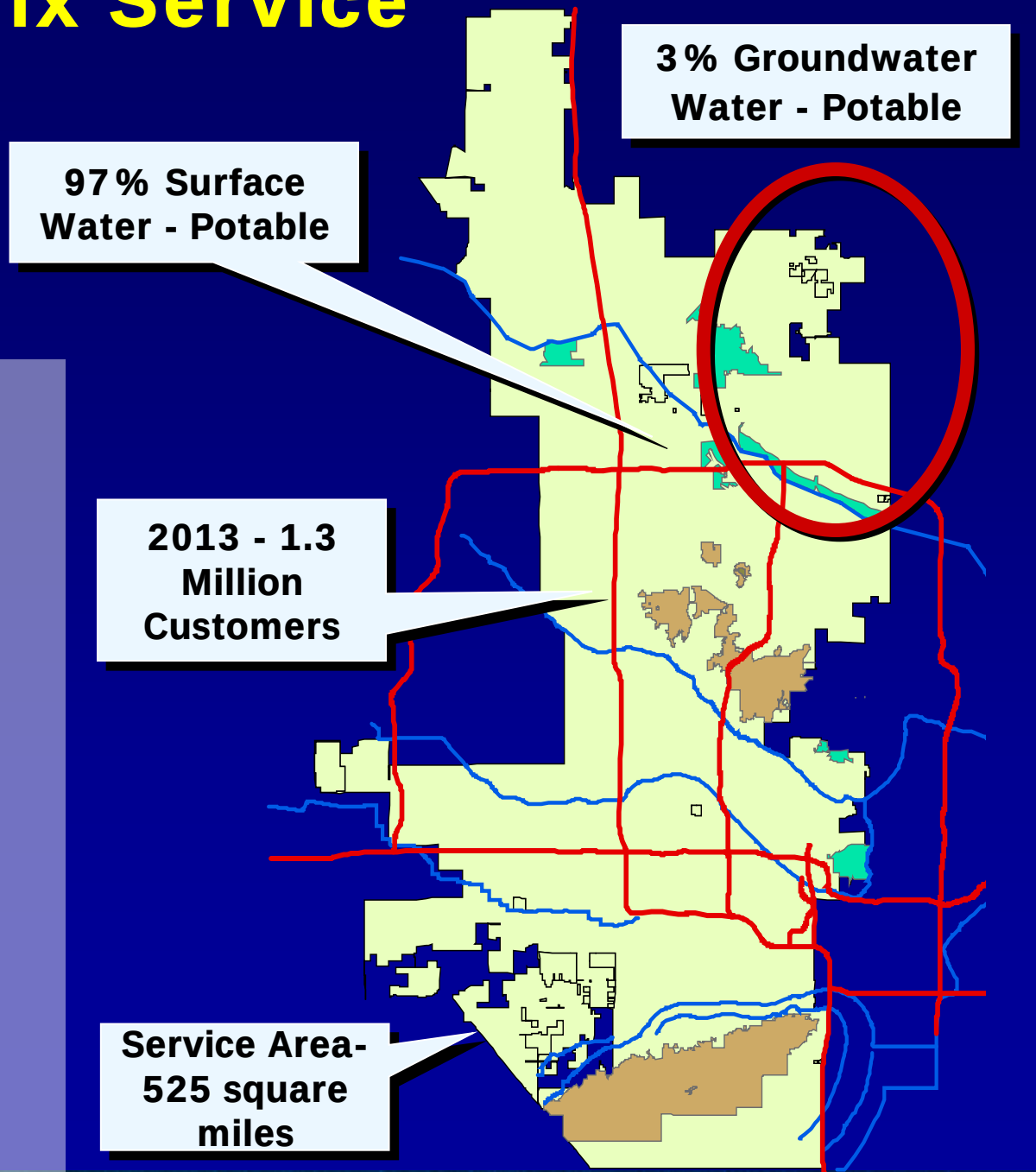
LeonardRice ENGINEERS, INC.

Advancements in ASR Well Design and Operations- City of Phoenix Case Study

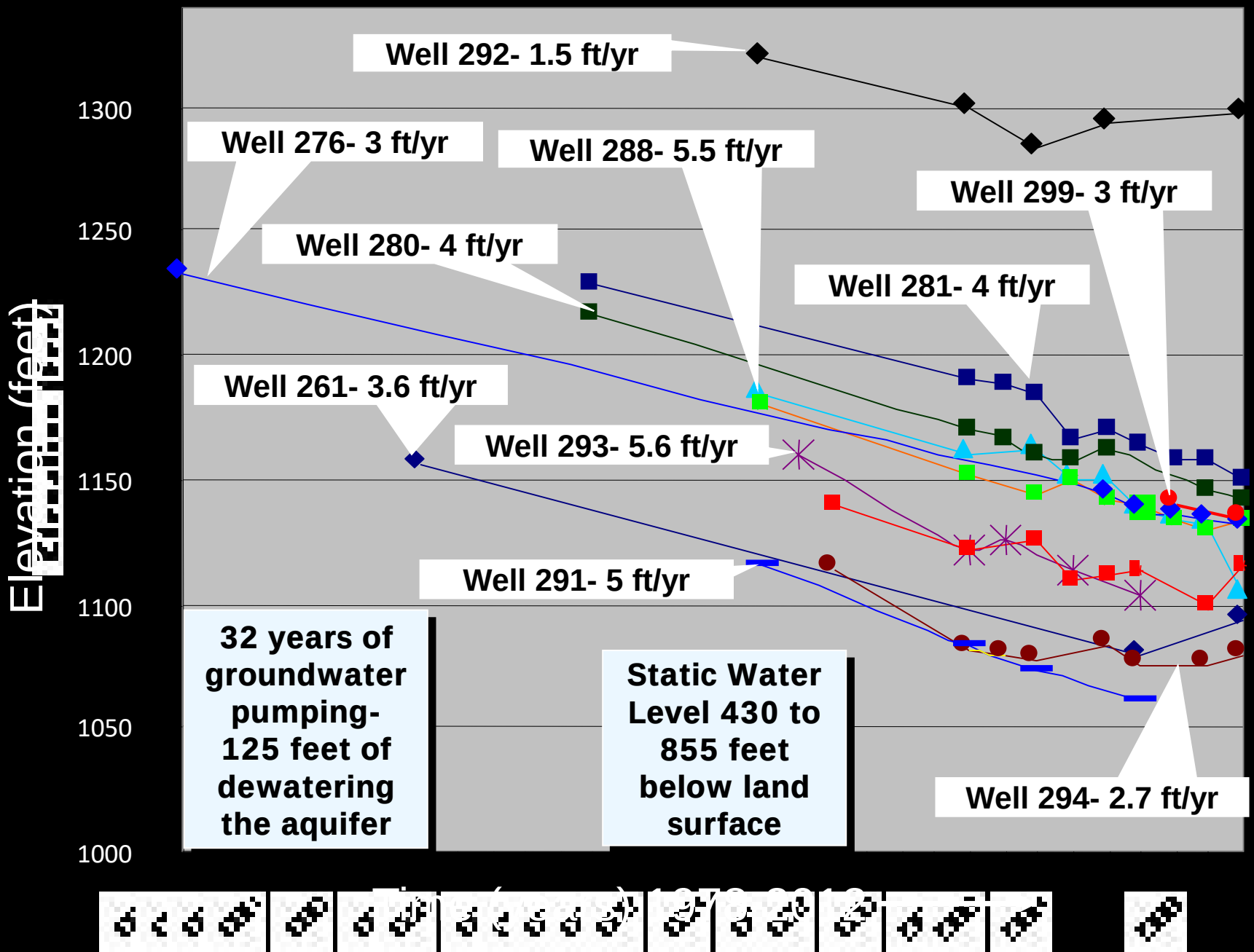
Presented By: Gary M. Gin, R.G., Vice President AZ Operations &
Aimée Conroy, P.E., Deputy Water Services Director

City of Phoenix

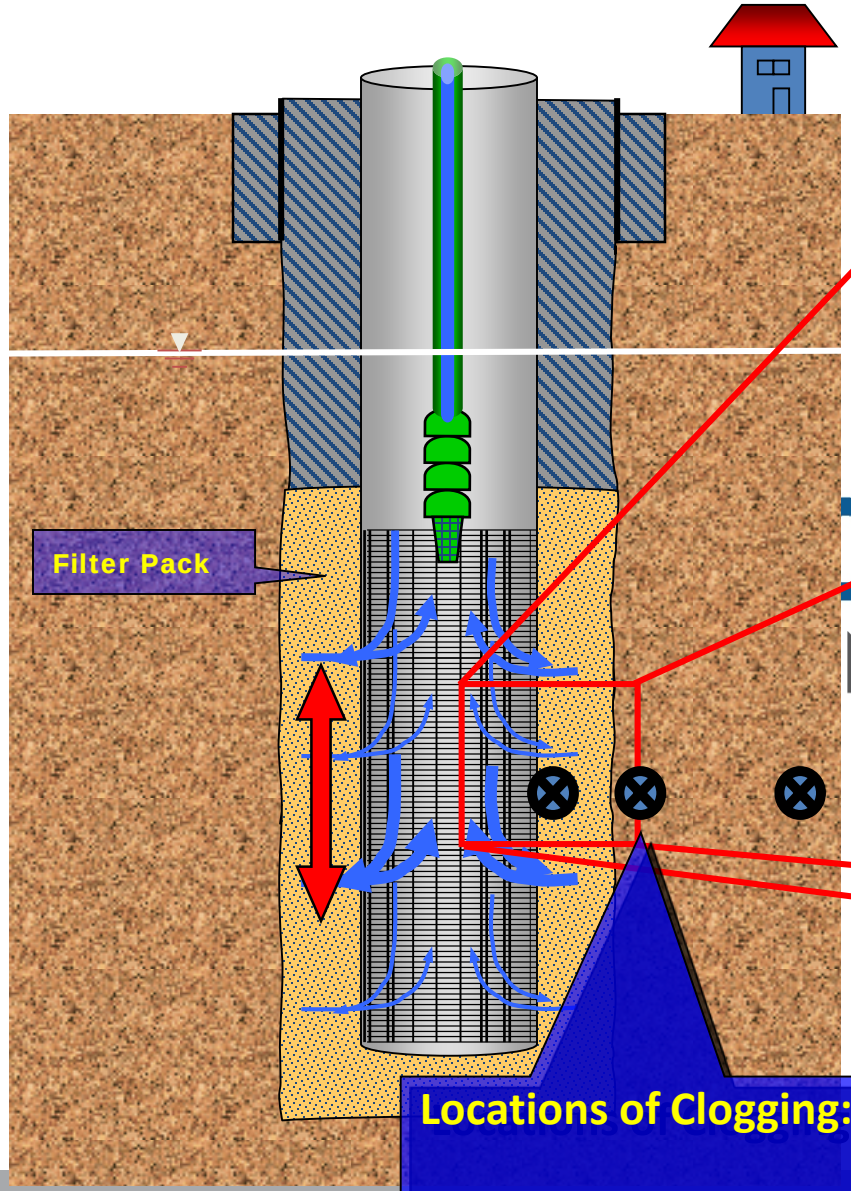
City of Phoenix Service Area



Phoenix Wells: Groundwater Levels



#1 ASR Well Issue: Reduced Injection Rates Due to Clogging



Increase connectivity between filter pack and borehole interface

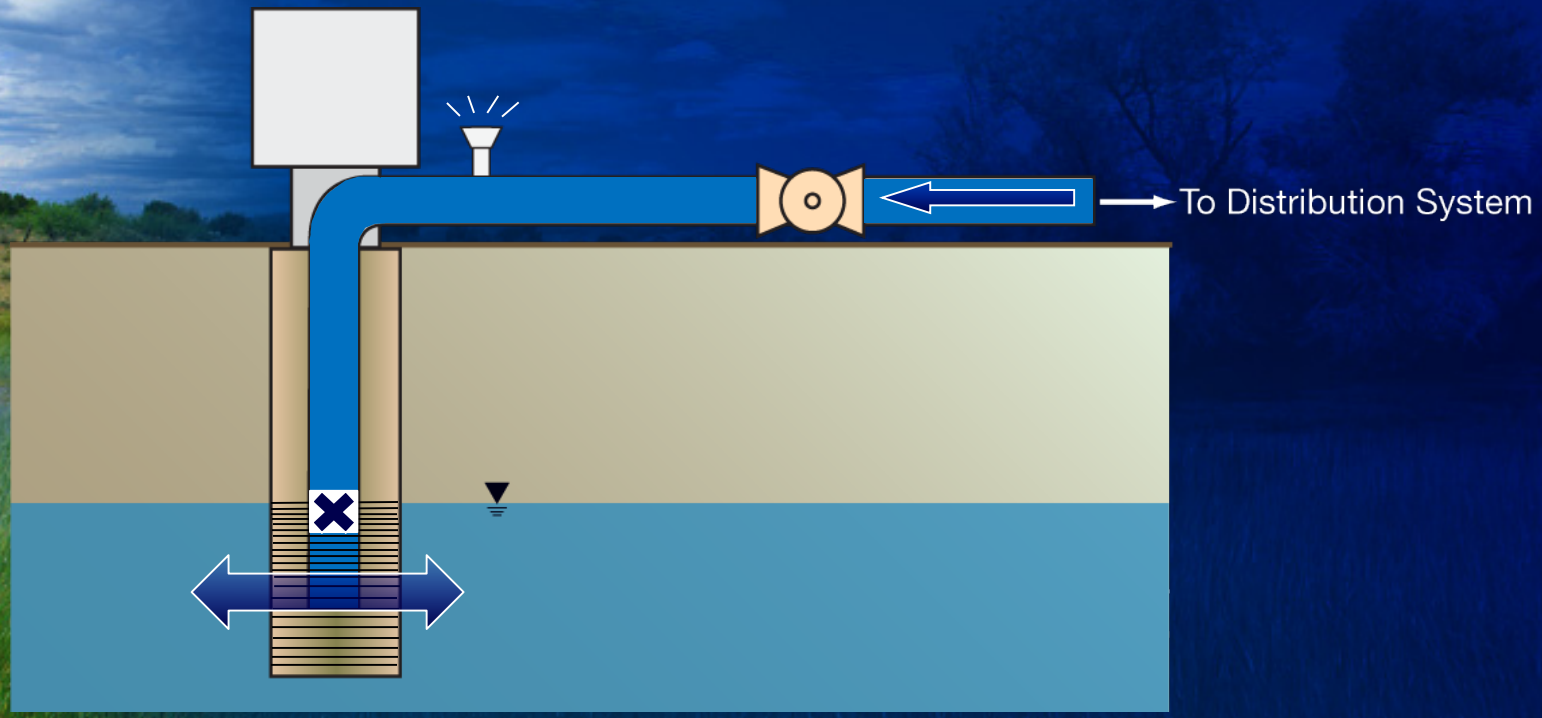
Implement injection and recovery cycles

- Air Binding
- Grain on Grain Contact: Abrasion
- Finer Grained Sediments and Particulates Filling Pore Spaces
- Cementation
- Dissolution
- Biofilm Development

Locations of Clogging:

Proximal Intermediate Distal

Down-Hole Flow Control Valve Concept



Conventional Methods of Recharge

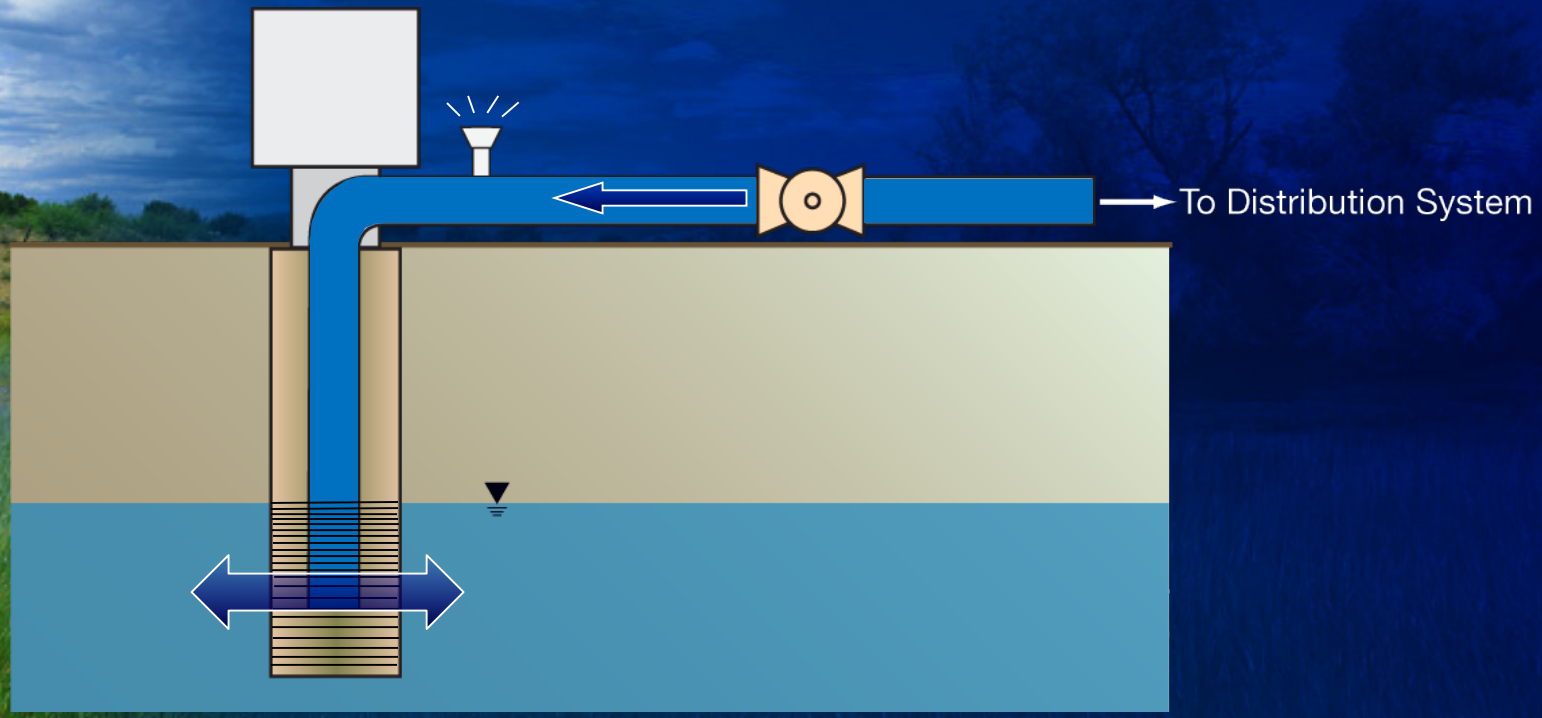
- Down-Hole Flow Control Valve
  - Eliminate Air Entrainment
  - Regulate Flow- Varied Supplies
- Down-Hole Flow Control Valve Issues
  - Not Operator Friendly
  - Valve Located Down-Well
  - Most Systems Cannot Determine Percent Opening
  - Valve has Potential to Leak
  - When Valve Fails- Requires the Valve and Pump to be Pull Out of Well- Extended Down Period.
  - Obtaining Manufacturer Replacement Parts May Require Long-Lead Time

Reverse Siphon Method

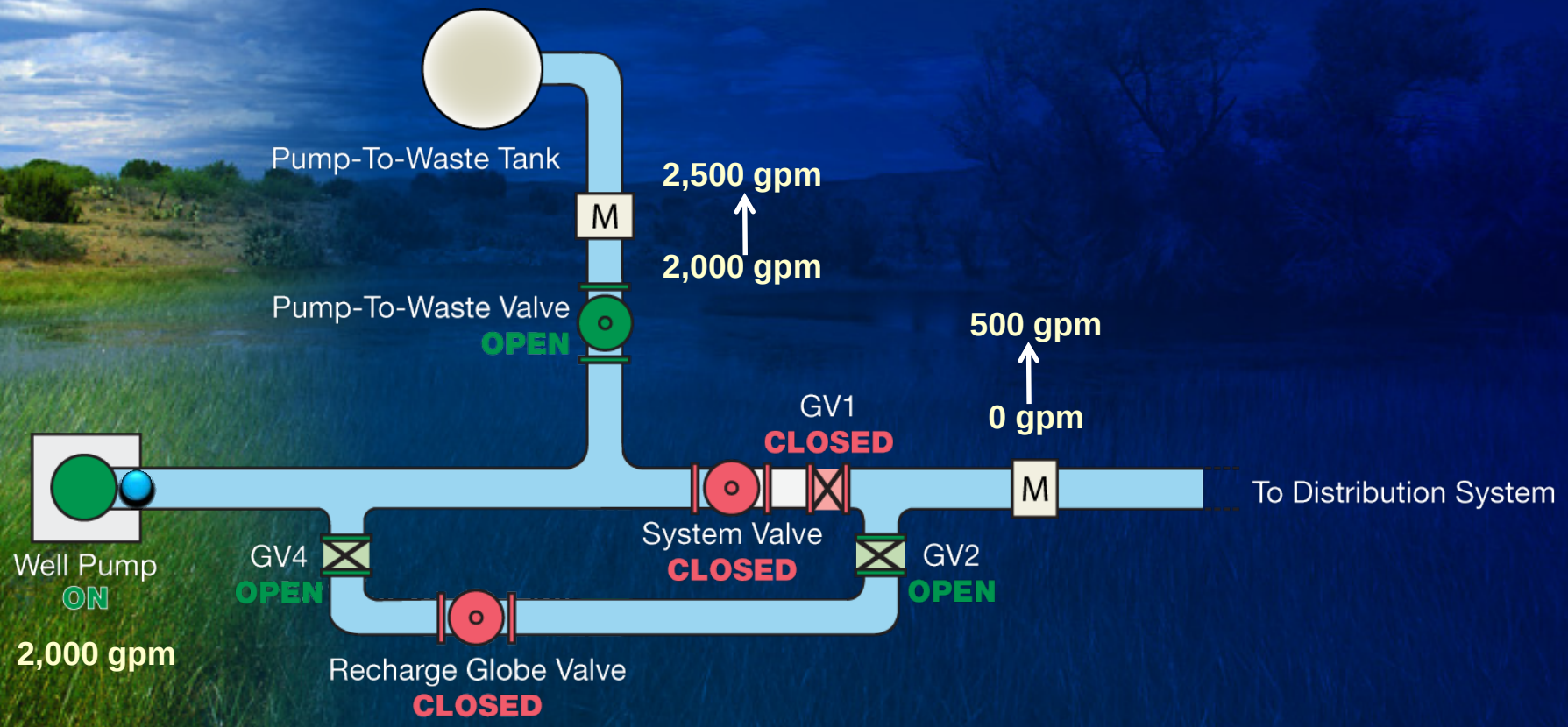
Our Goals & Priorities

- Reduce Air-Entrainment & Agents of Clogging
- All Equipment Serviceable & Not Exotic
- Fewer Mechanical Components = Lower O&M Costs
- Backwash Operations Achieved with Permanent Pump
- Automation-Reduce Labor Force Oversight
- Increase Recharge Utilization

Reverse Siphon Concept



Recharge Start-Up



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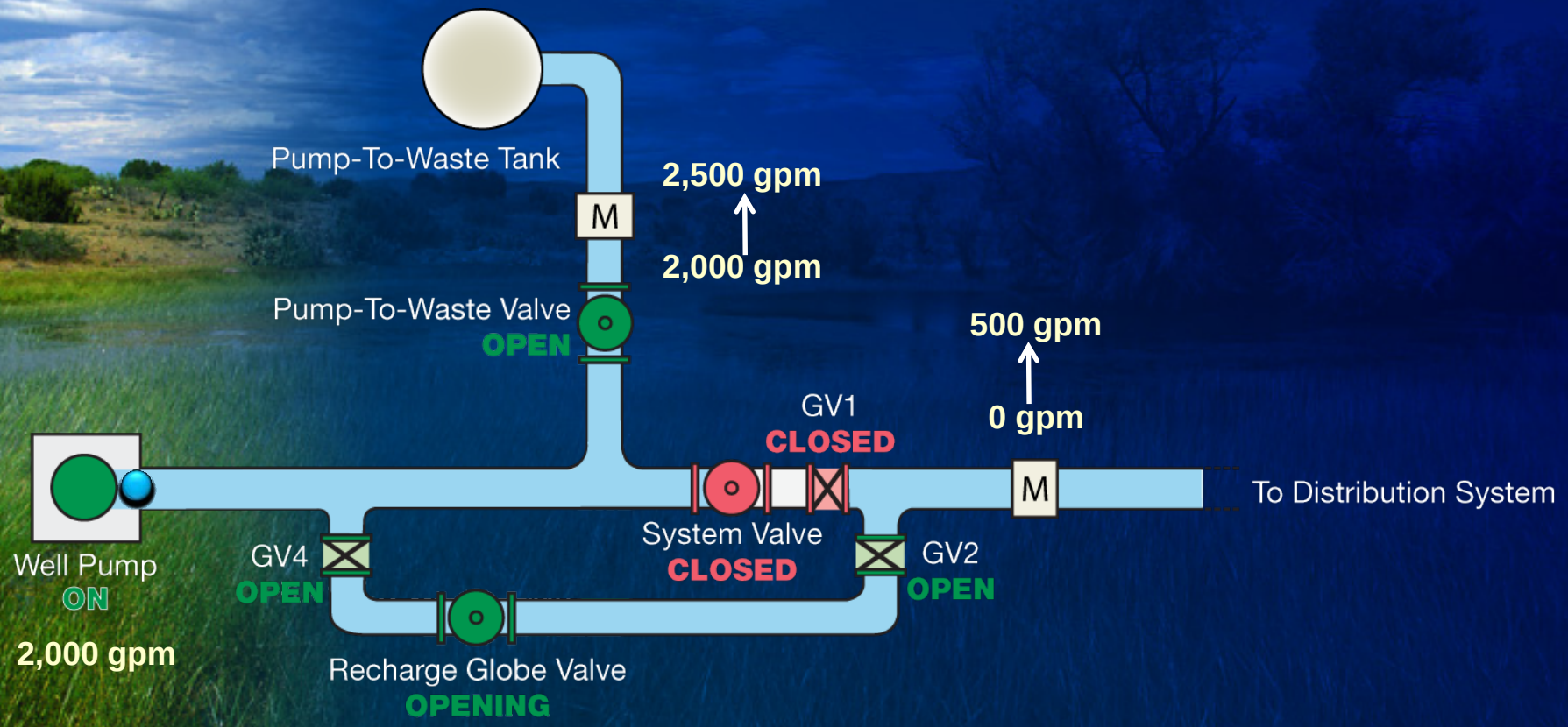

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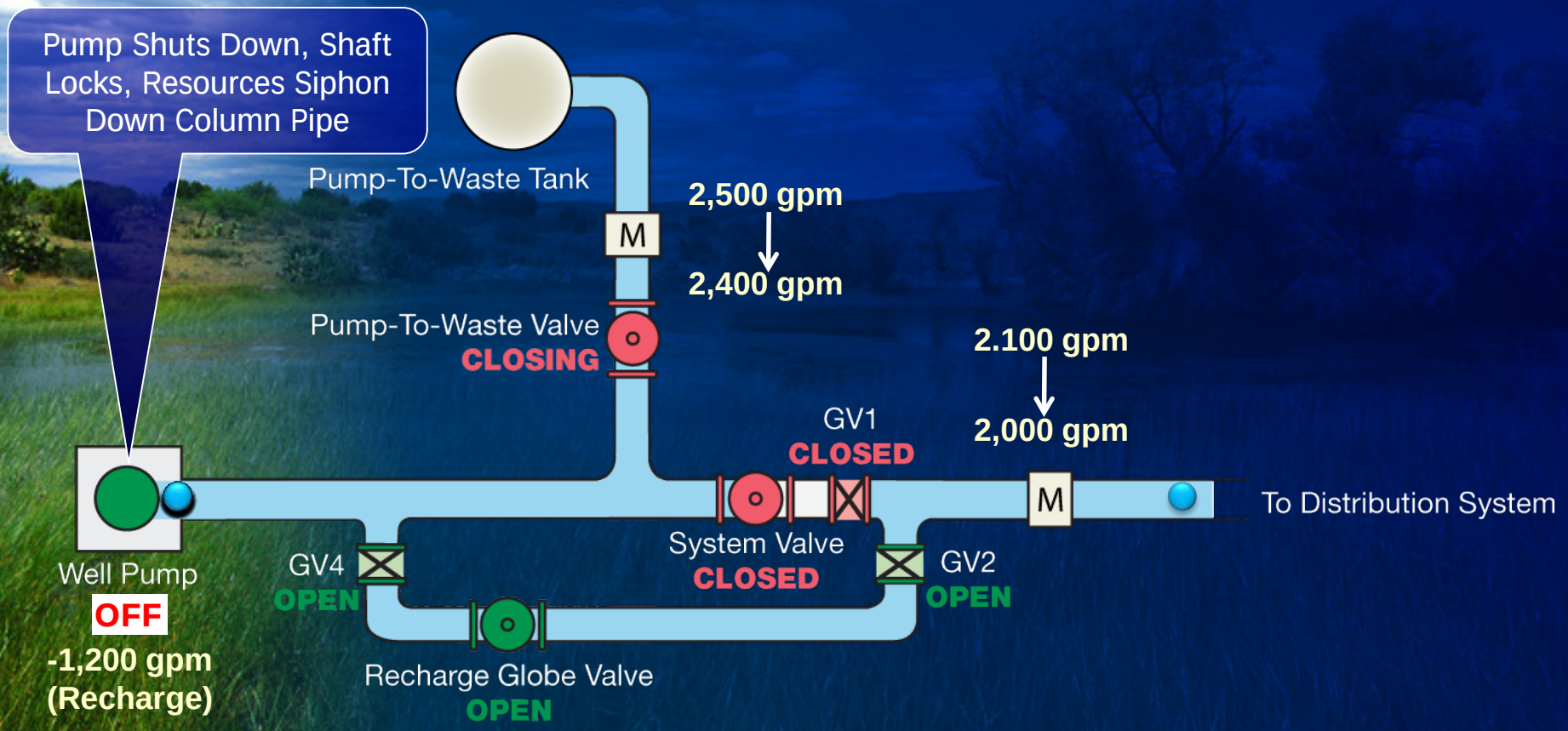

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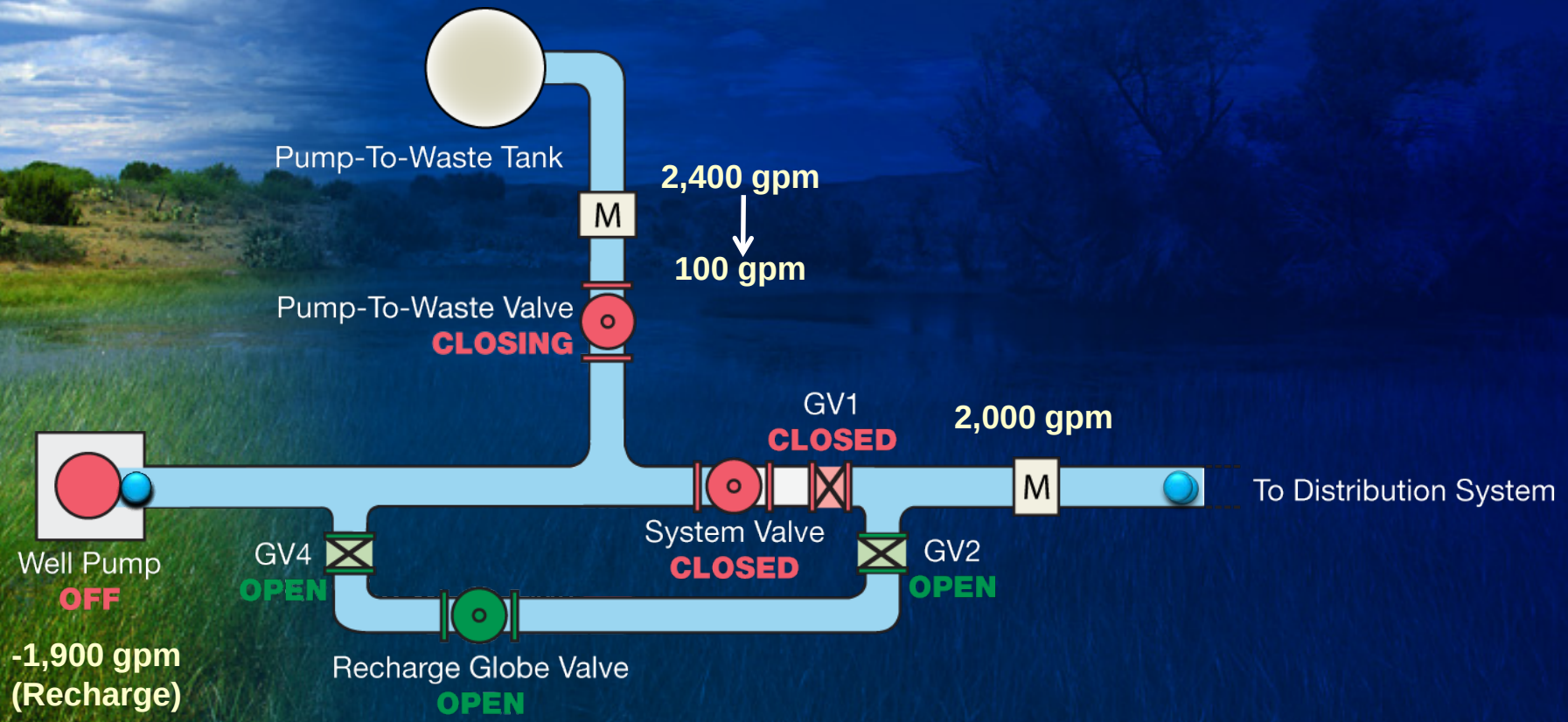

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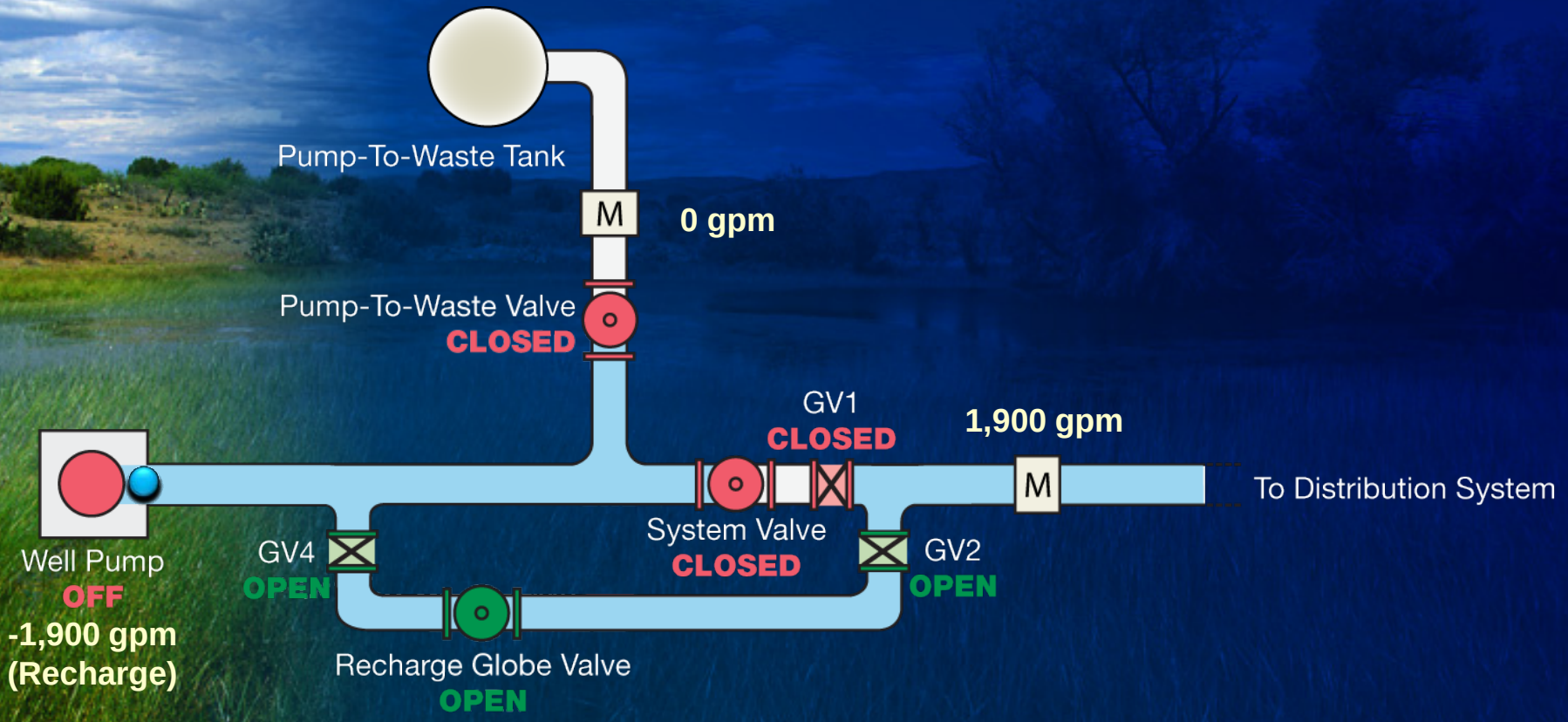
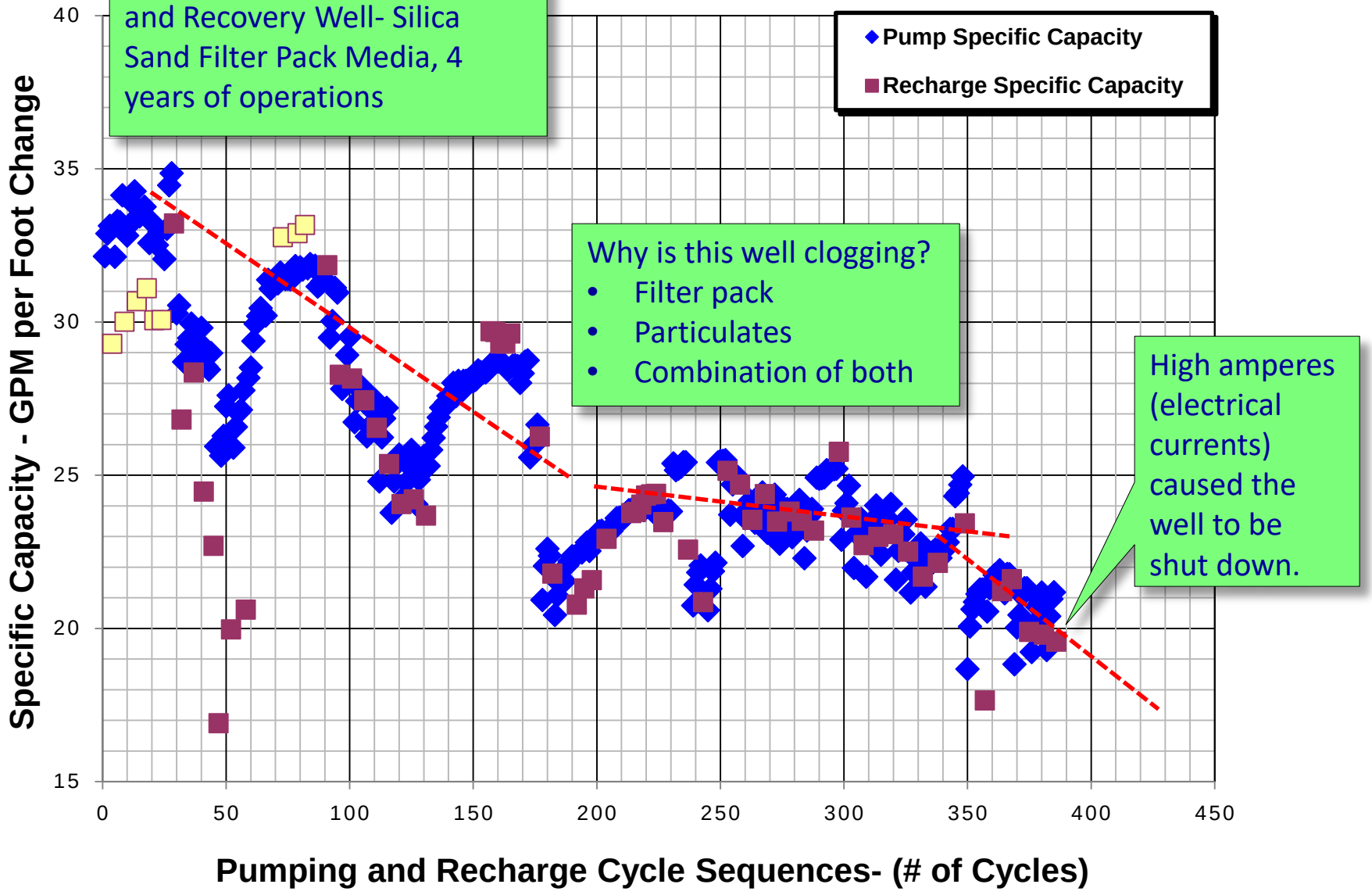
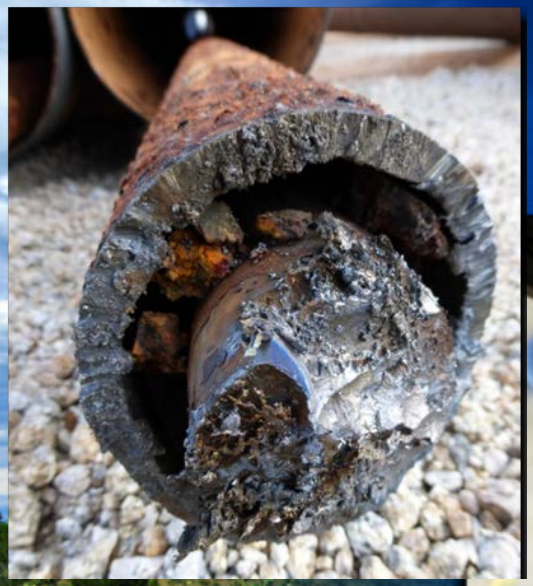


6A Well 299 Recharge Development and Operations
Specific Capacity

City of Phoenix



What Caused the Failure?



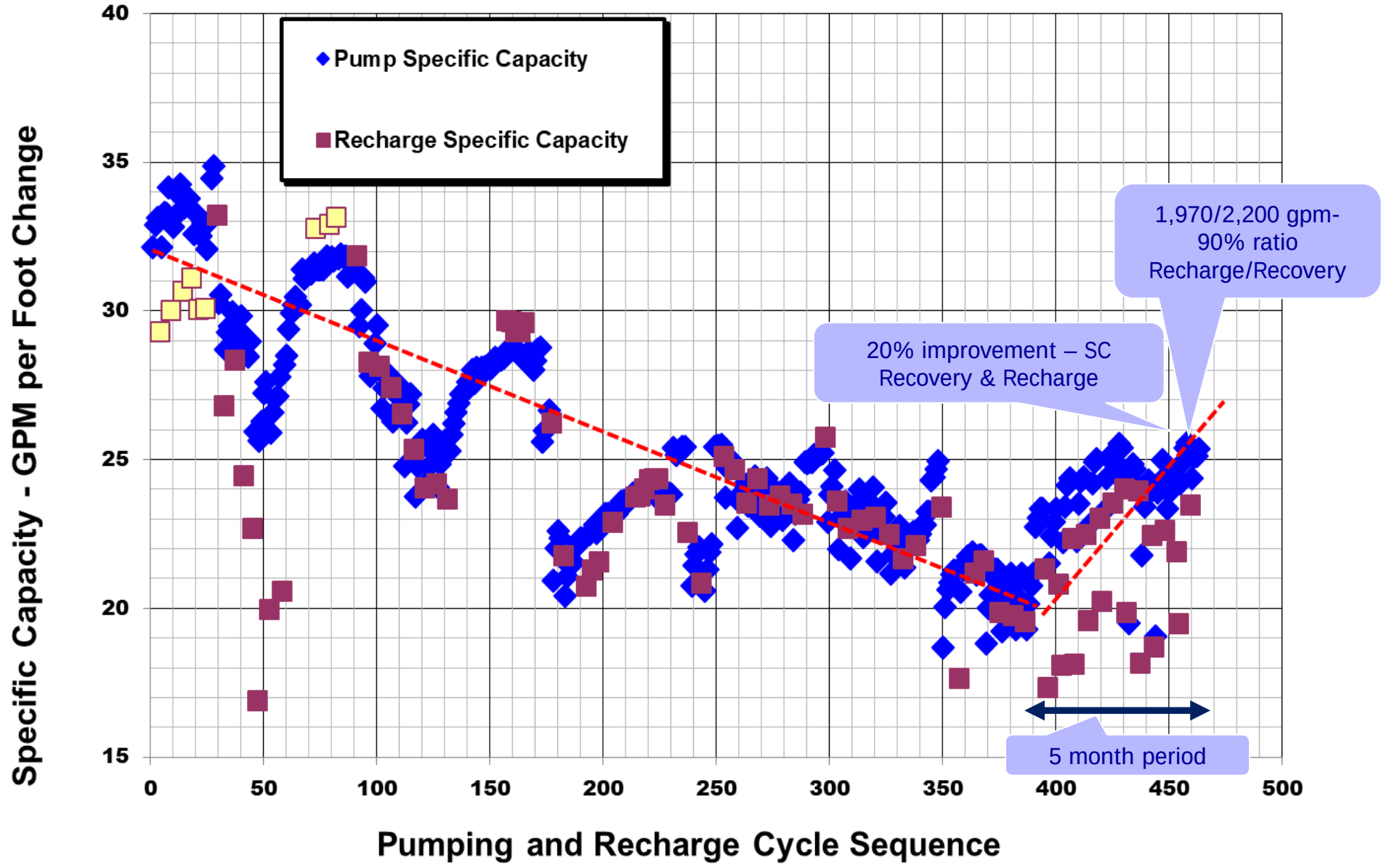
- Metallurgical & chemical reactions
  - Corrosion and pitting
  - Chemical cementation on shaft assembly
  - Formation of iron/manganese encrustation

Optimizing Well Performance

- Epoxy Coating:
  - Minimize clogging agents in well screens
  - Reduce chemical/biological reactions

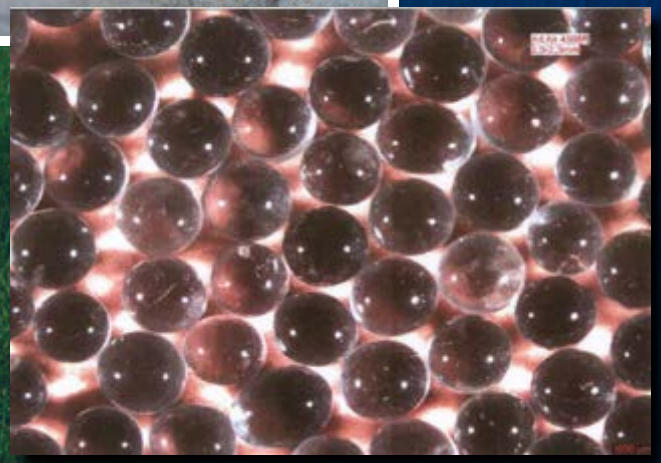
Phoenix 6A Well 299 Recharge Development and Ops
Specific Capacity Changes

City of Phoenix

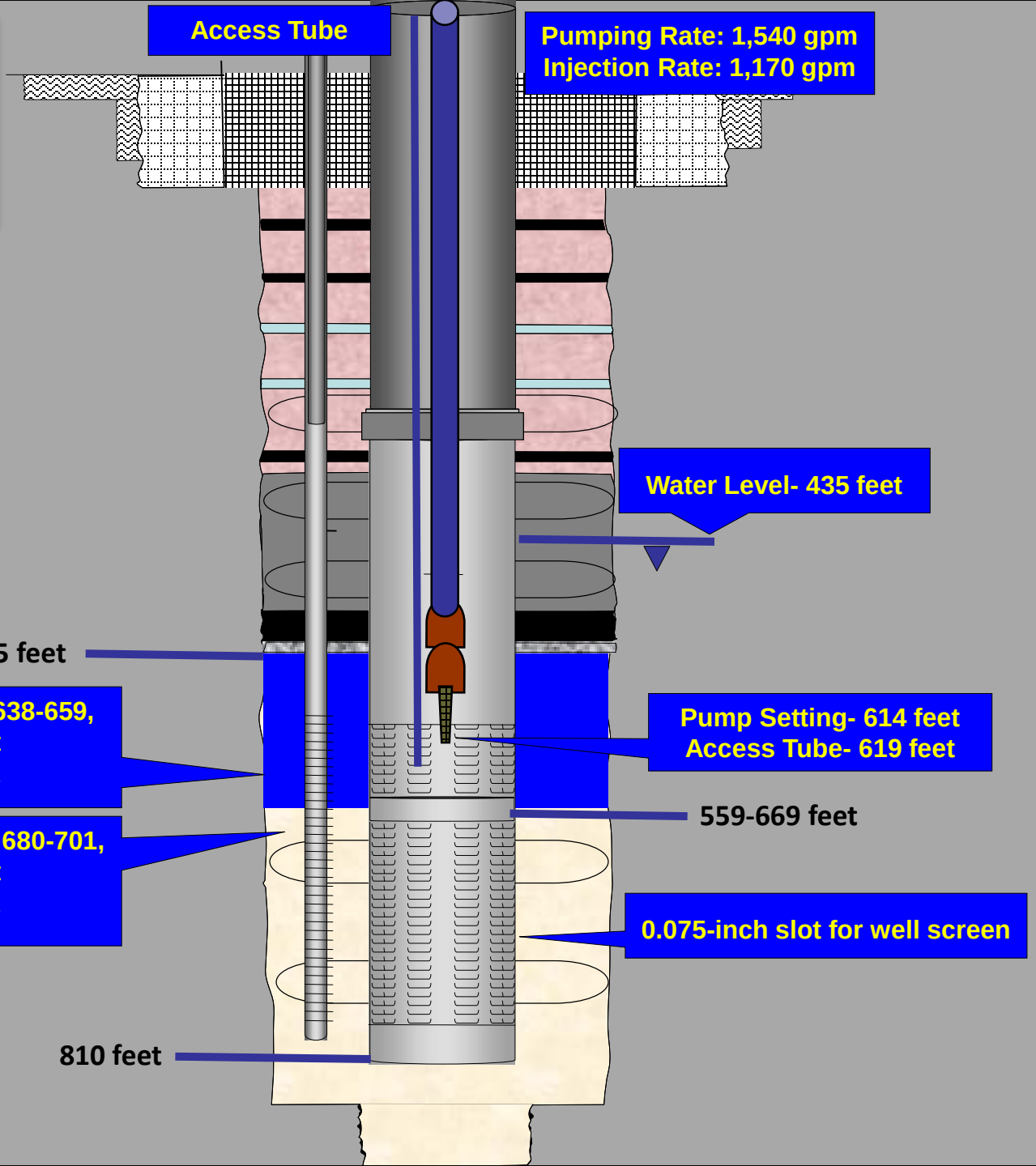


Advancements in ASR Well Design

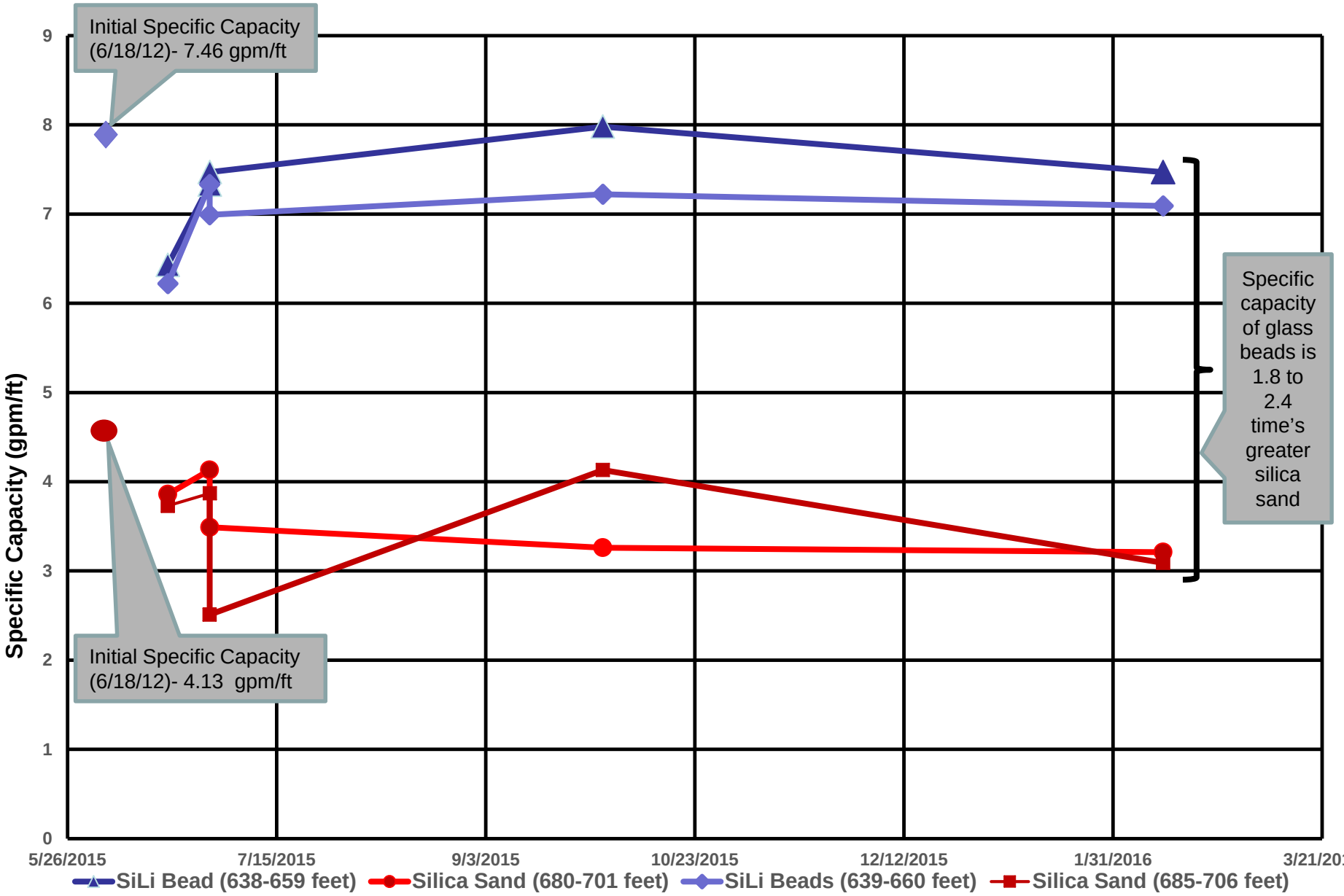
- Utilize Glass Beads as a Filter Pack Media:
  - Enhance recharge and recovery efficiencies
  - Compared SiLi Beads 2.4-2.9mm versus Silica Sand 6 x 9
  - Direct Relation Between Sorting and Porosity (Beard and Weyl, 1973 & Nagtegaal, 1978)



Cave Creek Aquifer Storage and Recovery Well: As-Built



Recovery: Formation Yield: Specific Capacity (gpm/ft): SiLi Beads (638-659, 639-660 ft) vs. Silica Sand (680-701, 685-706 ft)



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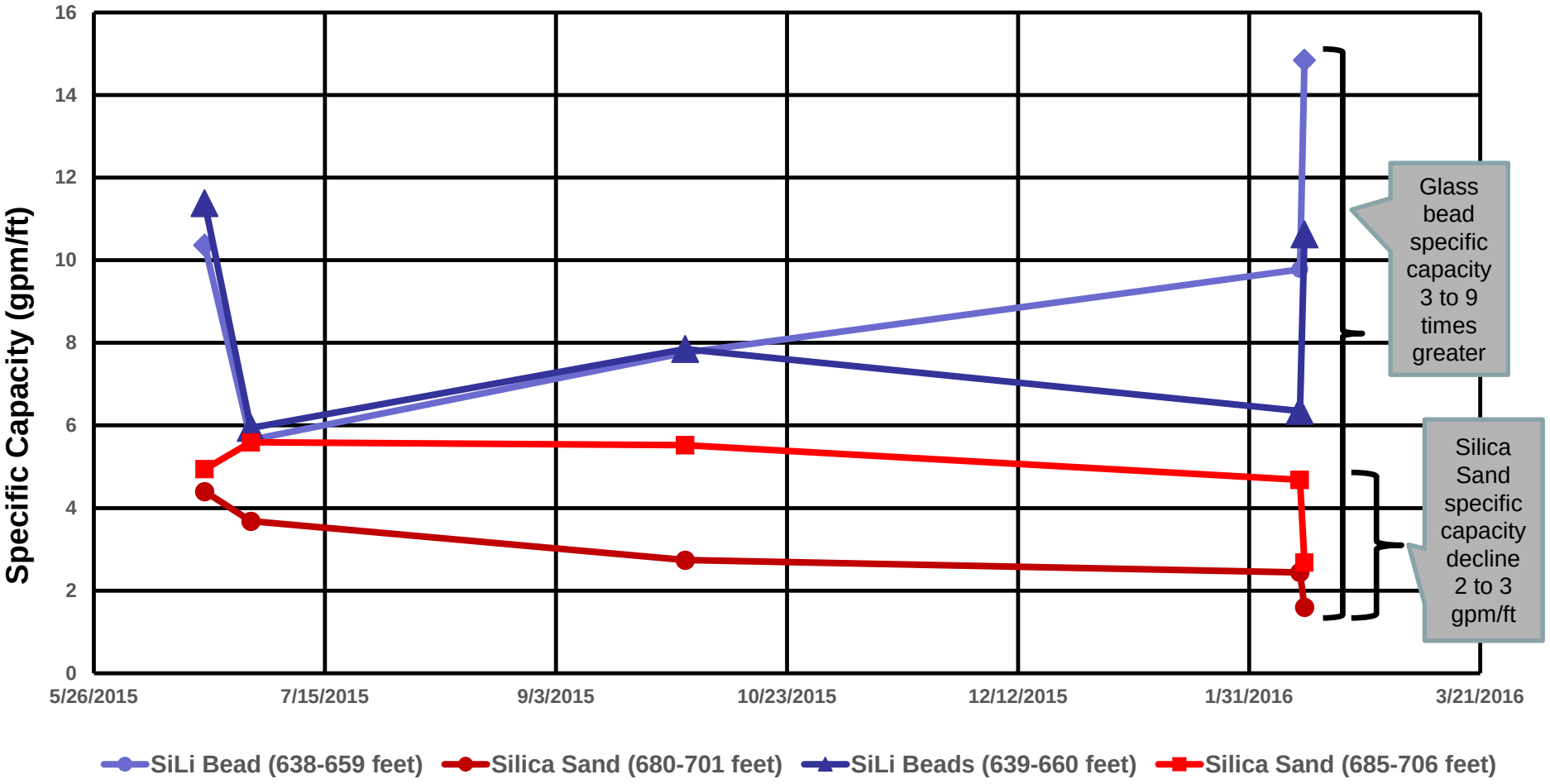
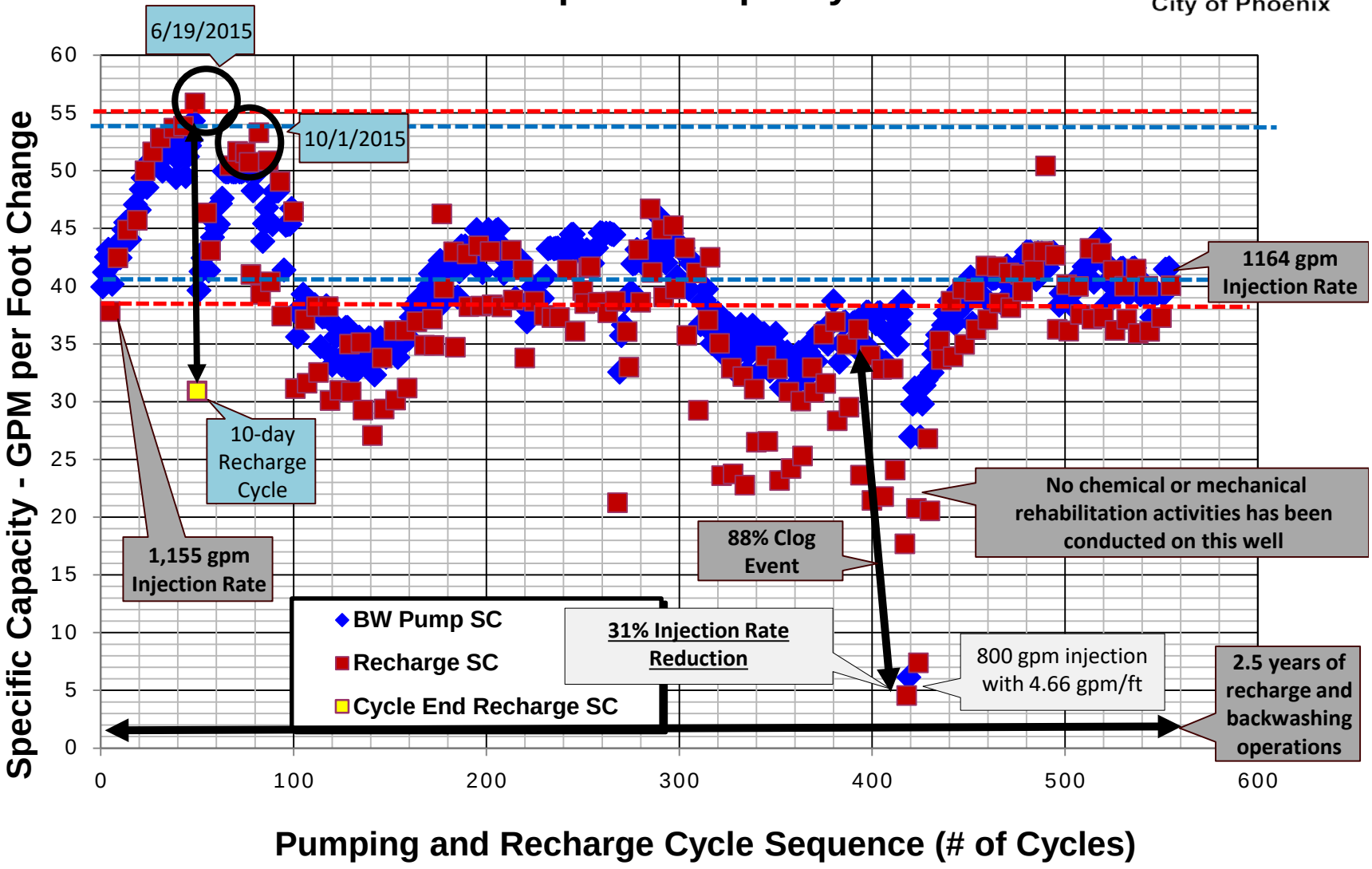


Cave Creek Water Reclamation Plant ASR Well-1
Specific Capacity

City of Phoenix



Clogging Agents- Recharge Source Line

Conclusions

- Glass Beads- Alternative Filter Pack
  - Improved Hydraulics
  - More Efficient Backwashing Operations
  - Increase Efficiency 50-60 % for Recharge Operations
- Epoxy Coating
  - Reduced clogging potential
  - Extended Life-Cycle of Column Pipe and Tube Assembly
  - Lowered O&M Costs
  - Less Expensive than Stainless Steel

Conclusions

- Reverse Siphon- Alternative Recharge Method
  - Operator Friendly
  - Efficient Backwashing Operations through Automation
  - Eliminates Air Entrainment and Reduces Clogging Agents
  - Well Development through the Permanent Pump Assembly
  - Capital Cost for the Surface Recharge Valve is less than Conventional Flow Controls Valves
  - Lower O&M Costs
  - Cost Effective (Well Rehabilitation Savings $110K to $150K/year per well)
  - Reliable and Stable Recharge Operations

Questions

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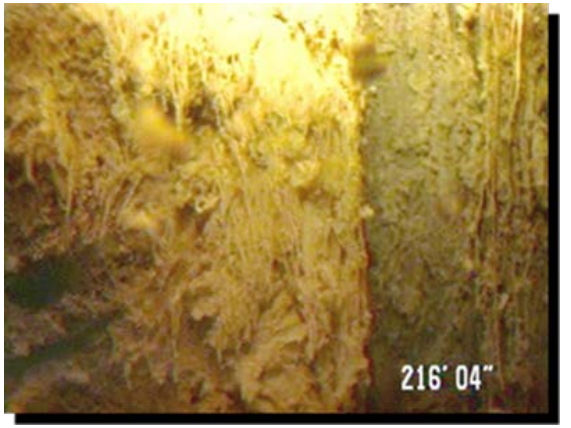

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