Appendix I. Riparian Evapotranspiration and Removal of Invasive Vegetation

Section Overview

This document outlines efforts to control and remove invasive vegetation in the Republican River Basin (Basin) as it relates to Goal 4 of the Republican River Basin-Wide Plan (Plan) (page *[#]*). Goal 4 and Action Item 4.2 of this Plan relate to removing undesirable riparian vegetation impacting water conveyance and managing reinfestation. This appendix provides background information about the relationship between removal of invasive vegetation and evapotranspiration, which should be considered as part of decisions related to the removal of invasive riparian vegetation from streams.

This appendix includes a summary of studies and other information about using removal of phreatophytic vegetation along streams (i.e., riparian vegetation) for water conservation. Phreatophytes are deep-rooted plants that obtain a portion of their supply from groundwater, and they comprise a large portion of riparian vegetation in the Basin. As such, phreatophytes have the ability to extract a large volume of water from groundwater. Removal of phreatophytic vegetation from riparian areas for water conservation should be assessed on a cost-benefit basis relative to other potential water conservation activities. This summary contains information about the costs and potential benefits of riparian vegetation removal.

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Brief Summary of Phreatophyte Studies

Phreatophytes are deep-rooted plants that obtain a portion of their water supply from groundwater. Phreatophytes comprise a large portion of riparian vegetation in the Basin. They include cottonwood, salt cedar, Russian olive, and phragmites. Due to the large role of riparian evapotranspiration (ET) in watershed-scale water budgets, phreatophytic vegetation removal is often proposed as a means of water conservation. The amount of water savings from phreatophytic vegetation removal depends on several factors, including:

- transpiration rates of the vegetation removed
- depth of the groundwater table
- transpiration rates of the regrowth
- change in evaporation rate from microclimate changes
- change in hydrologic conditions from ground cover removal and soil disturbances from the removal process.

In addition, the cost-benefit factor of vegetation removal and maintenance must be weighed against other water conservation activities. The following sections summarize relevant studies addressing these factors.

Phreatophyte Studies

Davenport et al. (1979) found that while the mean evapotranspiration rate per unit leaf area is very similar for several phreatophytes, ET per unit land area can differ substantially based on the density of vegetation rather than species. For instance, the mean ET value for salt cedars in June was approximately 0.32 inches per day. Phreatophyte control application on salt cedars initially reduced ET by approximately 20 to 35 percent but the reduction was only 10 percent in the subsequent months in response to the understory growth. Culler et al. (1982) reported that phreatophyte removal from river floodplains in Arizona reduced phreatophyte consumption of water from 43 inches per year by up to 19 inches per year; however, the reduction in transpiration did not translate into an increase in river flows as replacement vegetation was reestablished over the floodplain. Welder et al. (1988) also documented a similarly low increase in river flows because replacement vegetation transpired an equivalent volume of water. Wilcox et al. (2006) also found that conversion (removal) of salt cedars in riparian areas in favor of short-root vegetation may increase water yield by 1.5 to 3.1 inches per year in only small catchments.

Szilagyi et al. (2011) estimated that in the Nebraska Sand Hills, the evapotranspiration rate of Ponderosa pines that are introduced to the area can exceed annual precipitation rate by 5 to 10 percent; however, it is also worth noting that the discussion of evapotranspiration should consider the separate processes of evaporation and transpiration. The evaporation component will occur regardless of the presence of trees and may, in fact, be greater in grasses and open spaces than in the tree stands due to the shade provided by tree canopies. In a wetland, for example, Burba et al. (1999) found that evapotranspiration rates were up to 17 percent lower than open water evaporation rates. Transpiration rates, on the other hand, have been documented to vary based on the depth to water table and the root depth of the species, which can provide access to water from deeper sources.

Transpiration Rates of Phreatophytes

Phreatophytic vegetation typically consumes more water than other terrestrial vegetation due to nearly constant access to water from the capillary fringe or saturated zone. The Nebraska Department of Natural Resources (Technical Report Number 2008-01) compiled annual consumptive water use volumes from various studies in the West and Midwest U.S. and Canada (Table E.1). Consideration must be given to the transpiration rate of the vegetation population proposed for removal and the potential vegetation regrowth at the site. Flowering rush, phragmites, and salt cedar are considered invasive species or noxious weeds with established populations in Nebraska. These species compete with and crowd out existing vegetation, form dense stands and use water while restricting streamflow in riparian areas (Nebraska Invasive Species Program website 2017). Water savings from the reduction of transpiration will depend on which species is present, the potential spread or encroachment of non-native, invasive species to the cleared area, and the continued maintenance of any population.

Table E.1. Ranges of annual consumptive water use by common riparian and wetland vegetation, modified from Nebraska Department of Natural Resources (2008).

Common Name	Annual Consumptive Use (inches)
Arroweed	96
Cattail	35-198
Cottonwood	39.3-92.7
Bermuda Grass	28.8-73
Phragmites	7.2-30.71
Salt Grass	6.2-48.8
Rush	20.8-86.6
Russian Olive	18.6-114.6
Salt cedar (Tamarisk)	11.8-86
Willow	13.2-47.8
Riparian Woodland	13.2-22.4

Microclimate Changes due to Vegetation Removal

Woody vegetation and dense grass stands provide a significant amount of shade to the underlying surface, which reduces surface heat storage and energy available for surface evaporation from riparian areas. Potential water savings from complete removal of vegetation from riparian areas has been found to be offset by an increase in surface evaporation. Mykleby et al. (2016) studied the removal of phragmites from a wetland field west of Arapahoe, Nebraska. Results of the study suggested that transpiration savings during the year following phragmites removal, prior to significant regrowth, was reduced by approximately 60 percent due to the increase in surface evaporation.

Hydrological Alterations from Vegetation Removal

The physical structure of vegetation plays a large role in the hydrology and water flow within a riparian area. Huddle et al. (2011) summarize several studies on the relationship between the physical structure of vegetation and water flow in riparian areas and found that vegetation impacts vary between and within geographic regions and stream types. The vegetation structure can obstruct, facilitate, or divert water flow. Changing the vegetation structure of a riparian area has been found to have a variety of effects, including flooding and erosion due to removal of woody species, increased water flow pattern heterogeneity from vegetation colonization after a disturbance of the native vegetation, and limited surface water infiltration and fine sediment trapping, sustaining moisture levels in the upper soil profile, from proliferation of dense herbaceous cover (Huddle et al. 2011).

Cost Assessment of Phreatophyte Removal

Several economic variables should be taken into account when assessing the cost factor of phreatophyte removal (Table E.2).

Table E.2. The potential costs and benefits of phreatophyte removal.

Costs	Benefits
Physical removal	Woody harvest return
Maintenance of clearing	Consumptive water savings
Hydrologic alterations	Hydrologic alterations
Loss of ecosystem services	

A wide range of values can be found for each of these and should be assessed for each project. For example, the cost of salt cedar removal can vary from less than $50 to several thousand dollars per acre as summarized by Huddle et al. (2011) (Table E.3).

Table E.3. Summary of the cost of salt cedar removal by treatment type from various studies, modified from Huddle et al. (2011).

Salt cedar Treatment Type	Cost (US$/acre)
Helicopter herbicide application	$68
Fixed-wing herbicide application	$56
Cut-stump and herbicide application	$1,059
Foliar herbicide application	$344
Cut and sprayed with imazapyr	$506 ± $2,499
Aerial spray of imazapyr with and without glyphosphate; burning	$174 ± $57
Individual cut and spray imazapyr	$1,599 ± $2,499
Individual herbicide application or mechanical grubbing	$40 ± $300
Large-scale control methods	$409 ± $186

Nebraska legislative dollars have been appropriated for weed management, and are awarded to projects in the Basin by Nebraska Department of Agriculture (Table E.4). These projects have also used additional funding sources.

Table E.4. Legislative funding for weed management in the Basin by fiscal year.

Fiscal Year	Legislative Funding (US$)
2007-2008	$1,420,228
2008-2009	$1,119,000
2009-2010	$1,000,000
2016-2017	$100,000
2017-2018	$93,500

The Twin Valley Weed Management Area has been coordinating removal of salt cedar, phragmites, and Canada thistle around Harlan County Dam and downstream along the Republican River since 2006. Approximately $1.2 million has been invested in aerial and terrestrial herbicide applications, taking place each fall. Merle Illian, Project Coordinator, observed an annual decrease in the phragmites population around the dam and along the river since the project began in 2006 until an apparent population rebound in 2016 (conversation, Illian, 2017).

Platte Valley Weed Management Area and PRRIP, which has used vegetation control as a means of increasing conveyance and ecological enhancement, estimates approximately $85 to 105 per acre for aerial control of phragmites over the last five years and $120 to almost $500 per acre for airboat and land-based control methods of phragmites (correspondence, Walters, 2017).

Conclusion

Phreatophytes have the ability to extract a large volume of water from groundwater. Removal of phreatophytic vegetation from riparian areas for water conservation should be assessed on a cost-benefit basis. Consideration should be given to the type of vegetation to be removed and the potential regrowth, the depth to groundwater table, removal and maintenance procedures, and potential microclimate, biological, and ecosystem alterations before project initiation.

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