Planning Combined Municipal Use of Groundwater and Surface Water: Technical and General Results from a Case Study

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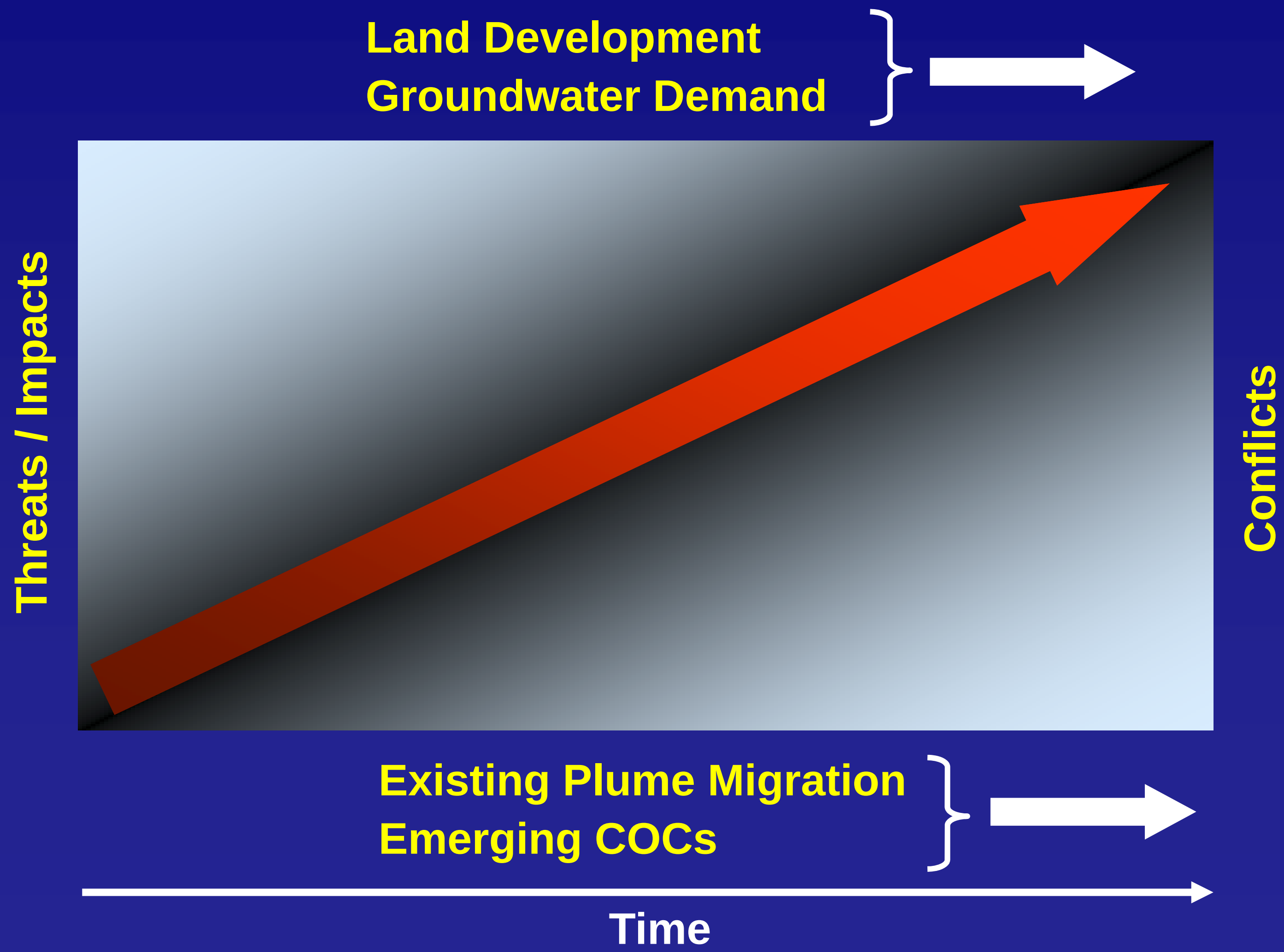
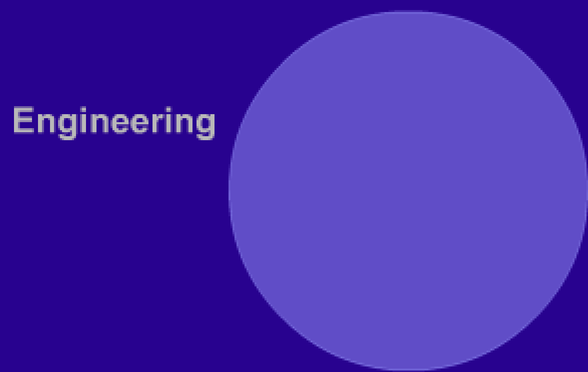
Complexity of Groundwater Pumping Management Likely to Grow



Another Reason for Complexity

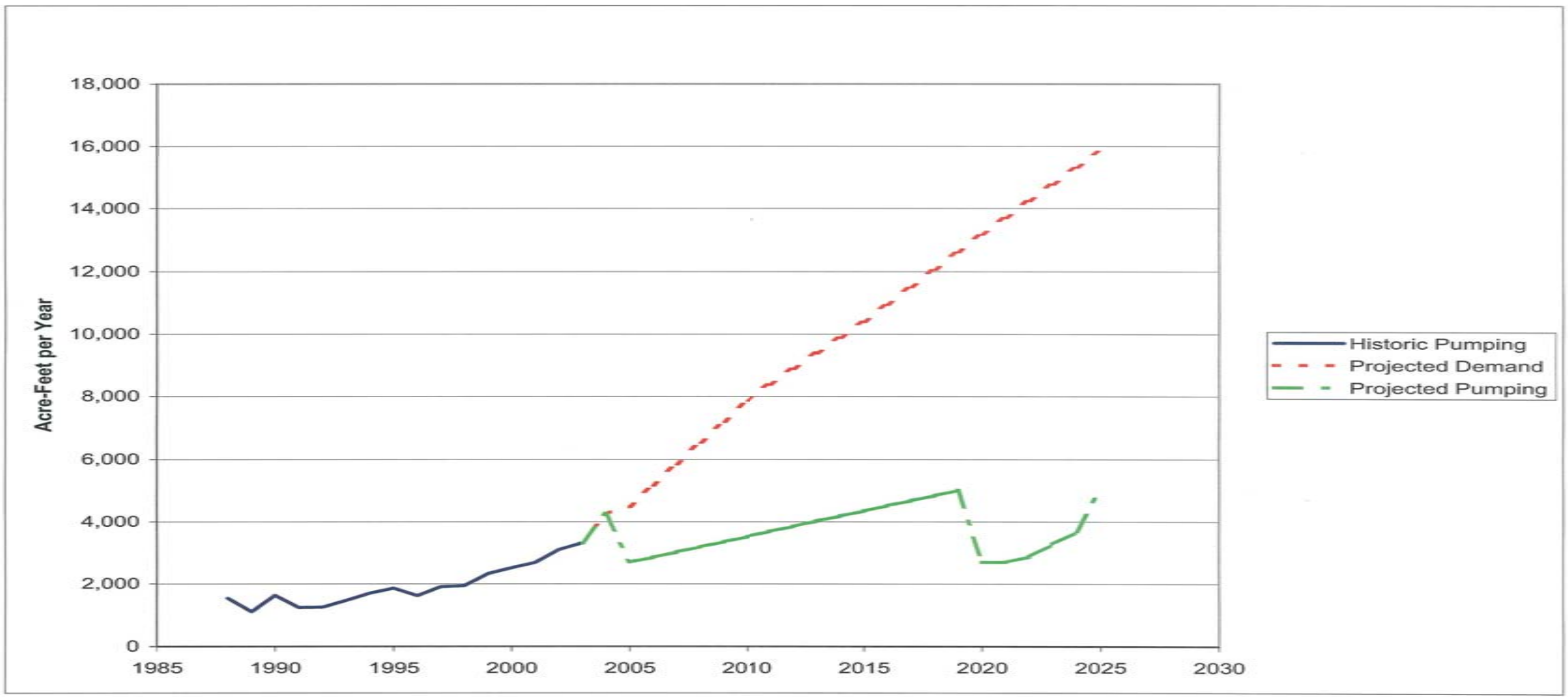
Many Solution Dimensions



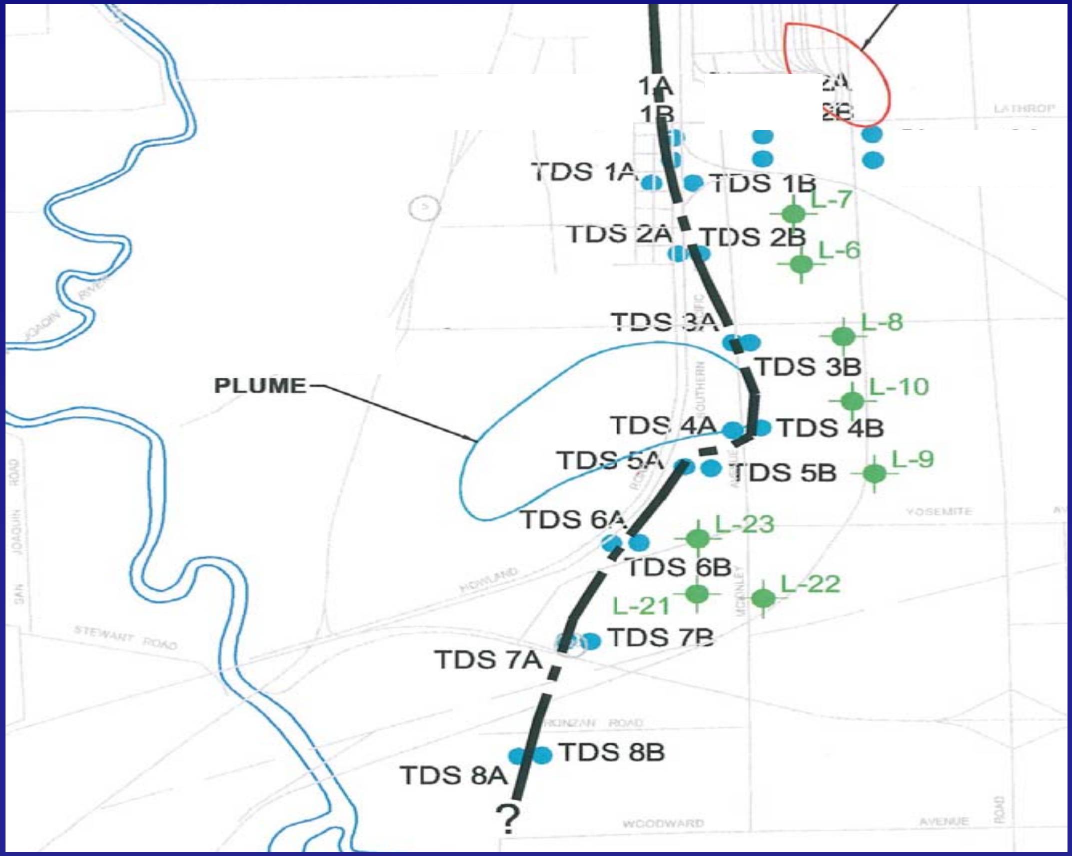
Case Study

- Municipal water supply planning
- Fast growing city in the Delta
- Groundwater currently meets total demand
- Surface water supply will soon become available
- Areas of undesirable quality groundwater located within potential capture zone (naturally occurring and anthropogenic)
- Need to manage groundwater resource use to preserve quality and control costs

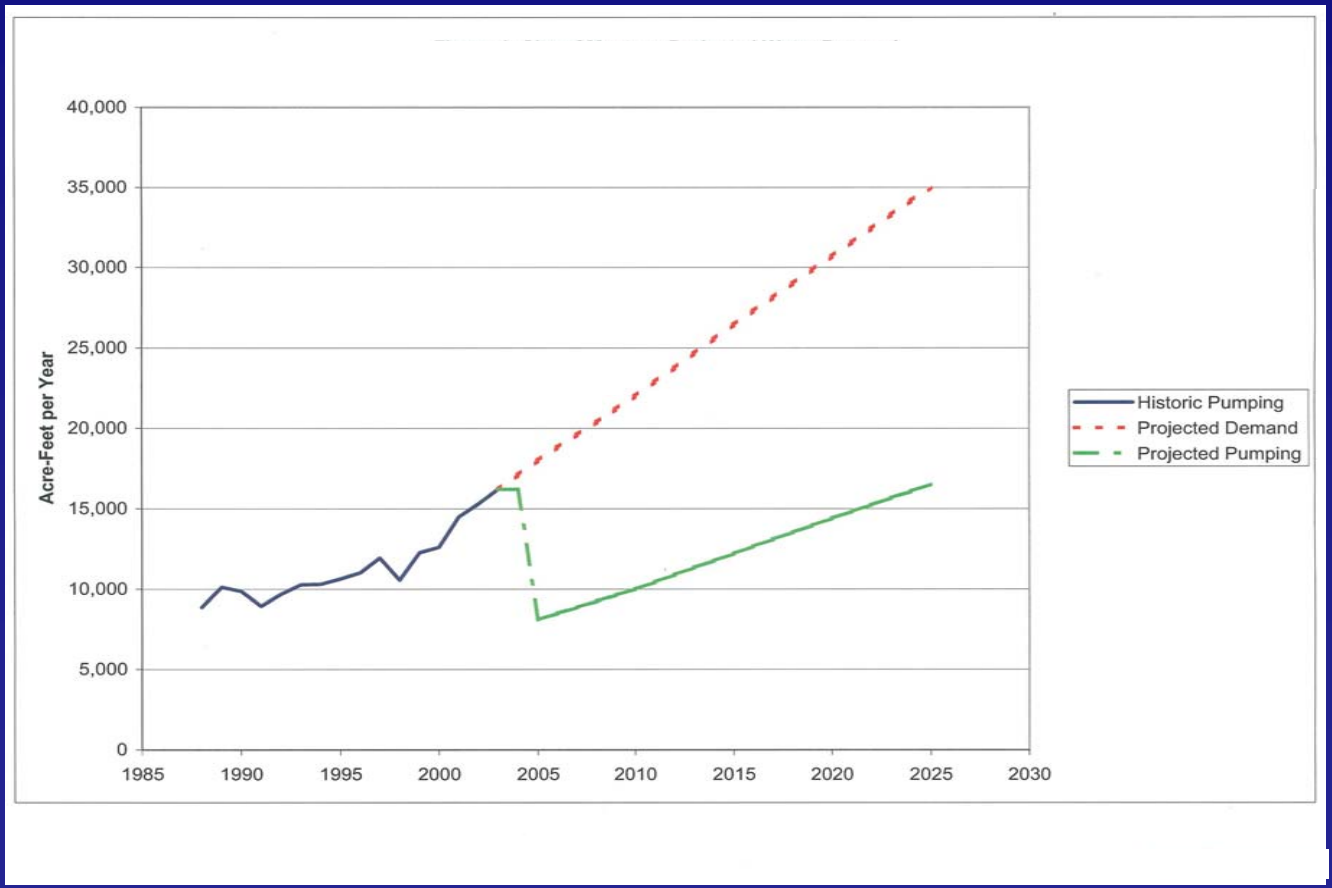
Projected Total Water Demand (City A)



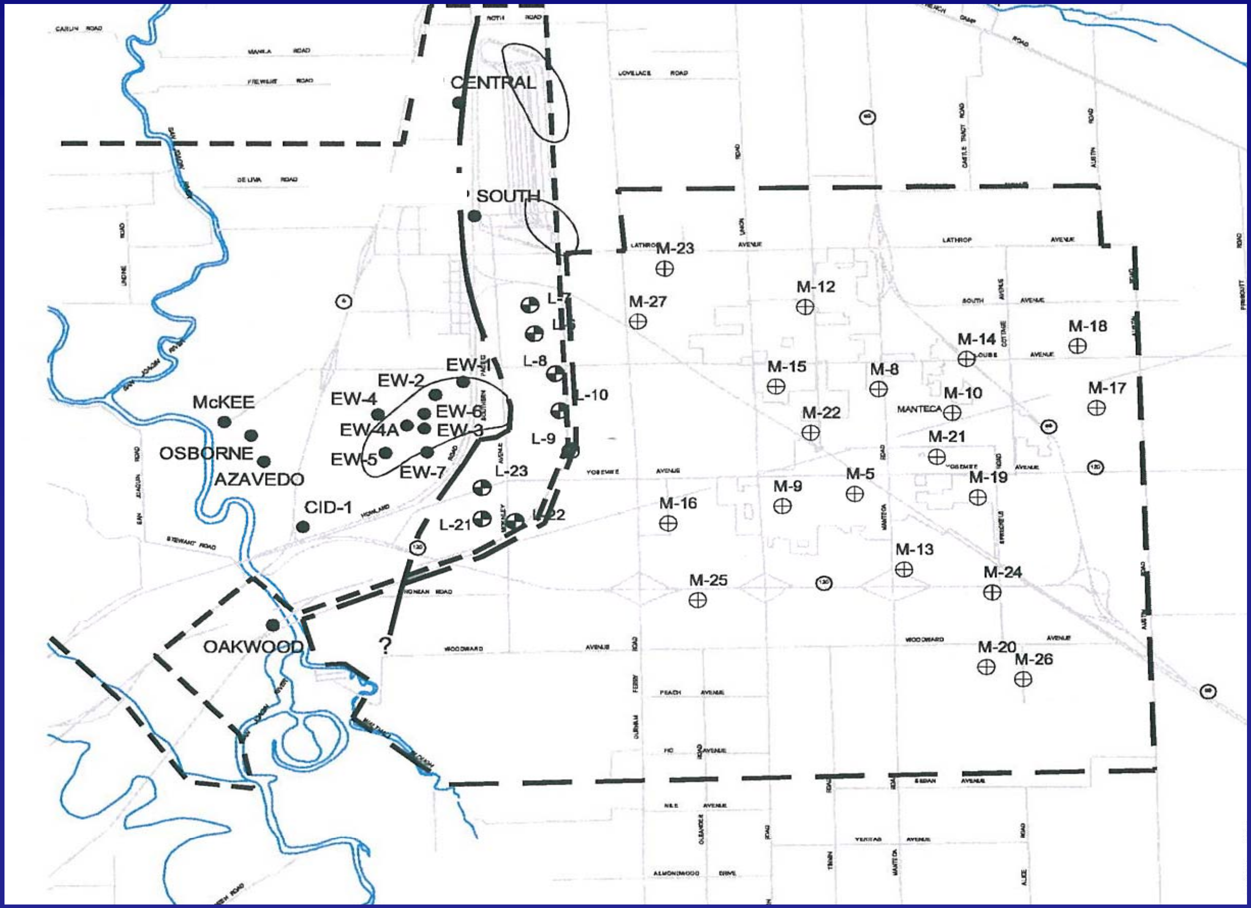
Pumping Well Vicinity



Projected Total Water Demand(City B)



Neighboring Groundwater Users



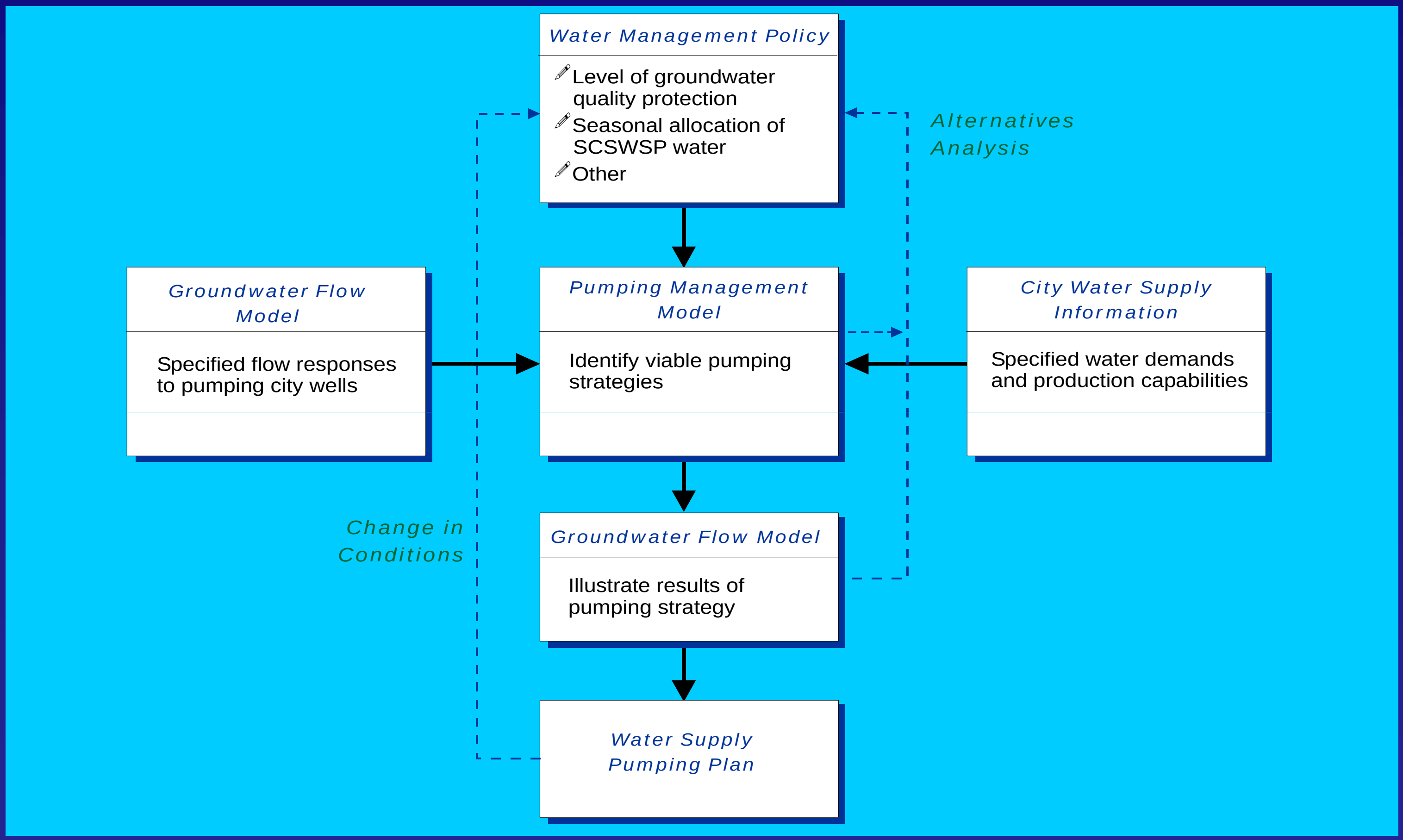
Questions

- **What is the best strategy for meeting City A's growing water demand currently projected out to 2025?**

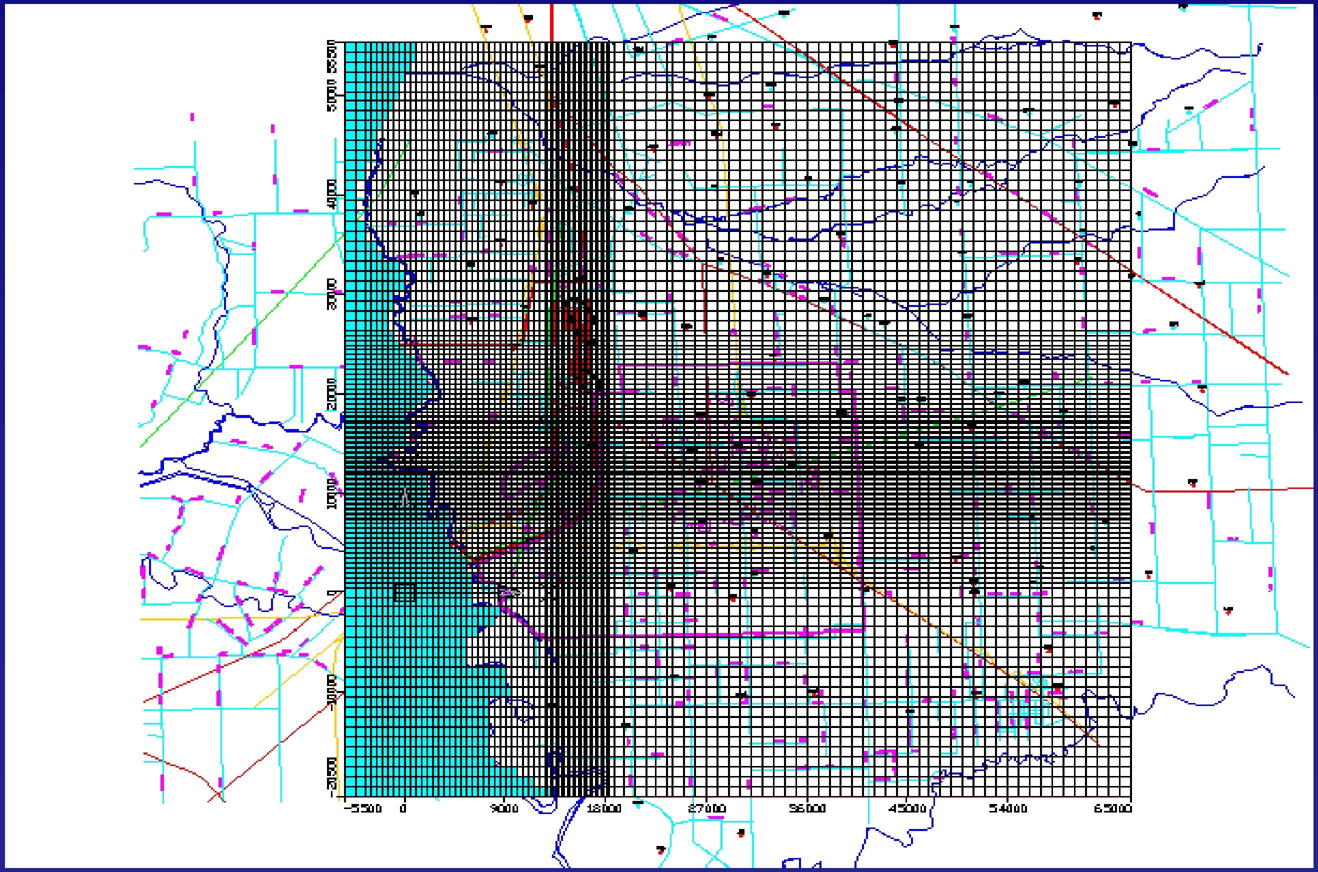
- **How do the following factors affect City A's ability to pump groundwater?**
  - ~ **Groundwater quality degradation induced by increased pumping**
  - ~ **Minimum production capacity requirements**
  - ~ **Minimum number of wells required to be held in reserve**
  - ~ **Increased pumping by City B**

- **What is the tradeoff between higher production and water quality degradation?**

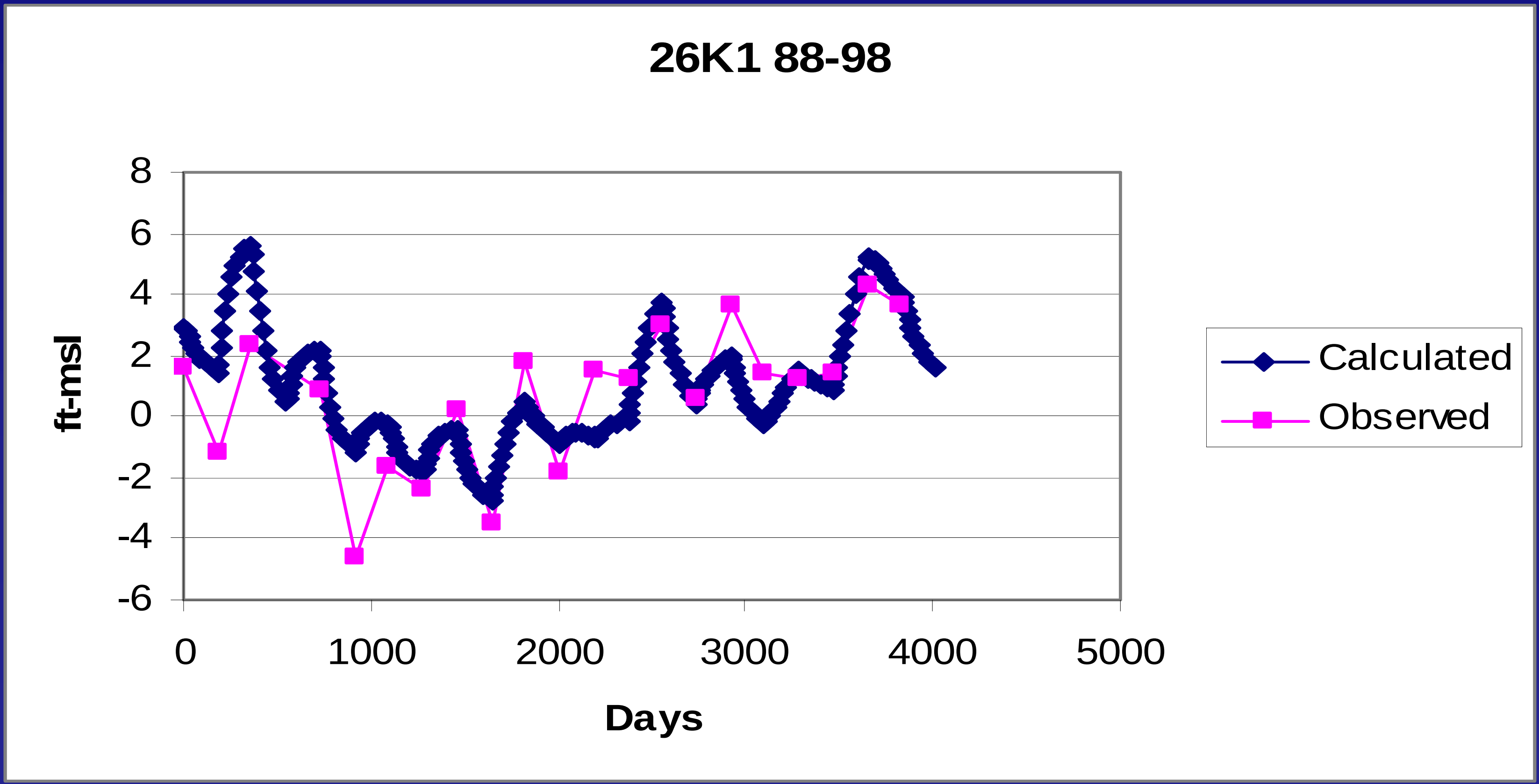
Pumping Alternatives Evaluation Process



Three-Dimensional Flow Model



Model Calibration



Project Scope of Work

- **Analysis Formulation**
  - ~ **Information Compilation and Integration**
  - ~ **Specify Operational Requirements**
- **Develop Operational Scenarios**
- **Evaluate Scenarios**

Analysis Formulation

Maximize Groundwater Production

Subject To:

- Projected Demand
- Well Capacity Limitations
- Groundwater Flow Limitations
- Sustainability Requirement

Tracking:

- Number of Wells in Reserve
- Total Supply Capacity Relative to Demand

Analysis Formulation

Maximize Groundwater Production – 2004 to 2030

- 22-year production period (2004-2025) with a 5-year sustainability period
- Biannual Management Periods Based on Water Year
  - Winter: October 1 to March 31
  - Summer: April 1 to September 30

Subject To:

- Projected Demands
- Well Capacity Limitations
- Groundwater Flow Limitations
- Sustainability Requirement

Analysis Formulation

Maximize Groundwater Production

Subject To:

- Projected Demands
  - Existing and New Development Together
  - Groundwater = Total – Surface Water
- Well Capacity Limitations
- Groundwater Flow Limitations
- Sustainability Requirement

Analysis Formulation

Maximize Groundwater Production

Subject To:

- Projected Demands
- Well Capacity Limitations
  - City A Pumping Activity
  - City B Pumping Activity
  - Seasonal Conditions
- Groundwater Flow Limitations
- Sustainability Requirement

Well Capacity Limitations

Based On:

- **Available drawdown (height of water above pump intake, NPSH not considered)**
- **Specific capacity (allowed to degrade over time)**
- **Wellfield drawdowns (flow model with City A pumping rates)**
- **Seasonal water level variations throughout the region (flow model with time-varying boundary conditions and City B pumping)**

Analysis Formulation

Maximize Groundwater Production

Subject To:

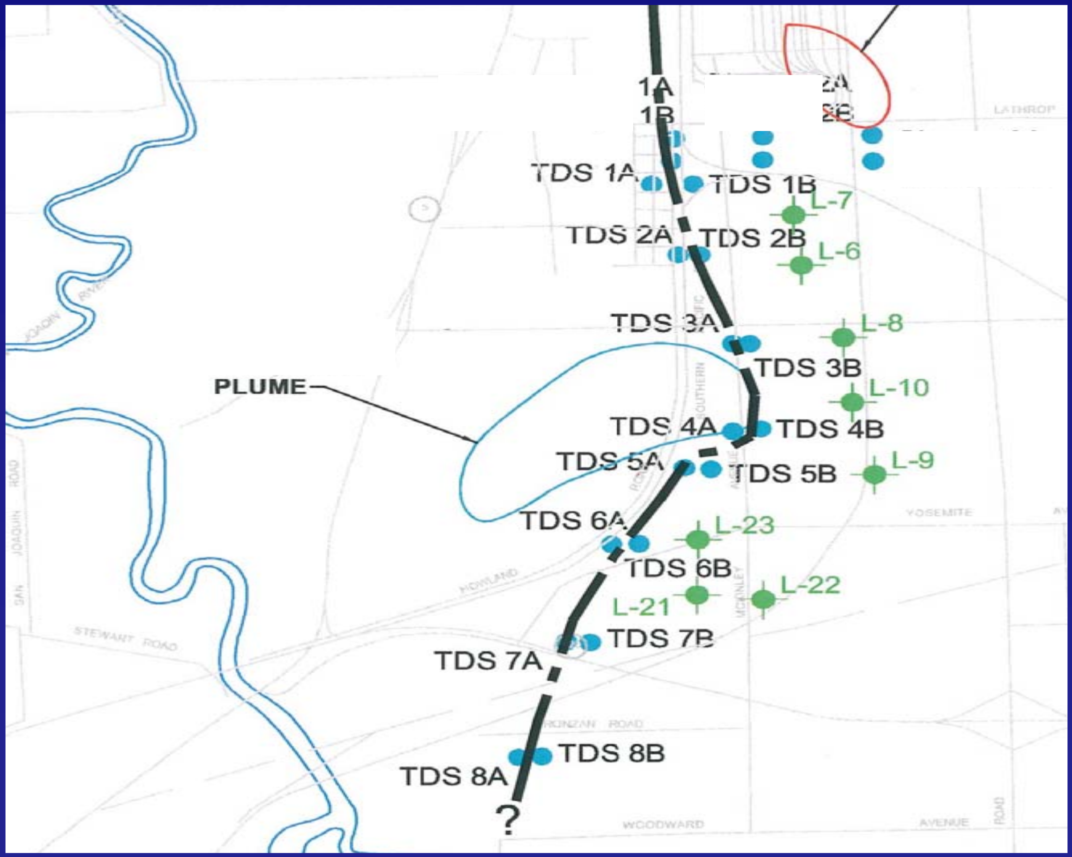
- Projected Demands
- Well Capacity Limitations
- Groundwater Flow Limitations
  - Direction (plumes and TDS)
  - Rate
- Sustainability Requirement

Groundwater Flow Limitations

Based On:

- **Gradients at sensitive locations in the groundwater system**
- **Groundwater flow velocity calculations**
- **Estimates for travel times to supply wells**

Gradient Evaluation Locations



Analysis Formulation

Maximize Groundwater Production

Subject To:

- Projected Demands
- Well Capacity Limitations
- Groundwater Flow Limitations
- Sustainability Requirement
  - Constant rates by season for final five years

Analysis Formulation

Maximize Groundwater Production

Subject To:

- Projected Demands
- Well Capacity Limitations
- Groundwater Flow Limitations
- Sustainability Requirement

Tracking:

- Number of Wells in Reserve
  - Backup
  - Standby
- Total Supply Capacity Relative to Demand
  - Average Daily Demand
  - Maximum Daily Demand

Analysis Formulation

Maximize Groundwater Production – 432 decisions

Subject To:

- Projected Demands – 54 constraints
- Well Capacity Limitations – 864 constraints
- Groundwater Flow Limitations – 594 constraints
- Sustainability requirement – 80 constraints

Tracking:

- Number of Wells in Reserve – 54 considerations
- Total Supply Capacity Relative to Demand - 54 considerations

Solution Process

- **Predict Drawdown Responses to Pumping (GW Model/ Modflow)**
- **Solve the Analysis Formulation (Optimization Model/ Excel & Lindo)**

Solution Process (cont'd)

- **Perform Parametric Analysis (Optimization Model/ Excel & Lindo)**
  - ~ **Level of Groundwater Quality Protection (adjust constraint values)**
  - ~ **Surface Water Seasonal Allocation (adjust constraint values)**
  - ~ **City B Groundwater Demand (rerun base case drawdown responses)**
- **Demonstrate Design Performance (GW Model/ Modflow & Modpath)**

Parametric Analysis:
Level of Groundwater Quality Protection

- **Unfettered Production:** highest production with unrestricted mobilization and degradation resulting in additional treatment (no gradient control)

- **Gradual Treatment:** higher production with managed mobilization and eventual water quality degradation leading to additional treatment requirements (medium gradient control)

- **Strict Sustainability:** limited production without mobilizing nearby waters of undesirable quality (maximum gradient control)

Parametric Analysis: Surface Water Seasonal Allocation

- **Proportional:** surface water supply used during both winter and summer proportional to total seasonal demand
- **Winter:** surface water supply used to satisfy winter demand first and any remainder applied toward meeting summer demand
- **Summer:** surface water supply used to satisfy portion of summer demand

Note: City B plans to concentrate groundwater extraction in the summer

Parametric Analysis: City B Groundwater Demand

- **Growing:** as projected in 2002 UWMP
- **Shrinking:** assumed a constant total demand and the projected increasing surface water allotment (for illustrative purposes)

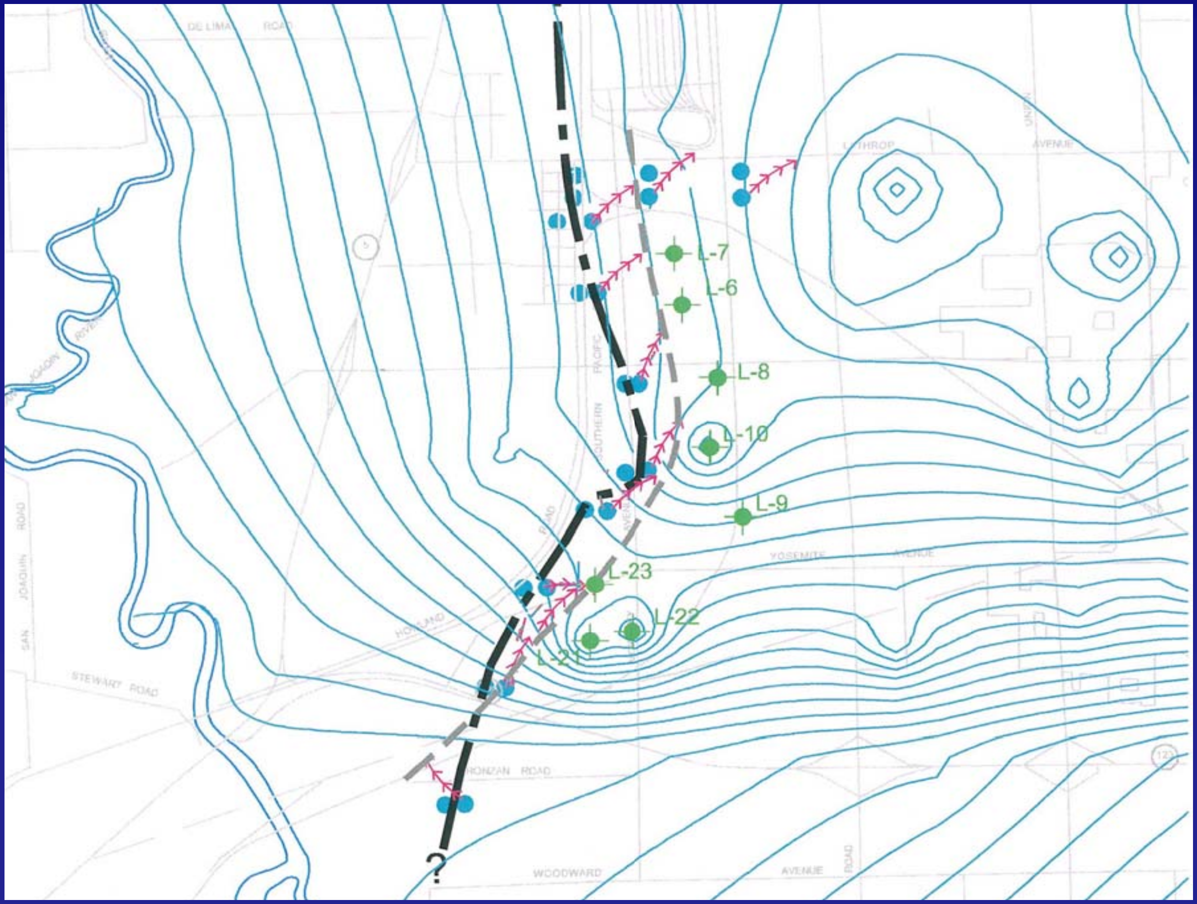
Results

- **Level of Groundwater Quality Protection**

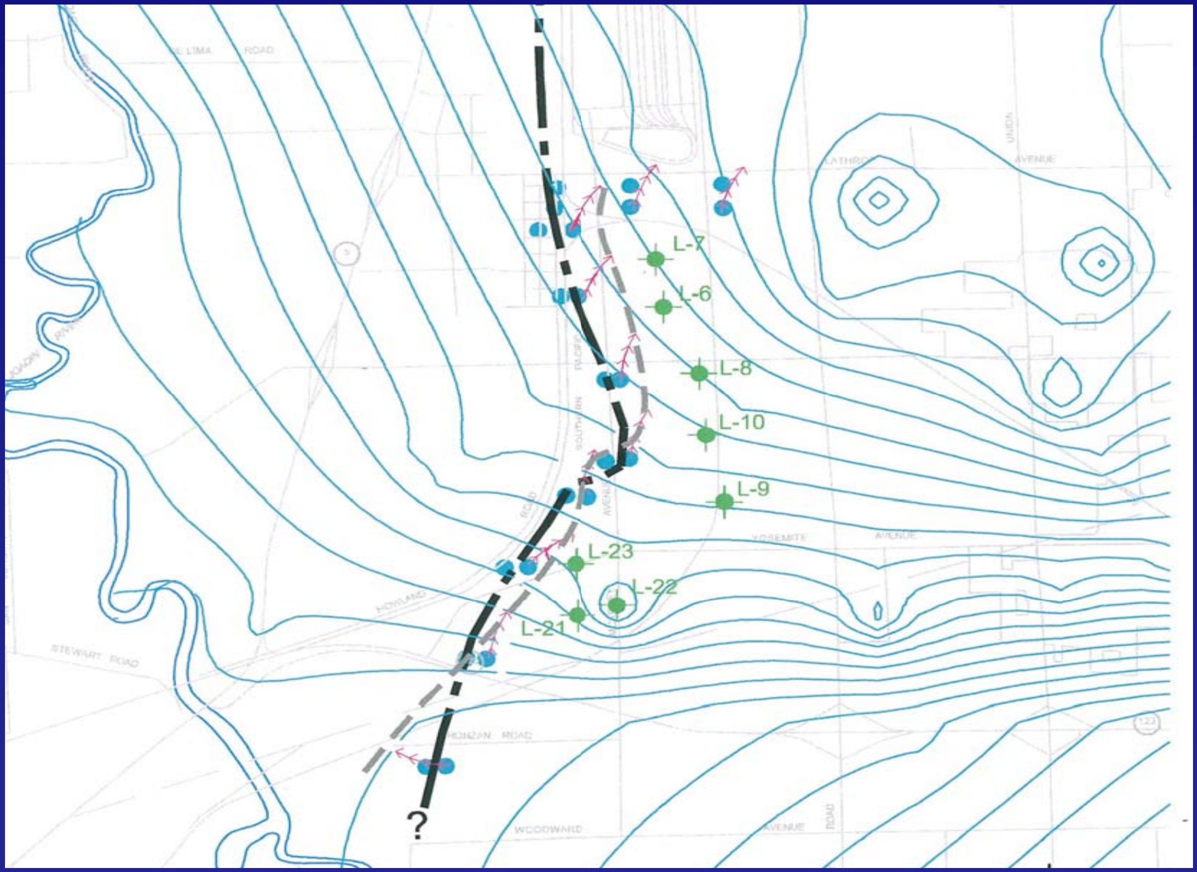
- **Surface Water Seasonal Allocation**

- **City B Demand**

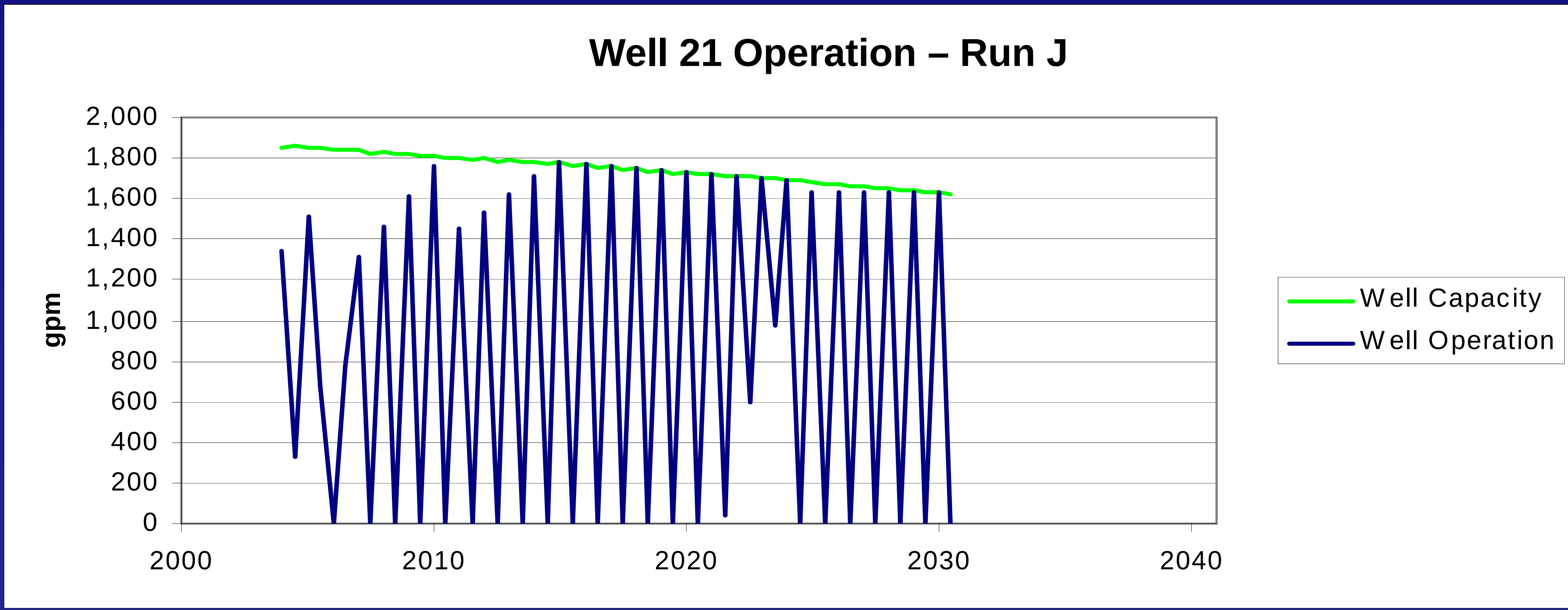
Level of Groundwater Quality Protection (No Control)



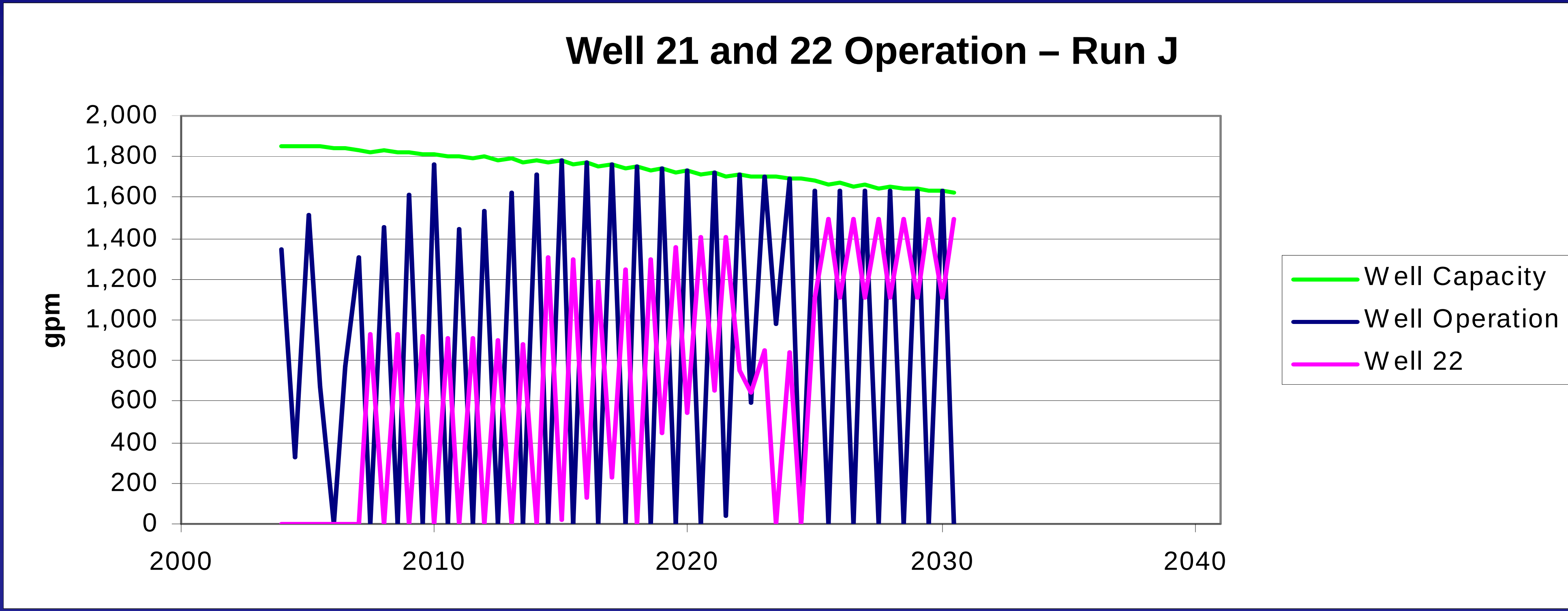
Level of Groundwater Quality Protection (Maximum Control)



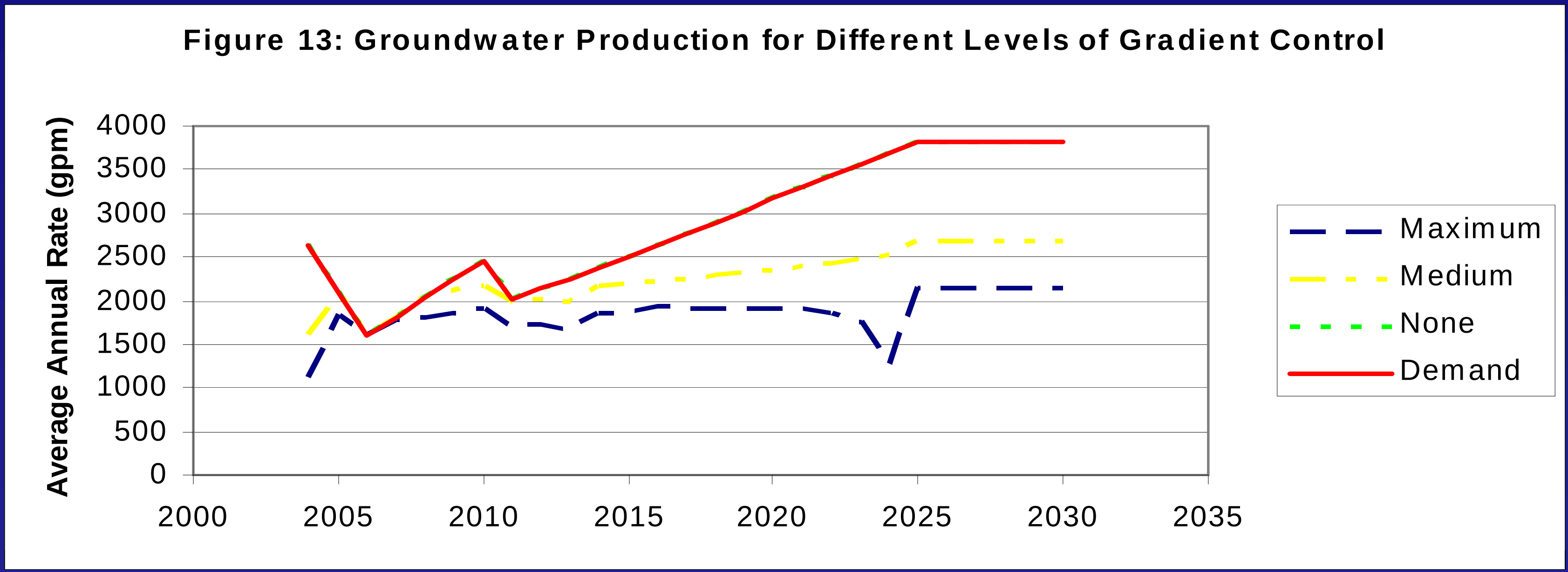
Level of Groundwater Quality Protection



Level of Groundwater Quality Protection

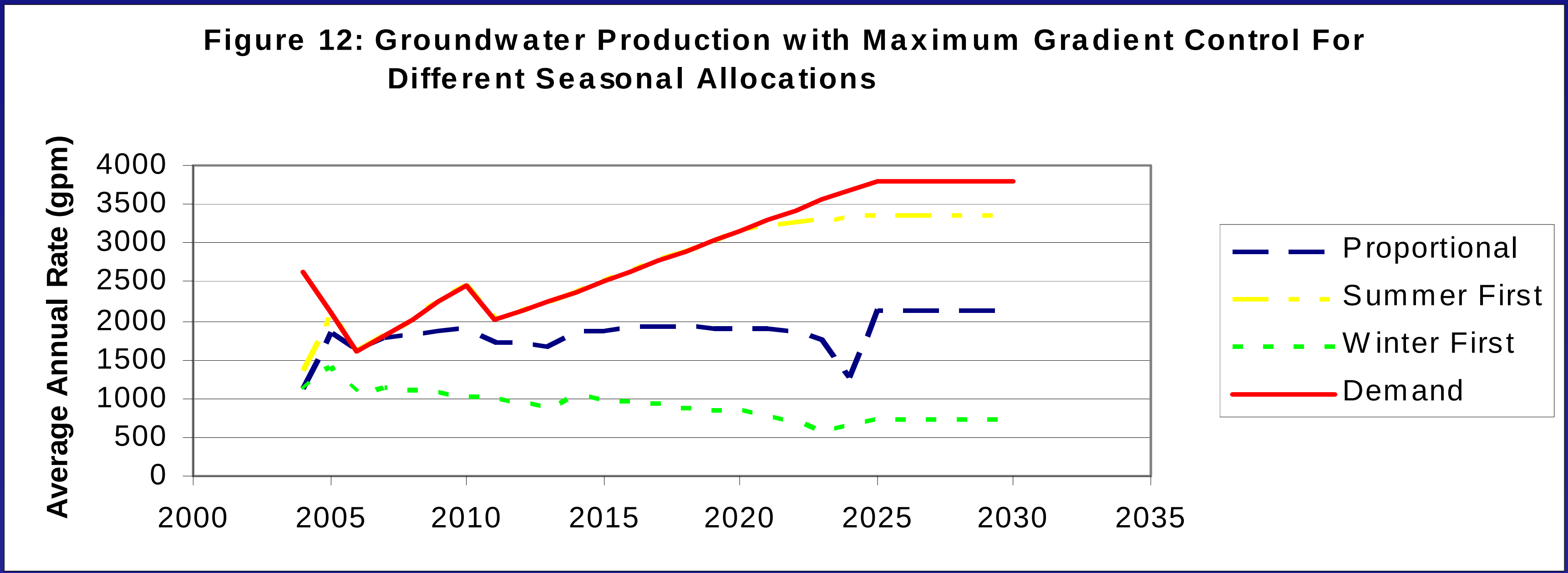


Level of Groundwater Quality Protection



Proportional Surface Water Allocation

Surface Water Seasonal Allocation



Maximum Level of Groundwater Protection

City B Groundwater Demand

Billions of Gallons Pumped By City A Over 27-Year Planning Horizon (under maximum gradient control)

GROWING

- **Proportional: 26**
- **Winter: 13**
- **Summer: 38**

SHRINKING

- **Proportional: 40**
- **Winter: 33**
- **Summer: 39**

Summary

- **Quality, rather than quantity, appears to be the issue.**
- **Unmanaged operation of the City wellfield would likely cause groundwater degradation by drawing high TDS water into the wellfield.**
- **Some wells are particularly vulnerable to the water quality degradation because of proximity to the TDS front.**
- **The water quality degradation problem could be exacerbated by City B’s pumping.**
- **Groundwater quality protection requires coordination between the two cities that pump groundwater.**

Summary (Cont.)

- **Current pumping rates may not be sustainable if groundwater quality is to be protected.**
- **Rotating the operation between wells could maximize the amount of pumping that can be performed.**
- **Allocation of surface water water to meet the summer demand would reduce the potential for water quality degradation.**

Questions

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