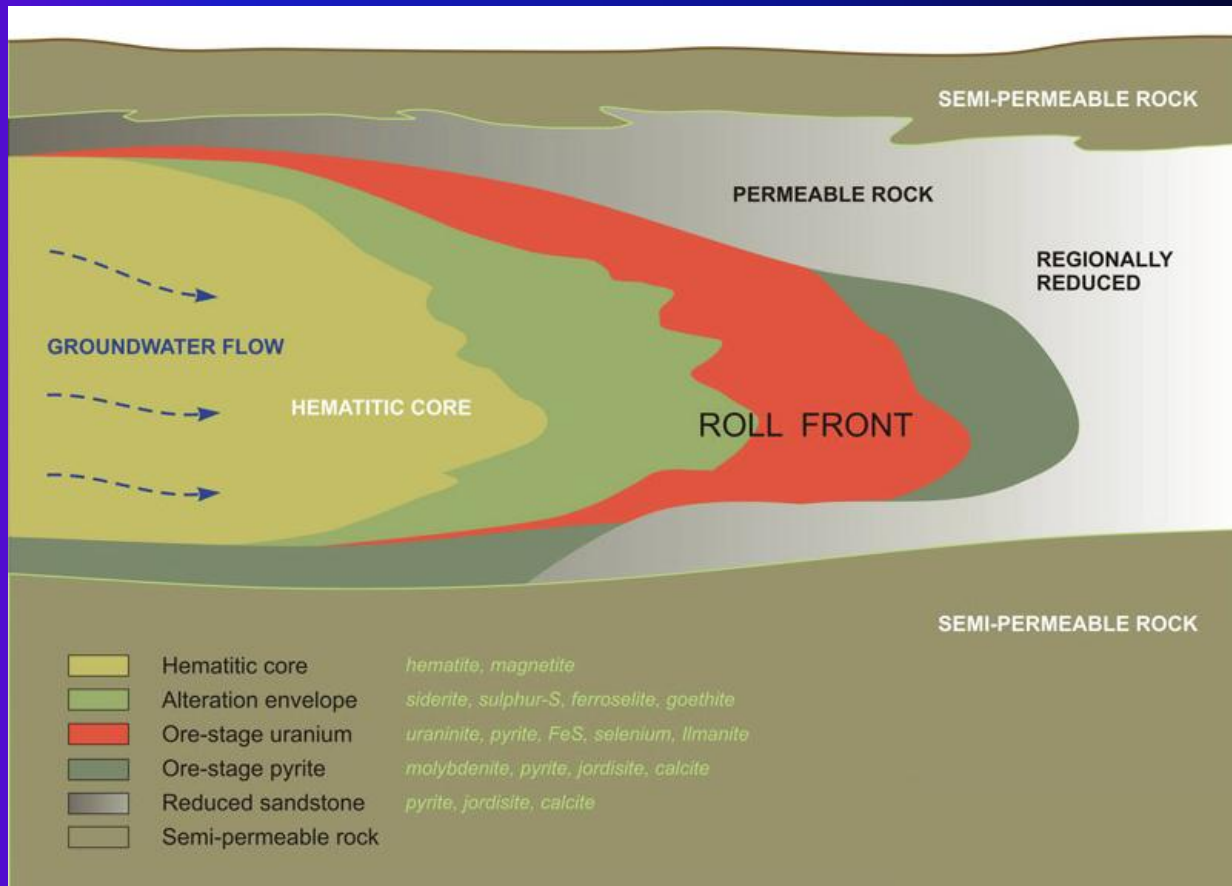
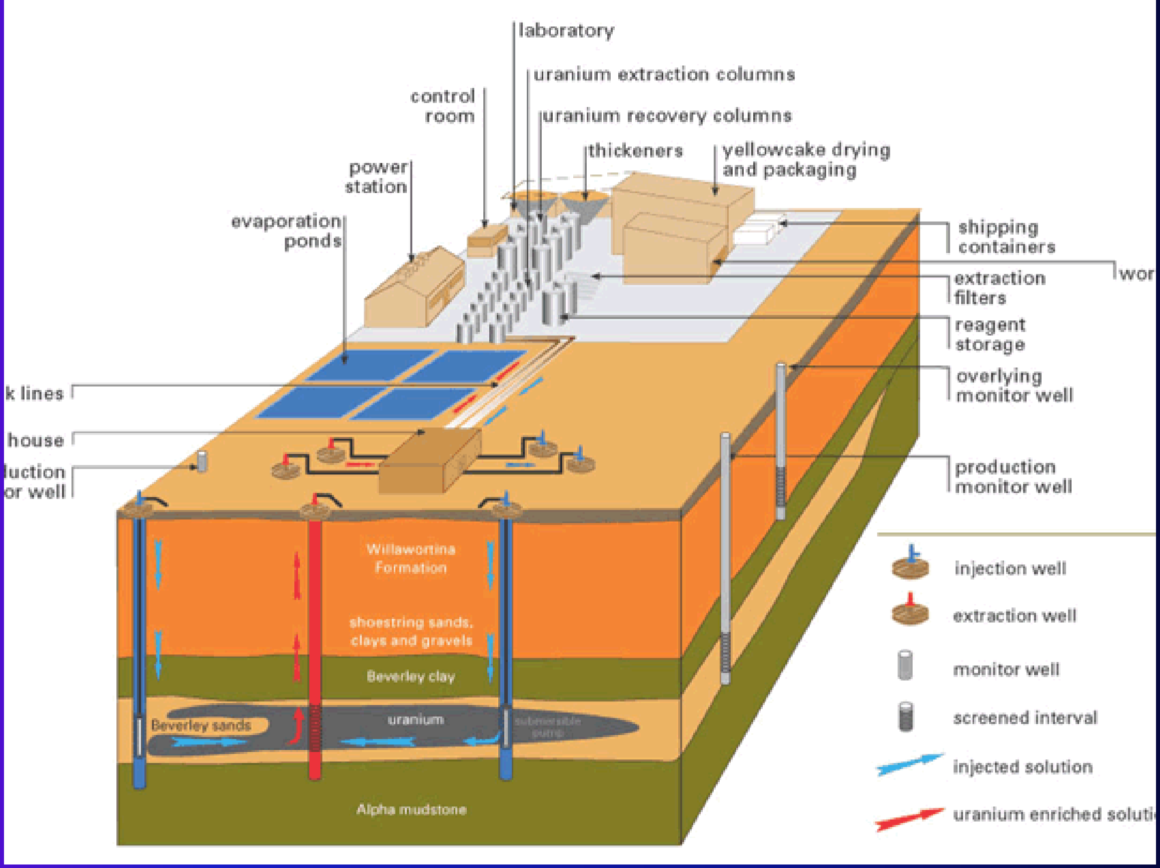
Evaluating the Effects of Uranium Kd on the Restoration of ISL Wellfields Using PHT3D



After Devoto, 1978

MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.



ISR MINING PROCESS

Inject Lixiviant
Recover Pregnant Solution
Ion Exchange
Reverse Osmosis
Reinjection Lixiviant With Make Up Water With Reactants

MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

What is K_d

- Distribution Coefficient
- Related to Solute Retardation

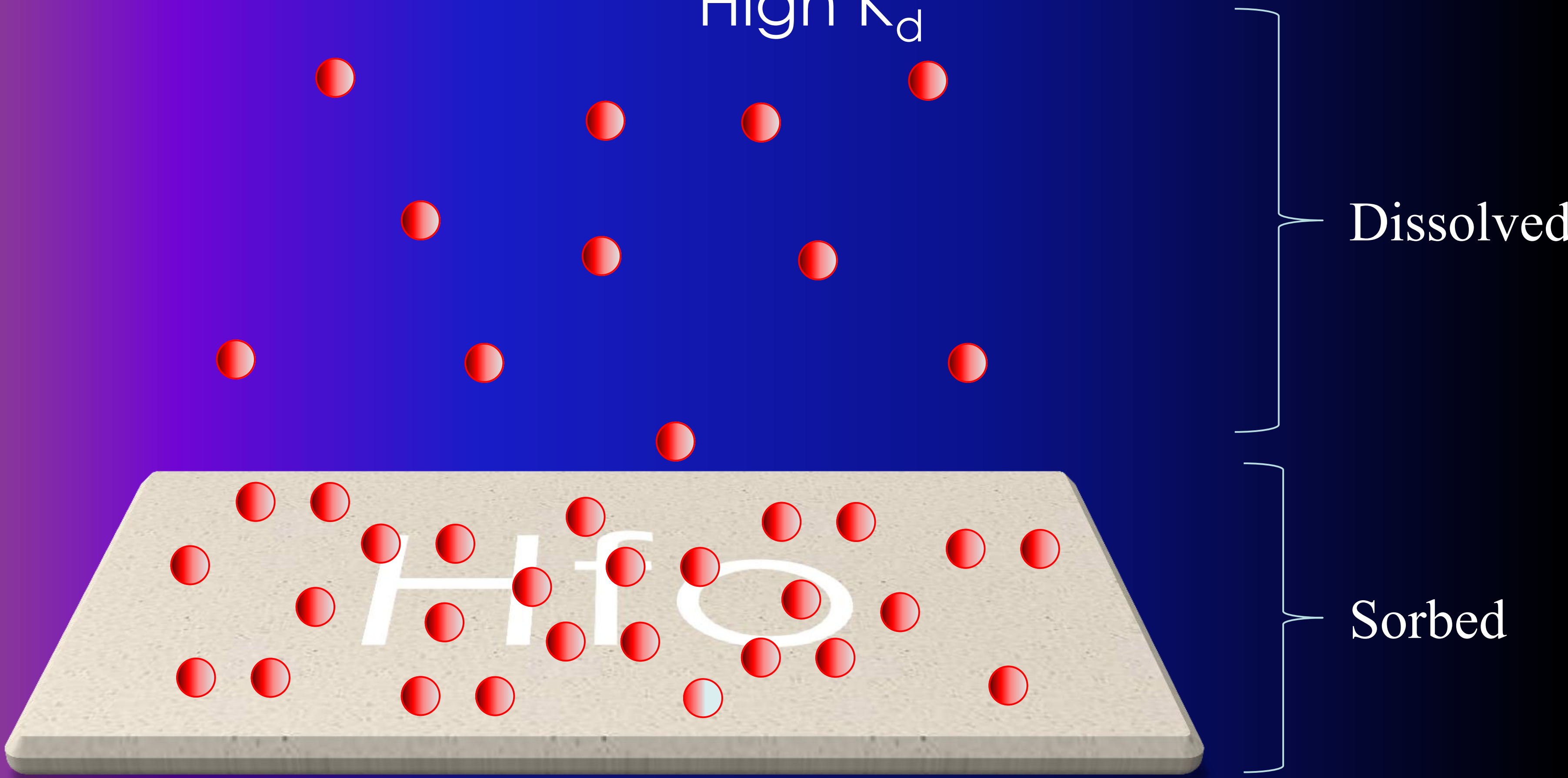
$$R = 1 + \frac{\rho K_d}{n_e}$$

- $R = \frac{Groundwater\ Velocity}{Solute\ Velocity}$
- K_d is Proportional to the Solute Velocity
- $K_d = \frac{Concentration\ of\ Sorbed}{Concentration\ of\ Dissolved}$

MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

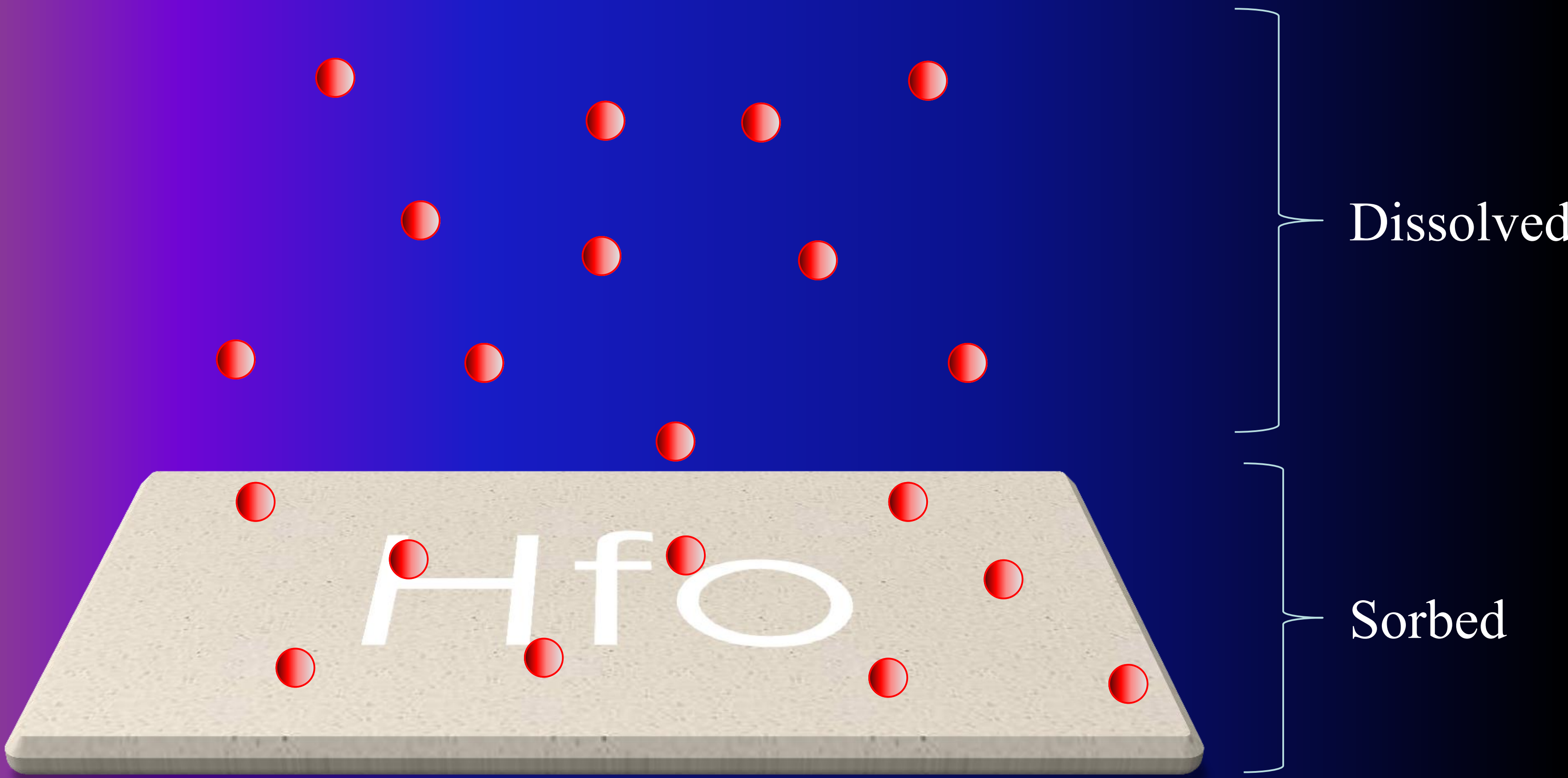
Surface Ionization and Complexation Model
High K_d



MGC MAHONEY GEOCHEMICAL CONSULTING

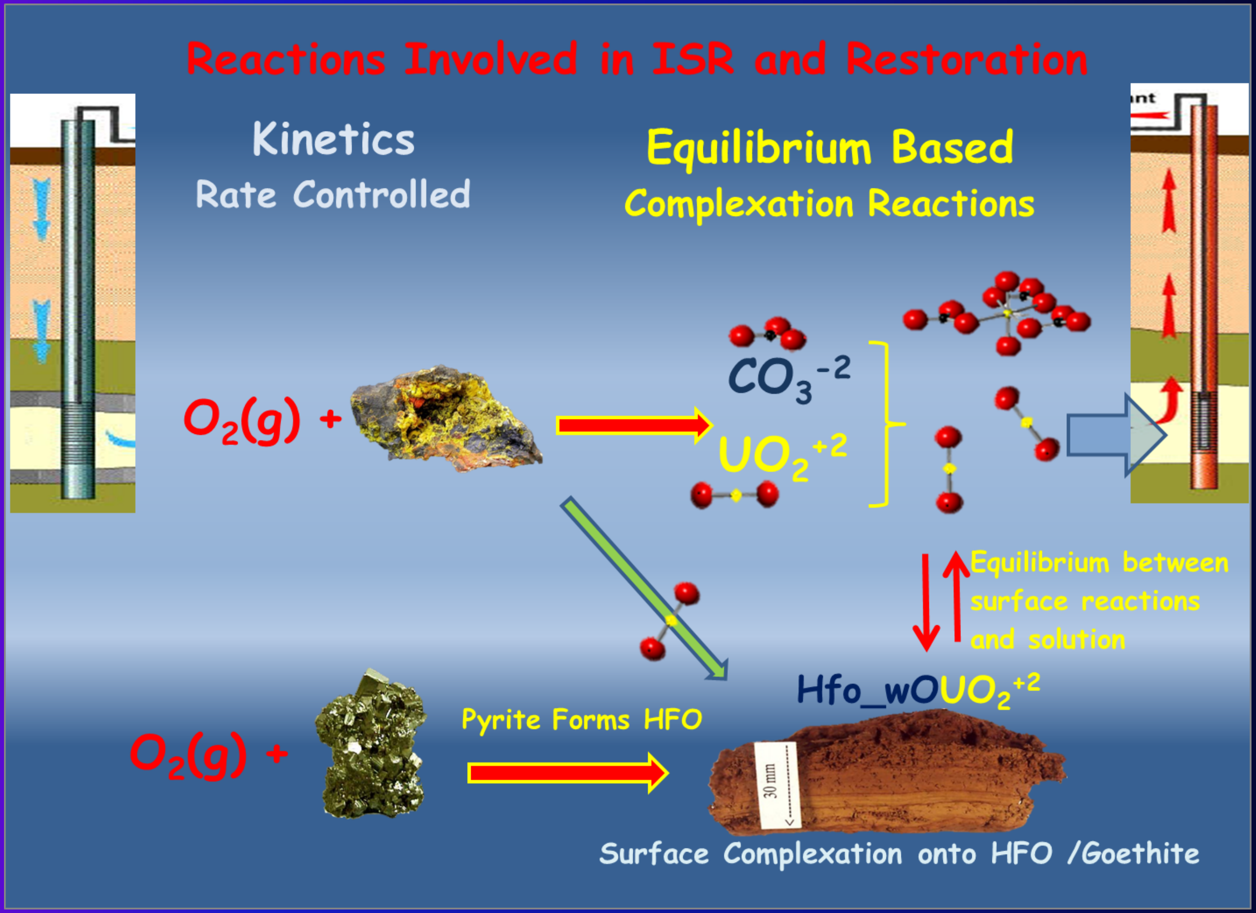
Gard water consultants, inc.

Surface Ionization and Complexation Model
Low K_d



MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.



Surface Complexation

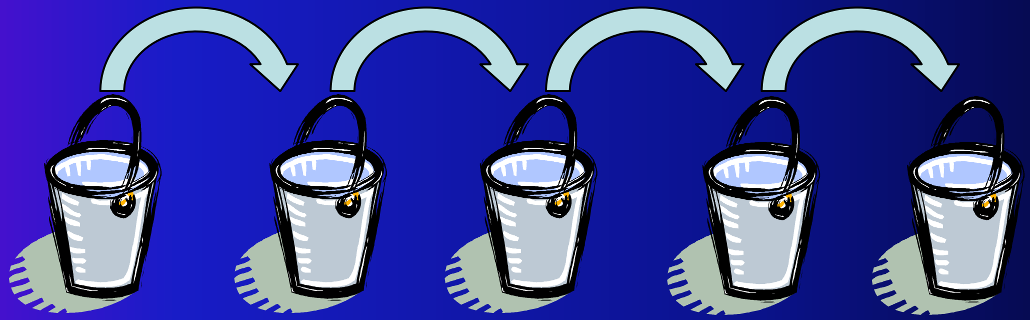
Uranium sorbing onto Hydro Ferrous Oxide (Hfo)

Modeling
How Do We Simulate All of the Processes

1. Obtain Publically Available “ADAMS” Data
2. Create a Modflow Flow Model
3. Create the MT3D Transport Model
4. Add PHT3D Reactive Transport and Surface Complexation Elements

MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.



PHREEQC

- One-Dimensional
- Fixed Groundwater Velocity
- Dispersion In One Direction
- Groundwater Is Passed Along a Line and Allowed to React With New Water And Minerals

MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

PHT3D

1. Three-dimensional
2. Variable Groundwater Velocity
3. Dispersion In Three Directions
4. Each Bucket Represents A Model Cell

Reactive Transport Model

1. Still Conceptual in nature
2. Proof of Concept
3. What Effect Does Surface Complexation Have on Uranium Restoration
4. How Can We Keep the Kd Low
5. Can PHT3D Be Implemented to Solve These Problems

MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

Mineral Phases Used in PHT3D

- Uraninite
- Pyrite
- Calcite
- Goethite Used For Complexation Sites
- Assume Quartz Inert

MAHONEY GEOCHEMICAL CONSULTING

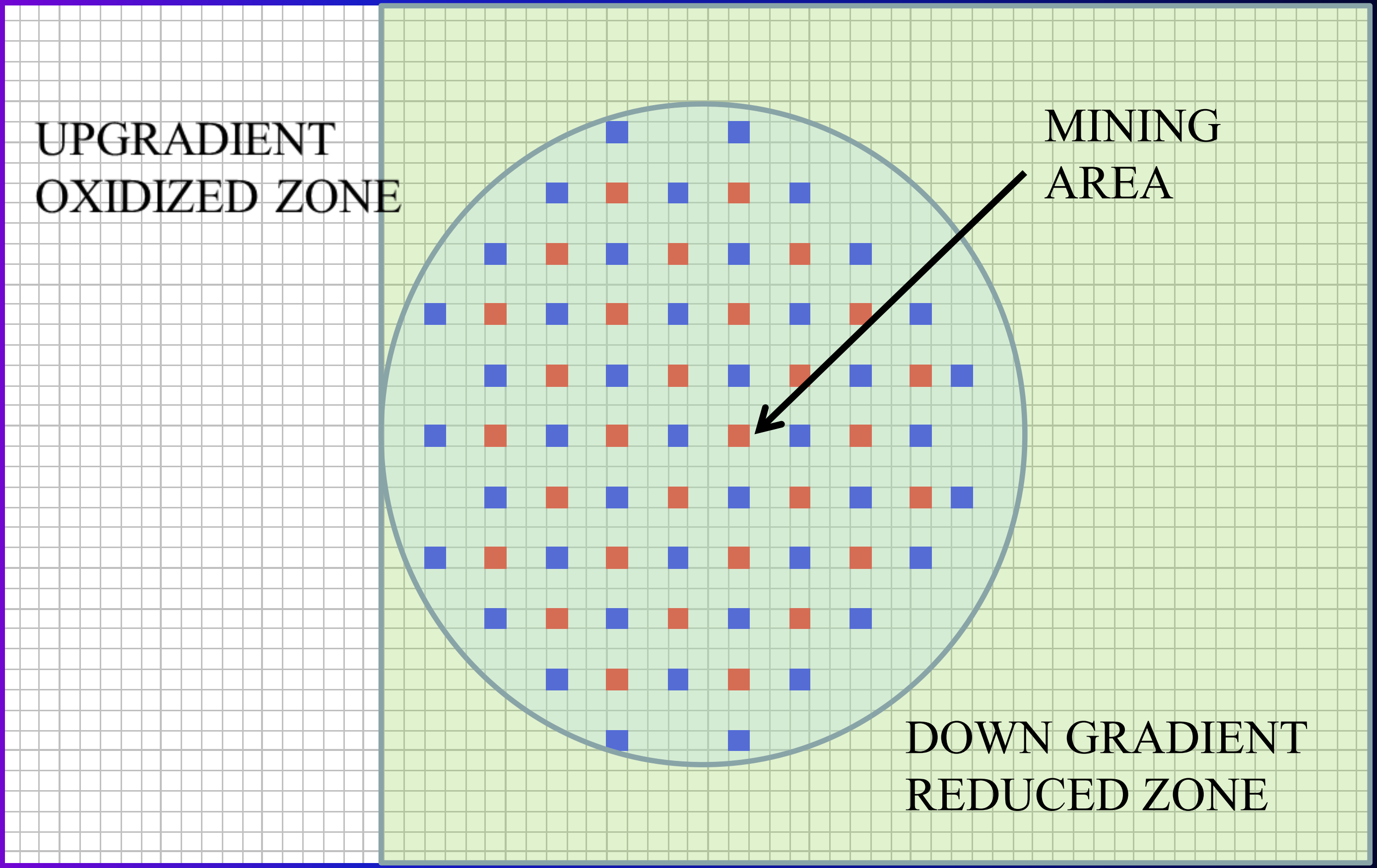
Gard water consultants, inc.

Components Used in PHT3D

- Oxygen
- Carbon
- Sodium
- Chloride
- Sulfate
- Calcium
- Iron
- Potassium
- pH
- pe

MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.



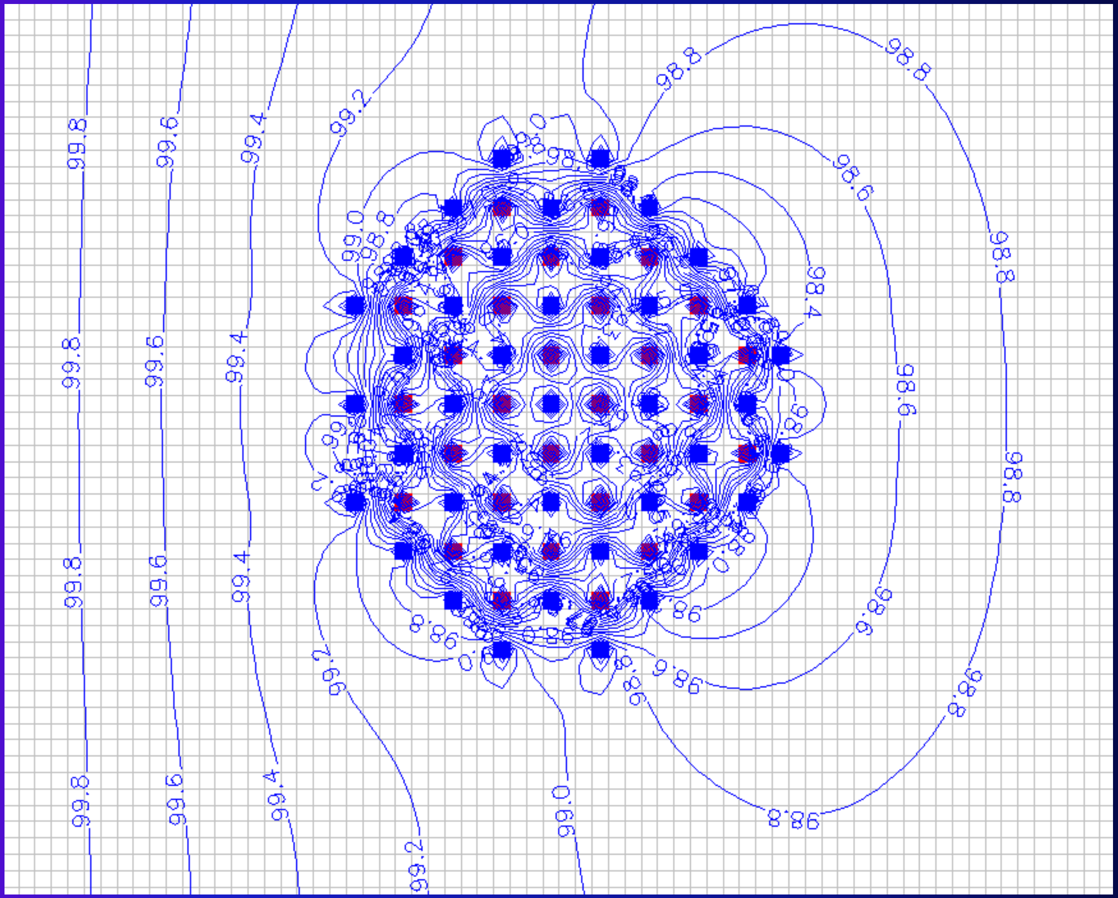
EXAMPLE ISR MINE UNIT

Up Gradient Groundwater Oxidized Carries Dissolved Uranium

Reducing Zone Forced Uranium to Precipitate In Roll Front

MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.



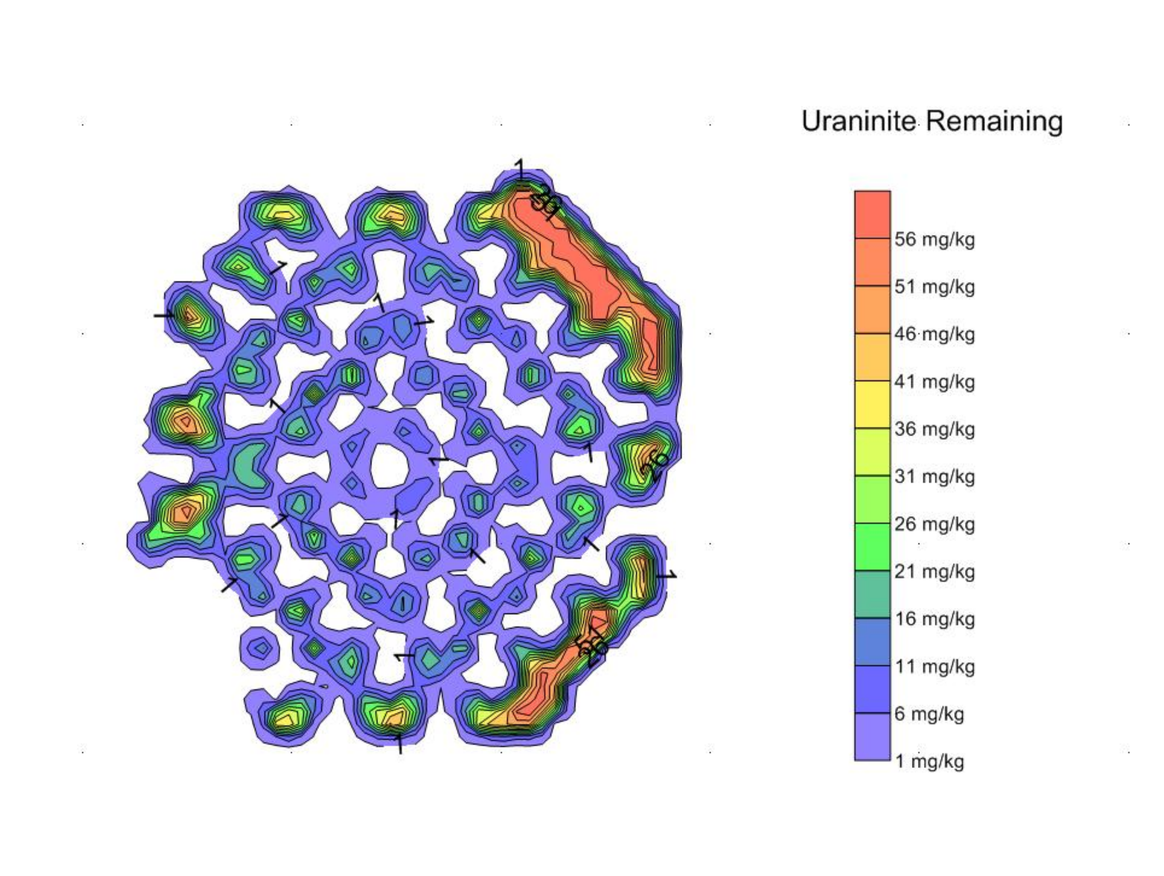
THEORECTICAL ISR URANIUM MINE

MODFLOW

- Maintain Gradient Towards Well Field During Mining
- Recovery Flow Greater Than Injection Flow

MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.



Post Mining Uraninite

Modflow/PHT3D modeling

MGC MAHONEY GEOCHEMICAL CONSULTING

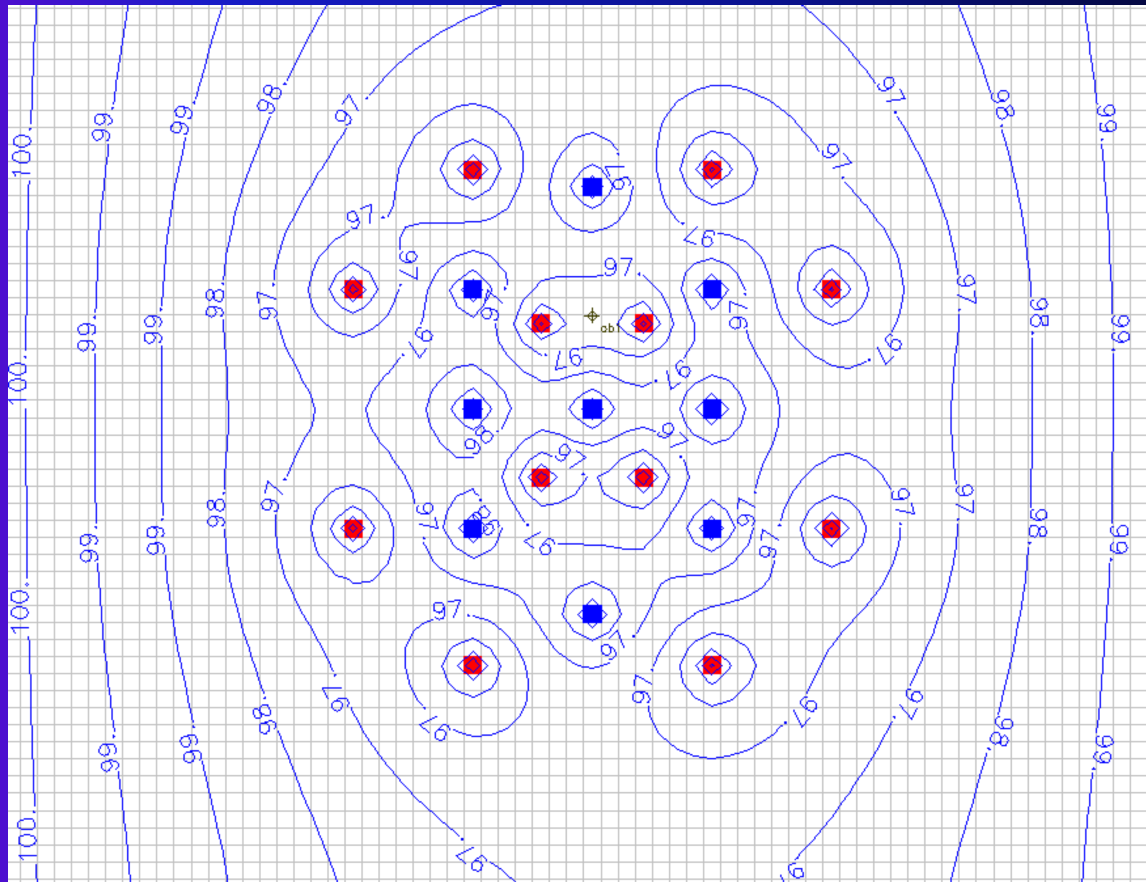
Gard water consultants, inc.

Restoration Model

- 2 ½ Years of Restoration
- Restoration Wells Different from Mining Wells
- Recovery Wells Below 30 µg/L
- Observe System for 7 Years After Restoration

MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

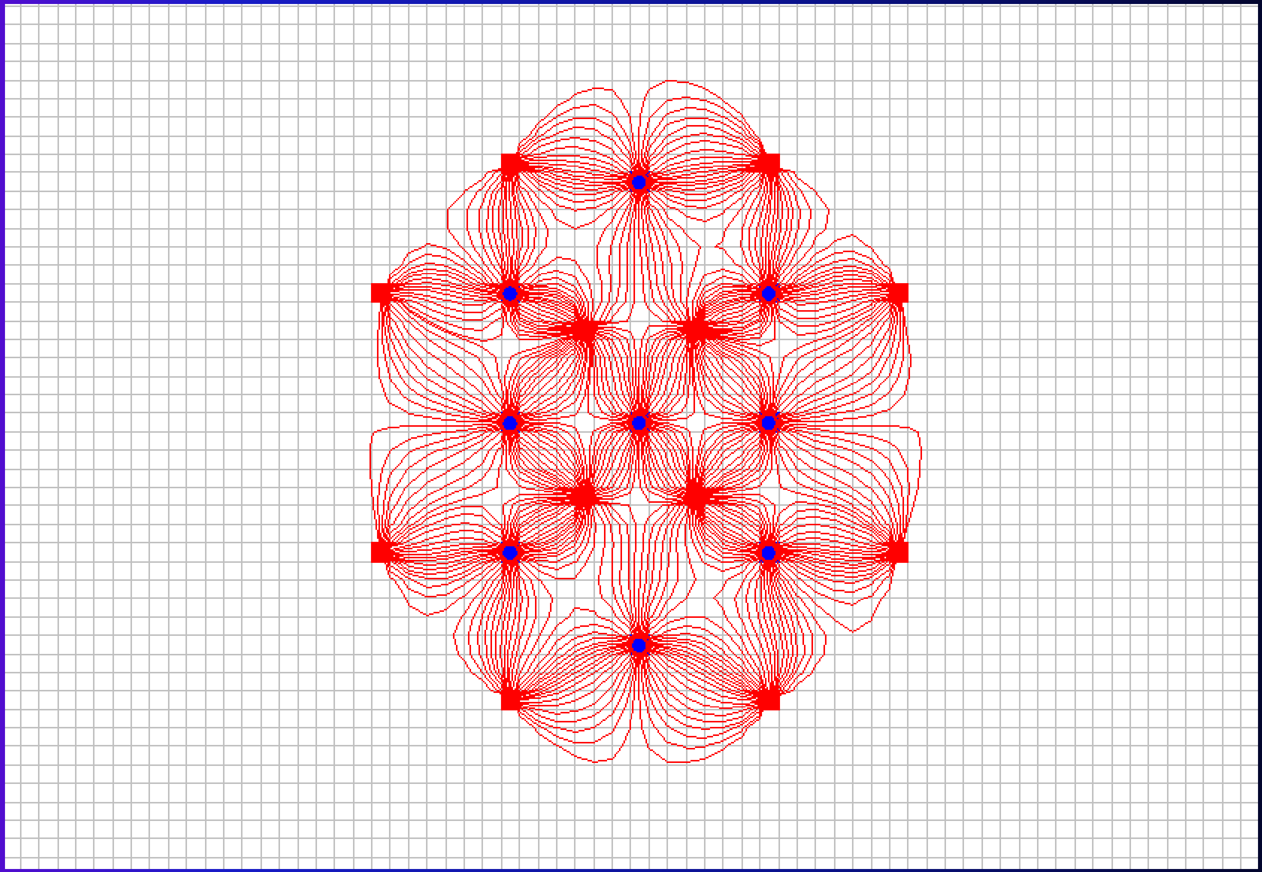


Example Reclamation of ISR Mine

- Maintain Gradient Towards Well Field During Mining
- Recovery Flow Greater Than Injection Flow

MGC
MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

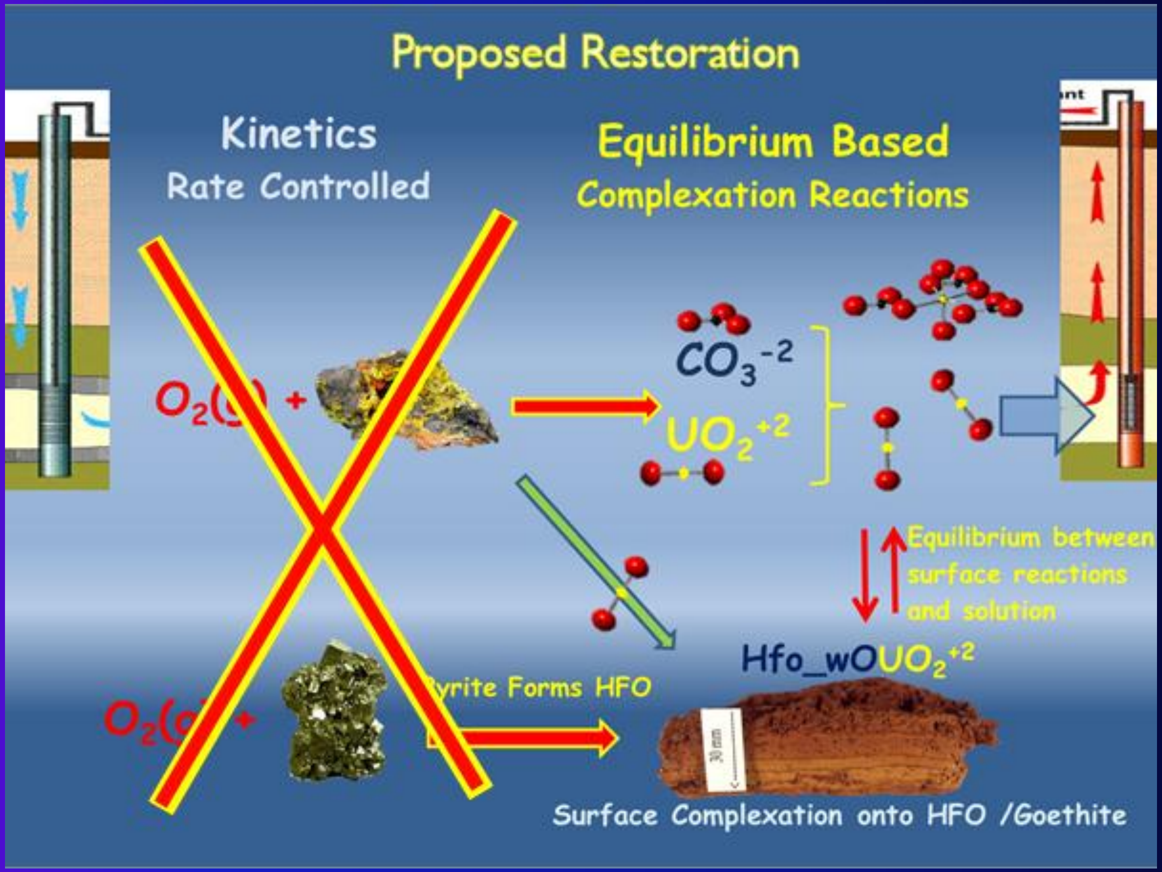


Particle Tracing

Illustrates Advective Flow Directions

MGC
MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.



Proposed Restoration

Terminate O_2 injection
Continue adding CO_3

MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

CURRENT RECLAMATION

MINING PHASE	RESTORATION PHASE
DISSOLVE AND MOBILIZE URANIUM	CEASE DISSOLING URANIUM MOVE URAMIUM TO SORBTION SITES
MINING O_2 INJECTION	
MINING $NaHCO_3$ INJECTION	FLUSH WITH REVERSE OSMOSIS WATER

MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

PROPOSED CHANGES IN RECLAMATION

MINING PHASE	RESTORATION PHASE
DISSOLVE AND MOBILIZE URANIUM	CEASE DISSOLING URANIUM BUT MAINTAIN MOBILITY
MINING O_2 INJECTION	
MINING $NaHCO_3$ INJECTION	CONTINUE $NaHCO_3$ INJECTION DURING RESTORATION

MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

Model Geochemistry

COMPOUND	UPGRADIENT CONCENTRATION (mg/L)	POST MINING CONCENTRATION (mg/L)	GRAMS/MOLE	UPGRADIENT CONCENTRATION (Moles/l)	POST MINING CONCENTRATION (Moles/L)	HIGH Kd INJECTION WATER (Moles/L)	LOW Kd INJECTION WATER (Moles/L)
Ca	44.1	313.4	40.078	1.10E-03	7.82E-03		
Mg	9	59.5	24.305	0.00037	0.002448056		
Na	12.2	80.8	22.98	5.31E-04	3.52E-03	0.0001	0.01
K	8	13.4	39.09	0.000205	0.000342799		
HCO3	215	720.2	61	3.52E-03	1.18E-02	0.0001	0.01
SO4	91	380.6	96.06	0.000947	0.003962107		
Cl	4.7	212.6	35.45	1.33E-04	6.00E-03		
ALK	177	591	100.9	0.00175	0.005857284		
Fe	0.05	0.05	55.84	8.95E-07	8.95E-07		
U	0.05	40.19	238.028	0.00000021	0.000168846		
O	7	0	16	4.38E-04	0.0	0.00044	0.00044
pH	8	6.78		6.78	8	8.2	8.2
pe	11	11		1.10E+01	1.10E+01	11	11

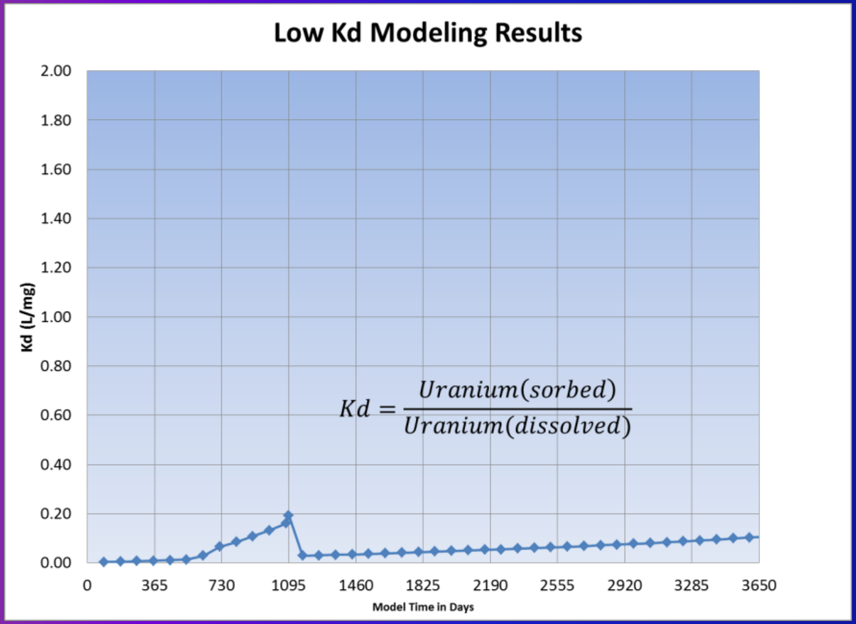
Mineral	MINIMUM PRE-RESTORATION CONCENTRATION (Moles/L)	MAXIMIM PRE-RESTORATION CONCENTRATION (Moles/L)
GOETHITE	1.13E-04	4.20E-04
URANINITE	0	4.90E-03
PYRITE	0	9.00E-02
CALCITE	0.1	0.1
Hfo	0.2	0.2

MGC MAHONEY GEOCHEMICAL CONSULTING

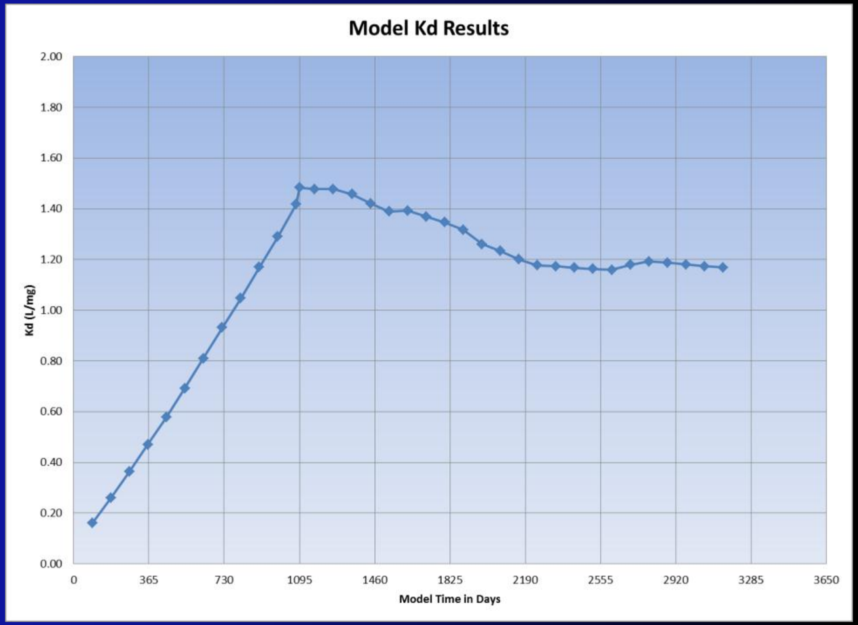
Gard water consultants, inc.

Model Resulting Average Model Kd

Model Average Low Kd
RO Water with $NaHCO_3$



Model Average High Kd
RO Water



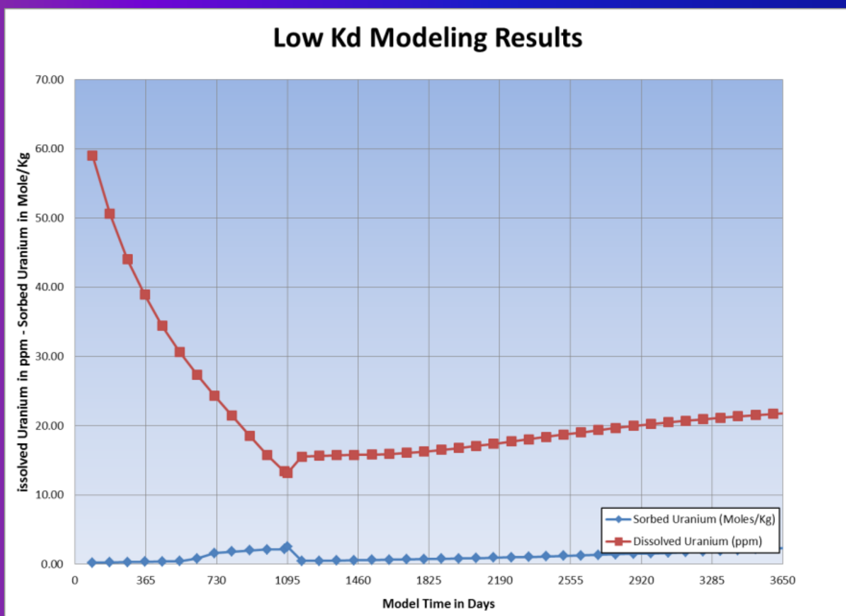
MGC
MAHONEY GEOCHEMICAL CONSULTING

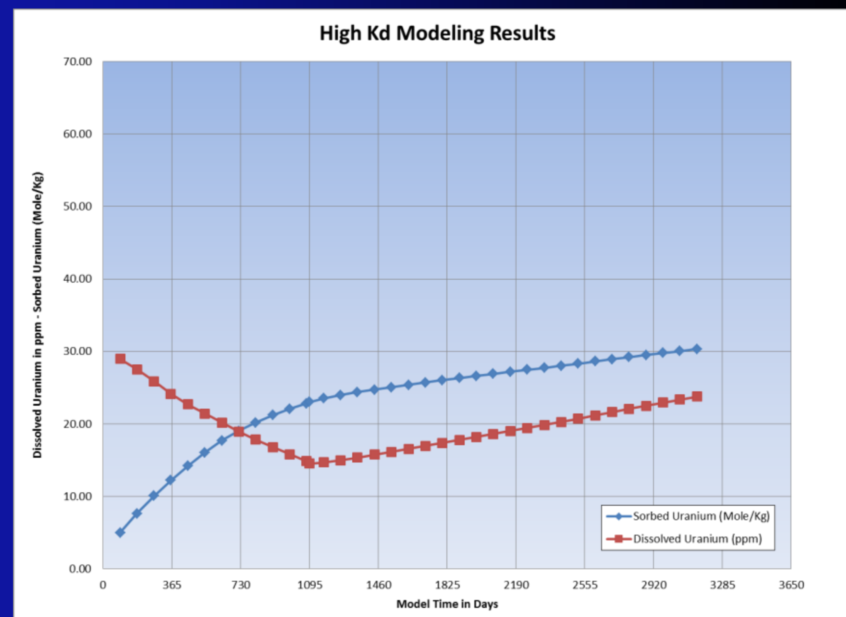
Gard water consultants, inc.

Model Resulting Average Uranium Concentrations

Model Average Low Kd
RO Water with $NaHCO_3$

Model Average High Kd
RO Water





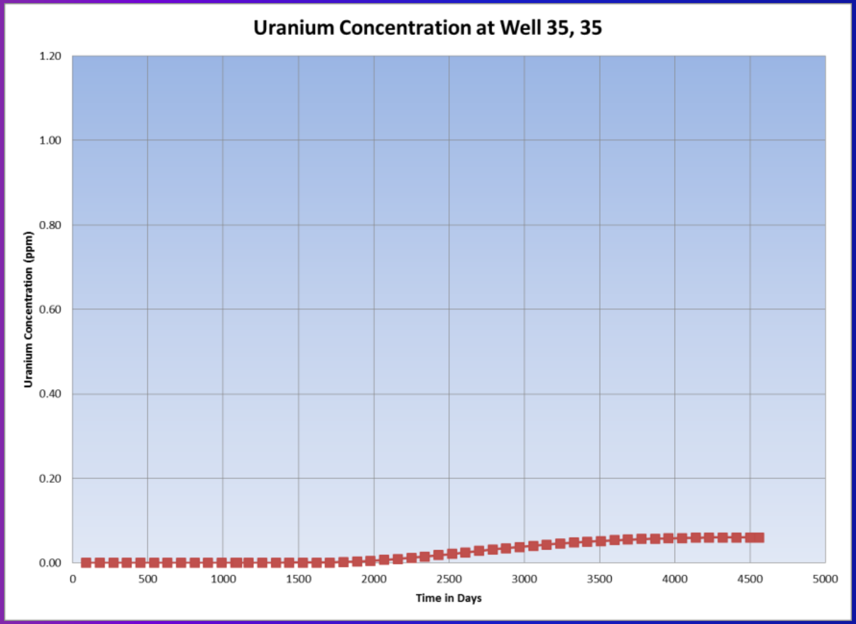
MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

Model Resulting at Extraction Well

Low Kd Model

RO Water with $NaHCO_3$



High Kd Model

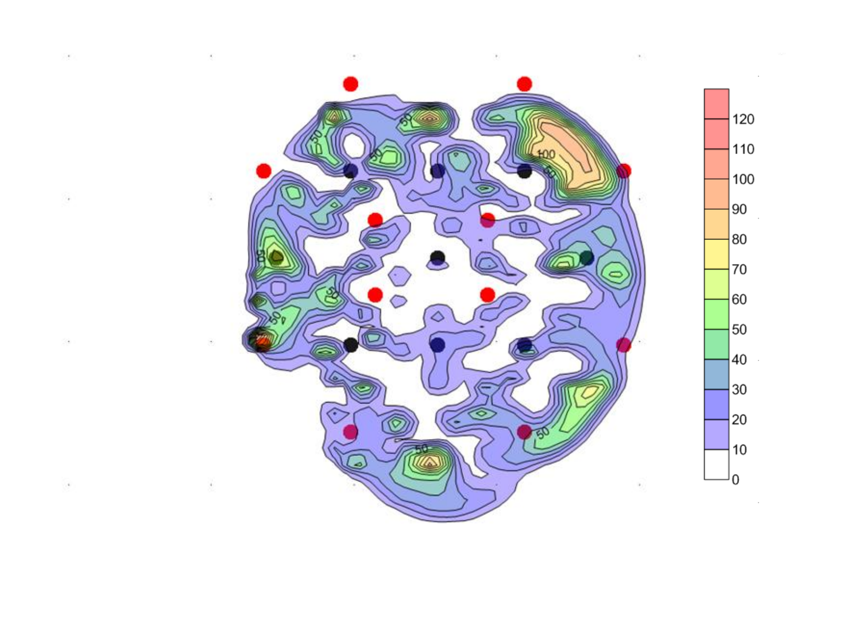
RO Water

MAHONEY GEOCHEMICAL CONSULTING

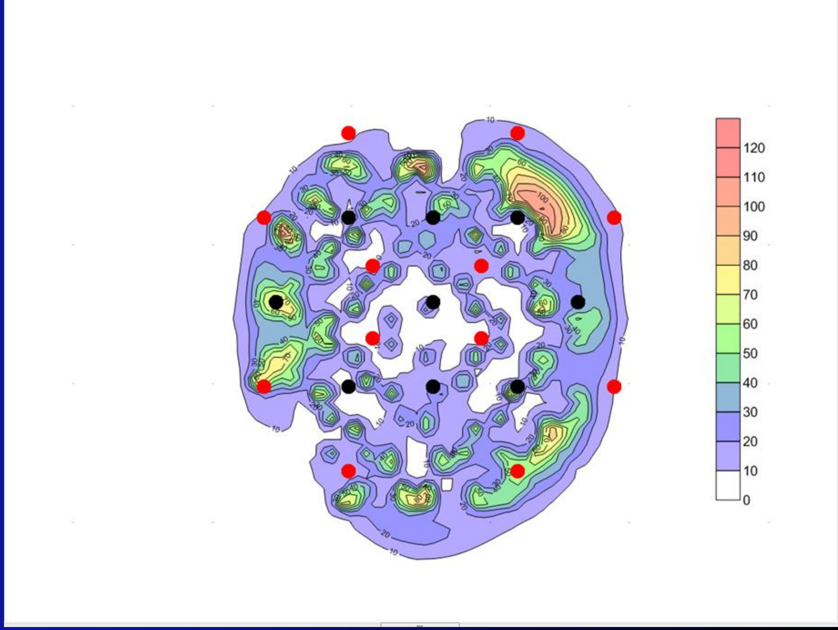
Gard water consultants, inc.

Final Sorbed Uranium (mg/kg)

Low K_d Model After Restoration



High K_d Model After Restoration



MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

Conclusions

- PHT3D Can Model the Flow and Reactive Transport of ISR Mines in 3-Dimensions
- PHT3D Can Help Identify Potential Trouble Spots Before Restoration
- High Kd (RO Water) Restoration Injection Water Results in More Sorbed Uranium That Will Desorb With Time
- Low Kd (High $NaHCO_3$) Restoration Injection Water Results in less Sorbed Uranium and Less Rebound

MGC MAHONEY GEOCHEMICAL CONSULTING

Gard water consultants, inc.

Next Steps

- Obtain Real World Data to Better Evaluate PHT3D as an Effective Tool
- Evaluate PHT3D for Use in ISR Mining Optimization

Questions

Micheal Gard (970) 690-3235
John Mahoney (303) 986-7643

MGC Mahoney Geochemical Consulting

Gard water consultants, inc.