# Monitoring Well Installation for Riparian Restoration

***"An Informed Approach to Riparian Restoration"***

Workshop

March 18, 2013

Palisade, Colorado

Western Water & Land, Inc.

# Riparian Monitoring Well Workshop

***"An Informed Approach to Riparian Restoration"***

OBJECTIVE

To provide workshop participants with a basic understanding of riparian monitoring well use and how wells are installed and monitored to aid in riparian restoration applications.



# Workshop Outline

- Monitoring Well Definition and Purpose
- Riverbank Hydrology and Riparian Vegetation
- Monitoring Well Permitting
- Monitoring Well Construction & Development
- Monitoring groundwater and water quality
- Cost Estimates



# What is a monitoring well?

Simply, a monitoring well is a constructed borehole with installed casing to monitor a known or expected hydrostratigraphic unit.

A hydrostratigraphic unit may consist of any geologic media that may yield groundwater to the well. Examples include unconsolidated alluvium, and consolidated rock such as sandstone, shale, and granite.

## What is the Purpose of Monitoring Wells?

- Monitoring wells are used to investigate the occurrence and nature of groundwater
  - Groundwater levels
  - Groundwater gradient and flow direction
  - Groundwater quality
  - How does groundwater relate or affect surrounding geology (adjoining units, slope stability), to surface water, to vegetation?



## Riparian Monitoring Wells

- This workshop focuses on relatively simple shallow monitoring wells installed in unconsolidated, unconfined aquifers typically associated with river or stream riparian zones
- No confining (low permeability) strata are present
- Shallow depths

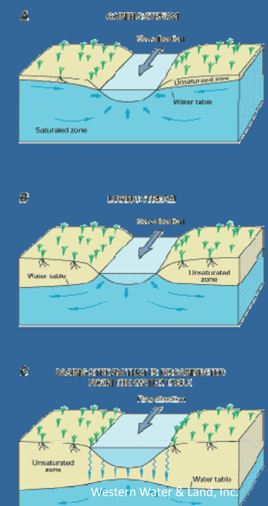


## Riparian Hydrology Applications

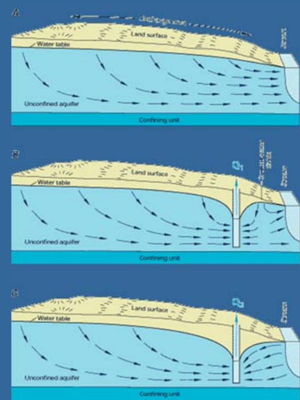
- Riparian: the transition zone between terrestrial and aquatic ecosystems that depend on surface or subsurface water flow (USGS Fact Sheet 2006-2037)
- Groundwater Fluctuation
  - Groundwater levels and fluctuations affect vegetation types and density (phreatophytes)
  - Native vegetation rely on seasonal precipitation and groundwater for water requirements



## Stream-Aquifer Interaction



## Groundwater Flow



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## Pay Attention to Local Hydrology

- What is the ordinary low-water stage of the river or stream?
- What are the recent affects of climate/weather?
- What are the long-term affects of climate?
- Other sources of groundwater recharge or discharge
  - Wells
  - Irrigation fields, ditches, canals
  - Drainage ditches

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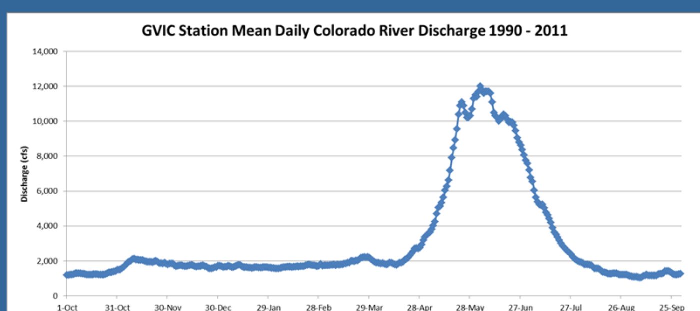
## Stream Discharge & Stage

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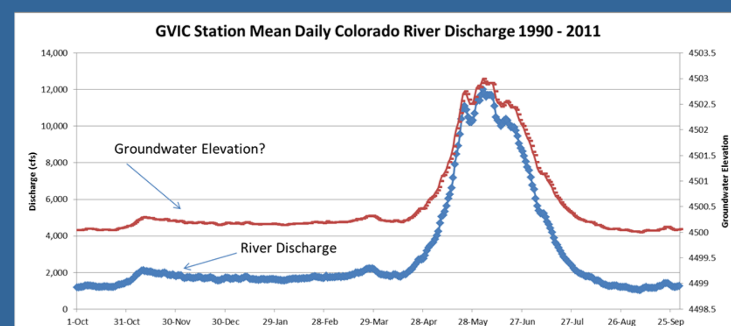
## Stream Discharge/Stage vs. GW Elevation

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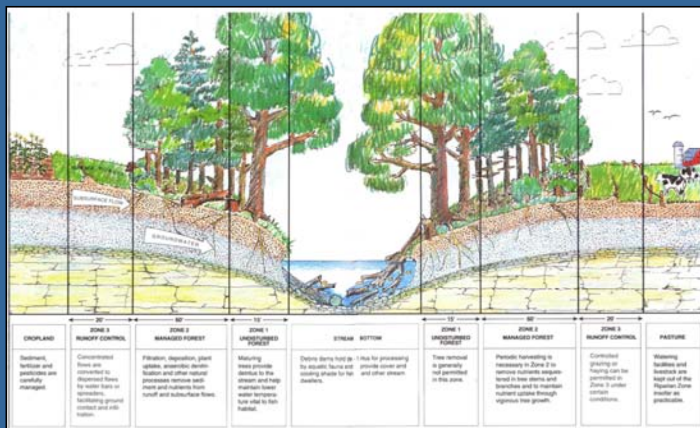
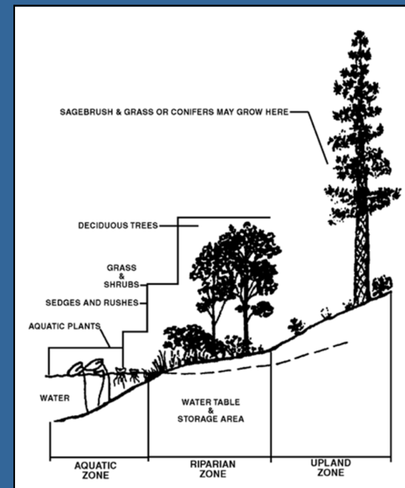
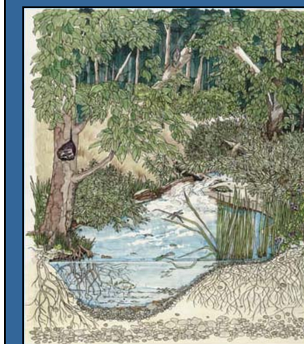
## Land Use Considerations





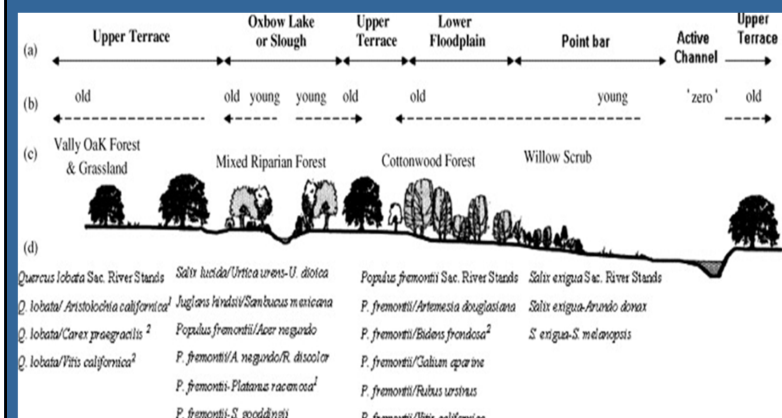
## Land Use Considerations



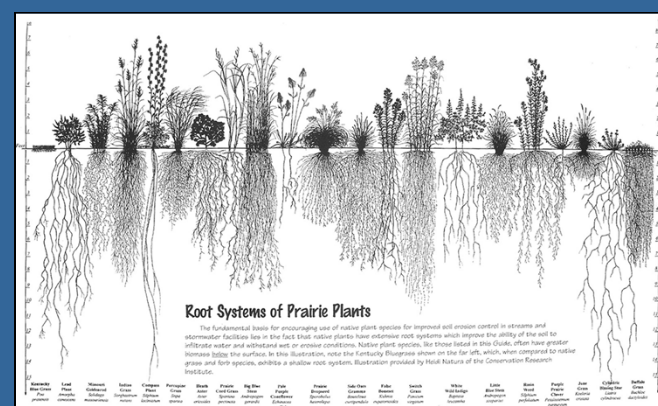


## Riparian Plant Communities






## Root Depth, the Water Table and Bank Stabilization



# Riverbank Stabilization

- Root density and tensile strength matter
  - Grasses
  - Shrubs and trees
  - Forbs

Increasing root density

(Polvi, L.E. and others, 2010)

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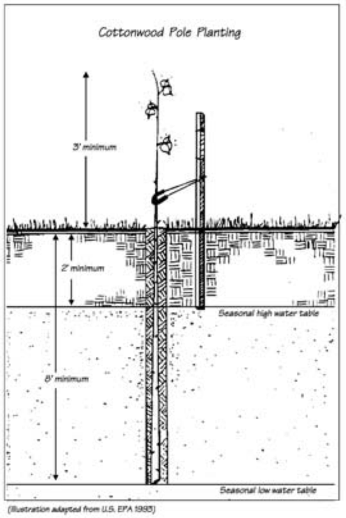


## Pole Planting

DEFINITION:

- The planting of tree cuttings that are approximately 3-5 years old and 3-4" in diameter

APPROPRIATE FOR:

- conditions where site is at waterline to mid-bank;
- conditions where erosion may threaten bank stability and secure rooting of all but deeply rooted plants;
- conditions where the water table remains at least 2' below the surface in most years and fluctuates no more than 6' during the growing season (e.g., cottonwoods on sites high above streams);
- conditions where salinity is less than 3,000 parts per million (ppm);
- conditions where weeds might shade and otherwise outcompete plantings;
- conditions where sloughing of the bank might otherwise bury plantings;
- conditions where browsing would damage smaller plantings.

DESIGN/IMPLEMENTATION:

- ✓ To select for populations that are best adapted to the new site, select cuttings from the nearest available site.
- ✓ Nursery stock must be grown from specimens collected at sites within 200 miles east and west, 100 miles north and south, and 2000' elevation range of the transplant site.
- ✓ Even aged stands 3-5 years old are ideal sources.
- ✓ Collect only where saplings are abundant. It is possible to collect up to 10-20% of stems without damaging the existing stand.
- ✓ Do NOT collect specimens that are water stressed or diseased.
- ✓ To minimize water stress when collecting non-dormant poles, strip all leaves and all branches except the top two before planting.

36 Plantings & Vegetation

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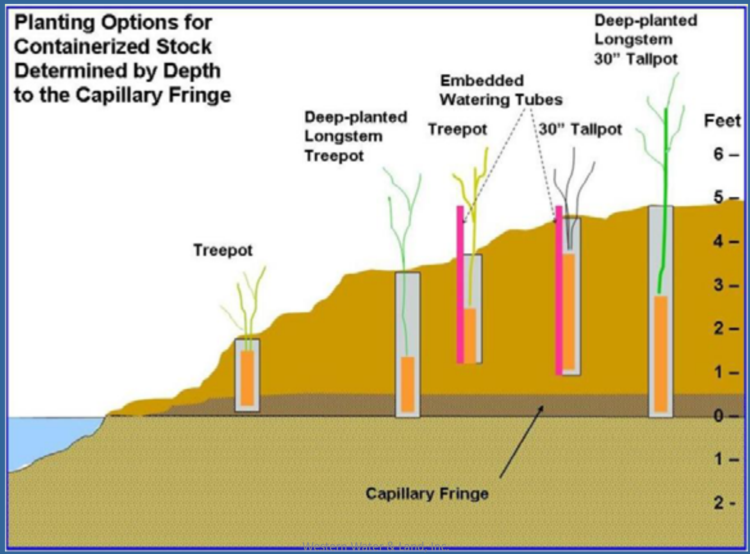
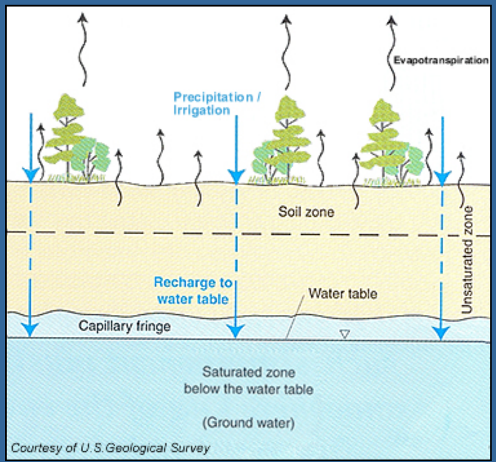



# Capillary Fringe

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# Capillary Fringe

Height of the capillary fringe depends on:
- The size of the largest pores
  - Fine soils have thicker capillary fringe
  - Cobble layers can form a capillary barrier
- A rising or falling water table
- Root uptake of capillary water

Monitoring Wells do not measure capillary fringe (water in tension)



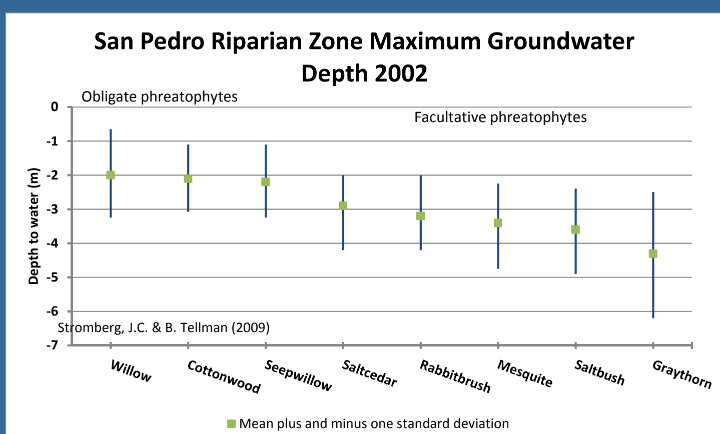
# Capillary Fringe

**TABLE 6.1** Height of Capillary Rise in Sediments

| Sediment | Grain Diameter (cm) | Pore Radius (cm) | Capillary Rise (cm) |
|---|---|---|---|
| Fine silt | 0.0008 | 0.0002 | 750 |
| Coarse silt | 0.0025 | 0.0005 | 300 |
| Very fine sand | 0.0075 | 0.0015 | 100 |
| Fine sand | 0.0150 | 0.003 | 50 |
| Medium sand | 0.03 | 0.006 | 25 |
| Coarse sand | 0.05 | 0.010 | 15 |
| Very coarse sand | 0.20 | 0.040 | 4 |
| Fine gravel | 0.50 | 0.100 | 1.5 |

*Source: www.uic.edu/.../lecture%2013-15%20**soil**%20water%20notes.ppt*








# Fremont Cottonwood (*Populus fremontii*)

## Coyote Willow (*Salix exigua*)



## Monitoring Well Permitting

- Colorado Division of Water Resources permits monitoring wells
- Rule 14 of Water Well Construction Rules (2 CCR 402-2)
- Go to : http://water.state.co.us/groundwater/wellpermit/Pages/default



## Monitoring Well Permitting

1. CDWR requires that all monitoring holes and wells be permitted
2. Must file Notice of Intent Form GWS-51, Notice of Intent for Monitoring Hole at least 3 days prior to installation
3. 90 days to complete hole construction
4. 60 days to submit Well Construction Form GWS-31
5. 1-year to apply for Monitoring Well permit (Form GWS-46) for $100 fee or abandon hole (Form GWS-9)
6. Monitoring well installation must be conducted by licensed contractor or, authorized individual for unconfined aquifer



## Permit Forms

- Notice of Intent (GWS-51)
- Well Construction Form (GWS-31)
- Monitoring Well Permit (GWS-46)
- Well Abandonment (GWS-9)

## Well Abandonment

**Unconfined/Unconsolidated Aquifers:**

- Plugged by filling the well to the static water level with drill cuttings, clean sand or clean gravel, then with clean native clays, cement or high solid bentonite grout to the ground surface.
- Uppermost 5 feet of casing filled with grout or a permanent watertight cover shall be installed at the top of the casing.
- If casing is removed, fill hole as described above to within 5 feet of the ground surface. Fill top 5 feet of the hole with materials less permeable than the surrounding soils.



## Well Construction

- Well Siting
- Well Design
- Procure Materials
- Contracts, if necessary
- Site preparation

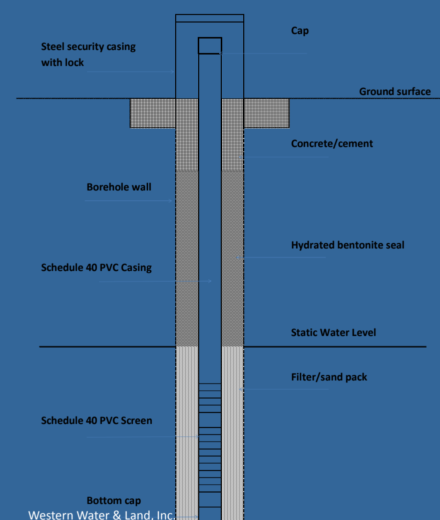


## Well Siting

- Select well sites based on:
  - Existing or historical native vegetation distribution
  - Bracket planting zone perpendicular to stream
  - Consider potential disturbance to wells
    - Stick-up
    - Flush mount
  - Consider "landscape design" aspects



## Typical Monitoring Well



## Borehole Equipment

- Borehole Excavation Methods:
  - Machine Drilling
    - Auger
    - Rotary – air only
    - Push tools – no cuttings
    - Back hoe
  - Hand Methods
    - Hand auger
    - Post hole tool



## Boring Equipment

- Auger – can describe lithology and observe moisture
- Rotary – as above and drill with air only; overkill for shallow wells
- Push tool – fast, simple, inexpensive, no cuttings, find water table, not capillary zone



## Ready the Site

- Call for utility checks
- Establish access for vehicle/equipment
- Secure the site during construction
  - Be aware of overhead electrical hazards
  - Drilling contractor to conduct tailgate meeting
  - Maintain worker and public safety



## Locate the Water Table

- Auger and Rotary
  - Go slow, stop occasionally, examine cuttings for moisture
  - Capillary zone when very moist or water sheen
  - Water table when material drips water
- Push tool
  - Use tool, tape or wooden pole as “dip stick”; or use temporary well casing

## Setting the Well

- Prepare all well materials before you start drilling; calculate annulus volume/ft hole
- Cut slots on bottom 4 to 5 feet of casing; two offset columns; rows 1-2 inches apart
- Once water table is defined, drill 2-4 feet deeper and center and set slotted casing
- Hand pour sand pack; use tape to assure sand is 1 -2 ft above top of slotted section

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## Setting the Well Cont'd

- Hand pour bentonite chips or pellets to within 2 ft of surface; pour 3 -5 gallons of water on chips to hydrate
- Cement grout from top of bentonite seal to surface
- Install surface security casing or flush-mount vault, if necessary
- Always mark well ID and cap and lock well!

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## Auger Drilling


http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dc283e6c5d6056f88257426007417a2/2fad55aa1c0a3f618825767200822686/$FILE/Appx%20B1%20-Sample%20Collection%20Photos.pdf

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## Auger Drilling


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## Rotary Drilling

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## Rotary Drilling

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## Push Tool – "The Stinger"

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## Planting Willow with "The Stinger"

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## Rotary Rig – Installing Well Casing

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## Lithology

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## Monitoring Well Supply List

1. 1 to 2 inch diameter by 10 ft long Schedule 40 PVC pipe
2. PVC end caps, 2 per well
3. Sorted medium-fine sand
4. Unwoven filter fabric (optional)
5. Bentonite chips or pellets
6. Duct tape or 3 to 4 inch zip ties
7. Hack saw with standard blade
8. Knife or scissors
9. Tape measure (fits inside PVC pipe)
10. Chalk
11. Sharpie marker
12. Notebook, pen
13. Camera
14. GPS

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## Slotted Schedule 40 PVC Casing

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## Slotted Schedule 40 PVC Casing with Centralizer

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## Bentonite Seal Materials


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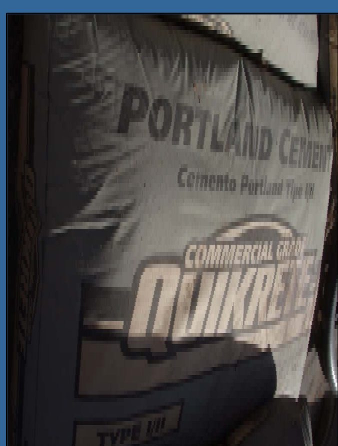
## Materials – Bentonite/Cement Grout

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## Well Development

- Well development should follow construction before monitoring begins
  - Develops aquifer formation and filter pack around screen
  - Reduces borehole skin effects (low permeability) and chemistry
  - Facilitates groundwater movement to the well
  - Most important for water quality sampling

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## Well Development Methods

- Shallow alluvial wells (<20 ft deep)
  - Hand bailing
    - Use plastic disposal bailer to pump well (may be limited by well casing diameter)
  - Peristaltic pump
    - Limited to about 33 ft of lift, need power source

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## Well Development

- Wells used for most environmental programs require strict protocols for achieving adequate development
  - Numerical criteria for pH, specific conductance, temperature, turbidity, dissolved oxygen, ORP
  - If you intend to use the well for long-term water chemistry evaluations

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## Riparian Well Development Suggestions

- Measure pre-development water level
- Develop until water turbidity decreases to steady, “clear” appearance
- Measure final water level

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## Water Level Monitoring

- Goal is to obtain a groundwater hydrograph of water level with time
- Suggest monthly measurements– minimum of one year
- Key season is low (base) flow periods
  - (September – November)
- Design and commit to a simple schedule

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## Measuring Water Levels

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## Measuring Water Levels

Methods

- Tape and chalk
- Electric sounder
- Repeat the measurement
- Occasionally check total depth of well
- Dedicate a notebook or form – record the date and time and depths

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## Water Quality Monitoring

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## Water Quality Monitoring

- Water quality monitoring may be applicable
  - Salinity (total dissolved solids, TDS)
    - Fremont Cottonwood < 1,500 mg/L
  - Potential for industrial or other contamination
  - Scientific investigations
    - Water quality with fluctuations in river stage
    - Plant uptake influences on water quality
    - Chemical loading to/from aquifers - irrigation impacts

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## Water Quality Monitoring

- Tools of the trade
  - New disposable bailer, new nylon cord
  - 5 gal bucket or carboy (decontaminated)
  - Sample bottles with labels
  - Chain-of-custody
  - Nitrile gloves
  - Plastic sheeting (Visqueen™)
  - Notebook

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## Monitoring Well Water Quality Sampling

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## Water Quality Sampling

- Strict well sampling protocols exist for scientific environmental programs
- If not conducting scientific program . . .
  - Goal: obtain a representative sample
  - Try to purge the well of at least 3 casing volumes before you sample (recovery dependent)
  - If field instruments are available, measure field parameters at beginning and end of purging
  - Sample when turbidity is believed at its lowest (clearest obtainable condition)

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## Water Quality Analysis

| Field Parameters | Common Ions | Wet Chemistry | Metals + |
|---|---|---|---|
| pH | Calcium | Alkalinity (all) | Iron |
| Temperature | Magnesium | TDS | Manganese |
| Specific Conductance | Potassium | Hardness | Boron |
| Diss. Oxygen | Sodium | SAR | |
| Oxy-Red Pot. | Chloride | | |
| Turbidity | Fluoride | DOC | Arsenic |
| | Sulfate | | Copper |
| | Nitrate/Nitrite | | Lead |
| | Phosphorus | | Selenium |

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## Water Quality Analysis – Other Considerations

- What is the historical use of the site area?
  - Agricultural
  - Industrial
  - Waste disposal
  - Underground storage tanks



## Cost Estimates

- Well materials are inexpensive for shallow wells – less than $50
- Surface security casings or flush mount completions add $25 to $100
- Drilling contractors – range from $80/hr to $250/hr hour for small machines
- Cost per well ~ $100 to $300 depending on labor source (DIY is pretty cheap!)



## Summary and Conclusions

- Riparian restoration can be enhanced and improved with knowledge of groundwater fluctuations
  - Planting depths can be optimized (plant cottonwoods at known ordinary low-water level)
- Monitoring wells are a useful tool to help obtain and understand groundwater fluctuations and chemistry
- Water chemistry data may supplement planting plans