The Use of R2Cross in Stream Management Planning Efforts: Practical Benefits and Limitations

River Network Stream Management Planning Peer Learning Workshop
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Overview

Diving into the details of the R2Cross methodology:

- Technical foundations and methodological background
- Data collection and flow threshold determination
- Use of outputs in planning processes

- R2Cross is one of many tools in use for characterizing relationships between streamflows and aquatic habitat quality
  - R2Cross, Wetted Perimeter, Tenet Method, 2D Habitat Suitability, etc.

- Understanding the details of the R2Cross methodology can help ensure that results produced in new locations are acceptable and defensible

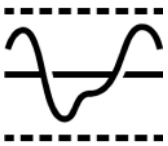
- Understanding limitations of R2Cross can help ensure that those results are used in an effective manner during planning and decision-making processes

Revisiting the last meeting...
Photo Courtesy Colorado Water Trust

Previously Covered E&R Assessment Techniques

1. Risk rating approaches based on hydrological alteration

2. Environmental flow threshold setting methodologies



3. Environmental response function development

4. Relating streamflow to recreational use opportunities

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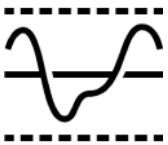

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Environmental flow threshold-setting

Use locally collected data to identify minimum or maximum flows necessary to support different environmental attributes. Examples include:

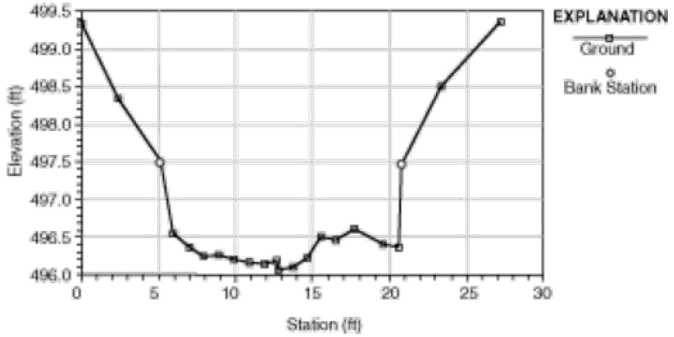
01 | Tennet Method: Minimum flows based on mean annual flows under natural conditions

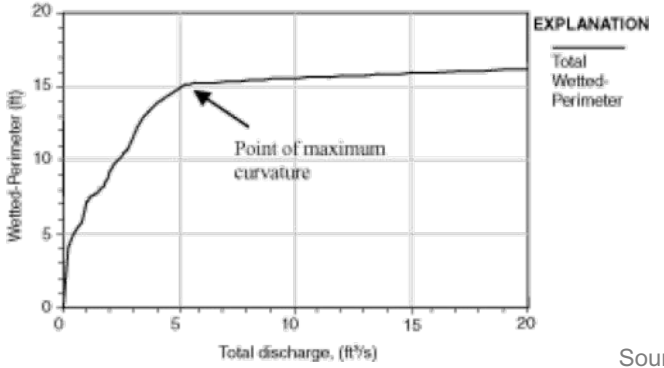
02 | R2Cross: Minimum flows based on channel geometry and hydraulic characteristics

03 | Wetted Perimeter: Minimum flow based on cross-sectional geometry and water depth

04 | Effective Discharge: regularly recurring flood flows based on channel geometry and sediment characteristics

Stream top width (ft)	Mean depth (ft)	Bankfull wetted perimeter (percent)	Mean velocity (ft/s)
1–20	0.2	50	1.0
21–40	0.2–0.4	50	1.0
41–60	0.4–0.6	50–60	1.0
61–10	0.6–1.0	> or equal to 70	1.0





Source: USGS

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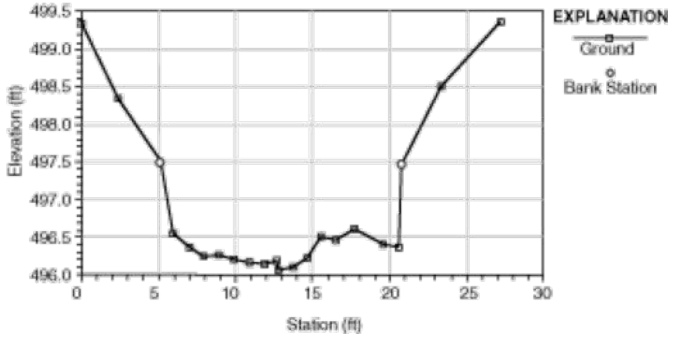

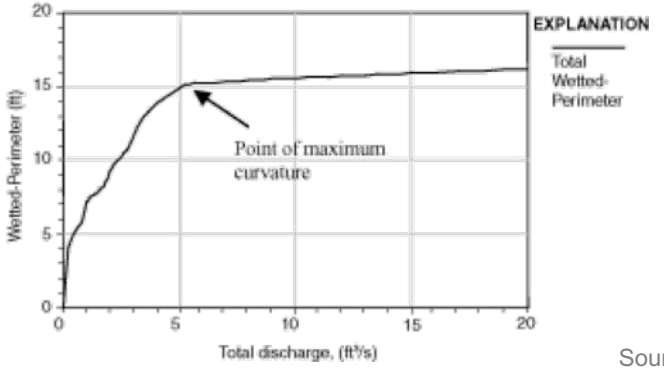

Source: USGS

Basic Assumptions of the R2Cross Methodology

1. Riffles are a critically important channel units for aquatic organisms (e.g. high macroinvertebrate production, spawning habitat)
2. During low flow periods, aquatic organisms' access to and/or ability to pass through riffles is limited before other channel units (i.e. pools, glides, runs)[1]
3. The ability of aquatic organisms to access and/or pass through a riffle is determined by water depth and velocity
4. Maintaining adequate streamflow in riffles also preserves the natural environment in other important stream habitat-types such as pools and runs[2]

[1] Espegren, G. 1996. Development of Instream Flow Recommendations in Colorado using R2Cross. Colorado Water Conservation Board.
[2] Nehring, R.B., 1979. Evaluation of instream flow methods and determination of water quantity needs for streams in the State of Colorado. Colorado Division of Wildlife, Fort Collins, CO.

Why use R2Cross instead of other approaches?

A **Time and Labor Efficient:** Requires minimal field data to conduct method in new locations. Results already exist for many streams in Colorado

B **Comparable Results**: Results found to be similar to those produced by more data-intensive methods like the Instream Flow Incremental Methodology[1]

C **Widespread Use:** Method is endorsed by CWCB and used as the basis for many instream flow water rights filings across Colorado (1970s – Present)

D **Available Tools:** Data collection forms, spreadsheets and web tools (r2cross.erams.com) exist to help users implement the method

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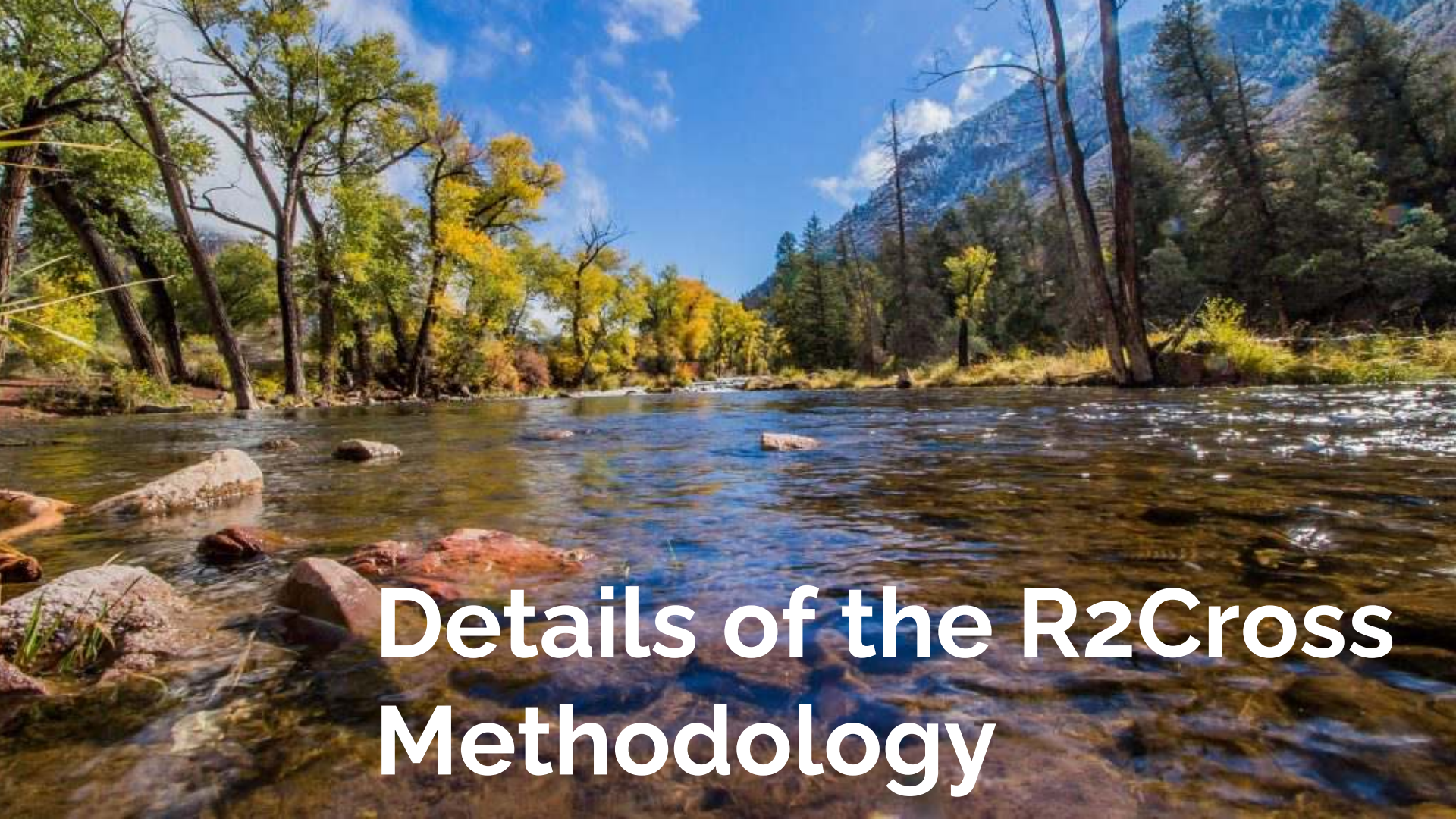


Details of the R2Cross Methodology

Reach Identification & Transect Selection

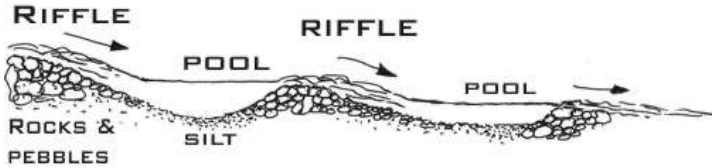
Identify one or more critical or representative riffles

01 | Channel hydraulics should not be impacted by downstream structures/channel characteristics

02 | Individual transect should reflect “typical” width, depth, slope characteristics of the riffle

03 | Avoid braided channels and areas with undercut banks

04 | Select at least 1 transect, 5 or more transects provides a better reach characterization



Hydraulic (& Biological) Data Collection

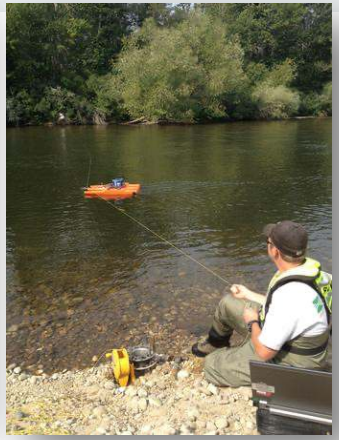
Characterize the geometric and hydraulic conditions at each transect

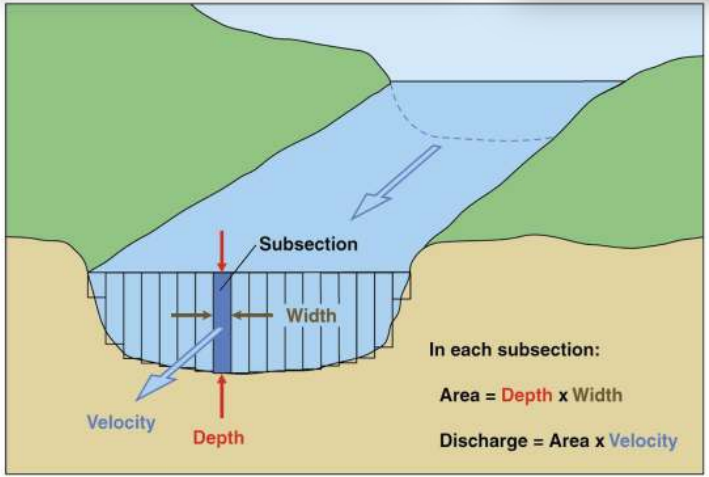
01 | Survey bed topography with optical level, sag-tape, total-station, RTK, or other means

02 | Measure water depth and velocity at multiple stations across the transect using velocimeter, ADCP, etc.

03 | Optional: collect particle size distribution sample using Wolman Pebble Count or sieve

04 | Optional: conduct/review fish survey or collect macroinvertebrate samples if appropriating ISF right





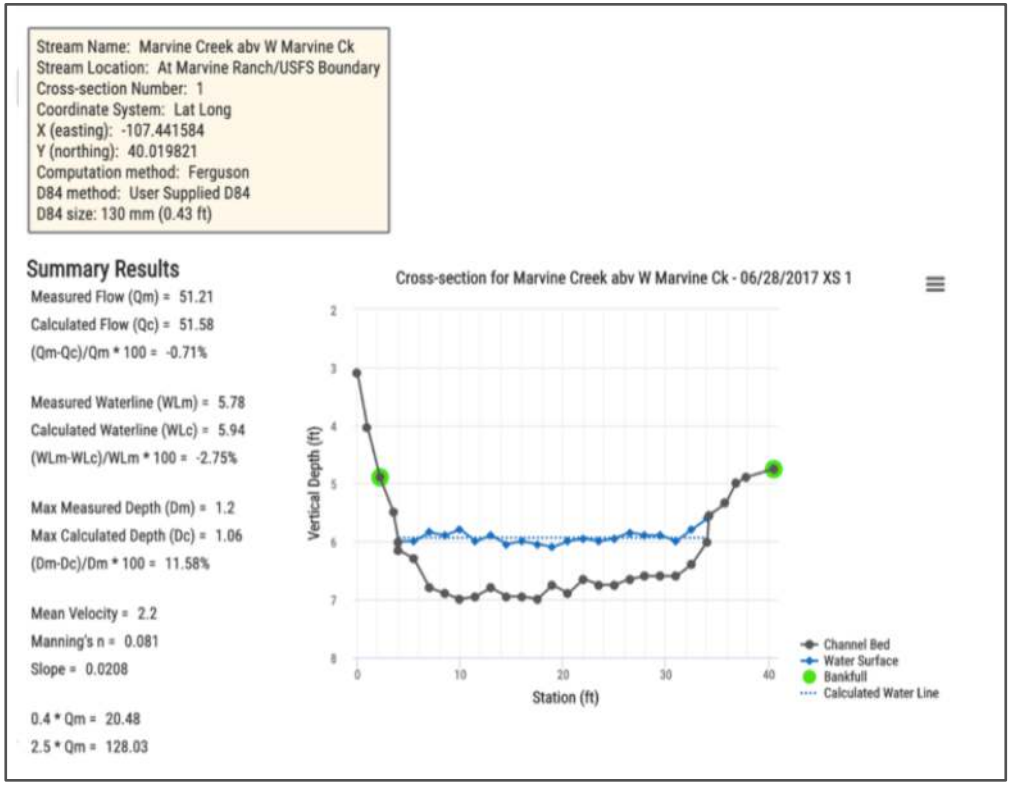
Hydraulic Modeling

Use hydraulic modelling approaches to estimate velocity and depth conditions at each transect across a range of stream flows

01 | If sediment data is available, calculate D84 and use Ferguson equation[1,2] to characterize hydraulics across a range of stream flows

02 | Otherwise, use Manning's equation to characterize hydraulic conditions across streamflows between 40-250% of the measured discharge.

03 | Create a table indicating the average water depth, average velocity, wetted perimeter associated with each simulated discharge



[1] Ferguson, R. 2010. Time to abandon the Manning equation? Earth Surface Processes and Landforms, 35(15), 1873–1876. https://doi.org/10.1002/esp.2091.
[2] Ferguson, R. 2013. Reach-scale flow resistance. In E. E. Wohl (Ed.), Treatise in Geomorphology: Vol. Volume 9: Fluvial Geomorphology (pp. 50–68). Amsterdam: Elsevier.

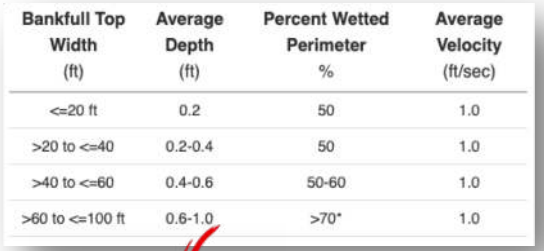
Threshold Setting

Use hydraulic modelling results and habitat criteria table from Nehring (1979) to identify threshold flows

01 | Use habitat criteria table from Nerhring[1] to identify the discharges that satisfy each condition

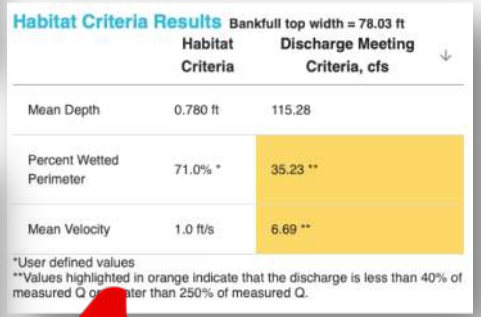
02 | Identify the flow where 2-of-3 criteria are satisfied: generally used to approximate winter minimum environmental flow

03 | Identify the flow where 3-of-3 criteria are satisfied: generally used to approximate summer minimum environmental flow



Bankfull Top Width (ft)	Average Depth (ft)	Percent Wetted Perimeter %	Average Velocity (ft/sec)
<=20 ft	0.2	50	1.0
>20 to <=40	0.2-0.4	50	1.0
>40 to <=60	0.4-0.6	50-60	1.0
>60 to <=100 ft	0.6-1.0	>70*	1.0

Top Width (ft)	Mean Depth (ft)	Maximum Depth (ft)	Area (SQ. ft)	Wetted Perimeter (ft)	Percent Wetted Perimeter	Hydraulic Radius (ft)	Mean Velocity (ft/s)	Discharge (cfs)
78.03	3.53	4.[illegible]	[illegible]	80.08	100.00%	3.44	6.63	1827.97
77.89	3.5	4.41	[illegible]	79.93	99.81%	3.41	6.6	1799.0
77.71	3.46	4.36	[illegible]	79.72	99.55%	3.37	6.55	1759.46
77.53	3.42	4.31	264.91	79.51	99.30%	3.33	6.49	1720.29
77.36	3.37	4.26	261.04	79.31	99.04%	3.29	6.44	1681.5
77.18	3.33	4.21	257.17	79.1	98.78%	3.25	6.39	1643.08
77.0	3.29	4.16	253.32	78.89	98.52%	3.21	6.34	1605.04
76.82	3.25	4.11	249.47	78.69	98.27%	3.17	6.28	1567.38
76.64	3.21	4.06	245.64	78.48	98.01%	3.13	6.23	1530.09
76.46	3.16	4.01	241.81	78.27	97.75%	3.09	6.18	1493.18
76.28	3.12	3.96	237.99	78.07	97.49%	3.05	6.12	1456.[illegible]
76.1	3.08	3.91	234.18	77.86	97.23%	3.01	6.07	1420.51
75.92	3.03	3.86	230.38	77.65	96.98%	2.97	6.01	1384.75
75.74	2.99	3.81	226.59	77.45	96.72%	2.93	5.96	1349.37
75.56	2.95	3.76	222.81	77.24	96.46%	2.88	5.9	1314.38
75.38	2.91	3.71	219.04	77.04	96.20%	2.84	5.84	1279.77



Habitat Criteria Results Bankfull top width = 78.03 ft

	Habitat Criteria	Discharge Meeting Criteria, cfs
Mean Depth	0.780 ft	115.28
Percent Wetted Perimeter	71.0% *	35.23 **
Mean Velocity	1.0 ft/s	6.69 **

*User defined values
**Values highlighted in orange indicate that the discharge is less than 40% of measured Q or [illegible]ater than 250% of measured Q.

[2] Nehring, R.B., 1979. Evaluation of instream flow methods and determination of water quantity needs for streams in the State of Colorado. Colorado Division of Wildlife, Fort Collins, CO.

Use of Flow Targets in Planning Processes

Existing Water Supply Deficits

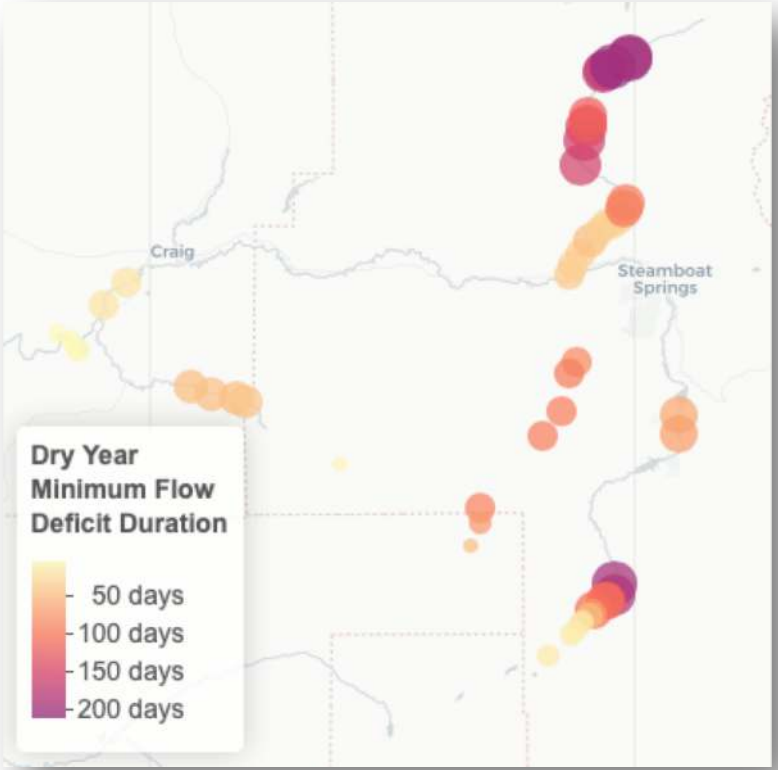
Where environmental and/or recreational use needs are stated as flow thresholds, water supply deficits can be computed across year types.

01 | Can be assessed in units of volume (acre feet) and/or duration (days).

02 | Useful approach for computing needs against ISF water rights

03 | Relative differences between reaches can help set geographic priorities

04 | Computed deficit volumes can be used to inform discussions (e.g. augmentation or water leasing)



Predicted Change Under Future Scenarios

Scenarios may be based on expected future projections of streamflow, climate, and/or infrastructure

01 | Colorado Water Plan Technical Update provides 5 scenarios for water supply planning

02 | Environmental thresholds can be assessed against typical flow conditions across scenarios on a given reach

03 | Outputs can help identify locations, year types, or times of year when certain attribute are at greatest risk

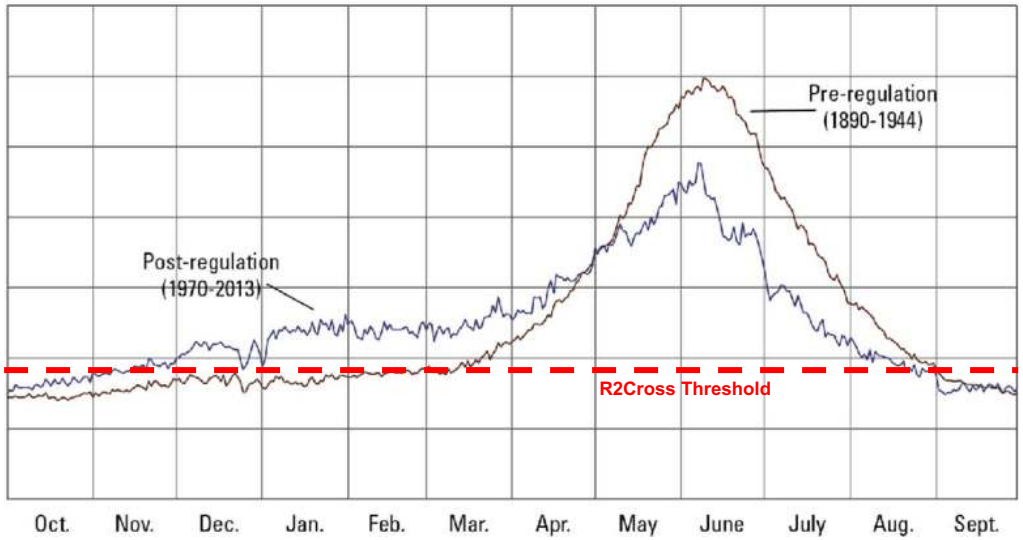
Evaluation of Specific Actions

The effect of specific management strategies or projects might be measured against R2Cross flow thresholds

01 | Characterize the expected impact of the project or management strategy on streamflows

02 | Compute the change in the number of days when 3-of-3 criteria or 2-of-3 criteria are met due to project

03 | Compute the changes in the volumetric water supply gap measured against the flow threshold(s) due to project



Important Considerations: Heuristic not Panacea

- ✓ R2Cross is intended as a method for identifying the **minimum**--not optimum--streamflows necessary for protecting aquatic life
- ✓ No guarantee that managing flows to the identified thresholds will preclude undesirable changes to the aquatic ecosystem
- ✓ Many other characteristics of flow (peak flows, rates of recession, inter-seasonable variability) are important to aquatic life and are not considered by this method
- ✓ Numerous non-flow characteristics (water quality, riparian condition, stream temperature, etc.) may limit aquatic ecosystems before flows do on some stream reaches

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