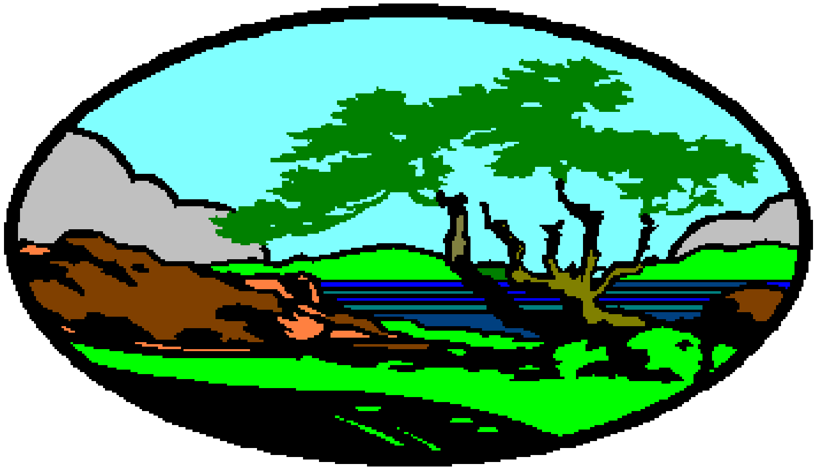
Key Solutions

Tritium Deposition



Jim Key

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Key Solutions

The Problem

- Tritium Released to the Atmosphere
  - "Recaptured" and seen in surface runoff.
  - See REMP Reports Statements Like:
    - "Tritium recapture (scavenging, deposition, etc.) by precipitation is a known phenomenon."
    - Only Anecdotal Evidence
- Can the high levels of H-3 in surface runoff be *truly attributed* to recapture of H-3 in the air?

Atmospheric Removal Mechanisms

- Wet Deposition (Precipitation Scavenging)
  - Rain Washout
  - Snow Scavenging
- Dry Deposition
- Condensation onto Surfaces
  - Contaminated Concrete

Rain Washout

- Vapor Exchange Process
  - Occurs both ways.
  - Rate of change not equal.
    - Lower Temps Favor Vapor To Liquid.
      - Think Condensation
    - Higher Temps Favor Liquid To Vapor
      - Think Evaporation

Modeling Rain Washout

- Short Term Precipitation Events Require
  - Detailed Meteorology
  - Cloud Base
  - Rain Spectra
  - Rain Rose
  - Etc.

Modeling Rain Washout

- Long Term Precipitation Washout Can Be Modeled
  - Assumes Along Period of Time
    - Seasonal or Annual
  - Uses Washout Factor
    - W_M – Mass Washout Factor (kg_{air} / kg_{rain})
    - W_V – Volumetric Washout Factor (m^3_{air} / m^3_{rain})
    - See NUREG/CR-3332

Key Solutions

Rainwater Concentration

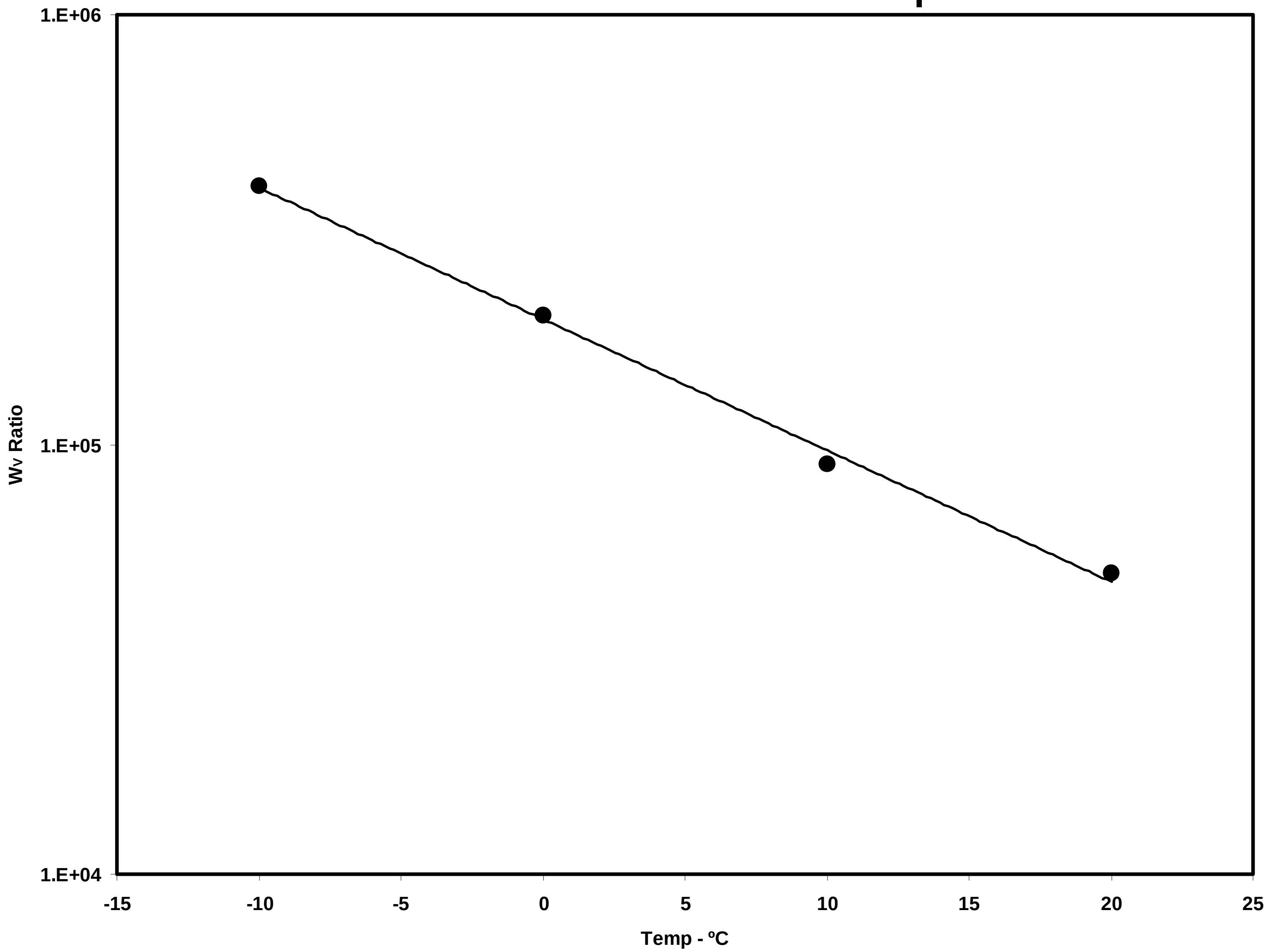
$$C_{RAIN} = 10^3\ \overline{\chi/Q}\ \ \dot{Q}\ W_V$$

C_{RAIN}	Is the estimated concentration in rain water in units of pCi/liter.
10^3	Conversion constant to convert from uCi to pCi and from m^3 to liters.
$\overline{\chi/Q}$	Atmospheric dispersion in units of sec/m^3.
W_V	Volumetric Atmospheric Washout Factor

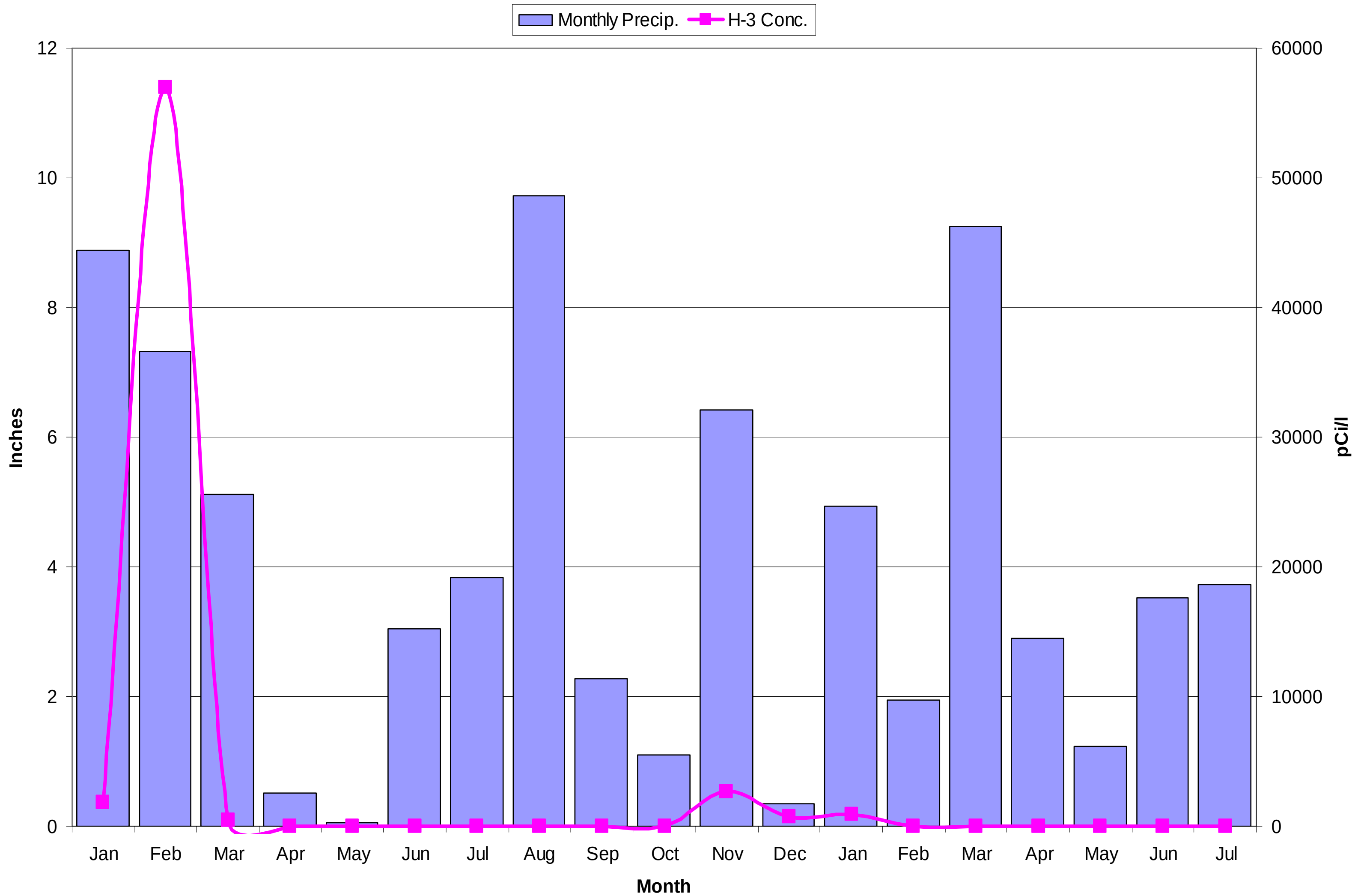
Tritium Washout Factors for Water Vapor

Atmospheric Temperature	Mass Washout Factor W_M (kg_{air} / kg_{rain})	Volumetric Washout Factor, W_V (m^3_{air} / m^3_{rain})
0°C	240	200,000
10°C	110	90,000
20°C	60	40,000

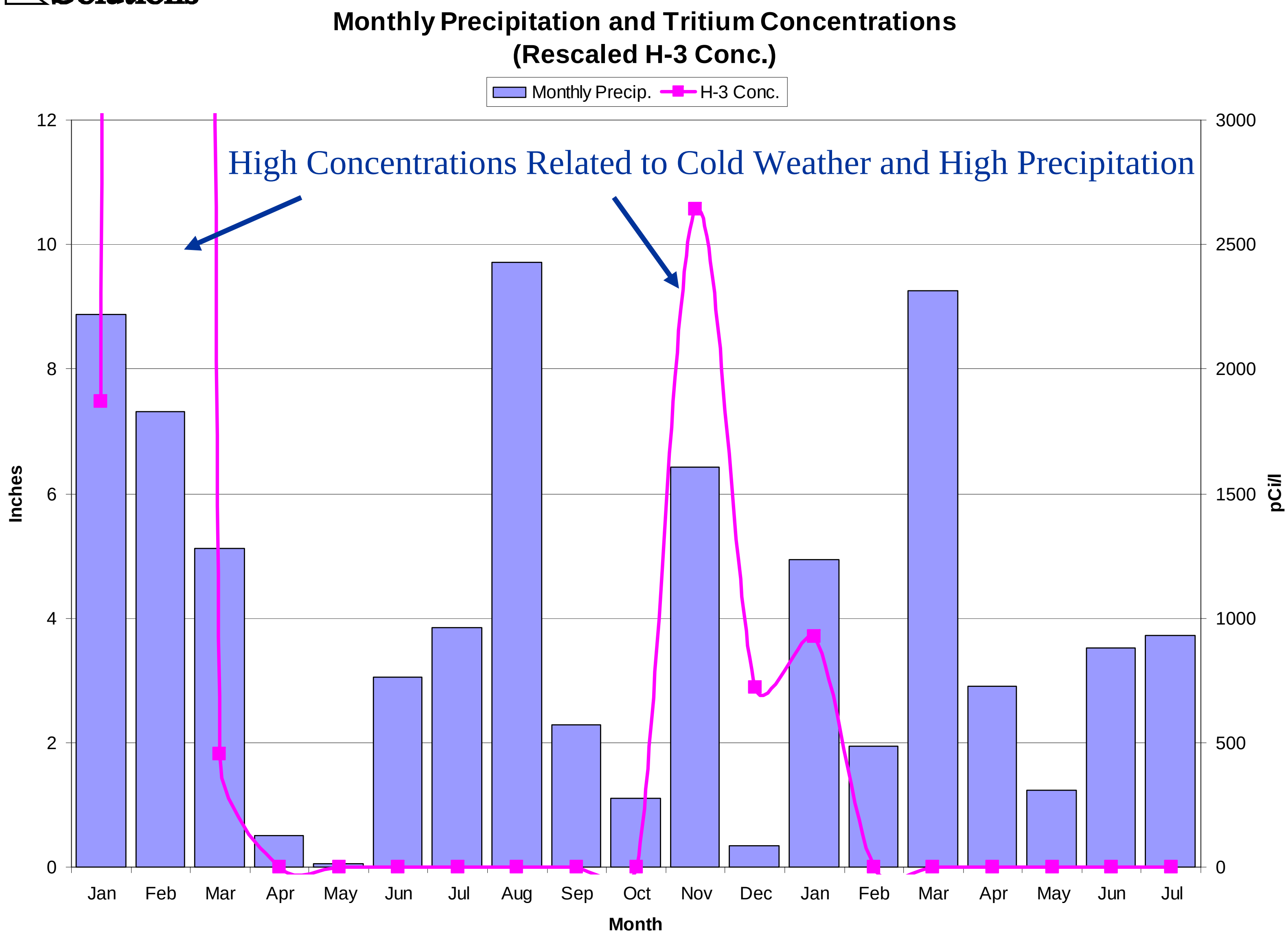
Volumetric Washout Ratio vs Temperature

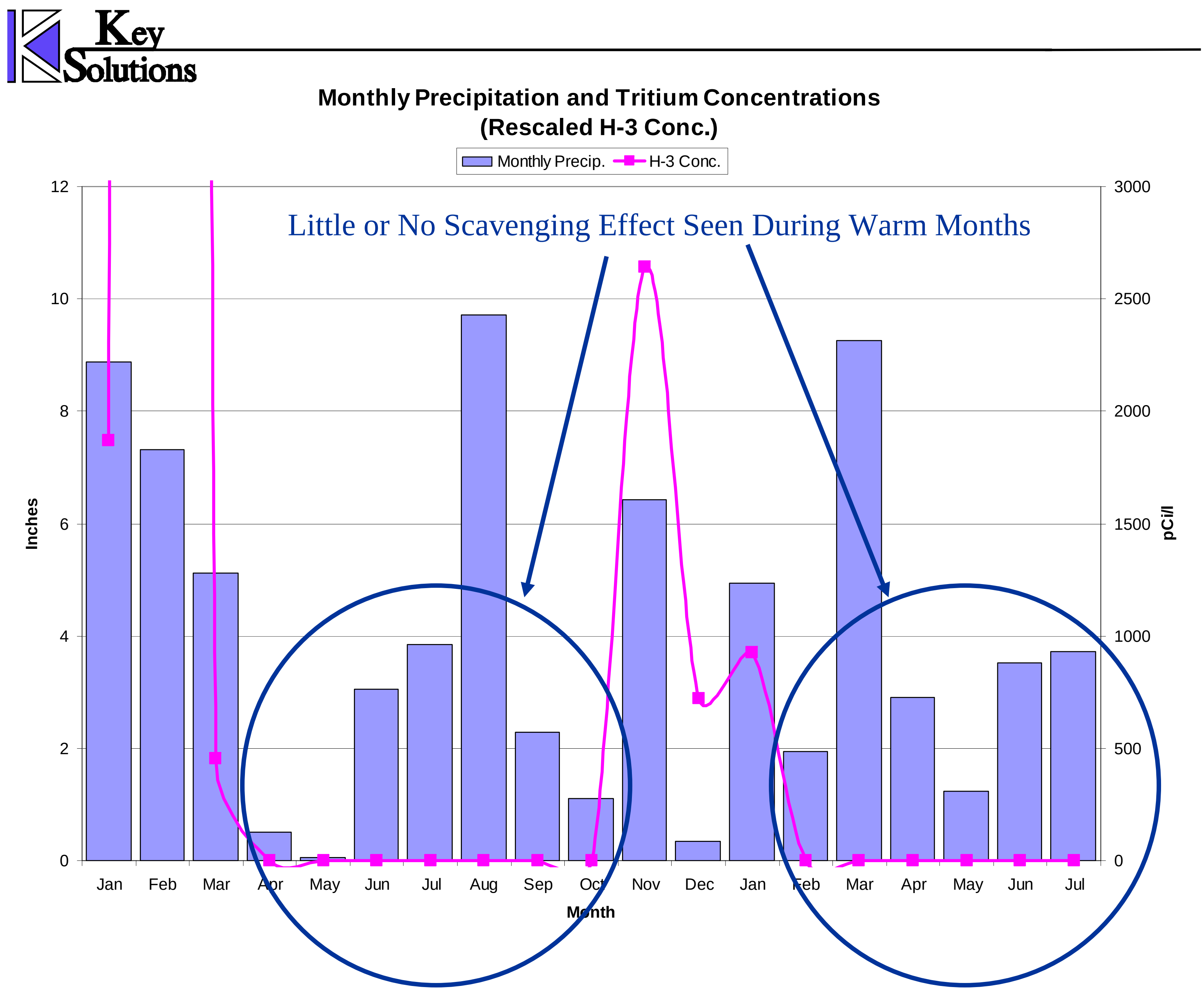


Monthly Precipitation and Tritium Concentrations
(Rescaled H-3 Conc.)



Key Solutions





Key Solutions
Monthly Precipitation and Tritium Concentrations
(Rescaled H-3 Conc.)
Monthly Precip.
H-3 Conc.
Little or No Scavenging Effect Seen During Warm Months
Inches
pCi/l
Month
0
2
4
6
8
10
12
0
500
1000
1500
2000
2500
3000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul

Snow Scavenging

- Dependant Upon Type of Snow
  - Power vs. Heavy Wet Snow
- Two Removal Processes by Snow
  - Scavenging by Snow as it Falls Through the Atmosphere (Snow Fall Scavenging)
  - Scavenging by the Snow Pack After Accumulating on the Ground (Snow Pack Scavenging = Dry Deposition)

Snow Fall Scavenging

- Wet Deposition Process
  - Same Process as Scavenging by Rain Fall
  - Modeled in Similar Way
- Studies Show Efficiency of Snow Fall Scavenging to be One or Two Orders of Magnitude Below Rain Scavenging

High Snow Pack Concentrations

- Hinchcliffe Master's Thesis (ISU)
  - DC Cook Study
  - Measured Only "Fresh Snow" Tritium Concentrations
  - Did See Much Higher Concentrations in "Old Snow" (Snow Pack)
  - High "Old Snow' Concentrations Remained Unexplained

Snow Pack Scavenging

- Dry Deposition Process
  - Direct Vapor Exchange Between Air and Snow Pack [CNSC, IAEA]
  - Long Exposure Time
    - Hours to Days
    - Equilibrium Reached Quickly ~ Hours
  - Results in Substantially Higher Concentrations Than be Explained by Snow Fall Scavenging (Wet Deposition)

Snow Pack Scavenging

- This is an Integrating Process
- H-3 Concentrations in Snow Can Remain High Long After Atmospheric H-3 Levels Have Dropped
- Specific Activity of Water in Snow Pack Can Be a Substantial Fraction of the Specific Activity of Atmospheric Water

Key Solutions

Tritium Dry Deposition Onto Snow Pack

$$C_S = 10^9 \frac{X/Q\,\dot{Q}\,\rho_W}{H}$$

Where:

C_S	**Tritium concentration in snow (water) in units of pCi/l.**
10^9	**Conversion constant to convert from uCi to pCi and from ml to liters.**
X/Q	**Short term atmospheric dispersion in units of sec/m^3.**
$\dot{Q}$	**Release rate in units of uCi/sec.**
ρ_W	**Density of water in units of gm/cc.**
H	**Absolute atmospheric humidity in units of gm/m^3.**

Key Solutions

Snow Scavenging Information

- Hinchcliffe, William, “Investigation of Tritium Recapture at Cook Nuclear Power Plant form Airborne Effluent Releases,” thesis draft, August 2010, Idaho State University, Pocatello (Dr. Jason Harris’s student).
- IAEA, “Modelling the environmental transport of tritium in the vicinity of long term atmospheric and sub-surface sources”
- Galerio, D., Melintescu, A., Attanasov, D., Guetata, P., and Patyl, L. “Review of HTO Washout,” Power Point presentation, Report to IAEA EMRAS Program Working Group, 2010.
- Orgam, G. L., “Precipitation Scavenging of Tritiated Water Vapour (HTO),” October 28, 1995. Ontario Hydro Research Division report number 85-233-K, Ontario Hydro
- Slinn, W. George N., “Precipitation Scavenging,” from *Atmospheric Science and Power Production*, Darryl Randerson, editor; DOE/TIC-27601, DOE 1984.

Tritium Retention and Release From Concrete

- "Hey it rained on my concrete and now I see tritium."
  - Containment
  - Other Site Structures
  - Security Barricades
- Concrete Can Act As a Sink and a Source of HTO.

Key Solutions

Lot's Going On

- Primary Mechanisms
  - Absorption
  - Adsorption
  - Ion Exchange
- Deep Diffusion
  - Slow Process
  - Small Impact on Short Term De-sorption from Runoff

Key Solutions

Lots of Water in Concrete

- *Cement* Is Major Component in Concrete
- Water is Substantial Component of *Cement*
  - 67% Pore and Capillary Water
  - 20% Water of Crystallization
  - 12% Constituent Water
    - Hydrogenated Calcium
    - Calcium Silicate

Concrete as a Sink

- Very Fast Shallow Permeation into
  - Concrete Pores
  - Concrete Capillaries
  - Capillary Action
    - Distributes Water Across the Surface of Concrete
    - And Into the Concrete to a Depth of a Few Millimeters
- Deeper Penetration Proceeds Very Slowly

Key Solutions

Concrete as a Source

- Water Stored in Shallow Layer of Pores and Capillaries
  - Highly Mobile
  - Exchanges Quickly and Freely With External Water
- Tritiated Easily Water Leaches Out
  - Contaminates Water That Comes in Contact With Concrete Surface
    - Precipitation
    - Condensate Runoff

Concrete as a Source

- Water In Pores and Capillaries
  - Shallow Layer
  - Subject to Removal By Weathering
  - Short Term Storage Mechanism

Cement Chemistry

- *Cement* is Self Desiccating
  - 20-25% of *Cement* In Initial Pour Can Remain Un-Hydrogenated
  - Over Time Un-Hydrogenated *Cement* Will Continue to Absorb Water
    - This is Why Concrete Gets Stronger as it Get Older
  - This Water is Incorporated Into *Cement* as Water of Crystallization

Water of Crystallization

- Not Available for Direct Exchange
- Is Available for Ion Exchange
- This is a LONG Term Storage Mechanism
  - Retains and Releases H-3 Well After Initial Exposure to HTO

Two Storage Compartments

- Short Term Storage
  - Concrete Pores and Capillaries
- Long Term Storage
  - *Cement* Continues to Incorporate Moisture As Water of Crystallization

(Note that concrete with a higher aggregate content has less water storage capacity.)

Key Solutions

Short Term Storage

- Fast Shallow Penetration into Concrete Pores and Capillaries
- Easily Removed from Pores and Capillaries
- Can Result in Very High HTO Concentration in Surface Runoff Water

Key Solutions

Long Term Storage

- Water Continues to be Incorporated into *Cement*
  - Water of Crystallization
  - Relatively Slow Process
- Ion Exchange Takes Place Slowly
  - Tritium Can Show Up Long After Initial Contact

Cross Over Pathways

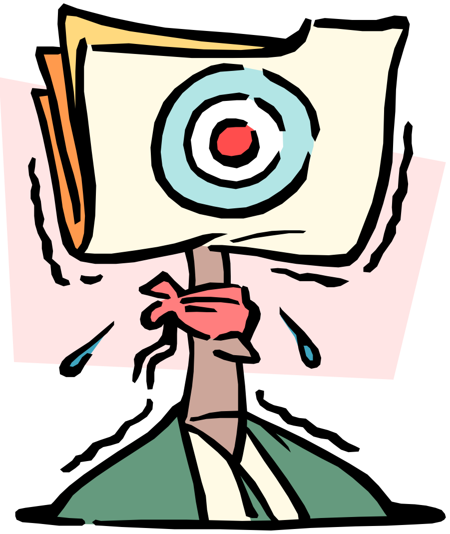
- Atmospheric Release Results in Dose Via Liquid Exposure Pathways
  - H-3 Deposition
- Liquid Release Results in Dose Via Gaseous Exposure Pathways
  - Pond Evaporation

What App I Limits Are Applicable?

- Dose Resulting From Tritium Recapture or Deposition…
  - App I Limits For Liquids?
    - 1.5 mrem/qtr and 3.0 mrem/yr Total Body
    - 5.0 mrem/qtr and 10.0 mrem/yr Any Organ
  - App I Limits for Airborne H-3?
    - 7.5 mrem/qtr and 15 mrem/yr Total Body and Organ

Who Do You Blame If You Challenge The Limits?

- Gaseous Radwaste Guy Say:
  - “It showed up in liquids? I don’t release liquids. It’s not my problem.”
- Liquid Radwaste Guy Say:
  - “Hey the Gas Radwaste guys had it last and they were the ones that let it go.”



Key Solutions

Purpose of App I Dose Values

- *Design* Requirements for Radwaste Treatment Systems
  - Liquid Radwaste
  - Gaseous Radwaste
  - Iodine, Tritium and Particulates Released to the Atmosphere

Why Three Separate Design Requirements?

- Physical Properties of the Effluent!!
  - Liquids
  - Noble Gases
  - Halogens, Tritium and Particulates
- Requires Three Distinctly Different Approaches to Effluent Processing System Design

10 CFR 50.34a

- Design objectives for equipment to control releases of radioactive material in effluents for nuclear power plants
  - (a) "The guides set out in appendix I to this part provide numerical guidance on design objectives…"
  - Radwaste Systems had to be designed to meet Appendix I

Appendix I

- Section II - Specifies Design Objectives for Specific Radwaste Treatment Systems
  - Liquid Effluents (Sec II.A)
  - Gaseous Effluents (Section II.B)
  - Radioiodines, Particulates and Tritium (Section II.C)

Appendix I - Section II.A

- …dose or dose commitment *from liquid effluents* for any individual in an unrestricted area *from all pathways of exposure*…
  - From Liquid Effluents
  - From All Pathways of Exposure
    - Dose Exposure Pathways (See Section III.A.1)
    - *Not Discharge* Pathways

Appendix I - Section II.B

- …not result in an estimated annual air dose *from gaseous effluents*….
  - – From Gaseous Effluents (Noble Gases)
  - – Air Dose in mrad (B.1)
  - – Total Body and Skin Dose in mrem (B.2)

Appendix I - Section II.C

- …all radioactive iodine and radioactive material ... released … in *effluents to the atmosphere* will not result in an estimated annual dose … *from all pathways of exposure*…
  - Iodine, Tritium and Particulates Released In Effluents to the Atmosphere
  - From All Pathways of Exposure

Applicable Limits

- If dose is a result of the release of liquid effluents:
  - Regardless of Dose Exposure Pathway(s)
  - 3 mrem Total Body
  - 10 mrem Organ
- If there is no liquid effluent release then no dose is generated.

Key Solutions

Applicable Limits

- If dose is a result of the release airborne release:
  - Regardless of Dose Exposure Pathway(s)
  - 10/20 mrad gamma/beta for Noble Gases
  - 15 mrem organ/total body for iodines, tritium and particulates
- If there is no airborne effluent release then no dose is generated.

Questions?