TREECS™ Overview, Validation, Example Applications

M2S2 MC Seminar
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Problem and Need

- Military firing/training ranges contain munitions constituents (MC) residue, including metals and explosives, that could migrate to surface water and groundwater off-installation, potentially threatening range sustainability.

- An assessment tool was needed to forecast if, when, and at what level MC concentrations in off-range media (groundwater, surface water, and sediment) may exceed protective health benchmarks.

TREECS Solution / Approach

Training Range Environmental Evaluation and Characterization System (TREECS™) is a client-based system that provides forecasts of MC fate on and off range based on munitions use and local site conditions for Active Training Ranges and Other than Operational Ranges

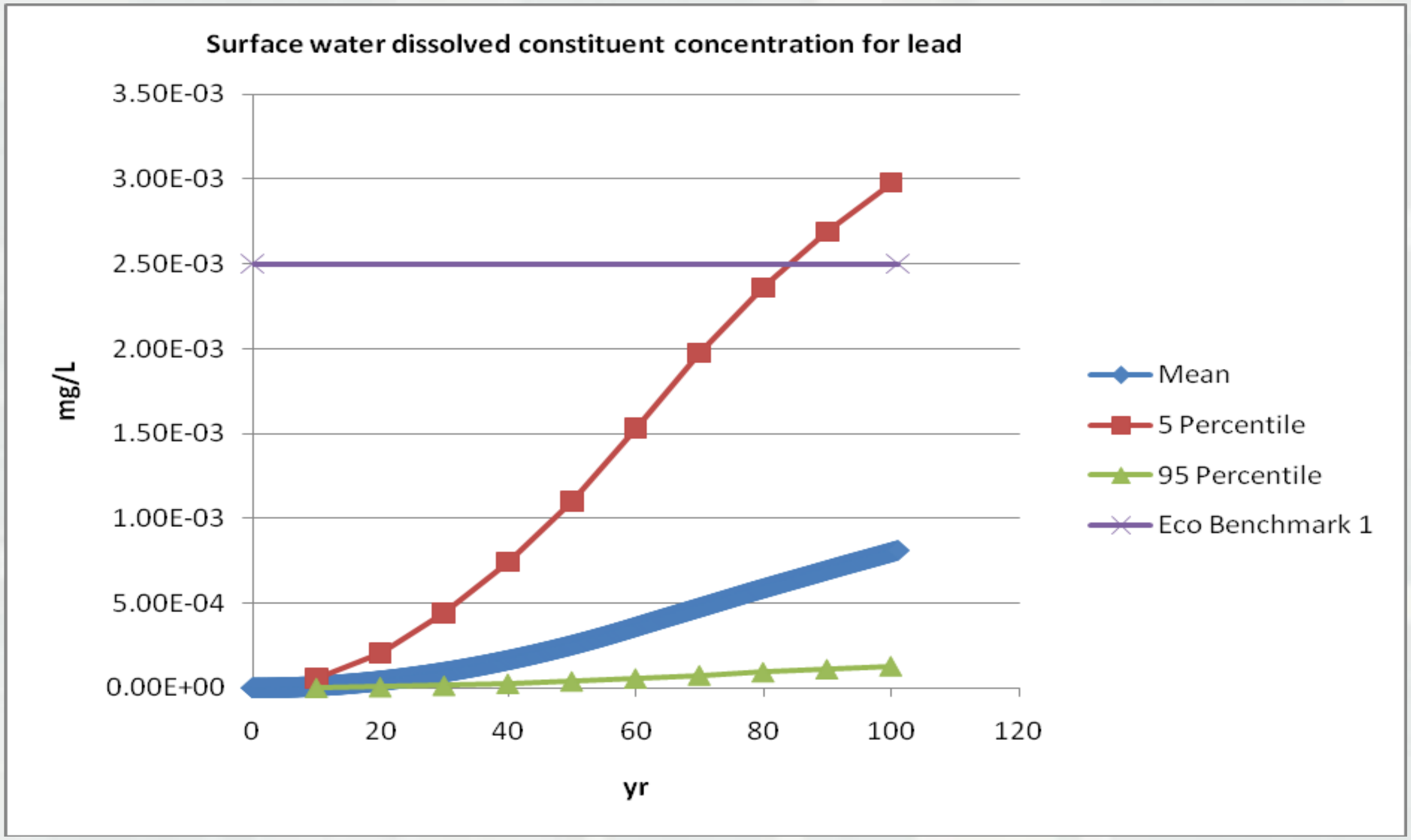
Development Approach: Multimedia fate/transport models of limited form were integrated within a modeling framework with graphical user interface (GUI) to expedite assessments with minimal amount of input data.

Status: Release version 5.0, October 2013; obtained CON for Army computers; validated (ERDC/EL TR-12-3); free download from http://el.erdc.usace.army.mil/treecs/

TREECS Components

- Tier 1, Tier 2, and advanced Tier 2 assessments
- 3 Constituent databases
- Health Benchmark database
- Munitions database
- MC residual mass loading module based on munitions use
- GIS module
- Hydro-geo-characteristics toolkit (HGCT) for estimating input parameters
- Models for soil, surface water, vadose zone, and groundwater
- Simplified user input interfaces for models (GUIs)
- Viewers for results
- Sensitivity and uncertainty module for Tier 2 assessments
- BMP assessment modules

Can Obtain Uncertainty Confidence Bounds

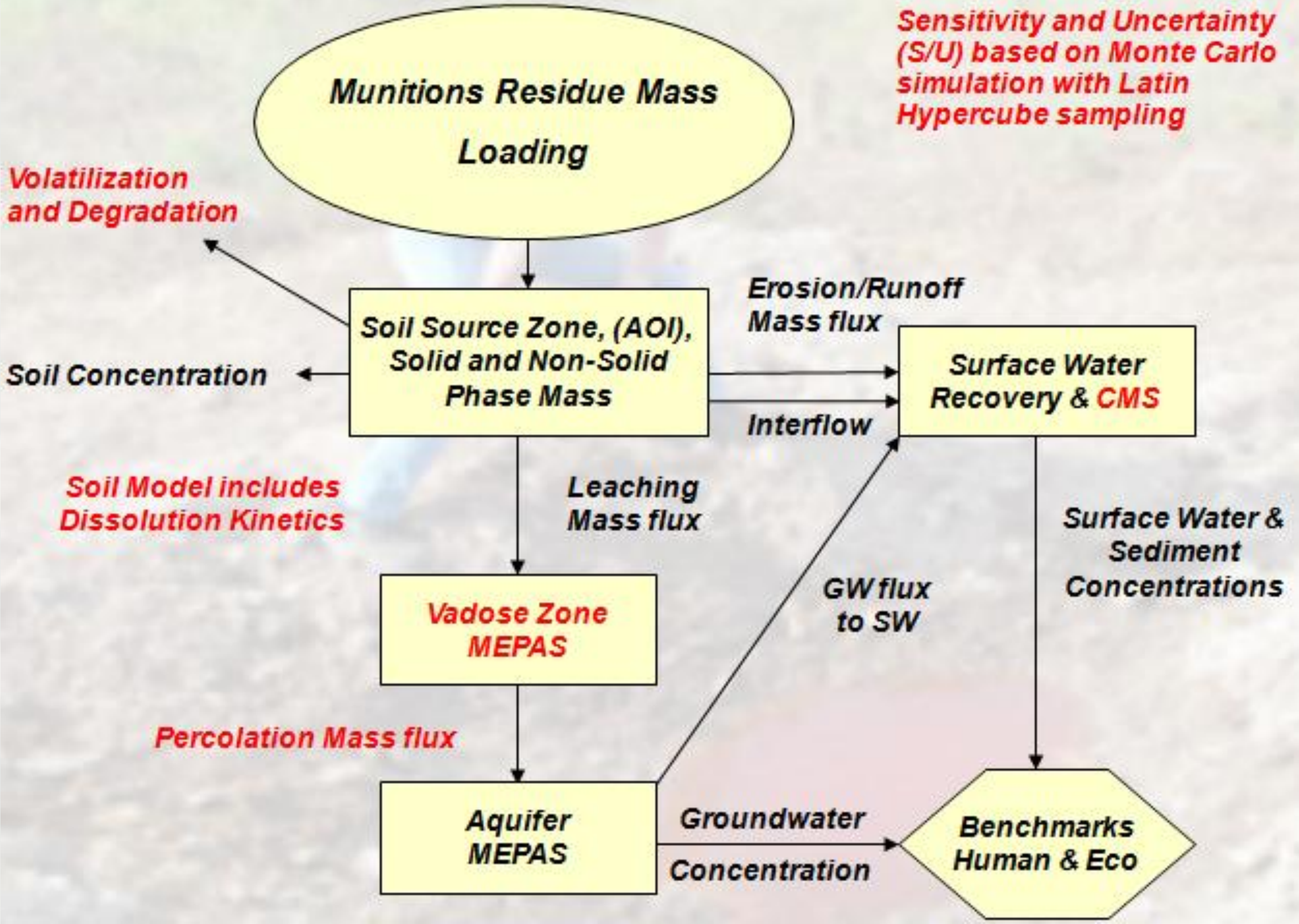


Tiered Approach

- Tier 1 (screening)
  - Steady-state, no degradation, worst case, highly conservative
  - Requires little data
  - Can be applied very quickly
  - Indicates whether a problem could ever potentially exist; if so, proceed to Tier 2

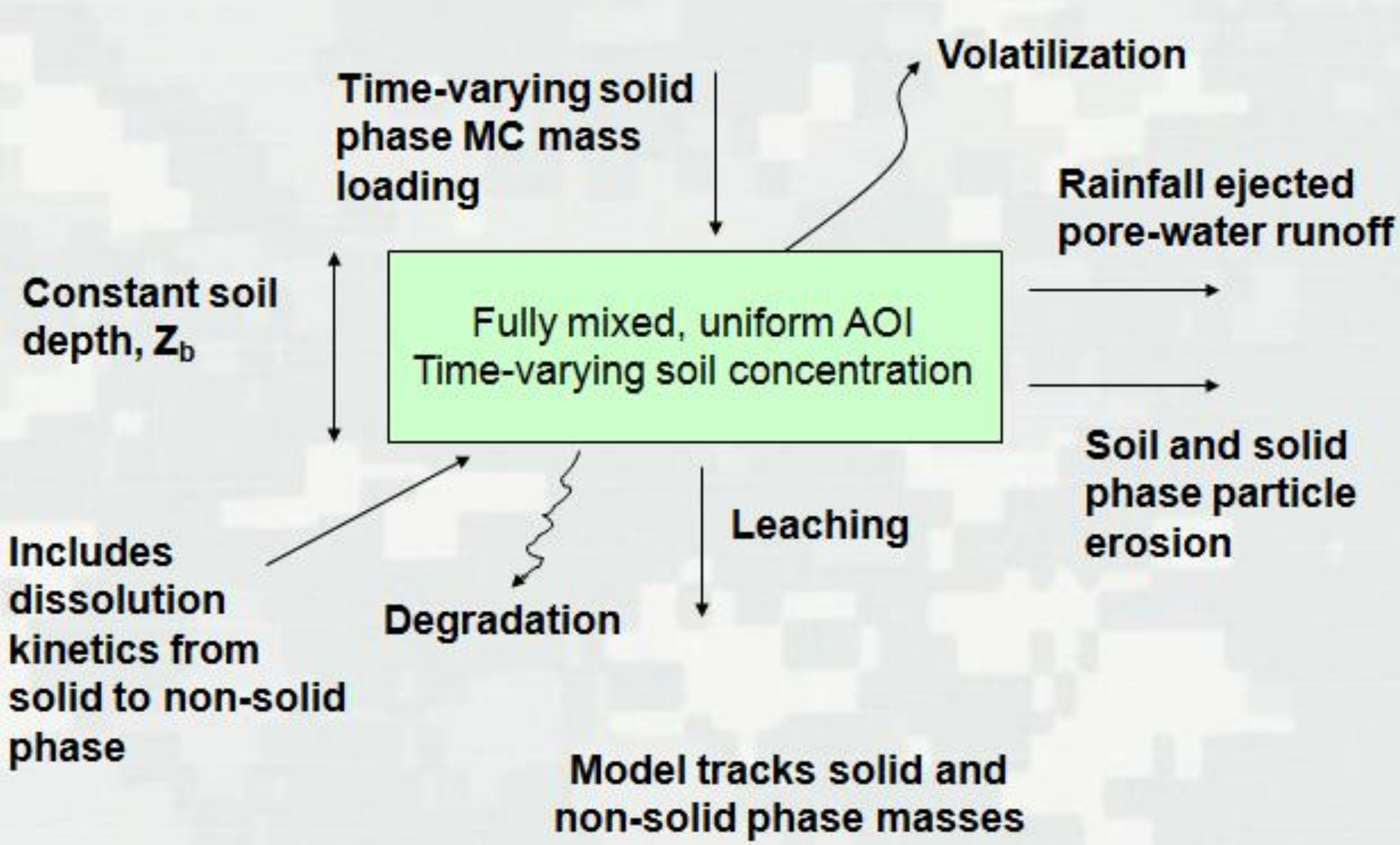
- Tier 2 (more comprehensive)
  - Time-varying, much more realistic and accurate
  - Requires more data
  - Requires more time to set up and apply, but still can be done relatively quickly
  - Can be used to determine when benchmark exceedence may occur
  - Useful for evaluating range management strategies

Tier 2 Conceptual Model

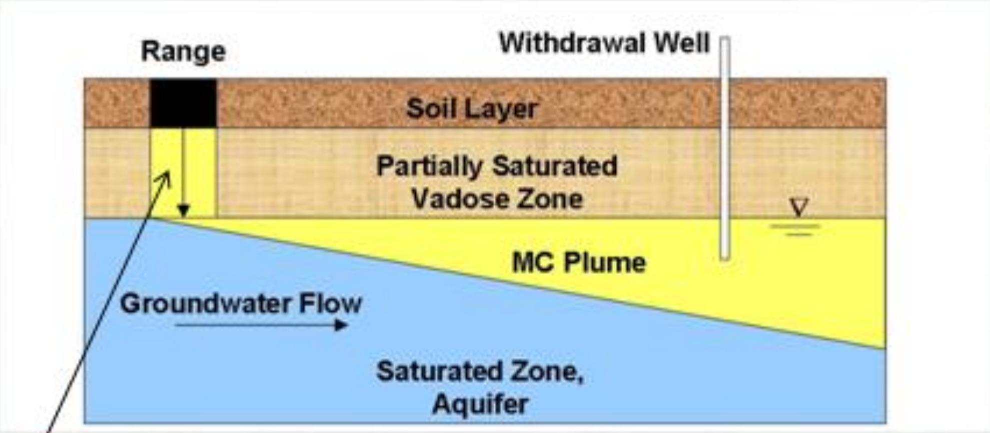


- Area of Interest (AOI) is homogeneous
- Inputs and model responses are time-varying
- There can be fate losses, such as degradation (1st order)
- Sorption is linear, reversible equilibrium
- Solid and non-solid phase mass are tracked with dissolution
- No losses between the AOI and receiving surface water for runoff/erosion and interflow
- Steady-state hydrologic inputs (average annual conditions) like Tier 1
- Vadose transport is 1D vertical

Soil Model (Tier 2)



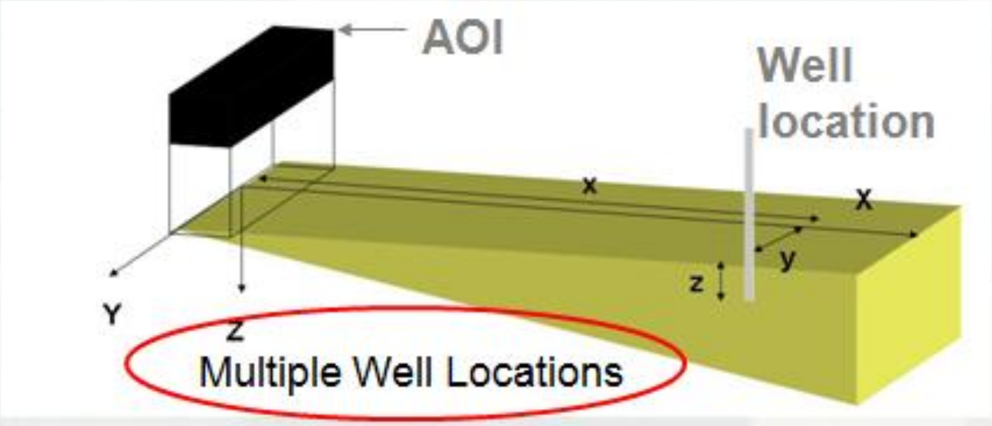
MEPAS Vadose & Aquifer Models (Tier 2)



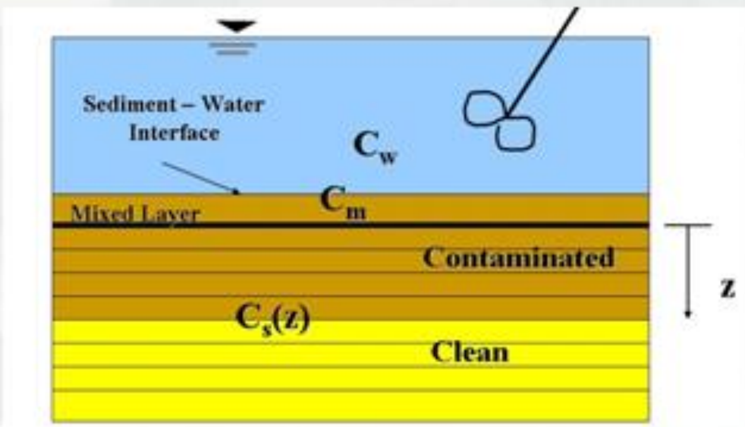
AOI length and width are input in Soil MUI

MEPAS coordinates

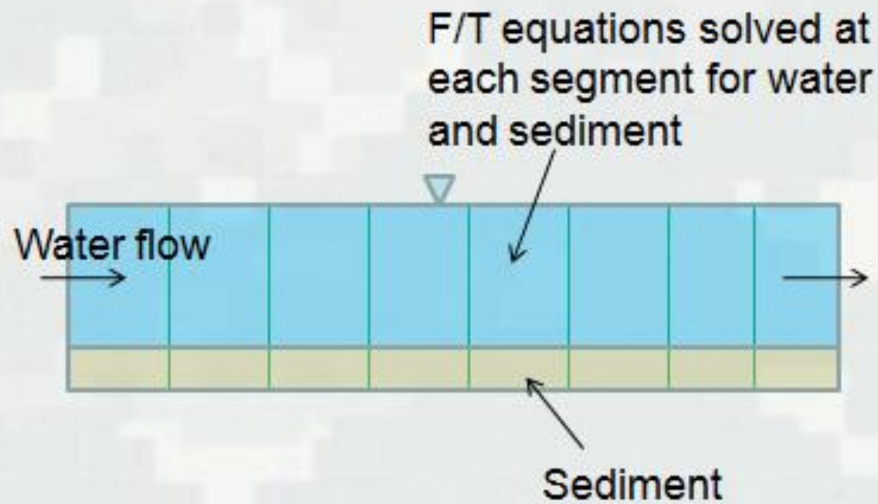
Vadose Zone included



Surface Water Models, RECOVERY and CMS



RECOVERY Model conceptualization

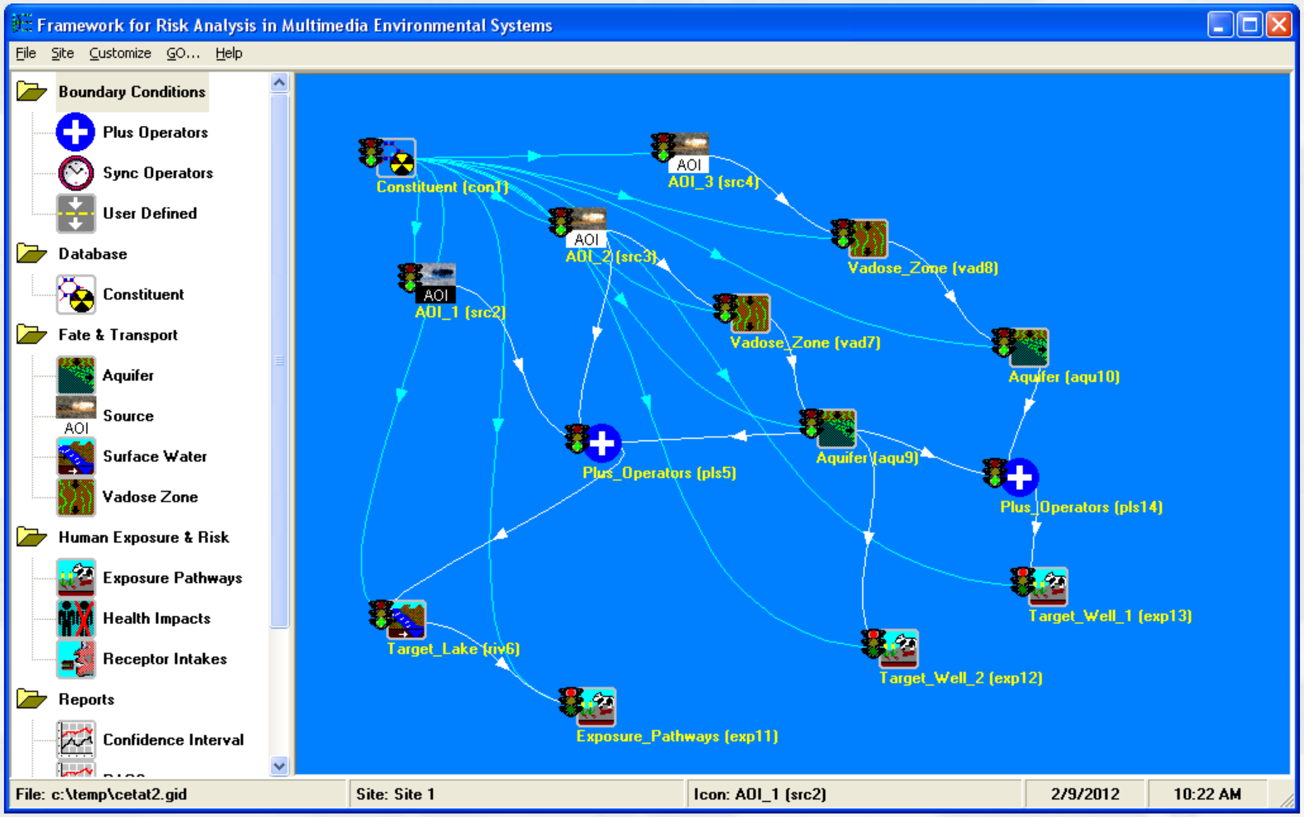


CMS conceptualization

Better for standing water, e.g., ponds, lakes

Better for flowing water, e.g., streams, rivers

Advanced Tier 2



- Multiple AOIs
- Complex Pathways
- Multiple Receptor locations
- Green Range BMPs

BMP Assessment Capabilities

- Source loading management (types and numbers of munitions fired and when fired, e.g., range rotation)
- Source removal from AOI
  - Soil removal
  - Burning
  - Phytoextraction
  - Selective chunk removal
- Source treatment within AOI (soil amendments and phytotransformation)
- AOI export treatment via sedimentation basin and/or degradation reactor and filter socks
- Down-gradient receiving water treatment

Validation Applications

- MMR, MA – Demo Area 2 for RDX in groundwater
- Fort AP Hill, VA – Impact area and SAFRs for RDX, TNT, perchlorate, lead, and copper in surface water, sediment, and groundwater
- West Point, NY – Medium and large caliber impact areas for RDX and SAFR for lead, all in surface water and sediment
- Fort Jackson, SC – SAFRs for lead, copper, zinc, and antimony in surface water and sediment
- Fort Leonard Wood, MO – SAFRs for lead in surface water and sediment

Validation Results

MC	Media	Computed, ppb	Observed, ppb
Lead	Lake sediment	3,550	6,000
copper	Lake sediment	1,900	2,900
RDX	GW	1.35	0.75 – 1.8
Lead	Pond sediment	30,100	30,300
RDX	Pond water	0.035	0.023
RDX	Drainage ditch water	1.13	0.77
RDX	Creek water	2.2	1.9
Lead	Pond sediment	1,214,000	257,000
Antimony	Pond sediment	3,000	32,000
Copper	Pond sediment	88,000	92,000
Zinc	Pond sediment	105,000	95,000

Also, there were computed values that agreed with observed values being below detection

Validation Results

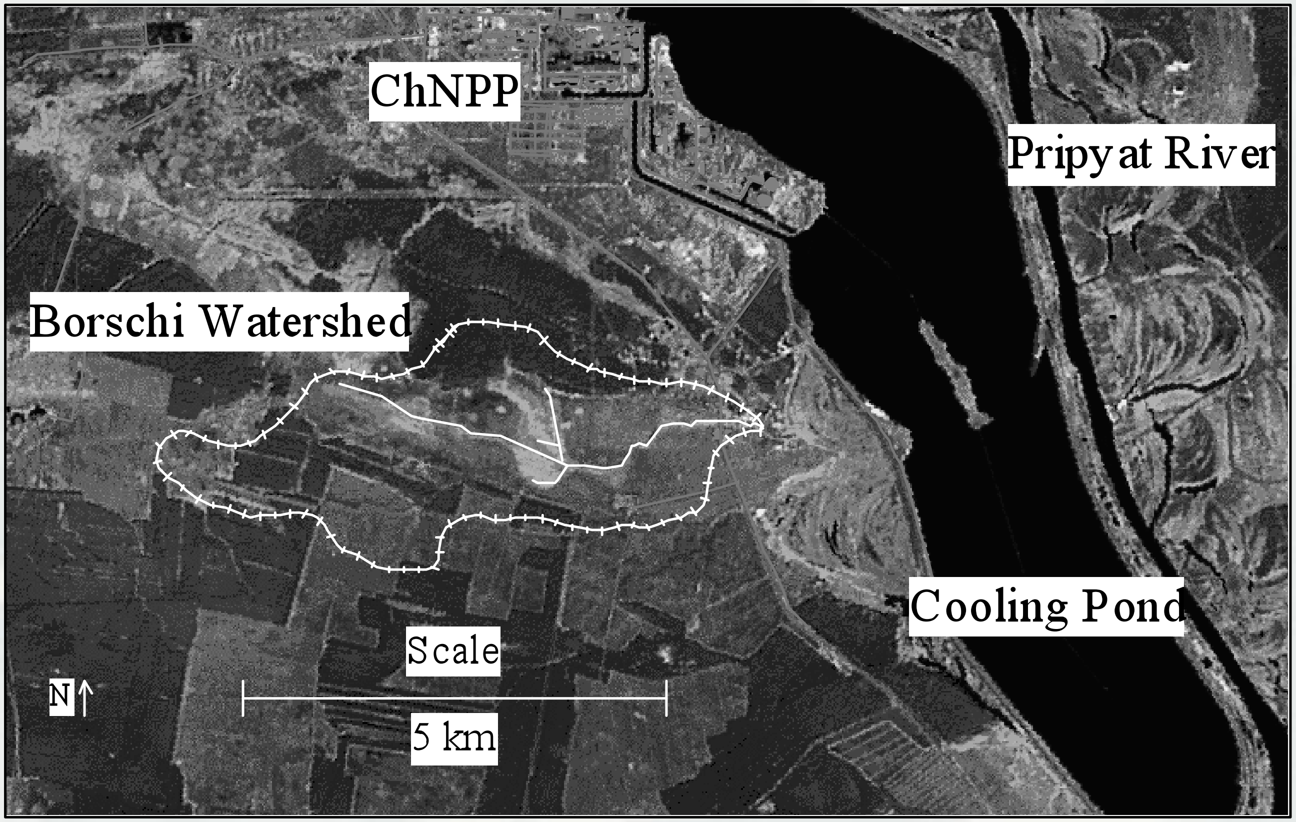
- All model results are within a factor of 4 or less of measured for all validations except antimony at Ft. Jackson which was off by a factor of 10
- Model results for HE and perchlorate were more accurate than for metals due to complexities associated with metal solubility and sorption

TREECS Input General Requirements

- MCs of interest and their properties
- Range munitions use and associated parameters
- Meteorology and hydrologic parameters
- Media properties/site-specific inputs (soil, vadose, groundwater, surface water, sediment)

Most applications require a few days to find information and assess for input, a few hours to set up the model, and a few days to make assorted runs and assess results. Models run within seconds, making Monte Carlo simulations practical.

Tier 2 Application to Borschi Watershed near Chernobyl for ^{90}Sr



This demonstrates the ability of the system to model legacy sites (Other than Operational Sites)

Borschi Watershed

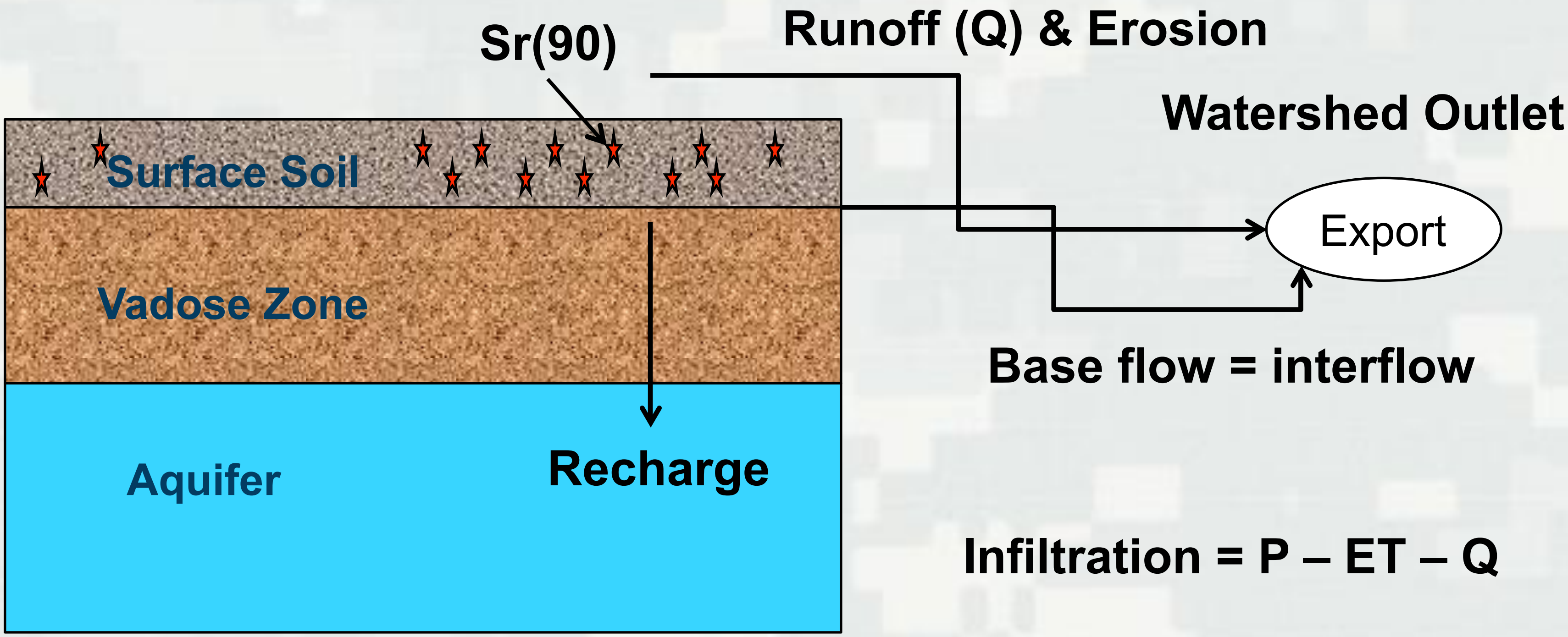
- 3 km south of CNNP
- 8.5 km^2
- Sandy soil underlain by clay marl
- Primarily formerly cultivated land and planted forests with two seasonal wetlands
- Flows into a cooling pond drainage ditch and then into the Pripyat River

Strontium-90 at Study Site

- Half life = 29 years
- Specific radioactivity = 143 Ci/g
- Approximate Borschi watershed inventory for year 2000 = 1.0 E13 Bq
- Watershed stream exit activity conc. (Bq/L) was monitored to estimate watershed export of 1.27 E10 to 1.62 E10 Bq/yr for 1999 – 2001, with average = 1.43 E10 Bq/yr, or <u>annual export of 0.14% of 2000 inventory</u>

Conceptual Site Model

AOI = Borschi Watershed



Infiltration = P – ET – Q

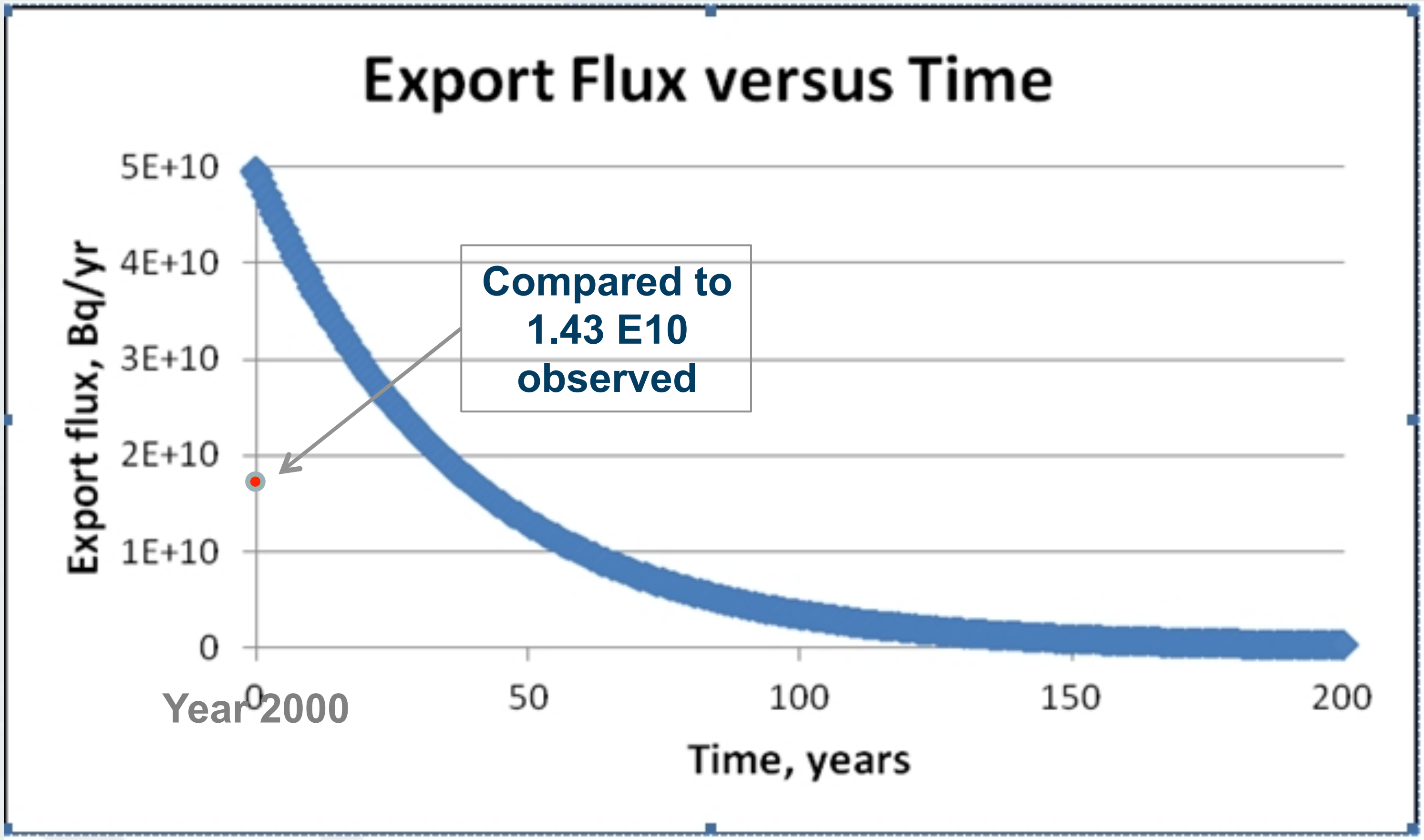
Infiltration = Recharge + Interflow

Model requires infiltration and % of infiltration going to interflow

Modeling Approach

- Only the Tier 2 soil model was needed (includes interflow pathway), recharge assumed lost
- No surface water model was used since watershed outlet is part of AOI or location of soil model export flux
- No AOI loading, only initial Sr inventory in 2000
- Information from site studies was used to estimate interflow, mobile/exchangeable fraction of Sr, and Sr partitioning to soil K_d

Computed Baseline Results



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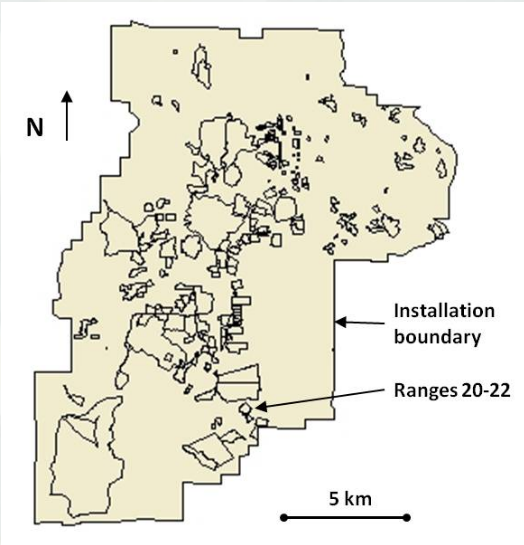
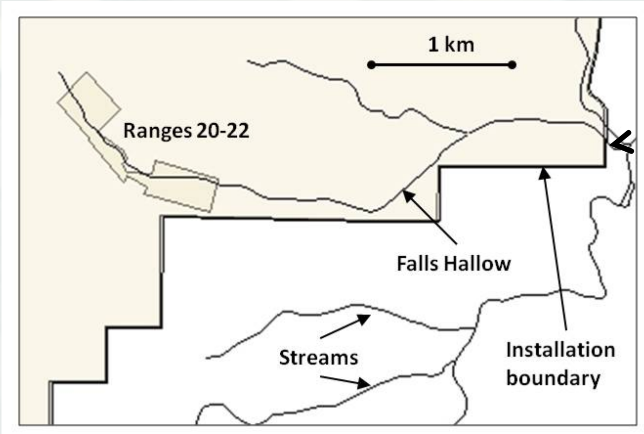
Borschi Conclusions

- Export of ^{90}Sr from the Borschi watershed to surface water is predominantly a result of soil pore water containing dissolved Sr being diverted to surface waters that eventually flow out of the watershed
- The percentage of non-exchangeable adsorbed Sr and the soil-water K_d are the two most sensitive and uncertain factors affecting the amount of export
- This application demonstrated how TREECS™ can be applied for a radionuclide

Application of TREECS to Ft. Leonard Wood, MO, for Lead Fate From SAFRs 20-22





Lead observation station at Falls Hallow bridge, 3.2 km from ranges

Document by ERDC TN-EQT-13-2

This study demonstrates the ability of the system to model an Operational Training Range

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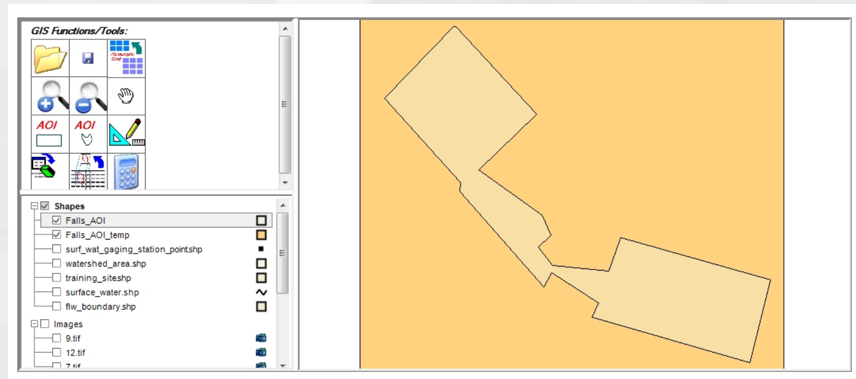
Application Procedure

- Used TREECS GIS to aid setting inputs, e.g., soils and erosion
- Used Tier 2 with surface water component
- Used Contaminant Model for Streams for surface water driven with average annual flow
- Applied site-specific inputs for soils, hydrology, etc.



TREECS GIS showing AOI

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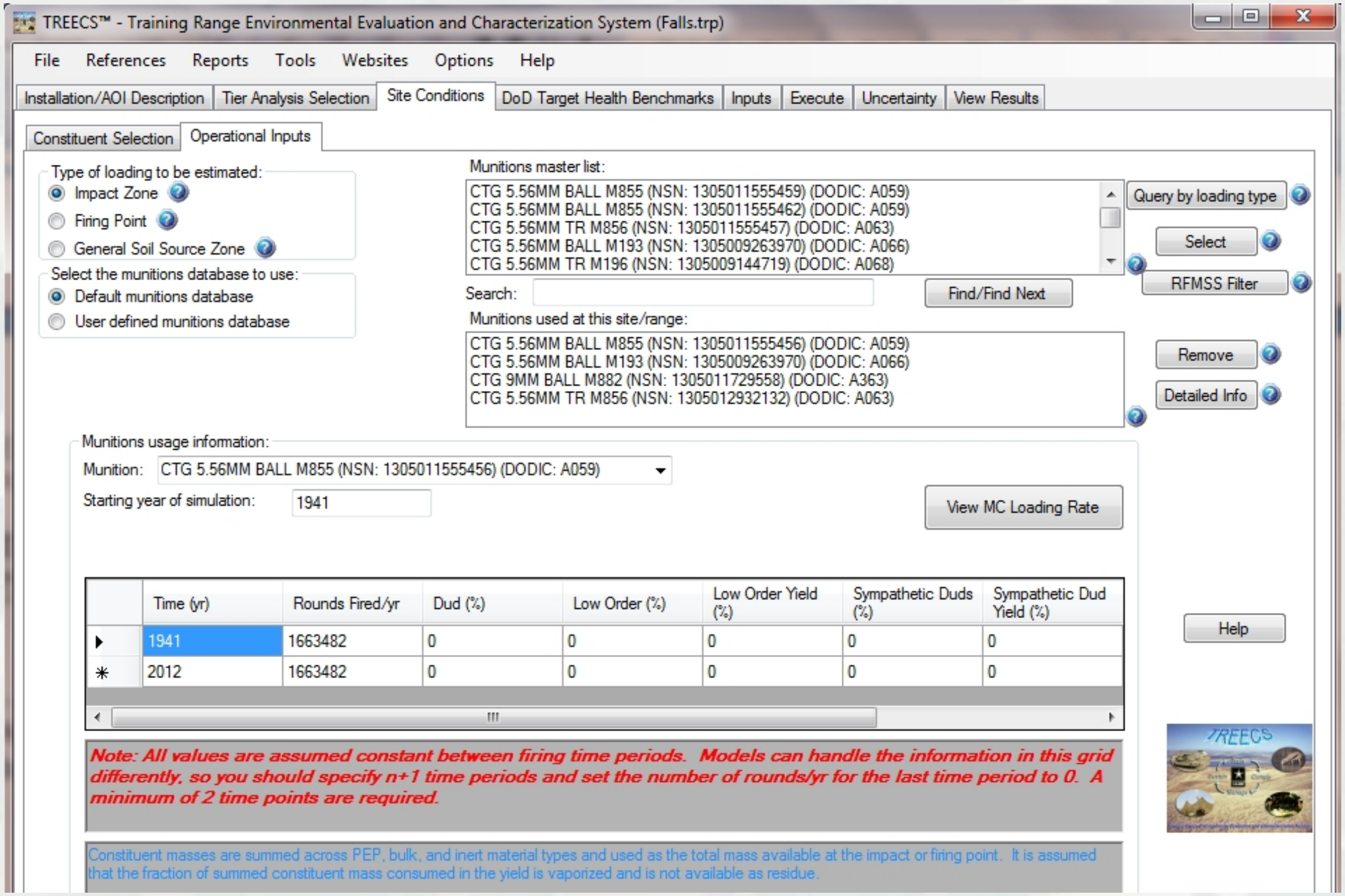
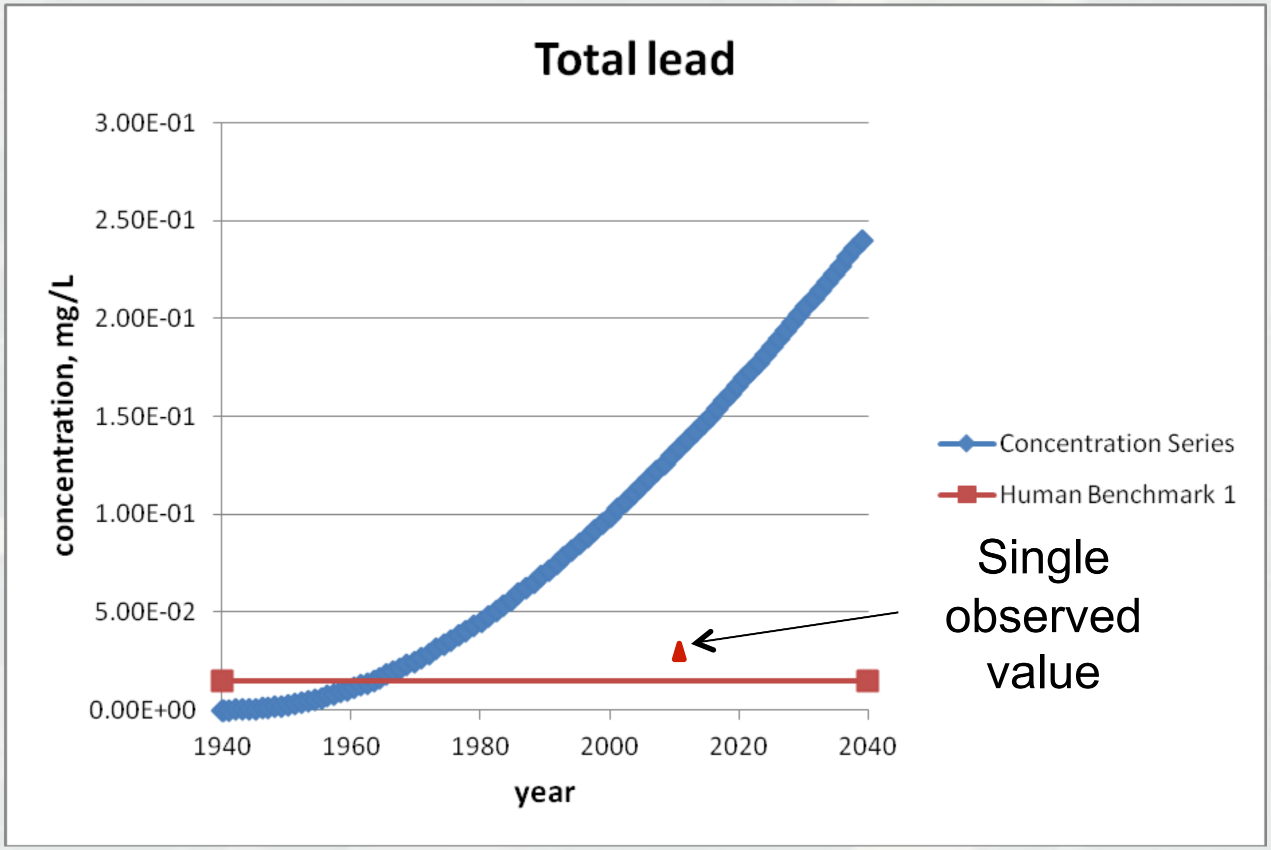
Key Input is Firing Records



- Used records for 1999-2012 to obtain average numbers fired/year
- Assumed same firing rates for 1941-2012

Computed Total Lead Concentration at Falls Hallow Observation Station



Leonard Wood Conclusions

- Computed lead concentration about 5 times observed, but represents an average annual value based on uniform firing rates over 70 years
- Solid lead mean particle size affects dissolution rate and is a highly uncertain input; value of 1 mm assumed; value of 5 mm dropped stream lead concentration five-fold
- Application demonstrated how available site information and other techniques can be used to readily assess MC fate for ranges

Benefits of using TREECS

- Allows the user to project future conditions
  - Answers the question of whether there will be a problem in the future, and if so, when, how much
- Can be used to develop and assess BMPs
- Can be used to help optimize and prioritize data collection sites for future assessment activities
- Can be used in designing new training ranges to help minimize migration of MC
- Is relatively easy to use with easily manageable and mostly available data requirements