Purpose of Memo

The Colorado Water Conservation Board requested Tamarisk Coalition (TC) assistance with a memo to the Colorado River Basin Salinity Control Forum detailing the theoretical water savings resulting from the restoration of approximately 198 hectares (490 acres) along the Colorado River previously occupied by tamarisk and Russian olive (TRO). Restoration work, which occurred on five Colorado Parks & Wildlife (CPW) parcels, was part of a Natural Resources Conservation Service (NRCS) salinity control project funded through the Environmental Quality Incentives Program (EQIP), which includes matching funds from the US Bureau of Reclamation (USBR) delivered through the Basin States Program (Figure 1). The goal of this program is to provide replacement habitat for habitat values lost through both the NRCS on-farm irrigation improvement program and USBR irrigation delivery systems improvements.

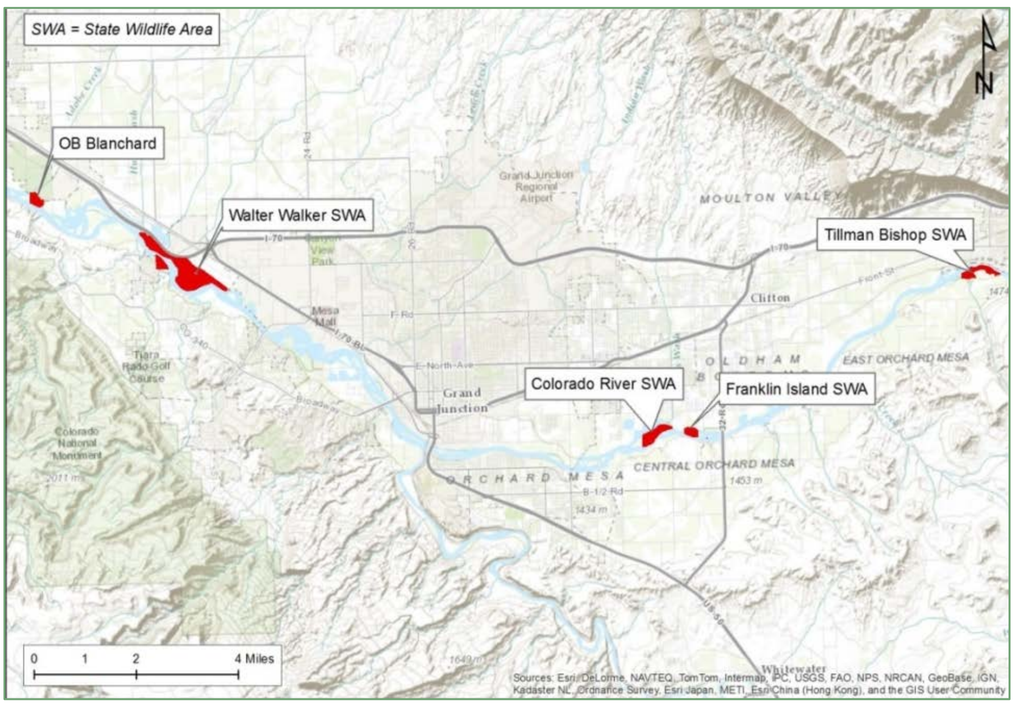

Figure 1 - Location of CPW Restoration Projects in the Grand Valley

With its coordination in 2009 of an independent peer panel review of TRO evapotranspiration (ET) in the Colorado River Basin, TC positioned itself as a resource for managers looking to understand this complex, and at times controversial, topic. Since this time, TC has continued to keep abreast of ET research in the Basin through its close coordination with leading researchers and institutions.

TC did not play a management role in this particular restoration project; however, due to its role coordinating riparian restoration in the Grand Valley, TC staff maintained close communication with NRCS and CPW personnel tasked with project design and implementation.

Summary of Findings

Based on the science and assumptions presented in this document, the theoretical change in ET resulting from restoration of 198 hectares (490 acres) of TRO bottomland are presented in the graphic below (Figure 2).

Utilizing low estimates for vegetation ET rates results in potential water savings of approximately 0.23 M m^3 (186 AFY); utilizing high estimates for ET rates results in potential water savings of approximately 0.44 M m^3 (356 AFY).

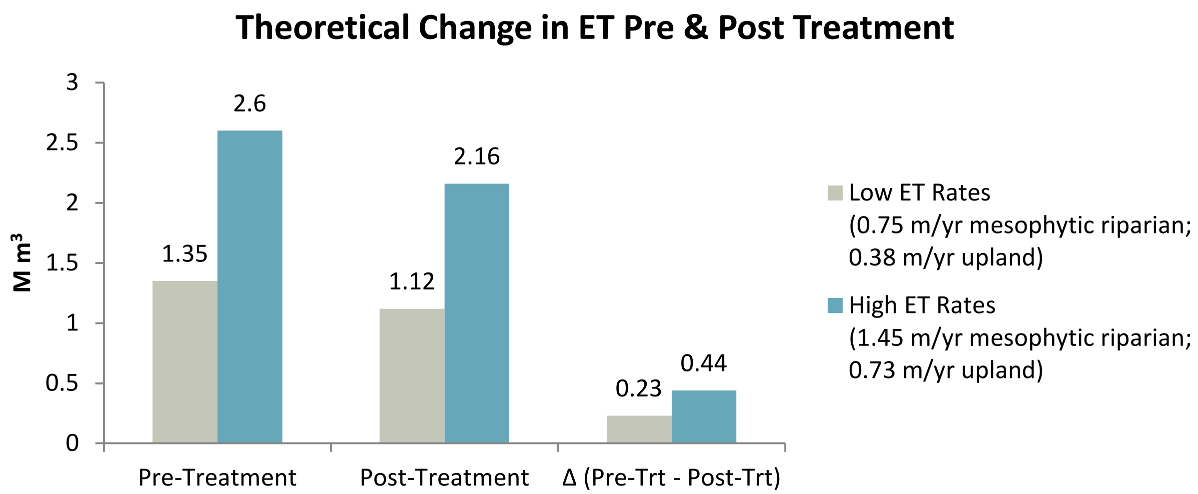

Figure 2 - Theoretical Change in ET Pre & Post Treatment

Theoretical Water Savings across Sites

Evapotranspiration Science

Woody invasive tree removal and revegetation projects typically have several objectives, ranging from reducing wildfire risk to increasing native plant cover and diversity. Over the past several decades, many managers have included potential water savings as a desired outcome of these projects. Tamarisk, in particular, is often portrayed as a water hog, sucking up water that could otherwise be put to beneficial use. Anecdotal reports once suggested that tamarisk could use as much as 750 liters a day (200 gallons), and early ET studies supported this idea, with some ET estimates for tamarisk exceeding 3 m yr^{-1} (Nagler et al. 2010). As noted by Nagler and others, these approximations, which are now considered high, indicated that tamarisk used considerably more water than native riparian plant species.

Recent ET studies, however, which use advanced techniques that include sap flow and micrometeorological moisture flux tower measurements, have demonstrated that tamarisk may use about the same or even less water than its native riparian counterparts, such as willow and cottonwood (Nagler et al. 2010). Based on current estimates, stand-level tamarisk ET averages approximately 1.0 m yr^{-1} in dense stands of tamarisk (range 0.75-1.45), whereas ET rates for cottonwood range from 1.0 to 3.3 m yr^{-1} (Nagler et al. 2010). ET rates for a cottonwood-willow mix average 0.5-1.0 m yr^{-1}. Insufficient knowledge exists for Russian olive to accurately estimate its water usage, although, a U.S. Geological

Survey (USGS) study using remote sensing data indicated that ET averages for Russian olive are similar to those of tamarisk (Irmak et al. 2005, 2009).

Based on these data, the greatest opportunity for potential water savings may be found on upper terraces located within the bottomland (Figure 3). Native species found in this region, such as mesquite or sacaton grass, are estimated to have relative ET values that are half the average amount of tamarisk (Tamarisk Coalition 2009). Whereas tamarisk can access groundwater in these areas, more shallowly rooted xeric species are restricted in their availability to access the capillary fringe or water table. As xeric species replace tamarisk during restoration efforts, the total amount of water used in these areas will likely be reduced.

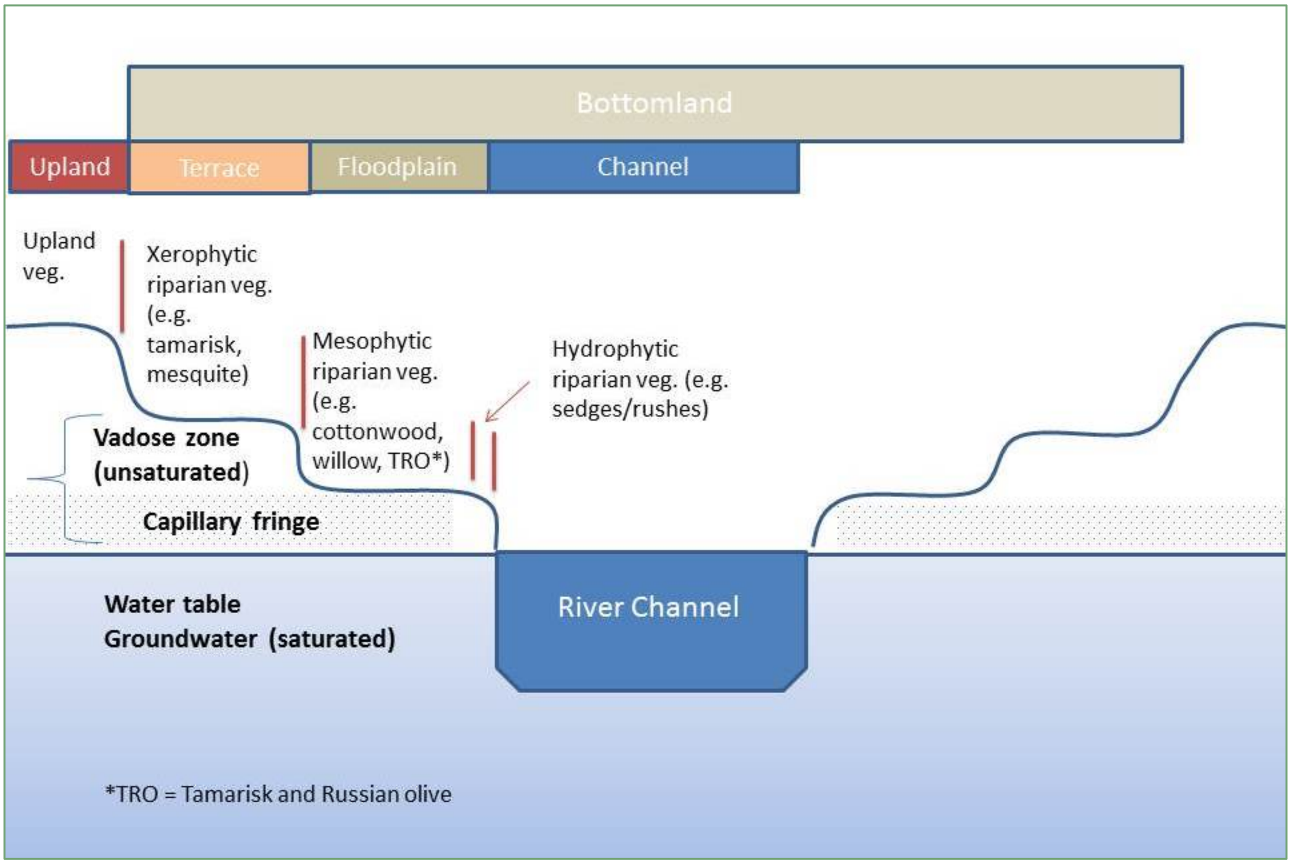

Figure 3 – Riparian Ecosystem Terminology (adapted from Nagler et al. 2010)

That being said, quantifying potential water savings from tamarisk control is complicated at best. As Nagler and others (2010) note, removal of non-native species can lead to changes in a number of factors, including plant transpiration, evaporation from both ground and water surfaces, and changes in total metabolic water use, all variables which can be difficult to measure. Furthermore, they note, complex surface and groundwater interactions must be considered. For example, rivers lined with silt or clay soils may have low hydraulic conductivity, resulting in little water movement between surface and ground water. The range of potential water savings from tamarisk removal is large, ranging from a maximum of 50 to 60% of the value of tamarisk ET to less than zero, in cases where replacement vegetation uses the same or more ET than tamarisk (Tamarisk Coalition 2009).

Additionally, it is important to note that in order to claim "saved" water, a change in volume "must be measurable as a change in subsurface storage or increased streamflow" (Nagler et al. 2010, pg. 39). To expound further, Nagler and others state: "it is important to distinguish between expected water savings based on evapotranspiration comparisons and actual water savings corroborated by increased streamflow or increased subsurface-water storage"(pg. 39).

Generally, water savings experiments in the western US have not demonstrated increased streamflow from large-scale experiments, however, a recent study commissioned by Utah State University demonstrated positive results for potential water savings at tamarisk removal sites (Shafroth et al 2010, Lewis et al. unpub.). This unpublished study, which compared ET and groundwater levels at two sites where tamarisk was removed by a large-scale fire, found that as ET decreased in the absence of tamarisk, ground water levels increased (Lewis et al. unpub.). Researchers also observed reduced groundwater extraction and more rapid groundwater recovery on sites void of tamarisk. Similarly, Nagler and others (2014) estimated potential water savings on the Virgin River based on observed tamarisk defoliation by the tamarisk leaf beetle, which resulted in a 50% reduction in leaf area index. It is worth noting that any potential water savings would likely be temporary due to regrowth of desirable or undesirable species on the site (Nagler et al. 2010).

Project Level Evapotranspiration Estimates and Assumptions

In order to accomplish habitat improvement, the objective of the CPW restoration work is to reestablish native riparian habitat in areas previously infested by woody invasive plants, namely TRO. Restoration work was initiated at five different CPW managed sites located across the Grand Valley, including: Tillman Bishop State Wildlife Area (SWA), Franklin Island SWA, Colorado River Island SWA, Walter Walker SWA, and the OB/Blanchard Property (Figure 1). At each of the sites, TRO were masticated, with the resulting mulch left on site. Secondary weed treatment has been completed or is planned for each site as is follow-up treatment of TRO re-sprouts. Revegetation with native species is a key component of project implementation and is described in detail below.

Water savings through phreatophyte removal was not considered a goal of this project. Therefore, estimations of potential water savings were not considered in project design or data collection. As such, several assumptions were made in order to estimate potential water savings resulting from habitat improvement work. Known and assumed variables are described below.

Pre-treatment

- ***Acreage & Mapping***
  The total acreage was determined by excluding any water, including the river and associated side channels, from the property boundaries. The total project area was determined to be 198 hectares (490 acres). The site was assessed prior to removal by NRCS staff to determine vegetation composition and to determine appropriate restoration actions.

- ***Mesophytic Riparian Plant Cover***
  The total mesophytic riparian plant cover across all five treatment sites was collected prior to treatment, with an average across sites of 81%. Cover ranged from 70% at Tillman Bishop SWA to 90% at Colorado River Island. These data included the cover of both native and invasive woody plant species; however, most sites were dominated by TRO. Walter Walker SWA was the

one exception; there is a healthy cottonwood gallery at this site with tamarisk predominating in the mid-story and on adjacent terraces.

- ***Upland Plant Cover***

  The remaining pre-treatment vegetation cover was assumed to be upland vegetation (19%), with a total pre-treatment cover for the site equaling 100% (Table 1). Although total cover would likely exceed 100% due to an overlap in vegetation types (e.g. grass and forb understory present below mid-story tamarisk stands), not enough is known about ET rates to assume an additive effect amongst different canopy cover types (P. Shafroth 2015, US Geological Survey, personal communication).

Post-treatment

- ***Acreage & Mapping***

  While the total number of acres remains unchanged after mastication and secondary weed spraying, the boundaries of the completed project have yet to be mapped due to access challenges as a result of spring flooding. NRCS staff will be completing mapping of the project site this summer.

- ***Mesophytic Riparian Plant Cover***

  The goal of this project was to masticate all populations of TRO within the project boundaries. As only one project site included a native component, the total cover for mesophytic riparian plants was drastically reduced across all sites.

  However, as restoration is a key component of this project, it is anticipated that the cover of mesophytic riparian plants will greatly increase over time. The restoration plan for these properties includes the planting of 11,900 cottonwoods, with a goal of 25% canopy cover at maturity. Cottonwoods will be planted in areas where the water table is 10' or less. An additional 4,500 willows will also be planted within 10' of the water's edge, with a canopy cover goal of 50% at maturity.

  Additional shrubs are expected to passively restore the site. As most of these areas were classified as riparian (as opposed to wetland or upland) in mapping completed by TC in 2010, it is anticipated that many of these areas could be populated by species including three-leaf sumac, silverleaf buffaloberry, golden current, Woods' rose, or other floodplain vegetation (TetraTech 2012). Based on these assumptions, it was estimated that the total mesophytic riparian plant cover would approximate 50% over time.

- ***Upland Plant Cover***

  Assuming 50% cover of riparian plant species, and given the hydrology and location of the project sites, it was projected that the remainder of the site (50%) would eventually be occupied by upland plants, such as rabbitbrush, fourwing saltbush, sagebrush, grasses, and/or other dryland species.

Evapotranspiration Rates

Table 1 provides two different scenarios for ET use by riparian and upland species on the CPW sites pre- and post-treatment. For purposes of this assessment, all riparian vegetation, including native and non-native species, were assumed to have similar ET rates, roughly 1.0 m yr^{-1}. While native ET rates are not as well studied as tamarisk, a cottonwood-willow vegetation mix exhibits ET rates comparable to tamarisk at maturity and full canopy closure (Tamarisk Coalition 2009). The ranges used below (0.75-1.45 m yr^{-1}), which are based on tamarisk ET, were determined using sap flow and micrometeorological moisture flux tower measurements that were scaled to entire river reaches using remote-sensing methods calibrated with tower results (Nagler et al. 2010).

While ET rates for upland species are also generally not as well studied as tamarisk, native species and plant community associations for upper terraces exhibit ET values ranging roughly from 50-75% of mean tamarisk stand values (Tamarisk Coalition 2009). For this report, all upland vegetation was assumed to use roughly half the amount of water as riparian species.

Vegetation cover percentages assume revegetation of the sites over time and do not represent the sites in their current condition.

PRE-TREATMENT (Total Project Area 2.0 M m^2)						
Vegetation Type	Percent Cover	Area of Project Affected (M m^2)	Low ET Rate (m yr^{-1})	Total Annual Water Volume Lost through ET (M m^3)	High ET Rate (m yr^{-1})	Total Annual Water Volume Lost through ET (M m^3)
Mesophytic riparian	81	1.6	0.75	1.20	1.45	2.32
Upland	19	0.4	0.38	0.14	0.73	0.28
Total Annual Water Volume Lost through ET			*@ Low ET Rate = 1.35 M m^3*		*@ High ET Rate = 2.60 M m^3*	
POST-TREATMENT (Total Project Area 2.0 M m^2)						
Vegetation Type	Percent Cover	Area of Project Affected (M m^2)	Low ET Rate (m yr^{-1})	Total Annual Water Volume Lost through ET (M m^3)	High ET Rate (m yr^{-1})	Total Annual Water Volume Lost through ET (M m^3)
Mesophytic riparian	50	1.0	0.75	0.74	1.45	1.44
Upland	50	1.0	0.38	0.38	0.73	0.72
Total Annual Water Volume Lost through ET			*@ Low ET Rate = 1.12 M m^3*		*@ High ET Rate = 2.16 M m^3*	
POTENTIAL CHANGE IN ET (Pre-Treatment – Post Treatment)**						
			@ Low ET Rate		*@ High ET Rate*	
Total Water Volume			*0.23 M m^3* *186 AFY*		*0.44 M m^3* *356 AFY*	

*For the purposes of this exercise, all mesophytic riparian vegetation was assumed to have ET rates similar to tamarisk. ET rates for tamarisk are derived from Nagler et al. (2010); these ranges were based on sap flow and micrometeorological moisture flux tower measurements that were scaled to entire river reaches using remote-sensing methods calibrated with tower results. The ET range for upland vegetation was calculated at half of that of mesophytic riparian vegetation; this is an attempt to capture the wide ET range of various upland species as detailed in Nagler et al. (2010).

** Change in ET does not equate to recovered water.

Table 1 – Theoretical Change in ET Based on Riparian Restoration Treatment

Conclusions

Based on the assumptions above, approximately 0.23 M m^3 (186 AFY) of water could be saved based on lower ET rates; this number rises to approximately 0.44 M m^3 (356 AFY) using higher ET estimates. Given the number of variables affecting the water budget, it should be reiterated that these numbers do not equate to water recovered. Furthermore, it should be emphasized that this exercise relied heavily on assumptions about vegetation recovery that have yet to be realized. Assessment of this project in five to ten years may provide a better indication of vegetation recovery trends on the site.

Nagler and others (2010) detail the challenges that must be addressed to adequately assess whether or not changes in ET result in expected water savings as subsurface storage or streamflow. They note that any future research or demonstration projects aiming to accurately quantify potential water savings must: 1) be of sufficient scale, 2) utilize accurate instrumentation, 3) measure or control for all system water variables, 4) control for natural variation, and 5) be of adequate duration to account for climate variability.

While restoration of the tamarisk-infested upper terraces likely have the most potential for water savings, it should be noted that restoration of the entire river bottomland could be highly beneficial for enhancing riparian health and benefiting humans and wildlife, as demonstrated by this project. To the extent possible, any efforts to restore the upper terraces for the purpose of potential water savings should be coordinated with those community groups focusing on restoring the lower, wetter portions of the bottomland in order to minimize costs and maximize benefits to the entire river corridor.

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