An Ecohydrological Approach to Riparian Restoration Planning in the American Southwest

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BACKGROUND

Riparian systems across the American southwest region are under threat from a growing and intertwined cast of natural and anthropogenic stressors, including flooding, drought, invasion by nonnative plants, wildfire, urban encroachment, and land- and water-use practices (e.g., Shafroth et al. 2002). In relatively remote and unregulated systems like the upper Gila River in Eastern Arizona, riparian habitat value has persisted reasonably well despite much of it being densely infested with non-native salt cedar (*Tamarix ramosissima* and other *Tamarix* species or hybrids, hereafter "tamarisk") (USFWS 2002, 2013). A new concern in the watershed, however, is the eventual arrival of the tamarisk leaf beetle (*Diorhabda carinulata* and *D. sublineata*) that is expected to soon colonize the tamarisk-infested riparian corridor as the beetle continues to spread across the southwest region (Tracy 2014). While there are numerous potential benefits to tamarisk suppression (e.g., groundwater conservation, riparian habitat recovery, fire-risk reduction), short-term negative consequences are also possible, such as altered channel hydraulics and canopy defoliation during bird nesting season (e.g., endangered southwestern willow flycatcher [*Empidonax traillii extimus*; SWFL] and threatened western yellow-billed cuckoo [*Coccyzus americanus*; WYBC]) (Paxton et al. 2011, Auerbach et al. 2013, Bean et al. 2013).

Need for Restoration

- Tamarisk infestation
- Critical habitat for listed avian species
- Anticipated arrival of tamarisk leaf beetle
- Episodic flood disturbance
- Wildfire exaccerbation

Tamarisk Stand

Planning Area in the Gila Valley

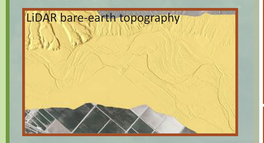
ECOHYDROLOGICAL ASSESSMENT

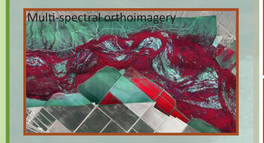
The Assessment entailed reach-scale data collection of high-resolution remote-sensing products, GIS-based delineation of geomorphic activity, and vegetation field mapping. These data along with site-scale information generated, including pre-biocontrol vegetation and wildlife monitoring, shallow groundwater availability, soil texture and salinity, and SWFL-habitat modeling, were synthesized in a GIS framework to highlight those areas of the riparian corridor best suited for active restoration.

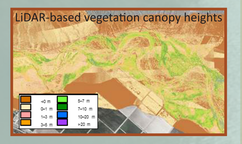
DATA COMPONENTS

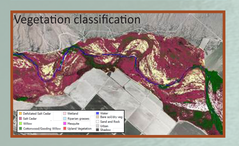
Remote-Sensing Data Collection

Example remote-sensing products from USU RS/GIS and post-processed by Stillwater Sciences









Flood-Scour Analysis

- The upper Gila River naturally experiences a wide variation of flows, punctuated episodically by flashy, but intensive flood events most frequently experienced in March (winter storms) and August (summer monsoons).
- River corridor transitions from a canyon-confined, coarse-grained channel with limited floodplain and some dense native riparian forest at the mouth of the Gila Box to a wide, drier, braided/meandering channel with sparse riparian (mostly tamarisk) bordered by a broad, cultivated and developed floodplain near Safford-Thatcher to a moister, fine-grained, braided/meandering channel system composed of a narrow single-thread channel during lower flows that is encroached upon by dense tamarisk forest.

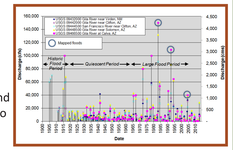
Hydrogeomorphic Characterization

Downstream views in the Planning Area: mouth of Gila Box in reach 3a (top); near Safford in reach 2g (middle); and near Eden in reach 2d (bottom)

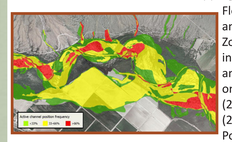
- The potential for channel-scouring floods to occur in any given year remains high despite an apparent lessening of large flood occurrence since the 1990s. Climate change predictions for the region estimate a likely increase in extreme events despite the expected increase in average temperatures and decrease in annual precipitation.

Hydrologic Analysis

Historical flood peaks through water year 2013 at five long-term streamflow gages on the mainstem upper Gila River and lower San Francisco River used in the Ecohydrological Assessment. Flood-scour mapping focused on three of the most recent large flood peaks, as indicated with blue circles.



Flood-scour Mapping



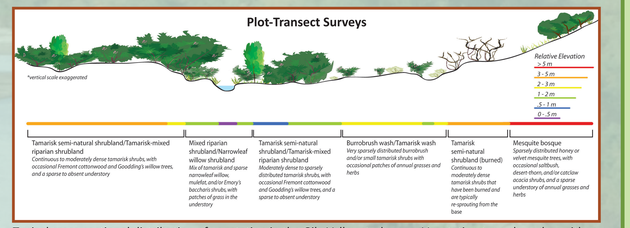
Flood-scour frequency and "Flood Reset Zone," delineated in an aerial imagery analysis based in part on methods by Graf (2000), Tiegs et al. (2005), and Tiegs and Pohl (2005).

- Position of the low-flow channel(s) changes rapidly and completely during flood events, while the boundary of the broader active-channel changes less frequently.

Riparian Vegetation Characterization

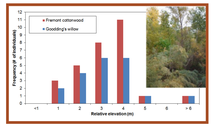
- The riparian corridor currently supports mostly tamarisk-dominated shrublands, although several other vegetation types are present, including Fremont cottonwood-Goodding's willow woodland and narrowleaf willow-mulefat shrubland

Plot-Transect Surveys

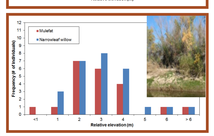


Typical cross-sectional distribution of vegetation in the Gila Valley study area. Vegetation types based on either the group or alliance level of the U.S. National Vegetation Classification system (USNVC 2014).

Vegetation Occurrences by Relative Elevation above the Low-flow River Channel Water Surface



Histogram of Fremont cottonwood and Goodding's willow occurrence by relative elevation category



Histogram of mulefat and narrowleaf willow occurrence by relative elevation category

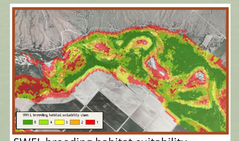
- Vegetation composition and cross-sectional distribution, and the physical conditions that shape these attributes, vary as a function of position along the river corridor (i.e., specific to hydrogeomorphic reach); density (growth potential) greatest downstream (ag return flows) and closest to river (surface water/shallow groundwater)
- Many occurrences of native trees and shrubs, and nearly all occurrences of floodplain wetlands, in the Planning Area appear to be highly influenced by, if not dependent upon, channelized tributary and/or agricultural return flows.
- Natural recruitment of native riparian tree and shrub species appears to be limited by high density of tamarisk coverage and water availability; much of the observed native tree and shrub stands appear to have been recruited in association with the 1993 flood event.

SWFL Conditions and Model-predicted High-Quality Areas

- SWFLs continue to inhabit portions of the Planning Area during the breeding season (spring/summer), and are most commonly present in the more densely vegetated riparian areas (mostly consisting of tamarisk) in the downstream reaches

Southwestern willow flycatcher (Photo by USGS)

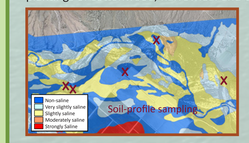
- Based on application of the "SWFL Satellite Model" methods originally developed by Jim Hatten and others (Hatten and Paradzyck 2003, Hatten et al. 2010), the predicted highest quality areas are concentrated in the downstream reaches, which correspond with those areas densely vegetated and outside of the Flood Reset Zone

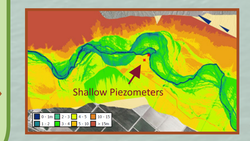


SWFL breeding habitat suitability (LANDSAT-based)

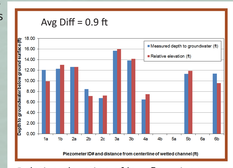
Soils and Groundwater Conditions

- Measured field-based soil sampling results and published reach-scale NRCS soils maps (SSURGO 2007) indicate soil texture, salinity, alkalinity are within the range of tolerance for most native riparian plant species. Shallow soils should generally be able to support plantings of cottonwood, narrowleaf and Goodding's willow, and other native woody riparian (e.g., Baccharis spp.) and upland species (e.g., Atriplex spp.), but may be too saline and/or alkaline to in a few areas to support plantings of native cottonwoods and willows.





- Groundwater measurements made throughout the Planning Area reveal generally shallow depths to the water table (6–16 ft bgs), which remain fairly static across the width of the riparian corridor regardless of proximity to the wetted channel.
- Comparisons between the groundwater measurements and the corresponding relative-elevation values at the piezometer locations reveal close agreement (<1 ft difference), indicating that use of the relative elevation surface to estimate depths to groundwater is an appropriate method for restoration planning in the Gila Valley.



Relative elevation of low-flow river channel water surface compared to piezometer well measurements

SYNTHESIS

Riparian Corridor:
Areas considered suitable for active restoration were within the boundaries of the Planning Area's riparian corridor

Flood Reset Zone:
Suitable active vegetation restoration areas would generally be those found safely outside of the Flood Reset Zone

Modeled SWFL Habitat:
Suitable vegetation restoration areas would be those found near areas modeled to currently host high quality SWFL habitat

Shallow Groundwater Depth (Relative Elevation):
Based on vegetation-transect survey data, suitable areas for active restoration would include those lying within the 0–4 m elevation range above the low-flow channel

Soil Salinity:
Suitable areas for active restoration would include those with soils having non-saline (<2 mmhos/cm) to very slightly saline (2–4 mmhos/cm) conditions

+

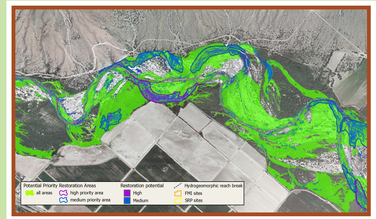
Growth Potential:
The high and medium priority areas would include those areas having lower-lying elevations (i.e., shallow water table) and tall canopy heights (i.e., most productive for woody vegetation growth)

High" restoration priority:
- Relative elevation = <0–0.5 m and Canopy height = >5 m
- Relative elevation = 0.5–2 m and Canopy height = >7 m

"Medium" restoration priority:
- Relative elevation = 0.5–2 m and Canopy height = 5–7 m
- Relative elevation = 2–3 m and Canopy height = >5 m

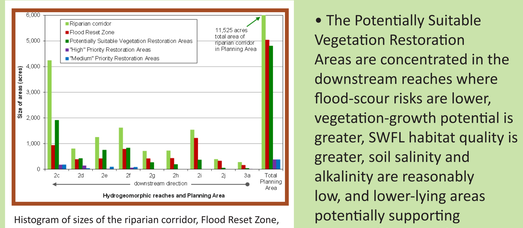
RESTORATION AREA SUITABILITY

- From the Ecohydrological Assessment, nearly half of the riparian corridor of the Planning Area was predicted to be suitable—"Potentially Suitable Vegetation Restoration Area"—for supporting active riparian restoration, amounting to about 4,800 acres.
- The "High" and "Medium" Priority Areas each account for nearly 400 acres (750 acres in total), which is a more manageable size for rapid and effective active restoration involving some level of tamarisk removal and native planting beginning in 2014–2015.



"High" and "Medium" Priority Restoration Areas (Stillwater)

All Potential Priority Restoration Areas ≈42% of riparian corridor (4,800 acres), concentrated downstream "High" and "Medium" Priority Areas together account for 750 acres.



Histogram of sizes of the riparian corridor, Flood Reset Zone, and Potentially Suitable Vegetation Restoration Areas within the Planning Area and each of the hydrogeomorphic reaches.

- The Potentially Suitable Vegetation Restoration Areas are concentrated in the downstream reaches where flood-scour risks are lower, vegetation-growth potential is greater, SWFL habitat quality is greater, soil salinity and alkalinity are reasonably low, and lower-lying areas potentially supporting wetter soils are readily available.

CONCLUSIONS

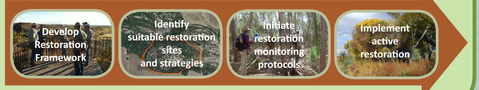
- The Ecohydrological Assessment synthesized several complex datasets representing bio-physical conditions of the upper Gila River, and highlighted those areas of the river best suited for active restoration and, ultimately, assists the restoration planners in development and prioritization of science-based, cost-effective restoration strategies.
- More intensive **active** riparian restoration should involve a phased, patch-work ("Propagule Islands") approach to: preserve much of the existing taller SWFL-suitable tamarisk structure (to minimize disturbances to existing viable SWFL-nesting habitat); remove/treat lower tamarisk structure (in patches) and replace with native plantings well suited to site conditions; avoid inducing channel instabilities and gradually expand treatment and revegetation footprint before and following beetle colonization.
- Lower effort strategies, or **passive** restoration, should be considered in areas disturbed by fires or floods where much of the tamarisk biomass has been naturally removed.
- Prior to any treatment/removal activity, coordination with the U.S. Fish and Wildlife Service will be necessary to secure the prerequisite permits for carrying out such work that could potentially be considered an unauthorized "take" of SWFL or other federally listed species in the implementation area, or to determine whether activities can safely be undertaken without risking take.
- Finally, pre- and post-implementation monitoring is recommended to demonstrate restoration success and justify ongoing activities.

Goodding's Willow Stand

Additional details provided in Orr et al. 2014
http://www.stillwatersci.com/resources/Orr_et_al_2014_UpperGilaRiverRestorationFramework_Final_compiled.pdf

APPROACH

In preparation for anticipated avian habitat impacts following beetle colonization, we developed a holistic restoration framework to promote recovery of native riparian habitat and subsequent local increases in avian population along the 85 km (57 mi) long Upper Gila River. Pivotal to this process was an Ecohydrological Assessment that identified suitable restoration sites based on consideration of natural and anthropogenic factors that, together, influence restoration opportunities—flood-scour dynamics, vegetation community structure and resilience, surface- and groundwater availability, soil texture and salinity, wildlife potential, and land-use activities.



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