

Fate of Groundwater Radionuclides Moving Through Small Community Systems

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Radionuclides in Drinking Water
Workshop on Implementing the Radionuclides Rule



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Chelmsford, MA



Acknowledgements

US EPA

NH WTTAC

VT DEC

NH DES

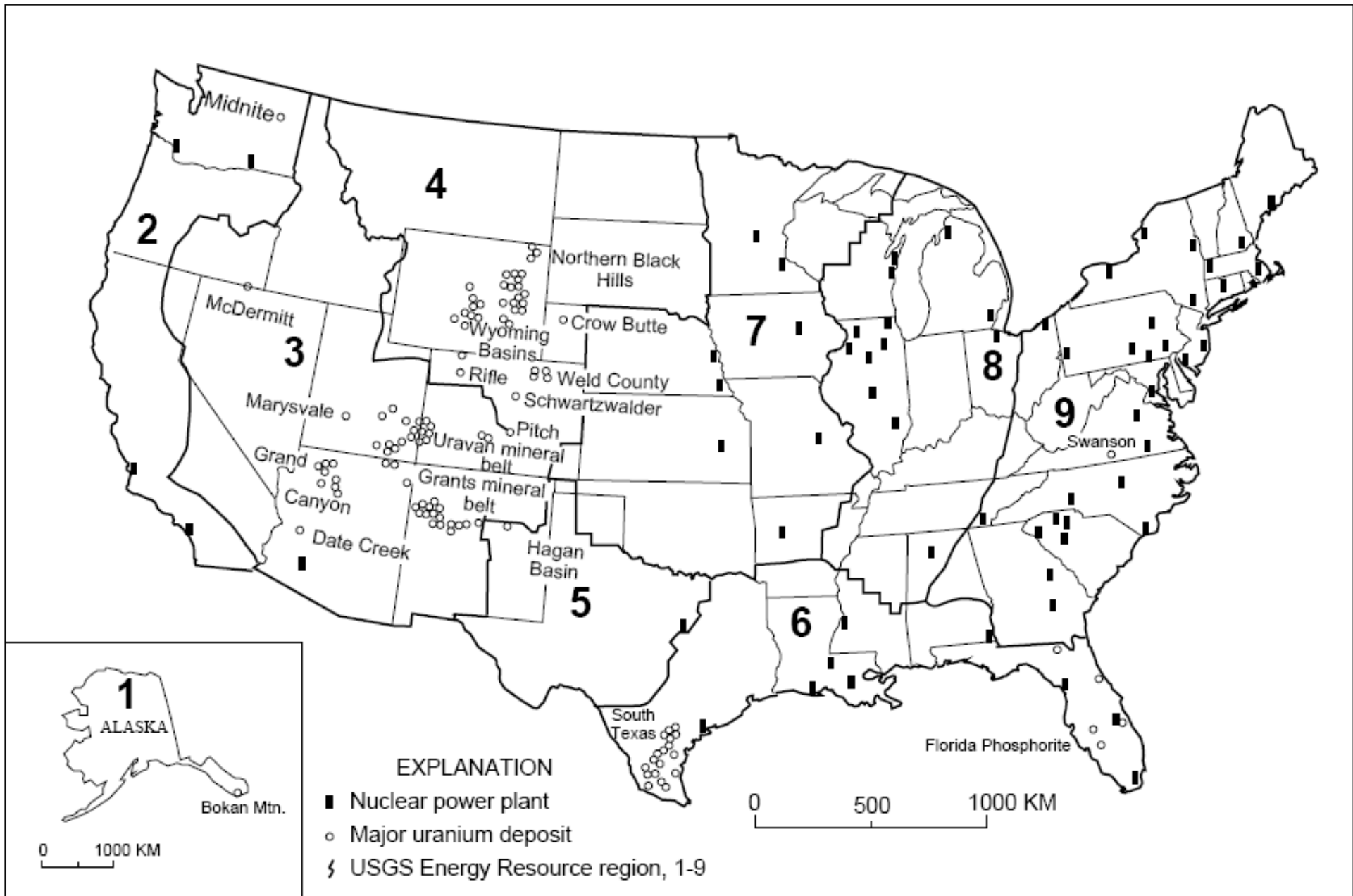
NEIWPCC

and Collaborating Sites

Presentation Available at:

<http://www.unh.edu/erg/wttac/>

or search for NH WTTAC



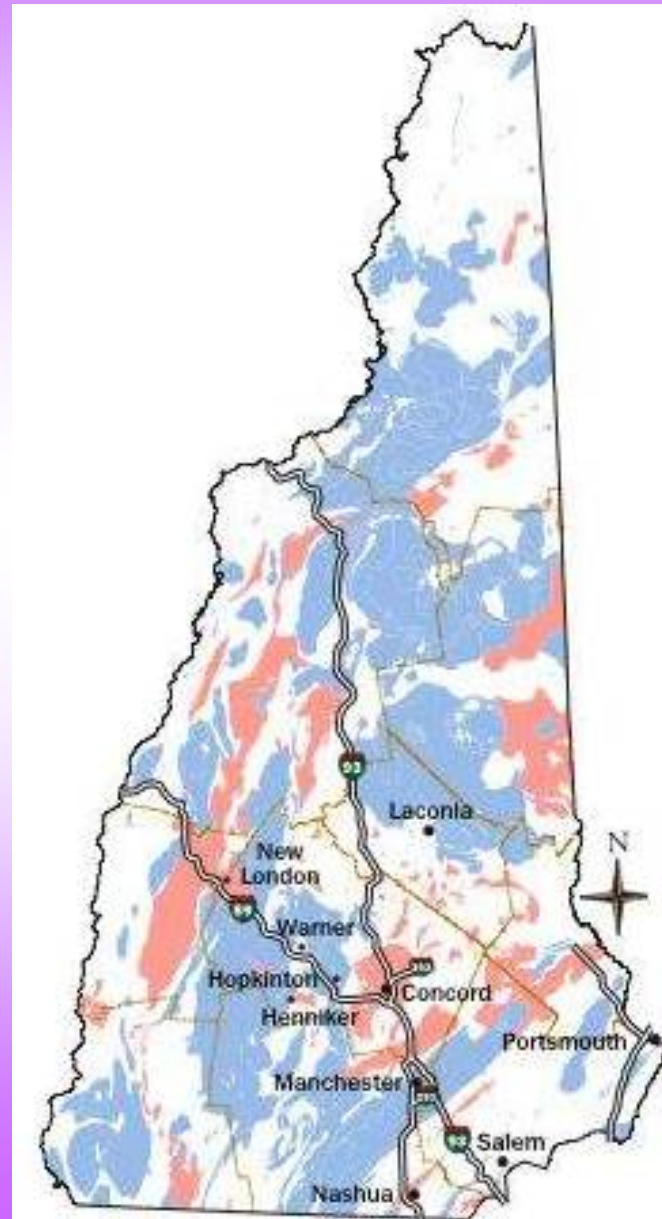
Radioactivity in Rock in New Hampshire



Igneous Rocks



Two-Mica Granite



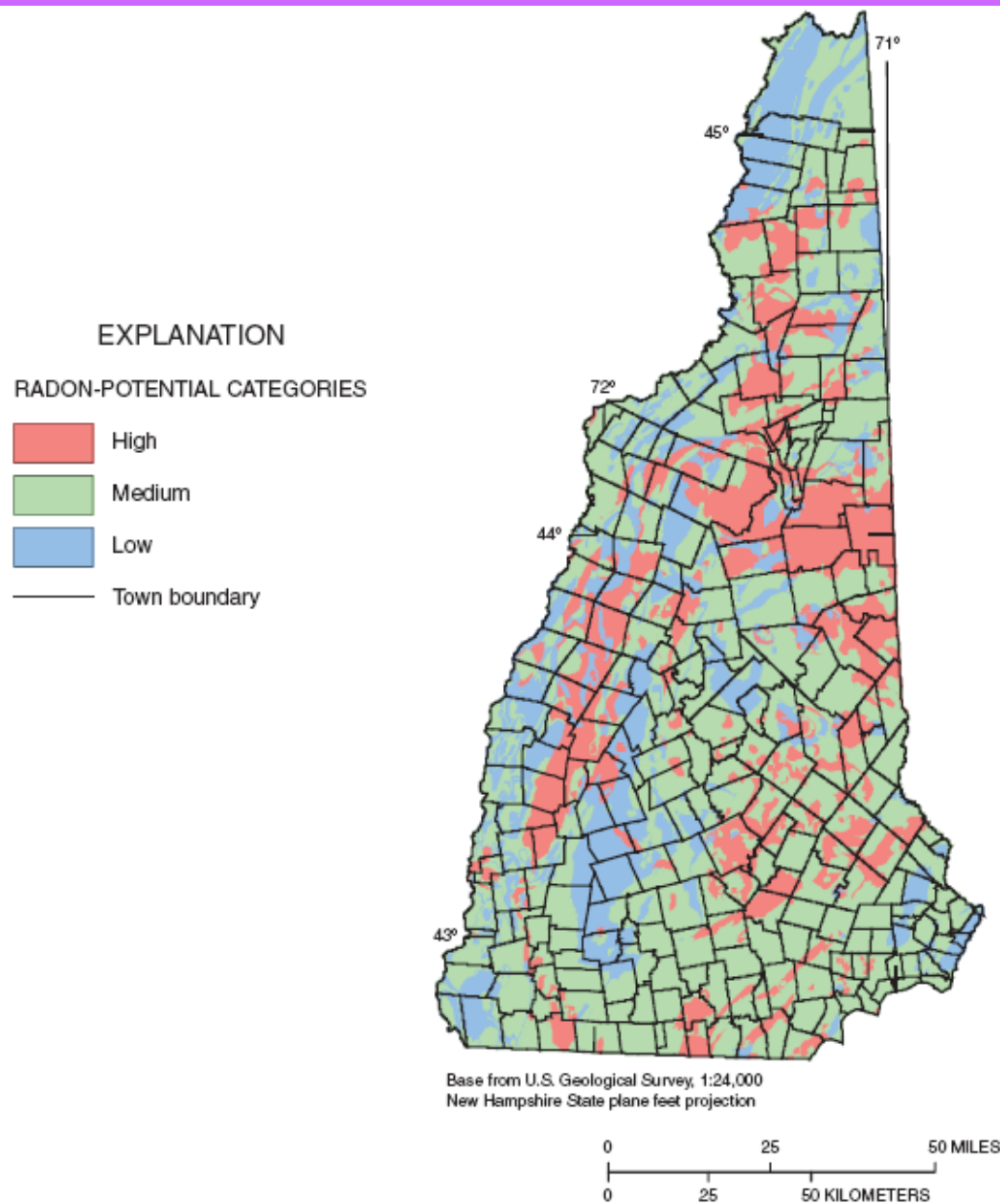
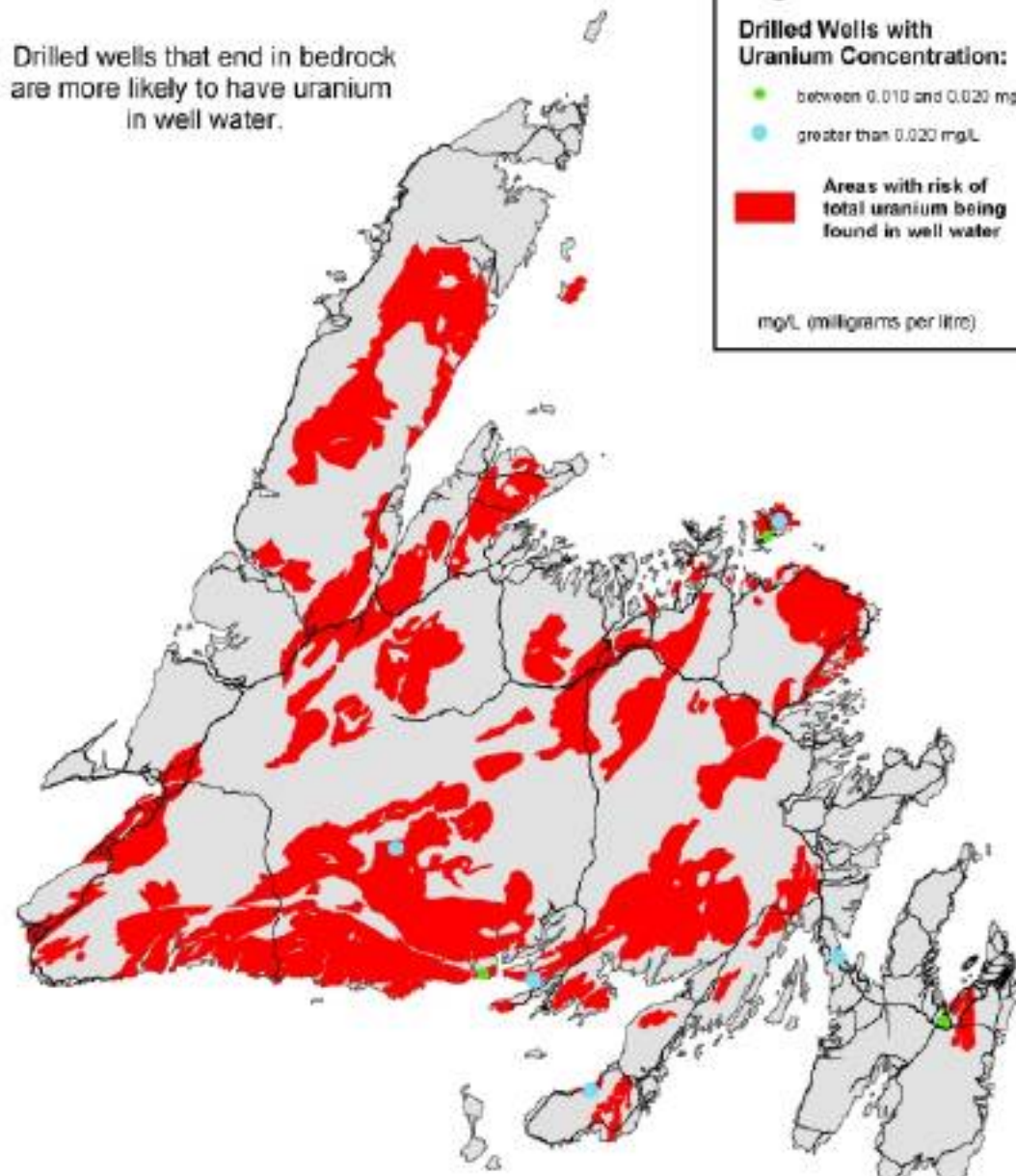


Figure 2. Areal distribution of radon-potential categories in New Hampshire used for statistical analyses. Mapped bedrock units (Lyons and others, 1997) were grouped for relative potential of producing radon gas.

Areas of Potential Uranium Concentration in Well Water

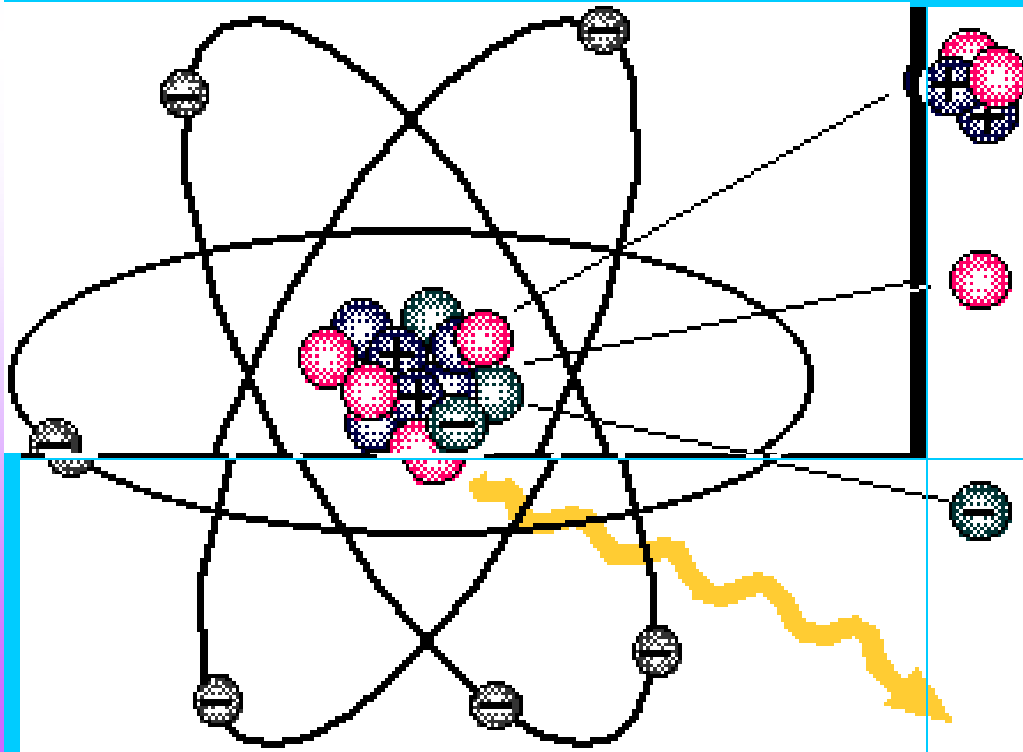
Drilled wells that end in bedrock
are more likely to have uranium
in well water.



Radiation

Radioactive Atom

Ionizing Radiation

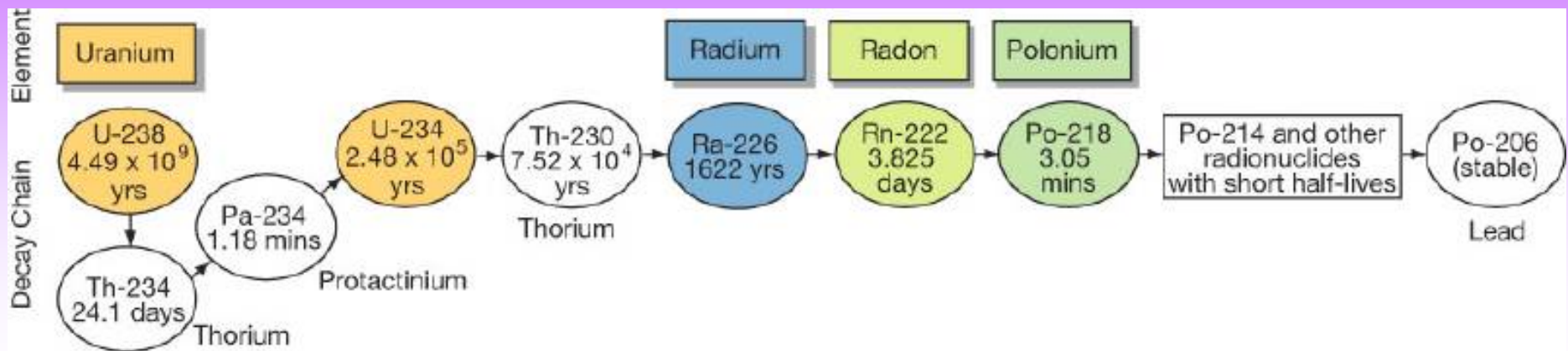


Alpha Particle

Neutron Particle
















Beta Particle

Gamma Ray (X Ray)



The Geology and Progeny of Uranium

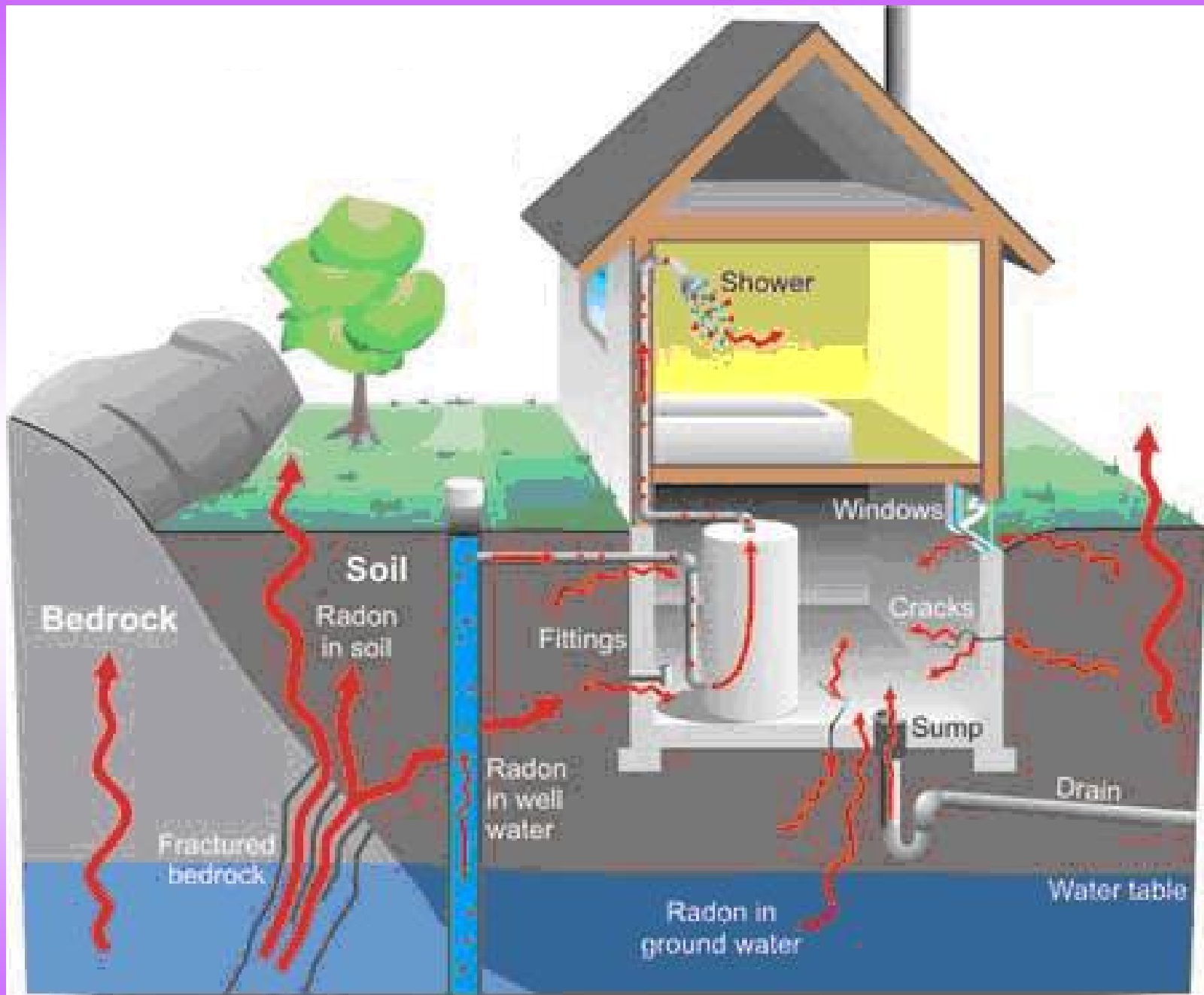
URANIUM 238 (U238) RADIOACTIVE DECAY

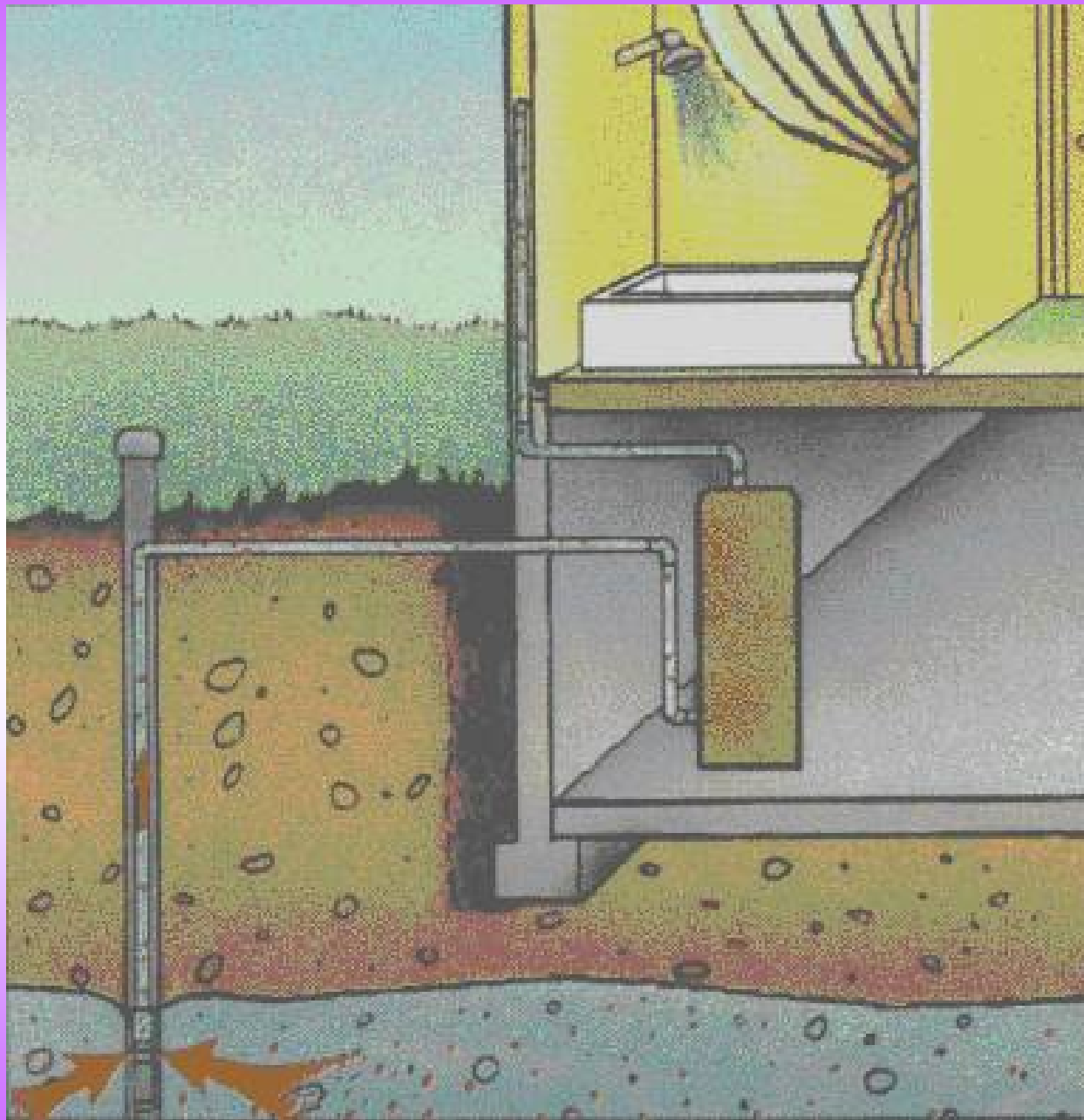
type of radiation	nuclide	half-life
	 uranium-238	4.47 billion years
α	 thorium-234	24.1 days
β	 protactinium-234m	1.17 minutes
β	 uranium-234	245000 years
α	 thorium-230	8000 years
α	 radium-226	1600 years
α	 radon-222	3.823 days
α	 polonium-218	3.05 minutes
α	 lead-214	26.8 minutes
β	 bismuth-214	19.7 minutes
β	 polonium-214	0.000164 seconds
α	 lead-210	22.3 years
β	 bismuth-210	5.01 days
β	 polonium-210	138.4 days
α	 lead-206	stable

GROUND WATER CONTAMINATION IN THE UNITED STATES

Pollutants	Found in No. of States
Nitrates	49
Volatile organic substances	48
Petroleum products	46
Metals	45
Pesticides	43
Brine/salinity	37
Synthetic organic substances	36
Arsenic	28
Other substances	26
Other agricultural chemicals	23
Radioactive material	23
Fluoride	20
Other inorganic substances	15

UN FAO, Control of Water Pollution from Agriculture",
www.fao.org/docrep/W2598E/w2598e00.htm (US EPA, 1994)





Technical Advisory Committee (TAC)

- NEIWPC
- NH DES
- VT DEC
- CT DEP
- ME DEP
- NH WTTAC

TAC Objectives

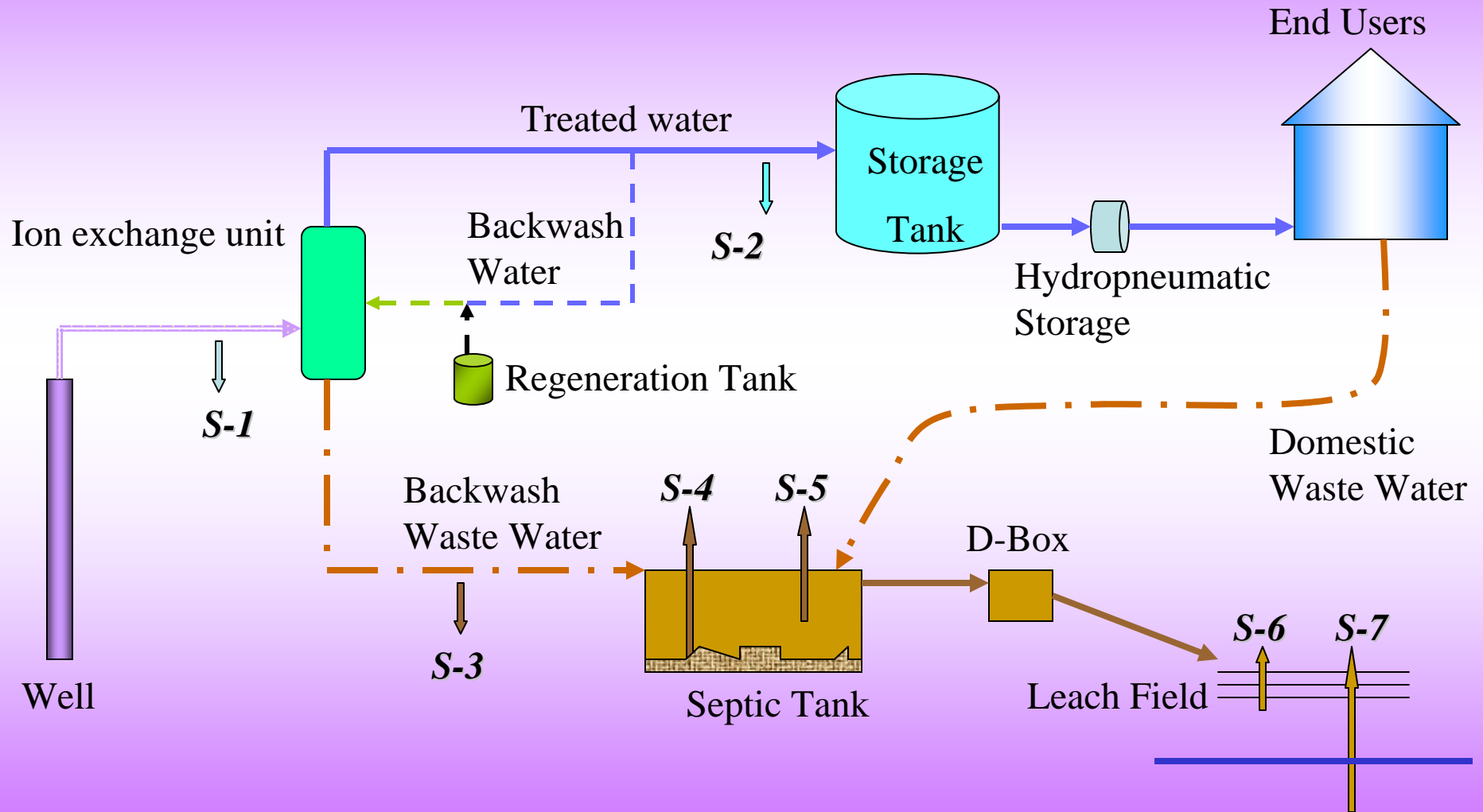
- Define the problem
- Number of systems currently affected
- Site specific characteristics
- Number of systems to be affected following implementation of the Radionuclides Rule
- Review QAPP

Site	RI - South Kingstown	CT - Morris	CT - Brookfield	VT - Colchester
Community or Private	COM	COM	COM	Private Home
System Population	175	40	132	1
Description	nursing home	elderly housing		adult

Site	NH - Fitzwilliams	NH - Canaan	NH - Pelham	NH - Pelham	NH - Pelham
Community or Private	COM	NTNC	NTNC	Private Home	COM
System Population	45	530	100 employees	3	24
Description	18 units	high school	shopping mall	2 adults/1 infant	22 elderly housing

Radionuclide Fate and Transport Study

Generic Monitoring Locations



Liquid Samples

1. Bedrock Groundwater
2. Treatment Unit Backwash
3. Finished Water
4. Household Wastewater Stream
5. Septic Tank Sludge/Scum/Liquid – Time since pumping/backwash
6. Septic Tank Effluent - Time since pumping/backwash
7. Vadose Zone Soil Moisture
8. Shallow Groundwater – Up- and Downgradient

Solid Samples

1. Bedrock
2. Native Soil
3. Leach Field Soil
4. Soil – In plume

Target Analytes - Liquids

Analyte
Gross Alpha
Gross Alpha less Radon and Uranium
Gross Beta
Radium - 226
Radium - 228
Uranium – assuming the activity of natural Uranium is 6.77×10^{-7} Ci/gm
Uranium as U ³⁰⁸

Target Analytes - Solids

Analyte
Gross Alpha
Gross Beta
Radium - 226
Radium - 228
Uranium as U ³⁰⁸

Analytical Methods - Liquids

Analyte	Method	Detection Limit
Gross Alpha	EPA 900.0	10 - 2.0
Gross Alpha less Radon and Uranium	EPA 900.0	10 - 2.0
Gross Beta	EPA 900.0	10 - 1.9
Radium - 226	SM 7500 - Ra B	0.1
Radium - 228	EPA Ra - 05	1.0 - 0.5
Uranium - assuming the activity of natural Uranium is 6.77×10^{-7} Ci/gm	ASTM D2907-97	0.5
Uranium as U^{308}	ASTM D2907-97	0.7

Analytical Methods - Solids

Analyte	Method	Detection Limit
Gross Alpha	EPA 900.0 (modified)	7.7 – 0.3
Gross Beta	EPA 900.0 (modified)	4.3 – 0.6
Radium - 226	SM 705 (modified)	0.7 – 0.01
Radium - 228	EPA Ra-05 (modified)	1.3 – 0.8
Uranium as U ³⁰⁸	ASTM D2907-97 (modified)	10 - 4

POU/POE systems shown to remove uranium include reverse osmosis, distillation, special adsorbent media (such as titanium dioxide) and anion exchange.

Residuals

The more effective the coagulant or adsorbent, the higher is the radioactivity in the residuals. (Clifford, 2001)

Ion Exchange Softening for Radium Removal	600 pCi/L spent brine 20 pCi/g dry resin
Coag-Filt w/ $\text{MnO}_2(\text{s})$ for Radium Removal	21,000 pCi/g dry $\text{MnO}_2(\text{s})$
Fe(III) Coag-Filtration for Uranium Removal	800 pCi/g $\text{Fe}(\text{OH})_3(\text{s})$
Anion Exchange for Uranium Removal	80,000 pCi/L spent brine (30,000 BV run length)

Selected Sites

- Morris, CT – Elderly Housing
- Middleton Springs, VT – Elementary School
- Bedford, NH – Residential
- Pelham, NH – Apartment Complex

Site Bedrock

Site	Surficial Geology	Well Depth	Geology at Depth
NH - Pelham Old Lawrence Road	Till (Pleistocene)	Well #2 575 ft Well #3 625 ft	Ayer Granite
NH - Bedford English Woods	Till (Pleistocene)	Well #1 473 ft	Rangeley Formation (Silurian)
NH - Bedford English Woods	Till (Pleistocene)	Well #4 65 ft	Light gray biotite- muscovite Schist
CT - Morris			Ratlum Mountain Schist
CT - Morris			Schist Granofels
VT - Middletown Springs	Till		Biotite/Garnet Types

	Gross Alpha (pCi/L)	Ra 226 + Ra 228 (pCi/L)
Morris, CT	4.5	4.2
Middleton Springs, VT - Short	25	16.6
Middleton Springs, VT - Long	240	68
Pelham, NH	88	14
Bedford, NH	12	10.5
Criteria	15	5

Radionuclides Rule

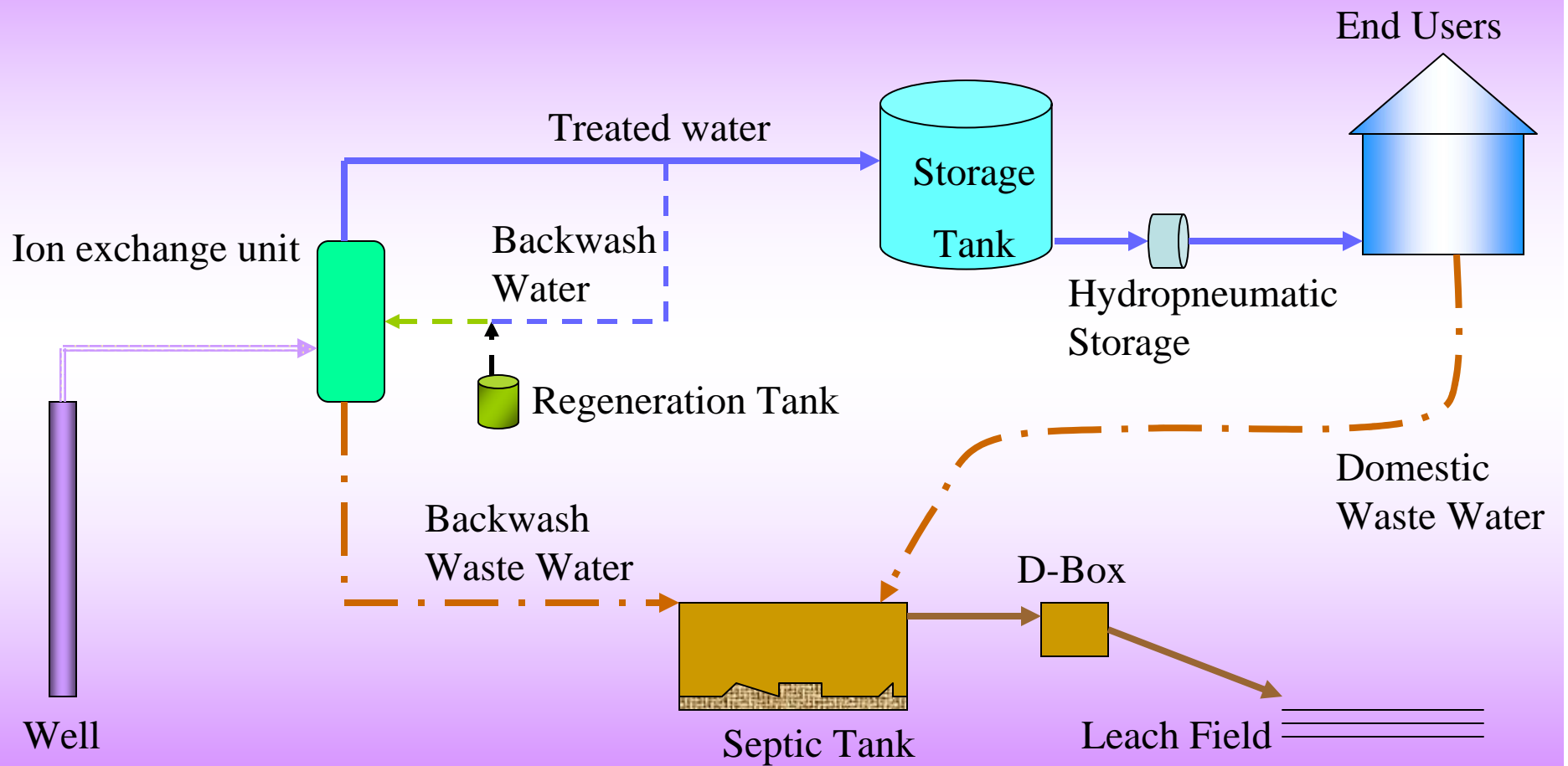
Combined radium 226 and 228	5 pCi/L
Gross alpha particle activity	15 pCi/L
Uranium	30 ug/L
Beta particle activity	4 mrem/yr

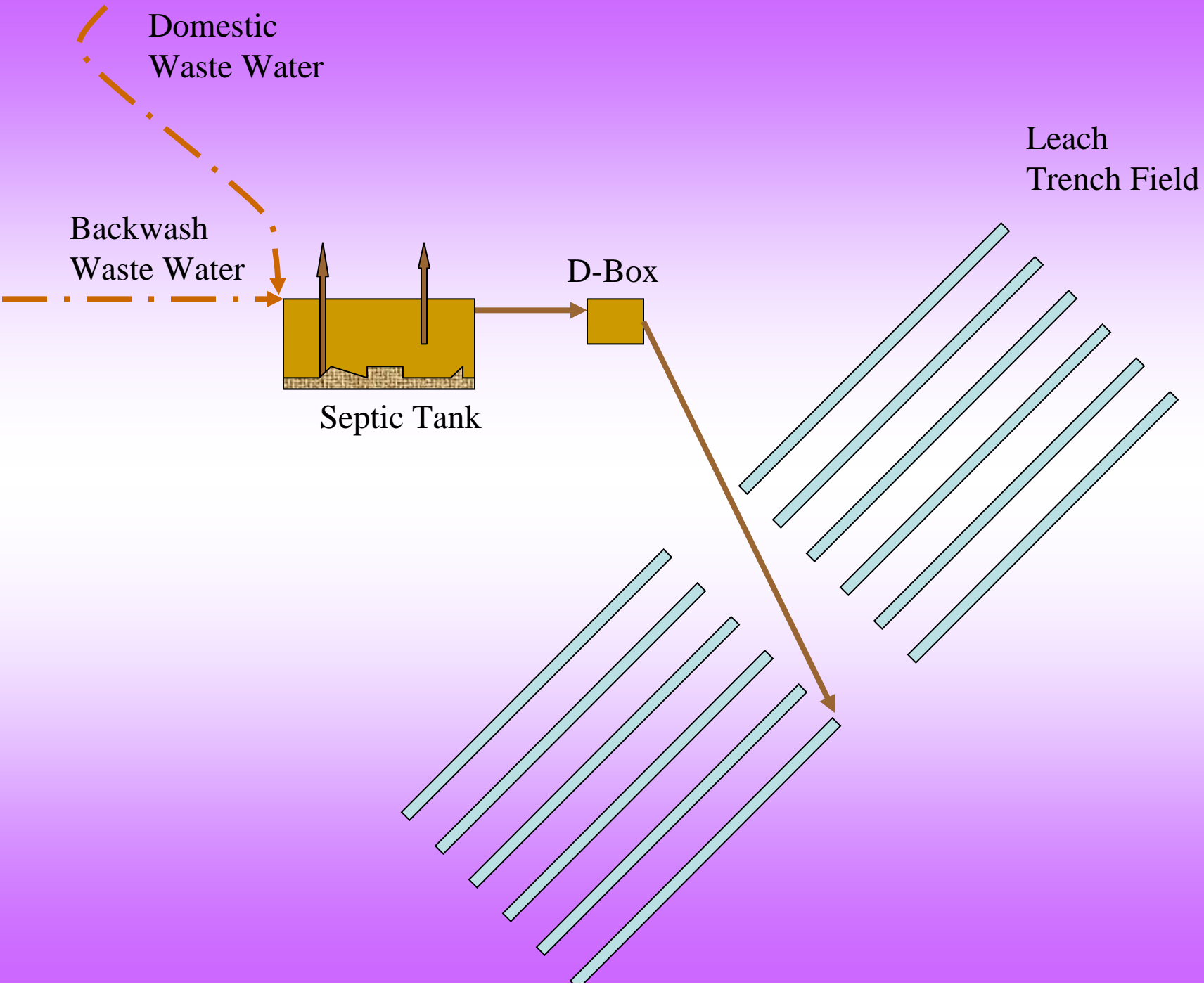
Morris, CT Site

Morris, CT System

Community Building (~100 gpd)

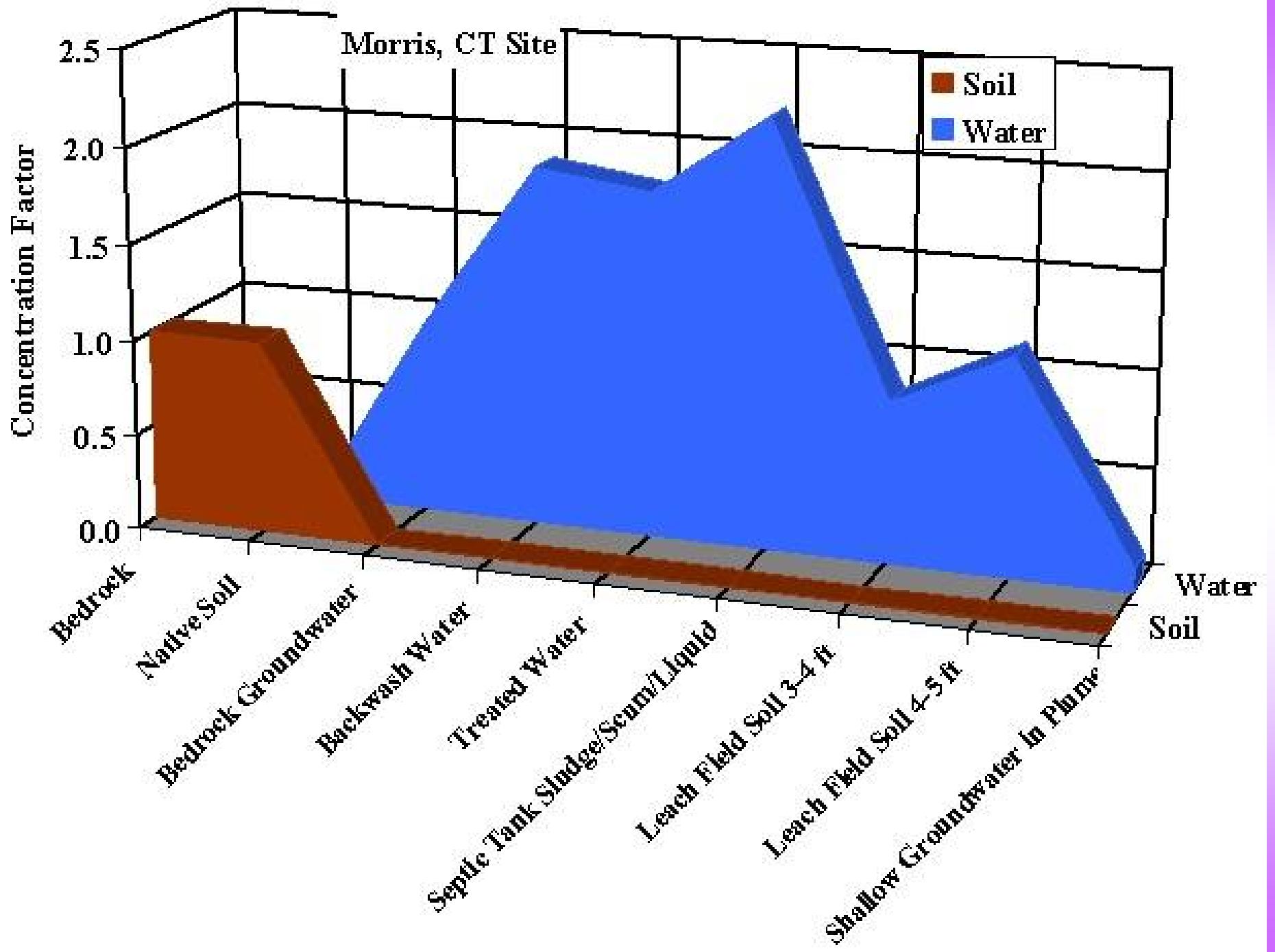
- Bedrock well
- Submersible pump
- Ion exchange
- ~2 - 5,000 gal atmospheric storage tanks
- 200 gal septic tank
- Linear leach trench





Morris, CT Groundwater

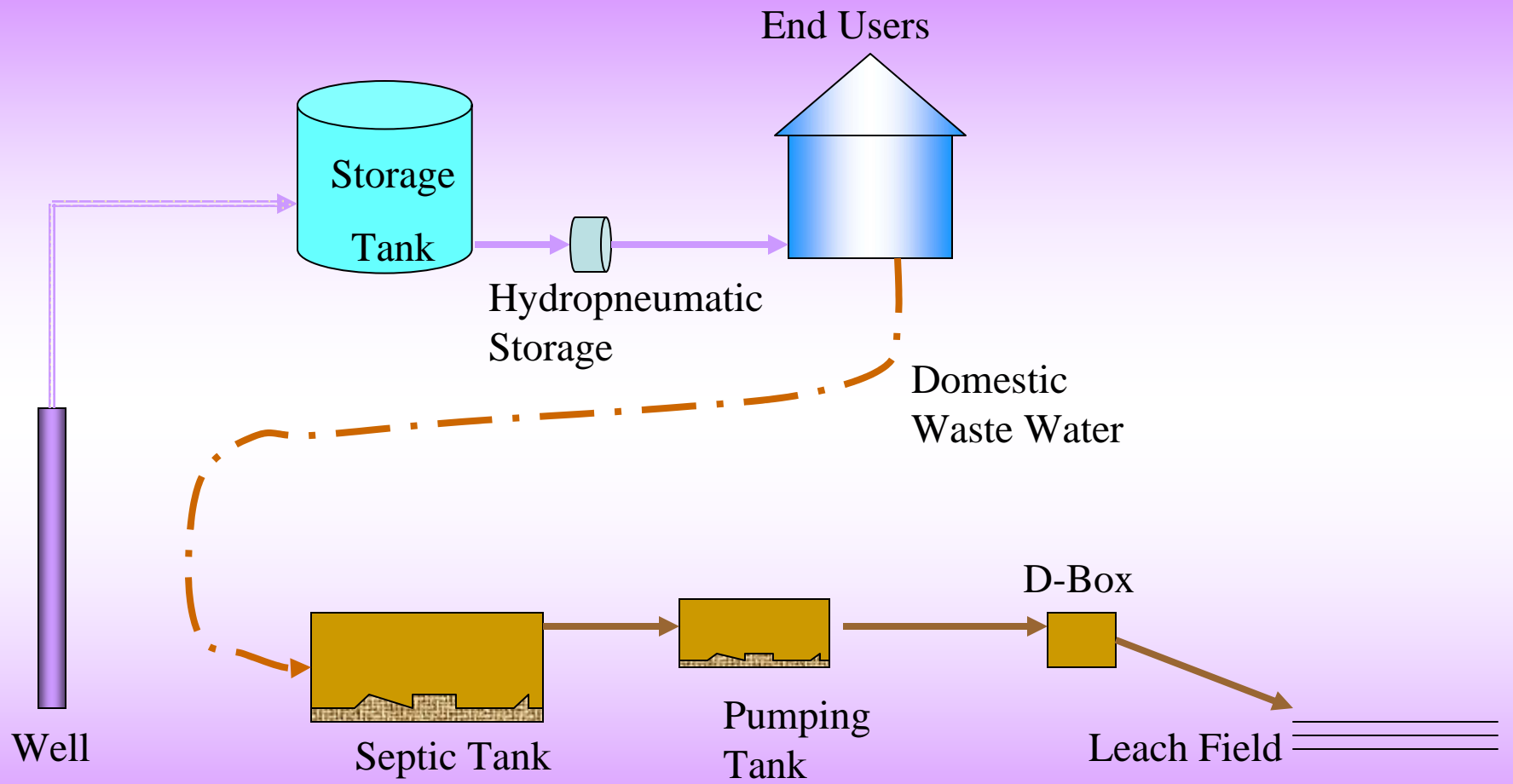
Gross Alpha (pCi/l)	Gross Alpha less Rn & U (pCi/l)	Gross Beta (pCi/l)	Radium 226 (pCi/l)	Radium 228 (pCi/l)	Uranium* (pCi/l)	Uranium (ug/l)
4.5	3.5	4.0	0.7	0.0	1.0	1.4

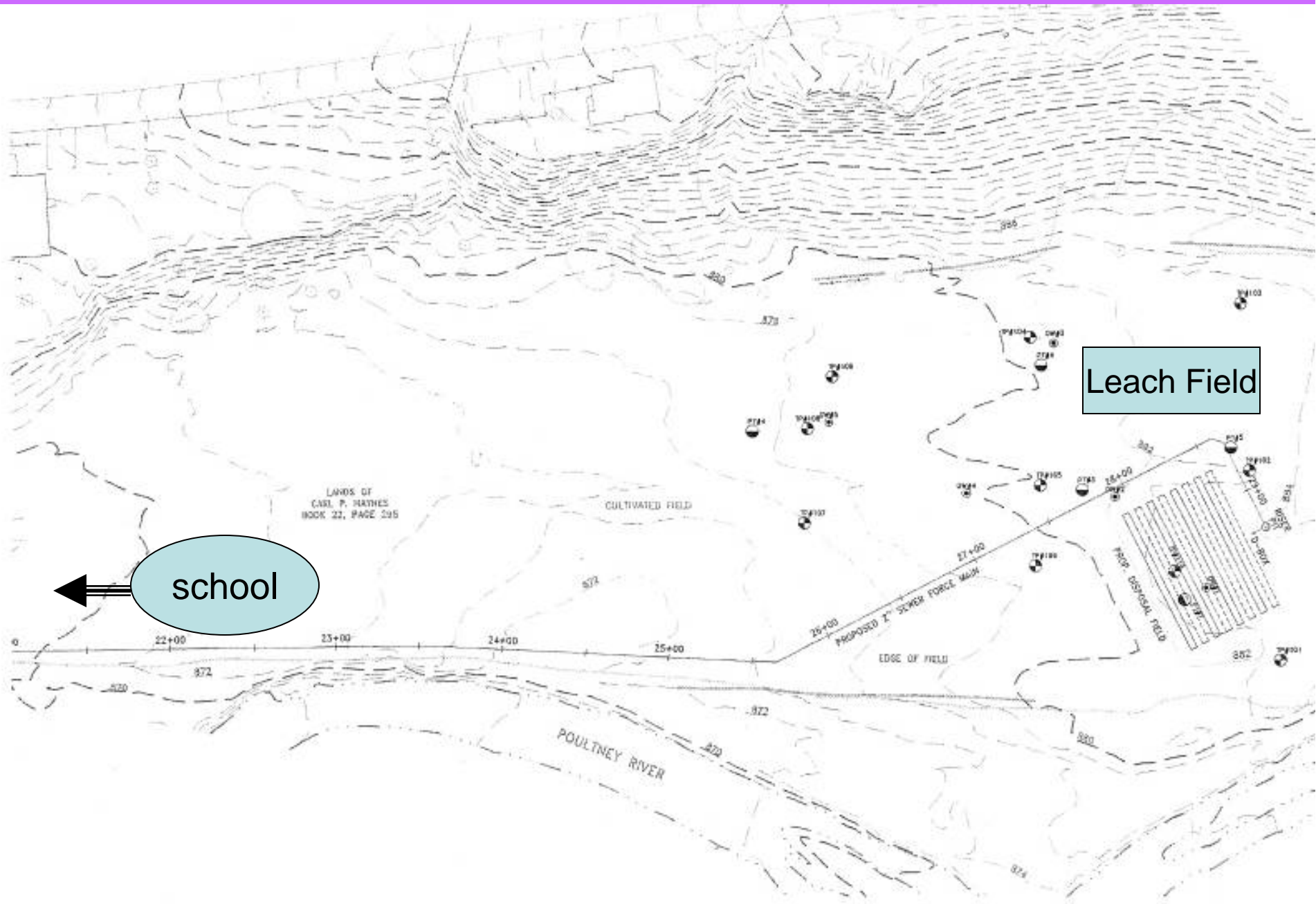


Middleton Springs, VT Site

Middleton Springs, VT System Elementary School (68 students, 9 faculty, 9 staff, ~1,000 gpd)

- Bedrock well
- Submersible pump
- 6,000 gal atmospheric storage
- 4 – 100 gal hydropneumatic storage tanks
- 10,000 gal septic tank
- 4,000 pumping tank
- Leach field trench system



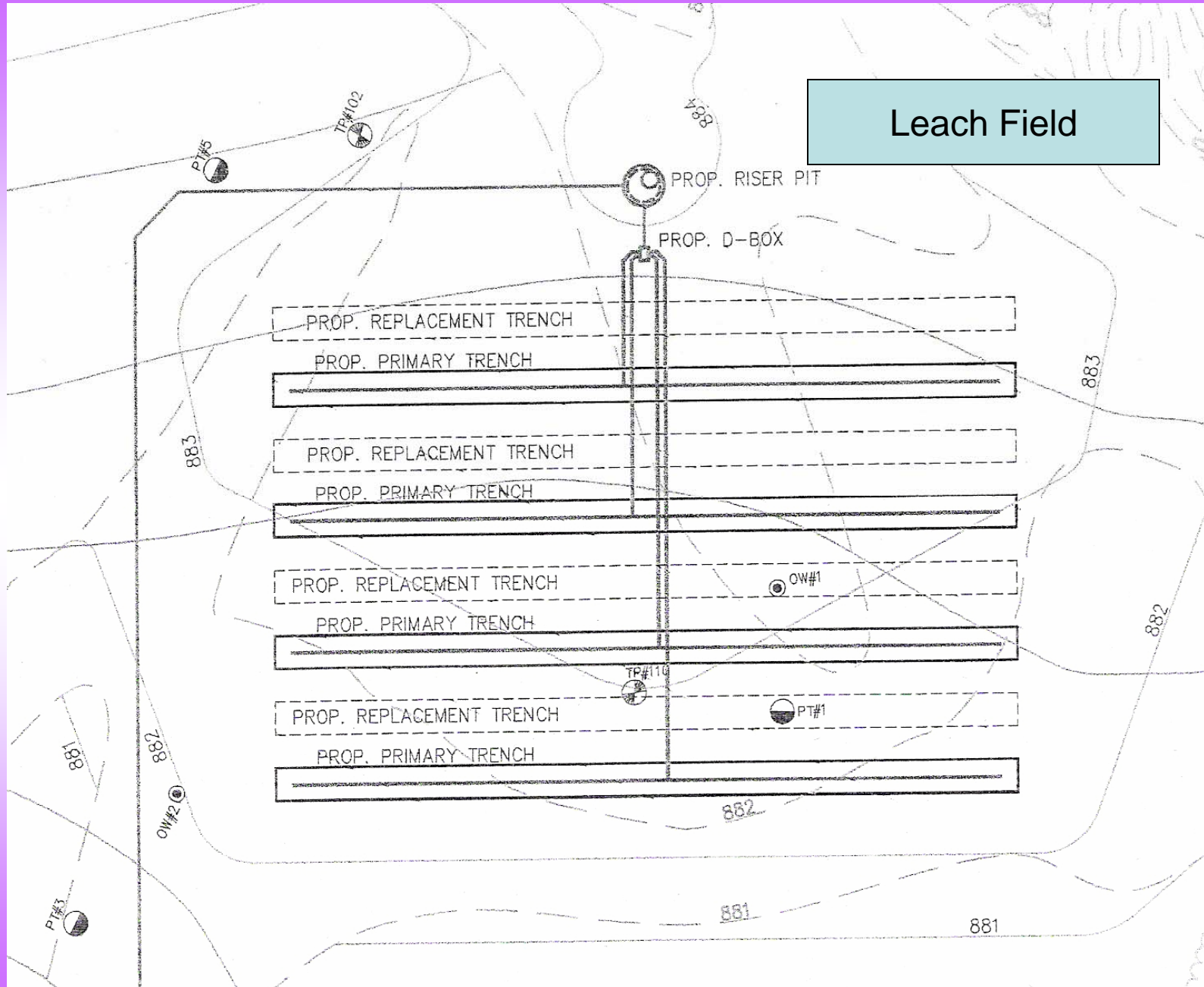


Leach Field

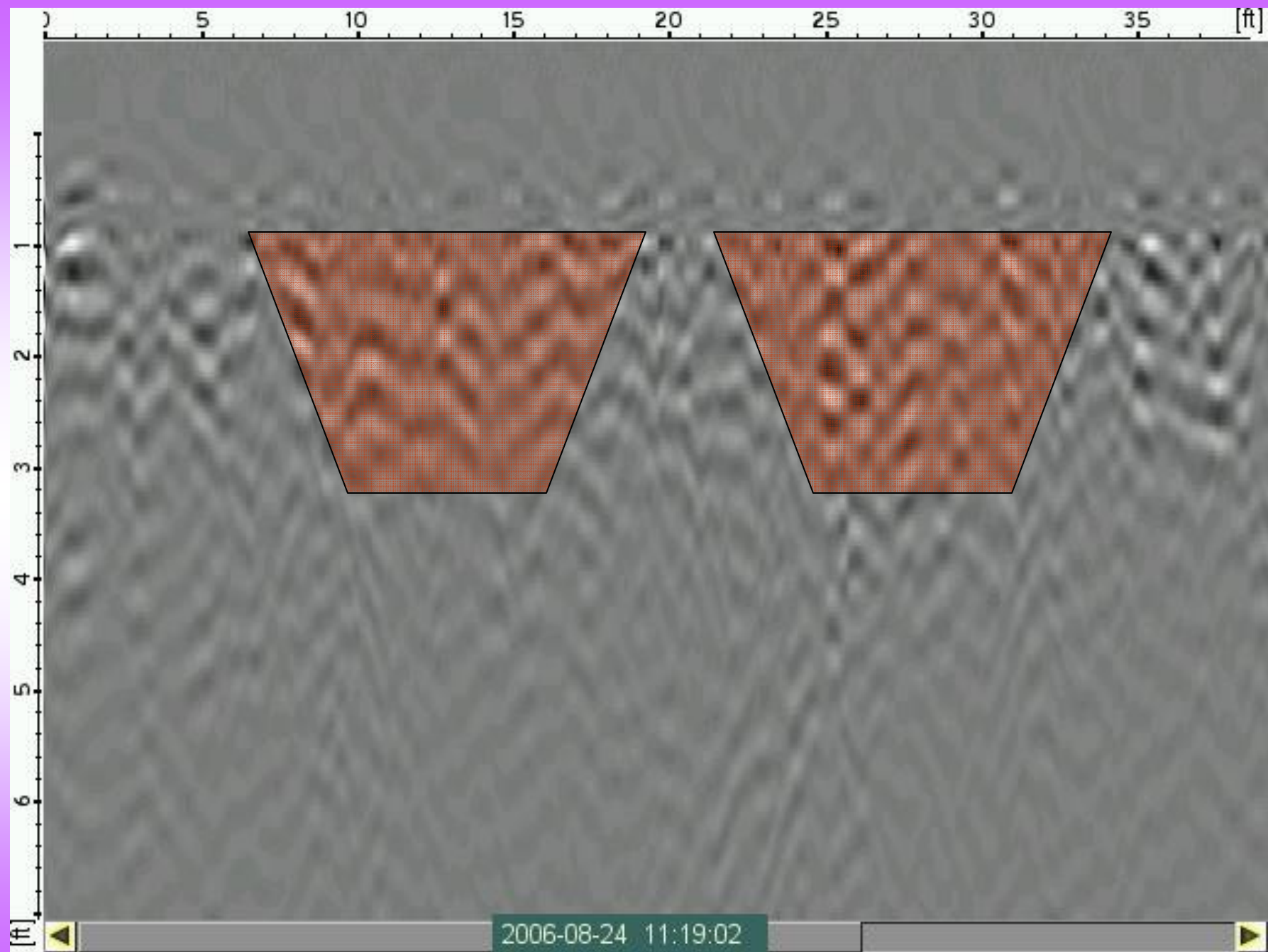
school



Leach Field













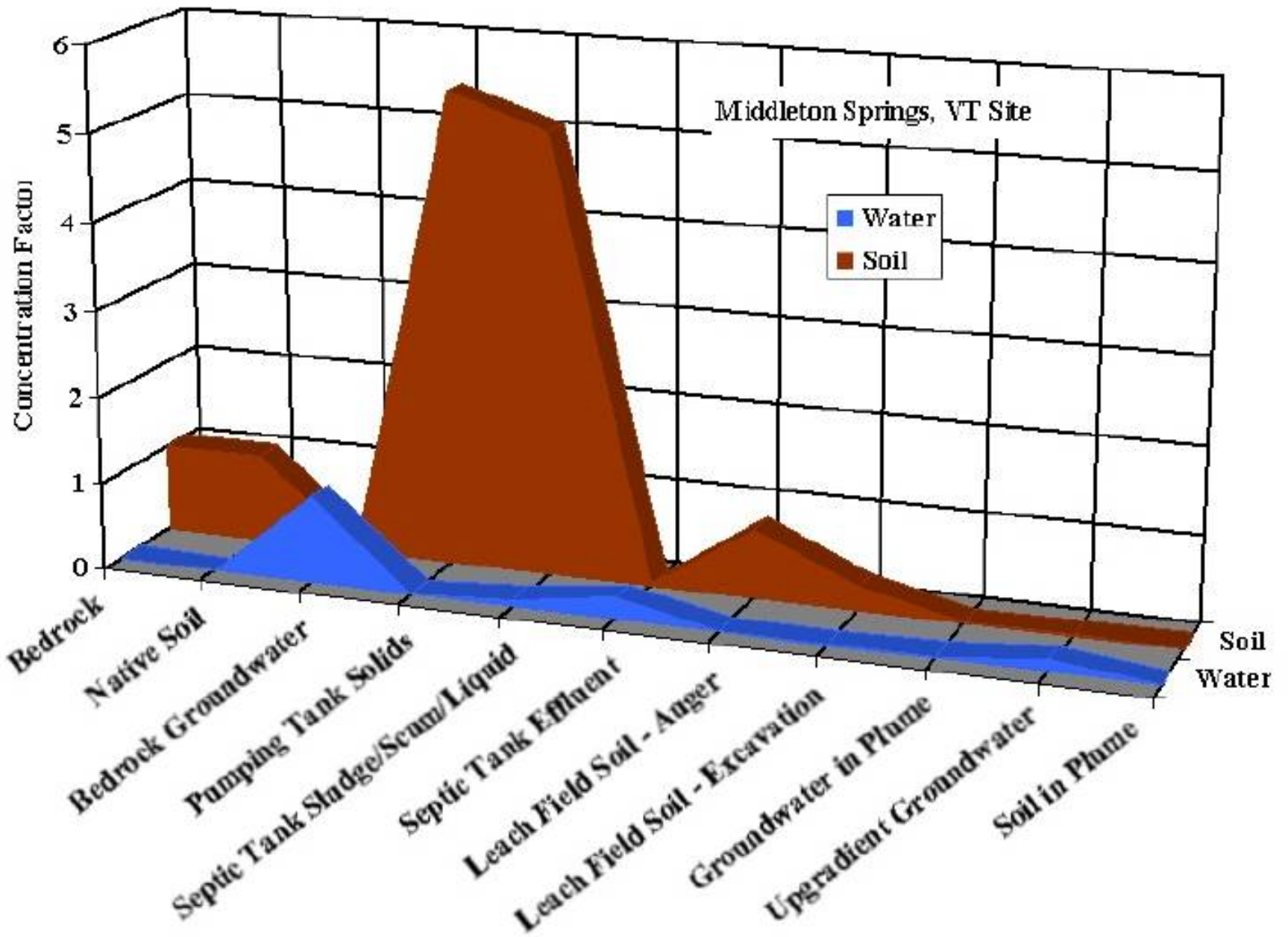




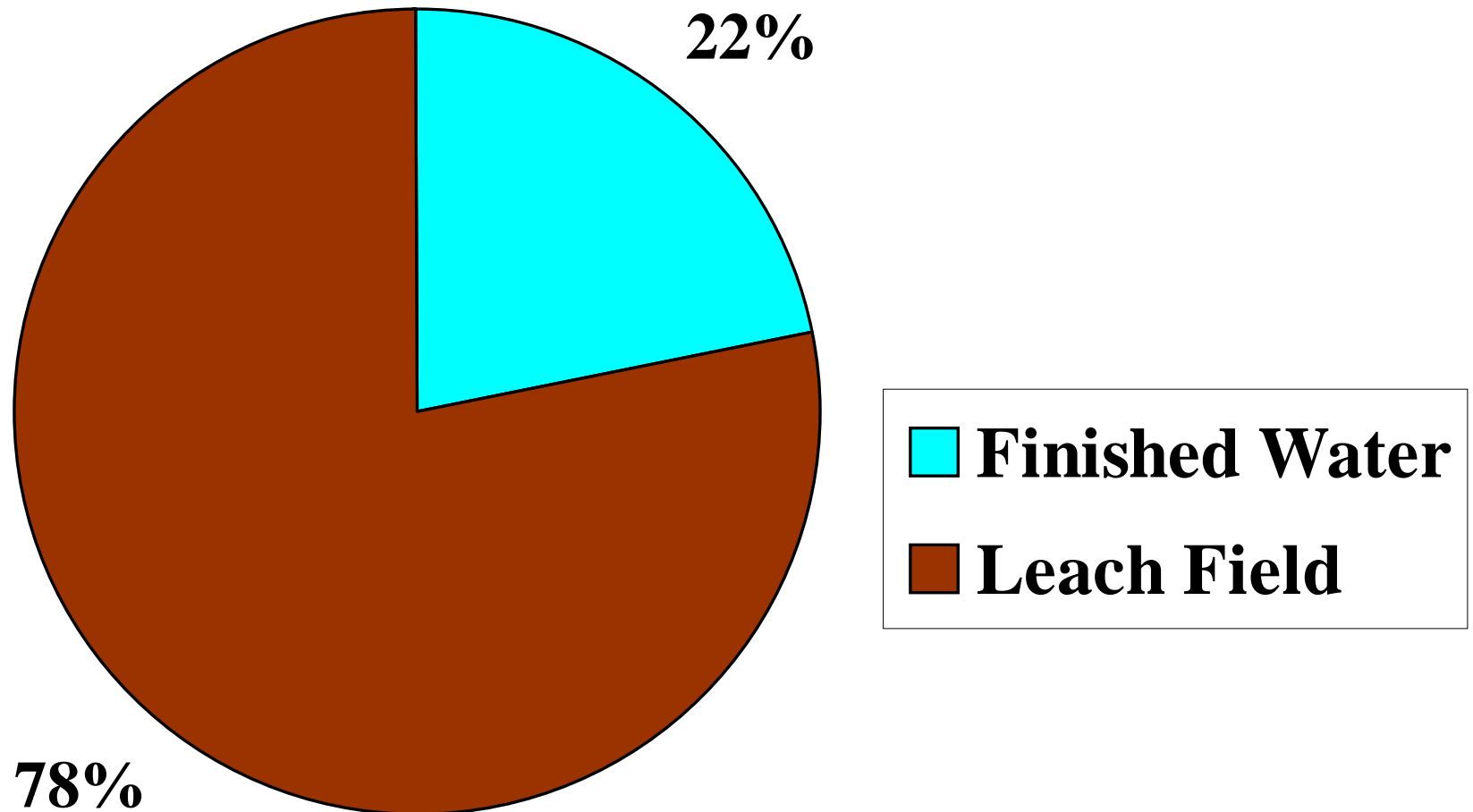


Middleton Springs, VT Groundwater

Gross Alpha (pCi/l)	Gross Alpha less Rn & U (pCi/l)	Gross Beta (pCi/l)	Radium 226 (pCi/l)	Radium 228 (pCi/l)	Uranium* (pCi/l)	Uranium (ug/l)
39	25	7.1	2.2	0.7	14	20
11	5	49	0.9	0.0	5.5	8.1
240	50	43	18	0.6	190	280



Middleton Springs, VT Radionuclides Fate

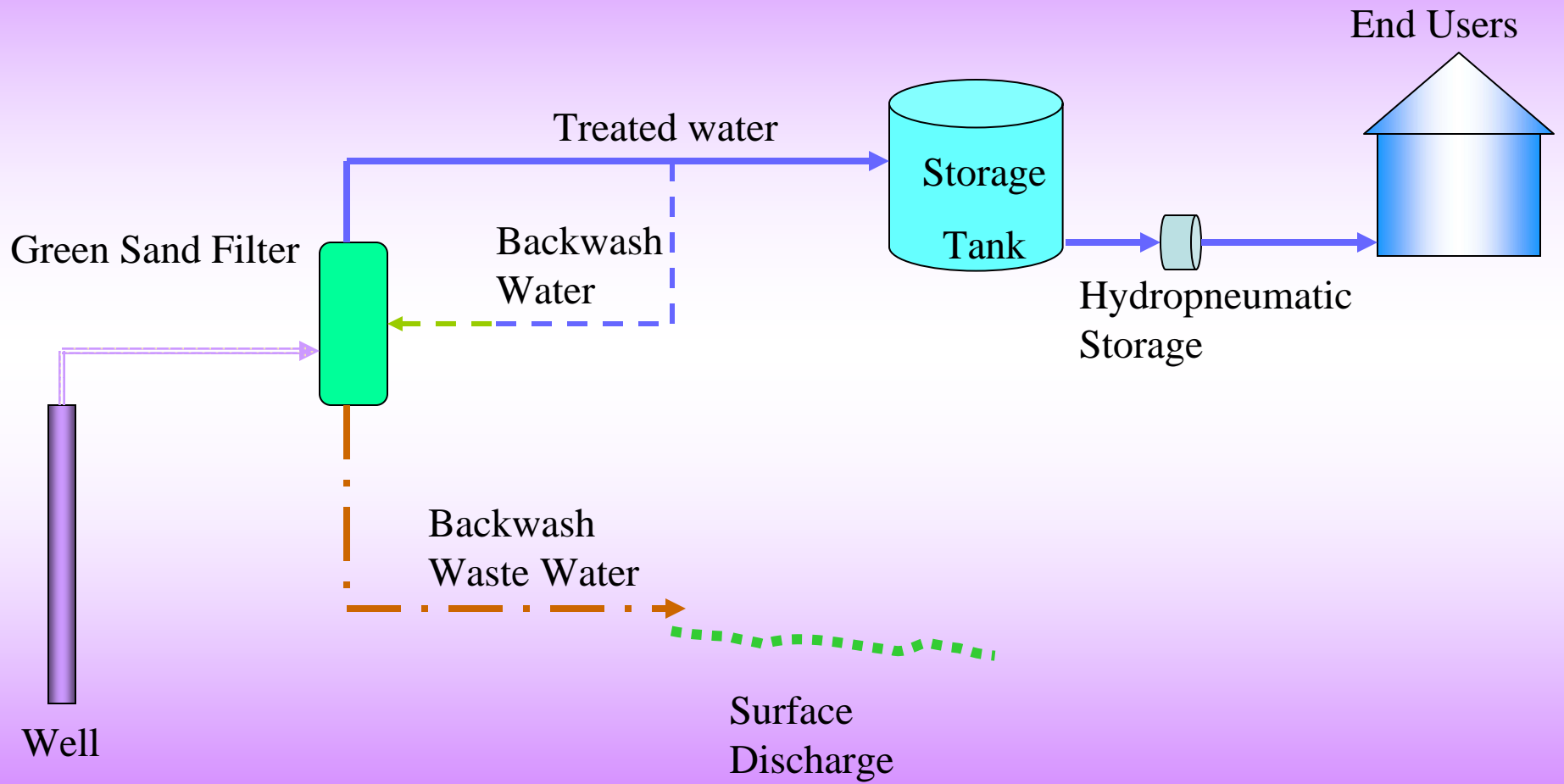


Bedford, NH Site

Bedford, NH System

Residential Community (pop. 50, 19 service connections)

- 2 Bedrock wells (473 ft and 65 ft)
- Submersible pumps
- Green sand filter (Manganese)
- Atmospheric storage
- Hydropneumatic storage
- Backwash directly to “pit”



Bedfrod, NH Bedrock

Sample Description	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Radium 226 (pCi/g)	Radium 228 (pCi/g)	Uranium as U238 (mg/kg)
Bedrock (Mt. Miner @ 250 ft)	12	28	1.0	0.0	<4
Bedrock (Mt. Miner @ 400 ft)	16	25	1.4	0.8	<4
Native Soil – Aug 2005	14	22	1.8	0.1	<4
Native Soil – Jul 2006 – sample 1	5.3	16	1.0	1.4	<4
Native Soil – Jul 2006 – sample 2	8.8	23	0.5	2.3	<4

Bedford, NH Groundwater

Gross Alpha (pCi/l)	Gross Alpha less Rn & U (pCi/l)	Gross Beta (pCi/l)	Radium 226 (pCi/l)	Radium 228 (pCi/l)	Uranium* (pCi/l)	Uranium (ug/l)
12	6.0	6.4	4.5	0.6	6.2	9.2
23	4.0	30	1.0	0.8	19	28



Well House and Treatment - Bedford, NH



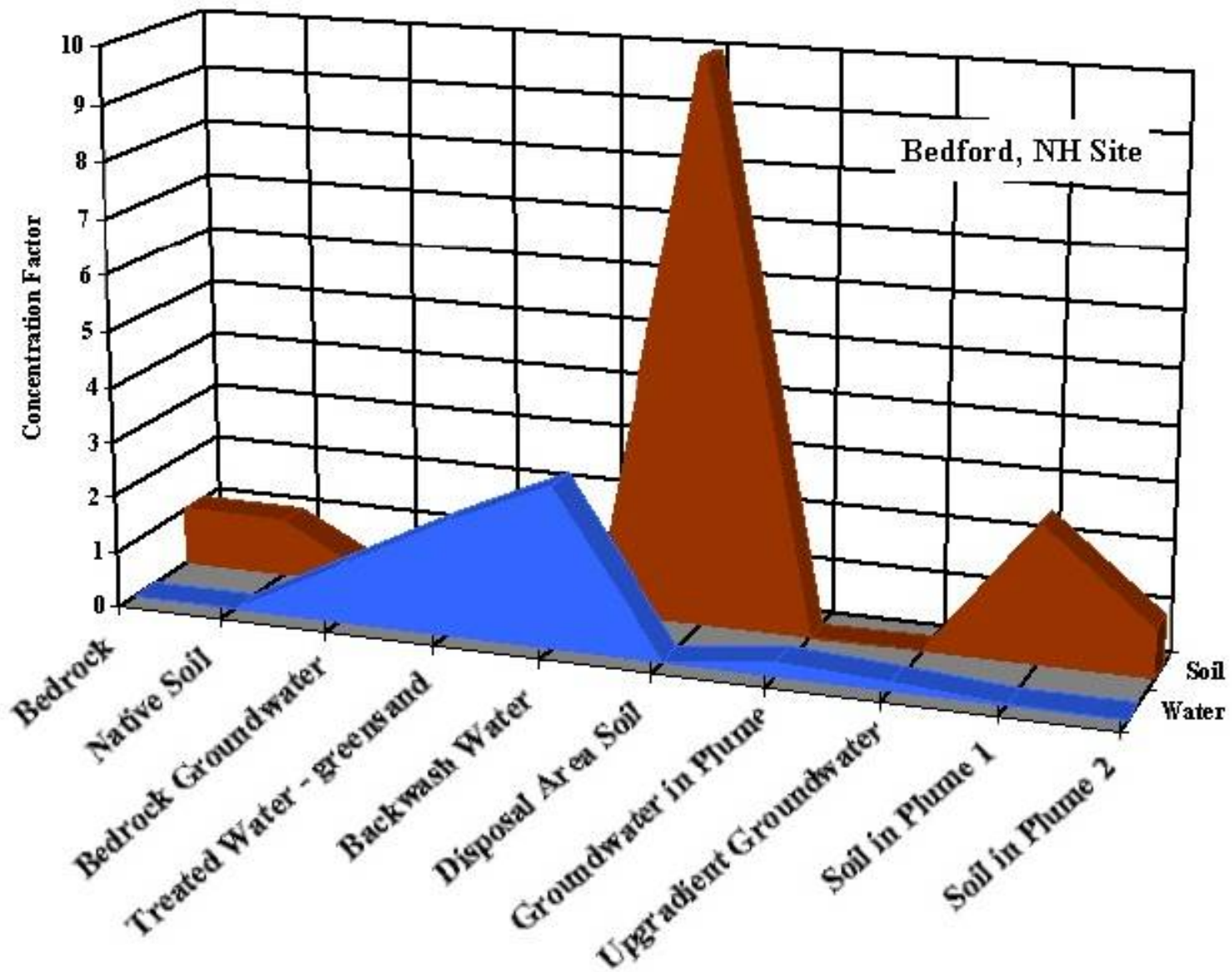
Well House and Discharge Pit - Bedford, NH



Downgradient of Discharge Pit - Bedford, NH



Upgradient of Discharge Pit - Bedford, NH

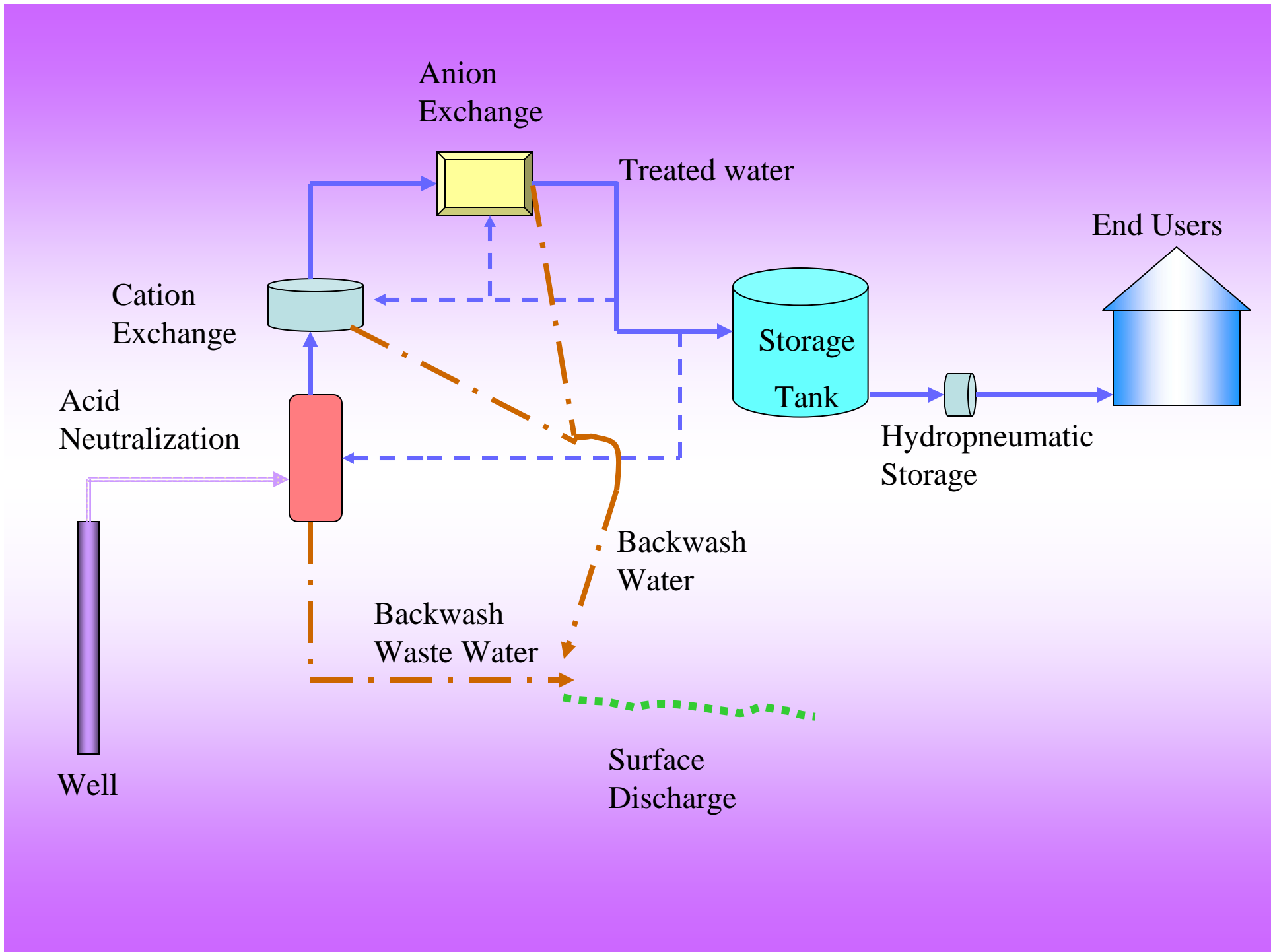


Pelham, NH Site

Pelham, NH System

Apartment Complex (pop. 25, 22 service connections)

- 2 Bedrock wells (575 ft and 625 ft)
- Submersible pumps
- Acid Neutralizer (Calcite)
- Cation Exchange Unit (Sodium form)
- Anion Exchange Unit (Chloride form)
- Atmospheric storage
- Hydropneumatic storage
- Backwash directly to “pit”



Treatment System Maintenance

Backwash:

- Acid Neutralizer twice per week
- Cation Exchange unit four times per week
- Anion Exchange every two weeks



Well House and Treatment - Pelham, NH



Discharge to Ground - Pelham, NH



Discharge Pit - Pelham, NH



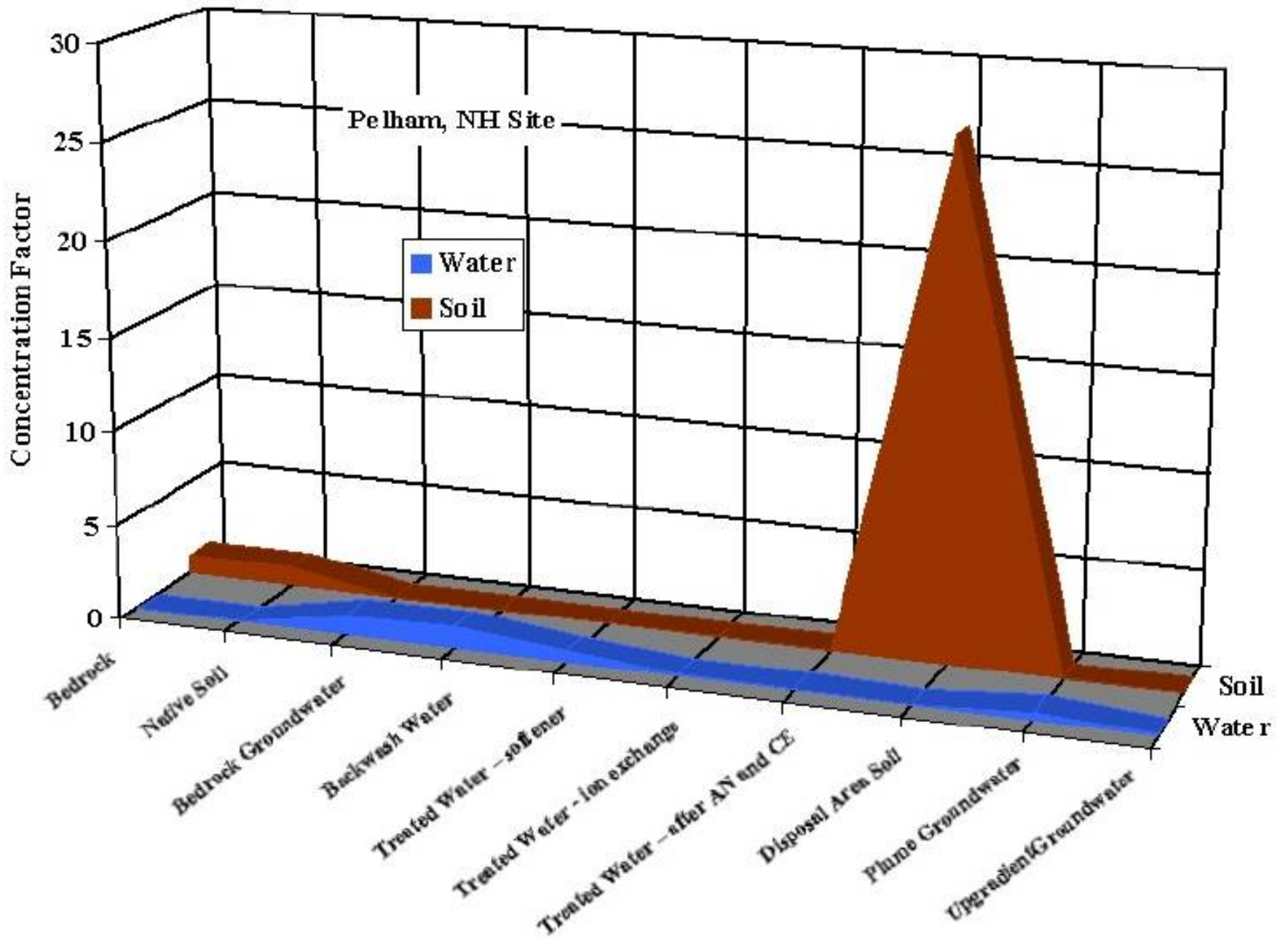
Downstream of Discharge Pit - Pelham, NH

Pelham, NH Bedrock

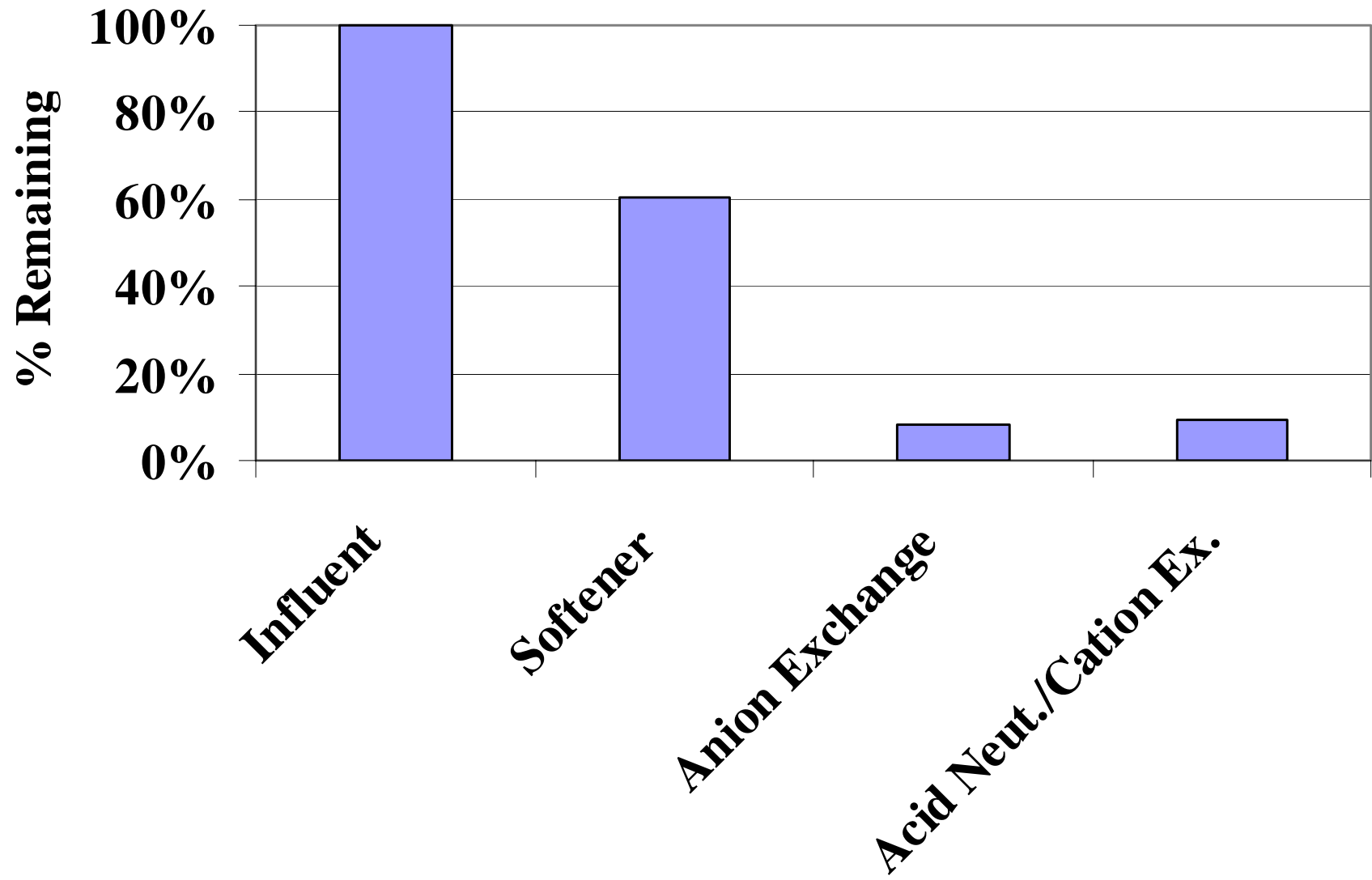
Sample Description	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Radium 226 (pCi/g)	Radium 228 (pCi/g)	Uranium as U238 (mg/kg)
Bedrock (Schist @ 160 ft)	9.8	26	1.4	0.8	<4
Bedrock (Ayer Granite @ 340 ft)	35	61	7.0	0.3	17
Bedrock (Sherburne Rd @ 300 ft)	8.9	19	0.9	0.0	<4
Bedrock (Sherburne Rd @ 500 ft)	3.5	14	1.0	0.7	<4
Native Soil	8.1	8.3	2.5	0.3	<4

Pelham, NH Groundwater

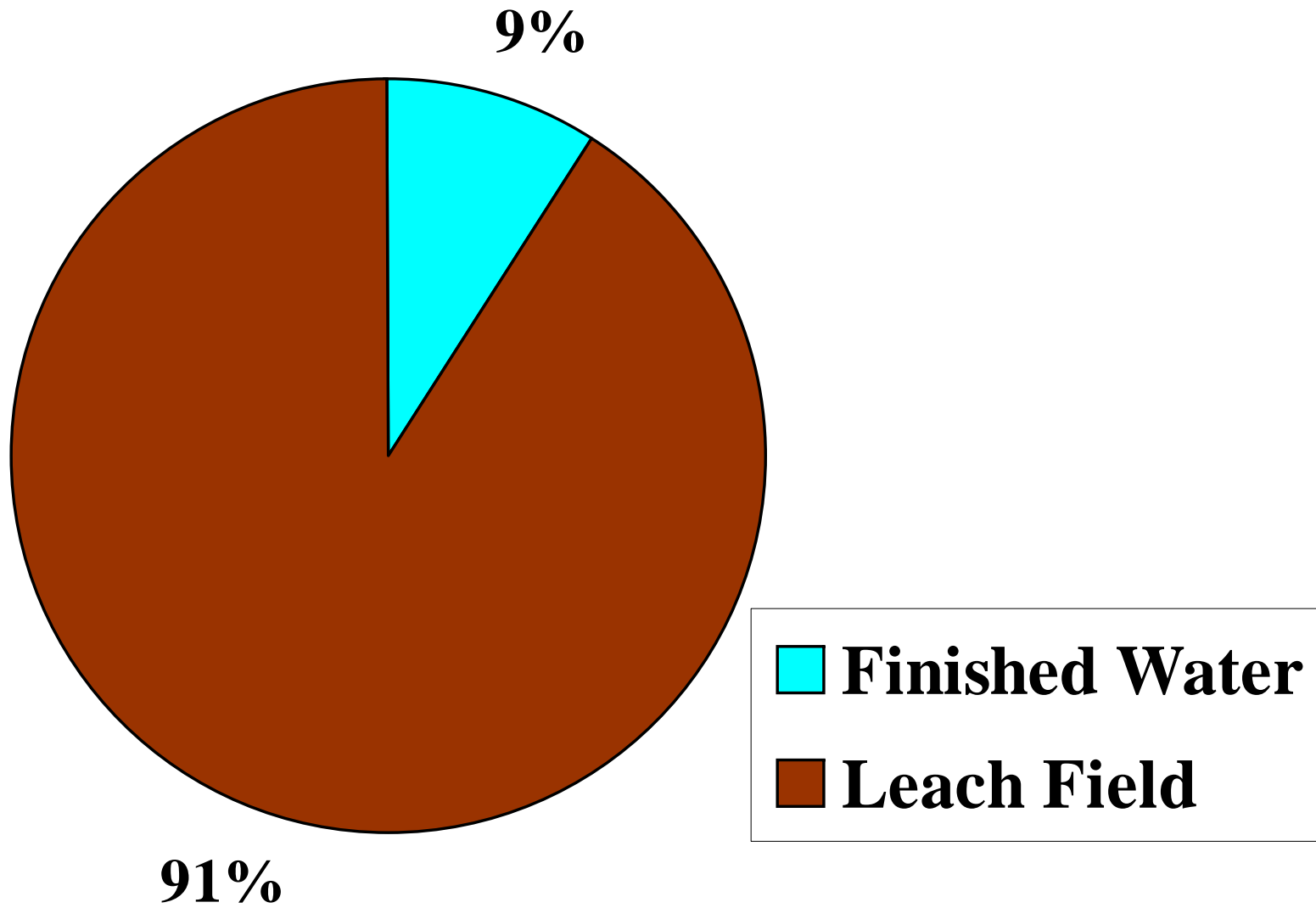
Gross Alpha (pCi/l)	Gross Alpha less Rn & U (pCi/l)	Gross Beta (pCi/l)	Radium 226 (pCi/l)	Radium 228 (pCi/l)	Uranium* (pCi/l)	Uranium (ug/l)
91	11	20	1.7	0.5	80	120
84	11	30	3.3	1.4	73	110



Post-Treatment Alpha Plus Beta Pelham, NH



Pelham, NH Radionuclides Fate



Test Name	EPA Standards
Compliance Gross Alpha*	15 pCi/L**
Uranium	30 ug/L (approx 20 pCi/L)***
Radium 226 + Radium 228	5 pCi/L
Radon	Proposed 300/4,000 pCi/L (CFR Nov. 1999)

*Compliance gross alpha equals the concentration of analytical gross alpha minus the concentration of Uranium

** pCi/L (picocuries per liter)

*** micrograms per liter (ug/L) can be converted to pCi/L by multiplying the U (mg/L) by 0.67.

Conclusions

- Radioactive species tend to associate with solids (soils, sediment)
- Anion Exchange system very effective at removing radioactive species
- Leach fields have an enormous capacity for radioactivity without reaching levels of concern
- TENORM waste not moving in groundwater
- Pumping strategies may impact radioactivity level from the well

