Ground Water and Wellfield Management

OTCO Class III/IV Workshop Deer Creek 2019

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Environmental OTCO Training Center Since 1994

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Ground Water (or if you prefer "Groundwater") and Wellfield Management

This is an introduction for the practical operations leader to groundwater occurrence, movement, and protection for groundwater-source systems, and also considering groundwater in watershed protection and management. We will look at how to

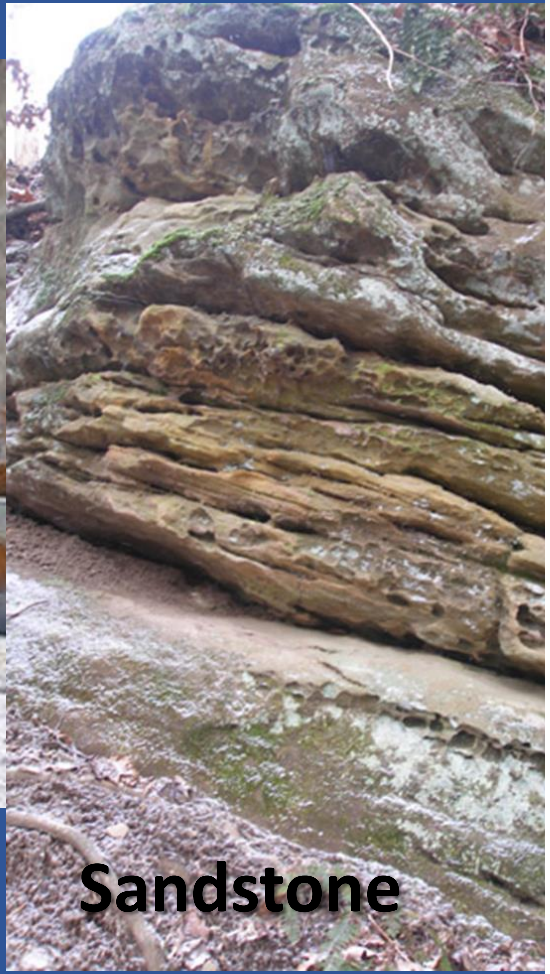
- locate wellfields and protect the ones you have
- maintain and enhance recharge
- avoid contamination of groundwater supplies
- account for natural water quality issues in daily operations
- operate wells sustainably

Ground Water Advantages as a Water Source

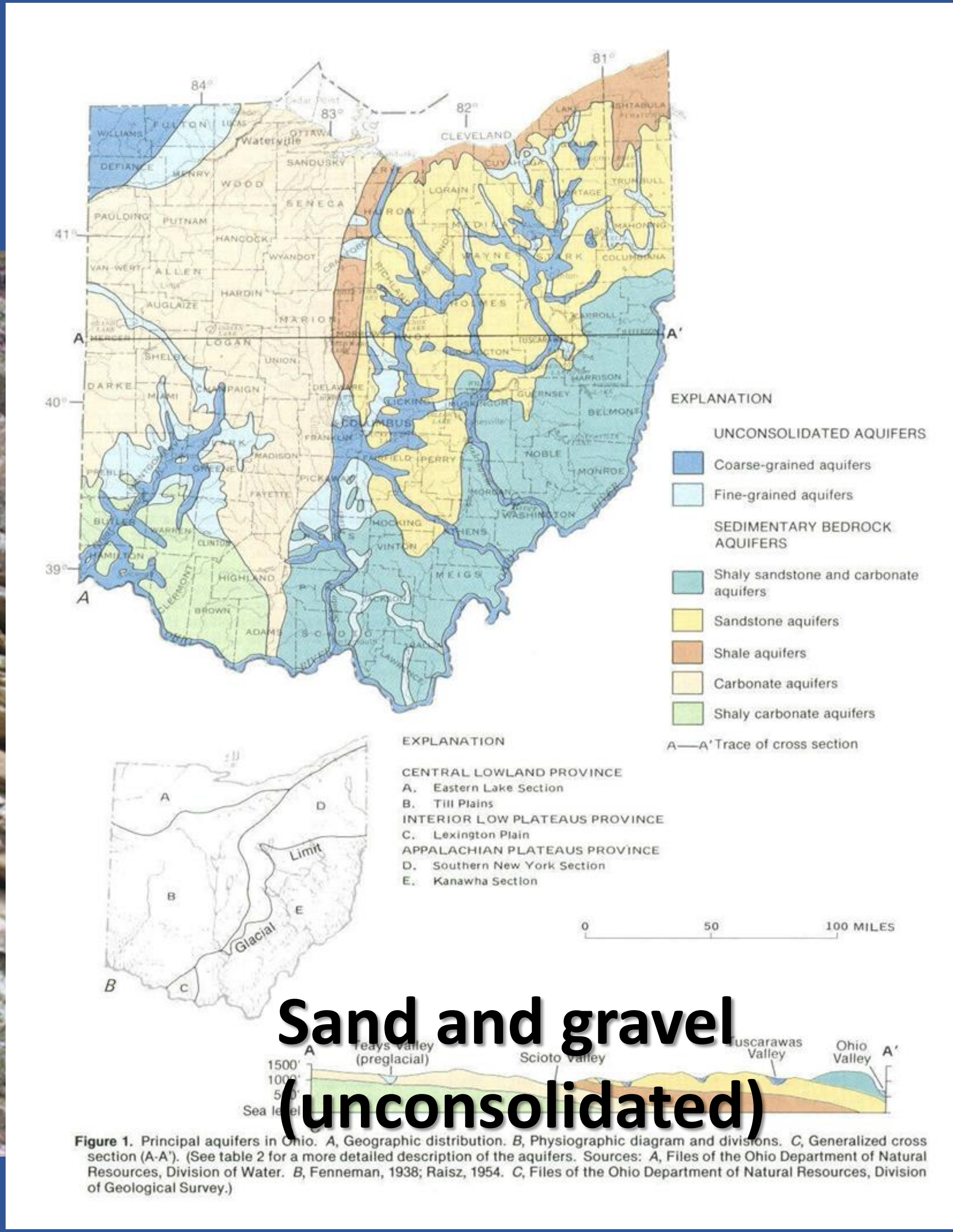
- Relatively – not absolutely – more protected from contamination, especially the potentially pathogenic
- Chemistry relatively stable – predictable and requiring less adjustment in treatment day-to-day
- Turbidity and microbial content usually much less than surface water
- Aquifers are bigger than constructed reservoirs by a long shot

Types of Aquifers in Ohio

Carbonate

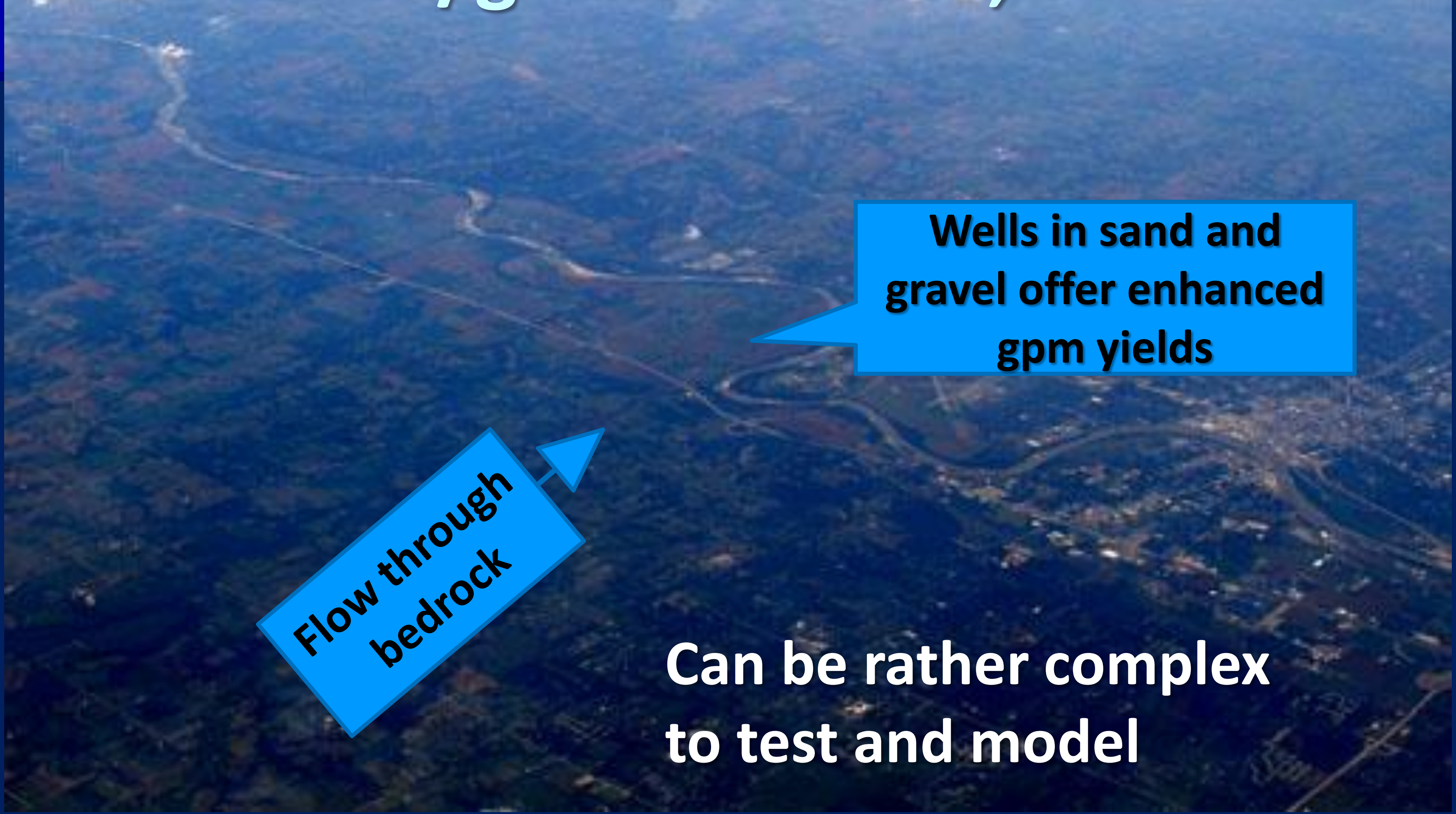


Sandstone

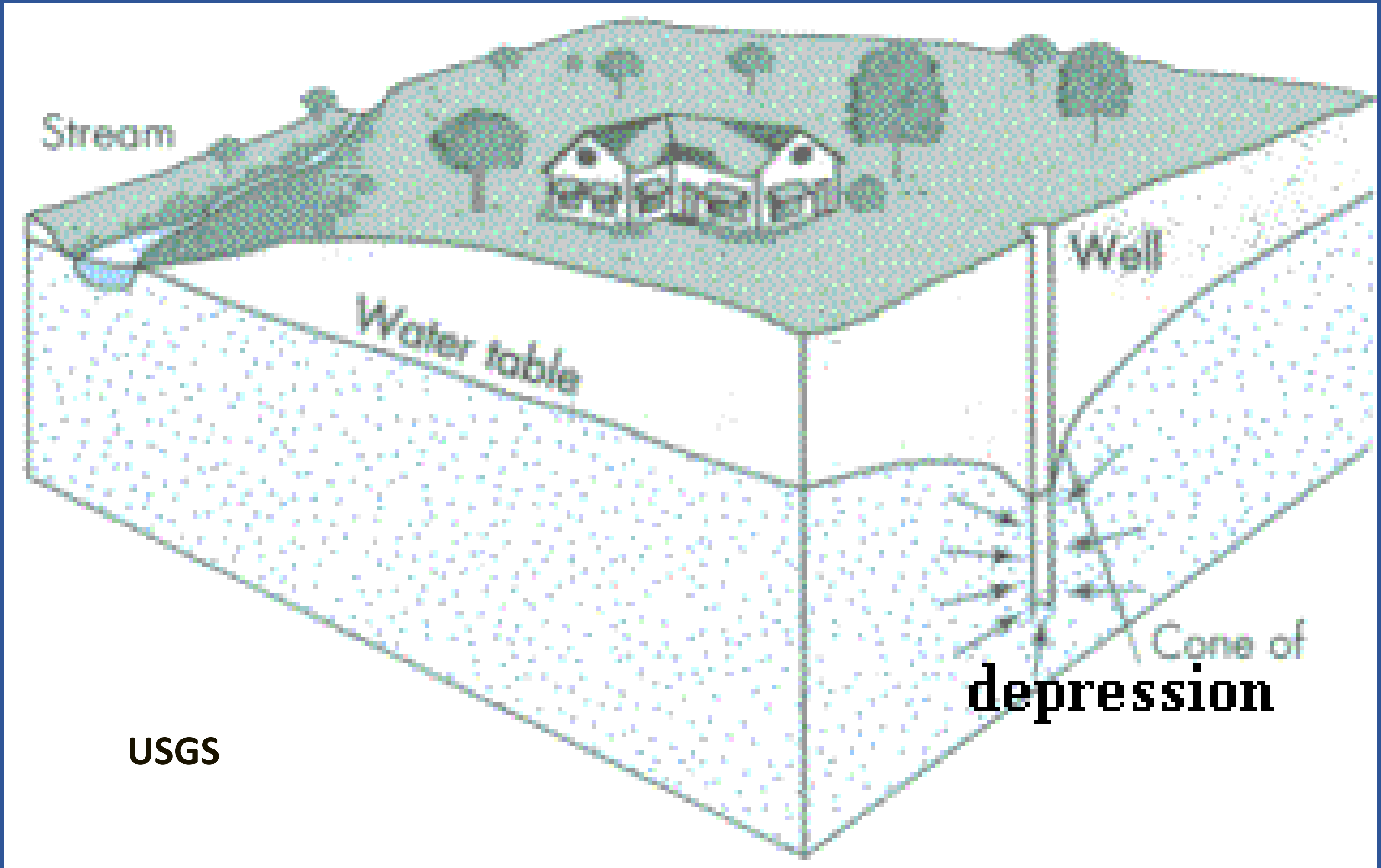


Sand and gravel (unconsolidated)

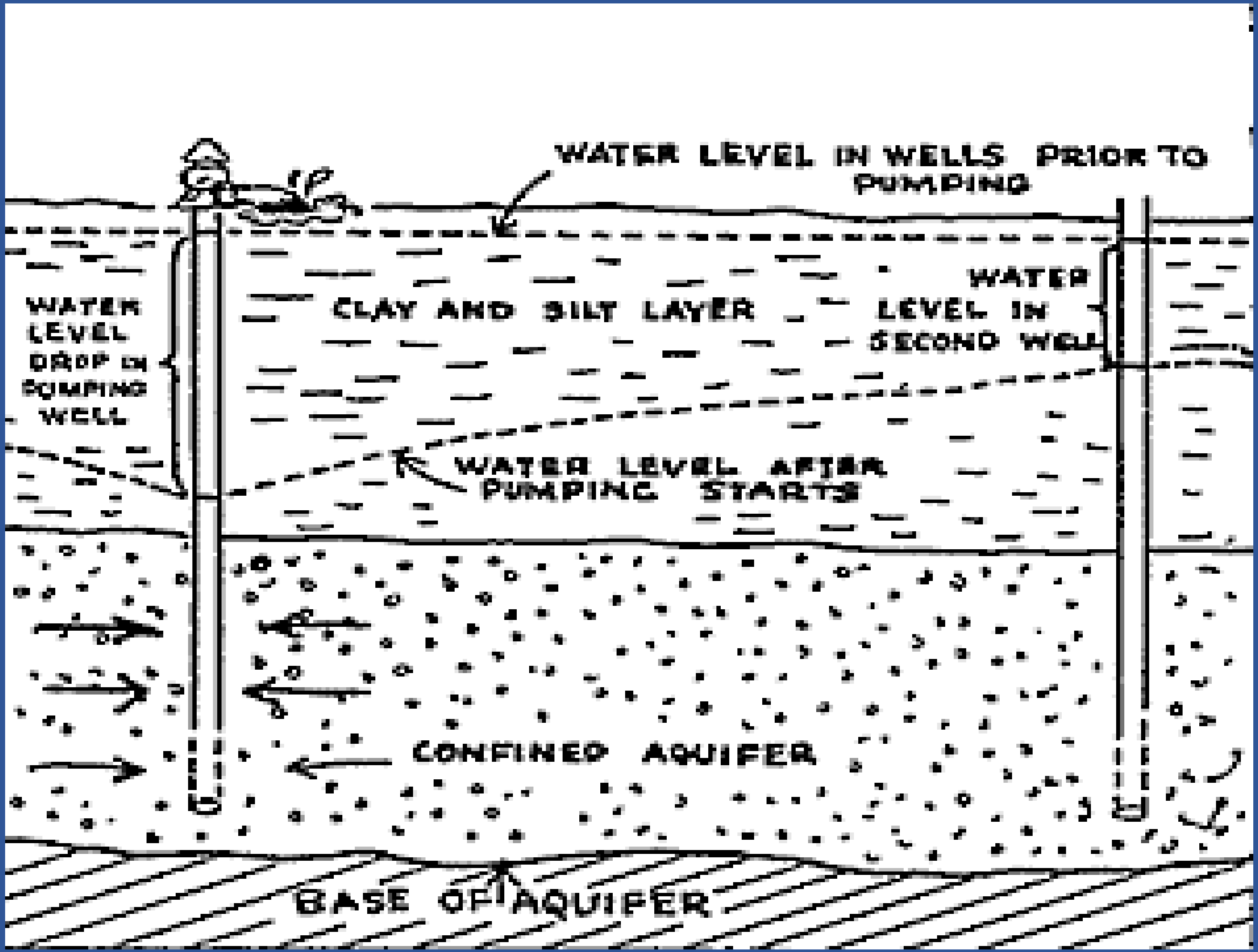
Typical Ohio: Bedrock + sand/gravel terrace, outwash



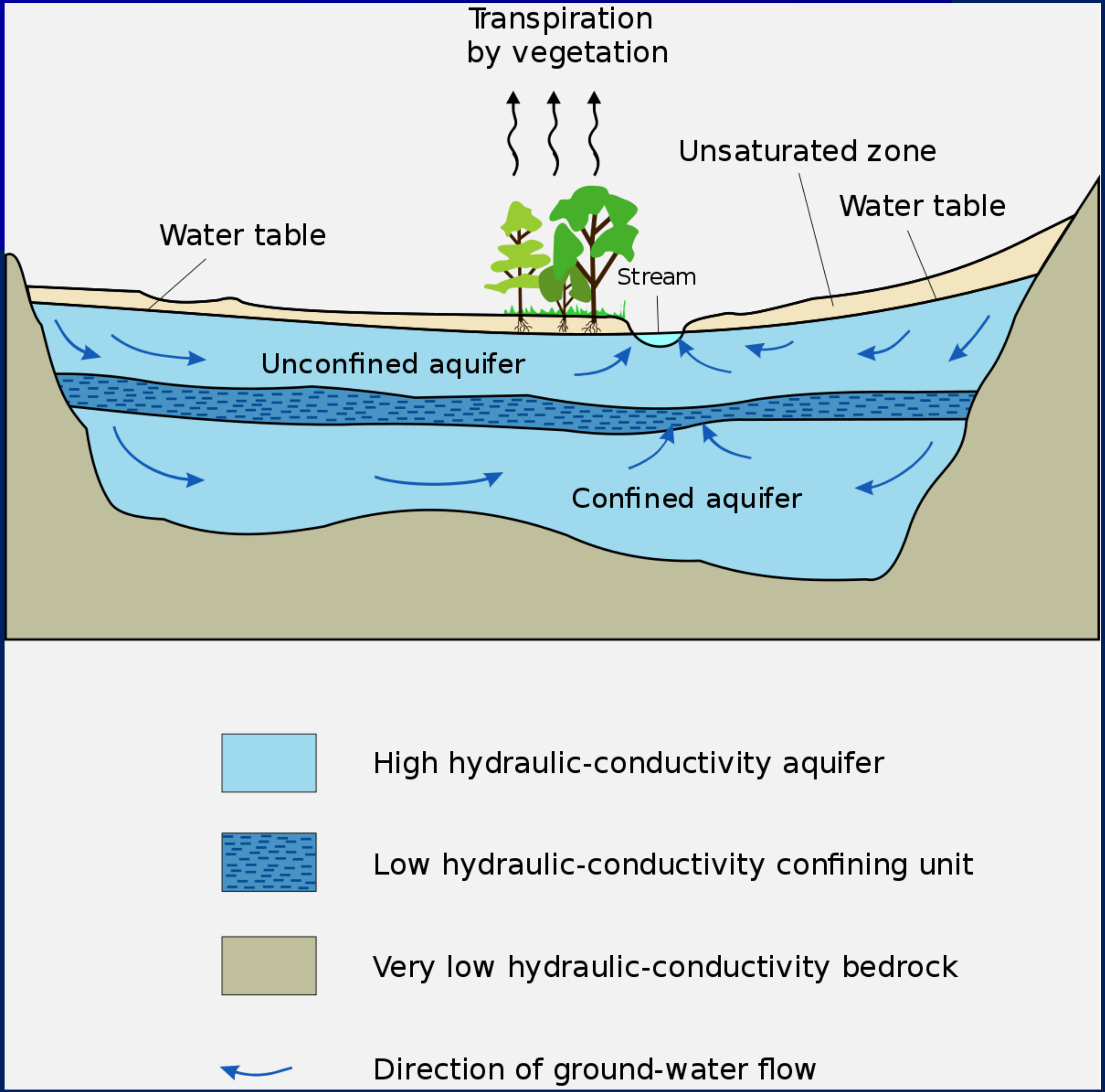
Unconfined aquifer configuration: water level within aquifer



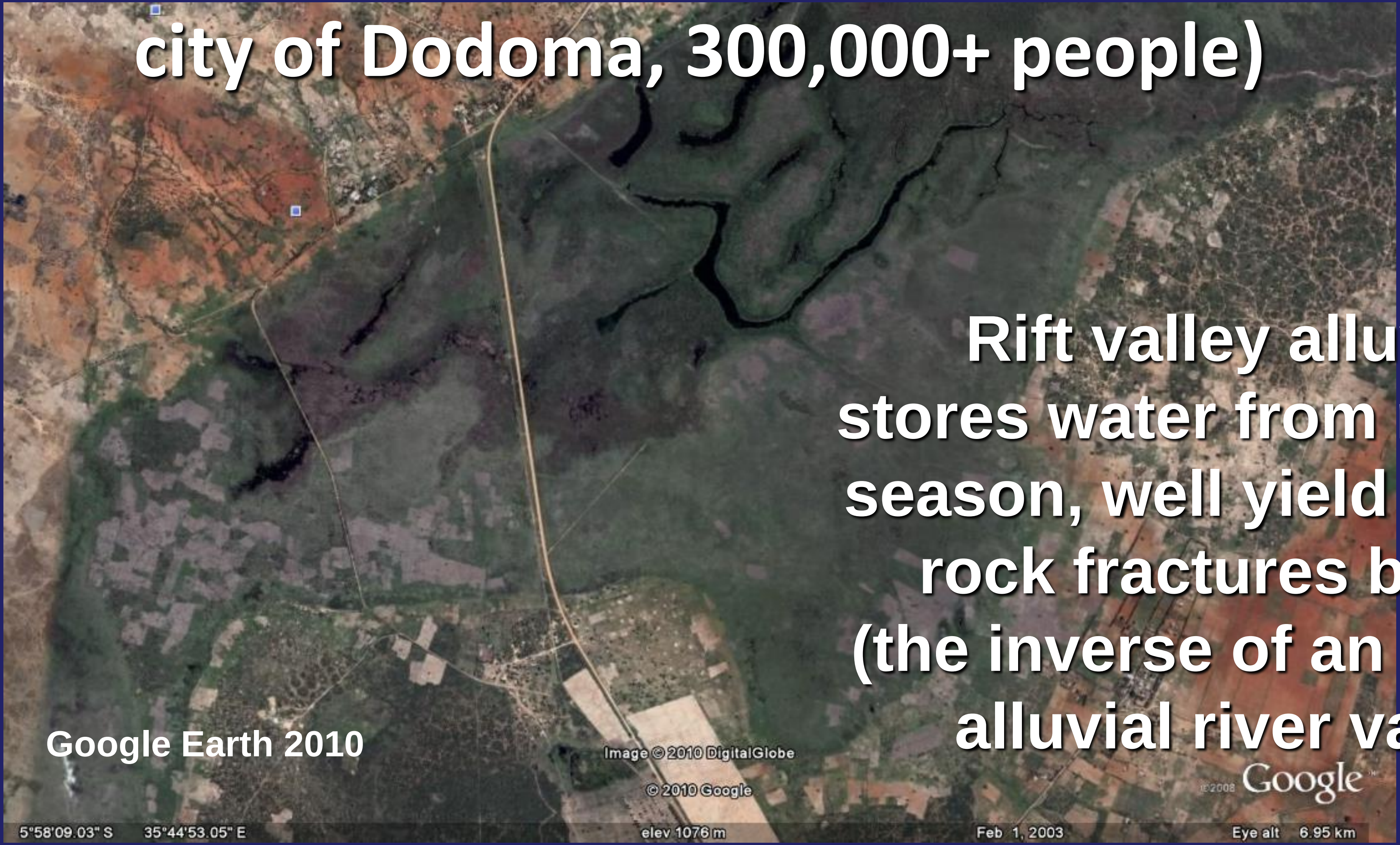
Confined aquifer configuration: Water level above top of aquifer



River valley multi-layer



Now for something completely different: Makutapora valley, Tanzania (wellfield for city of Dodoma, 300,000+ people)



Google Earth 2010

Rift valley alluvium stores water from rainy season, well yield from rock fractures below (the inverse of an Ohio alluvial river valley)

Water Well Design, Construction, Testing

Resource planning and protection

There are limits to everything, even stupendously productive Ohio glacial-alluvial aquifers

- manage them rationally
- and not "every man for himself"

A Ground Water Source as Water Supply

- Needed: Sufficient permeability and storage to supply the water to wells
- Needed: Sufficient recharge to replenish water extracted for water supply
- Needed: Absence of “deal-killer” water quality parameters
- Management: Protection of the resource for the long term
- Science: appropriate extraction design basis (not overdrafting), calculated long term (24 hr test may not do it)
- Engineering, craft: Wells/assets built for the long term

Geologist-led test drilling provides extensive information about a potential wellfield location in "real time"

Geophysics: Ra

- Various methods depending on geolo
- Pick drilling targets, reducing random dr
- Or walk away witho the expense
- Expert guidance anc performance

We can predict water quality changes that will affect water treatment design using onsite methods

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We can predict mechanisms that will degrade well performance, and the timing reasonably well – and you really should plan accordingly

Construction and contractor standards

- Are we installing a lifetime potable water supply or a hole in the ground?
- Standards and specifications – assuring that proper materials and methods are used: very specific.
- Inspection – Meeting the specifications and good practice.
- Communication: To explain and correct

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Construction: Follow "best practice" procedures

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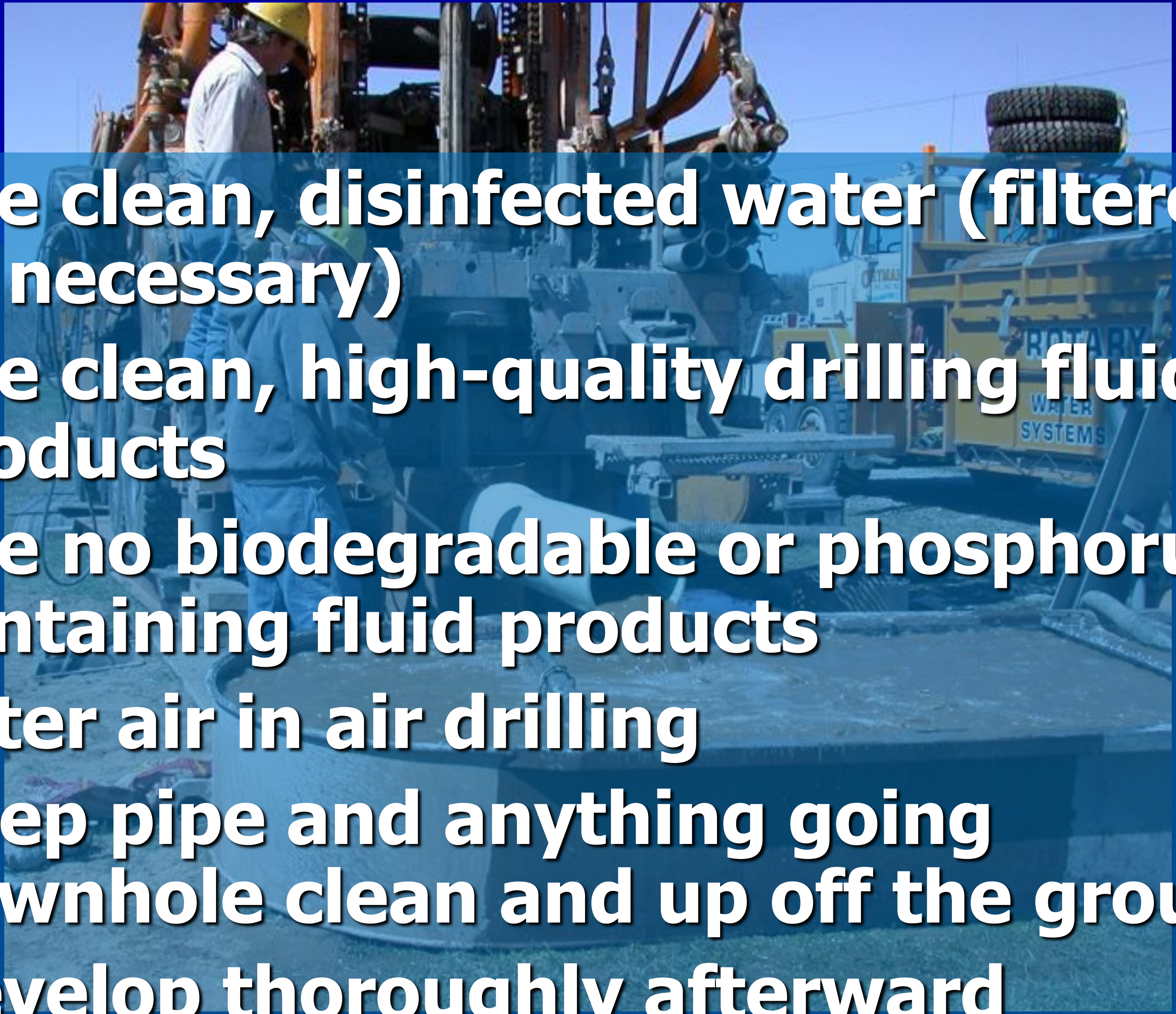
Preventive design

- As much open area as possible?
- Filter pack round (less angular), clean, and silicate
- Is this screen necessary?
- Modern standards



- Use clean, disinfected water (filtered as necessary)
- Use clean, high-quality drilling fluid products
- Use no biodegradable or phosphorus-containing fluid products
- Filter air in air drilling
- Keep pipe and anything going downhole clean and up off the ground
- Develop thoroughly afterward

Post-construction Development: Backwash for your water well

Standards for:

Turbidity and sediment content, usually until water free of turbidity and sediment.

Well efficiency, usually until most effects of drilling are removed and well has good connection with aquifer.

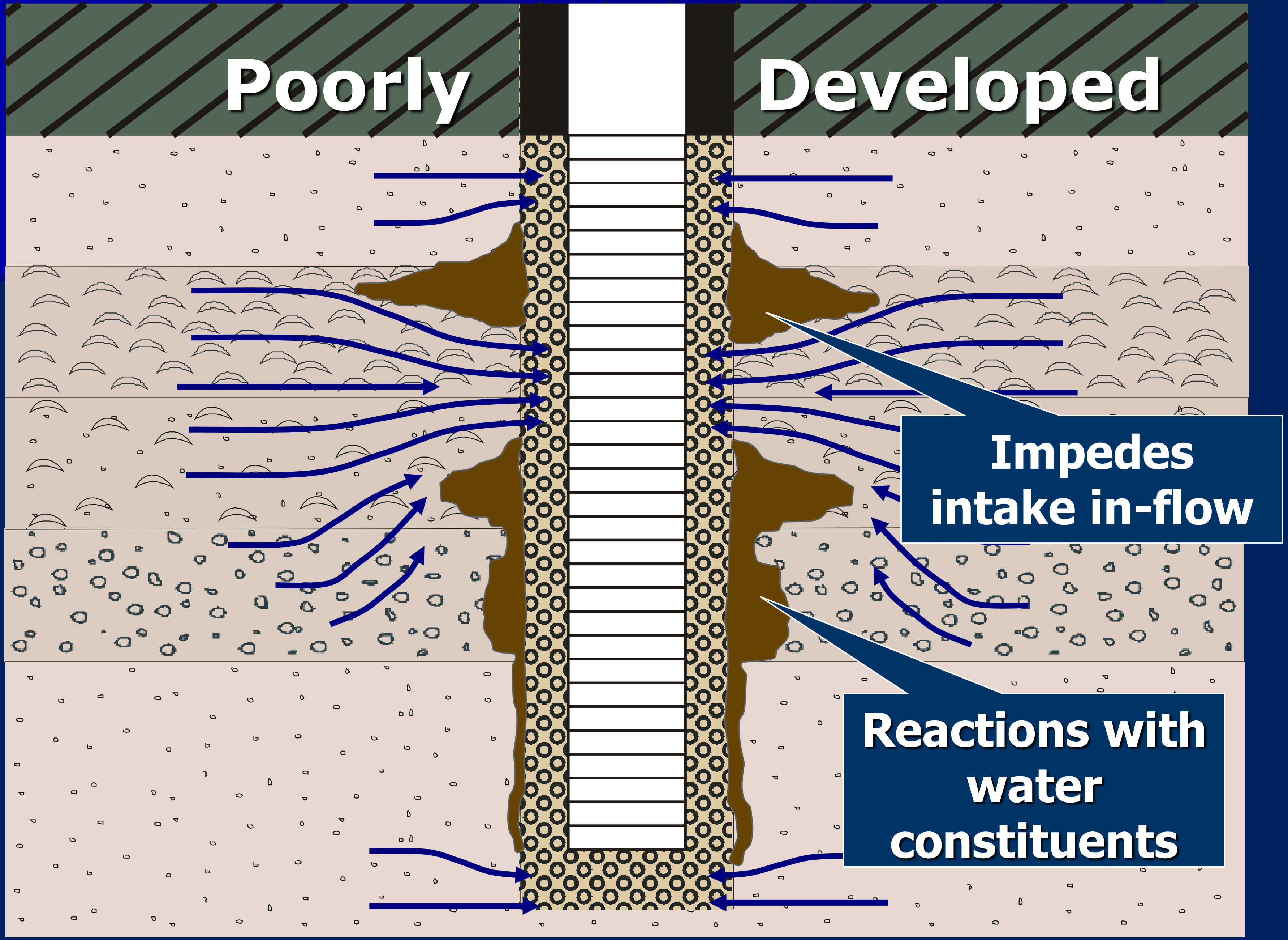
Post-construction Development

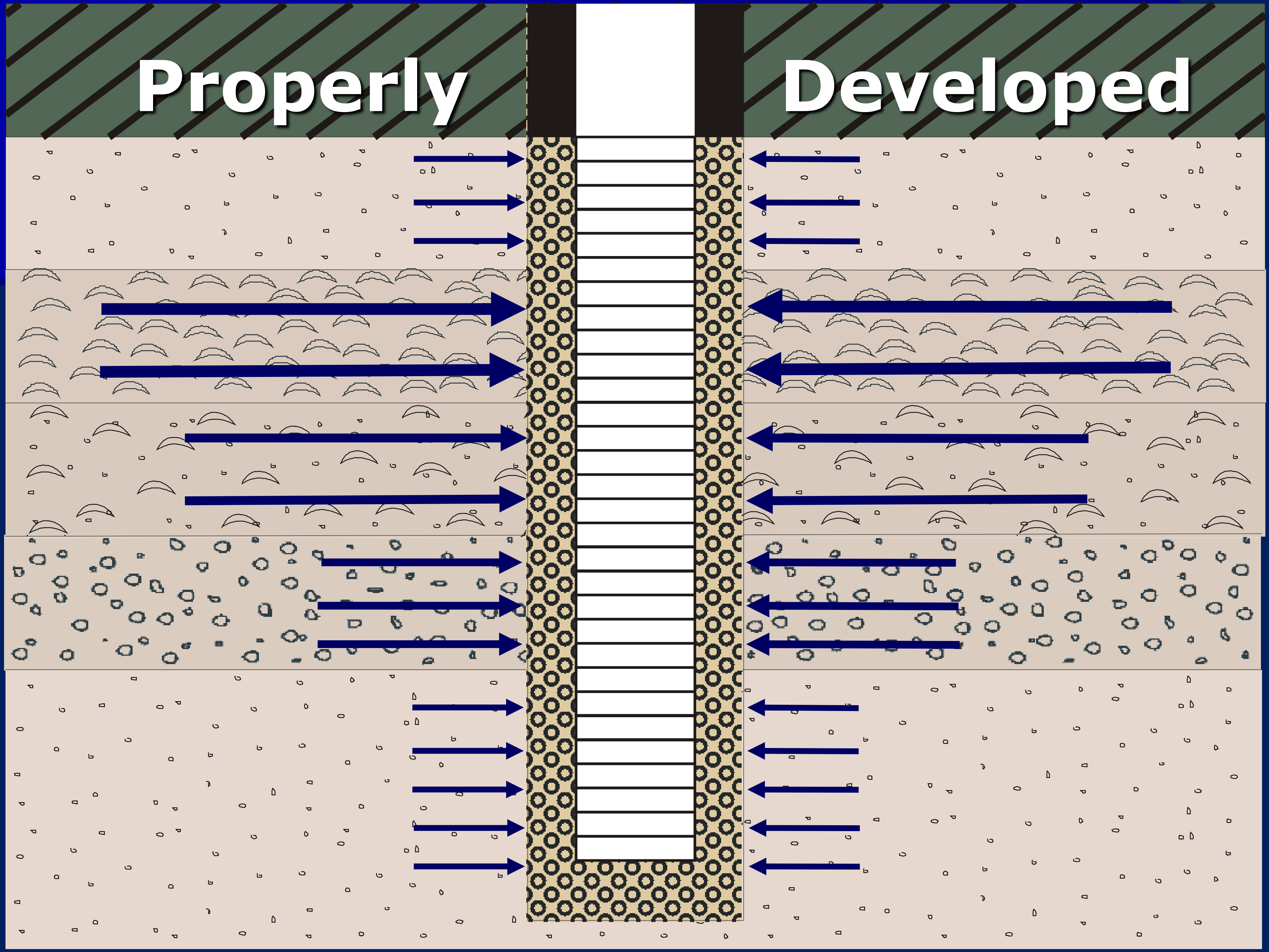
- Reduces impacts from drilling and well construction on the aquifer.

  (restores original permeability)

- Improves the connection of the well with the aquifer and the flow of water into the well.

  (maximizes well efficiency)


Poorly
Developed
Impedes intake in-flow
Reactions with water constituents


Properly
Developed

Secure the well top: Sanitary, secure

Sanitary, secure: well house

- Fenced, but crane access and room
- Overhead building access
- Line-of-sight from crane to casing top inside
- Room to work inside

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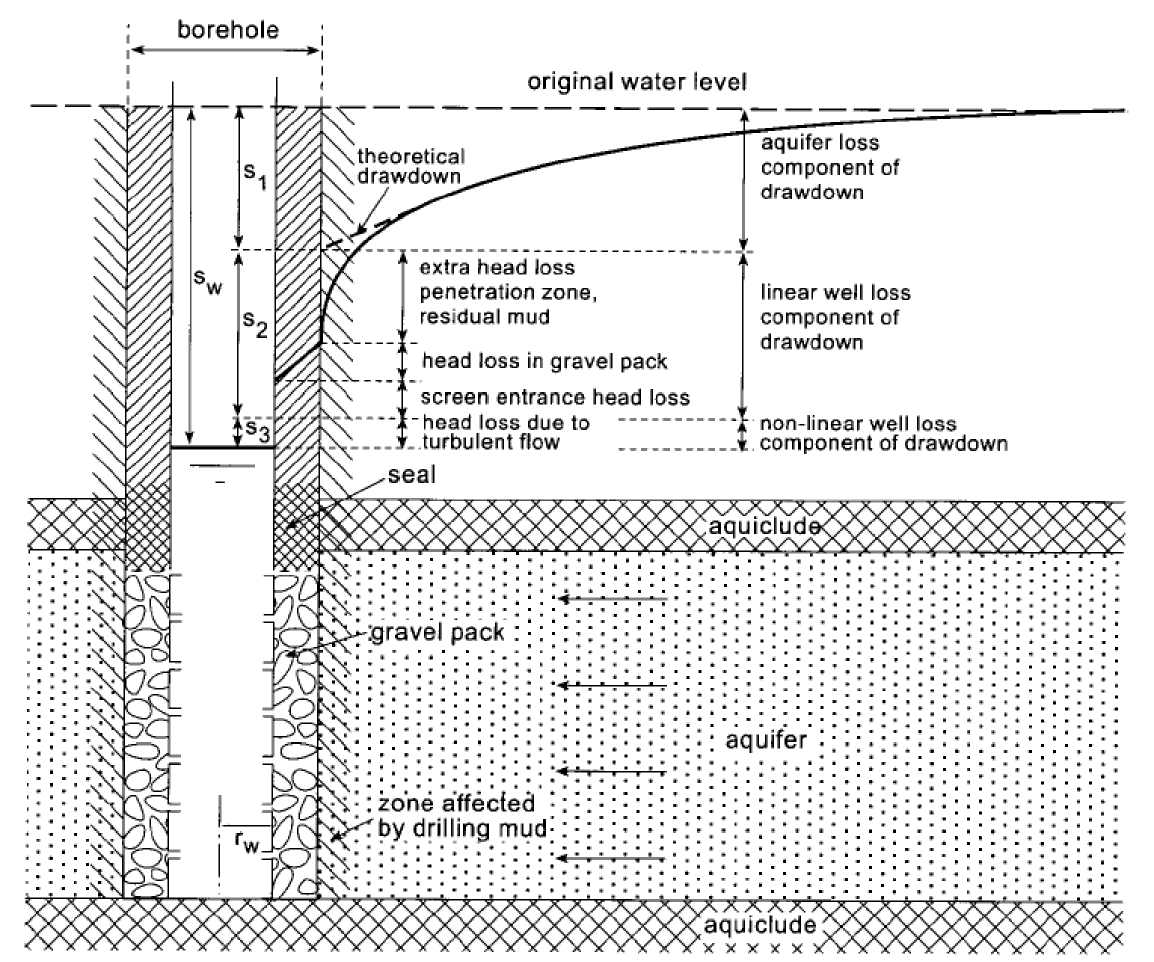
Towers and valve pits

Various ideas

Drawdown in a Well

- Drawdown in a pumped well has two components:
- Aquifer losses
  - Head losses occurring in the aquifer where the flow is *laminar*
  - Vary linearly with the well discharge
- Well losses
  - Aquifer damage during construction
  - *Turbulent* friction losses adjacent to well, in the well and pipe



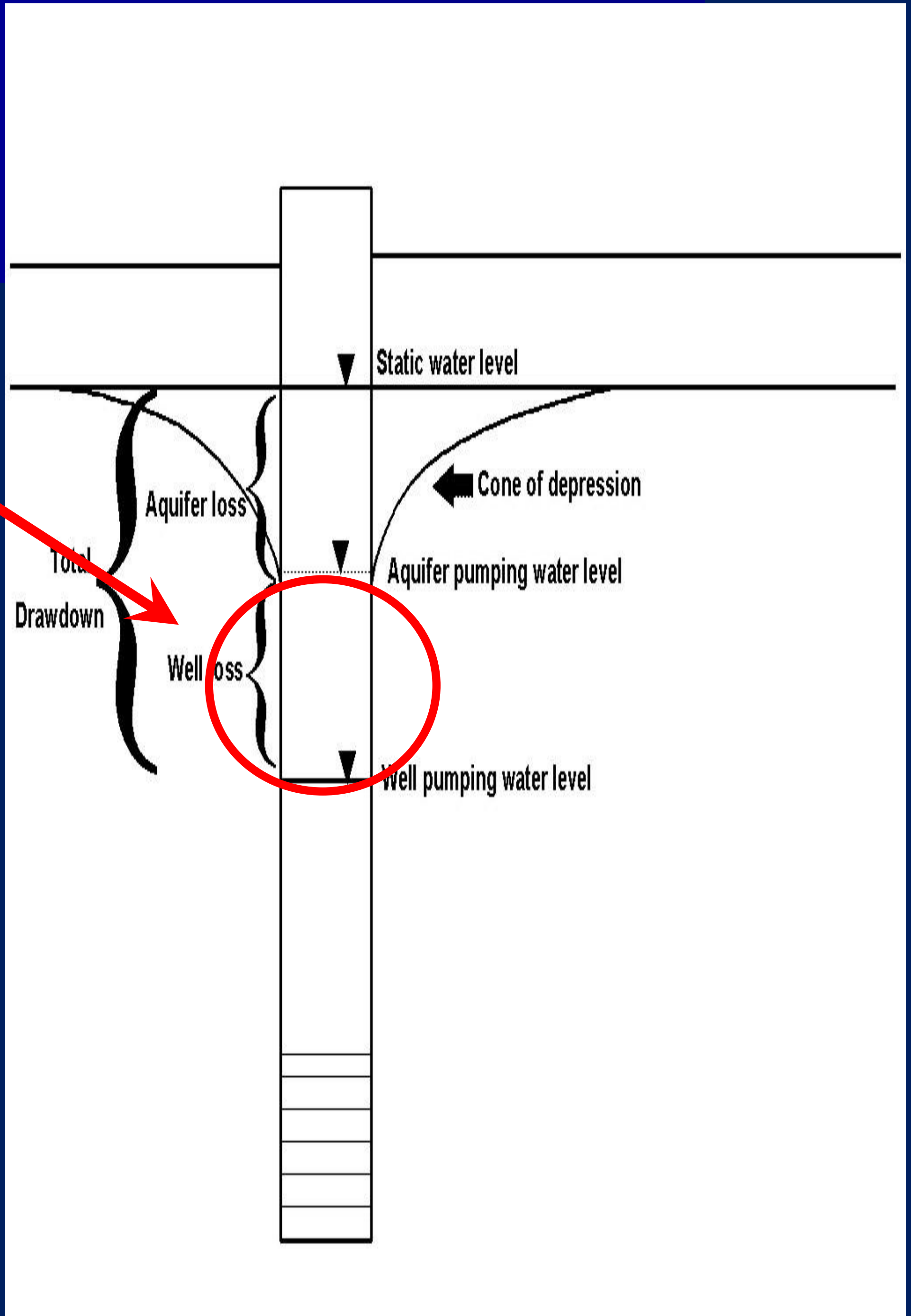
Why well efficiency is a concern to a major water producer:

This extra drawdown results in:

1. increased power consumption for pumping

2. greater wash zone in well, increased biofouling, greater rehab costs

3. less available drawdown, lower specific capacity



Testing wells for well and aquifer performance analysis

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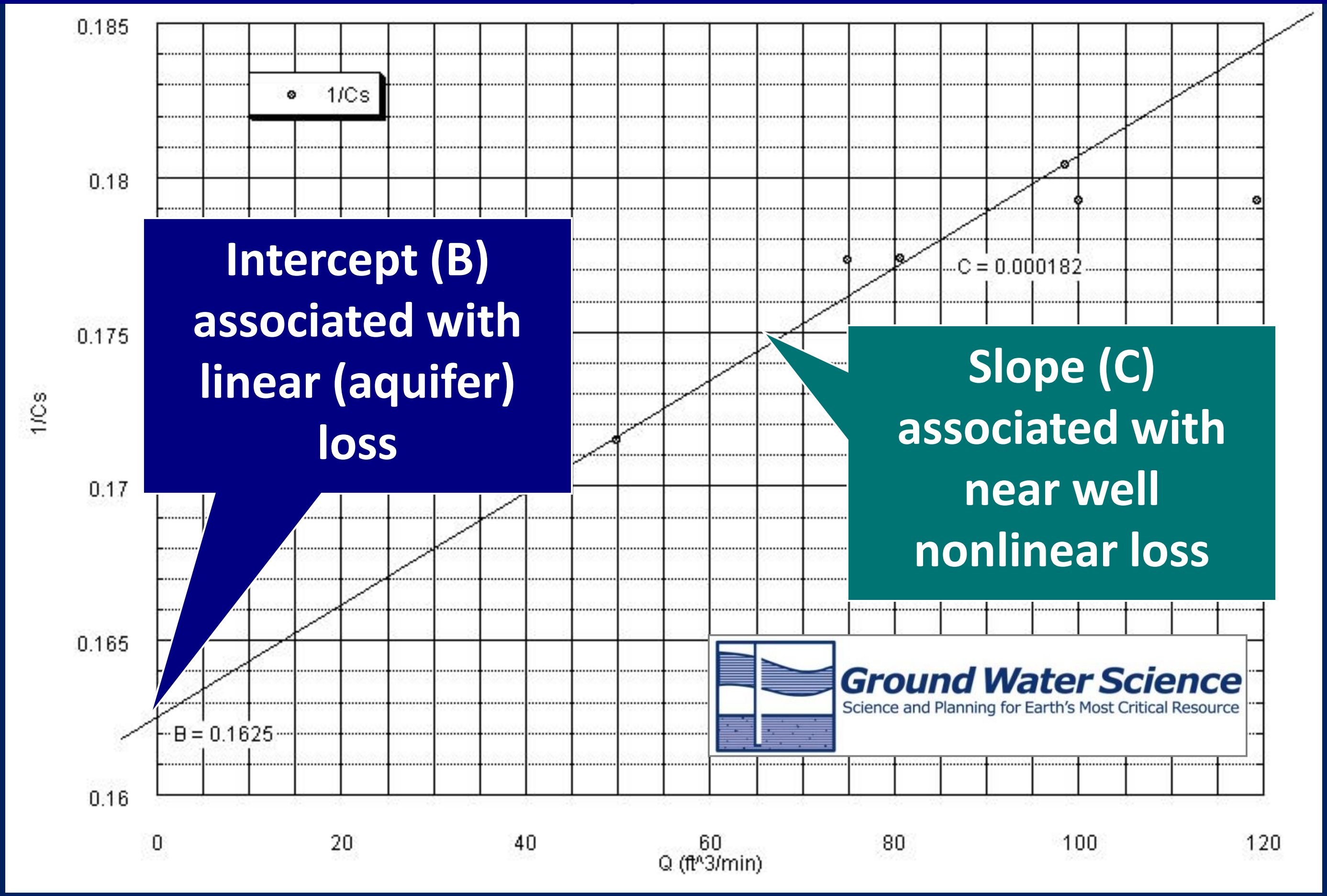
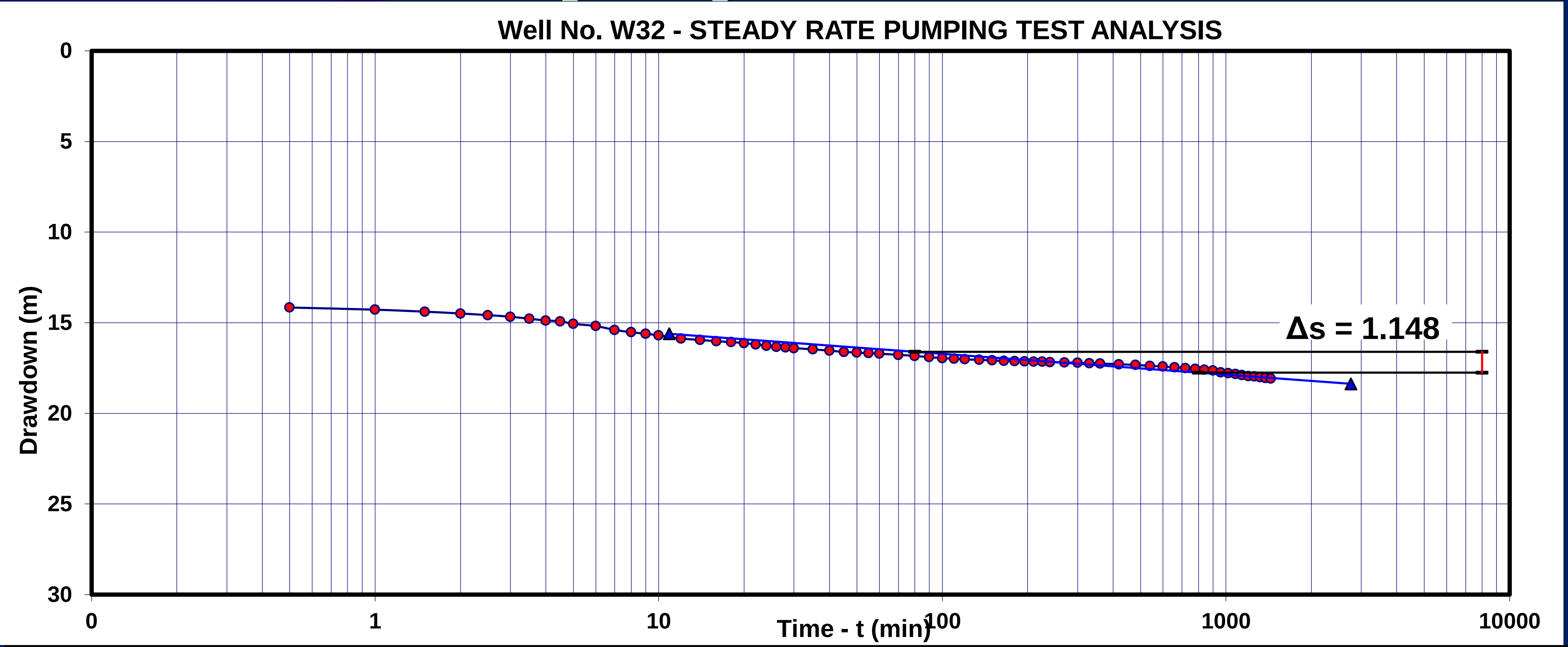
Well testing to evaluate yield, gauge effectiveness of well development or redevelopment

- Rig testing for preliminary tests
- Step testing to establish well properties: specific capacity, well loss and aquifer loss (by the book – do it right)
- Long-term constant-rate ("aquifer") tests to define aquifer-scale hydrology (by the book)
- Biological and physical-chemical water quality
- Visual assessments of sediment and debris

Specific capacity not the whole story: Step-drawdown test analysis to determine well loss components



Analyzing constant-rate (aquifer) pumping tests: aquifer-scale properties



Cooper - Jacob Analysis: Transmissivity T = 0.183 x Q/Δs (m^2/s)						
Start date and time	End date and time	Discharge-QAV	S.W.L.	Δs	Transmissivity - T	
11.10.2011	12.10.2011	(m^3/sec)	(mb.R.P)	(m)	(m^2/sec)	(m^2/d)
23:20	**23:20**	**0.08021**	**136.85**	**1.148**	**1.28E-02**	**1.10E+03**

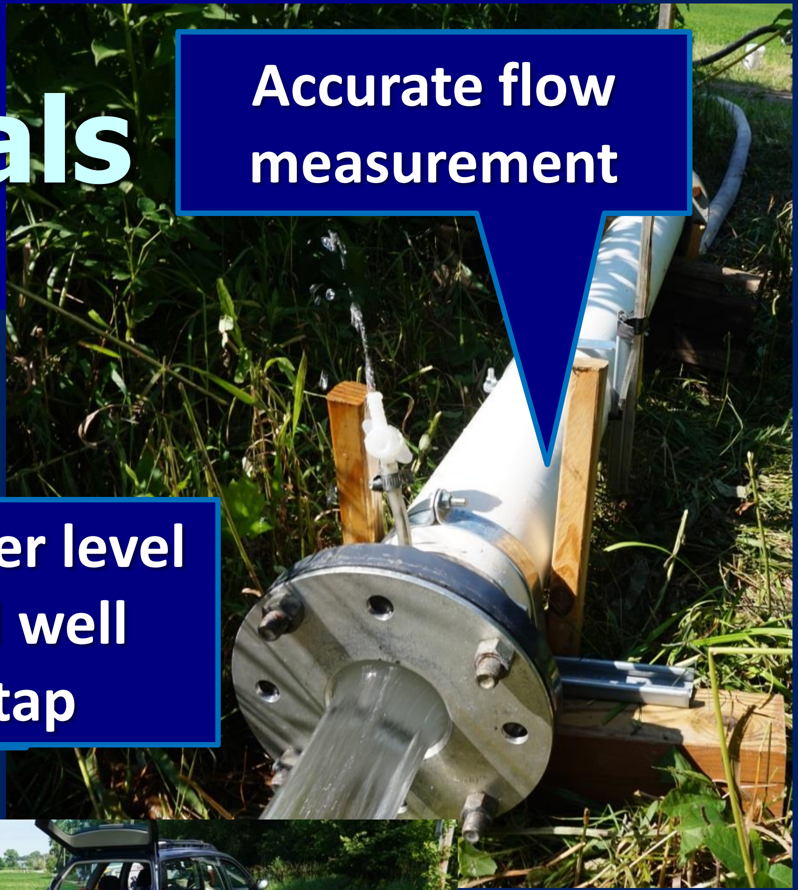
Controls on well yield and specific capacity

- Aquifer transmissivity (hydraulic conductivity x thickness)
- If unconfined (water table) aquifer, as T fluctuates, so does SC
- If aquifer is being dewatered, T and therefore SC decline
- Issues of original construction
- Clogging and attempts to reverse clogging

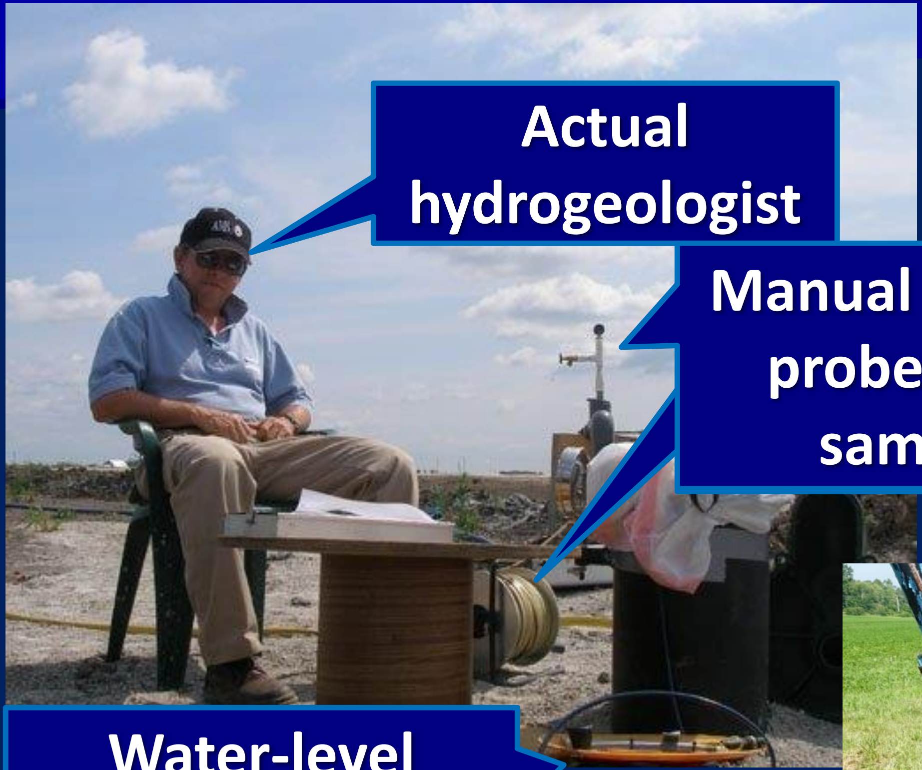
The step-drawdown test and well performance parameters helps the operator:

- determine if drilling contractor met performance specifications
- plan pump design and pump setting
- choose an efficient or "sustainable" pumping rate
- provide a baseline for monitoring performance changes

Well test essentials



Accurate flow measurement



Actual hydrogeologist

Manual water level probe and well sample tap

Water-level recorders (long-term tests)

Water quality analysis

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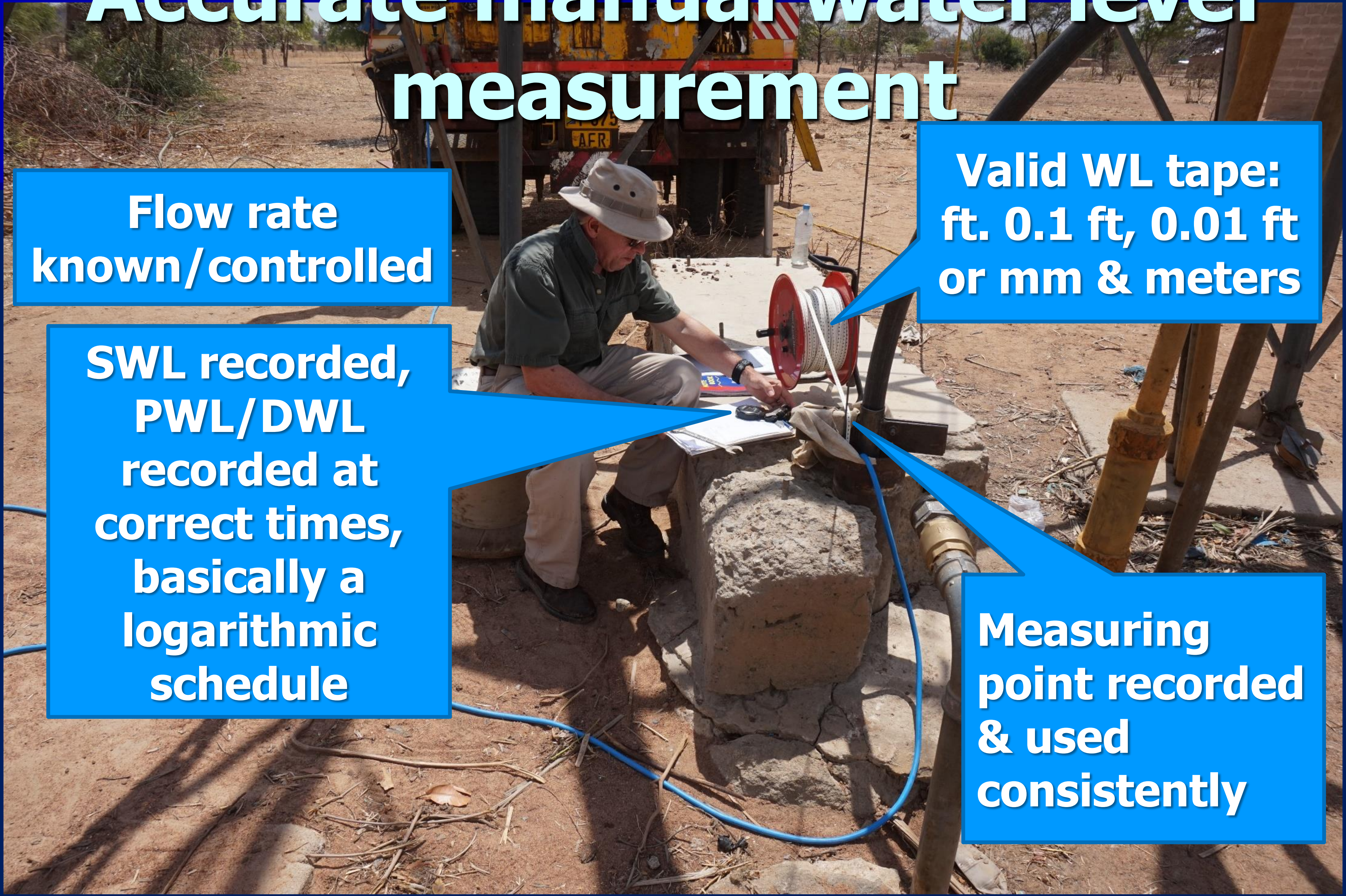
Accurate manual water level measurement



Flow rate known/controlled

SWL recorded, PWL/DWL recorded at correct times, basically a logarithmic schedule

Valid WL tape: ft. 0.1 ft, 0.01 ft or mm & meters

Measuring point recorded & used consistently

Philosophical interlude: Wells and wellfields are assets requiring planning and management

Wellfield asset management

- The “wild” – engineered interface
- Limited access
- Limited feedback

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- **Human and other environmental challenges**
- **Physical-chemical challenges**
- **Hydrologic issues**
- **Expensive and difficult to replace**
- ***Cannot afford NOT to plan for sustainability***

Wellfields: Town, municipal, industrial scale

Finding places to site new wellfields …

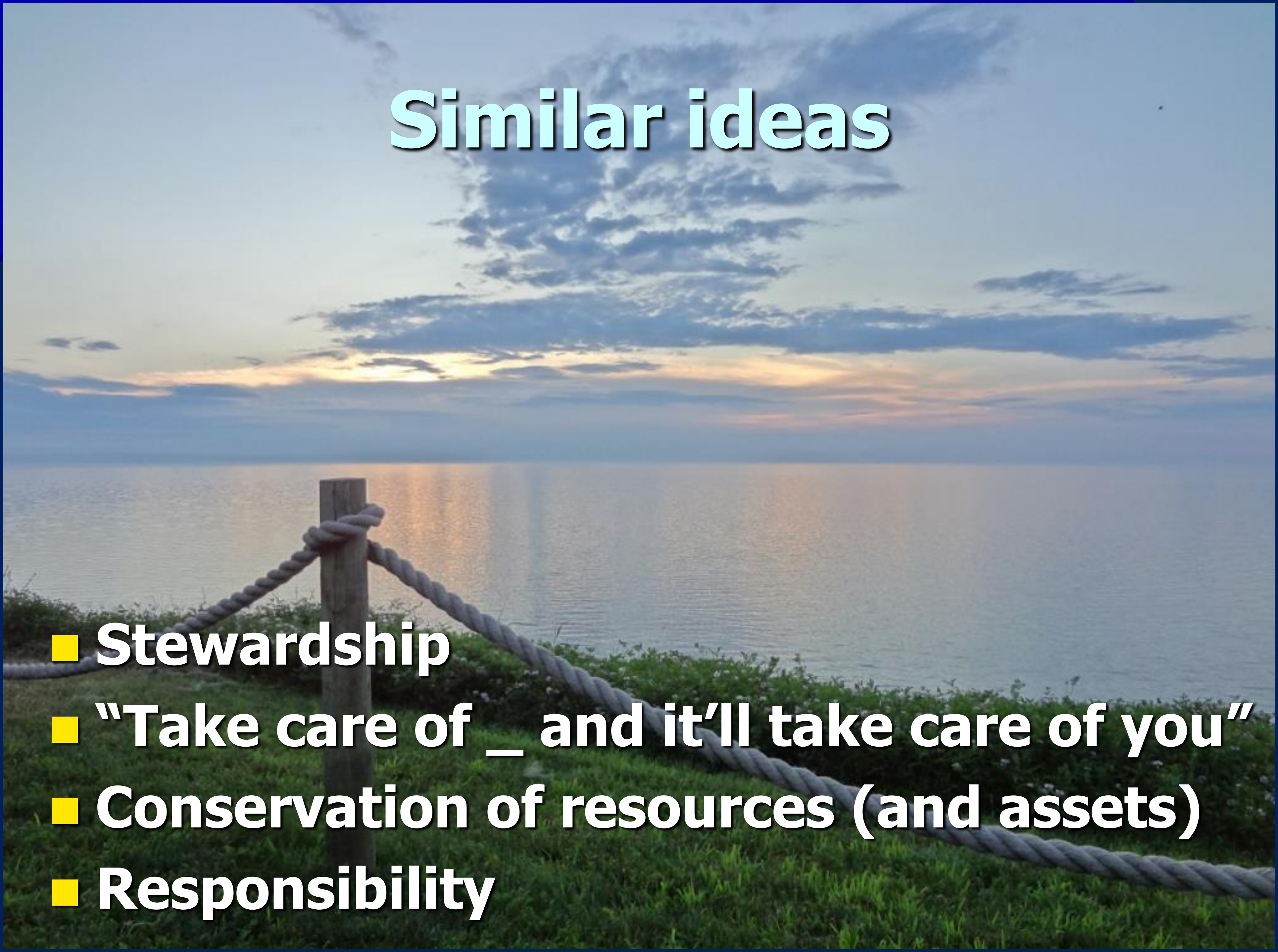
- Then: endless horizon

What Is Asset Management?

"A process for maintaining a desired level of customer service at the best appropriate cost."

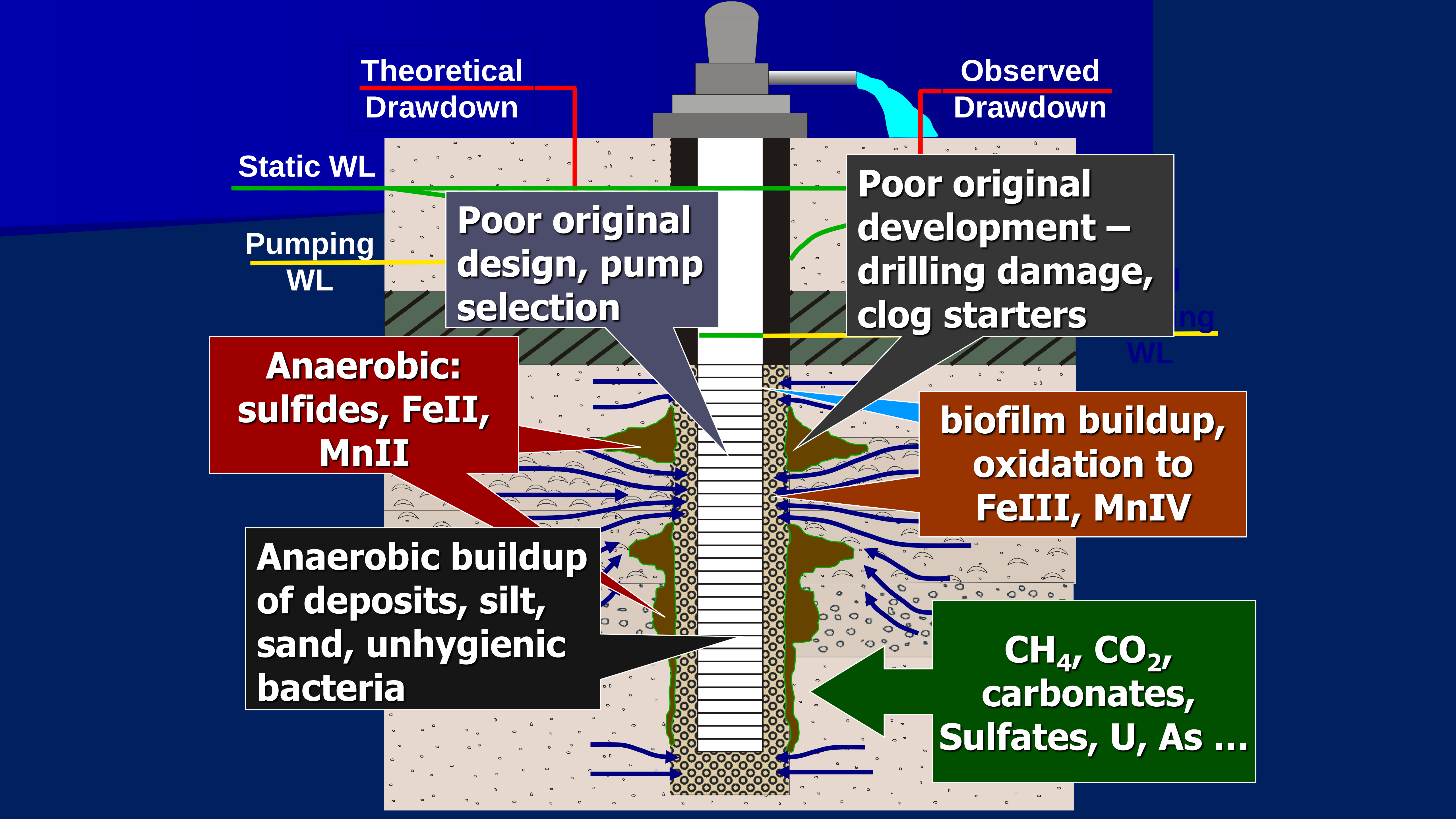
From USEPA 'Asset Management 101' presentation, Office of Groundwater and Drinking Water, Drinking Water Protection Division

Similar ideas



- Stewardship
- “Take care of _ and it’ll take care of you”
- Conservation of resources (and assets)
- Responsibility

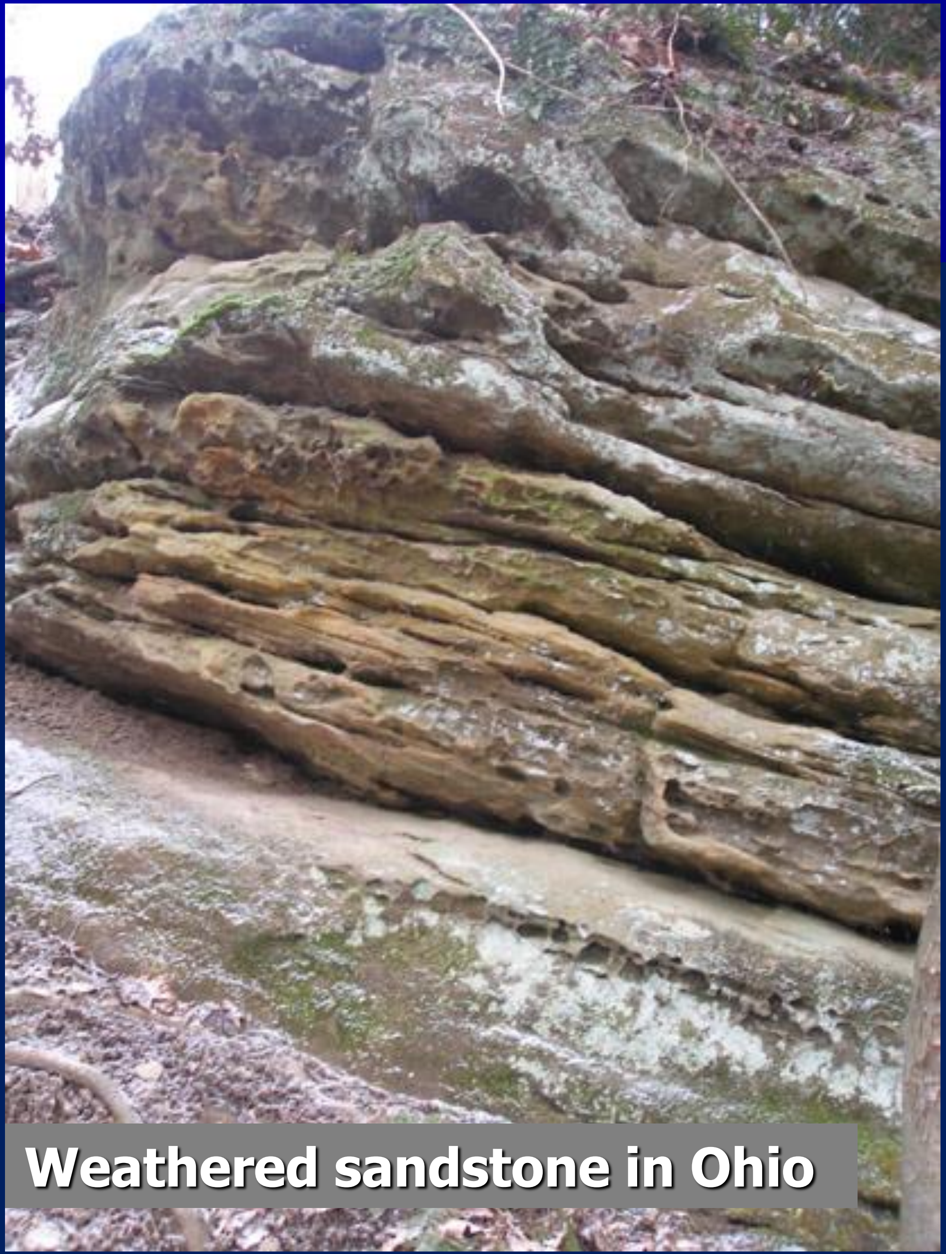
Many well owners' approach to potential well problems…



Theoretical Drawdown
Observed Drawdown
Static WL
Pumping WL
Poor original design, pump selection
Poor original development – drilling damage, clog starters
Anaerobic: sulfides, FeII, MnII
biofilm buildup, oxidation to FeIII, MnIV
Anaerobic buildup of deposits, silt, sand, unhygienic bacteria
CH_4, CO_2, carbonates, Sulfates, U, As …

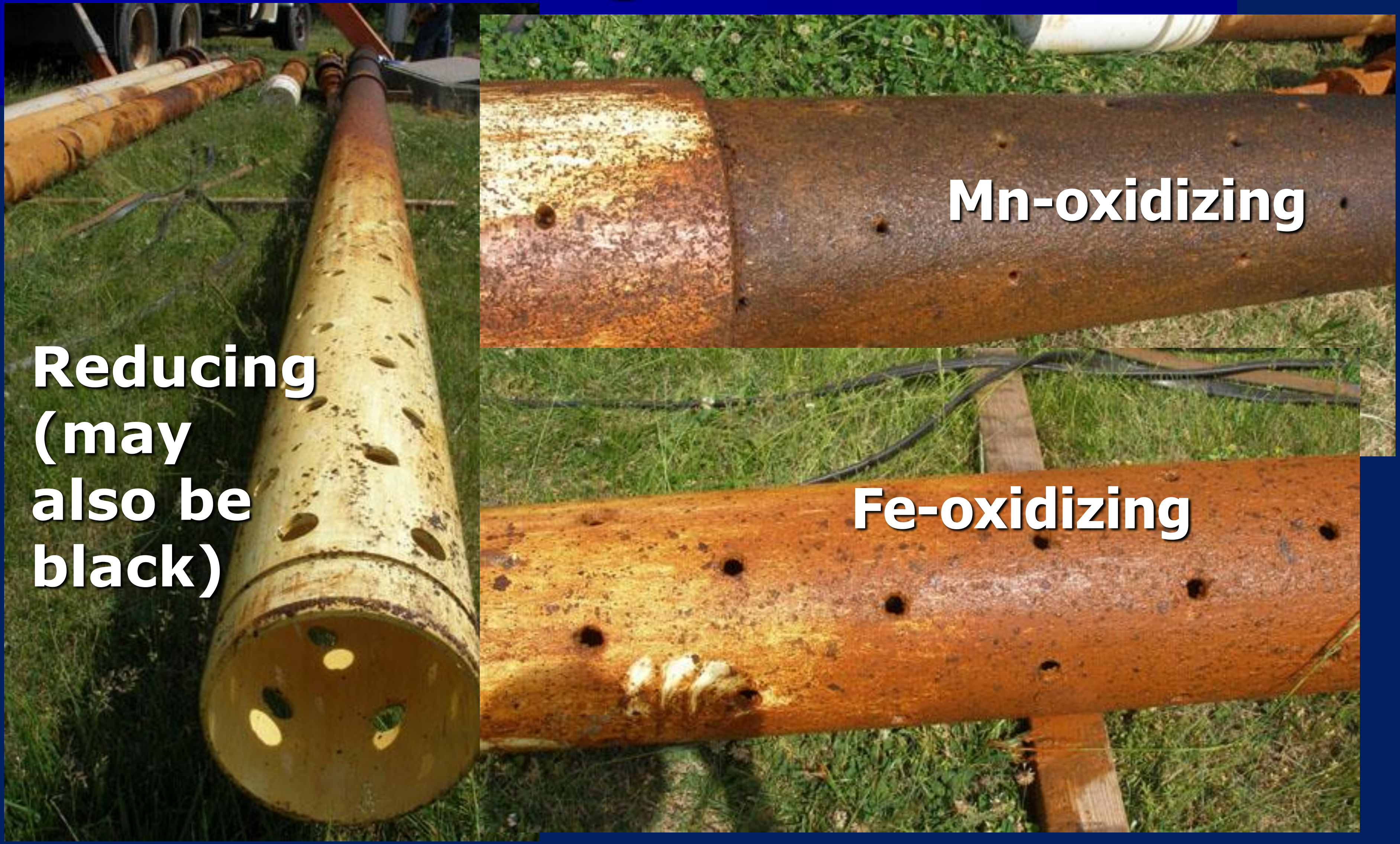
Microorganisms everywhere

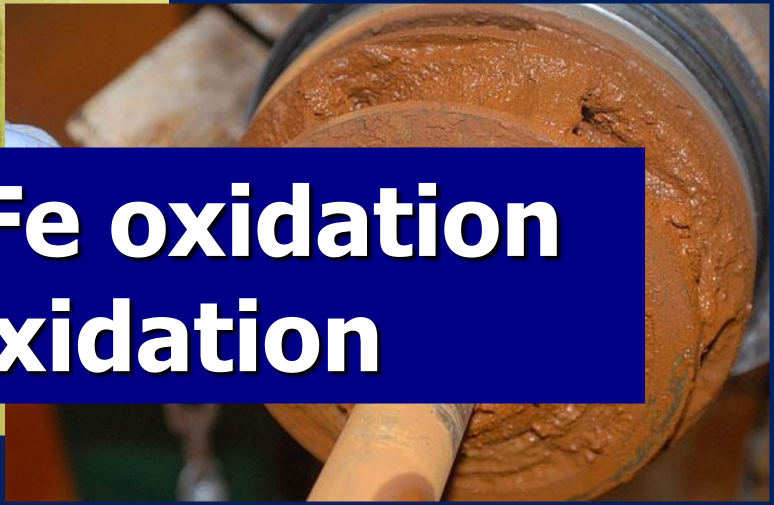
We now know that many types of microorganisms are native or adapted to saturated sediments and rock, and are indeed present in significant numbers in most water supply aquifers, <u>all over the world</u>, even deep formations – but very commonly in shallow ones.


Weathered sandstone in Ohio

There is not much keeping bacteria from moving in the earth

Redox gradations





***Bacteria accelerate* Fe oxidation and *Enable* Mn oxidation**

OK, friends, I deduce that we are participating in an iron geochemical cycle

Start fresh with a maintenance (or *asset management*) attitude (not because Senate Bill 2 makes you do it)

- Understanding that deterioration can occur and can be slowed and prevented
- This understanding often comes after a bad experience
- *Institutional* commitment to system maintenance including the wellfields
- Having a written but flexible plan to follow
- Training (frankly, indoctrination) so it isn't followed blindly

Commitment of everyone involved

Training, indoctrination!

Source Water Protection

- U.S. EPA Safe Drinking Water Act, administered in Ohio by Ohio EPA for public water supplies
- Four part definition and action (surface & ground water):
  - SWAP delineation (a real hydrogeologic one – ideally with <u>actual data</u>)
  - Risk assessment within delineated SWAP
  - Management plan to defend the SWAP (SWPP)
  - Implement the SWPP (*the hard part*)
- Necessary for negotiation with E&P, ODNR, and others
- Must be technically rigorous – then *be serious and defend it! It's your water supply.*

Source Water Protection and Monitoring task description

- Literally this is asset management
- Source water protection of a wellfield or surface water supply should be based on scientific analysis using site-specific and valid data
- Needed: active, regular water quality monitoring to detect contamination or change or to modify the risk assessment.

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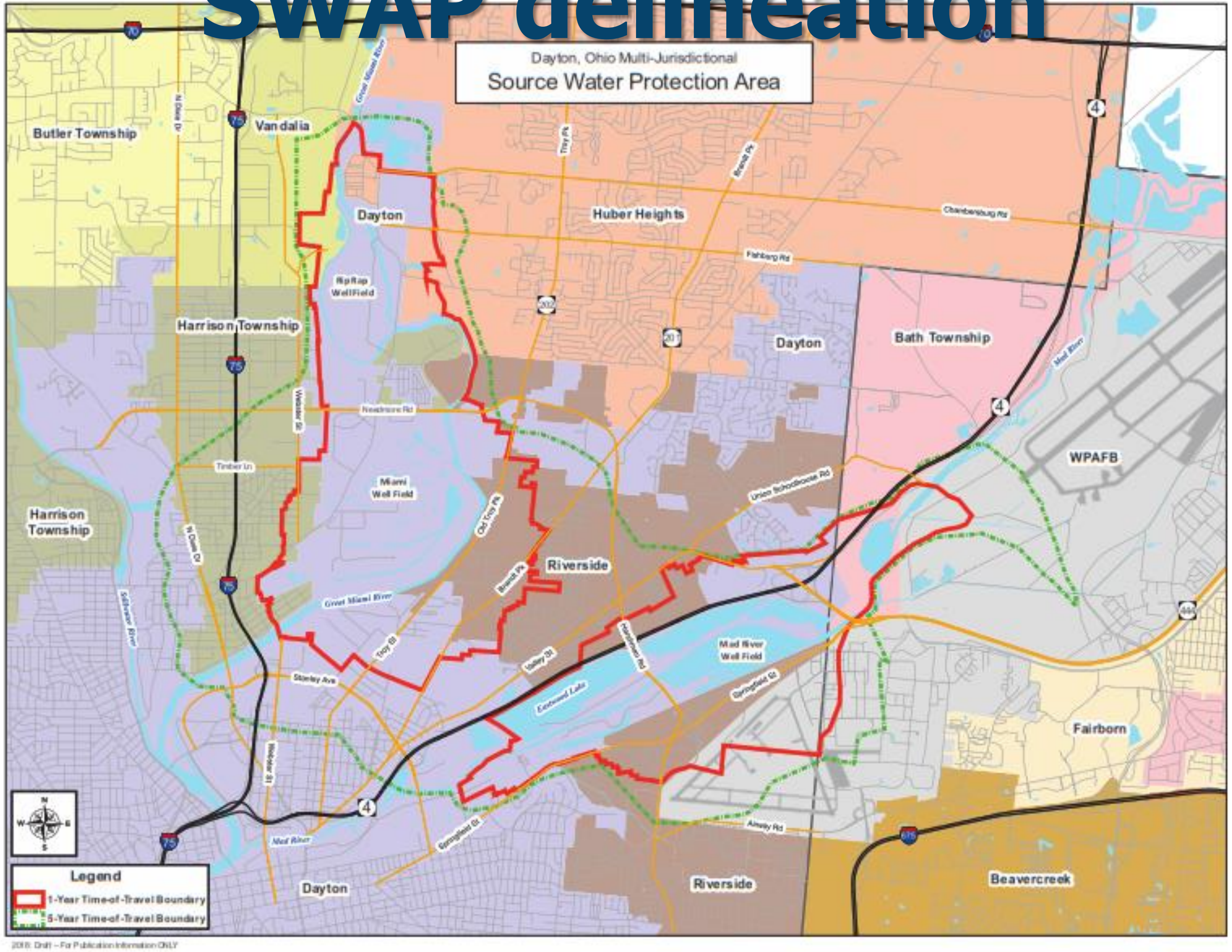
What can go wrong?

SWAP delineation



Plant Automation and Plant Intelligence

- Do you have abundant data? *Plan* how to manage and use them…
- Automation (sensors, software) means you can do more with finite people and resources
- Much confusion, many options – plan to simplify and streamline
- How to access to use – yourselves, analysts working remotely?

Then, use the information!

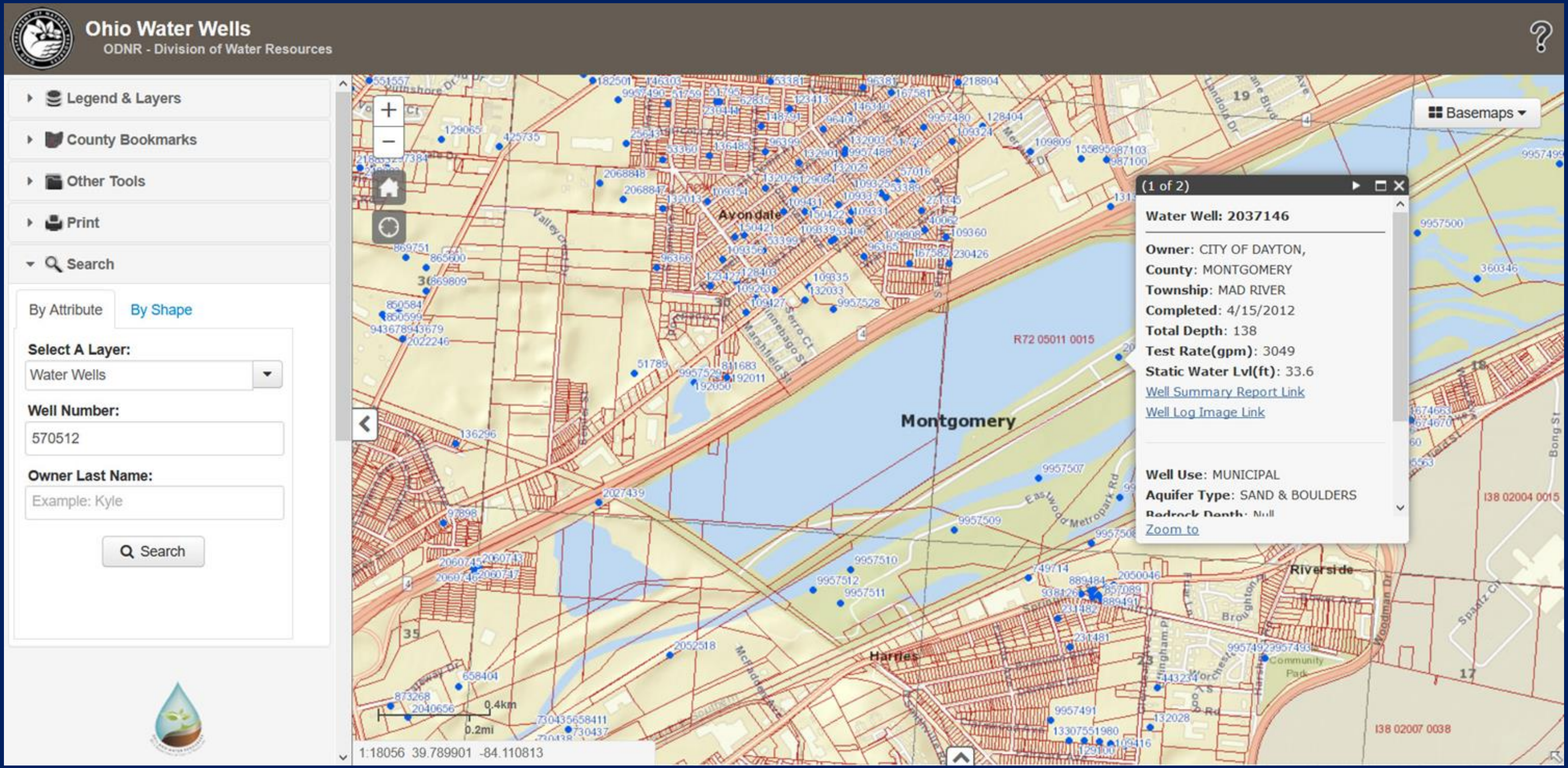
- You do not have to guess and work in the dark
- Knowing your costs, hydrologic factors such as specific capacity, water quality, power usage
- Keeping good records to do this
- Know your benefits as well as costs

Life-cycle cost

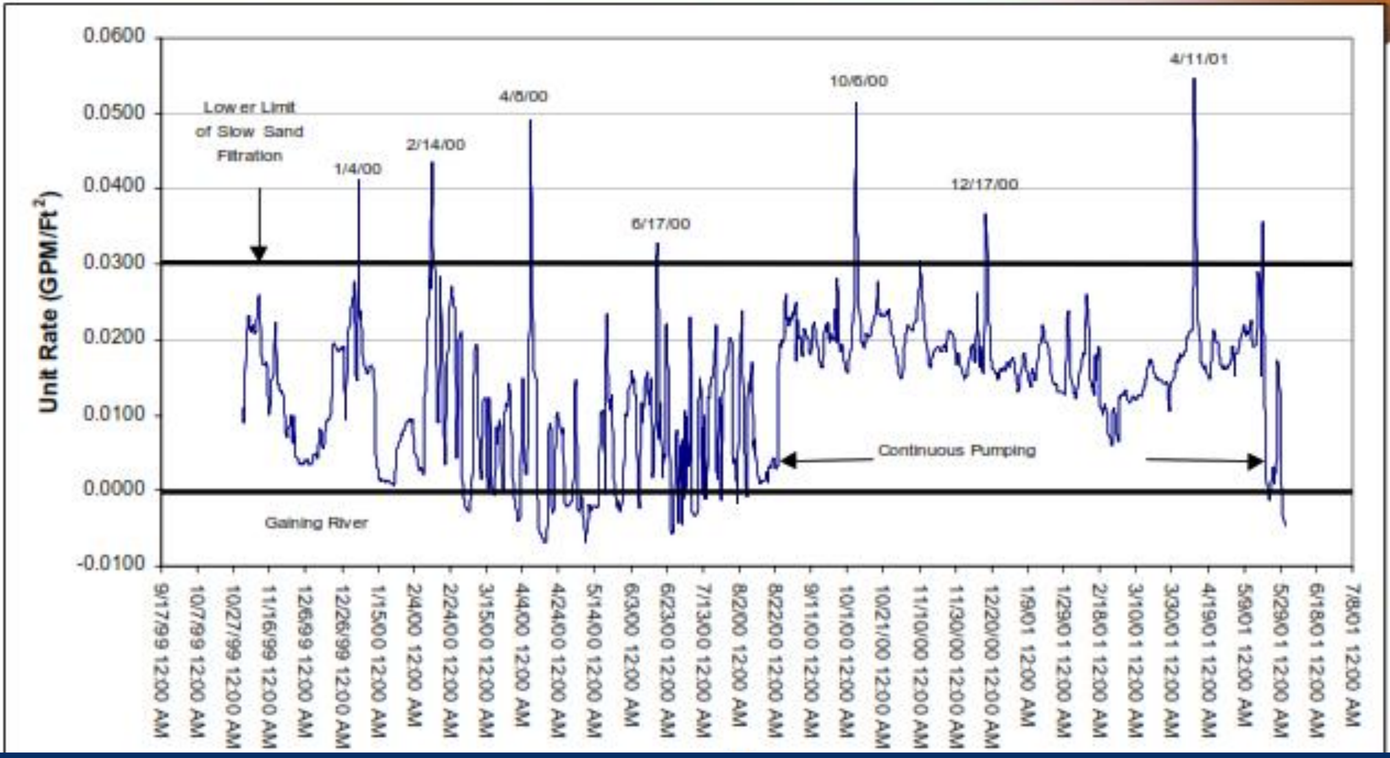
- Life-cycle cost (LCC) is the total cost of owning a product for a period of time.
- LCC includes the costs of design, construction and purchase, operation, maintenance, renewal, replacement or disposal

Do the math, but …. Probably best to keep what you have in good shape

Ground water under the influence

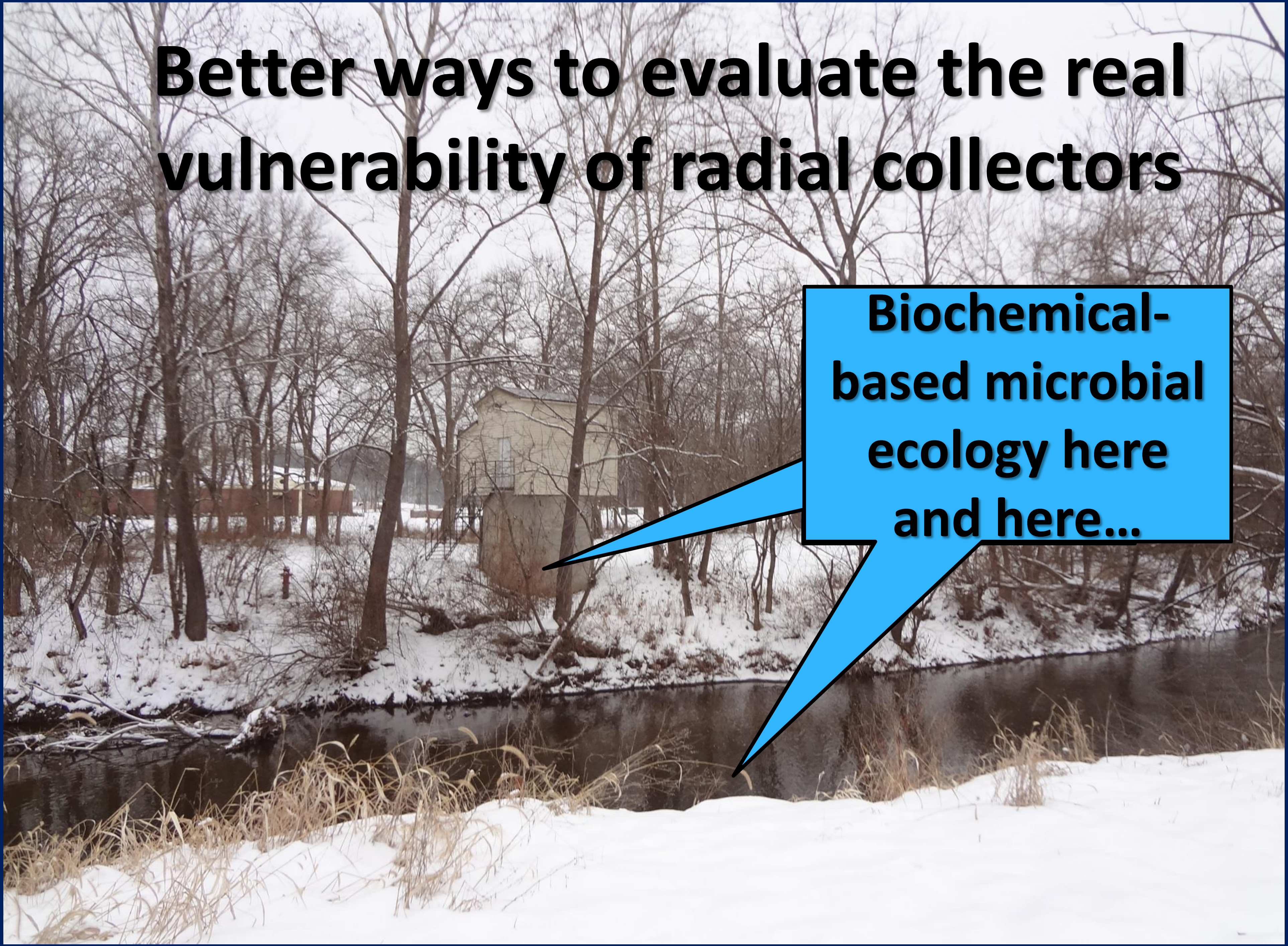


Potential Average Unit Rate of Infiltration



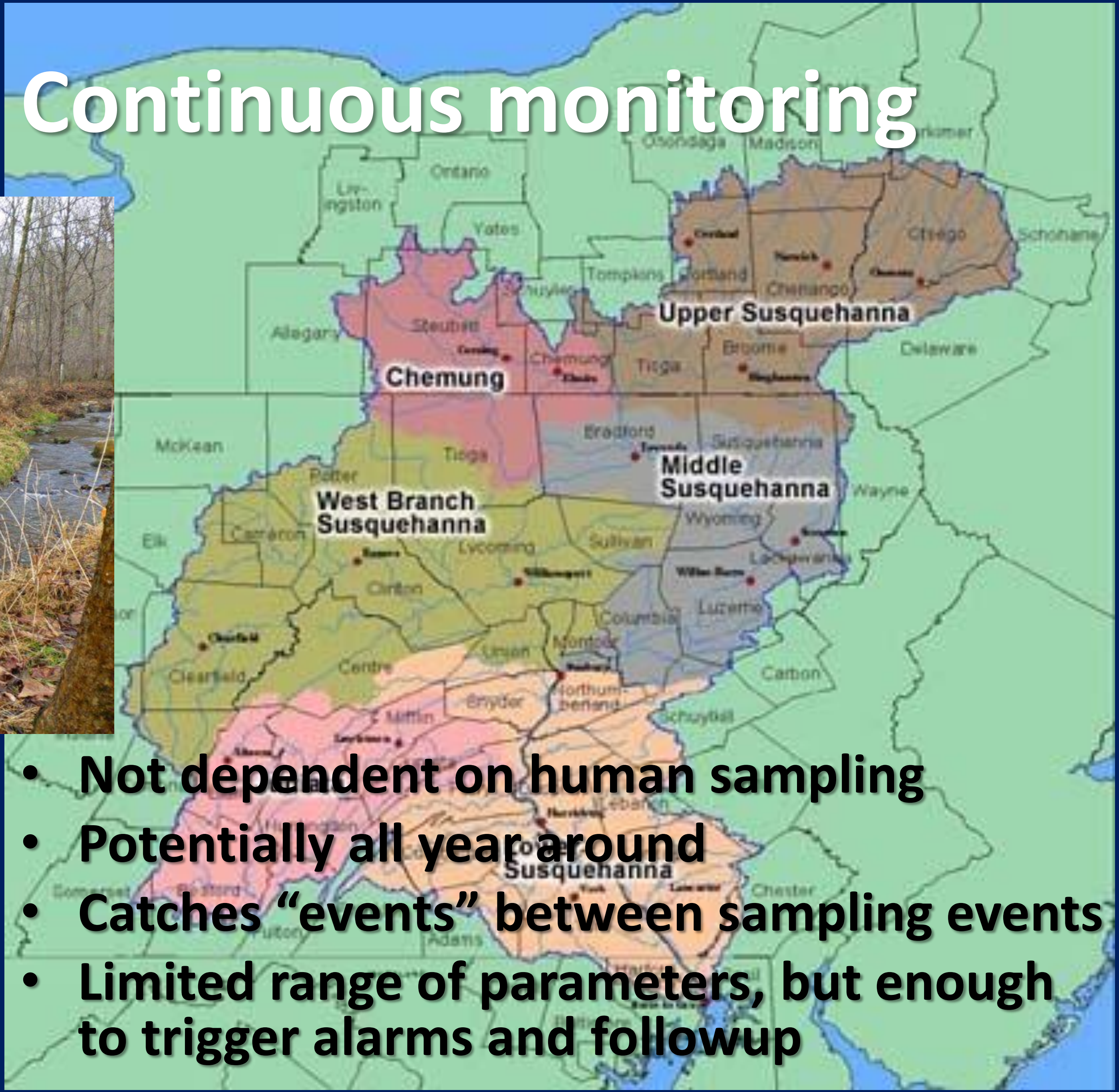
Cincinnati GWUDI study

Better ways to evaluate the real vulnerability of radial collectors



Continuous monitoring

Shop-built open-source monitor, design via Fondriest



- Not dependent on human sampling
- Potentially all year around
- Catches “events” between sampling events
- Limited range of parameters, but enough to trigger alarms and followup

Through planning, monitoring and education, it is possible to provide high quality drinking water without treatment in a landscape occupied since before Roman times

Ljubljana, Slovenia: this could be your future

- Ljubjana water supply for 300,000 people
- Sava River aquifer
- *No water treatment filtration*
- *No chlorination* for > 120 years
- Safe (and really good tasting) water
- High nitrate outside pumping areas being mitigated
- Maintained through strict source water protection (urban and ag uses – centuries old)

OK, quick summary

- Protect your assets (source water protection)
- Plan and design wells/wellfield scientifically
- Plan all based on life-cycle valuation
- Construct in a quality fashion
- Know the deteriorating factors and rates
- Practice preventive design and maintenance (don't wait until a well collapses, that sort of thing …)

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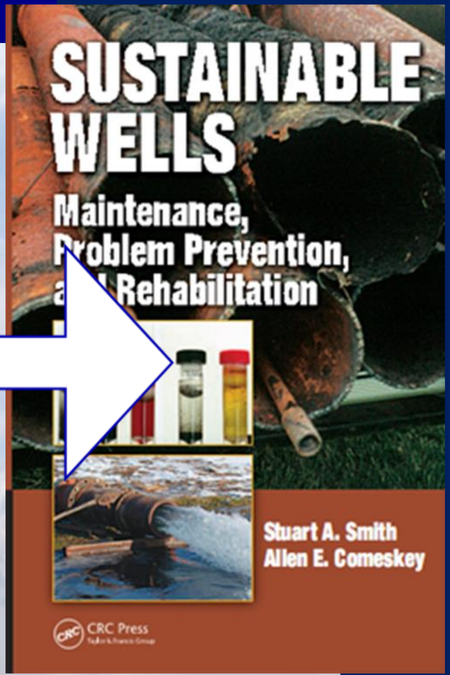
Any questions? You can do this.

I've got time or stay in touch

Did we mention the book?



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Ground Water and Wellfields: A Practical Primer

We can do this all day (5.5-6.0 hr) at your place of choice)

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Why we work to improve water supplies ...

No longer hauling nasty water for kilometers

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water for people
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