Pilot Testing of CO_2 Sparging for a Caustic Groundwater Plume in a Coastal Aquifer

presented by

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CO_2 Sparging

Common method of pH adjustment in WW treatment

Takes advantage of simple chemistry:

$2NaOH + CO_2 = Na_2CO_3$ (Sodium Carbonate) $+ H_2O$

$NaOH + CO_2 = Na_2HCO_3$ (Sodium Bicarbonate)

Reaction product is dictated by the water pH

CO_2 Sparging Benefits

Handling of acid eliminated

Risk of overdosing acid and associated problems eliminated

Equipment requirements less than other technologies

O&M requirements less than other technologies

Project Site

A portion of the groundwater beneath the chemical plant has pH values in excess of 7.0 (caustic)

High pH plume present in shallow, intermediate and deep groundwater zones corresponding to freshwater, freshwater/saltwater transition and saline zones

High pH plume discharging to marine environment

Client began site investigations in 2001 and continues to investigate and monitor the groundwater and receiving environment conditions

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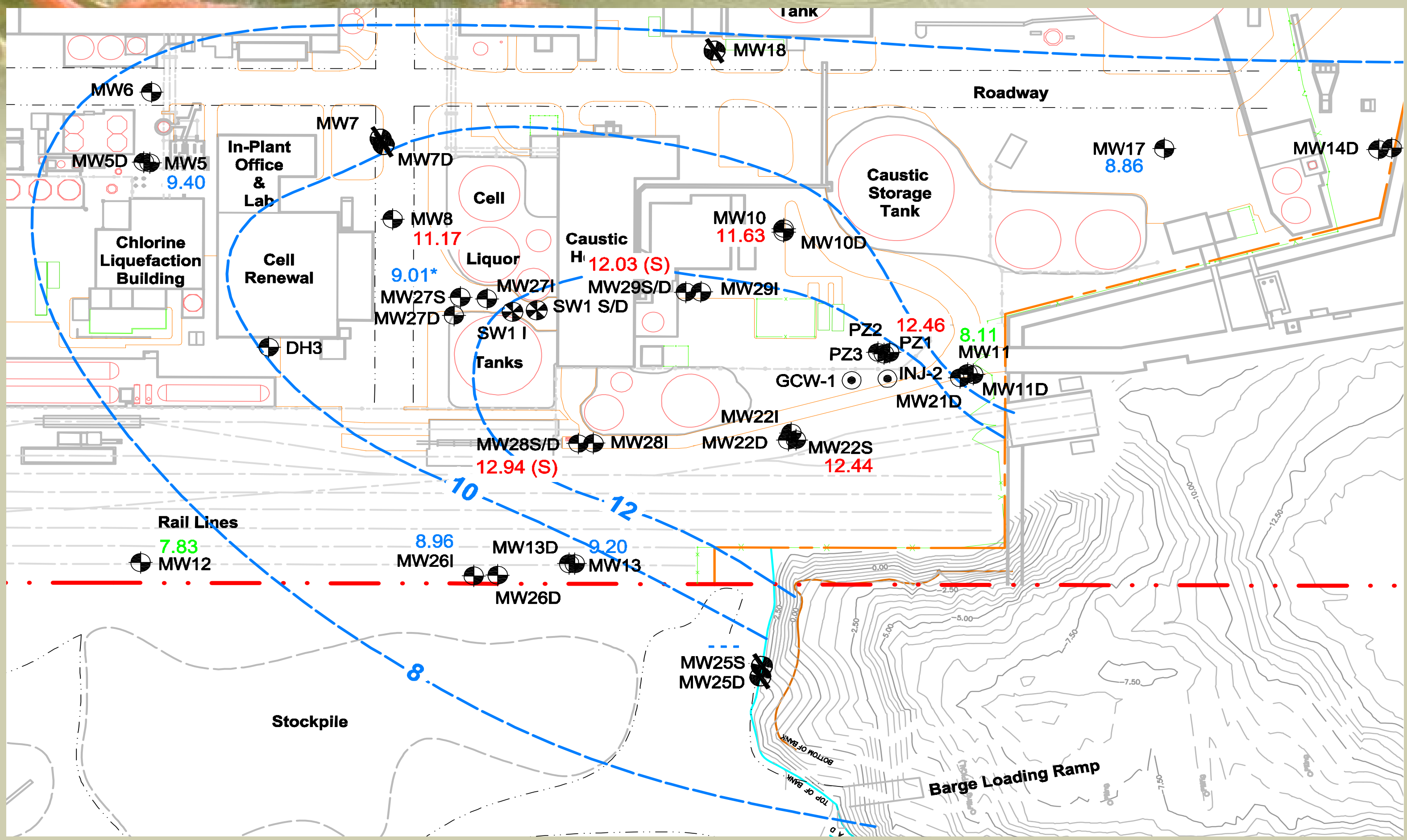
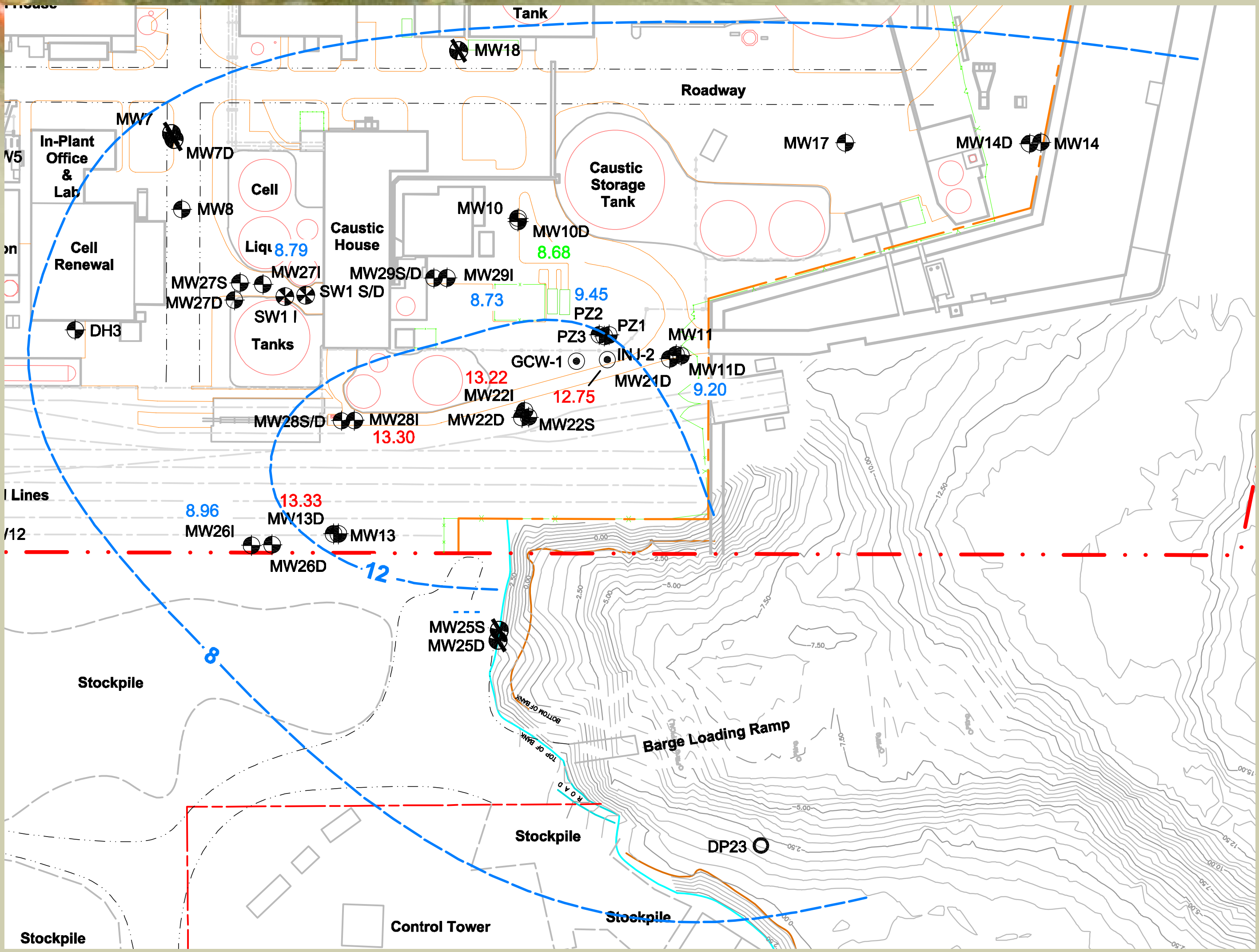
pH Plume Distribution

(Shallow: 2-11m bgs)



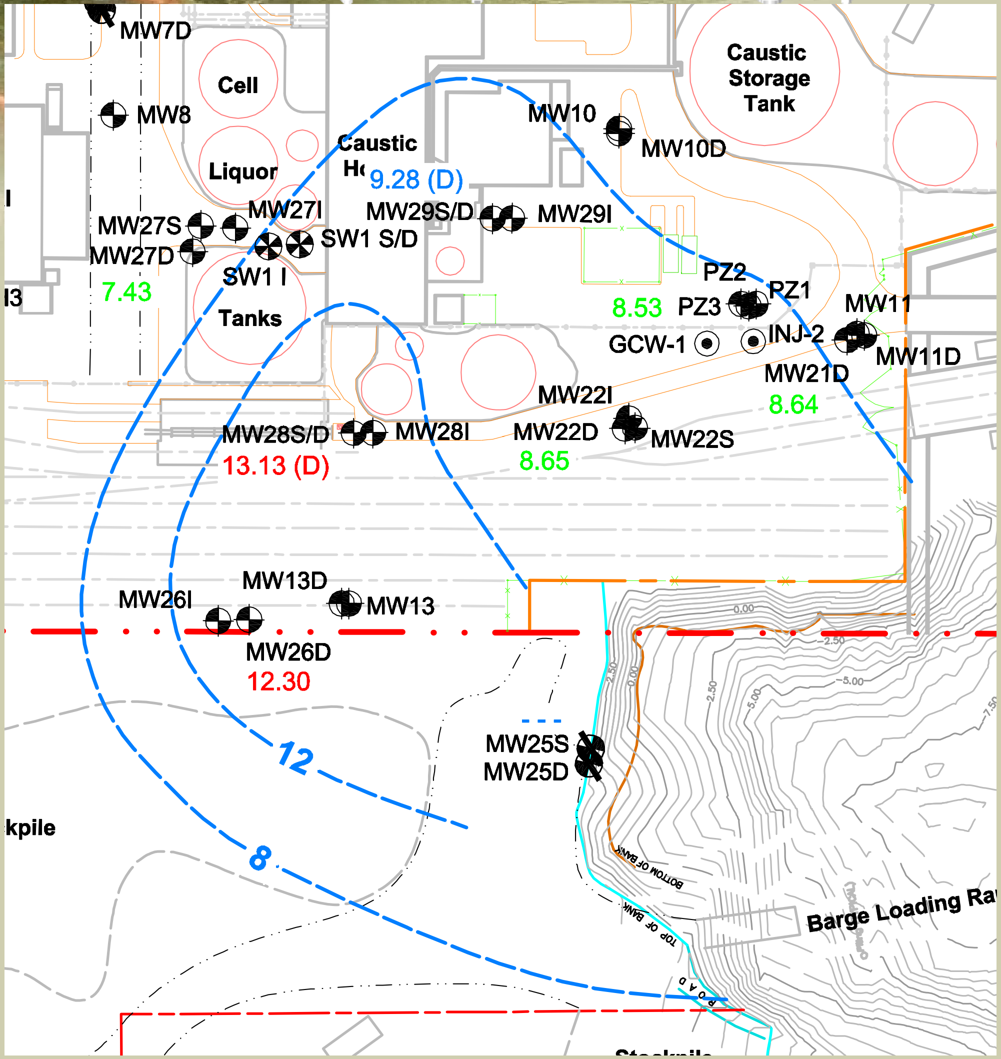
pH Plume Distribution

(Intermediate: 11-21m bgs.)



pH Plume Distribution

(Deep: >21m bgs.)



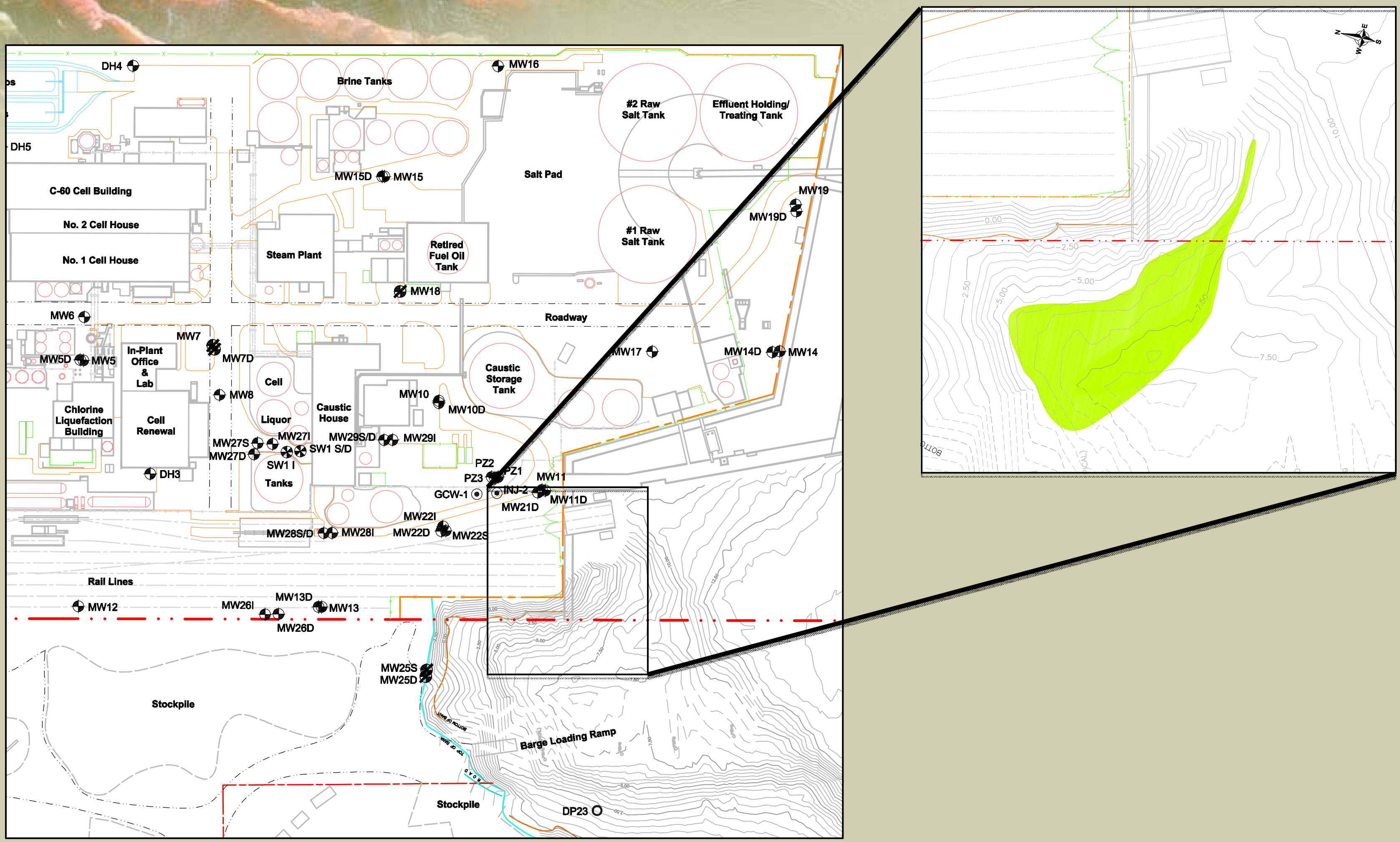
Summary of Receiving Environment Study Results

Discharge area defined by direct push sampling

Area of discharge approximately 75 m^2

Groundwater discharging from freshwater and saltwater/freshwater transition zones of aquifer

pH Plume Discharge Area

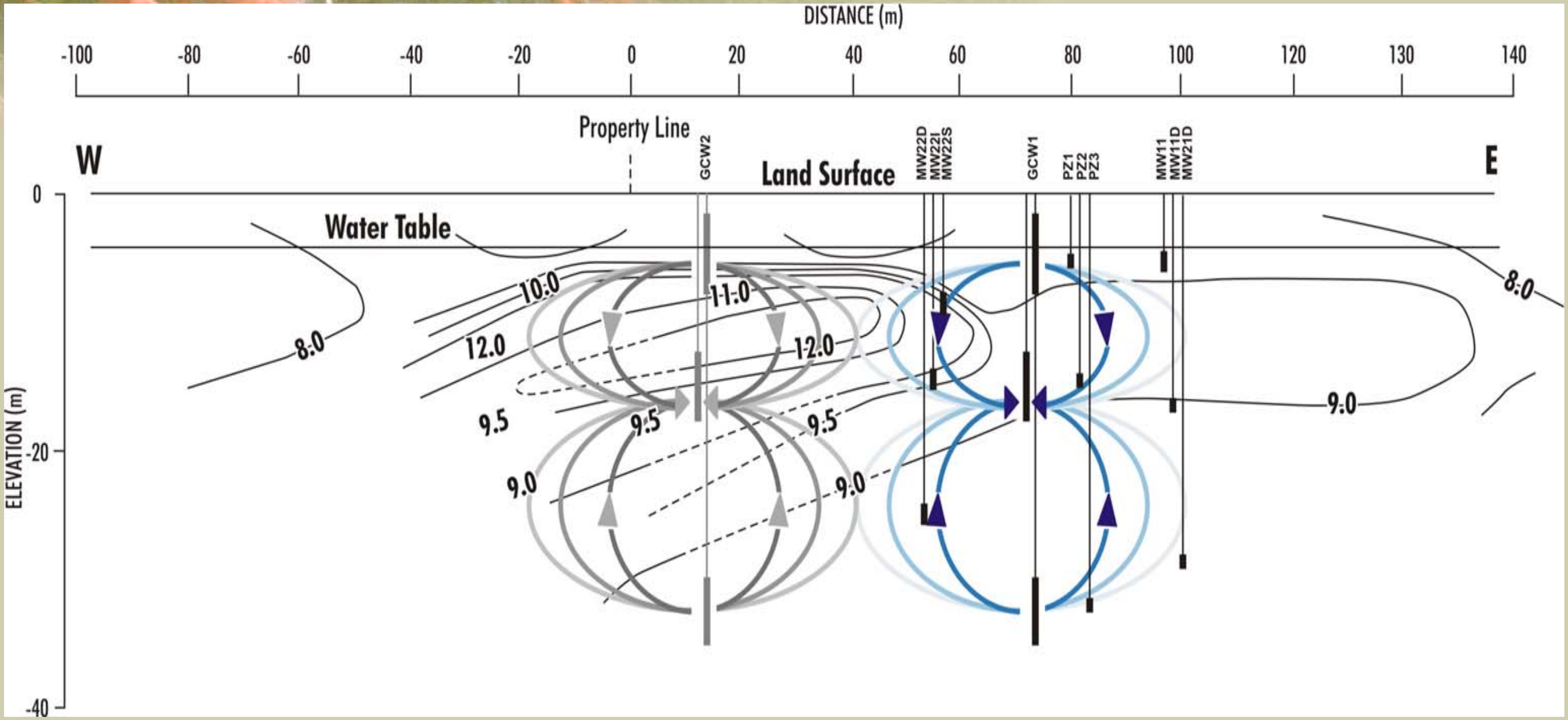


GCW Pilot Test

From 2004 to 2006 groundwater circulation well and pump and treat technologies were pilot tested to assess neutralizing the high pH groundwater using hydrochloric acid

GCW technology not viable but the findings led to the 09 CO_2 sparging pilot test

Initial GCW System Design

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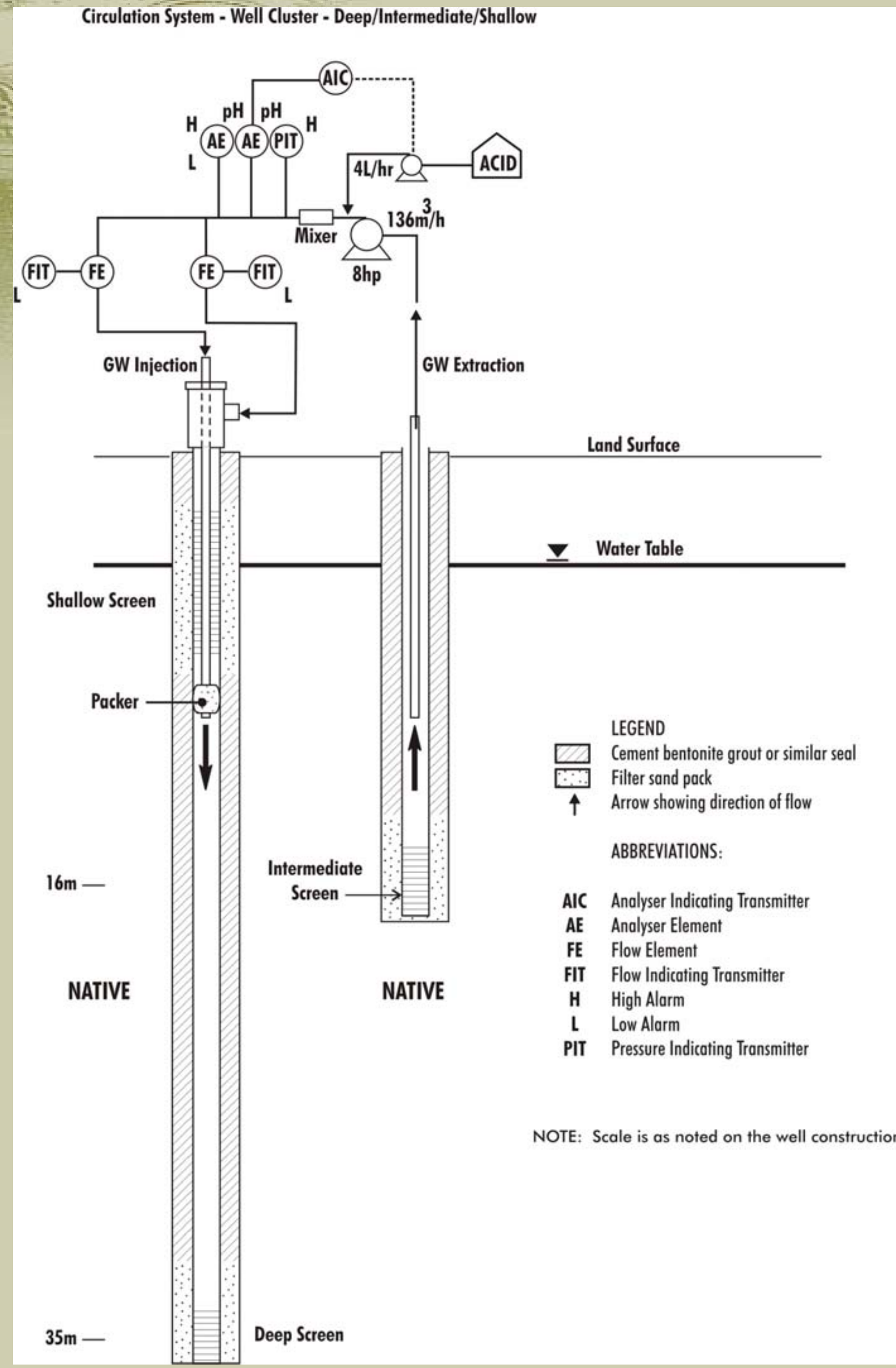
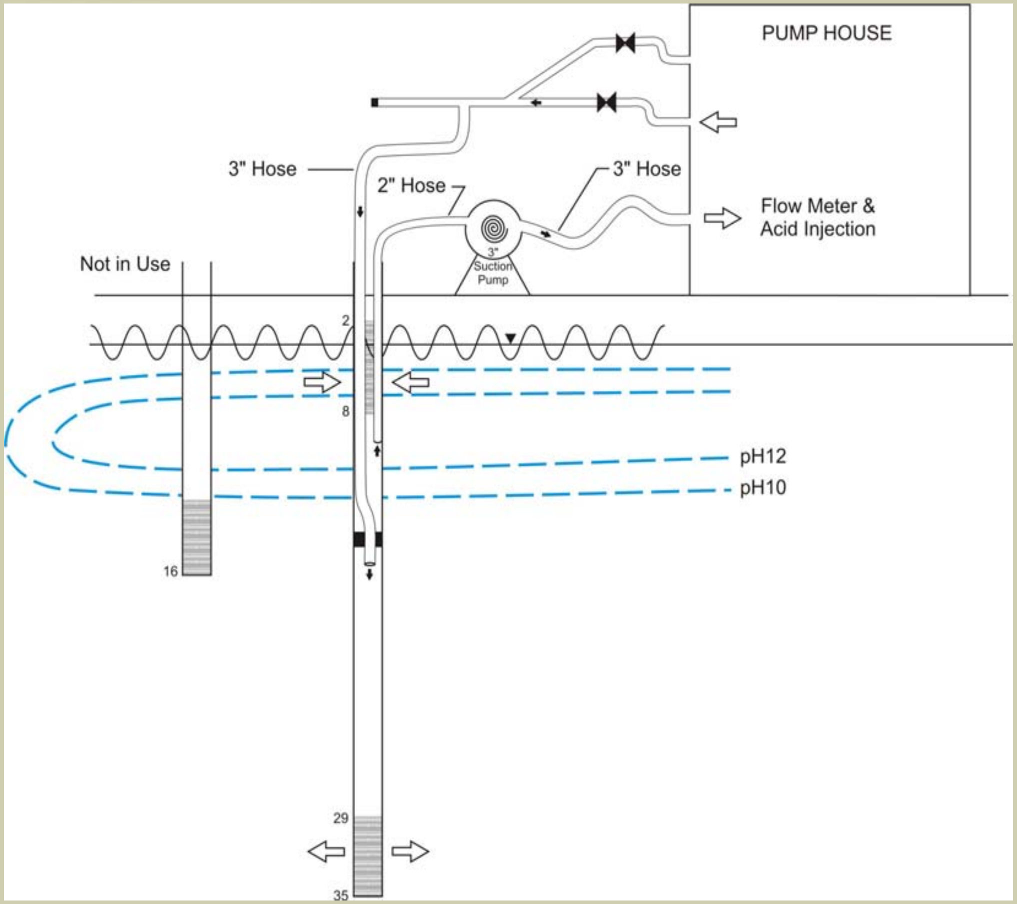

Circulation System - Well Cluster - Deep/Intermediate/Shallow
AIC
H
pH
pH
H
AE
AE
PIT
L
4L/hr
ACID
136m3/h
Mixer
FIT
FE
FE
FIT
L
L
8hp
GW Injection
GW Extraction
Land Surface
Water Table
Shallow Screen
Packer
LEGEND
Cement bentonite grout or similar seal
Filter sand pack
Arrow showing direction of flow
ABBREVIATIONS:
AIC Analyser Indicating Transmitter
AE Analyser Element
FE Flow Element
FIT Flow Indicating Transmitter
H High Alarm
L Low Alarm
PIT Pressure Indicating Transmitter
Intermediate Screen
16m
NATIVE
NATIVE
NOTE: Scale is as noted on the well construction
35m
Deep Screen

GCW Troubleshooting

- Several start-up issues including equipment scaling

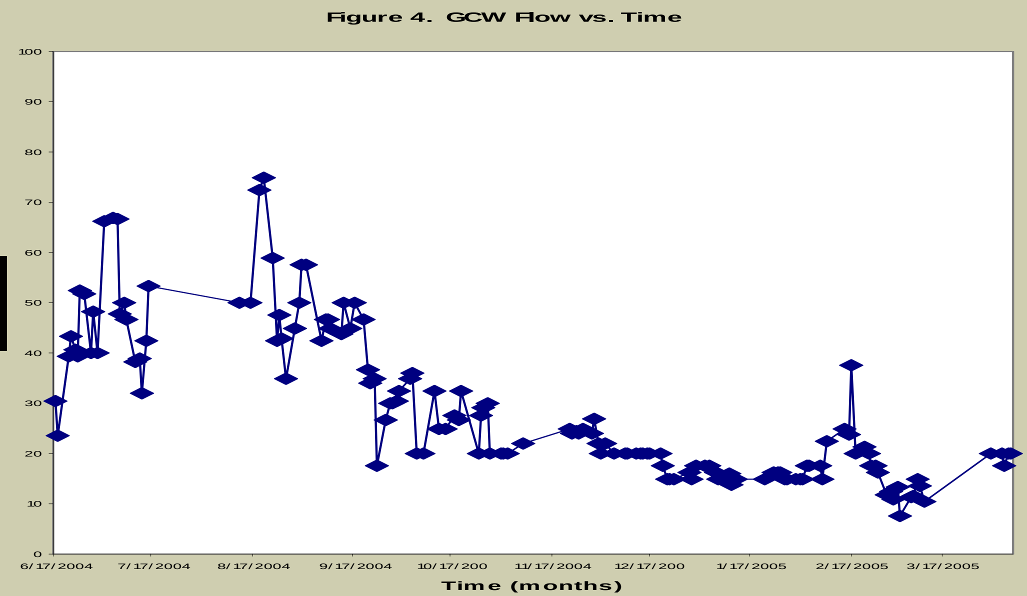
- System had to be re-configured and a new pump installed

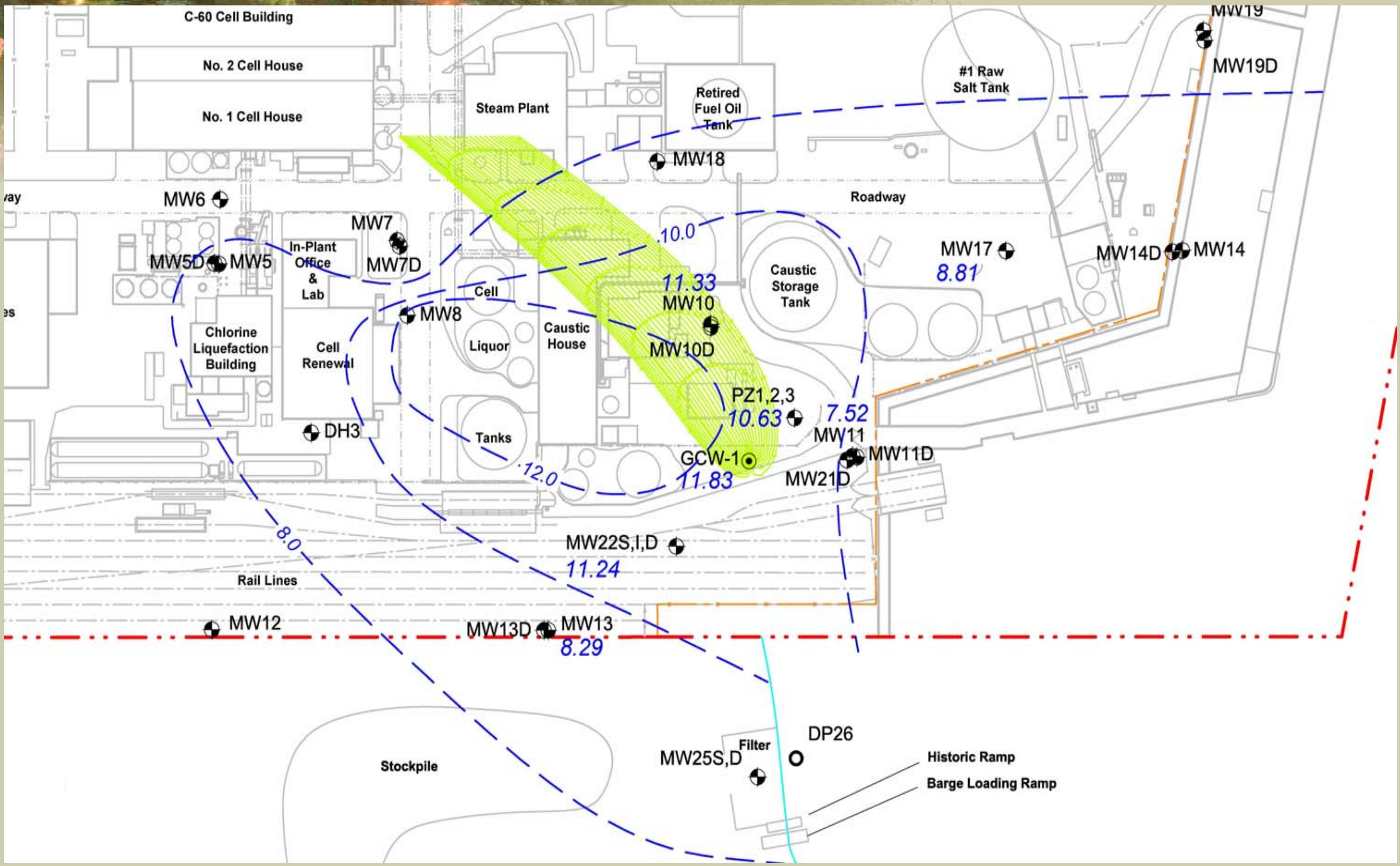


GCW Troubleshooting

- Pumping rate observed to decrease over duration of pilot trial

- Performed groundwater modeling to predict groundwater treatment zone at the end of the pilot trial




C-60 Cell Building
No. 2 Cell House
No. 1 Cell House
Steam Plant
Retired Fuel Oil Tank
#1 Raw Salt Tank
MW19
MW19D
MW18
Roadway
MW6
MW7
MW7D
MW5D
MW5
In-Plant Office & Lab
Cell
Liquor
Caustic House
10.0
11.33
MW10
MW10D
Caustic Storage Tank
MW17
8.81
MW14D
MW14
MW8
Chlorine Liquefaction Building
Cell Renewal
PZ1,2,3
10.63
7.52
DH3
Tanks
MW11
MW11D
GCW-1
11.83
12.0
MW21D
8.0
MW22S,I,D
11.24
Rail Lines
MW12
MW13D
MW13
8.29
DP26
Filter
MW25S,D
Stockpile
Historic Ramp
Barge Loading Ramp

GCW Troubleshooting

Decrease in pumping rate attributed to scale formation

Bench tests using soil and groundwater from transition and saline zones produced a white "gel" precipitate

Results indicated scale formed when treated saline groundwater was injected into untreated saline groundwater

GCW Troubleshooting

Bench tests using soil and groundwater from freshwater zone produced no precipitates

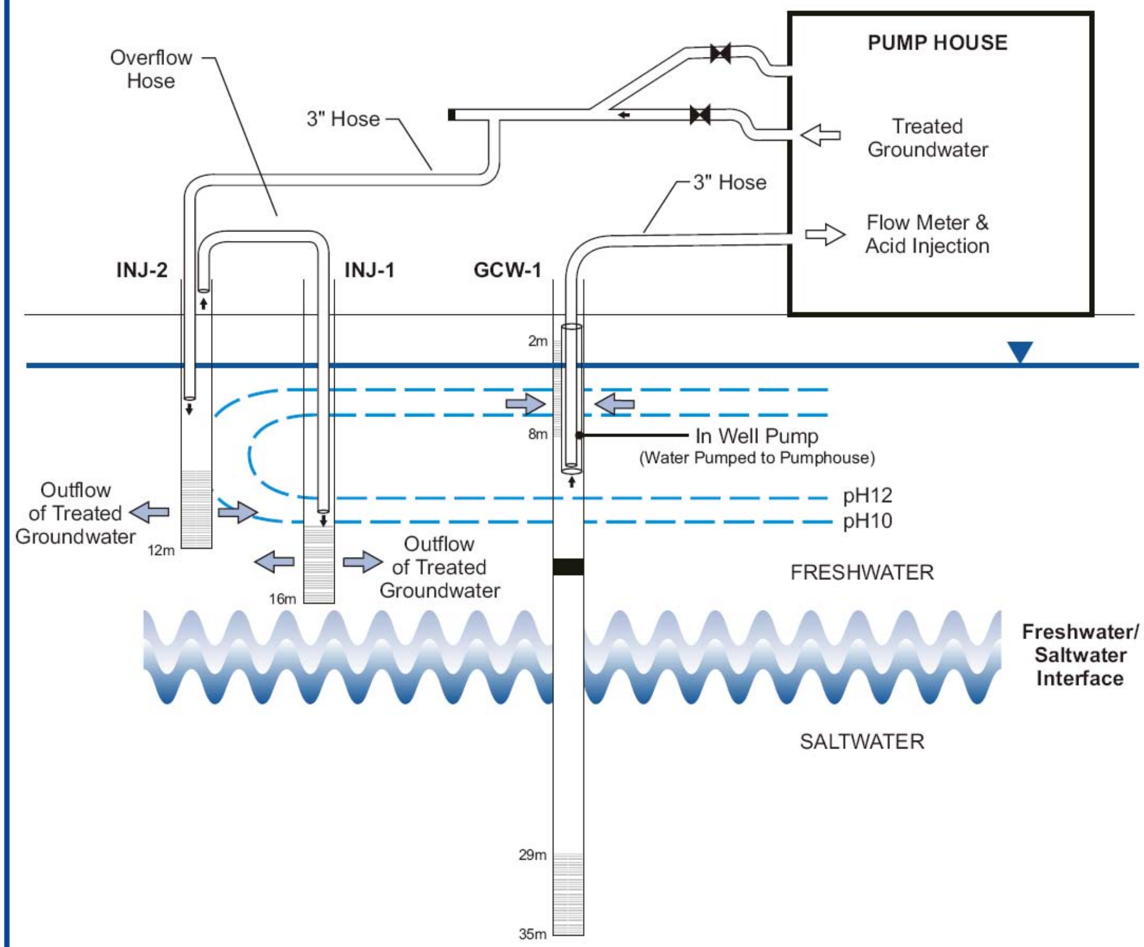
Bench tests suggested scale issues related to pH reduction in saline water

Supplemental Pilot Trial

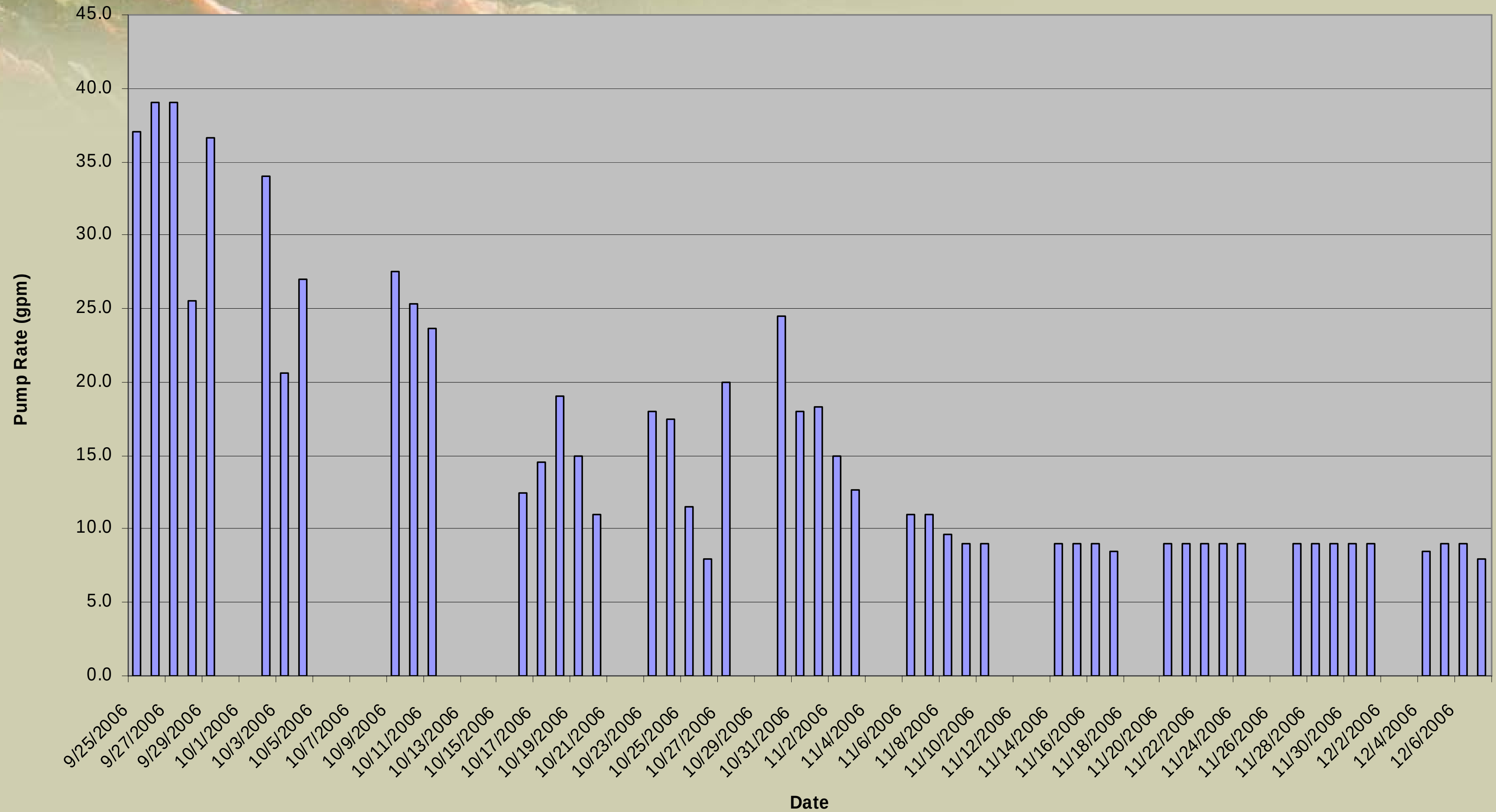
Re-configured the system in 06 to assess feasibility of intermediate injection point (well hydraulics / fouling / scaling)

Installation of an intermediate injection well above the depth of saline groundwater

Monitored pump rates, water levels and pH in surrounding monitoring wells


PUMP HOUSE
Overflow Hose
3" Hose
Treated Groundwater
3" Hose
Flow Meter & Acid Injection
INJ-2
INJ-1
GCW-1
2m
8m
In Well Pump
(Water Pumped to Pumphouse)
pH12
pH10
Outflow of Treated Groundwater
12m
16m
Outflow of Treated Groundwater
FRESHWATER
Freshwater/ Saltwater Interface
SALTWATER
29m
35m

Supplemental Pilot Trial – Average Daily Pump Rates



GCW Pilot Test Conclusions

Long term decreases in pH in system monitoring wells indicated the GCW pilot system had a positive effect but low pumping rates significantly decreased the size of the treatment zone

Direct cause of the scale formation could not be determined

Concluded GCW technology was not viable at the site

Column tests suggested treating GW in situ using CO2 may be possible without fouling the wells

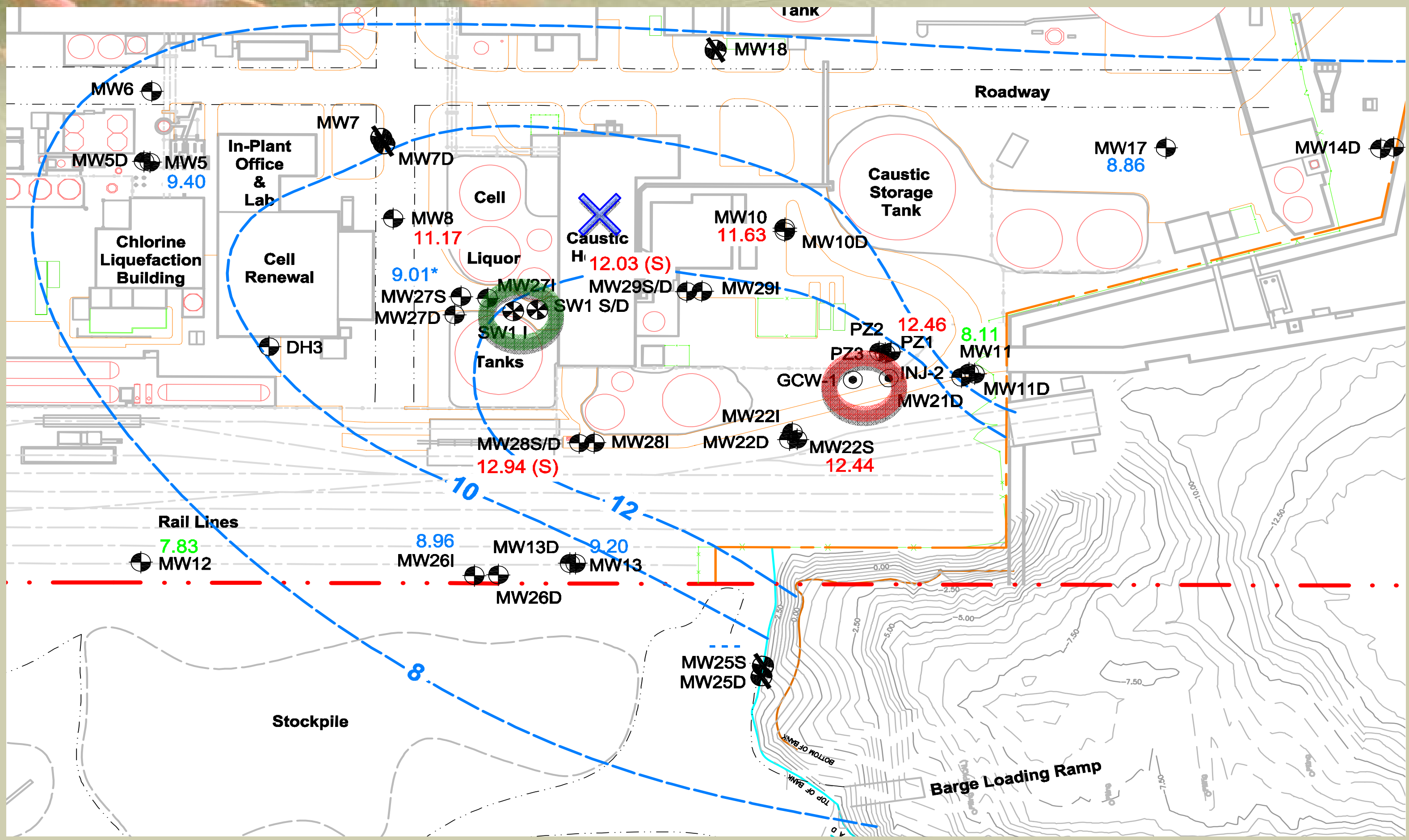
CO_2 Sparge Pilot Trial Setup

Three purpose built sparge wells screened in freshwater, transition and saline zones

Well ID	Screen Interval (mbgs)
SW1S	7.7-8.0
SW1I	16.7-17
SW1D	27.2-27.5

A temporary manifold was designed for the operation of the pilot system

CO_2 Sparge Pilot Trial Setup



CO_2 Sparge Pilot Trial Planning

Theoretical breakthrough pressures calculated based on the well construction and monitoring information

Breakthrough pressure is the pressure required to evacuate standing water from the well

Well #	Breakthrough (BT) Pressure (psi)	BT 110% (psi)	BT 125% (psi)	BT 150% (psi)
SW1S	6.7	7.4	8.4	10.1
SW1I	19.1	21.0	23.9	28.7
SW1D	33.1	36.4	41.3	49.6

CO_2 Pilot Trial Test Summary

Test #	Test Well ID	Test Description	Date of Test
1	SW1S	@ 110% Breakthrough Pressure	Mar-24
2	SW1S	@ 125% Breakthrough Pressure	Mar-24
3	SW1S	@ 110+% Breakthrough Pressure	Mar-25
4	SW1I	@ Breakthrough Pressure to 150% Breakthrough Pressure	Mar-26
5	SW1I	@ 125% to 150+% Breakthrough Pressure	Mar-27
6	SW1I	@ 125% to <150% Breakthrough Pressure	Mar-30
7	SW1I	@ Breakthrough Pressure	Apr-06
8	SW1D	@ 110% Breakthrough Pressure	Mar-31
9	SW1D	@ Breakthrough Pressure to 125% Breakthrough Pressure	Apr-01
10	Combined - all 3 wells	@ 125% Breakthrough Pressure / 110% Breakthrough Pressure / 110% Breakthrough Pressure	Apr-02
11	Combined - all 3 wells	@ 110% Breakthrough Pressure / Breakthrough Pressure / Breakthrough Pressure	Apr-07

CO_2 Sparge Pilot Trial Monitoring

To monitor for surrounding influence the surrounding sparge wells (during single wells sparge tests) were monitored for headspace pressure, O_2 and CO_2

Surrounding monitoring wells monitored for the above plus: pH, conductivity, ORP, temperature, DO, and salinity

Transducers placed in surrounding monitoring wells

Results

Well ID	Applied Pressure (psig) Pilot Range	CO2 Flow Rate (scfm) Pilot Range
SW-1S	5 to 9	0 to 8
SW-1I	15 to 19	0 to 15
SW-1D	28 to 41	36 to 85

Test well data demonstrated sufficient CO_2 flows achieved

Fugitive CO_2 encountered in sparge wells and nearby wells

As expected, higher flows translated into higher fugitive CO_2

Results

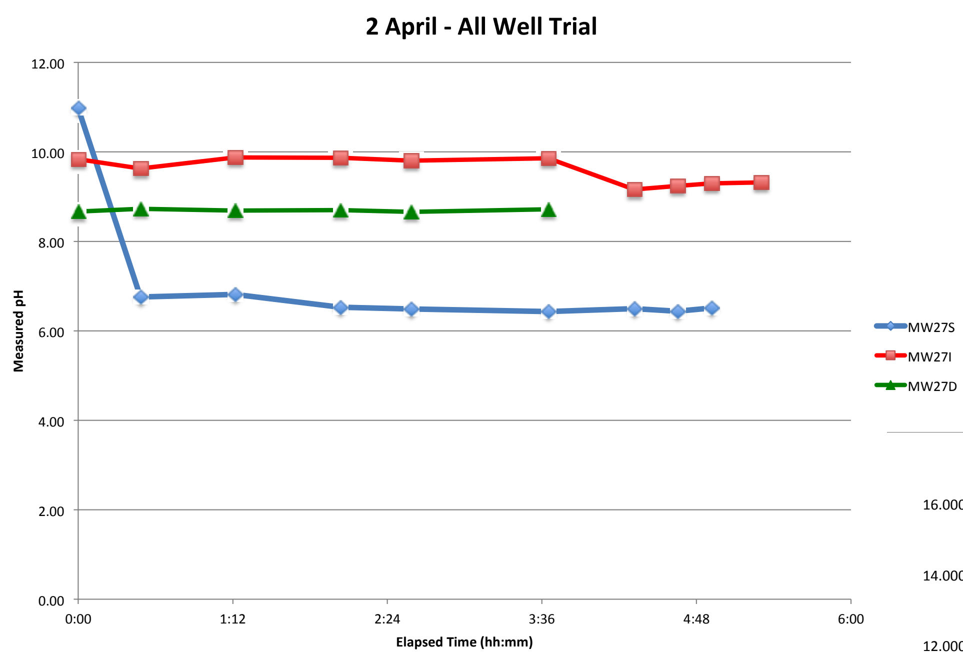
Positive radii of influence observed at 8 m distance from sparge well

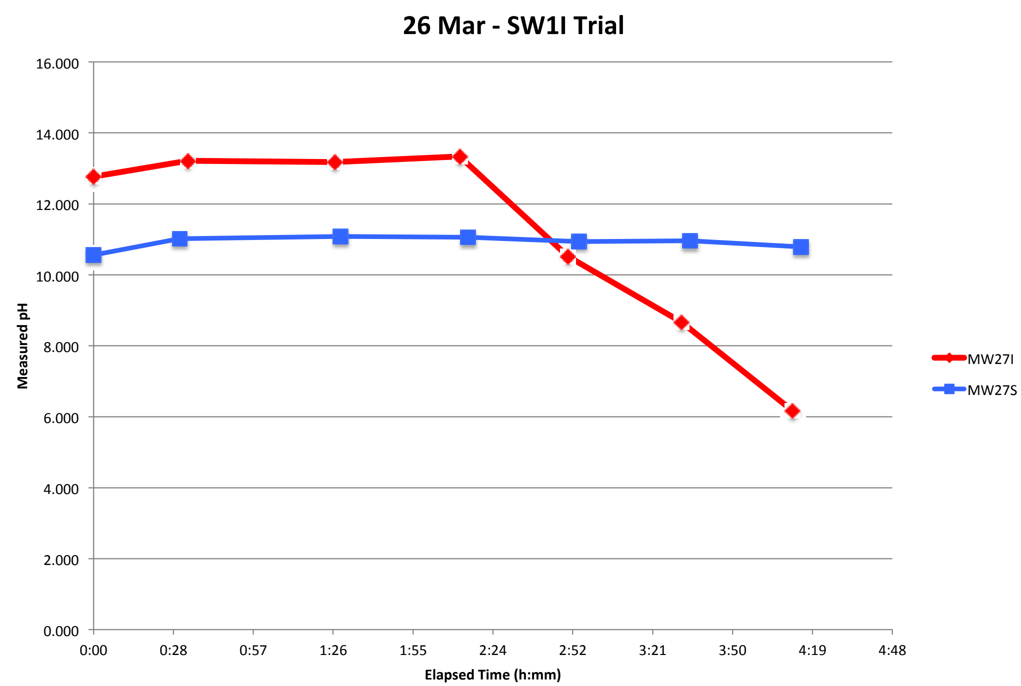
Reduction in pH observed 8 m from the sparge well between 15 minutes to 60 minutes from start of test

Observed pH reduction in both shallow and intermediate zones:

- –pH decreased from 11.14 to 6.43 in shallow MW (combined test)
- –pH decreased from 13.21 to 6.17 in intermediate MW (SW1I test)
- –Did not observe pH decrease in deep monitoring well

pH Reduction Observed





CO_2 Sparge Pilot Trial Hydraulic Conductivity Testing

Hydraulic permeability tests determined the hydraulic conductivity for the site to be 1.3×10^{-3} m/s

Permeability testing was conducted before and after the pilot trial to monitor for scaling identified during the GCW pilot test

Conductivity Testing Results

Well ID	Confined (Hvorslev) Hydraulic Conductivity (m/s)		Unconfined (Bouwer & Rice) Hydraulic Conductivity (m/s)	
	Pre-Test	Post-Test	Pre-Test	Post-Test
MW-27D	4.9×10^{-4} 4.5×10^{-4}	n/a	4.5×10^{-4} 4.1×10^{-4}	n/a
SW-1S	4.7×10^{-4} 5.4×10^{-4}	n/a	3.8×10^{-4} 4.5×10^{-4}	n/a
SW-1I	n/a	6.1×10^{-6} 5.2×10^{-6}	n/a	5.6×10^{-5} 4.8×10^{-5}
SW-1D	2.8×10^{-4} 2.3×10^{-4}	3.4×10^{-4} 2.4×10^{-4}	2.7×10^{-4} 2.2×10^{-4}	3.2×10^{-4} 2.3×10^{-4}
MW-27S	6.0×10^{-4}	3.3×10^{-4} 2.3×10^{-4}	1.6×10^{-3}	8.7×10^{-4} 6.0×10^{-4}

Conclusions

CO_2 sparging demonstrated effective pH buffering

No significant reduction of hydraulic conductivity observed following the completion of the pilot trial

Good radius of influence observed

Scaled-up or full scale CO_2 sparge system is a feasible option

Advantages

No groundwater extraction required, therefore, no wastewater generated

No ex situ treatment eliminating contact with equipment and piping materials

Pulsed operation could be an effective application to further reduce operating costs

A single technology would be applicable for both fresh and saline waters

QUESTIONS??