Quantifying Return Flow in the Upper Wind River Basin

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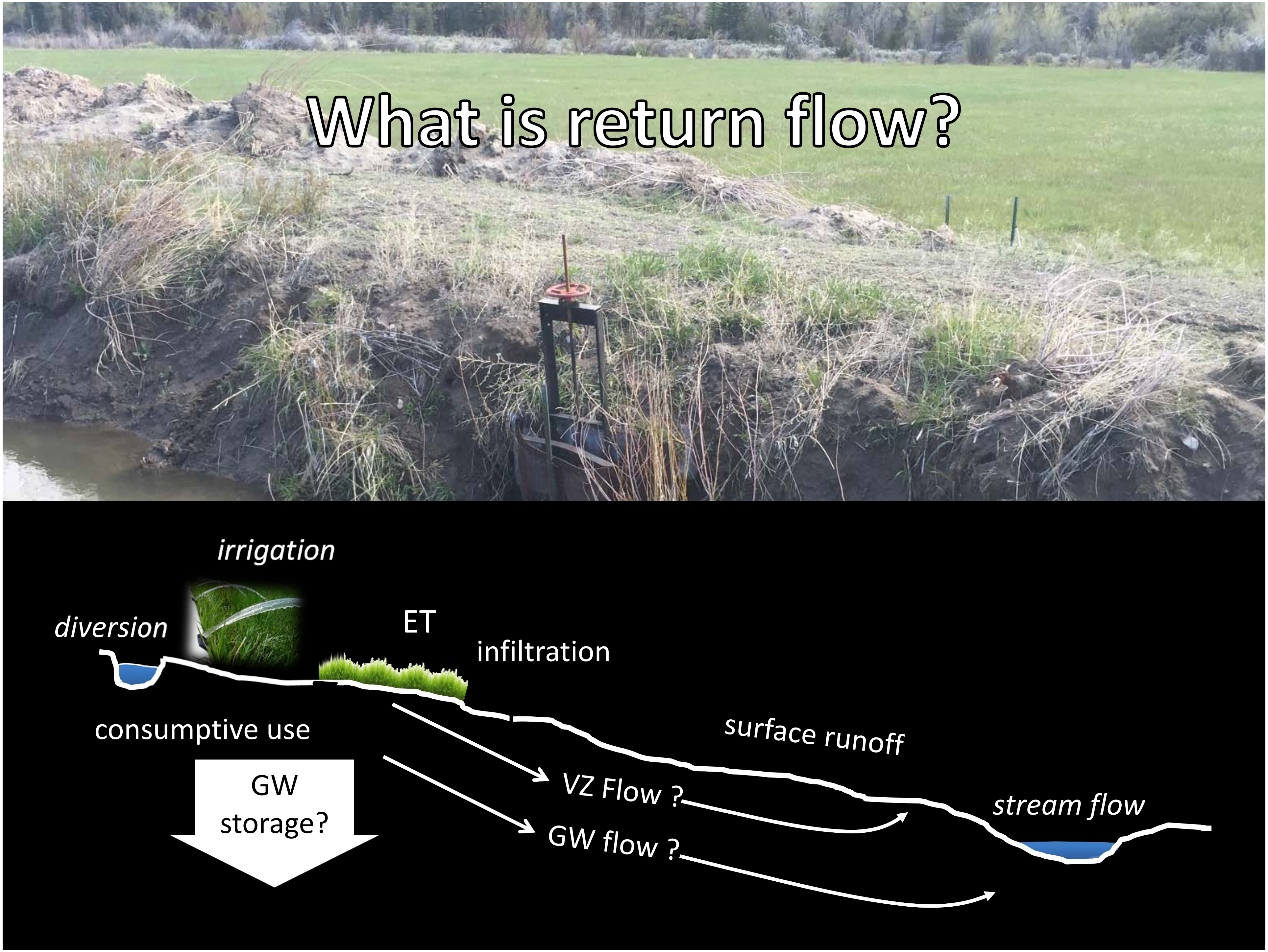
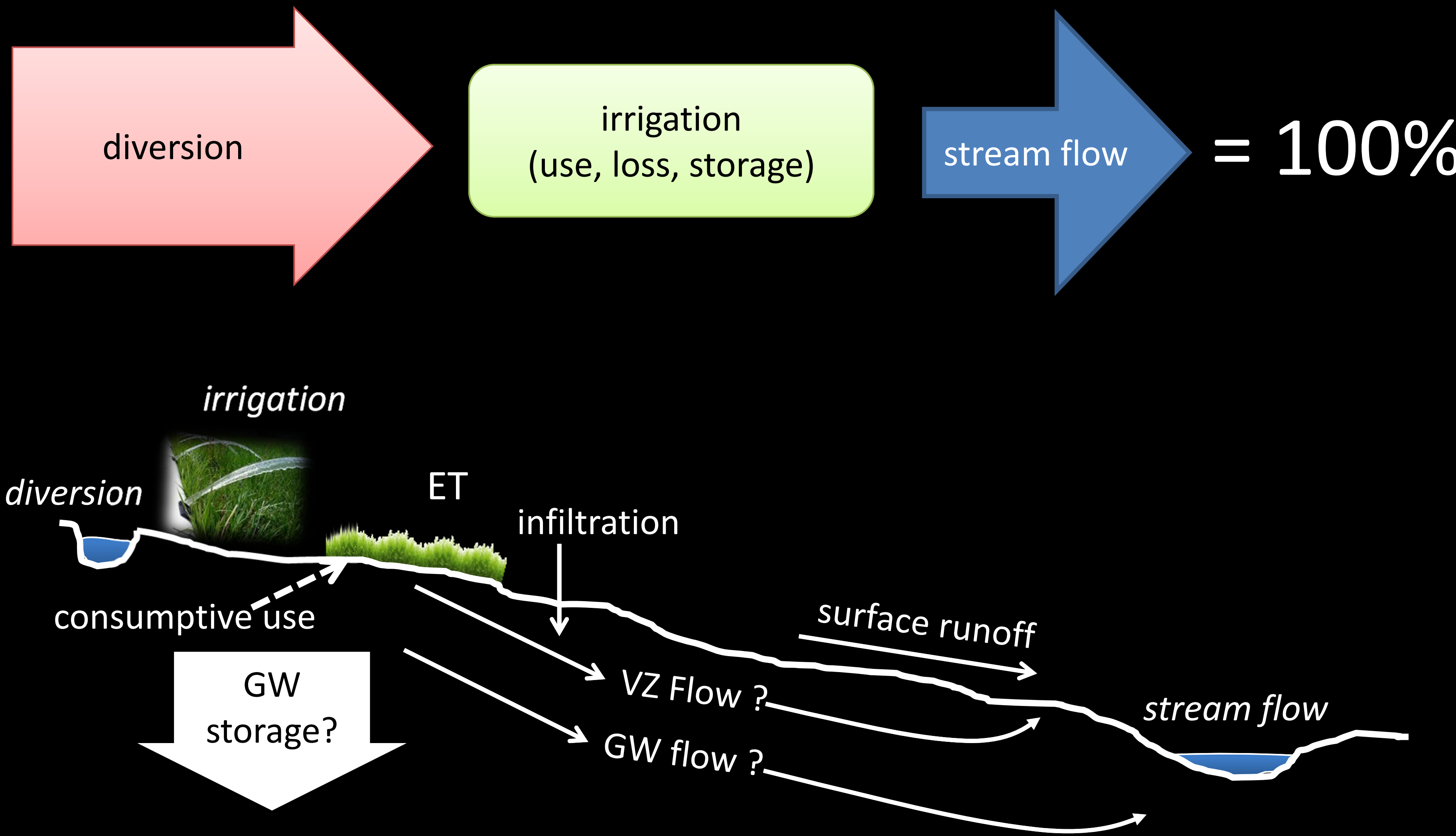
Issue

- In Western US - 80-90% of water is used by agriculture
- Flood irrigation is the most common irrigation method in WY
- Not all water applied is consumed by crops
- In general assume that 50% of applied water is “returned” to the stream


What is return flow?
irrigation
diversion
ET
infiltration
consumptive use
surface runoff
GW
storage?
VZ Flow ?
GW flow ?
stream flow

How is return flow measured?



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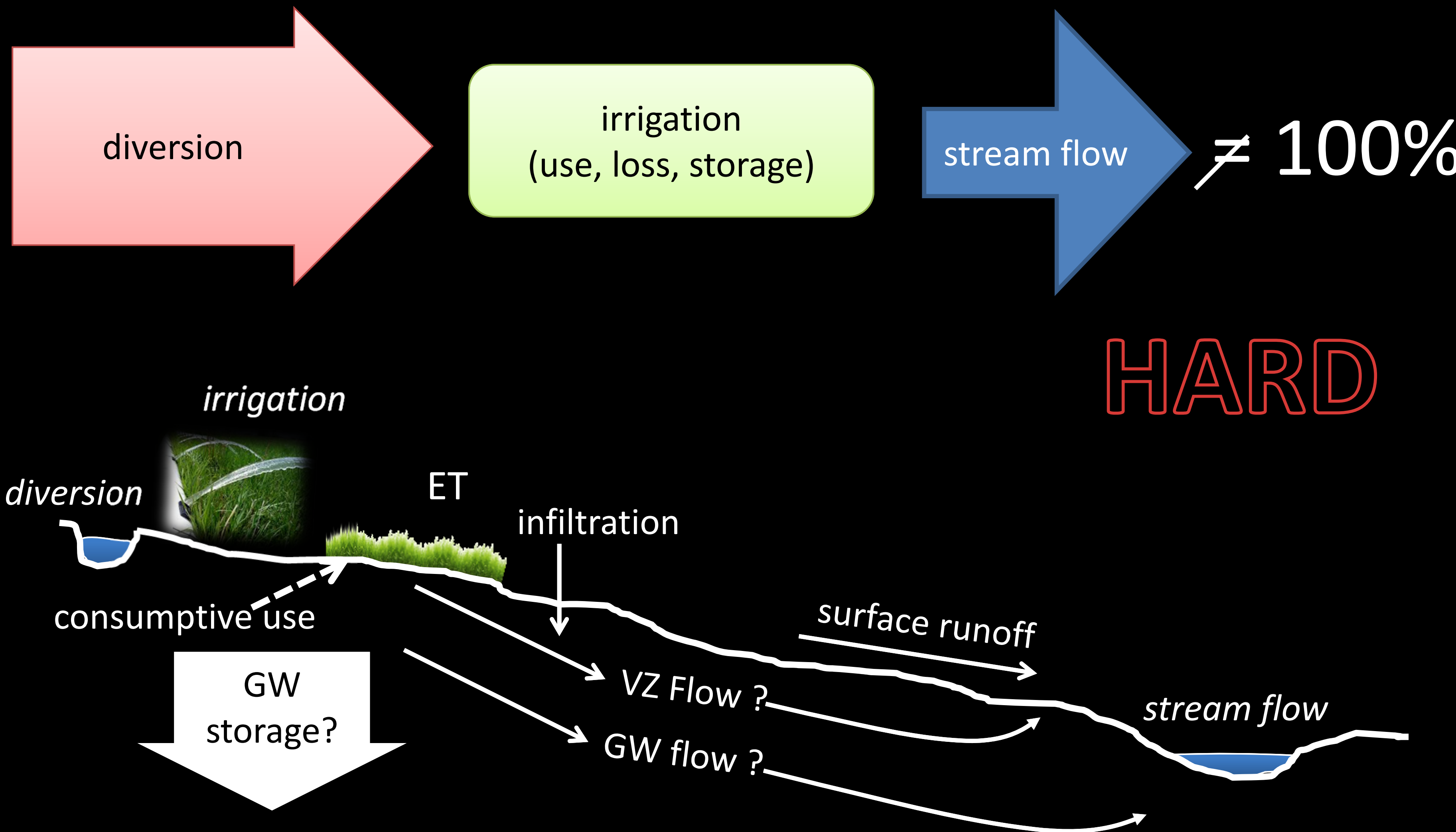


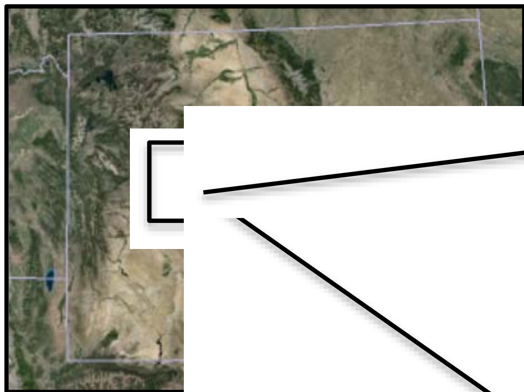
Objectives & Study Site

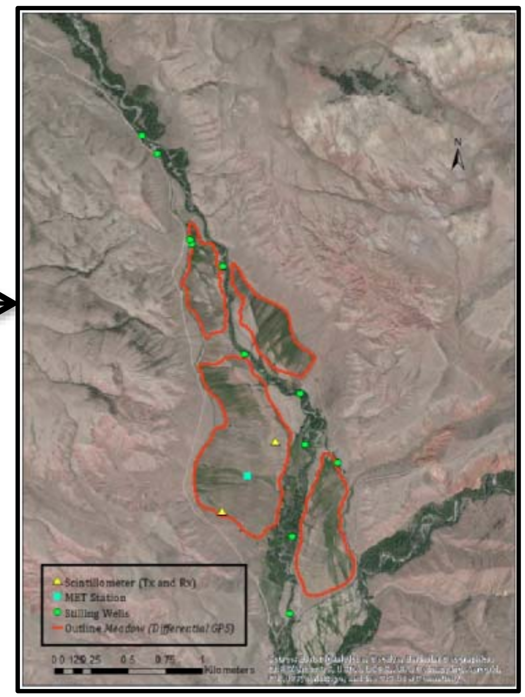
- Use a water balance approach coupled with intensive field investigations to quantify and document return flow process in the Spence/Moriarty WHMA in the Upper Wind River Basin.

  1) quantify the contribution of return flows to sustained late-season flow (baseflow);

  2) assess the quality of the return-flow water; and

  3) compare results to the results from the return flow study New Fork in the Upper Green River Basin





East Fork:

17% of the larger Upper Wind River Basin
Major tributary of the Wind River

Site location in northwestern Wyoming (left). Greater Bear Creek Watershed (middle). Bear Creek study site comprised of four agricultural fields (outlined in red) and adjacent stream (right).

Approach

- Reach water balance (Inputs & outputs)
  - Stream flow
  - ET
  - Changes in storage

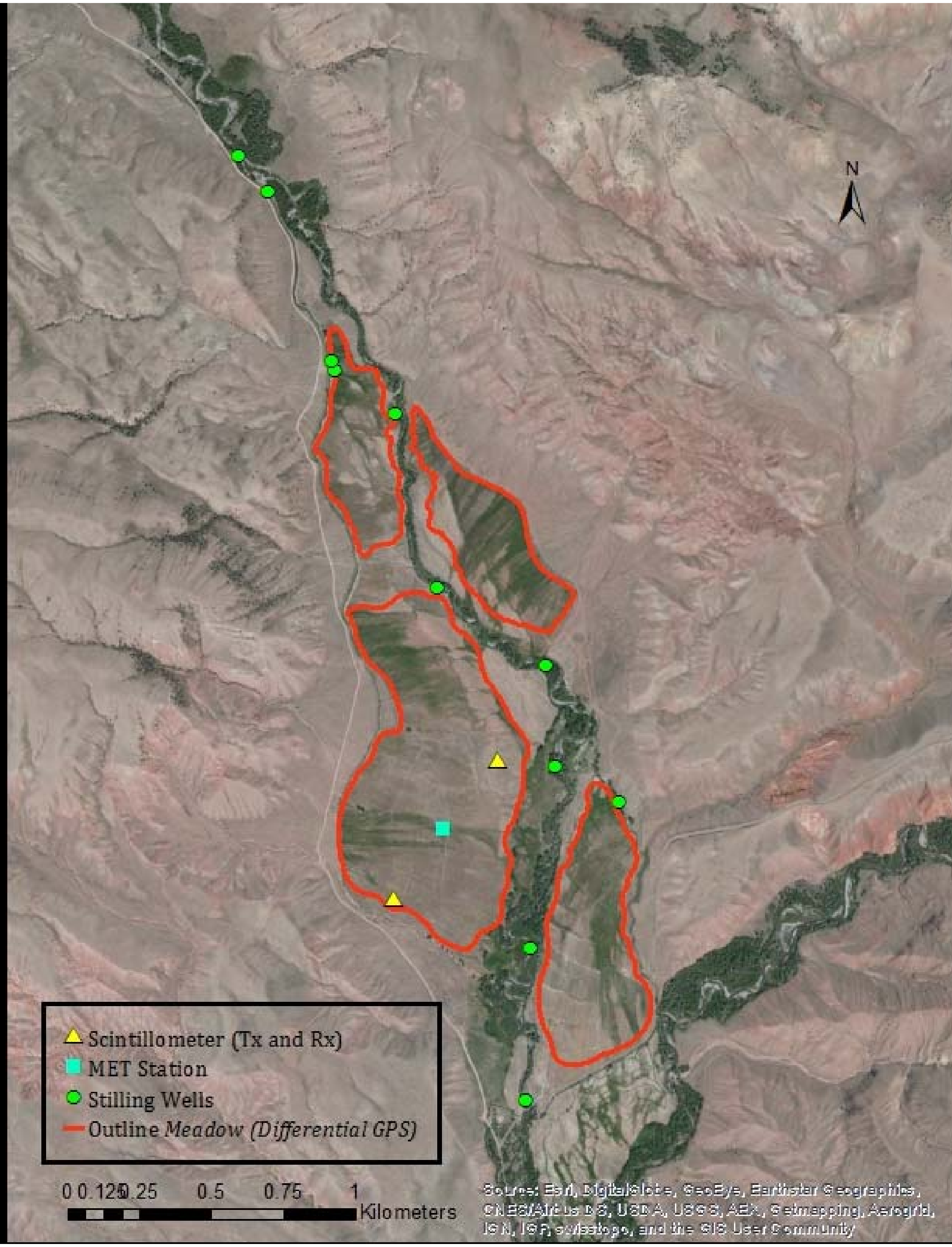
- Intensive field measurements to directly monitor and track water movement and use at the field scale – near surface geophysics

Field Measurements/Instrumentation

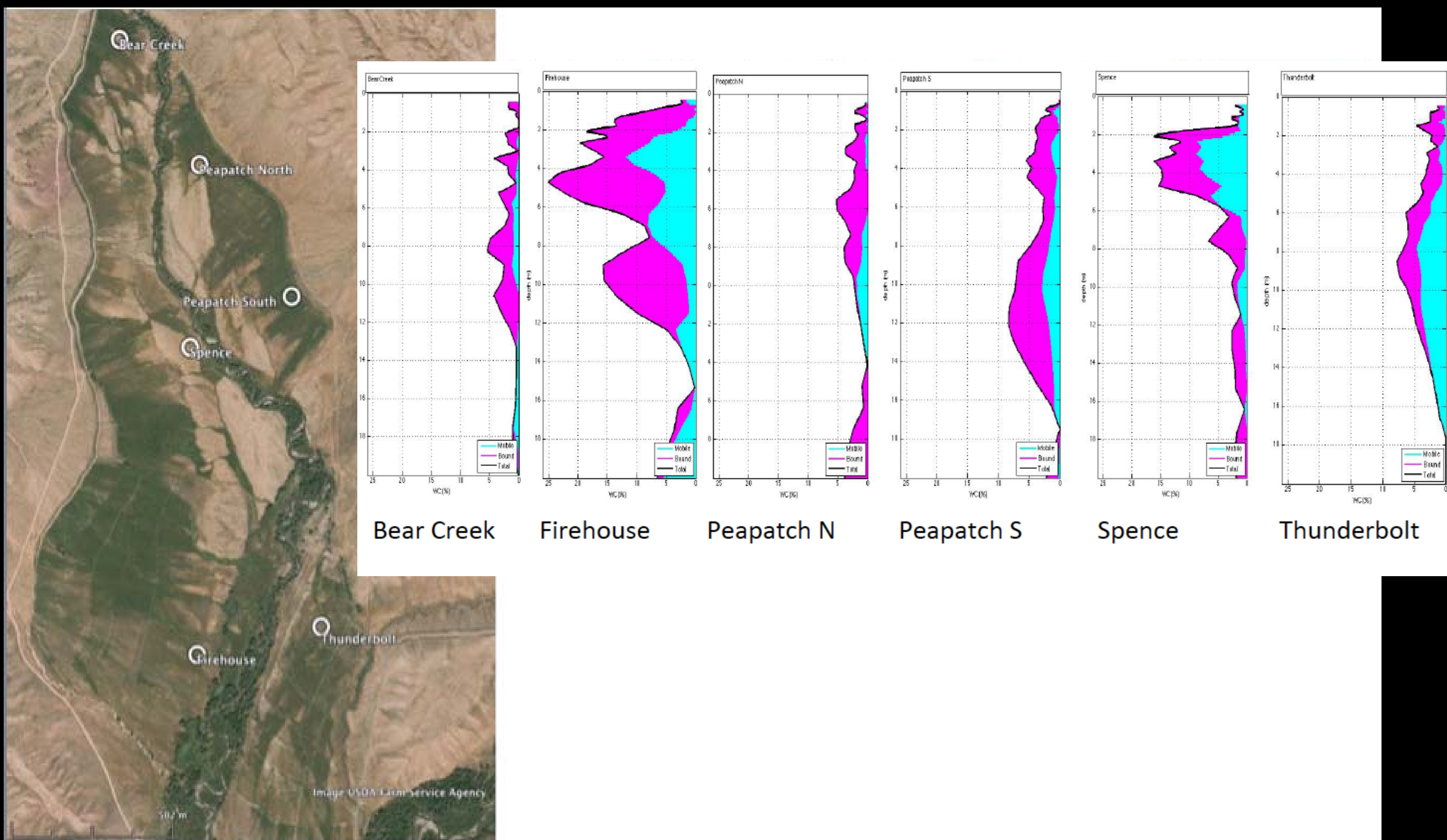
Instrument	Criteria Measured	Approximate Date
Permanent:		
8 Pressure Transducers (5 Bear Creek & 3 Focher Ditch)	Pressure, Depth, and Temperature	Jul-’14/Jun –’15
3 Conductivity Meters (2 Bear Creek & 1 Focher Ditch)	Specific Conductance and Salinity	Jul-’14
Meteorologic Station		
Anemometer	Wind Speed & Direction	Jul-’14
Net Radiometer	Net Radiation (Rs, Rl, Albedo)	Jul-’14
Air Temperature Sensor	Temperature, Humidity	Jul-’14
Tipping Bucket Rain Gage	Precipitation	Jul-’14
Soil Moisture Sensors	Volumetric Water Content	Jul-’14
Heat Flux Plates	Soil temperature	Jul –’15

Field Measurements/Instrumentation

Instrument	Criteria Measured	Approximate Date
Periodic Measurements:		
Nuclear Magnetic Resonance (NMR)	Water Content	Jun '14 Jun & Oct '14
Electrical Resistance Tomography (ERT)	Resistance	Aug '14 & Aug '15
Seismic/Ground Penetrating Radar/Electrical Magnetic	Subsurface Structures	Jul- Aug '15
Continuous		
Large Aperture Scintillometer	Sensible Heat Flux	Sept '14- on going
Eddie Covariance Flux Tower	Transpiration	Nov '15 – on going


N
Scintillometer (Tx and Rx)
MET Station
Stilling Wells
Outline *Meadow (Differential GPS)*
0 0.125 0.25 0.5 0.75 1
Kilometers
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

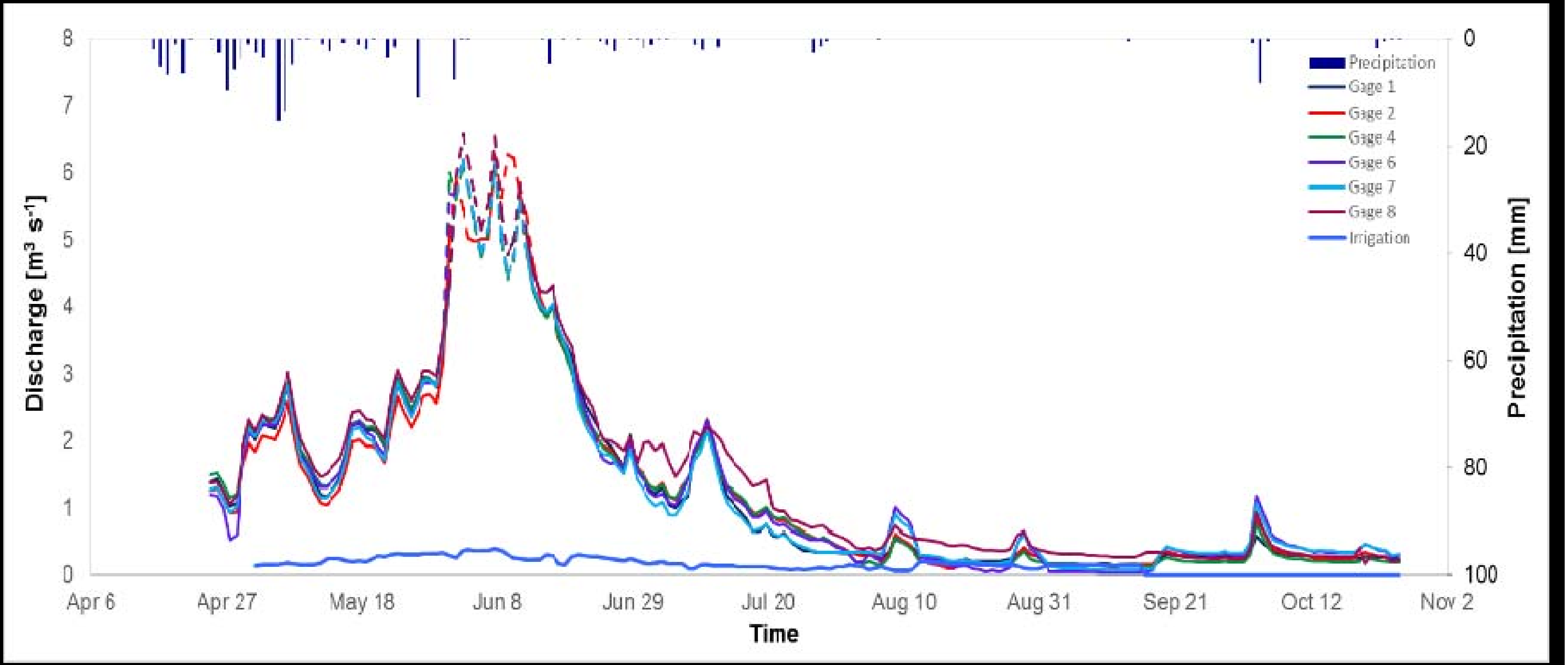
Background Geophysics



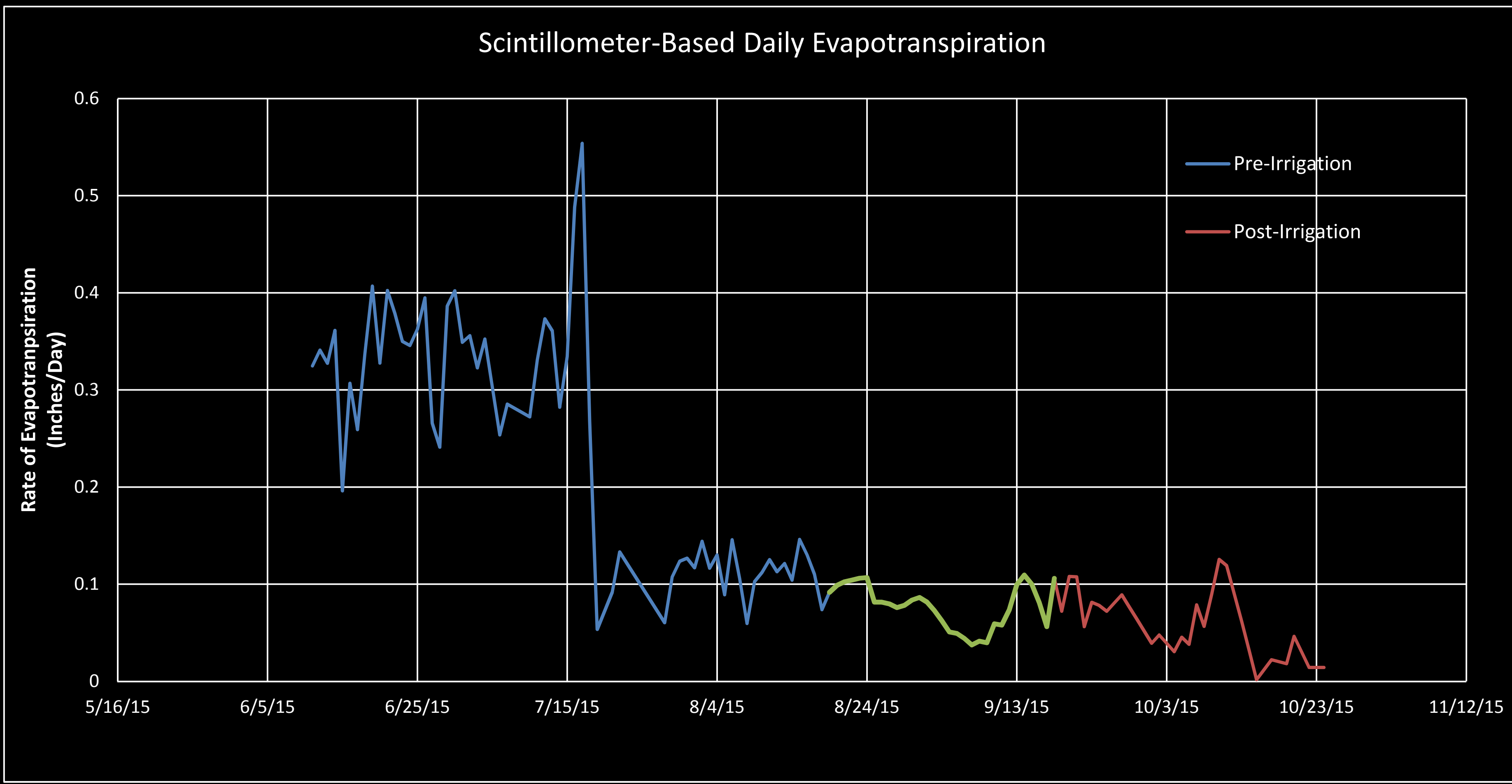
Results of Phase 1 surface NMR acquisition. Positions of soundings indicated by white circles on the aerial photo. (Andrew Parsekian)

Stream Flow/Runoff

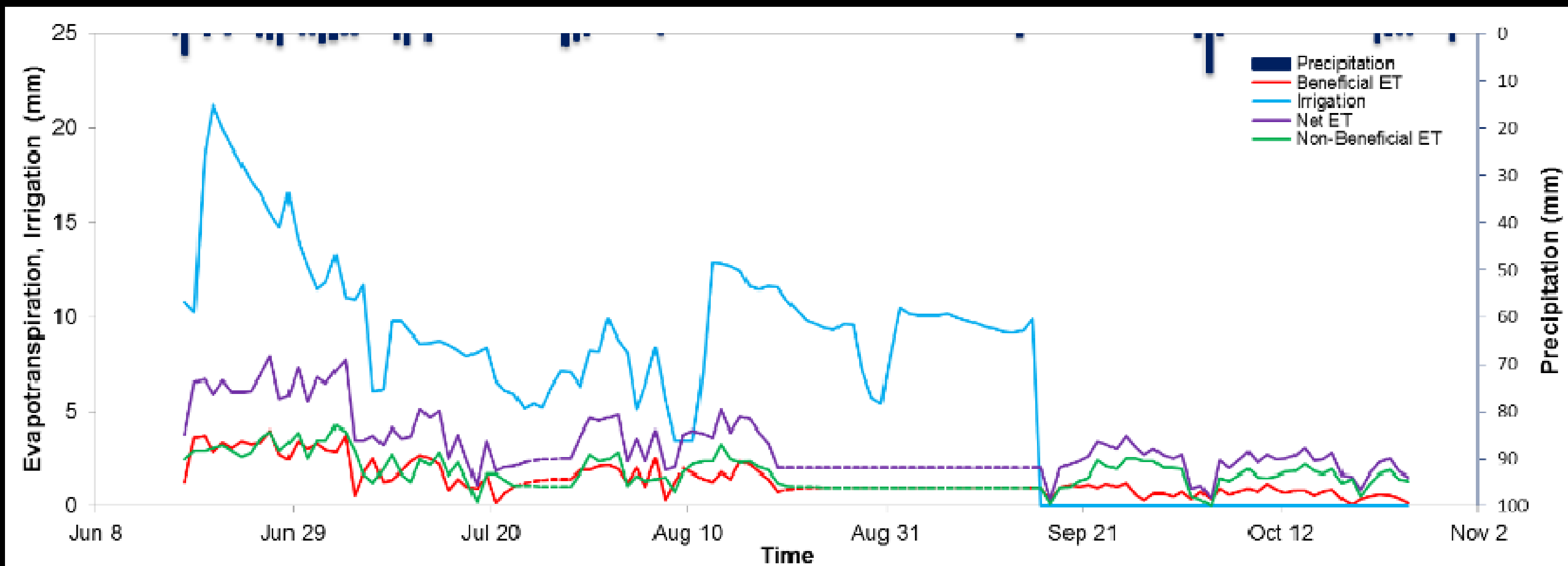
- Stilling wells installed
  - Recoding pressure transducer
- Periodic flow measurements
- Rating Curves developed
  - R^2 = 0.96 - 0.99
  - Beaver pond near Bear 3 (Sept)



Stream Flow & Irrigation 2015



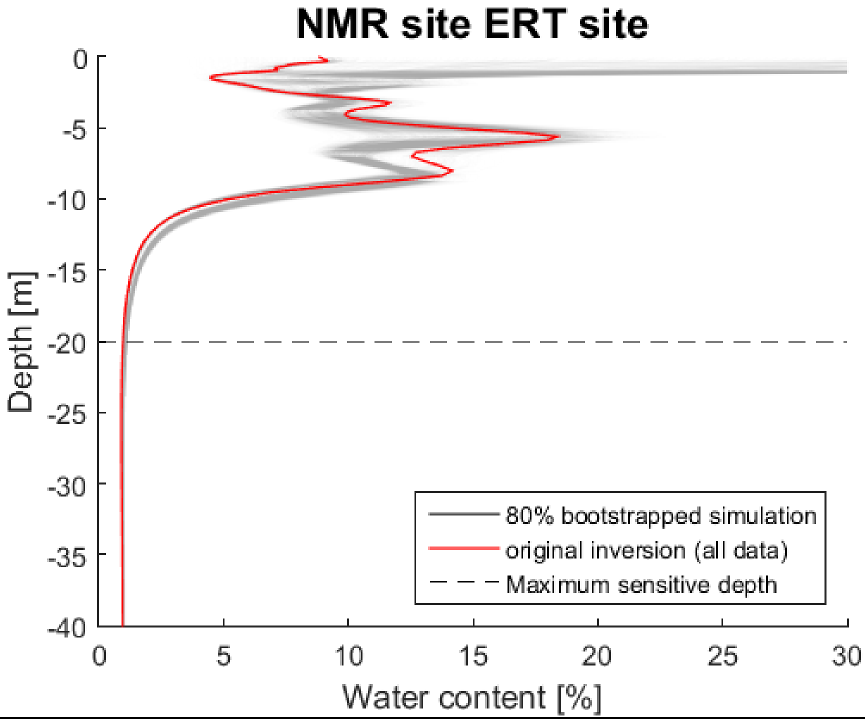
Scintillometer-Based Daily Evapotranspiration
Rate of Evapotranpsiration (Inches/Day)
0.6
0.5
0.4
0.3
0.2
0.1
0
5/16/15
6/5/15
6/25/15
7/15/15
8/4/15
8/24/15
9/13/15
10/3/15
10/23/15
11/12/15
Pre-Irrigation
Post-Irrigation

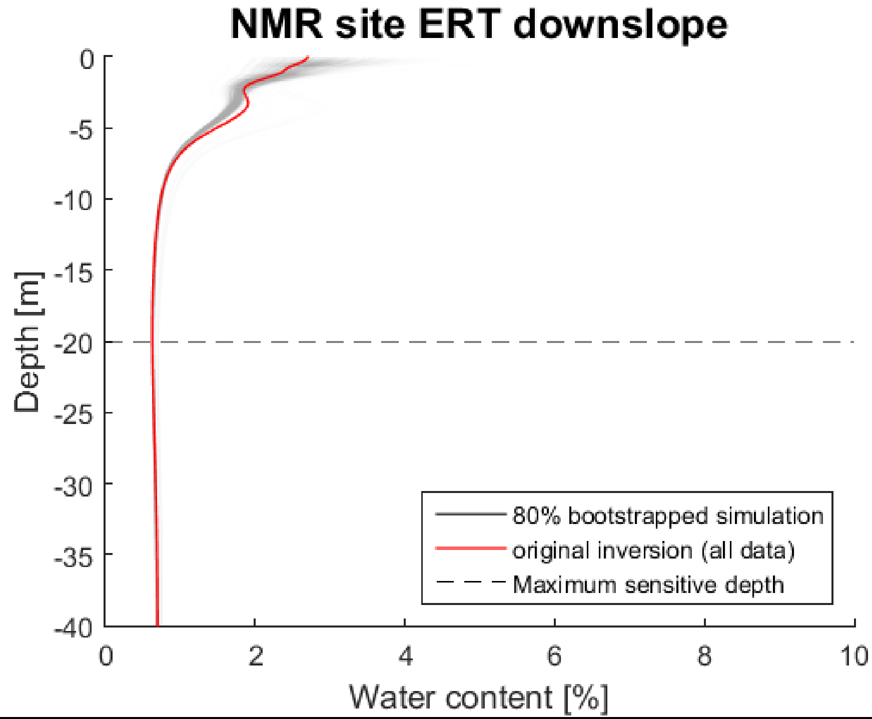


Evapotranspiration, Irrigation (mm)
Precipitation (mm)
Time
Precipitation
Beneficial ET
Irrigation
Net ET
Non-Beneficial ET
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Jun 8
Jun 29
Jul 20
Aug 10
Aug 31
Sep 21
Oct 12
Nov 2

Background geophysics - NMR

- Where is water storage and how much
- Spatial and Temporal variability



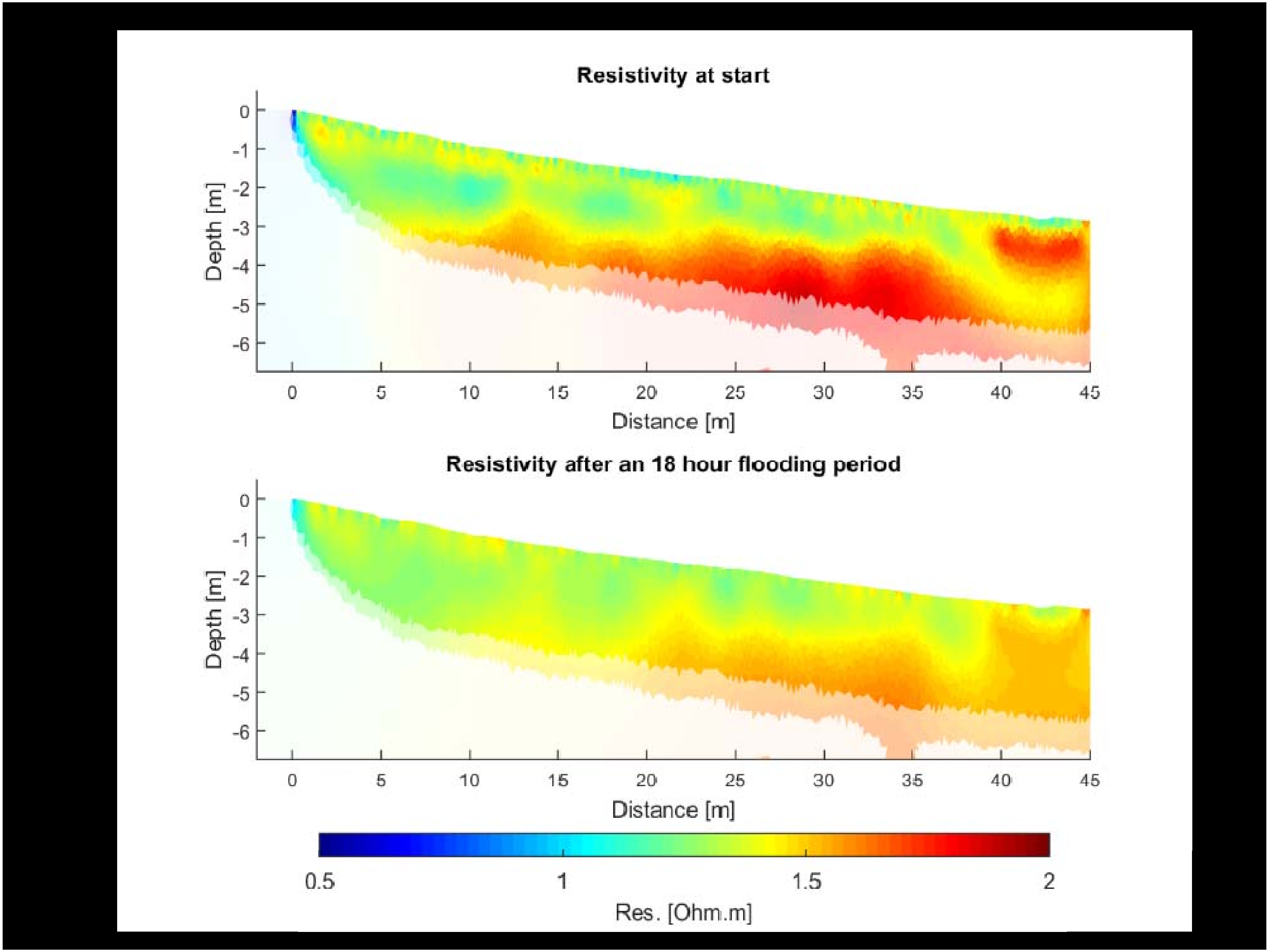


Field Scale Approach

Using hydrogeophysics to measure "flow" in the near subsurface during irrigation

Time Lapse ERT (MPT) during wetting and drying (before, during and after irrigation applications)

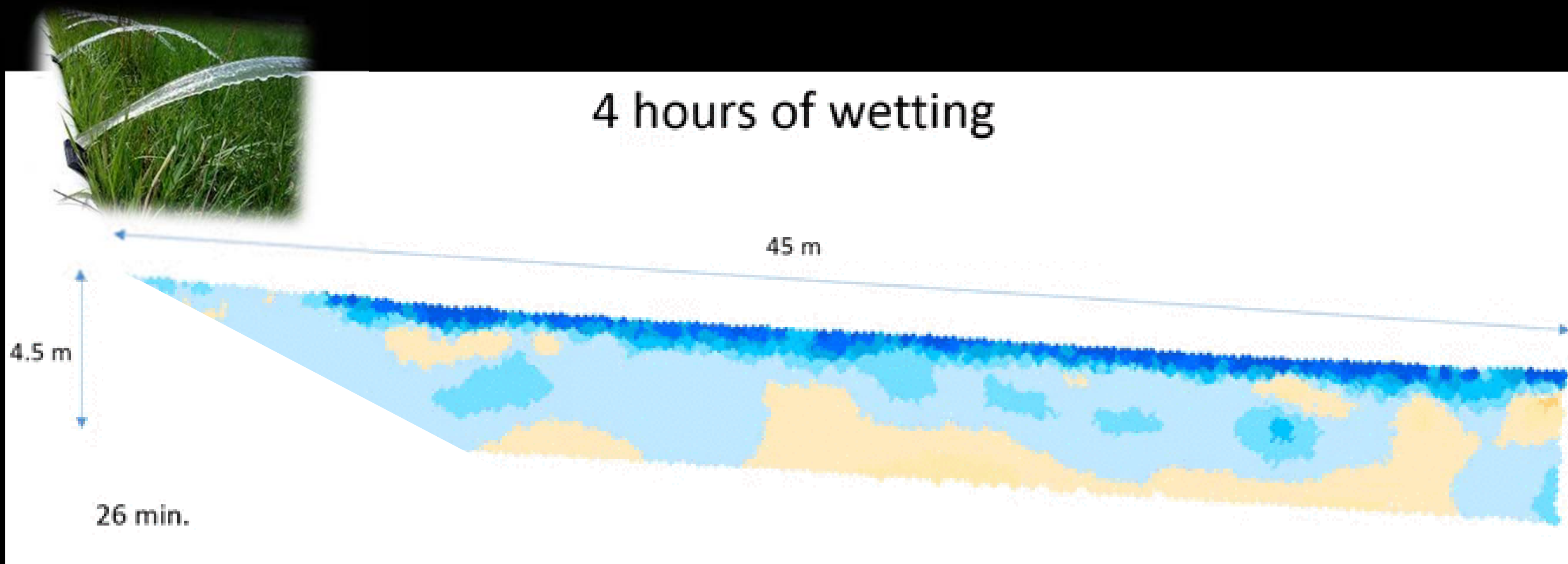
NMR – surface & borehole



Resistivity at start
Depth [m]
0
-1
-2
-3
-4
-5
-6
0
5
10
15
20
25
30
35
40
45
Distance [m]
Resistivity after an 18 hour flooding period
Depth [m]
Distance [m]
0.5
1
1.5
2
Res. [Ohm.m]

A view on subsurface processes

Where and how fast is change in the subsurface?



A view on subsurface processes

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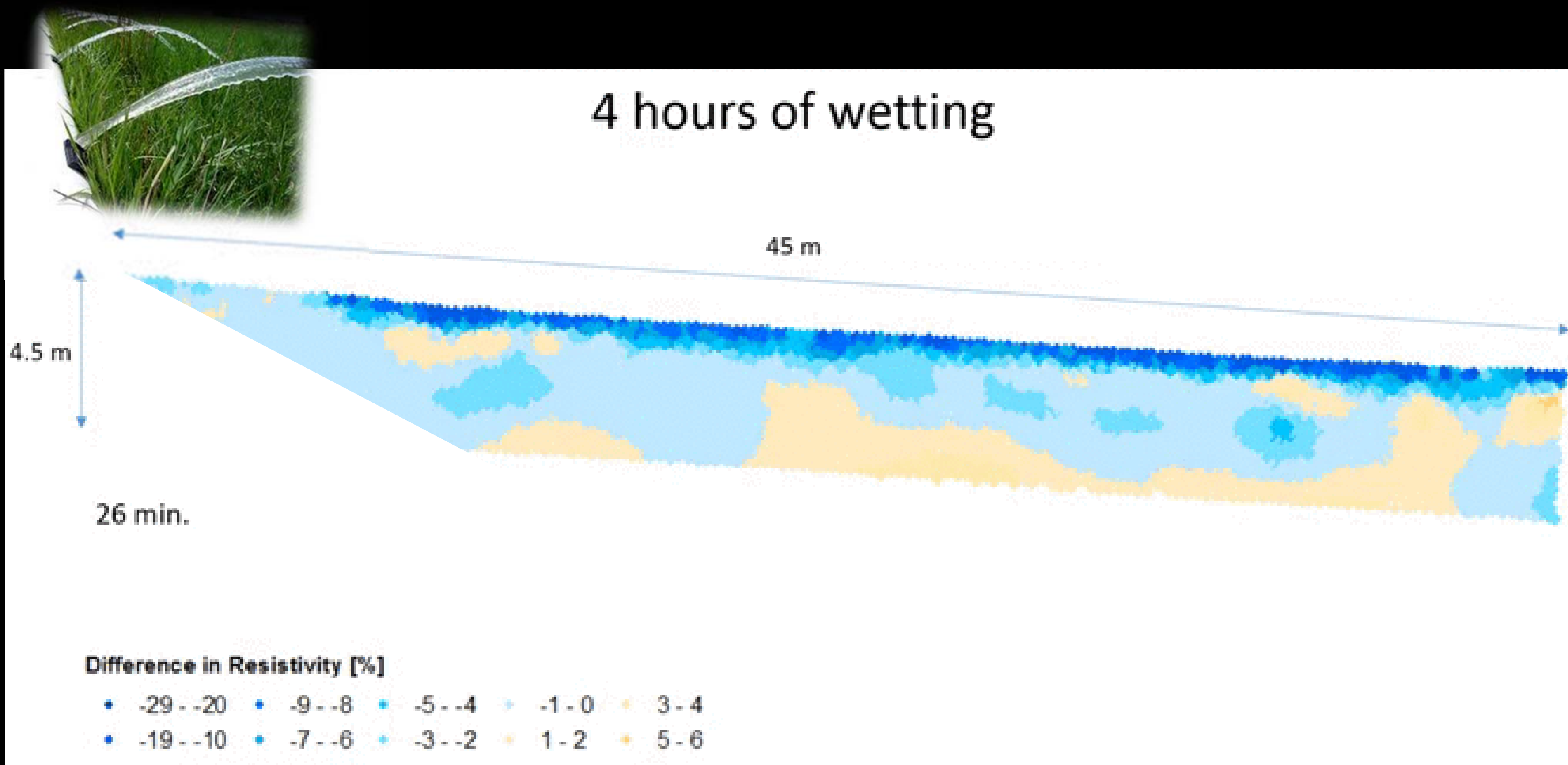

Water Balance

Putting together reach water balance

- Temporal changes in stream flow distributed along the reach.
- Amount (timing) of water applied
- ET quantified at the field scale
- Changes in deep storage

Detailed investigations into field scale processes

Next Steps

Summer 2016:

Continue stream flow & “ditch” measurements

Continue and expand background geophysics

(ERT, SP, DTS, NMR)

Expand system of bore holes to monitor subsurface flow

Intensive field scale studies – time lapse ERT (MPT) in multiple fields

Acknowledgements

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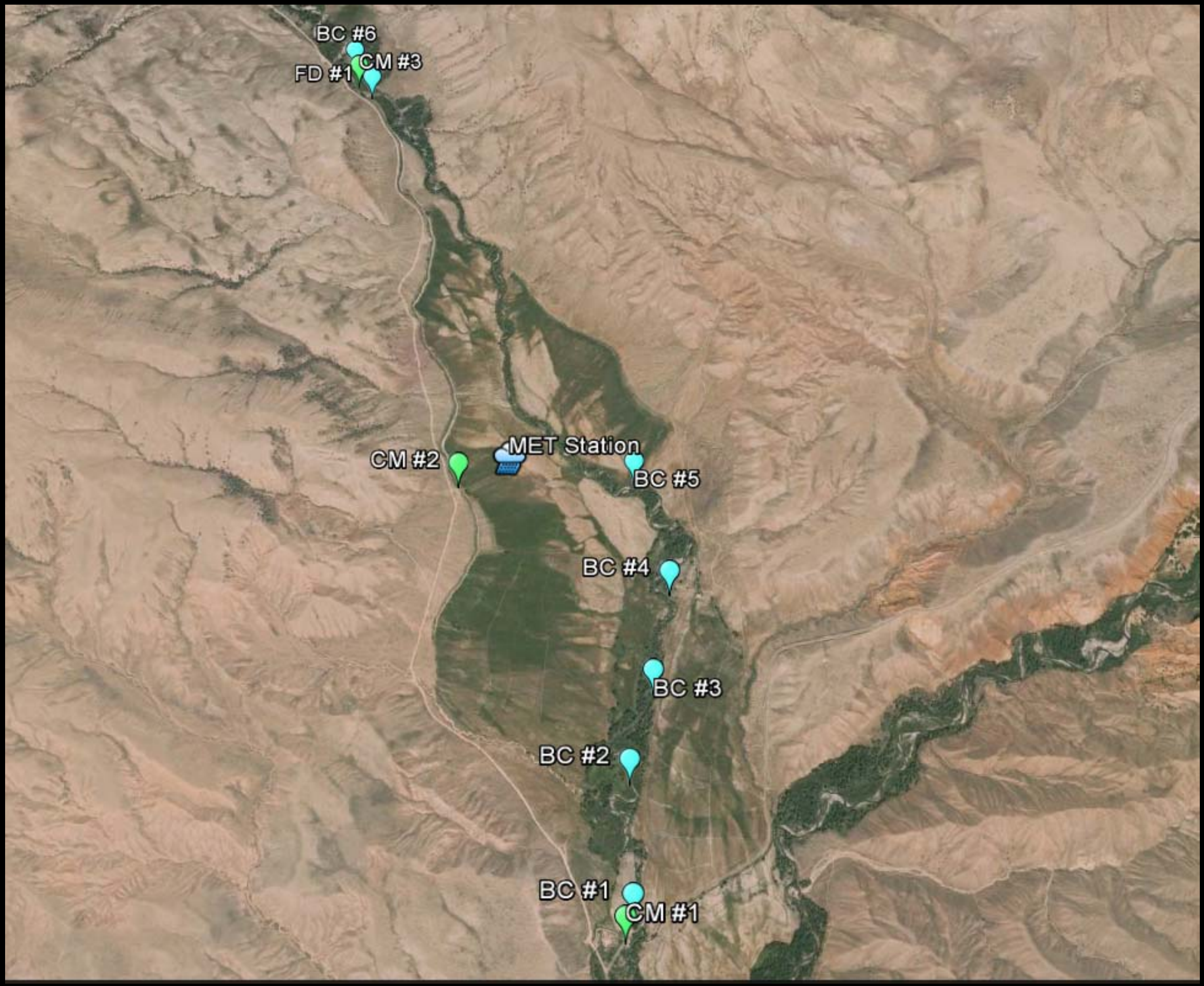
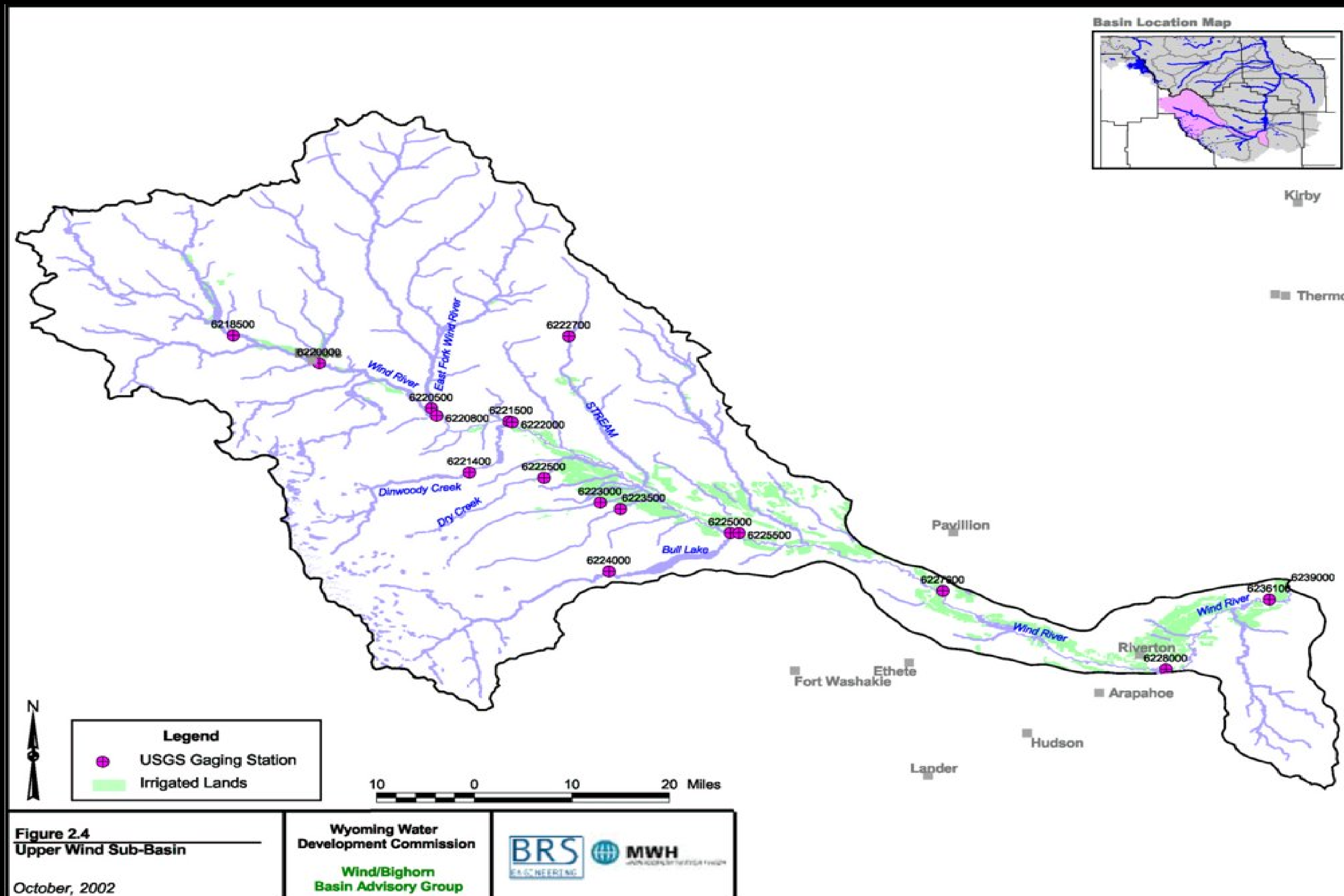
WyCEHG – Wyoming Center for Hydrology & Geophysics (NSF EPSCoR – UW)



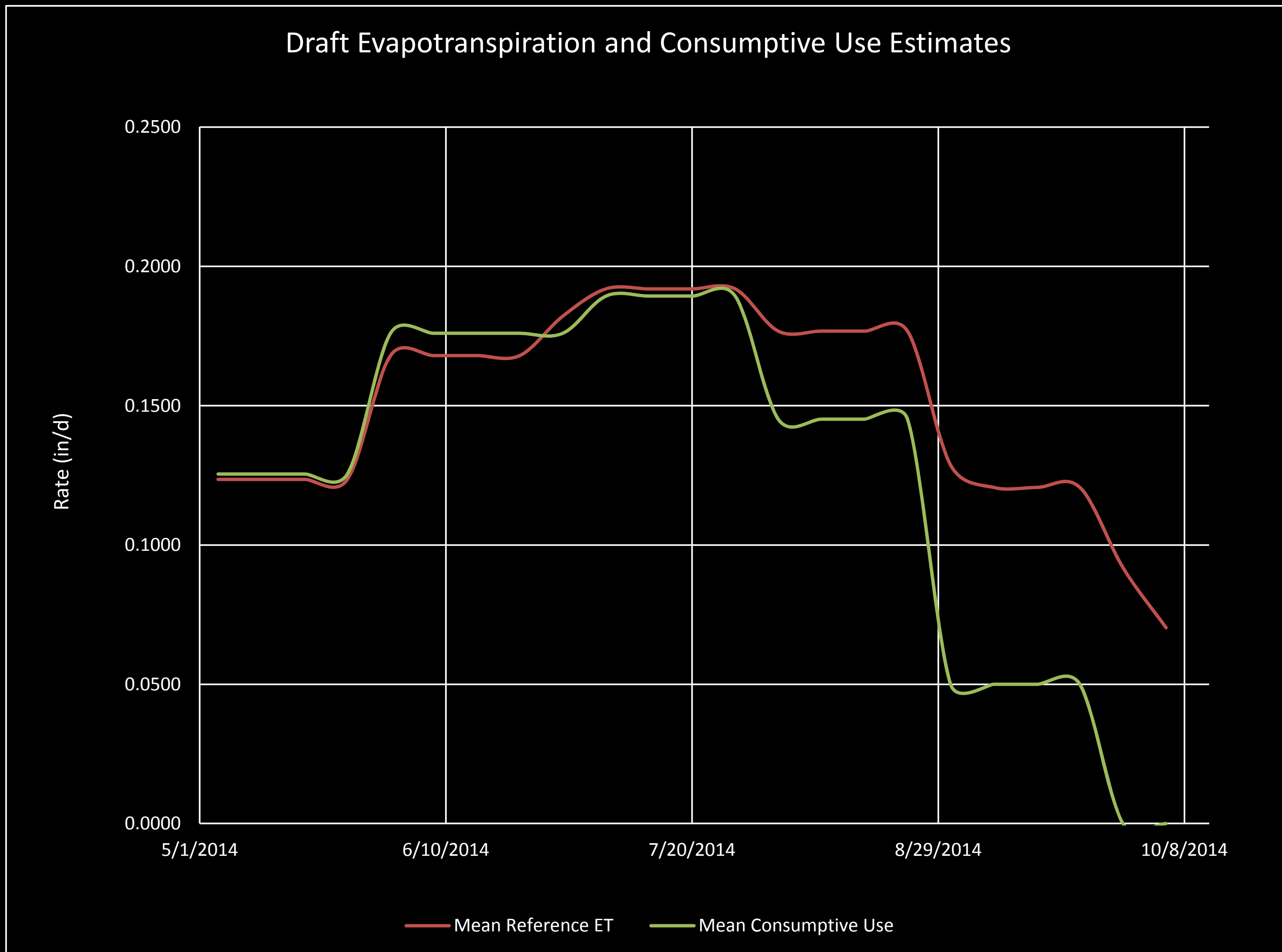
BC= Bear Creek Stilling Well; CM=Conductivity Meter; FD=Focher Ditch Stilling Well

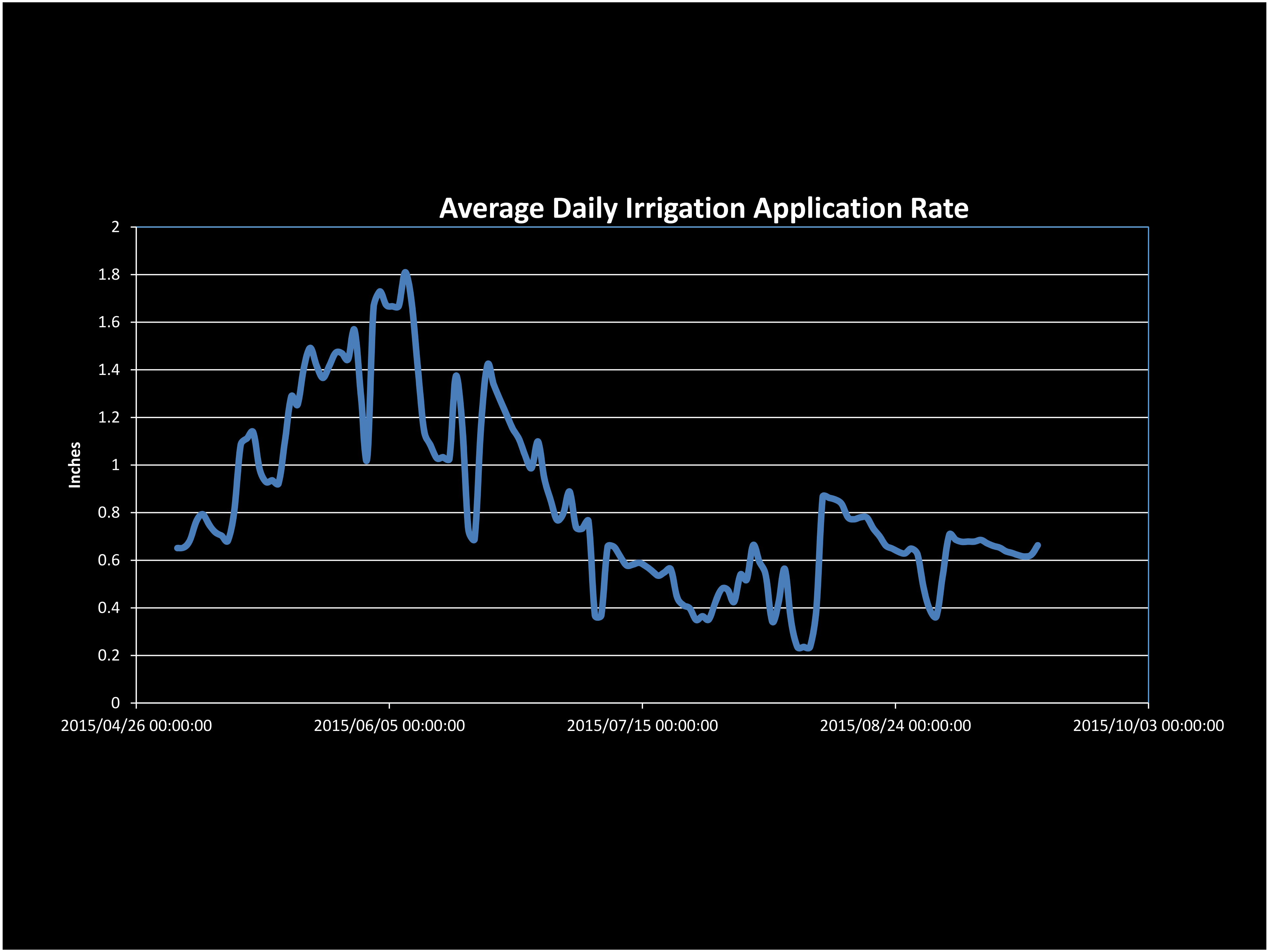


Location of the East Fork in the Upper Wind River Sub-Basin (courtesy: Wyoming Water Development Office *http://waterplan.state.wy.us/plan/bighorn/*)

Next Steps

- Recruit new Masters Student
- Continue Processing ERT and ET data
- Refine partial pipe flow measurements
- Finish Reach water balance for summer 2015


Draft Evapotranspiration and Consumptive Use Estimates
Rate (in/d)
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
5/1/2014
6/10/2014
7/20/2014
8/29/2014
10/8/2014
Mean Reference ET
Mean Consumptive Use


Average Daily Irrigation Application Rate
Inches
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2015/04/26 00:00:00
2015/06/05 00:00:00
2015/07/15 00:00:00
2015/08/24 00:00:00
2015/10/03 00:00:00

Reach Water Balance

- $Q_{RT} = Q_{IN}-Q_{OUT}$

a simplified equation to calculate return flow (Q_{RT}) as the difference between net channel outflow (Q_{OUT}) and net channel inflow (Q_{IN}).

When this value is positive, return flow is assumed to be the cause. Conversely, when this value is negative, Bear Creek is assumed to revert back to a losing stream.

Reach Water Balance

- $(P+Q_{IRR}) = Q_{RT} + (ET_B + ET_{NB}) + DS +$ Error

Q_{RT} is return flow,

DS is change in deep storage,

Q_{IRR} is irrigation water applied to the field,

P is precipitation

ET_B is beneficial evapotranspiration from the desired crops,

ET_{NB} is non-beneficial evapotranspiration (riparian)