr-90 highest in VZ
- Jet injection in VZ will augment upper GW component of barrier
- Preferred alternative limits VZ injections to zone of highest Sr-90 concentrations, the 1,000 ft section of the barrier where N-Springs occurred during reactor operations
Effluent Disposed to 1301-N & 1325-N LWDF

**Effluent Discharge to 1301-N and 1325-N LWDFs**

- 1301-N LWDF
- 1325-N LWDF

**Sr-90 Concentration in Effluent to 1301-N and 1325-N LWDFs**

- Average $^{90}$Sr Concentration