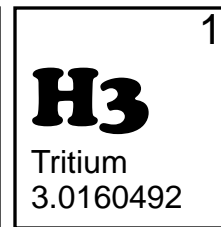
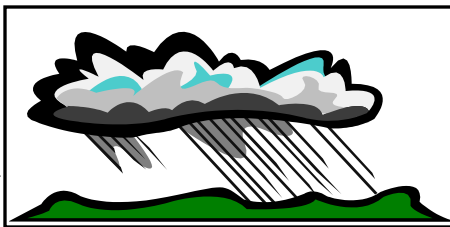
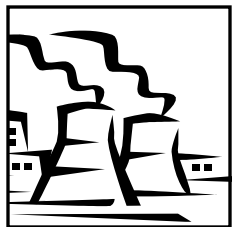


Radioactivity in Precipitation: Methods & Observations from Savannah River Site

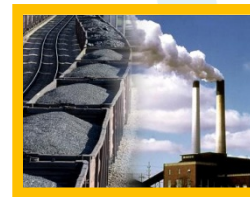
Dennis G. Jackson P.E. & Timothy Jannik – Savannah River National Laboratory
Miranda LaBone – Clemson University
Rebecca Scheffler – University of South Carolina



National Atmospheric Deposition Program

2011 Annual Meeting and Scientific Symposium
Providence, Rhode Island October 24 - 28, 2011

Significant Sources of Radionuclides to Atmosphere:

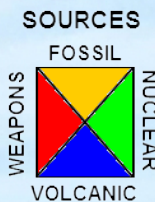


hydrogen 1 H 1.0079																	helium 2 He 4.0026						
lithium 3 Li 6.941	beryllium 4 Be 9.0122	Anthropogenic																boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305																	aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80						
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29						
caesium 55 Cs 132.91	barium 56 Ba 137.33	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]						
francium 87 Fr [223]	radium 88 Ra [226]	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnium 110 Uun [271]	ununium 111 Uuu [272]	ununium 112 Uub [277]												

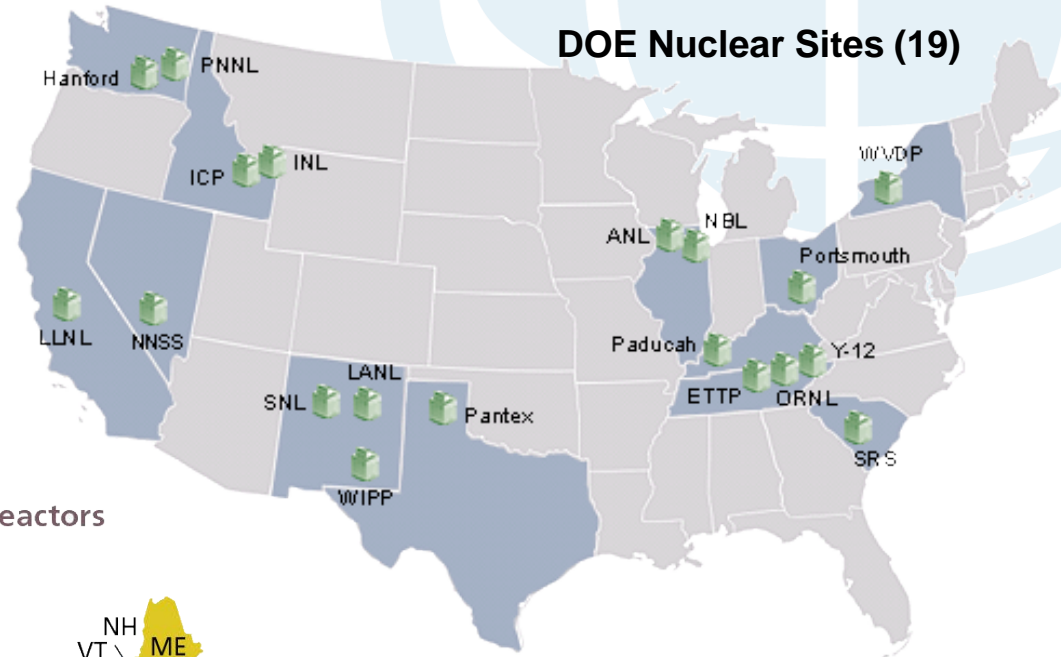
* Lanthanide series

** Actinide series

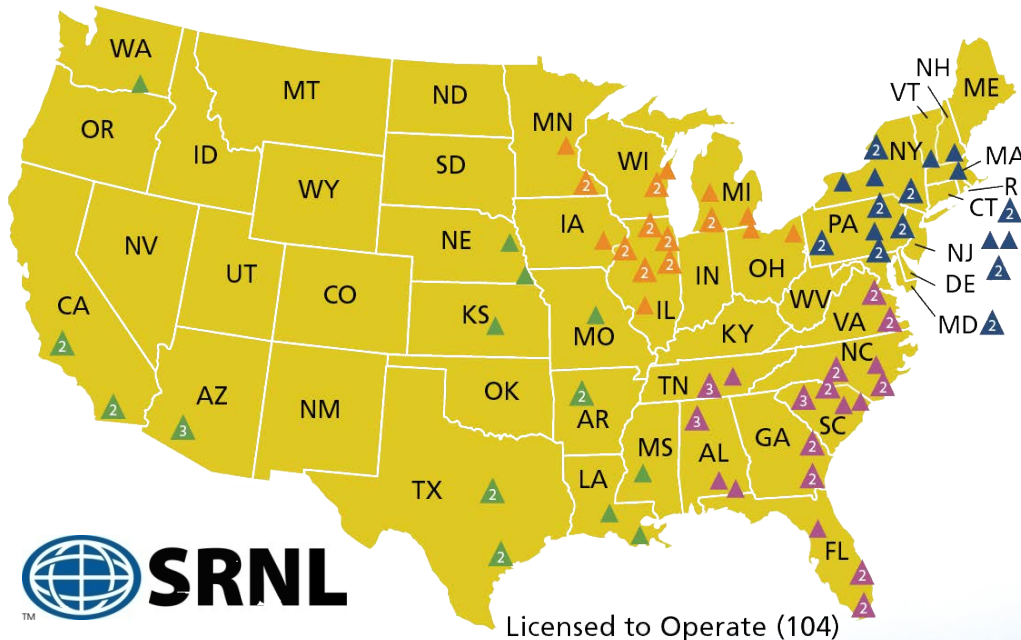
lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th [232]	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]



Major Atmospheric Sources in the United States:



U.S. Operating Commercial Nuclear Power Reactors



Licensed to Operate (104)

Annual Reporting



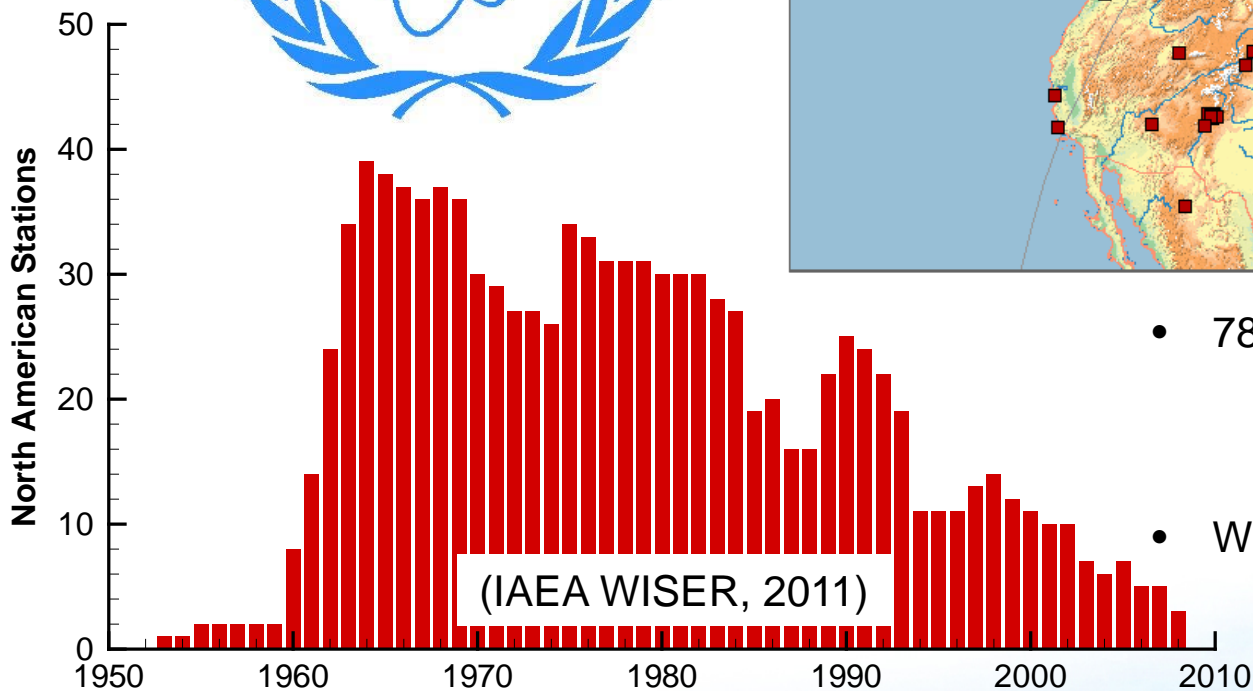
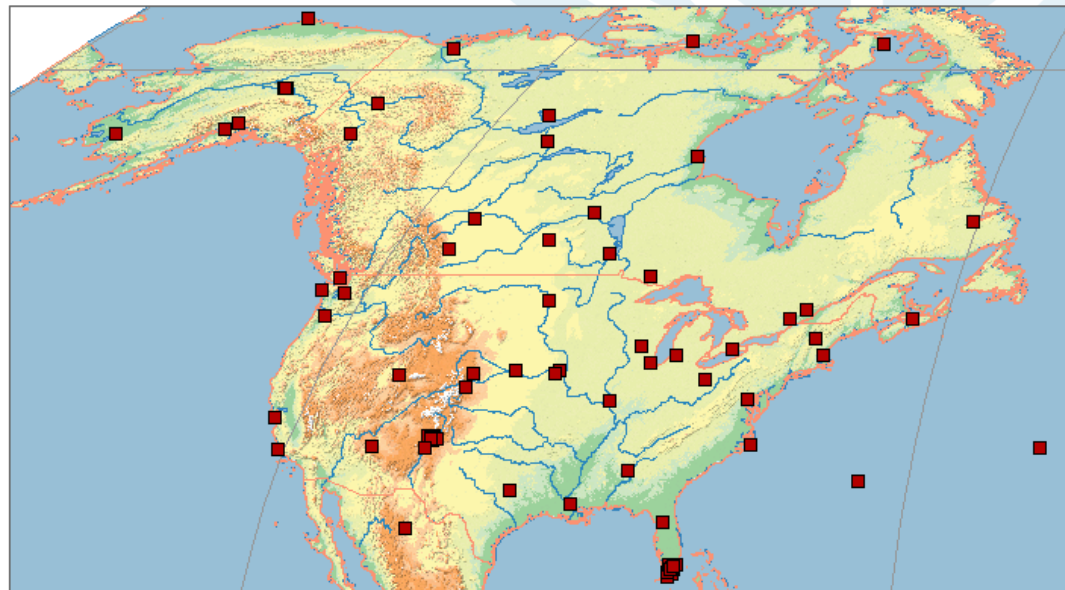
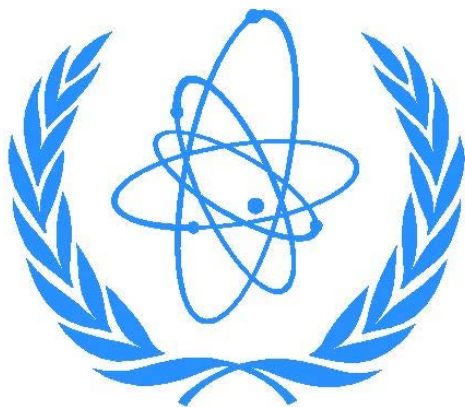
2007 Point Source Emissions:

- DOE: 39,542 Ci (25,088 Ci as H³)
- Nuclear: 10,746 Ci (6,419 Ci as H³)
- Fossil: 4,180 Ci (*Estimated*)

(Sources: Vazquez, 2009 & NRC, 2007)

Monitoring Radionuclides: IAEA-GNIP

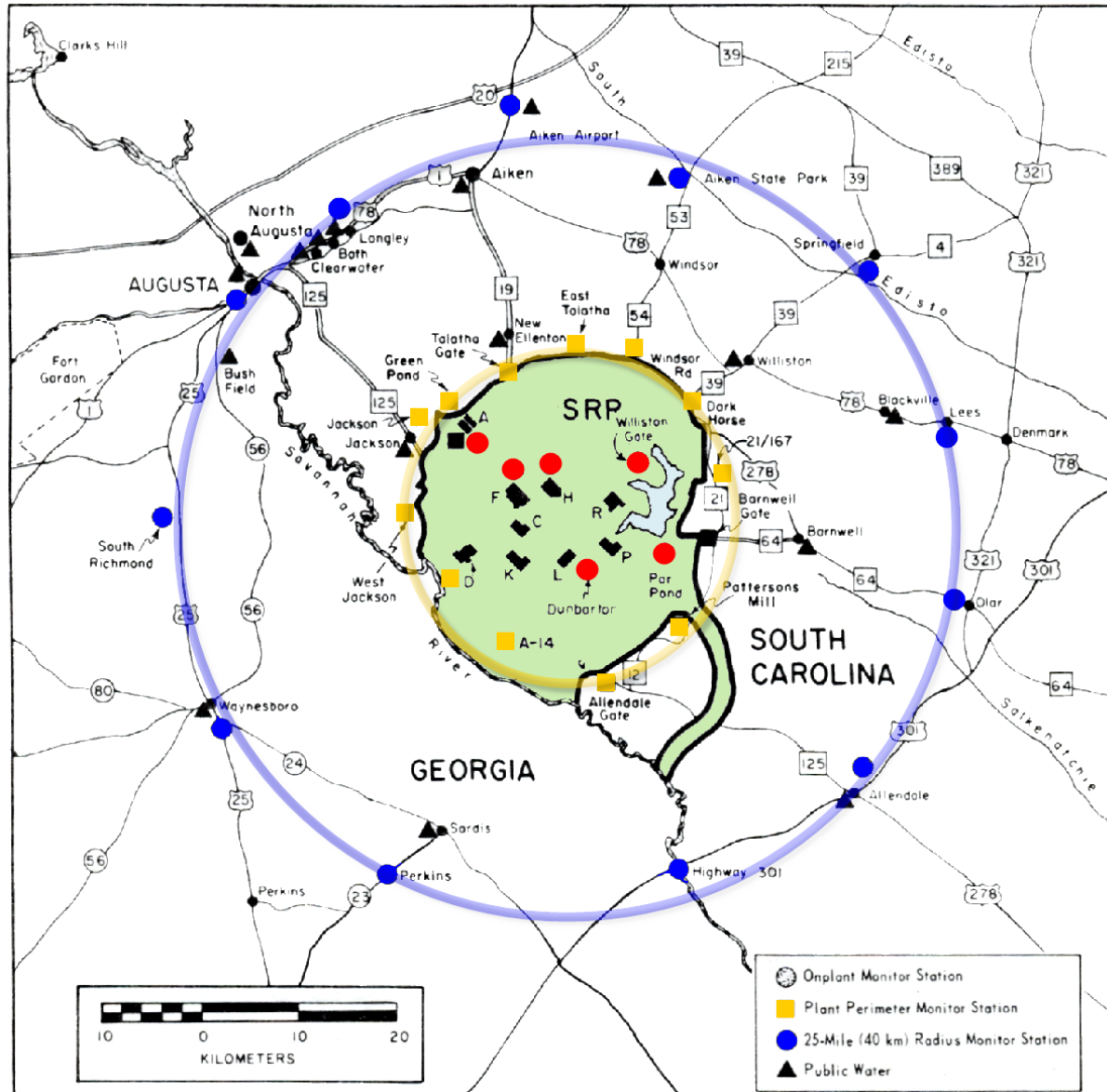
International Atomic Energy Agency (IAEA) Global Network for Isotopes in Precipitation (GNIP)



- 78 Stations in North America
 $\delta^{18}\text{O}$, H_2 , H_3

- Welker (2000) & Vachon (2007)
NTN 1989, 1991-1995

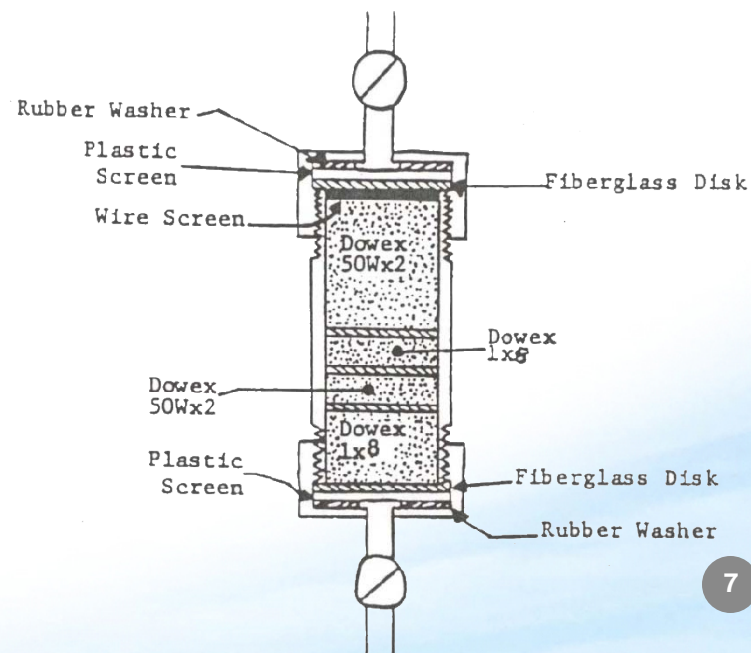
Savannah River Site Precipitation Monitoring Network:



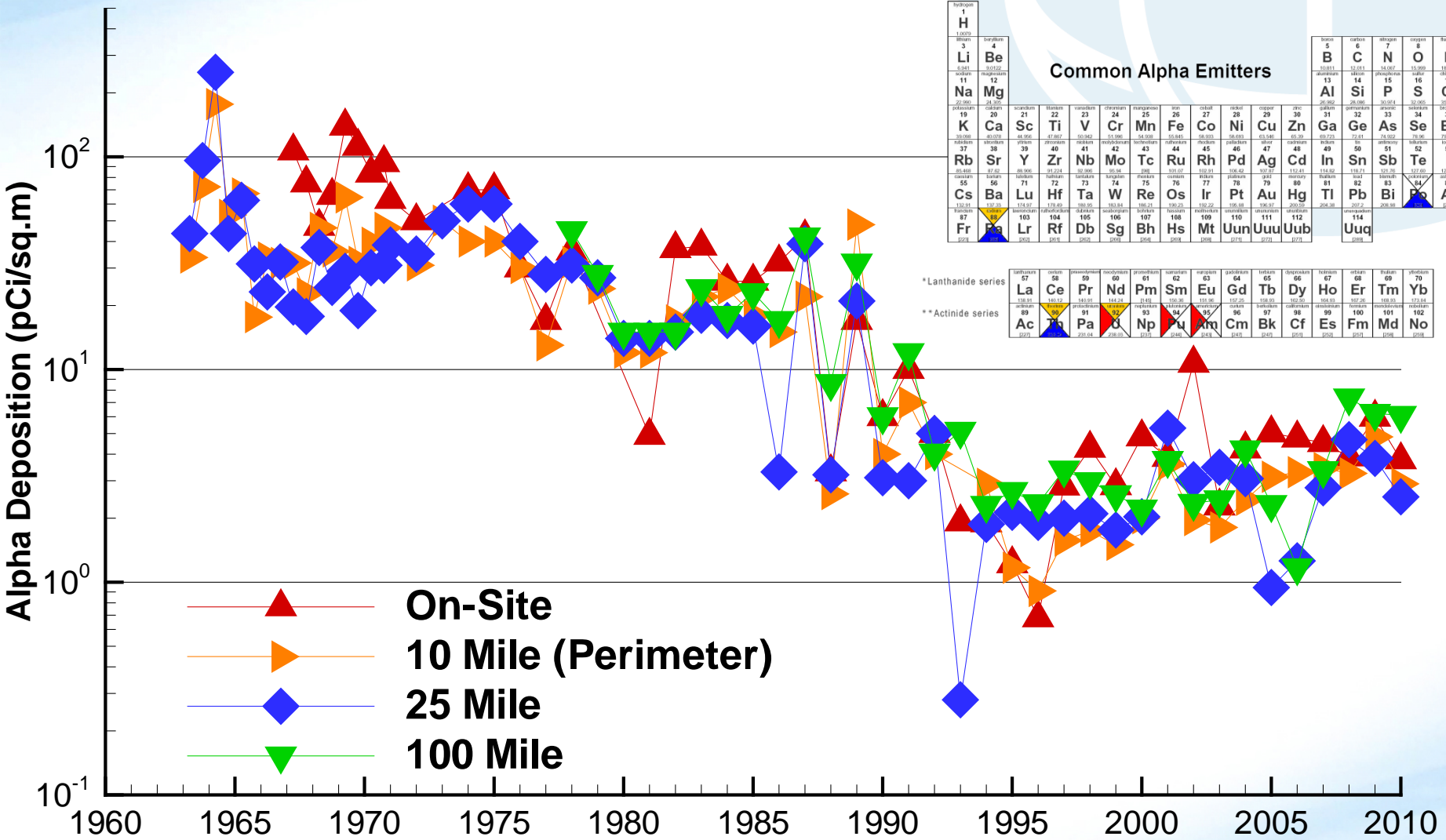
SRS Precipitation Sampling Equipment & Analysis:



Detail of Ion Exchange Column



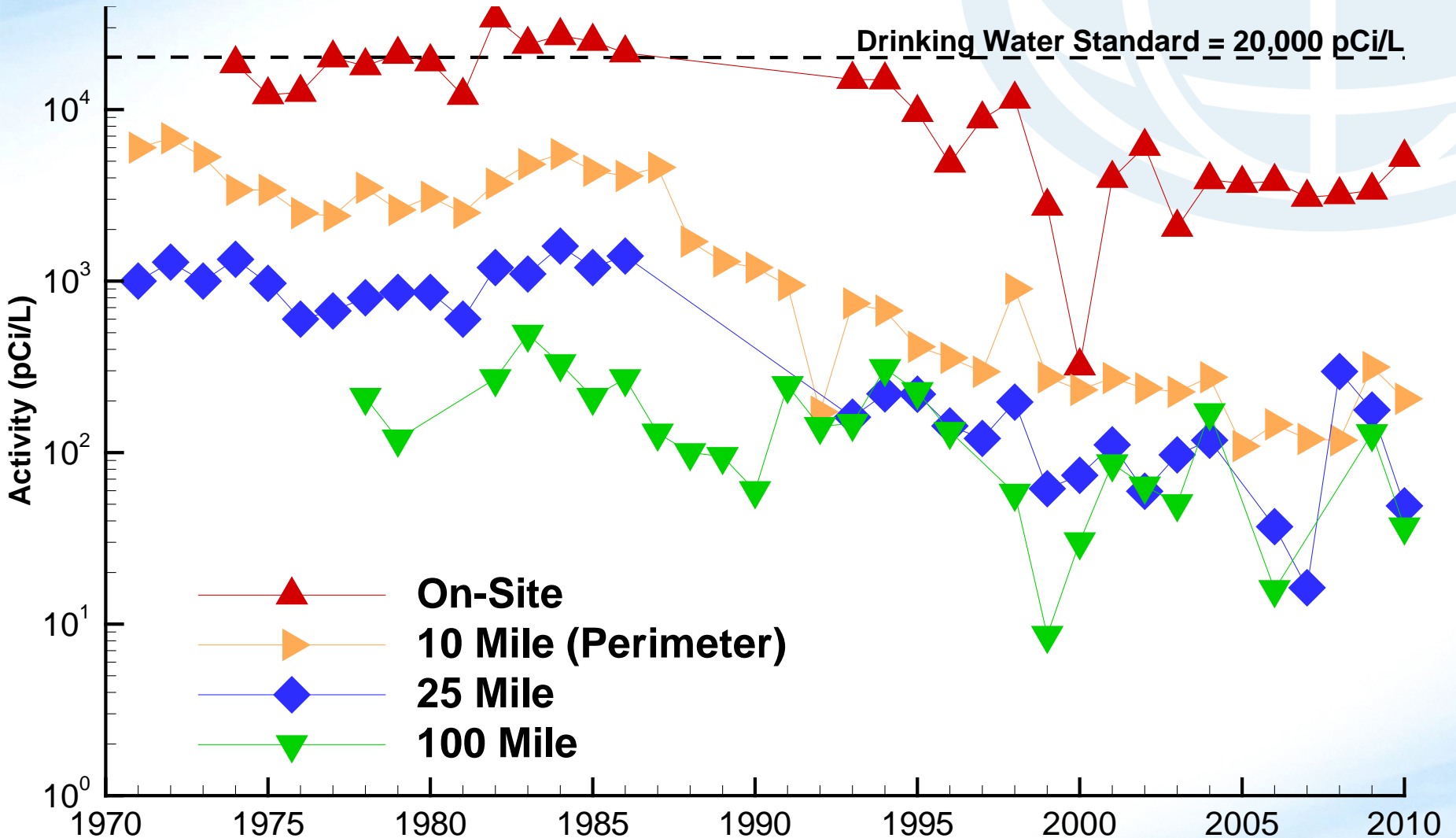
Average Alpha Deposition from Rainwater:



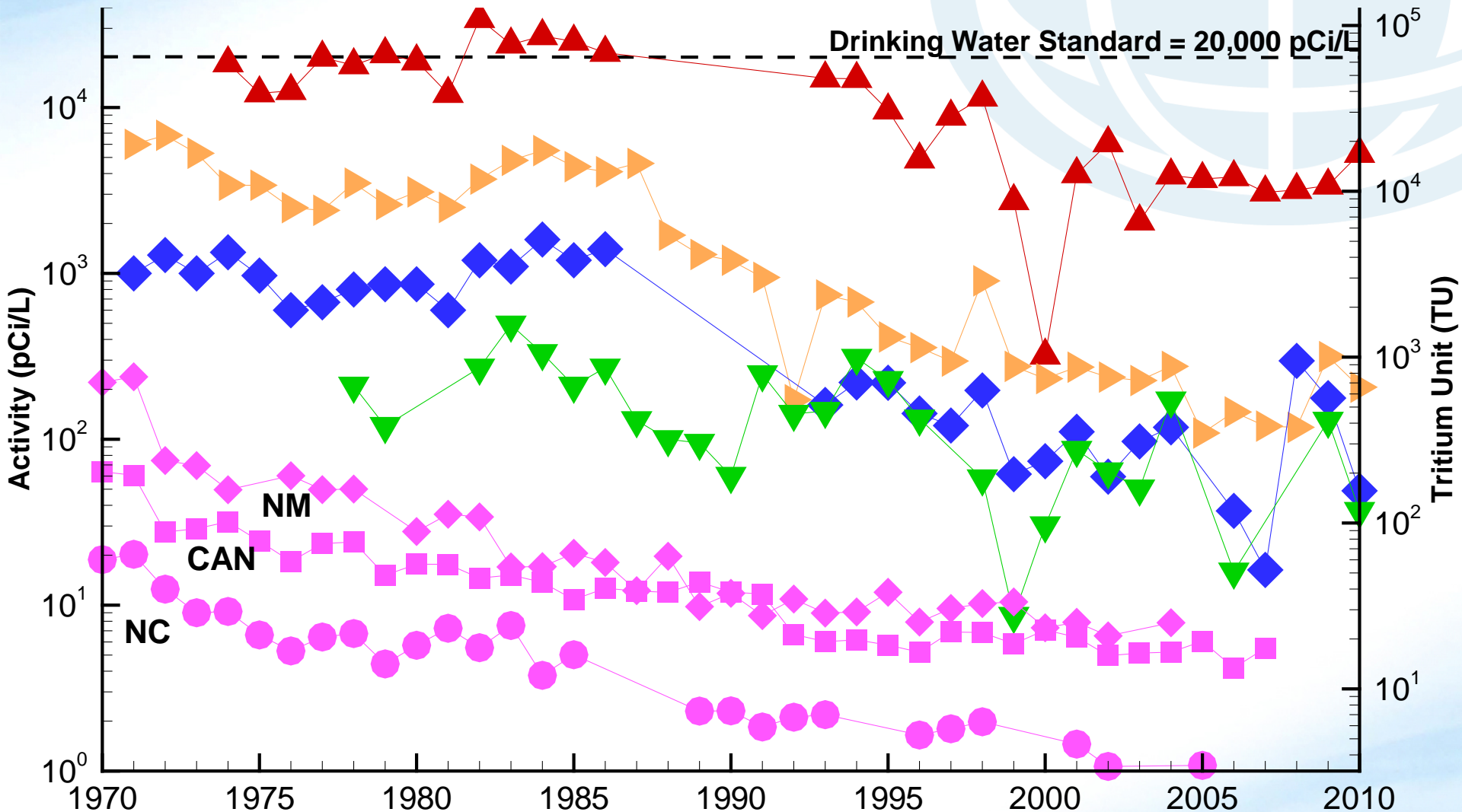
Common Alpha Emitters

Hydrogen 1 H 1.0079																	Helium 2 He 4.0026						
Lithium 3 Li 6.941	Boron 5 B 10.811	Carbon 6 C 12.011	Nitrogen 7 N 14.007	Oxygen 8 O 15.999	Fluorine 9 F 18.998	Neon 10 Ne 20.180																	
Sodium 11 Na 22.990	Magnesium 12 Mg 24.305																	Aluminum 13 Al 26.982	Silicon 14 Si 28.086	Phosphorus 15 P 30.974	Sulfur 16 S 32.06	Chlorine 17 Cl 35.453	Argon 18 Ar 39.948
Potassium 19 K 39.098	Calcium 20 Ca 40.078	Scandium 21 Sc 44.956	Titanium 22 Ti 47.88	Vanadium 23 V 50.942	Chromium 24 Cr 51.996	Manganese 25 Mn 54.938	Iron 26 Fe 55.845	Cobalt 27 Co 58.933	Nickel 28 Ni 58.69	Copper 29 Cu 63.546	Zinc 30 Zn 65.38	Gallium 31 Ga 69.723	Germanium 32 Ge 72.63	Arsenic 33 As 74.922	Selenium 34 Se 78.96	Bromine 35 Br 79.904	Krypton 36 Kr 83.8						
Rubidium 37 Rb 85.468	Sr 38 Sr 87.62	Yttrium 39 Y 88.906	Zirconium 40 Zr 91.224	Niobium 41 Nb 92.906	Molybdenum 42 Mo 95.94	Technetium 43 Tc 98	Ruthenium 44 Ru 101.07	Rhodium 45 Rh 102.91	Palladium 46 Pd 106.42	Silver 47 Ag 107.87	Cadmium 48 Cd 112.41	Indium 49 In 114.82	Sn 50 Sn 118.71	Sb 51 Sb 121.76	Te 52 Te 127.6	Iodine 53 I 126.905	Xenon 54 Xe 131.29						
Cesium 55 Cs 132.91	Barium 56 Ba 137.33	Lanthanide series	Lanthanum 57 La 138.905	Cerium 58 Ce 140.12	Praseodymium 59 Pr 140.908	Nd 60 Nd 144.24	Pm 61 Pm 144.913	Sm 62 Sm 150.36	Eu 63 Eu 151.96	Gd 64 Gd 157.25	Tb 65 Tb 158.925	Dy 66 Dy 162.50	Ho 67 Ho 164.93	Er 68 Er 167.26	Tm 69 Tm 168.93	Yb 70 Yb 173.054	Actinide series						
Francium 87 Fr 223	Radium 88 Ra 226	Actinium 89 Ac 227	Th 90 Th 232.038	Pa 91 Pa 231.036	U 92 U 238.029	Np 93 Np 237.048	Pu 94 Pu 244.064	Am 95 Am 243.061	Cm 96 Cm 247.07	Bk 97 Bk 247.07	Cf 98 Cf 251.08	Es 99 Es 252.083	Fm 100 Fm 257.10	Md 101 Md 258.10	No 102 No 259.10	Uuq 114 Uuq 288							

Average Tritium Activity in Rainwater - SRS



Average Tritium Activity in Rainwater – SRS & IAEA



Conclusions & Observations:

- **Gross Alpha Deposition:**

- SRS Contributions Are Indistinguishable from Surroundings,

- **Tritium Activity in Precipitation:**

- Activity Decreases as Distance from SRS Increases,
- Observations in Vicinity of SRS are Greater Than IAEA Observations,
- SRS & IAEA Indicate Overall Decrease in Tritium over 40 years.

- **What are Contributions from Nuclear Power Facilities?**

- **A Basis for Larger, Independent Monitoring Network?**

Additional Information & Resources:

SRS Environmental Reports:

<http://www.srs.gov/general/pubs/ERsum/index.html>

IAEA Water Isotope System for Data Analysis, Visualization, and Electronic Retrieval (WISER):

http://www-naweb.iaea.org/napc/ih/IHS_resources_isohis.html

US EPA RADMAP:

<http://www.epa.gov/narel/radnet/>

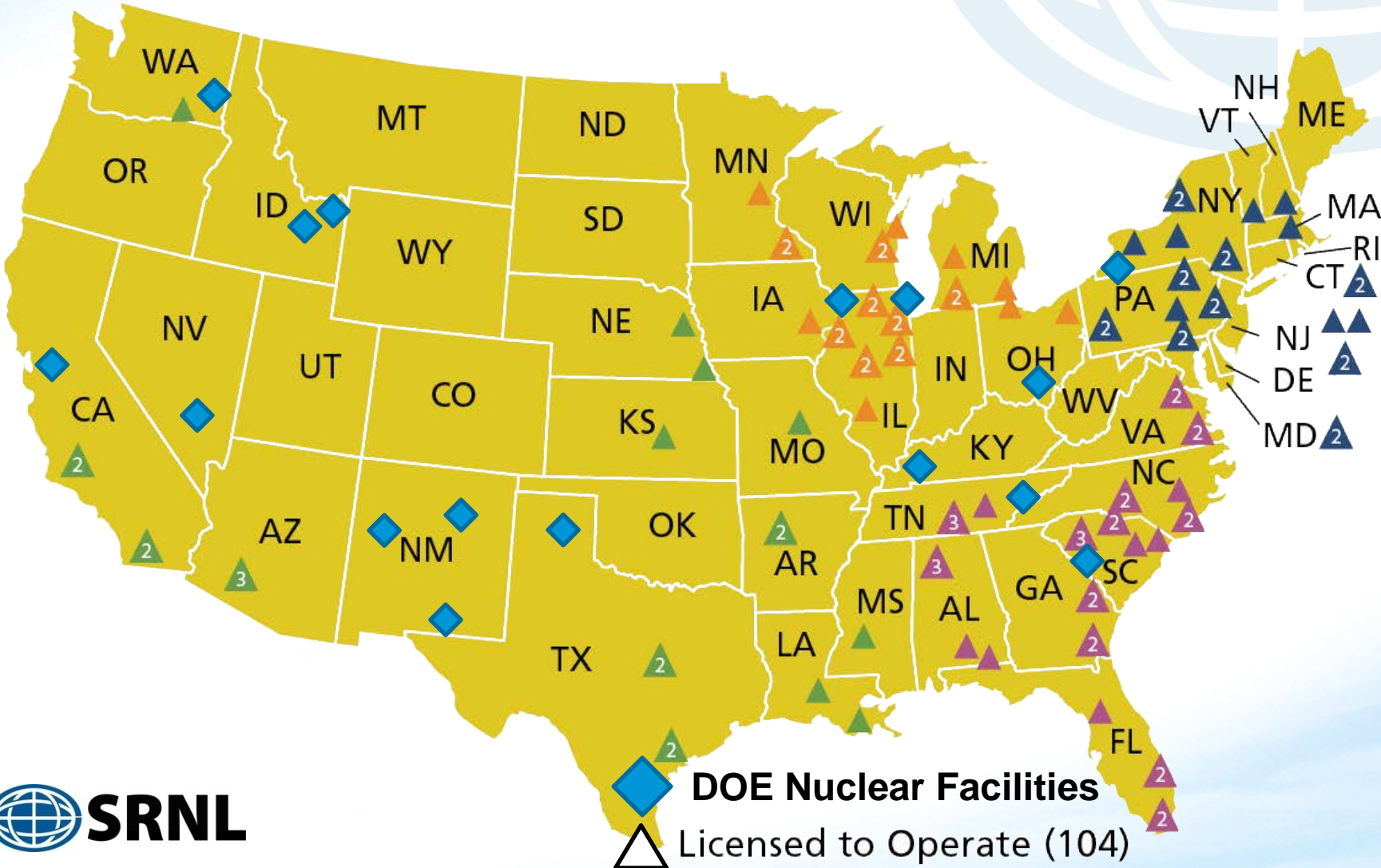
Nuclear Power Effluent and Environmental Reports:

<http://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html>



DOE Nuclear & NRC Licensed Reactors in United States:

U.S. Operating Commercial Nuclear Power Reactors



Potential Collaborators and/or Supporters:

EPRI

ELECTRIC POWER
RESEARCH INSTITUTE

