APPENDIX G

SIMULATION RESULTS FOR MITIGATION ALTERNATIVES

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SIMULATION RESULTS FOR MITIGATION ALTERNATIVES

Prepared for:

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FIGURES

1. INTRODUCTION

The response of the sulfate plume to the five mitigation alternatives was simulated using the numerical model created for the Feasibility Study (FS). Details of model construction and calibration are discussed in Appendix I of HGC (2007), and preparation of the model for predictive simulations of the mitigation alternatives is discussed in Appendix E of this FS. This appendix provides illustrations supplemental to the tables and figures of simulation results presented in the main body of the FS that are useful in evaluating and comparing the mitigation alternatives. These supplemental figures include the following:

- Mitigation pumping schedules for the five alternatives (Figures G.1 to G.5), and a comparison of total pumping rates and cumulative pumping volumes of the five alternatives (Figure G.6 and G.7)
- Sulfate concentrations (flow-weighted) in the water pumped by the mitigation wells for the five alternatives (Figures G.8 to G.12)
- Cumulative sulfate mass removed by mitigation pumping and added via the Sierrita Tailing Impoundment (Figures G.13 to G.17), and a comparison of net sulfate mass removal for the mitigation alternatives (Figure G.18)
- Hydraulic capture zones for the mitigation alternatives for simulations starting in the year 2010 and the year 2043 (Figures G.19 to G.28)

Explanations on the creation of these figures and the figures of the numerical model simulation results contained in the main body of the FS are provided in the following section.

2. EXPLANATION OF SIMULATION RESULTS

This section discusses the methods used to create the figures contained in the main text of the FS and in this appendix.

2.1 Sulfate Plume Extents Maps

The maps showing the sulfate plume extents (Figures 10, 12, 14, 16, 18 and 19 of the FS) were created by comparing, cell by cell, the model output of the sulfate concentrations in each of the three model layers and displaying the maximum sulfate concentration. Model cells with a saturated thickness less than 25 feet (7.5 meters) were not included in the model comparison. The saturated thickness was computed as the difference between the groundwater elevation in a model cell and the layer bottom elevation for that grid cell for cells where the groundwater level was below the layer top elevation. For cells where the groundwater level was above the top elevation, the saturated thickness was equal to the layer thickness. Displaying the sulfate plume extents using the maximum concentrations in each of the three layers is expected to give a conservative (i.e. maximum) estimate of the sulfate plume extents in relation to plume extents estimated from water quality sampling of regional wells.

2.2 Water Level Change Maps

The water level change maps (Figures 20 through 24 of the FS) show the net affect of mitigation pumping on groundwater levels. The net affect in this context refers to the difference between regional groundwater levels under mitigation pumping and regional groundwater levels assuming no mitigation pumping, except for a continuation of the current pumping at the Interceptor Well (IW) wellfield until the end of mine life assumed for the FFS. The water level change maps were created by computing, cell by cell, the difference between the groundwater elevations of a "reference case" simulation and the groundwater elevations of the simulation of the mitigation alternative (i.e. negative water level changes indicate water level declines resulting from mitigation activities relative to the reference case). The reference case simulation assumes the same pumping, recharge, and boundary conditions as the mitigation alternative simulations with the exceptions that the IW wellfield wells and the Canoa Ranch wells continue to pump at the averages of the 2006 and 2007 rates until the assumed end of mine life in 2043, at which time pumping in these wells ceases. The reference case simulations for Alternative 1, 2, and 3 assume that drain down of the STI begins in the year 2043, and the reference case simulation for Alternatives 4 and 5 assumes the start of drain down in the year 2016.

2.3 Mitigation Pumping

The figures showing the mitigation pumping rates for the five alternatives (Figure G.1 to G.6) were created from the tables of pumping rate schedules included in the FS (Tables 3, 5, 7, 9, and 11) and are reflective of the pumping rates used in the numerical model. Figure G.7 shows the running total of groundwater volume pumped in the five alternatives.

2.4 Pumped Sulfate Concentrations

The figures of pumped sulfate concentrations for the five alternatives (Figures G.8 to G.12) show the flow-weighted average sulfate concentration being pumped in each series of mitigation wells (e.g., Focused Feasibility Study [FFS] wells, Source Control [SC] wells, Plume Stabilization [PS] wells, etc.). The flow-weighted average concentration means that the sulfate contribution from each individual well is weighted by the pumping rate of that well. The flow-weighted concentration represents the sulfate concentration that would result if effluent from individual wells in each well series (FFS, SC, PS, etc.) were combined with effluent from other wells in the same series. The sulfate concentrations in individual wells are also flow-weighted according to the contribution of water from each model layer to the total pumping rate in that well. Flow-weighted concentrations in individual wells were computed internally by the modeling software; and flow-weighting the concentrations of well groups were computed externally during post-processing of the simulation results.

2.5 Cumulative Sulfate Mass

The figures showing cumulative sulfate mass removed and added (Figures G.13 to G.18) illustrate the running total of sulfate mass removed by the mitigation wells, the total sulfate mass entering the model domain via the STI, and net sulfate mass removed by mitigation wells. The sulfate mass removal rate in an individual well is the product of the well’s volumetric pumping rate and the sulfate concentration in the pump effluent. The total sulfate mass removal rate is the sum of the removal rate in all the individual mitigation pumping wells. Any incidental removal of sulfate mass in wells other than mitigation wells was not considered in computing sulfate mass removal. Similarly, the sulfate mass addition rate is the product of the volumetric water seepage rate in the STI and the sulfate concentration in the seepage water. The net sulfate mass removal rate is the difference between the removal and addition rates. The removal, addition, and net removal rates were converted to masses by multiplying the computed rate by the model time step over which the rate was operative. The cumulative masses are the running totals of the masses computed for each time step.

2.6 Capture Zones

The capture zone maps (Figures G.19 to G.28) outline the zone of hydraulic capture induced by mitigation pumping. Groundwater within the zone of hydraulic capture will either be removed or hydraulically isolated from the down gradient aquifer by pumping at the mitigation wells. The hydraulic capture zones were determined by numerical model simulations that tracked the flow paths of virtual water particles released at selected locations. The selected release locations included a line (i.e., linear array) of particles at the outer edges of the STI, two lines of particles at progressive down-gradient locations between the IW wellfield and the FFS wells, a line of particles between FFS-1 and PS-4, and a line of particles between PS-4 and PS-2. Two hydraulic capture zones are illustrated for each of the five alternatives. One shows the results of simulations beginning in the year 2010, and one shows the results of simulations beginning in the year 2043. These two years were chosen to begin the particle tracking simulations because they begin the two critical periods for maintaining hydraulic capture. The year 2010 is the assumed beginning of mitigation pumping and starts the period of the greatest seepage from the STI. The year 2043 begins the assumed post-mine life period when mitigation pumping is reducing to the minimum needed to meet the mitigation objective. The ability of an alternative to meet its mitigation objective was evaluated by the results of the particle tracking simulations and also by long-term transport simulations that estimated the sulfate plume migration under mitigation alternatives through the year 2110.

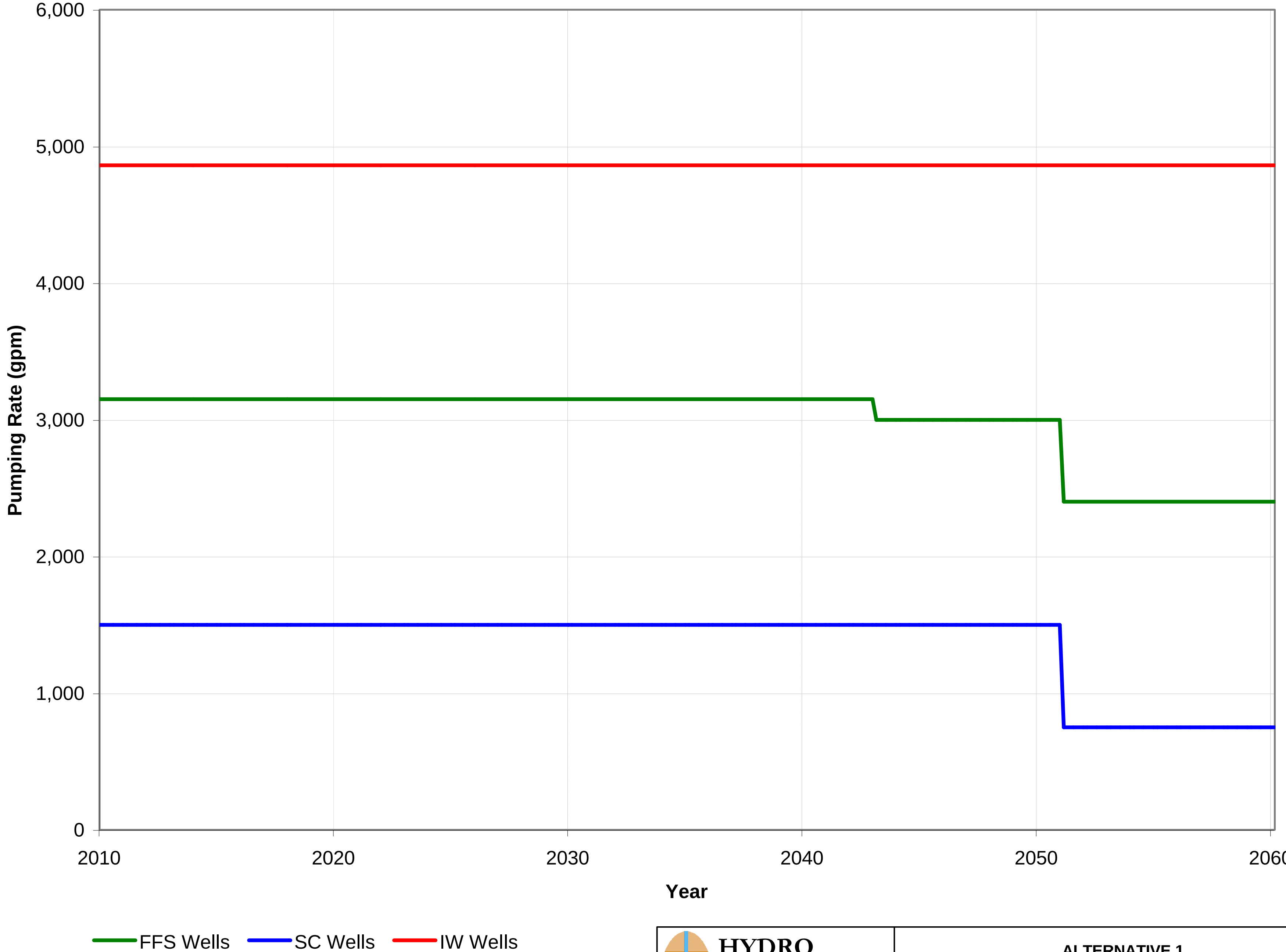
3. REFERENCES

Hydro Geo Chem, Inc. 2007. Aquifer Characterization Report: Task 5 of Aquifer Characterization Plan, Mitigation Order on Consent Docket No. P-50-06; Pima Country, Arizona. Prepared for Phelps Dodge Sierrita, Inc. December 28, 2007.

4. USES AND LIMITATIONS

The opinions and recommendations presented in this report are based upon the scope of services and information obtained through the performance of the services, as agreed upon by HGC and the party for whom this report was originally prepared. Results of any investigations, tests, or findings presented in this report apply solely to conditions existing at the time HGC's investigative work was performed and are inherently based on and limited to the available data and the extent of the investigation activities. No representation, warranty, or guarantee, express or implied, is intended or given. HGC makes no representation as to the accuracy or completeness of any information provided by other parties not under contract to HGC to the extent that HGC relied upon that information. This report is expressly for the sole and exclusive use of the party for whom this report was originally prepared and for the particular purpose that it was intended. Reuse of this report, or any portion thereof, for other than its intended purpose, or if modified, or if used by third parties, shall be at the sole risk of the user.

FIGURES



HYDRO GEO CHEM, INC.

ALTERNATIVE 1
MITIGATION PUMPING

Approved	Date	Author	Date	File Name	Figure
NWH	9/18/08	NWH	9/18/08	G.1 PumpRate1	G.1

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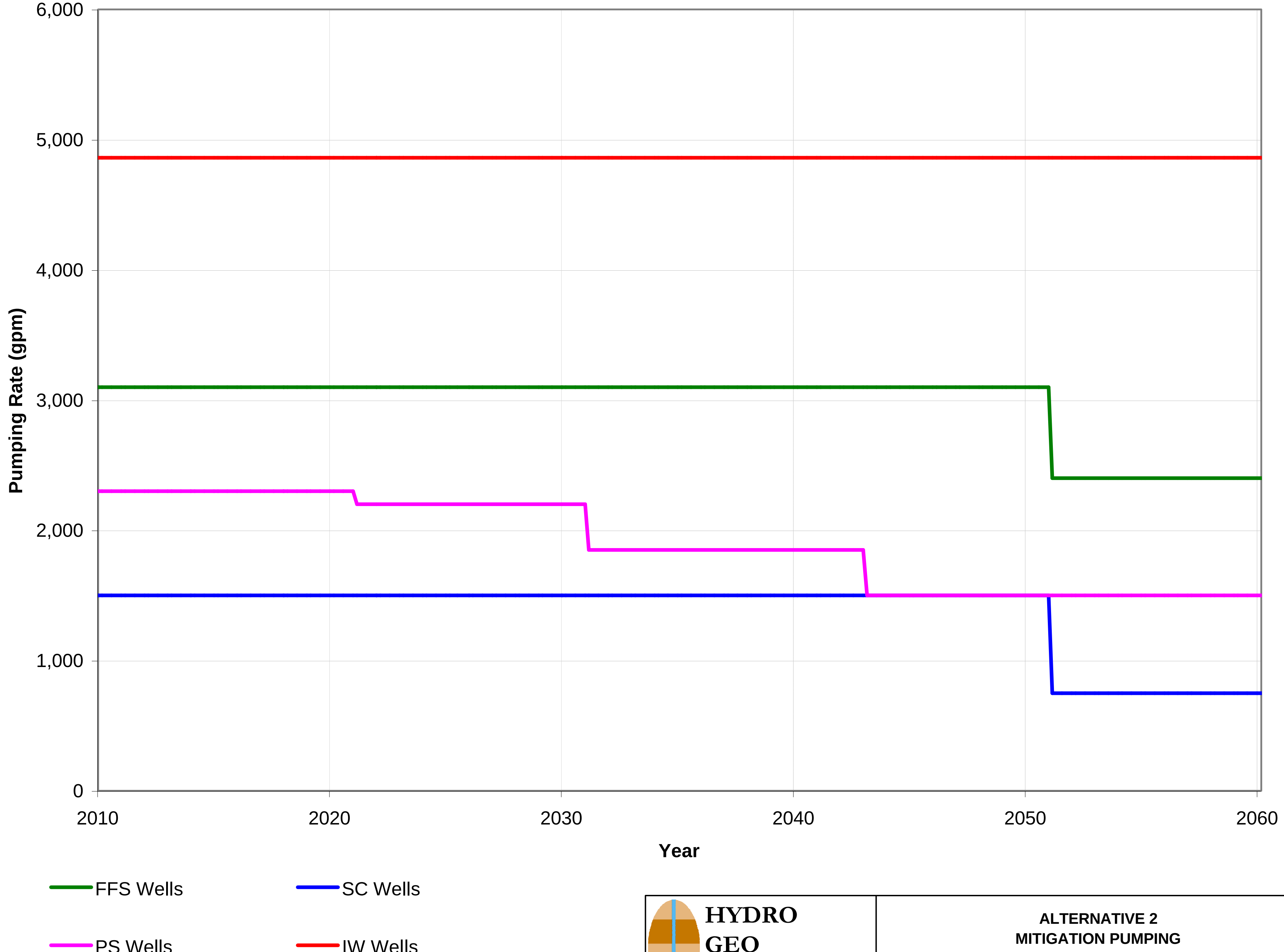

HYDRO GEO CHEM, INC.

ALTERNATIVE 2
MITIGATION PUMPING

Approved	Date	Author	Date	File Name	Figure
NWH	9/18/08	NWH	9/18/08	G2 PumpRate2	G.2

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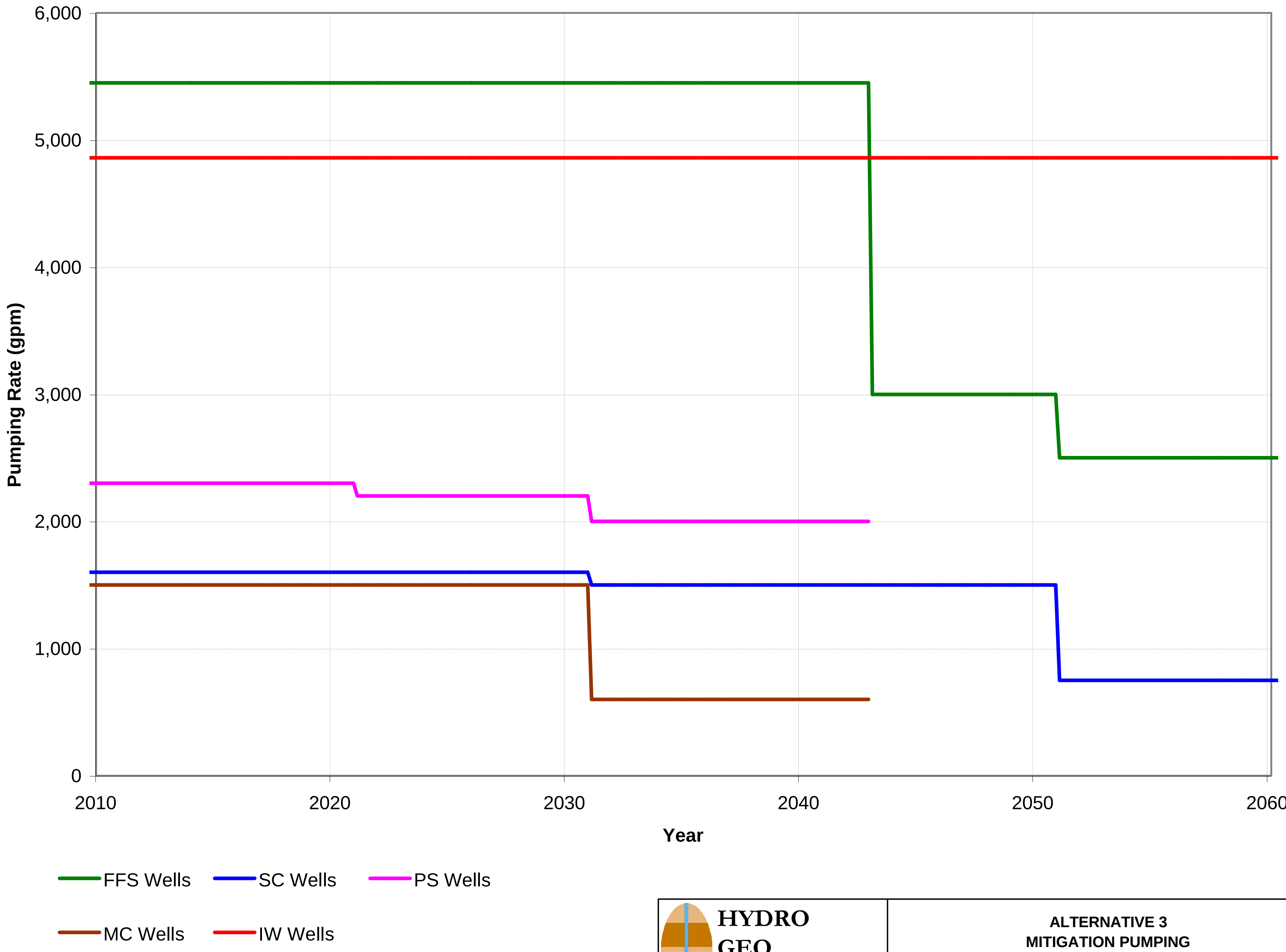

HYDRO GEO CHEM, INC.

ALTERNATIVE 3
MITIGATION PUMPING

Approved	Date	Author	Date	File Name	Figure
NWH	9/18/08	NWH	9/18/08	G3 PumpRate3	G.3

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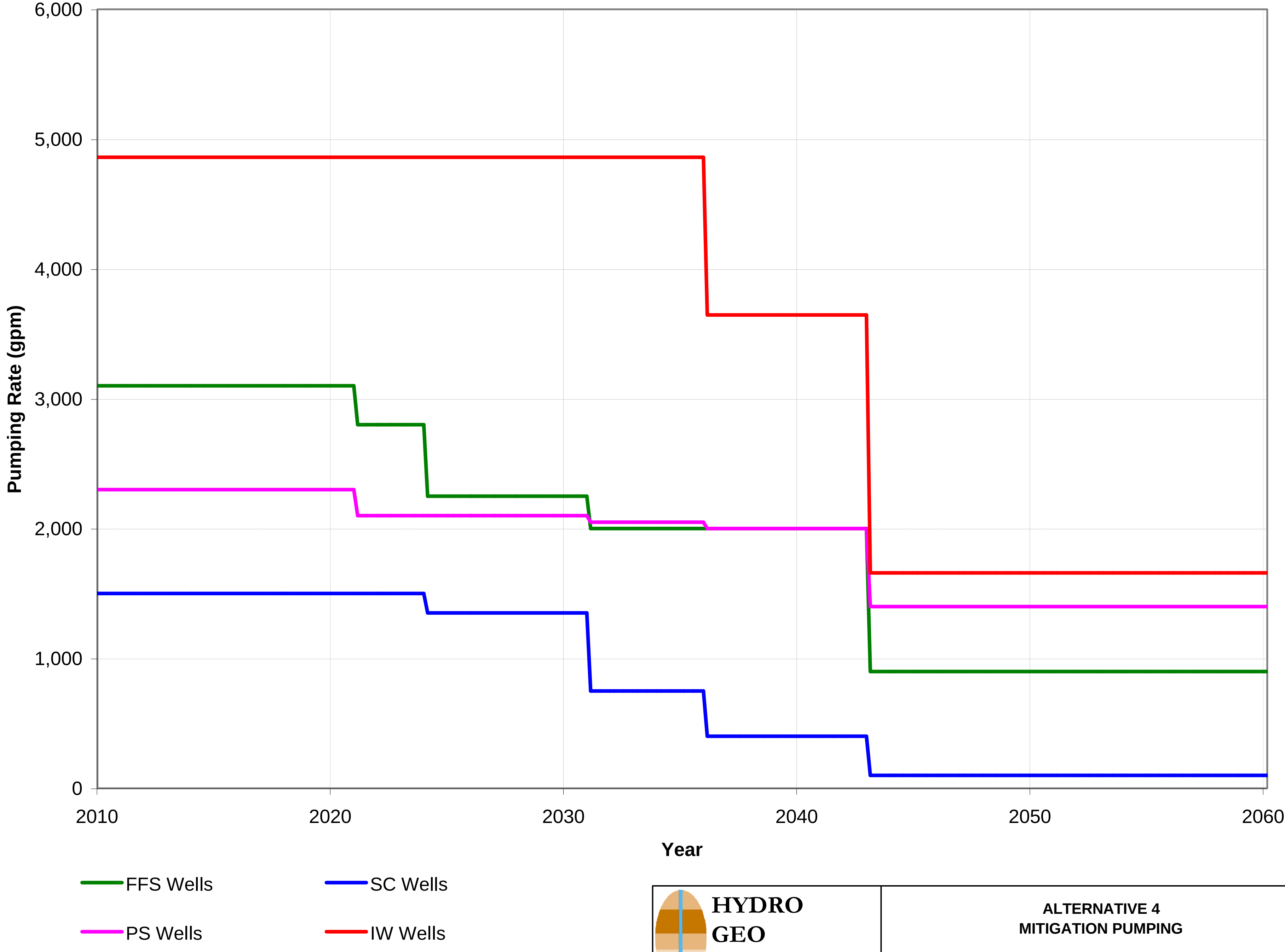

HYDRO GEO CHEM, INC.

ALTERNATIVE 4
MITIGATION PUMPING

Approved	Date	Author	Date	File Name	Figure
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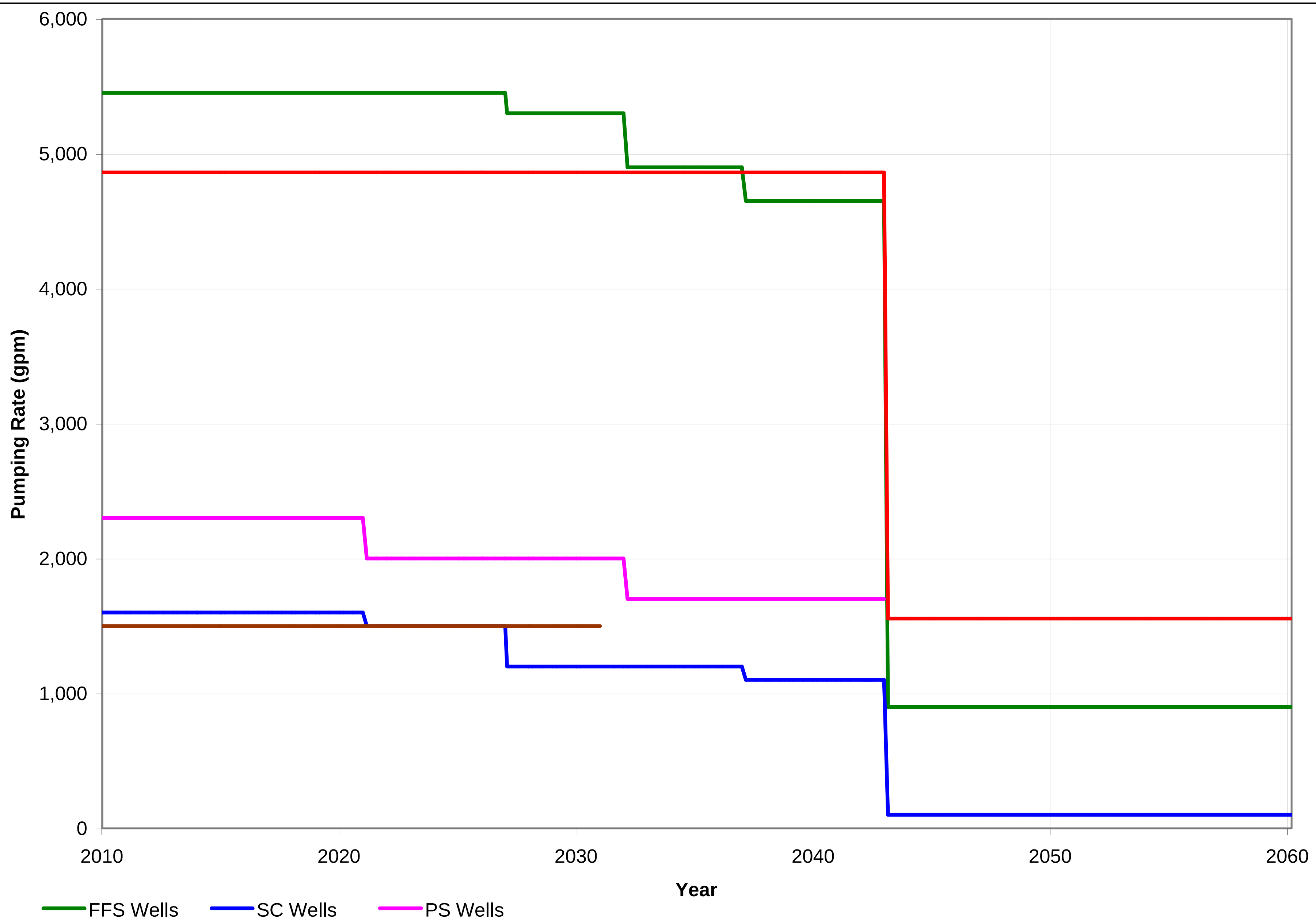
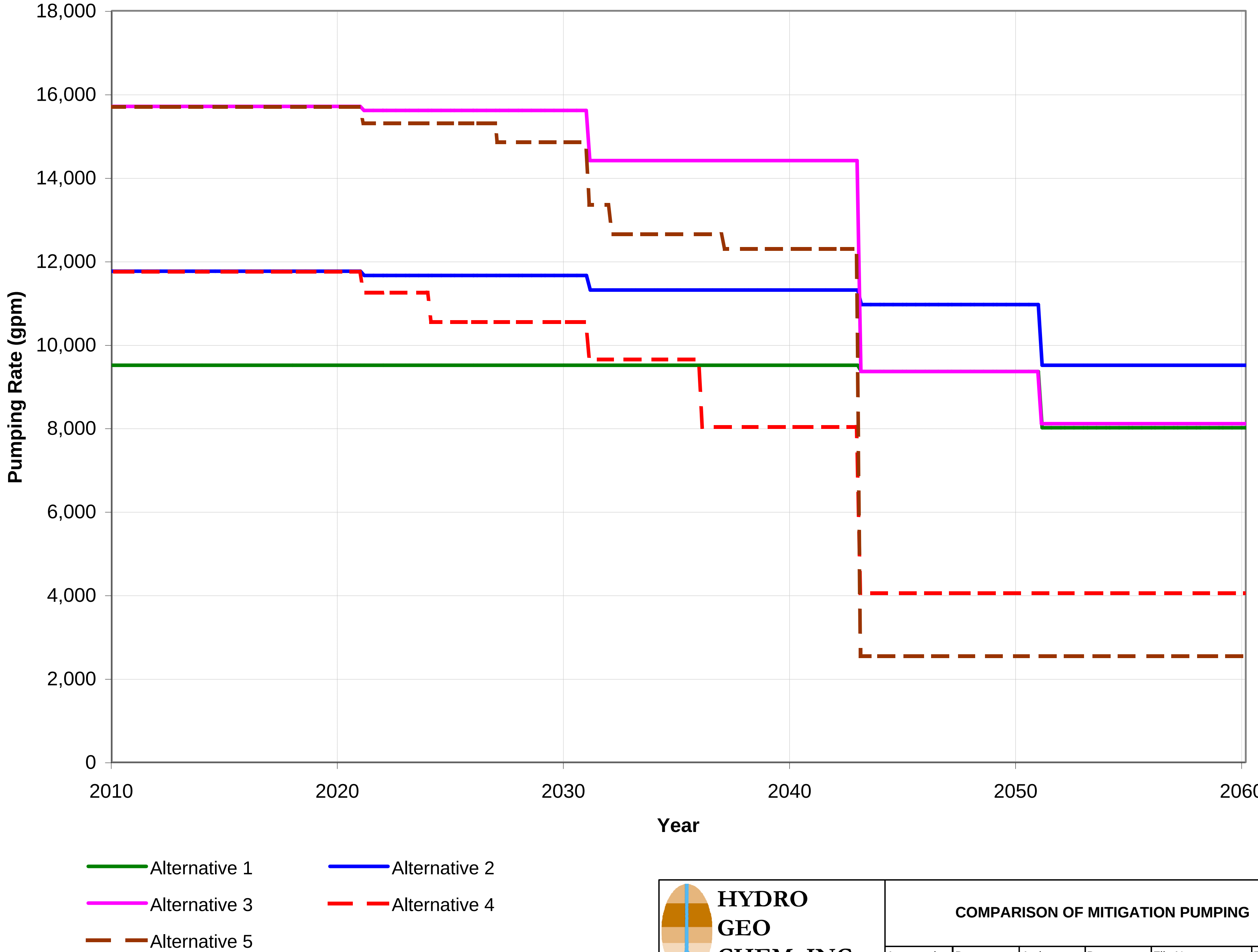


HYDRO GEO CHEM, INC.

ALTERNATIVE 5 MITIGATION PUMPING					
Approved	Date	Author	Date	File Name	Figure
NWH	9/18/08	NWH	9/18/08	G5 PumpRate5	G.5



HYDRO GEO CHEM, INC.	COMPARISON OF MITIGATION PUMPING					
	Approved NWH	Date 10/7/08	Author NWH	Date 10/7/08	File Name G6 PumpCompage	Figure G.6

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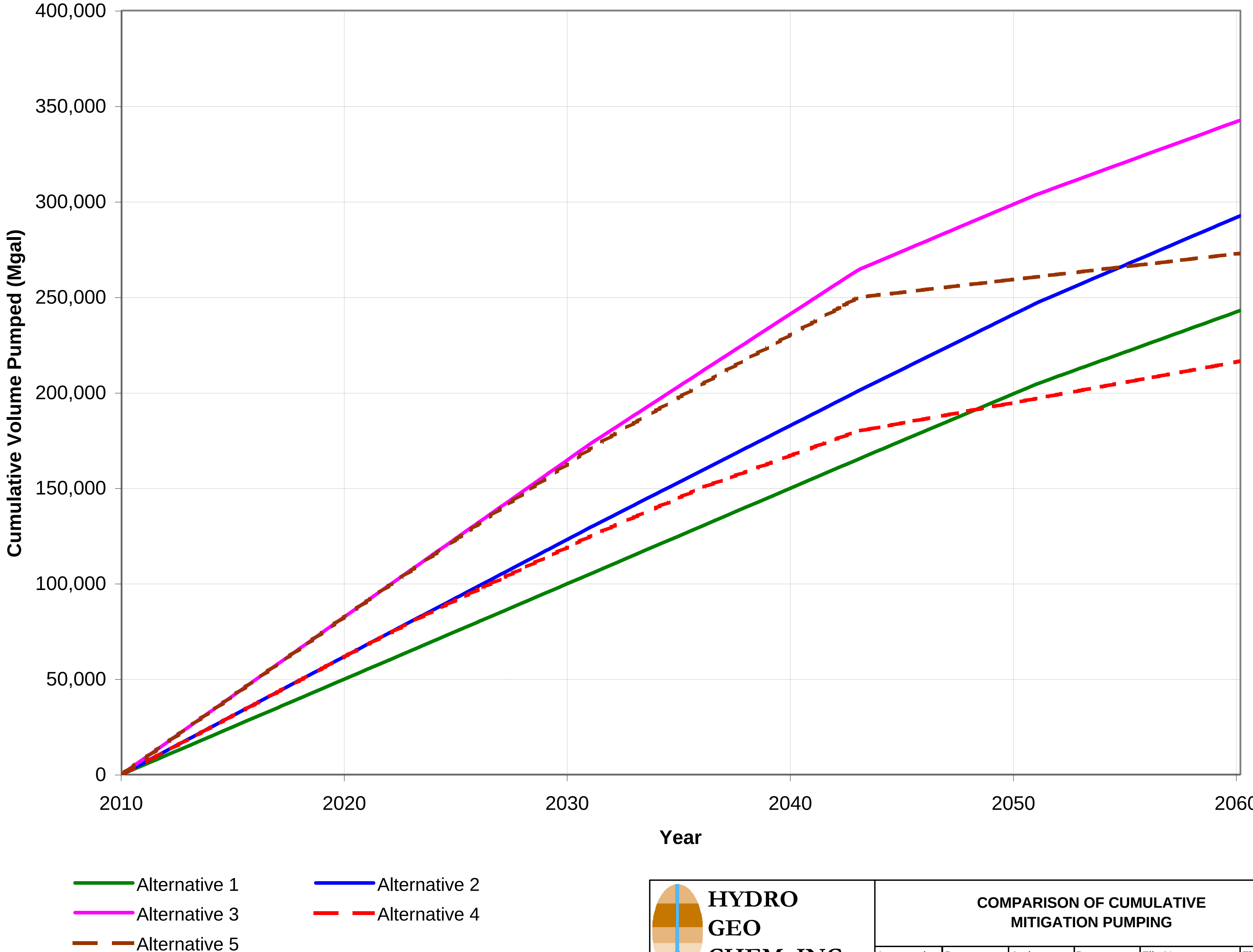

HYDRO GEO CHEM, INC.

COMPARISON OF CUMULATIVE MITIGATION PUMPING

Approved	Date	Author	Date	File Name	Figure
NWH	10/7/08	NWH	10/7/08	G7 CumPumpComp	G.7

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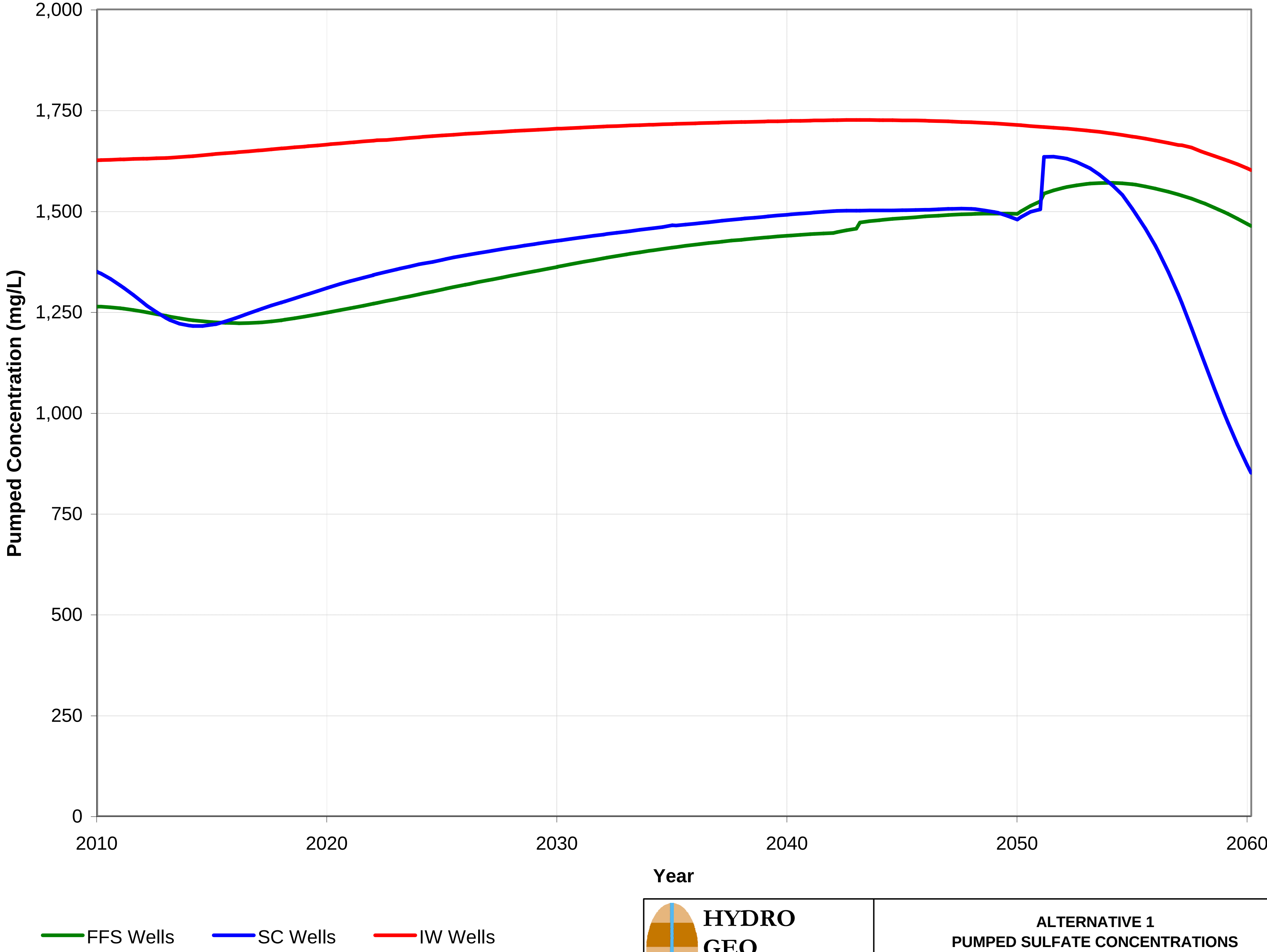

HYDRO GEO CHEM, INC.

ALTERNATIVE 1
PUMPED SULFATE CONCENTRATIONS

Approved	Date	Author	Date	File Name	Figure
NWH	9/18/08	NWH	9/18/08	G8 PumpConc1	G.8

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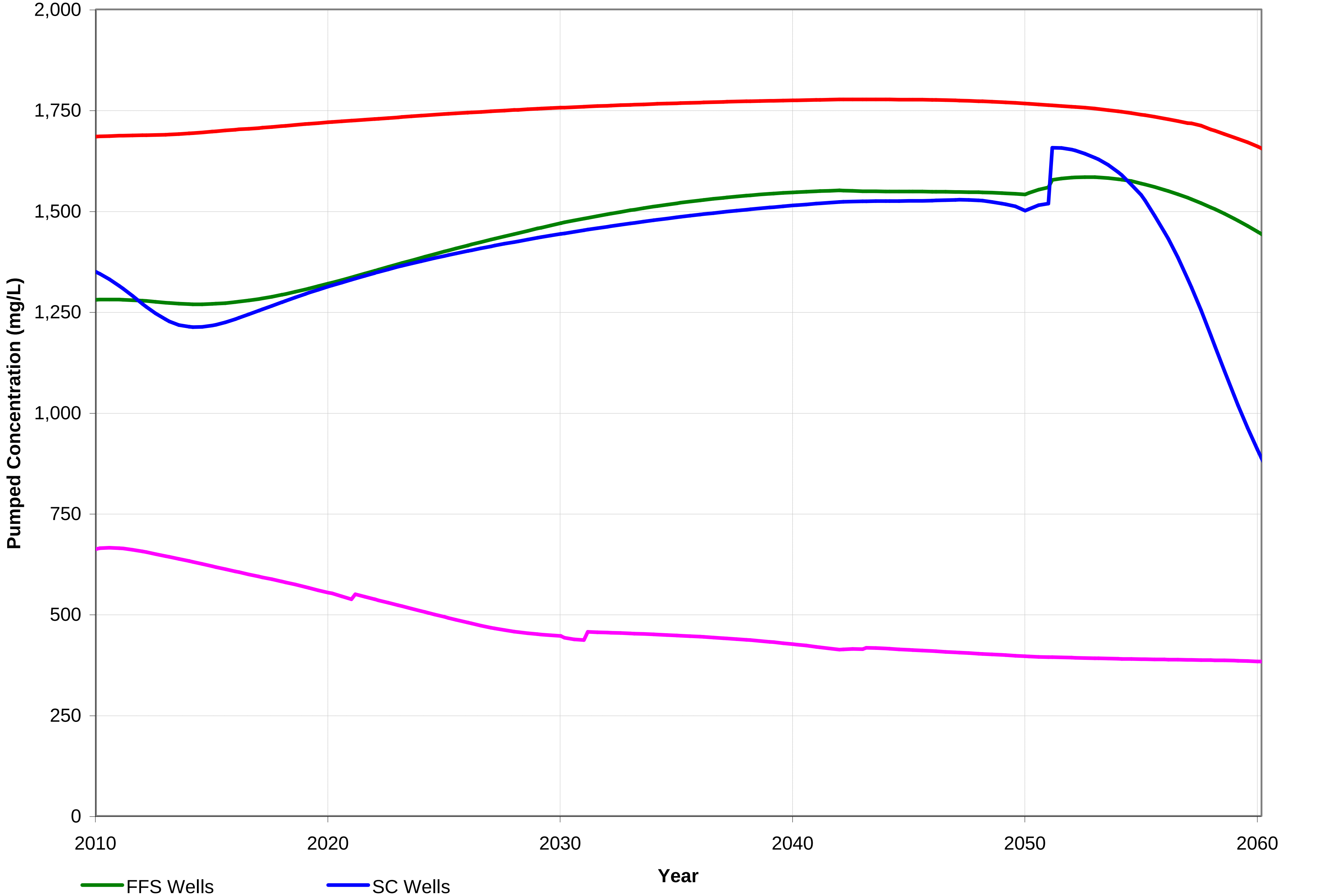

HYDRO GEO CHEM, INC.

ALTERNATIVE 2 PUMPED SULFATE CONCENTRATIONS					
Approved	Date	Author	Date	File Name	Figure
NWH	10/1/08	NWH	10/1/08	G9 PumpConc2	G.9

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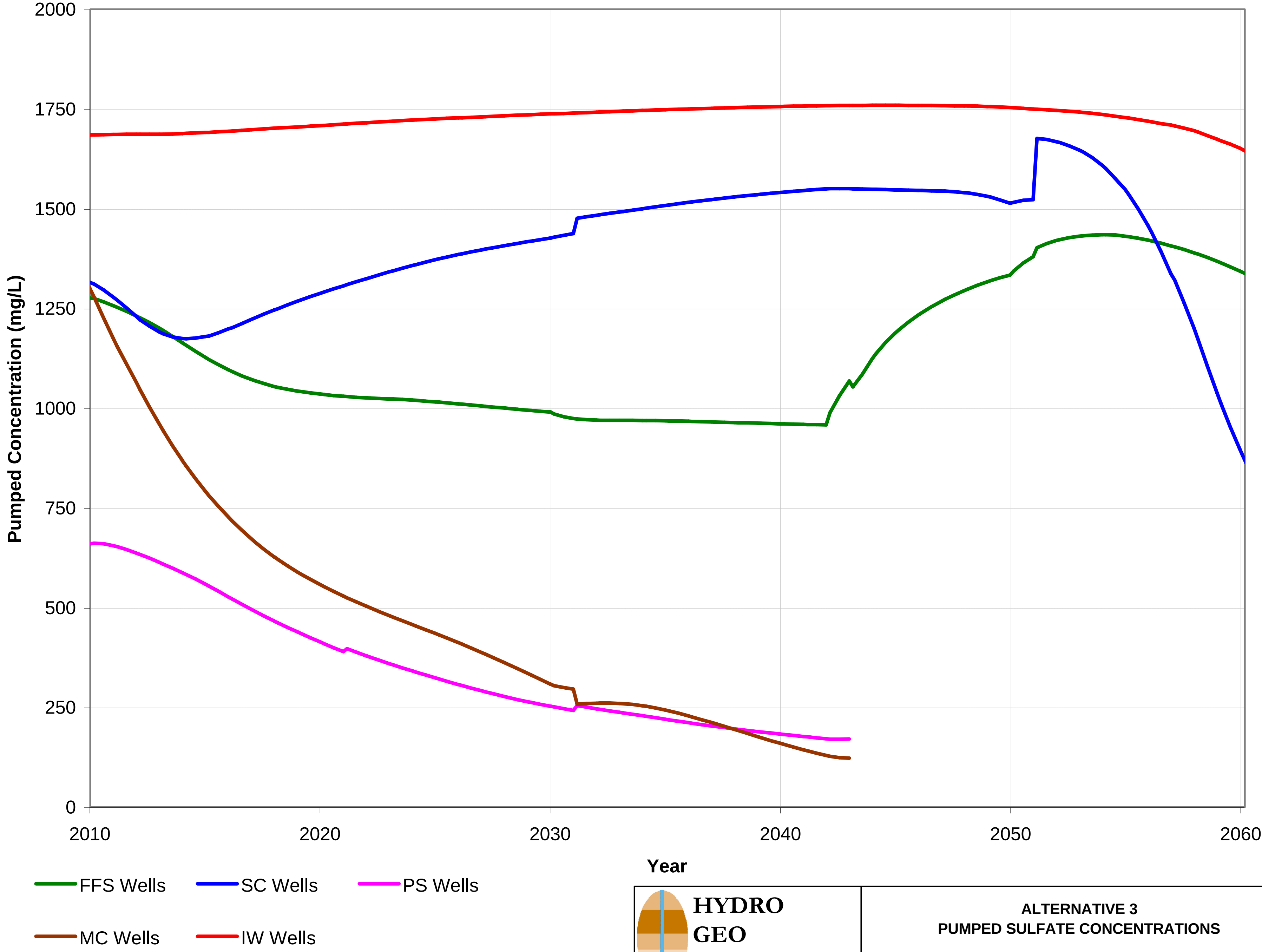

HYDRO GEO CHEM, INC.

ALTERNATIVE 3
PUMPED SULFATE CONCENTRATIONS

Approved	Date	Author	Date	File Name	Figure
NWH	9/18/08	NWH	9/18/08	G10 PumpConc3	G.10

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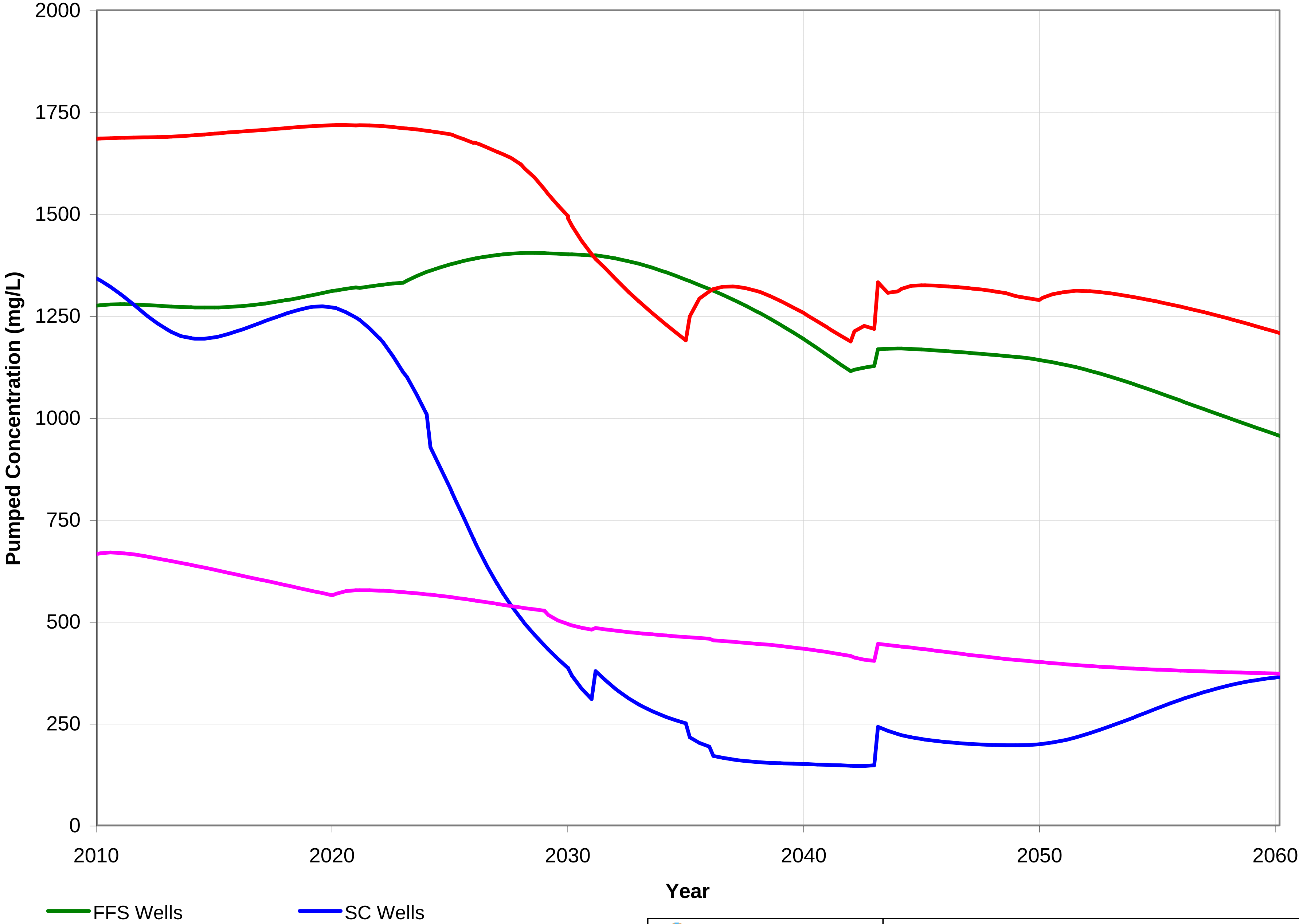

HYDRO GEO CHEM, INC.	ALTERNATIVE 4 PUMPED SULFATE CONCENTRATIONS				
Approved NWH	Date 9/18/08	Author NWH	Date 9/18/08	File Name G11 PumpConc4	Figure G.11

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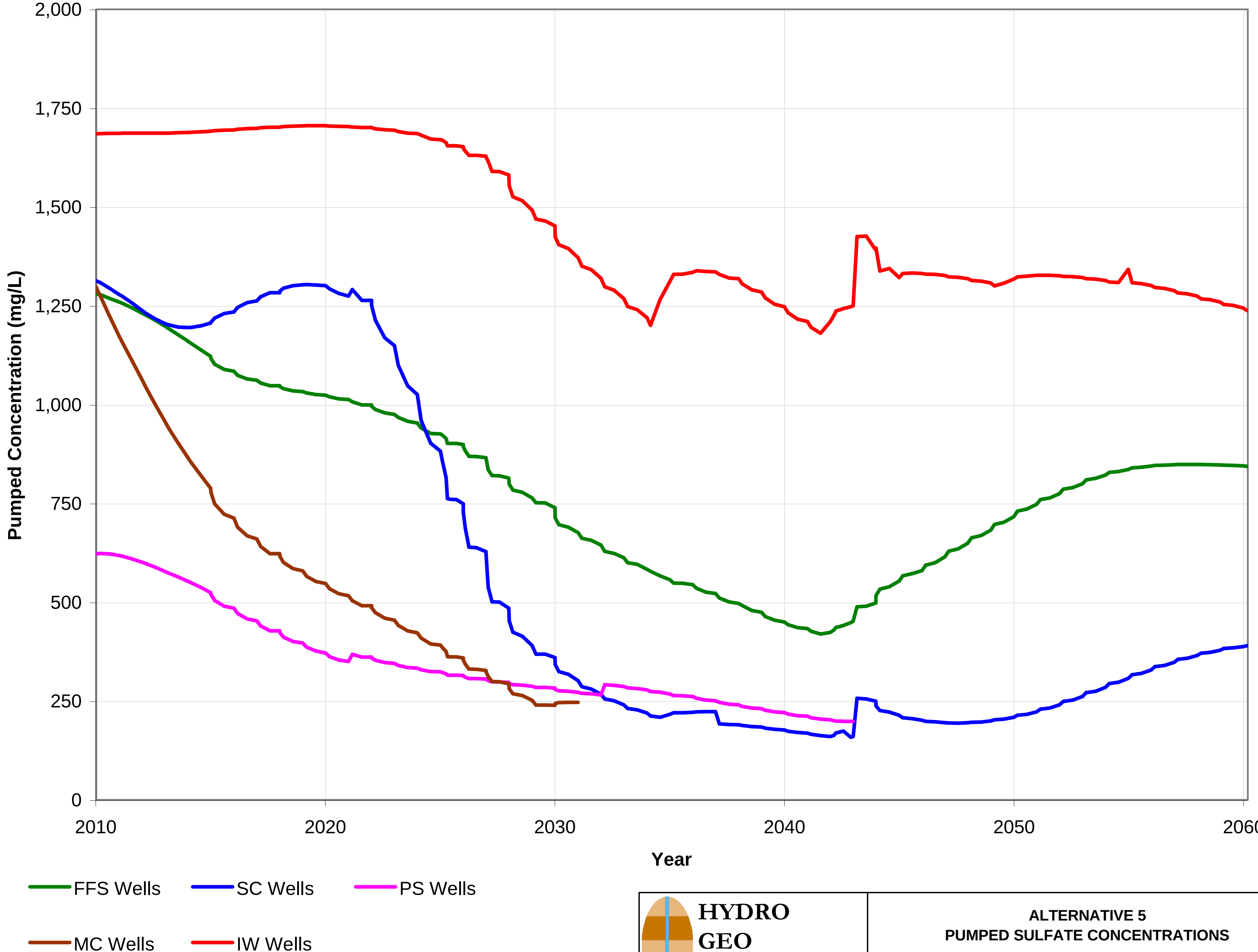

HYDRO GEO CHEM, INC.

ALTERNATIVE 5
PUMPED SULFATE CONCENTRATIONS

Approved	Date	Author	Date	File Name	Figure
NWH	9/18/08	NWH	9/18/08	G12 PumpConc5	G.12

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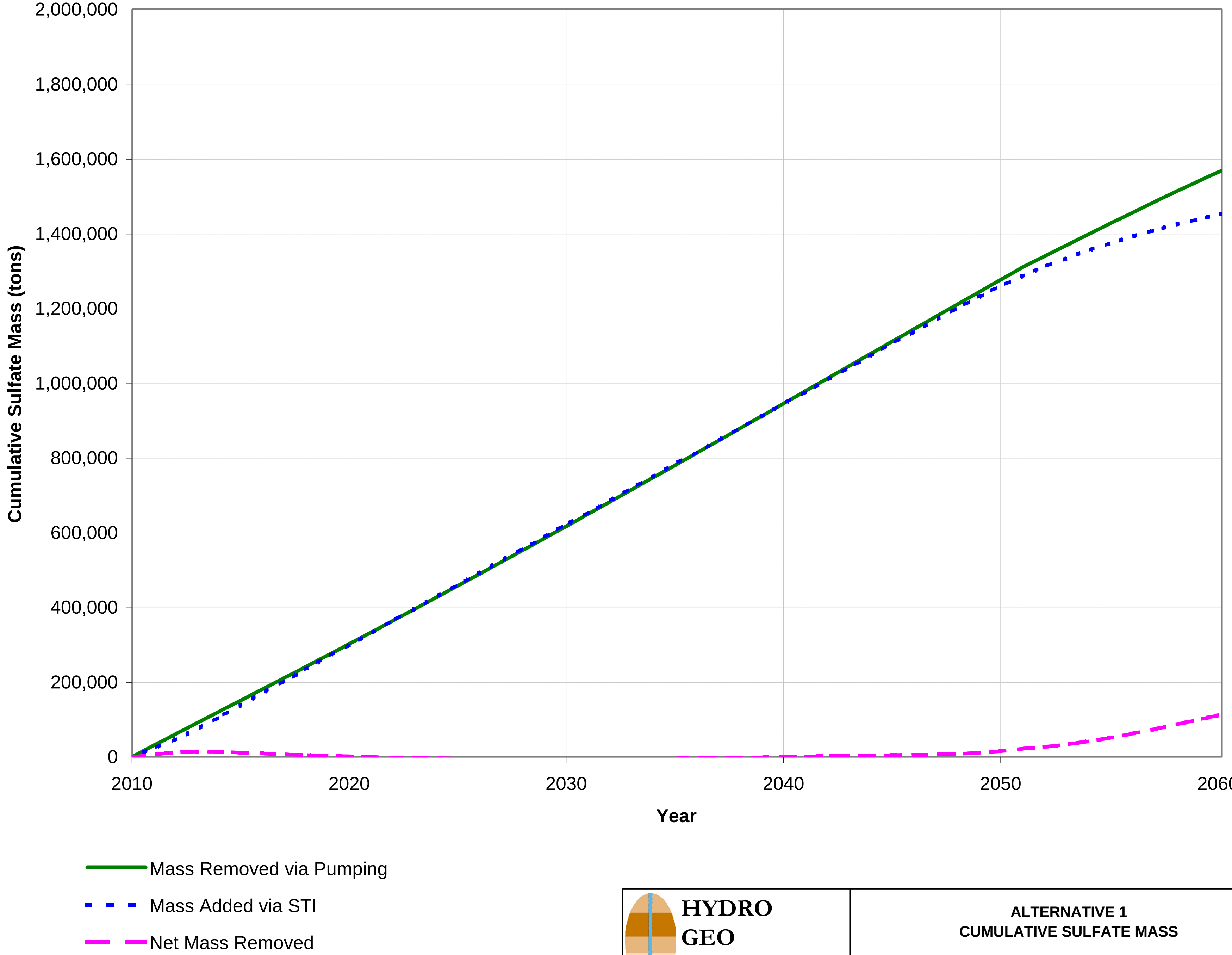
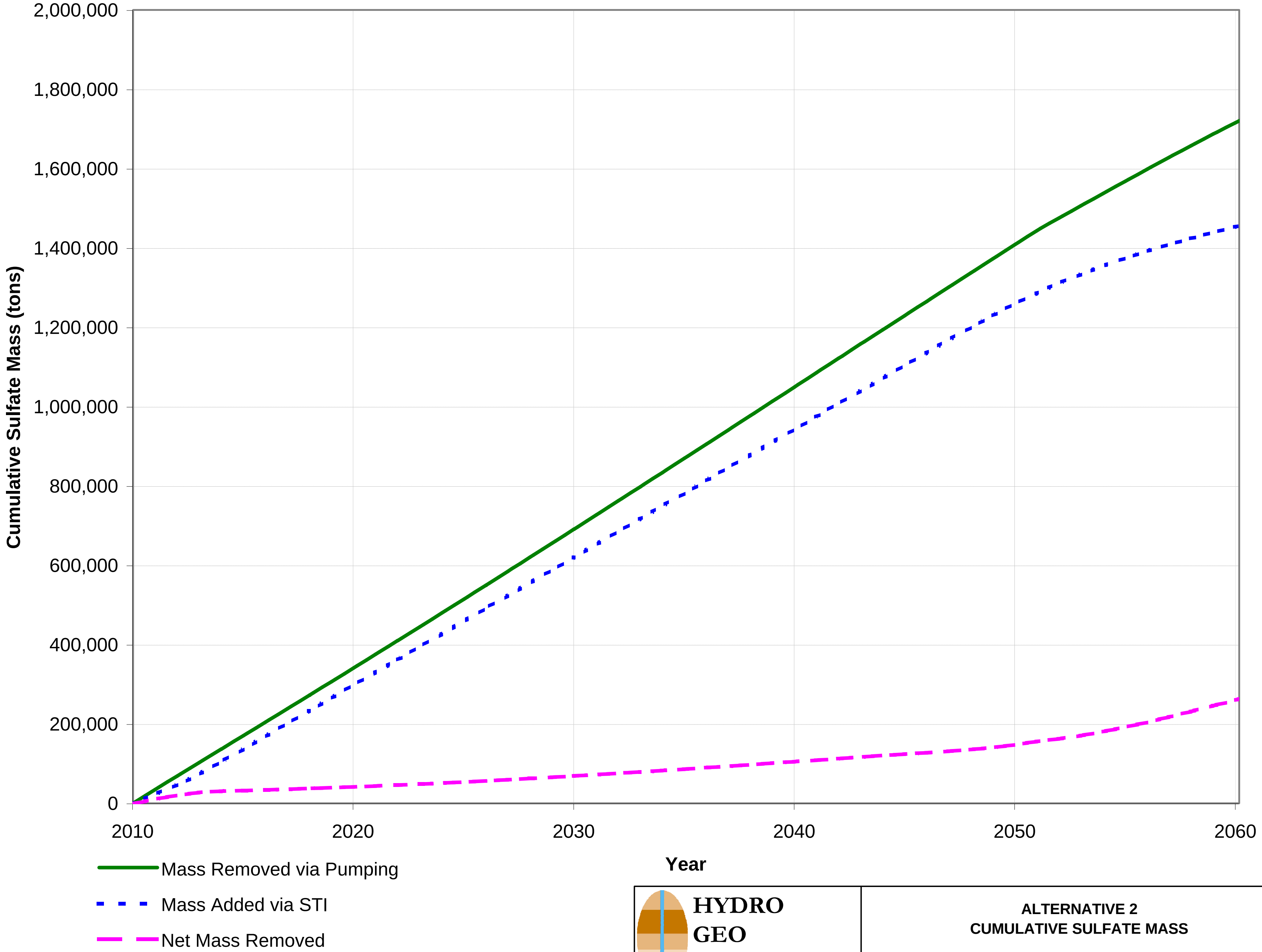


HYDRO GEO CHEM, INC.

ALTERNATIVE 1 CUMULATIVE SULFATE MASS					
Approved	Date	Author	Date	File Name	Figure
NWH	9/18/08	NWH	9/18/08	G13 Removal1	G.13



HYDRO GEO CHEM, INC.

ALTERNATIVE 2
CUMULATIVE SULFATE MASS

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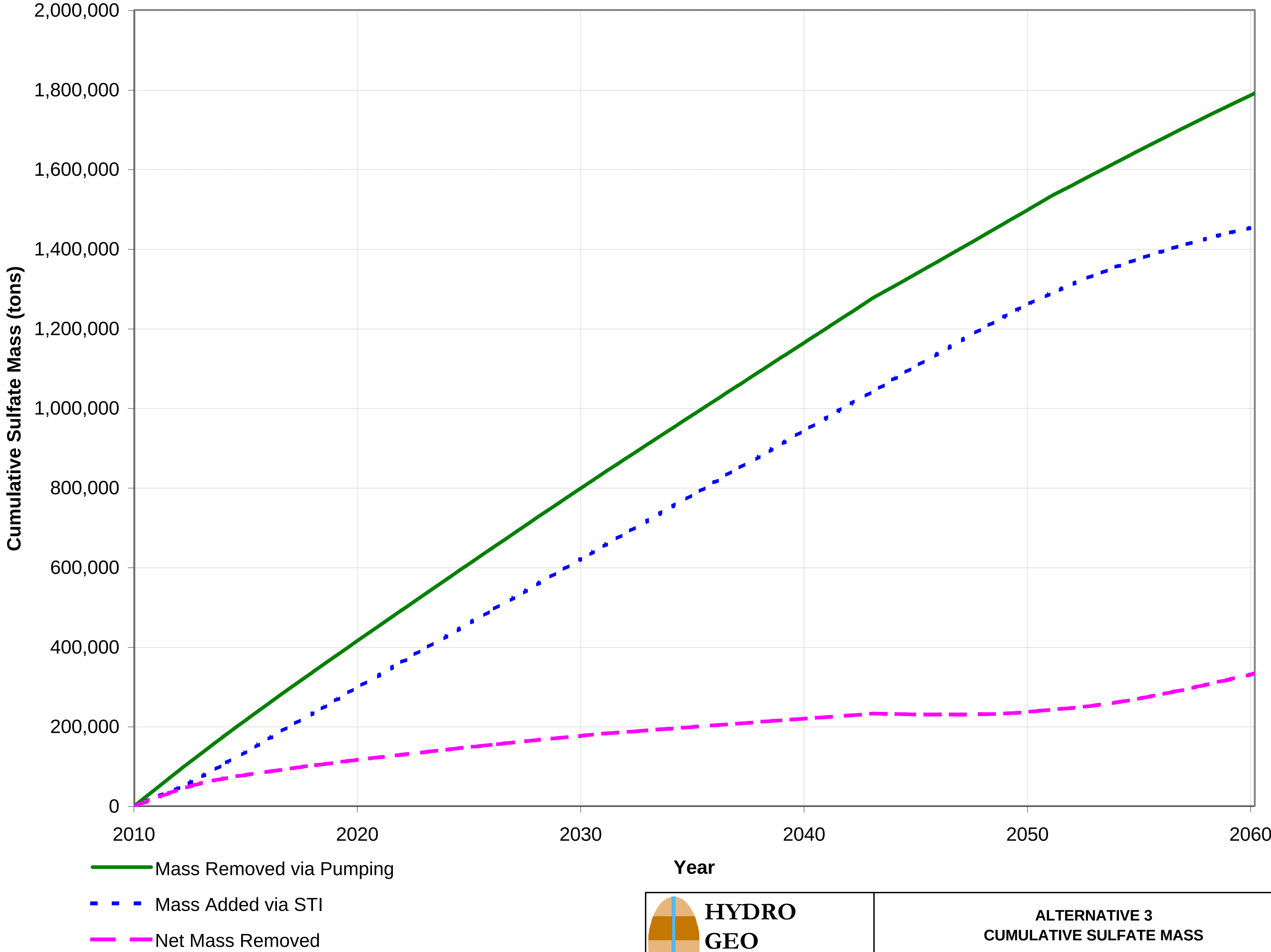
NWH	9/18/08	NWH	9/18/08	G14 Removal2	G.14



HYDRO GEO CHEM, INC.	ALTERNATIVE 3 CUMULATIVE SULFATE MASS					
	Approved NWH	Date 9/18/08	Author NWH	Date 9/18/08	File Name G15 Removal3	Figure G.15

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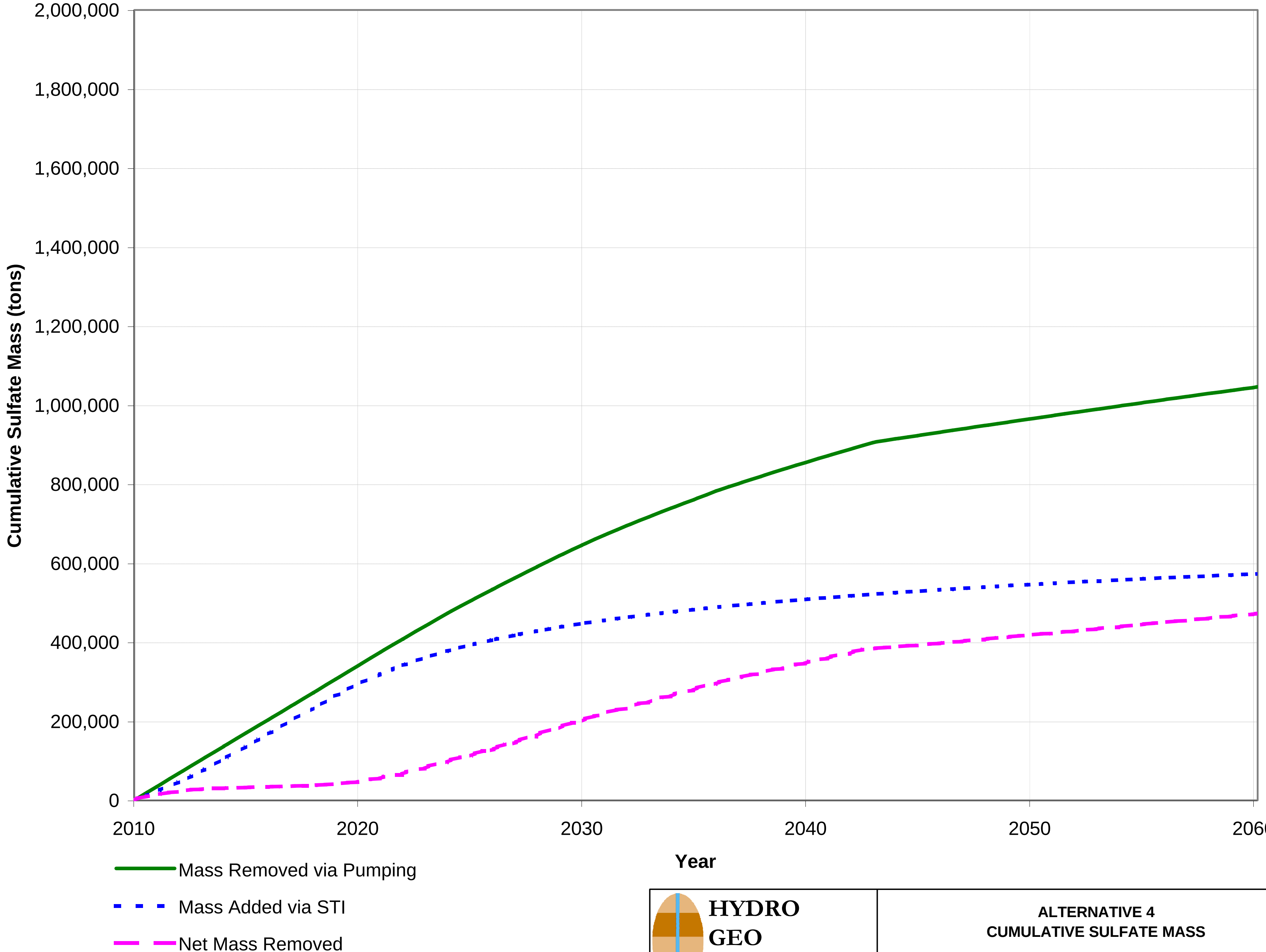

HYDRO GEO CHEM, INC.

ALTERNATIVE 4
CUMULATIVE SULFATE MASS

Approved	Date	Author	Date	File Name	Figure
NWH	9/30/08	NWH	9/30/08	G16 Removal4	G.16

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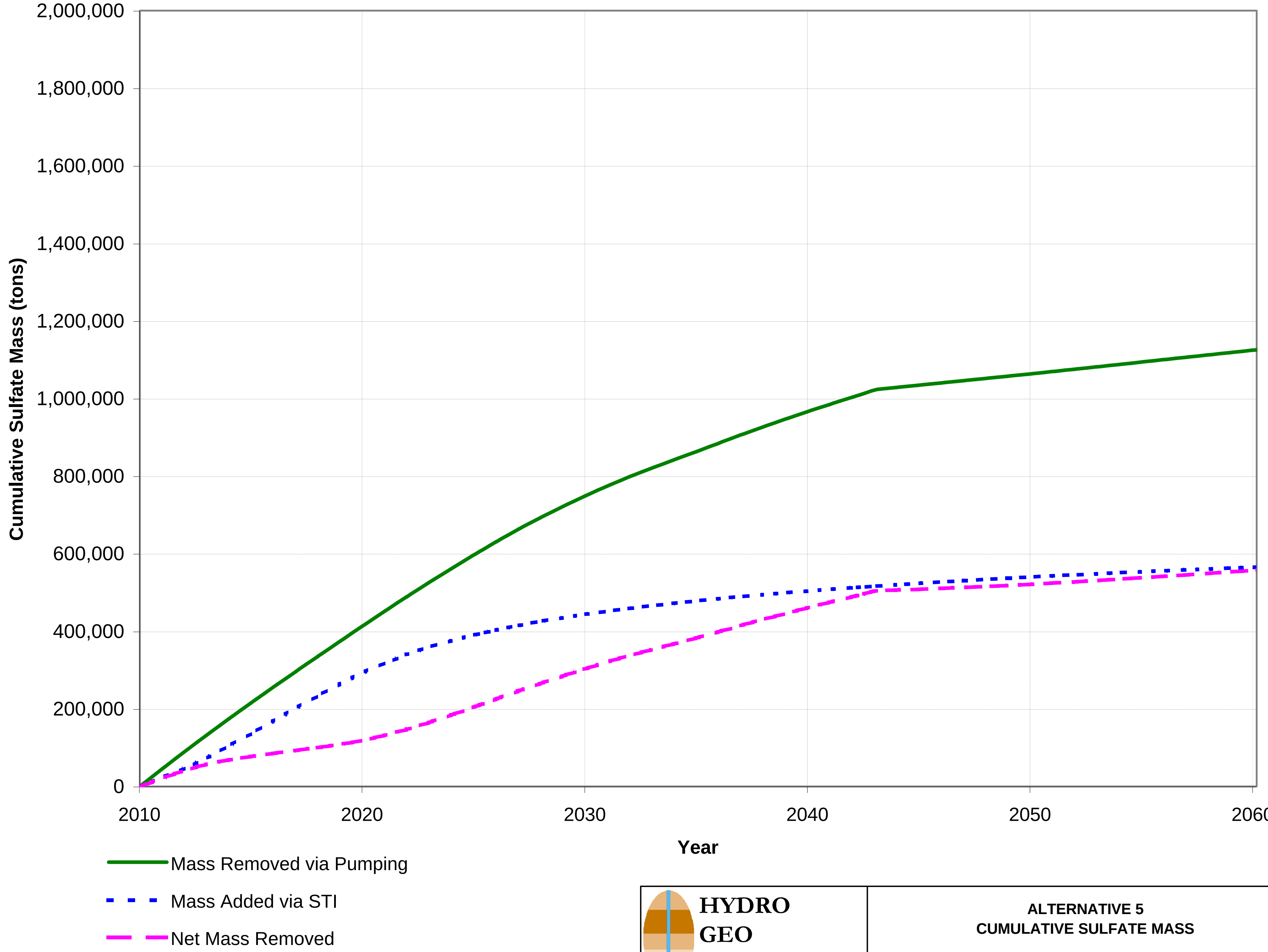

HYDRO GEO CHEM, INC.

ALTERNATIVE 5 CUMULATIVE SULFATE MASS					
Approved NWH	Date 9/18/08	Author NWH	Date 9/18/08	File Name G17 Removal5	Figure G.17

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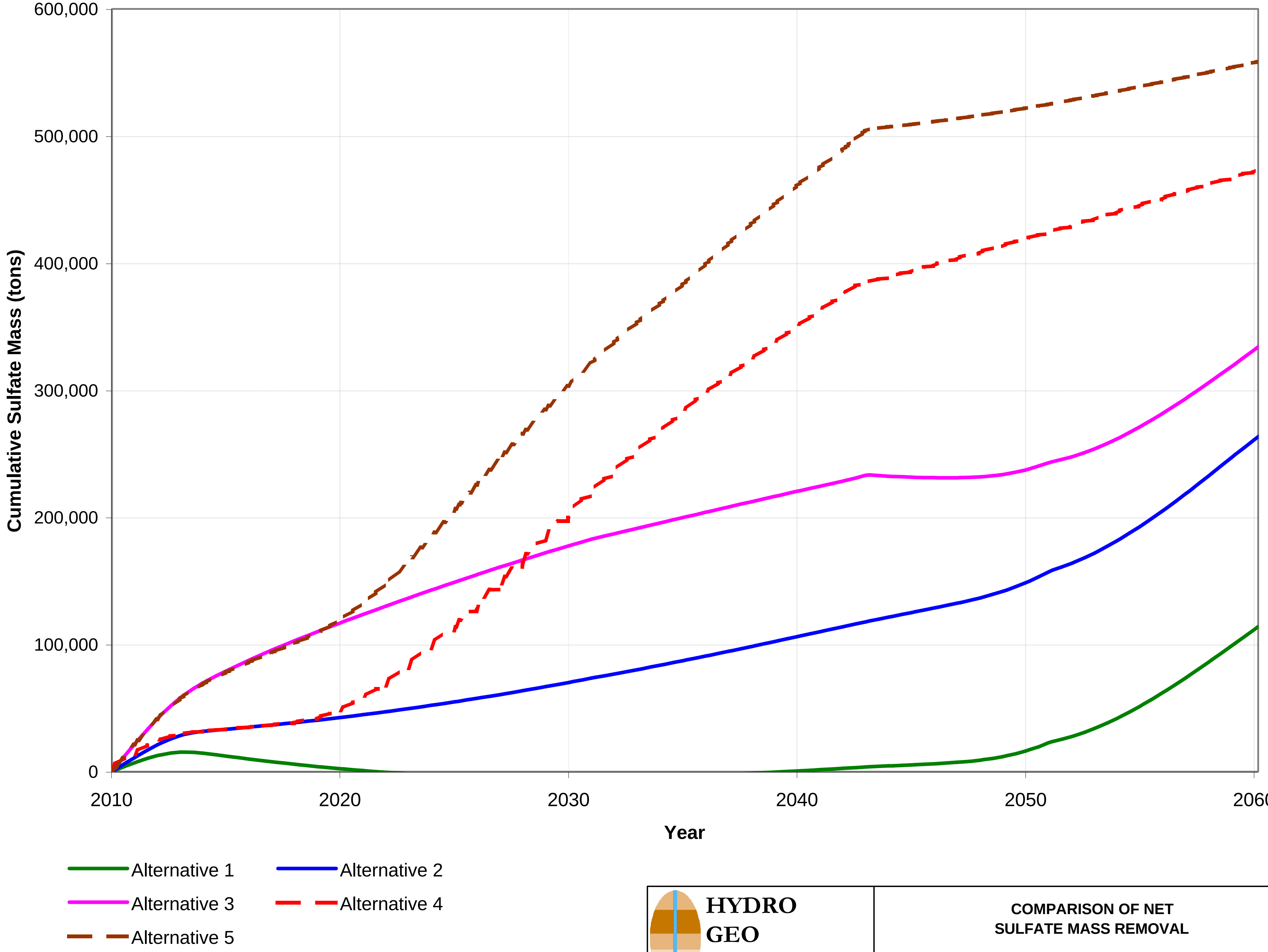

HYDRO GEO CHEM, INC.

COMPARISON OF NET SULFATE MASS REMOVAL

Approved	Date	Author	Date	File Name	Figure
NWH	10/1/08	NWH	10/1/08	G18 RemovalCompare	G.18

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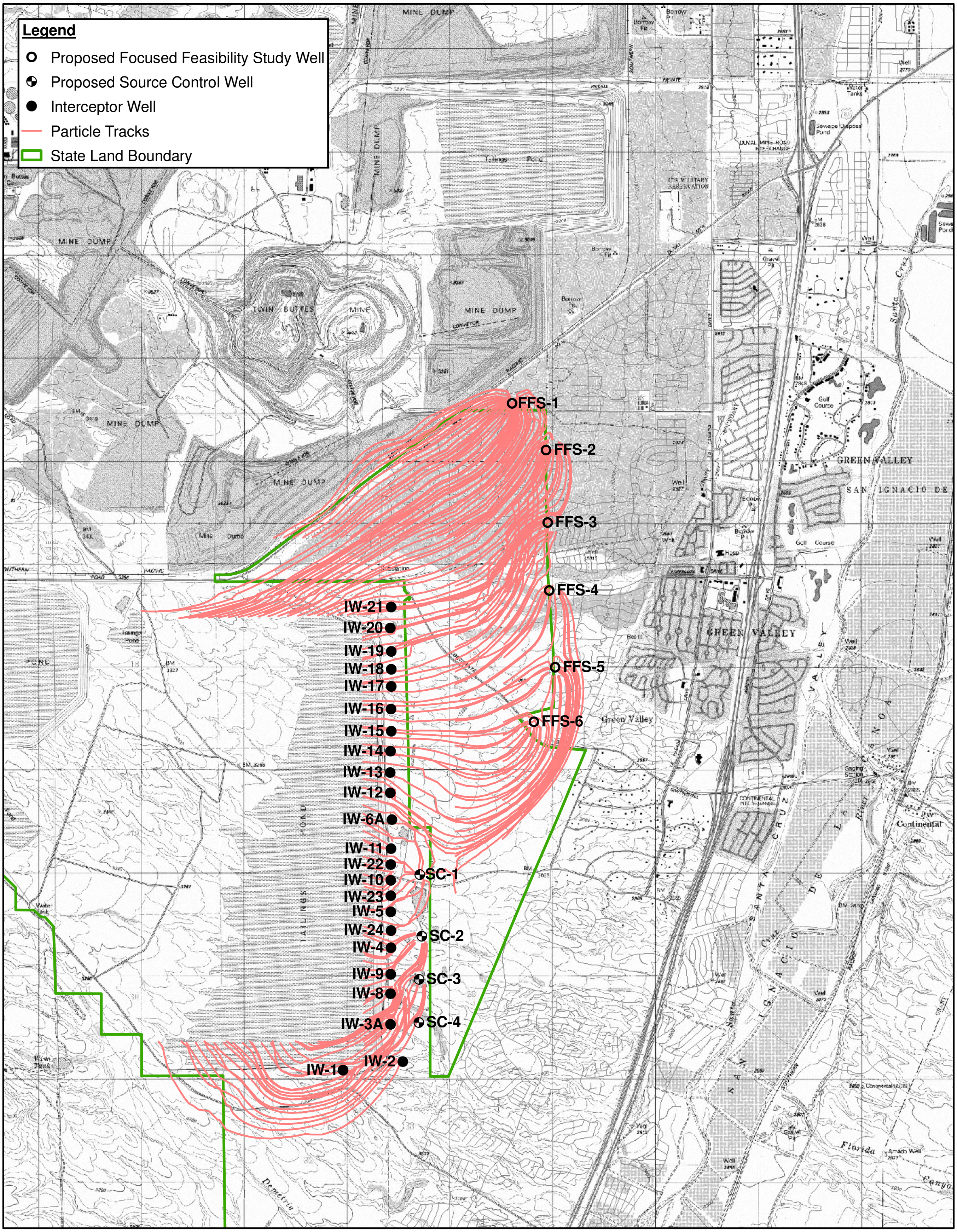

0 2,500 5,000 Feet

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

ALTERNATIVE 1 CAPTURE ZONE STARTING IN YEAR 2010

Approved	Date	Author	Date	File Name	Figure
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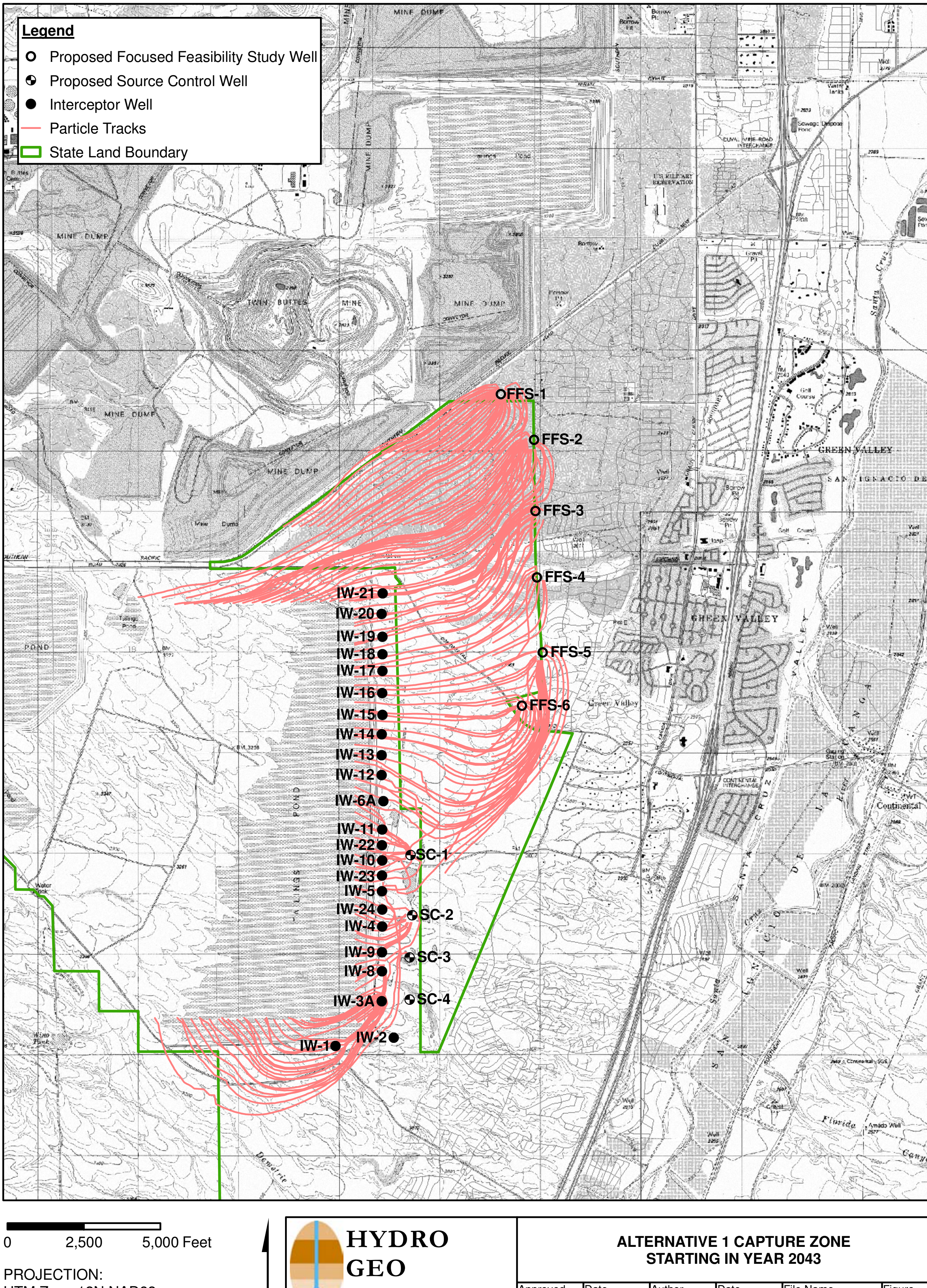

PROJECTION:
UTM Zone 12N NAD83

HYDRO GEO CHEM, INC.

ALTERNATIVE 1 CAPTURE ZONE STARTING IN YEAR 2043

Approved	Date	Author	Date	File Name	Figure
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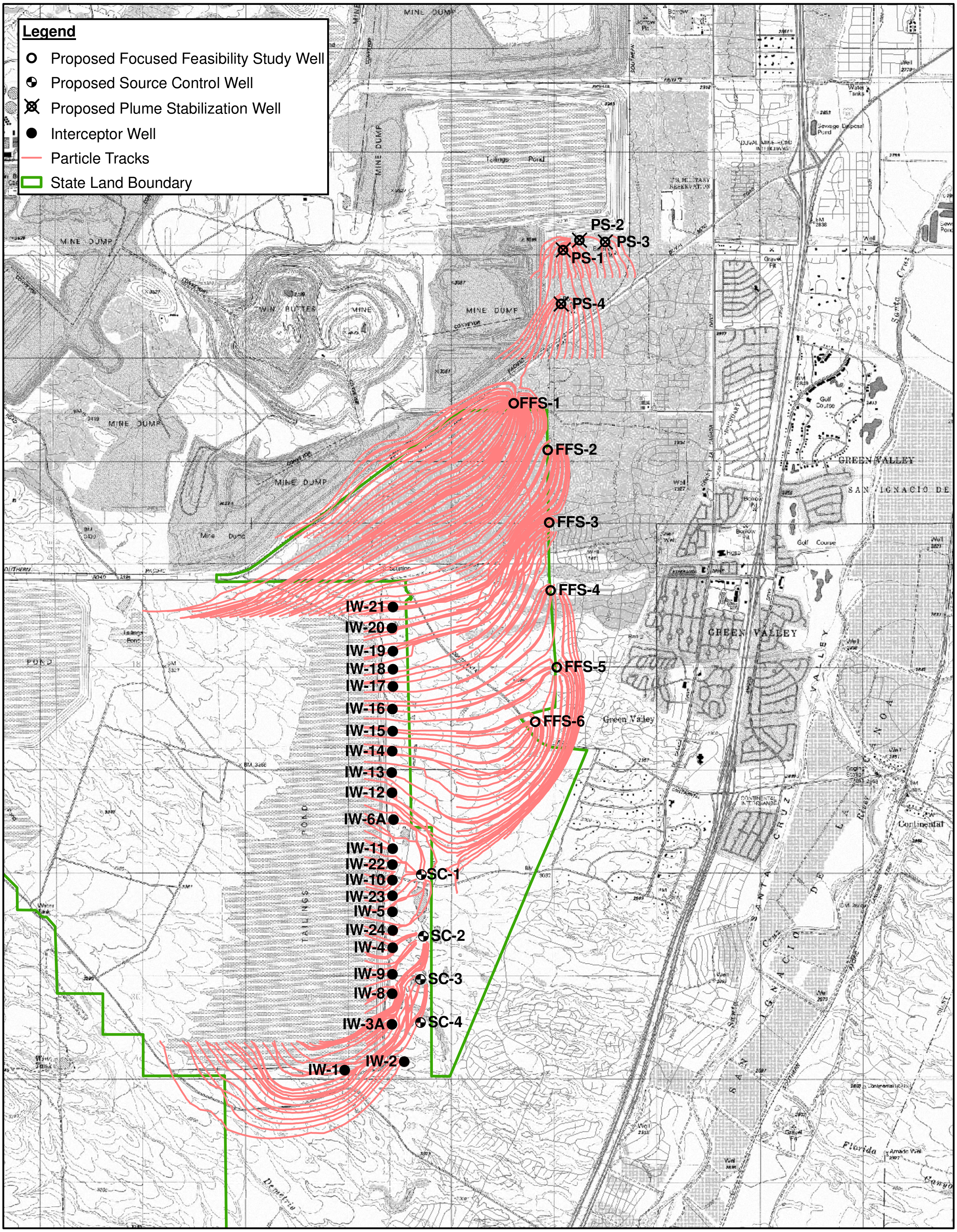

0 2,500 5,000 Feet

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

ALTERNATIVE 2 CAPTURE ZONE STARTING IN YEAR 2010

Approved	Date	Author	Date	File Name	Figure
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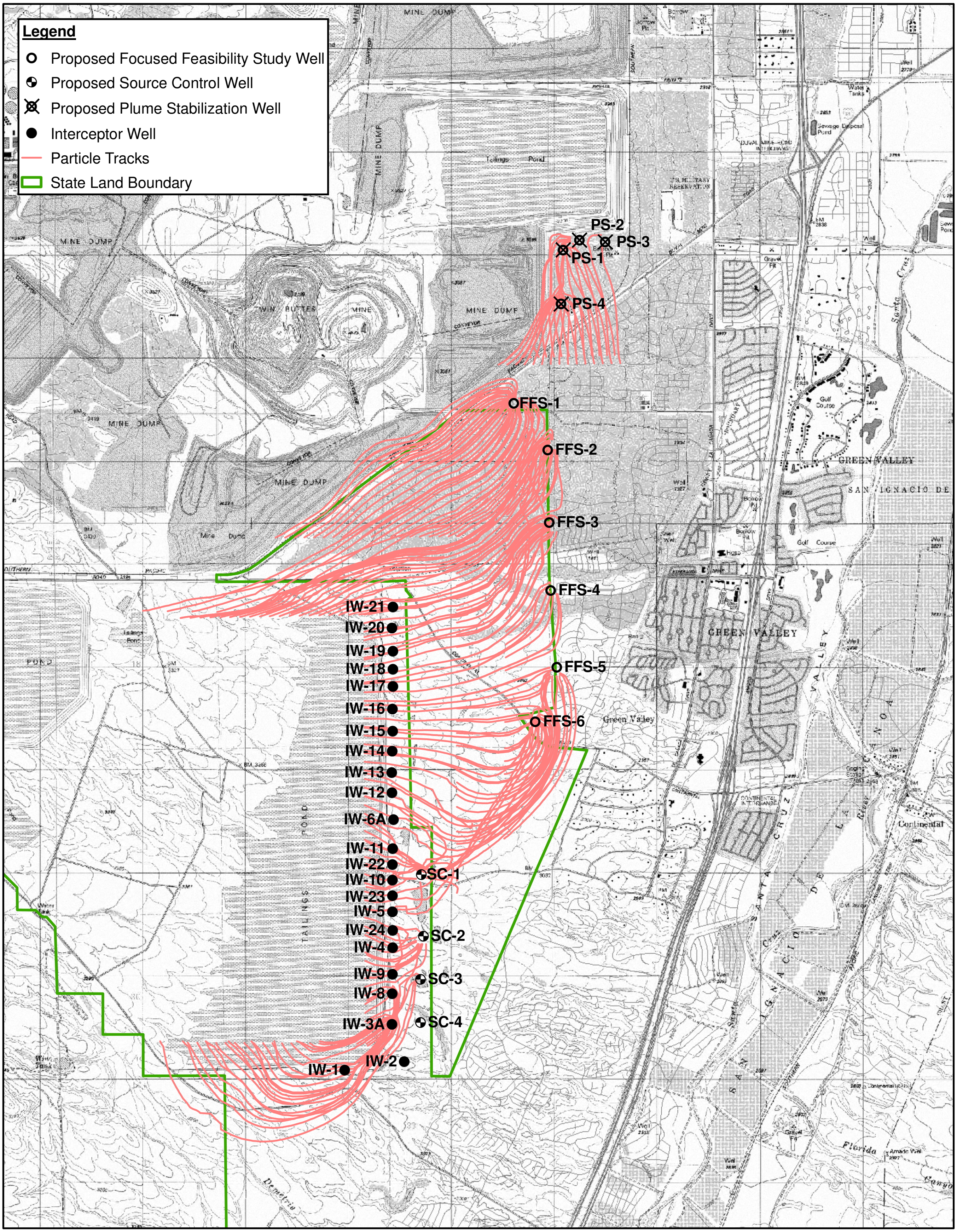

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PROJECTION:
UTM Zone 12N NAD83

N

HYDRO
GEO
CHEM, INC.

**ALTERNATIVE 2 CAPTURE ZONE
STARTING IN YEAR 2043**

Approved	Date	Author	Date	File Name	Figure
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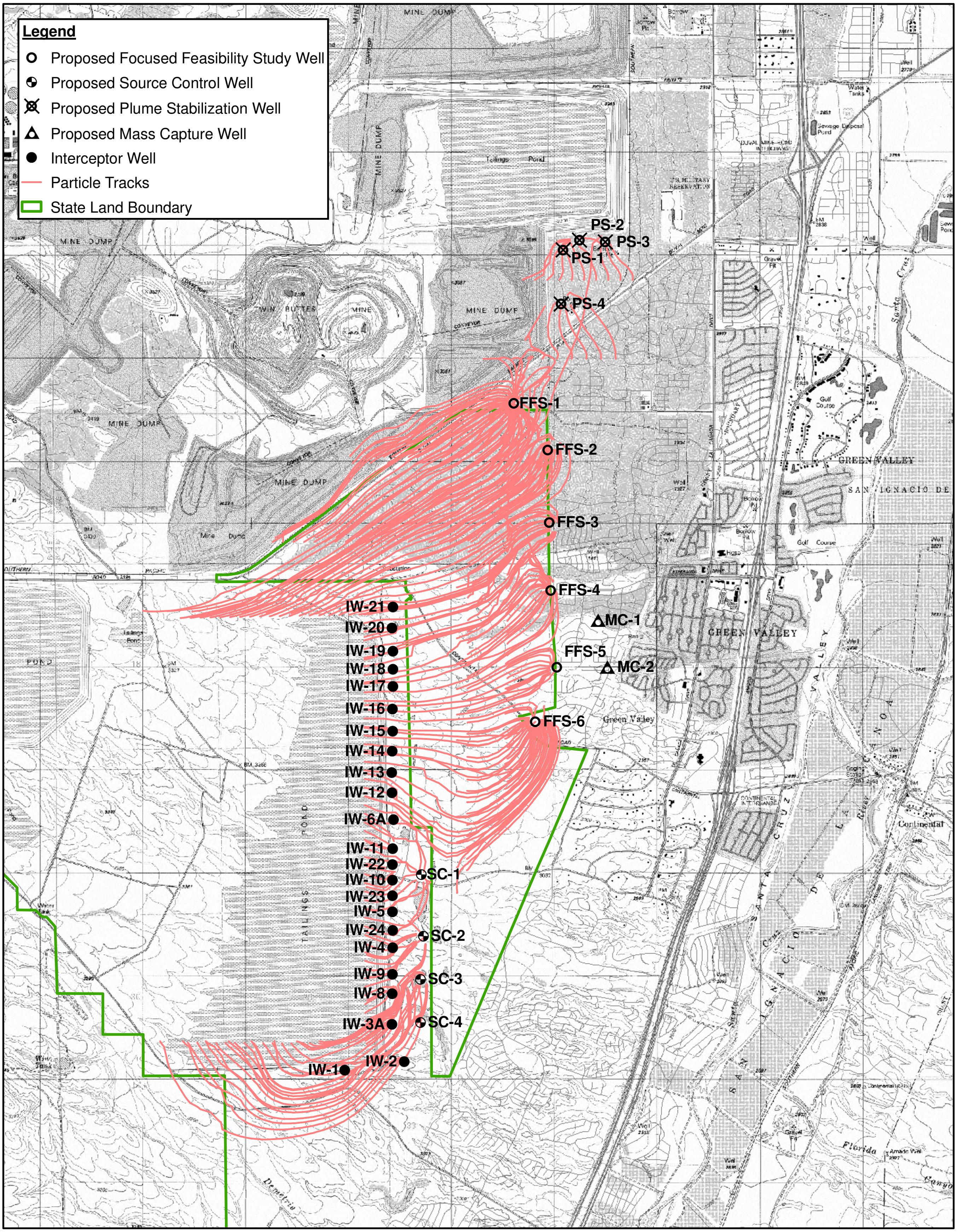


0 2,500 5,000 Feet

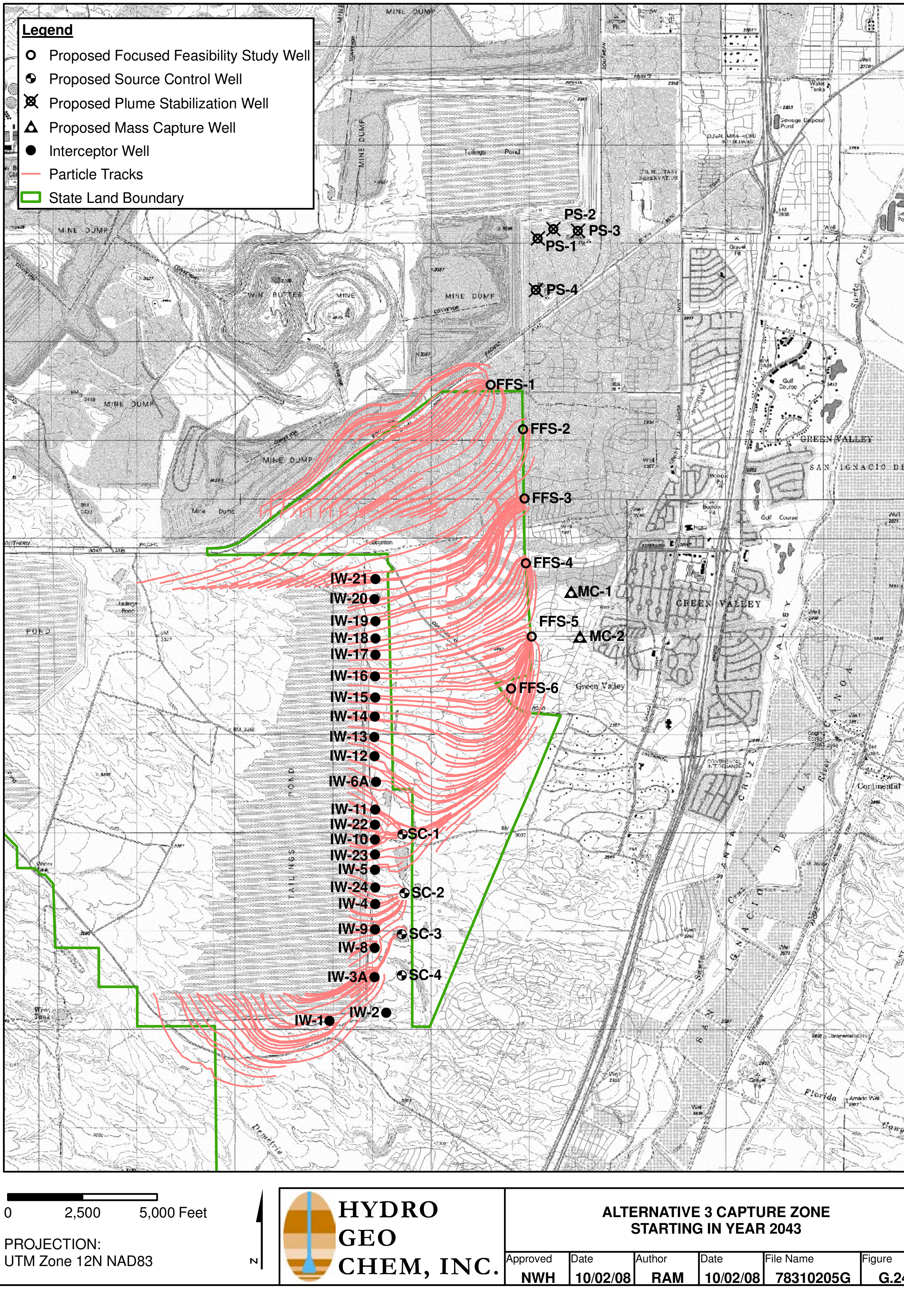
PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

ALTERNATIVE 3 CAPTURE ZONE STARTING IN YEAR 2010

Approved	Date	Author	Date	File Name	Figure
NWH	10/02/08	RAM	10/02/08	78310204G	G.23



PROJECTION:
UTM Zone 12N NAD83

HYDRO GEO CHEM, INC.

ALTERNATIVE 3 CAPTURE ZONE STARTING IN YEAR 2043

Approved	Date	Author	Date	File Name	Figure
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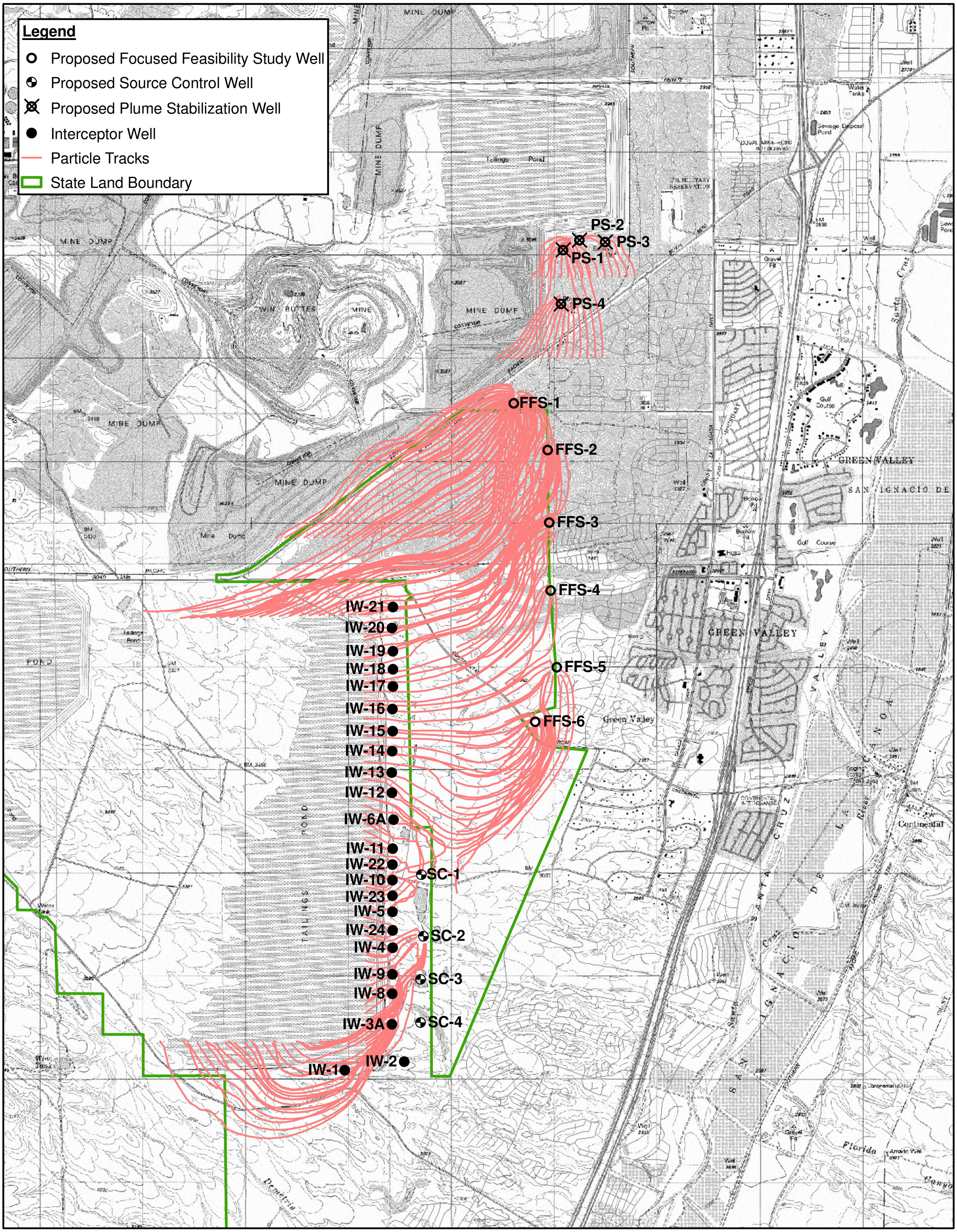

PROJECTION:
UTM Zone 12N NAD83

HYDRO GEO CHEM, INC.

ALTERNATIVE 4 CAPTURE ZONE STARTING IN YEAR 2010

Approved	Date	Author	Date	File Name	Figure
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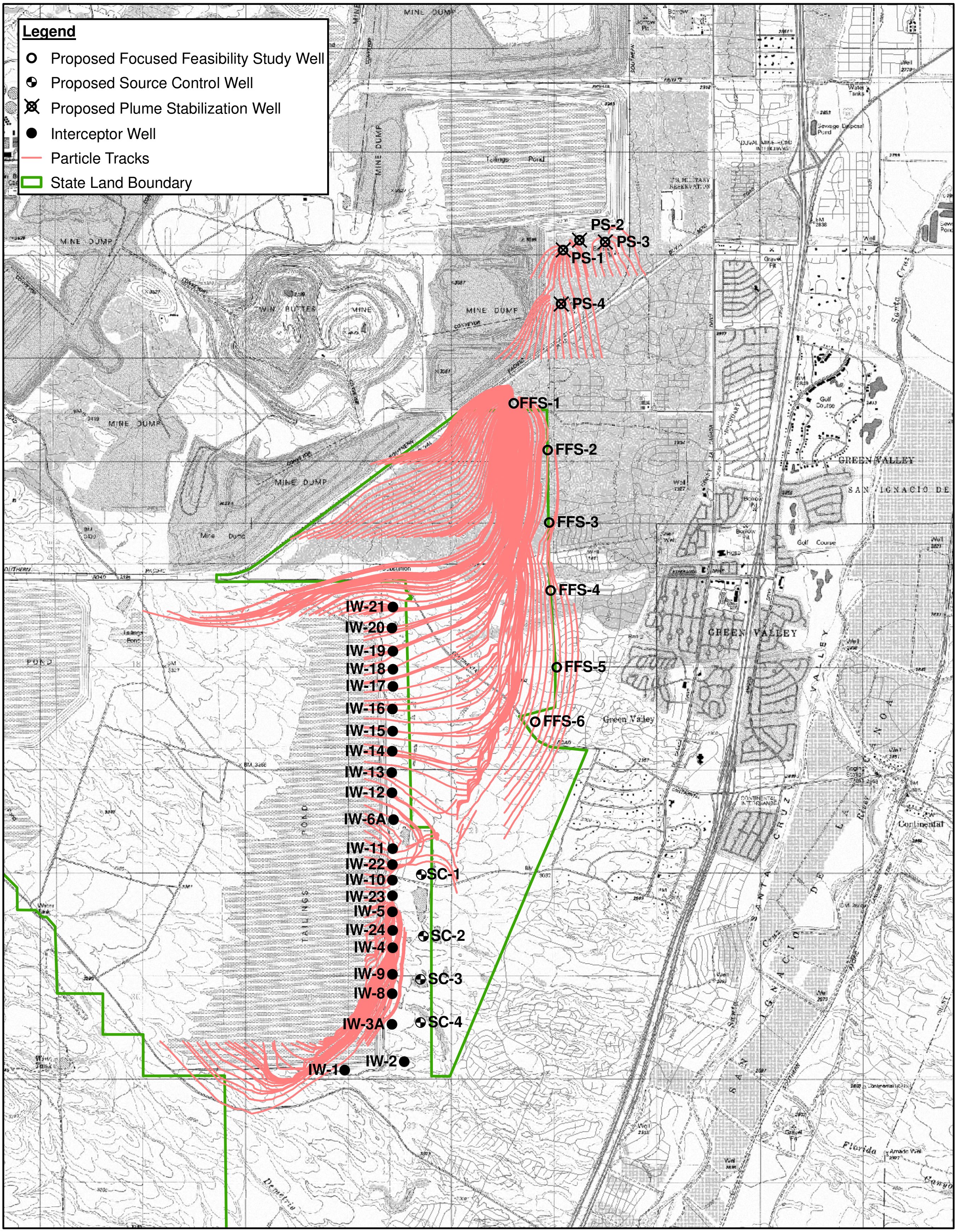

PROJECTION:
UTM Zone 12N NAD83

HYDRO GEO CHEM, INC.

ALTERNATIVE 4 CAPTURE ZONE STARTING IN YEAR 2043

Approved	Date	Author	Date	File Name	Figure
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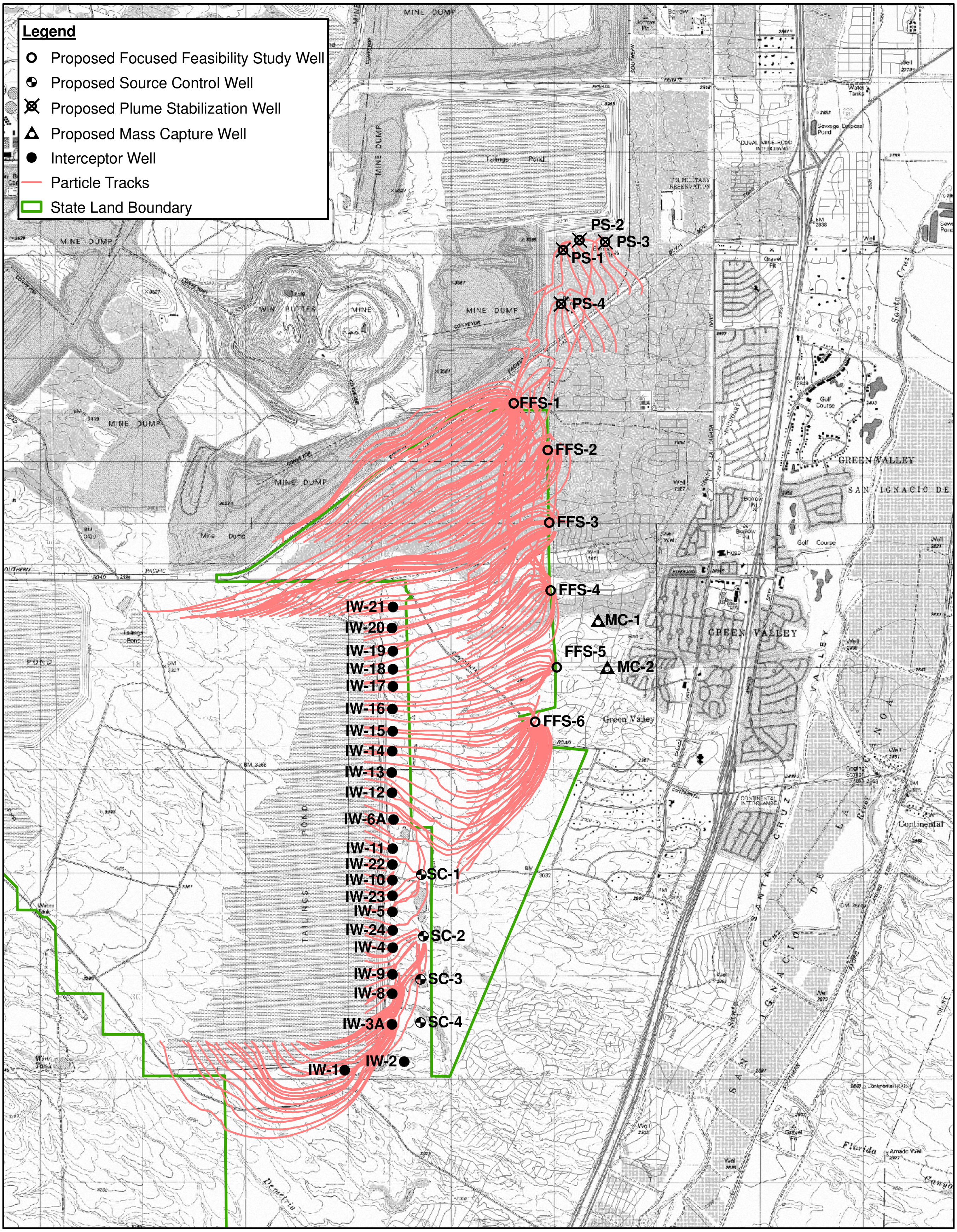

0 2,500 5,000 Feet

PROJECTION:
UTM Zone 12N NAD83

N

HYDRO GEO CHEM, INC.

ALTERNATIVE 5 CAPTURE ZONE STARTING IN YEAR 2010

Approved	Date	Author	Date	File Name	Figure
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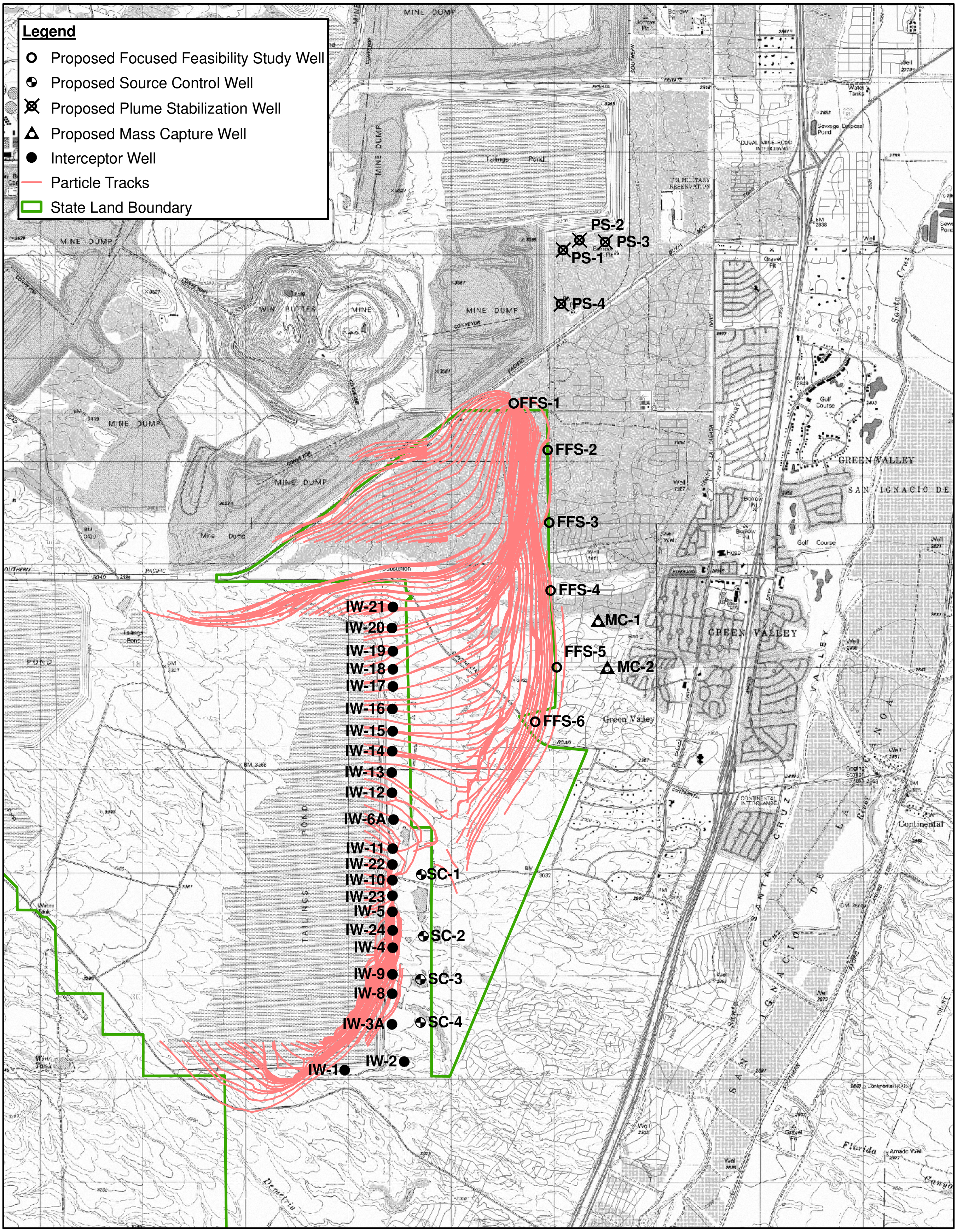

PROJECTION:
UTM Zone 12N NAD83

HYDRO GEO CHEM, INC.

ALTERNATIVE 5 CAPTURE ZONE STARTING IN YEAR 2043

Approved	Date	Author	Date	File Name	Figure
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