Agenda for Technical Interchange Meeting #2

Groundwater Monitoring - Delivery Order T0008

Long Term Monitoring Optimization Study – Draft Recommendations

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Date: Tuesday, March 8, 2005

Time: 9:00 am – 11:00

Place: Camp Stanley Storage Activity - Boerne, Texas

Proposed Order of Discussion

Time	Topic
10:00 am	Presentation of Draft LTMO study recommendations and methodology by Dr. Carolyn Nobel
10:30 am	Discussion of LTMO study evaluations and review of sampling recommendations

Camp Stanley Storage Area

3-Tiered Long Term Monitoring Optimization (LTMO) Analysis

Carolyn Nobel, Ph.D., P.E.

March 8th, 2005

PARSONS

LTMO

What's the Point?

- A **3-Tiered LTMO Approach** was applied to the CSSA monitoring program to evaluate the distribution and frequency of groundwater sampling.
- The combined qualitative, temporal & spatial statistical approach identified a **57% potential reduction** for on and off-post monitoring well sampling events.

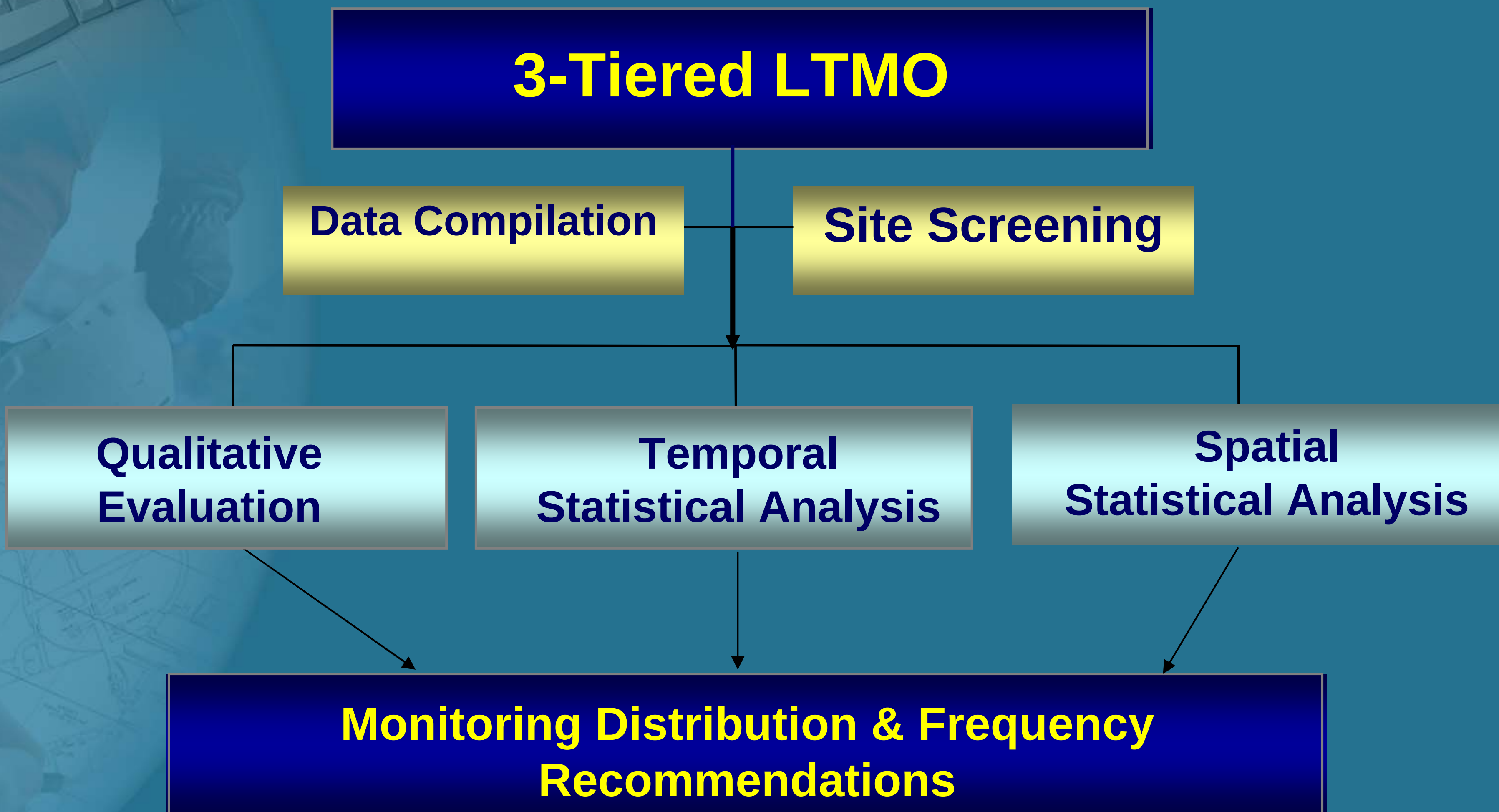
LTMO

Outline

- 3-Tiered Approach Overview
- Monitoring Program & Data Summary
- 3-Tiered Analysis & Results
  - – Qualitative Evaluation
  - – Temporal Evaluation
  - – Spatial Evaluation
  - – Combined Evaluation
- Recommendations & Future Applications

LTMO

3-Tiered Approach at A Glance



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3-Tiered Methodology

- Qualitative Evaluation
- Temporal Evaluation
- Spatial Evaluation
- 3-Tiered Summary

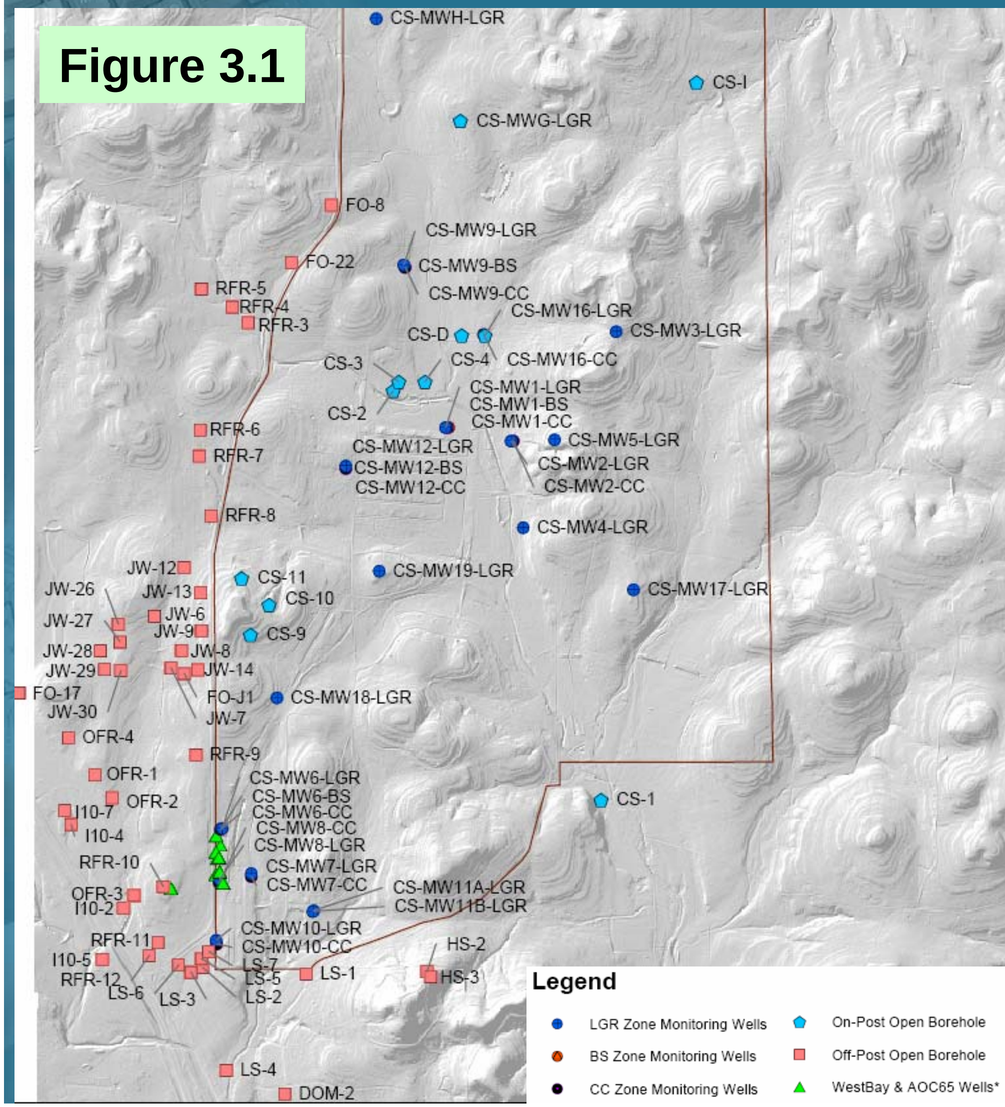
Data

Information

Solutions

Decisions

Current Monitoring Program



- 139 Sampling Locations Evaluated
- 41 On-Post Wells
  - Sampled Quarterly
  - 17 LGR Zone Wells
  - 11 Open Boreholes
  - 4 BS Zone Wells
  - 9 CC Zone Wells
- 44 Off-Post Wells
  - 18 Sampled Annually, 26 Quarterly
  - All Open Boreholes
- LGR MWs, On & Off-Post Open Boreholes → LGR Zone
- Westbay® & AOC65 Wells Evaluated in "Vertical" Analysis

"Vertical" Analysis: AOC65 & WestBay® Wells

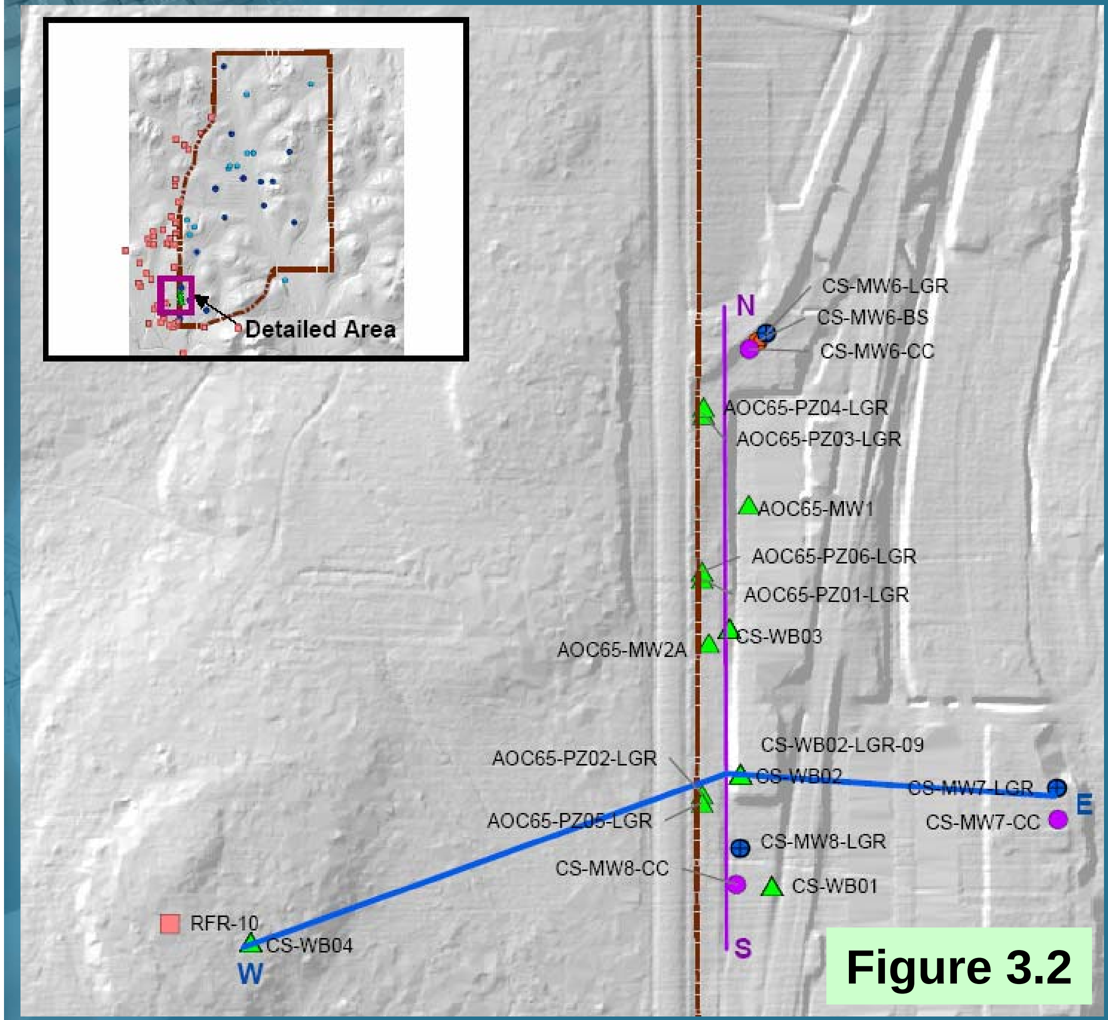


Figure 3.2

- "Screening Level" Data
- 8 AOC-65 MWs & PZs
- 4 Westbay® Wells
  - Sampled Monthly & After Rain Events
  - 17 zones with 46 Sampling Locations

LTMO

North to South & West to East Cross Sections

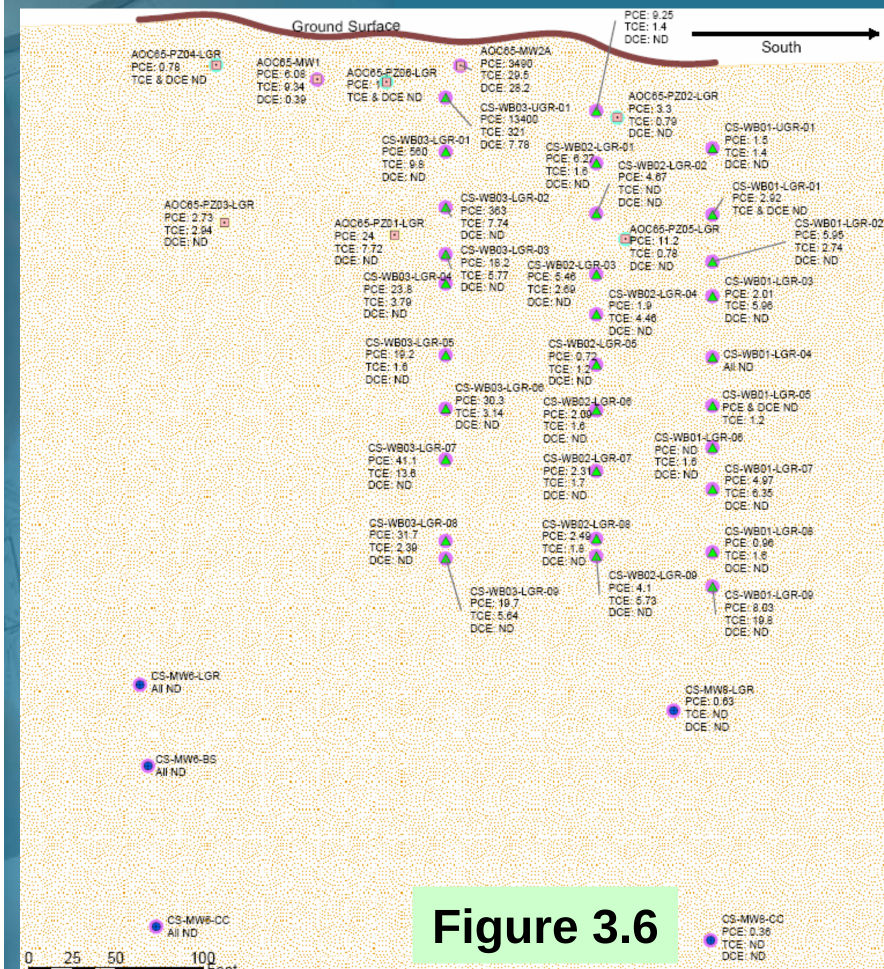


Figure 3.6

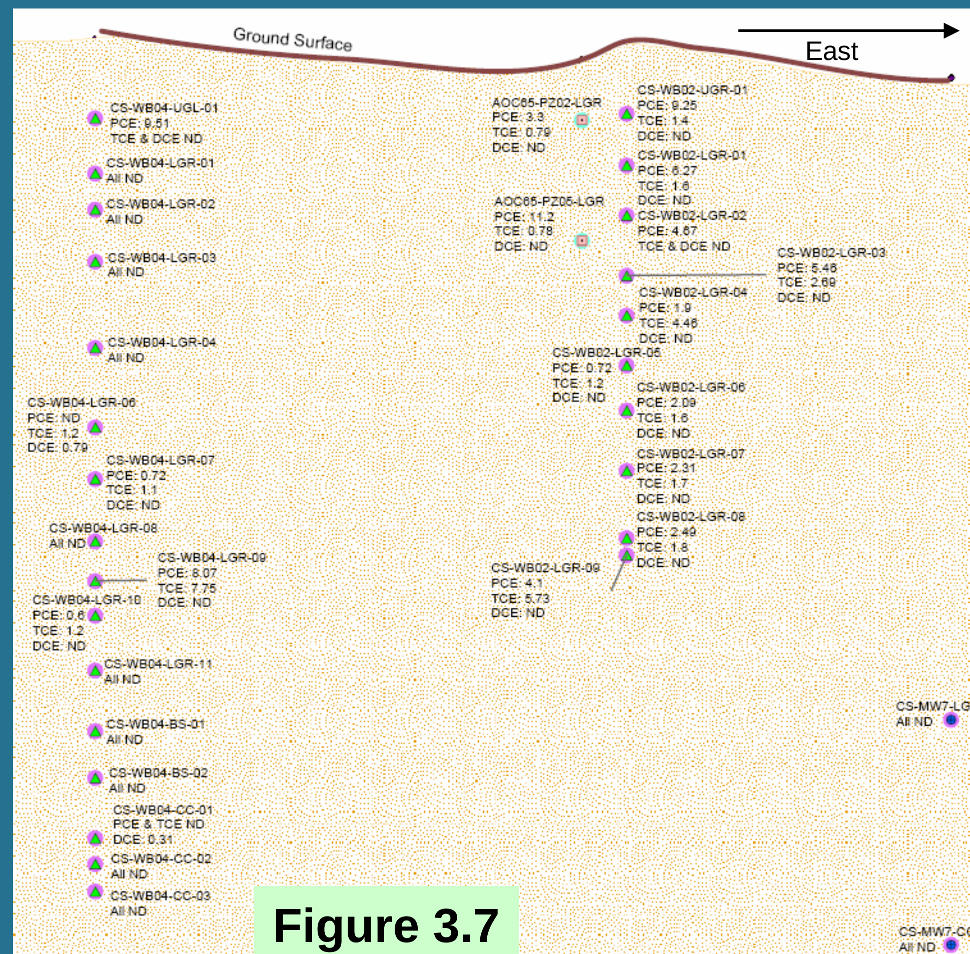


Figure 3.7

Data Statistical Analysis: All Wells

Table 3.2

Parameter	ParLabel	Total Samples	Range of Detects (µg/L)	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results	Number of Wells with Detections	Number of Wells with MCL Exceedances
Tetrachloroethene	PCE	1828	0 - 13,900	54.7%	22.6%	5	139	104	45
Trichloroethene	TCE	1826	[illegible]	[illegible]	16.9%	5	139	85	35
Lead	PB	[illegible]	[illegible]	[illegible]	7.0%	15	46	38	9
Dichloroethene, cis-1,2-	DCE12C	1783	0 - 290	15.5%	2.9%	70	139	44	3
Bromodichloromethane	BDCME	1073	0 - 6	1.5%	1.5%	0	85	8	8
Cadmium	CD	338	0 - 15	19.5%	0.9%	5	45	28	3
Methylene chloride	MTLNCL	1059	0 - 19	22.7%	0.8%	5	85	70	7
Nickel	NI	341	0 - 216	46.9%	0.6%	100	45	37	2
Bromoform	TBME	780	0 - 3	0.5%	0.5%	0	85	4	4

Primary COCs

- **Analytical Data from August 1991 through December 2004**
- **Primary COCs → PCE, TCE, C12DCE, PB**
- **Additional COCs → Bromodichloromethane, Bromoform, Vinyl Chloride & Toluene**

LTMO

Data Statistical Analysis: LGR Zone Wells

Parameter	ParLabel	Total Samples	Maximum Detection (µg/L)	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results	Number of Wells with Detections	Number of Wells with MCL Exceedances
LGR Zone Monitoring Wells									
Tetrachloroethene	PCE	234	41	57.7%	12.8%	5	17	15	2
Trichloroethene	TCE	234	40	38.0%	12.8%	5	17	12	2
Lead	PB	109	47	45.9%	3.7%	15	17	16	2
Nickel	NI	107	150	72.9%	0.9%	100	17	16	1
Cadmium	CD	109	7.0	23.9%	0.9%	5	17	11	1
Bromoform	TBME	150	0.1	0.7%	0.7%	0	17	1	1
On-Post Open Borehole Wells									
Tetrachloroethene	PCE	286	230	41.3%	19.9%	5	11	10	3
Trichloroethene	TCE	289	300	31.5%	19.7%	5	11	7	3
Dichloroethene, cis-1,2-	DCE12C	259	290	22.8%	16.2%	70	11	4	2
Lead	PB	169	250	72.2%	11.8%	15	11	11	7
Bromodichloromethane	BDCME	285	4.7	2.5%	2.5%	0	11	3	3
Methylene chloride	MTLNCL	287	9.6	21.3%	2.1%	5	11	11	5
Cadmium	CD	165	15.4	20.0%	1.2%	5	11	10	2
Bromoform	TBME	114	3.4	0.9%	0.9%	0	11	1	1
Nickel	NI	169	216	35.5%	0.6%	100	11	10	1
Off-Post Open Borehole Wells									
Tetrachloroethene	PCE	444	30	55.6%	9.0%	5	44	25	6
Trichloroethene	TCE	438	10	38.8%	4.1%	5	44	15	2
Bromodichloromethane	BDCME	413	5.9	2.2%	2.2%	0	44	5	5
Bromoform	TBME	408	1.1	0.5%	0.5%	0	44	2	2
Methylene chloride	MTLNCL	395	19	12.7%	0.3%	5	44	29	1

Table 3.3

Table 3.4

Table 3.7

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Qualitative Evaluation Methodology

- **DATA:**
  - Site characterization
  - Monitoring results
  - Monitoring Network DQOs, etc.
- **INFORMATION:**
  - Value of each well in big picture context
- **SOLUTION:**
  - Recommend:
    - Well retention or removal
    - Optimal sampling frequency
  - Provide Rationale

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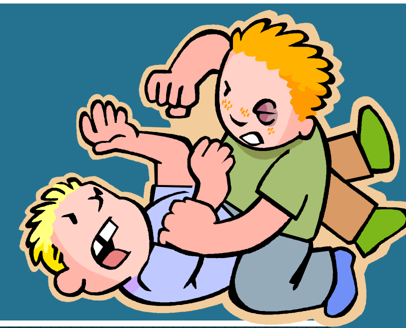
Everyone Weighs In: Initial Qualitative Evaluation



Well ID	E	Q	S	A	B	Summary of Rationale
CS-MW6-CC	2	1	1	3	1	BEAL:Never much to write about here. Just a few stray hits...(very low) BURDEY:No detections in CC well. Given lack of significant to CC vs LGR, continued monitoring is not that important from an investigative perspective. It may als be worthwhile to monitor the deep CC formation as part of groundwater enhanced bio-monitoring well network/tracer studies at AOC-65. (Corrective Action Monitoring, no longer investigative monitoring). ELLIOTT:Monitor annually until PCE/TCE is detected, then reevaluate. MARTIN: PEARSON:Once-a-year to verfily no leakage from LGR to CC RILEY: Well is important for defining the vertical extent of contaminants TENNYSON:Reduce frequency due to steady trends, retain to monitor plume concentrations moving toward private supply wells. BRV:No detections in CC well. Given lack of significant to CC vs LGR, continued monitoring is not that important from an investigative perspective. It may als be worthwhile to monitor the deep CC formation as part of groundwater enhanced bio-monitoring well network/tracer studies at AOC-65. (Corrective Action Monitoring, no longer investigative
CS-MW6-LGR	0	2	2	3	1	BEAL:Never seen much in the way of VOCs here, just a few stray hits. Lets keep it around though for it sentry location. BURDEY:No recent detections in LGR well. Given the importance of LGR monitoring and conceptual fault-block inter-relationships, it is worthwhile to continue monitoring this well. Increased off-post pumping could have effect on flow directions/plume migration on-post. This well would provide early data if that occurs. ELLIOTT:Monitor annually until PCE/TCE is detected, then reevaluate. MARTIN: PEARSON:Minor F-flagged hits in 2001-none since. Well appears to be upgradient to Plume 2 source area. RILEY: Well is important for defining the lateral extent of contaminants TENNYSON:Reduce frequency due to steady trends, retain to monitor plume concentrations moving toward private supply wells. BRV:No recent detections in LGR well. Given the importance of LGR monitoring and conceptual fault-block inter-relationships, it is worthwhile to continue monitoring this well on at least an ANNUAL basis, but may be important to continue on semi-annual basis for at least one more year. It will be worthwhile to monitor
CS-MW7-CC	2	1	1	4	0	BEAL:Again..not much forund with this well. VOCs are rare.. BURDEY:No detections in CC well. Given lack of significant to CC vs LGR, continued monitoring is not that important from an investigative perspective. ELLIOTT:Monitor annually until PCE/TCE is detected, then reevaluate. MARTIN: PEARSON:Once-a-year to verfily no leakage from LGR to CC RILEY: Well is important for defining the vertical extent of contaminants TENNYSON:Consistent trends. BRV:No detections in CC well. Given lack of significant to CC vs LGR, continued monitoring is not
CS-MW7-LGR	0	3	1	4	0	BEAL:Never seen much in the way of VOCs here, just a few stray hits. Lets keep it around though for it sentry location. BURDEY:No recent detections in LGR well. Given the importance of LGR monitoring and conceptual fault-block inter-relationships around building 90, it is worthwhile to continue monitoring this well on at least an ANNUAL basis. It may be worthwhile to include monitoring of this up/cross gradient well as part of any groundwater enhanced bio-monitoring well network/tracer studies at AOC-65. (Corrective Action Monitoring, no longer investigative monitoring). ELLIOTT: MARTIN: PEARSON:Single F-flagged PCE detection in 2002. Well is cross gradient to Plume 2 source area. RILEY: Well is needed to further characterize the site for monitor changes in concentrations over time. TENNYSON:Consistent trends. BRV:No recent detections in LGR well. Given the importance of LGR monitoring and conceptual fault-block inter-relationships around building 90, it is worthwhile to continue monitoring this well on at least an ANNUAL basis. It may be worthwhile to include monitoring of this up/cross gradient well as part of
CS-MW8-CC	1	2	1	3	1	BEAL:No hits here yet. Lets drop it back to annual. BURDEY:No detections in CC well. Companion LGR well has had only below MCL detections. Given lack of significant to CC vs LGR, continued monitoring is not important from an investigative perspective. ELLIOTT:Well is needed to further monitor changes in contaminant concentrations through time. MARTIN: PEARSON:Once-a-year to verfily no leakage from LGR to CC RILEY: Well is important for defining the vertical extent of contaminants TENNYSON:Steady trends. BRV:No detections in CC well. Given lack of significant to CC vs LGR, continued monitoring is not that important from an investigative perspective. It may als be worthwhile to monitor the deep CC formation as part of groundwater enhanced bio-monitoring well network/tracer studies (Corrective Action Monitoring, no longer investigative monitoring) or to assess for communication between the LGR and CC. I
CS-MW8-LGR	0	3	3	1	1	BEAL:Consistent low levels of VOCs here. Worth keeping an eye on. Sentry location is hard to beat also... BURDEY:Located in critical portion of aquifer south of apparent plume center at AOC-65 (Building 90). Detections have been below MCL, but are steady and continue to fluctuate slightly, so continued sampling of LGR at this locations provides critical data to assess plume characteristics and stability. ELLIOTT:Well is needed to further monitor changes in contaminant concentrations through time. MARTIN: PEARSON:Repeated F-flag hits are notable. Retain for semi-annual monitoring as a sentinel for changes in aquifer near plume area and off-post consumers. RILEY: Well is needed to further characterize the site for monitor changes in concentrations over time. TENNYSON:Steady trends. BRV:Located in critical portion of aquifer south of apparent plume center at AOC-65 (Building 90). Detections have been below MCL, but are steady and continue to fluctuate slightly, so continued sampling of LGR at this locations provides critical data to assess plume characteristics and stability.

- **8 Individual Qualitative Evaluations**
- **Group Discussion**
- **Agreement on Final Qualitative Recommendation**

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Summary Qualitative Evaluation

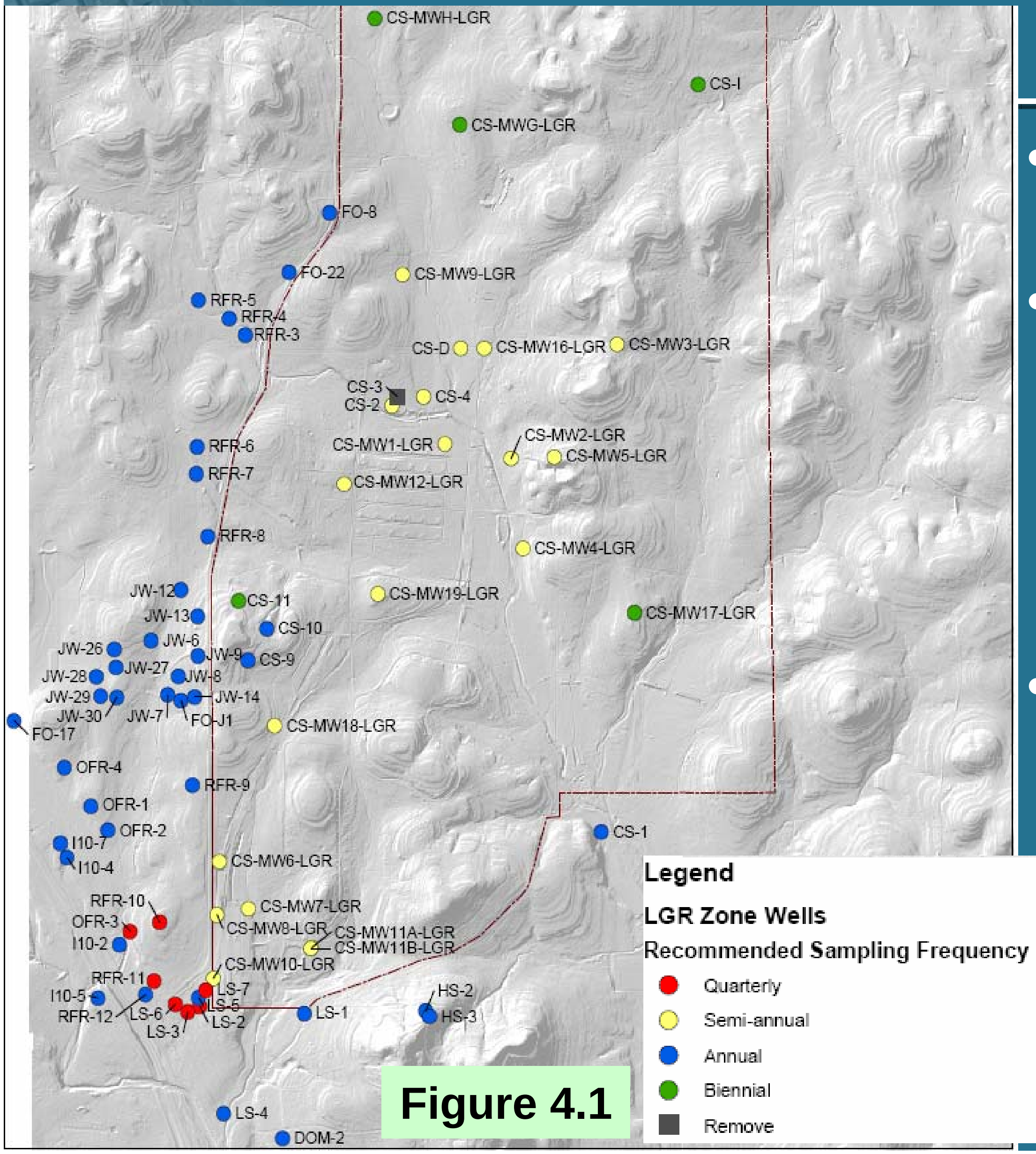

Figure 4.1

- Primarily Recommended Frequency Reductions
- On Post
  - SA → Plume definition or source characterization
  - A → Drinking supply well
  - B → BS, CC with low detections, non-plume def.
- Off Post
  - Q → Wells with GAC
  - A → Historically F-Flagged or TR detections, and/or drinking supply well

Temporal Statistical Evaluation Methodology

- DATA:
  - >4 sampling results over time
  - Well/plume location & GW direction
  - Chemical concentration
- INFORMATION:
  - Mann-Kendall Trend analysis
  - Automated process (GIS script)
- SOLUTION:
  - Recommend retention or removal/reduction based on decision rationale

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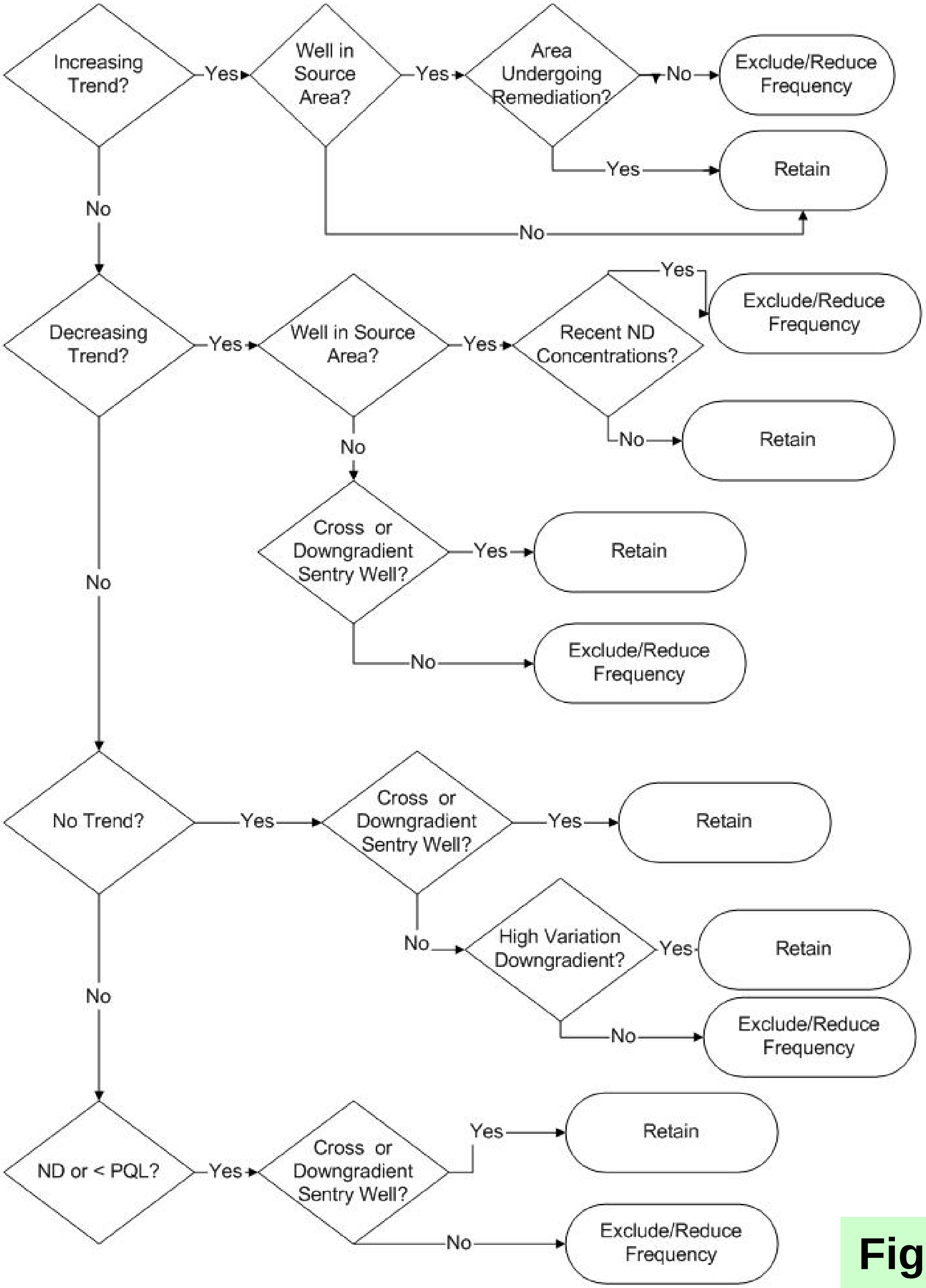
“ND” & “<PQL” Trend Classification

Well ID	COC	Date	Qualifier	Result	MDL
CS-1	PCE	8/9/91	ND	0.00	1
CS-1	PCE	11/3/92	ND	0.00	0.5
CS-1	PCE	5/26/94	ND	0.00	0.3
CS-1	PCE	9/30/94	ND	0.00	1
CS-1	PCE	12/19/94	ND	0.00	1
CS-1	PCE	3/30/95	ND	0.00	1
CS-1	PCE	6/13/95	ND	0.00	5
CS-1	PCE	8/11/95	ND	0.00	5
CS-1	PCE	8/25/95	ND	0.00	5
CS-1	PCE	2/28/96	ND	0.00	5
CS-1	PCE	11/6/98	ND	0.00	0.4
CS-1	PCE	9/9/99	ND	0.00	0.087
CS-1	PCE	12/14/99	TR	0.17	0.087
CS-1	PCE	3/20/00	TR	0.11	0.087
CS-1	PCE	6/14/00	ND	0.00	0.008
CS-1	PCE	9/13/00	ND	0.00	0.008
CS-1	PCE	3/19/01	TR	0.11	0.008
CS-1	PCE	6/12/01	ND	0.00	0.16
CS-1	PCE	9/17/01	TR	0.14	0.11
CS-1	PCE	12/11/01	ND	0.00	0.11
CS-1	PCE	3/19/02	TR	0.12	0.11
CS-1	PCE	6/17/02	TR	0.11	0.04
CS-1	PCE	9/10/02	TR	0.08	0.05
CS-1	PCE	12/10/02	TR	0.10	0.05
CS-1	PCE	3/19/03	ND	0.00	0.05
CS-1	PCE	3/19/03	TR	0.08	0.05
CS-1	PCE	6/19/03	TR	0.09	0.05
CS-1	PCE	9/16/03	TR	0.08	0.05
CS-1	PCE	12/16/03	TR	0.10	0.05
CS-1	PCE	3/11/04	TR	0.09	0.05
CS-1	PCE	6/22/04	TR	0.09	0.05
CS-1	PCE	9/15/04	TR	0.07	0.05
CS-1	PCE	12/2/04	ND	0.00	0.17

- “ND” classification assigned if all results are ND
- “<PQL” classification assigned if all results are all TR or ND and TR
- Prevents assigning spurious trends due to potential changes in MDL over time

Example of well resulting in “<PQL” trend classification



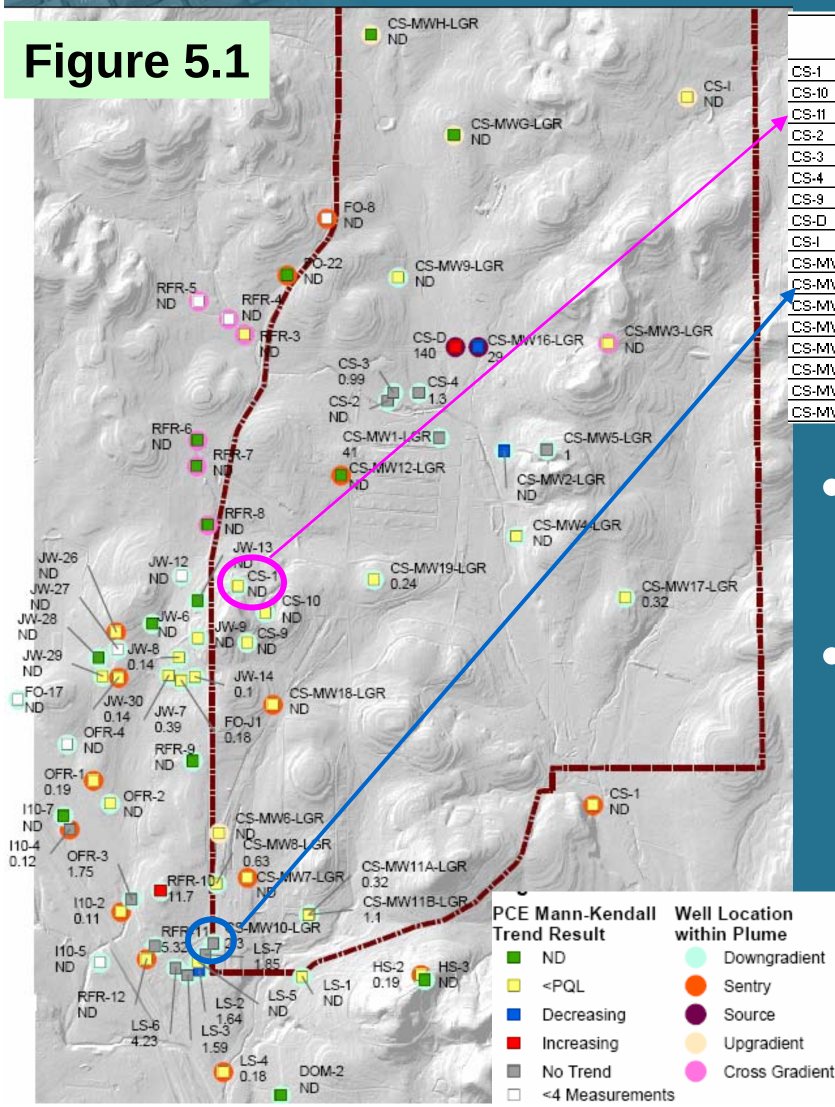
Temporal Trend Decision Rationale Flowchart

Figure 5.4

LTMO

Temporal Analysis Results

Figure 5.1



Well ID	PCE	TCE	cis-1,2-DCE	Lead	Bromo-form	Bromodi-chloromethane	Vinyl Chloride	Toluene	Exclude/ Reduce	Retain
CS-1	PQL	No Trend	ND	Decreasing	No Trend	No Trend	ND	No Trend		✓
CS-10	PQL	ND	ND	No Trend	ND	ND	ND	No Trend	✓	
CS-11	PQL	PQL	PQL	Increasing	ND	Decreasing	ND	No Trend		✓
CS-2	No Trend	PQL	ND	No Trend	ND	ND	ND	No Trend	✓	
CS-3	No Trend	ND	ND	No Trend	<4Meas	ND	ND	<4Meas	✓	
CS-4	No Trend	Increasing	Increasing	<4Meas	ND	ND	ND	PQL		✓
CS-9	PQL	ND	ND	Decreasing	ND	ND	ND	Increasing	✓	
CS-D	Increasing	Increasing	Increasing	No Trend	ND	ND	PQL	No Trend		✓
CS-I	PQL	PQL	ND	No Trend	ND	Decreasing	ND	No Trend		✓
CS-MW10-CC	PQL	ND	ND	PQL	ND	ND	ND	No Trend	✓	
CS-MW10-LGR	No Trend	PQL	ND	PQL	ND	ND	ND	No Trend	✓	
CS-MW11A-LGR	PQL	ND	ND	<4Meas	ND	ND	ND	PQL	✓	
CS-MW11B-LGR	PQL	ND	ND	<4Meas	ND	ND	ND	PQL	✓	
CS-MW12-BS	ND	ND	ND	<4Meas	ND	ND	PQL	Decreasing	✓	
CS-MW12-CC	ND	ND	ND	<4Meas	ND	ND	PQL	No Trend	✓	
CS-MW12-LGR	ND	ND	ND	<4Meas	ND	ND	ND	No Trend		✓
CS-MW16-CC	No Trend	No Trend	No Trend	<4Meas	ND	ND	PQL	PQL		✓

Table 5.1

- CS-11
  - ↑ Lead Downgradient = Retain
- CS-MW10-LGR
  - Stable PCE Trend downgradient
  - Others ND/PQL = Exclude/Remove

LTMO

Spatial Statistics Evaluation Methodology

- DATA
  - Spatial “Snapshot” of Plume
    - Most recent chemical concentrations
    - Indicator chemical
    - Wells in same zone
- INFORMATION:
  - Geostatistical (Kriging) Evaluation
    - Develop spatial model (semivariogram)
    - Calculate Kriging predicted standard error metric for each well
  - Conducted Using ArcGIS Geostatistical Analyst
- SOLUTION:
  - Recommend removal or retention based on relative value of spatial information of each well

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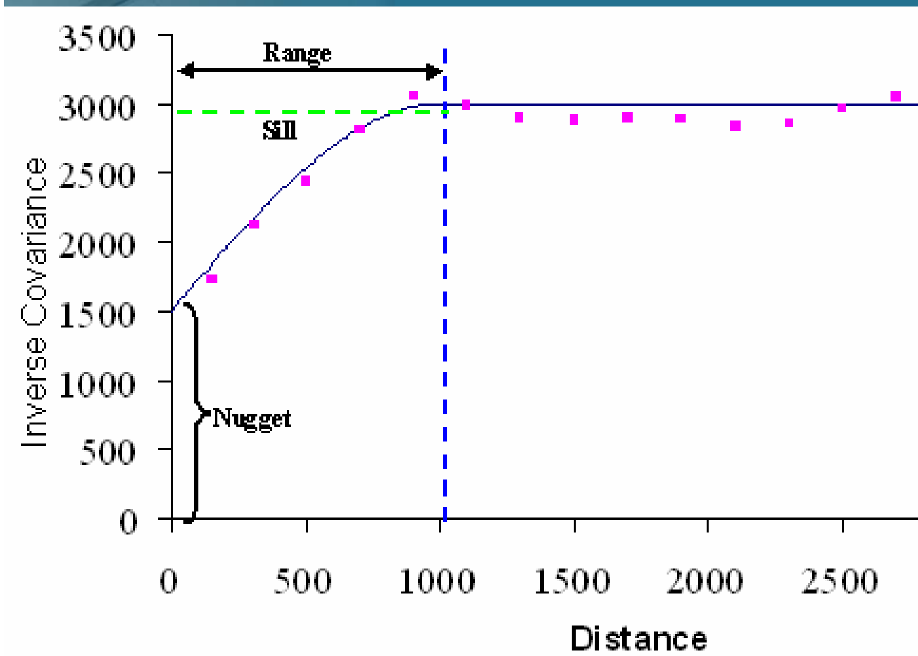
Spatial Statistics Well Selection & Data Preparation

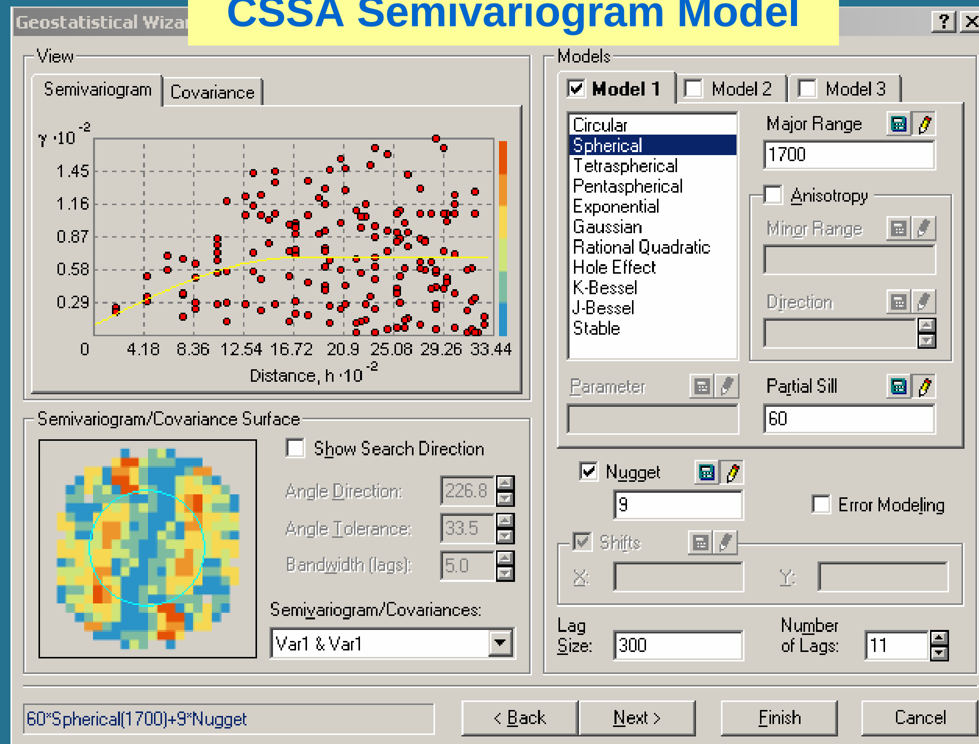
- Select spatial evaluation well set
  - Same zone
  - Same time
  - LGR Zone→ 71 Wells (Exclude CS-3)
  - BS/CC Zones < 11 Wells → Not Analyzed
  - Cross Sections → AOC65 MWs, WB & other MWs (exclude PZs)
- Define "Indicator" Chemical
  - Sum of PCE, TCE & C12DCE

Semivariogram Model Development

Idealized Semivariogram Model



CSSA Semivariogram Model



Model Used to Create Surfaces of Predicted Values & Associated Predicted Error

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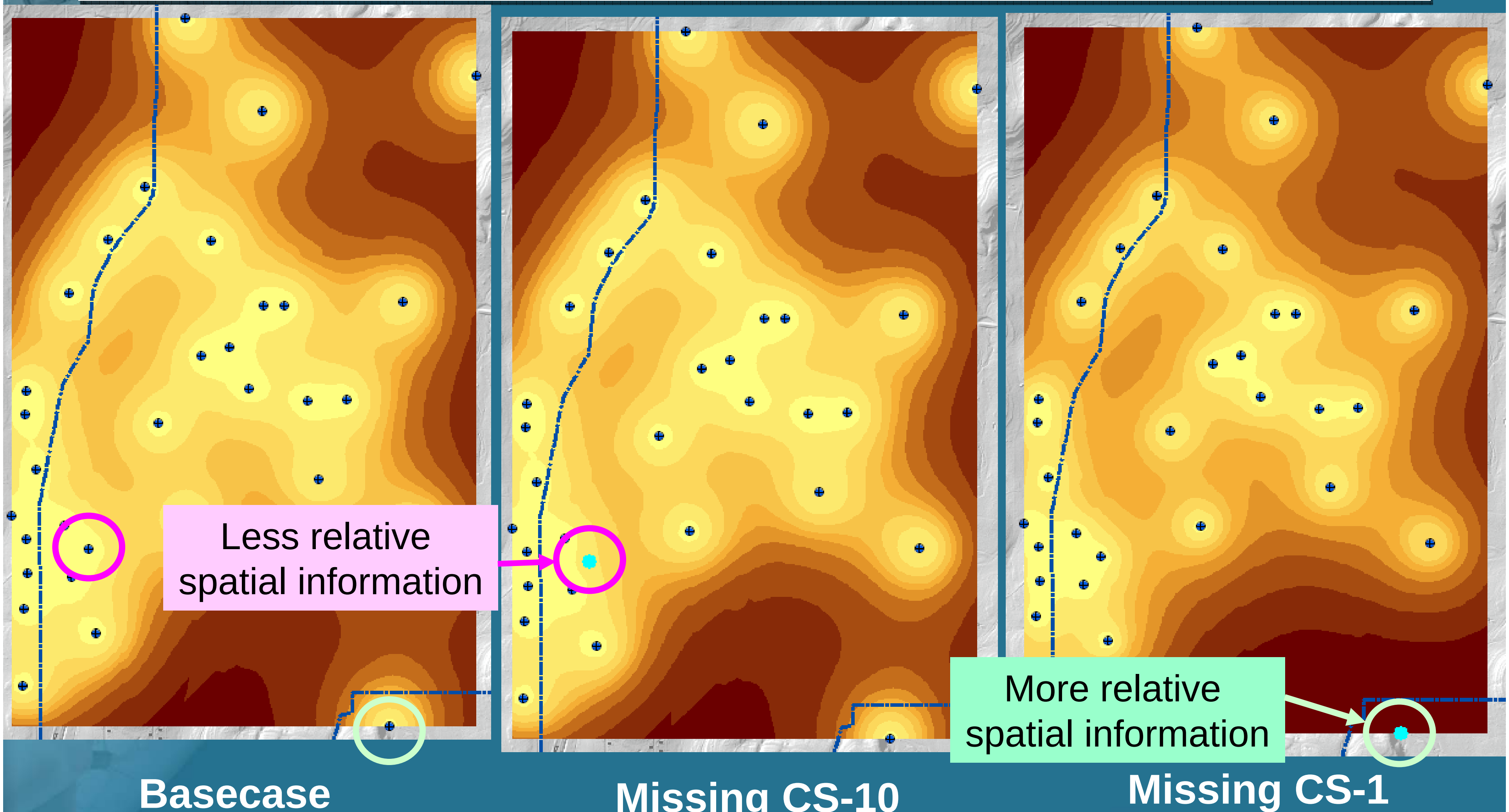
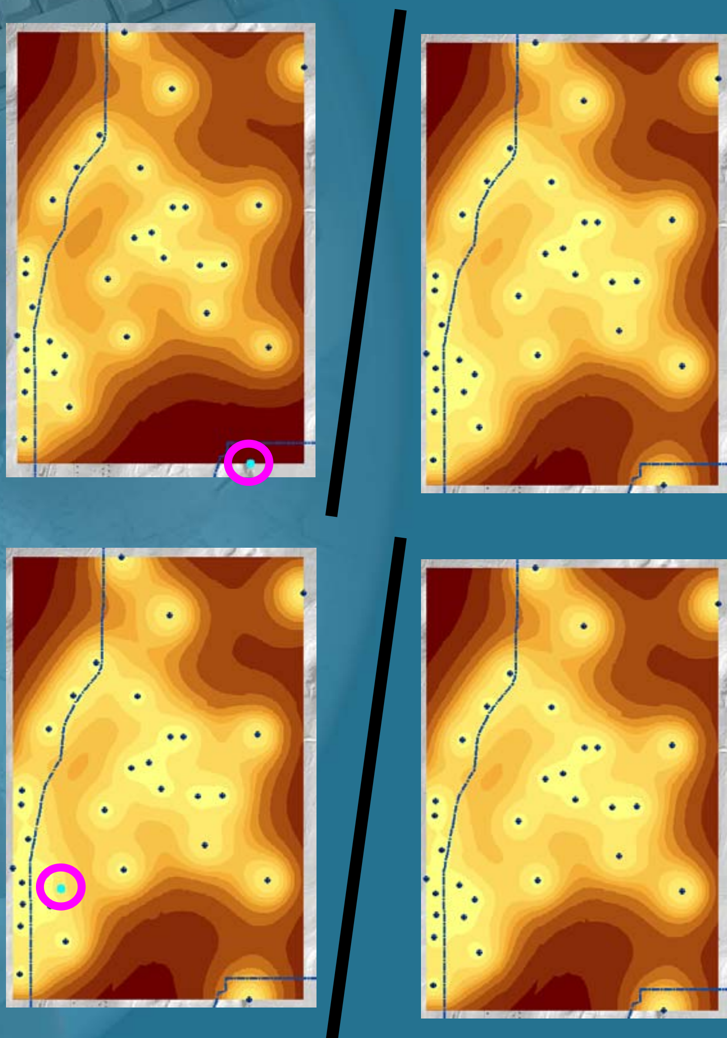
Calculate Predicted Standard Error for Basecase & "Missing Well" Scenarios



Calculate Spatial Metrics for Each Well



Missing CS-1/Basecase = 1.005
Rank = 67/71 → Retain

$$\frac{\text{Median Missing Well Grid}}{\text{Median Basecase Grid}} = \text{Spatial Metric}$$

Missing CS-10/Basecase = 1.0001
Rank = 29/71 → Intermediate (No Recommendation)

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Spatial Evaluation Results

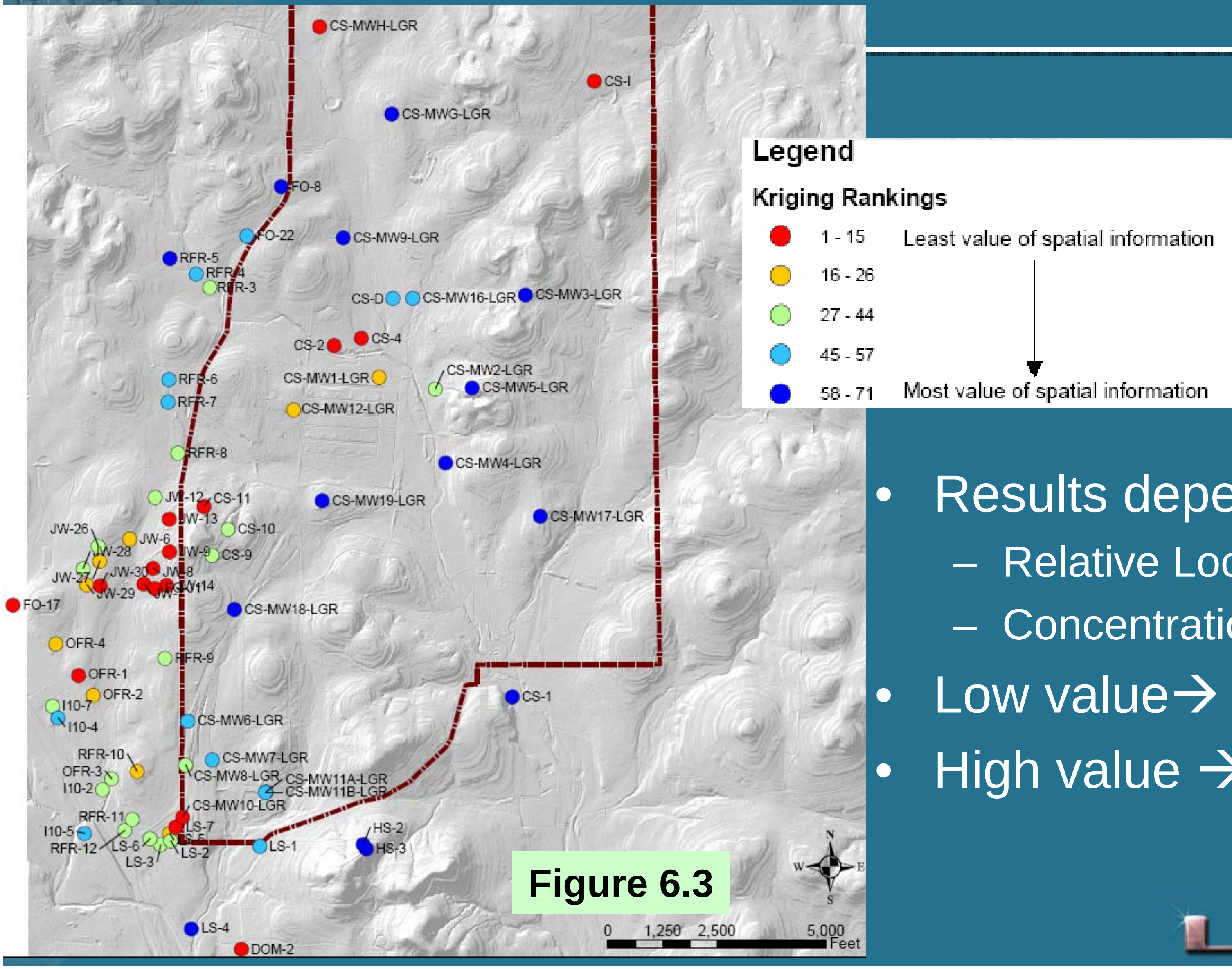


Figure 6.3

- Results dependant on:
  - Relative Location
  - Concentration
- Low value→ exclude
- High value → retain

Vertical Spatial Evaluations N-S & W-E Cross Sections

Figure 6.4

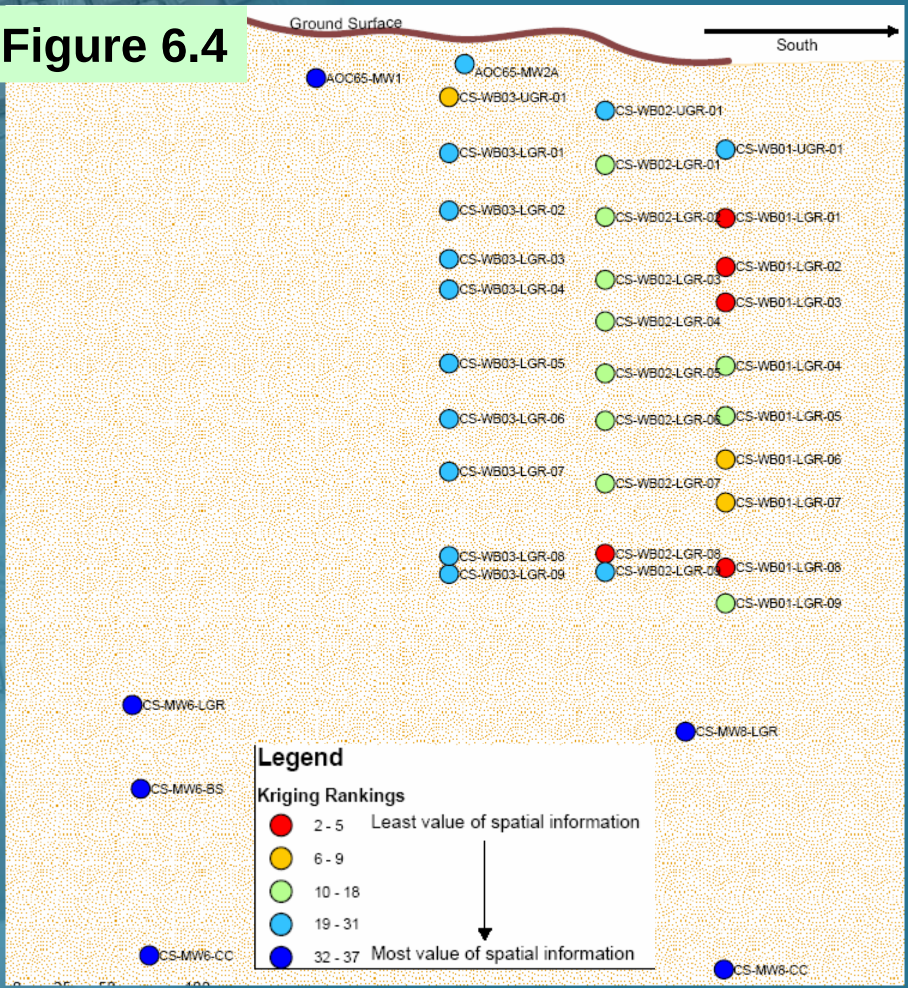
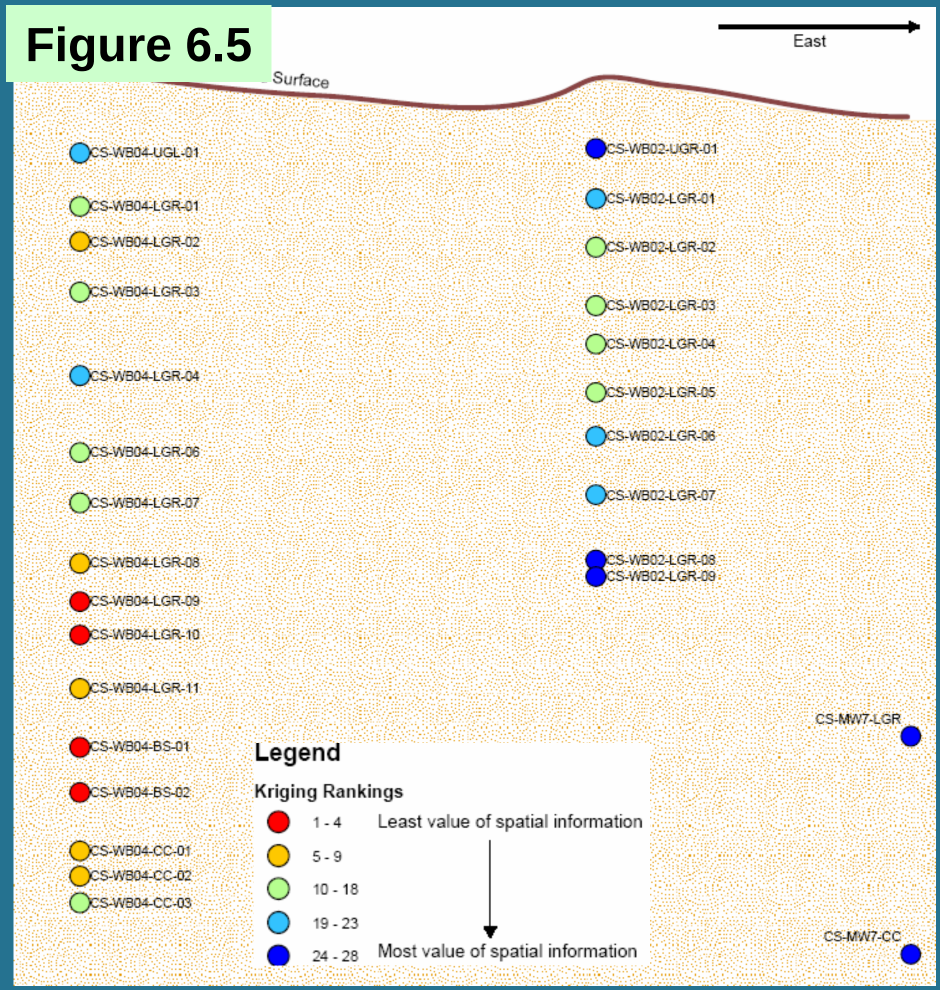


Figure 6.5



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3-Tiered LTMO Summary

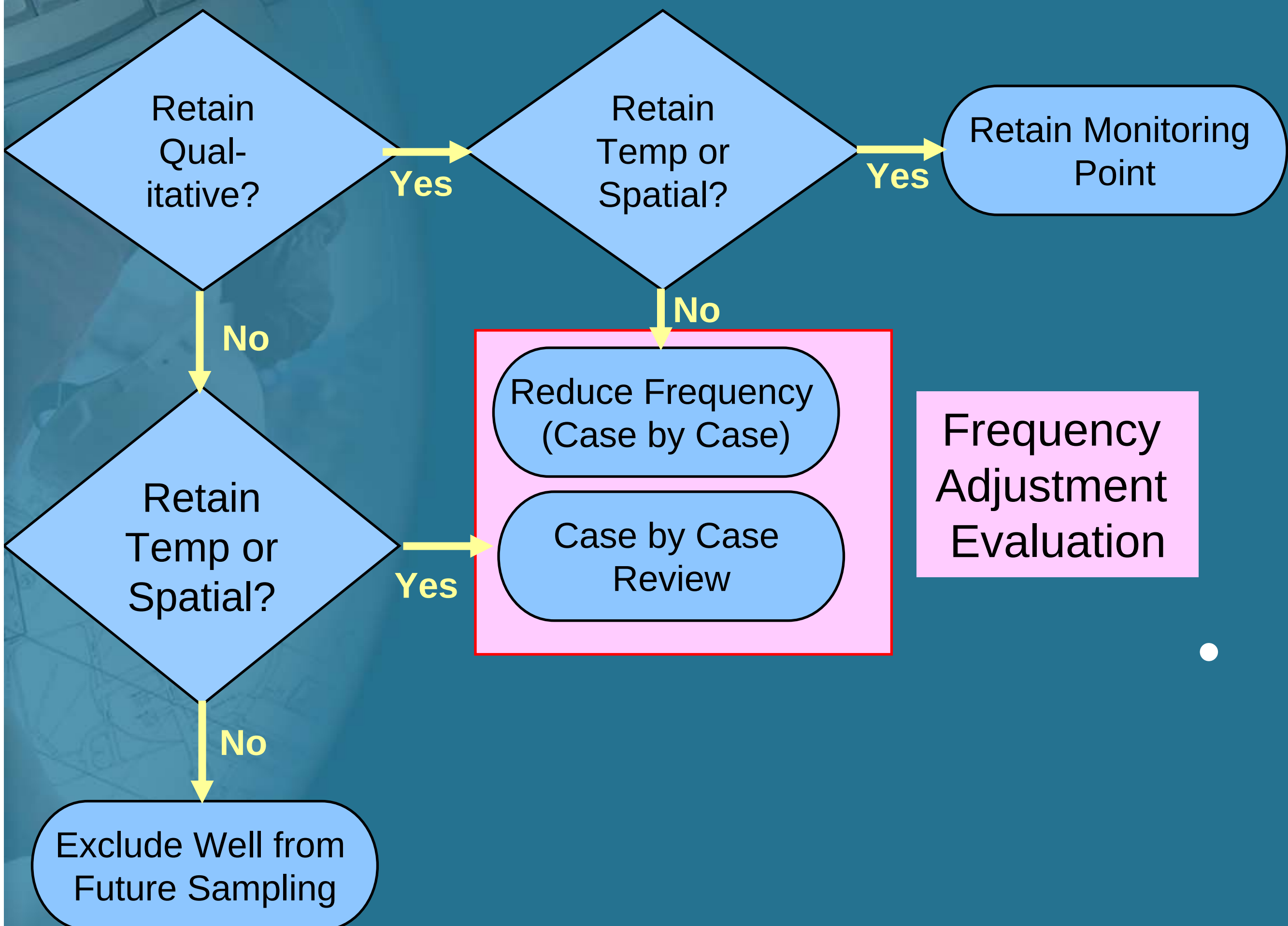
- Qualitative Evaluation
  - Experienced geologist big-picture analysis
- Temporal Statistical Evaluation
  - Mann Kendall trend analysis
  - Decision rationale
- Spatial Statistical Evaluation
  - Geostatisical Kriging predicted error analysis
  - Spatial metric & relative ranking

3-Tiered LTMO

Combines three evaluations to optimize the distribution and frequency of groundwater sampling.

LTMO

Combined Evaluation Summary



Combine 3 Analyses to Determine Final Distribution and Frequency Recommendation

- Qualitative Verified & Refined by Quantitative

Combined Evaluation Results

Well ID	Qualitative Evaluation			Temporal Evaluation		Spatial Evaluation		Summary		
	Exclude	Retain	Recommended Monitoring Frequency	Exclude/ Reduce	Retain	Exclude	Retain	Exclude	Retain	Recommended Monitoring Frequency
CS-9		✓	Annual	✓		--	--		✓	Annual
CS-D		✓	Semi-annual		✓		✓		✓	Semi-Annual
CS-I		✓	Biennial		✓	✓			✓	Annual
CS-MW10-CC		✓	Biennial	✓		Not Included			✓	Biennial
CS-MW10-LGR		✓	Semi-annual	✓		✓			✓	Annual
CS-MW11A-LGR		✓	Semi-annual	✓			✓		✓	Semi-Annual
CS-MW11B-LGR		✓	Semi-annual	✓			✓		✓	Semi-Annual
CS-MW12-BS		✓	Biennial	✓		Not Included			✓	Biennial
CS-MW12-CC		✓	Biennial	✓		Not Included			✓	Biennial
CS-MW12-LGR		✓	Semi-annual		✓	✓			✓	Annual
CS-MW16-CC		✓	Semi-annual		✓	Not Included			✓	Semi-Annual
CS-MW16-LGR		✓	Semi-annual		✓		✓		✓	Semi-Annual
CS-MW17-LGR		✓	Biennial	✓			✓		✓	Annual
CS-MW18-LGR		✓	Semi-annual		✓		✓		✓	Semi-Annual
CS-MW19-LGR		✓	Semi-annual	✓			✓		✓	Semi-Annual
CS-MW1-BS		✓	Biennial	✓		Not Included			✓	Biennial
CS-MW1-CC		✓	Biennial	✓		Not Included			✓	Biennial
CS-MW1-LGR		✓	Semi-annual		✓	✓			✓	Semi-Annual
CS-MW2-CC		✓	Biennial	✓					✓	Biennial
CS-MW2-LGR		✓	Semi-annual	✓		--	--		✓	Semi-Annual
CS-MW3-LGR		✓	Semi-annual	✓			✓		✓	Semi-Annual
CS-MW4-LGR		✓	Semi-annual	✓			✓		✓	Semi-Annual

Table 7.1

Refine Frequency Based on Statistics

- *Confirm qualitative sampling frequency*
  - CS-D: Temp/Spat "Retain" → Confirms SA
  - CS-MWH-LGR: Temp/Spat "Exclude/Reduce" → Confirms Biennial
- *Decrease sampling frequency*
  - CS-2: Temp/Spatial "Exclude/Reduce" → Reduce sampling from Semi Annual to Annual
- *Qualitative factor overrides statistics*
  - Well CS-10: Temp/Spatial "Exclude/Reduce" → Keep at Annual due to qualitative (drinking supply well)
- *Increase sampling frequency*
  - CS-11: Temp retain (increasing lead) → Increase sampling from Biennial to Annual

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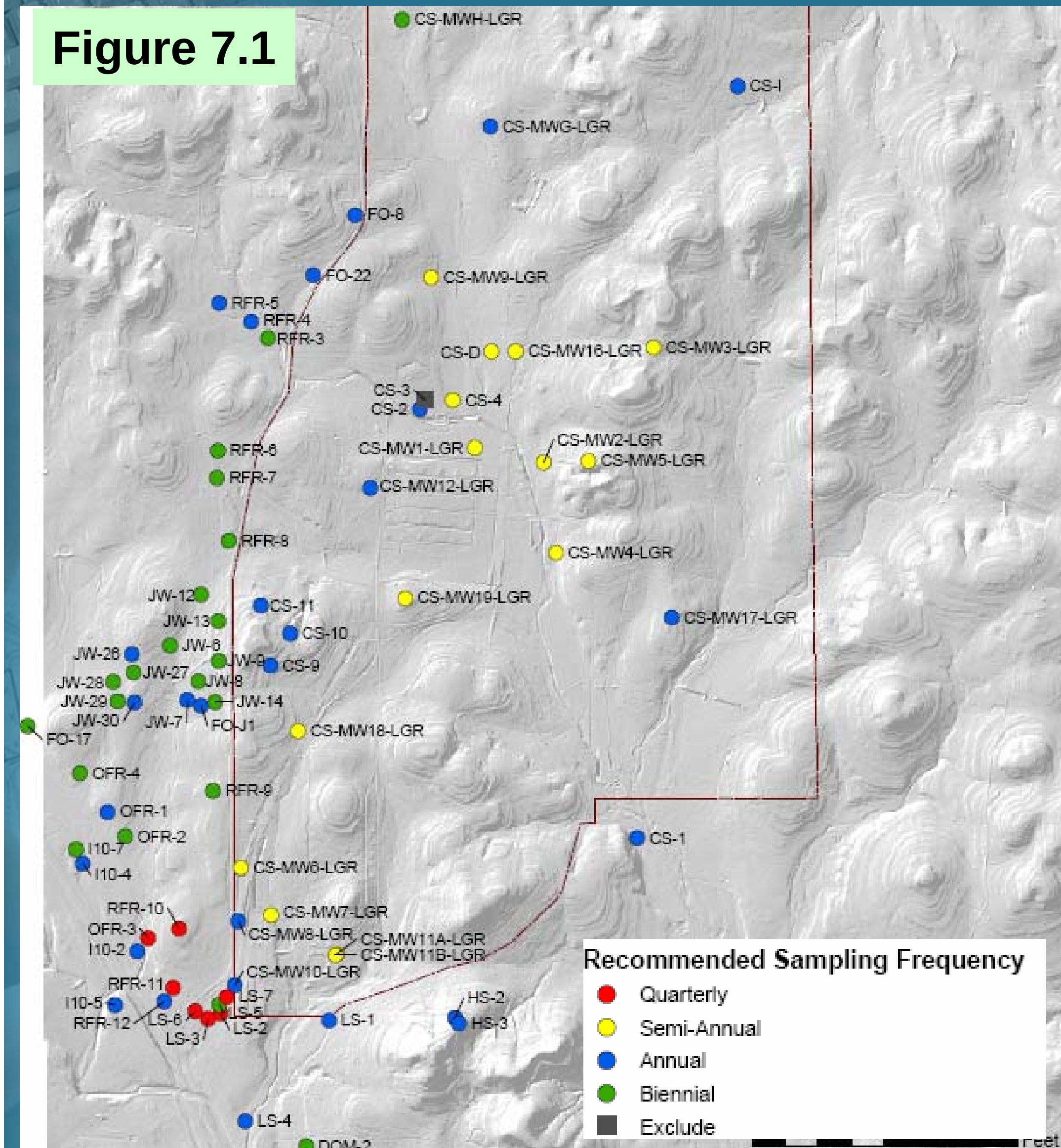
Combined Evaluation Summary



- 88 On & Off-Post Wells
  - 33 Biennial
  - 28 Annual
  - 16 Semi-Annual
  - 7 Quarterly
- WBs
  - Semiannual & after rain events
- AOC65
  - Exclude PZs
  - MWs after rain events

Recommendations

Type of Well	Monitoring Frequency						Total Sampling Points
	Not Sampled	Biennial	Annual	Semi-Annual	Quart-erly	After Rain Event	
On-post	1 (1)	13	11	16	(40)		**40 (40)**
Off-post		20	17(18)		7(26)		**44 (44)**
AOC-65	6				(8)	2	**2 (8)**
Westbay®				46		46 (46[b/])	**46 (46)**
Total Wells	**7 (1)**	**33**	**28 (18)**	**52**	**7 (74)**	**48 (46)[c/]**	**132 (138)**

Table 7.2

- On & Off-Post Wells
  - Reduce from 242 to 104.5 sampling events per year
    - On-Post: 120 to 49.5 events
    - Off-Post: 122 to 55 events
  - 57% reduction
- Westbay® Wells
  - Reduce from 528 to 88 events
  - 88% reduction

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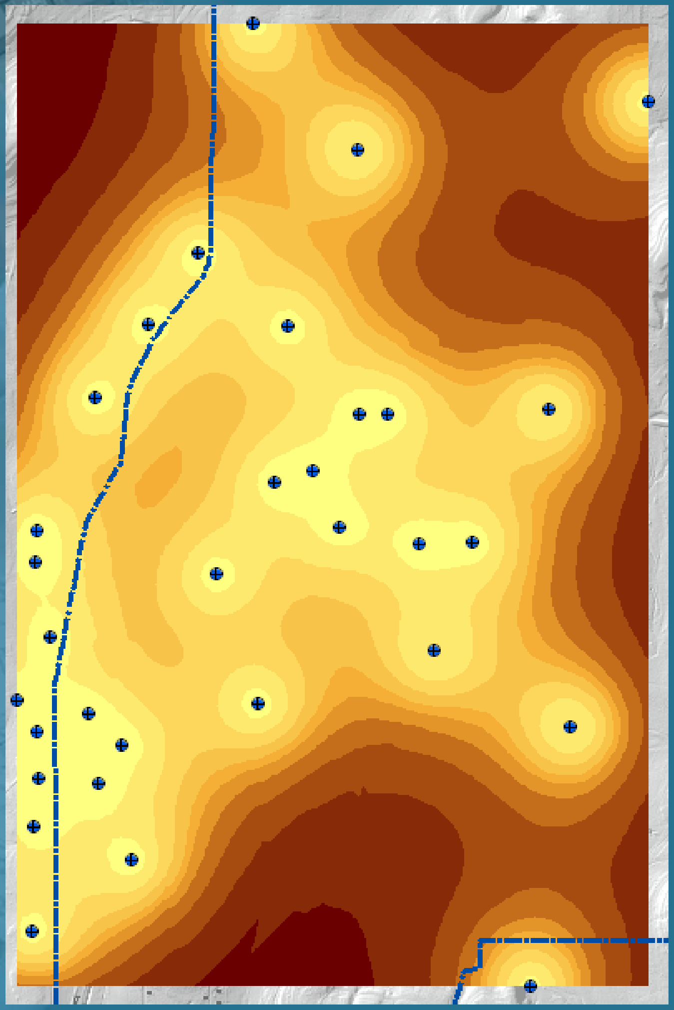
Future Applications



- Apply Spatial Statistics to Identify Potential New Well Locations
- Use Statistics to Refine WB Sampling Zones
- Integrate Temporal Trend Analysis into Existing GIS System
- Periodic Updated LTMO Analysis
- CSSA "Simplified" Case Study at EPA LTMO Workshop in Sacramento March 30-31st.

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"A conclusion is simply the place where someone got tired of thinking."

Arthur Block

Thank you!

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