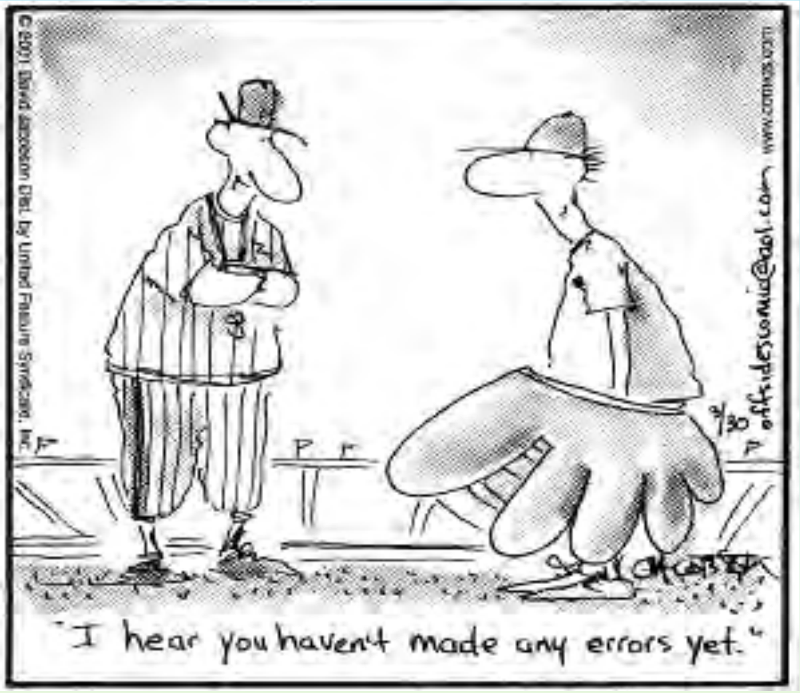
Science, Measurements, Uncertainty and Error



Measurement and Uncertainty

- Most experiments require scientists to make **measurements.**
- Measurements are **rarely** exactly the same.
- Measurements are **always** somewhat different from the “true value.”
- These deviations from the true value are called **errors.**

Sources of Error

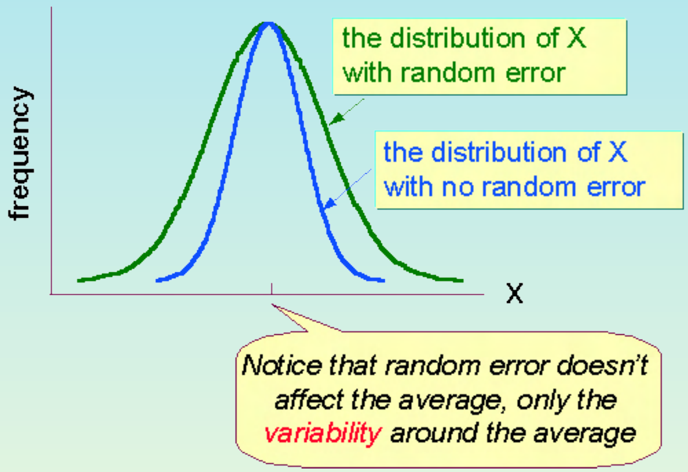
- Two sources of error in a measurement are
  - limitations in the sensitivity of the instruments
  - imperfections in experimental design or measurement techniques

- Errors are often classified as:
  - Random
  - Systematic

www.nabis.govt.nz

Random Errors

- **ALWAYS** present.
- Measurements are often shown as:

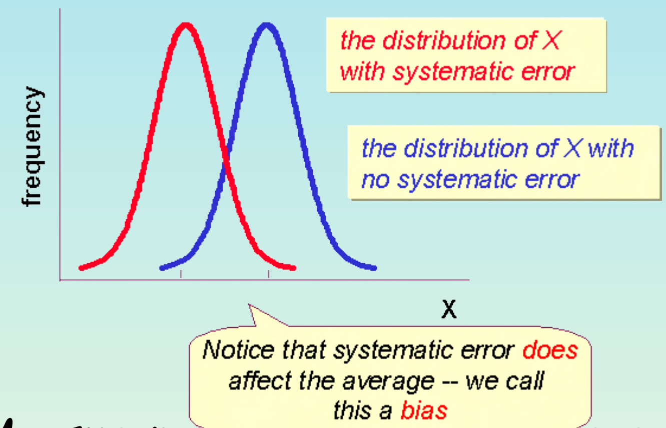


Measurement ± Random Error

- **Sources:**
  - Operator errors
  - Changes in experimental conditions
- **How to minimize them?**
  - Take repeated measurements and calculate their average.

Systematic Errors

- Are **TYPICALLY** present.
- Measurements are given as:



Measurement + Systematic Error

OR

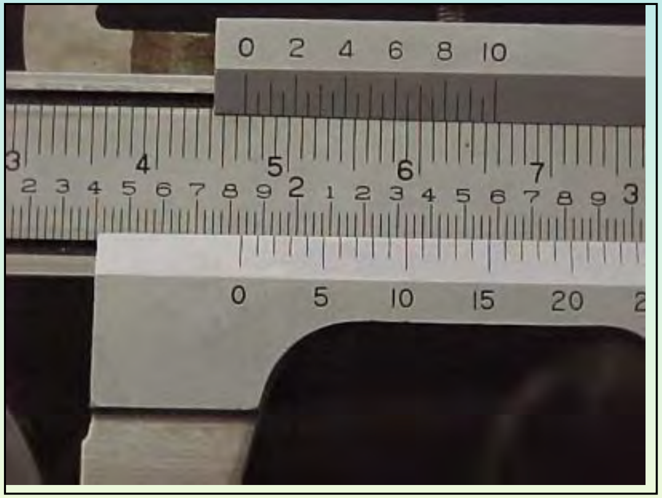
Measurement - Systematic Error

- **Sources:**
  - Instrumental, physical and human limitations.
    - Example: Device is out-of calibration.
- **How to minimize them?**
  - Careful calibration.
  - Best possible techniques.

Precision and Accuracy in Measurements

- **Precision**

  How reproducible are measurements?

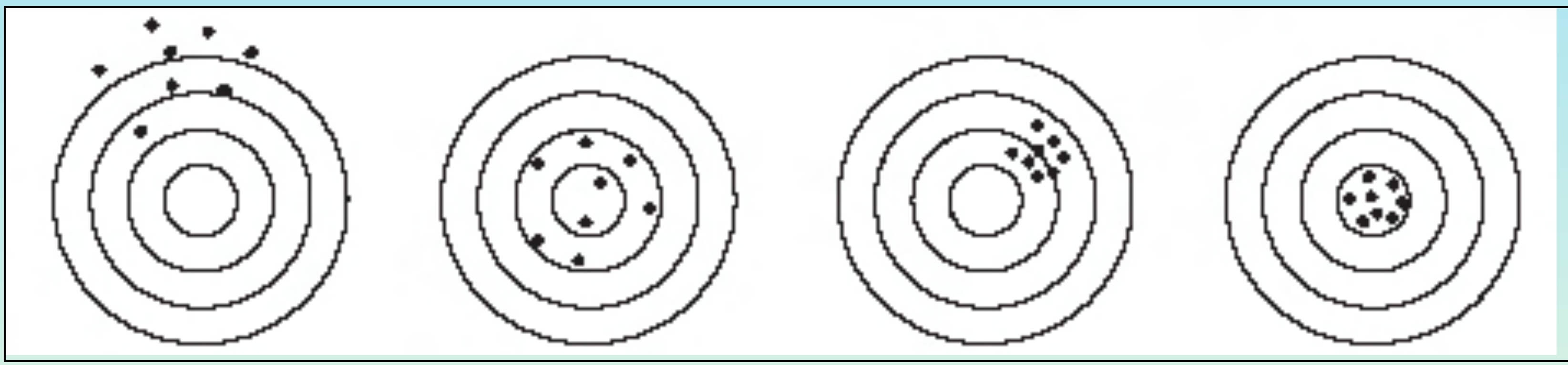


- **Accuracy**

  How close are the measurements to the true value.

Dartboard analogy

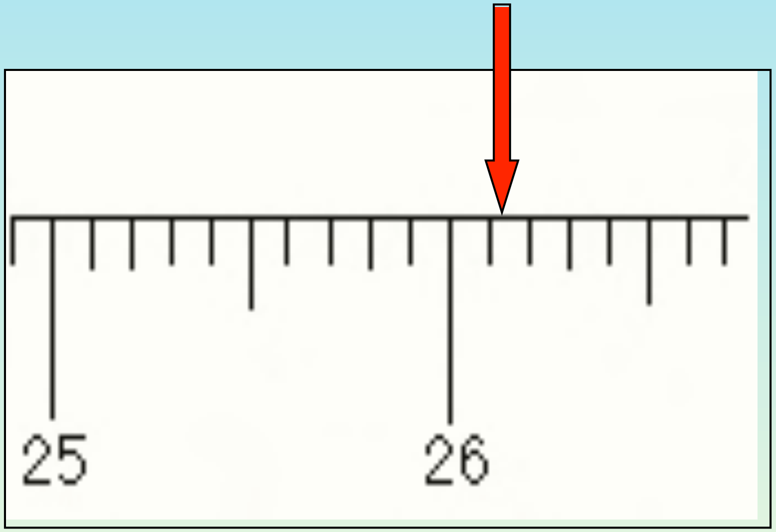
- Imagine a person throwing darts, trying to hit the bulls-eye.



Not accurate Not precise	Accurate Not precise	Not accurate Precise	Accurate Precise

Precision of a Measurement

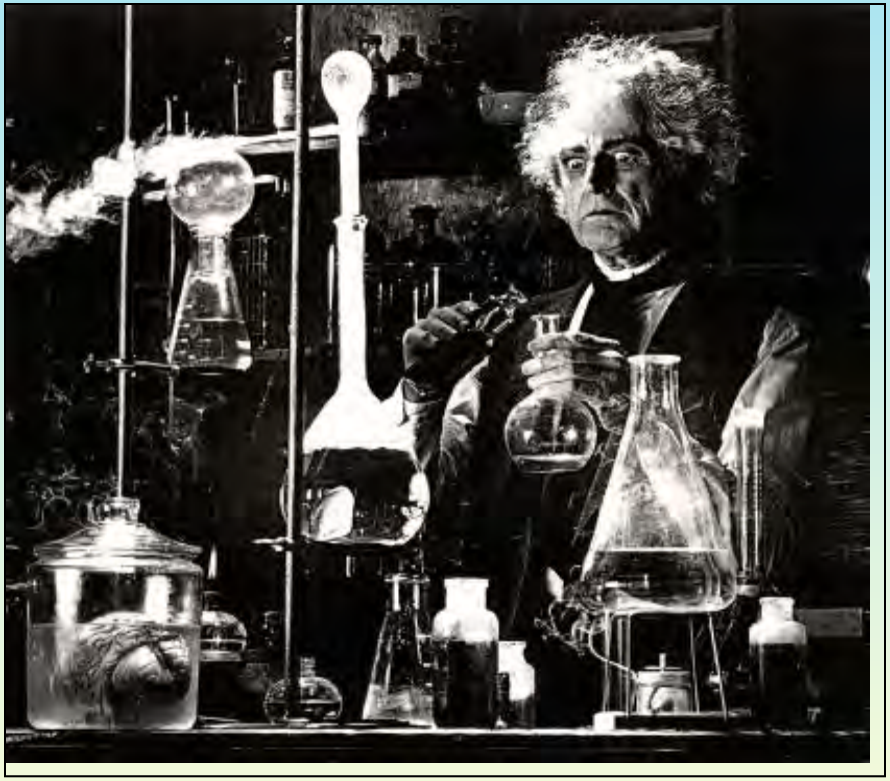
Measurement ≈ 26.13 cm



- The last digit is an **estimate.**
- The precision is limited by the instrument.

Scientific Data

Scientists always want the most ***precise*** and ***accurate*** experimental data.



The precision and accuracy are limited by the instrumentation and data gathering techniques.

Dealing with Errors

- Identify the errors and their magnitude.
- Try to reduce the magnitude of the error.

HOW?

- Better instruments
- Better experimental design
- Collect a lot of data

Bad news…

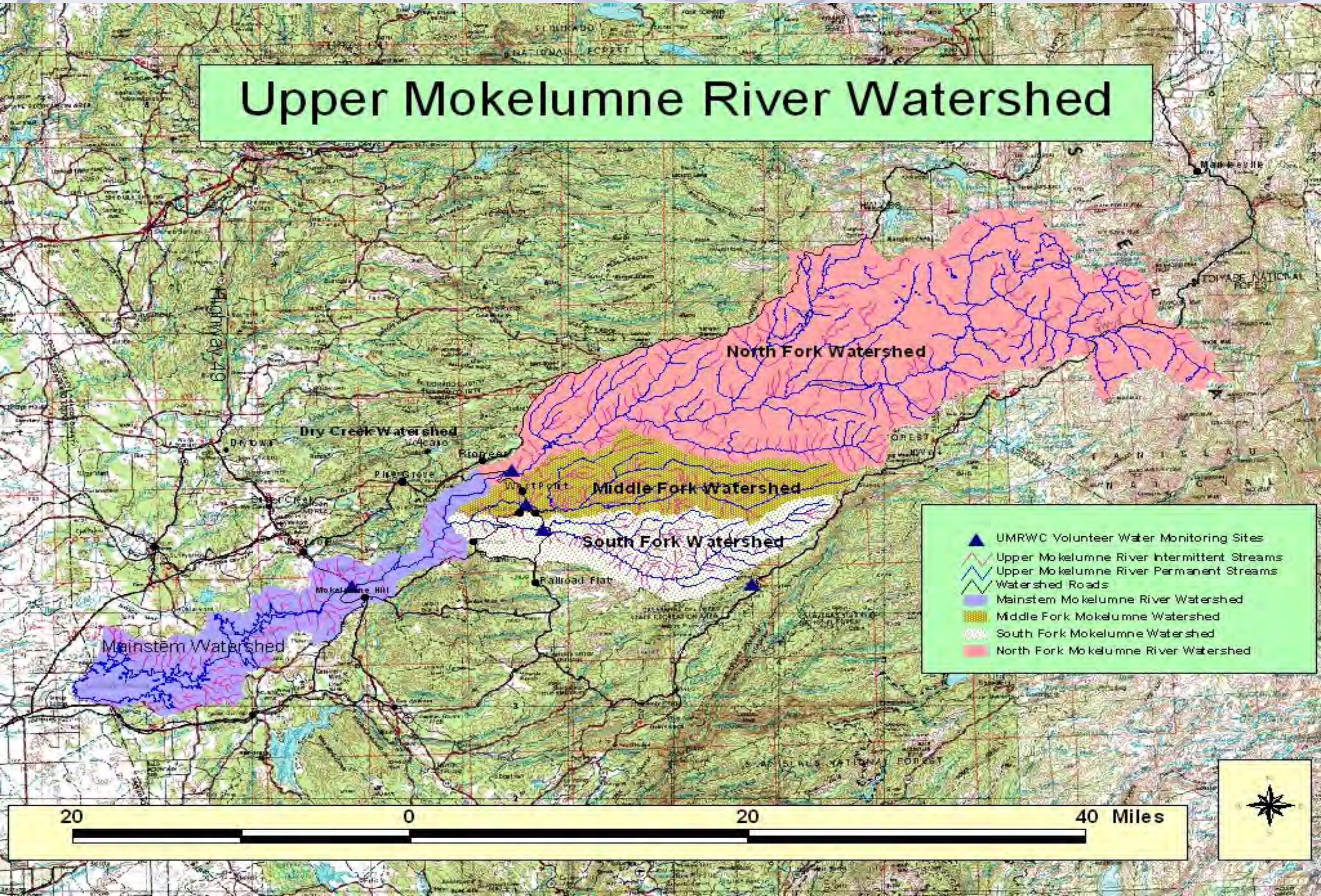
- No matter how good you are… there will always be errors.

- The question is… How to deal with them?

STATISTICS

Water Quality Monitoring

Rivers Describe the Watershed



Typical Water Quality Concerns in West Slope Sierra Watersheds

- *High Summer Temperature*
- *Low Summer Flow*
- *Recreational Use*
- *Bacteria*
- *Wastewater*
- *Septic Systems*
- *Abandoned Mines*
- *Construction*
- *Forest Management*
- *Catastrophic Fires*
- *Pesticide Drift from Valley*

Why Monitor Water Quality?

- *Safe source of drinking water*
- *Support aquatic life*
- *Assess current conditions*
- *Identify pollution sources/problems*
- *Monitor progress of restoration*

Basic Water Quality Parameters

- *Air and Water Temperature*
- *pH*
- *Dissolved Oxygen (DO)*
- *Conductivity*
- *Turbidity*

Why is Temperature the Most Important Measurement?

- *What rates are affected by temperature?*
  - *Metabolism of aquatic animals*
  - *Photosynthesis*
  - *Degradation of pollutants*

- *Temperature affects*
  - *amount of oxygen that can be dissolved in water,*
  - *sensitivity of organisms to toxic wastes, parasites, and diseases.*

- *Temperature changes*
  - *with the removal of riparian and emergent vegetation around and in the river,*
  - *soil erosion, storm water run off, power generation, and alterations to the river's flow.*

Air Temperature

- Indicates general weather conditions
- Usually relates to water temperature

Water Temperature

- *Fish and other aquatic life usually have a specific temperature range in which they survive.*
- *Streams are classified for cold water fisheries or warm water fisheries*

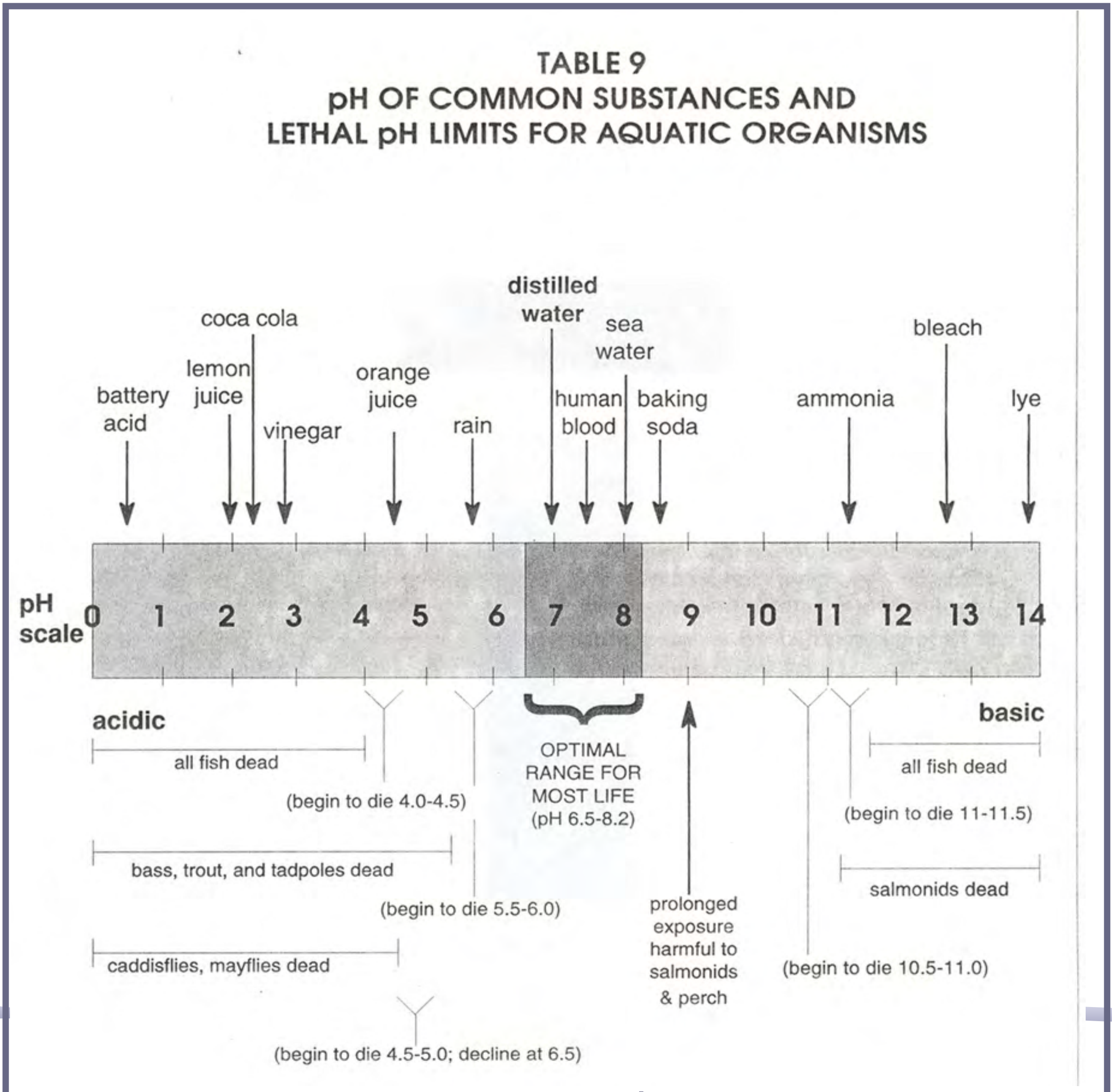
Trout

prefer water <68° Fahrenheit and cannot survive >75° Fahrenheit

pH

- Acid or alkaline
- Scale of 1-14
- pH 7.0 is neutral
- pH 6.5 – 8.2 = "safe zone" for fish and other aquatic life
- Affected by trees, soils, temperature, human activity, mining

pH Values of Common Chemicals



From Streamkeeper's Field Guide

Dissolved Oxygen (DO)

- Aquatic animals get their oxygen from water
- Trout & stoneflies need high DO
- Catfish, worms & dragonflies tolerate lower DO
- DO levels can decrease when dead organic matter, sewage, yard waste, and oil and grease enter the river

DO is affected by

- *Temperature*
- *Altitude*
- *Bacteria*
- *Algae*
- *Excess organic waste*

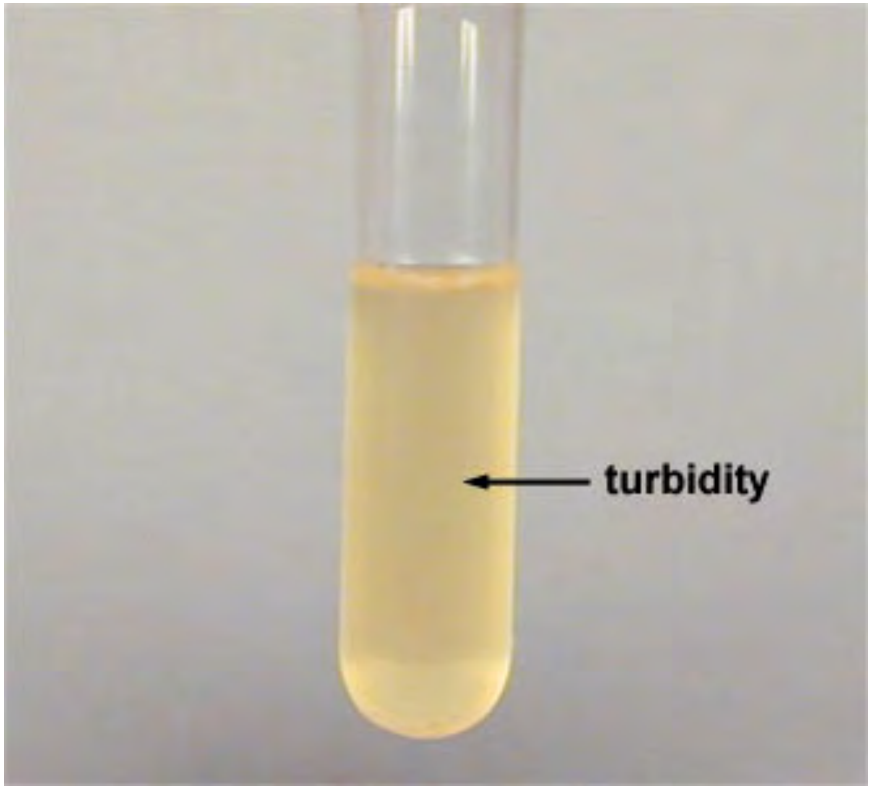
Winkler Titration Method

Conductivity

- *Ability of water to carry electrical current*
- *The more **dissolved salts** in the water, the more electricity the water will conduct.*
- *Depends on*
  - *Geology*
  - *Wastewater*

Turbidity

- Measure of cloudiness or color in water.
- Suspended sediment
- Huge problem in California



Turbidity

- Affects water temperature by absorbing sunlight, reduces photosynthesis and DO levels,
- Can clog fish gills, smother eggs
- Can be abrasive to organisms and sensitive tissues
- Reduces feeding efficiencies of sight feeders
- Relates to stream flow and velocity

Turbidity

Turbidity can be affected by:

- *soil erosion*
- *poor construction activities*
- *gold dredging*
- *waste discharge*
- *urban runoff and increased flows*

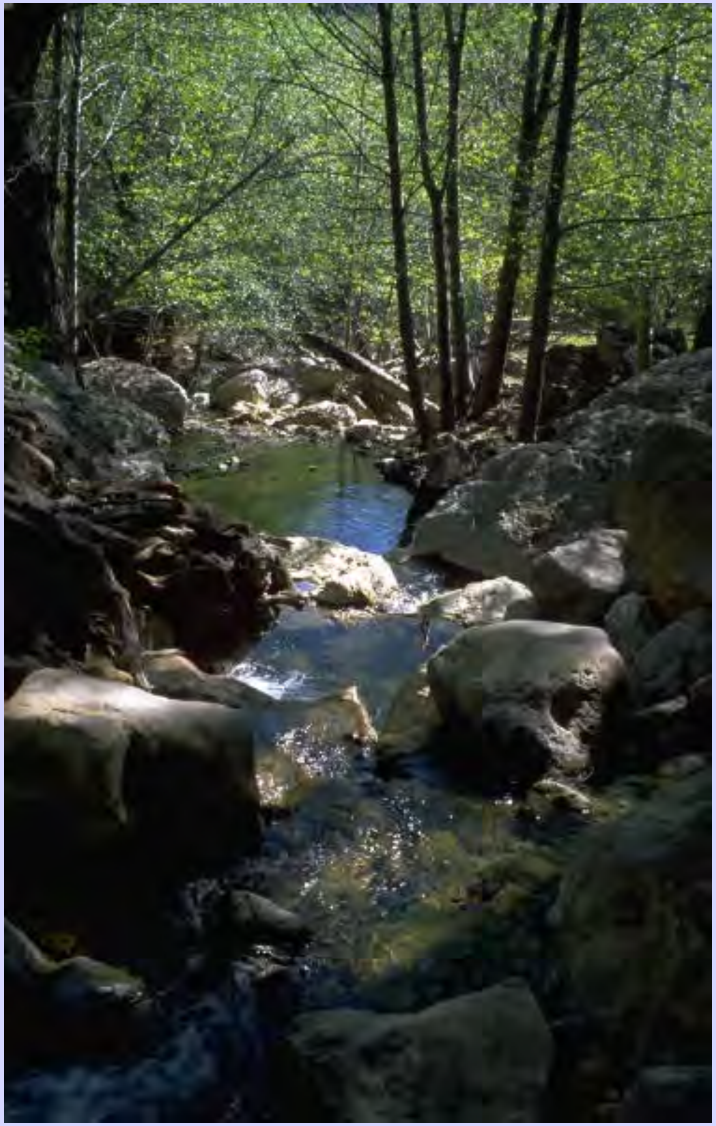
What are 5 important measurements of water quality?

- What factors affect
  - Temperature
  - pH
  - Dissolved oxygen
  - Turbidity
  - Conductivity
- Why are they important?

Instream Habitat

Habitat Complexity

- Plants
- Woody Debris
- Tree Roots
  - Stabilize bank
  - Refuges at edges
- Overhanging vegetation
- Undercut Banks
- Boulders

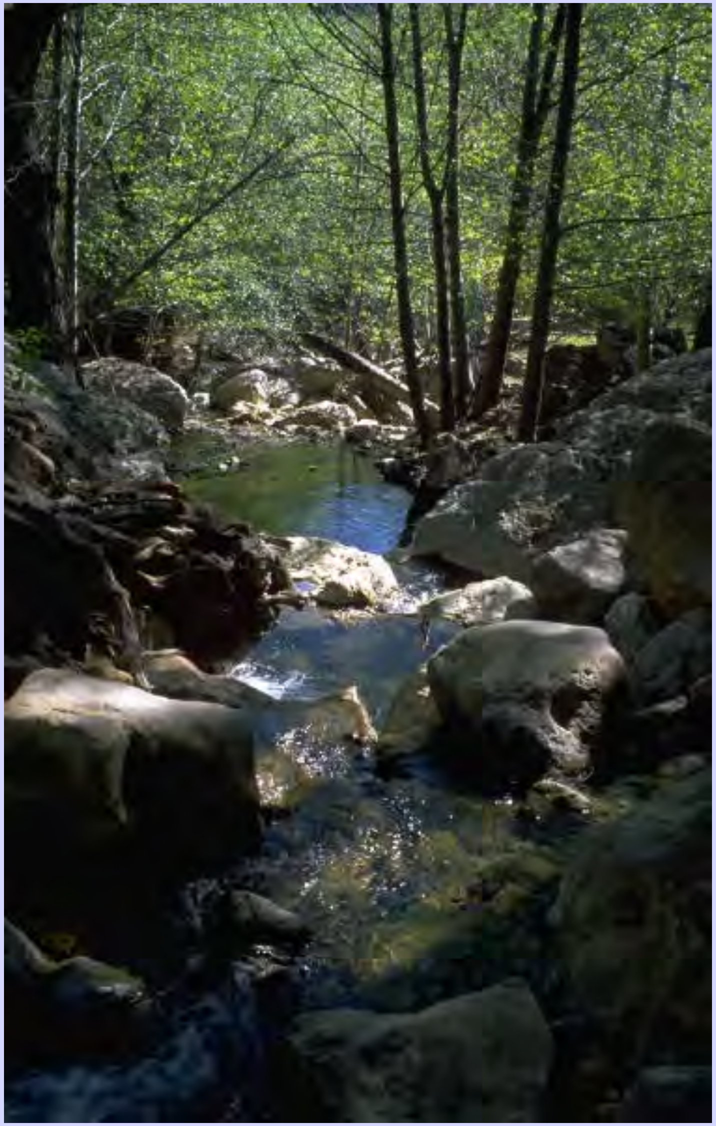


Plants in Stream

- Provide shade
- Leaf litter
- Refuge for small fry

Tree Roots

– Stabilize bank
– Reduce erosion and sediment
– Uptake nutrients
– Refuges at edges

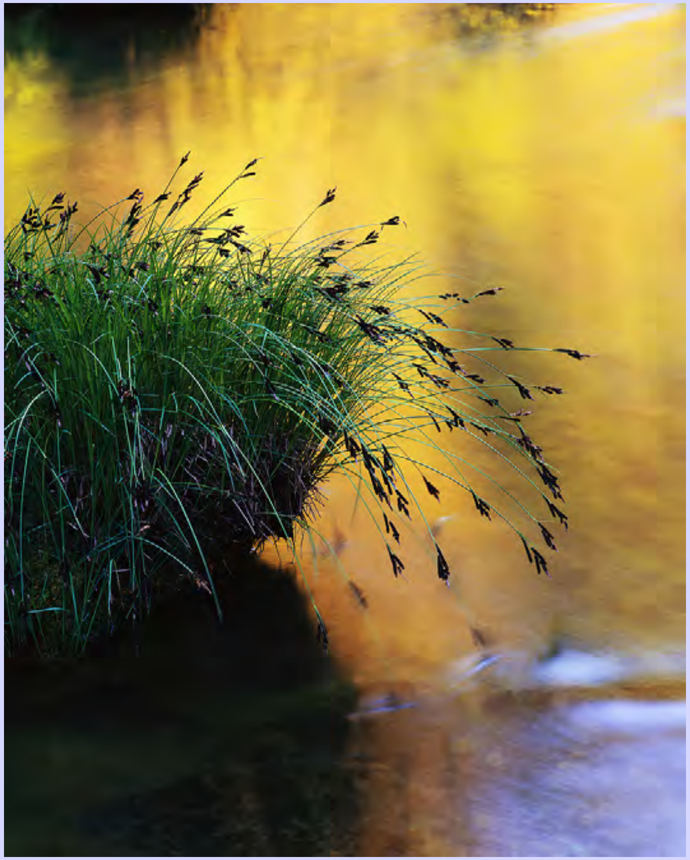


Overhanging Vegetation

- Shades river's edge
- Cools water

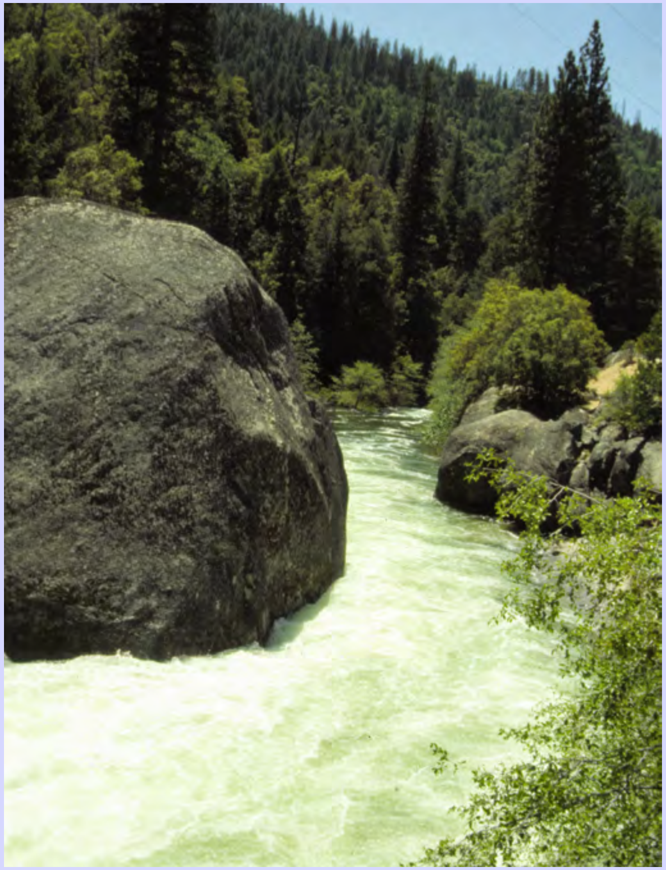
Undercut Banks

- Shades river's edge
- Cools water
- Hiding spot for fish



Boulders

- Block flow
- Create pools downstream
- Refuges at edges



Merced River

Mokelumne River

Woody Debris

- Log jams pool water
- Deep pools important for fish
- Increased habitat for aquatic insects
- Reduces flow, deposits sediment

Photo courtesy of Adam Wei. See **Wei,** Xiaohua and Dai Limin. 2006. Advancement on in-stream wood ecology. Journal of Plant Ecology, 30(6):1018-1029 (in Chinese).

Instream Habitat Estimate

Big Woody Debris - 3

Small Woody Debris - 1

Overhanging Veg. - 1

Importance of Riparian Vegetation

- Holds soil
- Provides shade
- Reduces temperature
- Provides food to aquatic insects

Loss of Riparian Vegetation

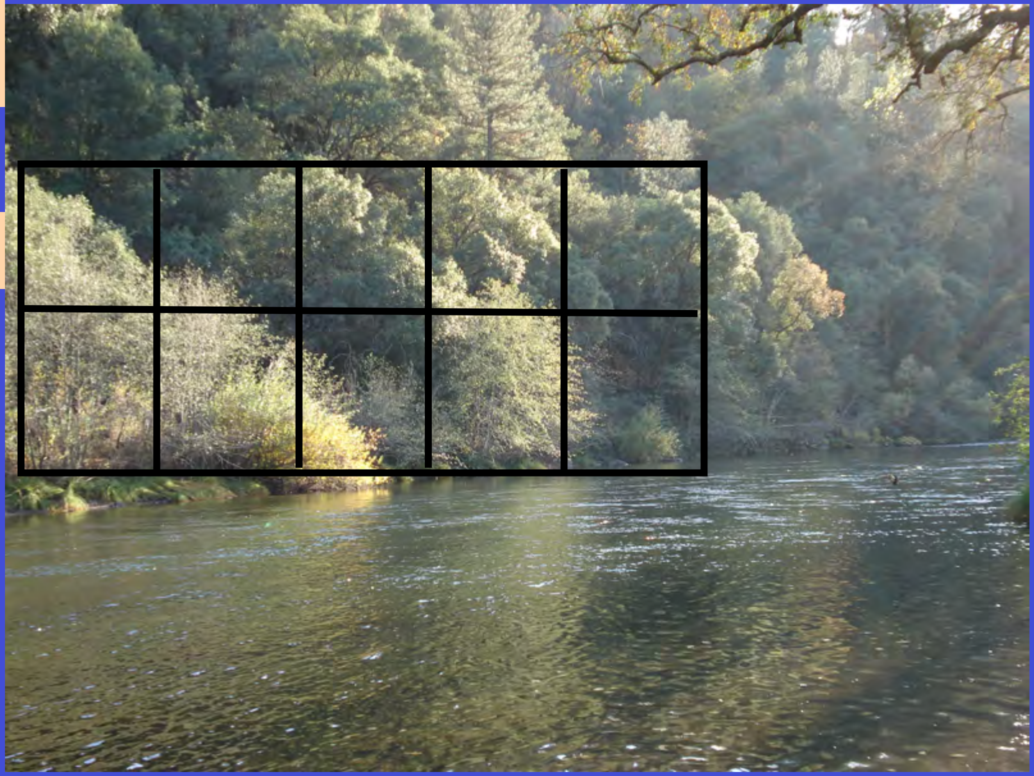
- Severe bank erosion caused by storm runoff from impervious surfaces

Photo from townhall.townofchapelhill.org

Visual Riparian Estimates

They can be tricky and subjective

Picture a grid over the bank



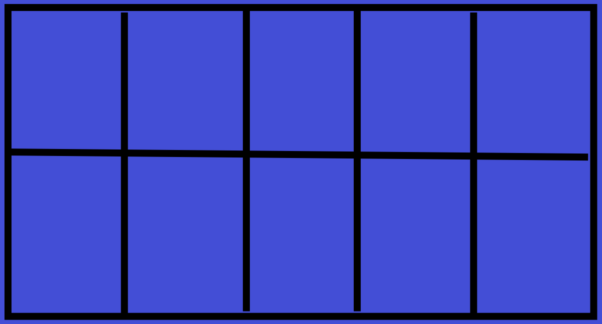
Remember to think about 3 layers:

- **Canopy > 5m**
- **Understory >0.5 up to 5 m**
- **Ground cover**

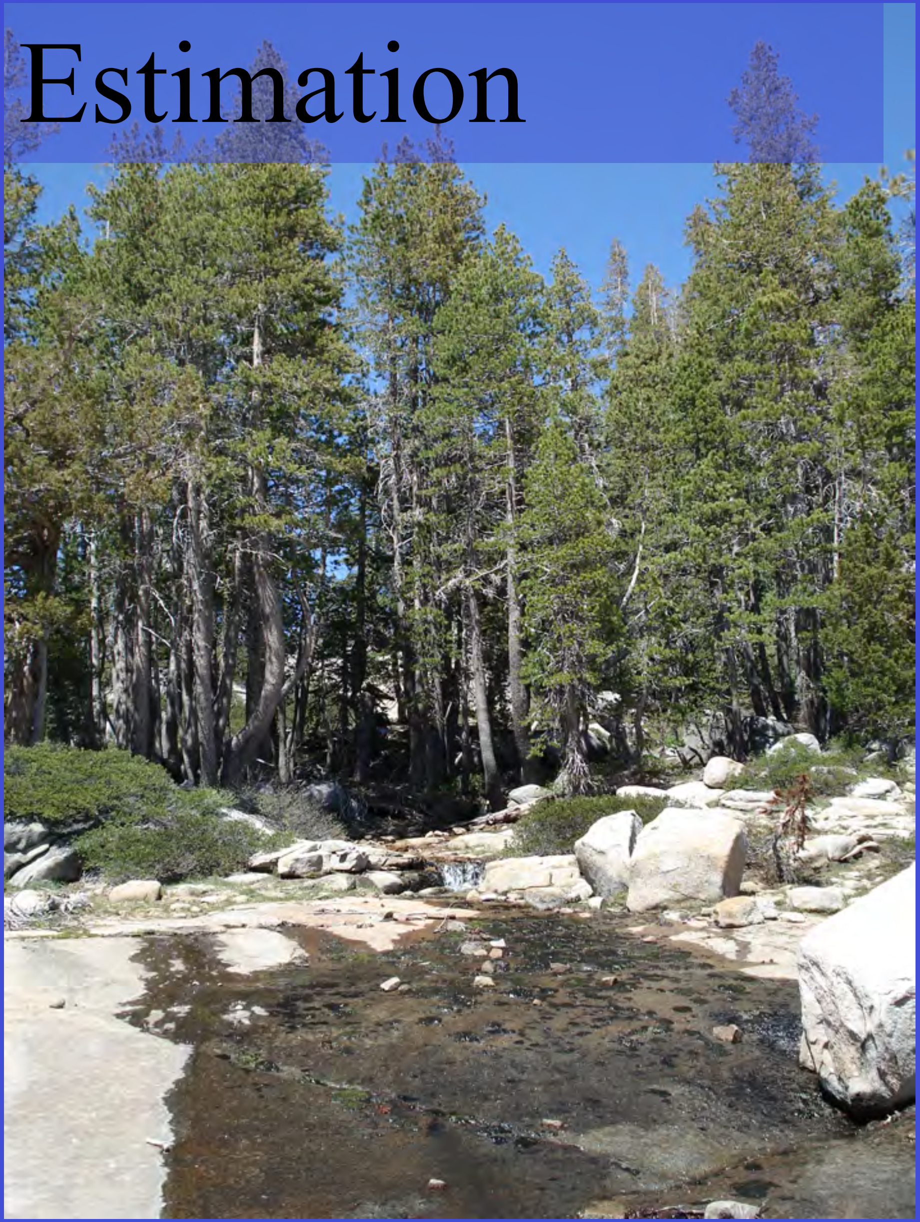
Practice Estimation

The sampling area is 10 meters by 10 meters

The slide grids are not square or to scale



Can you estimate barren vs. woody ground cover on the banks without a grid?




Canopy - 0
Understory 0
Grasses,
Forbes - 4
Bare Dirt - 1
Jackson Creek

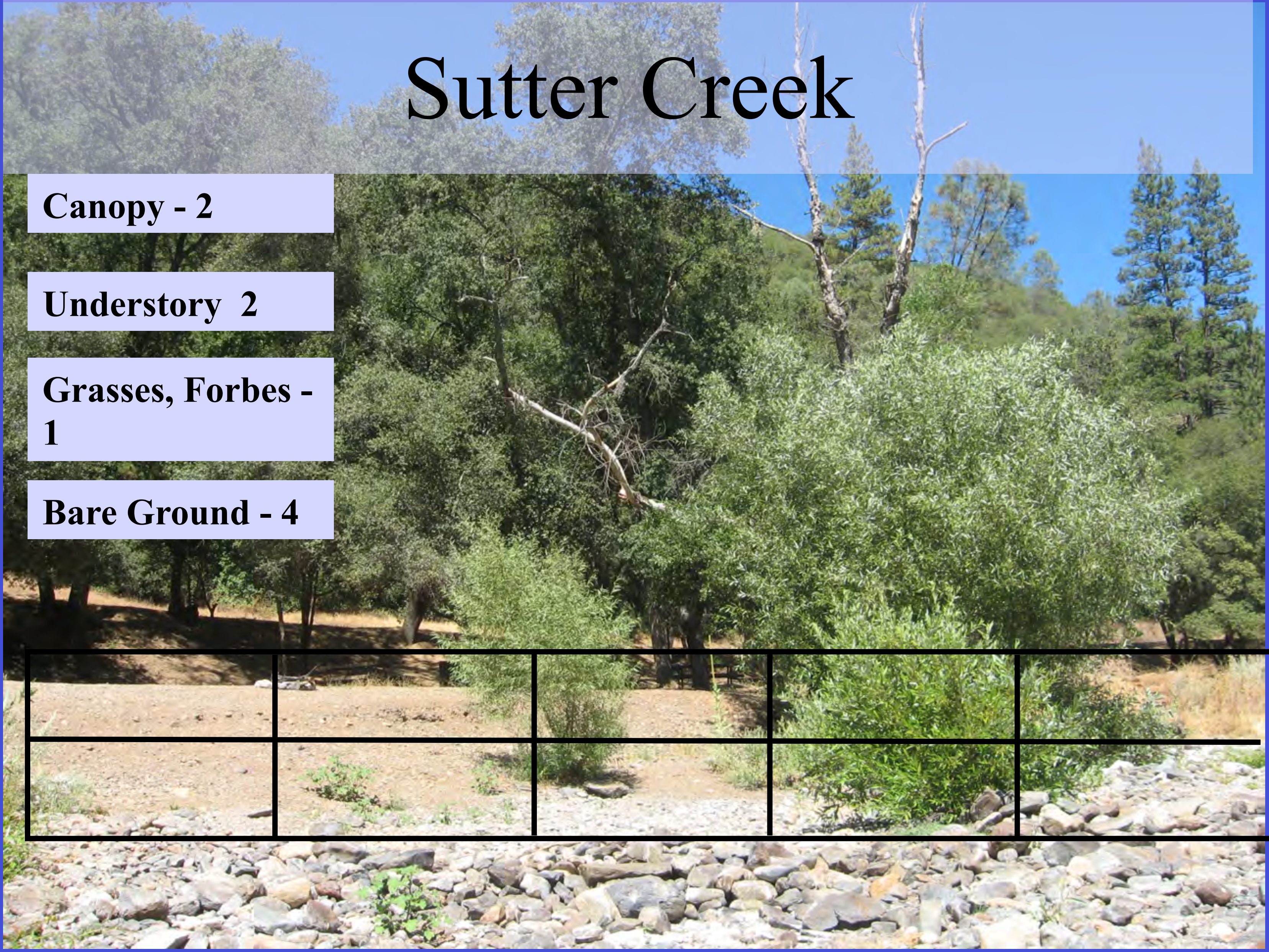
Sutter Creek

Canopy - 2

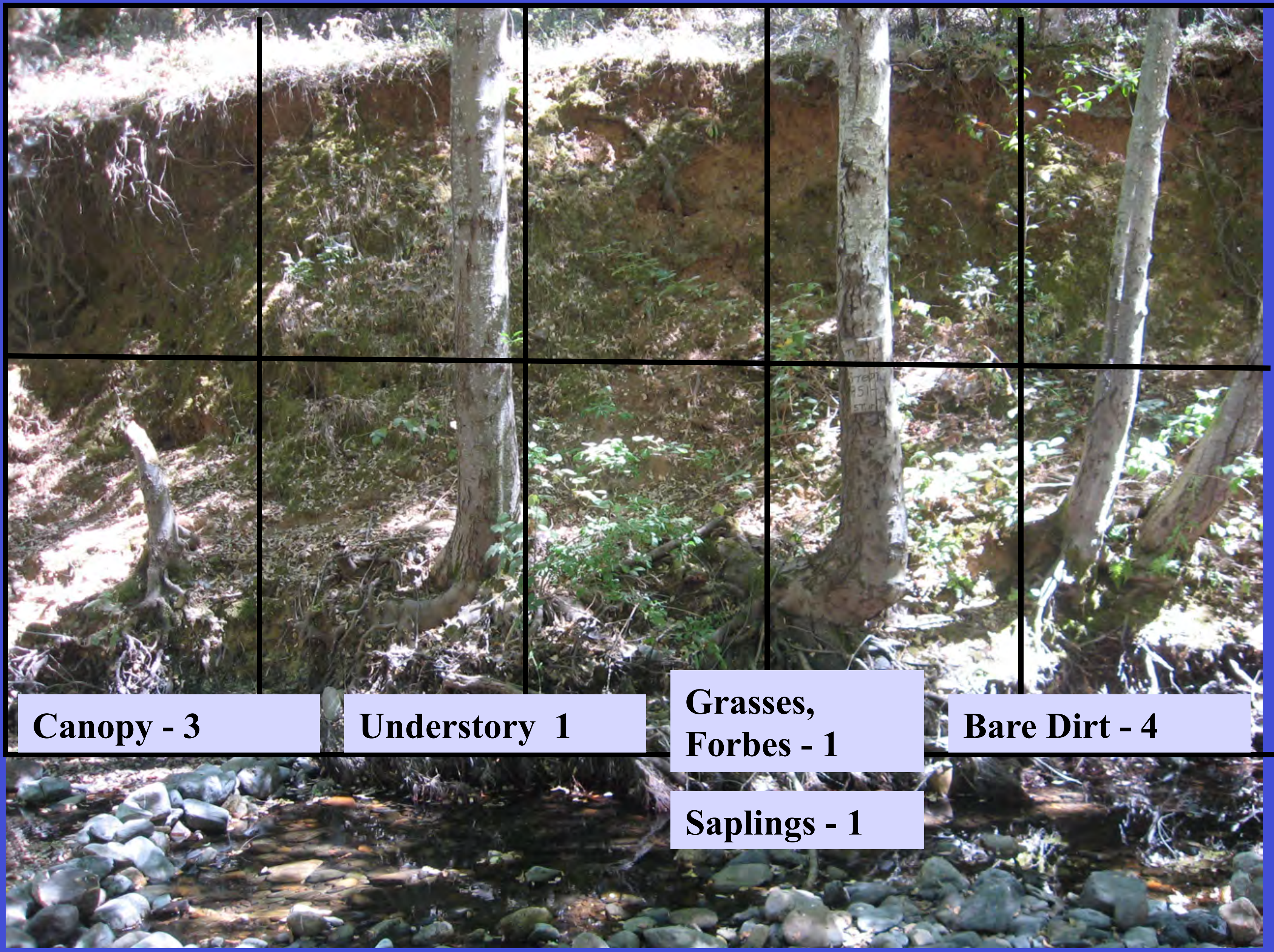
Understory 2

Grasses, Forbes - 1

Bare Ground - 4

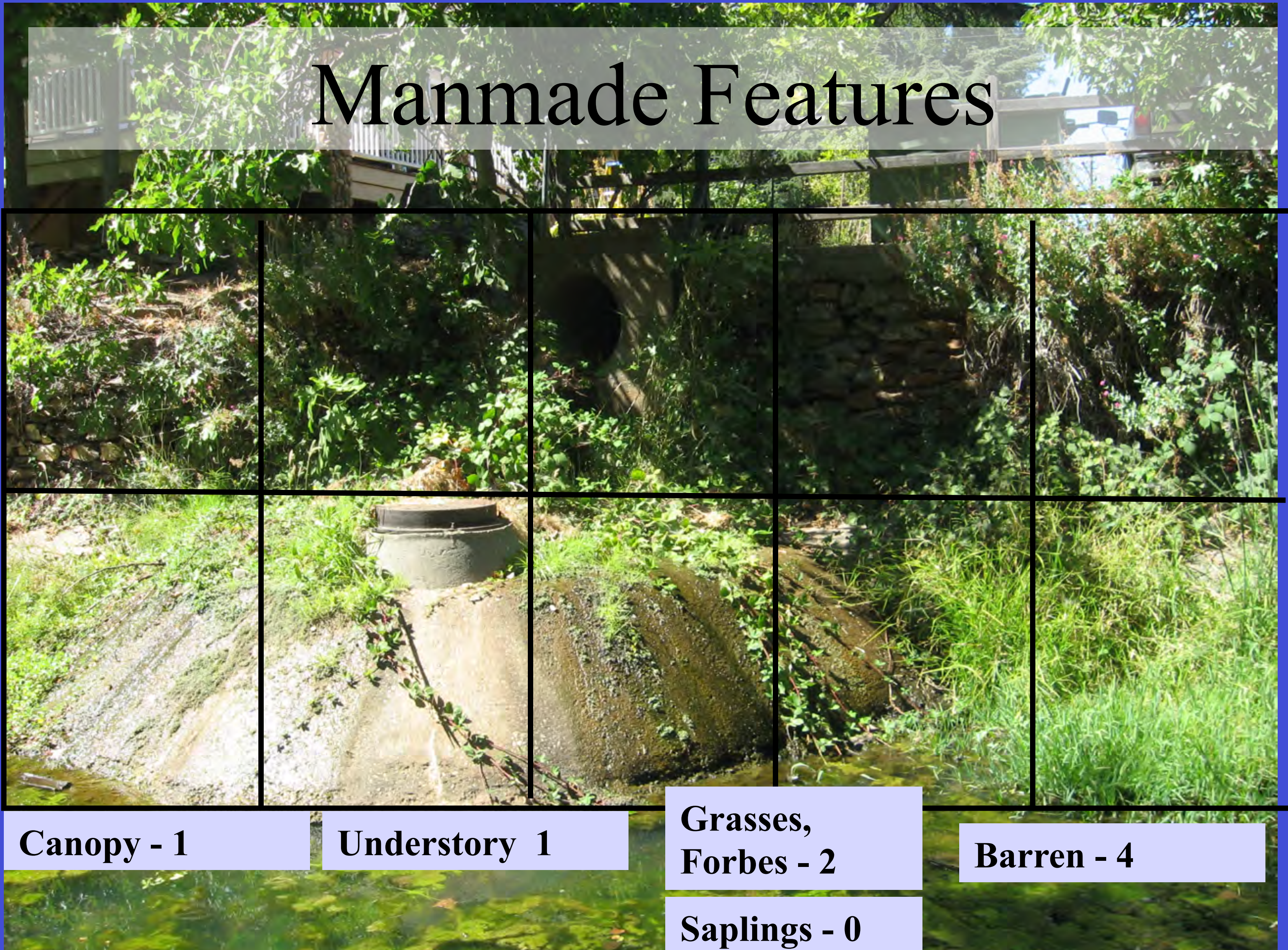



Canopy - 2
Understory - 3
Grasses, Forbes - 1
Bare Dirt - 2
Sutter Creek at Lions Club Park



Canopy - 3
Understory 1
Grasses, Forbes - 1
Saplings - 1
Bare Dirt - 4

Manmade Features



Canopy - 1

Understory 1

Grasses, Forbes - 2

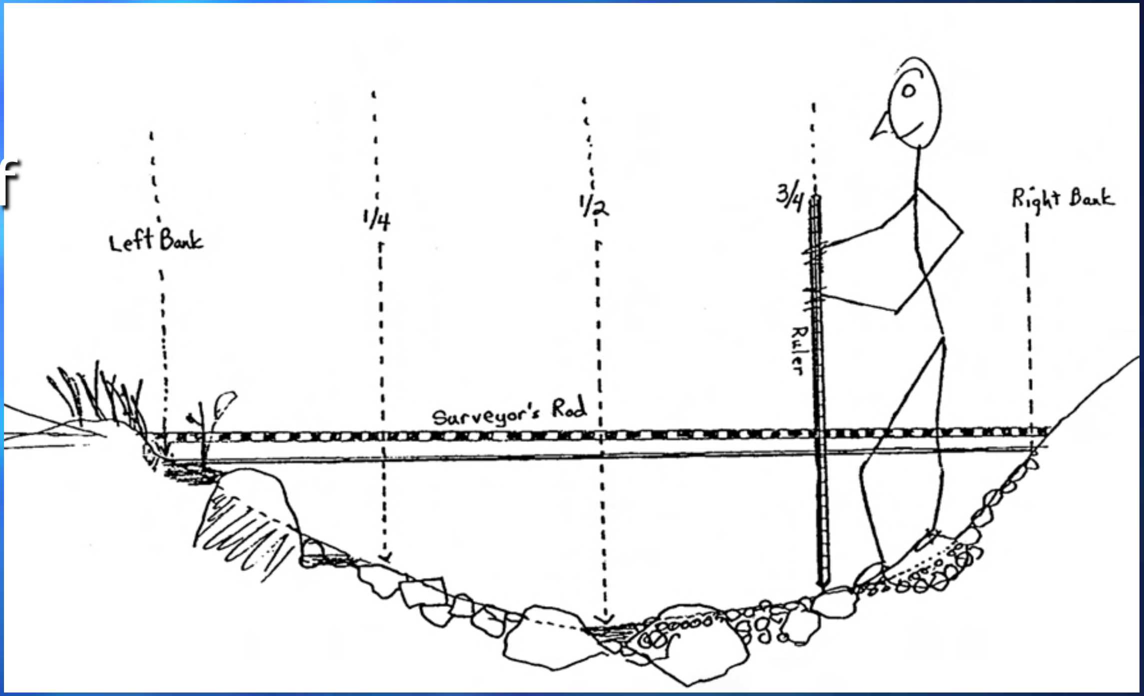
Saplings - 0

Barren - 4

Stream Habitat and Substrate

Stream Cross-Section

- Transect across stream
- Measure width of stream
- Measure depth of water
- Check substrate when check depth



Flows

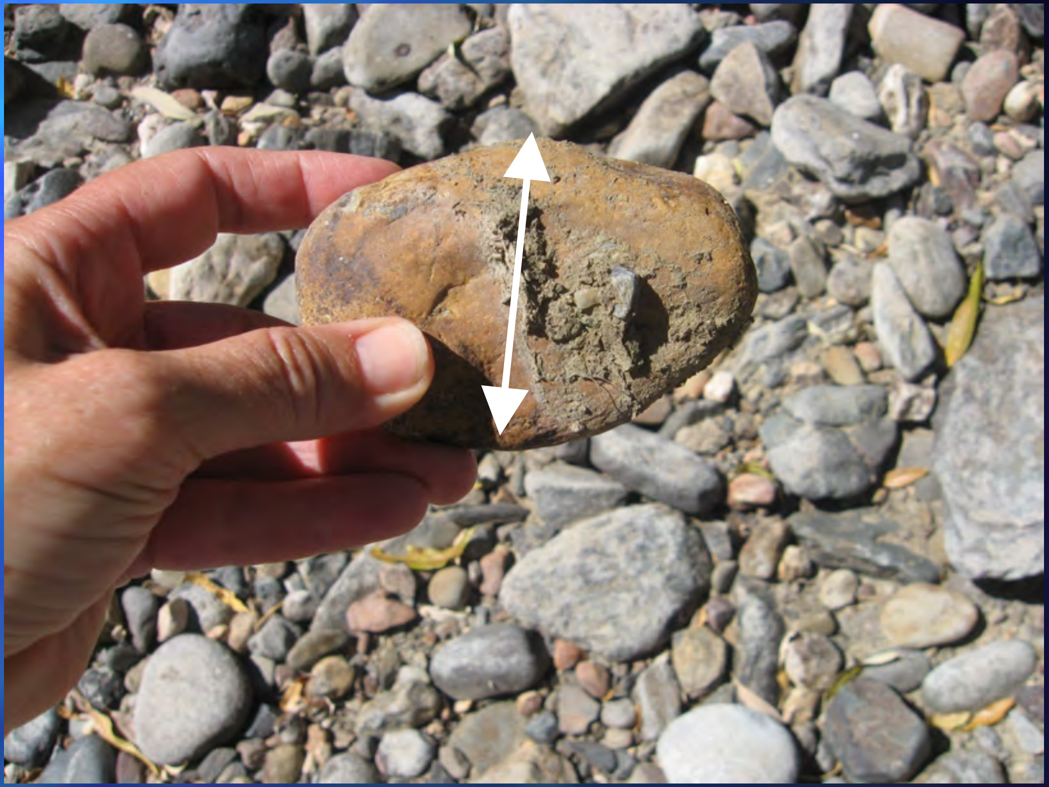
- Area: Use cross-section
- Measure flow by timing a float
- Discharge = area times flow

Substrate Sizes

- Bedrock – larger than a car
- Boulders – the big guys

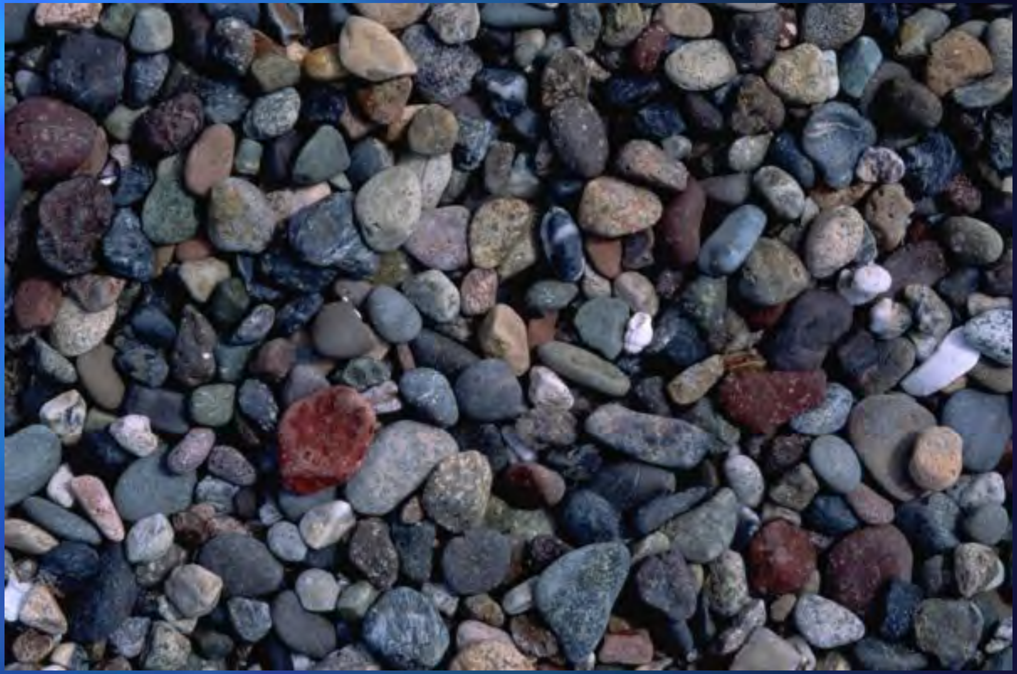
Substrate Sizes

- Cobble – tennis ball to basketball size
- Important for salmon
- Measure intermediate axis
- The axis that would get stuck if pushed through a sieve



Substrate Sizes

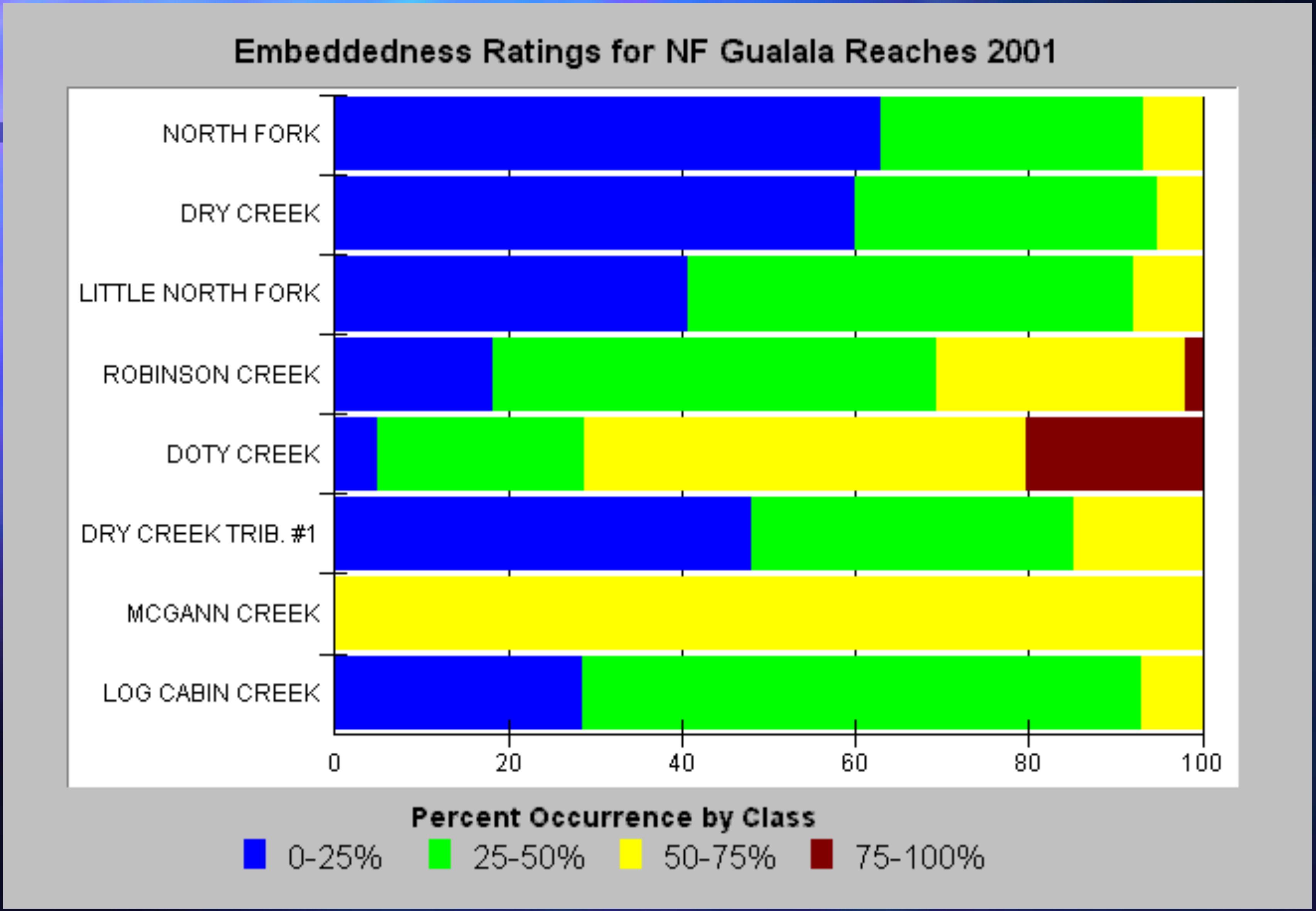
- Gravel – lady bug to tennis ball size
- Sand – gritty to lady bug size
- Silt – muck, not gritty



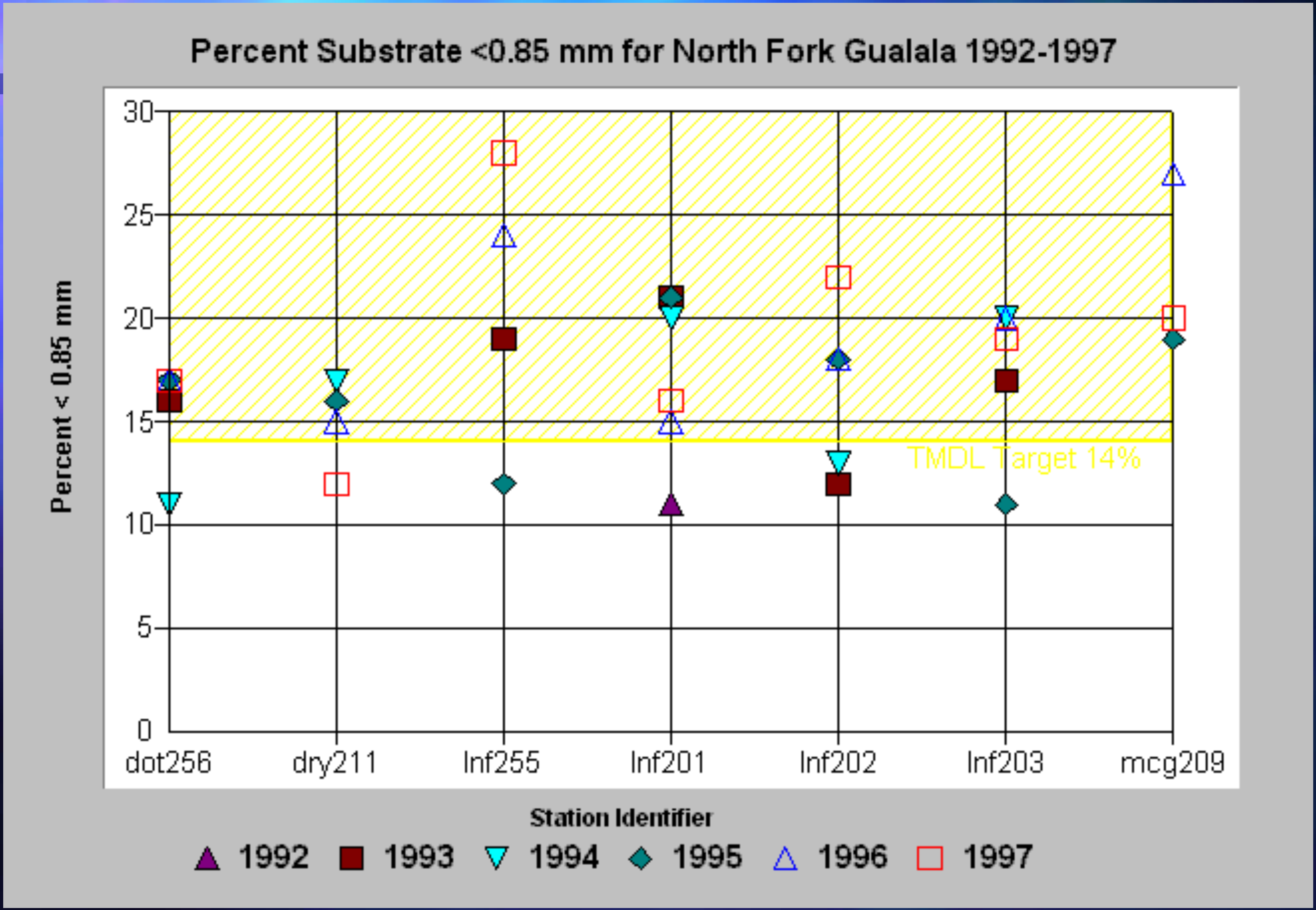
Embeddedness

- Look at cobble only
- How much is it embedded by silt?
- Pick up rock
- Estimate % of rock volume embedded

Embeddedness



Substrate Size Data



Sample ID: Sample Date:

Sampler(s): Data entry:

Category	Group	(enter) Number	%A	S
I-S	Mayflies		--	---
I-S	Stoneflies		--	---
I-S	Caddisflies (non-netspinners)		--	---
I-S	Hellgrammites		--	---
II-I	Riffle Beetles		--	---
II-I	Netspinners		--	---
II-I	Alderflies		--	---
II-I	Craneflies, odd Diptera		--	---
II-I	Other Beetles		--	---
II-I	Flatworms		--	---
II-I	Other/Unknown		--	---
III-T	Midges		--	---
III-T	Black Flies		--	---
III-T	Dragonflies, damselflies		--	---
III-T	Leeches		--	---
III-T	Snails		--	---
III-T	Clams		--	---
III-T	Scuds		--	---
III-T	Segmented Worms		--	---
	SUM:	**0**		**0**

Rating:

Key to abundance categories and scores: NO DATA ENTRY BELOW TH

	max % in sample	5	25	100	none
Abundance	%A	R	C	D	--
S(sensitive)	I-S	3	5	4	---
S(common)	II-I	2	3	2	---
S(dominant)	III-T	1	1	0	---

Ratings:	Poor	0	to	14
	Fair	15	to	20
	Good	21	to	25
	Excellent	26	or more	

Poor

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Sample ID: **Trout Creek** Sample Date:

Sampler(s): **Fish Squeezers** Data entry:

Category	**Group**	(enter) **Number**	**%A**	**S**
I-S	Mayflies	57	D	4
I-S	Stoneflies	7	C	5
I-S	Caddisflies (non-netspinners)	6	C	5
I-S	Hellgrammites	2	R	3
II-I	Riffle Beetles	2	R	2
II-I	Netspinners	8	C	3
II-I	Alderflies	3	R	2
II-I	Craneflies, odd Diptera	3	R	2
II-I	Other Beetles		--	---
II-I	Flatworms	2	R	2
II-I	Other/Unknown		--	---
III-T	Midges		--	---
III-T	Black Flies	10	C	1
III-T	Dragonflies, damselflies		--	---
III-T	Leeches		--	---
III-T	Snails		--	---
III-T	Clams		--	---
III-T	Scuds		--	---
III-T	Segmented Worms		--	---
	SUM:	**100**		**29**

Rating:

Key to abundance categories and scores: NO DATA ENTRY BELOW TH

	max % in sample	5	25	100	none
Abundance	%A	R	C	D	--
S(sensitive)	I-S	3	5	4	---
S(common)	II-I	2	3	2	---
S(dominant)	III-T	1	1	0	---

Ratings:	Poor	0	to	14
	Fair	15	to	20
	Good	21	to	25
	Excellent	26	or more	

1-May-00

AYF

Excellent

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This workbook was created as a companion to the California Streamside Biosurvey
Author: Arleen Feng, Alameda Countywide Clean Water Program (Hayward, CA)
This file may be freely reproduced and distributed for purposes of education and screening of stream and watershed conditions.
The scoring system may also be modified if the Biosurvey's version is not appropriate for your region's climate and stream types.
The blank "California Biosurvey" worksheet is protected against modifications but the "CA Biosurvey (example)" worksheet is not.
If you modify the file please save it under a different name and document the changes you have made in the spaces below.

INSTRUCTIONS: **Only enter data in the cells enclosed by colored or black borders.**
You will need to create a new copy of the blank worksheet for each site sampled on each date, and
you must have a separate CA Biosurvey Data Worksheet filled out with raw counts from each sample.
Enter the numbers of each Indicator Group in the Numbers column next to the Group name.
Formulas in other cells will automatically calculate relative abundance, index scores and
Water Quality Rating Scale according to the Sept. 2001 edition of the CA Biosurvey., and display the rating
At top of page, enter information about sample and who did the data collection and data entry
Save the completed worksheets in a new file. The "metadata" spaces below may be used to track
changes made to the file, which is useful when sharing or distributing your results with others.

METADATA RECORDS:

Filename (*.xls)	Modification date	Modified by	Worksheets affected	Data check status	Final?	comments
Biosurvey	7-Nov-01	A Feng	all	template OK	Yes	For SWRCB Clean Water Team website