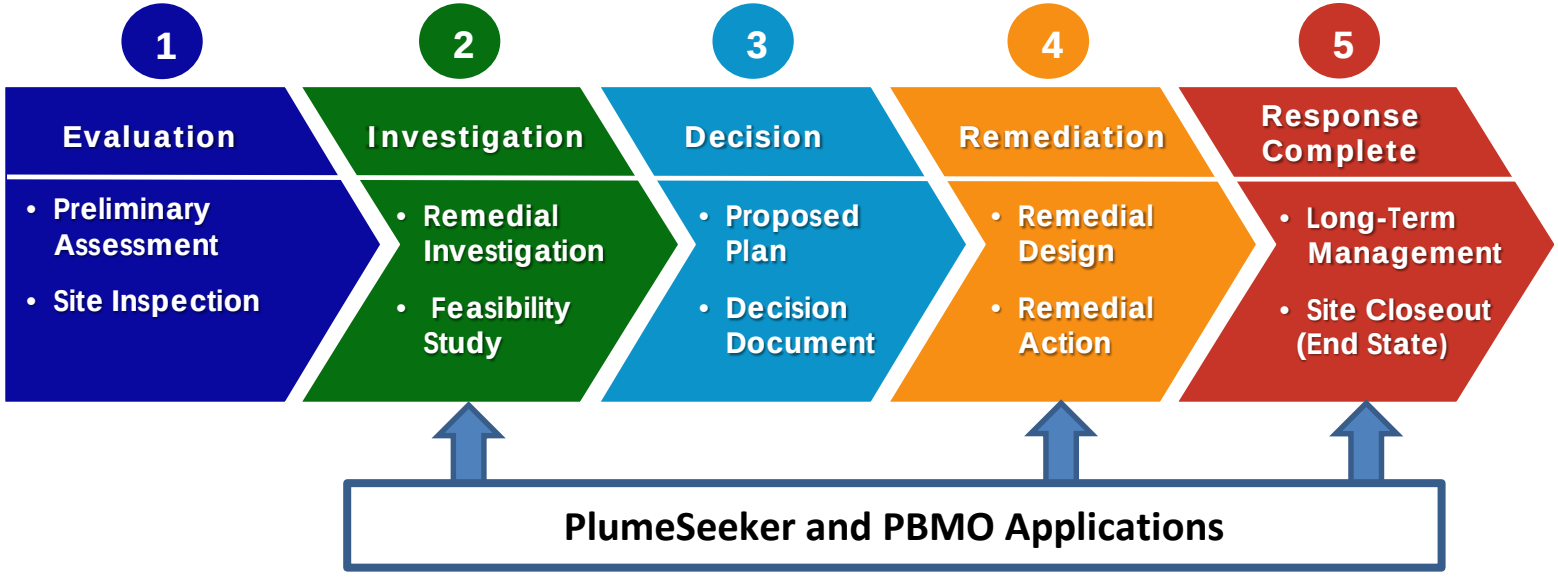
PlumeSeeker and PBMO Technologies for Optimization of Site Characterization and Remediation

Interagency Steering Committee on the Performance & Risk Assessment Community of Practice (P&RA CoP)
Webinar: Thursday, January 17, 2019

Presenters:
Varut (Dua) Guvanasen, Ph.D., P.E.
Larry M. Deschaine, Ph.D., P.E.

HGL
HydroGeoLogic, Inc

PlumeSeeker and PBMO Apply to Key Steps in the CERCLA Process

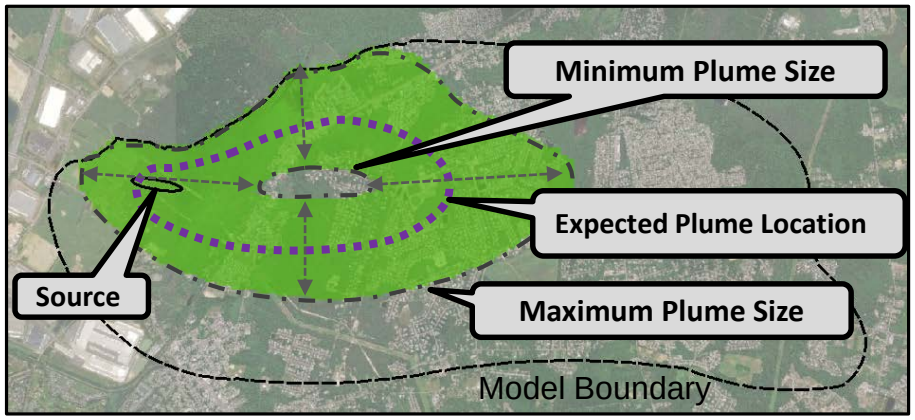


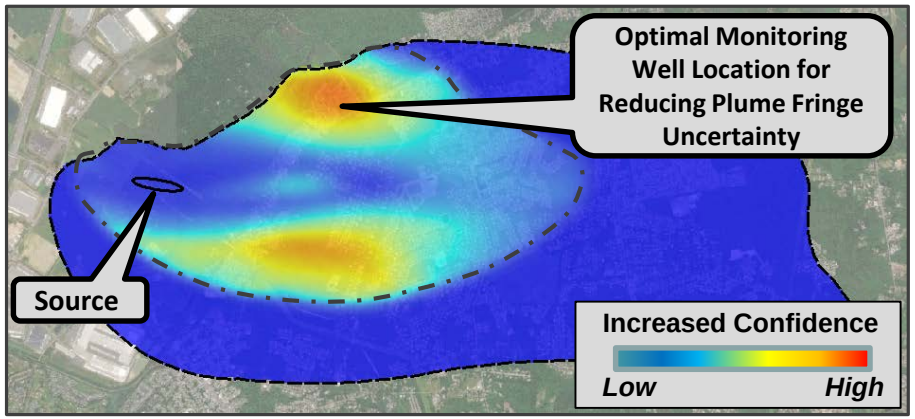
- **PlumeSeeker:** Technology for Optimizing Site Characterization and Long-Term Monitoring (LTM)
- **Physics-Based Management Optimization (PBMO):** Technology for Optimizing Remediation

PlumeSeeker Innovative Technology: Optimizing RI, Pre-Design Investigation, and LTM

- Integrates site hydrogeology, geostatistics, contaminant fate and transport, and operational history to:
  - Conduct stochastic simulations to identify plausible plume configurations
  - Increase confidence in plume delineation
  - Evaluate existing well networks
  - Determine optimal new well locations
- Achieves cost savings by optimizing the locations and number of new monitoring wells
- Achieves cost savings by eliminating redundant monitoring well sampling
- Enhances stakeholder acceptance and improves demonstration of protectiveness

Identify Plausible Plume Configurations and Increase Confidence in Plume Delineation



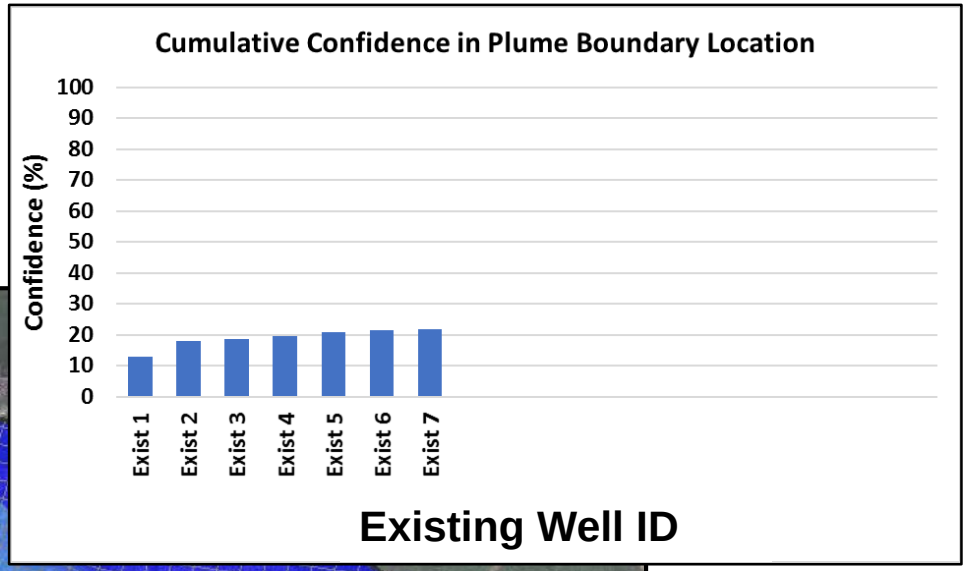


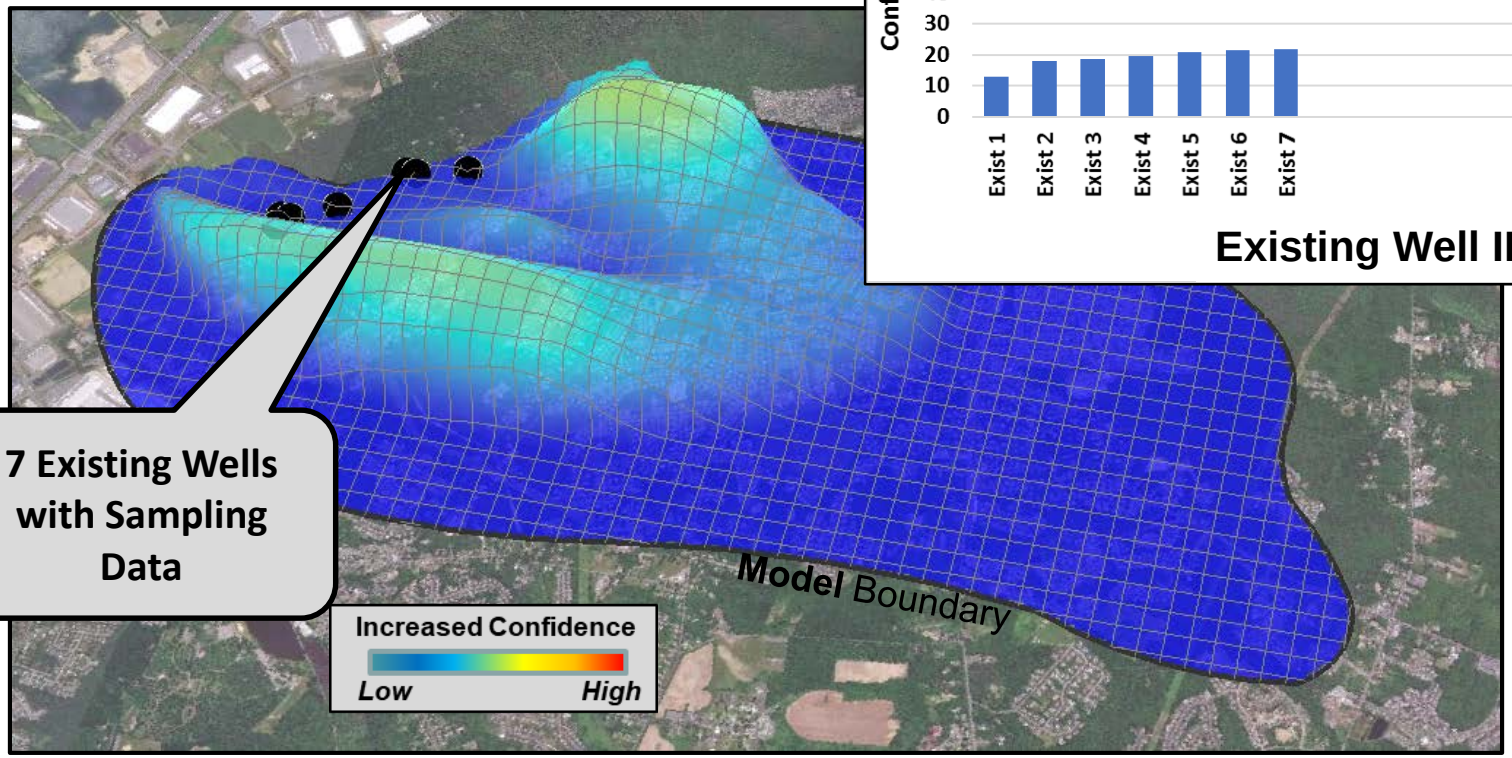
- Quantify the range of plausible plume locations
- Reduce the range of plausible plume sizes thereby increasing confidence in expected plume boundary

The above graphic depicts color coded plot of opportunity to increase confidence level. Red indicates locations to monitor for achieving the greatest reduction in uncertainty; Blue indicates the least reduction.

Evaluate Existing Monitoring Well (MW) Network

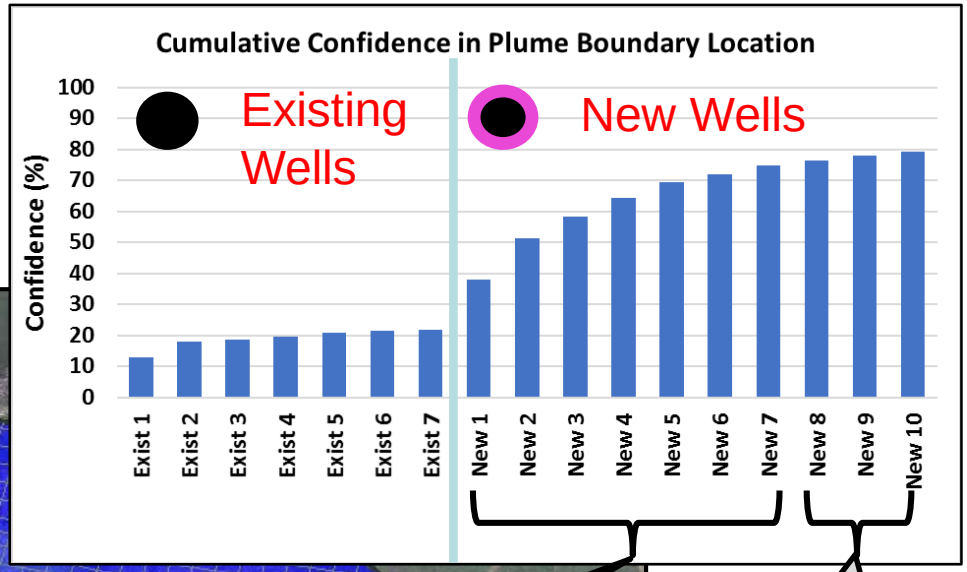
Existing MW network provides low confidence (20%) for plume delineation

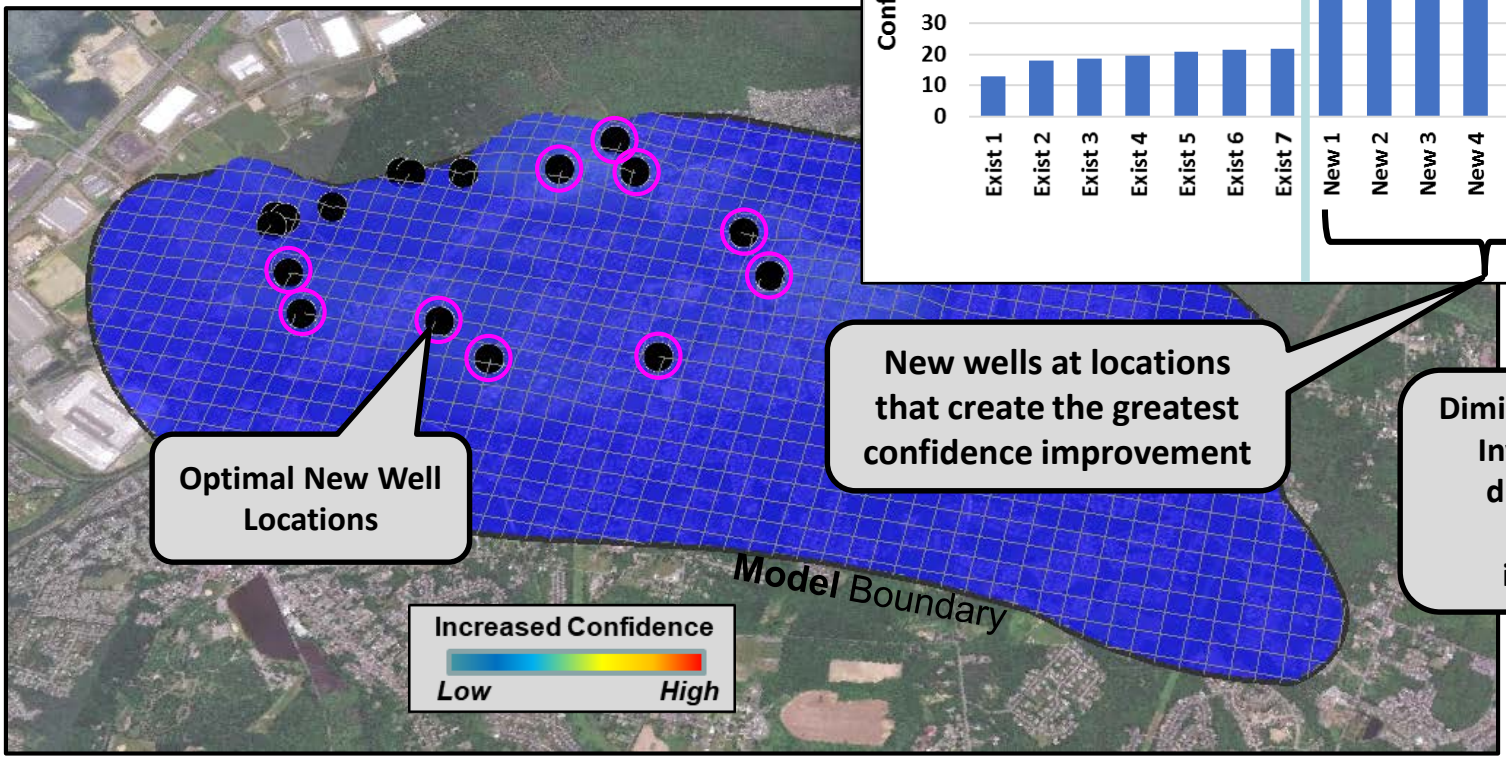




Determine Optimal New Well Locations

New monitoring wells at locations that provide most increase in confidence





PlumeSeeker helps decision makers decide when investigation is sufficient

PlumeSeeker Technology Achieves Cost Savings and Enhances Stakeholder Acceptance

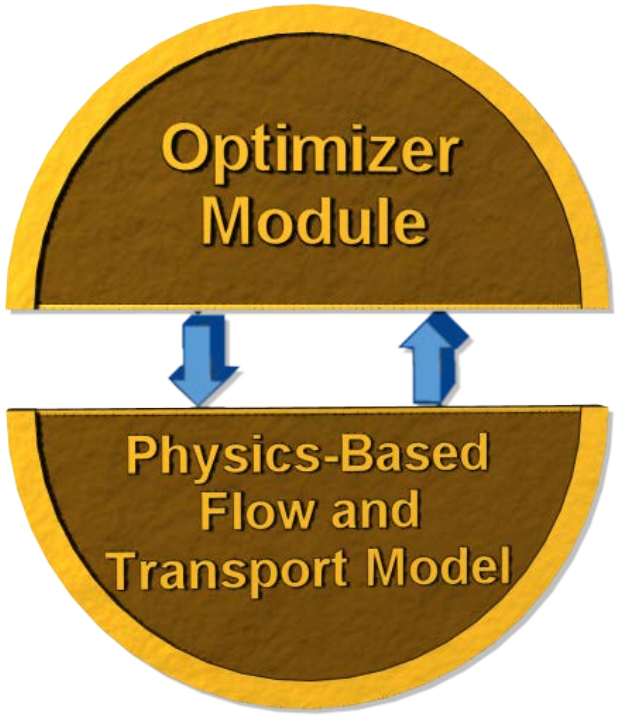
- Pantex Plant, TX
  - Assessed monitoring well network effectiveness at Burning Ground
  - Assessed optimal monitoring well placements in Ogallala aquifer
  - Supported remedial design
  - Realized $2M cost savings for $90K analysis (ROI ~20)
- Anniston Army Depot, AL
  - Optimized long-term monitoring
  - Reduced the sampling locations from 200+ to 40 monitoring wells, without reduction in confidence level
  - Realized $500K annual cost savings for $100K analysis (ROI ~50 over 10 years)
- PlumeSeeker Applicable at Other Sites where:
  - Monitoring well installation is expensive
  - Monitoring well network is extensive and sampling costs are high
  - Extent of contamination insufficiently defined

PBMO Innovative Technology: Optimizing FS/RD/RA/O&M

- PBMO system components:
  - Optimizer module finds best feasible solutions
  - Flow and transport module simulates site-specific conditions
  - System framework incorporates stakeholder input
- Cloud-based computing handles complex optimization problems
- Achieves cost and time savings and enhances stakeholder acceptance

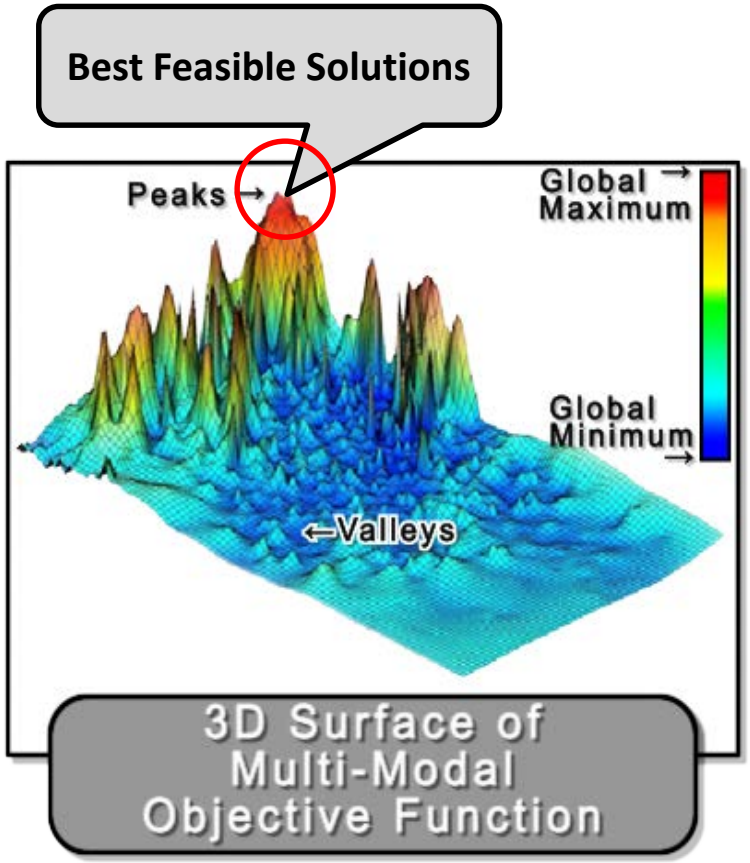
PBMO Conceptualization

- Links advanced optimization algorithms with site specific flow and transport models
- Incorporates multiple decision variables, constraints and management insight into the optimization process
- Considers the conceptual site model (CSM), available data, remedy goals, performance, protectiveness of human health, ecological and environmental risk, cost-effectiveness, and exit strategy



PBMO Medallion Conceptualization

Optimizer Module Finds Best Feasible Solutions

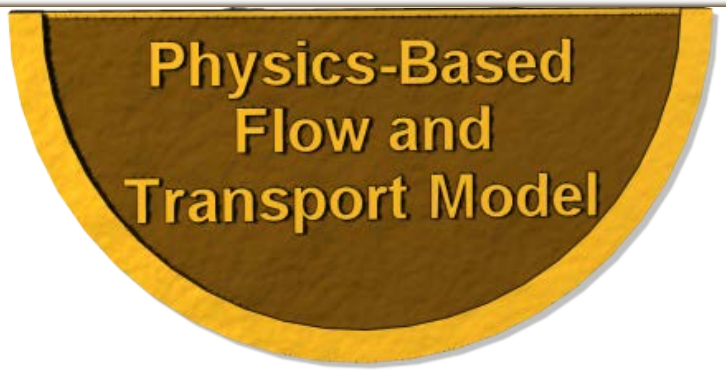


Key computational optimization elements include:

- Objective Functions
- Decision Variables
- Constraints

Flow and Transport Model Simulates Site-Specific Subsurface Conditions

PBMO works seamlessly with site-specific flow and transport model



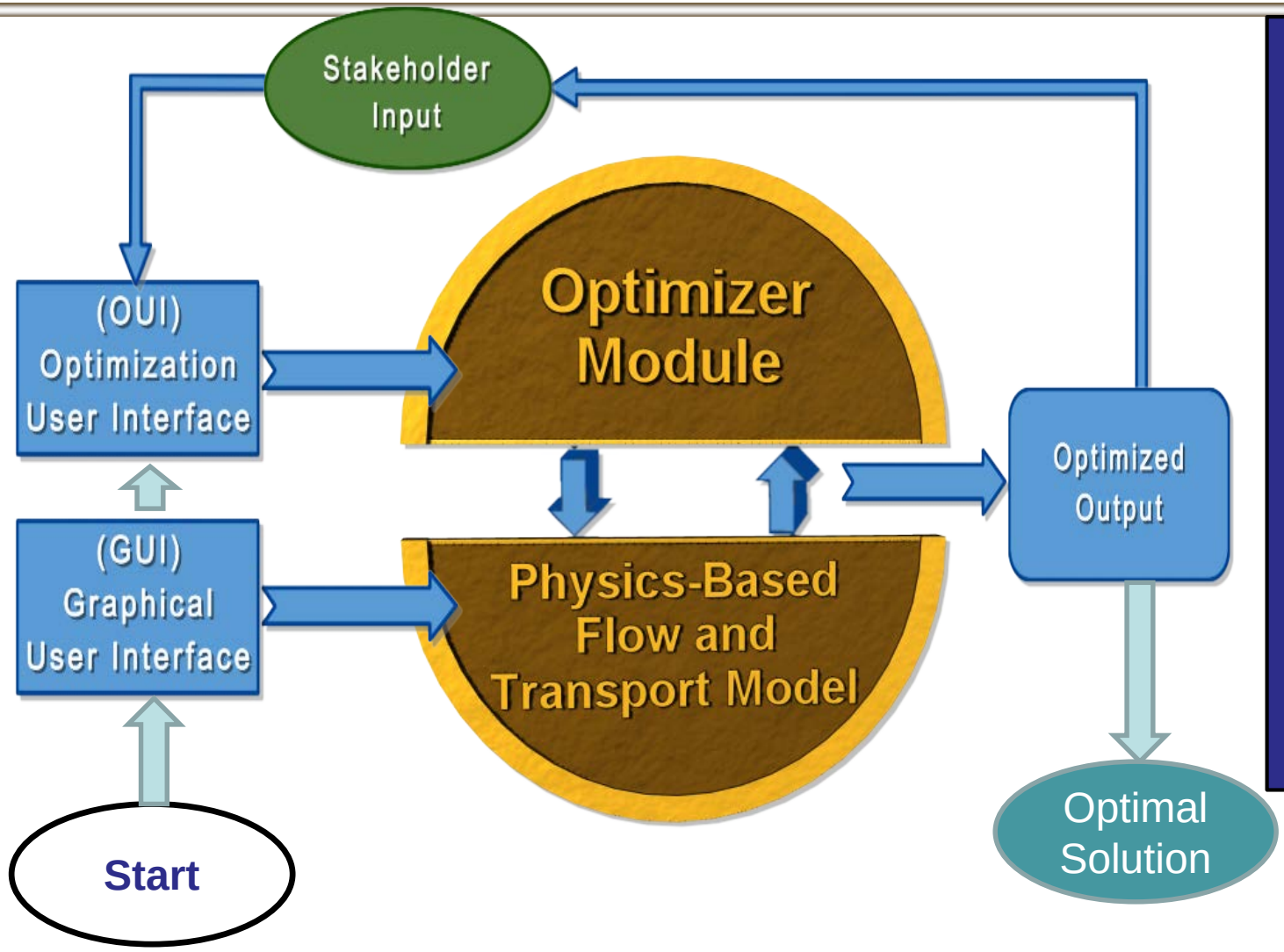
Incorporates the following modeling software:

- MODFLOW / MT3DMS and MODFLOW-SURFACT™

Customizable to non-MODFLOW-based software previously or currently used at DOE sites:

- FEHM
- STOMP
- BioF&T3D / BioSlurp
- Modeling codes with open access to the input and output files

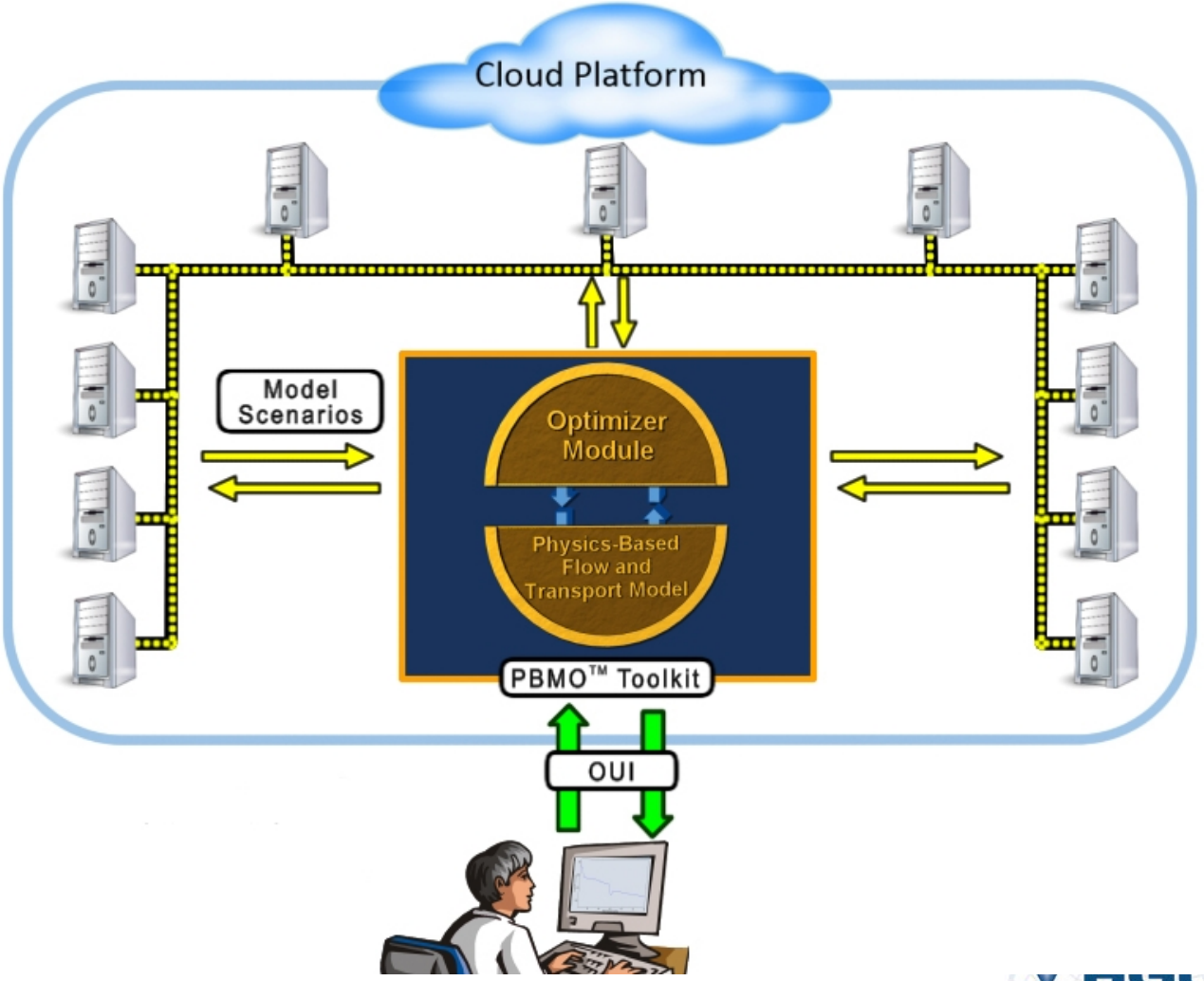
PBMO System Framework Incorporates Stakeholder Input



- User builds model with GUI
- User builds optimization with OUI incorporating Stakeholder input
- Optimized output generated for Stakeholder review
- Stakeholder insight incorporated into the OUI, analysis repeated
- Optimal solution meets Stakeholder requirements

Cloud-Based Computing Handles Complex Optimization Problems

- Cloud Computing accessible from a user's desktop
- Readily enables execution of thousands of scenario runs simultaneously
- Supports optimal remedial design selection, probabilistic performance and risk assessments



PBMO Application Examples

- **1. Former Ft. Ord, CA – Performance-Based Remediation Project**
  - Groundwater extraction and treatment system (GETS) remediation with optimized exit strategy toward site closure (End State)
  - Site closure and regulator acceptance achieved
- **2. National Priority List (NPL) Site at DoD Facility, NE – Optimization of Performance of Remedy-In-Place**
  - Determine optimal O&M of a 4,000 gpm capacity GETS
  - Implement sequential strategy of pumping followed by transition to monitored natural attenuation (MNA)
- **3. Industrial Superfund Site, NE – Complex Remedy Design for 4-mile Long VOC Plume**
  - Challenging optimization problem comprising over 4,400 decision variables and over 2.2 million constraints
  - 38,000 simulations required to achieve the accepted optimal design

Example 1: Former Fort Ord, CA

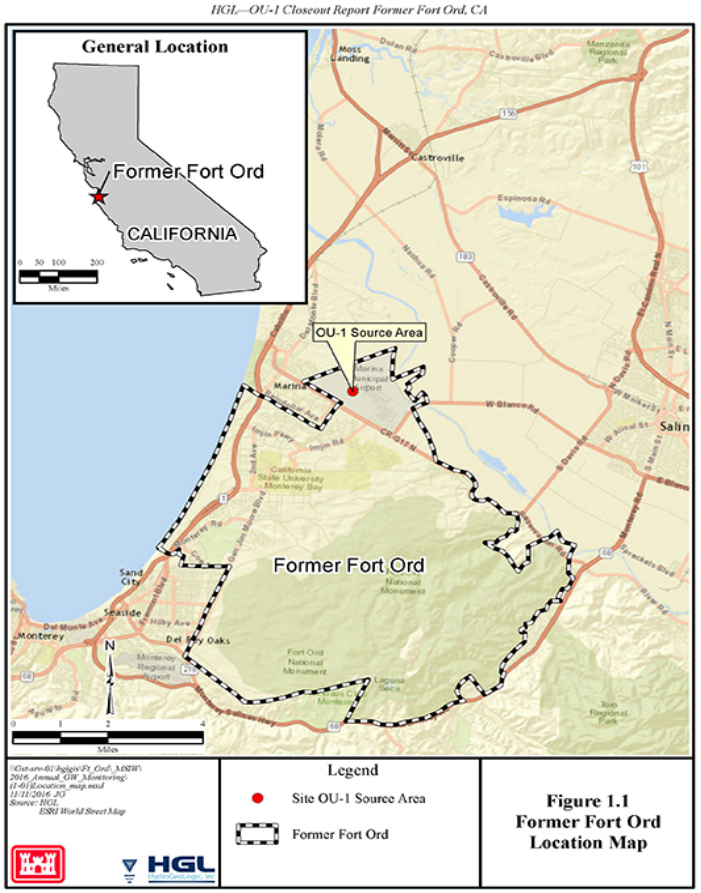
Client: US Army

Location: Former Ft. Ord, Monterey, CA

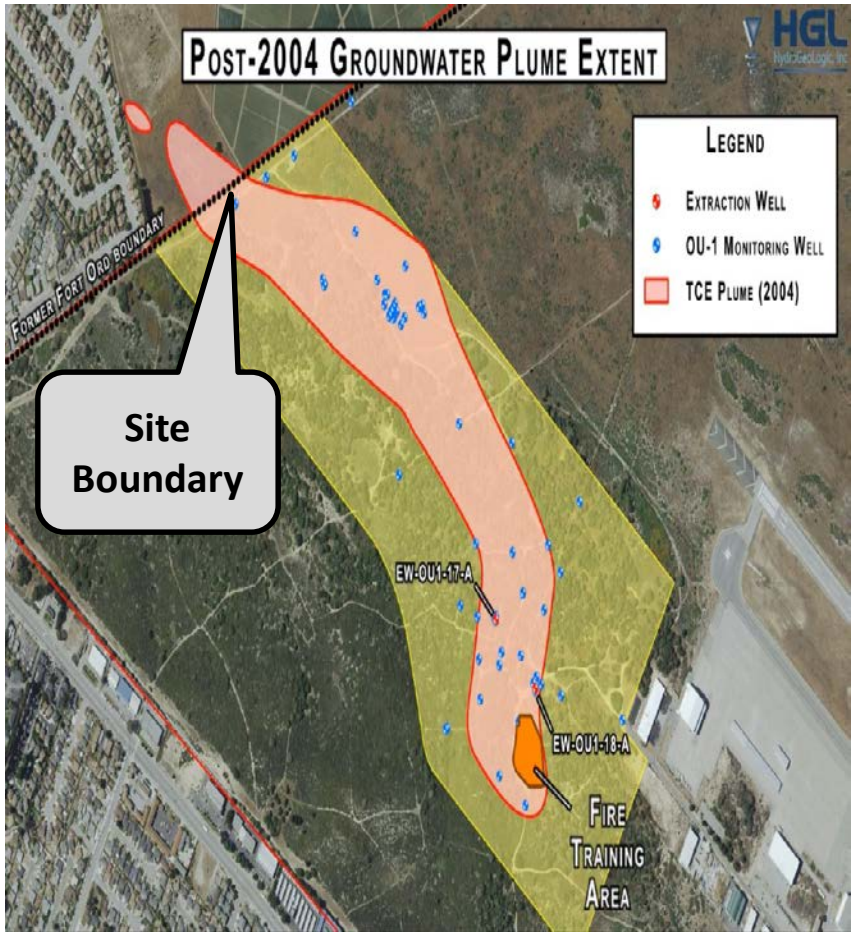
- Former fire training area (FTA)
- TCE above Aquifer Cleanup Level (ACL) since 2008

Optimization Scope:

- Enhance and optimize the existing GETS operation
- Determine optimal flow rates and pumping schedules to operate the remedy-in-place system to minimize total remediation and post closure monitoring costs while meeting cleanup time requirements

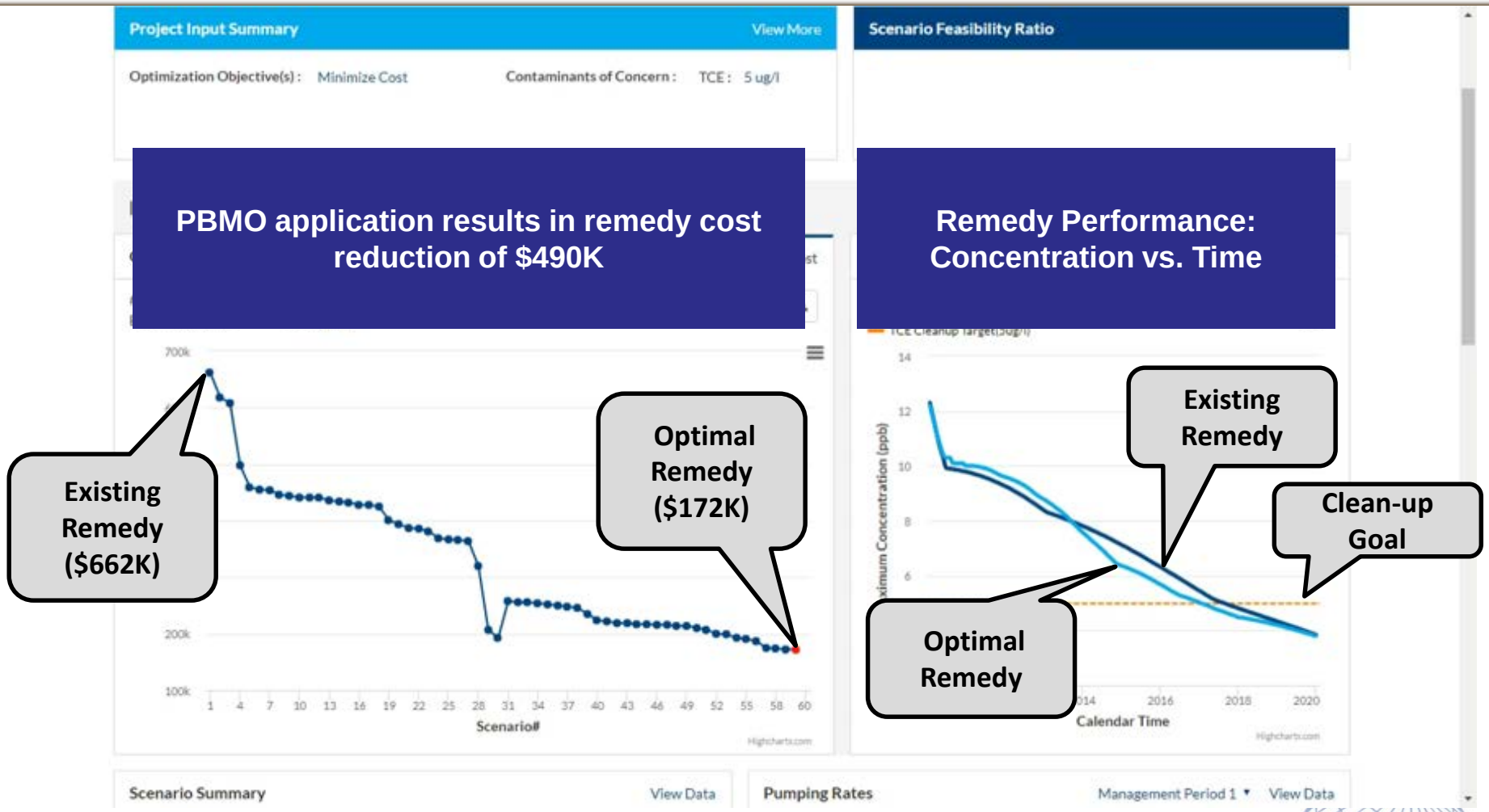


Problems / Challenges and HGL's Solution



- HGL was tasked to remediate the site and attain closure as part of a Fixed-Price Performance Based (end state type) Contract
- Plume had unexpectedly extended 1,500 ft beyond site boundary
- In order to meet the challenges, PBMO was used to optimize remedial system operation and facilitate transition to monitored natural attenuation
- HGL achieved early site closure within the fixed price project budget despite changed conditions

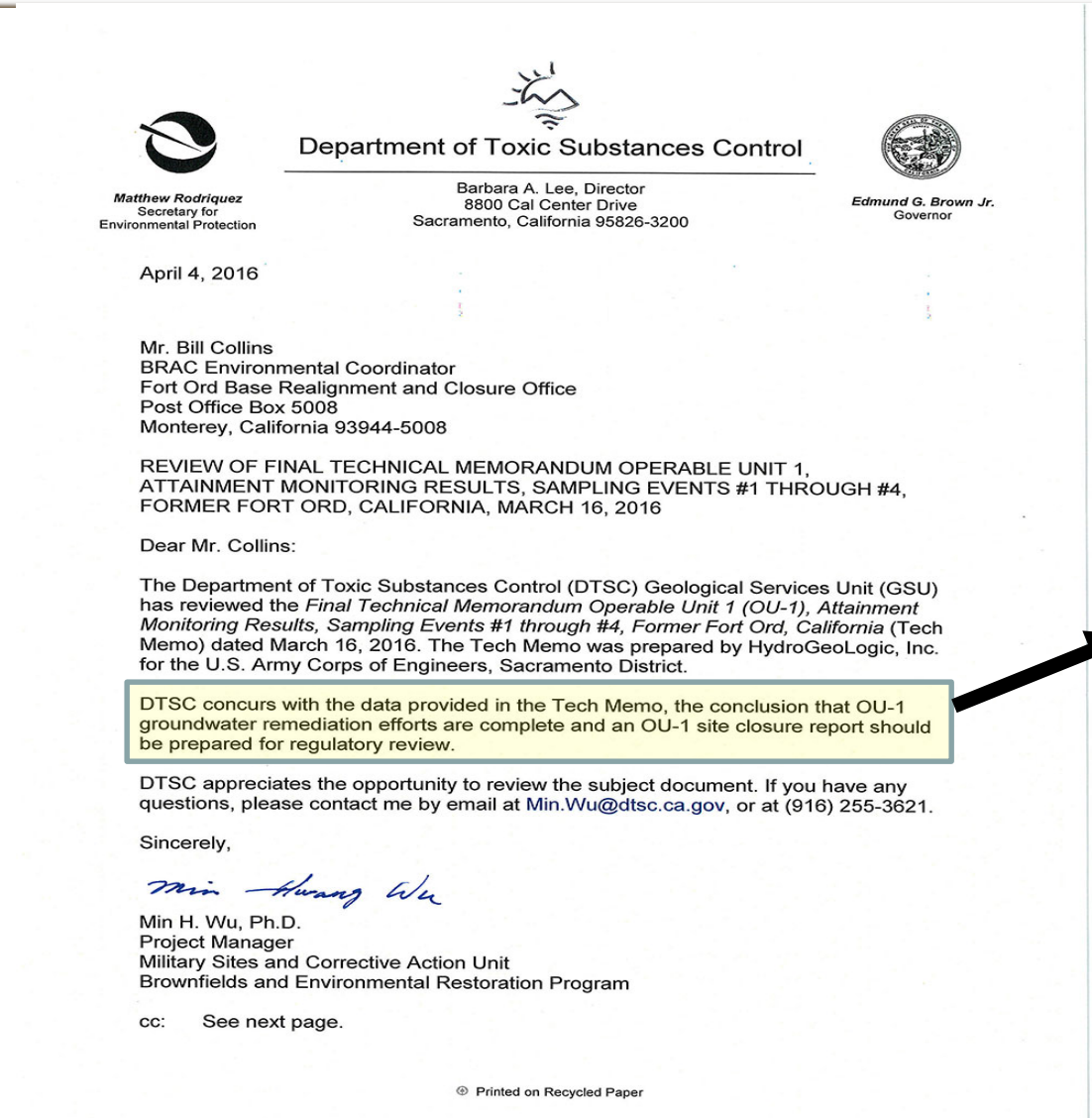
PBMO Application Result



Remedy Cost Components

Cost Components	Existing Remedy	Optimal Remedy
Utility Costs	$124,707	$21,745
Routine O&M Costs	$273,192	$59,560
Repairs and Maintenance Costs	$44,472	$19,894
Carbon Change-Out Costs	$39,040	$13,013
Extraction Well Sampling ODC Costs	$87,752	$11,431
Extraction Well Sampling Labor Costs	$11,672	$1,809
Groundwater LTM ODC Costs	$18,770	$11,376
Groundwater LTM Labor Costs	$13,998	$9,344
Semi-Annual Reporting Costs	$17,464	$10,121
Annual Reporting Costs	$30,437	$13,828
Remedy Cost	***$661,503***	***$172,121***

End State Achieved with Regulatory Concurrence



Department of Toxic Substances Control

Barbara A. Lee, Director
8800 Cal Center Drive
Sacramento, California 95826-3200

Matthew Rodriquez
Secretary for
Environmental Protection

Edmund G. Brown Jr.
Governor

April 4, 2016

Mr. Bill Collins
BRAC Environmental Coordinator
Fort Ord Base Realignment and Closure Office
Post Office Box 5008
Monterey, California 93944-5008

REVIEW OF FINAL TECHNICAL MEMORANDUM OPERABLE UNIT 1,
ATTAINMENT MONITORING RESULTS, SAMPLING EVENTS #1 THROUGH #4,
FORMER FORT ORD, CALIFORNIA, MARCH 16, 2016

Dear Mr. Collins:

The Department of Toxic Substances Control (DTSC) Geological Services Unit (GSU) has reviewed the *Final Technical Memorandum Operable Unit 1 (OU-1), Attainment Monitoring Results, Sampling Events #1 through #4, Former Fort Ord, California* (Tech Memo) dated March 16, 2016. The Tech Memo was prepared by HydroGeoLogic, Inc. for the U.S. Army Corps of Engineers, Sacramento District.

DTSC concurs with the data provided in the Tech Memo, the conclusion that OU-1 groundwater remediation efforts are complete and an OU-1 site closure report should be prepared for regulatory review.

DTSC appreciates the opportunity to review the subject document. If you have any questions, please contact me by email at Min.Wu@dtsc.ca.gov, or at (916) 255-3621.

Sincerely,

Min Hwang Wu

Min H. Wu, Ph.D.
Project Manager
Military Sites and Corrective Action Unit
Brownfields and Environmental Restoration Program

cc: See next page.

Printed on Recycled Paper

"DTSC concurs…that OU-1 [site] groundwater remediation efforts are complete..."

HGL HydroGeoLogic, Inc

Example 2: NPL Site at DoD Facility, NE

Client: DoD

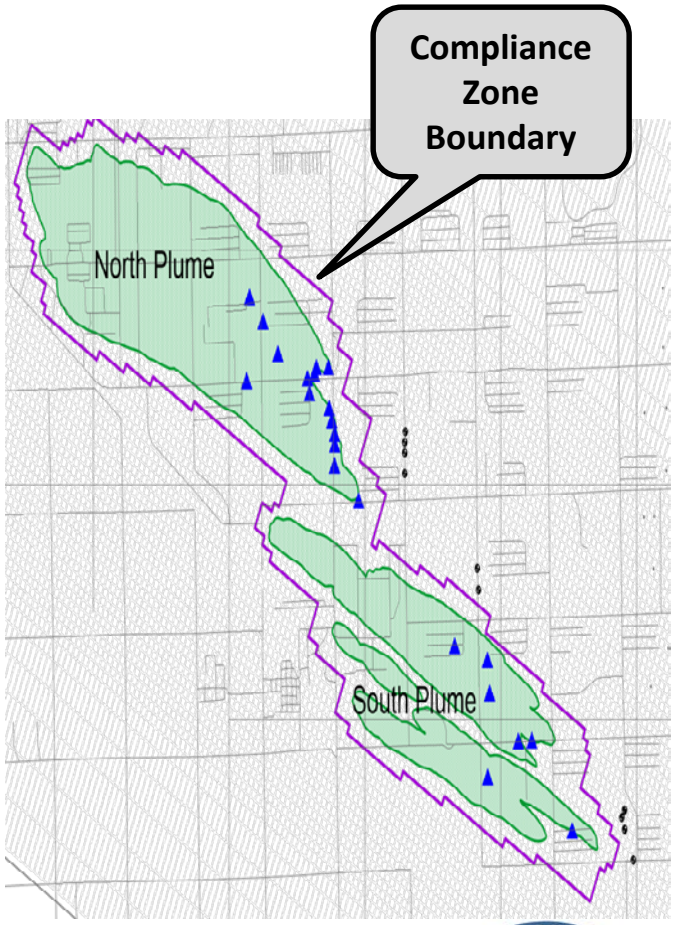
Location: Hastings, NE

Key Features:

- Sand and gravel aquifer 120-140 ft thick with discontinuous clay and silt aquitards
- Multiple VOC and explosives plumes:
  - 5.8 square-mile North Plume
  - 3.5 square-mile South Plume
- Large capacity (4,000 gpm) GETS

Optimization Scope:

- Re-establish confidence of plume containment
- In accordance with the Record of Decision (ROD), optimize the remedy performance of the existing GETS subject to the following constraints:
  - Maximize contaminant mass removal
  - Accelerate transition to MNA
  - Meet all compliance requirements
  - Adaptive management of GETS operations



PBMO Optimization Strategy

Current Operations

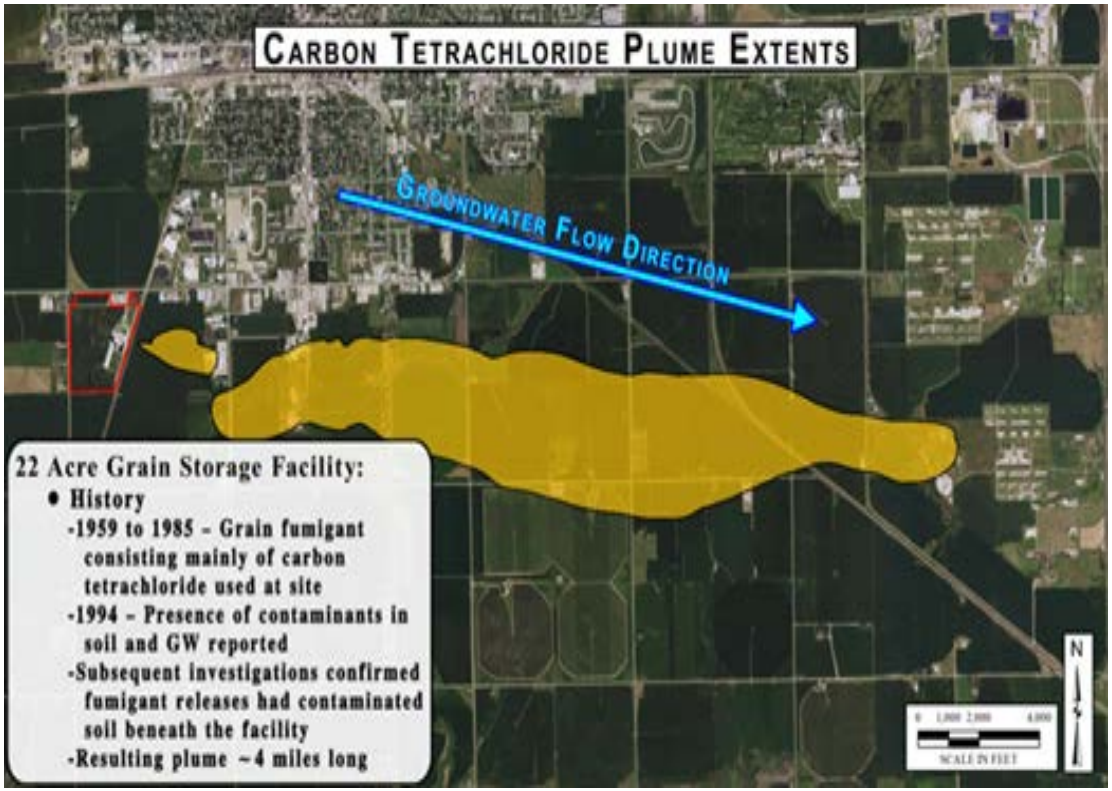
Implemented GETS Pumping Schedule

Extraction Well	MP-0	MP-1	MP-2	MP-3	MP-4	MP-5	MP-6
EW101	202	258	326	141	282	52	51
EW102	250	293	187	19	110	19	128
EW103	130	137	149	18	16	349	315
EW104	63	60	20	217	125	330	296
EW105	87	76	90	339	246	27	410
EW106	120	132	99	320	362	361	313
EW107	20	21	45	248	250	384	236
EW108	69	78	106	334	331	233	203
EW109	80	77	141	18	128	214	51
EW110	20	19	168	286	271	42	43
EW111	266	252	213	317	45	47	35
EW112	209	238	284	0	41	44	47
EW113	240	205	326	0	0	0	0
EW114	272	328	0	0	0	0	0
EW115	250	149	168	0	0	0	0
EW201	20	17	291	66	82	290	145
EW202	114	93	158	335	337	134	151
EW203	292	287	356	334	386	390	227
EW204	195	217	70	170	256	263	211
EW205	330	344	20	23	16	39	239
EW206	20	19	109	269	182	190	84
EW207	168	199	174	45	36	90	314
Total 22 Wells	3417	3499	3500	3499	3502	3498	3499

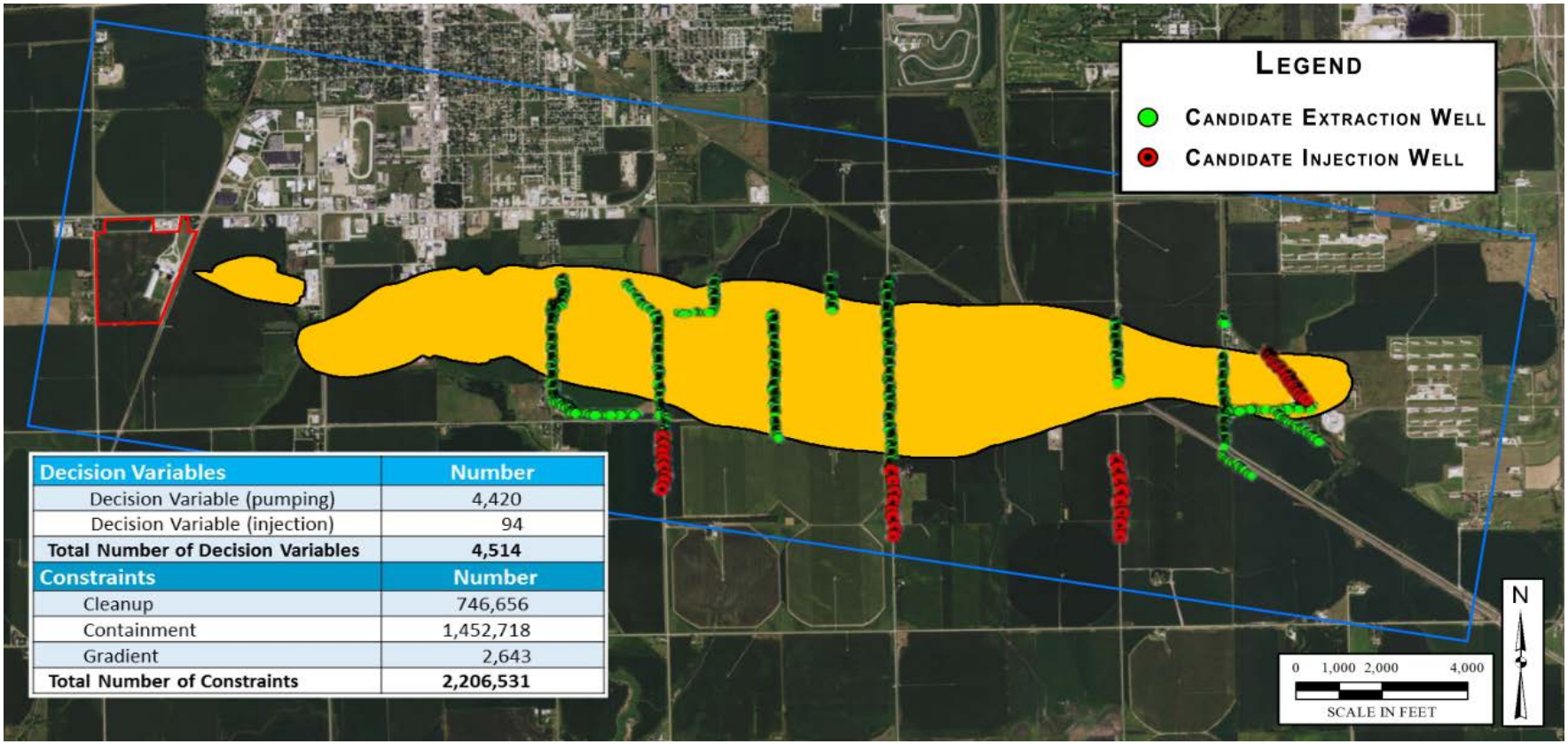
- PBMO developed the best use of the 22 existing wells within the constraints of the existing GETS
- PBMO sifted through possible ways to operate the system and developed an optimal solution that met all constraints
- Each Management Period (MP) length is 5 years and aligns with 5-year review cycle
- Monitoring conducted to assess remedy performance

Example 3: Industrial Superfund Site, NE

- **Client: US EPA**
- **Location:**
  - Hastings, NE
- **Key Features**
  - Carbon tetrachloride plume
    4 miles long
  - Agricultural area
- **Optimization Scope:**
  - Develop optimal remedial design of new GETS system
  - Satisfy well location constraints



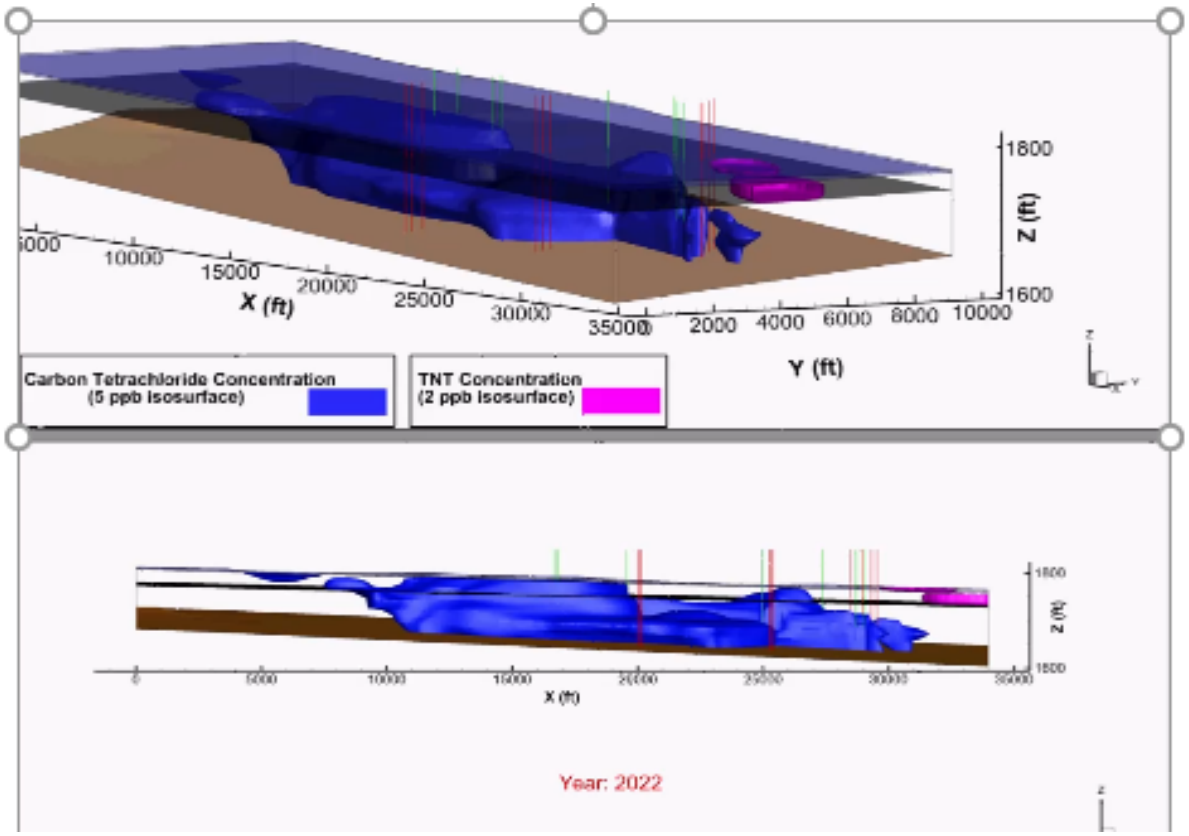
PBMO Design Criteria



Decision Variables	Number
Decision Variable (pumping)	4,420
Decision Variable (injection)	94
Total Number of Decision Variables	**4,514**
Constraints	**Number**
Cleanup	746,656
Containment	1,452,718
Gradient	2,643
Total Number of Constraints	**2,206,531**

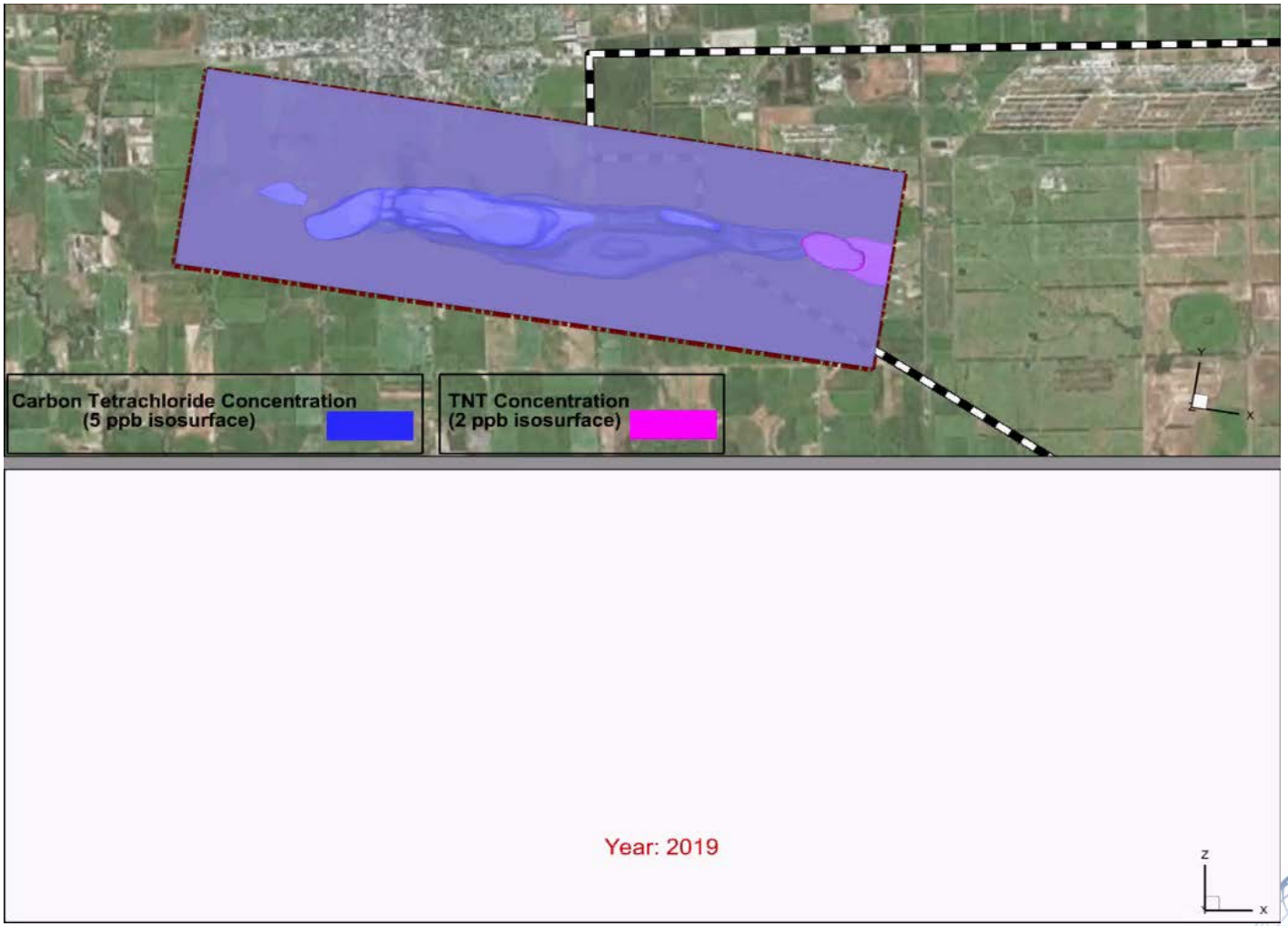
The design optimization tested 4,514 possible locations for candidate extraction and injection wells and their flow rates

PBMO Optimal Design

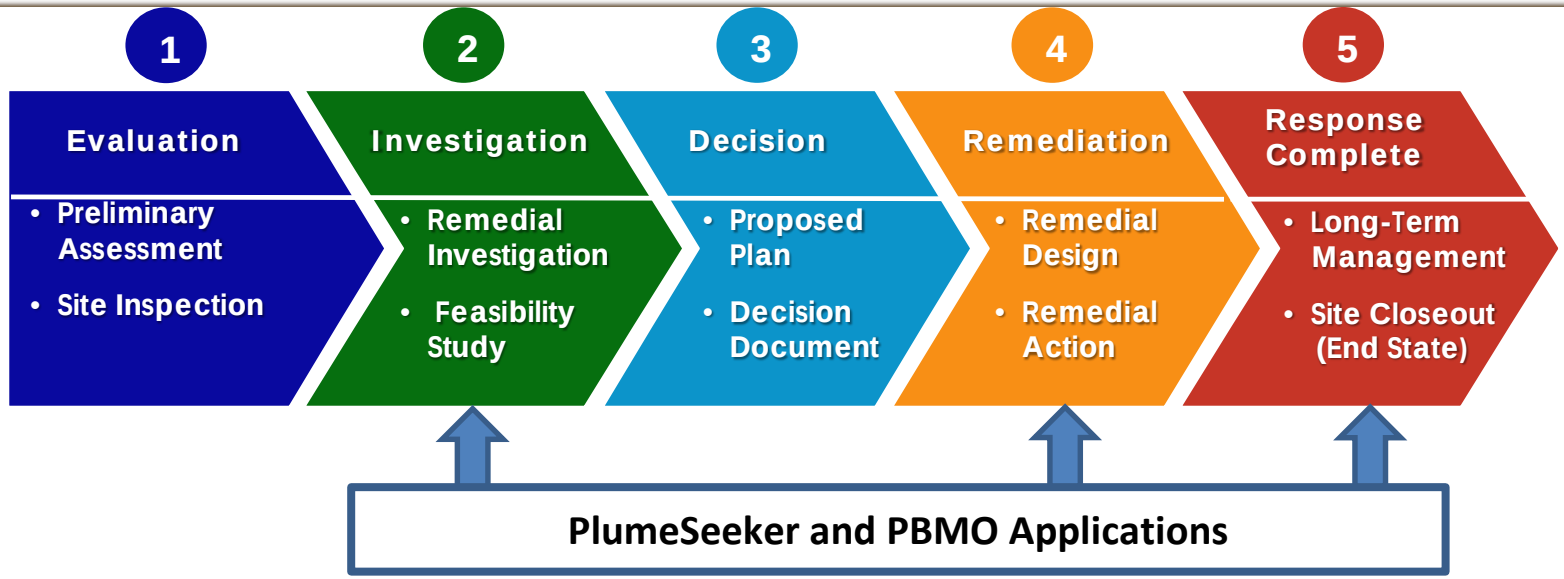


- Optimal remedial design approved for subsequent implementation
- 8 extraction wells (green)
- 10 injection wells (red)
- This design is approved for implementation in 2019

3-D Animation of Plume Response



Summary and Conclusions



- HGL has successfully developed and deployed innovative optimization tools (PlumeSeeker and PBMO) at complex DOE, DOD, and Industrial sites
- These tools support environmental decisions throughout key stages of the CERCLA process
  - Their applications improve efficiency and effectiveness resulting in substantial reduction of investigation and remedy costs
  - Optimal solutions transparent, reproducible, and accepted by regulators and other stakeholders

Additional Information and Contact:

PBMO Inquiries:

pbmo@hgl.com

PlumeSeeker Inquiries:

plumeseeker@hgl.com