A Practical Solution to Hanford's Tank Waste Problem

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A “Troubled” Project

- “Since 1988, roughly $2 billion per year has been spent on Hanford cleanup.”
- “Despite the big money and big employment figures (typ. 10,000)..., many feel that cleanup is off-track. Very little of the radionuclide and chemical inventory has been stabilized after thirty years of effort.”
- “GAO estimates that the final bill may be as much as $120 billion and may take another 50 to 60 years to complete.”

http://www.hanfordchallenge.org/the-big-issues/how-hanford-works/

A FEW EXAMPLES

http://www.power-eng.com/articles/2013/02/hanford-nuclear-waste-storage-site-panned-in-gao-report.html (Feb2013)

http://www.nwnewsnetwork.org/post/federal-report-blasts-hanfords-waste-treatment-plant-project (Jan2013)

http://www.forbes.com/sites/jeffmcmahon/2012/08/29/bechtel-incompetent-to-complete-hanford-nuclear-waste-cleanup-doe-memo/ (Aug2012)

http://ehstoday.com/safety/news/safety-board-hanford-site-atmoshpere-adverse-safety-0707 (Jul2012)

...etc., etc. back to the early-90’s

The National Academies identified the cultural “symptoms” responsible for Hanford’s (& INL’s) EM woes in 1996: *see “ Barriers to Science*: Technical Management of the Department of Energy Environmental Remediation Program”, *www.nap.edu/catalog/10229.html*

THE GALVIN COMMISSION'S REPORT (1995)[note]

•"Two yardsticks are useful in judging the EM program: progress toward cleanup goals and the costs incurred"

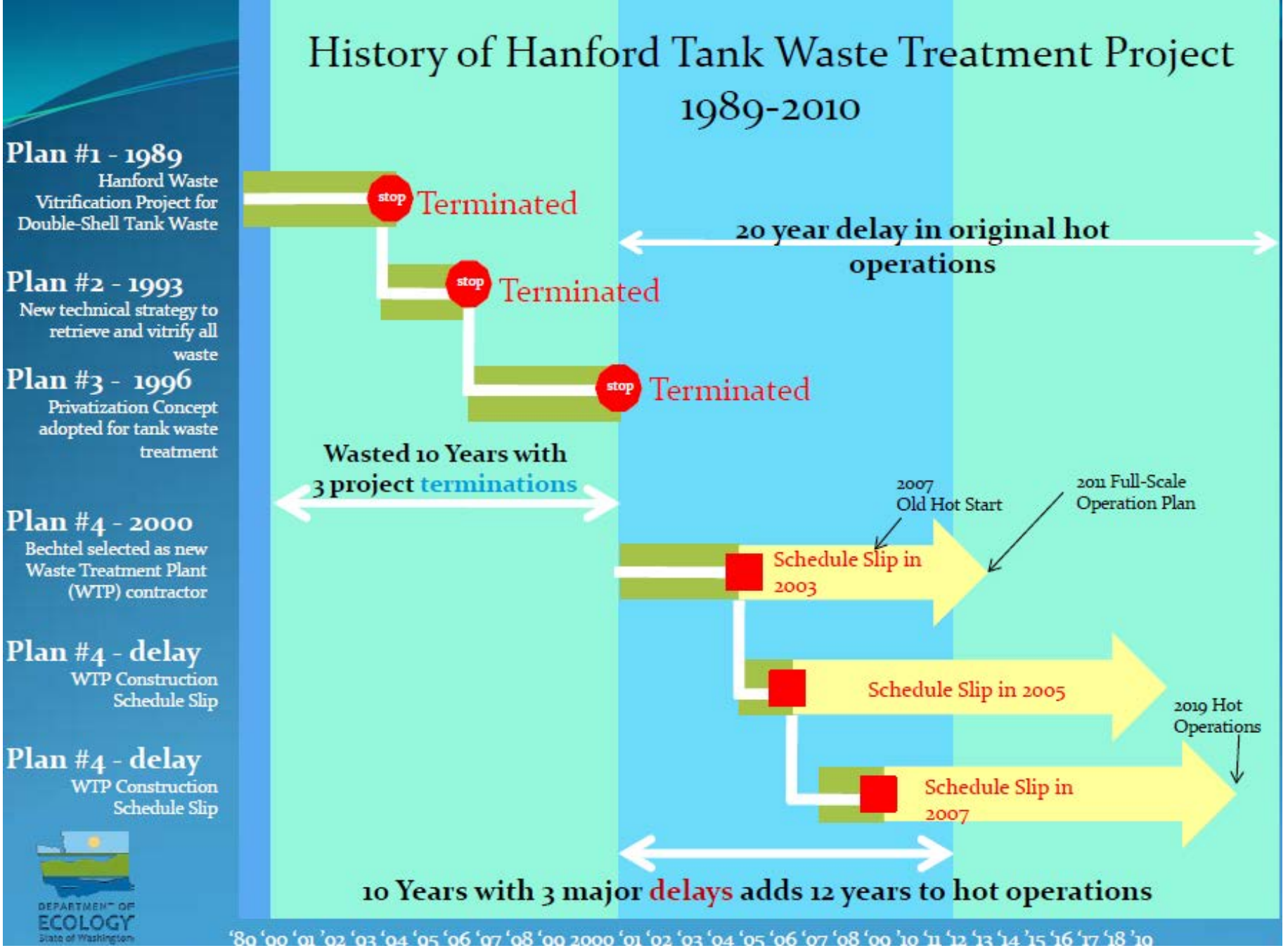
•"The remediation program has accomplished far less than many wish. The Government Accounting Office[8], ... concluded that while "DOE has received about **$23 billion for environmental management since 1989, .. little cleanup has resulted. "**

•"One of the consequences of the troubles has been the enhancement of a syndrome common to large bureaucracies: risk aversion. It has a name: "the Hanford Syndrome." It has become widespread and severe in the EM program. Its symptoms are an unwillingness to alter familiar behavior patterns, to stick with unproductive or failing procedures, to enhance tendencies for excessive resource allocation and regulation, and to oppose innovation. It is an important element in sustaining unproductive patterns of work."

•"The Tri-Party Agreement at Hanford, and similar ones elsewhere, have proven to constitute major constraints on remediation progress because, in many instances, they are unrealistic, not having had proper input from those experienced in actual cleanup. The milestones they incorporate, along with penalties for noncompliance, force continued activities, some of which are make-work and should be abandoned. Other activities should be delayed or modified so as to await more effective and less costly technologies. Virtually no one believes the timetables are achievable and DOE has already been forced into renegotiations...".

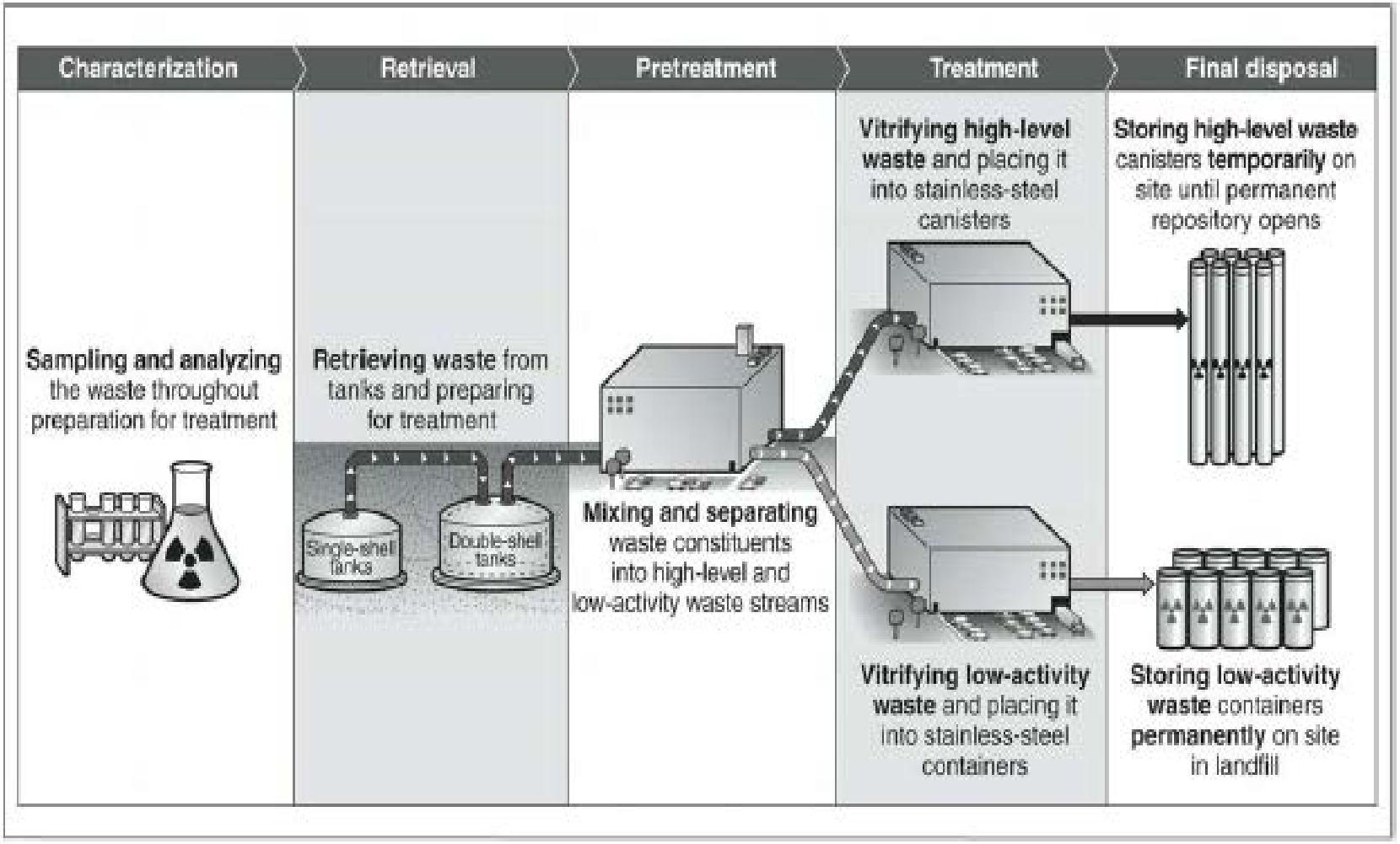
•"There is a marked incapacity within the Department's EM program to evaluate current and prospective technologies in a wide-ranging and competent manner based on well-assessed risks."

www.lbl.gov/LBL-PID/Galvin-Report/Galvin-Report.html



Slide 7, **"Tank Waste Final Waste Form Perspective", Suzanne Dahl, WA dept of ECOLOGY, Jan. 13, 2010**

Figure 1: WTP Waste Treatment Process



Sources: GAO and DOE.

from GAO-13-38, Dec 2012

Root Causes

The “technical” reason why WTP has proven to be a boondoggle* is that it is based upon two unrealistic assumptions

1. (most harmful) Hanford’s tank waste will/must be separated into “high” & “low” fractions so that the former can be dumped into someone else’s “back yard”[note1] **(politically & economically unrealistic)**
2. Both fractions will/must eventually be converted to borosilicate-type glass[note2] **(renders vitrification unnecessarily difficult/expensive)**

**www.gao.gov/products/GAO-13-38*

Recommended Approach

- Homogenize (not separate) Hanford's tank wastes: i.e., simultaneously retrieve from multiple depths from multiple tanks
- Pug-mill mix with crude phosphoric acid[note1] & powdered iron ore, vitrify with a *large*[note2] stirrer-equipped melter, and make "aggregate"* of the resulting glass
- Slurry this aggregate with a MgO/KH_2PO_4 ("Ceramicrete") - type grout & pump it back into Hanford's best-condition waste tanks**

* Either glass marbles, "gems" or cullet

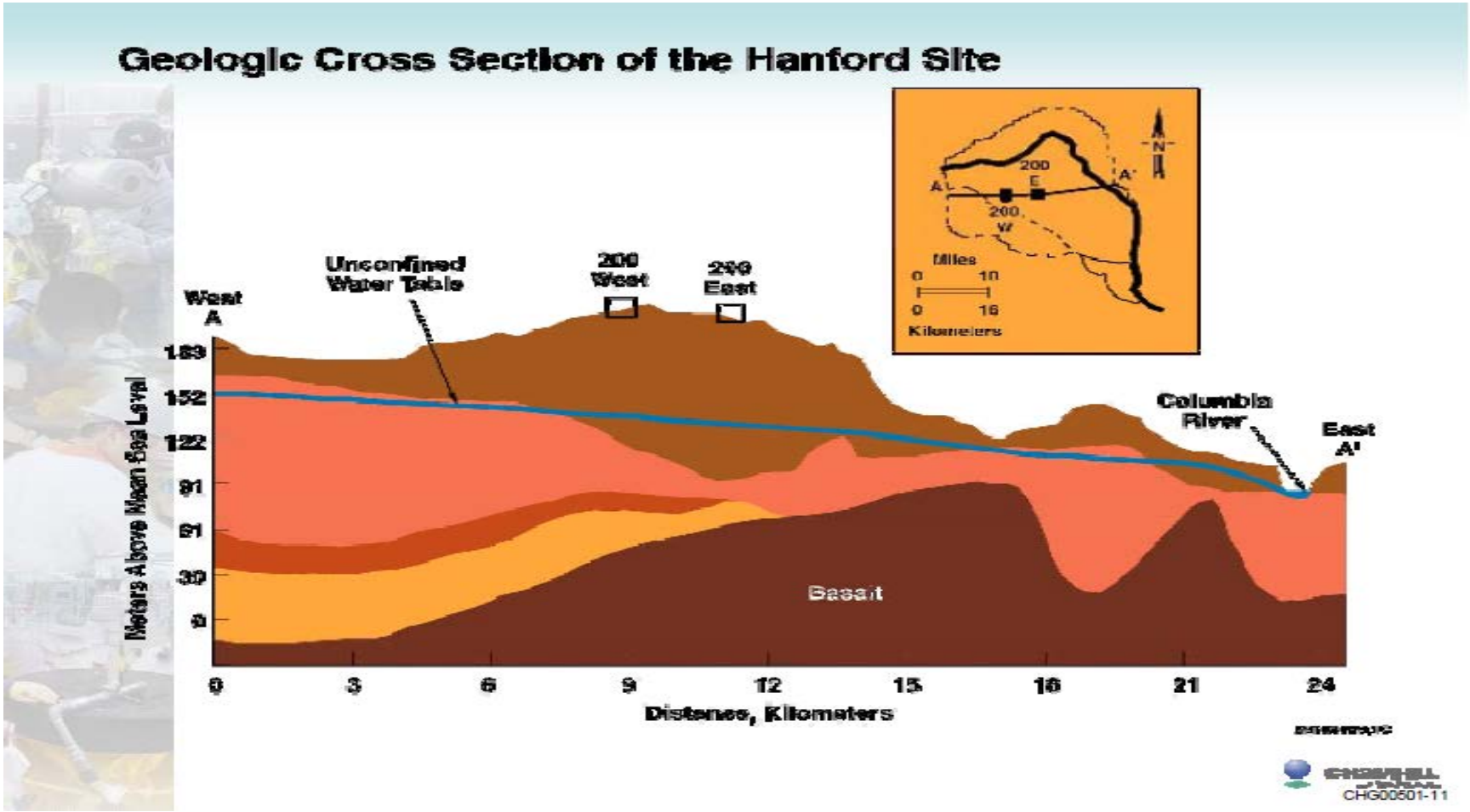
** this grout would serve to seal any existing leaks in those tanks

Background Slides*

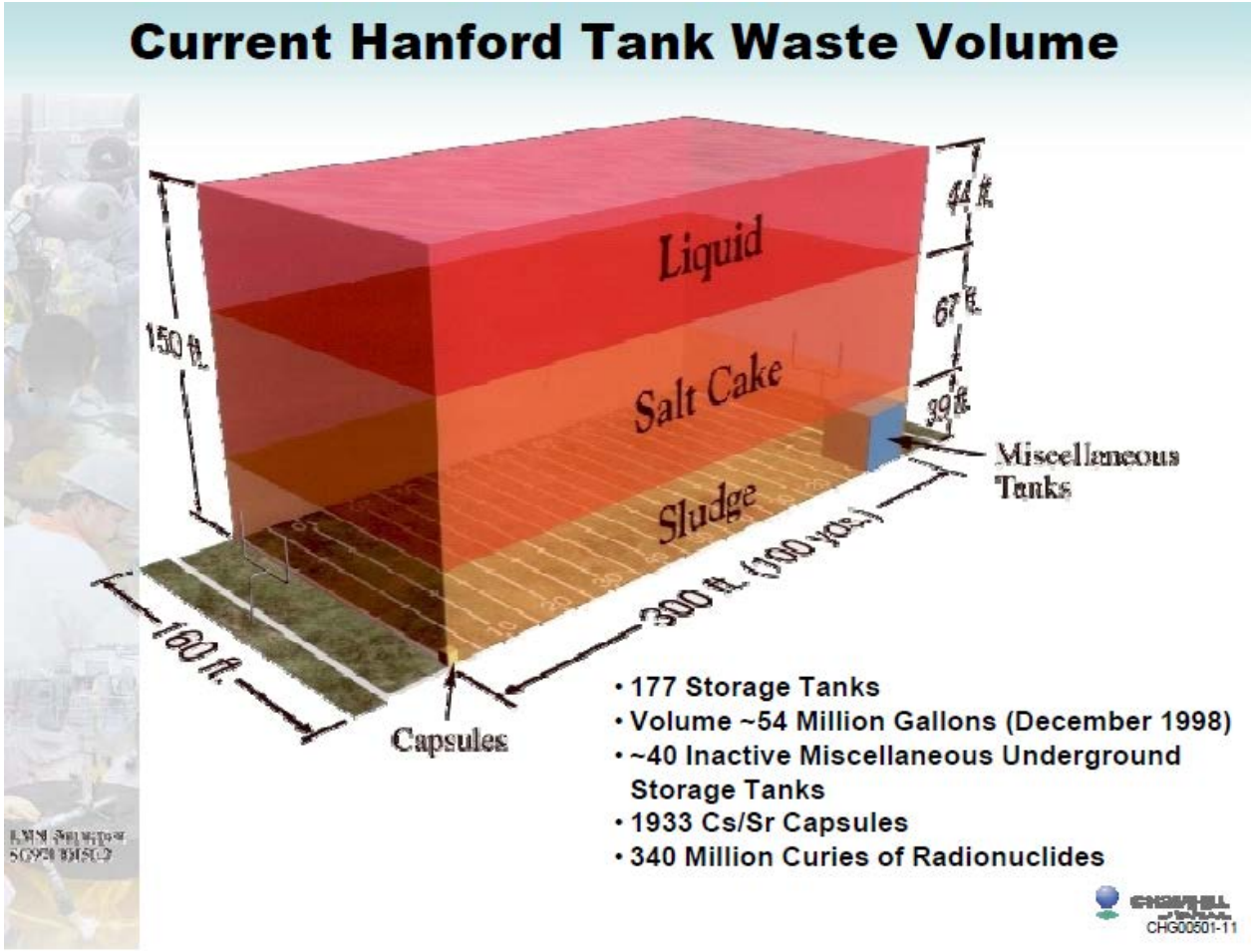
CHG00501-11

srnl.doe**.gov/emsp/day1_overv/**hanford**-gaspl.pdf* (CH2MHill, 2005)

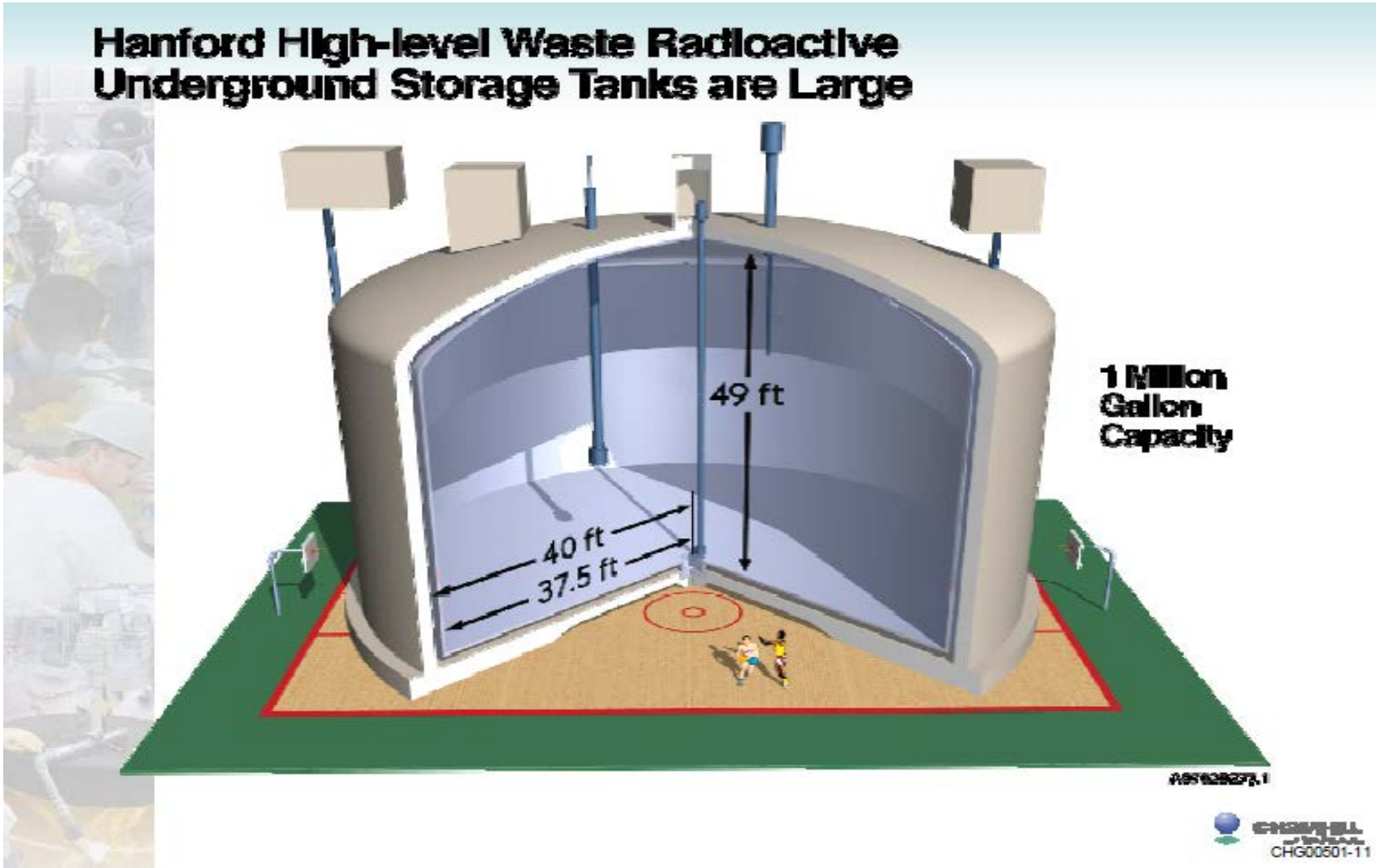
More background...note



more...note

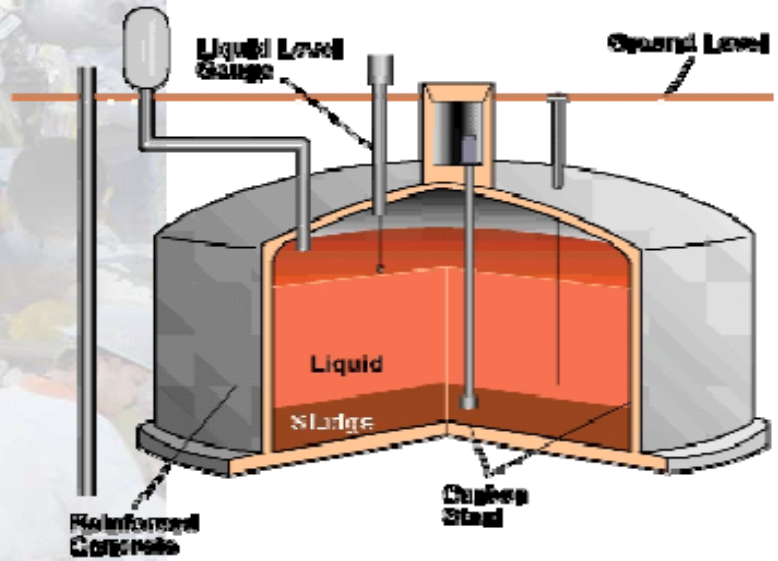

Current Hanford Tank Waste Volume
Liquid
Salt Cake
Sludge
150 ft.
44 ft.
67 ft.
39 ft.
Miscellaneous Tanks
300 ft. (900 yds.)
160 ft.
Capsules
• 177 Storage Tanks
• Volume ~54 Million Gallons (December 1998)
• ~40 Inactive Miscellaneous Underground Storage Tanks
• 1933 Cs/Sr Capsules
• 340 Million Curies of Radionuclides
CHG00501-11

more...


Hanford High-level Waste Radioactive Underground Storage Tanks are Large
49 ft
40 ft
37.5 ft
1 Million Gallon Capacity
CHG00501-T1

more...

Single-Shell Tanks



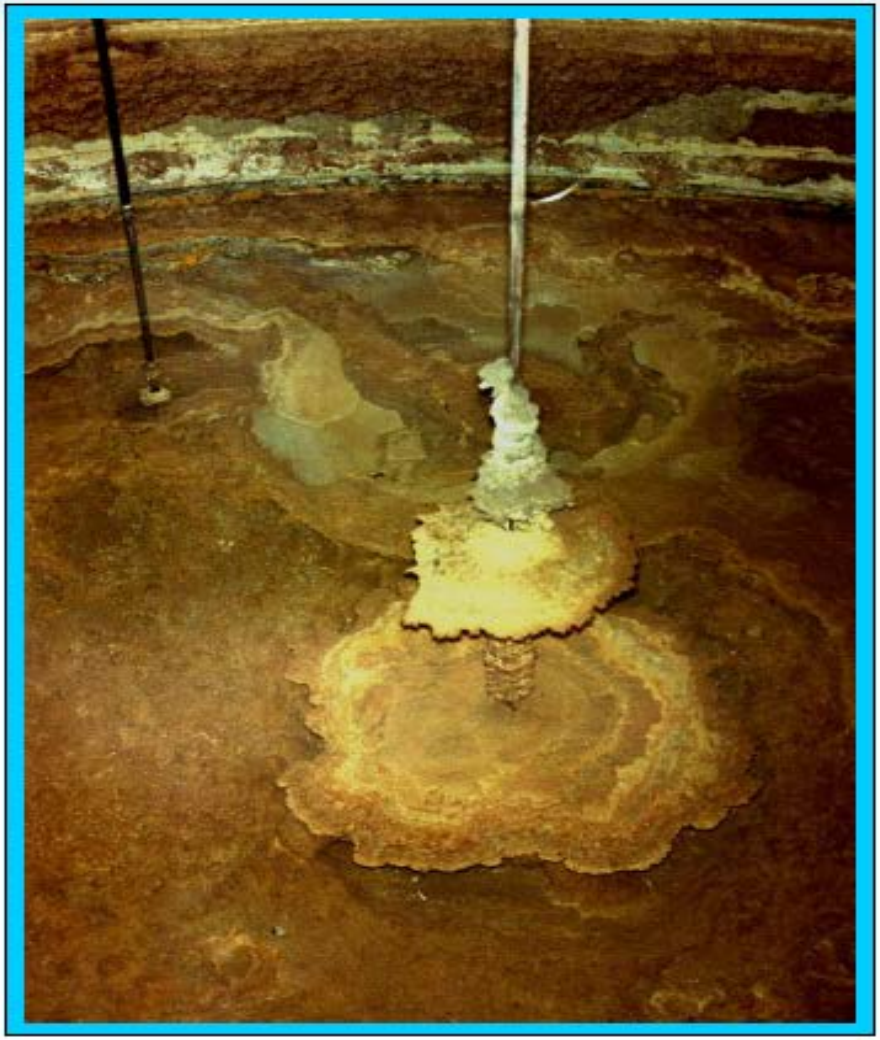
- 149 Tanks Constructed 1943-64
- ~210 m^3 to 3,800 m^3 Capacity (55 kgal to 1 Mgal)
- Bottom of Tanks at Least 50 m (150 Feet) Above Groundwater
- No Waste Added to Tanks Since 1980
- Tanks Currently Contain:

  ~132,500 m^3 (35 Mgal) of Salt Cake, Sludge, and Liquid

  ~407 x 10^{16} Bq (110 MCi)
- 67 Are Assumed to Have Leaked ~ 3,800 m^3 (~1 Mgal)

more...

Inside Tank SX-109



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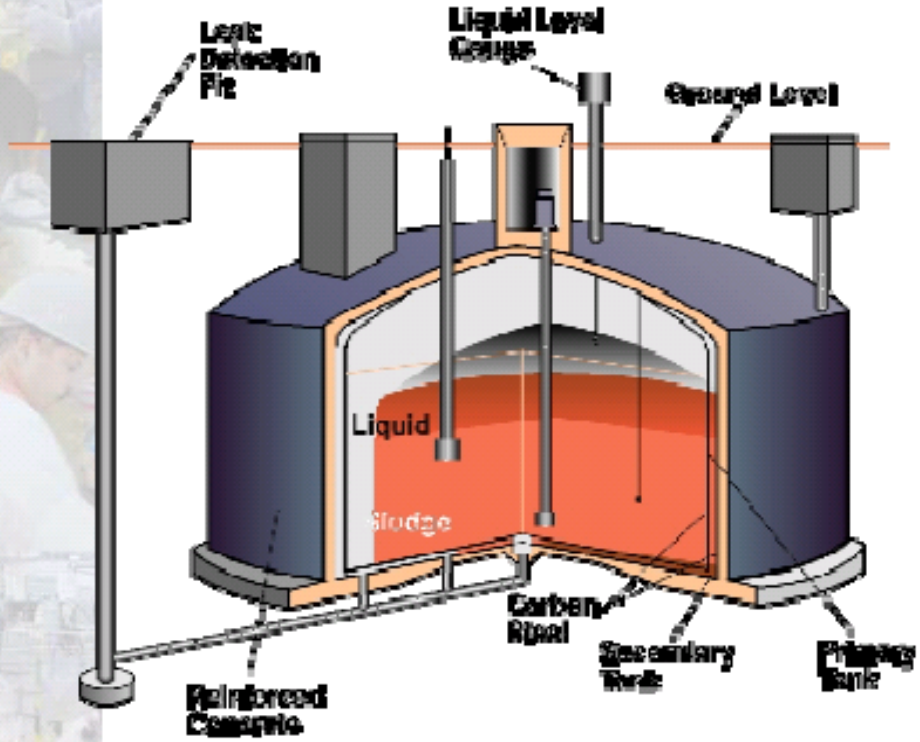
Double-Shell Tanks



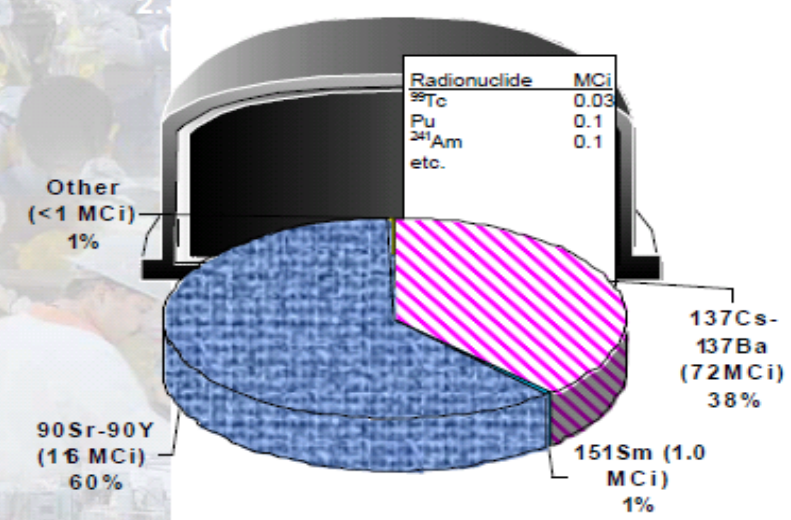
- 28 Tanks Constructed Between 1968-86
- ~3,800 m^3 to 4,300 m^3 (1 to 1.14 Mgal) Capacity
- Tanks Currently Contain
  - ~ 72,000 m^3 (19 Mgal) of Mostly Liquids (Also Sludges and Salts)
  - ~ 236 x 10^{16} Bq (63 MCi)
- None Have Leaked note

more...

more...note

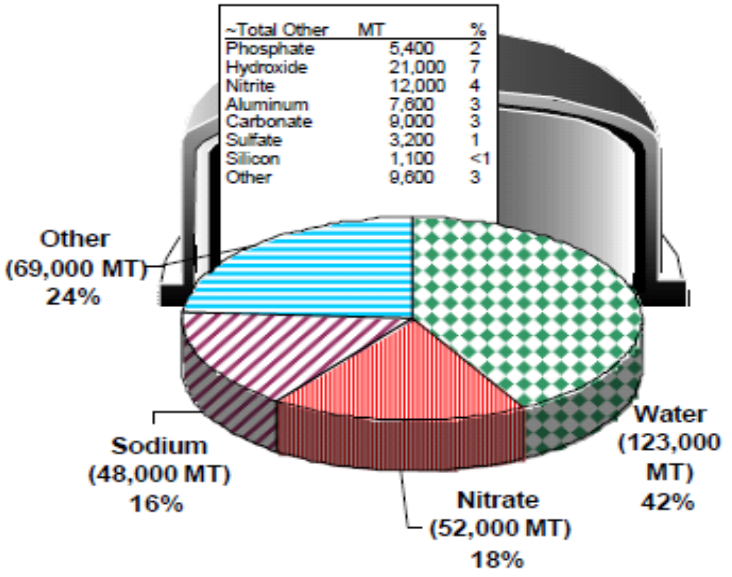
Hanford Site Waste Tanks Estimated Inventories

Radionuclide Inventory Decayed to 12/31/96*



Total in All Tanks
190 MCi

Chemical Inventory**



Total in All Tanks
292,000 Metric Tons

**Data Source:* DOE/RW-006, Rev. 13 1996 Integrated Data Base
**Tank Characterization Database, 9/97

CHG00501-11

More up to date figures

Table ES-1. Comparison of Global and Summation of Individual Tank Best-Basis Inventories for Nonradioactive Components. (2 Sheets)

Component	Summation of individual tank best-basis inventories (MT)[1]	Global inventory (MT) note	Corresponding document section
Aluminum	7,950	7,845	5.1
Bismuth	631	580	5.2
Calcium	319	214	5.3
Carbonate	9,390	4,830	5.4
Chloride	930	500	5.6
Chromium	670	785	5.7
Fluoride	1,190	1,360	5.8
Hydroxide	23,500	23,000	5.9
Iron	1,400	1,230	5.10
Lanthanum	51.3	51	5.11
Lead	84.0	279	5.12
Manganese	194	105	5.13
Mercury	1.81	2.1	5.14
Nickel	174	111	5.15
Nitrite and Nitrate	64,700	85,700	5.16
Phosphate	5,550	6,000	5.17
Potassium	874	481	5.18
Silicon	941	570	5.19
Sodium	48,800	54,200	5.20
Sulfate	3,330	5,000	5.21
Strontium	45.9	31.3	5.22
Total organic carbon	1,690	4,000	5.23
U_{total}	929	965	6.3
Zirconium	470	440	5.24

Mass sum oxides halides ≈107,000 tonnes (~70% of which is Na_2O) ~3.95wt% SO_3

"Ash" mass fraction of everything other than Na2O, K2O, Al2O3 Fe2O3 , P2O5 & SO3 ~5%

Some facts we don't hear so much about

- Hanford's tank farm is a good geological repository site[note1]
- Its radwaste is extremely dilute (not very "high"): ~90 tonnes[note2] initial FP ended up in about 290,000 tonnes of waste (0.03 wt%)*
- Its waste is thermally "cold": Current FP inventory includes 0.4 tonne (3.6E+7 Ci) of heat-generating ^{137}Cs/Ba & 0.25 tonne (3.3E+7 Ci) ^{90}Sr/Y or ~1.3 watts/tonne[note3]
- It's mainly comprised of sodium salts averaging about 10.4 moles/liter Na[note4] which means that its conversion to a "salt stone" would roughly treble its volume.[note5]
- It also contains lots of other stuff (aluminate, halides, chromate/chromite, sulfate, phosphate etc.) incompatible with high loading in borosilicate-type glasses (BSG)
- There's lots of "orphan" radwastes outside of its tanks

Hanford's Tank Waste is a "Greater than Class C LLW"[note]

	Class C LLW Limits*	∑Hanford's Waste**
^{90}Sr	4600 Ci/m^3	219 Ci/m^3
^{137}Cs	7000 "	142 "
^{63}Ni	700 "	0.38 "
^{14}C	8 "	0.023 "
^{99}Tc	3 "	0.15 "
^{129}I	0.08 "	0.0003 "
All α > 5 yr $t_{1/2}$	100 nCi/g	441 nCi/g

(why it's "greater than")

sum fractions save TRU = 0.125

*Upper Class C limits: Tables 1 & 2, 10 CFR§61.55 (from NRC website)

**assumes 19 yr decayed "global" figures of Table ES-2 HNF-SD-WM-TI-740 Rev OB, 1998 & a total of 322,000 tonnes (dry basis) or 55 million gallons of waste

Why Iron Phosphate Glass (Fe-P)?

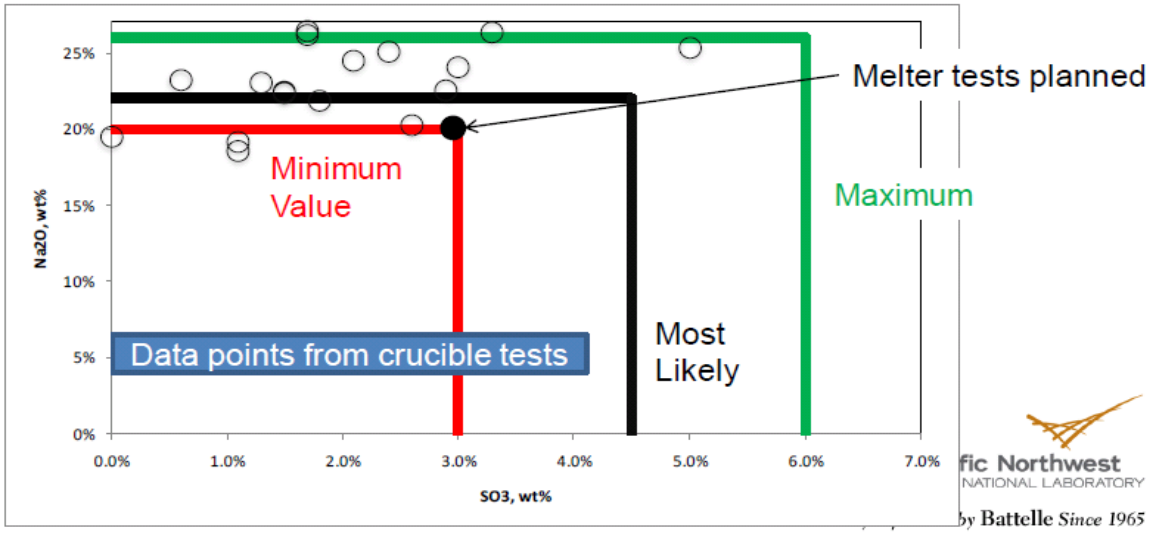
- More leach resistant than BSG glasses[note1]
- Easier to make - lower melting point/viscosity
- Accommodates much higher concentrations of "problematic" (for BSG) waste constituents – translates to having to making much less glass[note2]
- Already thoroughly studied/characterized for application to many DOE radwastes[1-4]
- Compatible with "mag phosphate" grout

1. **Huang et. al., Journal of Nuclear Materials, 327(2004) 46-57R.**
2. **Robert Leerssen, "Fe Phosphate Glass for the Vitrification of INEEL SBW and Hanford LAW", MS Thesis, UMR (now MST), 2002**
3. **Darryl Siemer, "Improving the Integral Fast Reactor's Proposed Salt Waste Management System", Nuclear Technology, 178(3), 2012, pp 341-352.**
4. **Sevigny, et. al., "Iron phosphate glass-containing Hanford Waste Simulant," PNNL 20670, August 2011**

Why Iron Phosphate... cont.

Phosphate Glass Loading Estimates*

- Insufficient data to refine loading estimates, however, based on preliminary assessments:
  - 20 wt% ≤ Na_2O ≤ 26 wt% → most likely 22 wt%
  - 3 wt% ≤ SO_3 ≤ 6 wt% → most likely 4.5 wt%
  - No halide, phosphate, or chromate limits



fic Northwest NATIONAL LABORATORY
by Battelle Since 1965

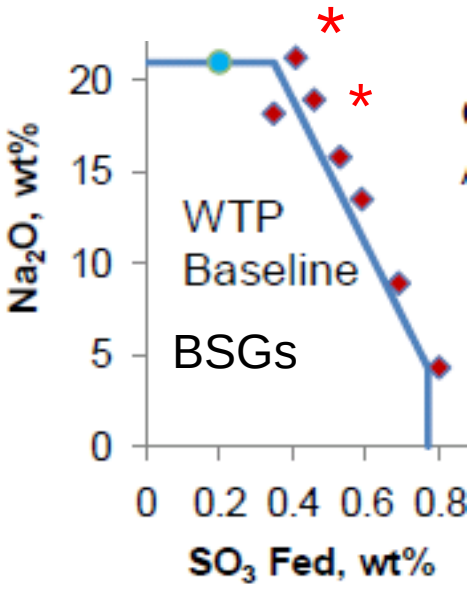
*Vienna et al., 2010: **http://energy.gov/sites/prod/files/em/112010Meeting/04-Vienna_ViennaRecycleCompImpactsonLAWAmount%2811-15-10%29.pdf**

Ball park calculations

- 22 wt% Na_2O waste loading* into Fe-P puts 54,200 tonnes of Na (100% of Hanford's tank waste) into ~330,000 tonnes of Fe-P glass
- Assuming 2.9 g/cc & 3785 cc/gallon, this translates to ~30 million gallons of glass
- Assuming 36% void volume[note1] for randomly dumped sphere "aggregate", this translates to a repository space requirement of 47 million gallons
- The total volume of Hanford's already-paid-for "canisters" (tanks) is ~172 million gallons[note2]

*slide 6, Vienna et al. 2010, http://srnl.doe.gov/techex_2010/pdfs/S02-04.pdf

Why not borosilicate glass?



The problem with bsg is that Hanford's waste contains enough sulfate (and halides too) to render their manufacture both more problematic & more expensive

Ignoring halide effects, this curve (WTP's basis) & current "global" SO_3/Na_2O tank waste inventories translates to making 688,000 tonnes of bsg if the waste is blended & 697,000 tonnes if it isn't

* **Excerpted from Vienna et al., "Impacts of Feed Composition and Recycle on Hanford LAW Glass Mass"**

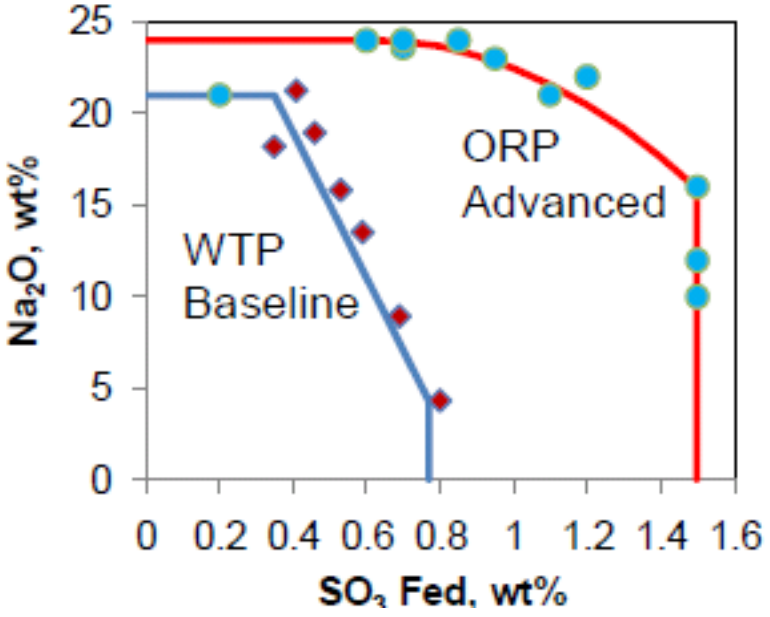
(http://energy.gov/sites/prod/files/em/112010Meeting/04-Vienna_ViennaRecycleCompImpactsonLAWAmount%2811-15-10%29.pdf)

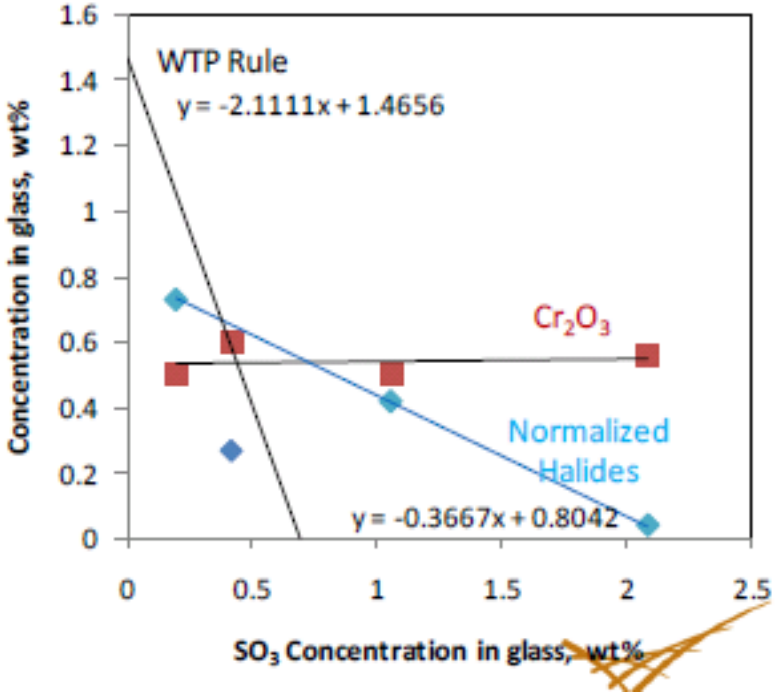
What about “Advanced” bsgs ?

Both sulfate and halides (H=Cl+0.3F) strongly affect (reduce) bsg waste loadings

Their effects upon bsg vitrification of the waste in each of Hanford’s tanks can be derived from data/formulae in PNNL/CSU reports (see figs. below)*

Bottom line: Even with today’s “advanced” formulations, implementing this proposal with bsg would require the manufacture of ~50% more glass





*plots excerpted from slide 4, Vienna et al. 2010, “Effect of Feed Composition...”

Tonnes Glass Generated From All Hanford Tank Waste* with different vitrification scenarios**

Glass tonnes produced from all Hanford tank waste

No Halide adjustment				Halide adjustment					
WTP basis B-Si Glass		Advanced B-Si Glass		WTP basis B-Si Glass		Advanced B-Si Glass		Fe-P Glass	
Unblended	Blended	Unblended	Blended	Unblended	Blended	Unblended	Blended	Unblended	Blended
697,000	**688,000**	**382,000**	**352,000**	**722,000**	**717,000**	**524,000**	**505,000**	**336,000**	**332,000**

*** No separations – the waste in each tank either goes directly into the melter (unblended) or is combined with everything in all other tanks & that combination fed to the melter (blended).**

**** Figures based upon, a) "Tank Waste Information Network System" (TWINS) queried 09/08/03)[note] ("Best Basis Summary Report") http://twins.pnl.gov/twins.htm, updated to reflect current total globalNa & SO4 estimates (54,200 & 5000 tonnes), & b) loading limits derived from data/equations in Vienna et. als, "Impacts of Feed Comp..."**
http://energy.gov/sites/prod/files/em/112010Meeting/04-Vienna_ViennaRecycleCompImpactsonLAWAmount%2811-15-10%29.pdf

BOTTOM LINE

In light of what's actually in Hanford's tanks, borosilicate glass's intrinsic waste loading limitations would turn what s*hould* be a relatively quick / simple / cheap / certain vitrification campaign into a slow / difficult / expensive / uncertain "Chinese Fire Drill"

note

WHY "STIRRED" MELTER

- **Mechanical mixing is apt to lessen semivolatile (e.g. Tc , Cs, & I) loss relative to bubbler mixing (WTP basis plan)**

- **Mechanical stirring greatly accelerates the melting process (smaller/cheaper melters could be used)**

- **They readily handle multiphasic ("chunky" or "stringy") feeds – non stirred melters can't (simplifies feed preparation)**

- **They have already been utilized/proven for several DOE/SRS projects[1,2]**

- **This project would <u>not</u> require high temperature melters or "advanced" glasses**

1. Marra, C., "Vitrification of Simulated Radioactive Rocky Flats Plutonium Containing Ash Residue with a Stir Melter System", Westinghouse Savannah River Company, WSRC-MS-96-0442.
2. D. F. Bickford et. al., TTP SRI-6-WT-31, Milestone XXX, Milestone C.I-2 Report: Functional Test of Pour Spout Insert and Knife Edge, WSRC TR 99 DO232, Rev 0, 1999.

Why “Ceramicrete”

Putting the glass back into Hanford’s tanks will require that it be rendered “pumpable” – a practical way to do this would be to make “aggregate” (marbles[1], “gems”[2], or cullet) which could be slurried with a suitable “grout” (cement + water + clay?) & pumped with conventional equipment

Fe-P glass is compatible[3] with magnesium phosphate based grouts because they share a common chemistry (components, pH, etc).

Ceramicrete has already been extensively studied as a stand-alone waste form[4]

[1]Germany’s PAMELA (“Vitromet”) process would have embedded HLW phosphate glass marbles in a molten lead “grout”

[2] Energy Solutions/VSL radwaste-to-glass “gems” project (Picket et al., “Vitrification and Privatization success“, **WSRC-MS-2000-00305, Rev. 1,** 1995)

[3] Borosilicate glasses are incompatible with the OPC/flyash-based grouts usually specified for EM work

[4] for example, Cantrell & Westsik, ”Secondary Waste Form Down Selection... CERAMICRETE”, PNNL-20681, August 2011.

Glass Aggregate Examples

1995 report ("Vitrification and Privatization Success“) describing the conversion of 670,000 gallons of "mixed" DOE radwaste to glass “gems” for $13.9 M[note]

http://sti.srs.gov/fulltext/ms2000305r1/ms2000305r1.html

Another 1995 report comparing cullet, “gem”, marble & monolithic options for DWPF's HLW glass*

http://www.osti.gov/bridge/servlets/purl/274186-Majyqw/webviewable/274186.pdf

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*since it was assumed that DWPF’s glass would be shipped off to YM, the simpler-to-produce & ~35% less voluminous monolith option was deemed "best"

WHY REUSE HANFORD'S TANKS?

- Its tanks are not evil
- They've already been paid for[note1]
- Steel-lined reinforced concrete "canisters" (tanks) are apt to much more durable than ORP's basis plastic-lined LAW disposal pits [note2]
- This waste management scenario would simultaneously "remediate" them[note3]
- No "interim" storage, packaging, or offsite transportation costs

Real World Glass Costs[note]

- **Current cost of glass "gems" or marbles, any size, is $2.49/# - free shipping! http://www.mcgillswarehouse.com/c/119/38**
- **Fiber glass is also made with electric melters**

  The USA made 3.04 million tons of fiber glass for $4.8 billion in 1999*

  Average inflation rate between 1999 & 2012 was ~3%

Consequently, making 330,000 tons of glass ***should*** cost about ...

$$\$4.8*(330{,}000/3{,}040{,}000)*1.03^{(2012-1999)} \approx \$0.77 \text{ billion}$$

ORP 11242 rev 6's cost estimate is ~ $61 billion

*http://www.nrel.gov/docs/fy02osti/32135.pdf

Additive Cost Ballparking

- A great deal of experience suggests that component ratios of 1.1 Na:1 P:0.6 (Fe+Al) would be OK for a sodium salt-based Fe-P. This means that vitrifying 100% of Hanford's waste* would require ~314,000 tonnes of fertilizer grade phosphoric acid (~3% of annual US consumption) and ~54,000 tonnes of iron ore - at current bulk commodity prices (~$600 & $2/ton) that adds up to ~$180 million

- At $500/ton, enough "Ceramicrete" to grout those gems/marbles would add another $10-15 million to the "additive" cost

An Important Bonus

Implementation of this proposal with "just" Hanford's tank wastes would utilize under 30% of the space in its disposal "canisters" (tanks)

Their headspace volumes should be filled with something that's both physically strong & chemically durable before final closure

Hanford has many miscellaneous radwastes ("crib" dirt, sludges*, etc.) for which no permanent solution has been implemented

These wastes could/should be coprocessed with the salt wastes & that glass grouted into the tanks too[note]

* e.g., Hanford's much-studied ~38 m^3 of K basin sludge represents about 0.01% of its total waste – adding it to the rest of the stuff going into the melter/tanks would <u>not</u> upset the system

Things Worth Studying

- **The interaction of conventional "grouts" with Fe-P type glasses:** BFS/OPC/flyash based grouts are cheaper and easier to use than is Ceramicrete & might be perfectly satisfactory[note1]
- **Tc & I behavior under the proposed conditions** (different glass, lower temperature, shorter in-melter residence time, and no bubblers)[note2]
- **Secondary waste generation/treatment/disposal:** how to best go about getting everything (e.g., I & Tc) that's in the waste into the disposal tanks/canisters in a way/ways that it can't get back out again[note3]

Summation

DOE EM/ORP should "study" this proposal because...

1) Nuclear power's future prospects depend upon what today's leaders do with existing reprocessing wastes & how much money they spend (the institution's viability is at stake)

2) That's important because the implementation of a sustainable* "nuclear renaissance" could head off otherwise almost inevitable environmental degradation[note 1]

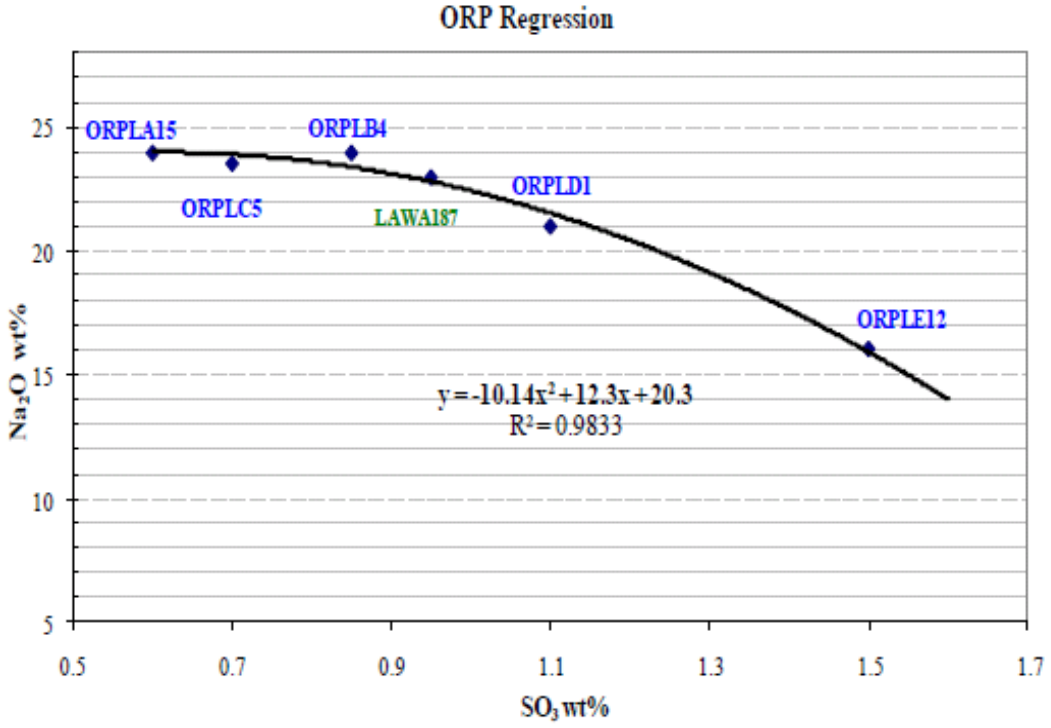
3) The USA can't afford to continue to waste $billions[note 2] on politically correct but technically unrealistic EM boondoggles

4) This proposal is simultaneously "doable", quick, affordable, and both technically & environmentally correct

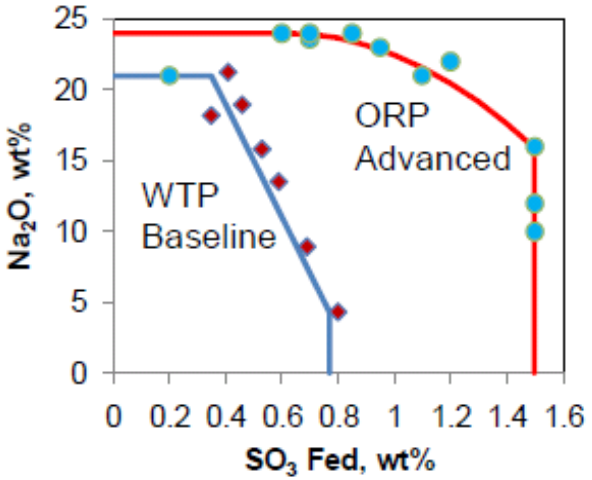
**** "sustainable" means breeder reactors which means more reprocessing waste***

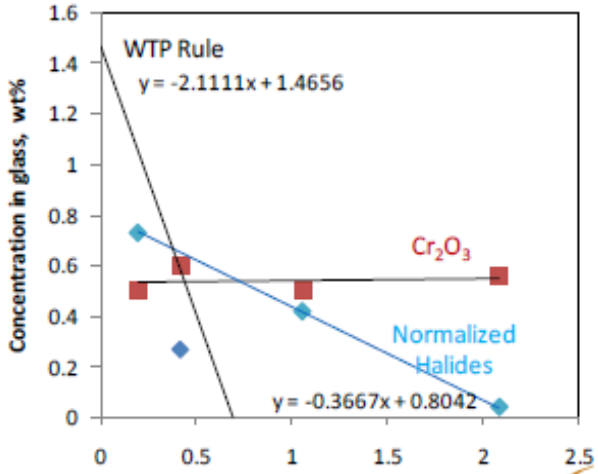
Extra slides

ORP Advanced Silicate Glass Formulation



Data points from scaled melter tests





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*slide 4, Vienna et al. 2010, http://srnl.doe.gov/techex_2010/pdfs/S02-04.pdf

Table 3-1. Tank Waste Remediation System Processing Inventory (December 31, 1999, Decay Date).

Radionuclide	Tank Waste Remediation System Processing[a] Inventory, MCi		
	Soluble	Insoluble	Total
^{137}Cs	34.1	3.01	37.1
^{90}Sr	1.89	52.5	54.4
Transuranics	0.00961	0.121	0.131
^{99}Tc	0.0228	0.0093	0.032
^{79}Se	0.00103	-	0.00103
^{14}C	0.0053	-	0.0053
^{129}I	0.000051	-	0.000051
^{3}H	0.01	-	0.01
^{126}Sn	-	0.0016	0.0016
Uranium	0.00006	0.00094	0.001
Total	36.0	55.6	91.6[b]

[a]The inventories of ^{3}H, ^{14}C, and ^{129}I are given in Colby (1994). The inventory for ^{79}Se and uranium is given in Mann et al. (1995). The inventory for ^{126}Sn is given in Schmittroth et al. (1995). The primary source of tank waste inventories are given in Orme (1995) for ^{137}Cs, ^{90}Sr, and TRU because additional detail is given for fractions of soluble and insoluble radionuclides. The values for ^{137}Cs, ^{90}Sr, and TRU are consistent with the Integrated Data Base Report-1994. See Appendix C for source of TWRS processing inventory.

[b]Round-off error can result in $\pm$ 0.2 MCi.

Table C-2. Estimated Discharges from Tanks to the Soil Column (December 31, 1999, Decay Date).

Radionuclide	MCi
^{137}Cs	0.0131
^{90}Sr	0.0108
^{99}Tc	0.0009
Transuranics	0.0007

Table C-3. Estimated Unplanned Releases to the Soil Column (December 31, 1999, Decay Date).

Radionuclide	MCi
^{90}Sr	0.0
^{99}Tc	0.00014
^{129}I	0.0000004
^{137}Cs	0.290 to 1.090
Transuranics	0.0

Table C-5. Tank Inventory (December 31, 1999, Decay Date).

Radionuclide	Tank waste inventory, MCi		
	Soluble	Insoluble	Total
^{90}Sr	1.89	52.2	54.1
^{137}Cs	31.4	3.01	34.4
TRU	0.00961	0.121	0.131
^{99}Tc	0.0228	0.00930	0.0321
Total	33.3	55.3	88.6
Tank total including daughters (^{137}Ba, ^{90}Y)	65.0	110.0	175.6

Current Reclassification Basis of ILAW*

- Current approach for Immobilized Low-Activity Waste (that allows the High-Level Waste to be disposed in near surface facilities, rather than a deep geologic repository licensed by NRC) comes from a series of technical letters between USDOE and the NRC in the 1980's and 1990's.
- In 1993, NRC spelled out three criteria in a letter to USDOE:
  1. Tank wastes have been processed (or be further processed) to remove key radionuclides to maximum extent technically and economically practical.
  2. Wastes will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C [low-level waste] as set out in 10 CFR Part 61.
  3. Wastes are to be managed so that safety requirements comparable to the performance objectives set out in 10 CFR Part 61 Subpart C are satisfied.

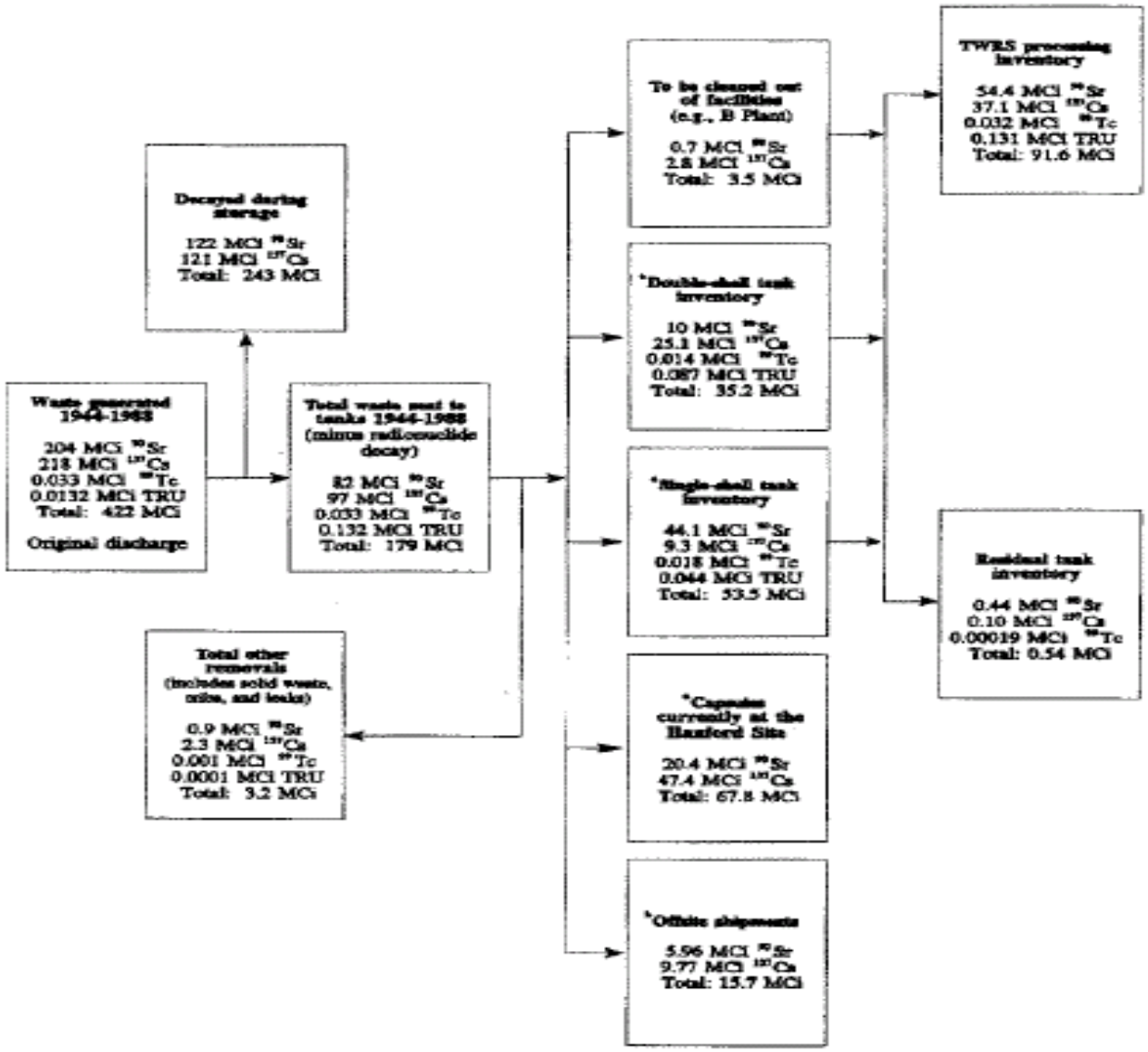
***slide 10,"Tank Waste Final Waste Form Perspective", Suzanne Dahl, WA dept of ECOLOGY, Jan 13, 2010**

Table 6.2-2. Simplified Hanford Site Underground Tank Cesium-137 and Strontium-90 Material Balance.

Material balance component	MCi[a]	
	^{137}Cs	^{90}Sr
Generated in Hanford Site reactors	119.1	101.3
In fuel not reprocessed at the Hanford Site[b]	14.5	11.2
In fuel input to Hanford reprocessing plants	104.6	90.1
Output to capsules[d]	56.7	22.3
Output to other DOE facilities[d]	2.5	3.9 to 4.6
Output to solid waste disposal[d]	0.47	0.47
Output to facility contamination[d]	2.7 to 3.7	0.9
Output in releases to soil[c]	1.8	0.44
Total tank inventory remaining[f]	39.4 to 40.4	61.4 to 62.1
Inventory in double-shell tanks[e]	25.4	11.4
Inventory in single-shell tanks[f]	14.0 to 15.0	50.0 to 50.7

[a]As of January 1, 2000

Figure 3-1. Estimated Hanford Site Tank Waste Radionuclide Inventory.[c,d]



[a]Curie values are based on the Integrated Data Base Report-1994, Rev. 11, Table 2.11 decayed to December 31, 1999.