



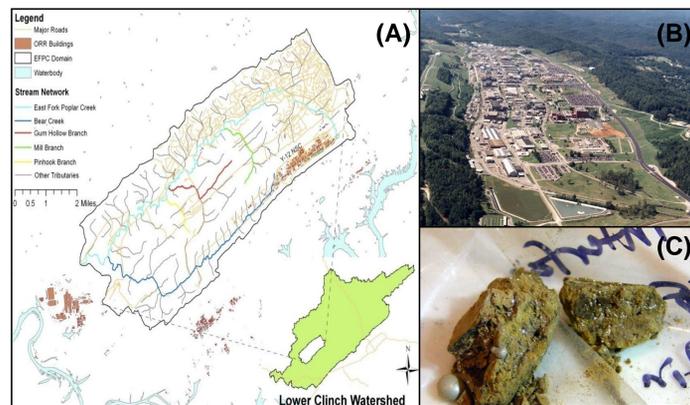
Improvements of an Integrated Flow and Mercury Transport Model in East Fork Poplar Creek Watershed, Oak Ridge, Tennessee



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Introduction

The environment in the vicinity of Y-12 National Security Complex (Y-12 NSC), Oak Ridge, TN has been contaminated by mercury due to nuclear processing activities during the 1950s. The contamination exists within the soil, shallow groundwater beneath and adjacent to former process buildings, storm sewers, drains, stream sediment, and surface water.



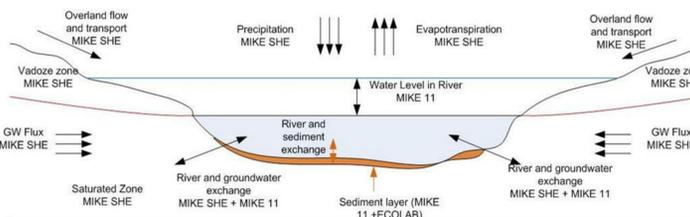
EFPC Watershed (A), Y-12 NSC (B), mercury contaminated soil (C)

Objective

Investigate the flow and transport of mercury in EFPC under the influence of a series of hydrologic events, to predict transport patterns within the watershed.

Numerical Model

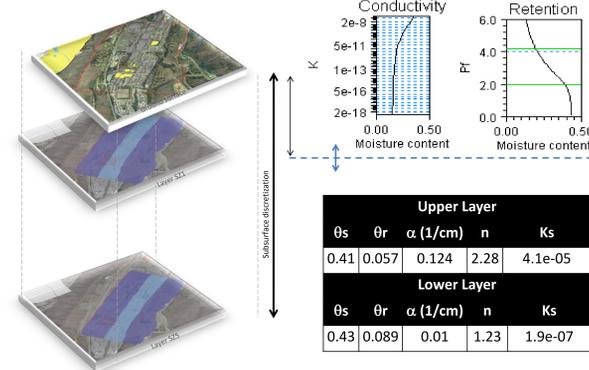
The model consists of MIKE 11, MIKESHE, and ECO-Lab. These components are designed to couple the watershed hydrology with mercury transport. MIKESHE describes the hydrologic processes using physical laws (conservation of mass, energy, and momentum). It is 2-D in the overland phase, 1-D in the unsaturated, and 3-D in the saturated and vadose layers. MIKE 11 details the river flow and transport model through the hydrodynamic and advection modules. ECO-Lab is an equation solver for the sedimentation and exchange of mercury within sediments, suspended particles, pore water, and dissolved mercury species.



Numerical model diagram depicting MIKE SHE, MIKE 11, and Eco-Lab.

Methodology

- Processed precipitation, discharges, total mercury, and methylmercury historical data from OREIS database.
- The water quality and sedimentation module was extended to include the entire EFPC, down to station EFK 6.4 and the Bear Creek.
- Update Van Genuchten's hydraulic conductivity and moisture content parameters for the upper and lower portions of the aquifer.



Model layers and soil properties

- Water quality, transport related, and sediment related parameters, such as carbon partitioning coefficient, adsorption rates of mercury species to sediment particles and water molecules, re-suspension rate of sediments, settling velocity of suspended particles, and critical current velocity for sediment re-suspension will be estimated from literature.

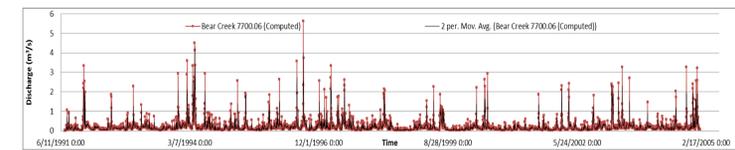
State Variables	Value	Constants	Value
Mercury	0.01 mg/l	Organic-carbon partitioning coefficient	50000 l/kg
Adsorbed mercury	0.1 mg/l	Desorption rate in water	1 day ⁻¹
Dissolved mercury in sediment pore water	0.1 g/m ²	Desorption rate in sediment	0.1 day ⁻¹
Adsorbed mercury in sediment	10 g/m ²	Fraction of organic carbon in SS	0.1
Suspended solids	50 mg/l	Fraction of organic carbon in sediment	0.2
Mass of sediment	10000 g/m ²	Thickness of water film	0.1 mm
Forcing		Mole weight of heavy metal	92 g/mole
Thickness	2 m	Density of dry sediment	250 kg/m ³ bulk
computational grid layer	8 m	Porosity of sediment	0.8 m ³ H ₂ O / m ³ Bulk
Total water depth	0.2 m/s	Settling velocity of SS	0.1 m/day

ECOLAB state variables, constants, and forcing

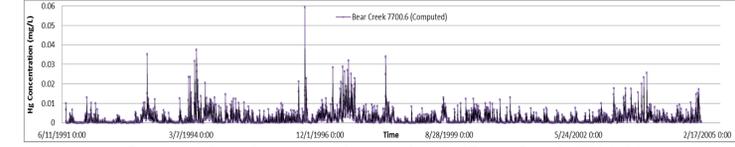
- Simulations executed for a range of input parameters to correlate stochastic hydrologic events with mercury distribution patterns.

Results

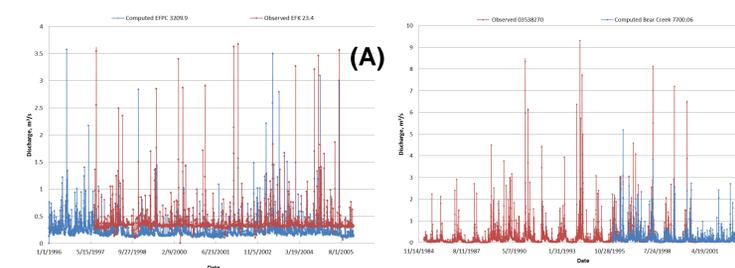
Successfully executed a 15 year simulation (1991 – 2005) for water movement and water quality, including Eco-Lab to assess the impact of the hydraulic parameters and determine the best fit with observed data.



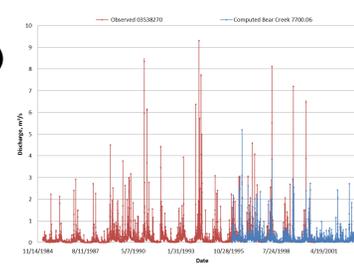
Computed discharge time-series for Bear Creek 7700.06



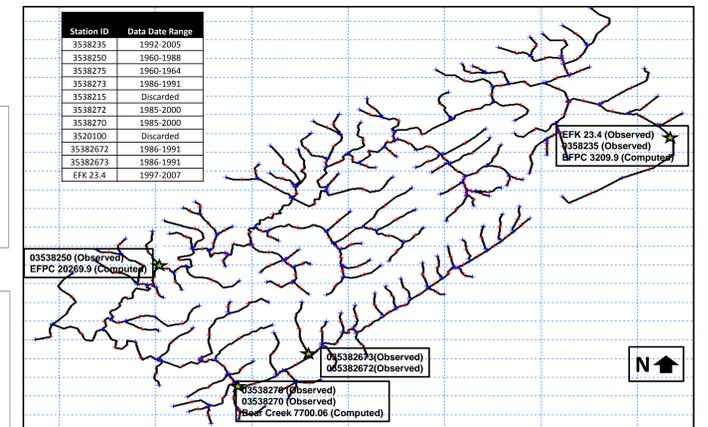
Computed total mercury time-series for Bear Creek 7700.06



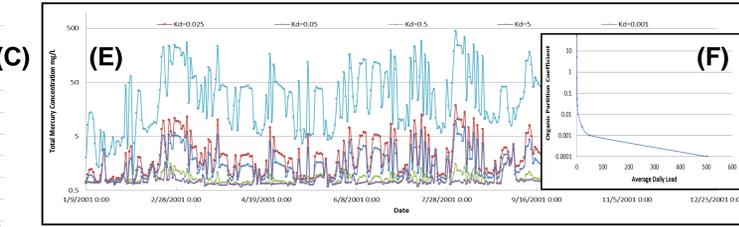
Comparison of computed discharges (A) & probability exceedance curves (B) at EFPC 3209.9 & field station EFK 23.4



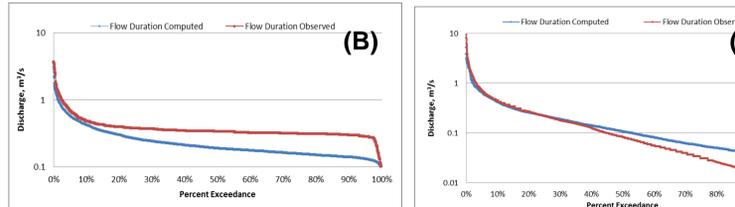
Comparison of computed discharges (C) & probability exceedance curves (D) at Bear Creek 7700.06 and field station 03538270



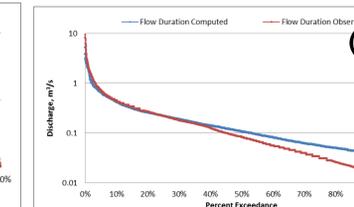
Model network depicting tributaries, computational nodes, and field stations.



Total mercury time series depicting sensitivity to organic partition coefficient (K_d) for various simulations (E) & pattern observed between average daily loads and K_d (F)



Load duration curves downstream EFPC



Load duration curves downstream Bear Creek

Conclusions

- Mercury attenuates downstream of EFPC
- Sediment-mercury interactions significantly affect Hg transport.
- High flow conditions re-suspend mercury particulates increasing concentration in the creek.
- Total mercury concentrations appear sensitive to the organic partition coefficient introduced via the water quality module.

References

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- Elsa Cabrejo, 2010, Mercury Interaction with Suspended Solids at the Upper East Fork Poplar Creek, Oak Ridge, TN, Florida International University, Environmental Eng. Dept., Master Thesis
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