KRCEE PGDP GW Model Activities

Independent Reviews, Applications & Recommendations

University of Kentucky

Kentucky Research Consortium for Energy and Environment (KRCEE)

Kentucky Water Resources Research Institute (KWRRI)

Kentucky Geological Survey (KGS)

Department of Civil Engineering (UKCE)

Department of Earth and Environmental Sciences (UKEES)

UK - KRCEE Historical Groundwater Model Activities

1. **Mid – Late 1990's** – KYRHB (KY Radiation Health Branch) + KYRHB-AIP, UKCE
   - Reviews and runs of PGDP 1994 GW Flow & Transport Models
2. **Late 1990's to early 2000's** – UKCE + KYRHB + KYRHB-AIP + KRCEE
   - Preliminary reviews and runs of PGDP 1998 GW Flow & Transport Models
3. **2003 to 2007** – KRCEE + KWRRI + UKCE + KGS + SAIC
   - Formal Review & Evaluation of PGDP 1998 GW Flow & Transport Models
   - Application of 1998 GW Flow & Transport Models for *Property Acquisition Study (KRCEE, 2007)* Congressional Report
4. **2006 to 2010** – KRCEE
   - Participation in PGDP 2008 GW Flow & Transport Model Update Development Team
5. **2010 to 2011** – KWRRI + KGS + UKCE + UKEES (note: no 'KRCEE')
   - Independent review of the 2008 PGDP GW Flow & Transport Models*

*Underlined Topics Covered in this Presentation

UK - KRCEE Historical Groundwater Model Activities (cont'd)

6. **2011** – KRCEE + KGS + UKCE + UKEES
   - Property Acquisition Study GW Modeling Update
   - Updated Study outcomes utilizing PGDP 2008 GW Flow & Transport Models
7. **2012 to 2016** - KRCEE
   - Participation in PGDP 2016 GW Flow & Transport Model Update Development Team
8. **2016 to 2017** - KWRRI + KGS + UKCE + UKEES (note: no "KRCEE")
   - Independent review of the 2016 PGDP GW Flow Model
9. **2018 to 2020** – KGS
   - Development of 'Interim Transport Model' utilizing 2016 PGDP GW Flow Model
10. **2016 to Present** - KRCEE
    - Participation in PGDP GW Modeling Project Team activities

*Underlined Topics Covered in this Presentation

KRCEE Independent Groundwater Model Reviews:

Independent PGDP GW Flow Model Reviews

Method - Same for 2008 Flow & Transport & 2016 Flow Models

1. Obtain Model Documents
2. Obtain Model Inputs
3. Review Model Documents
   - Model Objectives
   - Modeling Software (Core Flow Model +/- Modules + Transport Model + GUI)
   - Configuration (Flow System Discretization, Domain, Boundaries/Boundary Types)
   - Calibration (Target Data & Residuals)
   - Verification/Validation (Outcomes)
4. Meet and Discuss Observations
5. Run Model(s)
   - Verify Outputs
6. Meet and Discuss Observations
   - Discuss Recommendations
7. Write Summary, Recommendations & Submit to PPPO

KRCEE Independent Groundwater Model Reviews:

2008 GW Flow Model Review

Software - MODFLOW 2000 , PEST, GW Vistas

Steady State Model

Configuration

1. Domain – Ohio River north, PCC Terrace 315' amsl south, east & west SW divides
   a. RGA only - Exclude UCRS & McNairy[1]
   b. 3 equal layers based on local thickness
      i. Top Layer 1 = Bottom UCRS = Recharge Boundary
      ii. Bottom Layer 3 = Bottom RGA/Top McN Flow System = No Flow Boundary
2. Grid – 50' minimum telescopic mesh to 425'
3. Boundaries
   a. Ohio River - Drain Cells – all 3 layers - Stage 297 feet
4. PCC & east/west surface water divides – No Flow Boundary
5. LBC/BBC – Recharge Cells by reach
6. Metropolis Lake – 'pass through' – Layer 1 (K=50,000 ft/day)
7. Site industrial area relatively simple area recharge zonation – single zone offsite

KRCEE Independent Groundwater Model Reviews:

2008 GW Flow Model Review

Calibration

1. 1 Stress Period
2. Targets - 3 data types used
    a. Water Level Targets - 76 - all February 1995 (Layer 1 = 44; Layer 2 = 20; Layer 3 = 12)
    b. Flux Targets – Ohio River – 4837 gpm
    c. Angle Targets – 1704
        • Based on plume trajectories
3. Parameter estimation (K, Recharge & Flux)
    a. K estimated with PEST using specified pilot points
    b. Recharge – zoned on site/1 zone off site based on precipitation recharge

Results

1. Produced reasonable matches to WLE & potentiometric surfaces
2. Produced reasonable matches to targets (Flux & Angle)

KRCEE Independent Groundwater Model Reviews:

2008 GW Transport Model (MT3D)

Configuration

1. Utilized flow field/fluxes from 2008 MODFLOW Model
2. Transport parameters homogeneous (porosity, bulk density, K_d, half-life, dispersivities)
3. Utilized Finite Difference solution scheme
4. Simulated release/migration history
5. Handled 99Tc and TCE as separate model runs

Calibration

1. First step was estimation of TCE half-life
    a. 10-year half-life estimation based on trial runs of 6, 10 and 16 years
2. Followed by calibration & integration of individual NE, SW, NW Plume runs
    a. Varied spatial and temporal source loads
    b. Targets for NW and SW Plumes were monitored geometries
    c. Targets for NEP were concentration data from a few monitoring wells

KRCEE Independent Groundwater Model Reviews:

2008 GW Flow & Transport Models Review

Review Summary

1. Handling of boundary features based on relative aquifer functions reasonable
2. Auto calibration utilizing PEST achieved reasonable matches to targets
3. Manual adjustment of source and temporal loads achieved reasonable matches to plume geometries (Transport Model)

Review Recommendations

1. Incorporate stratigraphy materials properties to constrain flow model calibration
2. Incorporate site leakage to constrain anthropogenic recharge using upper and lower bounds
3. Calculate flow model w/o SVD to improve spatial distribution of K
4. Add pilot points to future plume flow paths to improve K estimation
5. Re-calibrate the NE TCE plume. Use strategy applied to NW and SW plumes
6. Investigate mass migration into McN by adding a layer beneath RGA Layer 3
7. Consider independent evaluation of UCRS and Terrace Gravels as sources of UCRS recharge

KRCEE Independent Groundwater Model Reviews:

2016 GW Flow & Transport Models Review

Software - MODFLOW 2005 , PEST, PEST-SVD, GW Vistas

Configuration (changes from 2008 Flow Model)

1. Domain – Southern model boundary revised to reflect areal changes to aquifer
2. Grid – remained 50’
3. Boundaries
    a. Ohio River – changed to River Cell Boundary
    b. East/west surface water divides – remained No Flow Boundaries
    c. LBC/BBC – Lower reaches of each changed to River Cell Boundary
4. SP2 included two pump and treat sites (combined 411 gpm)
5. Metropolis Lake remained ‘pass through’ – Layer 1 (K=50,000 ft/day)

KRCEE Independent Groundwater Model Reviews:

2016 GW Flow & Transport Models Review

Calibration (same method as 2008 flow model)

1. Stress periods calibrated independently
   a. SP1 'Plant Operating w/o Pump & Treat' calibrated to February 1995
   b. SP2 'Plant Shutdown with Pump & Treat' calibrated to September 2014 Targets
   c. 3 data types used both stress periods
      1. Water Level Targets = 76 (February 1995) & SP2 = 76 (September 2014)
      2. Flux Targets – Changed
         i. Targeted seepage measurements from LBC lower reaches
         ii. Ohio River Flux handled as minimal influence target in SP2
      3. Angle Targets – utilized in both SP1 and SP2
2. Parameter estimation (K, Recharge & Flux)
   a. K estimated with PEST using specified pilot points for each stress period
   b. SP2 Recharge – zoned on site relative to updated data analysis ~ 1 zone off site

Results - SP1 and SP2 calibration runs produced reasonable matches to SP1 & SP2 water level targets

KRCEE Independent Groundwater Model Reviews:

2016 GW Flow Model Review

Summary

1. Recent site data added and recalibrated to two stress periods however there is inconsistency in model calibration & verification
2. SP1 (February 1995) conceptualized at higher water level than SP2 (September 2014)
   a. SP2 total inflow 18% > SP1 total inflow.
   b. Not consistent with Site Conceptual Model as SP2 should have lower total flow
3. 2016 SP1 calibrated to same targets as 2008 flow model but with different total flows
   a. 2008 total inflow 5384 gpm versus 2480 gpm in 2016 SP1
   b. Predicts much slower gw flow in 2016 model than 2008 model which will be a transport problem (see ITM slide 2008)
   c. Suggest better understanding of groundwater basin water budget is needed
4. 2016 model update evaluated by running model with varying Ohio River stages.
   a. Hydraulic gradients did not capture responses to stage variation
   b. Suggest ambient and anthropogenic recharge also impacting gradients
5. Supplemental transient calibration for pump test showed systematic bias.

KRCEE Independent Groundwater Model Reviews:

2016 GW Flow Model Review

Suggestions

1. Revisit calibration of 2016 Flow Model
2. Focus future efforts on transient models utilizing initial conditions from updated flow model

Prologue:

THE FOLLOWING SLIDES for Interim Model

KRCEE Independent Groundwater Model Reviews:
Interim Transport Model Evaluation

Background

The 2016 model produced a groundwater flow field with a smaller total discharge than the 2008 flow model produced. The goal of this modeling activity is to evaluate impacts of changes in the flow field on simulating TCE plume migration history.

Objectives

1. Incorporate the 2008 transport model parameters into the 2016 flow model.
2. Simulate TCE plume migration for the period of 1966-2008.
3. Compare simulated TCE plume migration with results from the 2008 transport model (and with published/distributed site interpretations of plume concentration extents).*

Interim Model Configuration

- Expand stress periods to cover a period from 1966 to 2008;
- Incorporate 2008 TCE transport model parameters, including density, porosity, TCE distribution coefficient, TCE biodegradation parameter, and dispersivity values
- Incorporate 2008 TCE transport model TCE source terms, including first type TCE boundary for RGA, and secondary type TCE boundary for UCRS;

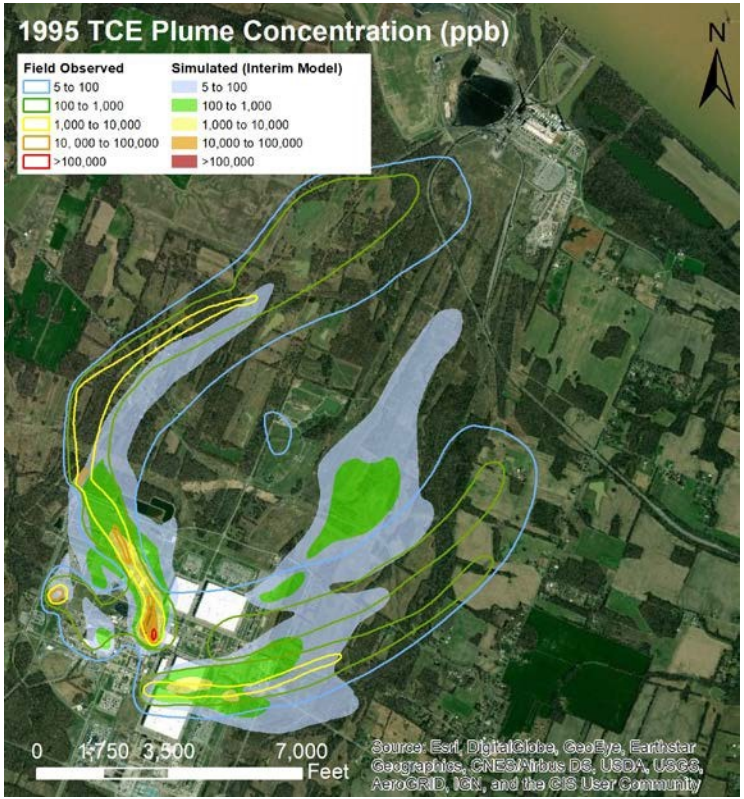
- Further extend the interim model simulation period to 2018, so that the model result can be compared with latest field data.
- Extend the 2008 model simulation period to 2018 for comparison

Preliminary Model Result Comparison

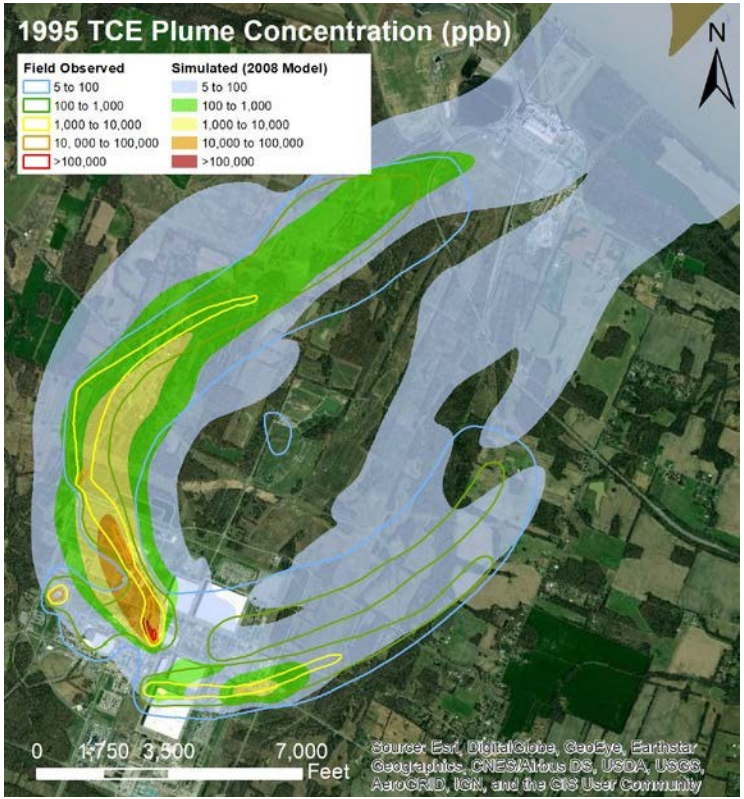
*Simulated results from this activity are illustrated in the following slides as ‘Interim Model’.
*Each ‘Interim Model’ result is illustrated adjacent to it’s corresponding 2008 (Transport) Model result.
*Published/distributed site plume interpretations based upon field monitoring are identified as ‘Field Observed’ on the following Interim Model and 2008 Model figures.

Compare Model Results:1995

Interim Model

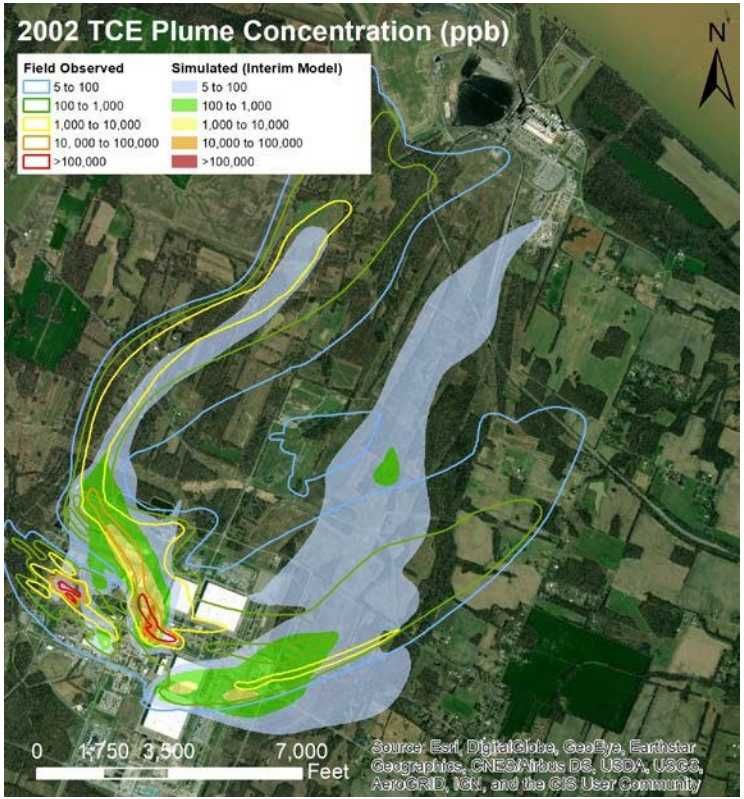


2008 Model

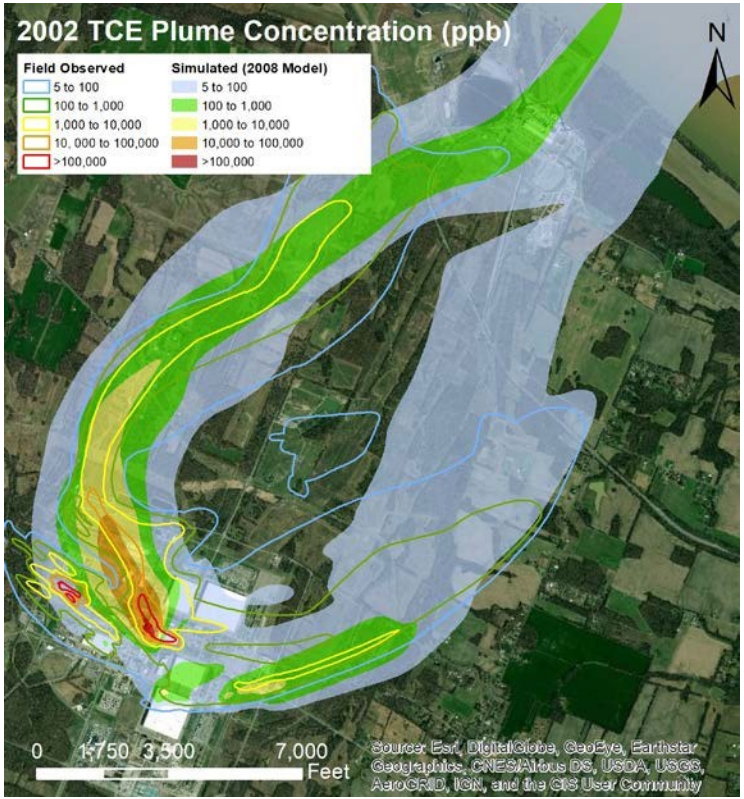


Compare Model Results:2002

Interim Model

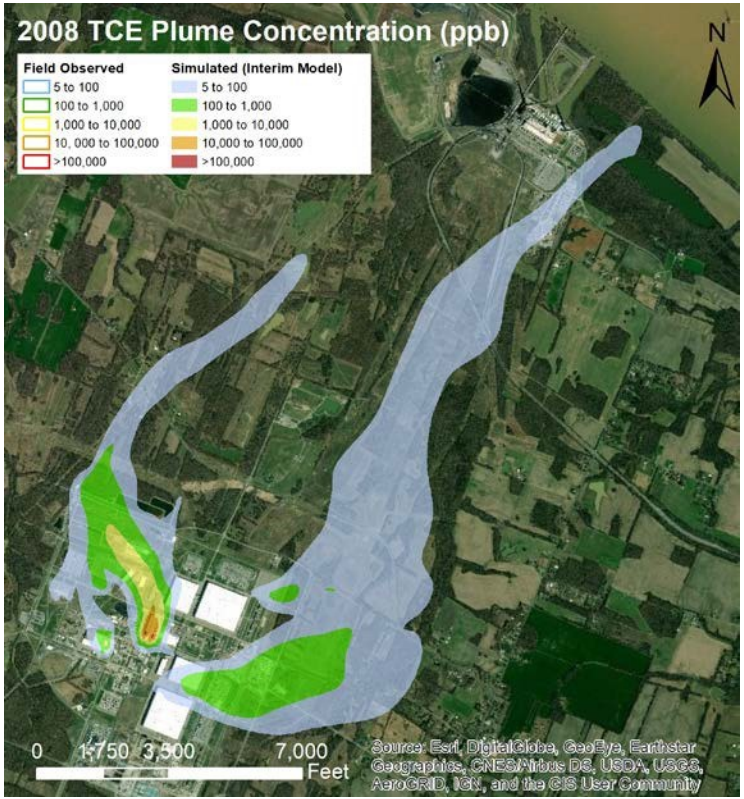


2008 Model

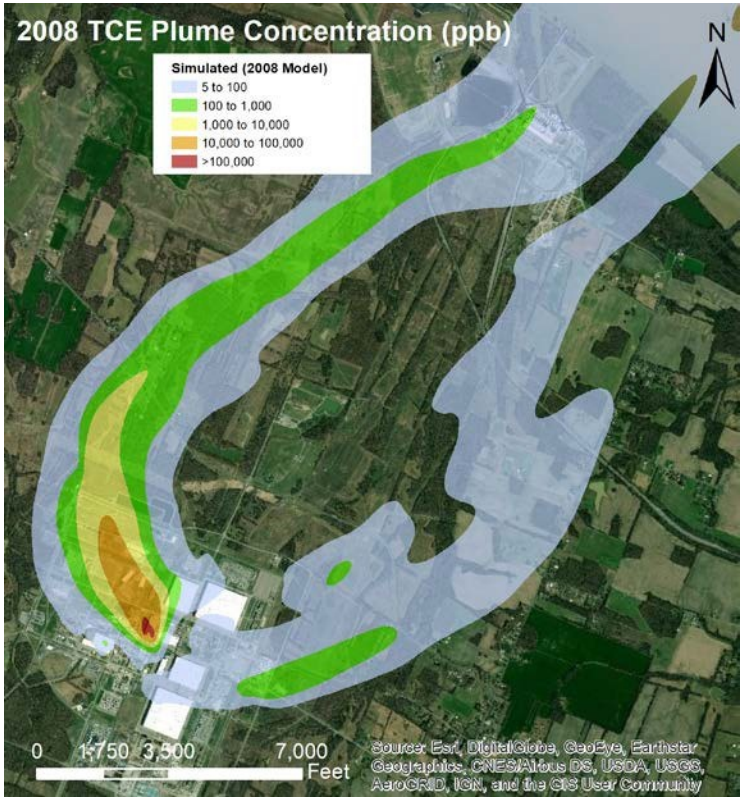


Compare Model Results:2008

Interim Model

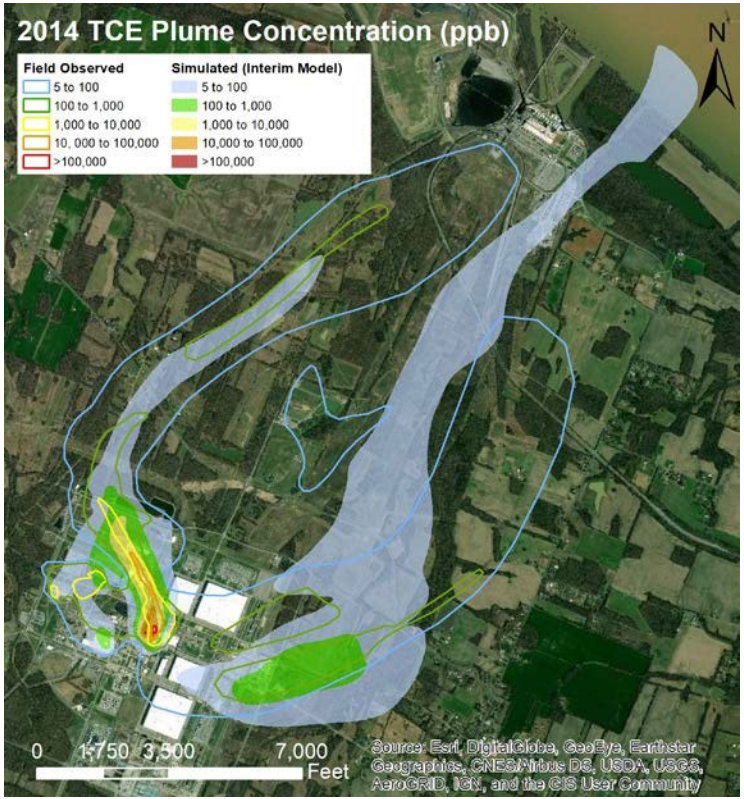


2008 Model

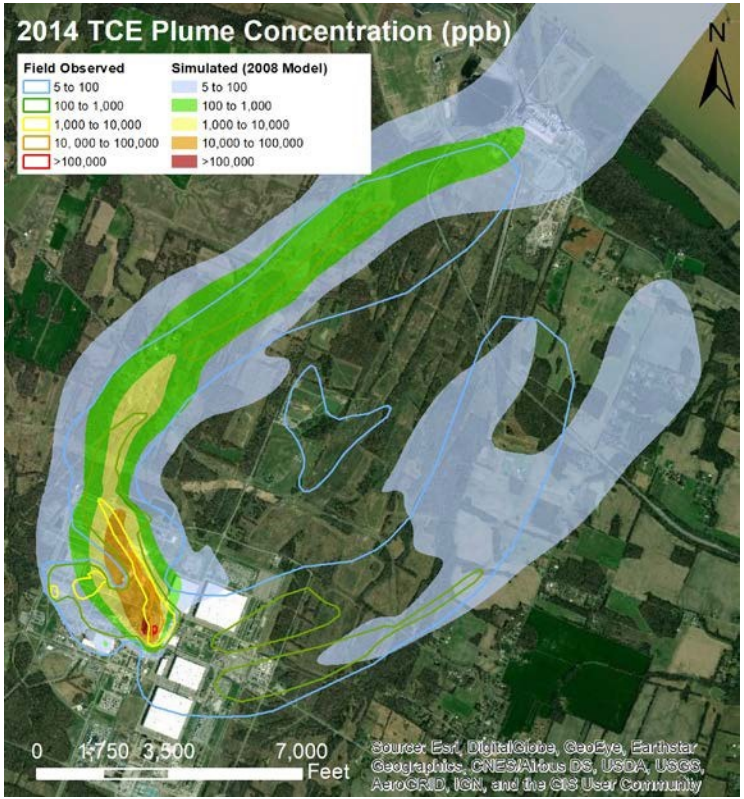


Compare Model Results:2014

Interim Model

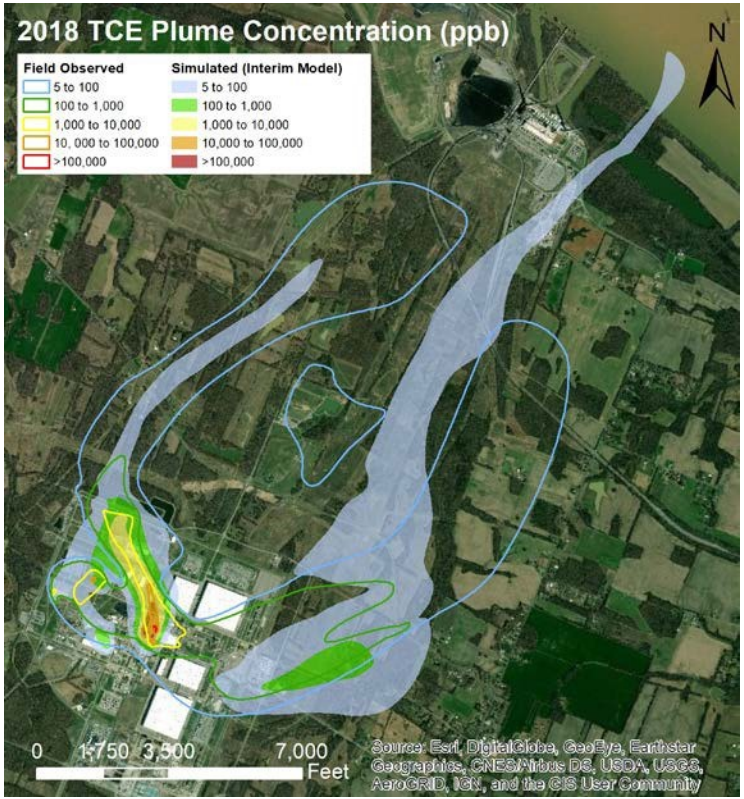


2008 Model



Compare Model Results:2018

Interim Model



2008 Model