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TEVA SPOT for Contamination Warning Systems

PNWS-AWWA Boise

May 6, 2011

Agenda

- TEVA-SPOT definition
- Contaminant Warning System (CWS) Background
- Online Water Quality Monitors
- TEVA-SPOT Application

What is TEVA-SPOT?

- **T**hreat **E**nsemble **V**ulnerability **A**ssessment **S**ensor **P**lacement **O**ptimization **T**ool
- TEVA-SPOT
- Online Water Quality Monitoring
  - Strategically locate sensors throughout distribution system
- EPANET (hydraulic model) based tool

Contaminant Warning System Background

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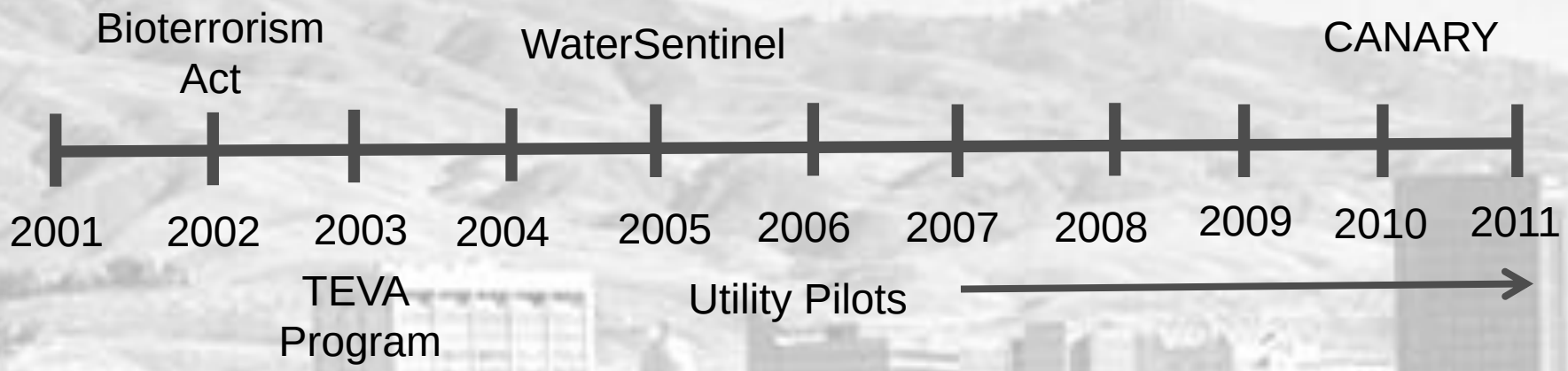
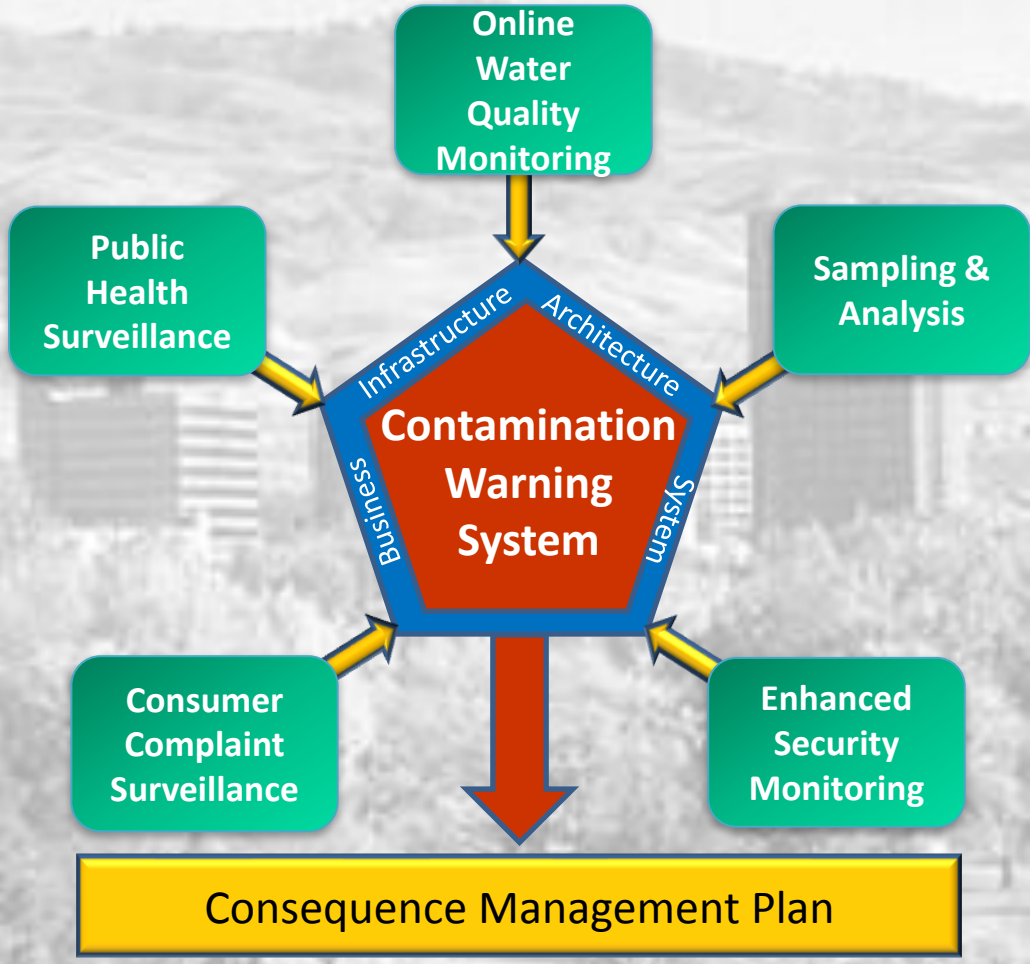


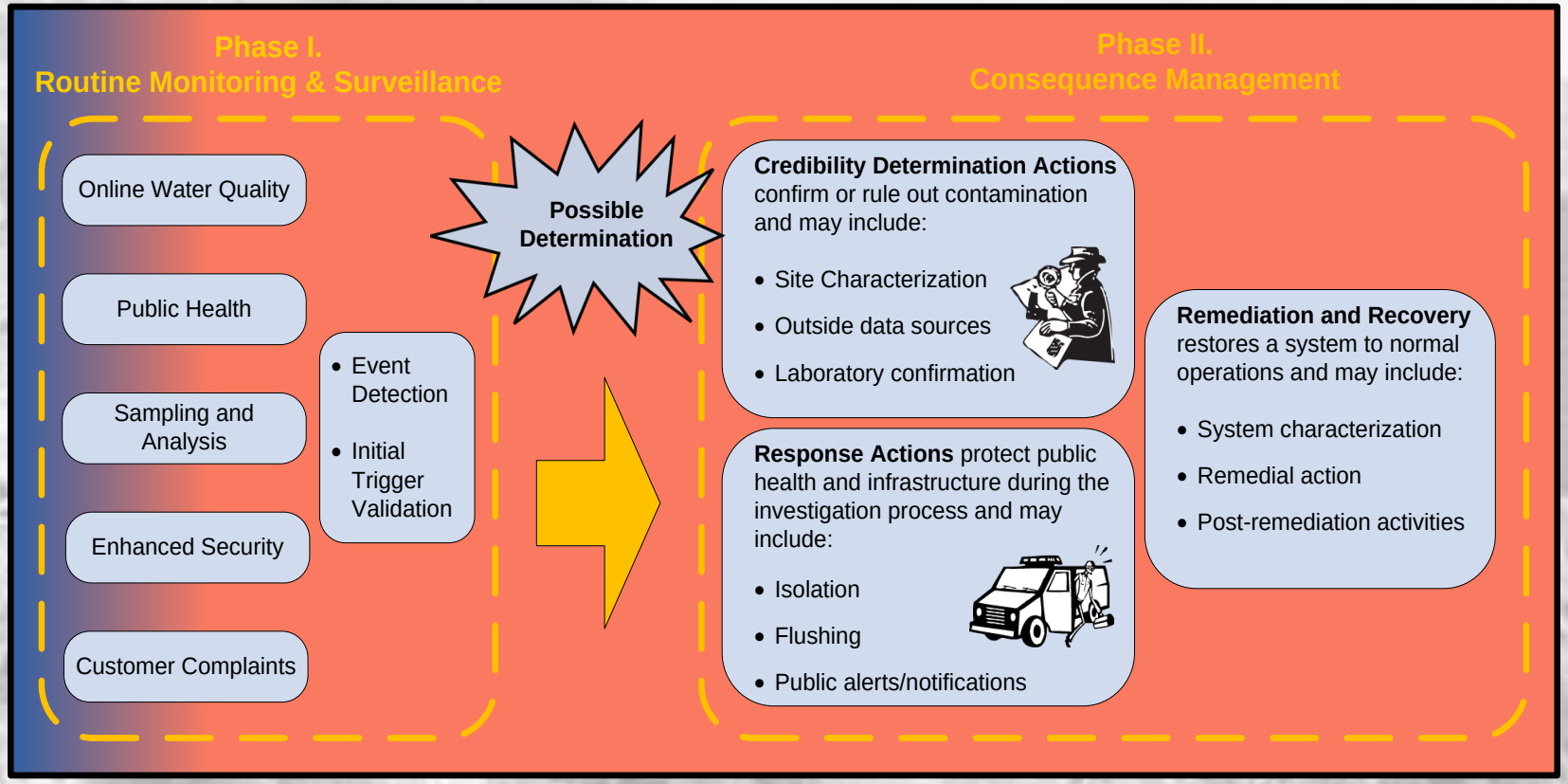
- National Homeland Security Research Center
- Water Security Initiative (WSi)
  - Address risk associated with the contamination of a drinking water system
  - Pilot test implementation of a Contamination Warning System
- Contamination Water System Pilot Utilities
- Piloting of sensors by other participating utilities
- CANARY: Event Detection System

Contaminant Warning System Background

- Systematic and comprehensive approach to monitor the distribution system
- Comprised of 5 components used to collect integrate, analyze, and communicate information



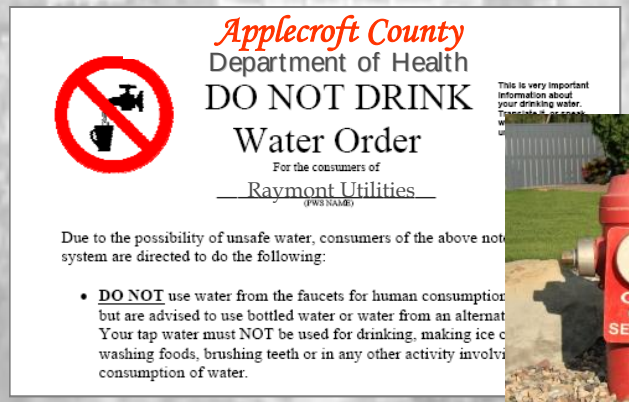
Contaminant Warning System Background



Online Water Quality Monitors

Maintain Water Quality in Distribution Systems to Prevent …

- Public health problems for consumers
- Damage to the system
- Waste of resources
- Compromised regulatory compliance
- Lack of water availability
- Loss of public confidence



Applecroft County
Department of Health
DO NOT DRINK
Water Order
For the consumers of
Raymont Utilities
(PWS NAME)

This is very important information about your drinking water.

Due to the possibility of unsafe water, consumers of the above not
system are directed to do the following:

- DO NOT use water from the faucets for human consumption
but are advised to use bottled water or water from an alternat
Your tap water must NOT be used for drinking, making ice c
washing foods, brushing teeth or in any other activity involvi
consumption of water.

Tuesday, July 19, 2005 | GUARDIAN NEWS 5

Belmont Valley Road woes

No water for 7 straight days

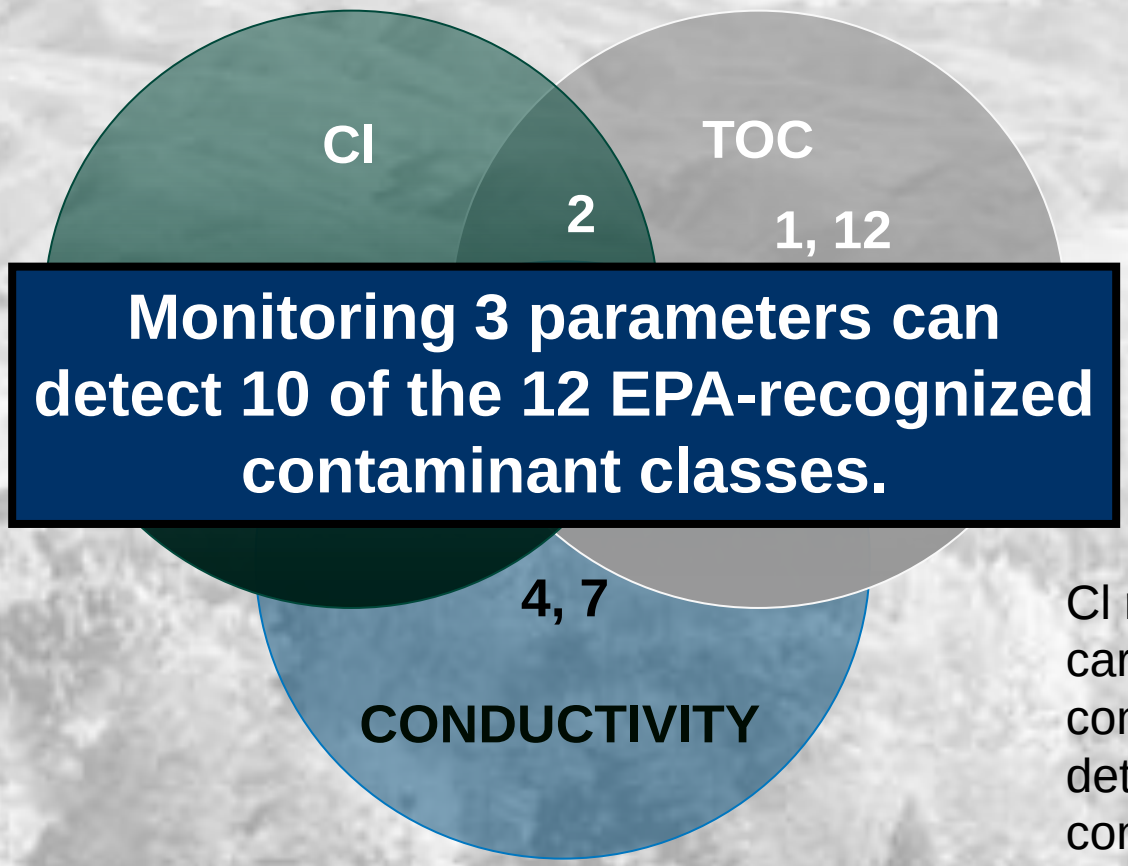
Contaminants of Concern defined by EPA

Contaminant	Description
1	Petroleum products
2	Pesticides (with odor or taste)
3	Inorganic compounds
4	Metals
5	Pesticides (odorless)
6	Chemical warfare agents
7	Radionuclides
8	Bacterial toxins
9	Plant toxins
10	Pathogens (unique symptoms)
11	Pathogens (common symptoms)
12	Persistent chlorinated organic compounds

Source: EPA

Online Water Quality Monitoring Station Design

Detection of Water Quality Deterioration Due to Contaminants



Monitoring 3 parameters can detect 10 of the 12 EPA-recognized contaminant classes.

Cl residual, total organic carbon (TOC), and conductivity are effective in detecting multiple contaminant classes.

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Source: U.S. EPA Water Sentinel System Architecture, Draft. Version 1.0

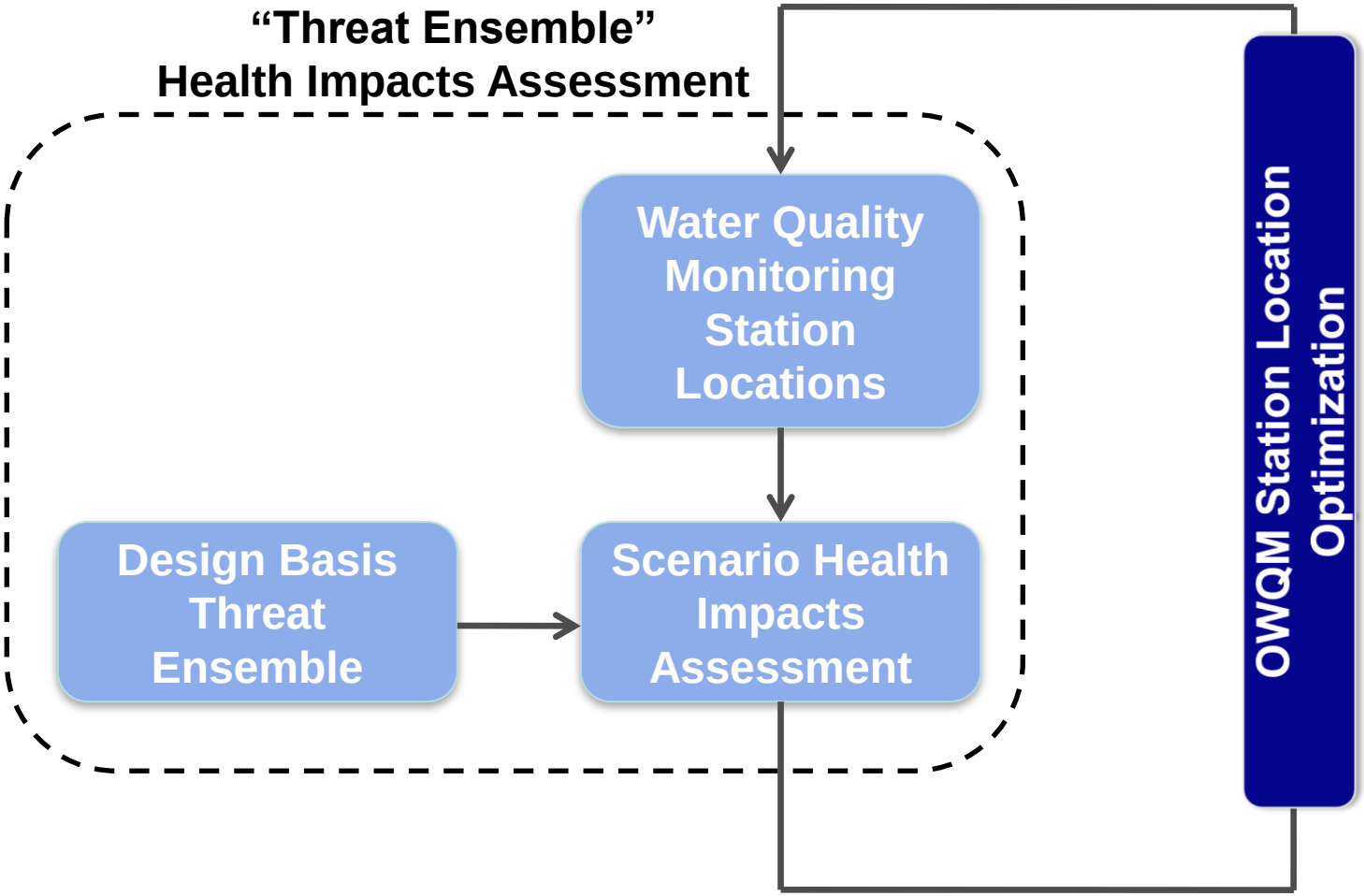
Example Stand-Alone Installation

TEVA-SPOT Application

Assessing Health Impacts from Distribution System Contamination Attacks….

- Unfortunately, we cannot predict the precise attack scenario prior to a terrorist attack
- We do know:
  - Health and economic impacts can vary widely depending upon the release location
  - Impacts can occur a great distance from the release location
- Best sensor location design approach:
  - looks at a range of “contamination scenarios”
  - estimates the range of health impacts
  - characterizes the average health impacts over the set of potential attacks

Sensor Location Methodology: Main Components



TEVA-SPOT Analyses and Inputs

- EPANET Simulations
  - Calibrated EPS hydraulic model
  - Scenarios (injection nodes – use all non-zero demand nodes)
  - Time, duration and rate of contaminant injection
  - Population of service area (demand based estimate)
- Health Impact Analysis
  - Contaminant properties
    - Can use high impact and low impact contaminants to capture range of results
- Sensor Placement
  - Sensor set size (number of sensors to locate)
  - Response time of utility to event detection
  - Sensor placement optimization objective (mean population exposed)

Selection of Candidate Monitoring Locations

- **Numerous potential locations**
  - Source water
  - Raw water conveyance
  - Treatment plant
  - Finished water reservoirs
  - Distribution system
  - Service lines
- **Potential end user locations**
  - Service organizations
    - Police, fire stations, schools
  - High-visible users
    - Stadiums, arenas, shopping areas
    - Prestige hotels and restaurants
  - Vulnerable populations
    - Hospitals, nursing homes, daycare centers

Criteria for Selecting Sensor Site

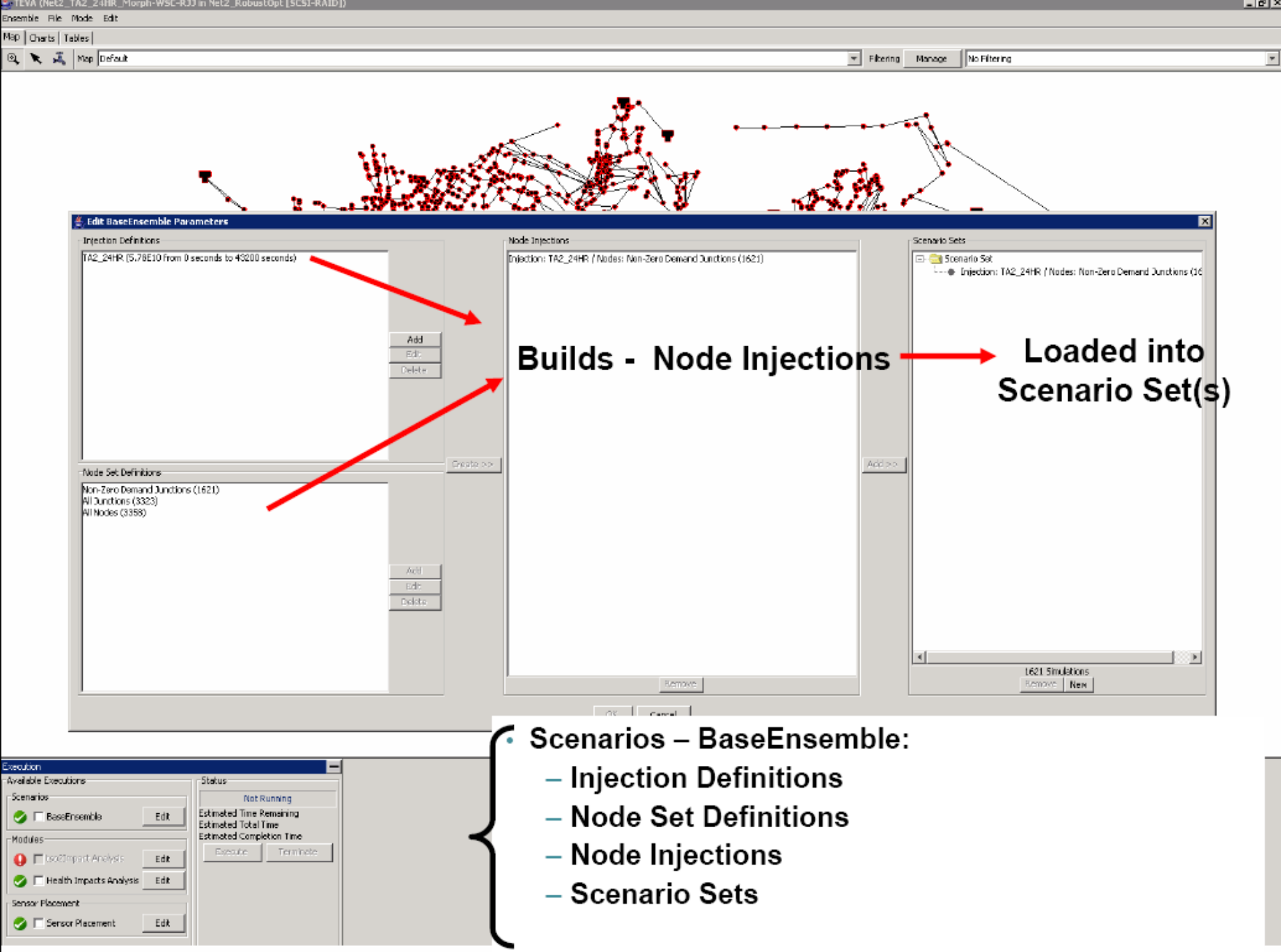
- TEVA-SPOT
  - Minimize mean population exposed
- On-site practical feasibility assessment
  - Location of building service connection
  - Access to location
  - Continuous water usage
  - Feasible space for instrumentation (i.e. electricity, sewer, physical space)
  - Diameter and length of service connection (increased travel times reduce effectiveness of sensor)

Design Basis Threat Ensemble –Design Parameters

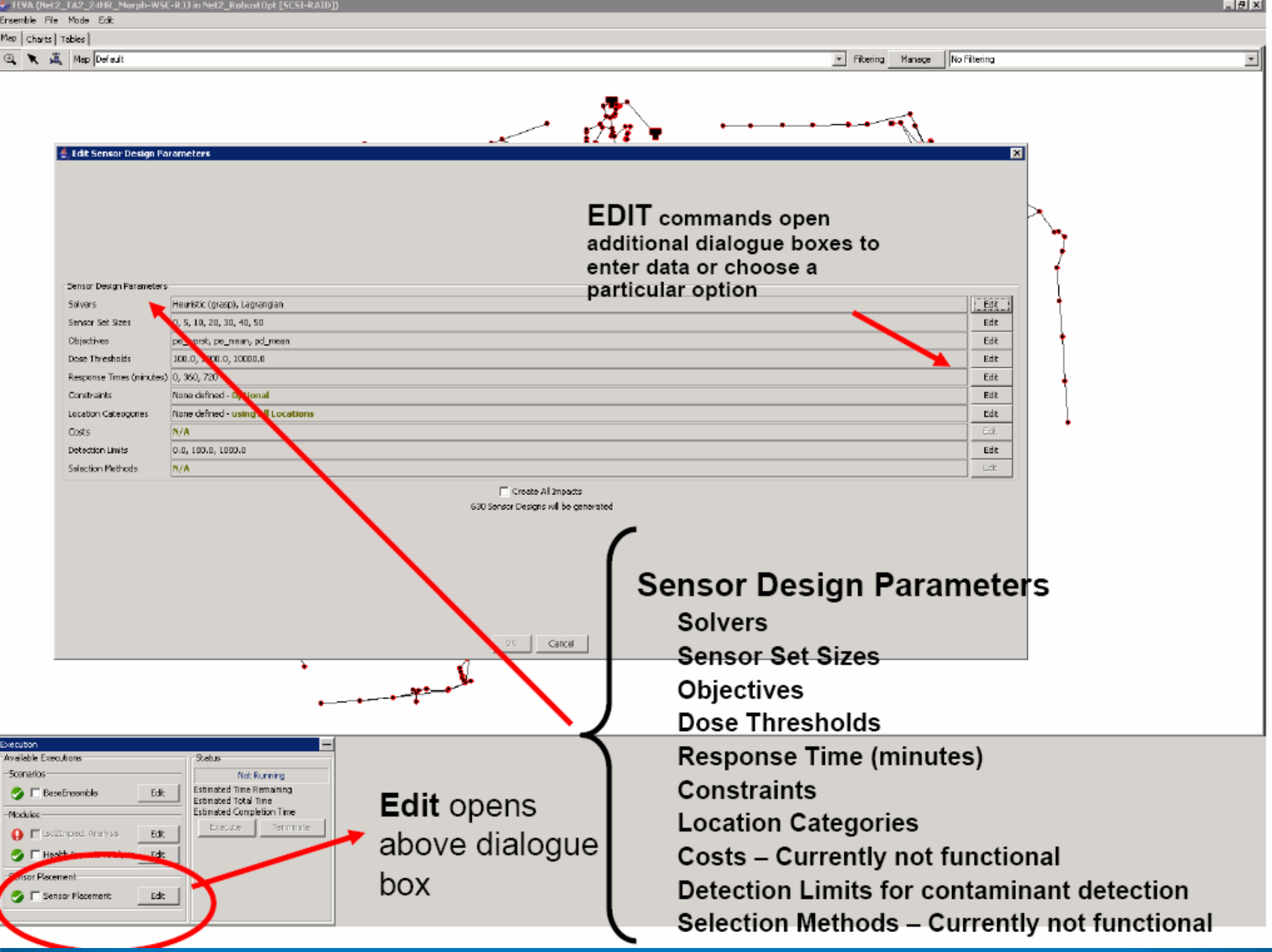
- Possible attack sites
- Contaminant
  - Chemical
  - Biological
- Rate of injection
- Duration of injection
- Time of day
- Sensor detection limit
- Response time
- Choice of performance objective

TEVA-SPOT Operation

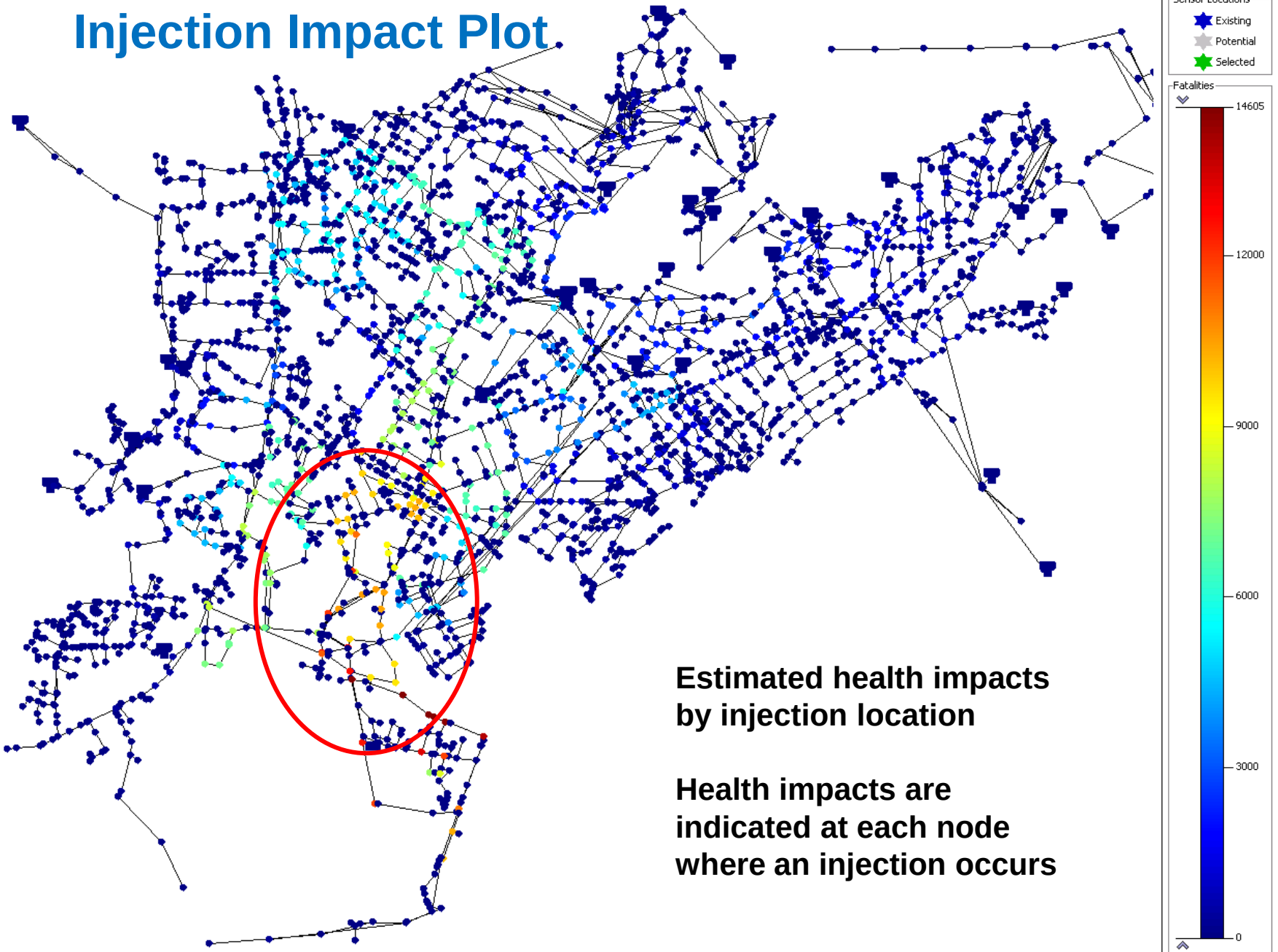
- **Scenario-** A specific release or injection of contaminant at a defined location
  - **Specify release rate and duration**
  - **Defines injection and "node set" for release**
- **Ensemble-** Collection of scenarios within the model
  - All nodes
  - All non-zero demand nodes
- **Ensemble Analysis Mode-**TEVA-SPOT mode where contaminant vulnerability assessment and sensor network designs (locating sensors) are performed
- **Regret Analysis Mode-**TEVA-SPOT mode to evaluate sensor designs (selected locations) are evaluated against a specific set of impacts to determine which locations perform best



- Scenarios – BaseEnsemble:
  - Injection Definitions
  - Node Set Definitions
  - Node Injections
  - Scenario Sets


Edit Sensor Design Parameters
Sensor Design Parameters
Solvers
Heuristic (grasp), Lagrangian
Sensor Set Sizes
0, 5, 10, 20, 30, 40, 50
Objectives
Dose Thresholds
Response Times (minutes)
0, 360, 720
Constraints
Location Categories
Costs
N/A
Detection Limits
0.0, 100.0, 1000.0
Selection Methods
N/A
Edit
Create All Impacts
630 Sensor Designs will be generated
OK
Cancel
Execution
Available Executions
Scenarios
BaseEnsemble
Modules
Sensor Placement
Status
Not Running
Estimated Time Remaining
Estimated Total Time
Estimated Completion Time
Execute
Terminate
EDIT commands open additional dialogue boxes to enter data or choose a particular option
Sensor Design Parameters
Solvers
Sensor Set Sizes
Objectives
Dose Thresholds
Response Time (minutes)
Constraints
Location Categories
Costs – Currently not functional
Detection Limits for contaminant detection
Selection Methods – Currently not functional
Edit opens above dialogue box

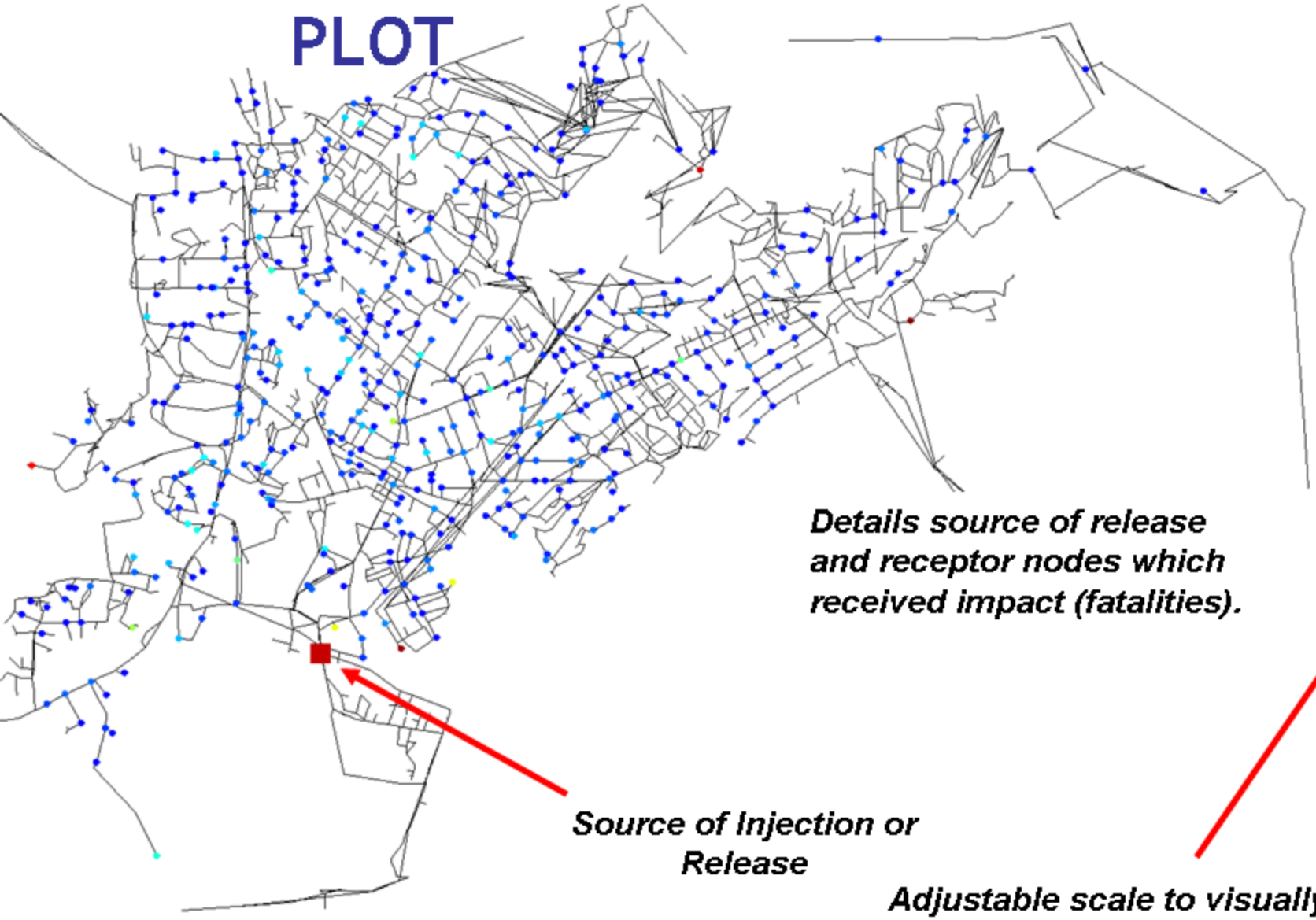
Injection Impact Plot

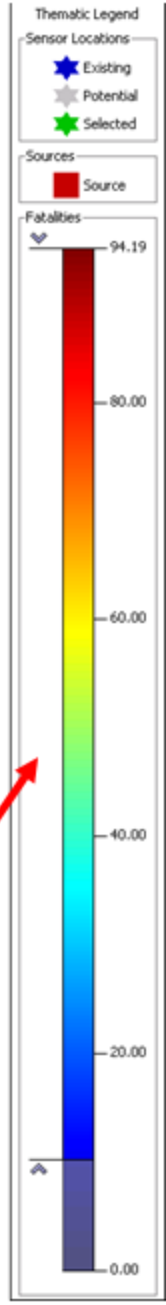


Estimated health impacts by injection location

Health impacts are indicated at each node where an injection occurs

EXPOSURE IMPACT PLOT

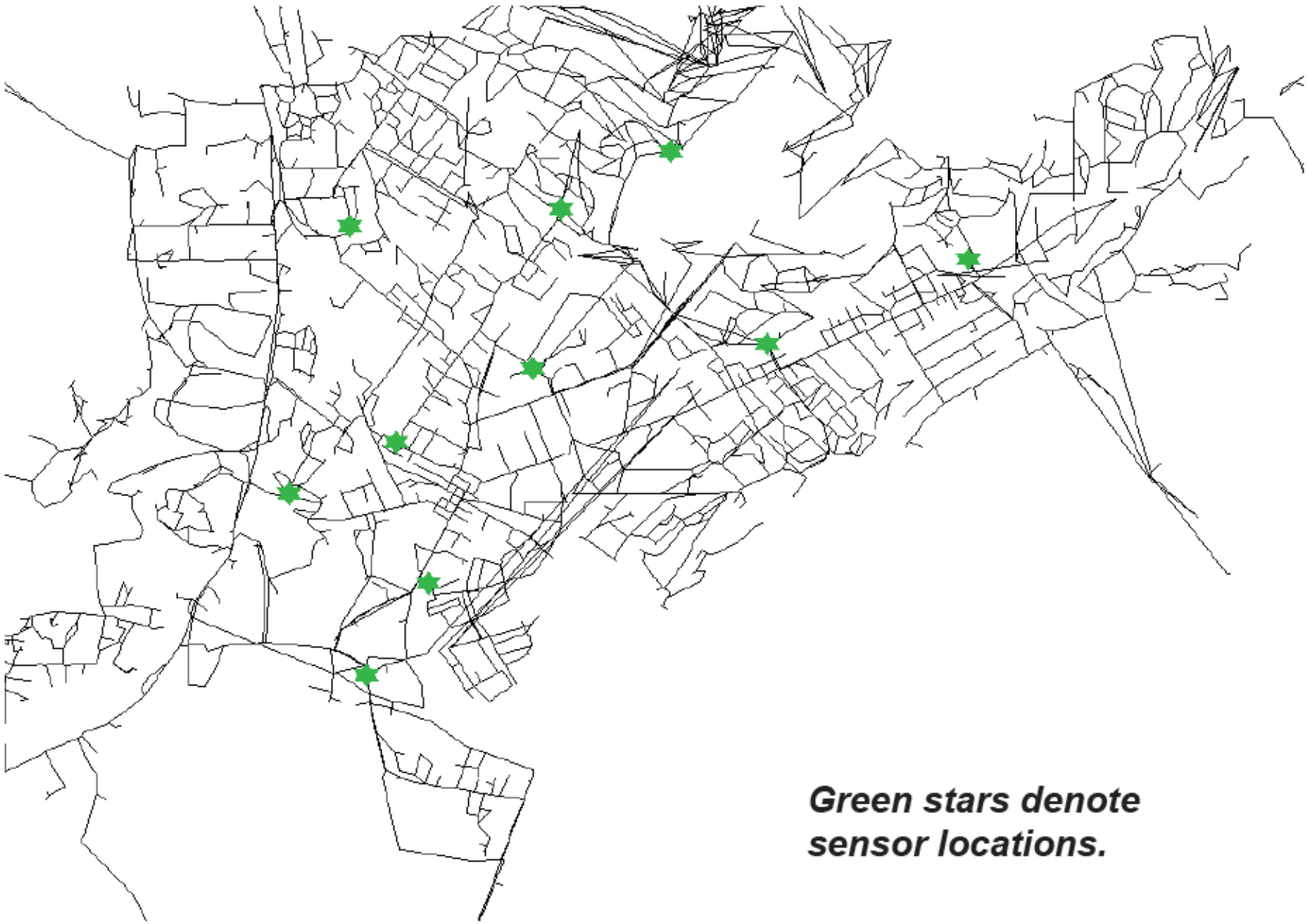




Details source of release and receptor nodes which received impact (fatalities).

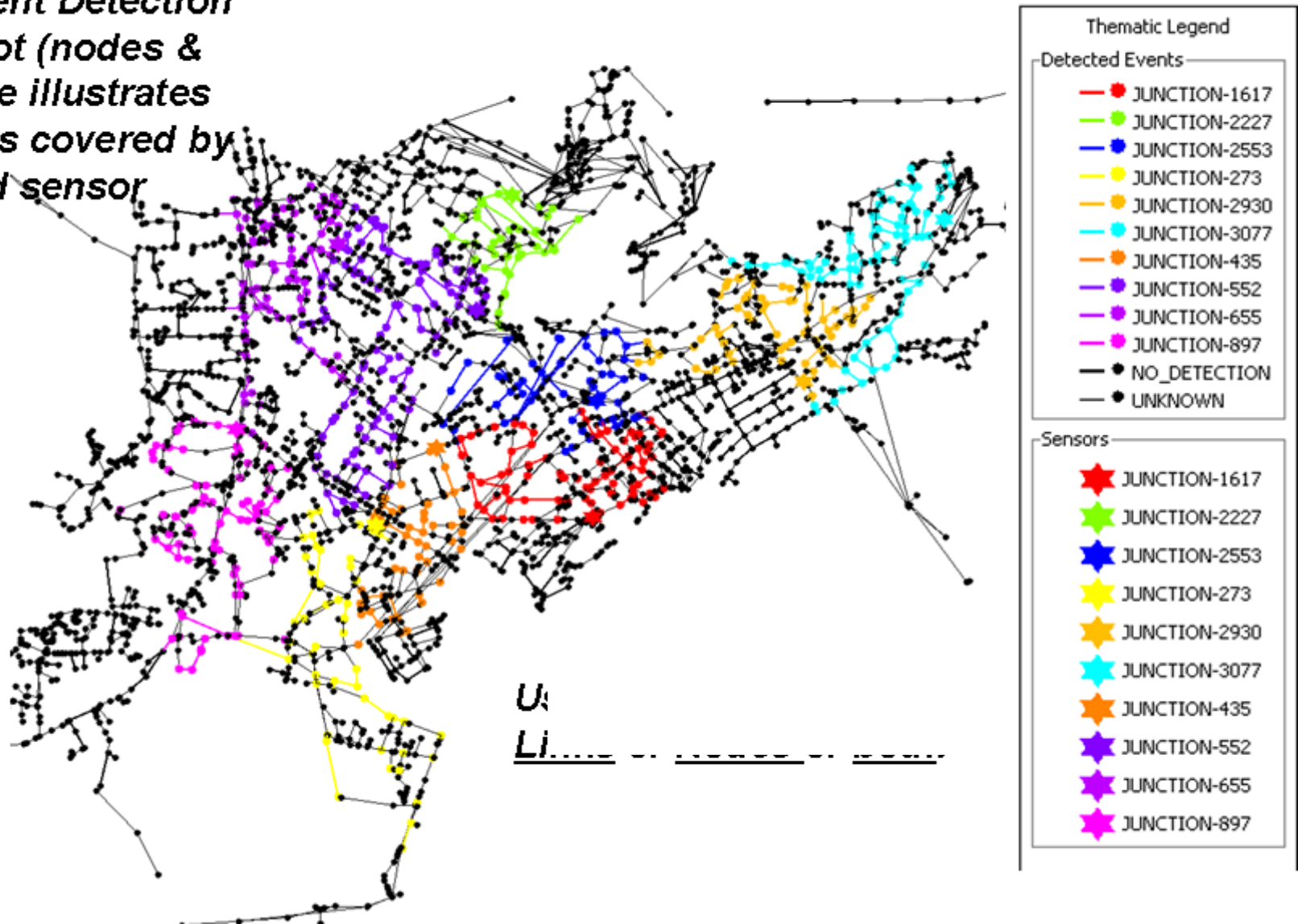
Source of Injection or Release

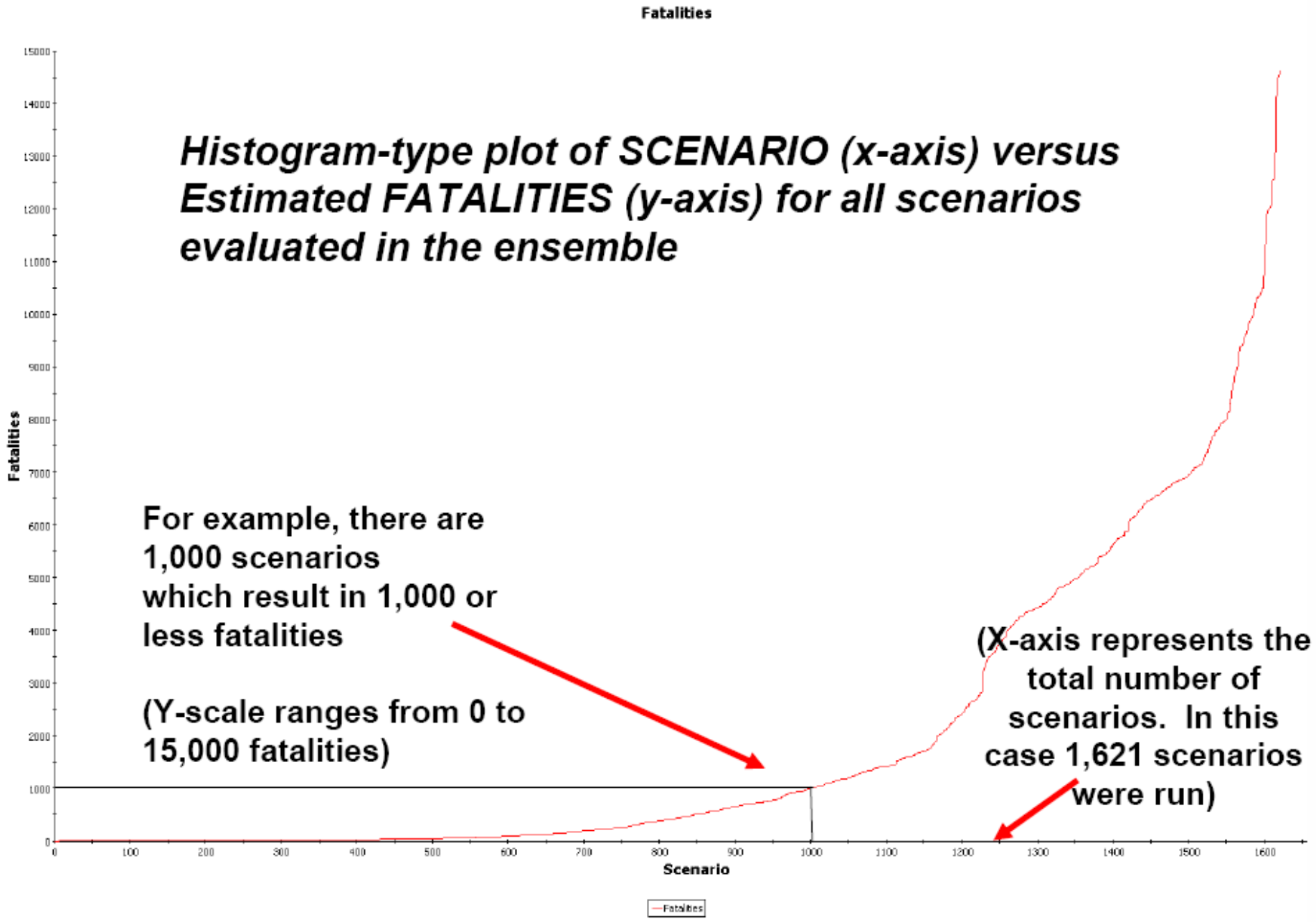
Adjustable scale to visually see where impacts occur above some threshold



Green stars denote sensor locations.

Scenario Event Detection Coverage Plot (nodes & links). Figure illustrates nodes & links covered by the identified sensor




Fatalities
Histogram-type plot of SCENARIO (x-axis) versus Estimated FATALITIES (y-axis) for all scenarios evaluated in the ensemble
For example, there are 1,000 scenarios which result in 1,000 or less fatalities
(Y-scale ranges from 0 to 15,000 fatalities)
(X-axis represents the total number of scenarios. In this case 1,621 scenarios were run)
Fatalities
Scenario
Fatalities

TEVA (Net2_TA2_24HR_Morph-WSC-RJJ in Net2_RobustOpt [SCSI-RAID])

Ensemble File Mode Edit

Map | Charts | Tables

Table [Health Impacts Analysis]: Ensemble Summary Table Filtering Mar

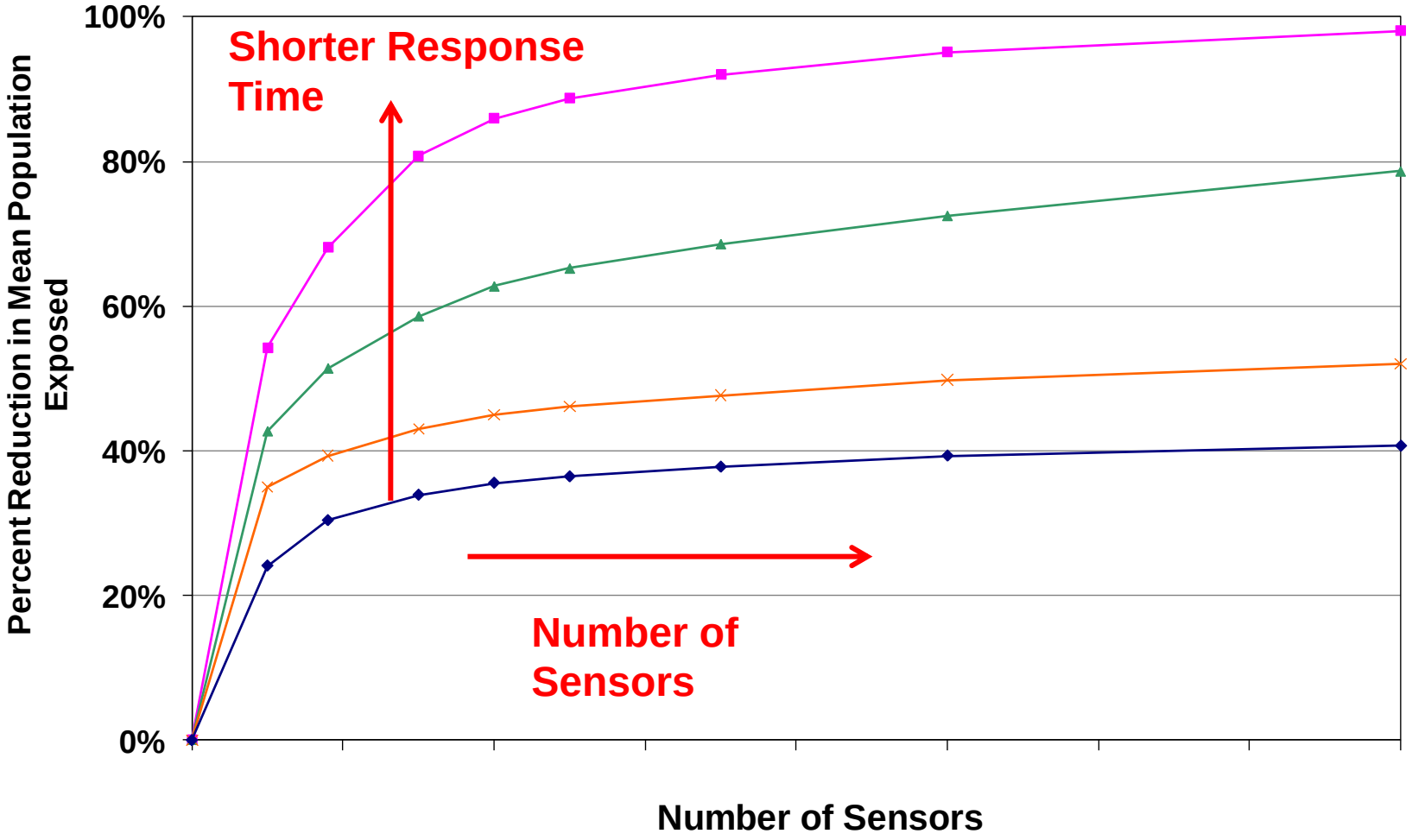
Injection Node	Max Concentration	Max Individual Dose	Number of Infected	Number of Fatalities	Nodes for 90% Fatalities	Nodes with Fatalities
JUNCTION-1042	1,185,898,112	74,394,550,272	148.013	44.404	1	
JUNCTION-1081	3,868,638,720	92,470,730,752	48.449	14.535	1	
JUNCTION-1062	857,696,320	19,572,797,440	513.503	154.051	8	
JUNCTION-1019						
JUNCTION-1078						
JUNCTION-1072						
JUNCTION-1095						
JUNCTION-1104						
JUNCTION-1075						
JUNCTION-1012						
JUNCTION-1080						
JUNCTION-1059						
JUNCTION-1083						
JUNCTION-1070						
JUNCTION-1086						
JUNCTION-1113						
JUNCTION-101						
JUNCTION-1103						
JUNCTION-1093						
JUNCTION-1111						
JUNCTION-1082						
JUNCTION-1000						
JUNCTION-1064						
JUNCTION-1149						
JUNCTION-1048						
JUNCTION-1069						
JUNCTION-1133						
JUNCTION-1061						

- **Ensemble Summary Table**
  - Complete compilation of ensemble results by scenario:
  - **Max concentration**: Maximum concentration observed at any corresponding receptor node.
  - **Max individual dose**: Maximum individual dose received at any receptor node for the scenario (injection node) identified.
  - **Number infected/fatalities**: Total number of individuals for the scenario, across all receptor nodes.
  - **Nodes for 90% fatalities**: Number of nodes required to obtain 90% of fatalities indicated for that scenario (measure of contaminant spread in network).
  - **Nodes with fatalities**: Number of nodes contributing fatalities to those indicated for the scenario.

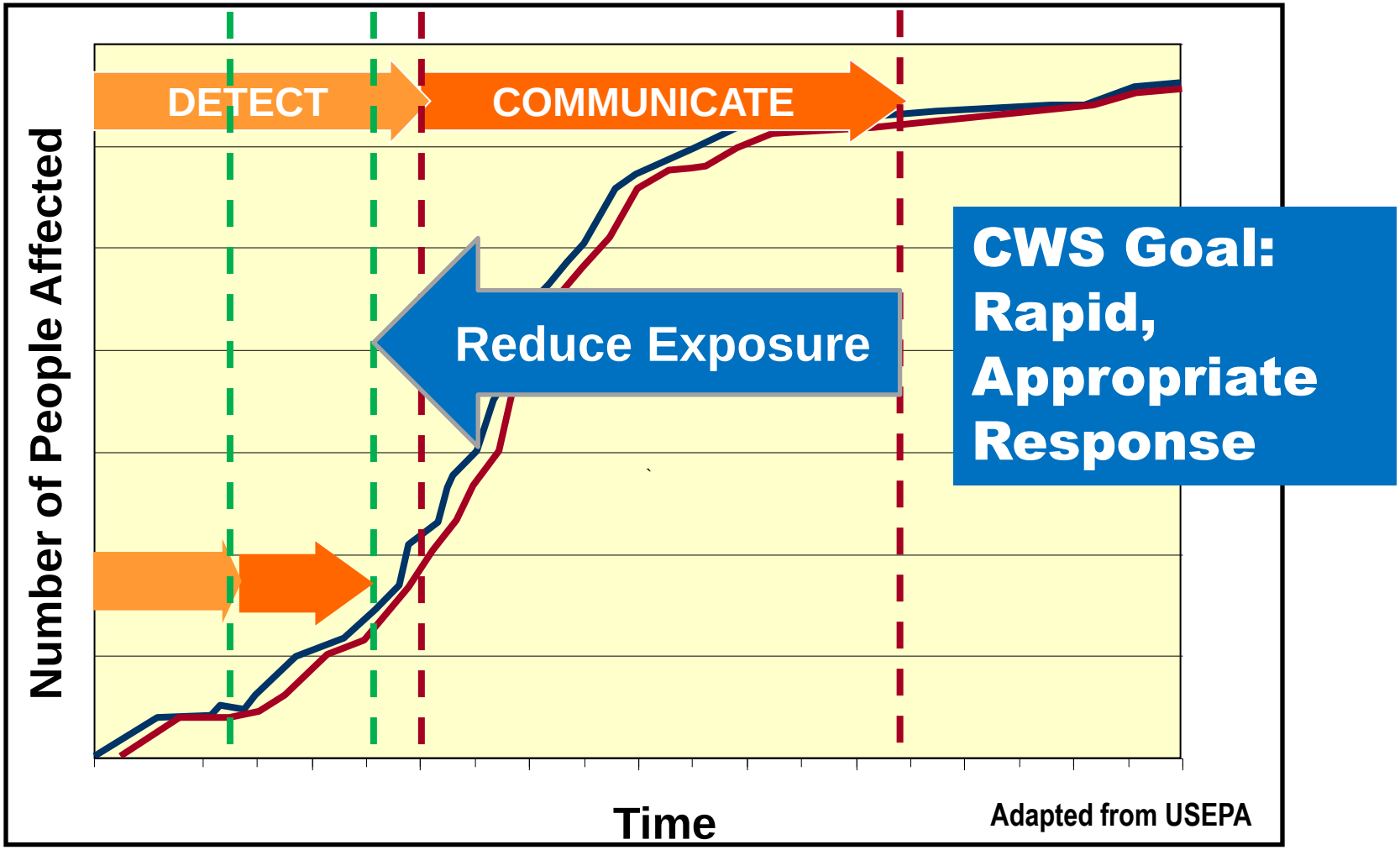
Final Sensor Placement

- Iterative decision process
- TEVA-SPOT output enables consideration of key design parameter impacts
- Final design is ***not*** specified by an algorithm
  - Progressive stages of analysis and discussion
  - Successively improving the design solution through ***utility feedback***

Response Time and Sensor Set Size



Select Sites to Minimize Contamination Event Impact on Public



Conclusions

- TEVA-SPOT provides objective and quantitative approach
- Hydraulic model demand allocation level of detail
- Reducing response time (operational strategy) can be as beneficial as additional sensors
- Must balance theoretical and feasible
  - Available sites
  - Desired geographical distribution
  - Look for opportunities for dual-benefit

Questions?