



Russian River Watershed Hydrograph Separation using Stable Isotopes and Natural Geochemical Tracers

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CW3E

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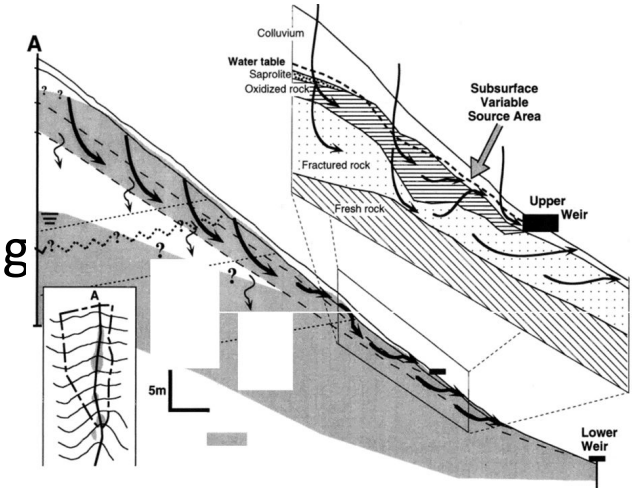
Purpose and Background

What information can measurements of stable isotopes and natural geochemical tracers provide in evaluating hydrology of the Russian River watershed.

- Volume of runoff in streams is composed of two primary components:
  - Overland flow (event water)
  - Groundwater (pre-event water)
- Groundwater flow on hill slopes is complicated
- We are most interested in measuring the groundwater component to streams for forecasting approx. 1 to 3 weeks into the future

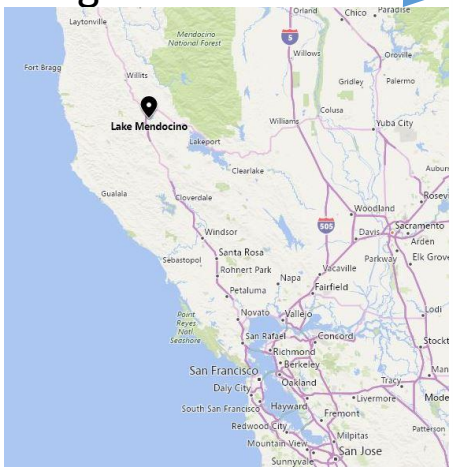


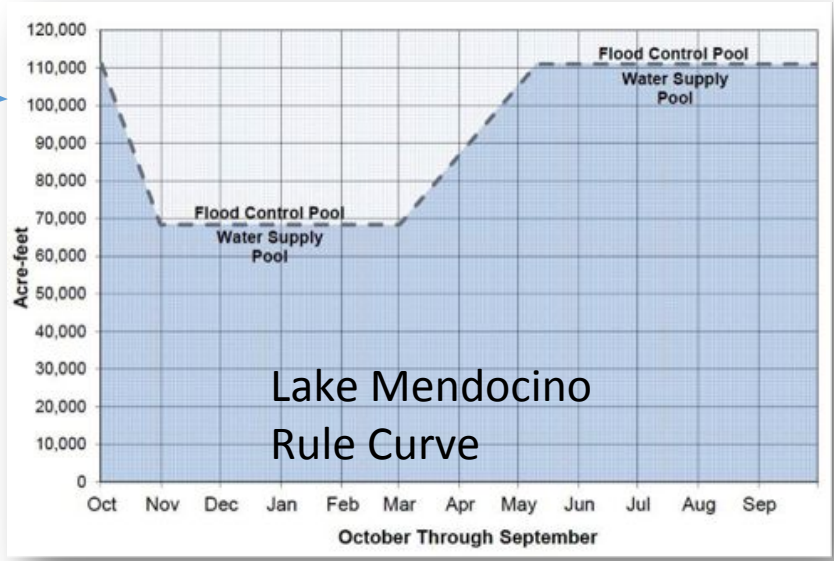
From Anderson (1997)

Forecast Informed Reservoir Operations (FIRO) Objectives

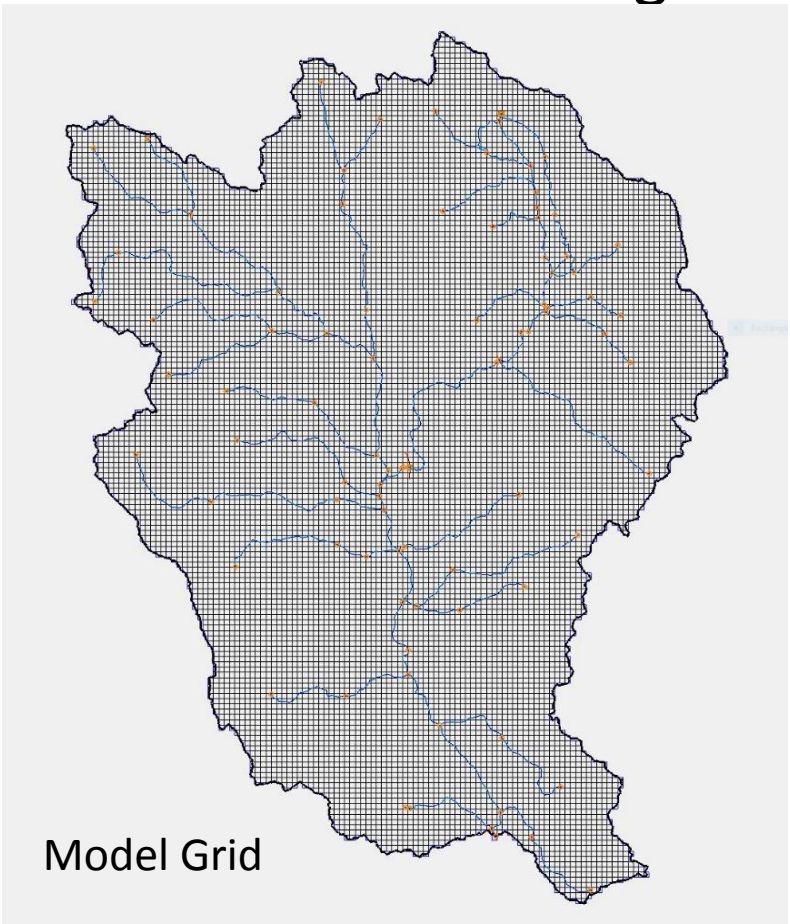
- Using hydro-meteorological forecasting to inform water supply and flood control operations
- Obtain a flexible balance between flood risk management, water supply and ecological needs

"Rule curves" based on flood risk management principles

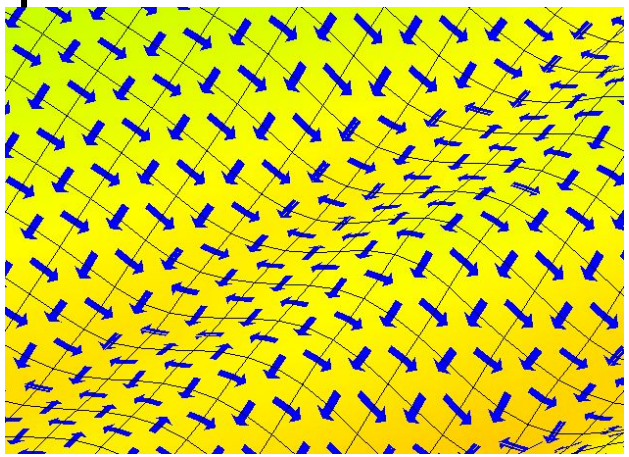




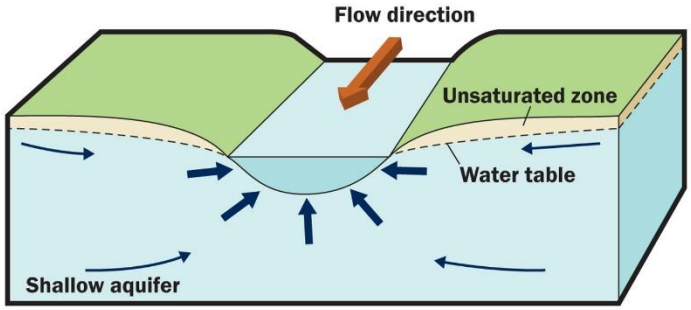
Gridded Surface Subsurface Hydrologic Assessment (GSSHA) Watershed Modeling of the Upper Russian River for FIRO



Model Grid



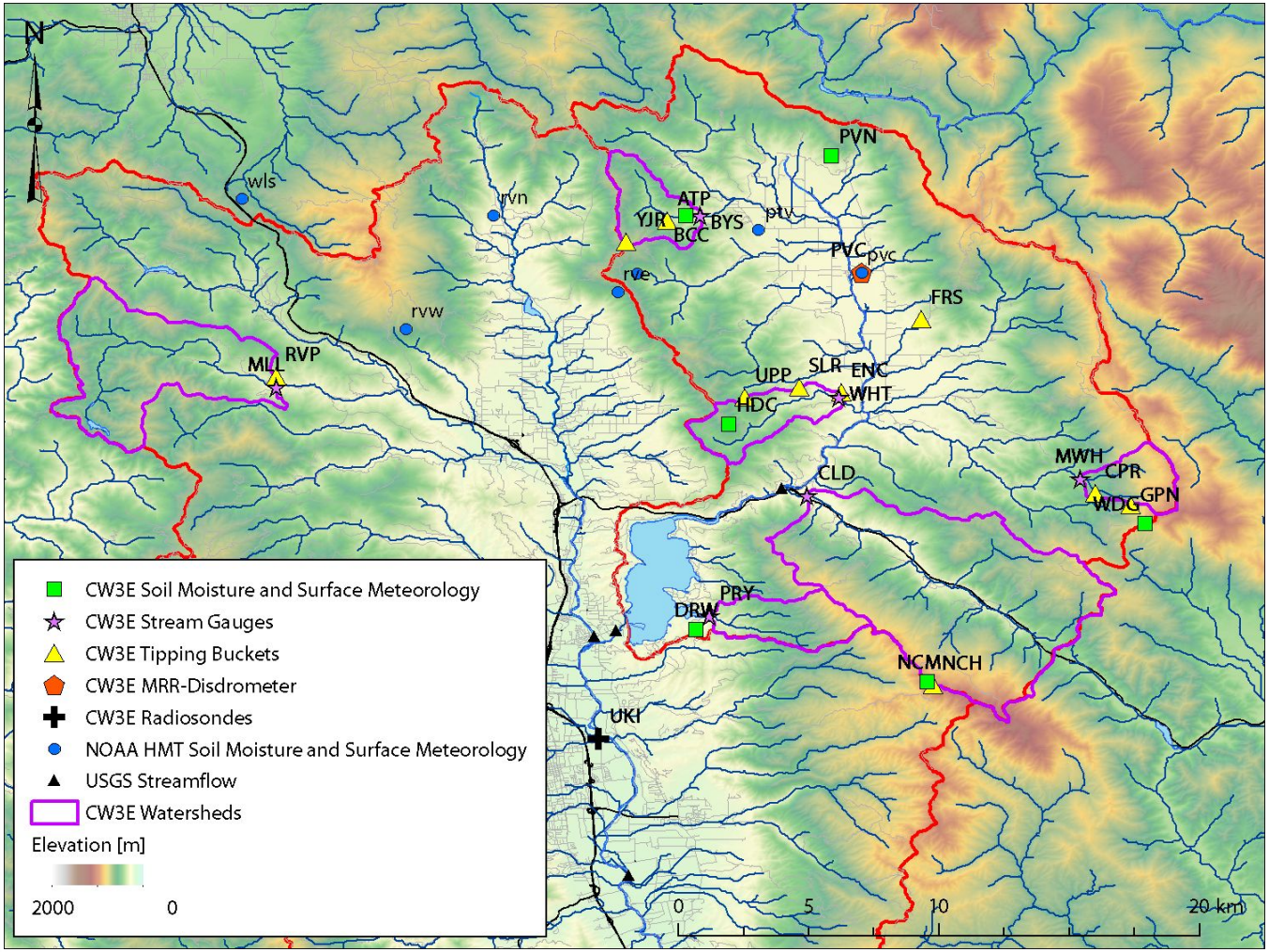
2-dimensional overland flow (event water)



2-dimensional groundwater flow (pre-event water)

Watershed modeling for the FIRO project separates event and pre-event water, so field measured data percentages of event and pre-event water would be helpful

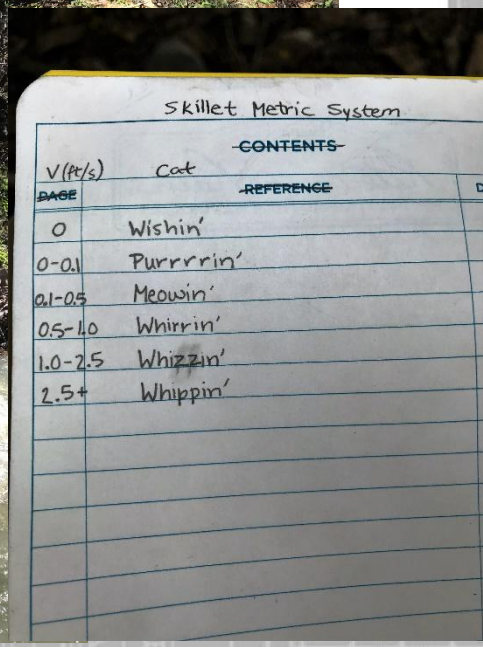
Russian River Valley Test Watershed Instrumentation



CW3E installed:

- 6 meteorological stations
- 6 soil moisture stations
  - Depths varying from 5 cm to 100 cm.
- 6 tributary streams gages
- 10 additional rain gages
- Augments 29 USGS gaging, 14 NOAA meteorology /soil moisture stations

Stream Flow Measurement and Water Sample Collection



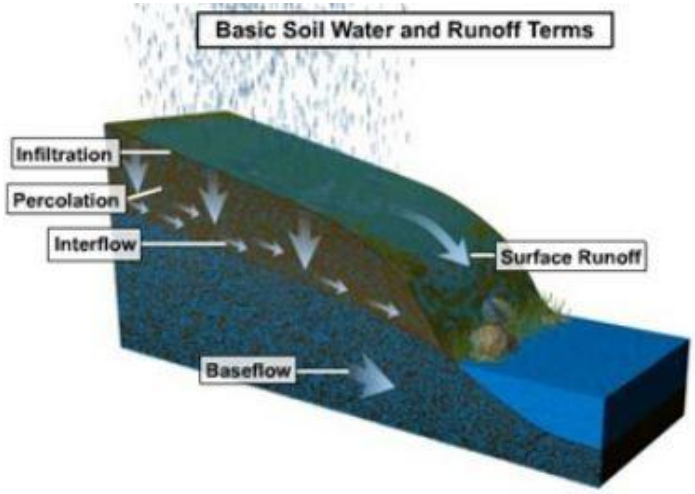
Hydrograph Separation Using Stable Isotopes and Natural Geochemistry

- Hydrograph separation previously done with graphical techniques
- Has resulted in major advances in catchment hydrology with occasional controversial conclusions:
  - Generally show much larger groundwater/soil water components
  - Stored, pre-rainfall event water dominated storm hydrograph even at peak flow in humid systems.

J. Klaus, J.J. McDonnell/Journal of Hydrology 505 (2013) 47-64

Isotope Hydrograph Separation Requires:

- Isotopic/geochemical content of event and pre-event water are different.
- Event water maintains a constant isotopic signature in space and time
- Isotopic/geochemical signature of soil water must be similar to that of groundwater.
- No surface storage (lakes)



from Tom Hopson, NCAR

Sampling Locations

- Streams (3 of 6 locations)

Large – East Fork of the Russian River

Medium – Cold Creek

Small - Boyes Creek

- Groundwater from Springs (8 locations)

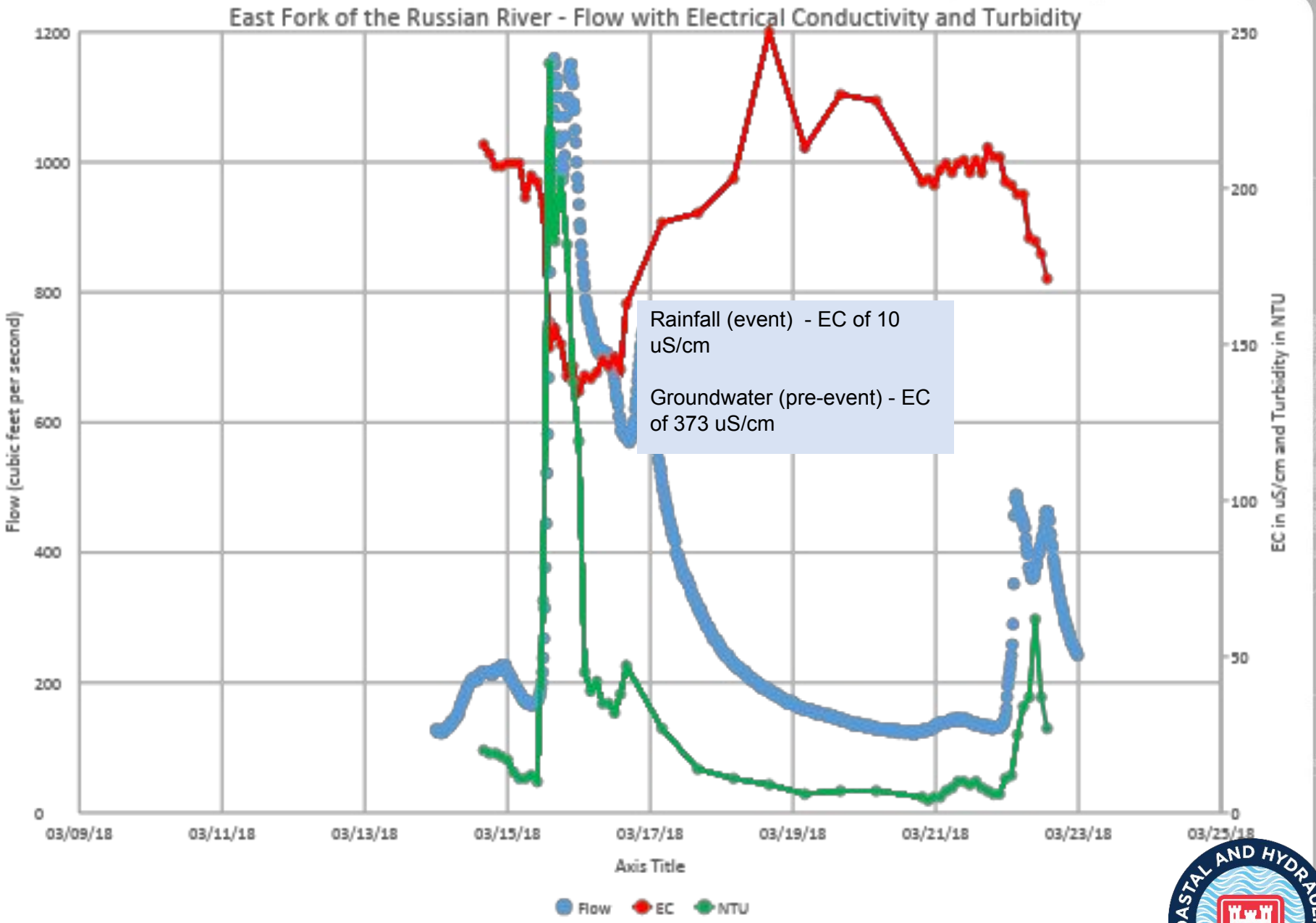
COASTAL AND HYDRAULICS LABORATORY

Anions and Cations Being Analyzed by Laboratory

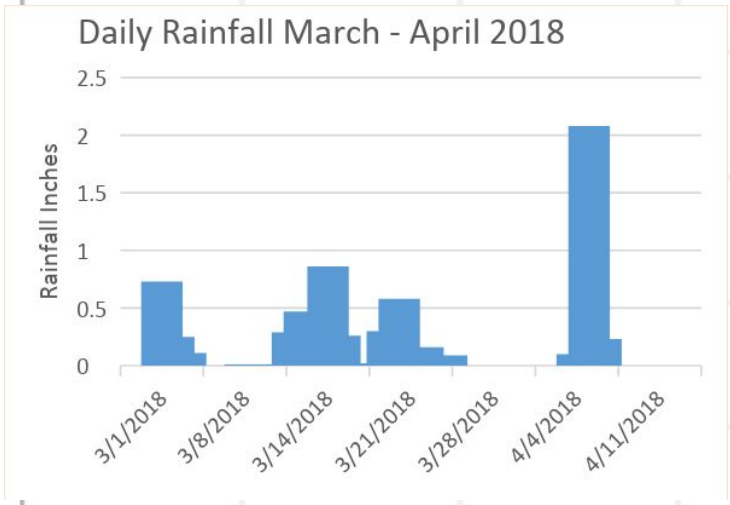
- Anions: Net - charge: carbonate, bicarbonate, chloride, fluoride, sulfate, phosphate, nitrate, silica

- Cations: Net + charge: calcium, magnesium, sodium, potassium, iron, manganese, Boron (sort of an cation).

In addition to Deuterium (^{2}H) and Oxygen-18

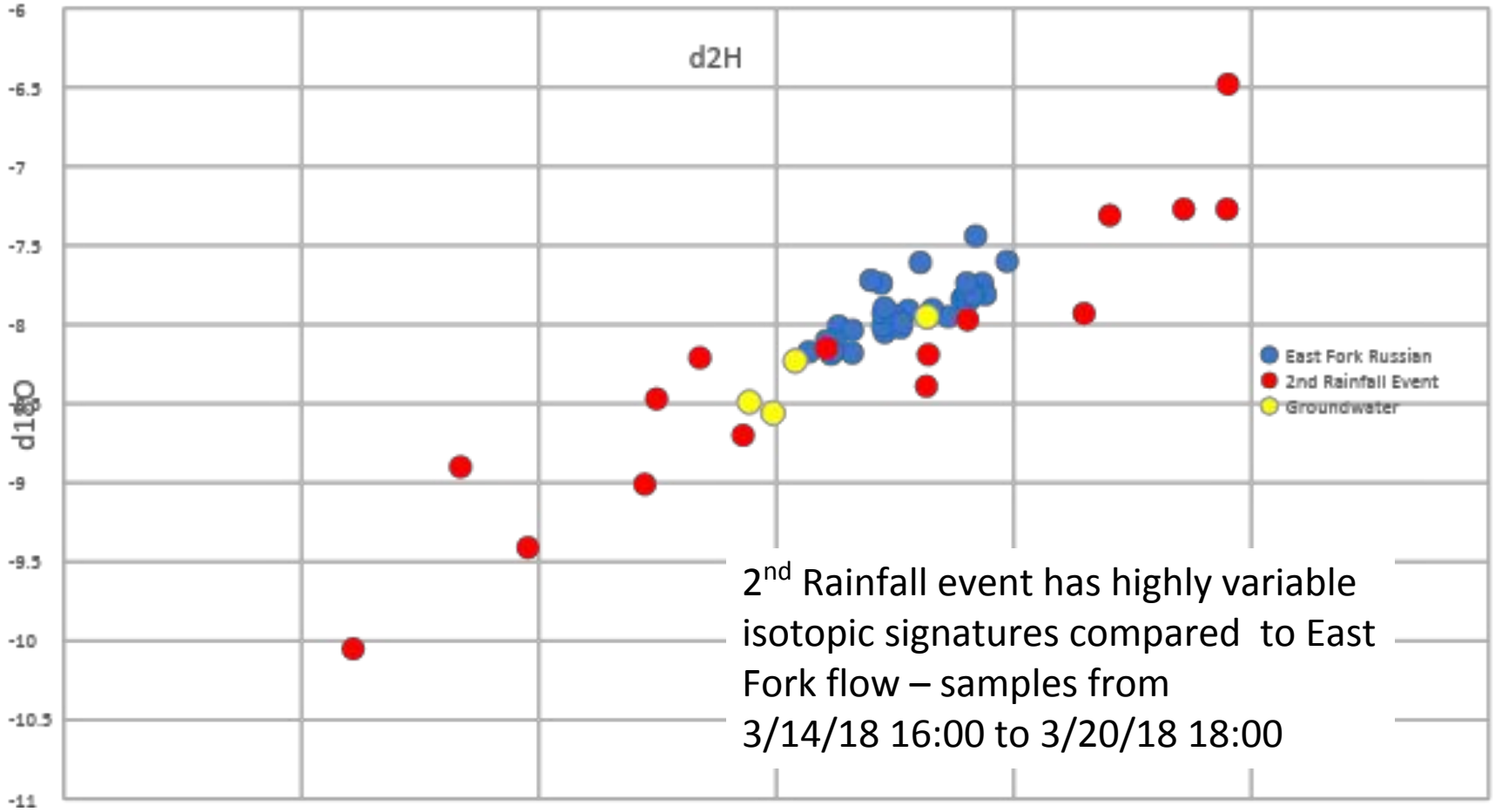

East Fork of the Russian River - Flow with Electrical Conductivity and Turbidity
Flow (cubic feet per second)
EC in uS/cm and Turbidity in NTU
1200
1000
800
600
400
200
0
250
200
150
100
50
0
03/09/18
03/11/18
03/13/18
03/15/18
03/17/18
03/19/18
03/21/18
03/23/18
03/25/18
Axis Title
Flow
EC
NTU
Rainfall (event) - EC of 10 uS/cm
Groundwater (pre-event) - EC of 373 uS/cm

Stable Isotopes in Rainfall (Event Water)

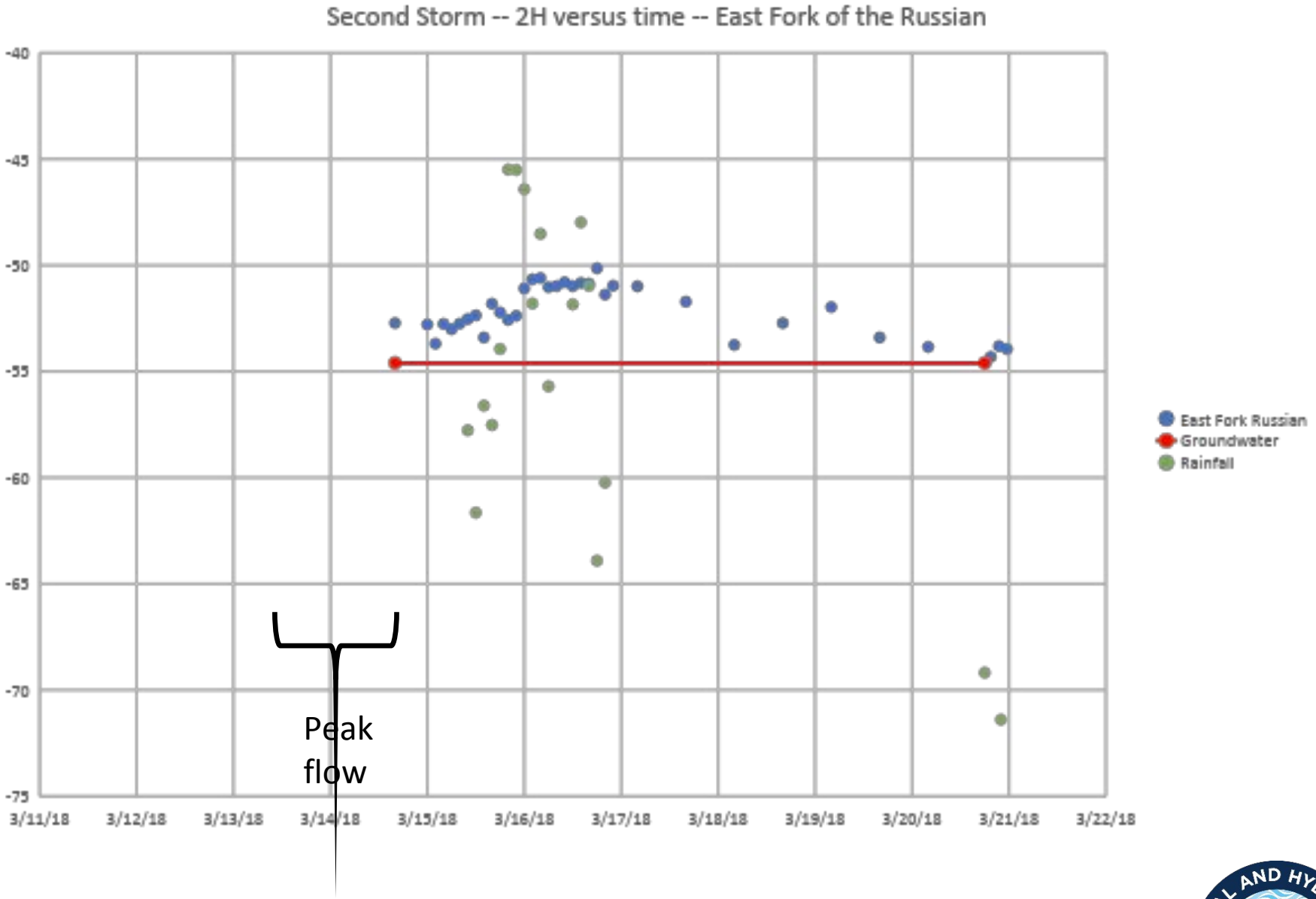


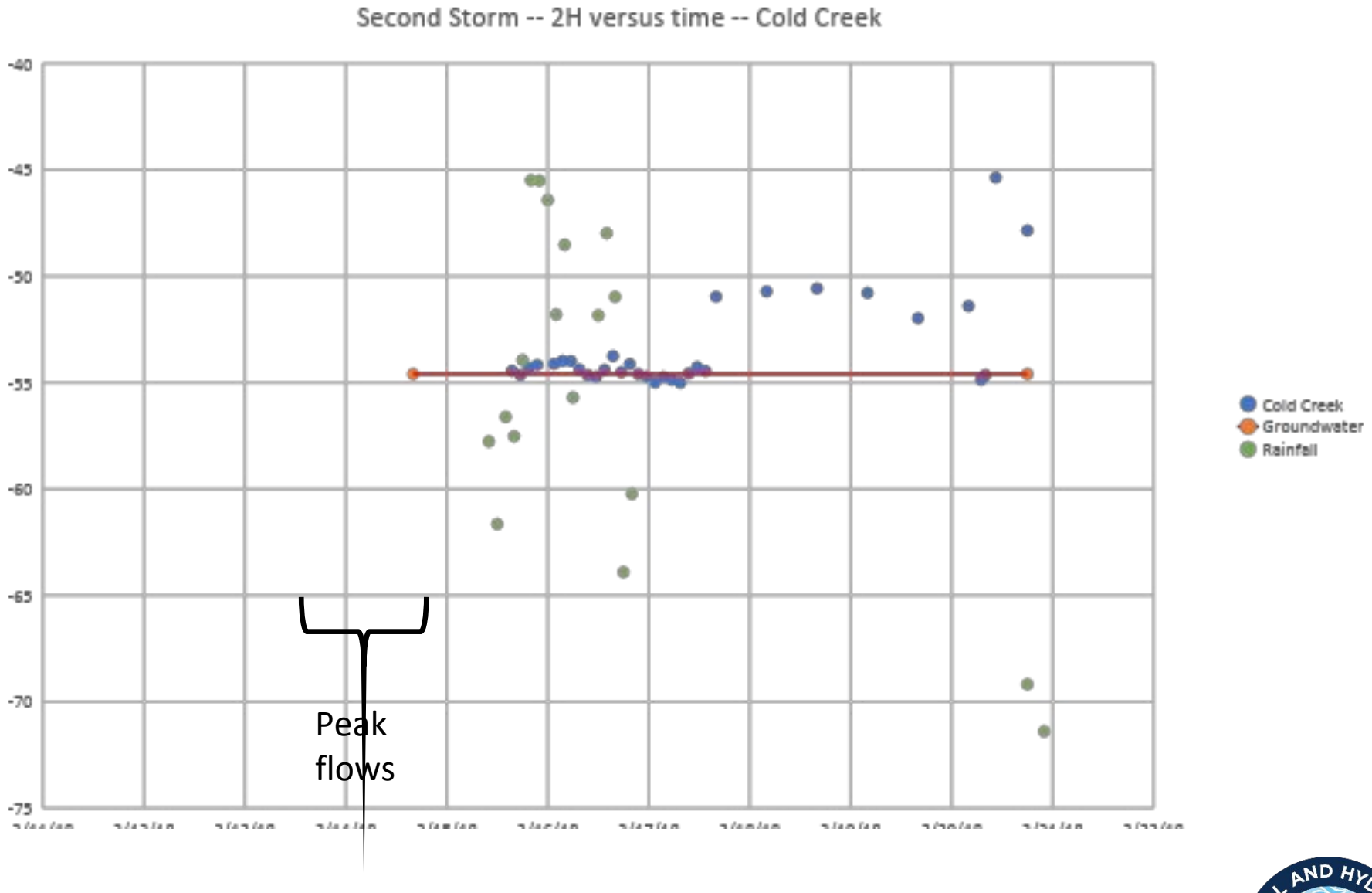
d^2H and $d^{18}O$ value are for the First, Second, Third and Fourth storms of March to April 2018

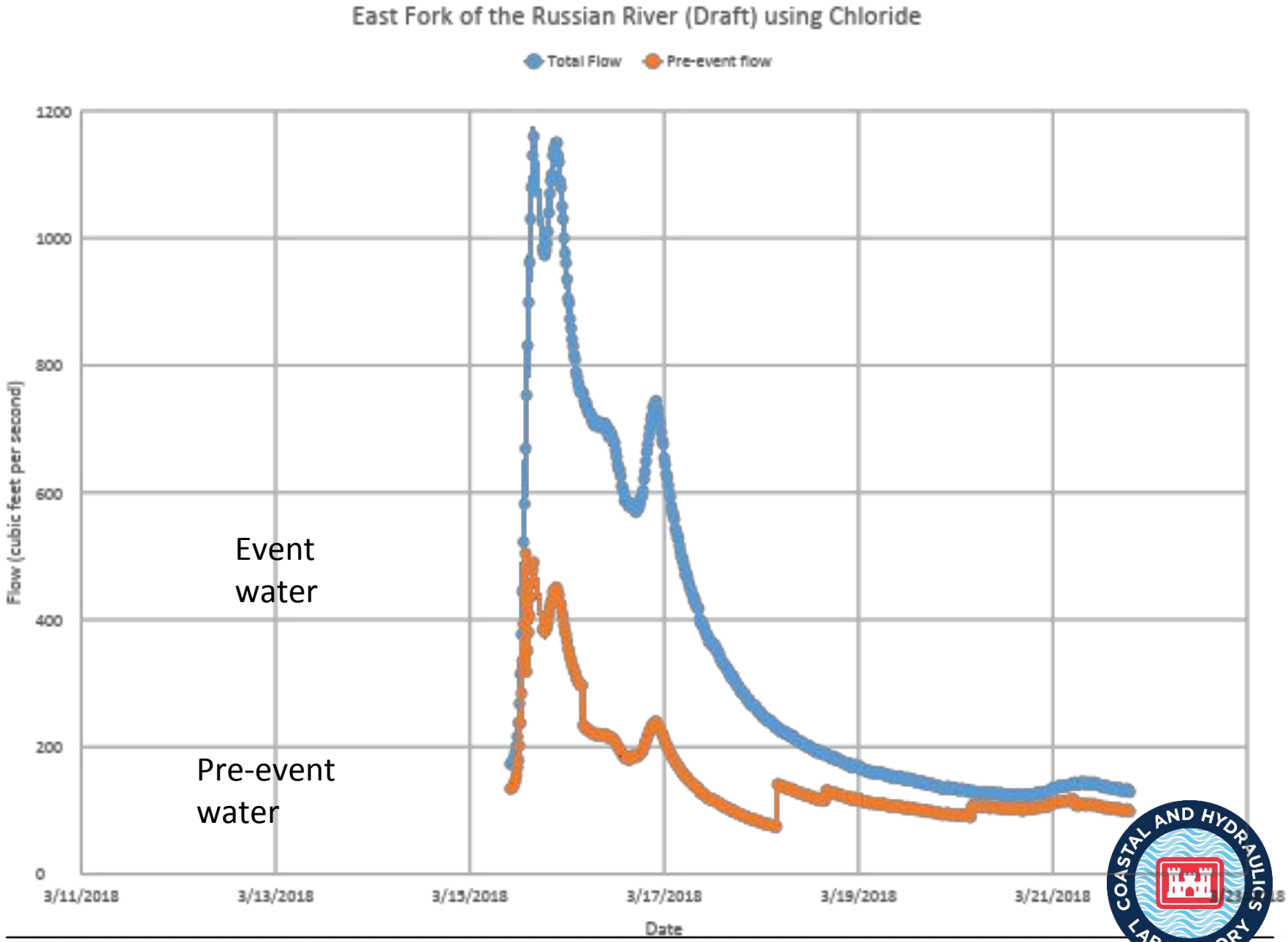
East Fork Isotopic Signatures Compared to Rain and Groundwater

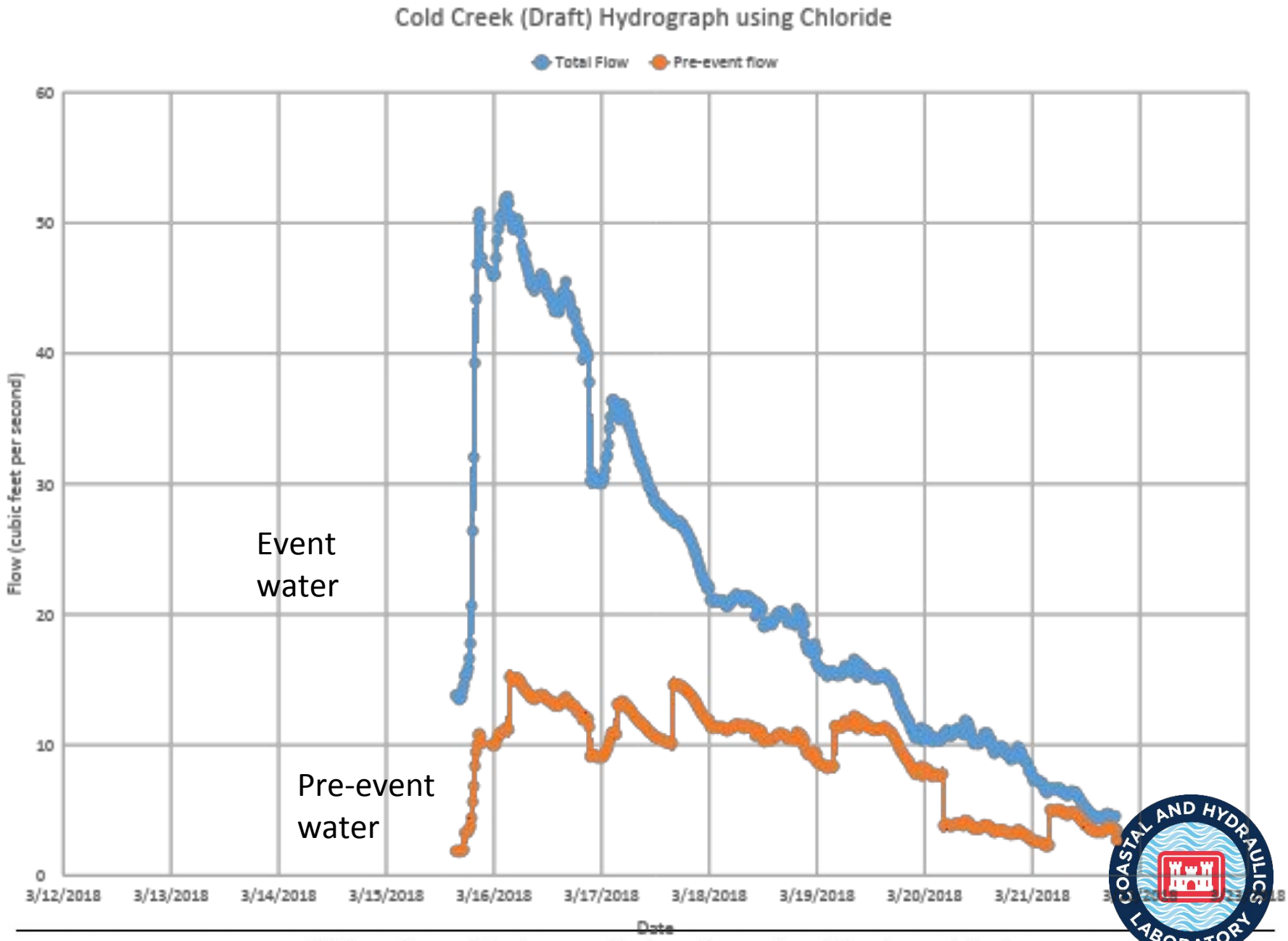


2nd Rainfall event has highly variable isotopic signatures compared to East Fork flow – samples from 3/14/18 16:00 to 3/20/18 18:00


Second Storm -- 2H versus time -- East Fork of the Russian
-40
-45
-50
-55
-60
-65
-70
-75
3/11/18
3/12/18
3/13/18
3/14/18
3/15/18
3/16/18
3/17/18
3/18/18
3/19/18
3/20/18
3/21/18
3/22/18
East Fork Russian
Groundwater
Rainfall
Peak flow


Second Storm -- 2H versus time -- Cold Creek
-40
-45
-50
-55
-60
-65
-70
-75
Peak flows
Cold Creek
Groundwater
Rainfall


East Fork of the Russian River (Draft) using Chloride
Total Flow
Pre-event flow
Flow (cubic feet per second)
1200
1000
800
600
400
200
0
3/11/2018
3/13/2018
3/15/2018
3/17/2018
3/19/2018
3/21/2018
Date
Event water
Pre-event water


Cold Creek (Draft) Hydrograph using Chloride
Total Flow
Pre-event flow
Flow (cubic feet per second)
60
50
40
30
20
10
0
3/12/2018
3/13/2018
3/14/2018
3/15/2018
3/16/2018
3/17/2018
3/18/2018
3/19/2018
3/20/2018
3/21/2018
Date
Event water
Pre-event water

Conclusions

- Rainfall/event water isotopic signatures are highly variable, and prevents calculation of event and prevent percentages or hydrograph separation at this time – some data are pending. This variability has been documented in ARs previously
- Calculation of hydrograph separation with natural geochemical constituents (such as chloride, EC) seems plausible
- Further analysis of isotope and geochemical data may allow for more accurate hydrograph separation
- Investigating use stable isotopes and natural geochemistry worth is an inexpensive method to gain further understanding of a watershed