Ground Water Quality Monitoring
Issues at In Situ Leach (ISL) Facilities

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Primary Goal of a Ground Water Quality Monitoring Program

- Collection of water quality data that is representative of conditions at the site
- Such data will enable one to perform
  - Intrawell comparisons – comparing new well measurements to previous results from the same well (temporal analysis)
  - Interwell comparisons - comparing new well measurements to other contemporary measurements within the area of interest (spacial analysis)

Primary Goal of a Ground Water Quality Monitoring Program

Establish objectives and procedures of monitoring program recognizing that

- Temporal and spatial variability are inherent
- Need to control avoidable causes of variability
  - Analytical methods
  - Inconsistency in sampling
  - Sampling errors

Ground Water Quality Monitoring

Objectives dictate

- Where and when you sample - monitoring points and schedule
- What your sampling - Performance Indicators
- How your sampling - Monitoring procedures and devices

Objectives of ISL Ground Water Monitoring Program

Dictated by:

- Regulatory Criteria
  - State regulations
  - NRC License Conditions
- Guidelines (examples)
  - WY LQD Guideline No. 4 – In Situ Mining
  - Texas Class II Injection Well Technical Guidelines
  - NUREG-1569 – Standard Review Plan for In Situ Leach Uranium Extraction License Applications
- Hydrogeologic Factors
  - Hydraulic
  - Chemical

Ground Water Quality Monitoring at ISL Facilities

- Pre-Operational Monitoring
- Monitoring for Excursions
- Excursion Status Monitoring
- Monitoring During Restoration
- Post-Restoration Stability Monitoring

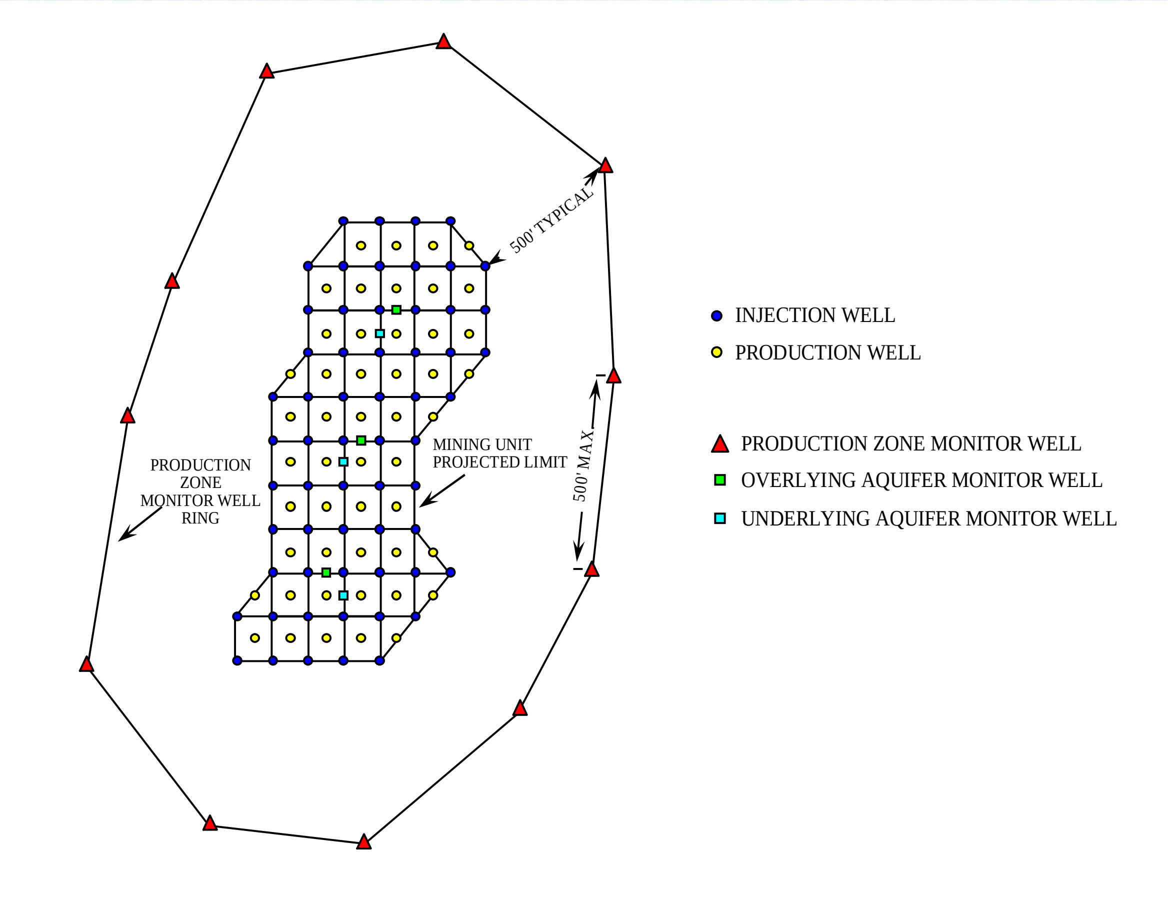
Ground Water Quality Monitoring

Objectives at ISL facilities vary depending on the monitoring phase

- Pre-Operational Monitoring
  - Establish baseline water quality conditions
  - Establish standards for determining when an excursion has occurred (upper control limits)
- Monitoring for Excursions
  - Provide early warning that leaching solution is moving away from well field
- Excursion Status Monitoring
  - Examine effect of measures taken to correct leaching solution excursion
- Monitoring During Restoration
  - Examine effect of measures taken to restore aquifer
- Post-Restoration Stability Monitoring
  - Confirm the absence of significant increasing trends of restored water quality

Ground Water Quality Monitoring

Generally occurs



- Within the ore zone
- Outside the ore zone
- In the overlying aquifer
- In the underlying aquifer

Ground Water Quality Monitoring

Typical sampling frequency for different monitoring phases

- Pre-Operational Monitoring
  - Two to three samples collected two weeks apart
- Monitoring for Excursions
  - Bi-weekly, 24-hour verification sample upon positive excursion results
- Excursion Status Monitoring
  - Weekly
- Monitoring During Restoration
  - Every 60 days
- Post-Restoration Stability Monitoring
  - Every two months

General Ground Water Sampling Procedures

- Installation and development of a monitoring well in hydraulic communication with the subsurface interval of interest (ore body, underlying, or overlying aquifer).
- Installation of a pump of proper size and depth within the well from which well water can be purged and a water quality sample can be collected.

General Ground Water Sampling Procedures

- Purge enough water to ensure that a water quality sample will represent conditions in the vicinity of the well
- Typical approaches
  - Purging based on set number of well volumes
  - Purging based on stabilization of water quality indicator parameters (typical ISL approach).

Purging - Well Volume

Standard Case - well volume = (total depth of well - depth of water in well) * cross-sectional area of well

USGS 1998 National Field Manual for the Collection of Water-Quality Data, Chapter A4, Collection of Water Samples

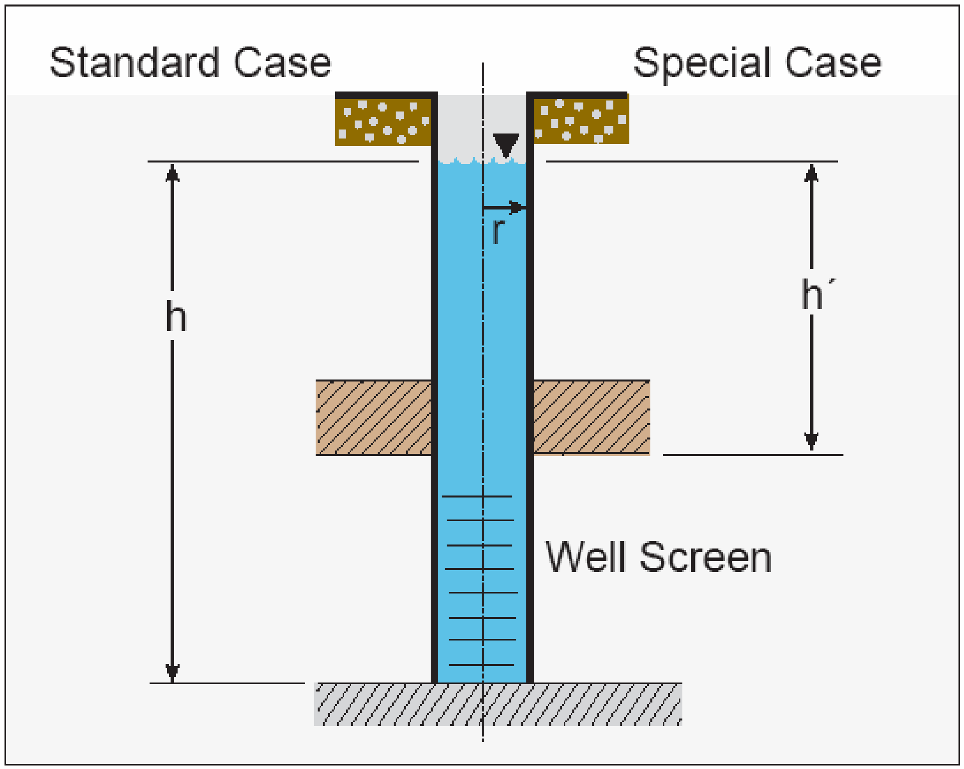
EPA 2002 *Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers*

Well Volume

Special Case - well volume may be calculated to exclude the well screen and any gravel pack if natural flow through these is deemed sufficient to keep them flushed out.

ASTM 1986 Standard Guide for Sampling Groundwater Monitoring Wells

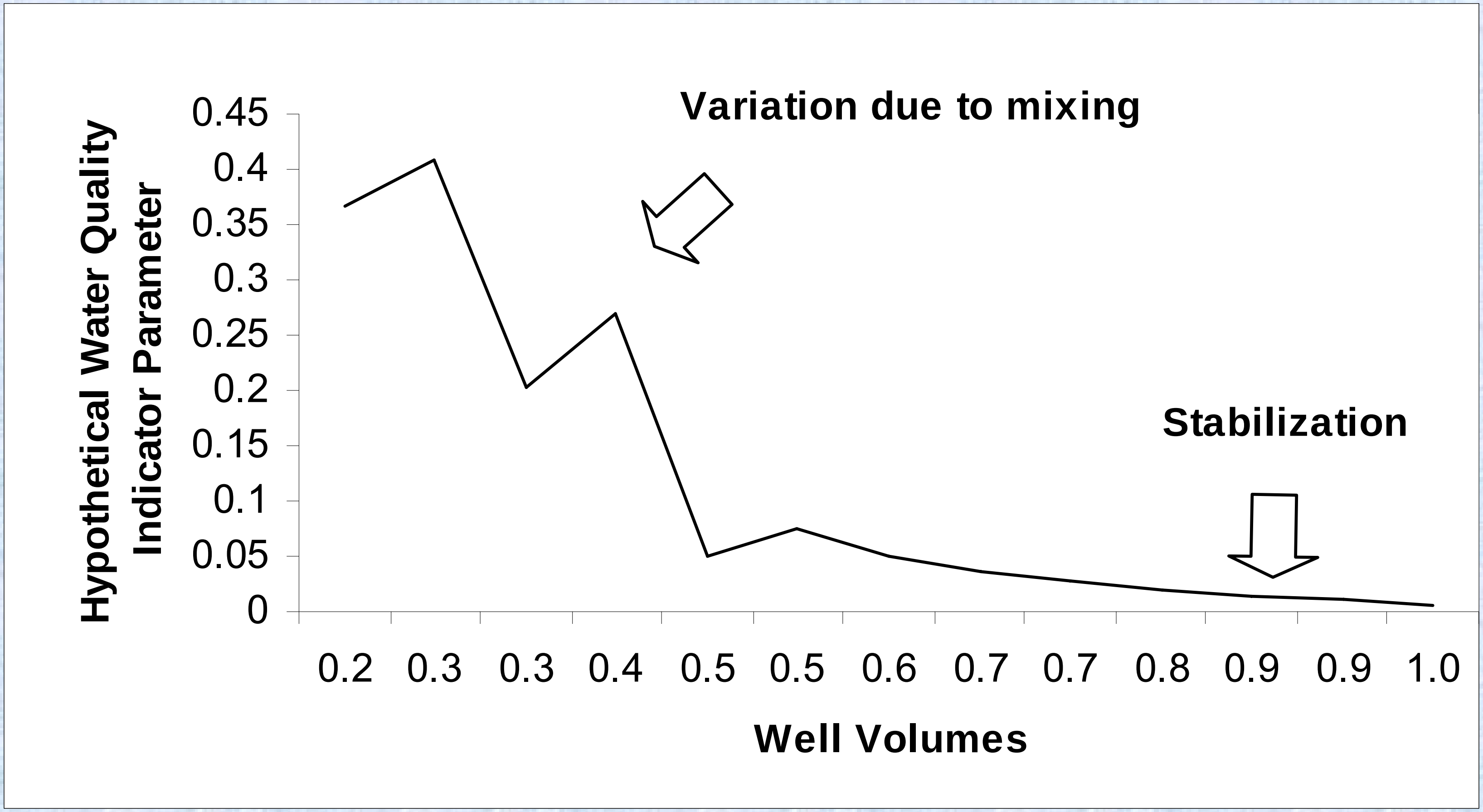
Well Volume = $\pi r^2 h$



Typical ISL Ground Water Sampling Approach

- Purge volume based on stabilization of water quality indicators (steady state).
- Purge volume based on stabilization of water quality indicators to within pre-determined range based on historical data.

Water Quality Indicator Stability



Typical Water-Quality-Indicator Parameters

- **SEC** - specific electrical conductance - electrical conductivity is an estimate of the amount of total dissolved salts (TDS) or the total amount of dissolved ions in the water. SEC is a measurement of conductivity that is adjusted to values at 25°C for an average ionic species (e.g. KCl).

Typical Water-Quality-Indicator Parameters (cont.)

- **pH** - A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity

- **ORP** - oxidation-reduction potential (also known as redox) is a measure of a water system's capacity to either release or gain electrons in chemical reactions. The process of oxidation involves losing electrons (valence increases) while reduction involves gaining electrons (valence decreases).

Typical Water-Quality-Indicator Parameters (cont.)

- **Turbidity** – a measure of suspended solids in the sample. Units reported as nephelometric turbidity units (NTUs). Nephelometer measures the amount of light scattering (due to suspended particles) in a water sample.

Typical Water-Quality-Indicator Parameters (cont.)

- **DO** – dissolved oxygen is a relative measure of the amount of oxygen (O_2) dissolved in the water (oxygen saturation). DO is measured in standard solution units such as milligrams O2 per liter (mg/L) or parts per million (ppm).

- **Temperature**

Water Quality Indicator Parameter Studies

- Study of 13 randomly selected monitor wells indicated field parameters stabilized within about one purged well volume and remained stable through three plus well volumes

- Minimizing purge volume reduces likelihood of drawing leaching fluid toward perimeter monitor wells

PRI – Highland Uranium Project 1993-1994
[Adams Accession No. ML061380619]

Typical Water-Quality-Indicator Parameters - Issues

Temperature, pH, and SEC generally stabilize before dissolved oxygen and nitrate.

Pionke and Urban 1987 Sampling chemistry of shallow aquifer systems – a case study. Ground Water Monitoring Review. Vol. 7, No. 2

Temperature, pH, and SEC generally stabilize within one well volume, dissolved oxygen and turbidity may require up to three well volumes.

Puls et al 1990 Colloidal-Facilitated Transport of Inorganic Contaminants in Ground Water: Part I, Sampling Considerations EPA/600/M-90/023

ISL Ground Water Sampling

- Current ISL approach analogous to Low-Flow (Minimal Drawdown) technique used in environmental remediation field
- Differences between approaches are essentially in scale
  - ISL wells 300+ feet deep vs. typical low-flow application well ≤ 25 feet
  - ISL monitor well pump rate between 5 to 10 gpm vs. typical low-flow application 250 ml/min
  - ISL screened interval ≥ 25 feet vs. typical low-flow screened interval ≤ 10 feet

Low-Flow vs. ISL Approach

Low-flow Sampling

- Pump in a manner that minimizes stress (drawdown) to the system (<0.1 meters)

Puls and Barcelona 1996 Low-flow (Minimal Drawdown) Ground-Water Sampling Procedures

ISL Ground Water Sampling

- Pump rate is kept low to reduce turbulence in the well (i.e., minimize drawdown)

Humenick et al 1980 Methodology for Monitoring Ground Water at Uranium Solution Mines

Low-Flow vs. ISL Approach

Low-flow Sampling

- Samples collected following stabilization (3 consecutive samples) of water quality indicator parameters (3 to 5 minute intervals)

Puls and Barcelona 1996 Low-flow (Minimal Drawdown) Ground-Water Sampling Procedures

ISL Ground Water Sampling

- Collect sample after water quality indicator parameters in discharging water have remained stable for at least 10 minutes

Humenick et al 1980 Methodology for Monitoring Ground Water at Uranium Solution Mines

Pump Location - Issues

Under high-yield conditions, placing the pump at the well intake and utilizing low pumping rates may serve to isolate stagnant water in the well bore above the pump

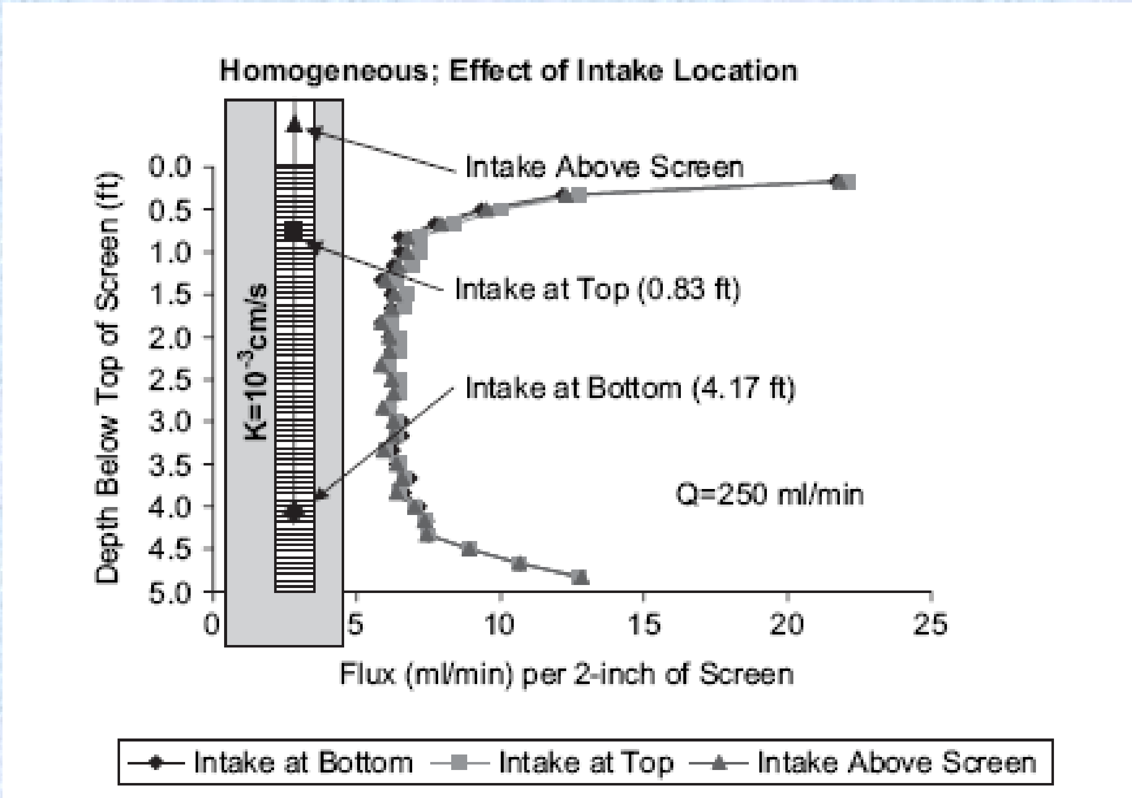
Pohlmann & Alduino 1992 Potential Sources of Error in Ground-Water Sampling at Hazardous Waste Sites EPA Ground-Water Issue

Placing the pump within the screened interval may result in the vertical portion of the sampled aquifer being smaller than the screen length

When placing pump above the well screen, the sample may represent a composite of water quality over the well screen

Yeskis & Zavala 2002 Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers Ground Water Forum Issue Paper

Effect of Intake (Pump) Location



Varljen et al, Ground Water Monitoring & Remediation, Vol. 26, No. 1, Winter 2006

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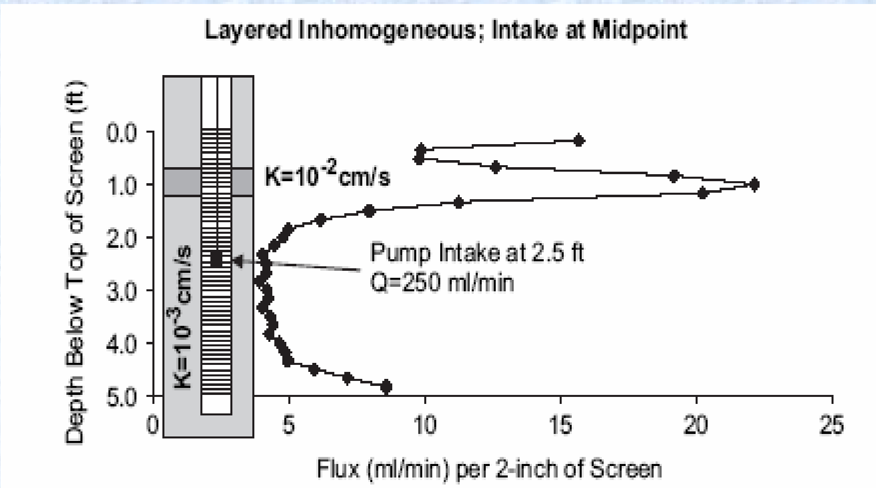

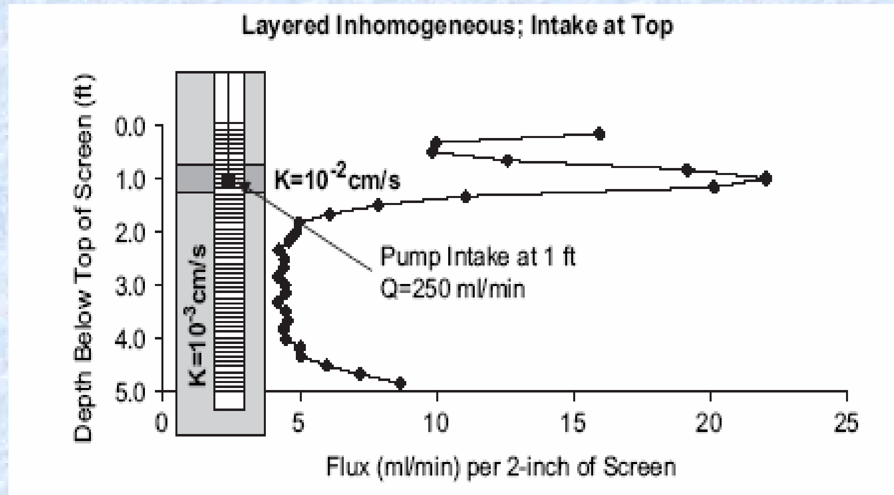

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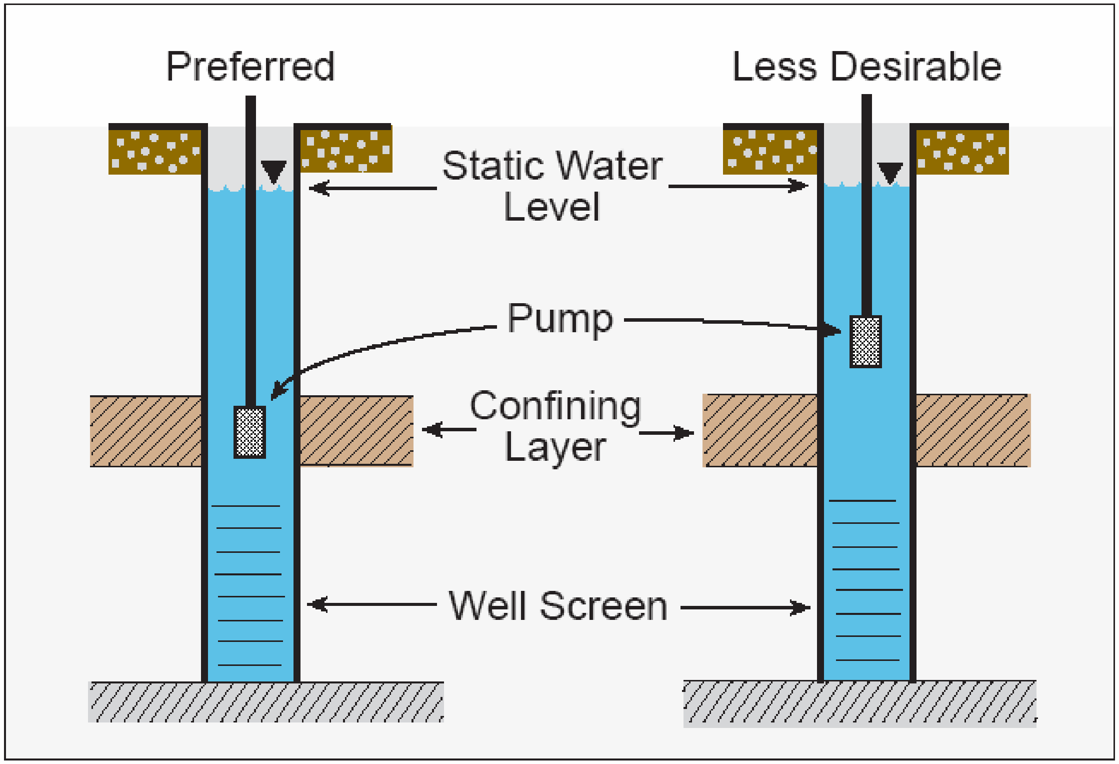
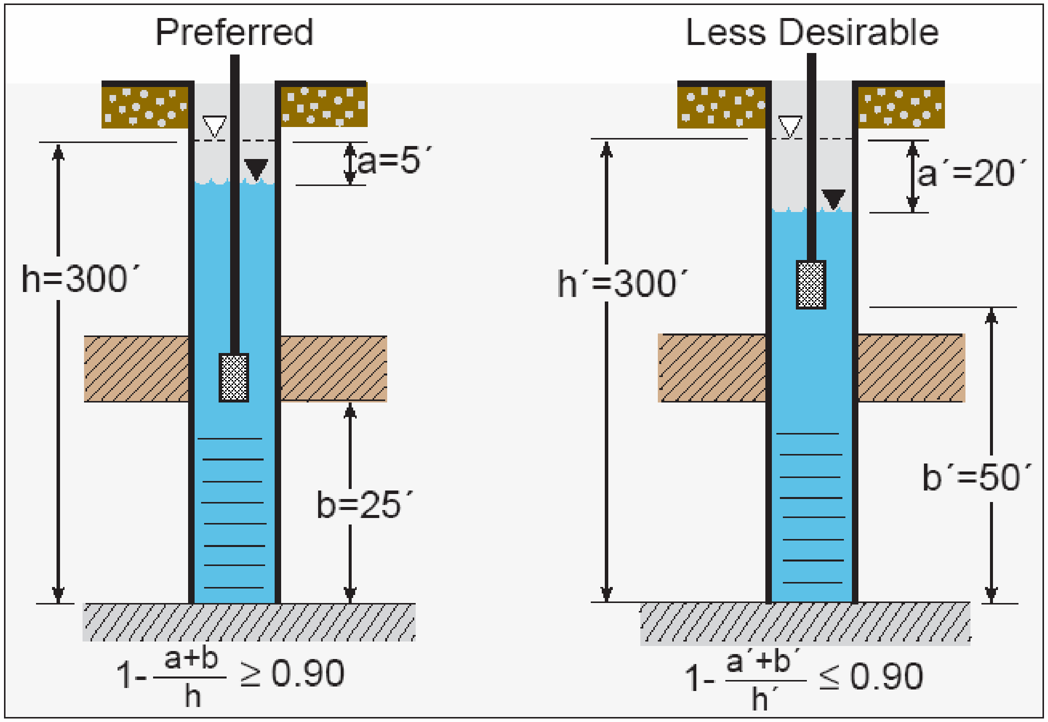
Optimal Pump Placement



Preferred pump location above (as shown) or within well screen (if drawdown is minimized).

Issue: Minimization of Drawdown



Assumes standard well volume case and stabilization of water quality indicator parameters within one well volume.

For special case, b = 0’, drawdown should be minimized to avoid turbulence in well

Summary

"Belt and Suspender" approach preferred

- Place pump no higher than just above well screen
- Sufficient number of water-quality-indicator parameters measurements to establish stabilization (current ISL approach)
- Water level measurements during purging to establish minimization of drawdown (i.e., turbulence) in the well