RiverSpill and the Incident Command Tool for Drinking Water Protection

A case study of the WV chemical spill

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Drinking Water Protection

- After a release of hazardous materials into a river or stream environment, drinking water protection and contamination risk mitigation require that information on the fate of waterborne contaminants be made available quickly to decision makers.
- On January 9, 2014, an estimated 10,000 gallons of 4-methylcyclohexane methanol (MCHM), which is used in coal processing, leaked from a ruptured container into the Elk River.
- The spill, just one mile upstream from a water-treatment plant, forced officials to ban residents and businesses in nine West Virginia counties from drinking the water.
- Downstream water utilities were also concerned about potential contamination.

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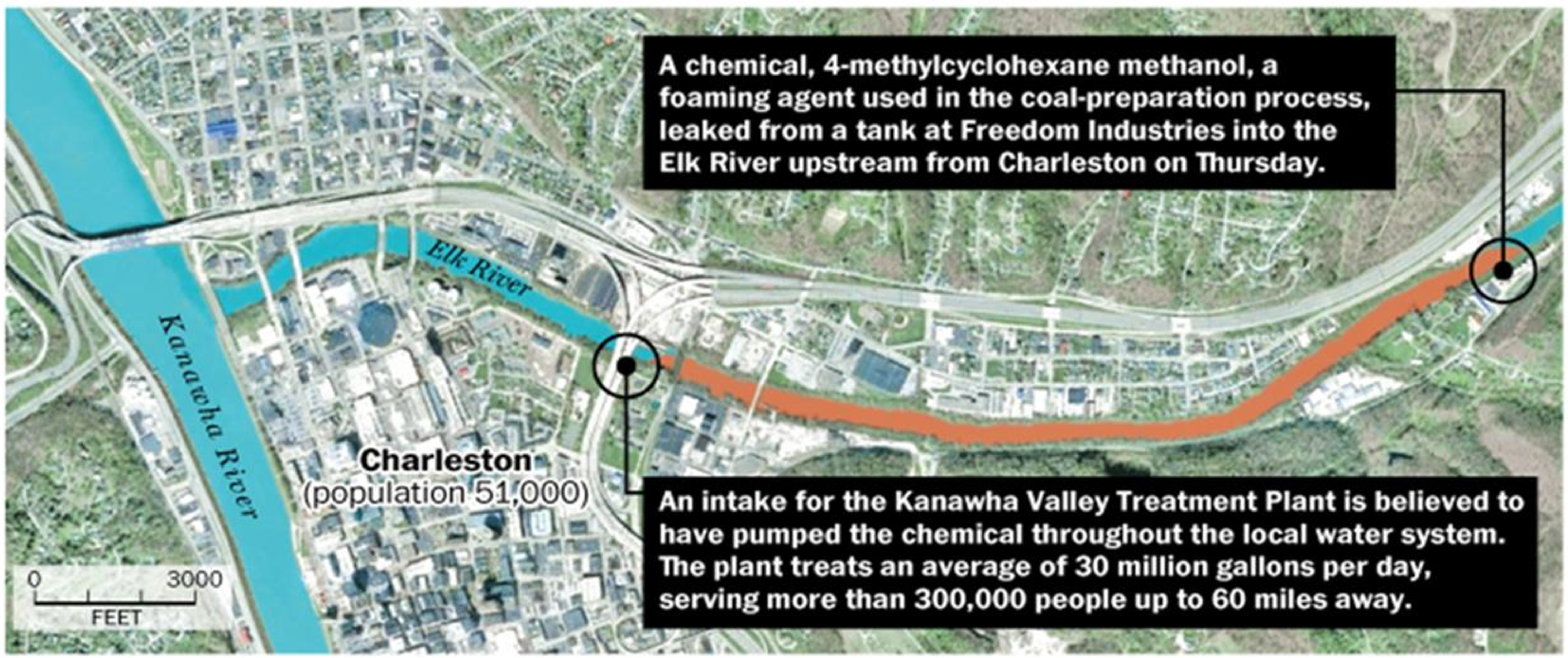
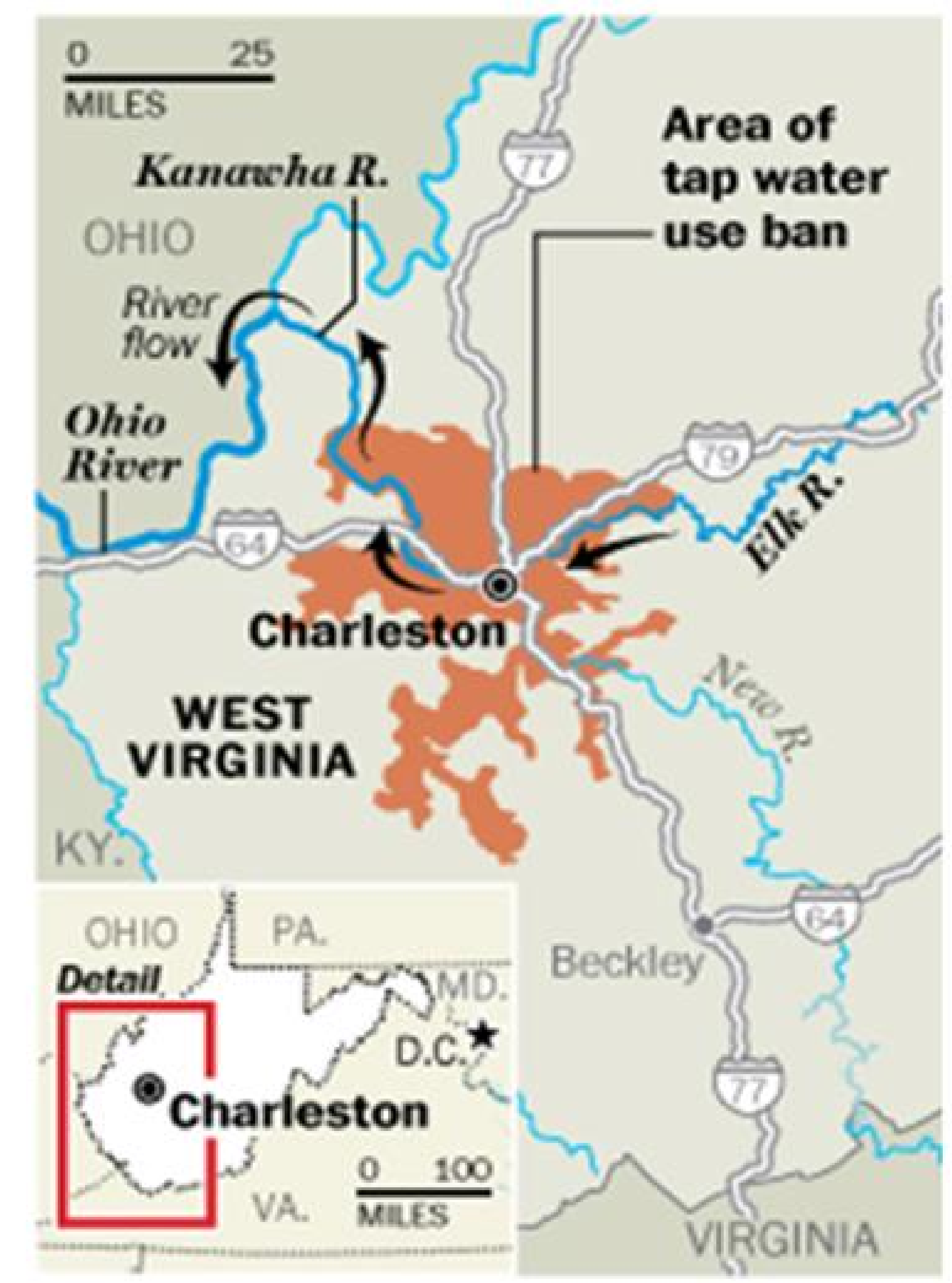
Chemical spill threatens thousands

A chemical, 4-methylcyclohexane methanol, a foaming agent, used in the coal-preparation process, leaked from a tank at Freedom Industries into the Elk River upstream from Charleston on Thursday. Read related article.





Population affected:

- Total population: 294,350; of that 65,237 are children
- 123,451 households
- Median household income is $47,191 (W.Va. average is $40,400)
- Number of families: 78,856; of those 8,445 in poverty; poverty rate 10.7 percent (W. Va. average is 12.8 percent)

Source: Google Earth and the U.S. Census Bureau. Gene Thorpe/The Washington Post. Published on January 10, 2014, 7:45 p.m.

Chemical Storage Tanks

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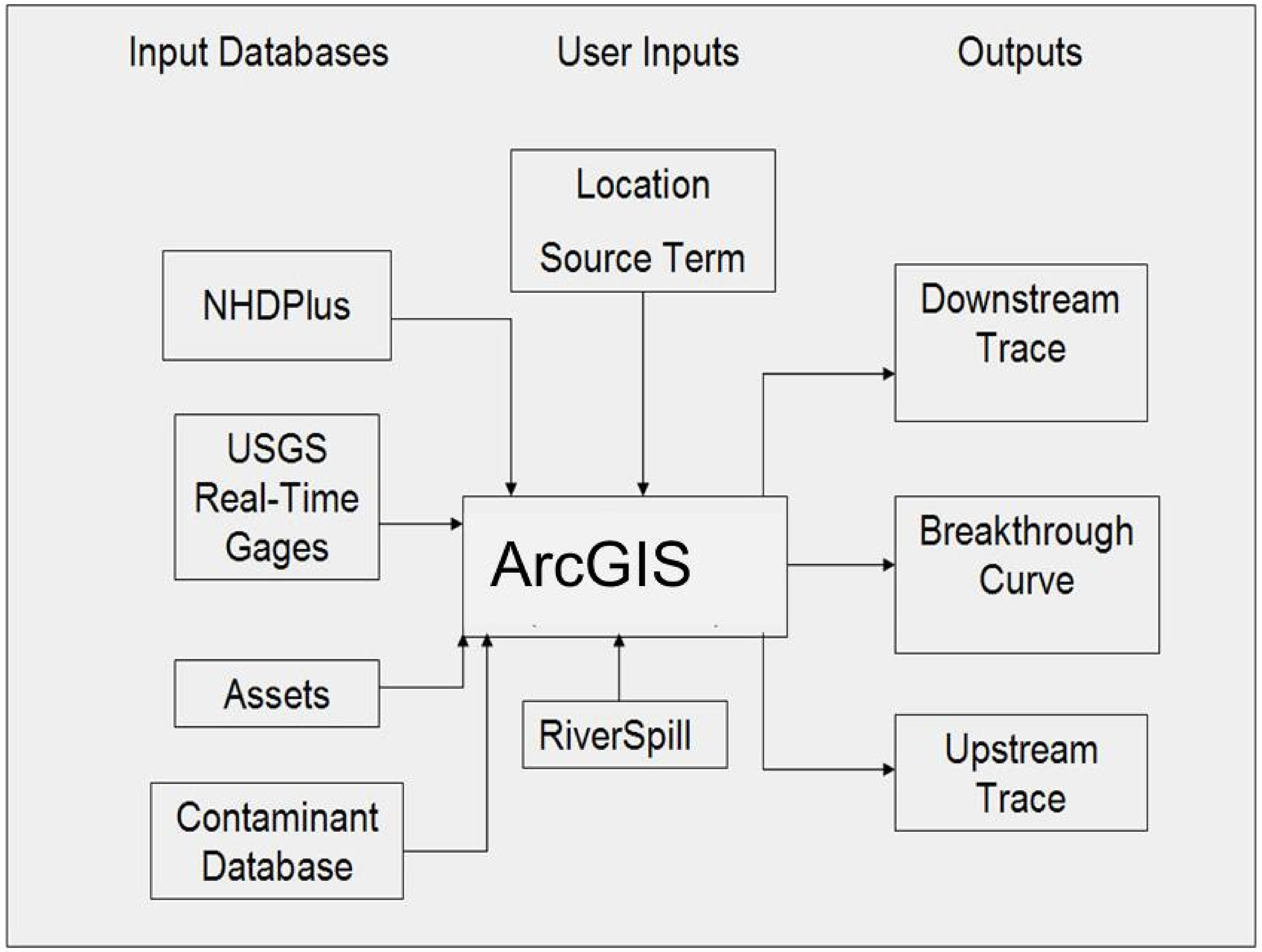
RiverSpill - ICWater



- Simulate fate and transport of the contaminants from point and non-point sources,
- Use minimum input data and user interface interaction for rapid emergency response modeling of toxic spills
- Perform hydraulic transport for the entire US river system
- Select water quality state variables that can represent the major processes that control water quality impacts and parameters available from national databases.

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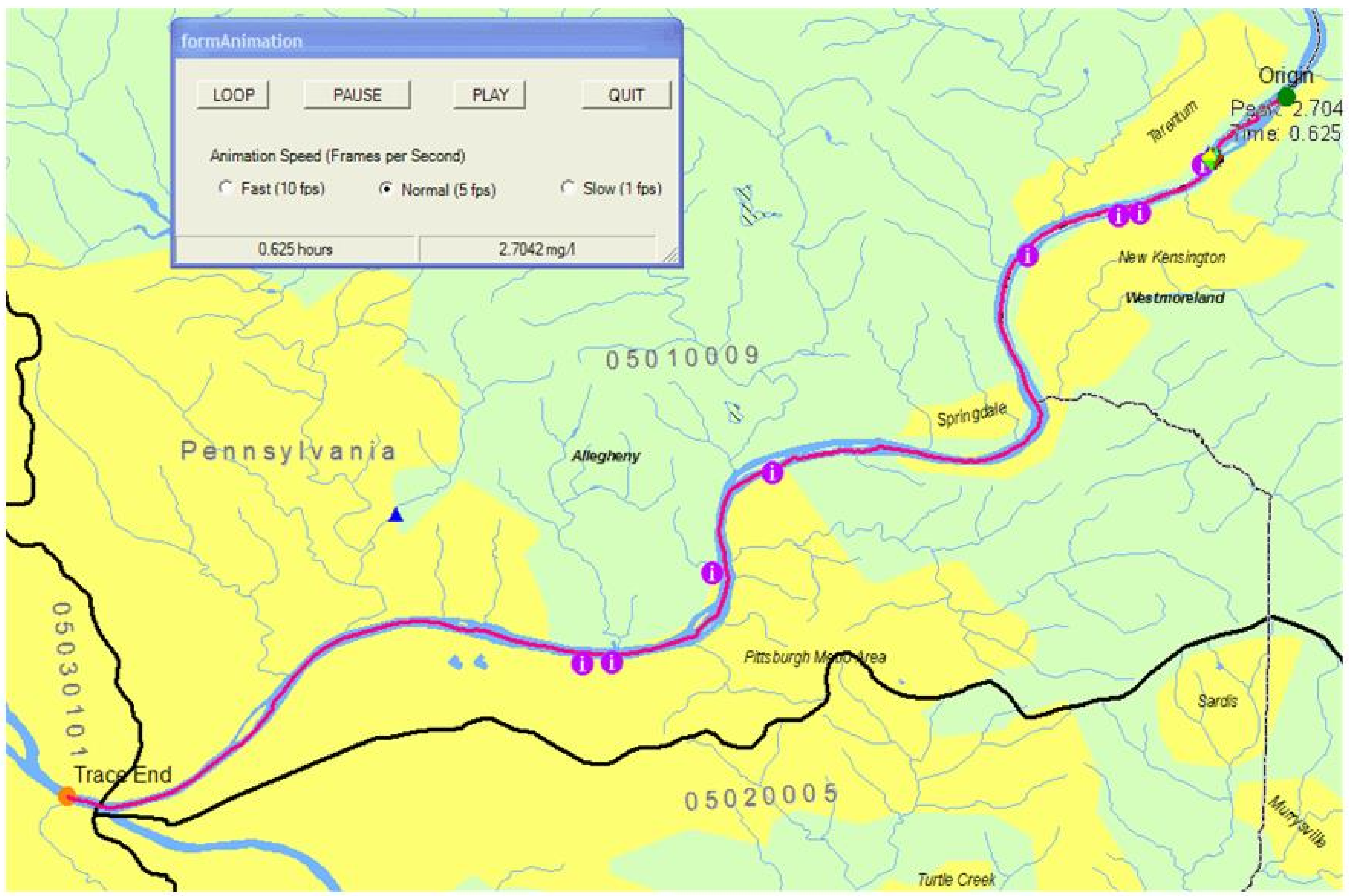
RiverSpill - ICWater



- Where is the contaminant going?
- Is there a drinking water intake in its path?
- When will it reach drinking water?
- Is its level high enough to be a human threat?

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RiverSpill - ICWater Modeling Principles

- Source Term
  - Instantaneous or continuous release
- Mixing
  - Instantaneous and complete mixing in the water column
- Velocity
  - NHDPlus mean flow and velocity updated with USGS real-time gages
- Dispersion
  - 1-D longitudinal dispersion
- Decay
  - First order exponential decay

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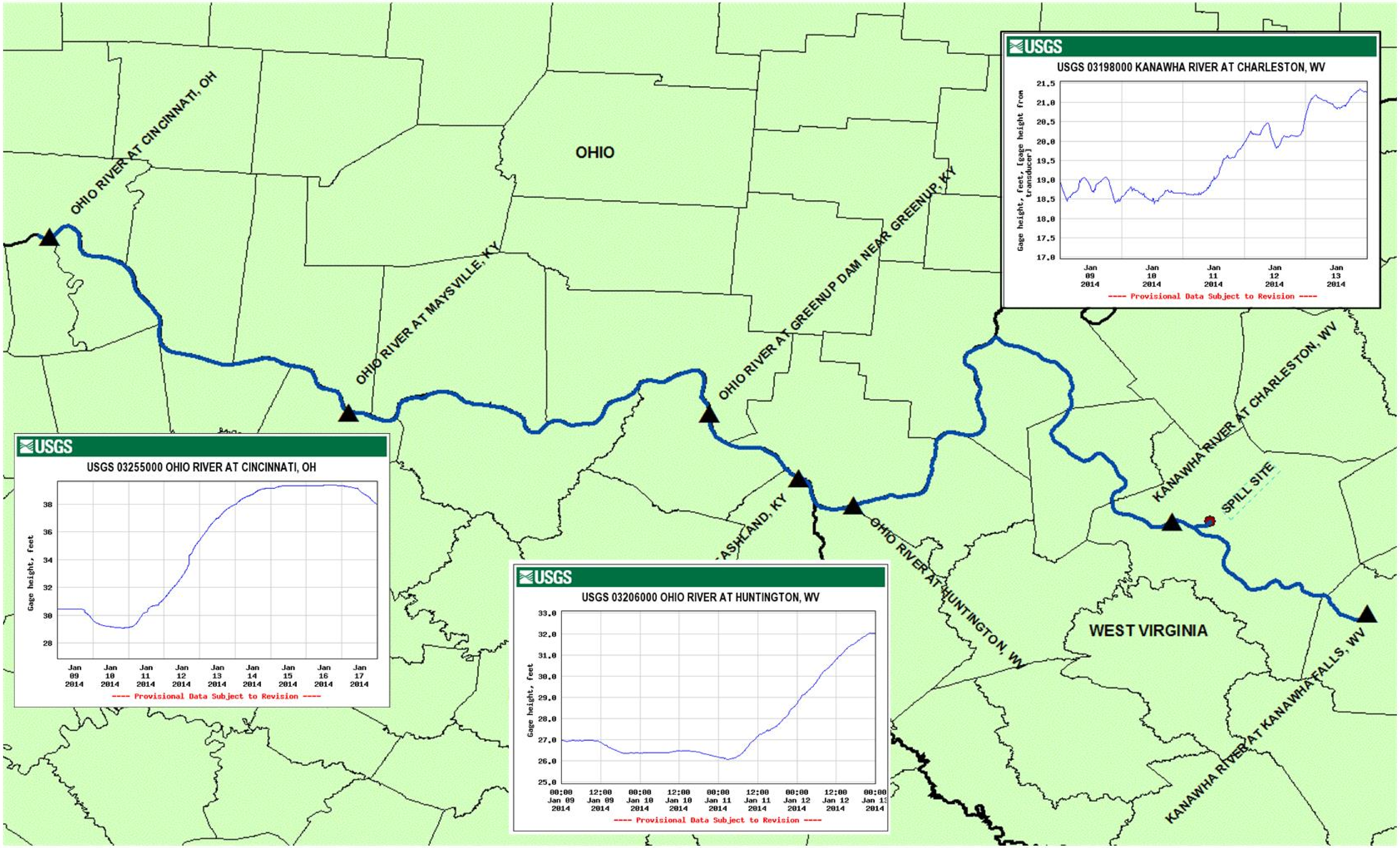
Stream velocity, feet per second
Most recent instantaneous value: 3.07 01-13-2014 11:00 EST
Measured velocity
USGS 03198000 KANAWHA RIVER AT CHARLESTON, WV
Stream velocity, feet per second
Jan 06 2014
Jan 07 2014
Jan 08 2014
Jan 09 2014
Jan 10 2014
Jan 11 2014
Jan 12 2014
Jan 13 2014
---- Provisional Data Subject to Revision ----
Discharge, cubic feet per second
Most recent instantaneous value: 41,200 01-13-2014 11:00 EST
USGS 03198000 KANAWHA RIVER AT CHARLESTON, WV
Discharge, cubic feet per second
---- Provisional Data Subject to Revision ----
Help
ICWater
HAZMAT: Hazardous Waste Sites
Dischargers: Municipal & Industr
Industrial Facilities
Sewage Treatment Plants
Public_Water_Supplies: Intakes
Scenario Layer
Point Sources
Polygon Sources
ICWater Base Map
Transportation Lines
NHD
NHDPlus05
Transportation Polygons
North America
World
West Virginia
Kanawha
Intake
Spill site
Edit Flow Factor
User Specified
Flow: 41200.000 cfs
Velocity: 3.149 fps
Model velocity
Flow Factor: 2.340
Velocity Factor: 1.260
Temperature: 20 °C
Selected Gage: KANAWHA RIVER AT CHARLESTON, WV
USGS Realtime
Gage Name | Realtime Flow | Realtime Velocity | NHD Flow | NHD Velocity | Flow Factor | Vel Factor
KANAWHA R ... | No Flow Found | N/A | 17606.42987 | 2.50441 | N/A | N/A
KANAWHA RI... | 41200 | 3.1487 | 17639.73754 | 2.5054 | 2.34 | 1.26

Flow Regime



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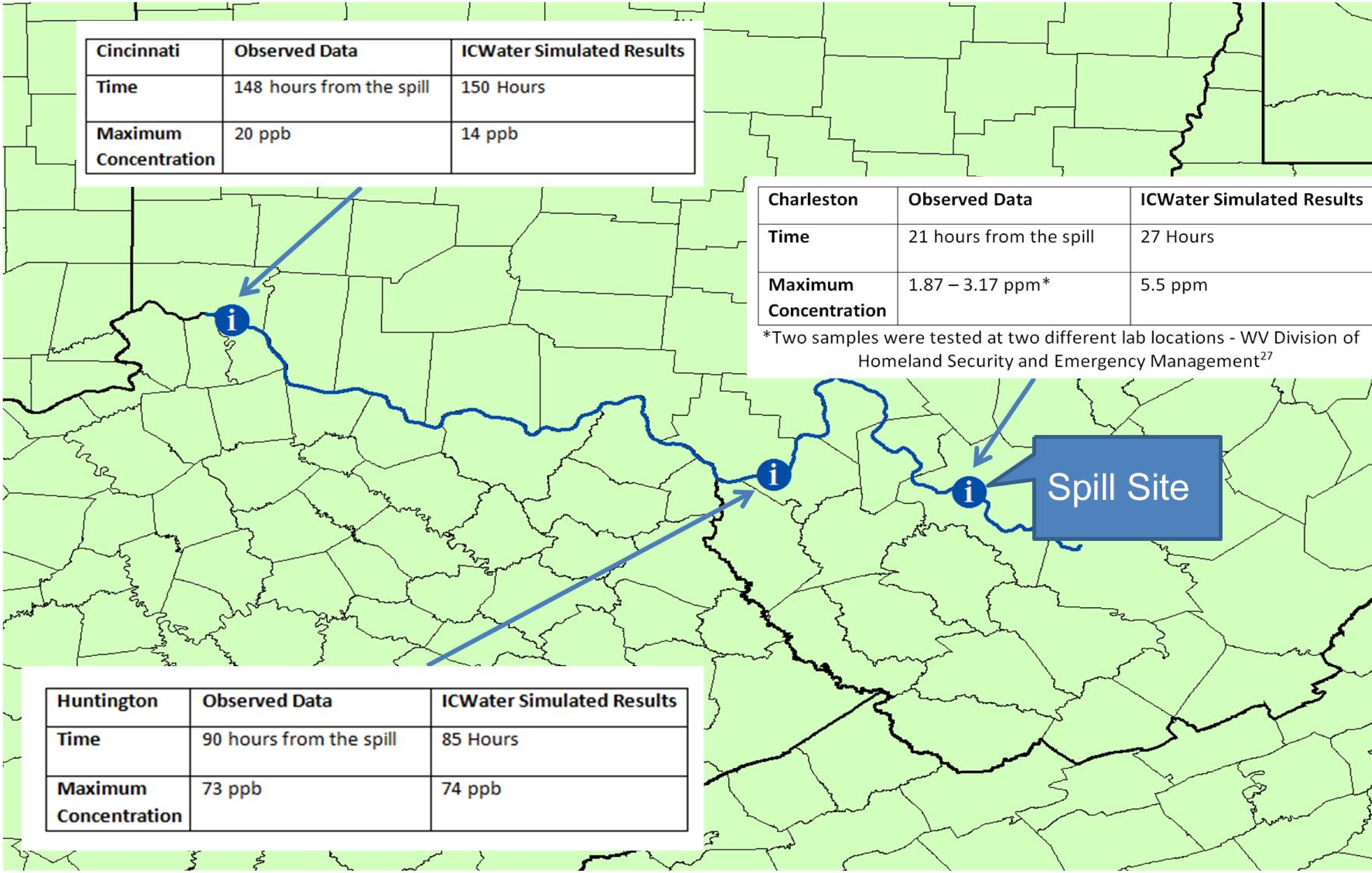
Downstream trace

24 hour downstream trace



Cincinnati	Observed Data	ICWater Simulated Results
Time	148 hours from the spill	150 Hours
Maximum Concentration	20 ppb	14 ppb

Charleston	Observed Data	ICWater Simulated Results
Time	21 hours from the spill	27 Hours
Maximum Concentration	1.87 – 3.17 ppm*	5.5 ppm

*Two samples were tested at two different lab locations - WV Division of Homeland Security and Emergency Management[27]

Huntington	Observed Data	ICWater Simulated Results
Time	90 hours from the spill	85 Hours
Maximum Concentration	73 ppb	74 ppb

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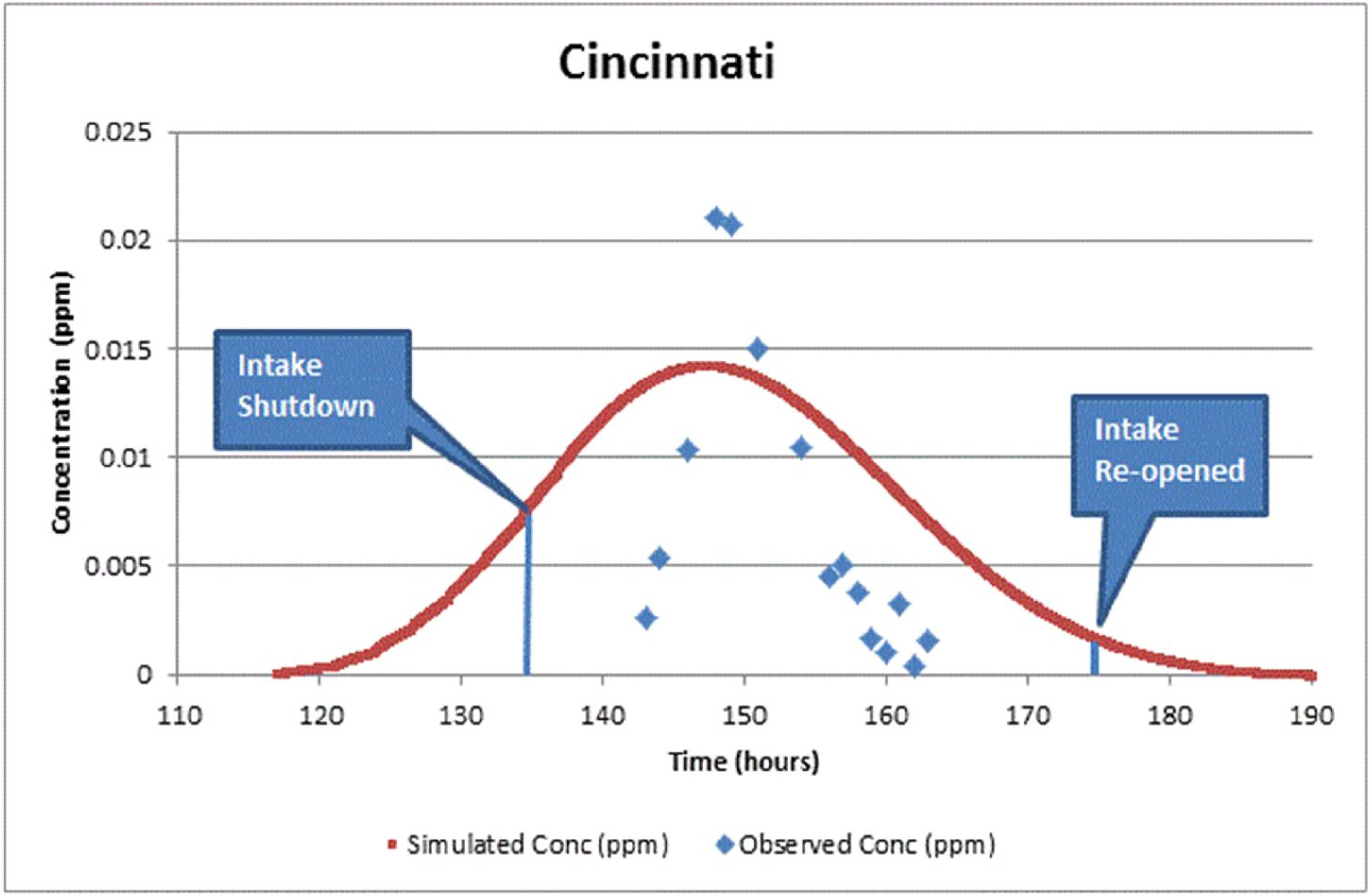
Cincinnati
Concentration (ppm)
0.025
0.02
0.015
0.01
0.005
0
Intake
Shutdown
Intake
Re-opened
110
120
130
140
150
160
170
180
190
Time (hours)
Simulated Conc (ppm)
Observed Conc (ppm)

Challenges

- A major challenge in modeling this spill was the characterization of the source term. Uncertainty of input parameters:
  - Spill duration
  - Release pattern
  - Volume released
- Toxicity levels of MCHM
- Accounting for how much mass was lost through downstream intakes
- Accuracy of MCHM measurements for model updates and comparisons
- In this particular spill, an added challenge was that the pollutant's delivery was attenuated by the soil that much of it had to seep through before reaching the river

Success Factors

- The NHDPlus national river network coupled with real-time stream flow data and river forecast data – this allowed for the ICWater model to simulate the leading edge, peak concentration, and trailing edge of the spill from its origin on the Elk River to intakes hundreds of miles downstream.

- Model runs were updated based on MCHM measurements at downstream locations on the Ohio River - this provided accurate forecasts to nearby water intakes.

- GCWW, a large water utility on the Ohio River, used ICWater along with river grab samples, to determine when to close its intake to allow the spill to pass by.

- Data for Cincinnati showed good agreement (within several hours) between the observed peak time of arrival and the model's estimated peak time. The leading- and trailing-edge predictions were also close to the observations.

Lessons Learned

- Initial spill reports are often inaccurate - constantly update forecasts based on changes in source term and environmental conditions
- Use both real-time gage data and stream flow forecasts
- Base decisions on both model forecasts and field observations – use measurements to update model inputs at intermediate downstream locations
- Teamwork – collaborate with local authorities, water utilities and data providers

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Conclusions

- For an event of this magnitude, this modeling response showed the utility of a national level toxic spill model (as opposed to regional river basin models) to simulate the entire pathway of the spill in a timely manner.

- The integration of a hydrologically connected - national level stream network, real-time steam flow, river forecast data and sampling observations enabled decision makers at a major water utility to take appropriate action to protect its water supply.

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Further Reading

Bahadur, R. and Samuels, W. (2014). "Modeling the Fate and Transport of a Chemical Spill in the Elk River, West Virginia." *J. Environ. Eng.*, 10.1061/(ASCE)EE.1943-7870.0000930

Samuels, W.B., Bahadur, R., Ziemniak, C. and Amstutz, D.E. (2014). “Development and Application of the Incident Command Tool for Drinking Water Protection”, Water and Environment Journal, http://onlinelibrary.wiley.com/doi/10.1111/wej.12097/abstract