Naval Facilities Engineering Command
ENGINEERING AND EXPEDITIONARY WARFARE CENTER

Open Environmental Restoration Resource (OER2) Webinar

Rehabilitation and Maintenance of Pump and Treat Systems

Presented by:
NAVFAC Environmental Restoration Program

January 31, 2018

Logistics

- **Submit all questions via chat box throughout the presentation**
- **Presentation is being recorded**
- **Complete the webinar survey (main feedback mechanism)**

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Speaker Introduction

Jennifer Segura, P.E. – Environmental Engineer

NAVFAC EXWC, Port Hueneme, CA

Experience in remediation and environmental compliance working for US Navy and private consulting. Focus areas include site characterization and monitoring, groundwater remediation, and remedy optimization. Has presented several remediation topics in various Navy and industry forums. Currently leading multiple ESTCP and NESDI projects on innovative technologies.

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Speaker Introduction

Fred Payne, Ph.D. – Chief Scientist, Arcadis

35+ years in soil and groundwater restoration. Early focus on in-situ remediation technology development; current focus on aquifer structure and its impact on contaminant flux and remedy effectiveness.

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Jay Erickson, P.G. – Technical Expert, Arcadis

27+ years in remediation system design, operation and optimization. Mr. Erickson works on large, complex groundwater remediation systems that utilize multiple technologies. Additionally specializes in well rehabilitation and design.

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OER2 Webinar Series

- **Why Attend?**
  - Obtain and hear about the latest DOD and DON's policies/guidance, tools, technologies and practices to improve the ERP's efficiency
  - Promote innovation and share lessons learned
  - **FEEDBACK** to the ERP Leadership
- **Who Should Attend?**
  - ERP Community Members: RPMs, RTMs, Contractors, and other remediation practitioners who support and execute the ERP
  - Voluntary participation
- **Schedule and Registration:**
  - Every other month, 4th Wed (can be rescheduled due to holidays)
  - Registration link for each topic (announced via ER T2 email)
- **Topics and Presenters:**
  - **ERP community members** to submit topics (non-marketing and DON ERP-relevant) to POCs (Gunarti Coghlan – gunarti.coghlan@navy.mil or Tara Meyers – tara.meyers@navy.mil)
  - Selected topic will be assigned Champion to work with presenter

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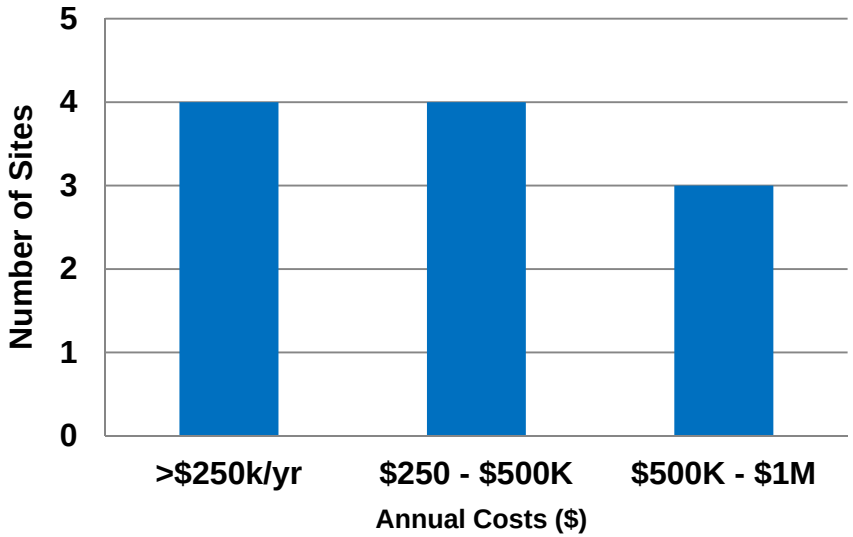
Rehabilitation and Maintenance of Pump and Treat Systems

Jennifer Segura, P.E., NAVFAC EXWC
Fred Payne, Ph.D., Arcadis
Jay Erickson, P.G., Arcadis

Navy Need
- Several legacy P&T Systems still functioning

- **Most were installed in the 1990's (oldest system is the one at NIROP Fridley, installed 1992)**
- **Capturing plumes of TCE, PCE, cis-1,2 DCE, VC, as well as emerging contaminants like 1,2 DCA, RDX, 1,4 dioxane**
- **Most P&T systems continue to effectively capture and treat target contaminants**



Breakdown of Annual O&M Costs for 11 P&T Systems (Data Source: NAVFAC)

Navy Need
- Several legacy P&T Systems still functioning

- **P&T systems included both injection wells and extraction wells**
- **Aging systems require periodic rehabilitation or replacement of wells/other components to avoid longer downtimes and loss of capture**
- **What are the best management practices (BMPs) that RPMs can use to get the most benefit out of and lower the cost of long-term O&M of P&T systems?**
  - **Production Well Construction and Maintenance Guide**

https://www.navfac.navy.mil/content/dam/navfac/Specialty%20Centers/Engineering%20and%20Expeditionary%20Warfare%20Center/Environmental/Restoration/er_pdfs/p/navfacexwc-ev-fs-1708-prodwellmaintenance-201704.pdf

Poll # 1

- **Are you currently managing or working at sites where P&T systems are installed?**
  - **Yes**
  - **No**

Poll # 2

- **For those of you working with P&T systems have you had significant downtime in the in the last 2 years?**
  - **Yes**
  - **No**
  - **Never worked with P&T systems before**

Poll # 3

- **For P&T systems experiencing downtime, is the cause primarily due to:**
  - **Well fouling or pump issues**
  - **Aboveground treatment system fouling**
  - **Mechanical/electrical breakdowns**
  - **Other**
  - **Never worked with P&T systems before**

Poll # 4

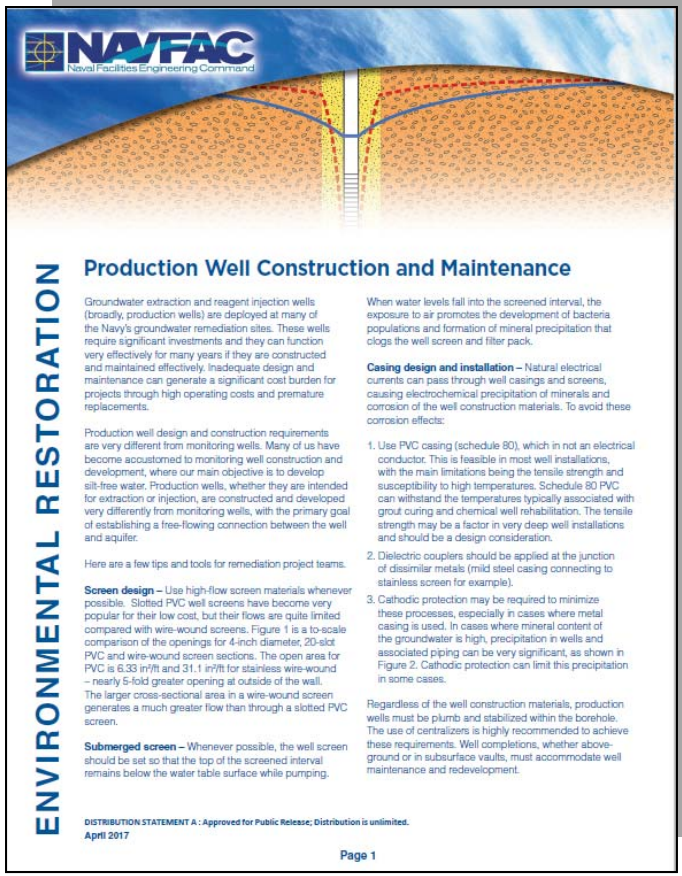
- **For those of you who have been involved with P&T systems before, have you had to replace an extraction well in the last 2 to 3 years?**
  - **Yes**
  - **No**
  - **Never worked with P&T systems before**

Outline

1. **Foundation – the importance of P&T system well maintenance, design and installation practices**
2. **Processes that reduce well performance**
3. **Tracking indicators and improving performance**
4. **Well maintenance methods**
5. **Case study examples**
6. **Key Tip for well installation**
7. **Importance of well development**
8. **Summary**

Overview

- **Maintenance programs:**
  - **Closely monitor well performance**
  - **Intervene to conduct maintenance before irreversible damage occurs**
  - **Continuously meet remedy objectives**
  - **Minimize project life-cycle costs**
- **Replacement Well Designs:**
  - **Focus on key installation QC elements**
  - **Invest in well development**
  - **Minimize project life-cycle costs**



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ENVIRONMENTAL RESTORATION

Production Well Construction and Maintenance

Groundwater extraction and reagent injection wells (broadly, production wells) are deployed at many of the Navy's groundwater remediation sites. These wells require significant investments and they can function very effectively for many years if they are constructed and maintained effectively. Inadequate design and maintenance can generate a significant cost burden for projects through high operating costs and premature replacements.

Production well design and construction requirements are very different from monitoring wells. Many of us have become accustomed to monitoring well construction and development, where our main objective is to develop silt-free water. Production wells, whether they are intended for extraction or injection, are constructed and developed very differently from monitoring wells, with the primary goal of establishing a free-flowing connection between the well and aquifer.

Here are a few tips and tools for remediation project teams.

Screen design – Use high-flow screen materials whenever possible. Slotted PVC well screens have become very popular for their low cost, but their flows are quite limited compared with wire-wound screens. Figure 1 is a to-scale comparison of the openings for 4-inch diameter, 20-slot PVC and wire-wound screen sections. The open area for PVC is 6.33 in²/ft and 31.1 in²/ft for stainless wire-wound – nearly 5-fold greater opening at outside of the wall. The larger cross-sectional area in a wire-wound screen generates a much greater flow than through a slotted PVC screen.

Submerged screen – Whenever possible, the well screen should be set so that the top of the screened interval remains below the water table surface while pumping.

When water levels fall into the screened interval, the exposure to air promotes the development of bacteria populations and formation of mineral precipitation that clogs the well screen and filter pack.

Casing design and installation – Natural electrical currents can pass through well casings and screens, causing electrochemical precipitation of minerals and corrosion of the well construction materials. To avoid these corrosion effects:

1. Use PVC casing (schedule 80), which in not an electrical conductor. This is feasible in most well installations, with the main limitations being the tensile strength and susceptibility to high temperatures. Schedule 80 PVC can withstand the temperatures typically associated with grout curing and chemical well rehabilitation. The tensile strength may be a factor in very deep well installations and should be a design consideration.
2. Dielectric couplers should be applied at the junction of dissimilar metals (mild steel casing connecting to stainless screen for example).
3. Cathodic protection may be required to minimize these processes, especially in cases where metal casing is used. In cases where mineral content of the groundwater is high, precipitation in wells and associated piping can be very significant, as shown in Figure 2. Cathodic protection can limit this precipitation in some cases.

Regardless of the well construction materials, production wells must be plumb and stabilized within the borehole. The use of centralizers is highly recommended to achieve these requirements. Well completions, whether above-ground or in subsurface vaults, must accommodate well maintenance and redevelopment.

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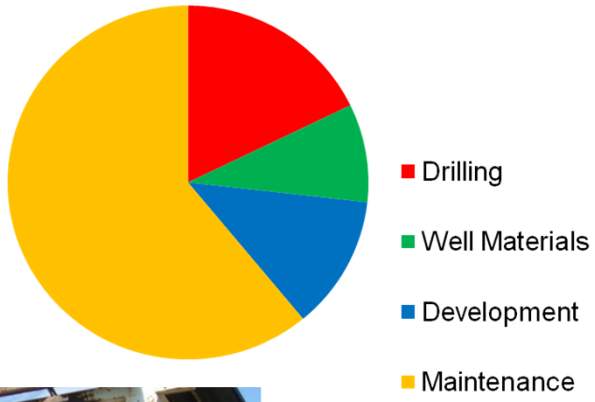
Page 1

Well Maintenance Programs

<u>Objective:</u> To monitor performance and step in proactively to maintain well performance and avoid costly failures.



Three areas of focus:

- **Processes that diminish well performance**
- **Performance tracking**
- **Deciding when to redevelop and rehabilitate**

Processes that Diminish Well Performance

- **Scaling**
- Sanding
- Bio-fouling
- Corrosion

- Calcium carbonate
- calcium sulfates
- iron oxides
- manganese oxides
- silica minerals

Forms on

- well screens
- pump impellers
- flow meters
- transducers
- level switches
- pipe surfaces
- treatment equipment

Processes that Diminish Well Performance

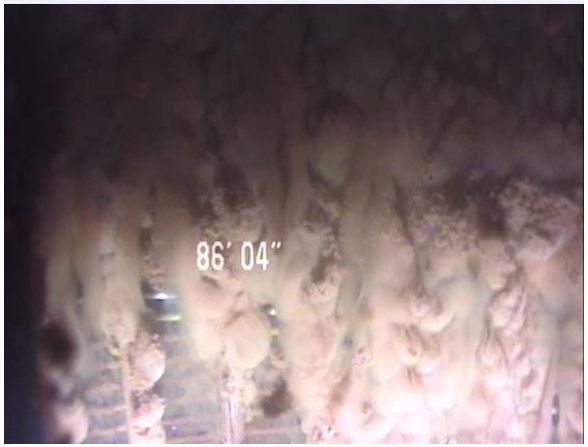
- Scaling
- **Sanding**
- Bio-fouling
- Corrosion

- **sand**
- **silt**
- **formation mud**
- **drilling solids**

- **abrasion on parts**
- **fills wells**
- **particulates in discharge**
- **ground settlement**

Processes that Diminish Well Performance

- Scaling
- Sanding
- **Bio-fouling**
- Corrosion



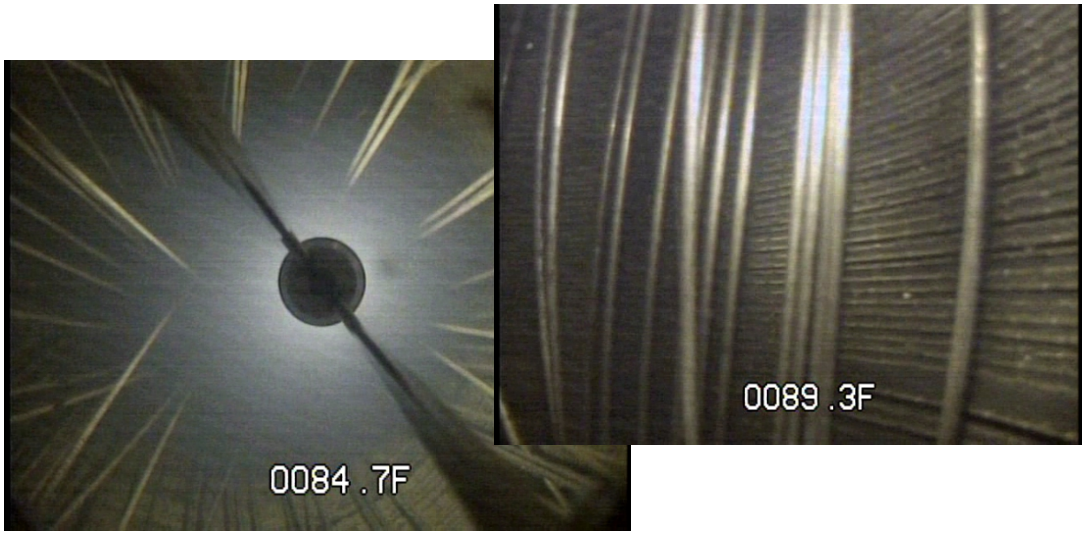
- **Extra cellular polymers (ECP) "slimes" deposited by a wide variety of bacteria**
- **Prevalent at fringes or borders**
- **Bio-accumulation of organic molecules and metals**
- **associated with gas generation and corrosion**

Clogs well screens, intakes, piping systems and components

Processes that Diminish Well Performance

- Scaling
- Sanding
- Bio-fouling
- **Corrosion**

- **microbial based corrosion**
- **aggressive water**
- **dissimilar metals**



Causes damage to

- **screen**
- **casing**
- **piping**
- **equipment**
- **valves/fittings**

Impacts of Deteriorating Well Performance

- **Increased electrical cost**
- **Increased O&M costs**
- **Failure to achieve remedial objectives**
- **Clogging or damage to downstream infrastructure**
- **Increased project life cycle cost and failure to meet projected timelines.**

Bag filters

Distribution piping

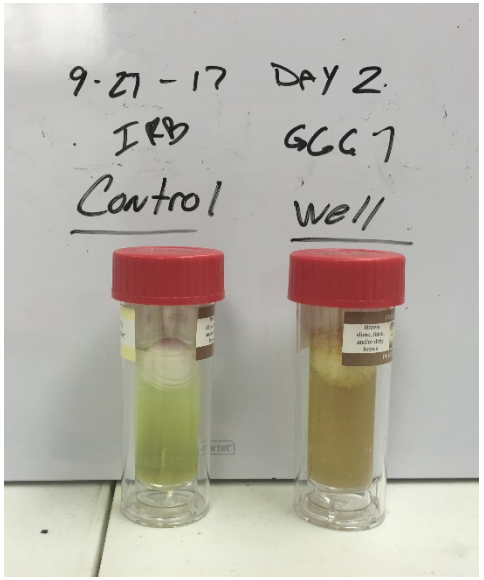
Well collapse

Performance Tracking – Knowing When to Rehab

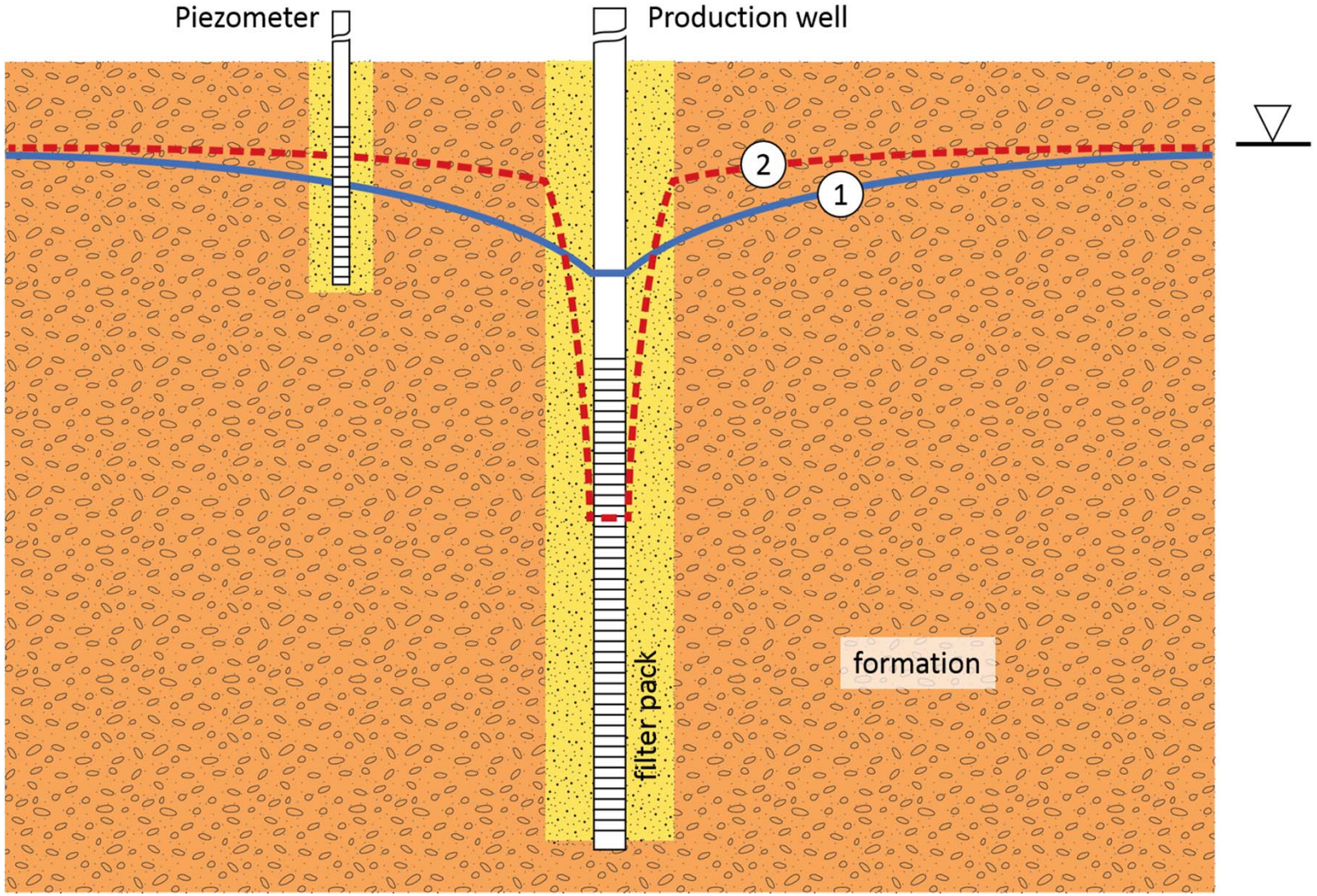
- **Leading indicators**
  - **Geochemistry**
  - **Biological residues**
  - **Produced sand**
- **Lagging indicators**
  - **Electricity consumption**
  - **Specific capacity (or Injectability)**
  - **Pump operation**
  - **Total depth**

Well Chemistry and Biology – Leading Indicators

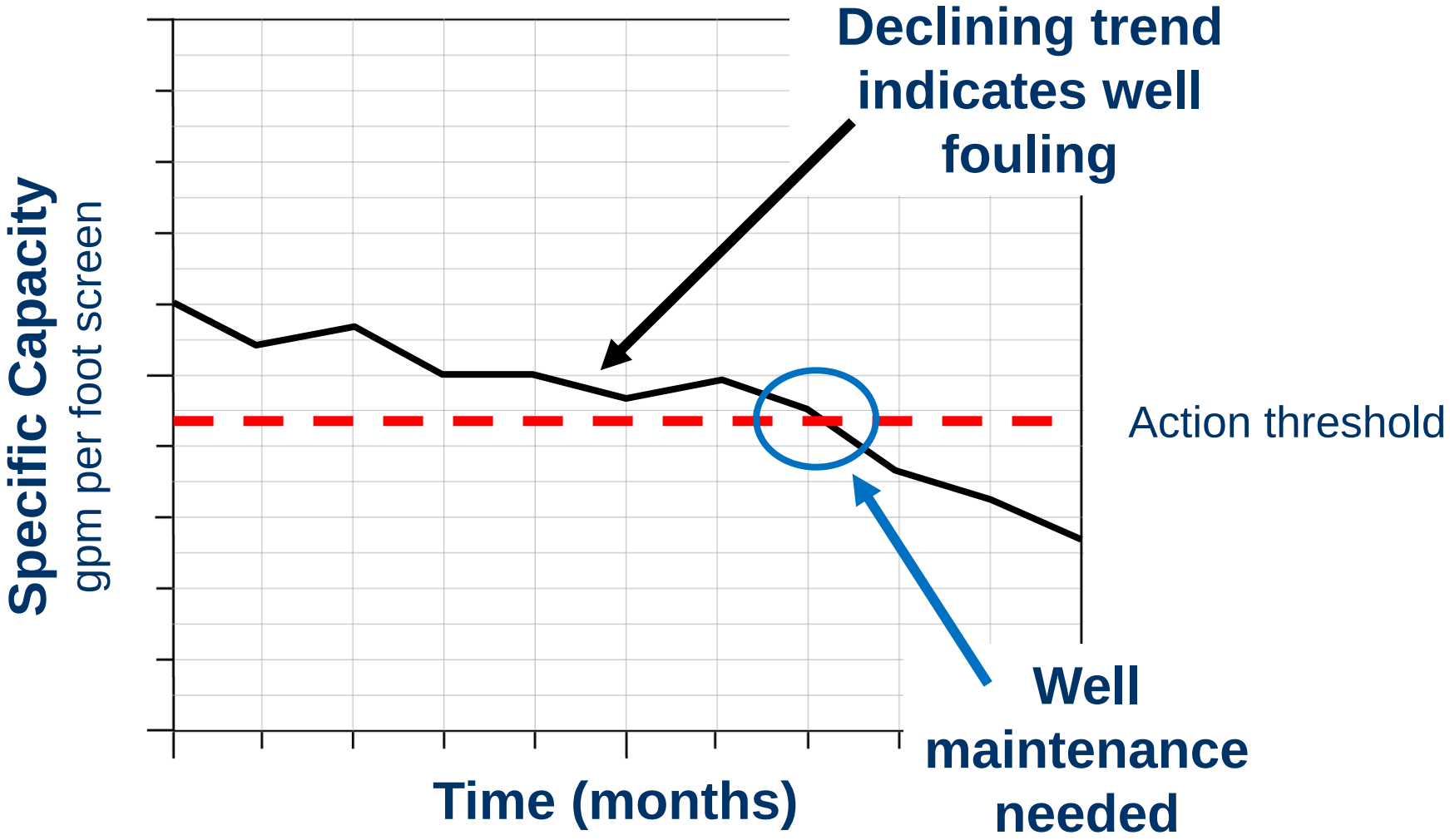
- **Bacterial indicators**
  - Sulfate reducers
  - Iron bacteria
  - Biofilm (slime) formation
- **Physical indicators**
  - Produced sand
- **Chemical indicators**
  - ATP – an indirect bio indicator
  - Dissolved oxygen



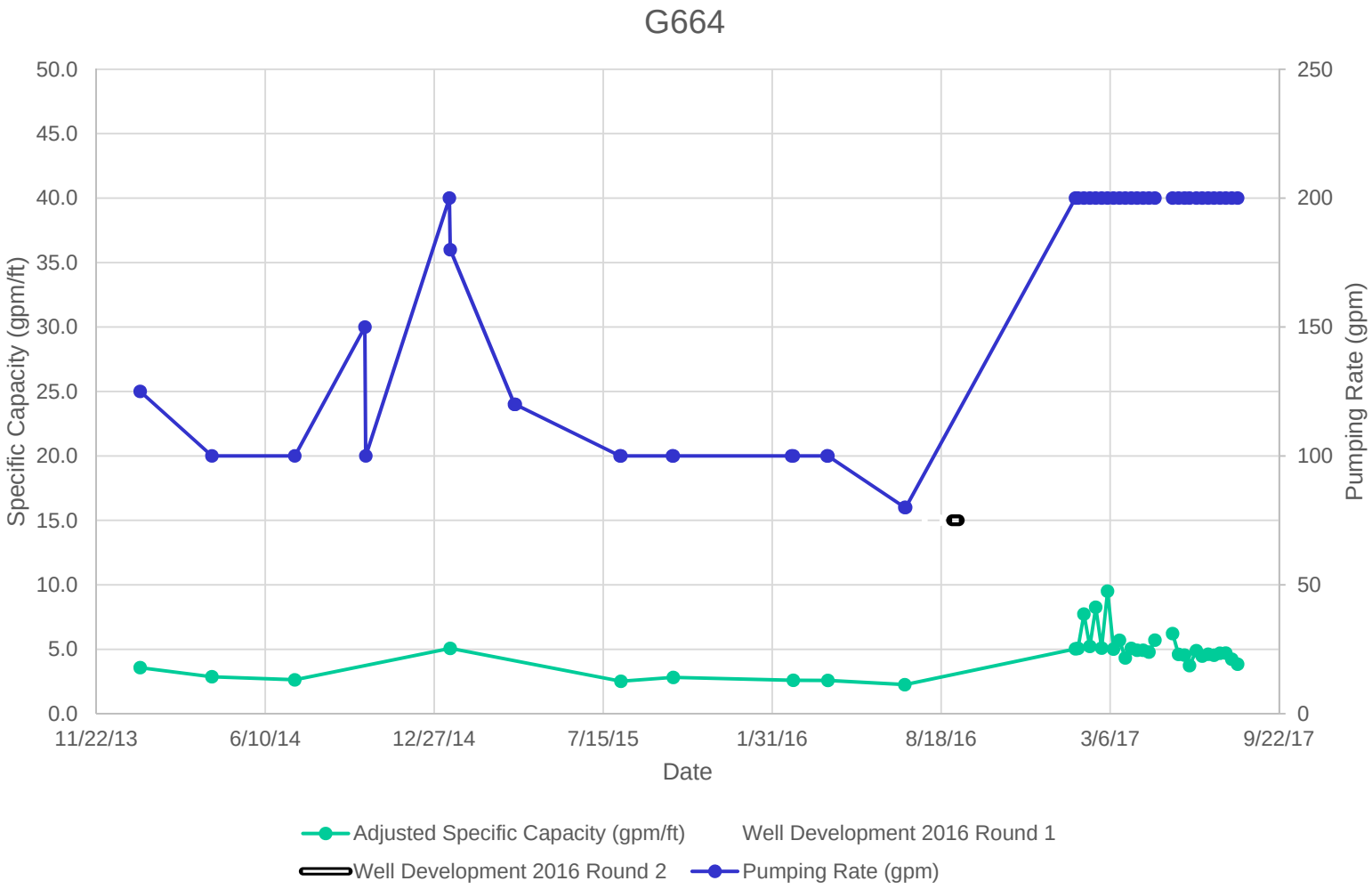
Loss of Well Efficiency – A Lagging Indicator



Specific Capacity – A Lagging Indicator



Using lagging indicators



Performance Tracking Schedules

Maintenance Test	Testing Regime	Interval
Physical Inspection	Video Surface Equipment Subsurface Equipment	Initial & Rehab Events Quarterly or Each Visit Annually
Hydraulic Performance	Flow Rates Drawdown/Mounding Specific Capacity Pump Performance	Continuous Continuous Continuous Continuous
Electrical Performance	Voltage, Amps, Ohms, Phase	Weekly
Geochemistry	Inorganics	Quarterly
Biofouling	Fouling Deposits and Water	Quarterly
Rehabilitation	Well Cleaning or Treatment	At 90% of Expected Performance (based on continuous trend line)

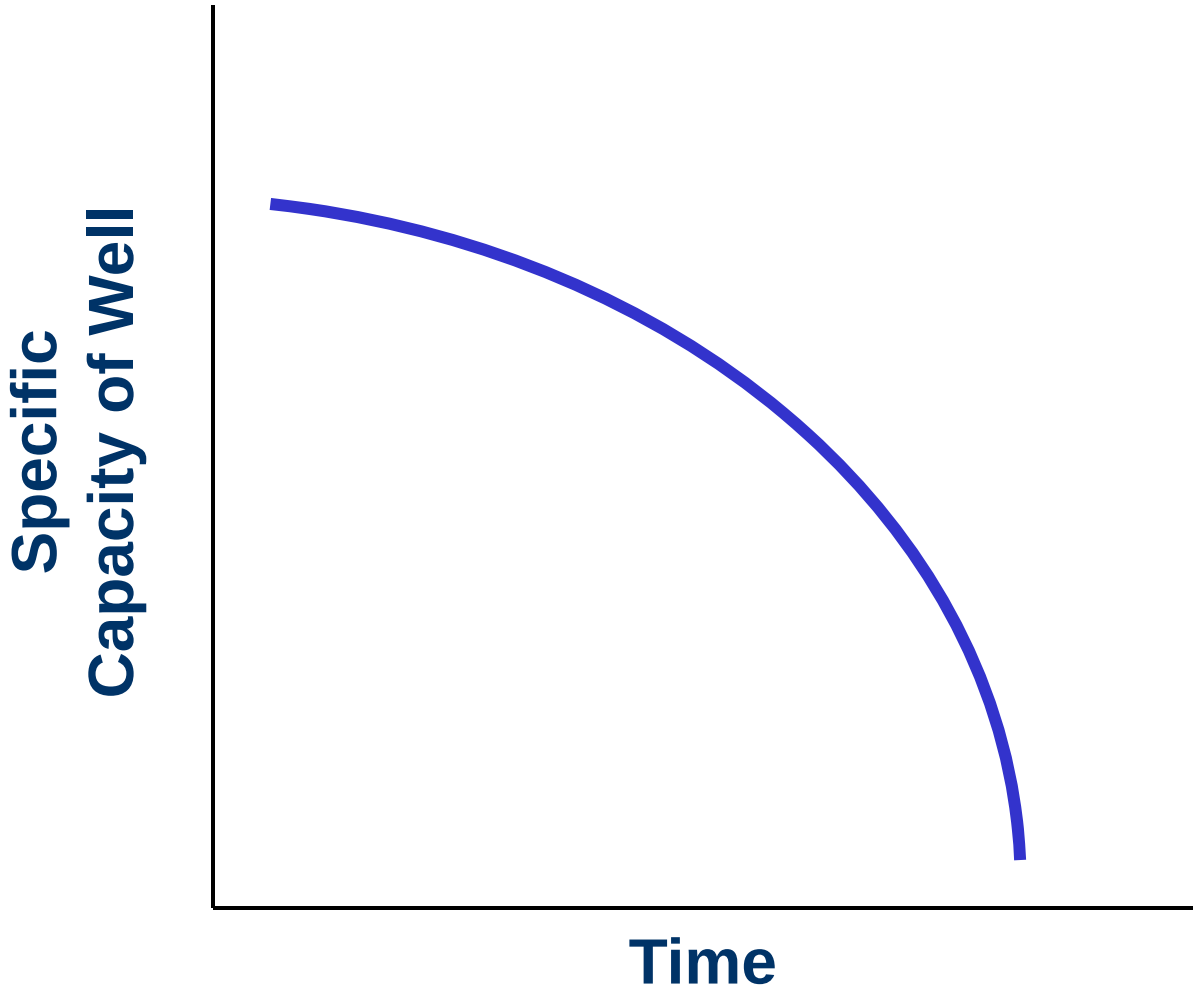
Well Maintenance – Mechanical Cleaning

- **Brushing –** knock off debris on inside of well, some surging benefit
- **Surging –** swabs and double surge blocks – most effective method
- **Jetting –** effective in more permeable formations, loosens materials, must be followed by surging, not used with slotted screen
- **Air Lifting –** good for debris removal
- **Other**

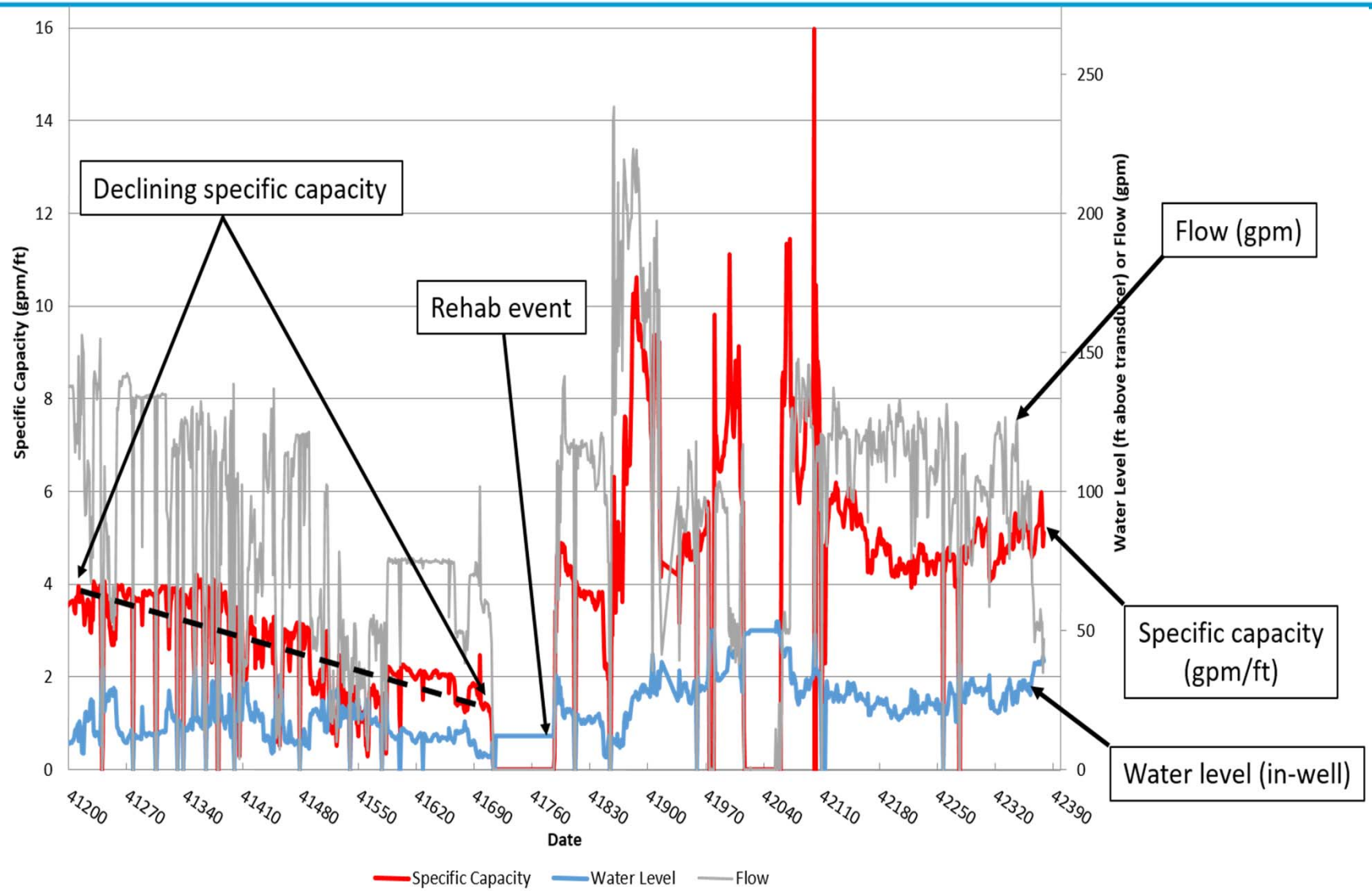
Well Maintenance – Chemical Additives

Chemical	Uses
Acetic Acid	Biocide and biofilm dispersing, Fe/Mn oxides
Sulfamic Acid	Scale removal, acid enhancement
Phosphoric Acid	Scale removal, Fe/Mn oxides
Hydrochloric Acid	Scale removal, Fe/Mn oxides
Oxalic or Citric Acid	Chelating agents for Fe/Mn oxides
Hydrogen Peroxide	Bioflim dispersing
Chlorine	Disinfection
Biocides	Kills bacterial colonies
Polyphosphates	Sequestration agents
Biodispersants	Bioflim dispersing
Caustics	Oils, biofilms
Mud Dispersants	Break down drilling fluids

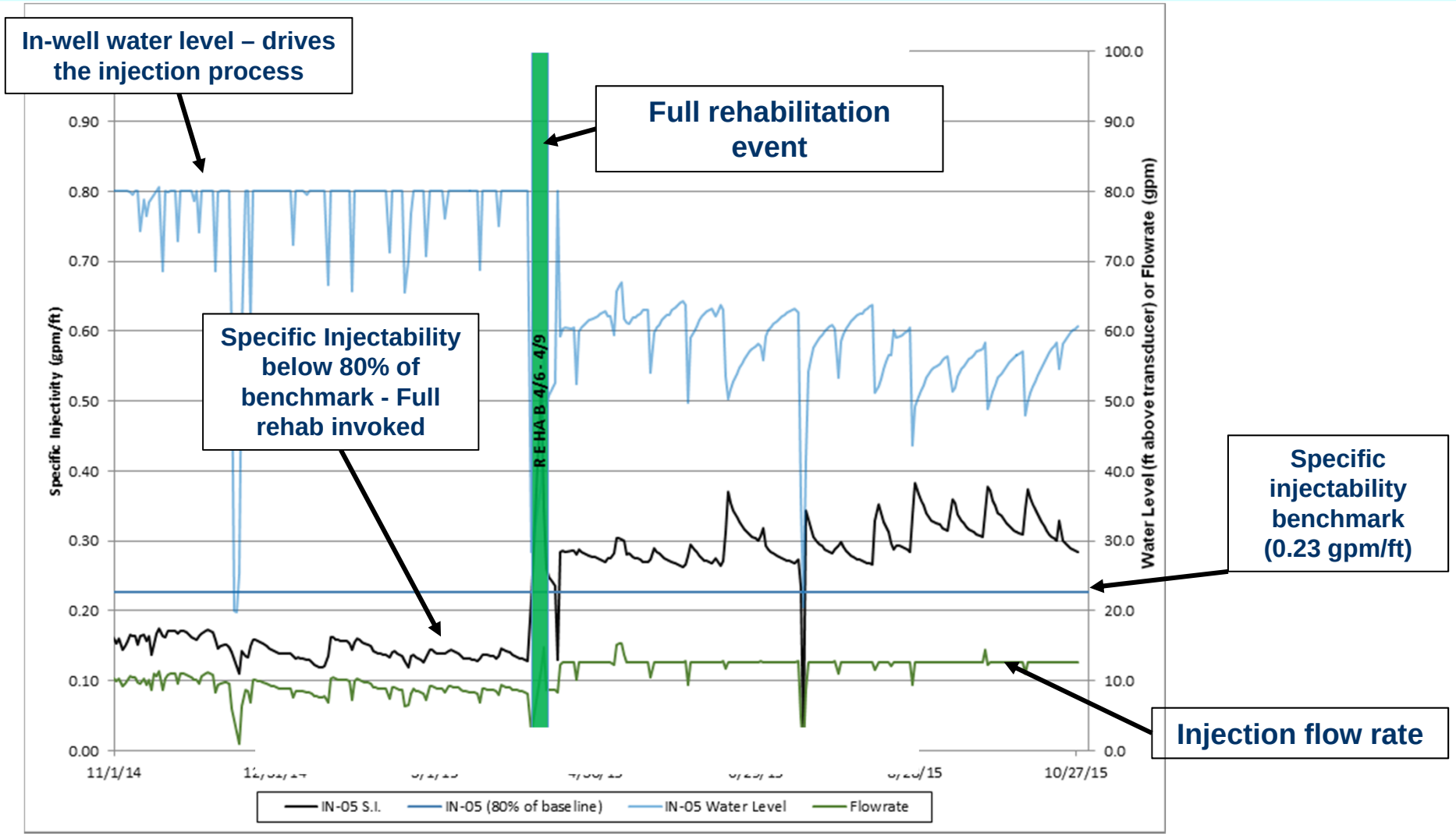
The Need for Early Rehabilitation



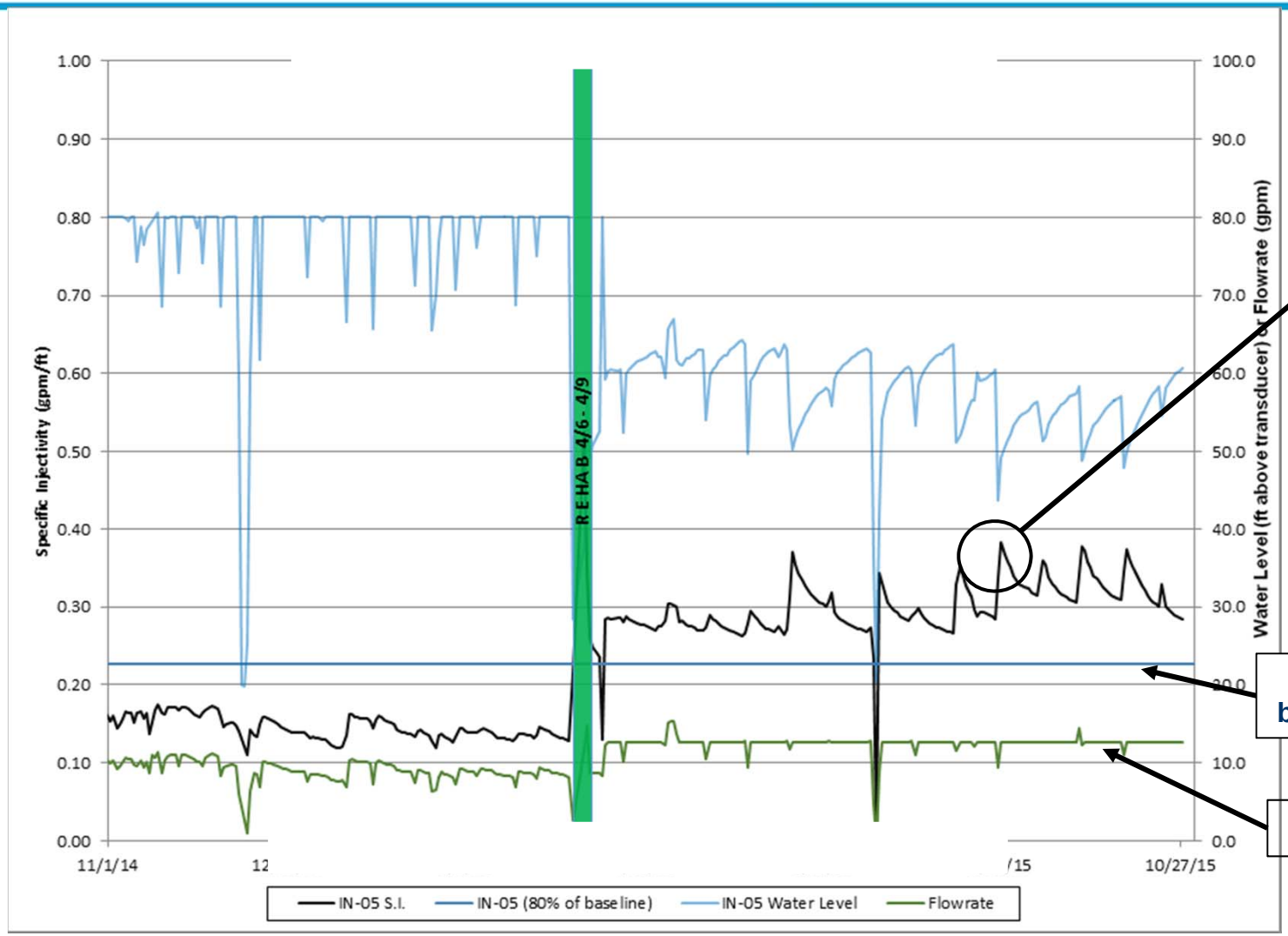
Extraction well case study



Injection Well Case Study



Opportunity for Improvement: Automating Maintenance



Built-in backwash pump activated every two weeks – each event improves specific injectability short-term

Specific injectability benchmark (0.23 gpm/ft)

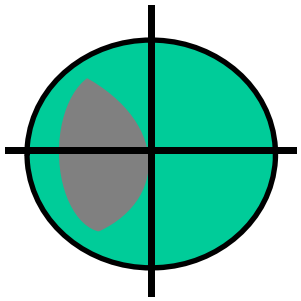
Injection flow rate

Replacement Well Design and Installation Practices

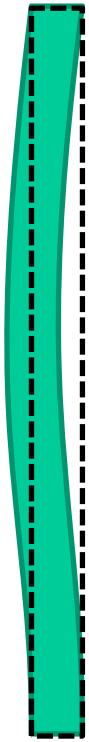
- **Correct Well Designs:**
  - **Assure that remedy objectives are met**
  - **Minimize project life-cycle costs**
- **Successful Installations:**
  - **Closely follow specifications**
  - **Focus on effective well development**

KEY POINT – Maximize Effective Well Diameter

Set Construction Specs and Supervise Construction to Achieve Plumb Wells

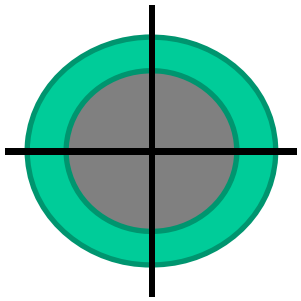


Off-plumb and meandering wells suffer reduced effective well radius



Off-plumb (meandering)

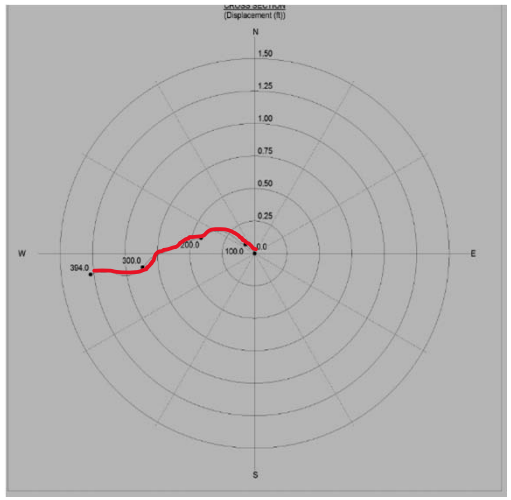
Plumb



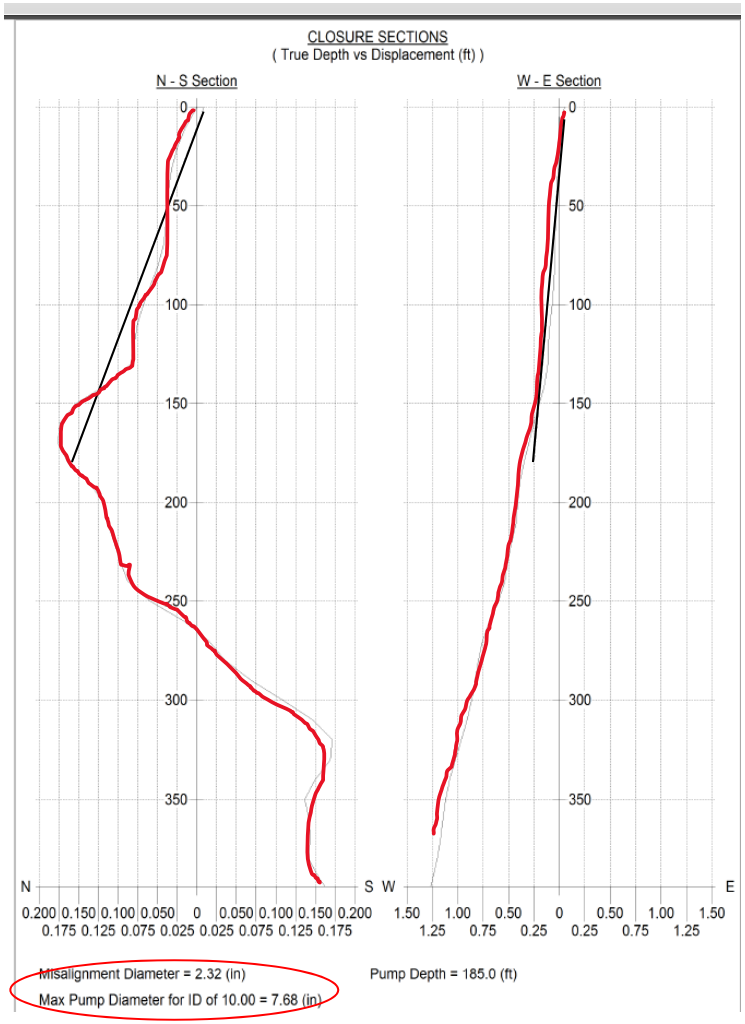
Plumb well provides full effective well radius

Plumb Well Case Example

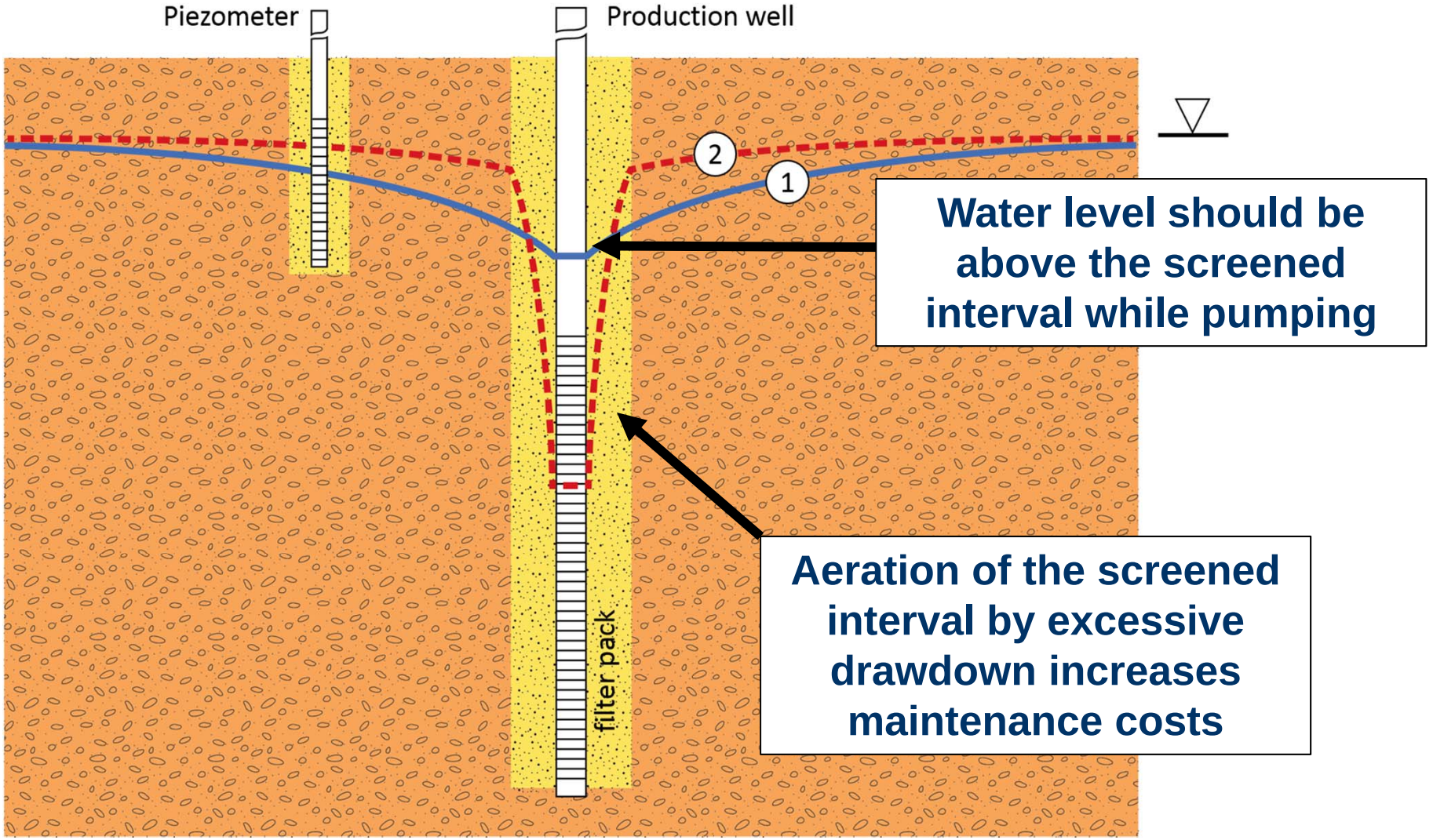
- **Site located in area of declining water levels due to drought**
- **Two 10-inch diameter production wells installed to depths of 400 feet – (gyroscopic survey part of scope)**
- **Six inch diameter pumps installed at 103 feet below top of casing**
- **Need to lower pumps due to lowering of the water table**



Calculation of effective radius restricted pump depth to 180 feet in one well and 140 feet in the second well



Key Point: Submerged Screens

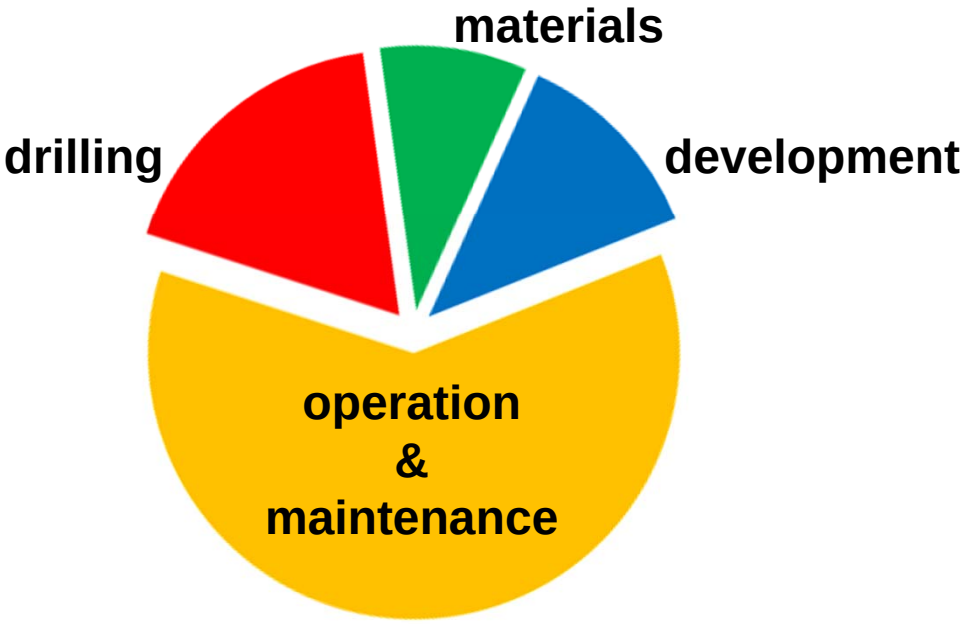


Well Installation – Development is Critical

Well development:

- **Repairs borehole damage, removes formation fines and drilling fluid, rearranges fluid pack**
- **Ensures effective connection between the well and aquifer formation**

Proper well development is a significant effort



Project Life Cycle Cost Breakdown

Summary – Managing Existing Systems

1. **Develop action plans for existing wells and networks**
2. **Set up monitoring programs to track leading and lagging performance indicators**
3. **Set threshold criteria that trigger preventive well maintenance**
4. **Conduct the required maintenance as soon as threshold criteria give the indication**

Summary – Replacement Well Design and Installation

1. **Design with the purpose of the well in mind**
2. **Conduct appropriate filter pack/screen design**
3. **Set construction specs and closely supervise installation – build plumb wells.**
4. **Design for submerged screens**
5. **Invest in well development**
6. **Set up tracking and maintenance from the beginning.**
7. **Include access for efficient well rehabilitation**

Questions

Wrap Up

- **Please complete the feedback questionnaire at the end of this webinar. We are counting on your feedback to make this webinar series relevant!**

- **Next OER2 Webinar Info….**

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