Representation of Vegetation in Two-Dimensional Hydrodynamic Models in both Laboratory and Field Applications

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USGS
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TETRA TECH

Agenda

How do we identify roughness in hydrologic modeling?

- Past
- Present
- Future

- What data do we need to collect today to answer tomorrow’s questions?

Past….and Present

For the past 130 years, Manning's roughness coefficients have been selected from published tables of generalized datasets using professional judgment.

214 *GENERAL FORMULA FOR UNIFORM FLOW OF WATER.* *TABLES FOR PRACTICAL USE.* 215

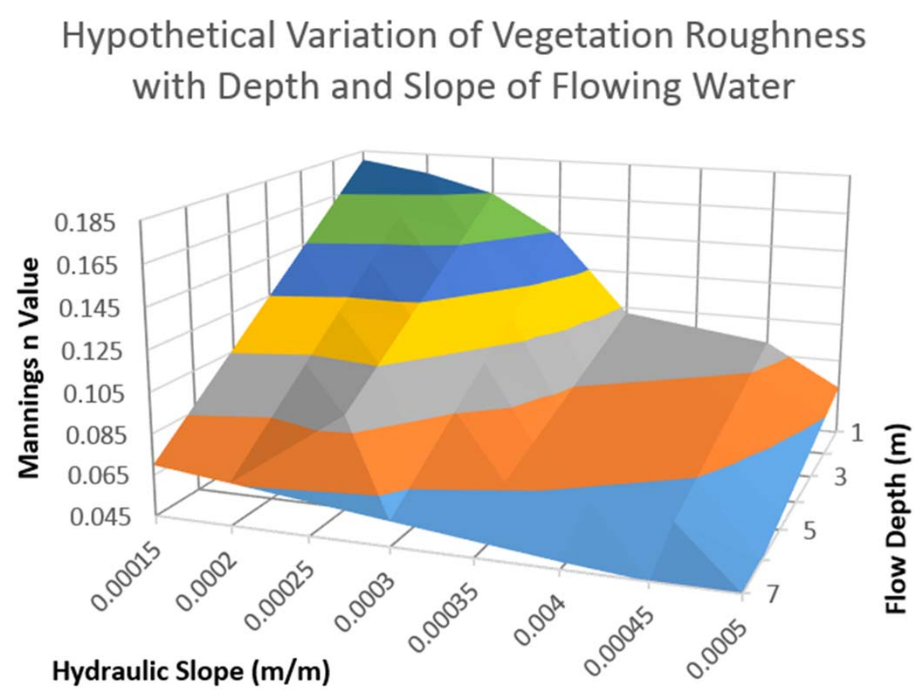
Class B. Open Channels, Creeks, and Rivers.

Location and Description of Channel. Method of Gauging.	Authority.	Author's No. of Series.	Surface Width in Feet.	Greatest Depth in Feet.	Mean Hydraulic Radius in Feet, R	Slope of Water Surface per Thousand, $1000\,S$	Mean Velocity per Second in Feet, v	Coefficient, in Formula $v = c\sqrt{RS}$, c	Coefficient of Roughness, n
Rivers and Canals, more or less Irregular, with Detritus, Vegetation, or other Obstructions—Continued.									
Seine at Meulan, Triel, and Poissy. Floats used in all experiments, except Nos. 2 and 4, for which current meter was taken. Experiments Nos. 1 and 2 at Meulan; Nos. 3 and 4 at Triel; remainder at Poissy. Reaches fairly regular.	Bonnet. Experiments under the direction of M. Emmery, 1852–3. (See Darcy and Bazin.)	1 2 3 4 5 6 7 8 9			7.10 7.68 11.24 12.43 13.57 14.20 15.86 16.85 17.87	0.090 0.087 0.057 0.060 0.050 0.054 0.062 0.067 0.075	2.310 2.313 2.362 2.359 2.372 2.595 2.910 3.101 3.330	91.3 89.5 93.3 86.4 91.1 93.6 92.7 92.4 91.1	.0236 .0245 .0263 .0295 .0287 .0278 .0285 .0288 .0293
Rhine at Flurlingen, above the Rhine Falls. Reach slightly irregular. Bed of gravel. Channel near left bank. Water turbid at time of gauging. Current meter.	Epper, 1887.				6.732	0.1573	2.965	91.8	.0226
Rhine at Noll, below the Rhine Falls. Reach fairly regular. Bed of gravel, with occasional boulders; shallow near shores. Water turbid at time of gauging. Current meter.	Do.				7.00	0.1618	2.834	84.2	.0250
Rhine at Bâle (near the bridge). Coarse detritus, coarse gravel. Current meter.	Grebenau, 1867.				6.89 6.89	0.928 1.218	6.363 6.380	79.6 69.7	.0259 .0300
Rhine at Germersheim. Fine detritus and gravel. Current meter.	Do.	1 2 3			10.85 12.11 17.27	0.247 0.307 0.349	5.051 5.215 6.101	97.2 85.4 78.7	.0230 .0265 .0303
Rhine at Neuburg. Detritus.	Quoted by Kutter.				13.91	0.391	5.838	78.9	.0297
Rhine at Pforz. Detritus.	Do.				13.94	0.357	5.642	79.8	.0294
Rhine at Speyer. Fine detritus and gravel. Current meter, at a large number of points.	Strauss. (Grebenau, "Zusätze," etc.)		1440		9.72	0.112	2.909	88.0	.0258

Ganguillet and Kutter, 1889

The Future!

There is a need for a fundamental change in the way roughness coefficients are understood and applied to better describe the complex interactions of vegetation with flowing water.



Recent Laboratory Flume Research

- UC Davis Flume Study (2009)
- Hydraulic roughness decreases with increasing velocity

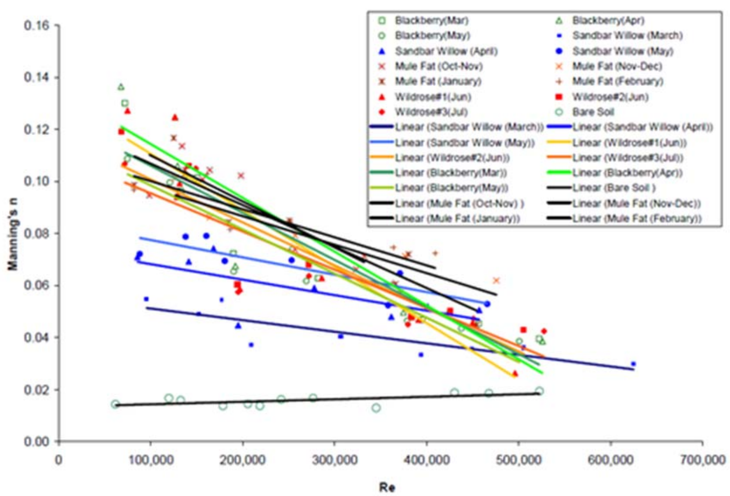
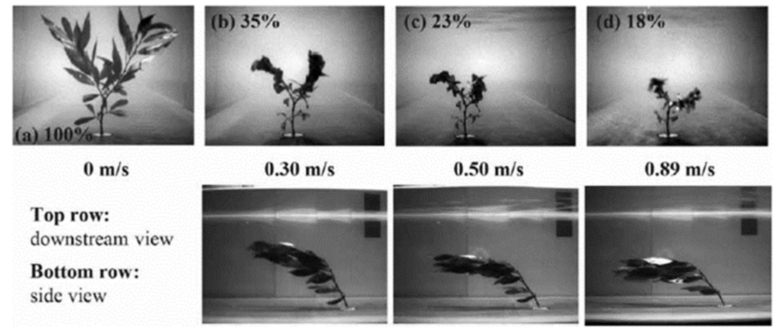


Figure 50 - Manning's roughness coefficient as function of Reynolds number under various California native riparian vegetation canopy conditions



From: Schoneboom (2011) and Aberle and Jarvela (2013)

- Projected area of plant decreases with increasing flow velocities.
- Percentages are the Projected Area vs. Full Area at No Flow
- Streamlining reduces drag and flow resistance.

Comparison of Methods to Estimate the Hydraulic Roughness of Vegetation (Shields, Coulton, Nepf, 2017)

- For all methods, roughness generally increases with increasing depth for emergent conditions, then decreases or remains constant for submerged conditions.
- One cause of variation likely due to methods derived from field measurements vs. laboratory flume studies.
- For flexible methods, results begin to converge where h/H > 0.8.

Rigid Vegetation

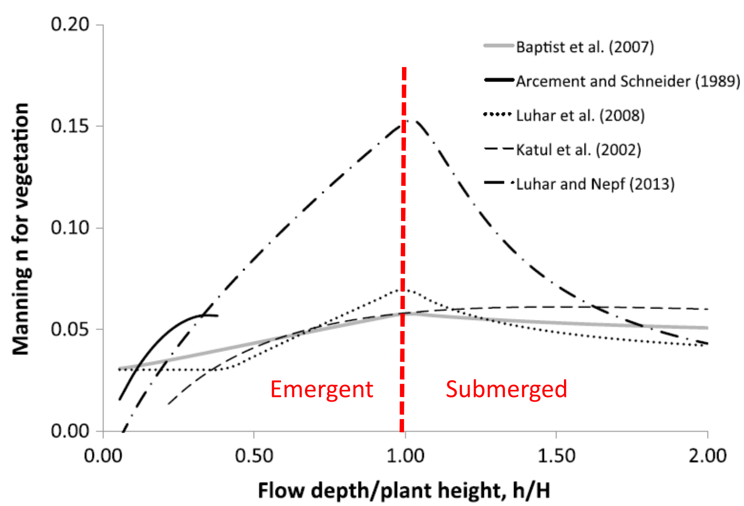


Fig. 4. Comparison of Manning *n*-values for flow through rigid vegetation computed using five approaches

Flexible Vegetation

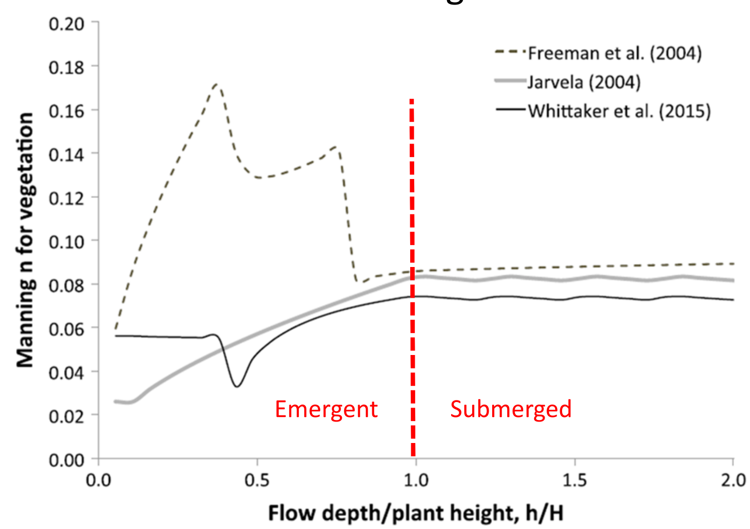


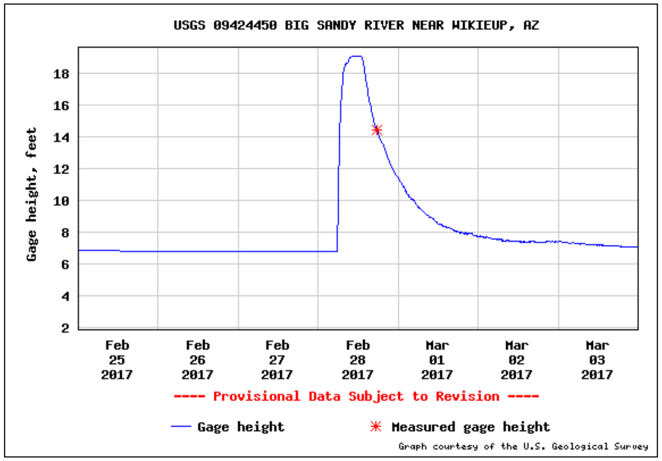
Fig. 5. Comparison of Manning *n*-values for flow through flexible vegetation computed using three approaches

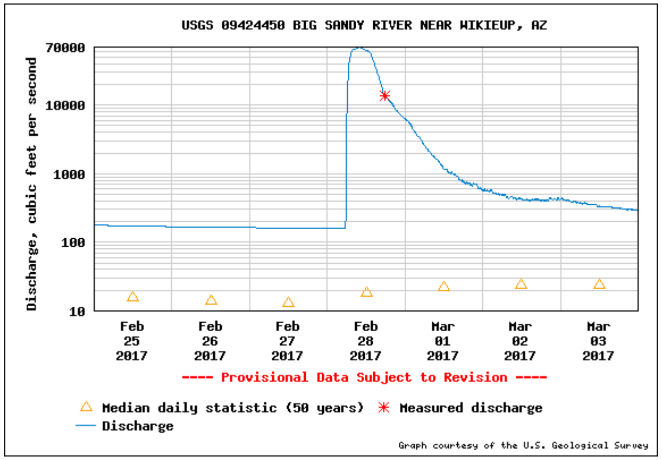
Reach Monitoring at Gages with Changing Channel Conditions

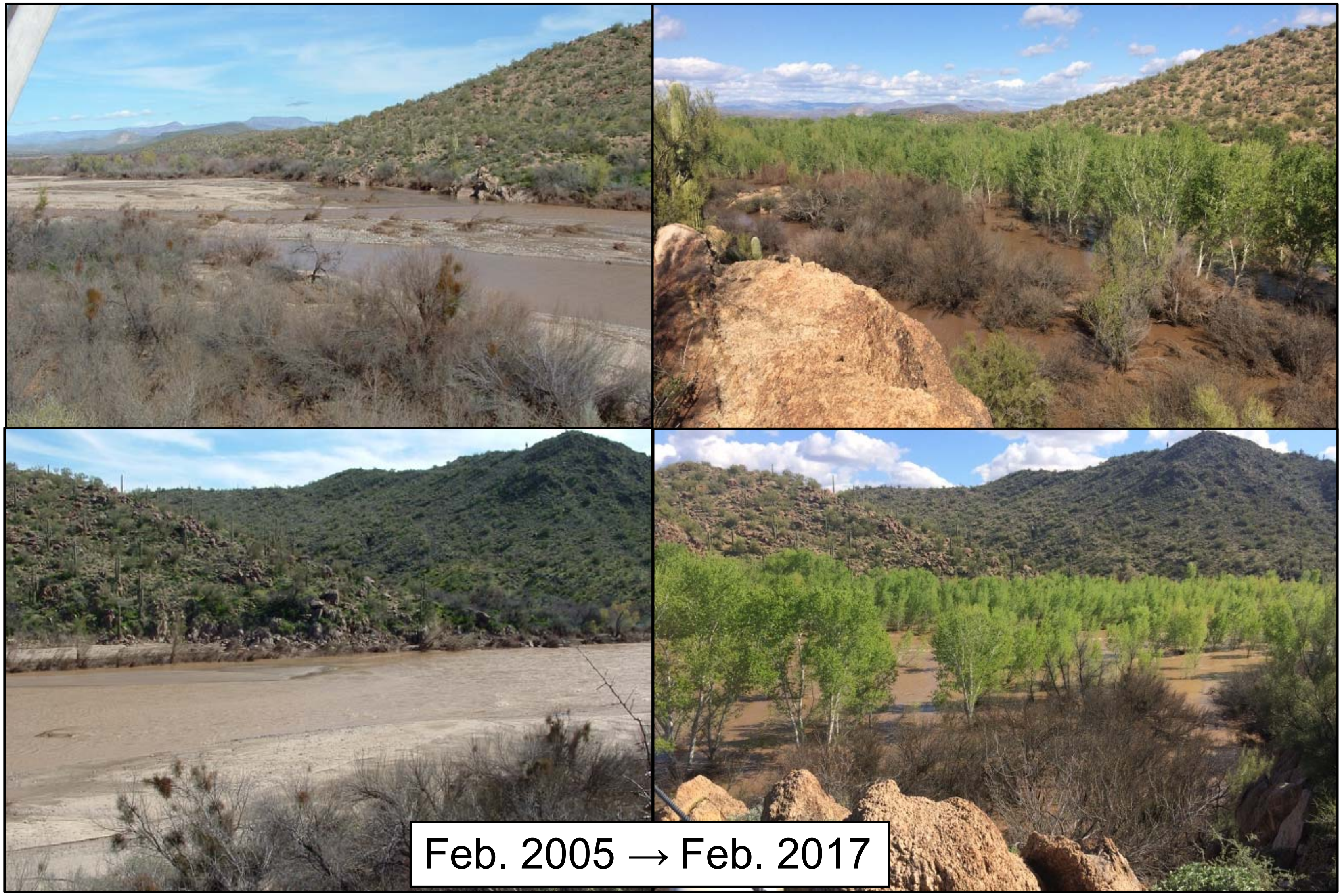
Impacts of changes in vegetation on gage calibration

09424450 – Big Sandy River near Wikieup, AZ

- February 28th, 2017 flow event:
- Caused by a wide spread winter storm.
- Gage height and discharge on NWIS-Web.






Feb. 2005 → Feb. 2017

Reach Monitoring at Gages with Changing Channel Conditions

Impacts of changes in vegetation on gage calibration

- **Lack of large flow events has allowed vegetation to propagate and thrive.**
- **Caused the channel to have a much lower conveyance and resulted in our rating computing a much higher discharge value than reality.**

Reach Monitoring at Gages with Changing Channel Conditions

Impacts of changes in vegetation on gage calibration

February 28th, 2017 Flow Event

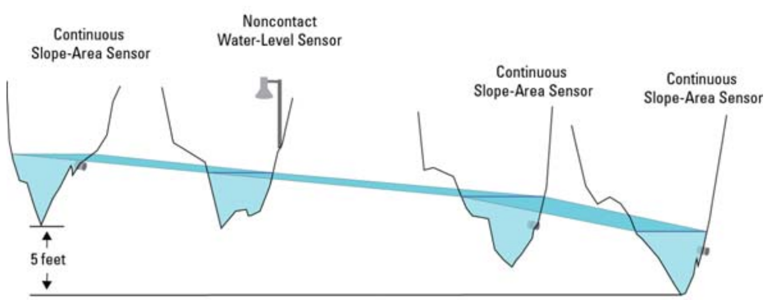
- **Indirect discharge measurement with Leica GPS equipment.**
- **Calculated 28,000 ft^3/s vs. 70,000 ft^3/s computed with current rating.**

What is Reach-Scale Monitoring?

Thinking beyond the cross section

Application of new and existing methods and technologies to:

- **Monitor channel change, including vegetation**
- **Verify Manning's n**
- **Continuously measure water surface profiles**
- **Measure surface velocity**
- **Develop and calibrate 2D models**



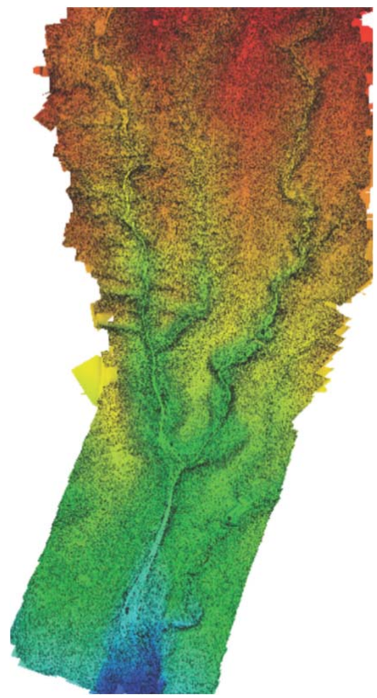
What is Reach-Scale Monitoring?

Thinking beyond the cross section

Reach-Scale Monitoring methods and technologies:

Thinking beyond the cross section

- **Topography!**
- **Indirect measurements of discharge**
- **Continuous slope-area method**
- **Gaging water surface profiles**
- **Surface velocity**
    - **Non-contact velocity sensors**
    - **Particle tracking**
- **3D land surface models**
    - **Ground-based LiDAR**
    - **Air-based photogrammetric surveys**
- **2D modeling**

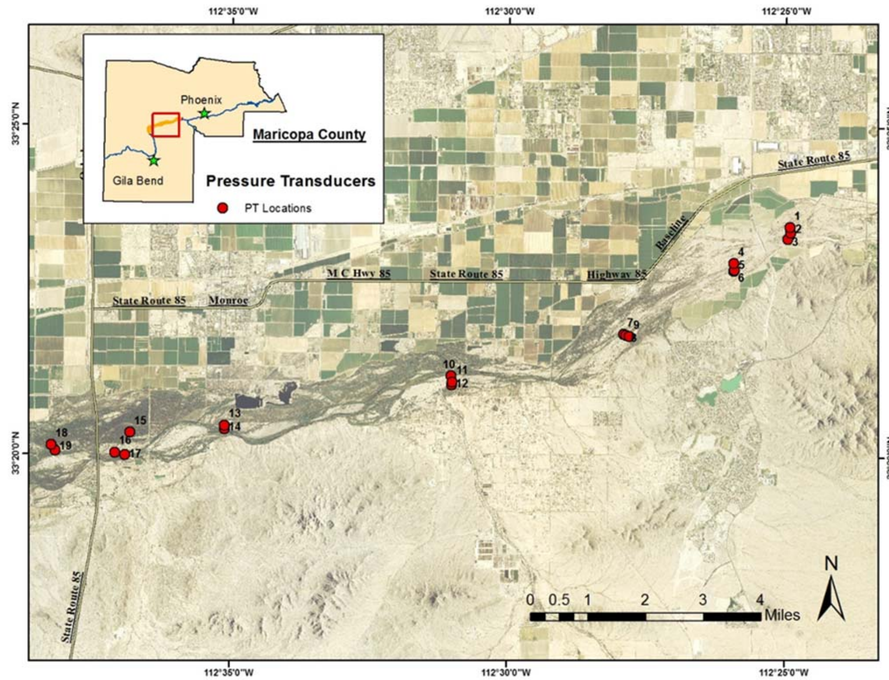


Reach Monitoring for n-Verification

Quantifying vegetation properties affecting conveyance

Gila River downstream from Estrella Parkway, near Goodyear, AZ

- Drainage area = 45,585 mi^2 (highly regulated).
- Streamgage at Estrella bridge (09514100).
- Seventeen mile study reach.
- Extensive and thick stands of tamarisk (salt cedar) with some non-vegetated areas.



Objectives are to quantify:

- Manning's n values,
- vegetation properties affecting conveyance,
- and Manning's n as it varies throughout the hydrograph.

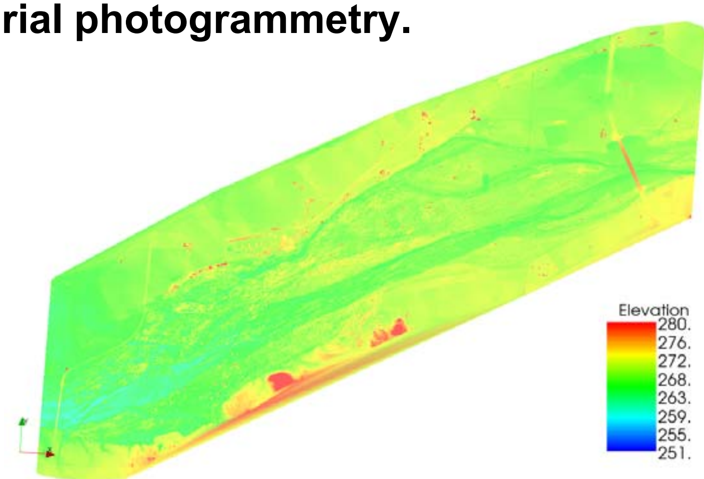
Reach Monitoring for n-Verification

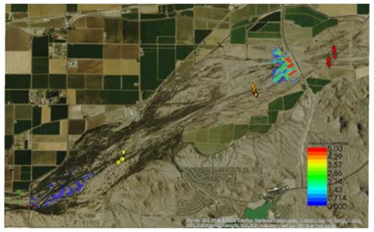
Quantifying vegetation properties affecting conveyance

Gila River downstream from Estrella Parkway, near Goodyear, AZ

Prior to flow event:

- **Water surface profile sensors.**
- **Tilt sensors.**
- **Aerial photogrammetry.**



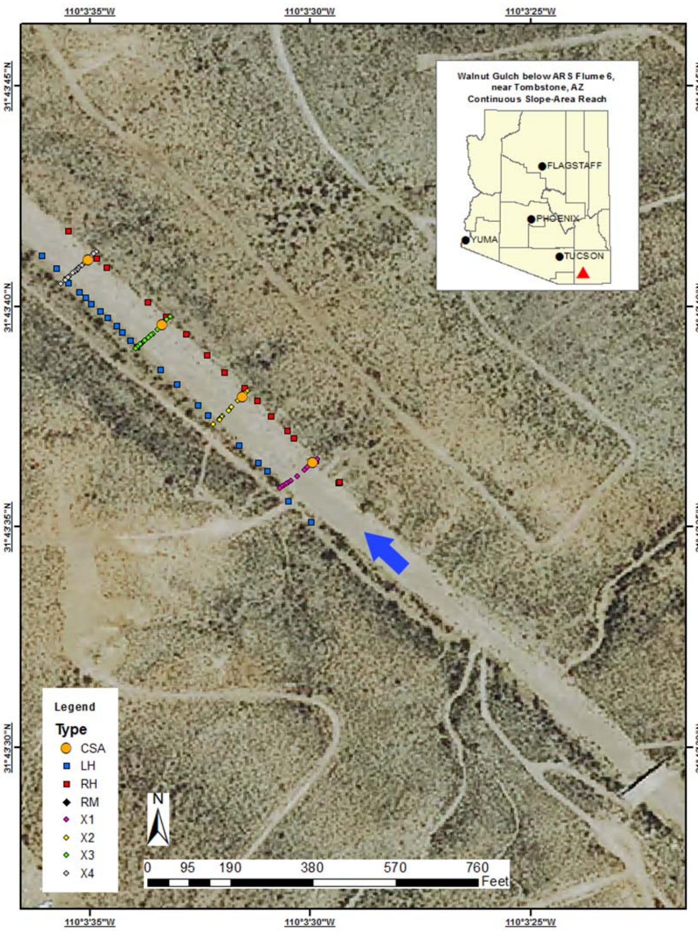


Reach Monitoring Experiment

Testing methods with known discharges

Walnut Gulch Experimental Watershed

- **Reaches instrumented at two ARS flumes**
- **Four water-surface profile sensors at each flume**
- **Flumes provide known discharge during events**



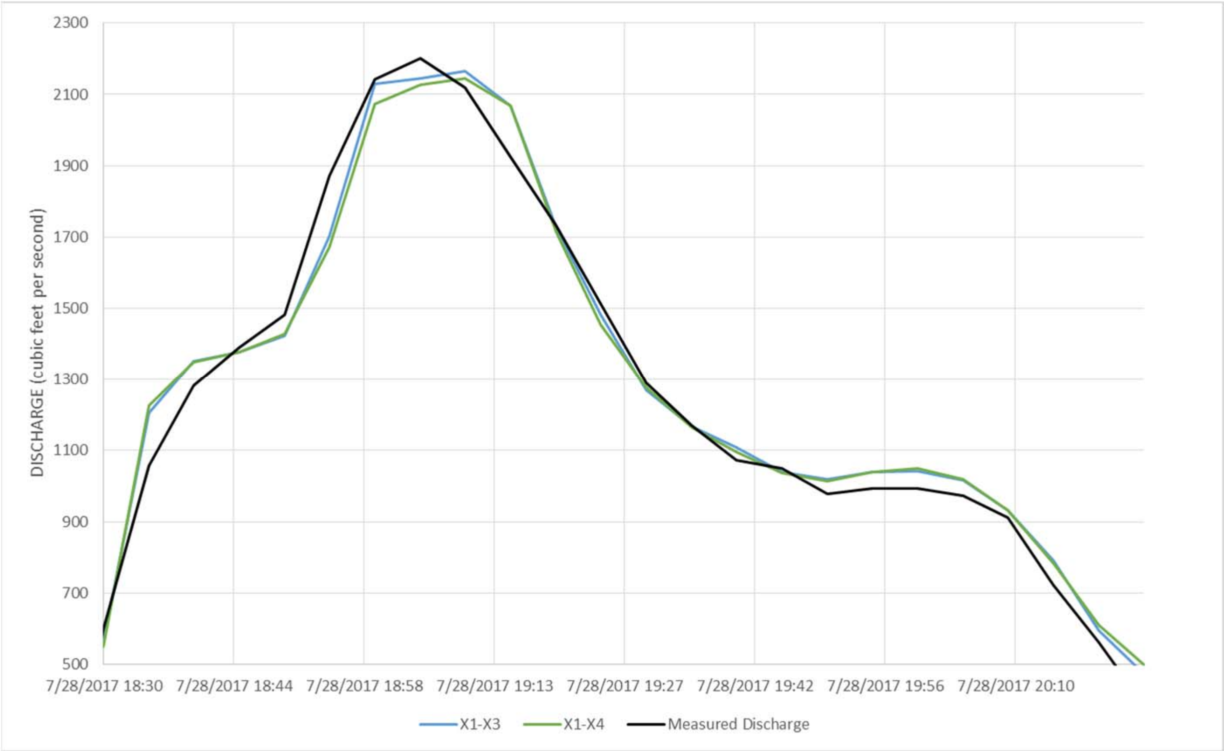
Reach Monitoring Experiment

Testing methods with known discharges

Walnut Gulch Experimental Watershed

<u>**Largest event of the year**</u>

- **July 28, 2017**
- **Indirect measurement of 2,310 cfs**
- **2,200 cfs measured at Flume 6**
- **Verified n-value of 0.030**



Reach-Scale Monitoring

Current surface water network

09382000 - Paria River at Lees Ferry, AZ

09424580 - Upper Little Sycamore Wash near Bagdad, AZ

09424600 - Little Sycamore Wash near Bagdad, AZ

09470700 - Banning Creek near Bisbee, AZ

09470800 - Garden Canyon near Fort Huachuca, AZ

09471310 - Huachuca Canyon near Fort Huachuca, AZ

09486800 - Altar Wash near Three Points, AZ

09488650 - Vekol Wash near Stanfield, AZ

09502800 - Williamson Valley Wash near Paulden, AZ

09512800 - Agua Fria near Rock Springs, AZ

09513780 - New River near Rock Springs, AZ

09513820 - Deadman Wash near New River, AZ

09513860 - Skunk Creek near Phoenix, AZ

09517000 - Hassayampa River near Arlington, AZ

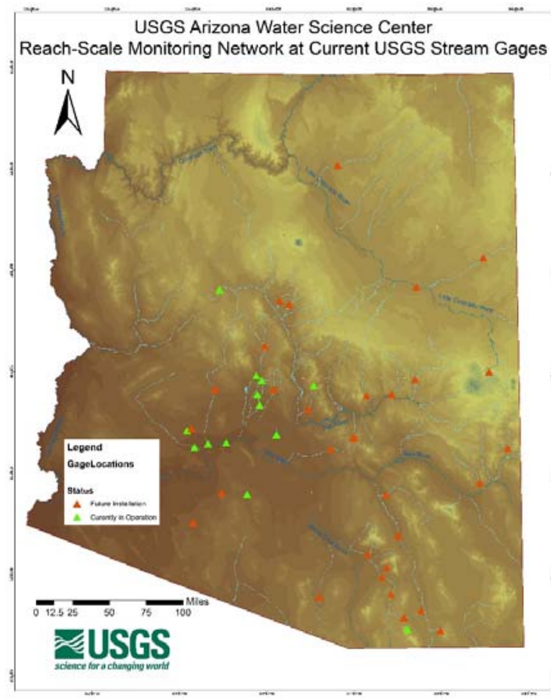
09517280 - Tiger Wash near Aguila, AZ

09517430 - Delaney Wash near Tonopah, AZ

09517490 - Centennial Wash near Arlington, AZ

Sycamore Creek – Sunflower Fire gage

Flume 6 and 11 – Walnut Gulch



Summary

- Numerical models can be a powerful tool to help achieve multi-objective benefits in floodplain management and use of 2D models is increasing.
- The data necessary to run these models can not be collected locally and affordably.
- Roughness is commonly over-simplified in models leading to missed opportunities for risk reduction and ecological enhancement.
- Data needs to be collected today to help answer these difficult questions in the future.

Copies of the ASCE forum article are available after the session

Questions?

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