Conservation of surface and ground water in a Western watershed experiencing rapid loss of irrigated agricultural land to development

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Outline

- USDA-funded project description
- Basin description
- Water supply calculation methods and results
- Canal system water budget methods and results
- Basin water budget
- Plans for USDA project's final year
- Desired future work

APOLOGY AHEAD OF TIME FOR NOMENCLATURE INCONCISTENCIES: I generally use "local" usage, e.g., "Henry's" instead of "Henrys", "Henry's Lake Outlet" instead of "Henrys Fork below Henrys Lake", "Fall River" instead of "Falls River". See Van Kirk and Benjamin, 2000, Intermountain J. Sci.

USDA Project

- Cooperative State Research, Extension and Education Grant
- $620,000
- Project time span: Calendar years 2009-2011

Objectives

1. Model ground and surface water flow under historic, current and future land and water use scenarios
2. Identify socioeconomic factors that determine water use on formerly irrigated land that has been developed and on irrigated land in proximity to development
3. Provide information on hydrology and water use to decision-makers and stakeholders
4. Develop strategies to increase water availability for agriculture while enhancing ecological benefits in key stream reaches
5. Train an interdisciplinary team of graduate students

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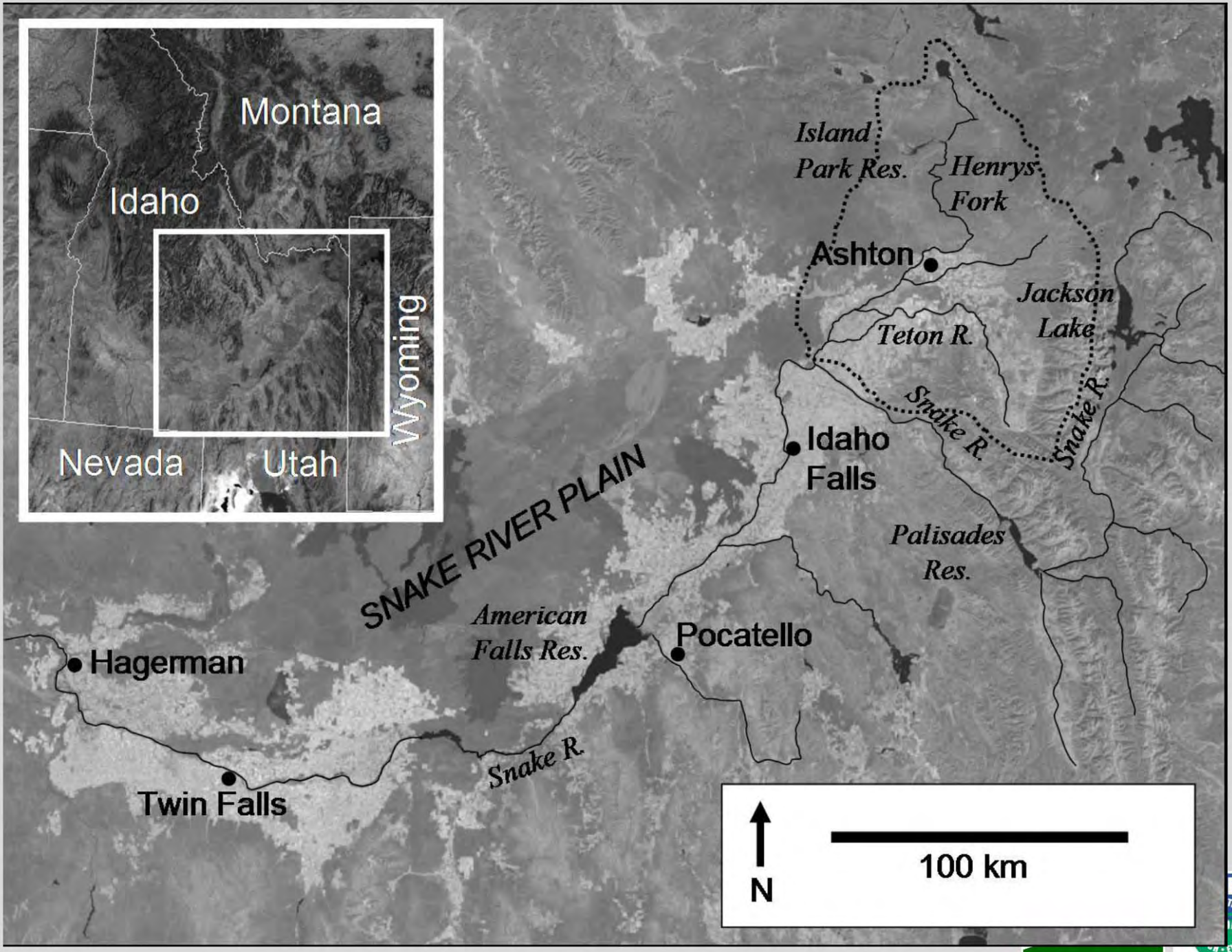
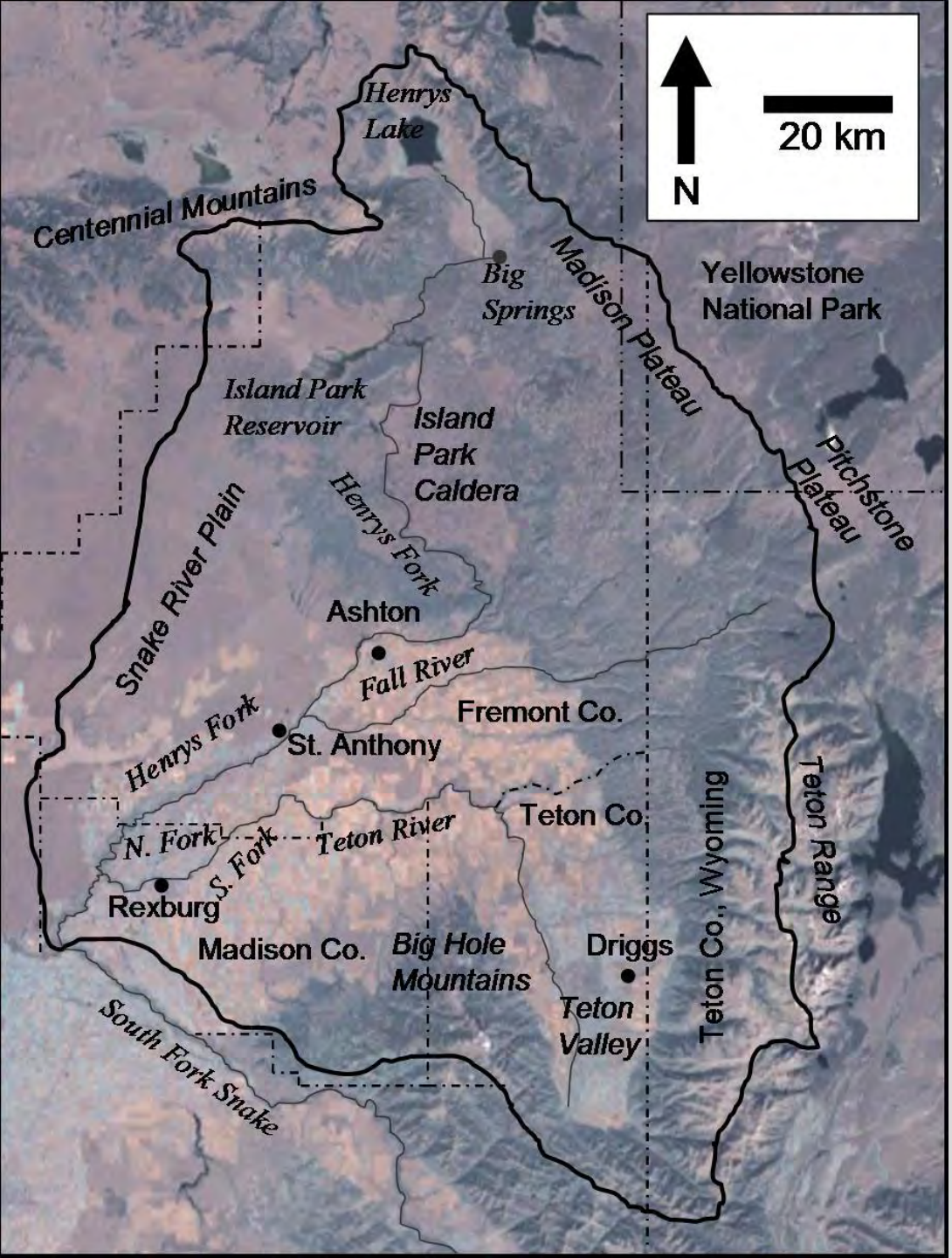
http://www.humboldt.edu/henrysfork/

USDA

CSREES EDUCATION USDA RESEARCH • EXTENSION


Montana
Idaho
Wyoming
Nevada
Utah
Island Park Res.
Henrys Fork
Ashton
Jackson Lake
Teton R.
Snake R.
Snake R.
Idaho Falls
SNAKE RIVER PLAIN
Palisades Res.
American Falls Res.
Pocatello
Hagerman
Snake R.
Twin Falls
N
100 km



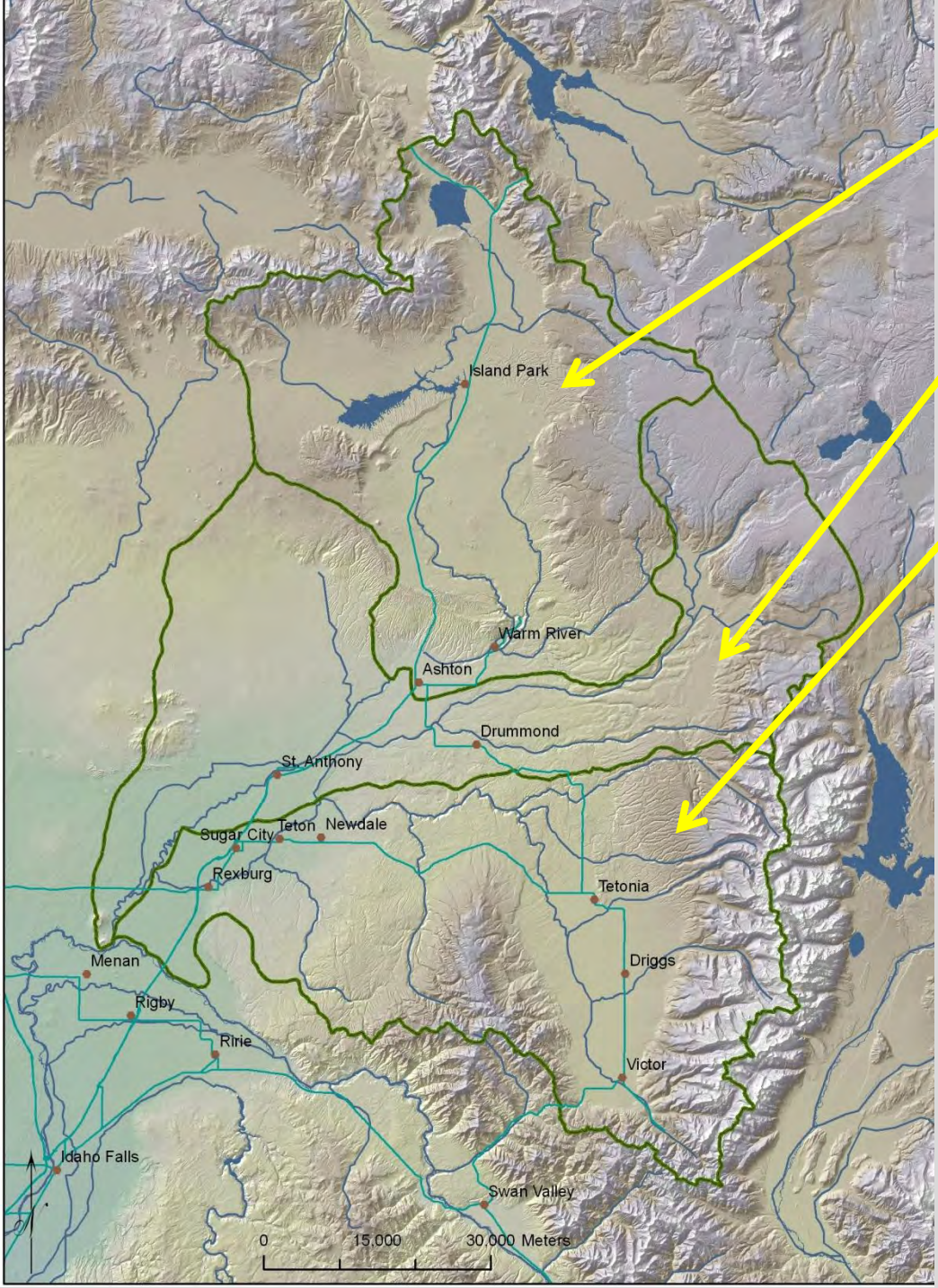
- Area: 3,250 sq. mi
- Mean ann. precip.: 28.2 inches
- Min. elevation: 4,820 ft.
- Max. elevation: 11,400 ft.
- Forested area: 36.7%
- Agricultural land: 20.9%
- Water & perennial snow: 1.89%
- Urban land cover: 1.5%

Source: StreamStats
http://streamstats.usgs.gov

<u>Storage Reservoirs</u>

- Henrys Lake*: 90,000 a-f
- Island Park Res.: 135,000 a-f
- Grassy Lake: 15,000 a-f

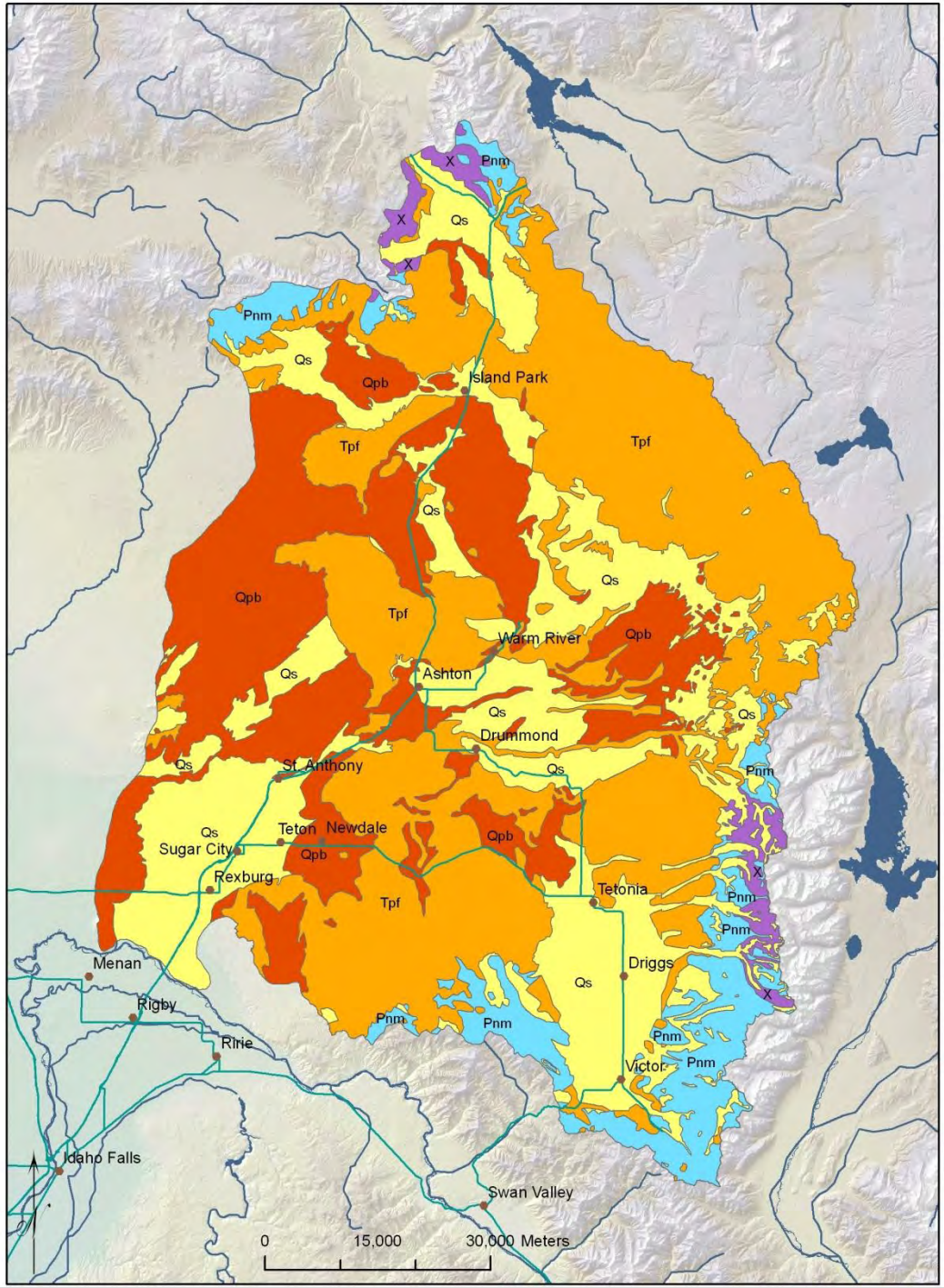
*Original, natural lake held about 25,000 a-f



Hydrologic Units

- Upper Henrys 17040202
  - -HF above Ashton
- Lower Henrys 17040203
  - -Fall River and lower HF
- Teton 17040204
  - -Teton River watershed

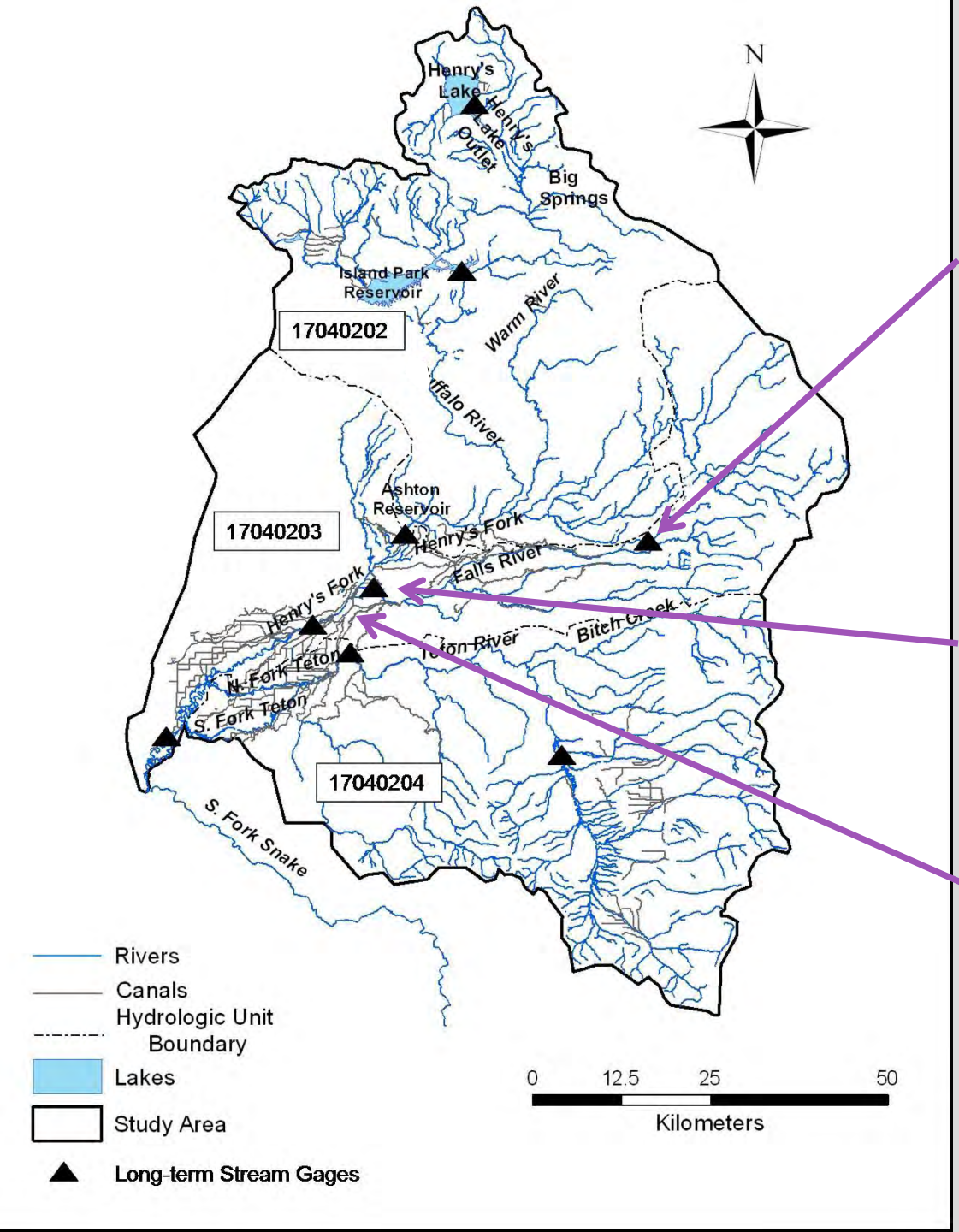
Map produced by Digital Mapping Laboratory, Dept. of Geosciences, Idaho State University



Surface lithology

- Precambrian
- Paleozoic and Mesozoic sedimentary
- Cenozoic silicic volcanics from Yellowstone hotspot explosive eruptions
- Quaternary basalts
- Quaternary alluvium and glacial drift

Source: Bayrd 2006 M.S. Thesis, Idaho State University



Long-term USGS Flow Gages

-Henrys Fk. nr. Lake 13039500

-HF nr. Island Park 13042500

-HF nr. Ashton 13046000

-Falls River nr. Squirrel 13047500
(between Marysville hydroelectric diversion and return since August 1993; two new gages added in WY 1994; USE CAUTION with FR flow and IDWR accounting!)

-Falls R. nr. Chester 13049500

-HF at St. Anthony 13050500

-Teton R ab S Leigh Cr. 13052200

-Teton R. ab. St. Anth. 13055000
(immediately downstream of Crosscut canal delivery; INTERPRET CAREFULLY!)

-HF nr. Rexburg 13056500

(Surface) Water Supply Calculation Methods

- Water years 1979 – 2008 used in analysis
- Surface supply defined as natural flow at:
  - HF nr. Ashton (all contributions from upper Henry's Fork)
  - Fall River nr. Chester (all contributions from Fall River watershed)
  - Teton River at. St. Anthony (all contributions from Teton above that point)
- Natural inflow not captured at these locations:
  - Sand Creek on west side of HF below Ashton: ≈ 6,000 a-f/year
  - Moody Creek on south side of Teton R. ab. Rexburg: ≈ 15,000 a-f/year
  - Most of the supply of these streams is diverted before reaching river
- Natural flow defined as:

  Regulated flow + Δstorage +res. evap. + diversion– return (surf. and ground)
- IDWR accounting travel times used
- Moving averages used to smooth resulting calculations (7-day in most cases, but Henry's Lake required more sophisticated moving-window averaging)
- Data: IDWR (diversion), USGS (streamflow), USBR (reservoir contents)
- Evaporation rates from ET Idaho (Allen et al.) applied to reservoir surface area (difference between modern and natural Henry's Lake)

Comments

- Electronic diversion data available from IDWR only since 1978
- 30-year period in post-1977 climatic regime (since last major PDO shift)
- Minimal interaction with ESPA aquifer above selected gage points
- Irrigation return flow reasonably well constrained in Teton Valley and nr. Ashton

- Some water supply calculation components were outputs of canal budget model

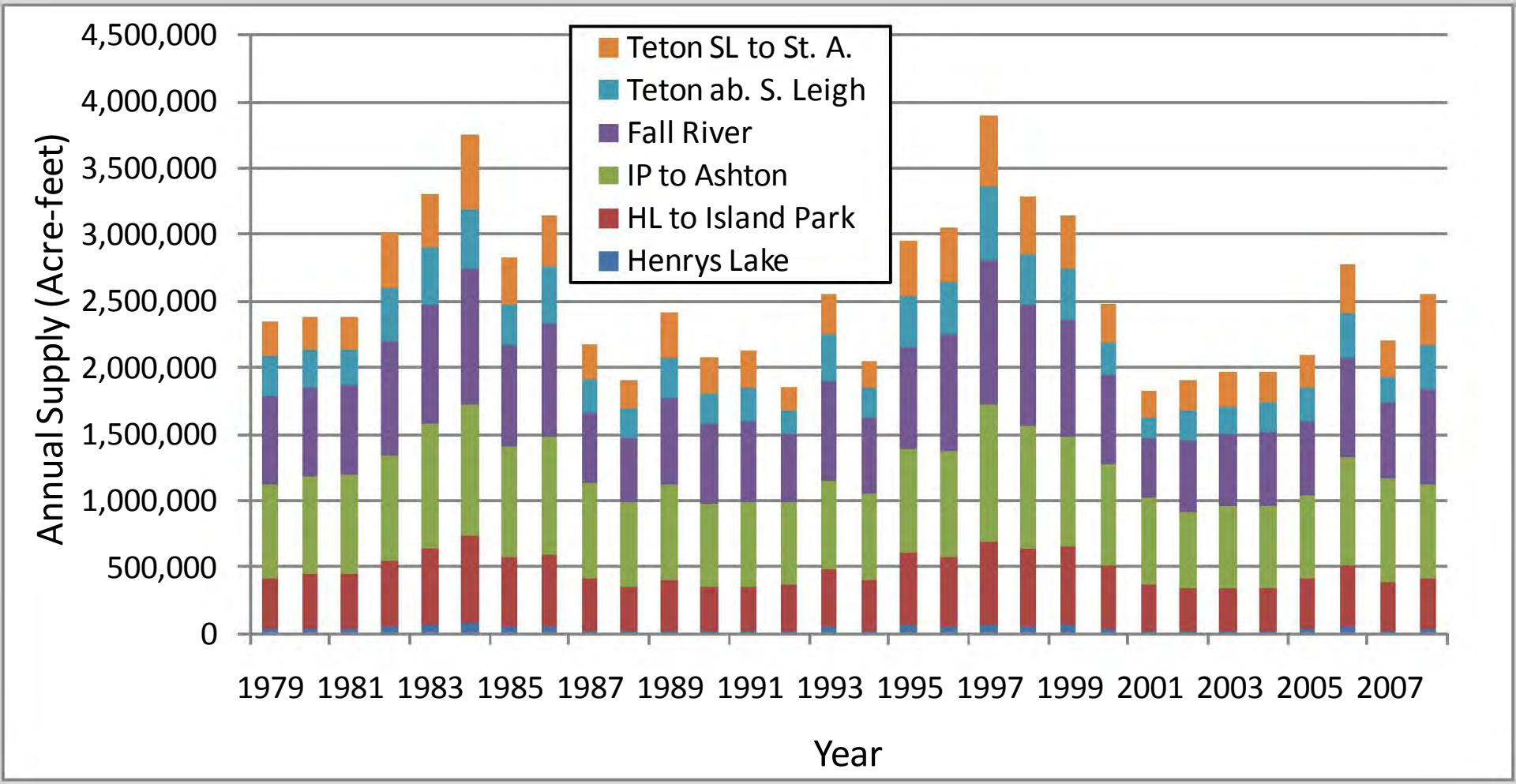
- Most of natural surface flow in HF above Ashton and some of natural flow in FR originates from GW springs at the base of rhyolite flows in the SW part of Yellowstone National Park.
- This GW is all forced to surface upstream of gage points and therefore constitutes surface supply, not GW supply.

- My use of “natural flow” terminology is consistent with IDWR and USBR use, although my calculations are smoothed. This term does not imply valuation of natural flow vs. regulated flow nor that any natural flow regime components be “restored” or maintained.

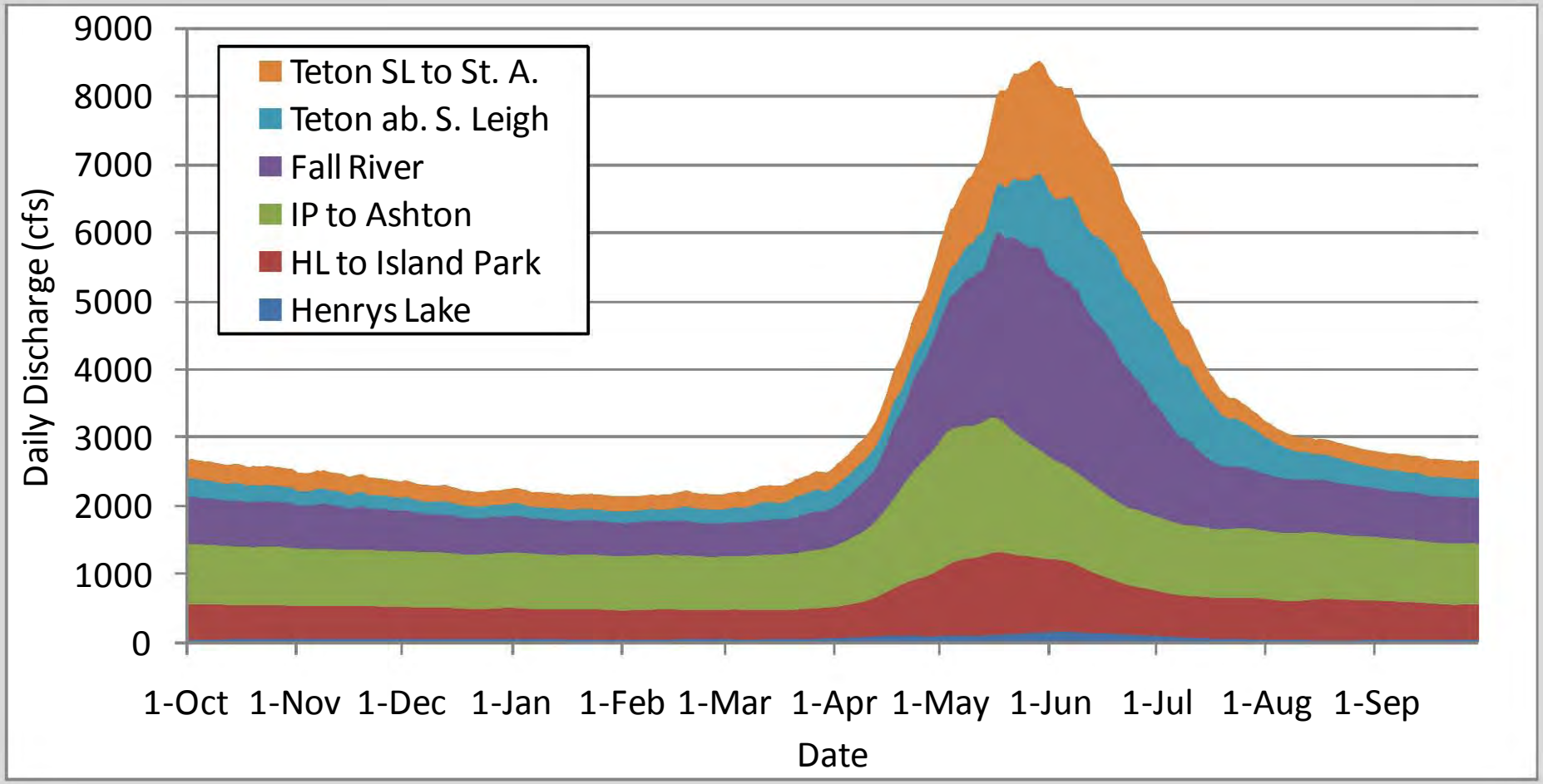
Water Supply Summary

Source	30-year mean annual natural flow (a-f)	% of TOTAL
Henry's Lake	41,768	1.6%
HL to Island Park	439,072	17.3%
Island Park to Ashton	744,516	29.3%
UPPER HF TOTAL	**1,225,356**	**48.2%**
FALL RIVER TOTAL	**699,914**	**27.5%**
Teton ab. S. Leigh	304,084	12.0%
Teton S. Leigh to St. Anth.	314,779	12.4%
TETON RIVER TOTAL	**618,863**	**24.3%**
TOTAL	2,544,133	100.0%

Water Supply by Year

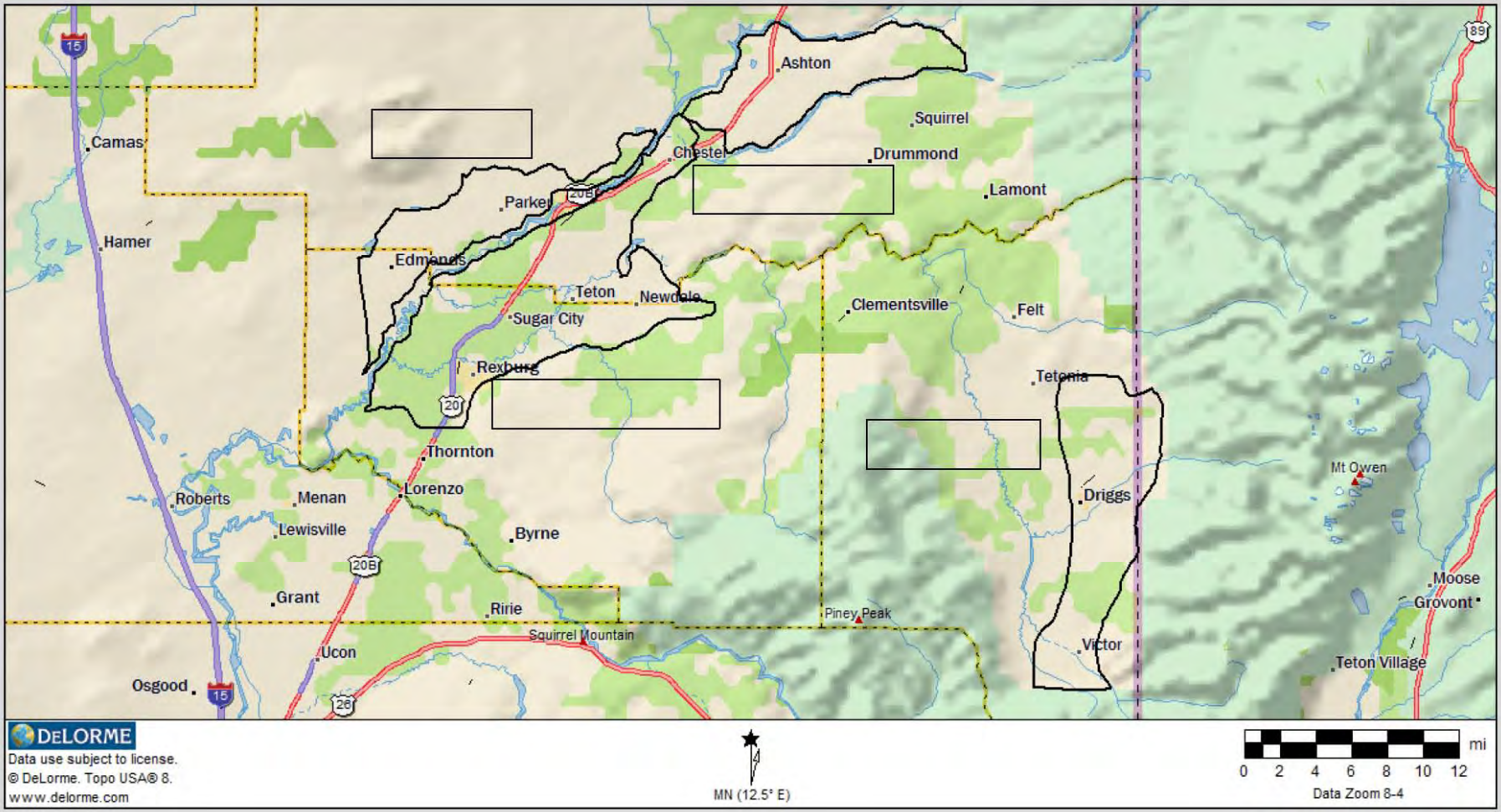


30-year Mean Water Supply Hydrograph



Canal System Water Budget Methods

- Canal system supplies majority of irrigation water to four regions



Summary of the four canal-irrigated regions

Region	Irr. Area acres	Can. Lngth. miles	Diversion acre-ft	Notes
Egin Bench	30,500	111	368,351	Includes Dewey Canal
Lower Watershed	73,000	222	641,724	Includes Crosscut
North Fremont	32,500	51	41,681	North of Fall R.
Teton Valley	45,000	80	81,161	East of Teton R.
TOTAL	181,000	463	1,132,917	

- Gross area measured on topographic maps and Google Earth images
- Areas of water bodies, towns, and large non-irrigated areas removed from total
- Areas of roads, buildings, fallow ground, etc., NOT removed

Comments

- Irrigated areas not included in this analysis
  - Pasture irrigation in Island Park (mostly in Shotgun Valley, H.L. Flat)
  - Area west of HF near Ashton but north of Fall River
  - Area south of Fall River and north of Bitch Cr./Teton Canyon
    - -Much dry farming
    - -Some GW irrigation
    - -Most historic canal systems (Squirrel/Conant cr.) now in pipelines
    - -Direct pumping from Teton River included in water supply calculations
  - Teton Valley west of river (Bighole R. tribs)
  - Rexburg Bench/South of Teton Canyon
    - -Much dry farming
    - -Some GW irrigation
    - -Direct pumping from Teton River included in water supply calculations
- Rough estimates from these areas included in water budget
  - 240,000 acres
  - 70,000 acre-feet of surface water diverted (compare with 1.13 million)

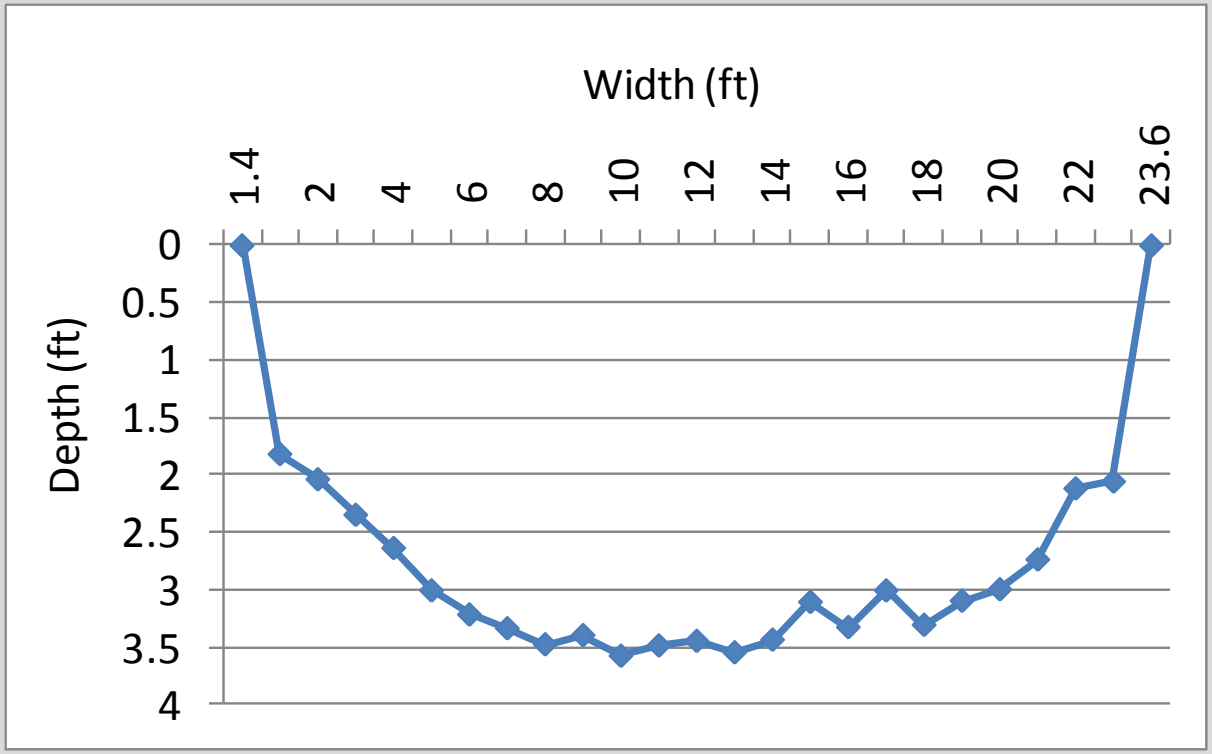
Basic Methodology

- Estimate mean seepage rates and other parameters from field measurements
- Divide canal systems into reaches (branches; 42 canal systems, > 300 branches)
- Measure canal branch lengths and widths and vegetation on Google Earth
- Use daily diversion data from IDWR (except in Teton Valley; interpolated weekly measurements to estimate daily diversion)
- Canal flow components:
    1. Total loss (seepage rate x wetted perimeter x length)
    2. Evaporation from canal surface (using ET rates from ET Idaho)
    3. ET from canal-side vegetation
    4. GW recharge = total loss – evaporation – ET
    5. Return flow to streams via surface
    6. Outflow to other canals (added to diversion in receiving canals)
    7. Delivery = diversion – loss – return flow – outflow
    8. Applied to crop ET = minimum of delivery or crop ET
    9. “Delivery in excess of crop ET” is remainder, if any

Measuring canal loss and geometry…

…a difficult task!

Canal and Stream Channel Gain/Loss Estimation



- Measure discharge at top and bottom of reach
- Measure wetted perimeter (e.g., 26.4 feet for this canal)
- Measure length of reach from map
- Total wetted area = length × average wetted perimeter
- Gain or loss rate = $(Q_{bottom} - Q_{top})$/wetted area
- Loss expressed in $ft^3/day/ft^2$ (or ft/day)

Canal and Stream Channel Loss Statistics

Based on all usable observations made in 2009, made in a pilot study in 2005, and obtained from IDWR records

	n	Mean loss (ft/day)	95% Confidence interval
Canals in Ashton/St. Anthony/Rexburg area	19	2.66	(1.73,3.59)
Streams on Teton Range alluvial fans	50	3.40	(2.83,3.97)
Canals on Teton Range alluvial fans	10	3.66	(2.38,4.94)

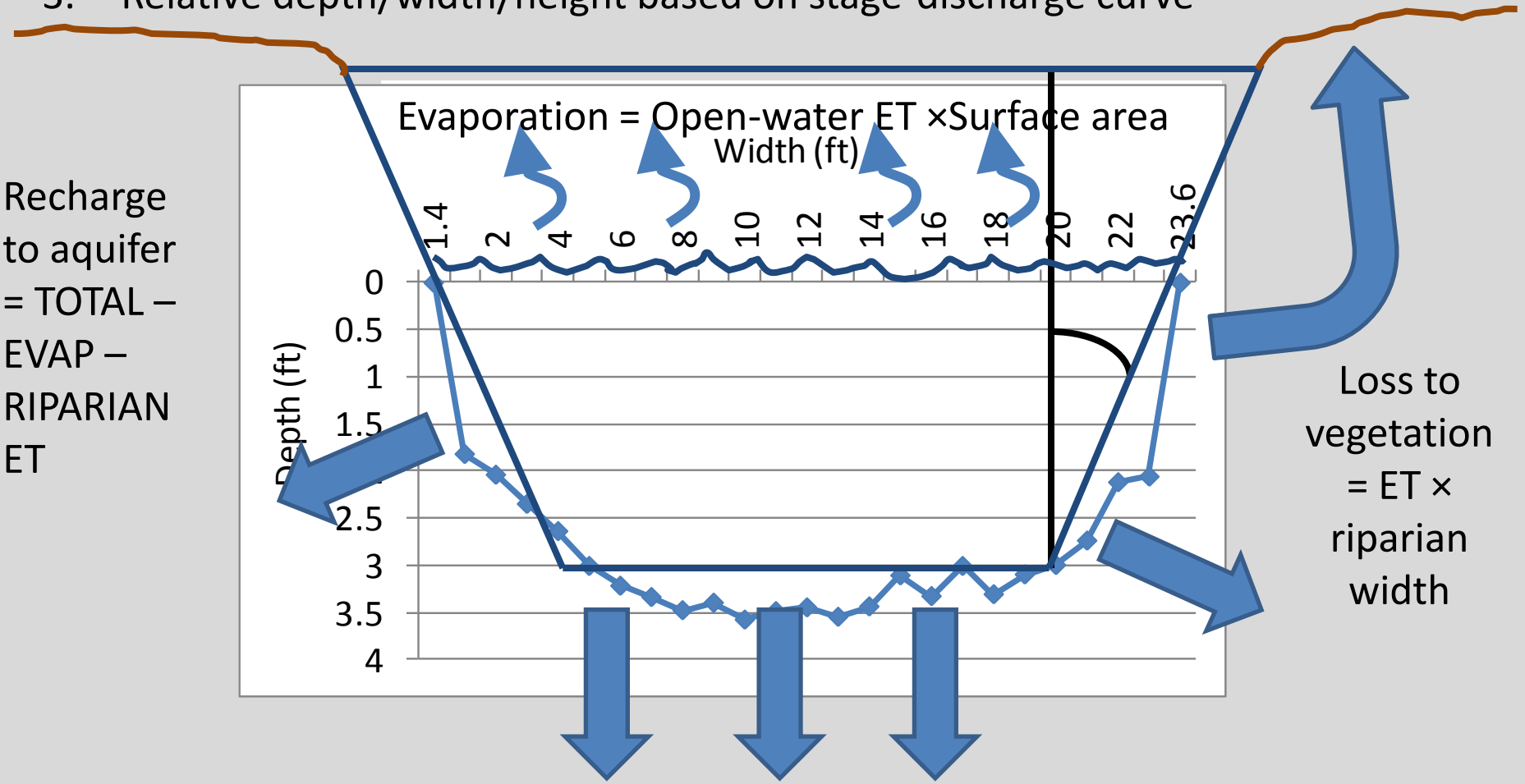
University of Idaho estimates for Rigby Fan, made in 1970s

Range: 2-3.5

Mean used in Wytzes' ground-water model: 2.5

Canal Loss Model

1. Calculate wetted perimeter and water surface area from geometry and flow
2. Canal shape assumed constant throughout system
3. Relative depth/width/height based on stage-discharge curve



Measuring canal parameters from satellite images

Widths measured on images corrected by statistical relationship fit to data collected at random sample of locations in field area.

Crop ET Calculations

- Mean crop mix estimated from data reported by National Agricultural Statistics Service (some data back to 1979, most based on data since 1997)

	BY COUNTY (as reported)			BY IRRIGATED AREA (estimated)			
	FREMONT	MADISON	TETON	N Fremont	Egin Bench	Lower	Teton Valley
Alfalfa	7%	9%	12%	10%	10%	10%	25%
Grain	35%	38%	32%	50%	50%	35%	45%
Potatoes	16%	19%	18%	25%	30%	20%	5%
Pasture/Other	42%	34%	39%	15%	10%	35%	25%

- Crop distribution applied to total area in each irrigated region
- Daily actual ET rates obtained from ET Idaho and applied to area within each crop type
- Actual ET assumes full irrigation and so overestimates actual ET in areas where full irrigation is not available
- Total ET demand not very sensitive to crop types: alfalfa (1 to 3 cuttings/yr), grain, and pasture/other are all very similar in demand

Notes

•As many parameters as possible estimated from hard data, including as much as we could learn from canal systems to which we had permission to access
•Map, GIS, and Google Earth measurements verified as much as possible from small aircraft flights, driving county roads, and floating the river in a drift boat
•Some minor adjustments of IDWR diversion and flow data required to account for travel times, major headgate adjustments, large river stage fluctuations, etc.
•Personal knowledge of region used when appropriate

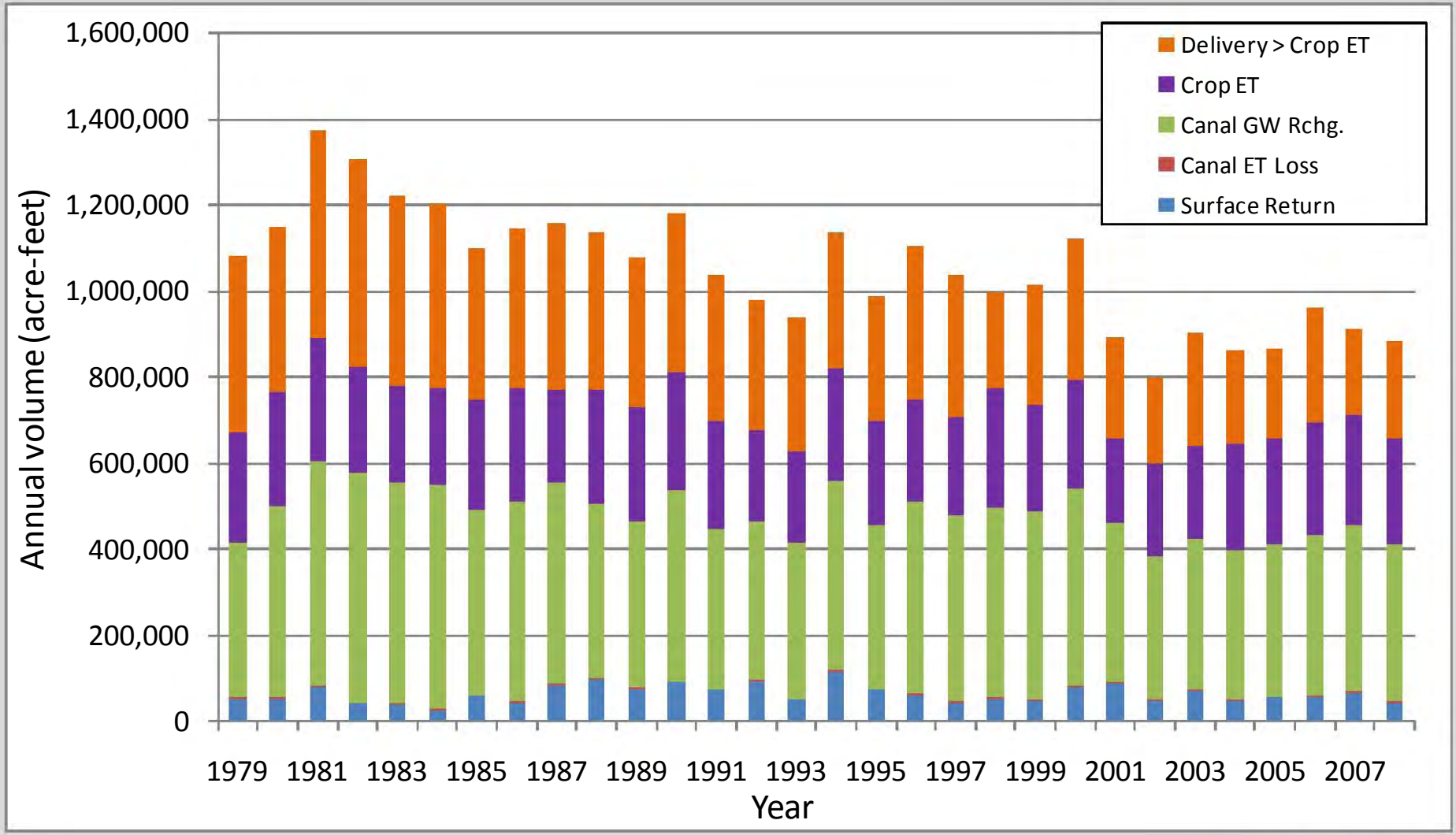
Canal Water Budget Summary

Region	Irr. Area acres	Diversion acre-ft	Surf. Return acre-ft	Canal ET acre-ft	Can. Seep. acre-ft	Delivery acre-ft
Egin Bench	30,500	368,351	11,588	1,298	176,232	179,235
Lower Watershed	73,000	641,724	53,007	1,705	218,322	368,689
North Fremont	32,500	41,681	575	261	22,578	18,268
Teton Valley	45,000	81,161	0	384	37,001	43,776
TOTAL	181,000	1,132,917	65,169	3,649	454,132	609,968
Fraction of diversion		100.0%	5.8%	0.3%	40.1%	53.8%

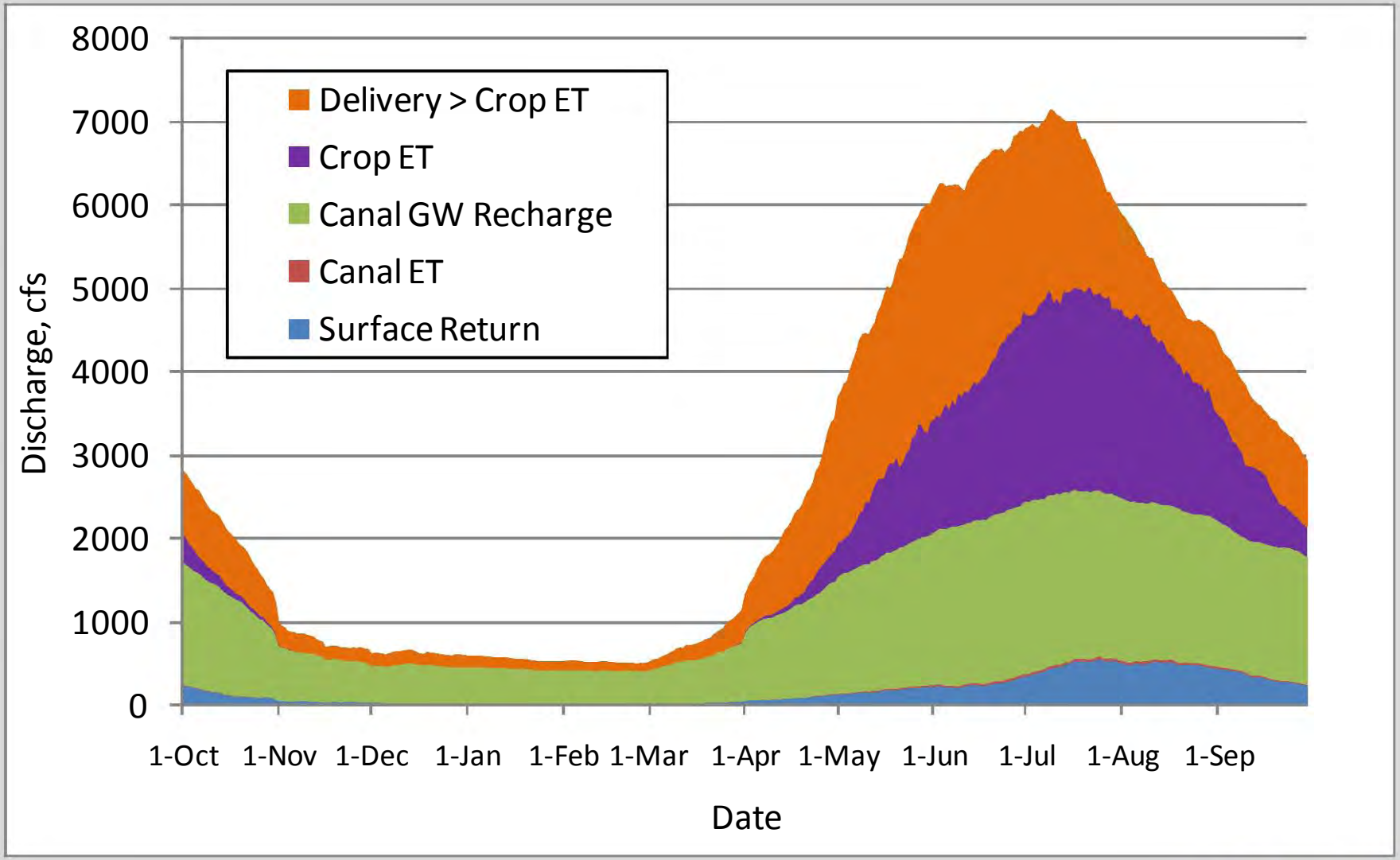
Canal Delivery and Crop ET

Region	Irr. Area acres	Crop Demand acre-ft	Applied ET acre-ft	Delivery > ET acre-ft	% Demand met by irr.	App. ET ft
Egin Bench	30,500	68,670	68,120	111,115	99.2%	2.23
Lower Watershed	73,000	163,123	158,053	210,636	96.9%	2.17
North Fremont	32,500	76,267	17,938	330	23.5%	0.55
Teton Valley	45,000	106,596	39,222	4,554	36.8%	0.87
TOTAL	181,000	414,657	283,333	326,635	86.7%	1.57
Fraction of delivery			46.5%	53.5%		

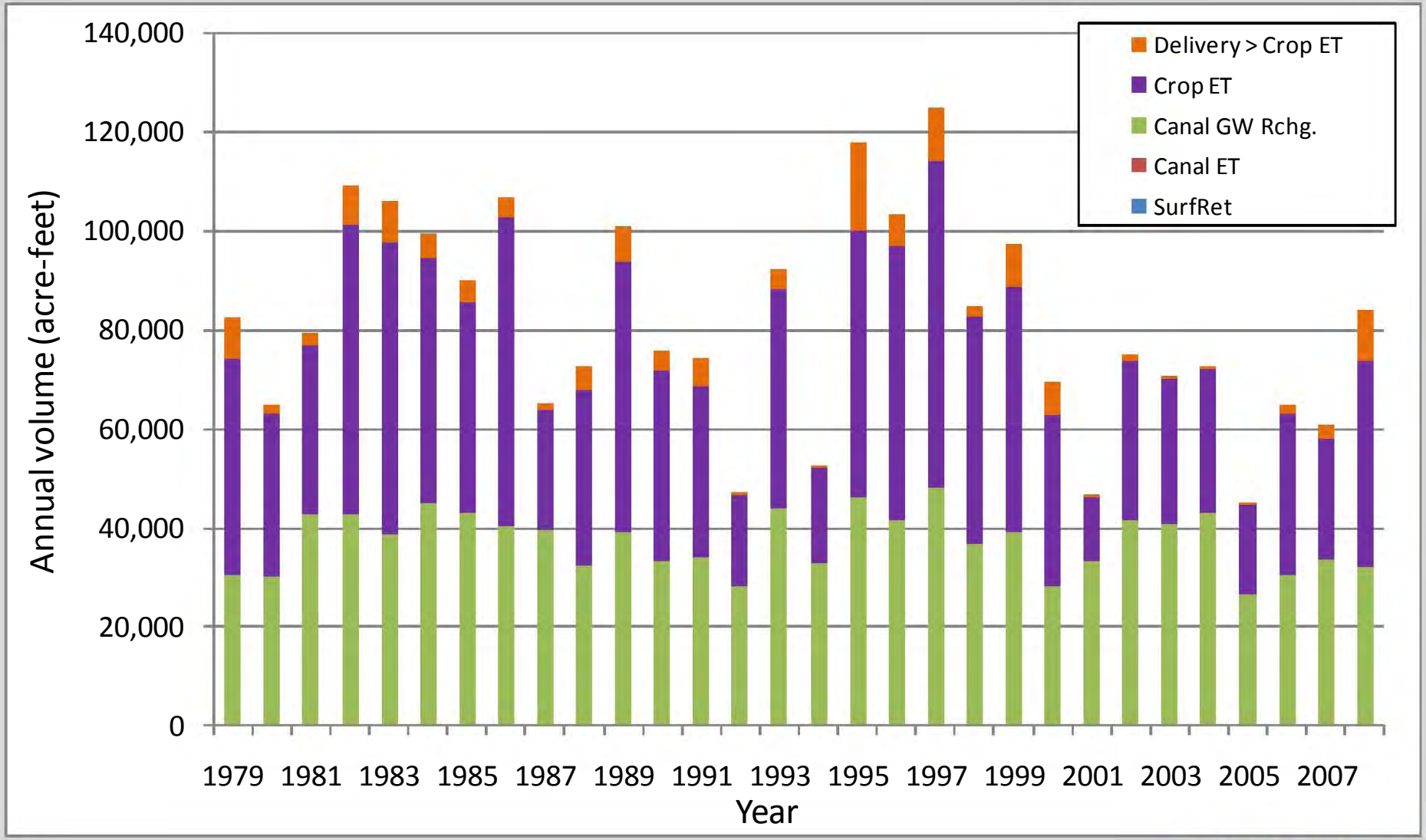
Canal Budget by Year—all but Teton Valley



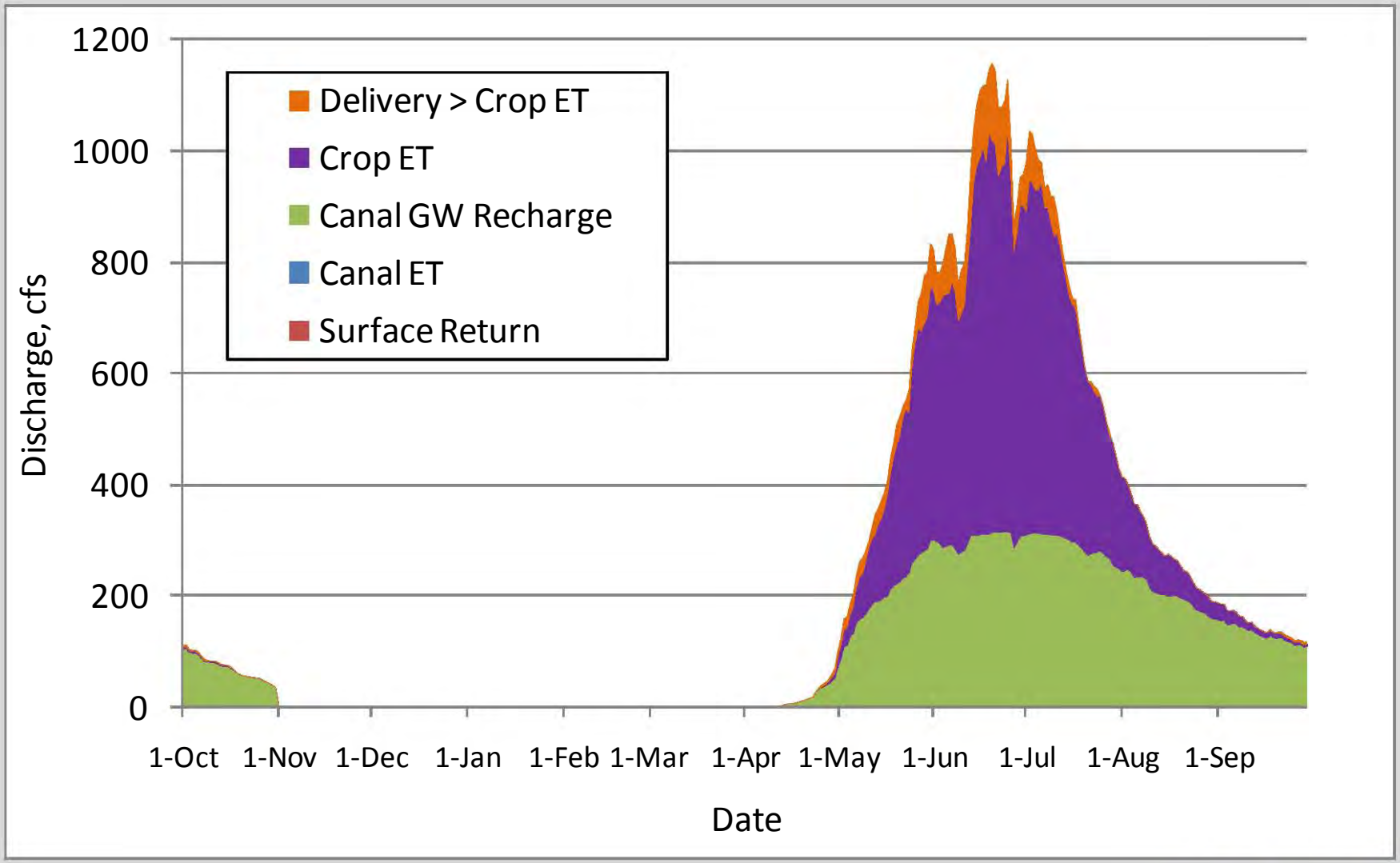
30-year Mean Canal Hydrograph—all but TV



Canal Budget by Year—Teton Valley



30-year Mean Canal Hydrograph—Teton Valley

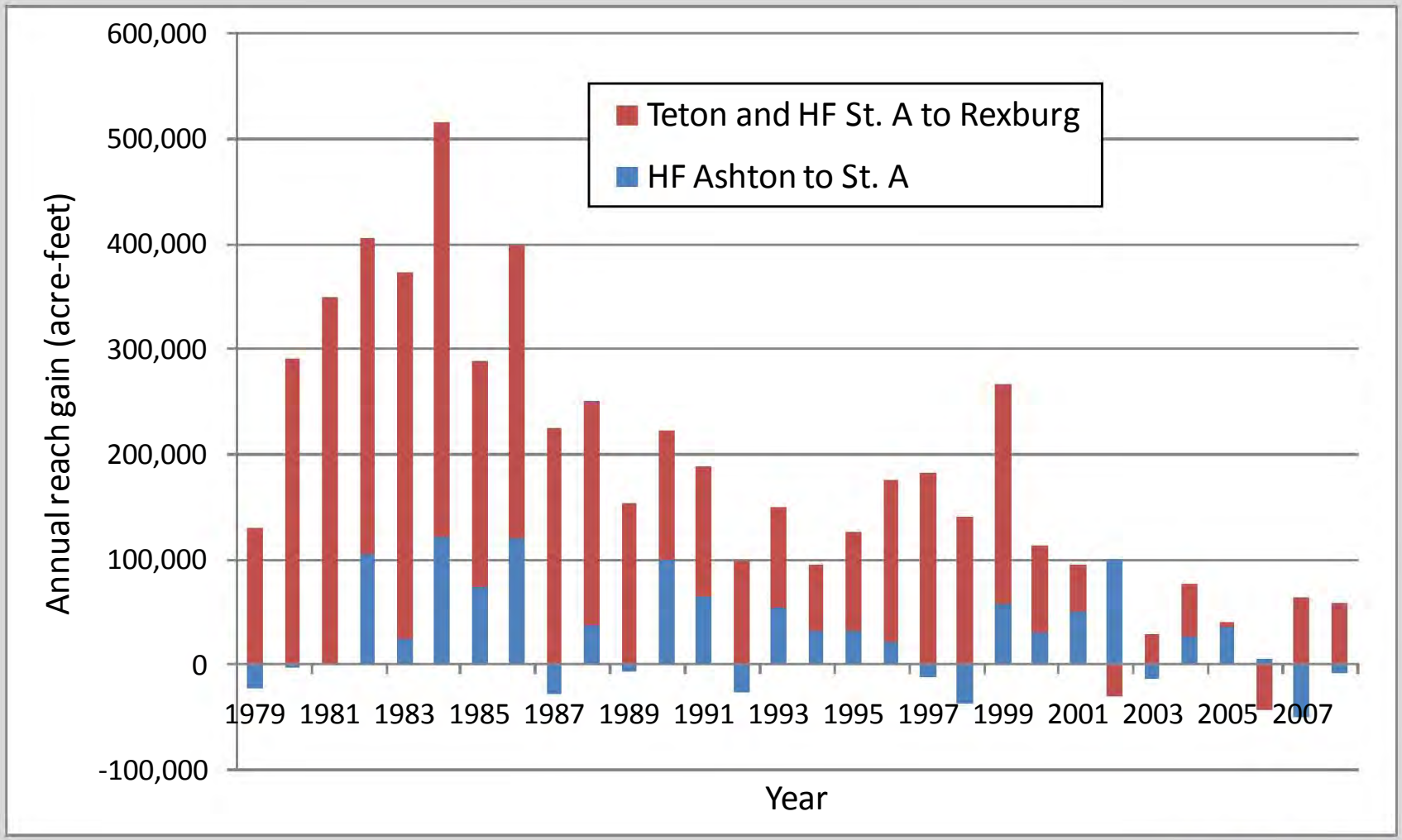


Basin Water Budget (mean annual)

- Total supply as precipitation = basin area x mean basin precipitation
- Total supply – surface supply = loss to non-irrigated ET and deep GW
- Return of irrigation recharge to surface water within basin:
  - Teton Valley: 41,000 a-f (100%, timing estimated from earlier modeling, see Van Kirk and Jenkins, 2005, report to Friends of Teton River)
  - North Fremont: 20,000 a-f (90%, timing based on flow in Black Spring near Ashton, measured by IDWR 2003-2004
  - Lower Watershed Canals: about 169,000 a-f (43%) based on reach gains
  - Detailed models yet to be completed for GW return
- Difference between surface outflow at Rexburg and known components of water budget are lost to ET or exported from basin as GW

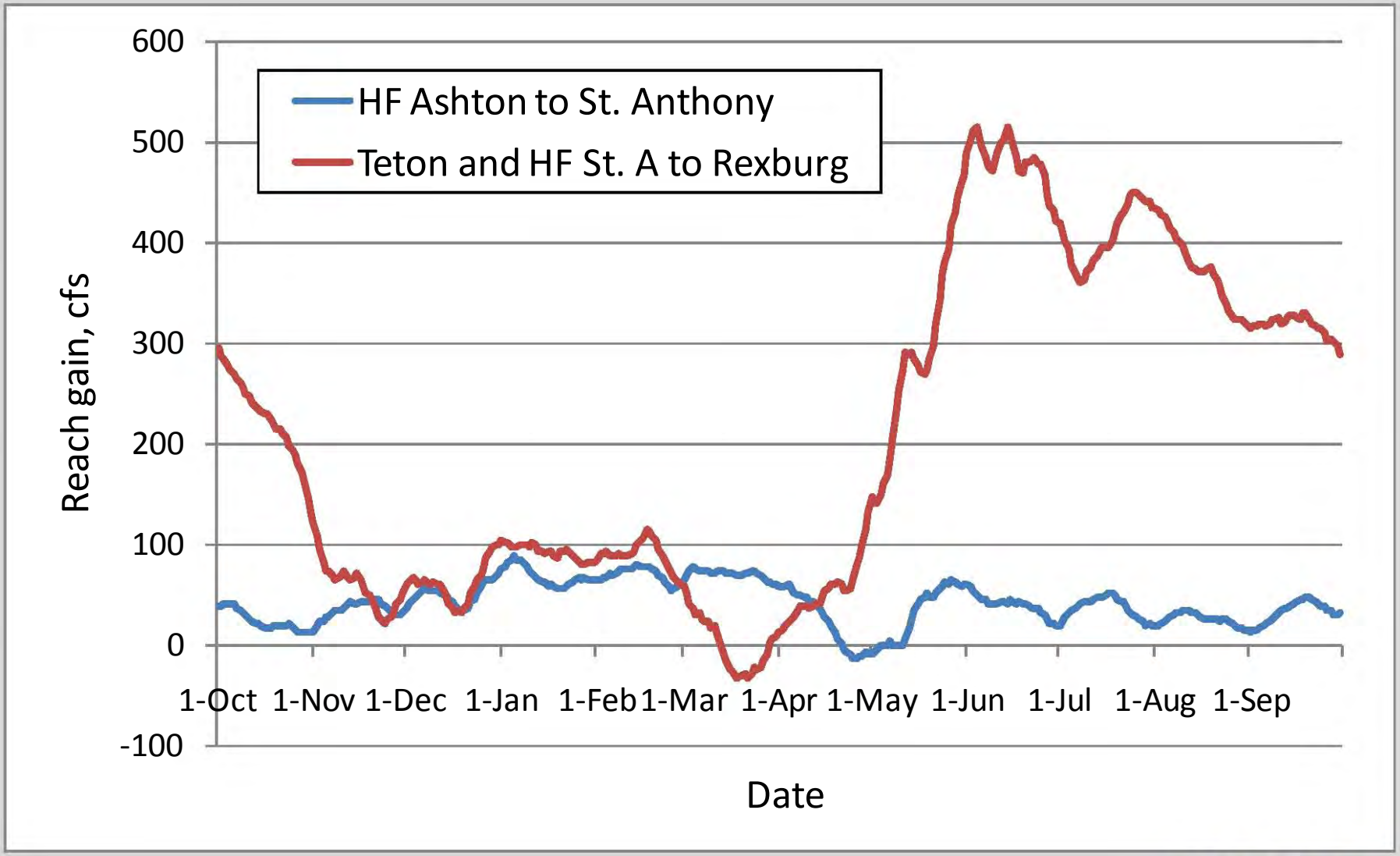
Reach gains in lower Teton and HF

Reach gain = Q at bottom – Q at top + diversions – surface return



Annual means: Ashton to St. A.: 30,096 a-f; to Rexburg: 147,717 a-f

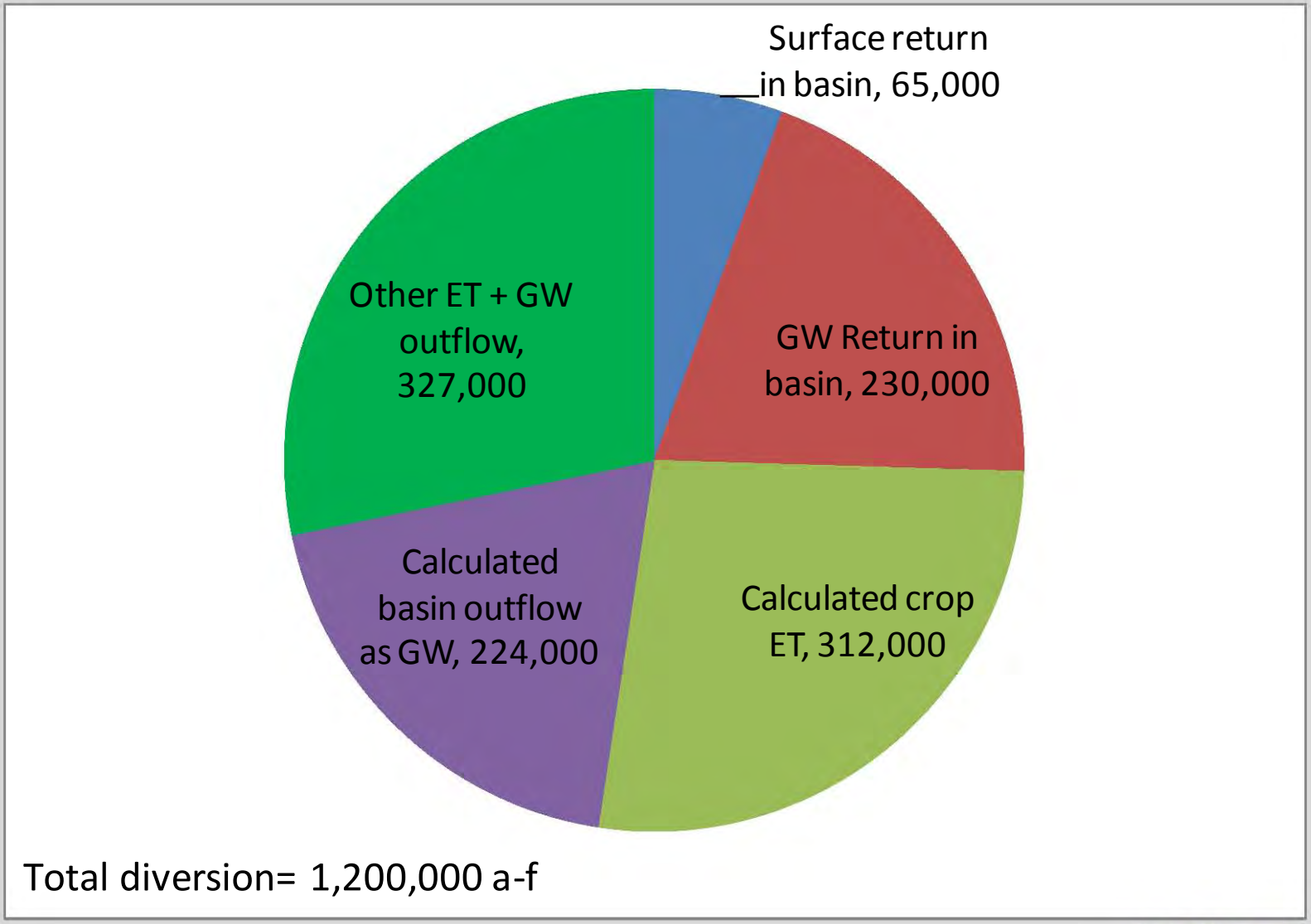
Reach Gain Hydrographs



Water Budget Summary

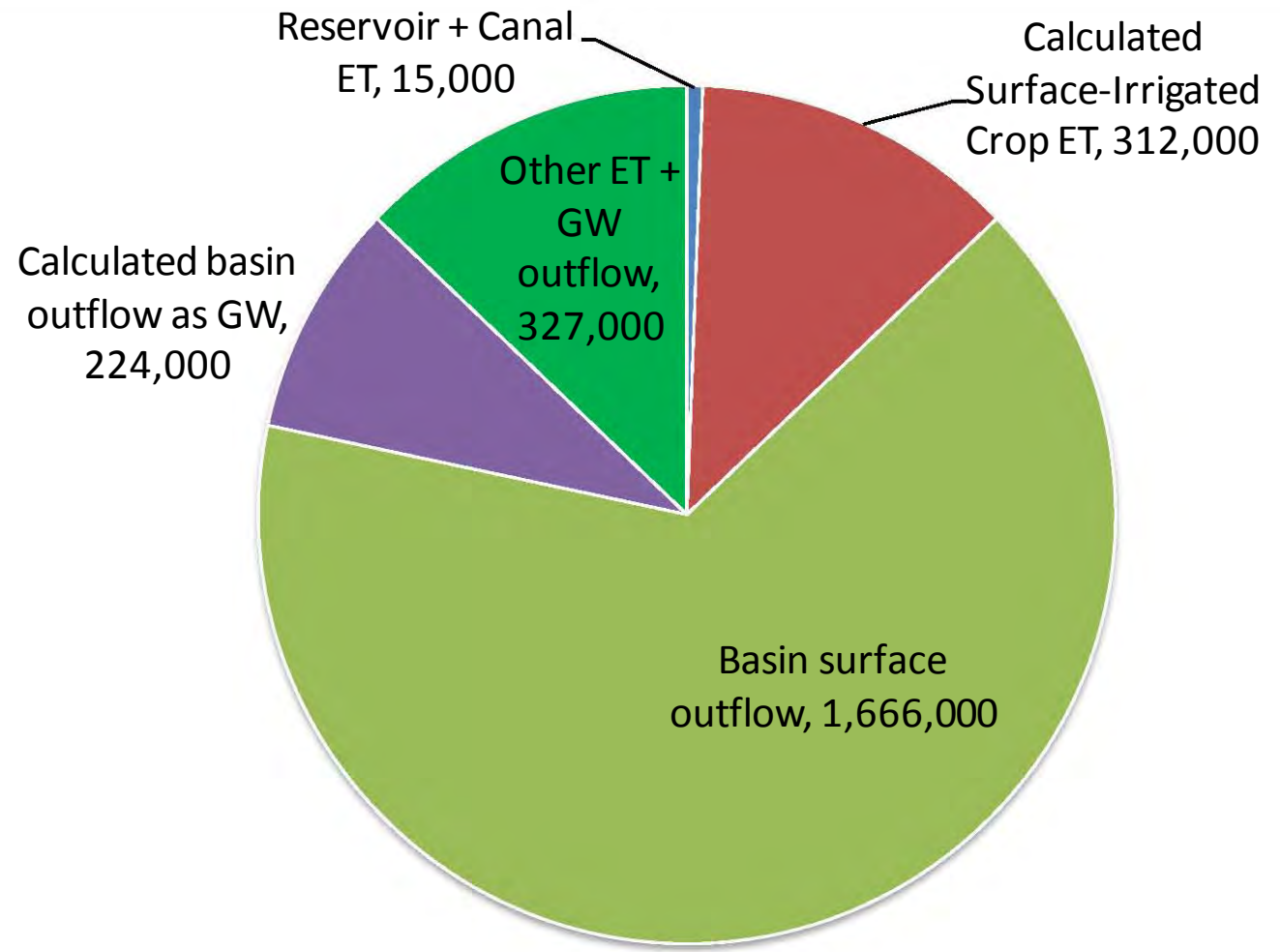
Component	Flow (a-f/yr)
Reservoir + Canal ET	15,000
Surface-Irrigated Crop ET	312,400
Basin surface outflow	1,666,000
Known basin outflow as GW	224,000
Other ET + GW outflow	327,000
Total Surface Supply	2,544,400
Deep GW + Non-irrigated ET	2,333,600
Precipitation (total supply)	4,878,000

Water Budget for Henry's Fork Surface Diversions



Total diversion= 1,200,000 a-f

Water Budget for Henry's Fork Surface Supply: a-f



Total surface supply = 2,544,000 a-f

Plans for final year of USDA project

- Model GW flow in canal-irrigated regions; one model for Teton Valley and another for the lower watershed area
- Emphasis of GW models will be on return flow to rivers and flow out of basin
- Use models to investigate GW flow under four scenarios:
    1. Actual 1979-2008 conditions
    2. All application under flood irrigation ("historic" scenario)
    3. All application under current conditions (90% sprinkler)
    4. 100% irrigation efficiency (no seepage or application in excess of ET)
- Complete analysis of conversion of irrigated land to suburban and resort use
- Present results at two conferences:
    - World Water and Environmental Congress (ASCE), May
    - Annual meeting of American Water Resources Association, November
- Prepare and submit journal articles for peer-reviewed publication
- Produce summary report for Henry's Fork Watershed Council
- Develop water management strategies with Council (focus on land conversion)
- Develop and distribute educational materials

Desired Future Work

- Prepare detailed written report of HF water supply and budget analysis
- Perform more careful GIS analysis of irrigated and other crop lands
- Perform more detailed study of water use beyond four main canal-served areas, including GW use (irrigation and domestic/commercial/industrial)
- Apply IDWR water rights accounting model to river flow under various canal system management scenarios
- Extend canal system analysis to other areas of upper Snake River system