Maximizing the Capital Efficiency of Contaminated Upstream Oil and Gas Sites Assessments by Using Geostatistical Modeling Approach

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Integrated Environments (2006) Ltd.

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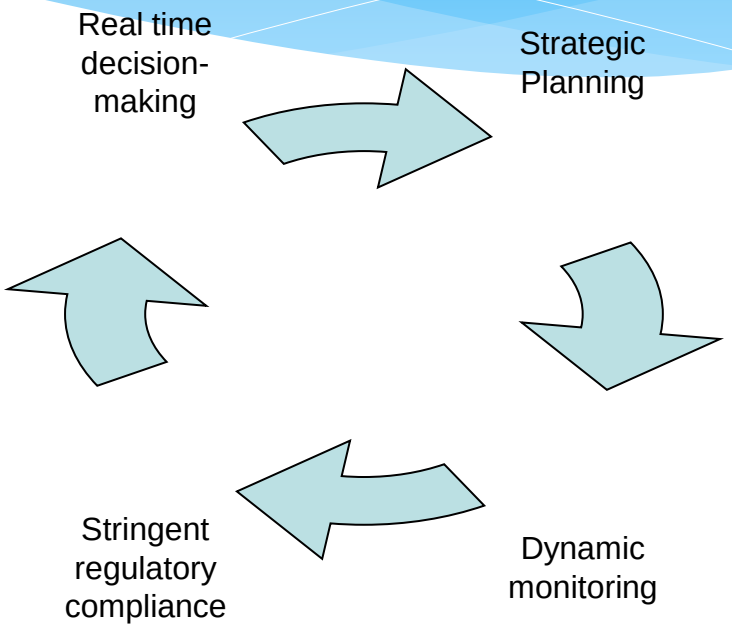
Integrated Environments
Planning • Integration • Management

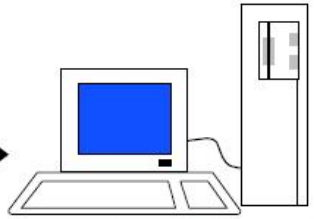
Contaminated Site Liability Management Processes

Next step switches from Lab analysis uncertainty to decision uncertainty based on the geostatistical prediction



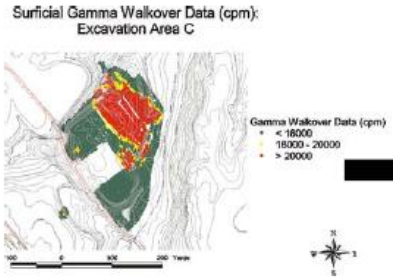
Existing Information

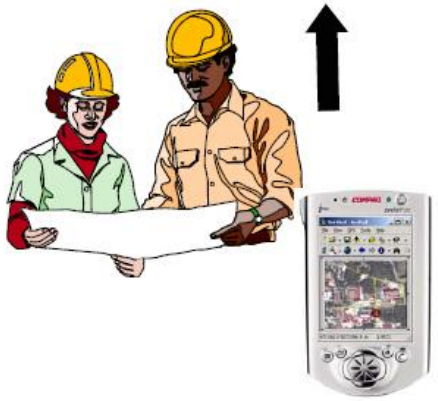
- Base maps
- Geology
- Boring samples
- ……..



Results on Web

Rapid field data acquisition





Decision makers, stakeholders, ...

Cited: Argonne National Laboratory, 2003

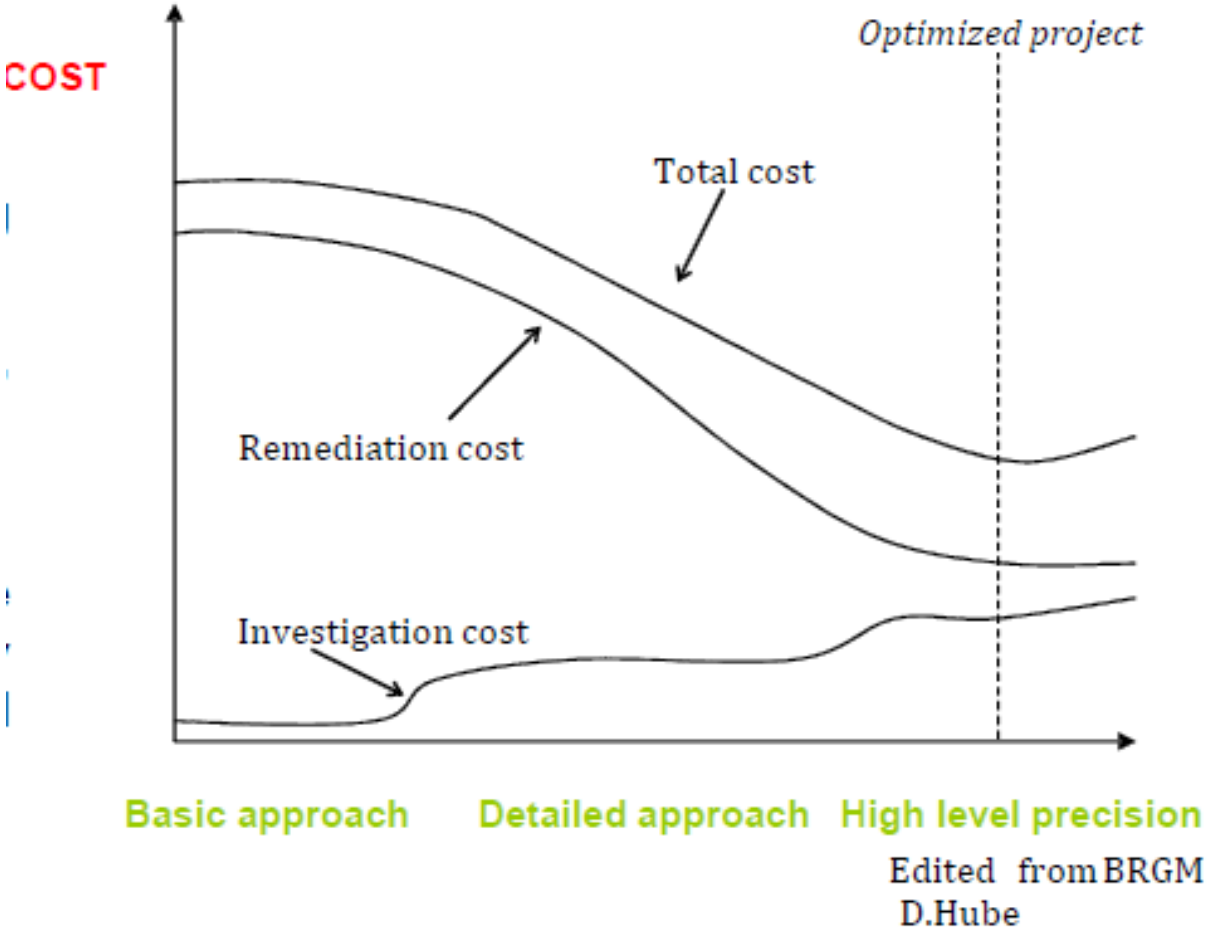
Site Conceptual Model

- Base Map
- Site Geological Information
- Sampling Data

Quantitative

- **Contaminant extent**
- **Sampling and prediction**

Life-cycle Cost Curve of Remediation



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D.Hube

Introduction to Geostatistics

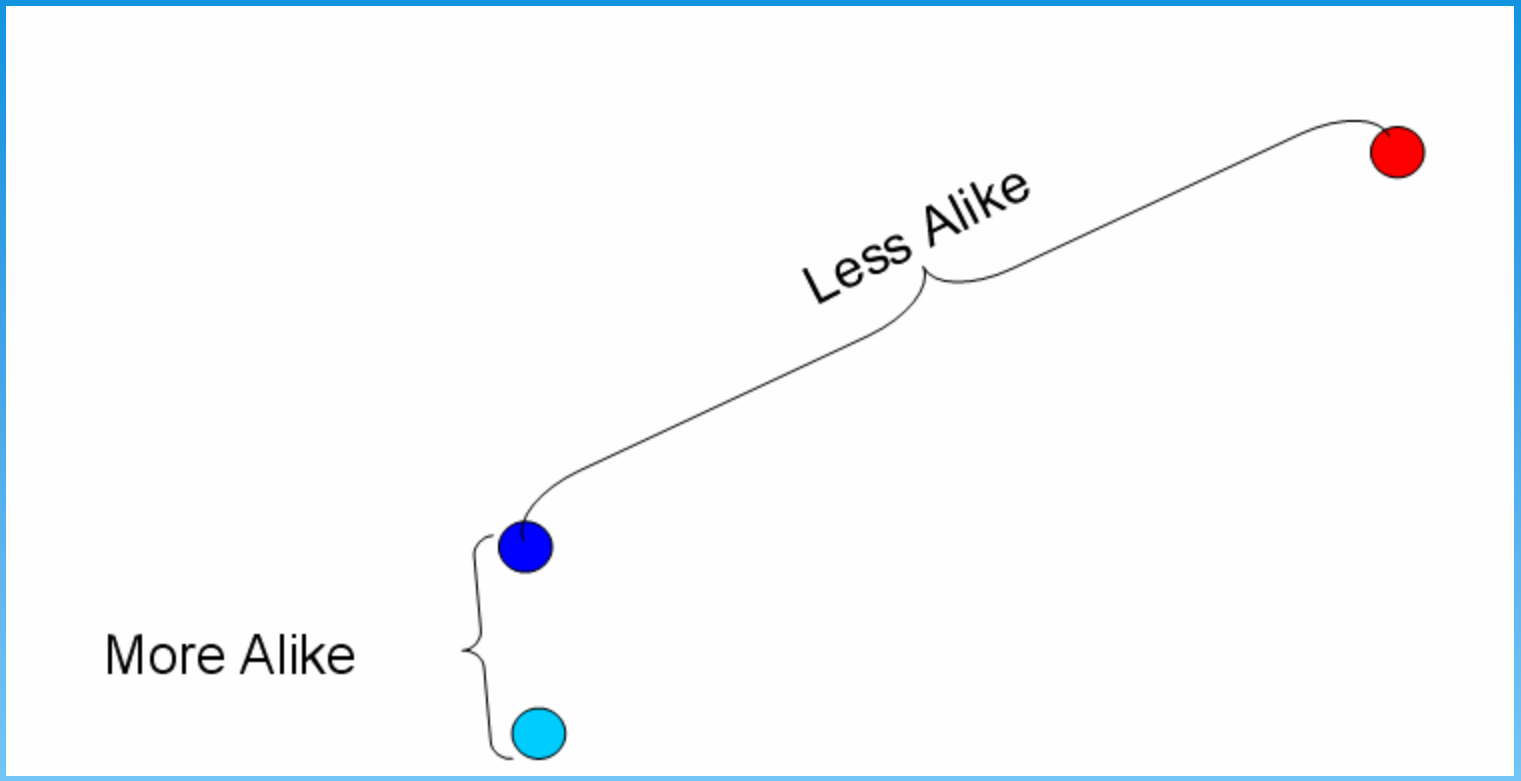
Developed in the 1960s, by the South African mining engineer Danie G. Krige (1919).

Principle: spatial and temporary autocorrelation, interpolating the unsampled locations.

Purpose:

Generally: spatial pattern, spatial interpolation and modeling if local and spatial uncertainty exist.

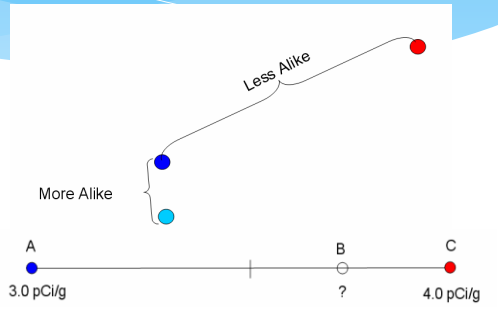
For contaminated site investigations: visualize and analyze the monitoring data, predicted the unsampled locations and delineate the boundary of impacted environmental media for further remediation.


Less Alike
More Alike

Regionalized Variables and Kridging

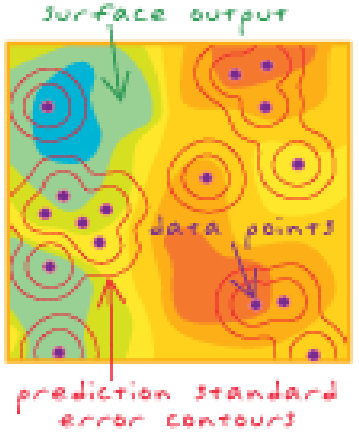
Regionalized Variables

The attributes of contaminated sites are regionalized variables, not deterministic or random.



Kriging - An interpolation technique

The surrounding measured values are weighted to derive a predicted value for an unmeasured location. Weights are based on the distance between the measured points, the prediction locations and the overall spatial arrangement among the measured points.



Application in Environmental Modeling

* Regional air monitoring modeling
* Soil and groundwater site investigation results and contamination plume remediation and predictions
* Soil site characterizations
* Optimizations of remediation parameters

ESRI® ArcGIS® Geostatistical Analyst

A suite of statistical models and tools for spatial data exploration and surface generation create statistically valid prediction surface, along with prediction uncertainties, from a limited number of data measurements.

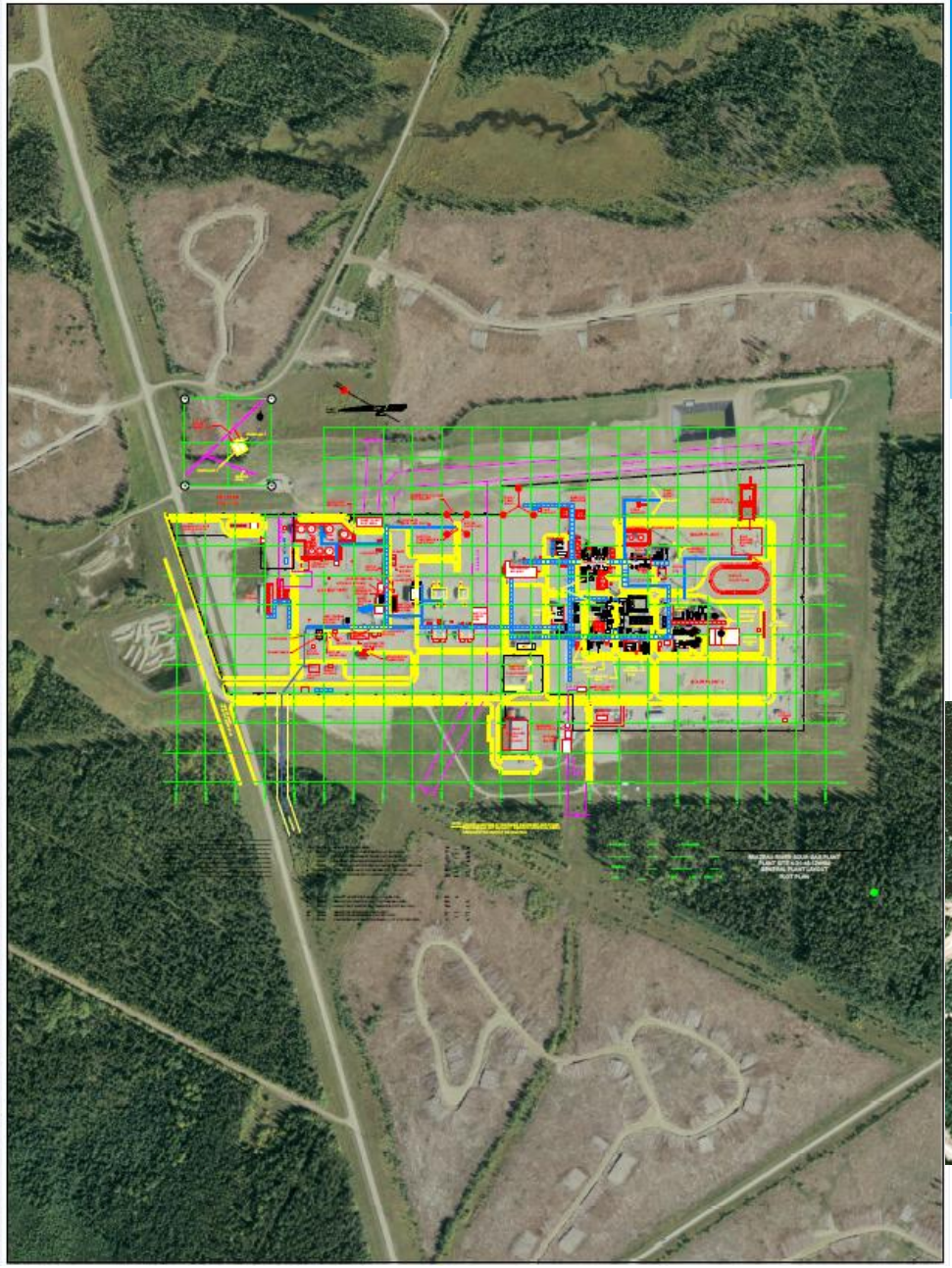
Outcomes:

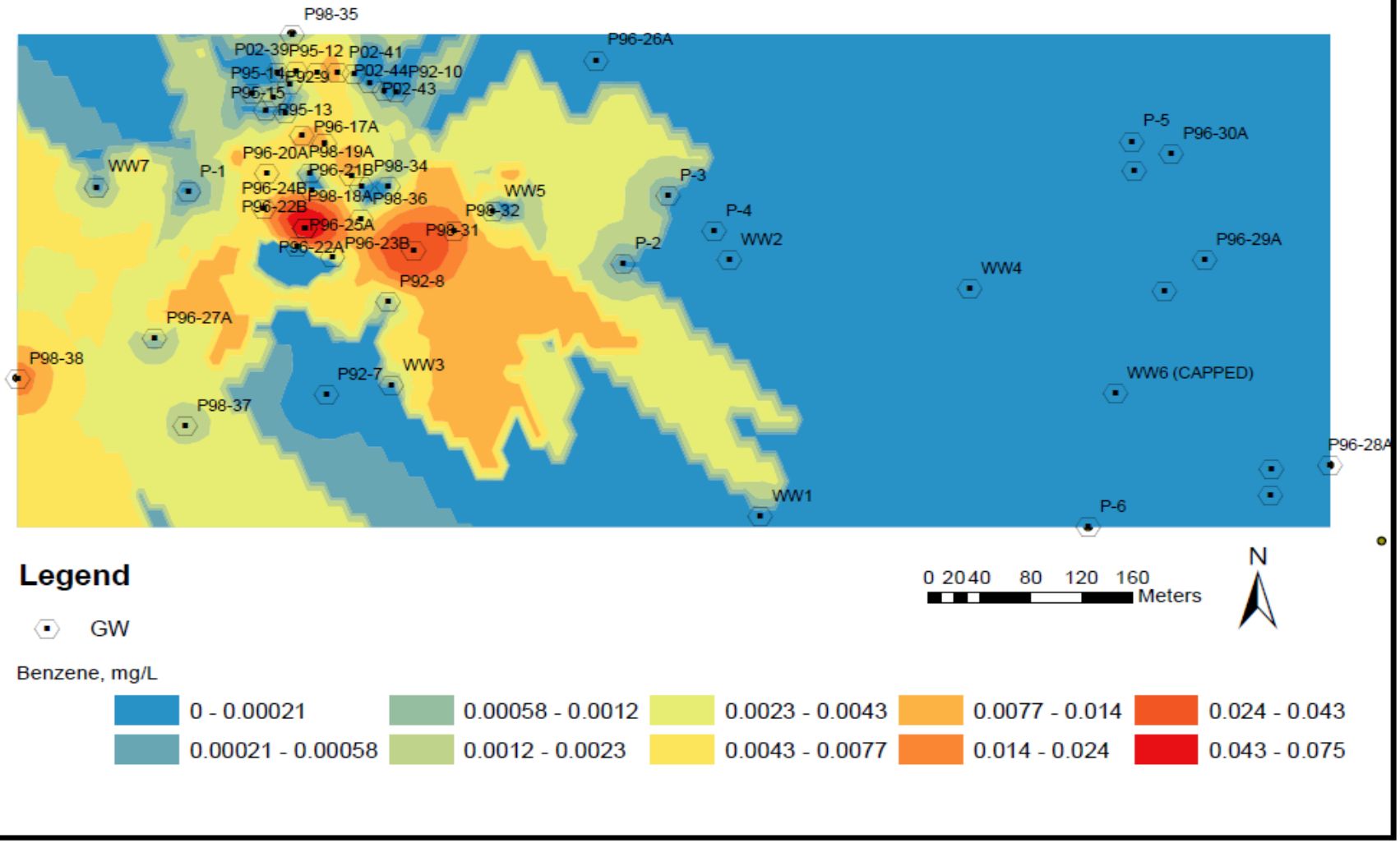
- **Threshold mapping:** Probability mapping can be generated to predict the area to exceed the threshold.
- **Prediction mapping**
- **Quantile**

Case studies

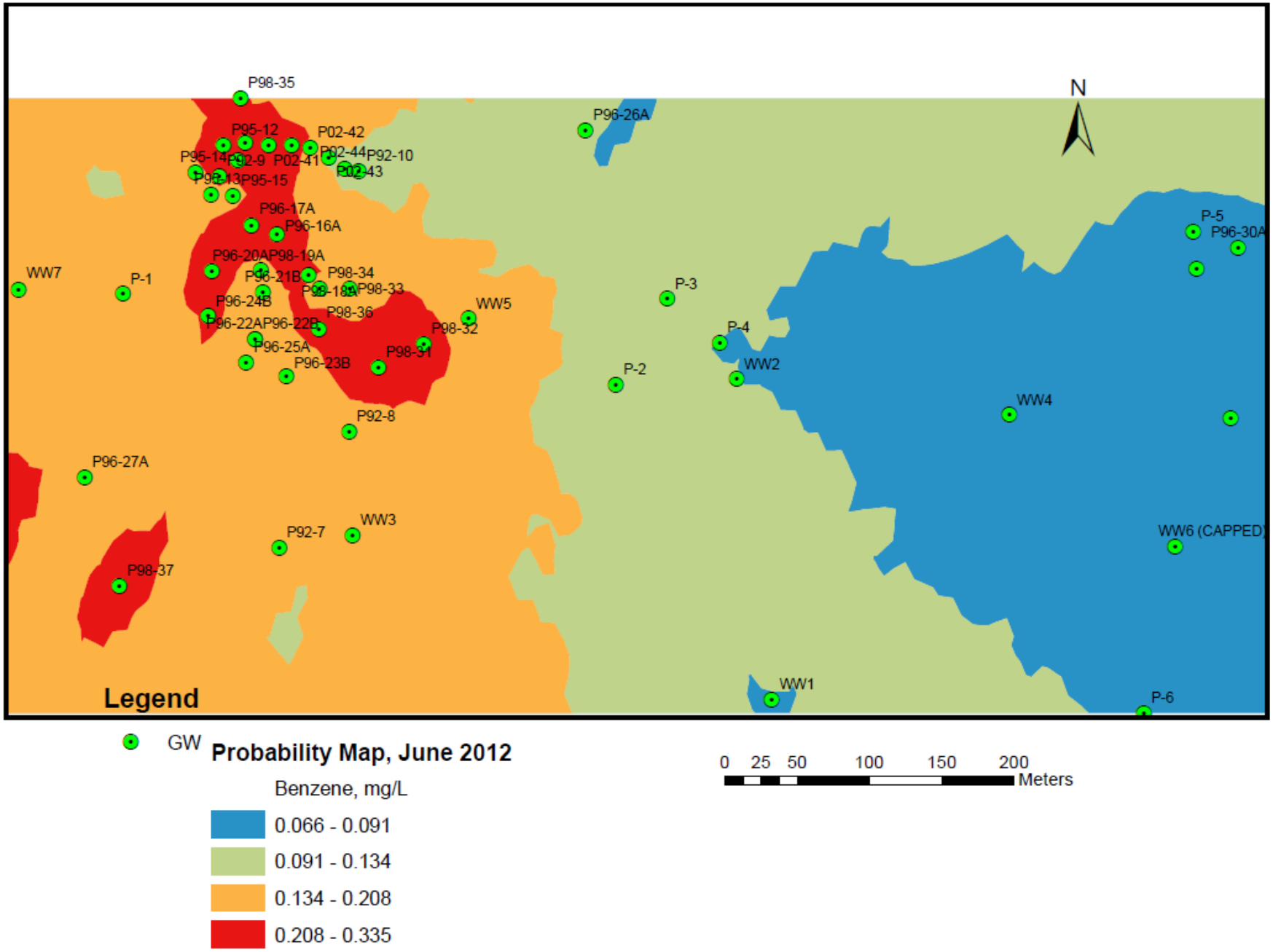
* Impacted soil volume estimation for flare pit sites
* Groundwater contamination mapping for a gas plant

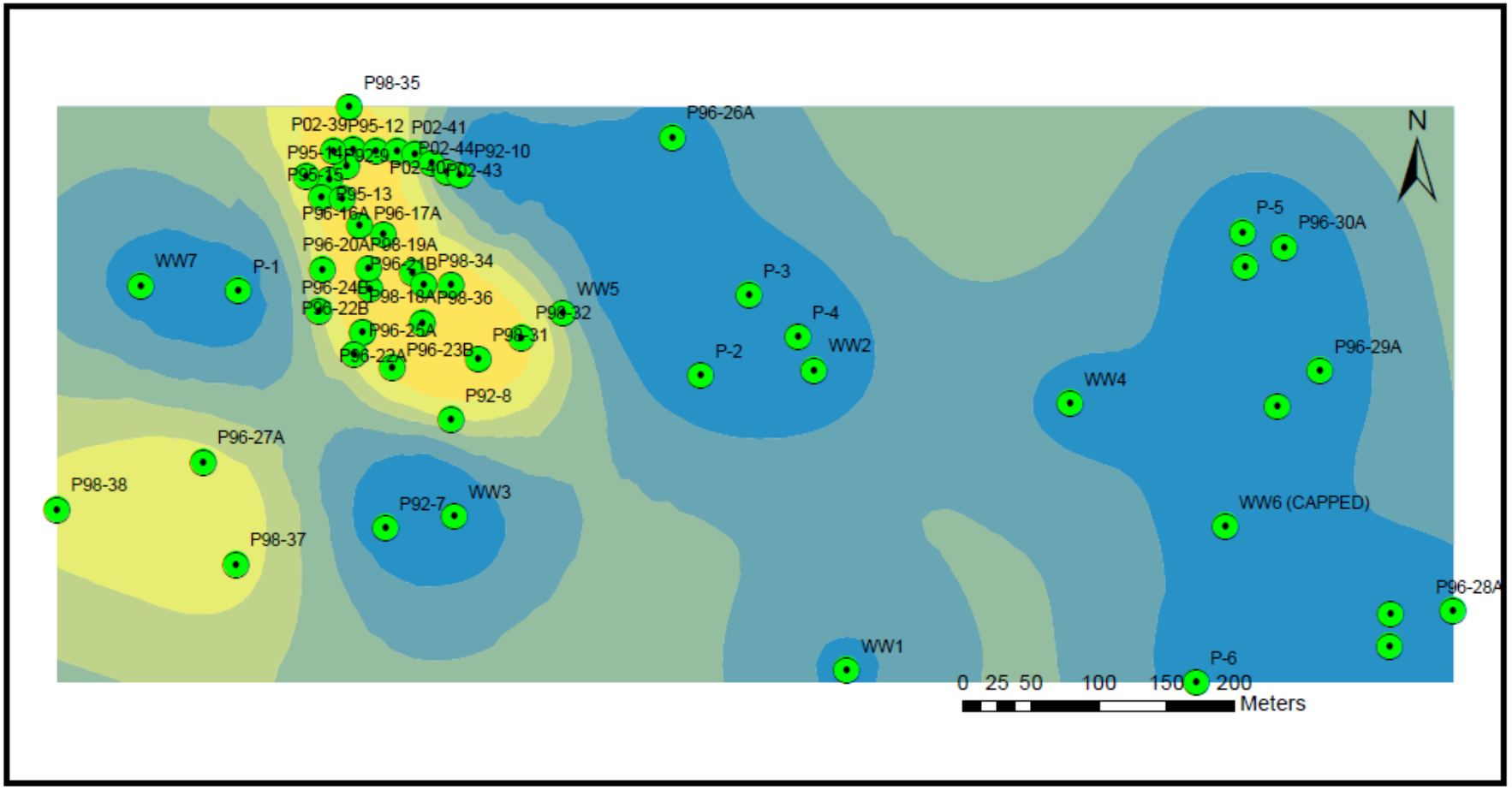
Groundwater Monitoring for A Gas Plant





Benzene in groundwater June 2012


P98-35
P95-12
P02-42
P02-44
P92-10
P95-14
P92-9
P02-41
P02-43
P92-13
P95-15
P96-17A
P96-16A
P96-20A
P98-19A
WW7
P-1
P96-21B
P98-34
P98-18A
P98-33
P96-24B
WW5
P96-22A
P96-22B
P98-36
P98-32
P96-25A
P98-31
P96-23B
P92-8
P96-27A
WW3
P92-7
P98-37
P96-26A
P-3
P-4
P-2
WW2
P-5
P96-30A
WW4
WW6 (CAPPED)
WW1
P-6
N
Legend
GW
Probability Map, June 2012
Benzene, mg/L
0.066 - 0.091
0.091 - 0.134
0.134 - 0.208
0.208 - 0.335
0 25 50 100 150 200
Meters

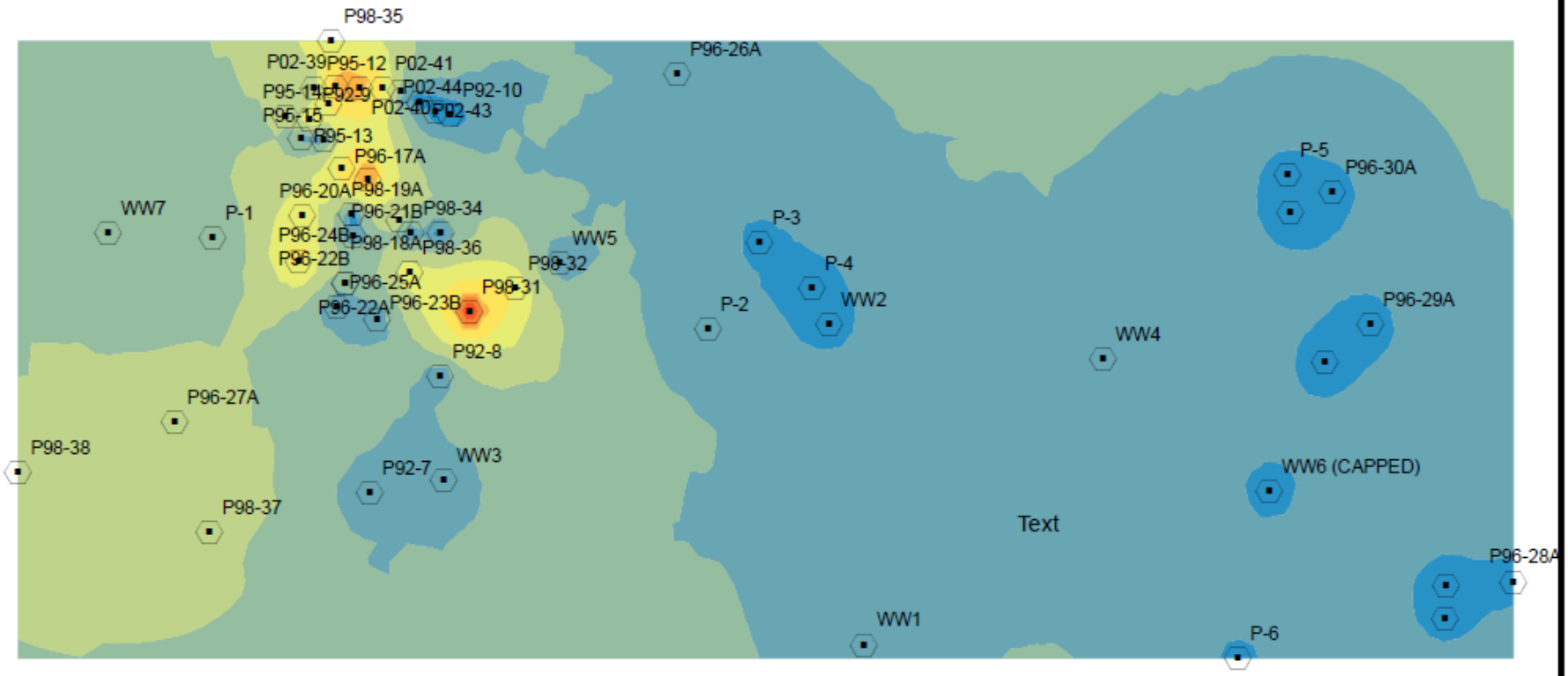


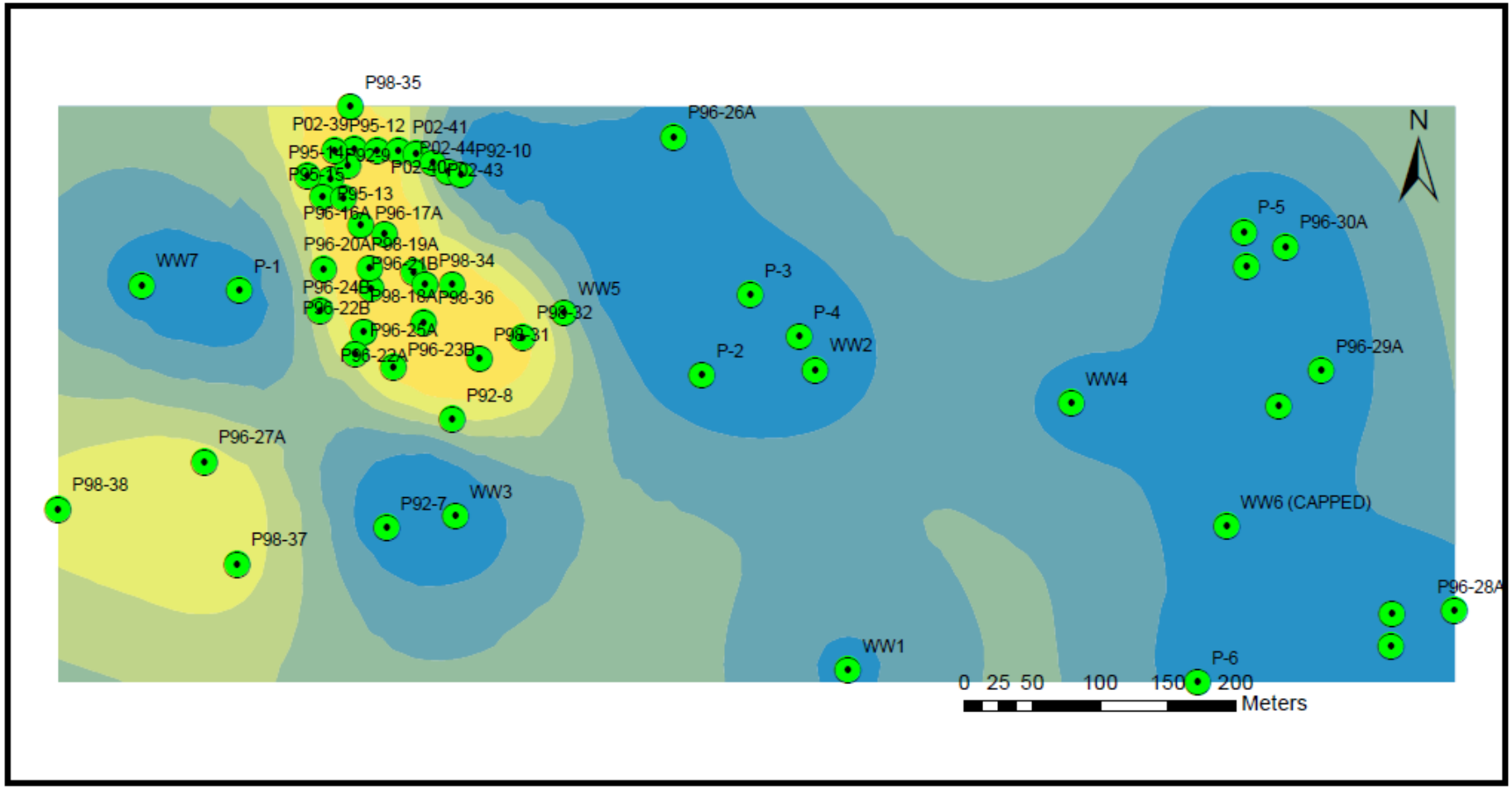
Legend

GW

Prediction Map June 2011 Toluene (mg/L)

0 - 0.00009	0.00009 - 0.0002	0.0002 - 0.0003	0.0003 - 0.0004	0.0004 - 0.0005
0.0005 - 0.0005	0.0005 - 0.0006	0.0006 - 0.0007	0.0007 - 0.0008	


P98-35
P02-39
P95-12
P02-41
P95-11
P92-9
P02-44
P92-10
P02-40
P02-43
P96-15
P95-13
P96-17A
P96-20A
P98-19A
WW7
P-1
P96-21B
P98-34
P96-24B
P98-18A
P98-36
WW5
P96-22B
P98-32
P96-25A
P98-31
P96-22A
P96-23B
P92-8
P96-27A
P98-38
P92-7
WW3
P98-37
P96-26A
P-3
P-4
WW2
P-2
P-5
P96-30A
P96-29A
WW4
WW6 (CAPPED)
Text
P96-28A
WW1
P-6
Legend
GW
F1, mg/L
0 - 0.039
0.039 - 0.067
0.067 - 0.11
0.11 - 0.16
0.16 - 0.24
0.24 - 0.35
0.35 - 0.5
0.5 - 0.71
0.71 - 1
1 - 1.4
0 20 40 80 120 160
Meters
N

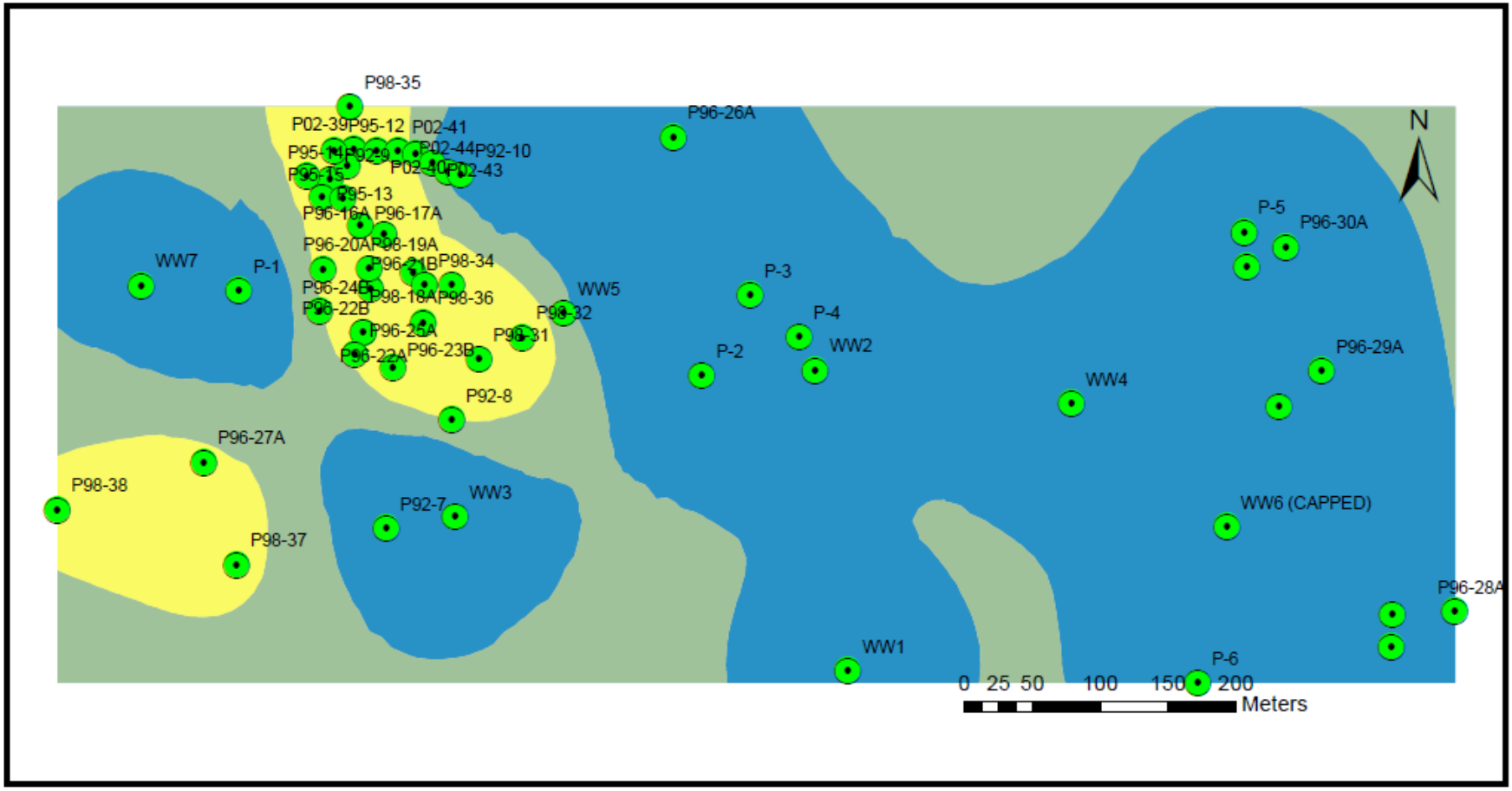


Legend

GW

Prediction Map June 2011 Toluene (mg/L)

0 - 0.00009	0.00009 - 0.0002	0.0002 - 0.0003	0.0003 - 0.0004	0.0004 - 0.0005
0.0005 - 0.0005	0.0005 - 0.0006	0.0006 - 0.0007	0.0007 - 0.0008	



Legend

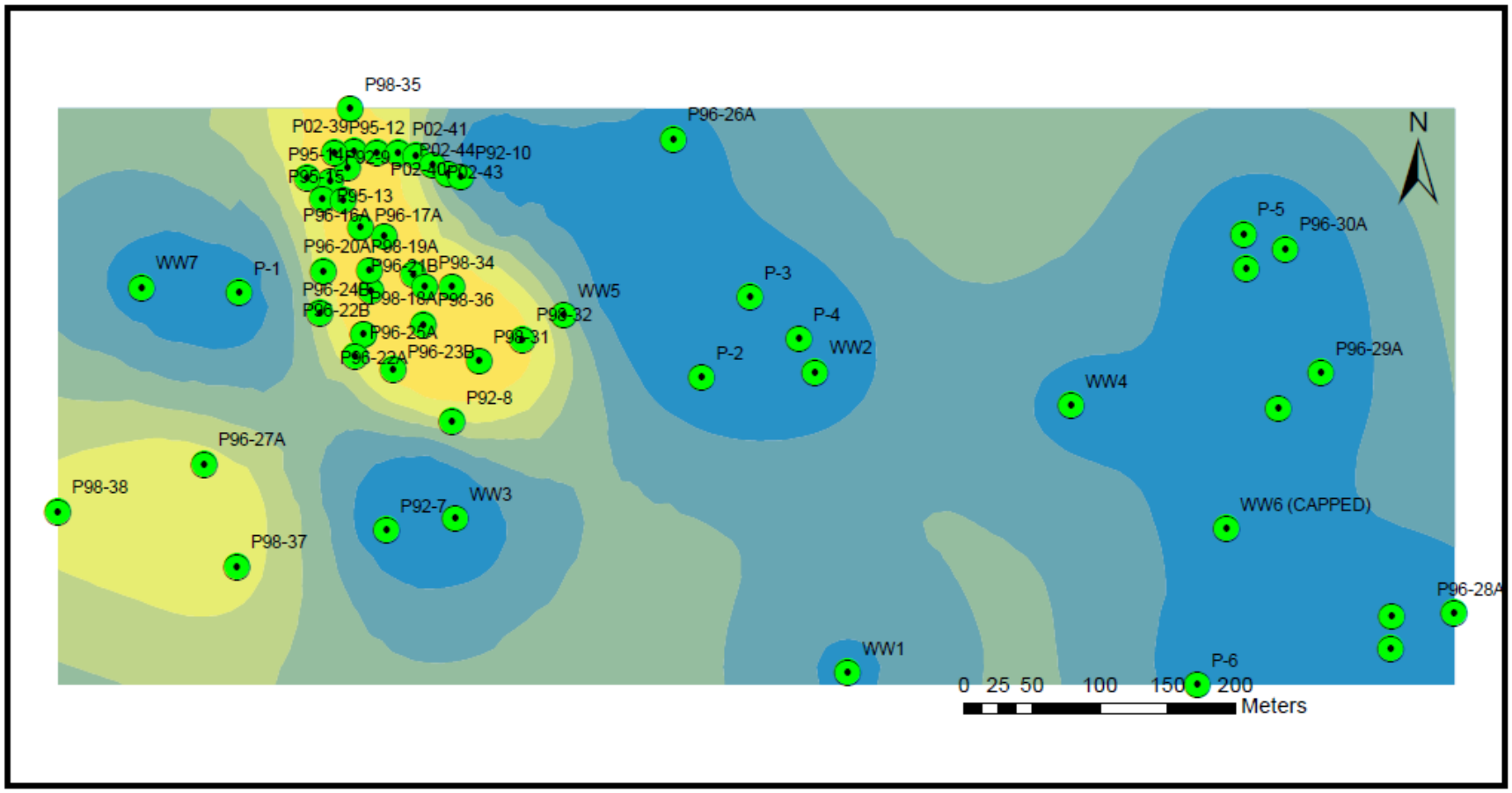
GW

Prediction Map Oct.2011 Toluene (mg/L)

0 - 0.0002

0.0002 - 0.0004

0.0004 - 0.0005

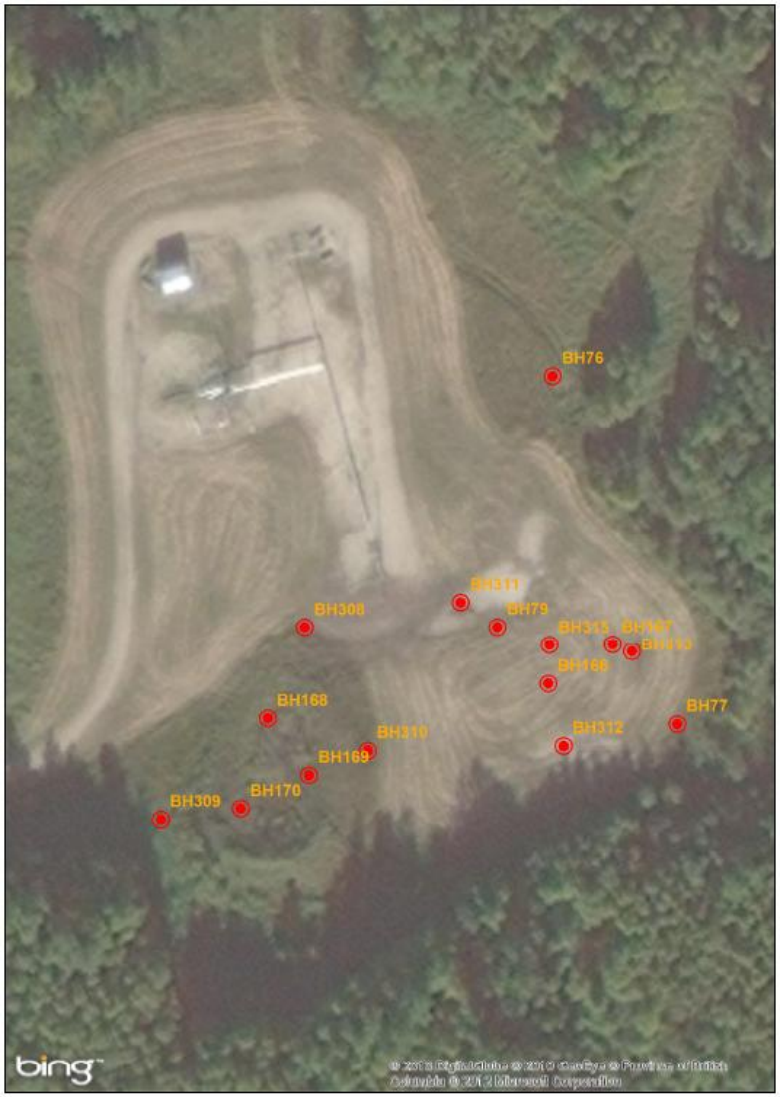


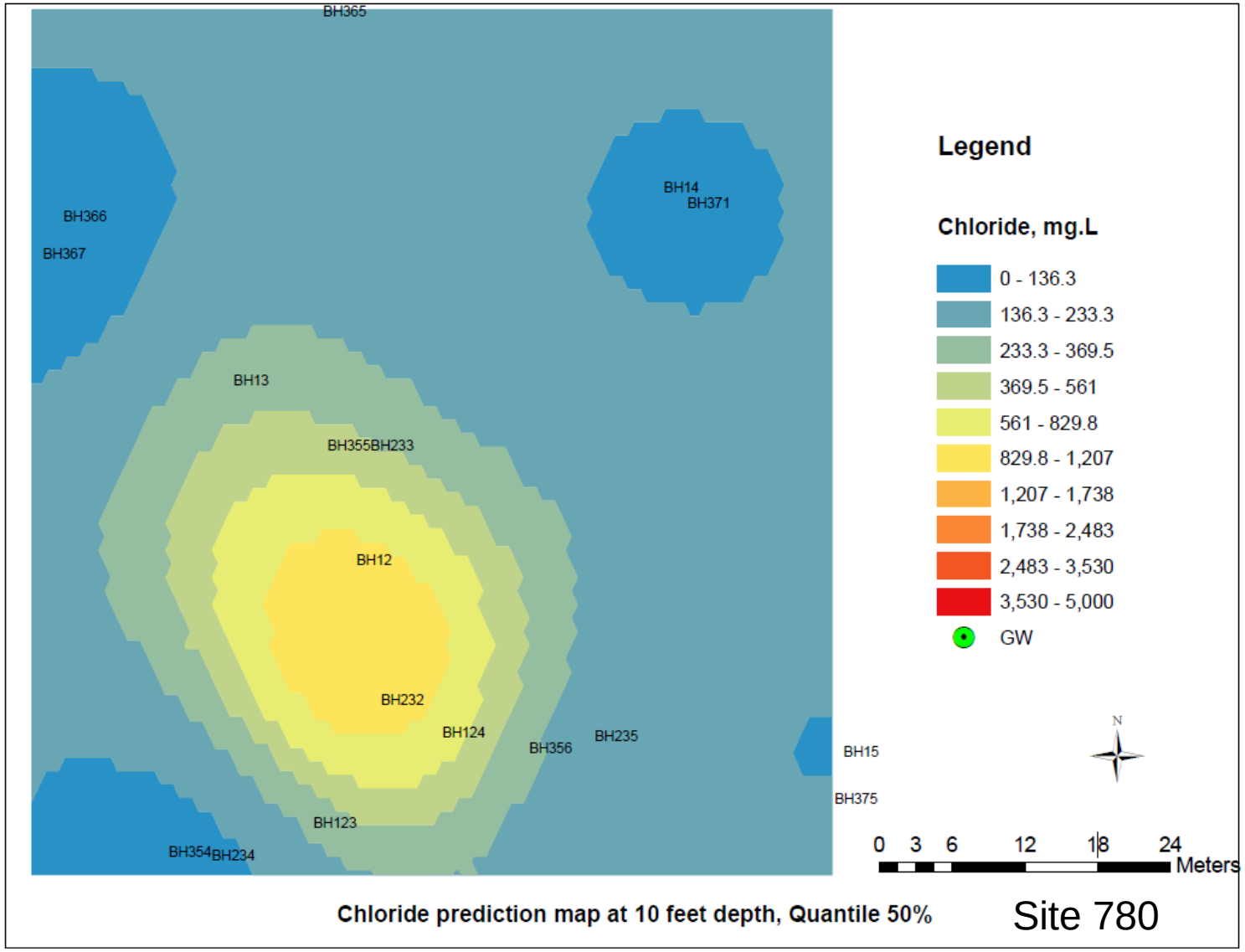
Legend

GW

Prediction Map June 2011 Toluene (mg/L)

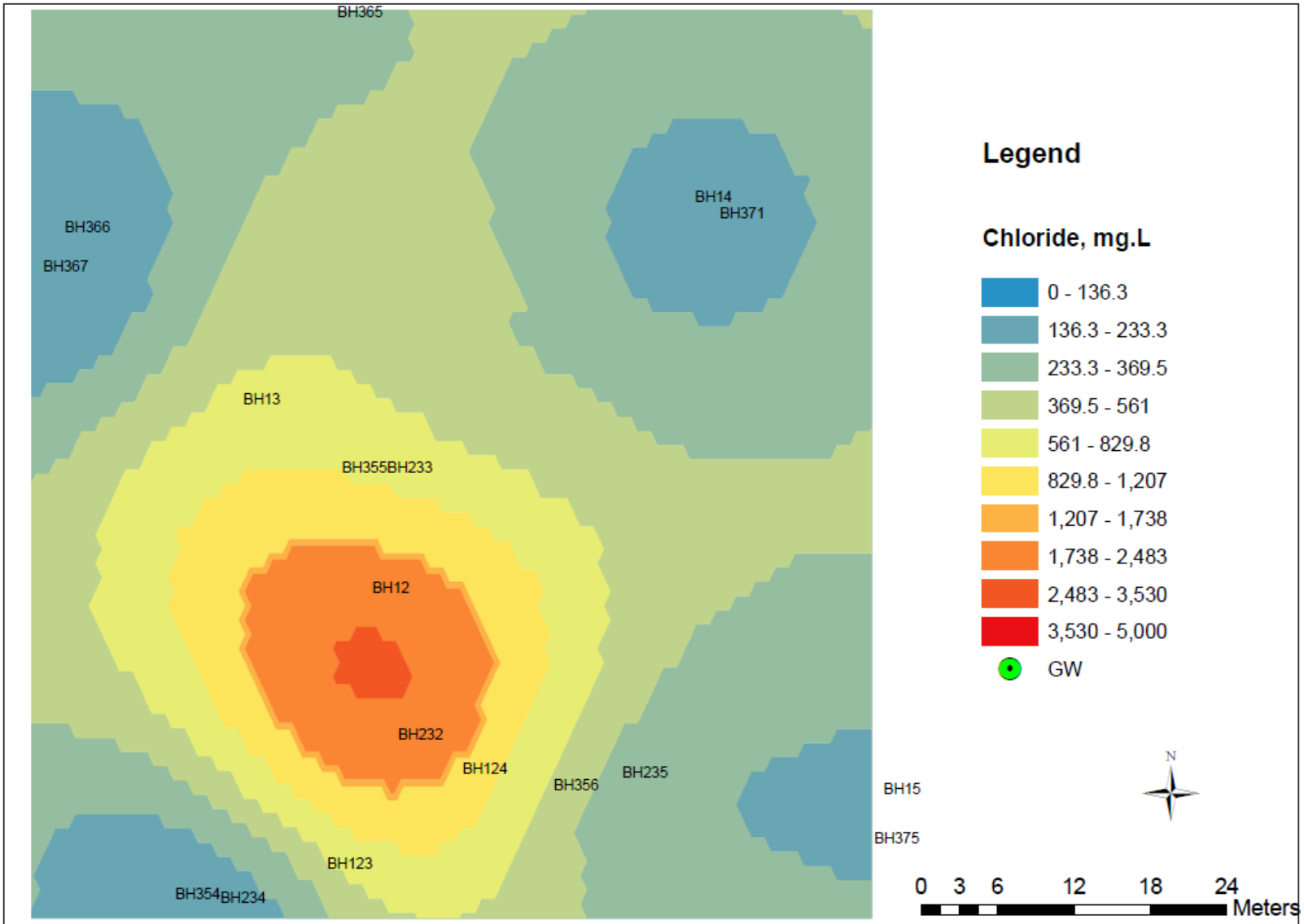
0 - 0.00009	0.00009 - 0.0002	0.0002 - 0.0003	0.0003 - 0.0004	0.0004 - 0.0005
0.0005 - 0.0005	0.0005 - 0.0006	0.0006 - 0.0007	0.0007 - 0.0008	


BH76
BH311
BH308
BH79
BH315
BH167
BH313
BH166
BH168
BH77
BH312
BH310
BH169
BH309
BH170
bing

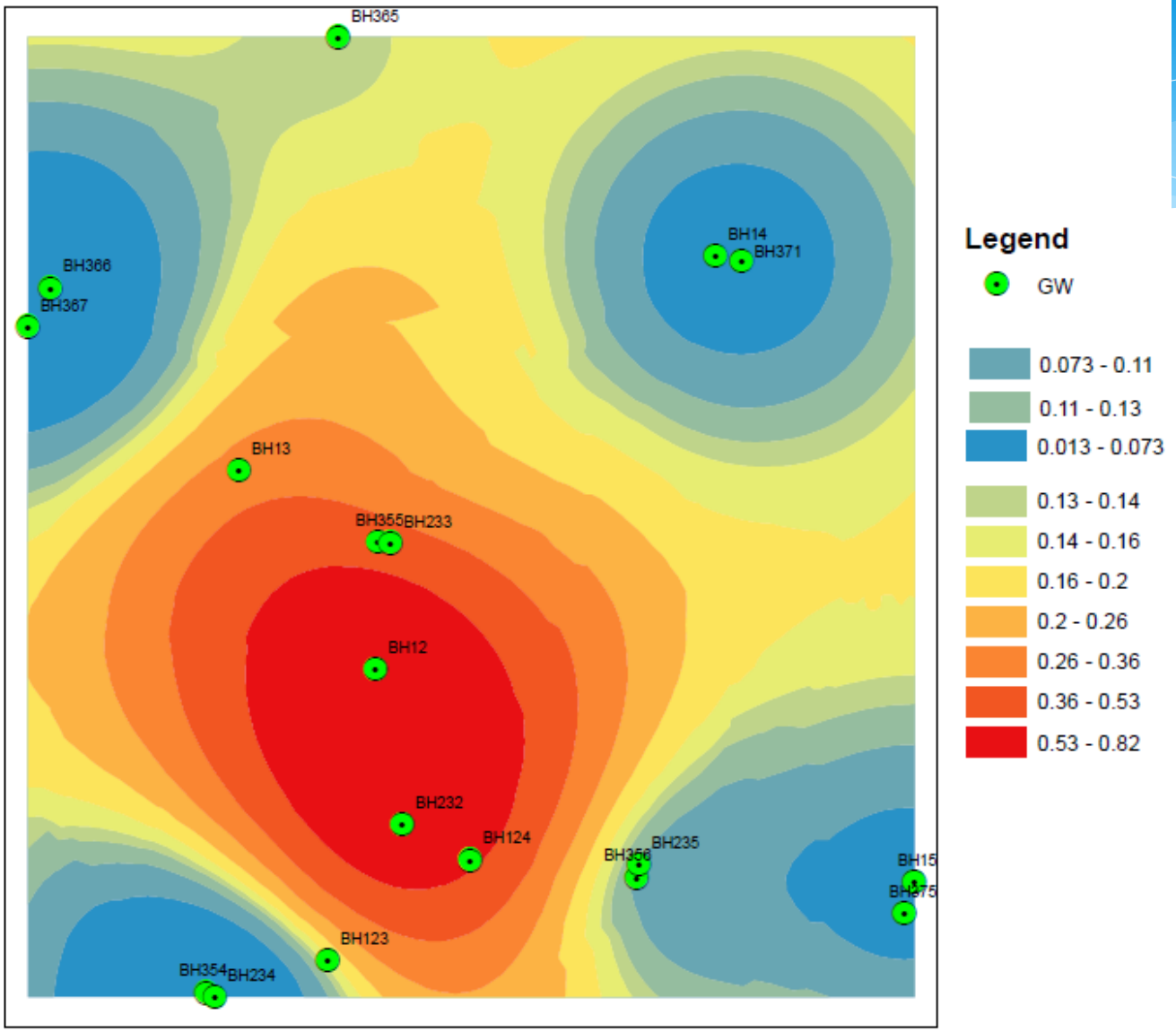


Chloride prediction map at 10 feet depth, Quantile 50%

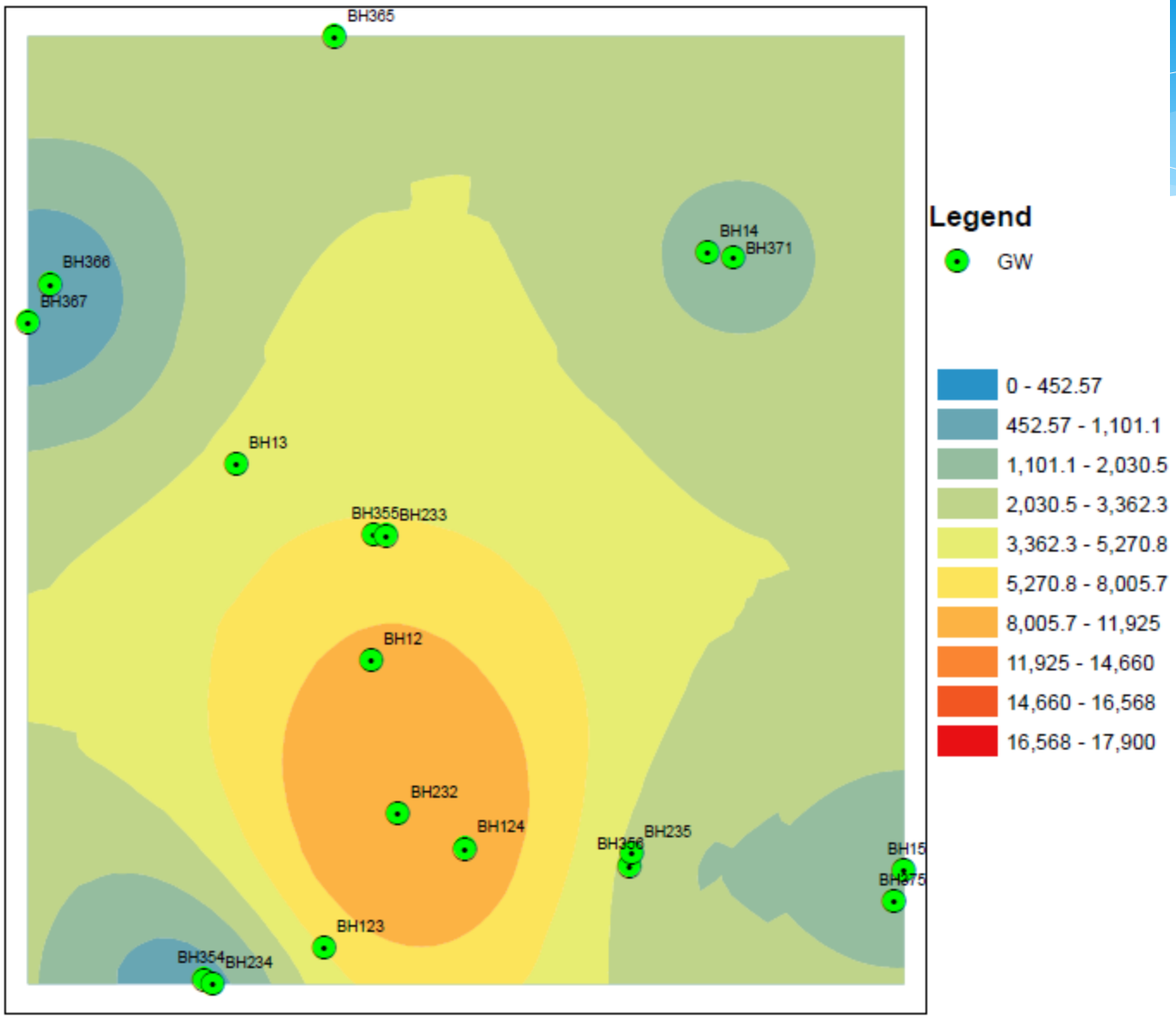
Site 780



Chloride prediction map at 10 feet depth, Quantile 75%

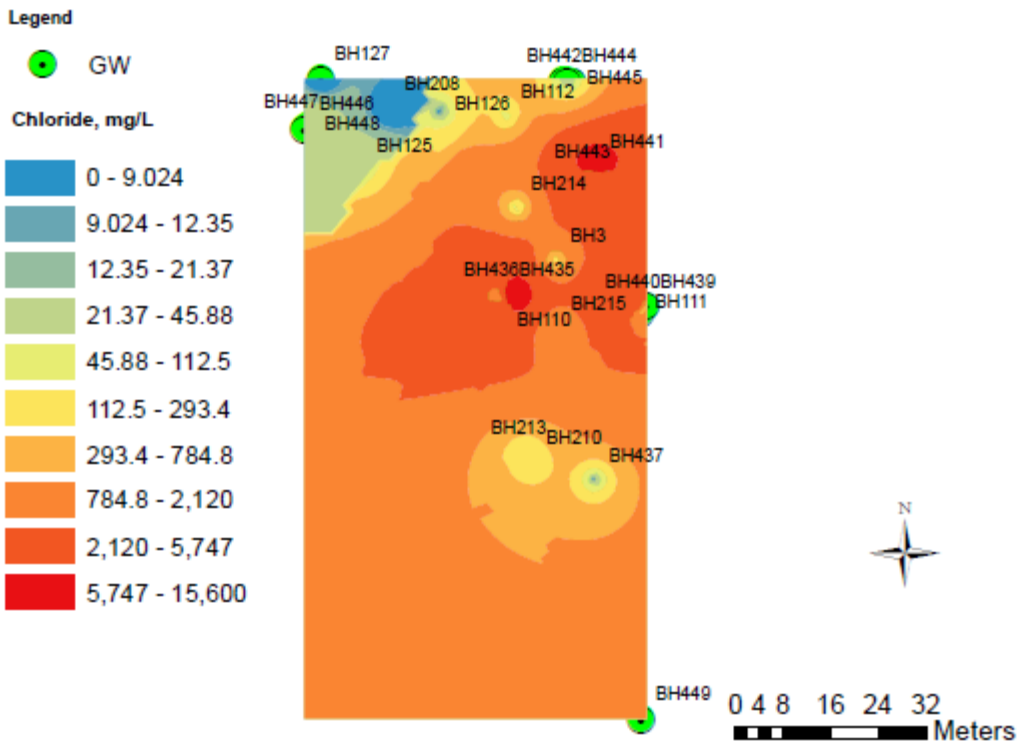


Chloride probability map at 10 feet depth

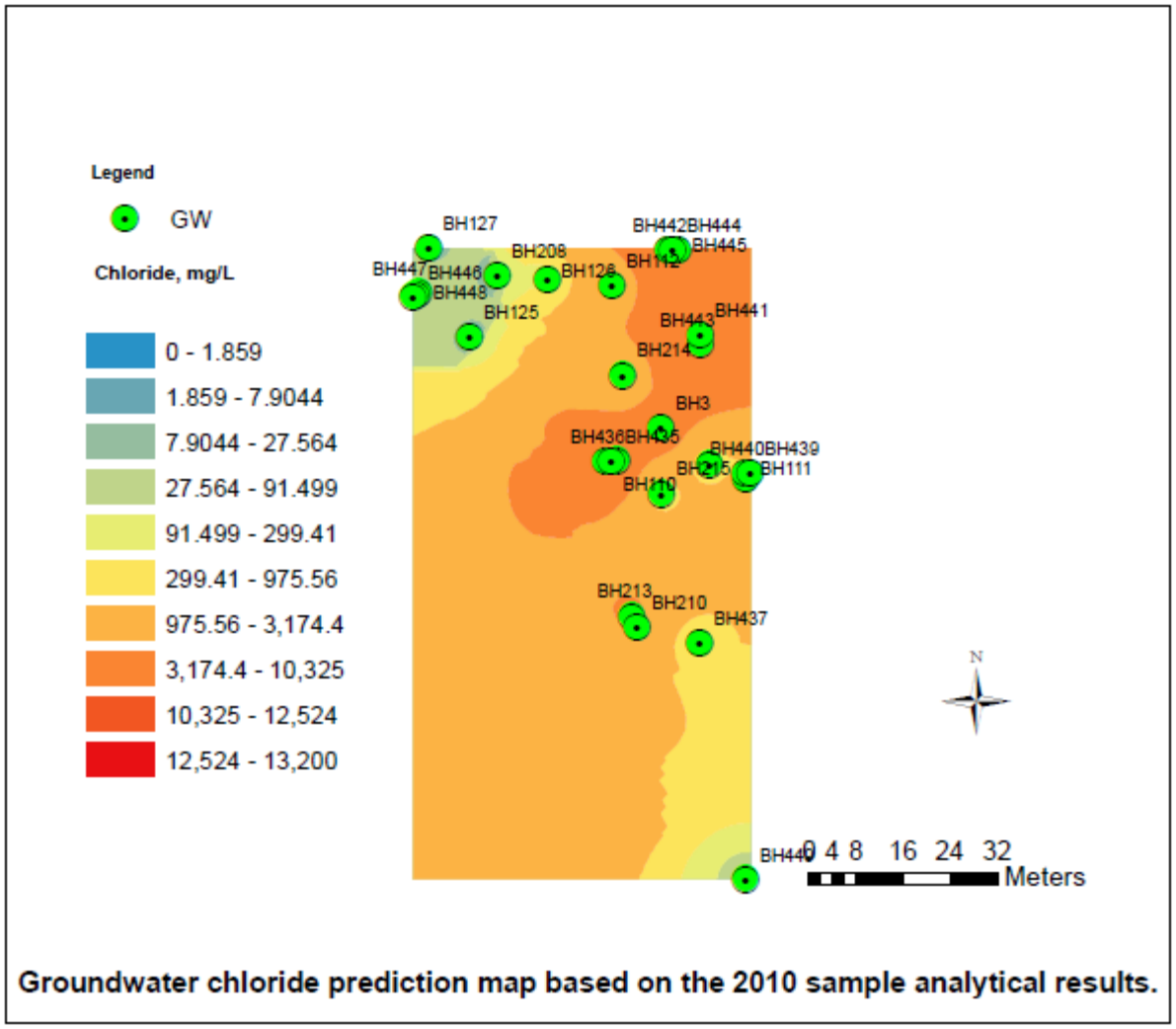


Chloride prediction map at 30 feet depth

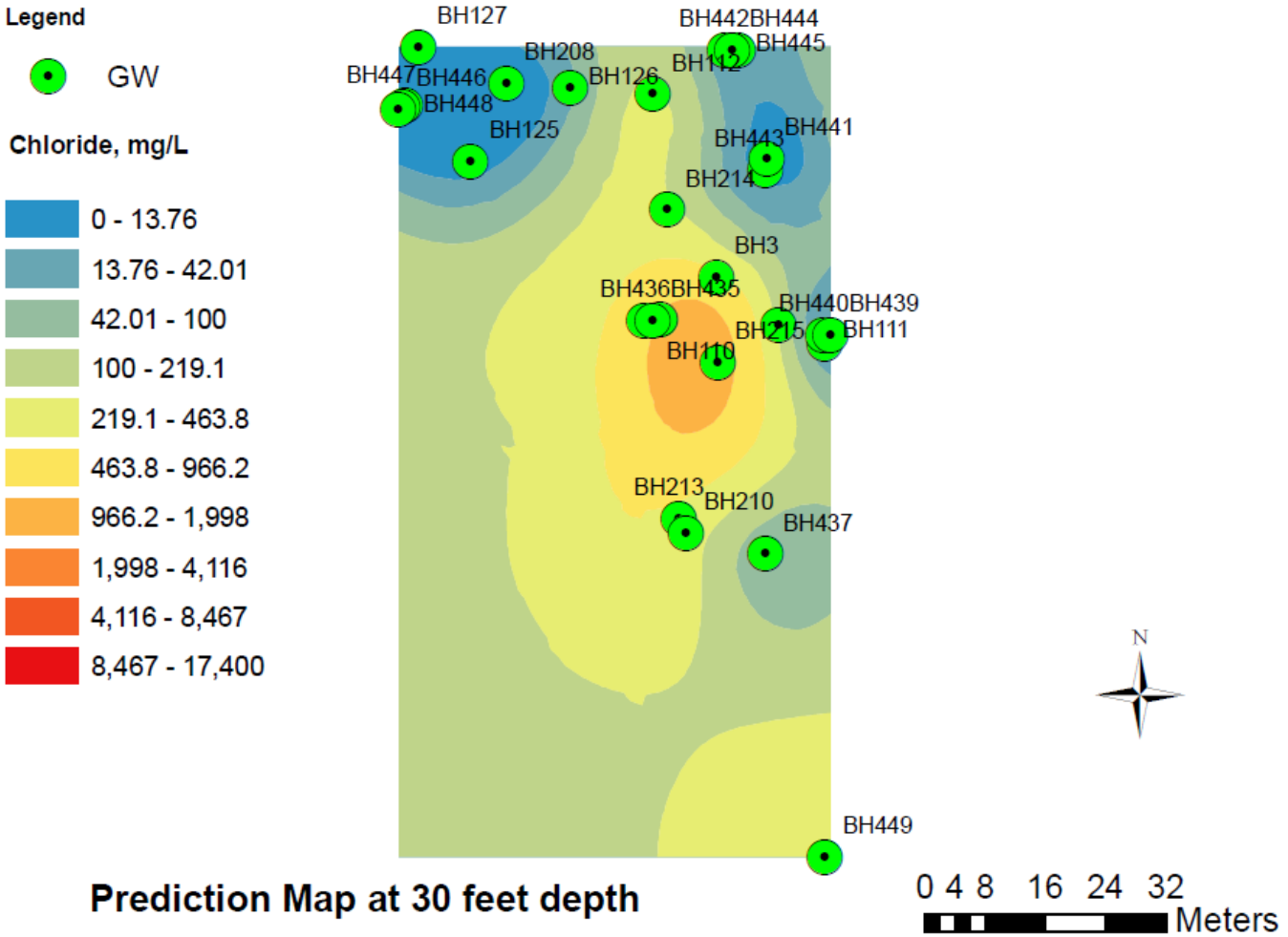

BH127
BH442
BH444
BH445
BH208
BH126
BH112
BH447
BH446
BH448
BH125
BH441
BH443
BH214
BH3
BH436
BH435
BH209
BH440
BH439
BH110
BH111
BH210
BH437
BH449
bing



Soil chloride prediction map at 50 feet depth.



Groundwater chloride prediction map based on the 2010 sample analytical results.



Prediction Map at 30 feet depth

Estimate the volume of impacted soil

- Geometric estimation of the potentially contaminated layer via 2D kriging to determine the distribution of contaminants at certain depth of contaminated sites.
- Calculated the volume of impacted soil.

Estimated Volume of impacted soil amount

Comparison of estimated contaminated soil volume by conventional and geostatistical method (m^3)		
	Geostatistcal Method	Conventional method
Flare pit 1 (786)	64097	81000
Flare pit 2 (15256)	45621	61000
Flare pit 3 (10295)	46089	38200

Conclusions

Geostatistics provide a relevant prediction of the contaminated volumes and uncertainty if remediation constraints are taken into account

1. Real integration of geostatistics in the remediation workflow

2. Geostatistical approach outcomes:
   - Data quality control
   - Relevant estimates
   - Coupled with uncertainty quantification, or both contaminated and excavated volumes.
   - Cost / benefit analysis via progress of site investigations proceed

3. Such results are useful to optimize the planning of the excavation phase and better assess its related costs.

Contact

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