Are there other inputs?

COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

PRECIPITATION + SW INFLOW + GW INFLOW + IMPORTED WATER =

TCB 50000 AF

PAN 500 ml

OUT'S

ET + EVAPORATION + SW OUT + GW OUT + EXPORT + CONSUMPTION

TCB 45000 AF + 0

PAN 0 + 160 ml

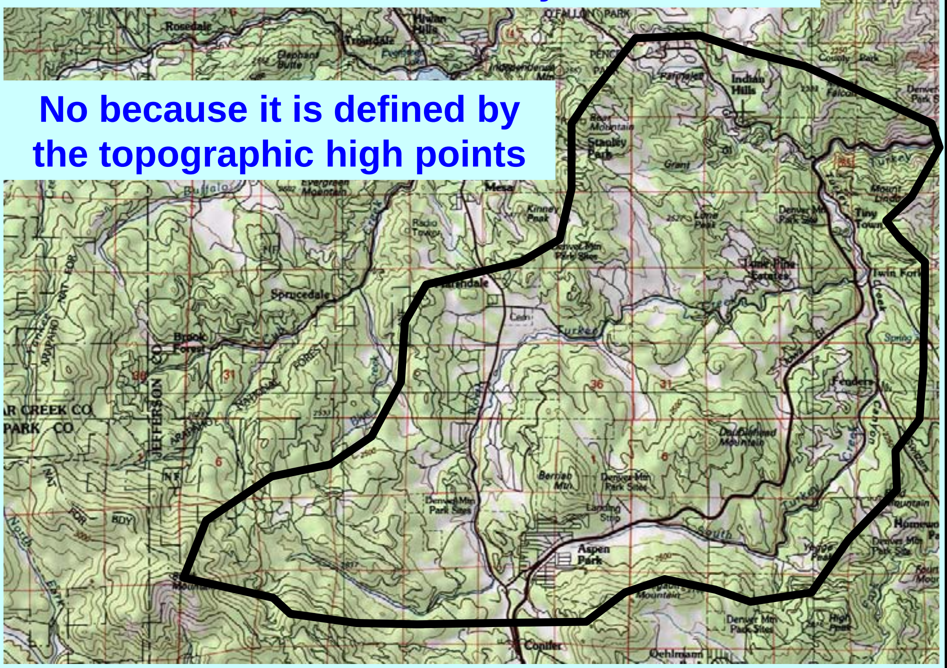
STORAGE

+ INCREASE IN SW STORAGE + INCREASE IN GW STORAGE

No potential for surface water inflow here

Surface Water Inflow to Turkey Creek Basin?

No because it is defined by the topographic high points



Are there other inputs?

COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

PRECIPITATION + SW INFLOW + GW INFLOW + IMPORTED WATER =

	PRECIPITATION		SW INFLOW
TCB	50000 AF	+	0
PAN	500 ml	+	0

OUT'S

ET + EVAPORATION + SW OUT + GW OUT + EXPORT + CONSUMPTION

	ET		EVAPORATION
TCB	45000 AF	+	0
PAN	0	+	160 ml

STORAGE

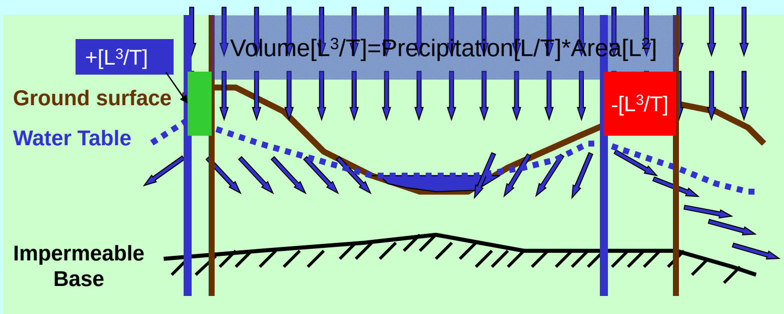
+ INCREASE IN SW STORAGE + INCREASE IN GW STORAGE

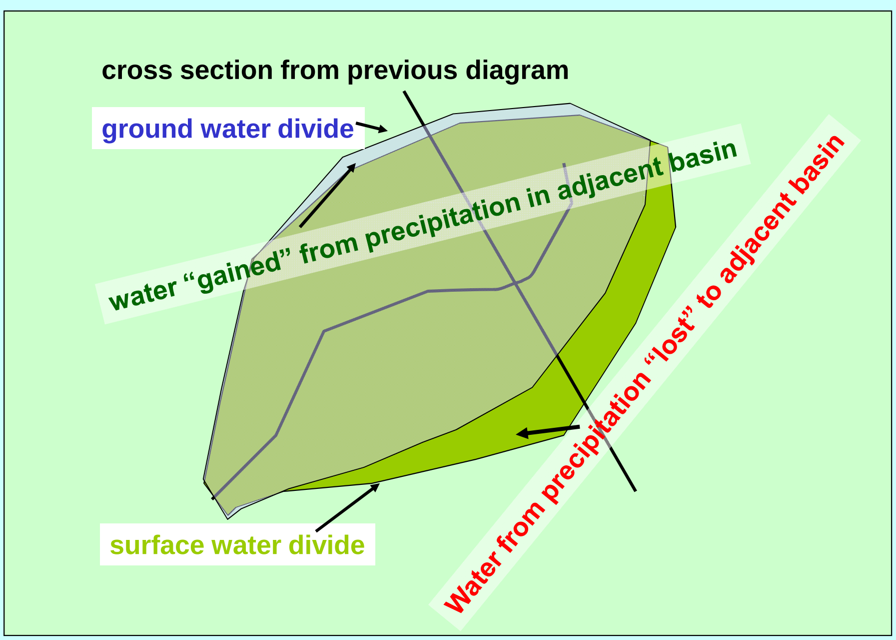
Ground Water Inflow

DRAINAGE BASIN - Area Surrounded by a Topographic Divide
May Differ from Ground Water Basin

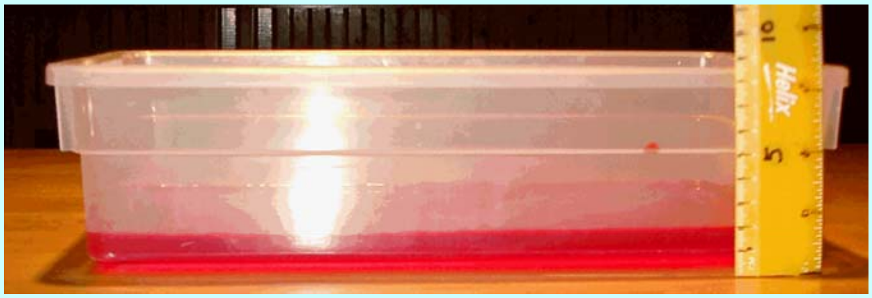
GROUNDWATER BASIN - Surrounded by Phreatic (Water Table) Divide
- **Water Table** - Surface below which all cracks and pores in the subsurface are full of water (saturated zone)
- **Phreatic** - Zone at and below the Water Table

WHEN DIVIDES DO NOT CORRESPOND - INTERBASIN FLOW





No potential for ground water inflow here

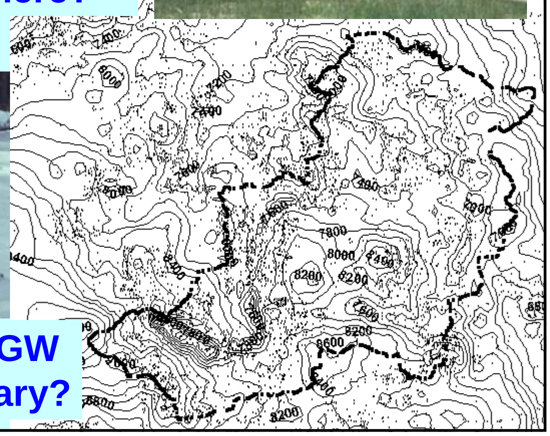


Ground Water Inflow to Turkey Creek Basin?

What do the dots and contours represent?

No significant ground water inflow across the boundaries

How do we see that here?



Where do you expect GW flow across the boundary?

Are there other inputs?

COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

	PRECIPITATION	+ SW INFLOW	+ GW INFLOW	+ IMPORTED WATER =
TCB	50000 AF	+ 0	+ 0	
PAN	500 ml	+ 0	+ 0	

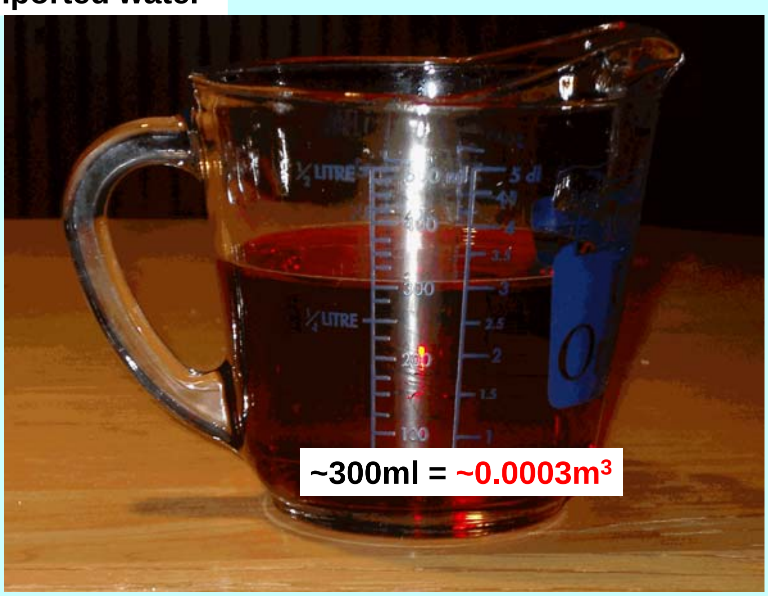
OUT'S

	ET	+ EVAPORATION	+ SW OUT + GW OUT + EXPORT + CONSUMPTION
TCB	45000 AF	+ 0	
PAN	0	+ 160 ml	

STORAGE

+ INCREASE IN SW STORAGE + INCREASE IN GW STORAGE

"imported water"



"importation"

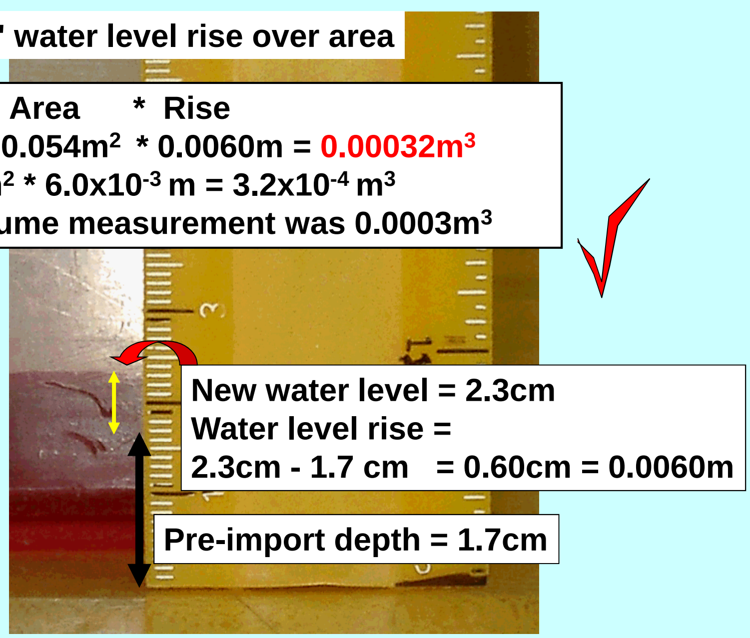
"import" water level rise over area

Volume = Area * Rise

Volume = $0.054m^2$ * 0.0060m = $0.00032m^3$

$5.4x10^{-2}\ m^2 * 6.0x10^{-3}\ m = 3.2x10^{-4}\ m^3$

direct volume measurement was $0.0003m^3$



Is water imported to Turkey Creek Basin?

Community water systems have their supply within the basin (e.g. wells near Tiny Town for Indian Hills)

Likely insignificant amounts of bottled water

COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

	PRECIPITATION	+	SW INFLOW	+	GW INFLOW	+	IMPORTED WATER	=
TCB	50000 AF	+	0	+	0	+	0	
PAN	500 ml	+	0	+	0	+	300ml	

OUT'S

ET + EVAPORATION + SW OUT + GW OUT + EXPORT + CONSUMPTION

TCB	45000 AF	+	0
PAN	0	+	160 ml

STORAGE

+ INCREASE IN SW STORAGE + INCREASE IN GW STORAGE

WATER BUDGETS continued …

COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

	PRECIPITATION	+	SW INFLOW	+	GW INFLOW	+	IMPORTED WATER =
TCB	50000 AF	+	0	+	0	+	0
PAN	500 ml	+	0	+	0	+	300 ml

OUT'S

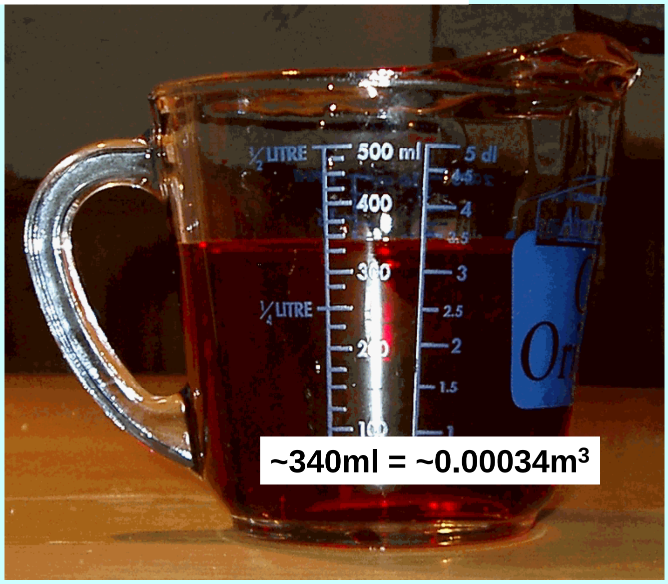
	ET + EVAPORATION	+	SW OUT + GW OUT + EXPORT + CONSUMPTION
TCB	45000 AF	+	0
PAN	0	+	160 ml

STORAGE

+ INCREASE IN SW STORAGE + INCREASE IN GW STORAGE

"stream flow out of basin"

Collected "stream discharge water"

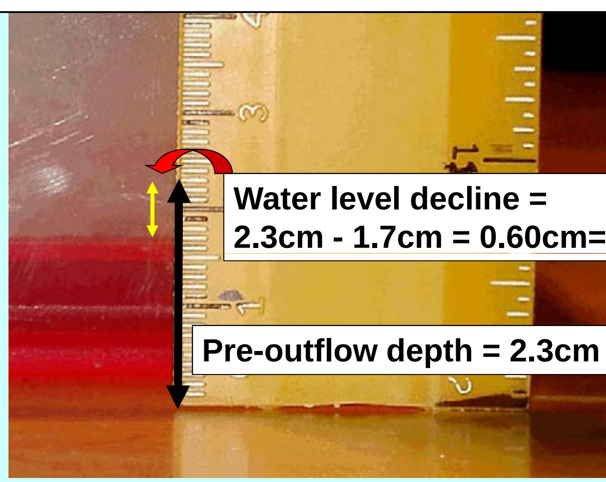


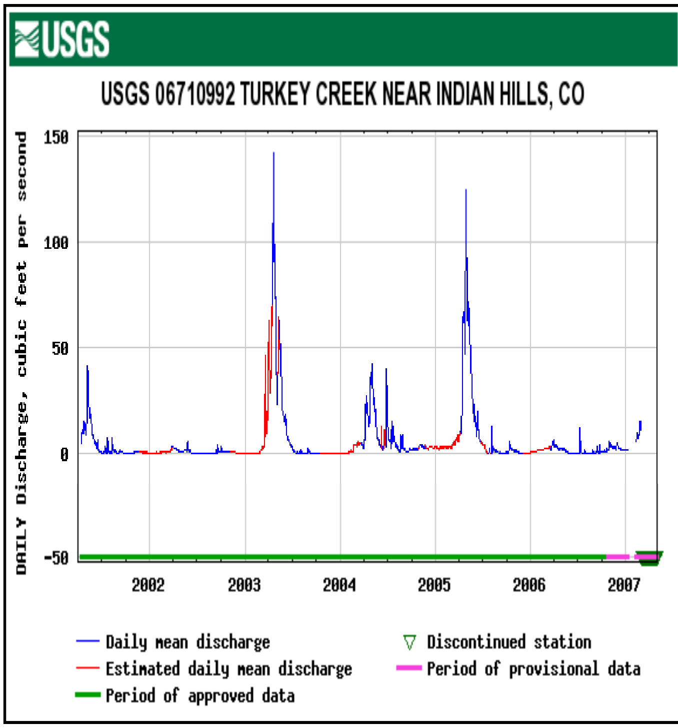
"stream flow" water level decline over area

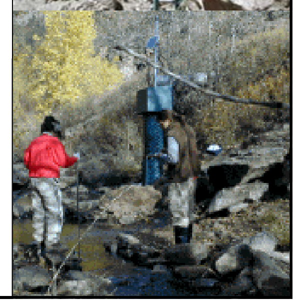
Volume = Area * Decline

Volume = $0.054 m^2 * 0.0060 m$ = ~$0.00032 m^3$

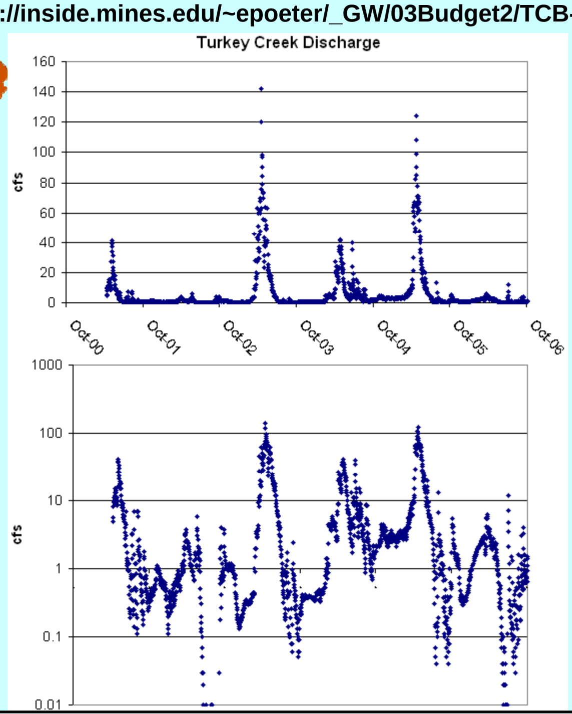
direct volume measurement was $0.00034 m^3$







http://inside.mines.edu/~epoeter/_GW/03Budget2/TCB-StreamGage-GWclass.xls



The volume of water discharged over a period of time is the area under the curve

$$\frac{ft^3}{sec}\ sec = ft^3$$

If you estimate the average flow rate and multiply by the # secs in a year you will have the average volume per year.

WATER BUDGETS continued …

COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

	PRECIPITATION +	SW INFLOW +	GW INFLOW +	IMPORTED WATER =
TCB	50000 AF +	0 +	0 +	0
PAN	500 ml +	0 +	0 +	300 ml

OUT'S

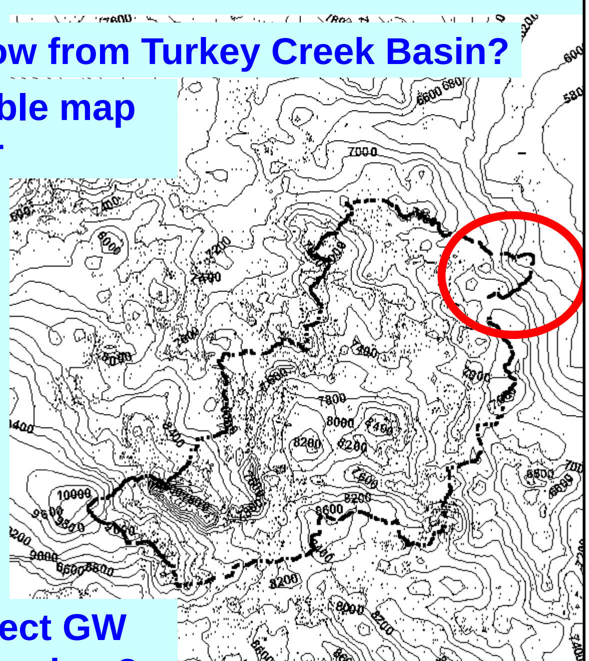
	ET +	EVAPORATION +	SW OUT +	GW OUT + EXPORT + CONSUMPTION
TCB	45000 AF +	0 +	4000AF	
PAN	0	+ 160 ml +	340ml	

STORAGE

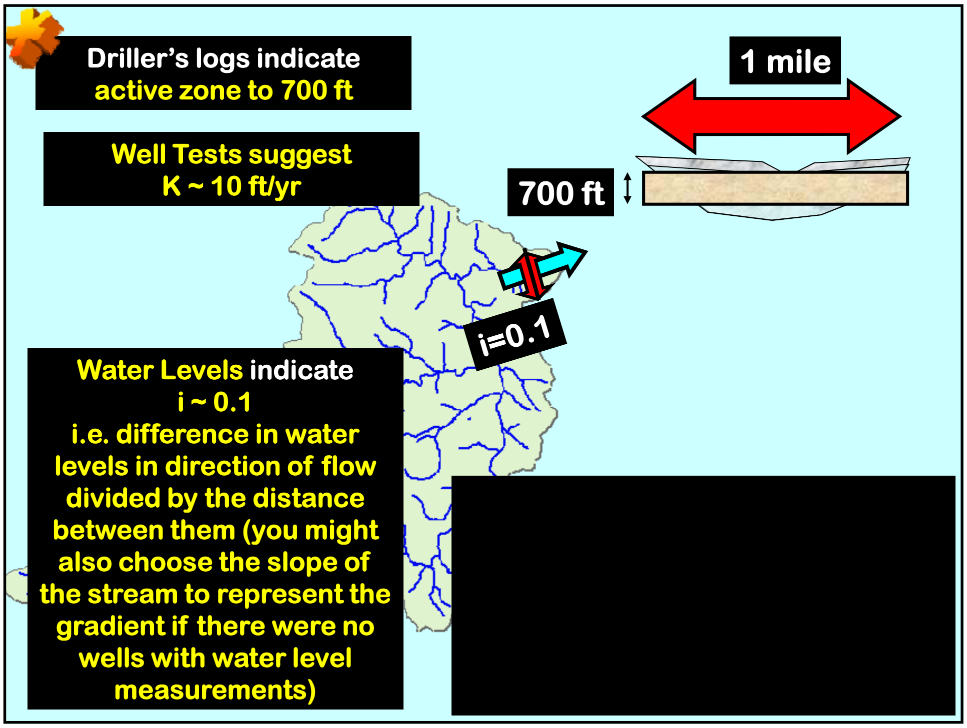
+ INCREASE IN SW STORAGE + INCREASE IN GW STORAGE

Ground Water Outflow from Turkey Creek Basin?

Recall the water table map from earlier



Where do you expect GW flow across the boundary?



WATER BUDGETS continued …

COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

	PRECIPITATION	+ SW INFLOW	+ GW INFLOW	+ IMPORTED WATER =
TCB	50000 AF	+ 0	+ 0	+ 0
PAN	500 ml	+ 0	+ 0	+ 300 ml

OUT'S

	ET	+ EVAPORATION	+ SW OUT	+ GW OUT	+ EXPORT	+ CONSUMPTION
TCB	45000 AF	+ 0	+ 4000 AF	+ 80 AF		
PAN	0	+ 160 ml	+ 340ml	+ 0		

STORAGE

+ INCREASE IN SW STORAGE + INCREASE IN GW STORAGE

Is water exported from Turkey Creek Basin?

Likely insignificant amounts of bottled water

No water is exported from our kitchen pan either

WATER BUDGETS continued …

COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

	PRECIPITATION	+ SW INFLOW	+ GW INFLOW	+ IMPORTED WATER =
TCB	50000 AF	+ 0	+ 0	+ 0
PAN	500 ml	+ 0	+ 0	+ 300 ml

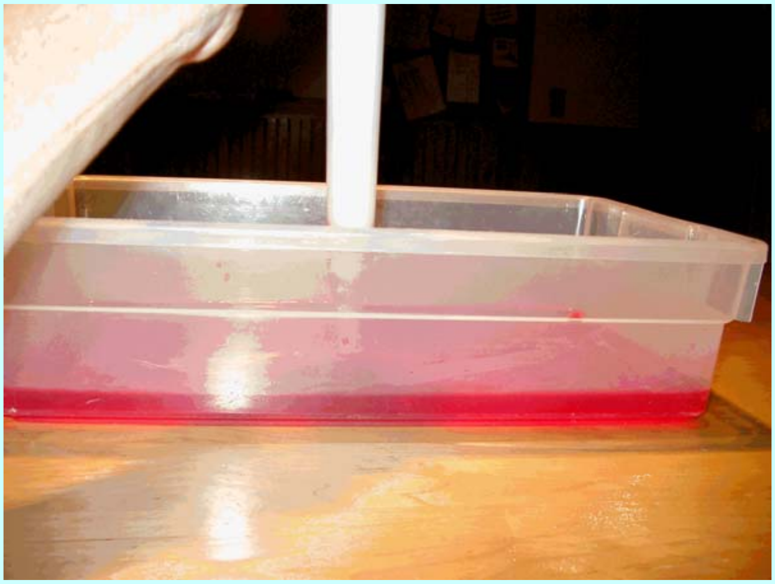
OUT'S

	ET	+ EVAPORATION	+ SW OUT	+ GW OUT	+ EXPORT	+ CONSUMPTION
TCB	45000 AF	+ 0	+ 4000 AF	+ 80 AF	+ 0	
PAN	0	+ 160 ml	+ 340ml	+ 0	+ 0	

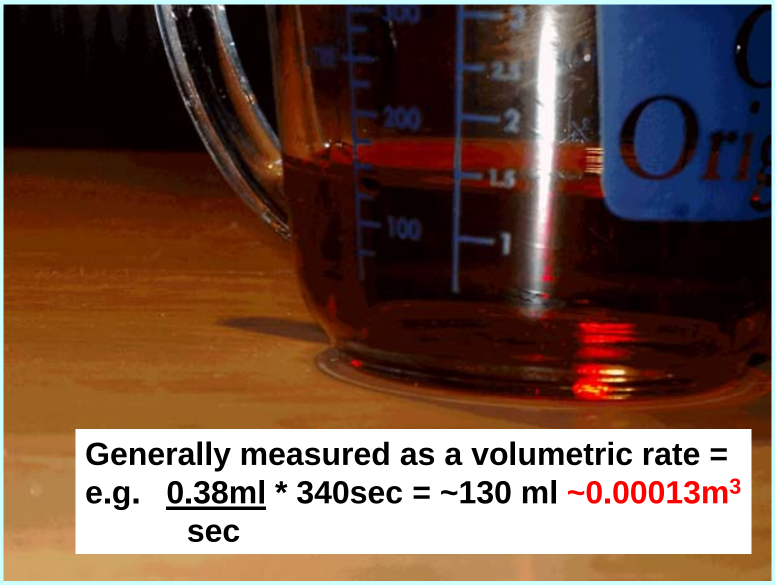
STORAGE

+ INCREASE IN SW STORAGE + INCREASE IN GW STORAGE

"pump"

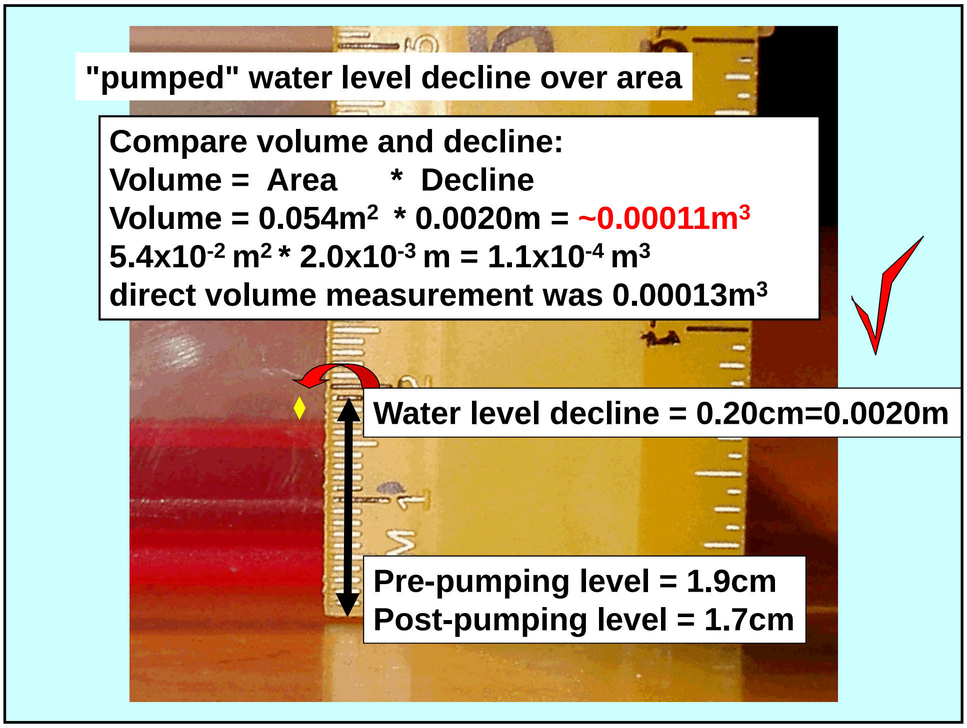


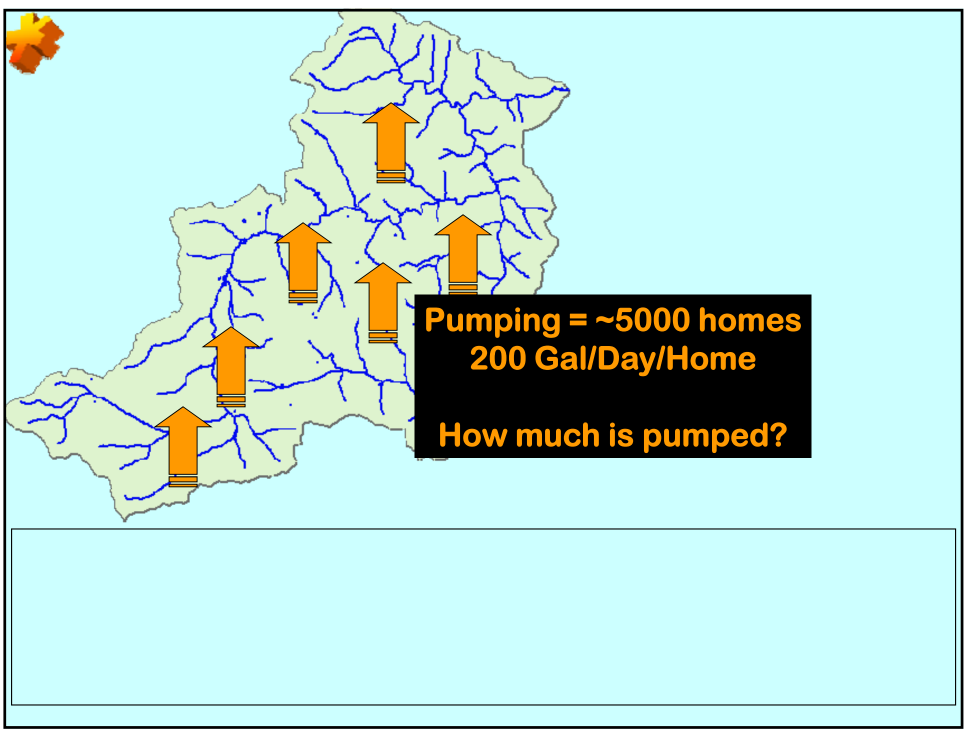
"pumped" volume



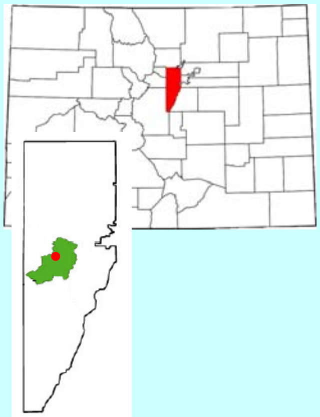
Generally measured as a volumetric rate =

e.g. $\frac{0.38\text{ml}}{\text{sec}}$ * 340sec = ~130 ml ~0.00013m^3

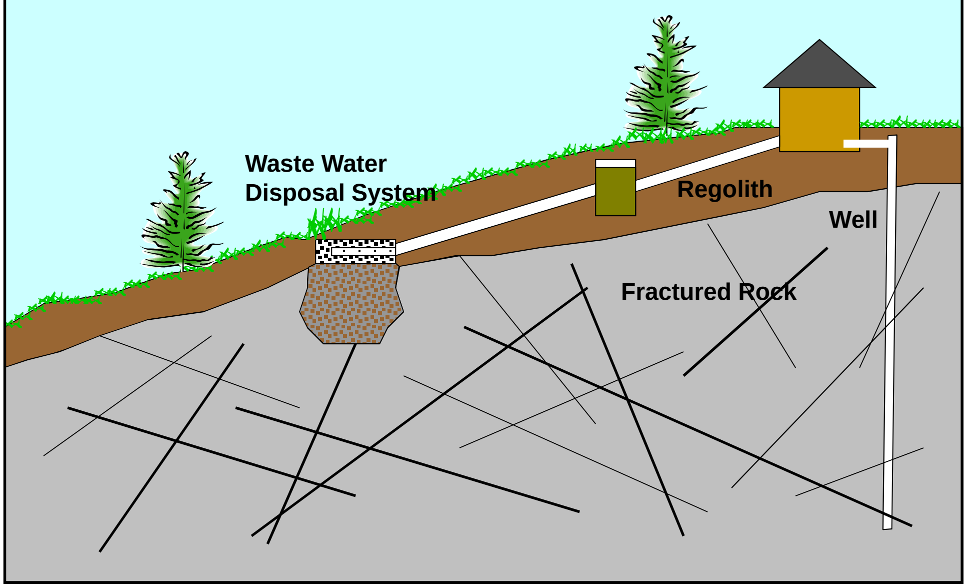

"pumped" water level decline over area
Compare volume and decline:
Volume = Area * Decline
Volume = 0.054m2 * 0.0020m = ~0.00011m3
5.4x10-2 m2 * 2.0x10-3 m = 1.1x10-4 m3
direct volume measurement was 0.00013m3
Water level decline = 0.20cm=0.0020m
Pre-pumping level = 1.9cm
Post-pumping level = 1.7cm


Pumping = ~5000 homes
200 Gal/Day/Home
How much is pumped?

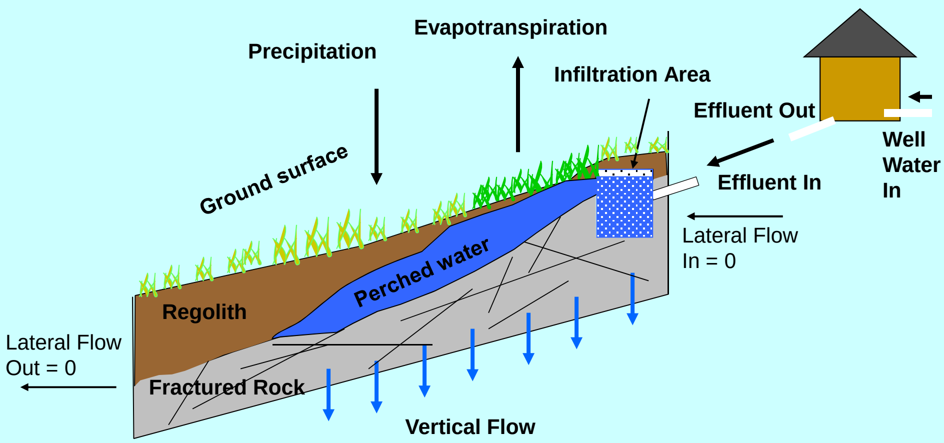
A few years ago we completed a Consumptive Use Study



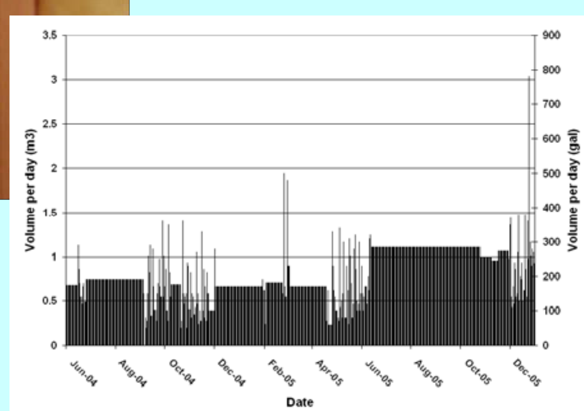
Cross Section of Study Site



Conceptual Model of Study Site

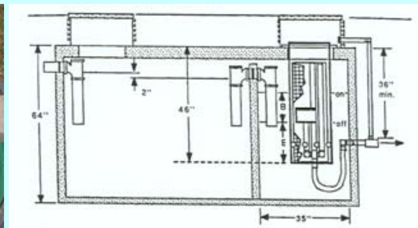


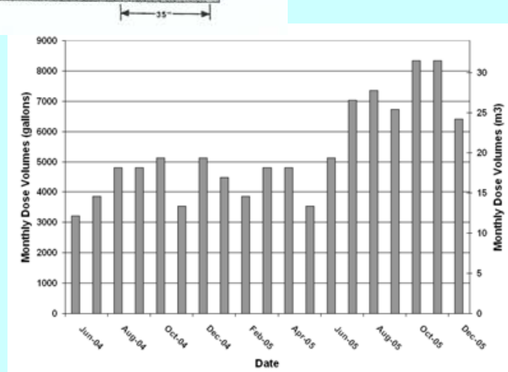
Water Pumped to Home



Effluent to ISDS

(Individual Sewage Disposal System)





% Returned from the Home

% Pumped that flows to the ISDS =

$$\frac{\text{Volume Pumped} - \text{Volume Dosed}}{\text{Volume Pumped}} \quad 100$$

AVERAGE RETURNED ~ 85 %

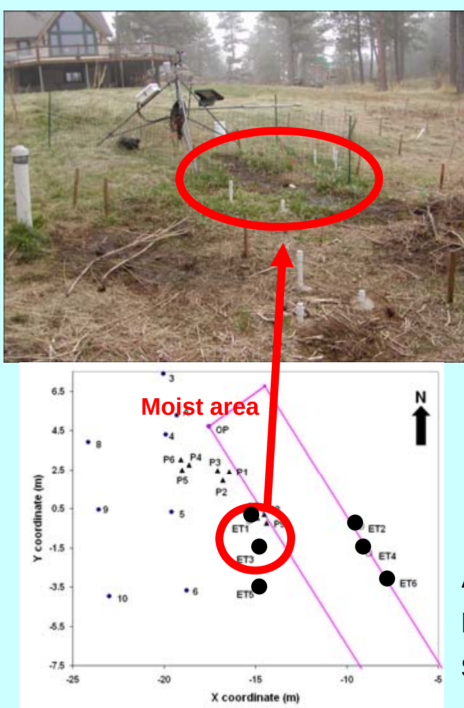
Owner 1 83.9% (loss of 33.3 gal/day)
Owner 2 88.0 % (loss of 43.6 gal/day)

How Much is Lost to ET?

Need to Know Actual Evapotranspiration

- **Continuous POTENTIAL ET** from climate data
- **Net Radiation**
  Soil Heat Flux
  Temperature
  Relative Humidity
  Wind Speed
  Soil Moisture

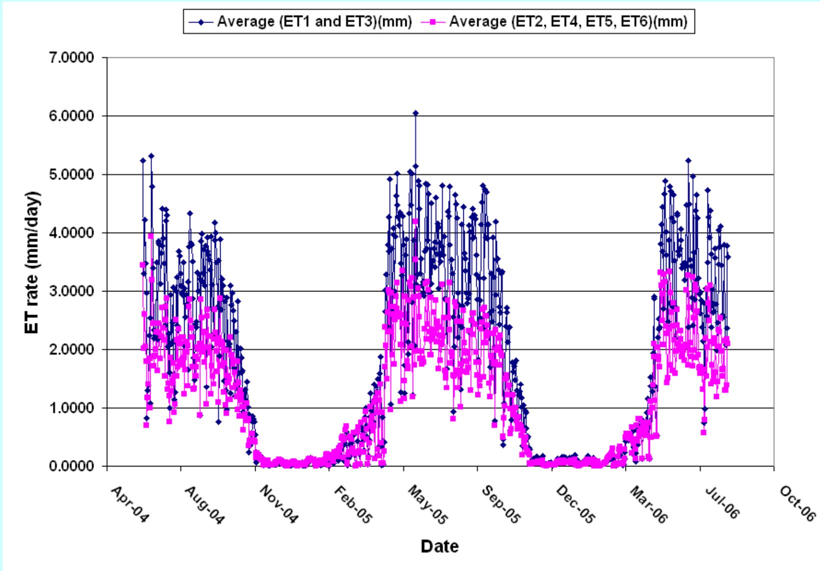
- **Intermittent ACTUAL ET** measured using ET chamber
- **Used to calibrate a model of continuous AET based on continuous PET**



Moist Area 12 m^2 represented by AET stations 1 and 3

AET stations 2,4,5,6 represent the rest of the site

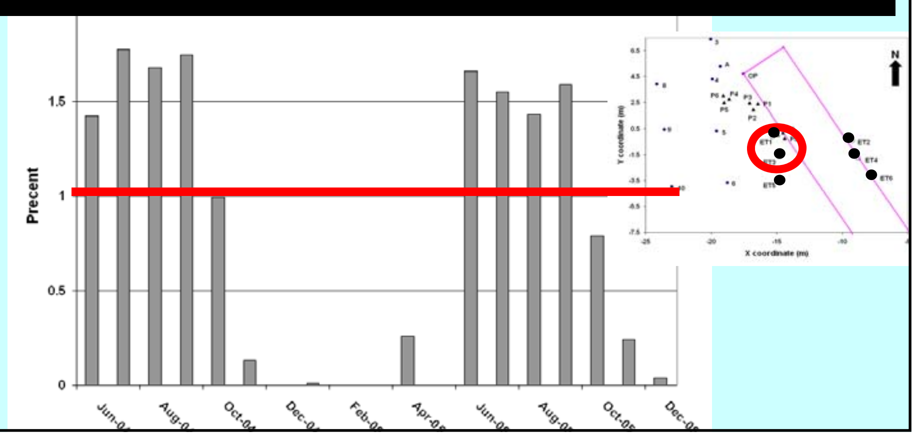
Actual Evapotranspiration



% of Pumped Water Lost to ET

Calculation of Effluent Lost to ET assumes the only loss is the incremental ET over the anomalous area

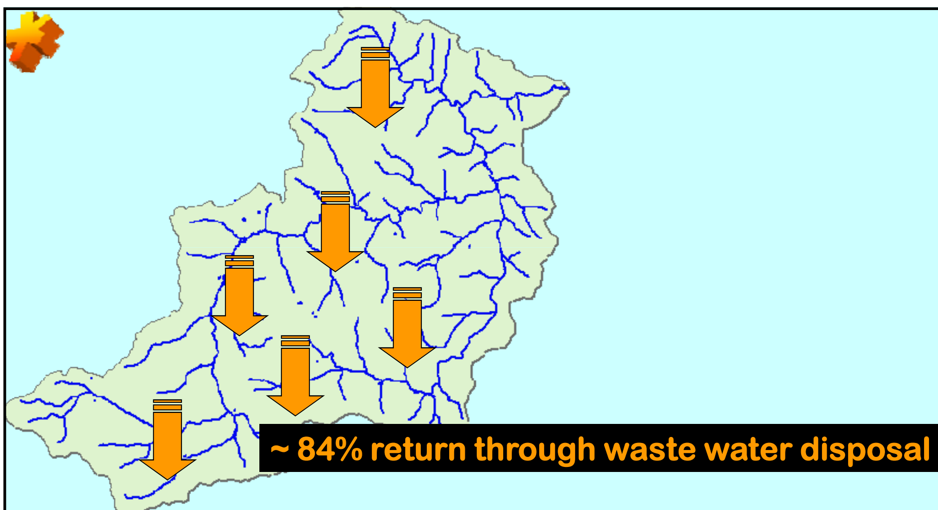
Preliminary Annual Average ~ 1% FOR THIS SITE



PRELIMINARY CONCLUSION
AT THIS SITE

- Residential loss (~15 %)
- Loss to ET(~1 %)

- OVERALL 84% +/- 4 %
  of pumped water returns to subsurface



WATER BUDGETS continued …

COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

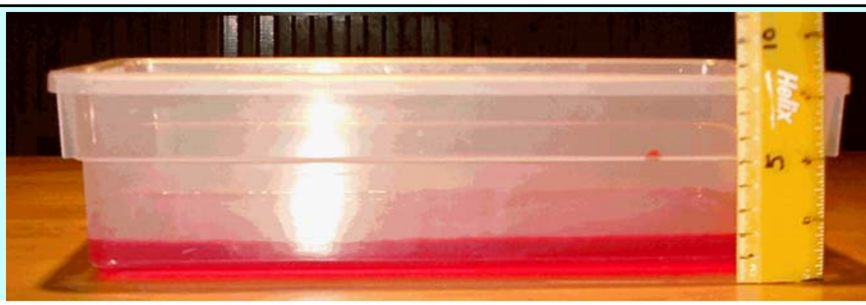
	PRECIPITATION	+	SW INFLOW	+	GW INFLOW	+	IMPORTED WATER	=	
TCB	50000 AF	+	0	+	0	+	0	=	50000 AF
PAN	500 ml	+	0	+	0	+	300 ml	=	800 ml

OUT'S

	ET	+	EVAPORATION	+	SW OUT	+	GW OUT	+	EXPORT	+	CONSUMPTION	=	
TCB	45000 AF	+	0	+	4000 AF	+	80 AF	+	0	+	200AF	=	49280 AF
PAN	0	+	160 ml	+	340ml	+	0	+	0	+	130ml	=	640 ml

STORAGE

+ INCREASE IN SW STORAGE + INCREASE IN GW STORAGE



We started with a water level of 0.9cm (considering the false bottom of the tank) and ended with 1.4cm, so:

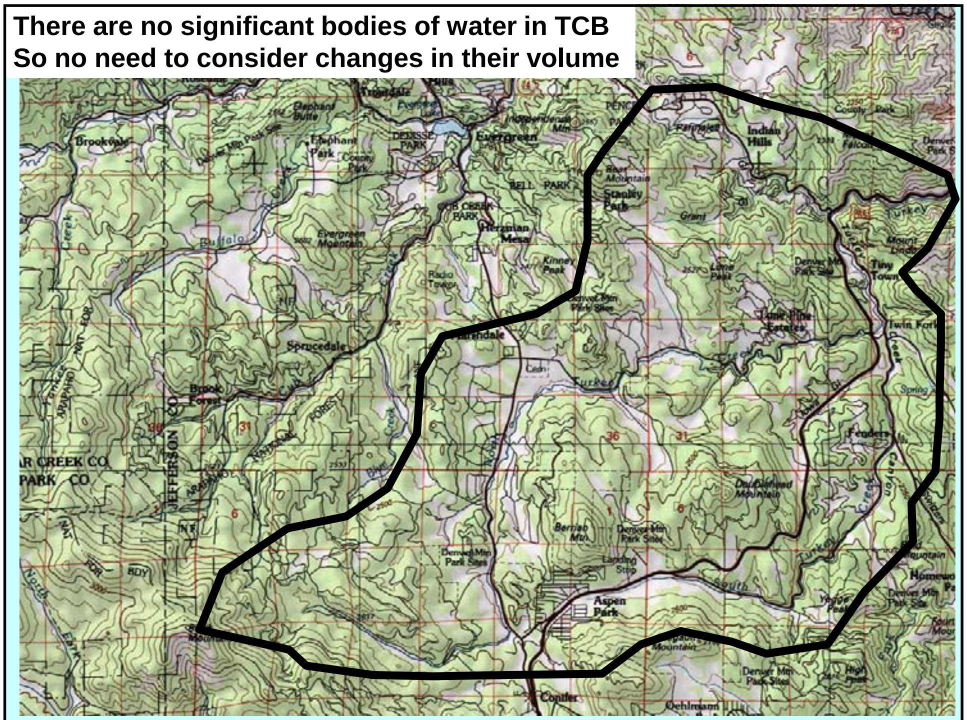
Change in Storage = water level change * area

$$= (1.4\text{cm} - 0.9\text{cm}) * \frac{1\text{m}}{100\text{cm}} * 0.054\text{m}^2$$

$$= 0.00027\text{m}^3 = 270 \text{ ml}$$

Note: Increase in storage is taken a positive change

There are no significant bodies of water in TCB
So no need to consider changes in their volume



WATER BUDGETS continued …

COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

	PRECIPITATION	+ SW INFLOW	+ GW INFLOW	+ IMPORTED WATER	=
TCB	50000 AF	+ 0	+ 0	+ 0	= 50000 AF
PAN	500 ml	+ 0	+ 0	+ 300 ml	= 800 ml

OUT'S

	ET	+ EVAPORATION	+ SW OUT	+ GW OUT	+ EXPORT	+ CONSUMPTION	=
TCB	45000 AF	+ 0	+ 4000 AF	+ 80 AF	+ 0	+ 200AF	= 49280 AF
PAN	0	+ 160 ml	+ 340ml	+ 0	+ 0	+ 130ml	= 640 ml

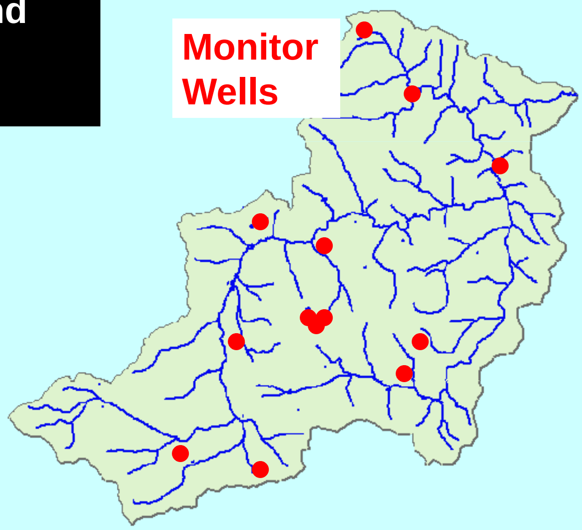
STORAGE

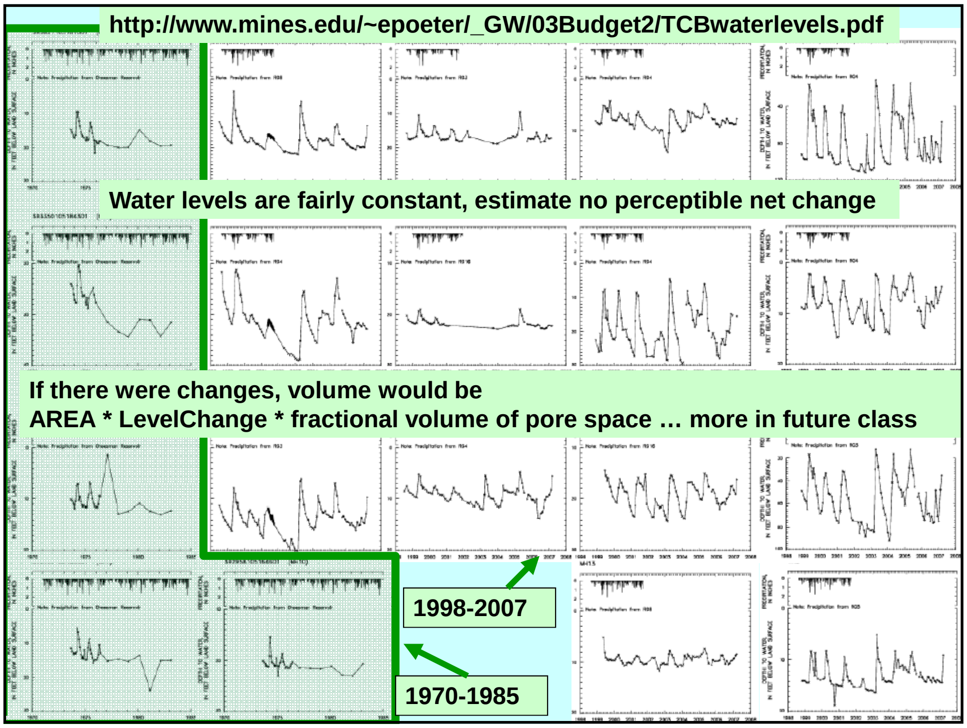
	+ INCREASE IN SW STORAGE	+ INCREASE IN GW STORAGE
TCB	+ 0	
PAN	+ 270 ml	

There is no ground water in the pan

So Increase in Ground Water Storage = 0 ml

Change in Ground Water Storage Volume?





COMPONENTS OF A BASIN WATER BUDGET

INFLOW = OUTFLOW + CHANGE IN STORAGE

IN'S

	PRECIPITATION	+ SW INFLOW	+ GW INFLOW	+ IMPORTED WATER	=
TCB	50000 AF	+ 0	+ 0	+ 0	= 50000 AF
PAN	500 ml	+ 0	+ 0	+ 300 ml	= 800 ml

OUT'S

	ET	+ EVAPORATION	+ SW OUT	+ GW OUT	+ EXPORT	+ CONSUMPTION	=
TCB	45000 AF	+ 0	+ 4000 AF	+ 80 AF	+ 0	+ 200AF	= 49280 AF
PAN	0	+ 160 ml	+ 340ml	+ 0	+ 0	+ 130 ml	= 630 ml

STORAGE

	+ INCR SW STORAGE	+ INCR GW STORAGE	=	(OUT+INCR STOR)
TCB	+ 0	+ 0	= 0	(49280 AF)
PAN	+ 270 ml	+ 0	= 270 ml	(900 ml)

Budget =

Inflow = Outflow + Change in Storage =

(Rain + Imports) = (Evaporation + Streamflow + Consumption) + (Change in Storage) =

IN OUT STORAGE ERROR

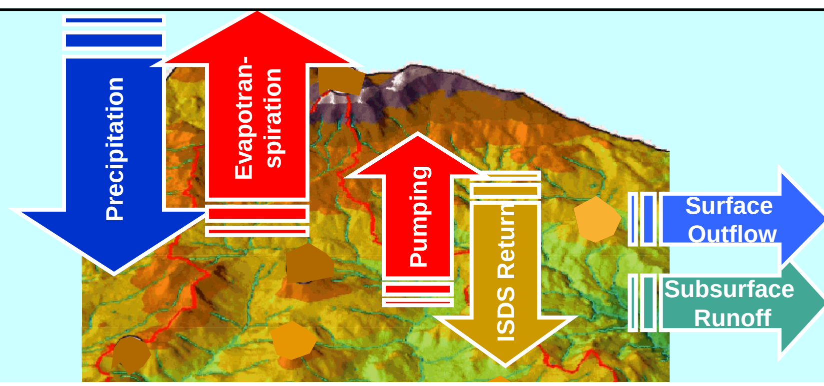
($0.0005m^3$+$0.0003m^3$)=(0.00016^3+$0.00034m^3$+$0.00013m^3$)+($0.00027m^3$) + ?

ERROR = IN - OUT including STORAGE

ERROR = ($0.0008m^3$) - ($0.0009m^3$) = $-0.0001m^3$

% imbalance = 0.0001 / 0.00085 = 12.0% error

Often a budget item is calculated rather than measured so the error is unknown



Budget =

Inflow = Outflow + Change in Storage =

(Precip) = (ET + SrfWaterOut + GrndWaterOut + Consumption) + (Change in Storage) =

IN OUT STORAGE ERROR

(50000AF) = (45000AF+4000AF+80AF+200AF) + 0 + ?

ERROR = IN - OUT including STORAGE

ERROR = 50000AF - 49280AF = 720AF

% imbalance = 720 / 49640 = 1.5% error

Note error is larger than some of the components

Consider a BUDGET for a STREAM SEGMENT

Conceptually isolate the system and consider the boundaries

Join with a fellow student

Pull a "Domain" from the hat

Talk for a few minutes to Determine the budget items for the Domain for One Year

Take a few minutes to:
Quantify Each by Assigning Numerical Values that you feel are Reasonable
USE: Precipitation in/year   Area ft^2 OR mi^2 Flux ft^3/sec OR AcreFeet/year
Choose your own units for any parameter that cannot be defined by these units

Take a few minutes to calculate the budget

Questions?
Observations?