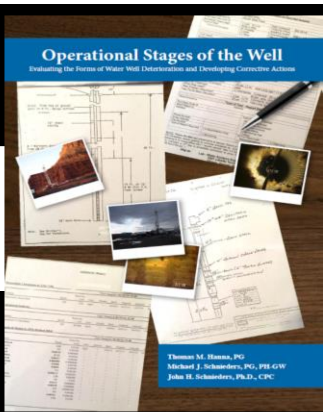
Johnson Screens



2017 NGWA

Thomas M. Hanna
Mike J. Schnieders
John H. Schnieders

The Team – Long Hours and Hard Work

Johnson Screens

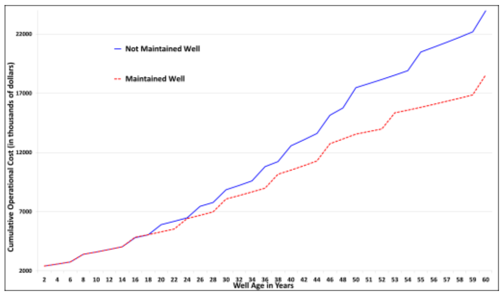
Operational Stage of a Well

Johnson Screens

- Being able to track a wells aging and determine when to rehabilitate or replace a well.
- Be proactive and not run to failure.

Cumulative Ownership Costs

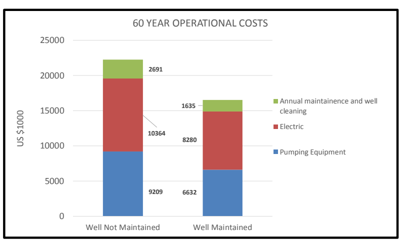
Johnson Screens



Maintenance Will Save Money

Johnson Screens

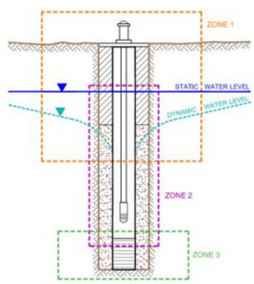
Saving of $5 M over 60 year life in operational costs



FACTORS THE EFFECT WELL PERFORMANCE / LIFE

Johnson Screens

- Aquifer changes
- Water chemistry
- Biology
- Well design
- Well construction
- Well and power plant aging
- Maintenance history



THREE FORMS OF WELL CHANGES

Johnson Screens

PHYSICAL				BIOLOGICAL					CHEMICAL				
				Increase in Biological Activity					Water Chemistry				
Decrease in Specific Capacity	Decrease in Wire to Water Efficiency	Corrosion Structural Issue	Increase in Sand Pumping or Turbidity	IRB per 10 ml	SRB per 5 tube culture	Anaerobic	Population	Coliform or Pathogen	TDS	Ca/Mg	Fe / Mn	ORP	Contaminant
< 1% 0	< 1% 0	No Change 0	No change 0	Absent 0	Absent (0 tubes) 0	< 1% Present 0	ATP <20,000 or HPC <100 0	Absent 0	<5% increase 0	<10% increase 0	<10% increase 0	<10% change 0	Absent 0
0 - 3% decrease 2	0 - 3% decrease 2	Slight corrosion of casing 2	Increase of 2 ppm or total < 3 ppm sand 2	Low Occurrence (1-3 bactira) 2	Low Occurrence (1 of 5 tubes) 2	2- 10% Present 2	ATP 75,000 - 100,000 or HPC 200-400 2	Present 35	6-10% increase 2	11 - 20% increase 2	11 - 20% increase 2	11 - 25% change 2	> water quality objective (MCL/MAC) 35
3 - 10% decrease 4	3 - 10% decrease 4	Significant corrosion of casing small holes in casing or screen 12	Increase of 2 - 7 ppm or total < 6 ppm or > 1.0 ntu 4	Moderate Occurrence (4 -7 bacteria) 6	Moderate Occurrence (2 or 3 tubes) 6	11-20% Present 6	ATP 125,000-175 or HPC 500-1000 6		11-20% increase 4	21 - 40% increase 4	21 - 40% increase 4	26 - 40% increase 4	
> 10 % decrease 6	> 10 % decrease 12	Loss of significant portions of screen or holes in casing 20	Increase of 2 - 7 ppm or total < 7 ppm, or > 1.0 ntu 6	Heavy Occurrence (>7) 8	Heavy Occurrence (4 or 5 tubes) 8	> 20% Present 8	ATP >200,000 or HPC >1000 8		>20% increase 6	>40% increase 6	>40% increase 6	> 40% increase 6	
0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

OPERATIONAL STAGE QUANTIFIED

Johnson Screens

Quarterly Monitoring of Physical, Chemical, and Biological Evolution to Identify Change

Total Points	Operational Stage	Action
0 - 12	A	Monitor
13 - 25	B	Plan Rehab within 18 months
26 -35	C	Plan Rehab within 4 months
> 35	D	Immediate Rehab or Replace

Operational Stage B

Johnson Screens

Decrease in Specific Capacity	Decrease in Wire to Water Efficiency	Corrosion Structural Issue	Increase in Sand Pumping or Turbidity	Increase in Biological Activity: IRB per 10 ml	SRB per 5 tube culture	Anaerobic	Population	Coliform or Pathogen	Water Chemistry: TDS	Ca/Mg	Fe / Mn	ORP	Contaminant
< 1% 0	< 1% 0	No Change 0	No change 0	Absent 0	Absent (0 tubes) 0	< 1% Present 0	ATP <20,000 or HPC <100 0	Absent 0	<5% increase 0	<10% increase 0	<10% increase 0	<10% change 0	Absent 0
0 - 3% decrease 2	0 - 3% decrease 2	Slight corrosion of casing 2	Increase of 2 ppm or total < 3 ppm sand 2	Low Occurrence (1-3 bactira) 2	Low Occurrence (1 of 5 tubes) 2	2- 10% Present 2	ATP 75,000 - 100,000 or HPC 200-400 2	Present 35	6-10% increase 2	11 - 20% increase 2	11 - 20% increase 2	11 - 25% change 2	> water quality objective (MCL/MAC) 35
3 - 10% decrease 4	3 - 10% decrease 4	Significant corrosion of casing small holes in casing or screen 12	Increase of 2 - 7 ppm or total < 6 ppm or > 1.0 ntu 4	Moderate Occurrence (4 - 7 bateria) 6	Moderate Occurrence (2 or 3 tubes) 6	11-20% Present 6	ATP 125,000-175 or HPC 500-1000 6		11-20% increase 4	21 - 40% increase 4	21 - 40% increase 4	26 - 40% increase 4	
> 10 % decrease 6	> 10 % decrease 12	Loss of significant portions of screen or holes in casing 20	Increase of 2 - 7 ppm or total < 7 ppm, or > 1.0 ntu 6	Heavy Occurrence (>7) 8	Heavy Occurrence (4 or 5 tubes) 8	> 20% Present 8	ATP >200,000 or HPC >1000 8		>20% increase 6	>40% increase 6	>40% increase 6	> 40% increase 6	
2	**0**	**2**	**0**	**6**	**0**	**0**	**6**	**0**	**2**	**0**	**2**	**2**	**0**

Total = 22

Planning

Johnson Screens

- Eliminate run to failure
- Ensure water quality
- Ensure water quantity
- Reduce ownership costs

Physical Changes

Johnson Screens

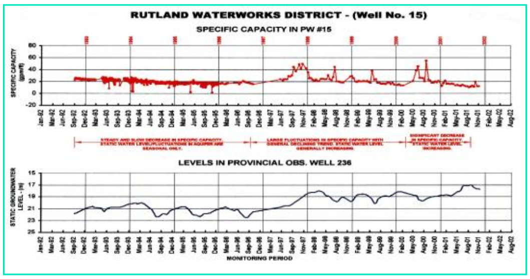
Tracking Physical Changes			
Decrease in Specific Capacity	Decrease in Wire to Water Efficiency	Corrosion or Structural Issue	Increase in Sand Pumping or Turbidity
<1% 0	<1% 0	No Change 0	No Change 0
0-3% decrease 2	0-3% decrease 2	Slight corrosion of casing 2	Increase of 2 ppm 2
3-10% decrease 4	3-10% decrease 4	Significant corrosion of casing 12	Increase of 2-7 ppm or >1 ntu 4
>10% decrease 6	>10% decrease 12	Los of portions of casing or screen 20	Increase of >7 ppm or >1 ntu 6

Causes of change in Specific Capacity

Johnson Screens

- Changes in aquifer
- Recharge/discharge boundaries
- Aquifer thickness
- Migration of fines
- Corrosion/structural damage
- Biological
- Chemical

ON-GOING CALCULATION OF SPECIFIC CAPACITY (SC)



Calculation of Wire to Water Efficiency

$$We = \frac{Q * TDH * SG * 0.746}{3960 * kW}$$

$$kW = \frac{Volts \times Amps \times 1.73 \times P.F.}{1000}$$

0.746 = conversion from horsepower to kW (1 HP = 0.749 kW)

$$Pump\ Efficiency = \frac{GPM \times TDH \times SG}{3960 \times \text{Brake Horsepower}} \qquad Motor\ Efficiency = \frac{We}{Pump\ Efficiency}$$

WIRE TO WATER EFFICIENCY

- Allows operators to identify inefficient systems
- Schedule maintenance
- Estimate potential energy savings
- Predict pump/motor failure

Motor Hp	Low	Fair	Good	Excellent
3 - 7.5	< 44	44 - 49.9	50 - 54.9	> 54.9
10	< 46	46 - 52.9	53 - 57.9	> 57.9
15	< 48	48 - 53.9	54 - 59.9	> 59.9
20 - 25	< 50	50 - 56.9	57.0 - 60.9	> 60.9
30 - 50	< 52.1	52.1 - 58.9	59 - 61.9	> 61.9
60 - 75	< 56	56 - 60.9	61 - 65.9	> 65.9
100	< 57.3	57.3 - 62.9	63 - 66.9	> 66.9
150	< 58.1	58.1 - 63.4	63.5 - 68.9	> 68.9
200	< 59.1	59.1 - 63.8	63.9 - 69.4	> 69.4
250	< 59.1	59.1 - 63.8	63.9 - 69.4	> 69.4
300	< 60.0	60 - 64.0	64.1 - 69.9	> 69.9

(PG&E, 1987)

CORROSION AND WELL DETERIORATION

CORROSION AND WELL DETERIORATION

- Corrosion
- Holes in screens
- Holes in casing (splash zone)
- Packer failure

CAUSES OF SAND PUMPING

- Improper sizing of filter pack/slot size
- Blockage of screens causing increased flow velocities
- Incomplete placement of filter pack
- Poor sampling and sediment size identification leading to poor design
- Insufficient well development
- Corrosion of casing and screen

SYMPTOMS OF SAND INTAKE

Johnson Screens

- **Abrasion of screens, piping and valves**
- **Destruction of impellers**
- **Filling of well with sand**
- **Ground settlement around well**
- **Sand in discharge**

If you are increasing sand production > 3ppm redevelopment or video might be warranted

INCREASE IN TURBIDITY

Johnson Screens

- **Indication of changes in flow**
- **Increased intake blockage**

Physical Changes

Johnson Screens

Tracking Physical Changes			
Decrease in Specific Capacity	**Decrease in Wire to Water Efficiency**	**Corrosion or Structural Issue**	**Increase in Sand Pumping or Turbidity**
<1% **0**	<1% **0**	No Change **0**	No Change **0**
0-3% decrease **2**	0-3% decrease **2**	Slight corrosion of casing **2**	Increase of 2 ppm **2**
3-10% decrease **4**	3-10% decrease **4**	Significant corrosion of casing **12**	Increase of 2-7 ppm or >1 ntu **4**
>10% decrease **6**	>10% decrease **12**	Los of portions of casing or screen **20**	Increase of >7 ppm or >1 ntu **6**

Two Main Components of the Progressive Stages of Well Deterioration:

1. Chemistry changes in a well
2. Biological changes in a well

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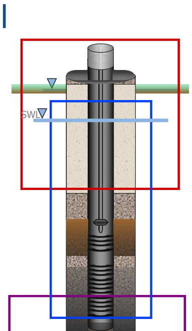
Geography of The Well

The three areas which account for the primary changes in chemistry and biology of a well.

Secondary changes would be caused by contamination or natural occurrences of the aquifer which then influences the well.



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Primary reasons for changes in the biology

- 1. Initial well construction introduces air (oxygen) to the water.
- 2. Pumping causes accumulation of fines, minerals, and other debris which harbor bacteria and encourage near well growth.
- 3. Well cycling encourages large growth of aerobic bacteria. During idle periods the aerated water feeds the bacteria. As growth occurs the air (oxygen) is depleted and the dying bacteria settle to the bottom.
- 4. Organic debris from dying aerobes provide food for the anaerobic zone with resulting anaerobic growth

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Primary reasons for chemical change in well water?

Changes in pH, alkalinity, and TDS are caused by:

- 1. Alkalinity changes do to CO_2 degassing from the aquifer
- 2. Calcium precipitation in the casing or immediate formation
- 3. Anaerobic acid gas production in the well bottom
- 4 Release of cellular acids from dyeing bacterial populations in the standing casing water
- 5 Corrosion (oxidation) of iron

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Some Truisms to Keep in Mind!

- There is chemistry and biology present in every aquifer and they flow into the well.
- The chemistry/biology changes that take place in a well environment are often tied together with a change in one propagating a change in other parameters.
- There are specific parameters in the Operating Stage Well Chart which will help you tract these changes in your well.

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An Example:

- Bacteria increase in the well water.
- Cycling allows standing (static) well water.
- Death of aerobic bacteria release cellular acids and promote pH decline.
- Bacterial death provides food source for anaerobic bacteria in well bottom—pH decline
- Lower pH promotes corrosion of available iron.

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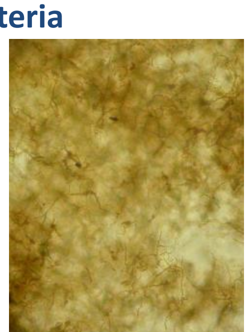
Tracking Biological Activity

Iron Bacteria	Sulfate Reducing Bacteria	Anaerobic Growth	Population (ATP or HPC)	Coliform or Pathogen Presence
absent **0**	absent **0**	< 1% present **0**	ATP < 20,000 HPC <100 **0**	Absent **0**
low occurrence **2**	low occurrence **2**	2 to 10% presence **2**	ATP 75,000 to 100,000 HPC 200-400 **2**	present **35**
moderate occurrence **6**	moderate occurrence **6**	11-20% presence **6**	ATP 125,000 to 175,000 HPC 500-1000 **6**	-
heavy occurrence **8**	heavy occurrence **8**	>20 % present **8**	ATP >200,000 HPC >1500 **8**	-

Iron Bacteria

- This is a microscopic test which counts the specific stalked iron related bacteria in a 10ml sample after centrifuge.
- The increases in the number of observed stalks dictate the seriousness of the infestation.



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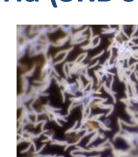
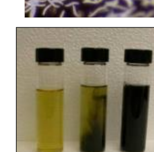
Sulfate Reducing Bacteria (SRB's)

This test estimates the destructive size of the infestation by growth rates as observed in a tube culture. The more tubes that are positive the more growth in the well.





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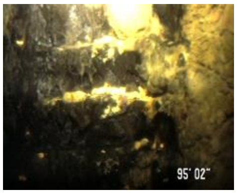
Anaerobic Population

This test is a measure of the anaerobic population as a percentage of the total population of bacteria. It is a way of measuring the condition of the lower portion of the well. Figures in excess of 15 to 20% indicate a more serious condition as to possible well blockage, taste and odor issuess as well as coliform contamination.



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Total Bacterial Populations

- Increase in numbers indicates increase in bacterial growth that attracts mineral deposits.
- HPC records cfu (colony forming units)/ml.
- ATP counts record individual cells per ml.
- The degree of increase or decrease is the controlling parameter.

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Tracking Water Chemistry Changes

TDS (mg/L)	Ca / Mg (mg/L)	Fe / Mn (mg/L)	ORP (mv)	Contaminant
<5% increase **0**	<10% increase **0**	<10% increase **0**	<10% increase **0**	absent **0**
6-10% increase **2**	11-20% increase **2**	11-20% increase **2**	11-25% increase **2**	>WQ objective (MCL) **35**
11-20% increase **4**	21-40% increase **4**	21-40% increase **4**	26-40% increase **4**	-
>20% increase **6**	>40% increase **6**	>40% increase **6**	>40% increase **6**	-

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Total Dissolved Solids (TDS)

- An increase or decrease in the TDS can indicate almost any of the activities referred to in slide No 4.
- We can rule out excessive corrosion if our iron concentration remains steady or non existent.
- If hardness or calcium levels remain the same the possibility of mineral deposits are minimal.

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Oxidation-Reduction Potential (ORP)

- Measure of chemical activity in the well can be used to track corrosion, solids formation, and to an extent bacterial activity.
- If there is cascading water in the well or other form of aeration, the ORP will increase.
- A decrease in ORP could indicate an increase in anaerobic activity in the well bottom yielding acid production.

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Resolution

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Maintenance Observations

- Maintenance is generally not planned
- When cleaning, wells are considered all the same:
  - Chemicals and mechanical methods are not tailored to the well
- Monitoring during treatment is not conducted
- Little follow-up is performed
  - Pump testing
  - Water testing

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How do we Improve Resolution?

- Understand the issue
- Differentiate the response
- Tailor the response to the well and the degree of impaction

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Stage	
Stage A (0-12 pts)	• Monitor • Most Regularly Operated Wells
Stage B (13-25 pts)	• Fouling is present and beginning to impact well • Plan Rehab within 18 months
Stage C (26-35 pts)	• The well is impacted, but failure is not imminent • Plan Rehab within 4 months
Stage D (>35 pts)	• Significant Event / Fouling • Immediate Rehab or Replacement

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Well Maintenance

Disinfection – chlorine treatment of the well to target bacteria

Cleaning – combined chemical and mechanical treatment of the well targeting biofouling and/or mineral scale

Re-development – combined chemical and mechanical efforts targeting muds and sediment within the borehole and aquifer

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4 Key Points of Response

- Do we know what the problem is?
  - Hard scale, sediment, biology
  - Level of impaction
- Are we using the correct methods & the right stuff?
  - Targeting the problem
- Are we using it correctly?
  - Application, Amount, Time
  - Health & Safety of Crew and Environment
  - Monitoring during treatment
- Are we limiting harmful impacts?
  - Well Structure
  - Aquifer & Environment

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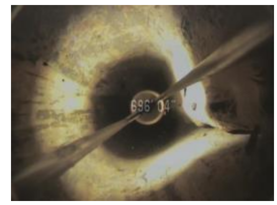
Procedure	Objective	Optimal Use
Chemical (dump/pump)	Breakdown of mineral scale or targeted disinfection of biomass	Light fouling or non-aggressive bacterial problems
Brushing	Physical breakdown of accumulations within the inner well	Targeting biomass or scale prior to evacuation and subsequent chemical treatment
Mechanical Surging Single or double disc, bailer	Agitation within the screened zone	Combined with chemicals to target fouling within the filter pack; development
Jetting with water	Focused energy that agitates and "fluffs" the filter pack	When used in conjunction with pumping to remove disrupted material
Airlift	Used to remove detritus and fill within the well	Evacuation of debris from idle wells; evacuation of material post-treatment
Gas Impulse	Focused release of high energy within the screened zone to target sediment or scale within the filter pack and formation	Following mechanical pre-treatment for combined chemical cleaning or redevelopment

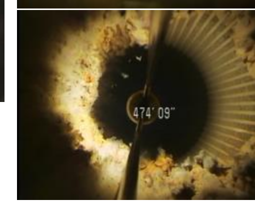
Characteristics of Common Well Cleaning Acids					
Acid	Phosphoric	Sulfamic	Hydrochloric	Hydroxyacetic	Oxalic
Common Strength	75%	99%	31.5% (20°)	70%	99%
Weight	13.14 lbs/gal	~ 10 lbs/gal	9.7 lbs/gal	10.4 lbs/gal	~ 10 lbs/gal
Appearance	Clear Liquid	White Crystal	Yellowish Liquid	Clear Liquid	White Crystal
Formula	H_3PO_4	H_2NSO_3H	HCl	$(HO)C_2COOH$	$(COOH)_2$
Type	Mineral	Mineral	Mineral	Organic	Organic
Hazardous Fumes	None	None	High	Some	None
Relative Strength	Strong	Strong	Strong	Weak	Moderately Strong
pH at 1%	1.5	1.2	0.6	2.33	1.25
Use Range (% by Volume)*	1 to 10%	1 to 5%	1 to 15%	1 to 5%	1 to 5%
Relative Reaction Time**	4 – 5	< 2	1	4 - 5	2
Corrosiveness to:					
Metals	Slight	Moderate	Very High	Slight	High
Skin	Moderate	Moderate	Severe	Slight	Severe
Reactivity vs:					
Carbonate Scale	Very Good	Very Good	Very Good	Poor	Moderately Good
Sulfate Scale	Fair	Poor	Good–Poor	Very Poor	Poor
Fe/Mn Oxides	Good	FAir	Very Good	Good	Good
Biofilm	Poor	Poor	Poor	Moderately Good	Moderately Good
Pounds of Acid (100%) required to dissolve 1-lb of Calcium Carbonate.	0.65	2.0	0.73	4.5	2.0

*Typical Ranges Used in Well Cleaning

**Reaction Time: (1 = Fast, 10 = Slow)

WATER SYSTEMS ENGINEERING





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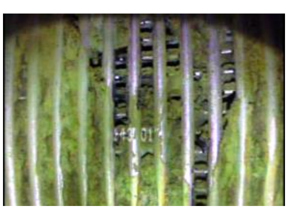

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Monitoring During Treatment & Evacuation

- pH
- TDS / Conductivity
- Visual turbidity


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Post-Rehab Video


Photos courtesy of Hydro Resources, Ft Lupton, CO

Post-rehab video completed to check integrity of screens, create visual record of well and measure degree of success

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Post-Rehab Pump Test

- Flush any residual debris from the well
- Establish new baseline of well performance
- Evaluate effectiveness of cleaning efforts

Photo courtesy of Layne, Aurora, IL

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Post-Rehab Sampling

- State Requirement (Coliform)
- Establish new baseline of chemical, biological, and physical conditions
- Compliments pump test and video to develop new monitoring requirements

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Summary: Maintenance is a Process

- Identify the problem
- Select the right methods
- Select the right chemicals
- Verify reactions / interactions
- Be actively safe
- Monitor the reactions
- Evacuate, Neutralize, Dispose Correctly
- Follow-up

WATER SYSTEMS ENGINEERING

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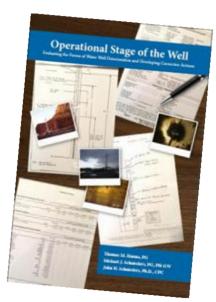
Operational Stage of the Well

NGWA Bookstore



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Questions?

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