Consumptive Use Panel

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Water Balance

(In=Out +- Storage)

- Simple Accounting
- Modeling Is a Fancy Way of Accounting

- Terms in the equation can be rearranged

- Usually, all error is assembled in the Evaporation or Ground-Water Term

Estimates of potential error

Dingman, 1993 after Winter, 1981

Range of Uncertainty in Precipitation and Streamflow Values Used in Computing Lake Water Balances[a]

Time Interval	Precipitation	Streamflow Inputs[b]	Streamflow Outputs
		General Range	
Daily	60–75	5–15 (50)	5 (15)
Monthly	10–25	5–15 (50)	5 (15)
Seasonal/annual	5–10	5–15 (30)	5 (15)

[a] Values are percentages of the true values. Those without parentheses are for "best" methodology; those in parentheses are "commonly used" methodology.

Cottonwood Creek, West of Bridgers

Hay, 1997

$P = 8{,}340$
$I_{SW} = 6{,}73$
$ET = 7{,}72$
$O_{GW} = 1{,}3$
$O_{SW} = 83$
$U_{IRR} = 48$
$ET_D = 0$
$R_{GW} = 5{,}1$

$P = 8{,}340 \pm 1{,}700$ ac. ft. — 20% Error

$I_{SW} = 6{,}730 \pm 340$ ac. ft. — 5% Error

$ET = 7{,}720 \pm 3{,}100$ ac. ft. — 40% Error

$O_{GW} = 1{,}300 \pm 1{,}300$ ac. ft. — 100% Error

$O_{SW} = 832 \pm 43$ ac. ft. — 5% Error

$U_{IRR} = 48 \pm 24$ ac. ft. — 50% Error

$ET_D = 0$

$R_{GW} = 5{,}100 \pm 3{,}800$ ac. ft. — 75% Error

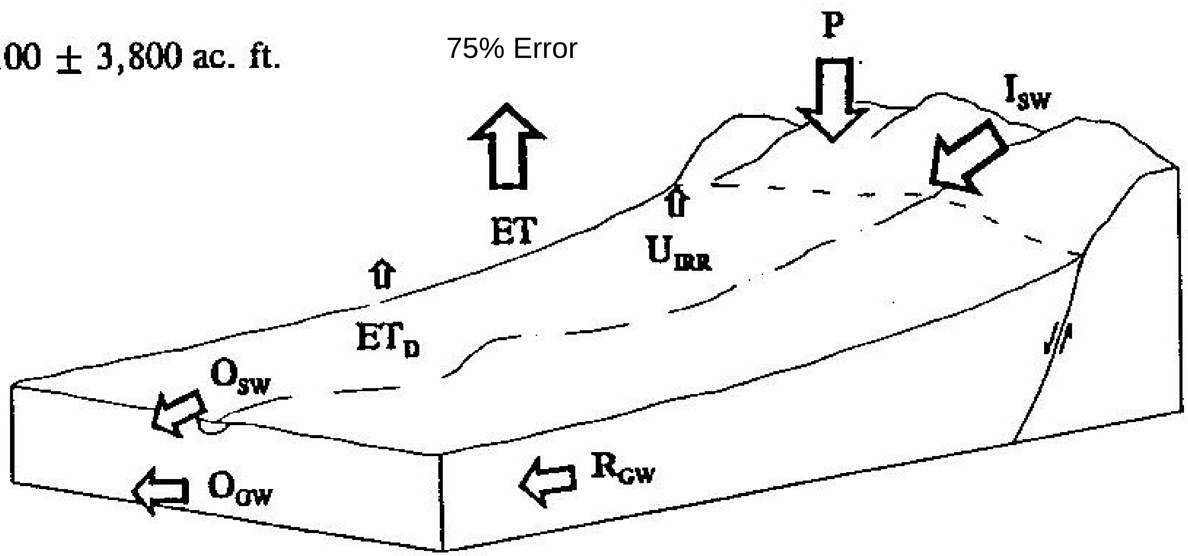
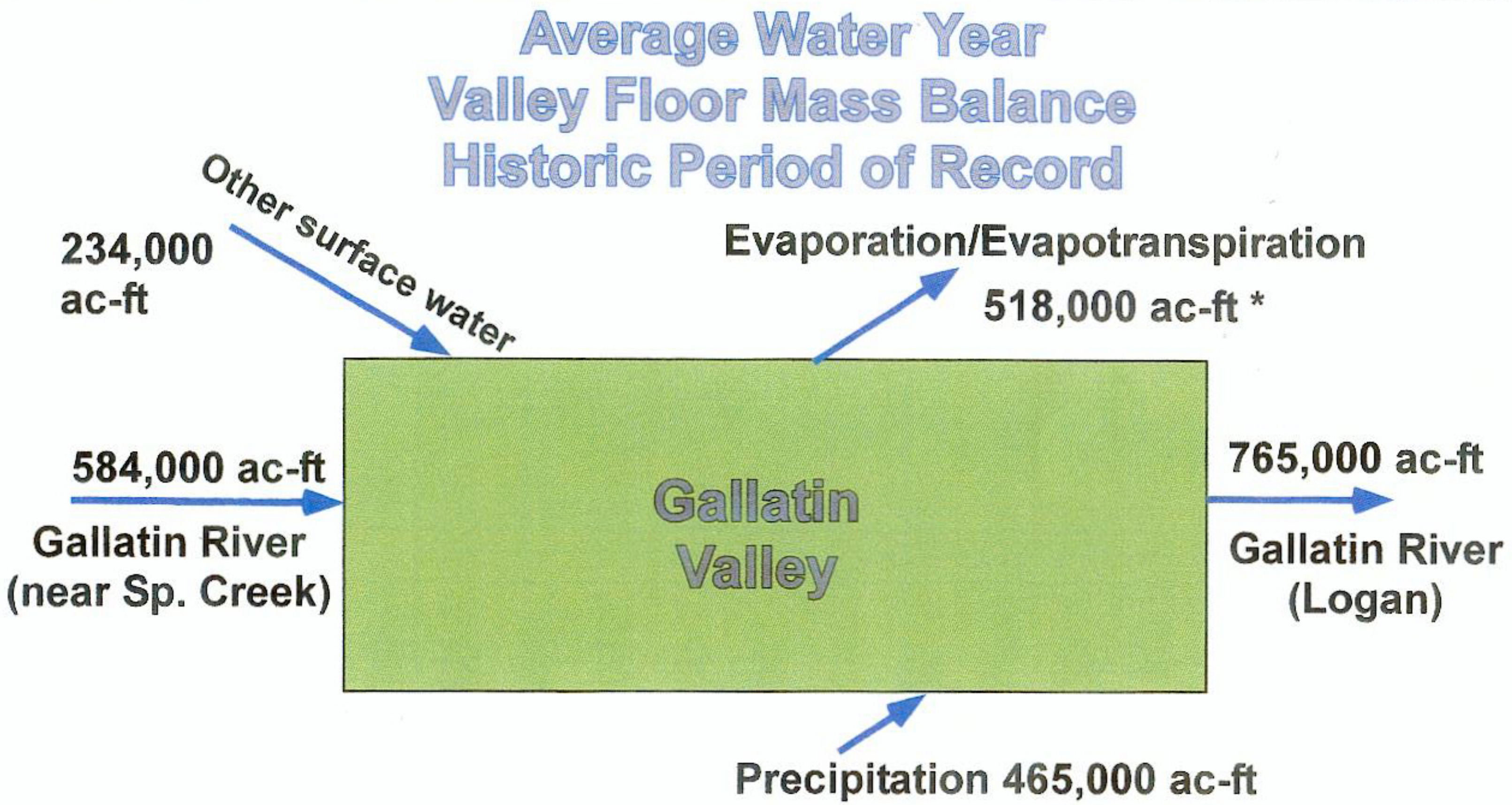


Figure 17. Actual physical water-budget quantities. No scale implied.

Variable Definitions for Hay

R_{GW} = ground water recharge (also equivalent to the change in ground water storage), P = precipitation, I_{SW} = surface water inflow, I_{GW} = ground-water inflow, ET = evapotranspiration, ET_D = evapotranspirative loss from septic discharge, E_R = evaporation from reservoirs, O_{SW} = surface water outflow, O_{GW} = ground-water outflow, U_{IRR} = lawn irrigation, and S_{SW} = the change in surface water storage.

Basin Analysis

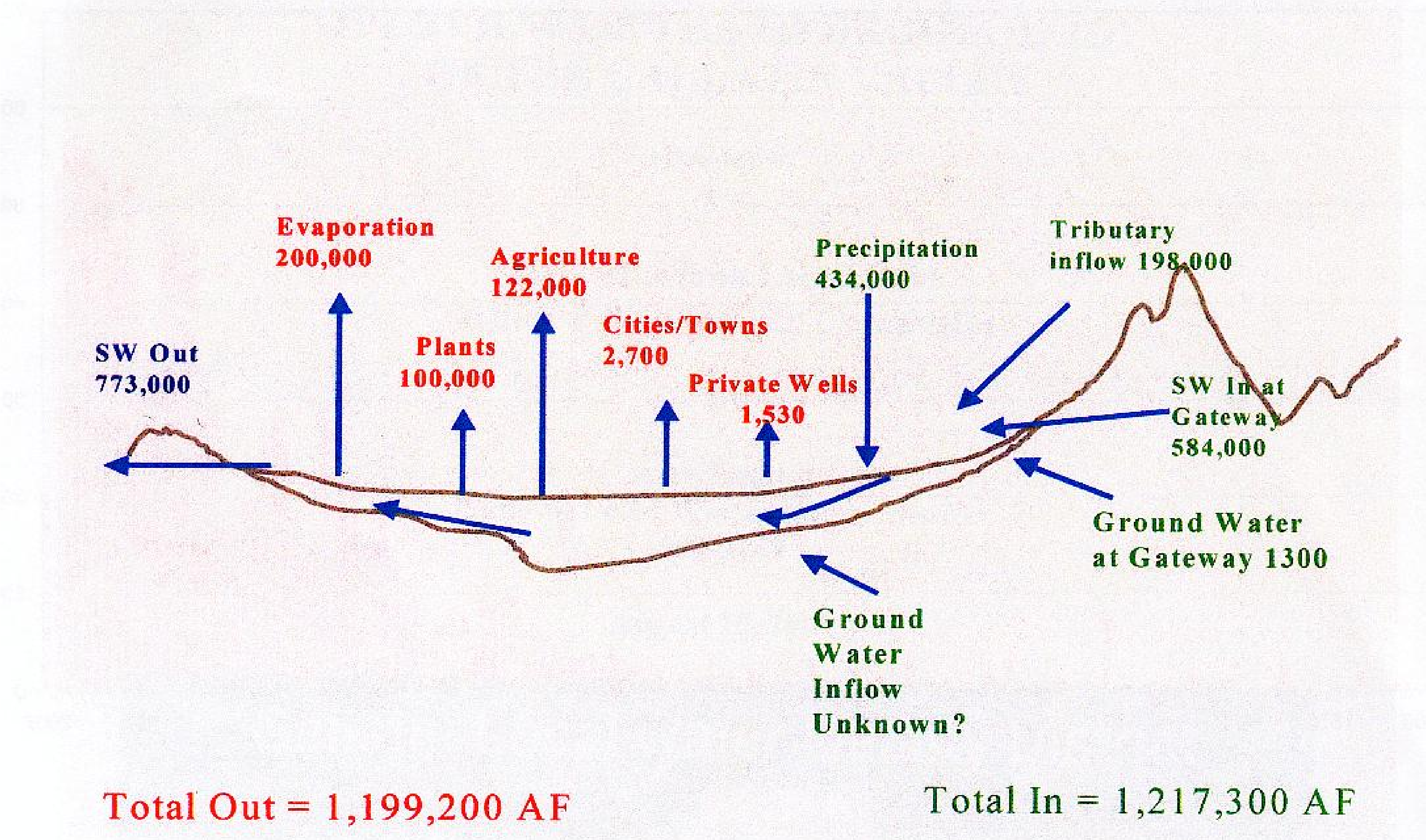


\# USGS 06052500 Gallatin River at Logan MT (period of record)
USGS 06043500 Gallatin River near Gallatin Gateway MT (period of record).
Other surface water defined on the basis of 1952 and 1953 interpretations by Hackett, et al (1960)
Precipitation based upon PRISM Interpretations. (see Figure 4).

* This value computed on the basis of the difference between other inputs and outputs. Storage changes over the period of record are assumed to equate to zero. Furthermore, ground-water contributions and losses at valley periphery are assumed to be small. This evaporation/evapotranspiration includes that due to natural factors and that associated with irrigation activity. This value equates to 1.50 feet or 18 inches per year valley wide.

Date: 01/02/07 c:\leg\gal\rep\fig_14 For Doney Law Firm	NICKLIN EARTH & WATER, INC.	Water Balance Average Year Gallatin Valley	Figure 14

Similar Estimate by English on Bozeman Field Trip



Difference between two independent basin estimates

- Precipitation (7%=31,000 ac ft)
- Main Gallatin (5%=29,000 ac ft)
- Tributaries (20% = 36,000 ac ft)
- Evapotranspiration (17% = 190,000 ac ft)

Consumptive use attempts to circumvent the problem of error

- An understandable and logical goal

Misses an important point

- Is it correct to conclude that consumptive use is the best approach?
  - The style of irrigation in a subdivision (sprinkler) may apply a different amount of water than flood irrigation in the previous agricultural setting.
  - These two approaches have different excess recharge.
    - Excess recharge = Water applied – Consumptive use

Irrigation Efficiency

- Water the plant used/water applied
  - Depends on the crop irrigated
  - Depends upon type of irrigation
  - Depends on irrigation practice
  - Depends on the soil irrigated
    - Loam
    - Gravel

Flood Irrigation

- 15-30% efficient

Sprinkler (Wheel Line)

- 65% efficient
- 12 h sets
- 4” in 12 hours
- 10-11 days between sets (depends on operator) can be as low as 48 hours between sets.

Sprinkler (Center Pivot)

- 85-90 % efficient
- 1.25 inches of water every fourth day
- Designed for crop need
- Little to ground water
- Little to Evaporation since head is low to ground (less wind drift)

House Irrigation (Sprinkler; Drip)
Some compute consumptive use is same as agricultural irrigation.
Is this true of recharge?

Ditch Loss

Not all ditches are created equal in terms of loss to the ground-water system.

Flint Creek (Kauffman, 1999)

- Advantage (no significant ground-water influx into the basin)
- There are control points where flux can be measured
- Return flow can be assessed
- Kauffman (1999) developed a basin model to explore return flow and pumping.
- Model based on data from Warren and Voeller (DNRC)

Net Recharge =
Water applied - Consumption

Kauffman, 1999

Land-use	Net recharge (in/season)
Sprinkler irrigation	0 - 8
Flood irrigation	13 - 21

Irrigation style does matter

Estimate of ground-water recharge from different irrigation types for Flint Creek Basin

Table 12. Net irrigation recharge based on consumptive use for Climatic Zone 5

Recharge Parameter	Sprinkler Grass	Sprinkler Alfalfa	Flood Grass	Flood Alfalfa
Net irrigation (in/season)[1]	19	19	32	32
Effective precipitation (in/season)[2]	5.11	3.74	5.11	3.74
Consumptive use (in/season)[2]	-15.83	-14.33	-15.83	-14.33
Net recharge (in/season)	8.28	8.41	21.28	21.41

Note: (1) derived earlier in thesis, (2) from Montana Irrigation Guide for Climatic Zone 5 in a normal year

Table 14. Net irrigation recharge based on consumptive use from sites similar to the Flint Creek valley **(Belgrade, Montana)**

Recharge Parameter	Sprinkler Grass	Sprinkler Alfalfa	Flood Grass	Flood Alfalfa
Net irrigation (in/season)[1]	19	19	32	32
Effective precipitation (in/season)[2]	5.11	3.74	5.11	3.74
Average consumptive use (in/season)[3]	-20.87	-22.71	-20.87	-22.71
Net recharge (in/season)	3.24	0.03	16.24	13.03

Note: (1) derived earlier in thesis, (2) from Montana Irrigation Guide, Climatic Zone 5 in a normal year, (3) from Table 13 above

Flint Creek Pumping Effects During Irrigation Season
200 gpm for 81 days (72 ac ft)

Kauffman, 1999

Distance From River (mi)	% from Storage	% from return flow to Flint Ck
0.25	54% (40 ac ft)	44% (32 ac ft)
0.5	81% (58 ac ft)	18% (14 ac ft)
0.75	89% (64 ac ft)	9% (8 ac ft)

Gains and Losses to Flint Creek During 1995 Irrigation Season

- Withdrawal from surface water for irrigation and used by evapotranspiration
  - 5000-8000 ac ft
- Stream gain from ground water return flow
  - 3079 ac ft
- 200 gpm withdrawal from alluvial well
  - 72 ac ft
  - (2% of ground-water return flow to creek)

Width of Alluvial Fill Has an Impact On Flint Creek

- Pumping well has larger effect on the river in a narrow alluvial fill zone than a wide alluvial fill zone
  - Holding pumping rate constant
  - Holding distance constant

Timing is important in the Flint Creek system Kauffman 1999 p. 127

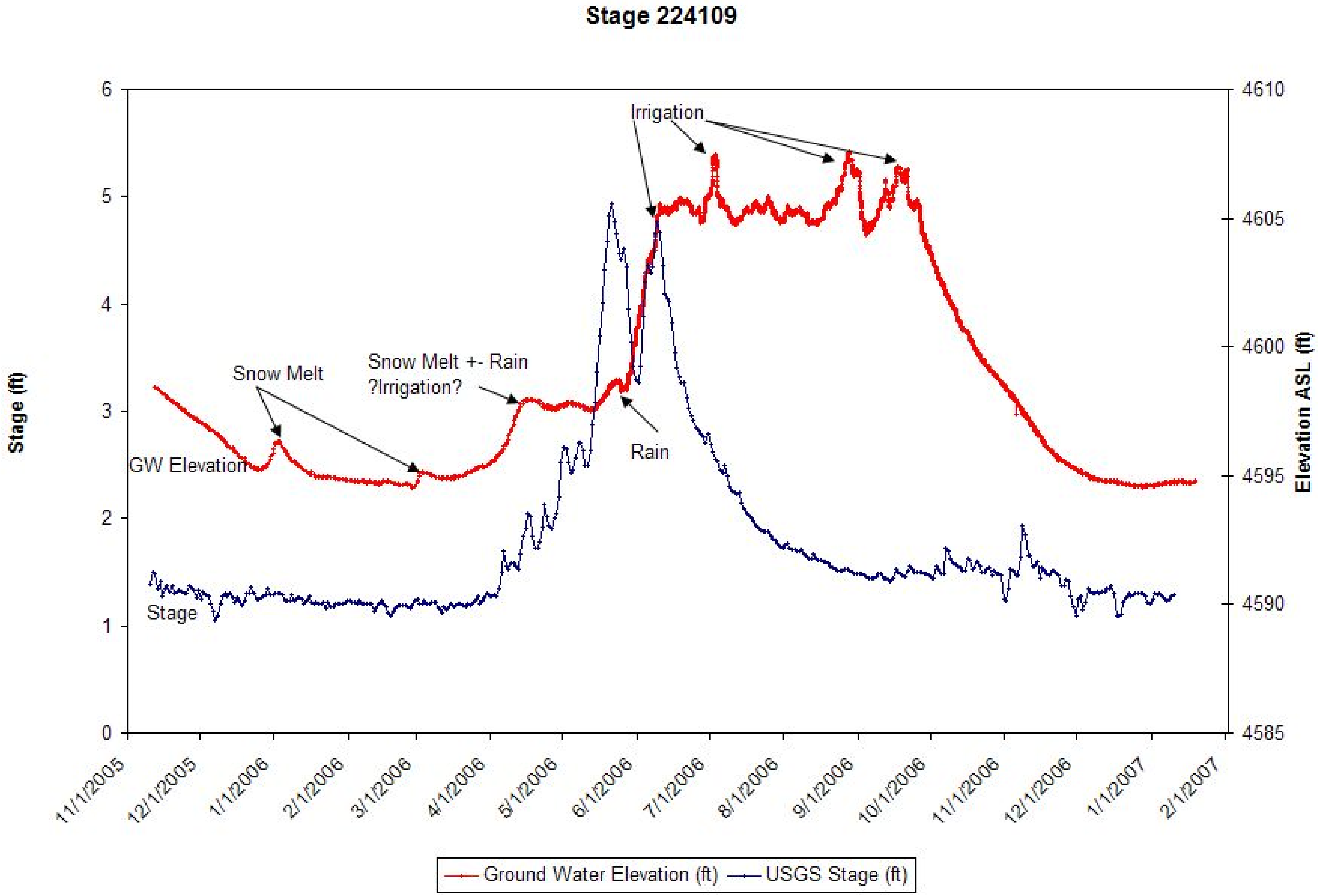
- Changing proximity of well to stream changes timing of return flow capture
- 0.75 and 0.5 mi from stream, well captures the peak amount of stream flow in the fall
- 0.25 mi from stream, well captures most stream flow during irrigation season
- Flint Creek flow is lowest in August
- A well drilled 0.25 mi from stream would have the greatest impact during the period of lowest flow

A question of scale and location.

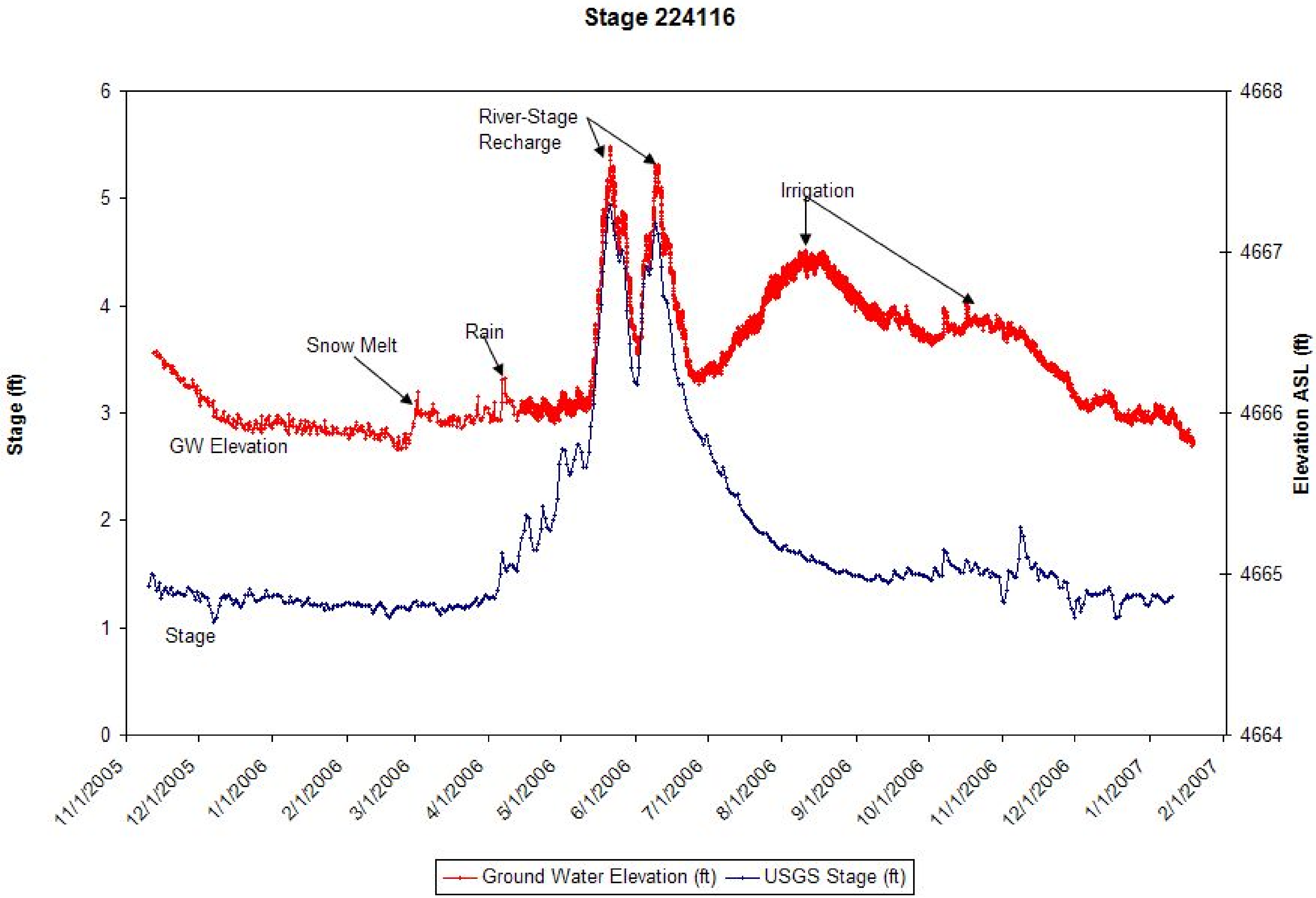
- Is it true that there is enough ground water at a basin scale? Yes
- Is it also true that near the river withdrawals can impact the river? Yes
- Is that impact significant?
  - Depends on pumping rate, aquifer properties, and number of wells
- Does irrigation style matter? (Yes)
- Does change in storage matter?
  - Some argue yes (less flow to river due to lower gradients).
  - Some argue no (Irrigation replenishes the system)
  - What happens if irrigation disappears? (presume recharge disappears)

Irrigation response in Gallatin Valley

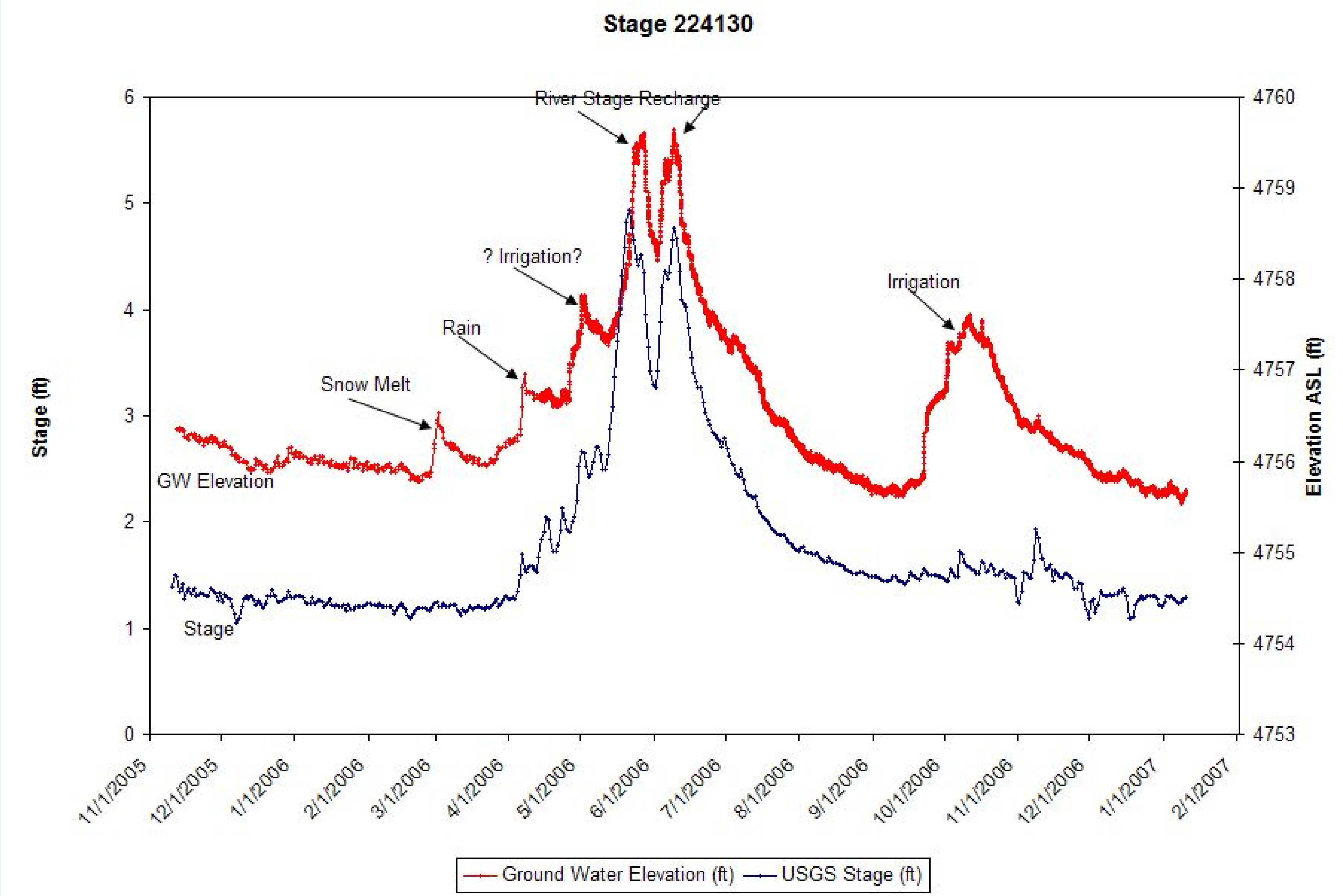
Irrigation No River Signal



River and Delayed Irrigation



River and Delayed Irrigation



River Dominated

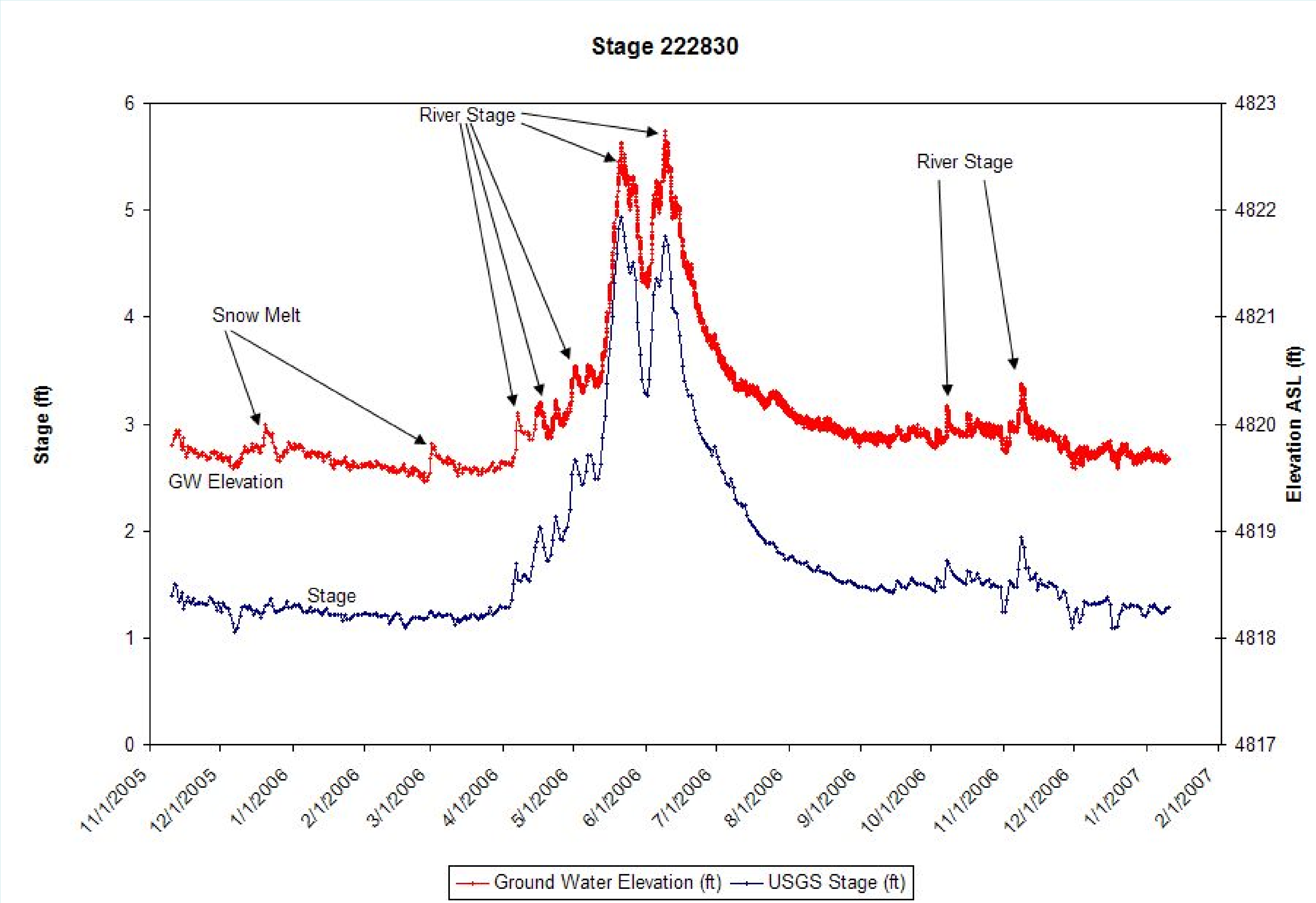


Table 22. Acceptable range, initial estimate and calibrated values of parameters assigned in the model

Parameter	Description	Acceptable Range[1]	Initial Estimate	Calibrated Value
T (gpd/ft)	Quaternary Alluvium - Lower Willow Creek	200 – 86,100	5,000	10,500
T (gpd/ft)	Quaternary Alluvium - Flint Creek, northeast			19,400
T (gpd/ft)	Quaternary Alluvium - Flint Creek, southwest		-	29,900
T (gpd/ft)	QT(?) gravel cap	9,700 - 36,600	15,000	15,000
T (gpd/ft)	QT(?) gravel cap - north end of west bench		-	1,500
T (gpd/ft)	Tertiary clay	$4x10^{-5} – 4x10^{3}$	2	11
T (gpd/ft)	Tertiary deep aquifer	30 - 17,400	60	300
S_y (dimensionless)	Quaternary Alluvium - Lower Willow Creek	0.004 - 0.46	0.02	0.1
S_y (dimensionless)	Quaternary Alluvium - Flint Creek, northeast			0.1
S_y (dimensionless)	Quaternary Alluvium - Flint Creek, southwest		-	0.2
S_y (dimensionless)	QT(?) gravel cap	0.13 - 0.44	0.1	0.1
S_y (dimensionless)	QT(?) gravel cap - north end of west bench		-	0.1
S_s (ft^{-1})	Tertiary clay	$6x10^{-4} – 6x10^{-3}$	$7x10^{-4}$	$7x10^{-6}$
S_s (ft^{-1})	Tertiary deep aquifer	$1x10^{-6} – 3x10^{-4}$	$3x10^{-6}$	$5x10^{-6}$
R (in/season)	Sprinkler	0 - 8	5	8
R (in/season)	Flood	13 - 21	20	18
R (in/season)	Unirrigated - Riparian and dry pastures		0	1

Note: T=transmissivity, S_y=specific yield, S_s=specific storage, R=recharge; (1) transmissivity values are from Table 6, Specific yield and specific storage values are from Table 11, and recharge values are from Table 15 in this thesis

Estimate of ground-water recharge from different irrigation types Flint Creek using Gallatin Valley Data

Kauffman (1999) assumed 24 inches of water applied for a center pivot with Q=1000 gpm; 12 weeks, 5 days/week, 24 h/d, 130 acres; 20% loss to evaporation before ET begins.

Flood irrigation estimated based on an application of 12,500 ac-ft or approximately 54 inches, evaporative and leakage losses in ditches of 40%.