
Stream Enhancement Evaluation

Queen Creek through the Town of Superior, Arizona Resolution Copper



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EXECUTIVE SUMMARY

The objective of this study was to assess the geomorphic condition and riparian character of Queen Creek through the town of Superior, AZ and downstream to the Boyce Thompson Arboretum and provide conceptual level practices for improving the health and resilience of the channel and associated riparian zone.

Crews conducted field surveys of channel morphology and riparian community through the reach. Field assessments were also made to determine the character of intermittent flows throughout the reach when the stream was near base flow. Additional data from hydrology reports, geology/groundwater mapping and plant community mapping provided by others was incorporated into the study to provide a more comprehensive assessment of channel/riparian function and potential.

The channel is an intermittent stream with loosing reaches through limestone bedrock outcrops in the canyon above Superior. Surface flows are increased via releases from the wastewater treatment plant and the perlite mine downstream of town. Subsurface flows are at variable depths depending on the depth to bedrock below the alluvium. Subsurface flows are generally shallower in reaches between Magma Avenue and Route 60 in Superior then dive deeper into the alluvium downstream of Route 60 until the influence of additional flow and geology bring flows to shallow depths again below the inflow of the perlite mine. Localized areas of shallow groundwater within the canyon and downstream of Route 60 are evident by the presence of cottonwood and sycamore trees in areas upstream of shallow bedrock outcrops.

Channel condition and stability is generally good with only minor areas of bank erosion or aggradation. Most stream types are stable with only shorter reaches of stream types that have high shear stress near the banks or are prone to lateral migration. There were limited areas where channel work is recommended. These include cleanup of dumped debris and trash and most importantly the repair of two headcuts which have the potential to lower the channel and water table in the lower portions of the reach. It is also recommended to reshape the channel in the vicinity of the proposed campground, where an old low water crossing has changed channel shape and is degrading sediment transport capacity.

The riparian community of the study reach is in relatively good condition and typical of an ephemeral desert stream. More mesic riparian trees are present in isolated areas where bedrock can keep subsurface flow in the rooting zone and in the lower portions of the reach where more permanent surface water and shallow groundwater predominate. There are several areas where invasive tamarisk and fountain grass are becoming established. These areas were mapped and an invasive species management plan accompanies this report.

Given the channel type and stability, changes to the watershed and hydrology are not expected to have a heavy impact on the types of vegetation or on channel stability at the levels of disturbance described by the mining company. The vegetation community is already adapted to ephemeral flows throughout most of the reach and changes in channel size are expected to be minor.

While the channel and riparian zone are in relatively good condition, there is a desire to increase the density and distribution of cottonwood along the channel, especially near town. Additionally, the town would like to see surface water in the channel for more extended periods of time. If additional water is provided from mining activities it will need to be piped to a point just above Magma Avenue in order to reduce losses to bedrock fissure in the lower portion of the canyon. The proposed additional discharge (~25 gpm) would provide minimal surface water exposure through the reach. However, the flows could support several acres of cottonwood plantings in an area where groundwater is generally shallow (presumably from bedrock outcrops shallow in the alluvium). The area around the town park near the Route 60 Bridge is a likely candidate for this type of project.

Several investigations are needed to support this use of additional water. These include looking at the fate of surface water entering the alluvium around Queen Creek to determine where it enters the wider aquifer and where it might remain close enough to the surface to provide a water resource to the riparian ecosystem. Additionally, it is suggested to conduct a test release of surface water into the stream to determine areas of loss along with a system of surface water gages to gather data for development of a more detailed surface water budget for the reach.

PROJECT DESCRIPTION

Resolution Copper proposes to conduct underground mining of a copper-molybdenum deposit using a method known as panel caving. The East Plant Site encompasses the proposed underground mine and is located east of Superior, AZ near Oak Flat. The mine is near the top of the Apache Leap escarpment and would cause a land subsidence that would over many decades capture approximately 16% of the existing surface watershed flow to upper Queen Creek where it enters the town of Superior (JE Fuller, Inc. 2020).

The Town of Superior, Arizona in cooperation with Resolution Copper is seeking to enhance the riparian and stream function of Queen Creek from upstream of the town and downstream to near the Boyce Thompson Arboretum. Changes in the nature and amount of watershed runoff created by expansion of the mining activities in the area are anticipated to affect runoff amount and timing. These changes can potentially affect, channel morphology and stability, the riparian community composition and extent. The town and Resolution Copper have a mutual interest in anticipating these changes and mitigating the effects through enhancement of the creek and associated riparian habitat. They are seeking a set of alternatives that can be implemented to improve current habitat quality through modest additions of surface water or channel manipulation that can stabilize channels and improve water availability for riparian plant communities.

Natural Channel Design, Inc. (NCD) is working with the Town of Superior, Resolution Copper, Montgomery & Associates (M&A) and others to collect and analyze available data, identify data gaps, collect additional data as needed and determine ecologic potential for specific reaches of Queen Creek within the study area. This project is focused on assessment of the channel and riparian condition of Queen Creek and determining what measures could be utilized to enhance or protect the channel in light of impacts from the mining project. In addition, the potential for improving the habitat, aesthetic value, groundwater recharge and other resources provided by Queen Creek are being assessed. This report is aimed primarily at identifying potential effects and mitigation measures for prioritization, design, funding and implementation in future efforts.

LOCATION

The Town of Superior is located approximately 65 miles east of Phoenix, AZ in Pinal County. The town is located at the mouth of Superior Canyon at the foot of the Apache Leap cliffs. The headwaters of Queen Creek are east of the town and the creek flows through town (generally parallel to Route 60) and into the San Tan Valley. The town is located at about 2888 feet above sea level, and the top of the watershed is near 5500 feet. The environment is semi-arid with approximately 15 to 18 inches of precipitation each year. The mine affected area is upstream of the town, directly affecting a portion of the surface watershed in the headwaters of the Queen Creek watershed.

The Boyce Thompson Arboretum is located along Queen Creek several miles downstream of the town. The arboretum is dependent on surface water flows and groundwater which is linked to discharge from the water treatment plant activities in the town and dewatering discharge from a nearby perlite mine. Further downstream, all of the surface flows of Queen Creek are discharged through Whitlow Ranch, a flood control structure operated by the US Army Corps of Engineers.



Figure 1. Project Location

The Town of Superior is located east of Phoenix, AZ at the base of the Apache Leap escarpment. Queen Creek headwaters are to the east of Superior and flow generally westward through the town towards San Tan Valley and are captured in Whitlow Ranch Reservoir.

PROJECT OBJECTIVES

The Town of Superior and Resolution Copper wish to understand the effects of reduced watershed size on the surface water related resources of Queen Creek and then to understand what viable options can be utilized to mitigate or reduce the effects. This study focuses on understanding:

- Current conditions of the channel and how they might be enhanced
- Potential changes to channel condition caused by loss of watershed and runoff
- Current condition of the riparian zone
- Potential changes to the riparian zone caused by loss of watershed and runoff
- Potential for positive change to channel and riparian features created by additional surface water from sources outside runoff. How best to utilize this potential water source for riparian health, aesthetics and groundwater recharge
- Current needs for enhancement and stabilization within the channel and riparian zone, including weed management

PROJECT APPROACH

Natural alluvial stream channels are composed of a set of distinct features. These include the active or “bankfull” channel, associated geomorphic floodplain, and one or more terrace features. Each of these features is created by the fluvial processes of the river and is characterized by a distinct width and elevation that are predictable given the hydro/geographic setting and the watershed size. The bankfull channel carries moderate, frequent flow events and is sized and shaped to carry the stream’s sediment load. The bankfull channel commonly carries approximately the 1.5-year return interval flow event.

Bankfull discharge is generally characterized by a mean flow rate of 3 to 6 cubic feet per second (cfs) and is capable of carrying a significant proportion of the stream's total sediment load. The floodplain is adjacent to the bankfull channel, created by the stream in present times, and is overtopped by moderate, frequent flow events. The purpose of the geomorphic floodplain is to spread high flows and dissipate energy.

The cross-sectional area of a riffle section of the stream during bankfull flows can generally be predicted by watershed size (Leopold et al., 1964). The width and depth of the stream at this point are important characteristics as well. Greater depth and narrower widths are generally associated with higher shear stress (given equal flow and channel slope) than wider and shallower channels. Higher shear stress allows the stream to move larger sediment sizes. Effects to the stream from changes to width and depth of the bankfull channel can become evident after just a few years since moderate, frequent flood events are responsible for creating the forces in this portion of the channel.

Stream meander, pool depth and frequency, substrate size, and other aspects of stream morphology are directly related to bankfull channel dimensions and are a product of the forces produced by this channel. These aspects of channel morphology are important since they help to dissipate the energy produced by the stream during frequent, moderate flooding events.

Floodplain width is also related to the bankfull or active channel size. The width and elevation of the floodplain helps to determine the shear stress developed by less frequent, more intense runoff events. Wide floodplains that allow flood flows to spread produce lower shear stress than narrowed floodplains. The effects of changes to the floodplain are not usually evident on a year to year basis, but become evident over several years of moderate flood events or during very large, infrequent flooding events.

Riparian vegetation is supported by stream flows but is also an integral part of stream channel stability. In addition to providing important habitat, roots strengthen banks and influence stream width. Ideally, vegetation types are organized by zones relative to the channel morphology. Generally short, flexible species are located closest to the active (bankfull) channel where shear stress is higher and more frequent. Larger, stiffer species are generally located farther from the active channel on the flood plain where stresses are lower and less frequent. The composition of natural riparian communities is a product of both the base flow regime of the stream (ephemeral or perennial), but also the inundation frequency and extent of flood flows. Invasive species, changes in flood frequency, and other issues can alter this arrangement, change the composition and function of the riparian community and ultimately affect stream bank strength and channel function.

Assessment of channel geometry and dimensions, hydrologic parameters and riparian composition of Queen Creek provides insight into the potential function of the stream and associated riparian zone as conditions are altered by mining activities, climate fluctuations or other proposed management alternatives.

EXISTING CONDITIONS

GEOMORPHOLOGY

Natural Channel Design, Inc. (NCD) conducted a geomorphic assessment of Queen Creek in October 2019 with additional data collected in November 2019 and March 2020. The channel was surveyed from upstream of Magma Ave down to the campground area, approximately 3.75 miles using RTK GPS equipment. NCD collected a continuous longitudinal profile of the channel, 18 representative cross sections, and bankfull and terrace elevations. Locations of bedrock, headcuts and cutbanks were noted along with invasive vegetation and more water dependent native species such as cottonwoods and willows.

Bankfull Channel Geometry

Eighteen channel cross sections were surveyed throughout the project area to determine bankfull dimensions within the reach and compare with regional data and reference data. The locations of cross sections are provided in Figure 2. Dimensions for each cross section are provided in Table 1.

Cross sectional area and other related dimensions are typical for the watershed size and geomorphic setting of Queen Creek. Figure 3 shows how three cross sections fit on the regional curve for the central/southern Arizona region which shows the correlation of bankfull cross-sectional area as a function of watershed area (Moody, et, al 2003). There were no abnormalities or large-scale stream instabilities indicated from the cross section or longitudinal profile data. Longitudinal profile data indicate that channel slopes are relatively constant at approximately 2% with minor anomalies associated with low water road crossings and minor headcuts. See Appendix A for full geomorphic data. These data suggest that the geomorphology of the stream is not a general limiting factor for support of riparian habitat and good stream function.



Figure 2. Location of geomorphic cross sections

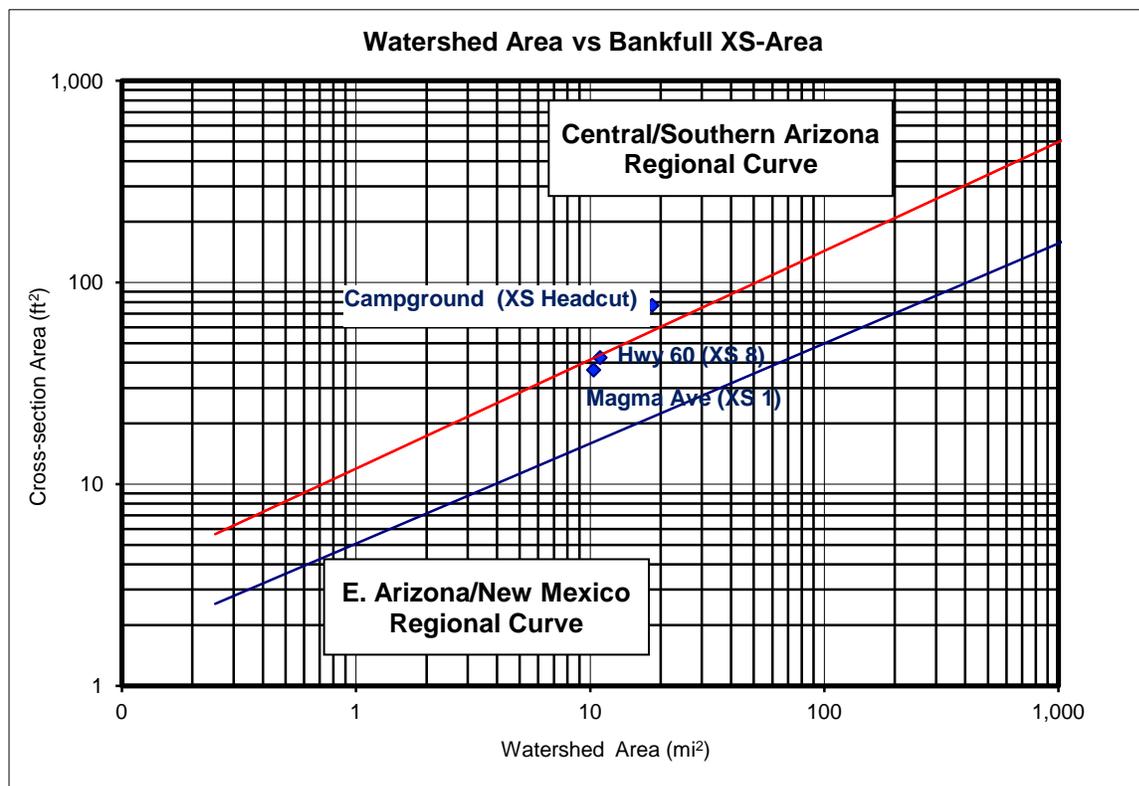


Figure 3. Regional curve for project area.

Stream Types

Cross sectional data was used to determine stream types throughout the project area (Figure 4). Stream types are based on the Rosgen classification system and are indicative of channel and floodplain dimensions, showing the ability of the channel to hold water in a single channel, spread water on to floodplain and support vegetation (Rosgen, 1996). As such they can be utilized to rapidly assess stream function and stability for a specific reach. Within this reach of Queen Creek, stream types generally indicate that the majority of the length of the stream is in a relatively stable form, compatible with the geologic and hydraulic setting. There are several reaches with stream types that are more prone to bank erosion and lateral or vertical migration. Multichannel ‘D’ type streams generally function as aggrading streams which are prone to lateral migration and incised ‘F’ channels have less access to floodplains, meaning that stress during flooding is high and vegetation on the floodplain will likely not be inundated during brief flood events. These stream types are not uncommon in the southwest but are less capable of sustaining robust riparian vegetation. The number following the stream type classification indicates the bed material of the active or bankfull channel: 1 for bedrock, 2 for boulders, 3 for cobble, and 4 for gravel.

Table 1. Cross section dimensions for Queen Creek

Cross Section	Station	XS Area (ft ²)	Bankfull Width (ft)	Floodprone Width (ft)	Mean Depth (ft)	Entrenchment Ratio	Width-Depth Ratio	Channel Slope	D50 (mm) Bed Material Classification	Stream Type
XS 1	100+09	36.8	32.8	55.2	1.12	1.68	29.3	0.029	64 Gravel (and Bedrock)	B4/1
Bedrock XS	104+10	32.6	29.1	43	1.12	1.48	25.8	0.029	Bedrock	F4/1b
XS 2	118+79	41.0	32.6	54.3	1.26	1.67	25.9	0.024	64 Gravel	B4/1
XS 3	124+19	40.6	32.8	51.1	1.24	1.56	26.5	0.024	69 Gravel	B3
XS 4	127+41	41.9	48.2	56.8	.87	1.18	55.44	0.024	69 Gravel	F4b
XS 5	133+86	37.0	26.6	48.2	1.39	1.81	19.2	0.017	41 Gravel	B4/1
XS 6	138+94	28.1	24.8	47.9	1.13	1.93	22.0	0.017	62 Gravel	B4
XS 7	152+05	35.6	23.6	34.4	1.51	1.46	15.6	0.01	28 Gravel	B4c
XS 8	155+15	42.4	59.9	82.8	0.71	1.38	84.3	0.015	28 Gravel	F4
XS 9	169+77	42.5	30.4	51.6	1.4	1.7	21.7	0.013	50 Gravel	B4c
XS 10	176+53	36.4	32.0	45.8	1.14	1.43	28.1	0.015	18 Gravel	B4c
XS 11	182+08	34.5	23.4	37.4	1.48	1.6	15.8	0.017	18 Gravel	B4c
XS 12	227+42	34.2	28.3	43.9	1.21	1.55	23.4	0.014	30 Gravel	B4
XS 13	237+17	34.2	25.9	41.2	1.32	1.59	19.6	0.014	30 Gravel	B1
XS 15	208+35	46.7	127.1	280.9	0.37	2.21	343.5	0.016	30 Gravel	C4
XS 16	218+74	34.8	23.9	34	1.46	1.42	16.3	0.016	30 Gravel	B4
XS Headcut	~273+85	76.9	42.9	95	1.79	2.2	24.0	.01	30 Gravel	C4

The descriptions for the stream types found in Queen Creek include:

B channels: moderately entrenched, moderate gradient, riffle dominated channel with infrequently spaced pools. Very stable plan and profile. Stable banks. Moderate relief, colluvial deposition and/or structural (human or fault induced) valleys. Moderate entrenchment and width-to-depth ratio. Narrow, gently sloping valleys. Rapids predominate with scour pools. These stream types can support relatively robust vegetation on relatively narrow flood plains and have relatively narrow channels that can support surface flows during low discharge.

C channels: Low gradient, meandering, point bar, riffle/pool, alluvial channels with broad, well-defined floodplains. Broad valleys with terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology. These channel types can support wider bands of riparian vegetation since floodplains are usually wider and easily accessed by

frequent flooding. They are extremely susceptible to bank erosion and lateral migration if vegetation supporting bank strength is removed.

D channels: Braided channel with longitudinal and transverse bars. Very wide, shallow channel, Generally, with eroding banks. Broad valleys with alluvium, steeper fans. Glacial debris and depositional features. Active lateral adjustment with abundance of sediment supply. Generally, contain multiple small channels with convergence /divergence bed features. These channel types are typically poor transporters of sediment and the channel may aggrade rapidly during periods of high sediment supply. D type channels in Queen Creek are relics of past high sediment loads from the upper watershed and do not seem to be actively aggrading.

F channels: Entrenched meandering riffle/pool channel on low gradients with high width-to-depth ratio. Entrenched in highly weathered material. Gentle gradients with a high width-to-depth ratio. Meandering, laterally unstable with high bank erosion rates. They generally have a riffle/pool morphology but lack an adequate floodplain for reduction of flood flow energy or establishment of riparian vegetation.

B and C stream types are the expected, stable channel forms for the project reach based on channel slope. F, D and split channels are less stable areas with increased lateral instability and bank erosion. Queen Creek in Superior is predominately a stable B channel changing to a C channel where the slope flattens out. There is a brief section of an F stream type where the channel has a very low slope and a wide, flat bed. There is one section of a braided D channel and three sections of split channels.

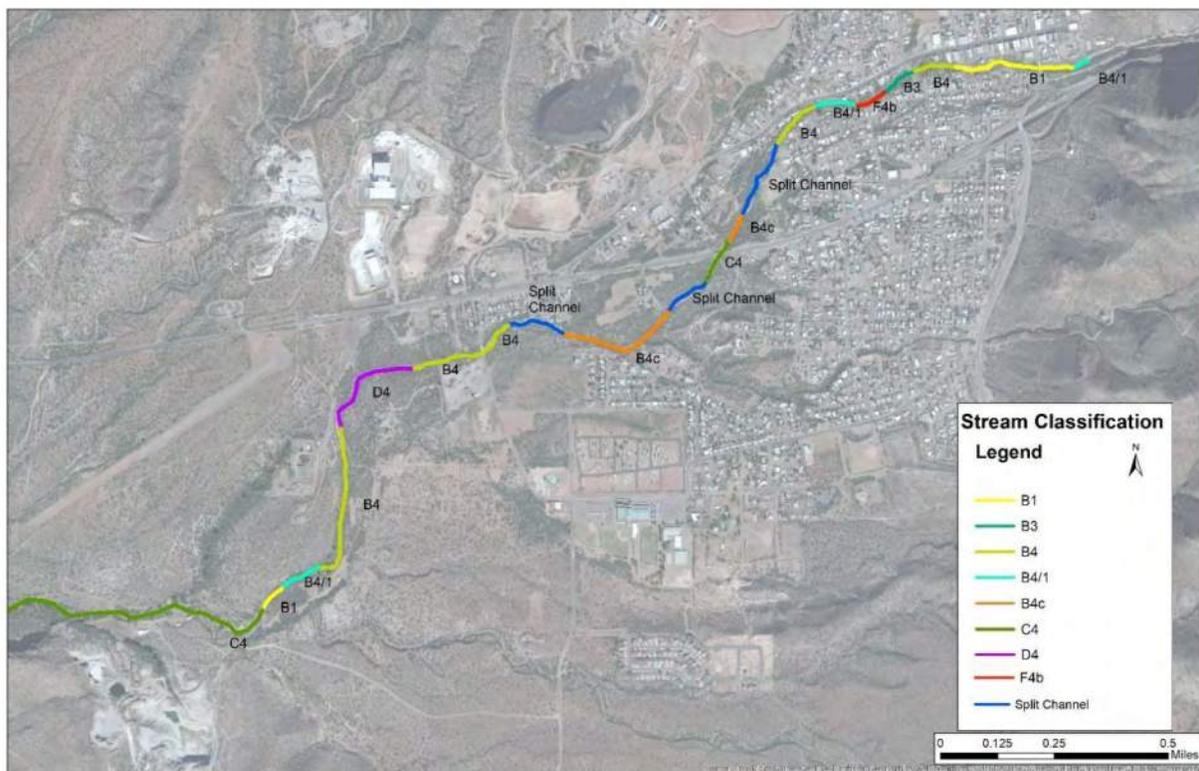


Figure 4. Stream types in Queen Creek.

The number following the stream type classification indicates the bed material of the active or bankfull channel: 1 for bedrock, 2 for boulders, 3 for cobble, and 4 for gravel.

PERTURBATIONS AND CHANNEL INSTABILITY AREAS

While the great majority of the channel through the reach appears to be stable, there are several limited areas of instability that should be monitored or managed to prevent more widespread degradation.

Low Water Crossings

NCD surveyed the low water crossings within the project area. Low water crossings on stream channels are frequently problematic, leading to sediment deposition or sometimes excessive erosion due to the wide shallow cross section compared to the typical stream crossing and local disruptions in slope. The crossings at Stone Ave, Mary Dr, and Airfield Rd are not an ideal design, they are above the grade of the channel bed and overly wide and shallow. The stream channel has adjusted to the changes in slope and width and they do not appear to be causing undue impairment to stream function or road maintenance at this time.

The unpaved crossing at the campground has caused a channel split below the crossing and this section of the stream can be expected to grow wider and less stable laterally over time. Relatively dense vegetation in the reach around the campground is expected to help resist this lateral instability and reduce bank erosion. However, the geomorphic dimensions of this crossing are not ideal and should be considered a higher priority for restoration efforts.

Bank Erosion

Bank erosion is not generally a concern in the Queen Creek project area. During the geomorphic survey, one actively eroding bank was documented upstream of Mary Dr (Figure 5). Several tall, vertical banks were also noted, however, these are not causing impairment or providing excess sediment (Figure 6). The active channel has pulled away from the bank due to the building of a bench or fallen debris. Bank erosion is not prevalent enough to create sediment supply issues for the stream. However, few localized bank erosion sites may warrant attention to prevent degradation of habitat or loss of private property.



Figure 5. Actively eroding bank.



Figure 6. Vertical banks that are not contributing excess sediment.

Headcuts

A headcut is a nick point or an abrupt vertical drop in the channel bed that creates erosion into the stream bed. This erosion migrates upstream and can move rapidly through a reach, given enough discharge. Over time the stream will continue to deepen and become incised and disconnected from its floodplain. Additionally, incised streams can lower the local water table affecting shallow rooted species dependent on a high water table. This process can also initiate headcuts in the stream's tributaries, all of which can lead to excessive erosion and instability in the watershed.

Headcutting is a minor problem in Queen Creek. Two headcuts were documented in the project area: one near the road to the wastewater treatment plant gate and the other upstream of the campground (Figure 7 & Figure 8). Because headcuts can move rapidly during a single run-off event with devastating effects on stream stability and habitat, repair of headcut areas should be a paramount priority for management action.



Figure 7. Two headcuts: near treatment plant (left) and upstream of campground (right).

The Google Earth image on the left shows that as the channel goes around the corner (stream flows toward bottom of image), it suddenly becomes incised and develops a vertical bank (shadow on left bank).



Figure 8. Above and below campground headcut.

The channel immediately upstream of the campground headcut (left) can easily access its floodplain, while the channel immediately downstream (right) is incised and cut off from its floodplain.

Potential changes to channel morphology

Bankfull channel dimensions are closely tied to watershed size. As watershed size decreases the channel can be expected to decrease over time as well. The projected reduction in watershed size for Queen Creek will likely only result in minor changes to the dimension of Queen Creek. Utilizing the regional curve for the area indicates that a reduction of 2.1 mi² in effective watershed size from 10.4 mi² to 8.3 mi² or 20% at Magma Ave (and a 12% reduction at the campground) should only result in a cross sectional area reduction of 4.8 ft² to a mean area of 37.4 ft². This reduction is not likely to seriously affect channel stability. However, aggradation of sediment at low water crossings may become more pronounced as sediment transport efficiency decreases in these reaches which are already somewhat at risk for aggradation.

RIPARIAN VEGETATION

The project area riparian vegetation has recently been mapped by Westland Resources, Inc NCD field work focused on location of more mesic riparian species as well as location and identification of non-native species.

The riparian vegetation along Queen Creek is diverse and relatively healthy xeric riparian community. Xeric implies that most of the species don't require permanent water and can live with intermittent wetting from flooding. This community may consist of the same species found on higher ground but have forms that are more robust and communities that are denser than those found on adjoining hill slopes. This is a common condition throughout the arid southwest and provides high quality habitat. While the xeric community of mesquite and associated plants is widespread through the corridor, there are pockets of more water loving riparian plants not associated with the hill slopes. These pockets consist of riparian trees including cottonwood, Goodding's willow, Arizona sycamore, Arizona walnut, velvet ash, netleaf hackberry and yellow and blue palo verde. The locations of these patches of more water-loving trees may indicate that shallow groundwater is available to the roots during most, if not all, of the growing season. These areas of mesic vegetation are more widely dispersed in the lower portion of the project area as flows from the wastewater treatment plant and a local perlite mining operation increase the length of time base flows exist in this reach. Older cottonwoods in the lower reaches exhibit dead tops, indicating that they may have been stressed for water at some point. It is suspected, but not confirmed, that the die off in the tops of these trees may have been associated with lack of flow from the Perlite mine during extended mine shutdowns, since the discharge is reliant on pumping from the mine. Monitoring wells in this area

indicate that ground water is relatively shallow below the discharge points for the perlite mine and wastewater treatment plant (<10 feet).



Figure 9. Location of mesic riparian trees.

While the riparian community is generally in good condition, there are some nonnative species of concern. Two of the most problematic are tamarisk (*Tamarix ramosissima*) and fountaingrass (*Pennisetum setaceum*) (see Figure 10). Both species are aggressively invasive and have the potential to greatly diminish the quality of the riparian habitat if allowed to disperse further. There are other nonnative species that are found within the corridor. However, these two species currently are the most widely dispersed and are recognized as the most aggressive invaders. NCD has written an invasive plant management plan that provides detailed information on managing all the existing invasive plant species. See Appendix B.



Figure 10. Tamarisk distribution in Queen Creek.

Fountaingrass is distributed throughout the project area within the riparian zone.

HYDROLOGY

The surface hydrology of the Queen Creek drainage has been reported by others (Brown and Caldwell, JE Fuller, and Montgomery & Associates), especially as related to potential loss of peak discharge and total runoff volume. Estimates of peak discharges and return interval for Queen Creek at Magma Ave are provided by JE Fuller (2020) for reference. It should be noted also that our estimate of bankfull discharge or the flow most responsible for shaping channel morphology is approximately the 1.5-year reoccurrence flow and is somewhere between 150 and 250 cfs. A Brown and Caldwell (2008) report also indicated that a portion of the watershed targeted for mining and loss of input is also relatively impervious, with high runoff coefficients.

Table 2. Peak Flood Discharges and Return Interval for Queen Creek

Estimates from JE Fuller 2020.. Estimates for Queen Creek Canyon at Magma Avenue in Superior, AZ.

	100 year	50 year	10 year	2 year
Discharge (cfs)	4,595	3,433	1,484	356

Queen Creek is an ephemeral/intermittent stream through the Town of Superior and becomes nearly perennial downstream of Apache Tear Road where treated water from the wastewater treatment plant and discharge from the perlite mine enters the channel. This flow appears dependent on discharges from both operations and diel fluctuations are tied to variations in outflows from the mine and treatment plant through this reach down to the Arboretum.

Bedrock and Surface Water Locations

Flows in Queen Creek are intermittent throughout the reach. Losses of surface flows appear to be tied to two different causes which have different implications for stream and riparian function.

A large concern is loss through deep, exposed fissures in bedrock to deep ground water aquifers. This flow does not return to surface flow at downstream locations. Previous reports have speculated that exposed cracks in upthrust limestone within the canyon upstream of town have historically been responsible for loss of base flows. NCD and M&A personnel walked this reach during a November 2019 runoff event to visually locate loss of flow. Water was clear and flowing at < 1.0 cfs (visual estimate). We were able to locate crevices in exposed limestone downstream of the old Rt. 60 bridge. Visual estimation of loss of flow was minimal or slight at this point. Surface discharge did diminish through the reach, however it appeared to be lost to alluvium and reappeared downstream at bedrock exposures. The largest losses to ground water appeared to be in the vicinity of the Concentrator Fault just upstream of Magma Avenue. Surface flows on exposed bedrock were greatly diminished beyond this point. Surface discharge losses to geologic formations are unquantified at this point and will require a careful gaging system to pinpoint the area of loss and determine the amount of loss.

Intermittent flows throughout the remainder of the reach appear to be driven by depth of alluvium. When alluvium is deep flows tend to be lost to the deeper soils. When bedrock is near the surface, underground flows are forced to the surface. NCD conducted a survey in March 2020 to map surface water locations during an intermittent flow period from Magma Avenue downstream. Runoff was very low with discharge through some sections and no surface water at all in others (Figure 11). The surface flows match up well with the exposed bedrock locations mapped during previous surveys (Figure 12). These locations are also aligned with higher incidence of more mesic vegetation noted in the vegetation survey (Figure 9).

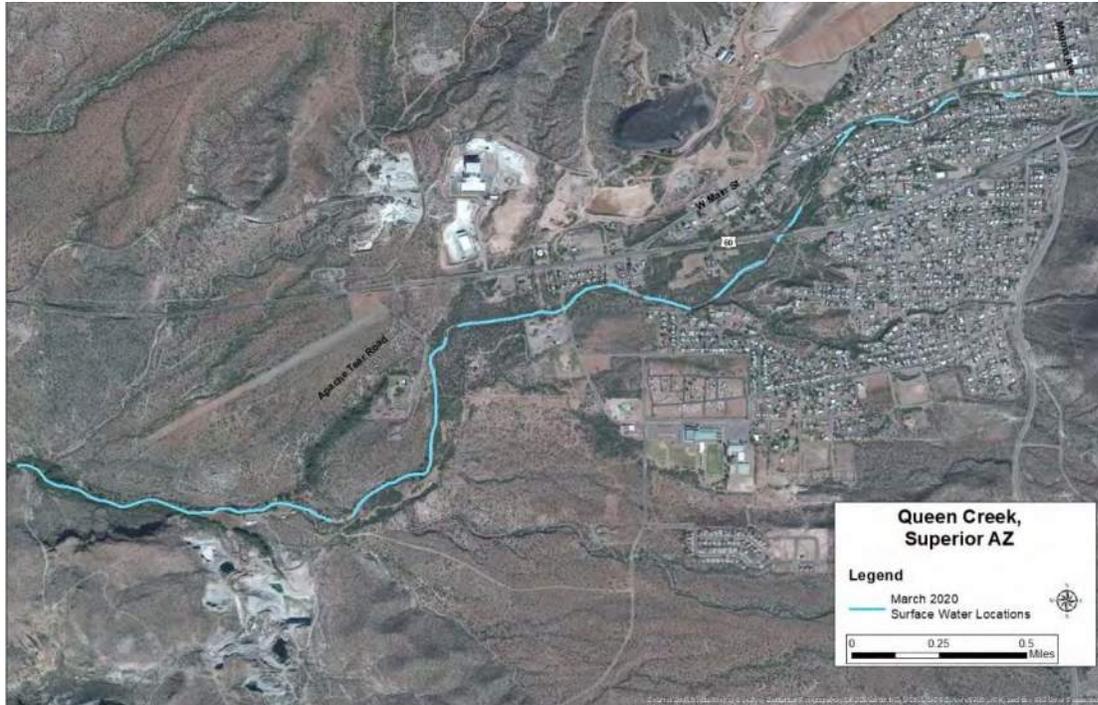


Figure 11. Surface water locations during a March 9, 2020 survey.

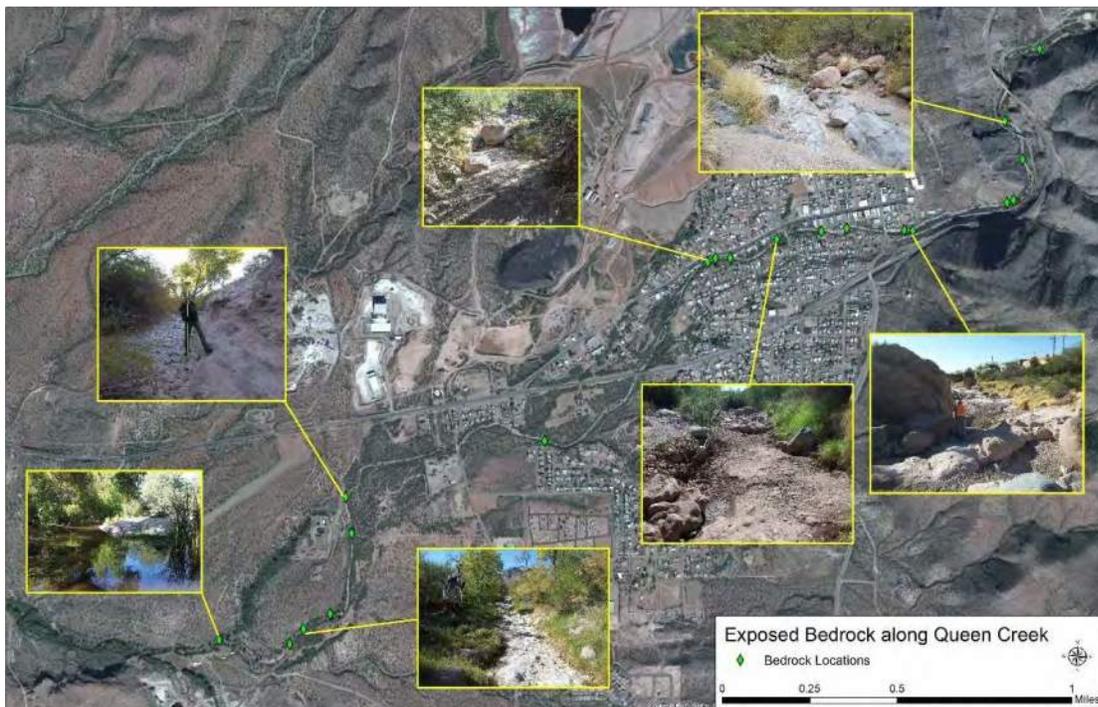


Figure 12. Locations of exposed bedrock.

Shallow groundwater linkages

The quaternary alluvium deposits under Queen Creek generally get deeper with distance downstream from the mouth of the canyon. Through town the alluvium is generally 10 feet or less deep down to the

Rt 60 bridge. Alluvium in the channel and riparian zone in the upstream portion of the town (Magma Avenue) are very shallow as evidenced by the bedrock channel substrate and may be too shallow for rooting of larger trees. Once below the Rt. 60 bridge the alluvium is generally 30 to > 70 feet deep (M&A data). Intermittent sills of bedrock are present within the alluvium and force groundwater towards the surface. If the groundwater is shallow enough (generally less than 10 feet), the riparian community can respond by maintenance of more mesic tree species. Established mesic riparian zones in the lower portion of the reach are associated with groundwater elevations 4 to 8 feet deep. Establishment of these trees requires considerably shallower moist soil conditions until roots can establish deeper. This pattern is evident throughout the reach as cottonwood, willows and other mesic trees occur predominantly in areas with alluvial soils upstream of bedrock outcrops. These areas present opportunities for expansion and rejuvenation of the riparian zone. If younger trees can be nursed into maturity until roots can establish in deeper groundwater pockets, they should be sustainable for the remainder of the tree's lifespan. Further investigation of these potential pockets of shallow groundwater is warranted to determine residence time and extent of shallow ground water. While they are generally already inhabited by desirable native vegetation, there may be opportunities to enhance and protect native riparian trees in these smaller habitat areas.

EVAPORATION AND TRANSPIRATION LOSSES

Potential evapotranspiration is the amount of evaporation and transpiration that would occur if a sufficient water source were available. We modeled potential evapotranspiration for Superior, Arizona using the Penman-Monteith Equation. Potential evapotranspiration was modeled and calculated using the SPEI package in RStudio. The equation requires the following inputs: precipitation, minimum temperature, maximum temperature, dew point temperature, daily wind speed, daily solar radiation, latitude and elevation. All data was obtained for the time period spanning January 1, 2000 to December 31, 2018. Precipitation and temperature data were obtained from modeled PRISM climate data (PRISM Climate Group, 2019) with a location centered over Superior Arizona. Wind speed was obtained from the National Climate Data Center for the Deer Valley Airport; this was the closest available location with data that covered the desired time period. Solar radiation is modeled data obtained from the National Renewable Energy Laboratory based on a location centered over Superior. Resolution Copper is collecting weather data, including all the parameters mentioned above but for a shorter period of time (since 2012).

The model calculates potential evapotranspiration (PET) for shorter vegetation (< 2 meters) and taller vegetation (> 2 meters). The results are shown below in Table 3. June has the highest PET rate while December has the lowest.

The question of interest is if additional water is pumped to Queen Creek, how much additional tall vegetation, such as cottonwoods and willows, could be supported. The existing water regime in Queen Creek, between Magma Ave and Hwy 60, supports shorter vegetation including mesquite and other primarily native shrubs and small trees.

Table 3. Potential Evapotranspiration (PET) rates for Superior, AZ.

Month	Average Monthly Potential ET for Short Vegetation (in/month)	Average Monthly Potential ET for Tall Vegetation (in/month)	Difference in PET between Shorter and Taller Vegetation (in/month)
January	2.1	2.8	0.76
February	2.8	3.6	0.82
March	4.8	6.0	1.29
April	6.3	8.1	1.75
May	7.9	10.0	2.10
June	8.7	10.9	2.24
July	8.1	10.2	2.09
August	7.6	9.3	1.70
September	6.8	8.4	1.60
October	5.0	6.4	1.34
November	3.0	3.9	0.98
December	1.8	2.5	0.69

The modeled PET rates above suggest that an additional 2.24 inches per month (June data) would be required to shift the existing vegetation from primarily shorter vegetation to taller vegetation. However, we assume that during the hot, dry month of June, mesquite and the other native drought-adapted plants slow down their growth and thus their transpiration rate. We do not assume the same is true for cottonwoods and willows. If we assume the actual PET is closer to 3 in/month in June for shorter vegetation, then an additional 8 in/month is required to shift the vegetation.

An extra 25 gallons per minute of water translates to an additional 3.4 acre-feet per month. This would provide enough water to shift approximately 5 acres from mesquite to taller vegetation. Since these calculations require quite a few assumptions, we suggest using a more conservative range of 3 to 4 acres of taller vegetation (cottonwoods and willows) can be supported with an additional 25 gallons per minute.

POTENTIAL ALTERNATIVES CONSIDERED

There are several potential enhancement alternatives that can be considered as stand-alone projects or in combination with other alternatives (Figure 13). The alternatives can roughly be divided into two types, those that aim to rehabilitate, restore, preserve and conserve the current stream and riparian character and those that have the potential to alter the stream or portions of it into a more desirable state. It should be noted that the ‘rehabilitate, restore, preserve and conserve’ actions are generally more assured of positive results and sustainable. Alternatives that involve the ‘restructuring and changing of the stream’ to wetter and more vegetated state would require considerably more information to be collected before success can be assured, more water than the stream currently experiences, and are less sustainable. Alternatives are discussed in more detail below.

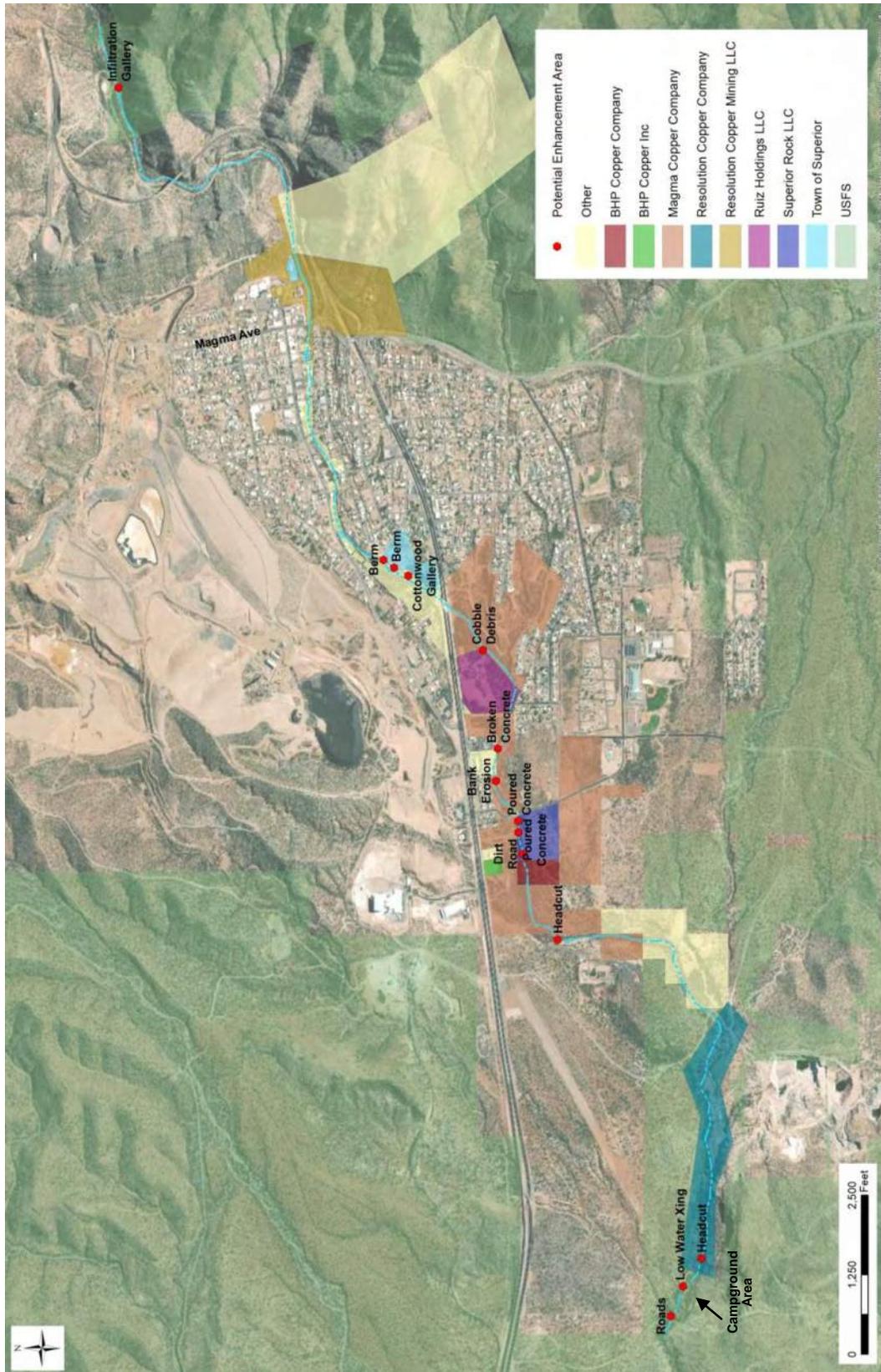


Figure 13. Locations of various problem areas in Queen Creek.

REHABILITATE, RESTORE, PRESERVE AND CONSERVE ALTERNATIVES

Clean Up / Debris Removal

Several key locations of the channel and floodplain have been impacted by debris and fill (Figure 14). This material affects water quality, flows, floodplain function, and aesthetics. Removal will require heavy machinery, dump trucks for haul away and a secure dumping site. The largest area for removal is downstream of Mary Dr near the concrete yards. It is difficult to accurately measure the total amount of material but 50 to 100 cubic yards of material have been pushed over the bank into the channel and floodplain. The majority of this material is concrete either in broken slabs or as poured and solidified form. There is also some native fill that has been pushed into the channel as well. Material should be removed, exposing native soil. All disturbed areas should be planted with native grass and shrub seed. Other areas up and down the channel have collected trash and litter which can be cleaned out by volunteer or hand crews. Cleanup efforts should be announced and utilized as an outreach and education effort for the community.

Cost estimates to clean up these debris areas are \$950 for the cobble pile, \$1,900 for the broken concrete pile, \$18,000 for the poured concrete, and \$600 for the dirt road crossing.



Figure 14. Typical non-native fill in the channel.

Broken concrete upstream of Mary Dr (left photo) and poured concrete in channel below Mary Dr (right photo).

Headcut and Bank Erosion Treatments

Headcuts were the most problematic geomorphic issue found on the channel and should be addressed as a priority. Headward erosion lowers the stream bed and can lower the water table for those nearly perennial reaches with high groundwater. This can lead to stress on riparian vegetation and eventual community shift in these reaches.

The suggested treatment for these areas is a cross vane weir such as the one shown below in Figure 15. These structures are constructed from large native rock placed in a chevron formation in the stream. The 'V' is on the upstream side placed at the grade of the stream. The 'arms' reach downstream at a slight angle upwards to the floodplain elevation. The structure forms protection against headward erosion while maintaining channel dimensions and sediment transport capability. Installation requires some design work to determine rock size, and weir dimensions. Installation requires an excavator with the ability to lift the proper sized rock. Weir construction is within the jurisdictional waters protected by the federal Clean Water Act and will require an appropriate permit from the Army Corps of Engineers.

Both headcuts (near the treatment plant and above the campground) will likely require a two-step cross vane weir which NCD estimates will cost \$15,000 for each weir (or \$30,000 total).



Figure 15. Cross Vane Weir example.

This cross vane weir protects the stream gradient and defines the active channel dimensions.

Bank erosion is less of a problem throughout the reach but is impacting one area. There are two aspects of bank erosion that should generally be addressed. The first is the banks susceptibility to erosion. This can be addressed by easing the vertical angle of the bank and planting with appropriate vegetation. The second is reducing the amount of shear stress that the lower portion of the bank experiences during flooding. This can be done with rock along the toe of the bank or changing the shape of the bank with barbs or channel reshaping to reduce shear stress on the toe. NCD estimates that the cost to slope the bank, place toe rock and revegetate the bank is around \$25,000.

This work does require some engineering and heavy machinery to place large native rock. Use of native rock reduces cost and the aesthetic impact of working in the channel. This practice would also require appropriate permitting from the Army Corps of Engineers.

Road at Campground and Riparian Buffer

While the campground area riparian zone and channel are generally in good condition, the roadway drains poorly to the stream and in places is too close to the stream to allow an effective riparian buffer. More importantly there is an old stream crossing that has widened the stream and started to cause a split flow condition at low flows. Both of these conditions should be rectified as part of the campground development. The roadway should be located far enough from the stream to allow at least 50 feet of buffer between the stream and road drainage. This drainage and its sediment load should be dispersed through the vegetation prior to entering the stream

The old road crossing should be graded back to proper stream channel dimensions and stabilized if the road can be abandoned. If it will continue to be utilized, a native stone hardened low water crossing should be designed and installed that will protect the stream by maintaining appropriate width depth ratios and sediment transport conditions. The relatively bare area near the stream in this area should be replanted and allowed to revegetate. This work should be done in conjunction with campground development. However, the channel work will require engineering and permitting through Army Corps of Engineers.

Design and construction costs for the stream portion of this work area are likely \$60,000 to \$80,000 if the road crossing is to be abandoned with a higher cost if the crossing is to be formalized.

Berm Removal at Town Park

There is a relict flood control berm or spoil pile on land owned by the town at the park along Rt. 60. Its current condition indicates that it is no longer providing any flood control function. However, it does impede flood discharges from spreading across portions of floodplain in this area. It is recommended that this berm be removed and the floodplain regraded to its original elevation. The disturbed area should be revegetated. The volume of material is approximately 70 to 100 cubic yards. The berm is outside of jurisdictional waters and will not require a federal permit. It will likely require a grading permit and because it is located within a FEMA designated floodplain, a hydraulic report will have to be provided by an engineer to the floodplain manager as part of the report. Cost for the actual earthwork and revegetation is estimated to be \$5,800.

Weed Management

Tamarisk and fountaingrass have been identified as the most problematic nonnative species in the corridor. We are aware that volunteer organizations working in conjunction with the USFS and other agencies are organizing to tackle this issue. This will undoubtedly be a multiyear effort. We have provided a weed management plan in Appendix B of this report. It utilizes both mechanical and chemical means of removal along with revegetation with native plants as needed. The plan has treatment timing, control methods and estimated costs outlined. The guidelines are meant to provide a 'living' document which can be built upon as tasks are accomplished and the non-native community responds to management.

For the first year, NCD estimates that Fountaingrass will take one week to treat and the woody species will take three weeks for a total cost of \$28,000. The second year we estimate the fountaingrass will still take a week and the time to treat the woody species should take half the time, for a cost of \$17,500. We estimate the treatment time for third year will take two weeks for a cost of \$14,000.

ALTER, RESTRUCTURE AND CHANGE ALTERNATIVES

It has been suggested that additional water resources could be added to Queen Creek to mitigate the reduction in flow from the watershed. Flows could be diverted from either the Wastewater Treatment Plant, the Never Sweat Tunnel or other sources identified during the mining process. The approximate flow from either of these sources is 25 gallons per minute. Large questions remain about how to best utilize this resource to mitigate the loss of surface flows in the channel, corresponding stress on the channel and riparian area and importantly loss to groundwater recharge. These questions focus on the amount and timing of the discharge addition as well as the location of the discharge point (s).

In discussions about the source of additional discharge, the flows from the wastewater treatment plant has been dropped from consideration for two reasons. First, the discharge is likely responsible for maintenance of high groundwater below the confluence with Queen Creek which is responsible for maintenance of a relatively healthy mesic riparian area. These flows are also likely responsible for recharge of the well gallery utilized by Boyce Thompson Arboretum that relies on well water to keep the arboretum healthy. While these connections are not confirmed, the lay of the land and groundwater suggest that it is highly likely. The second reason is that the wastewater treatment plant is downstream of the reach likely to be utilized for addition of water. This will require pumping, which is maintenance less passive and less sustainable approach. Hence, the Never Sweat Tunnel is the only additional source of discharge utilized for further discussion.

Hydraulic Modeling

Cross sections from the geomorphic study were also used in preliminary hydraulic modeling to show potential visual effect of increased water in the channel at various locations. Figure 16 shows the water level for 1 cfs (450 gpm) at three different cross sections which results in a water level that is about 0.2

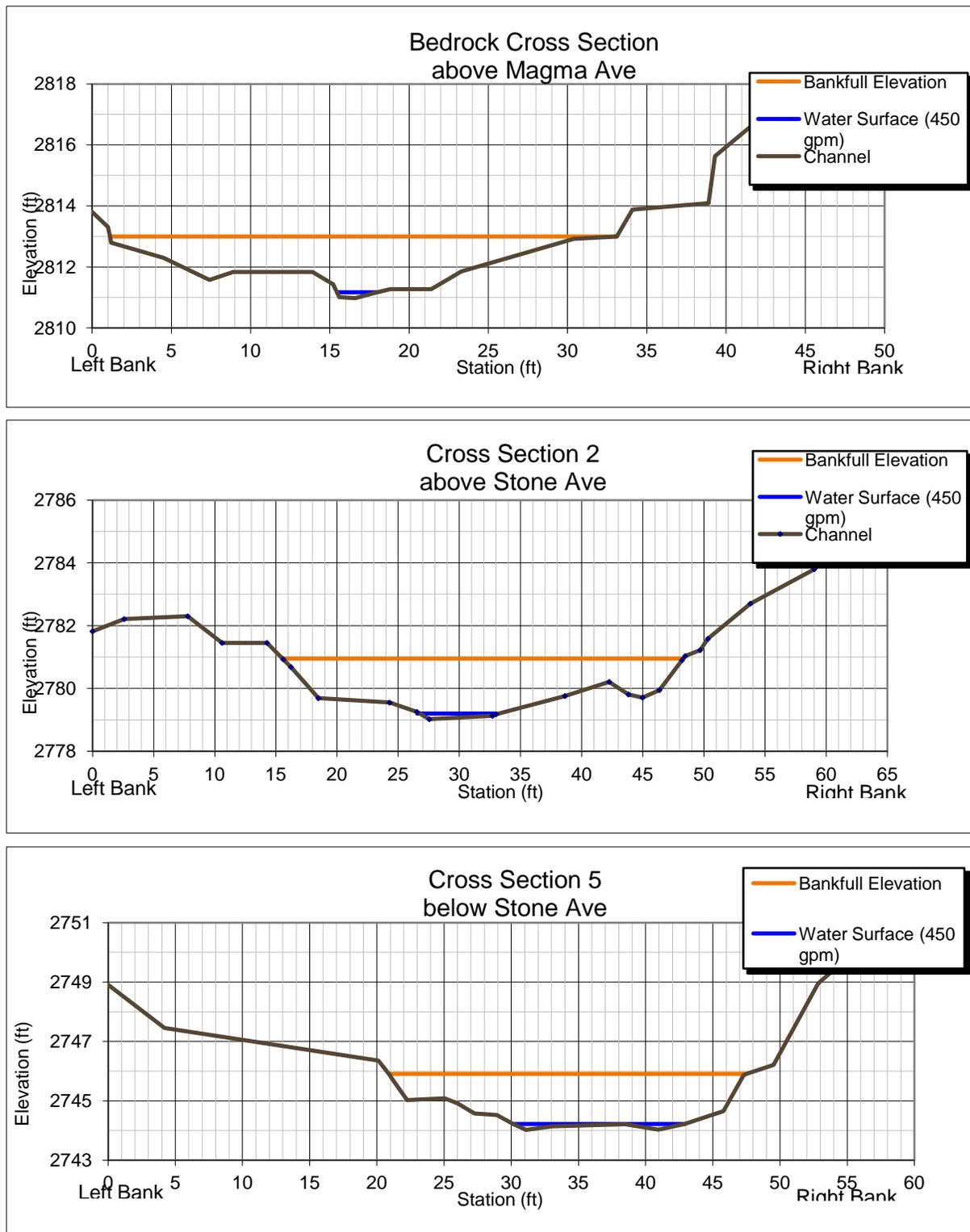


Figure 16. Hydraulic analysis of 450 gpm in typical stream cross sections.

450 gpm is 18 times the available additional flow but is smallest flow that could be modeled with this method.

feet deep. One cfs is 18 times the additional water available but is shown because that is the lowest flow that can be input into the model. Results indicate that surface flows should be visible but will not cover a wide portion of the channel. Observations from the wet/dry mapping indicate that areas with thick alluvial layers may not exhibit continuous surface water during a 25 gpm release.

Because the flow is relatively small, the alluvium has the potential to sink the surface flows. Releases for aesthetic viewing are best done in an area where bedrock is relatively shallow. Magma Ave to Stone Ave provides a good location for adding small surface flows in a portion of the channel that will be easily accessed by the public. Limited alluvium and shallow bedrock indicate that flows should remain on the surface to downstream of Stone Avenue. Surface flows beyond this point are dependent on groundwater conditions between Stone Ave. and the Rt 60 bridge. It is unlikely that surface flows would continue beyond Rt. 60 during a low flow condition since the alluvium becomes much deeper at that point.

Concerns about mosquito control due to the surface flows are easily addressed by turning the flow off for several days on 7 to 10-day cycles to dry the channel and disrupt the mosquito life cycle. Additionally, even a small amount of water velocity is enough to discourage mosquito larva survival.

Storage Facility and Pipe around Fault Line and Sinkholes

Flows from the Never Sweat Tunnel are limited to 25 gpm. However, they are continuous, resulting in approximately 40 acre-feet of water per year. If stored, the accumulated flows could be released in higher amounts that might be more meaningful to aesthetic and riparian resources. Stored flows could be utilized to extend natural runoff periods or provide additional water during periods of drought and base flow.

Area for storage of these flows is problematic. There is little room in the area for a dam or storage tank with adequate capacity. However, some existing but unutilized infrastructure may be able to provide storage and is under investigation for functionality and legal aspects. Arizona Water Company operated an instream, gravel infiltration gallery in the lower portion of Queen Creek Canyon. This gallery was utilized to trap and store flows through the alluvium. The area was pumped (maximum rate of 60 gpm) and utilized for drinking water. The project was abandoned when water quality was impaired (exceedance for turbidity). Infrastructure for the project is still in place. However, it has not been tested in several decades. Consequently, the storage capacity and pump capacity are unknown at this time but may be adequate for some storage and augmentation of flow downstream. Water rights and access to the project infrastructure are being explored with Arizona Water Company by Resolution Copper and M&A.

Transfer of water downstream to the Magma Avenue reach would be via a pipeline to avoid losses as the streambed crosses fissures in limestone outcrops. Portions of the original pipeline are in place but likely require maintenance or replacement. The pipeline would have to be approximately 1.2 miles long to connect the infiltration gallery to the Magma Avenue outlet area. Additional pipeline would be required to connect Never Sweat Tunnel with the infiltration gallery. Cost for renovation of the gallery, pumps and other appurtenances is unknown until further investigation of the gallery condition.

Creation of Cottonwood Gallery at Town Park

The Town of Superior and other stakeholders have expressed an interest in conversion of a portion of the xeric riparian zone into a more mesic riparian community given that additional water may be available in the future. The added 25 gpm of water will not be enough to allow extensive conversion of the riparian community. However, if conditions are amenable, the evapotranspiration model indicates that up to 5 acres of xeric community could be converted. These 5 acres are likely an optimistic value with a realistic goal from a previous study indicating that approximately 3 acres would be appropriate. However, whether it is 3 acres or 5 acres, this is a less sustainable alternative and presents a higher degree of risk and failure, especially during extended drought.

In order to utilize, the additional water fully, conditions need to be conducive. Alluvium needs to be deep enough for rooting (>4 ft) and shallow enough that surface flows will not percolate below the rooting depth (4 to 8 feet). This situation occurs where bedrock sills are pushing subsurface flows closer to the surface. Additionally, the area should be on land that is publicly available. Mesic riparian trees naturally grow in areas where flood inundation is on a 2 to 25-year frequency. Planting areas should meet all of these specifications.

The area closest to meeting all of these requirements is at the Town Park upstream of the Rt. 60 bridge. There are several mature cottonwood trees already in this area indicating that once trees reach maturity they can survive. Establishment of young trees appears to be the bottleneck to cottonwood growth. The area east of the channel is town property; the western side of the channel is vacant private land that could be utilized for this purpose since the landowner would not be able to develop within the floodway where the trees are best suited. A strategy for conversion of this site to mesic riparian would require extensive effort and active maintenance and would likely require the following:

- Perform geologic and groundwater testing to ensure that groundwater and alluvium are within the tolerance ranges. Shallow well monitoring will be needed to ensure that groundwater is actually within range of mature roots
- Establish irrigation with water piped from the Never Sweat tunnel. This can be in the form of either furrow or drip irrigation with furrow being preferred.
- Remove existing berm and ensure that planting area will flood at 5 to 10-year return interval. Some minor grading may be needed.
- Remove non-native vegetation.
- Plant cottonwood poles or containerized stock. Suggest working with Northern Arizona University Cottonwood research group to select genotypes that are drought tolerant and adapted for likely climate conditions over the next 50 years. This research group can select stock and will use data collected from the site for scientific research on community genetics.
- Establish trees with irrigation for 3 to 5 years
- Once trees are established, the irrigation water can be turned into the stream channel at Magma Avenue. Flows will provide surface flow amenity and recharge the alluvium at the cottonwood restoration site (Figure 17) for long-term sustainability. Excess flows will continue past the bridge and recharge the deeper alluvium.



Figure 17. Potential cottonwood planting area at Town of Superior Park.

Additional vacant private land on west side of channel is high elevation but can provide some suitable planting space.

Subsurface Water Gradient Control with Structures

The reach from US Rt. 60 downstream to the proposed campground is generally deeper alluvium and groundwater depths are correspondingly deeper. Surface flows are generally not present during low intermittent flow periods in the remainder of the stream. However, towards the lower end of this reach, there are some mesic trees indicating groundwater is closer to the surface. There are also bedrock outcrops in the area.

It may be possible to utilize the outcrops and enhance them to help push ground water closer to the surface. This practice would consist of exposing the existing bedrock then adding on a concrete sill to the appropriate elevation and length to capture groundwater flow and push it towards the surface where it can be utilized by vegetation or potentially surface flows. The surface would be refilled with native soil and recontoured back to the original condition. The area affected by the treatment would be limited to the area of land upstream of the sill that could be saturated with groundwater to within 6-8 feet of the surface. So, the practice would be most effective on low slope reaches of channel. This treatment is not widely utilized but would act in a similar manner to sheet pile applications to block groundwater from construction sites.

Closer observation, studies with ground penetrating radar and shallow groundwater monitoring will be required to determine if this practice is feasible in this reach. The area where it appears to offer the most promise is on private lands. Costs would have to be compared to amount of habitat that could be enhanced.

ADDITIONAL DATA REQUIREMENTS

There are several data gaps that have been identified through the assessment process. These gaps are related to other, ongoing studies but are specific to the types of practices proposed in the assessment. The implementation of the treatments, especially the treatments focused on changing surface flows and riparian communities should be dependent on the results of these data collection efforts.

STREAM GAGING ABOVE CONCENTRATOR FAULT, AT MAGMA AVE. AND RT 60

There is a need to understand channel losses at base flow conditions (< 3 cfs). Gages should be set at hardened channel areas (bed rock) so that errant measurements due to water flow in alluvium are minimized. The goal of the gaging should be to determine losses in the lower canyon and across the Concentrator Fault, through the reach from Magma Ave. to Stone Ave., and from Stone Ave to above the Rt 60 Bridge during runoff events.

There is also a need to understand the timing and amount of surface flows contributed from the waste water treatment plant and the perlite mine. These systems should be monitored with weirs and continuous recording pressure transducers. Metal weir plates can be installed for a semi-permanent measuring station.

TEST FLOWS

A steady flow release of water from Arizona Water Company should be utilized to test the results of the gaging study. The test flow should be a relatively small discharge similar to 45 gpm proposed augmentation flows. Test flows can enter the channel near Magma Ave. to avoid losses in the limestone layers upstream of the town of Superior.

MONITOR PRIVATE WELLS AND SHALLOW GROUNDWATER IN COMBINATION WITH GAGING AND TEST FLOW STUDIES

There is a need to understand how the shallow ground water around the channel is influenced by both flood flows and low steady flows. Monitoring of existing wells and the installation of alluvium groundwater wells within 12 to 20 feet of the ground surface will be necessary to understand the recharge of this system and extent of the streams influence on water available to plants. This study is important in the area of the Town Park where revegetation is most likely to occur. Alluvium groundwater depth information within a 200-foot radius of the active channel is the most important for informing riparian revegetation projects.

CONDITION ASSESSMENT OF THE ARIZONA WATER CO. INFILTRATION GALLERY

This structure provides an excellent potential resource for storage of water from the Never Sweat Tunnel or as an alternative source of surface flows. There needs to be a condition assessment of this structure for capacity and water quality. The water rights to this structure needs to be explored as well before it can be considered for utilization.

SURFACE WATER RECHARGE TO AQUIFER MECHANISMS

The critical link between surface water and recharge of essential groundwater resources needs to be made for small surface flows that are limited to the short reach upstream of the Rt. 60 bridge. The fate of flows released into this reach is key to understanding the full effects of some of the proposals in this report. M&A are working to understand if water entering the alluvium in this area enters the deep ground water system or if it is captured in the alluvium and eventually returned to plants or stream flows.

REGULATORY AND PERMITTING CONSIDERATIONS

Work within the project corridor will require two main permits. The first is a floodplain use permit related to FEMA regulations for work in the floodplain. This permit is generally dealt with through the local floodplain manager. The purpose of the permit is to ensure that any changes to the channel or floodplain do not cause an increase in stage for the 100-year flood event. For some projects, this may require a hydraulic model which shows pre- and post-project flood elevations with an objective of no rise or a lowering of flood stage.

The second required permit would be the Clean Water Act Section 404 permit. This permit is processed by the Army Corps of Engineers Regulatory Branch for the Los Angeles District (offices in Phoenix). Only projects that take place inside the jurisdictional limits (roughly the active channel) are required to obtain these permits. It should be noted that rules for jurisdictional waters designation are in flux at this time and ephemeral portions of Queen Creek may not be jurisdictional if these changes are made.

The Army Corps also requires a biological evaluation of the site, explaining any potential impacts to endangered species, and a letter of concurrence from the State Historical Preservation Office (SHPO) that the project will not affect any archaeological resources.

NEXT STEPS

While additional data is required to act on several practices provided in this project, others can be adopted relatively quickly. We recommend that the multi-year weed management plan proposed here be adopted to prevent further infestation. Designs for the headcut remediation should be finalized and implemented to prevent further degradation of the channel and associated riparian area. Planning for campground improvements should include specific considerations for channel and riparian improvements in that area.

Test flows from Arizona Water Company are tentatively scheduled for November 2020. Stream gages for surface water and shallow groundwater monitoring for specific areas should be set up. More detailed data on groundwater, depth to bedrock, and sources of water need to be investigated before a decision is made specifying the location where surface water could be replaced.

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APPENDIX A

Geomorphic Data

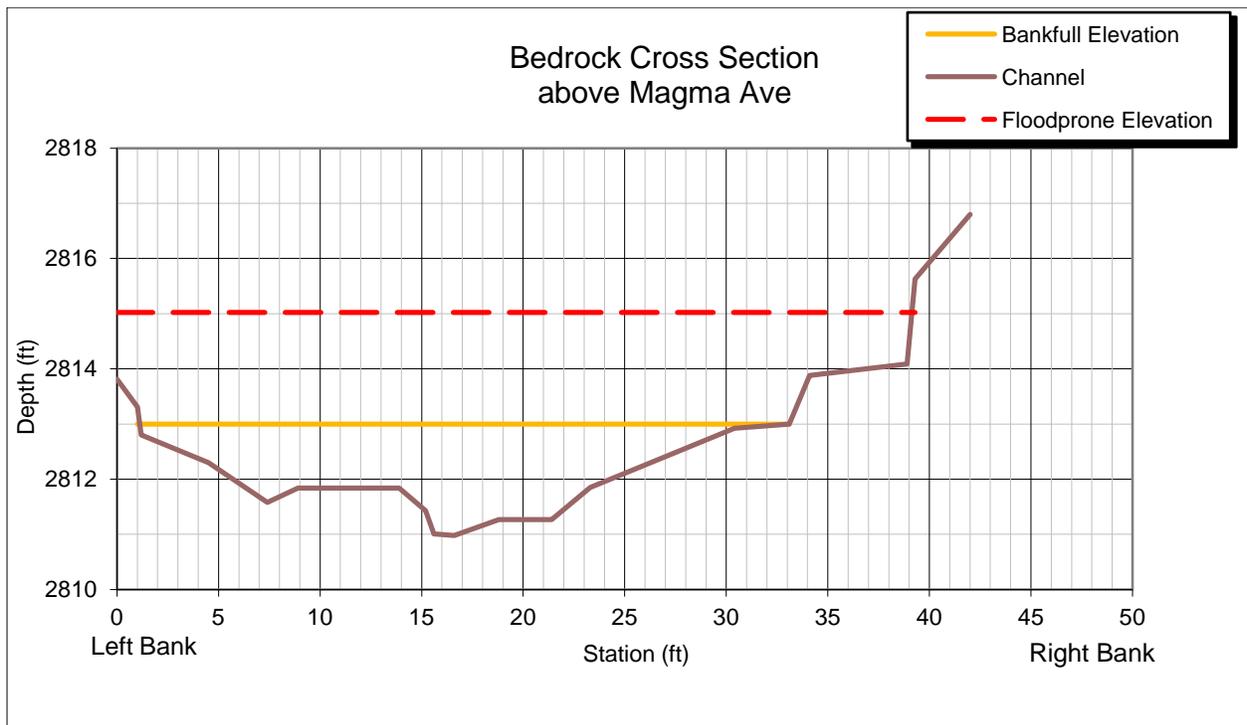
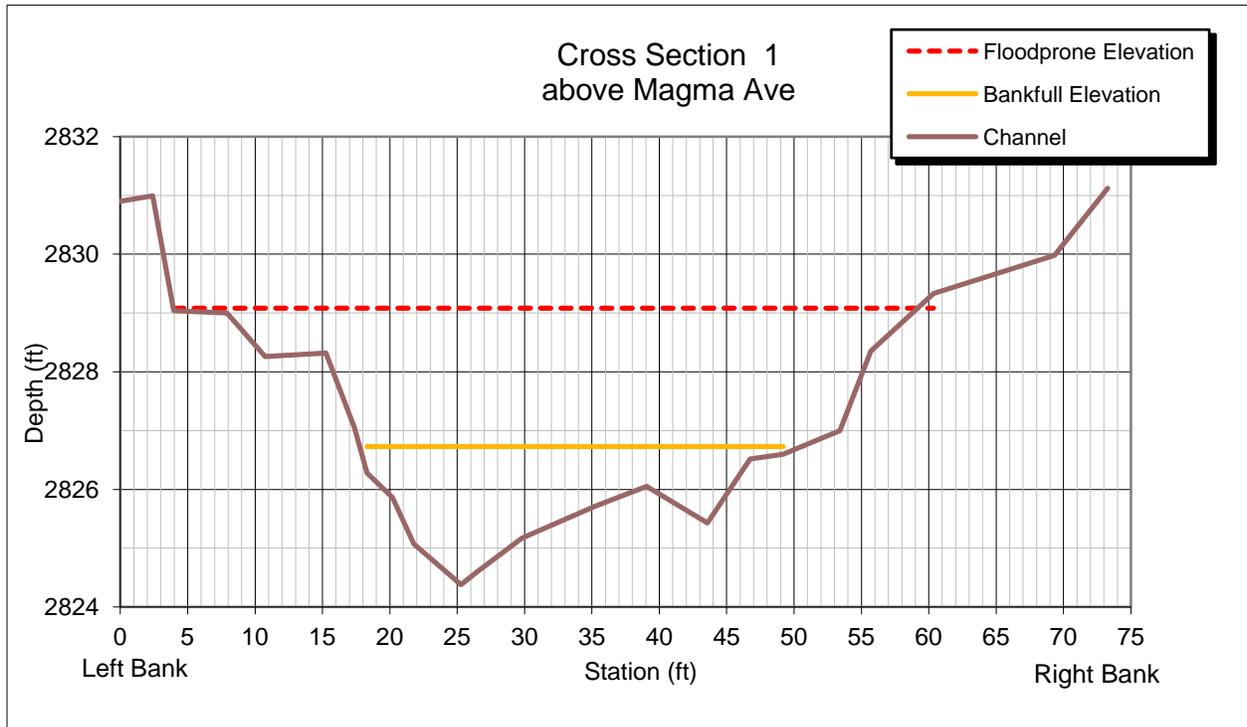
Cross Section Location Map

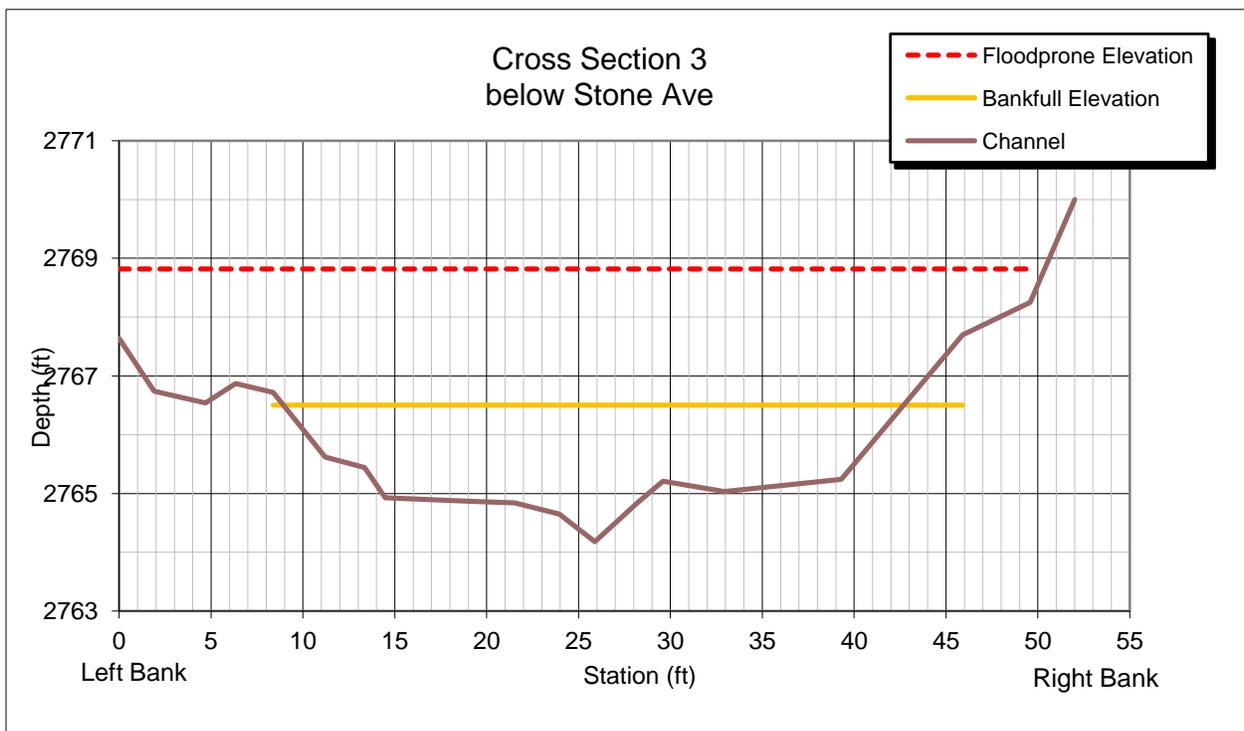
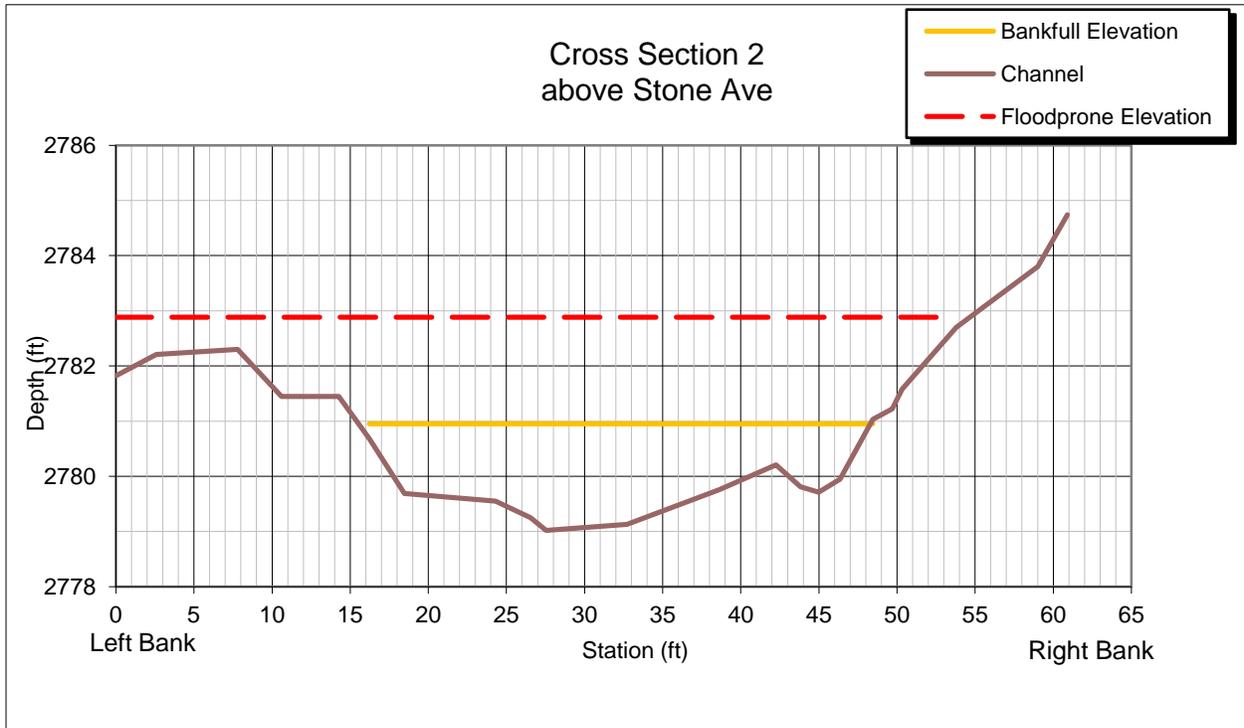


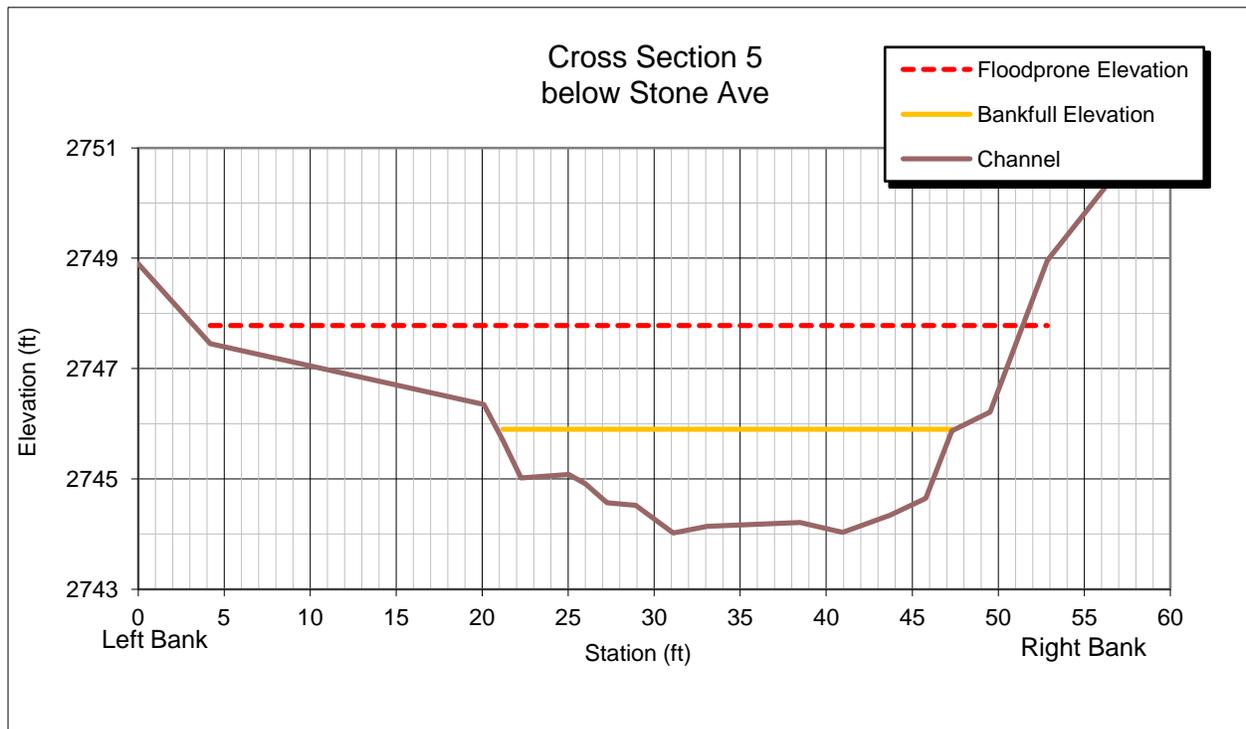
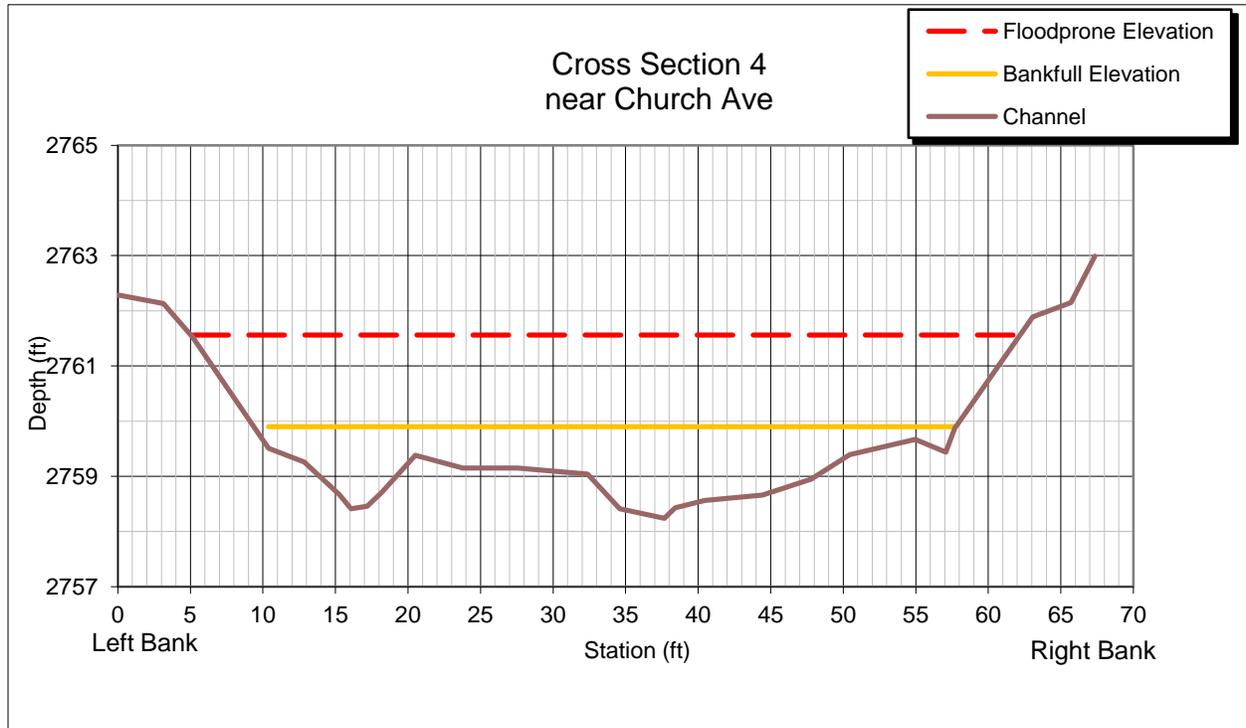
Geomorphic Dimensions and Information for Cross Sections

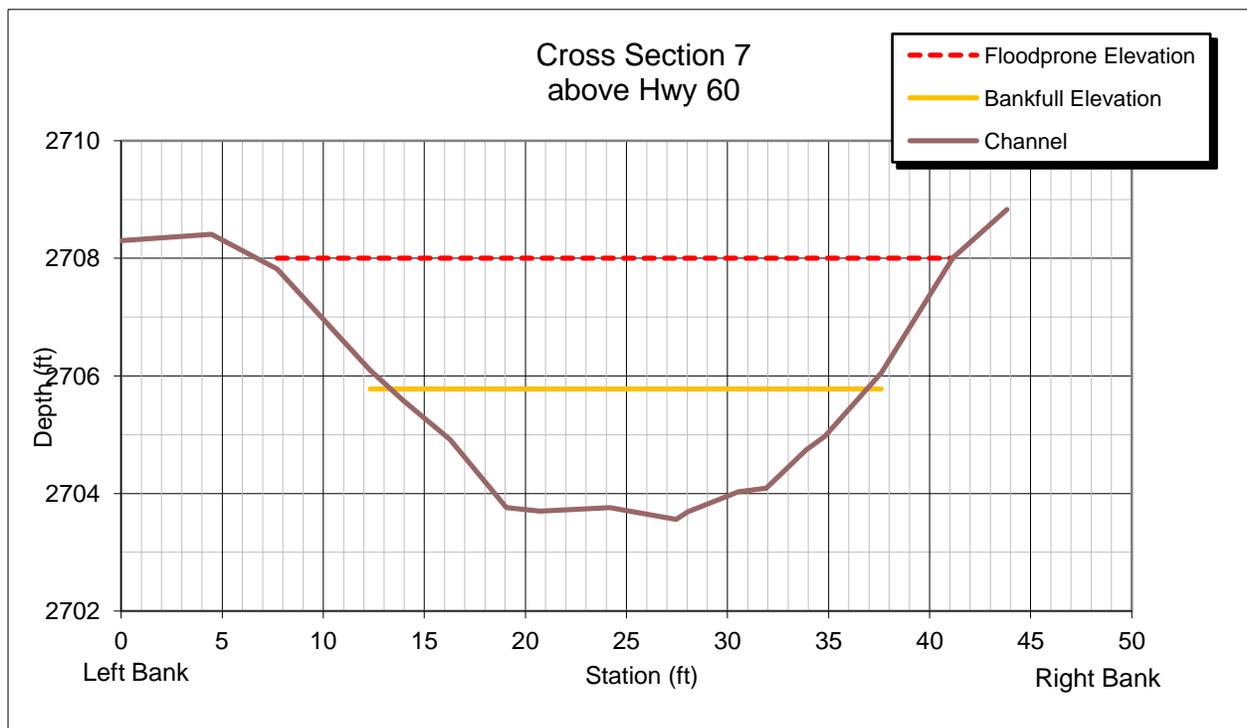
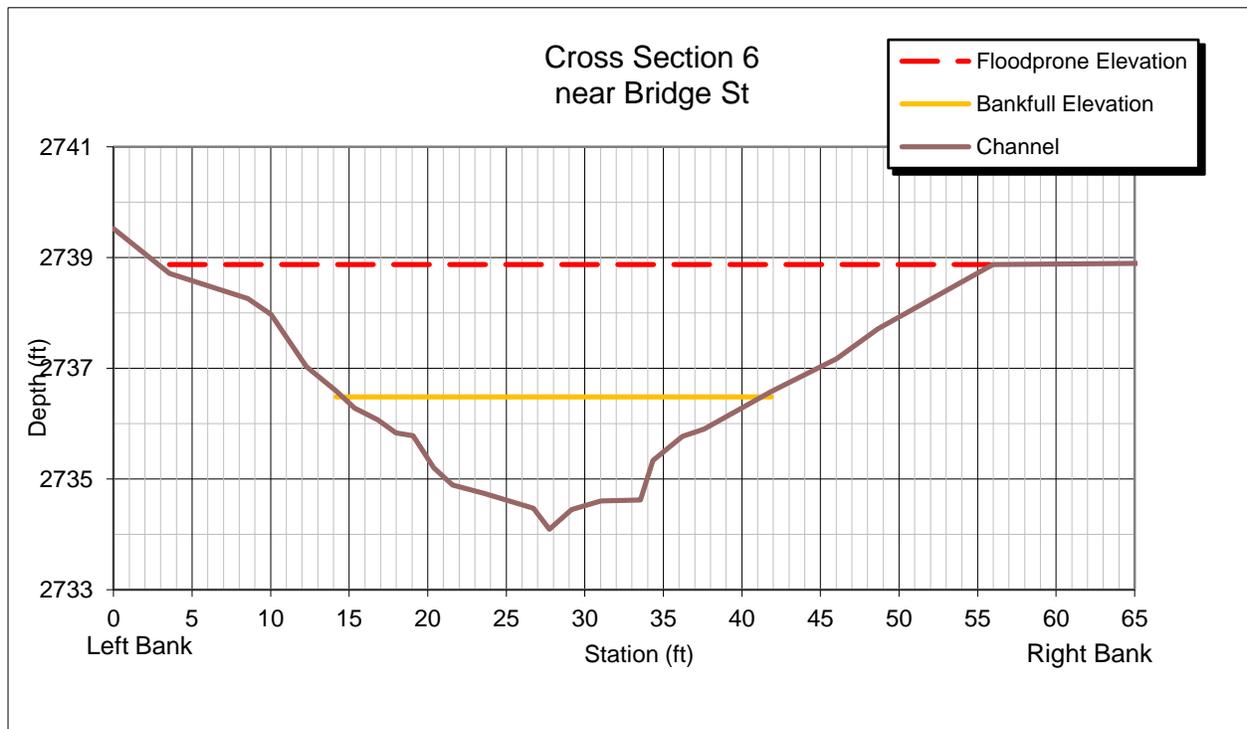
Cross Section	Station	XS Area (ft ²)	Bankfull Width (ft)	Floodprone Width (ft)	Mean Depth (ft)	Entrenchment Ratio	Width-Depth Ratio	Channel Slope	D50 (mm) Bed Material Classification	Stream Type
XS 1	100+09	36.8	32.8	55.2	1.12	1.68	29.3	0.029	64 Gravel (and Bedrock)	B4/1
Bedrock XS	104+10	32.6	29.1	43	1.12	1.48	25.8	0.029	Bedrock	F4/1b
XS 2	118+79	41.0	32.6	54.3	1.26	1.67	25.9	0.024	64 Gravel	B4/1
XS 3	124+19	40.6	32.8	51.1	1.24	1.56	26.5	0.024	69 Gravel	B3
XS 4	1127+41	41.9	48.2	56.8	.87	1.18	55.44	0.024	69 Gravel	F4b
XS 5	133+86	37.0	26.6	48.2	1.39	1.81	19.2	0.017	41 Gravel	B4/1
XS 6	138+94	28.1	24.8	47.9	1.13	1.93	22.0	0.017	62 Gravel	B4
XS 7	152+05	35.6	23.6	34.4	1.51	1.46	15.6	0.01	28 Gravel	B4c
XS 8	155+15	42.4	59.9	82.8	0.71	1.38	84.3	0.015	28 Gravel	F4
XS 9	169+77	42.5	30.4	51.6	1.4	1.7	21.7	0.013	50 Gravel	B4c
XS 10	176+53	36.4	32.0	45.8	1.14	1.43	28.1	0.015	18 Gravel	B4c
XS 11	182+08	34.5	23.4	37.4	1.48	1.6	15.8	0.017	18 Gravel	B4c
XS 12	227+42	34.2	28.3	43.9	1.21	1.55	23.4	0.014	30 Gravel	B4
XS 13	237+17	34.2	25.9	41.2	1.32	1.59	19.6	0.014	30 Gravel	B1
XS 15	208+35	46.7	127.1	280.9	0.37	2.21	343.5	0.016	30 Gravel	C4
XS 16	218+74	34.8	23.9	34	1.46	1.42	16.3	0.016	30 Gravel	B4
XS Headcut	~273+85	76.9	42.9	95	1.79	2.2	24.0	.01	30 Gravel	C4

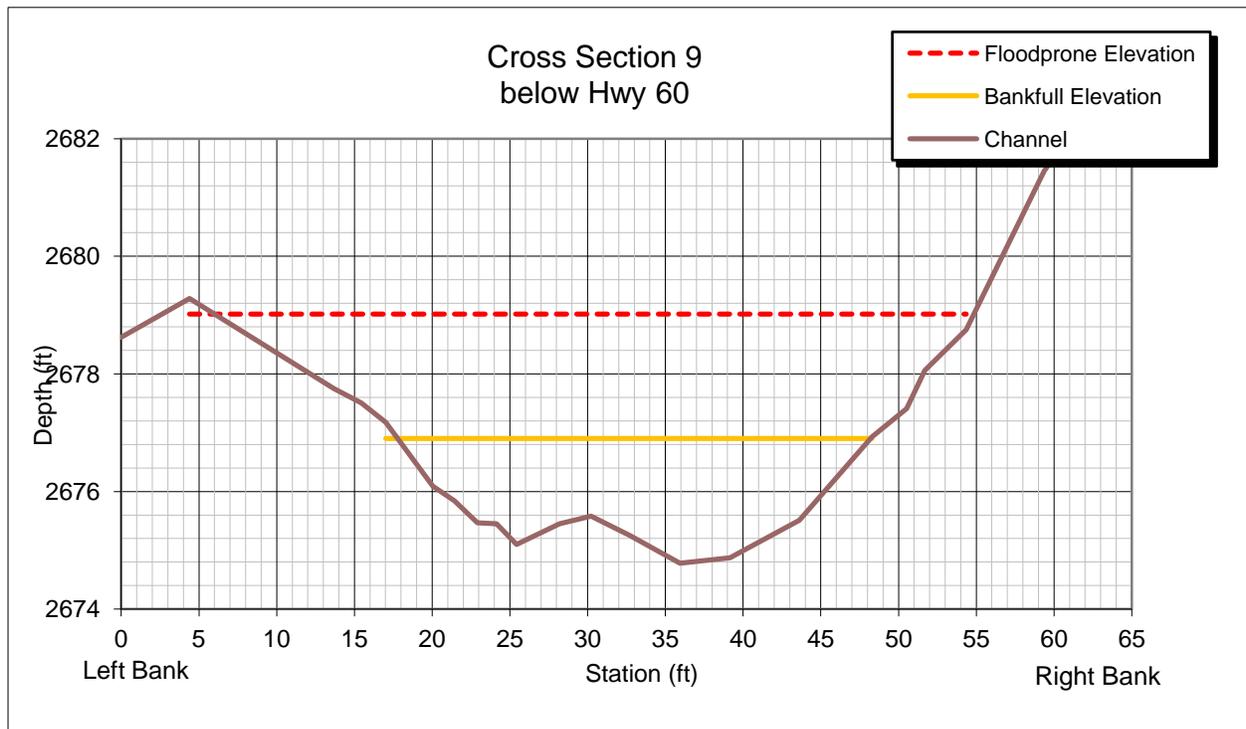
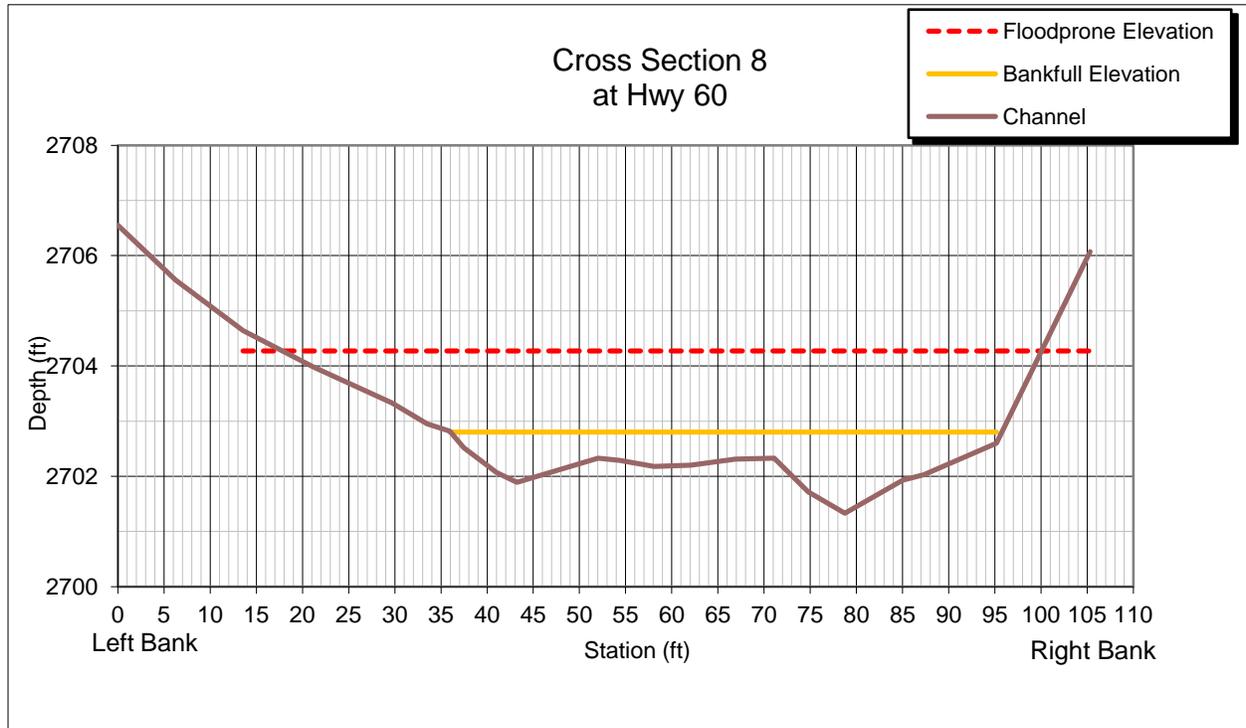
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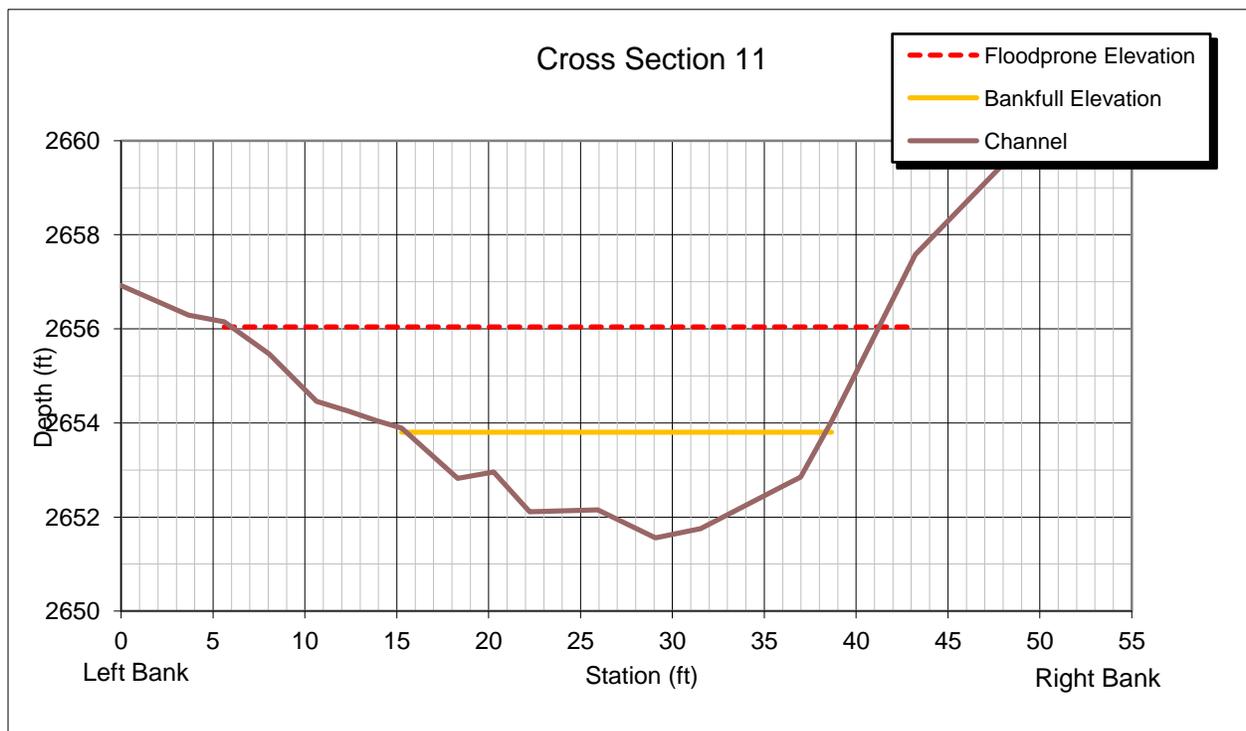
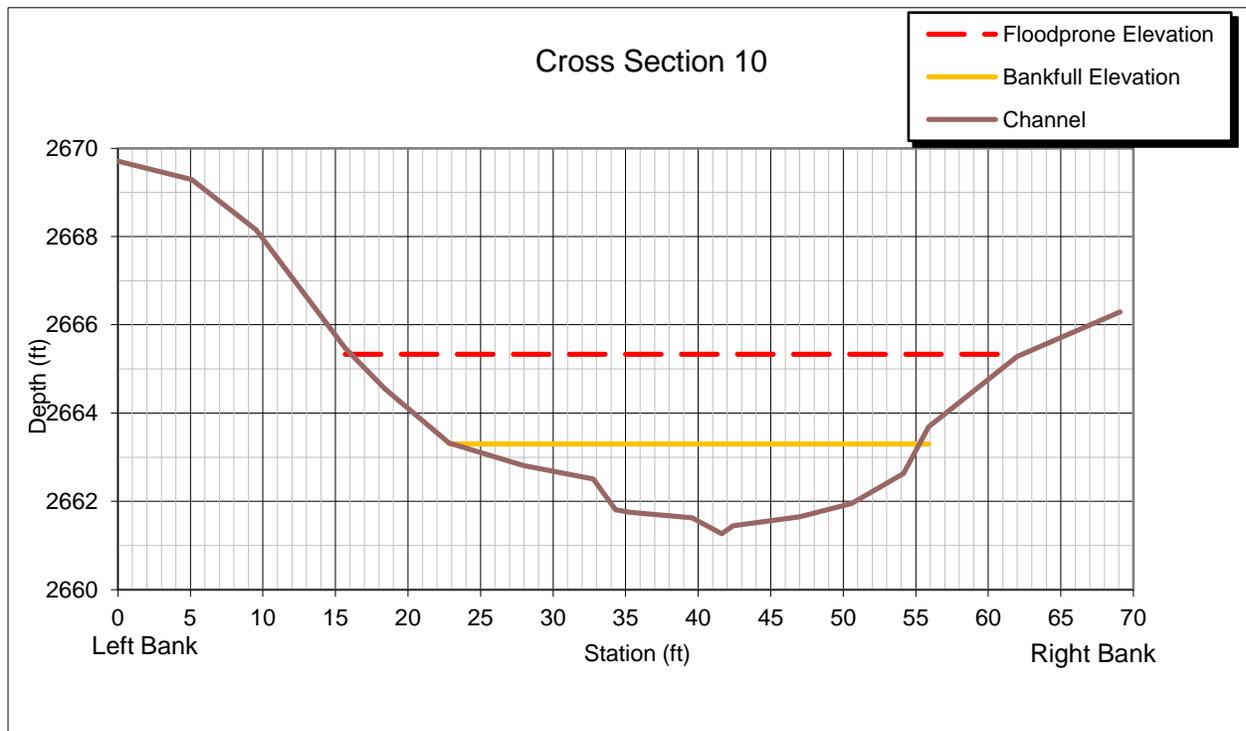


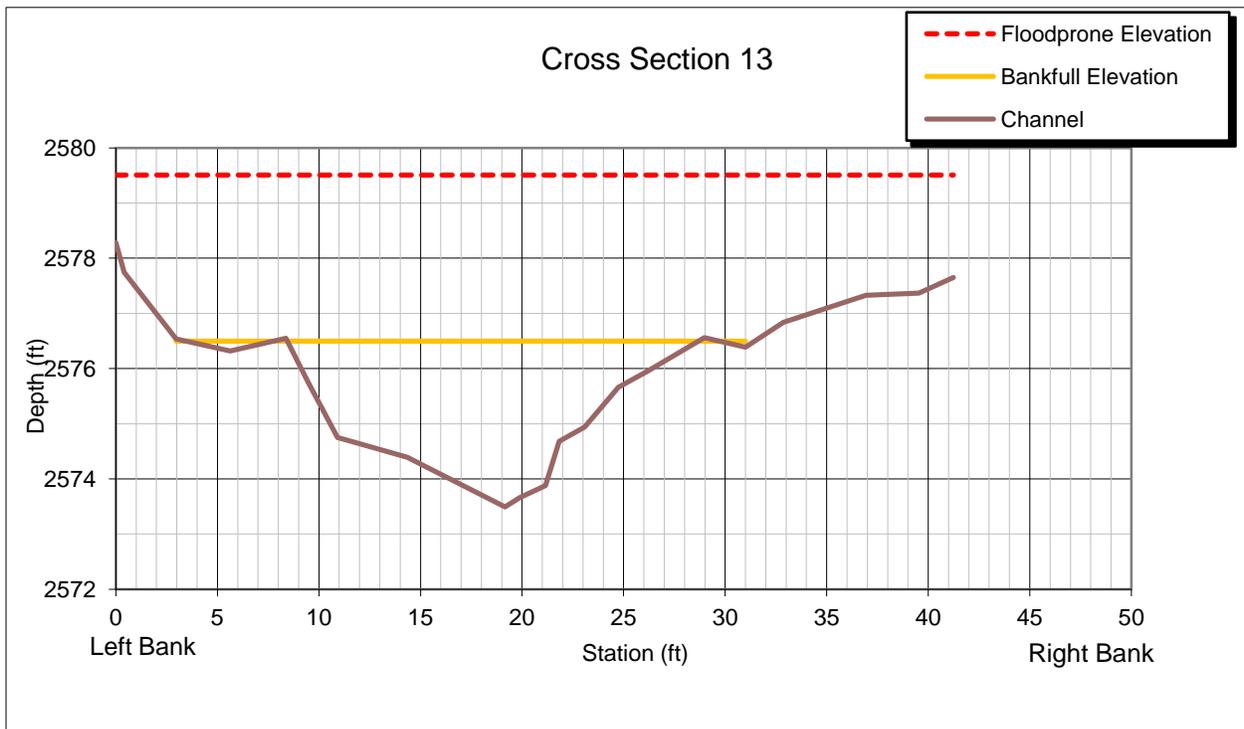
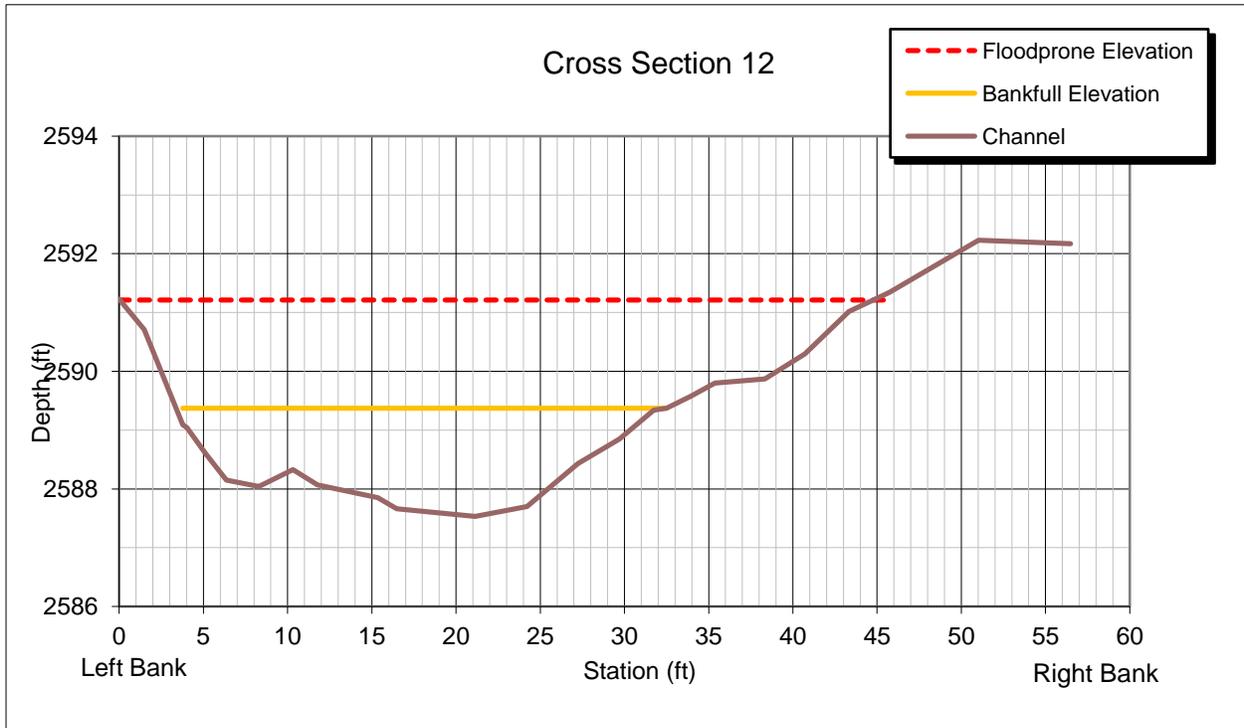


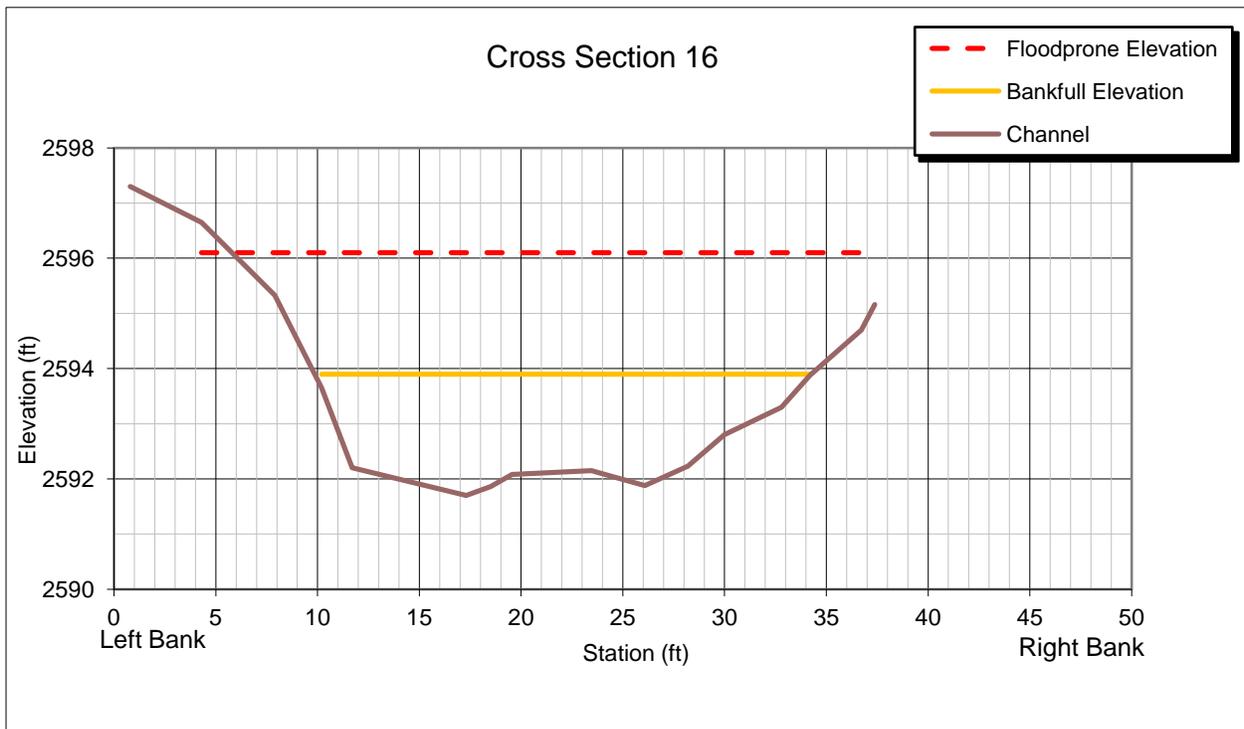
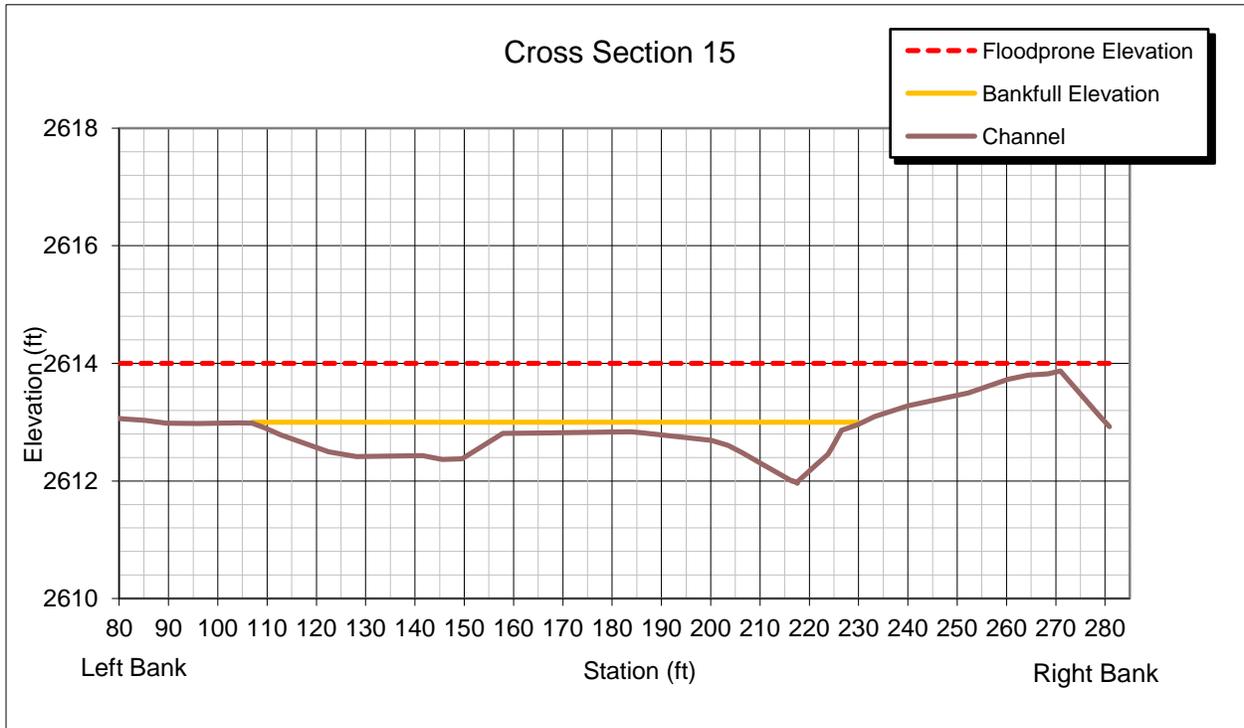


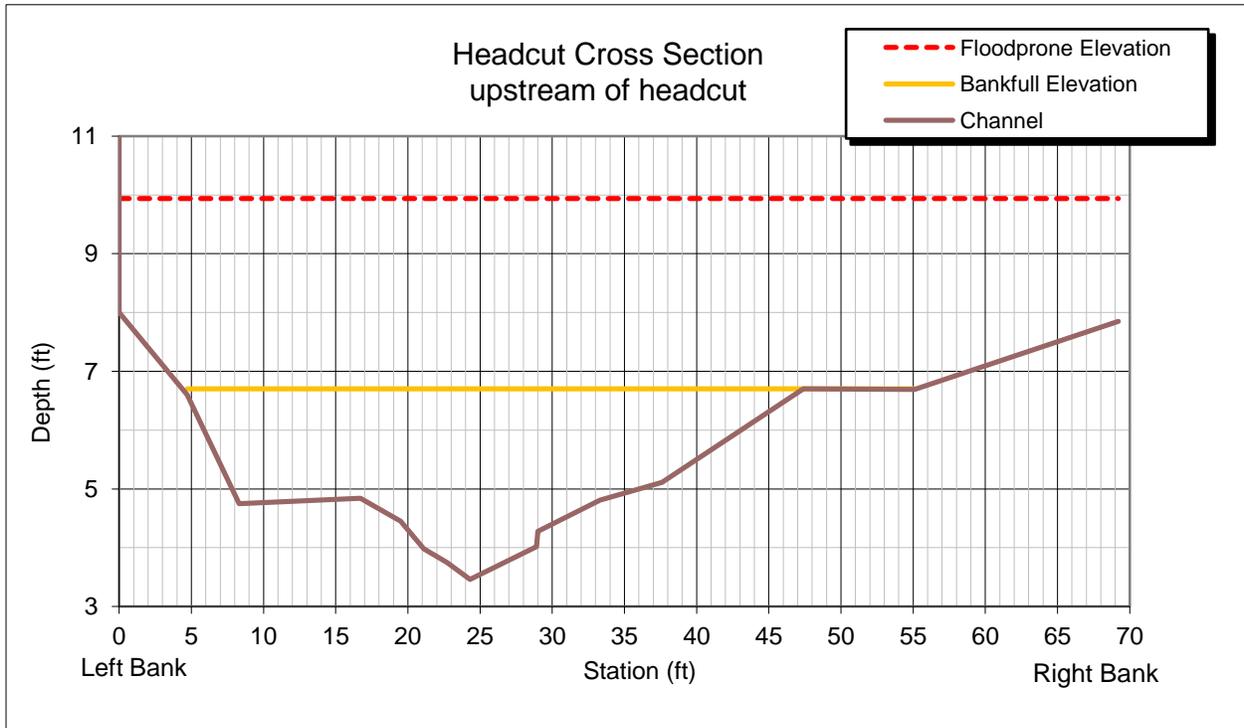




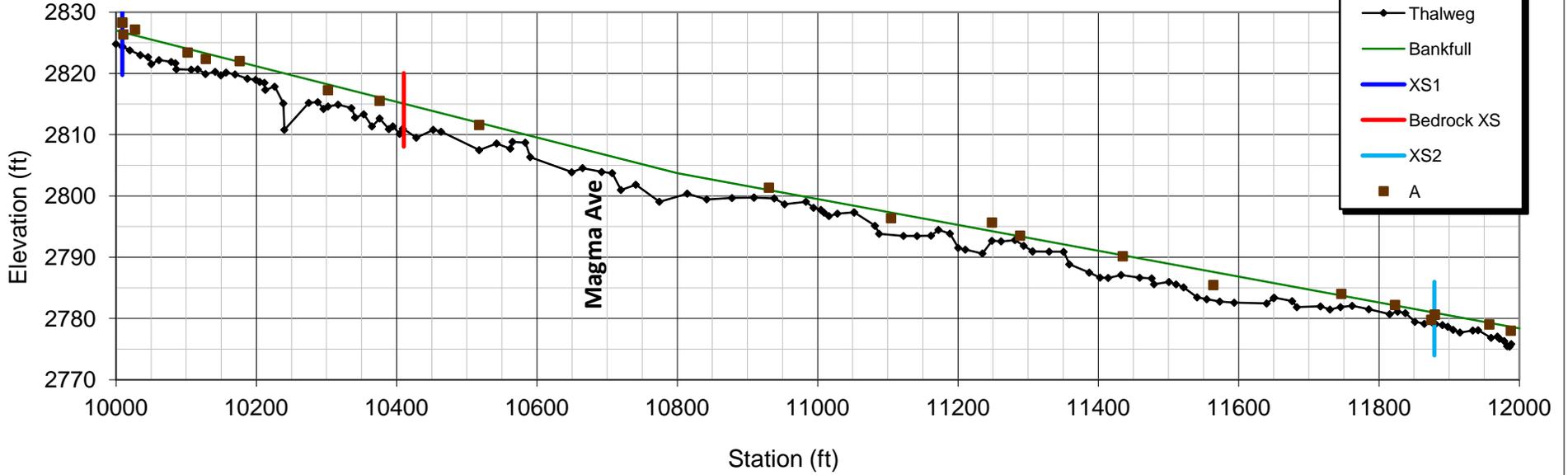




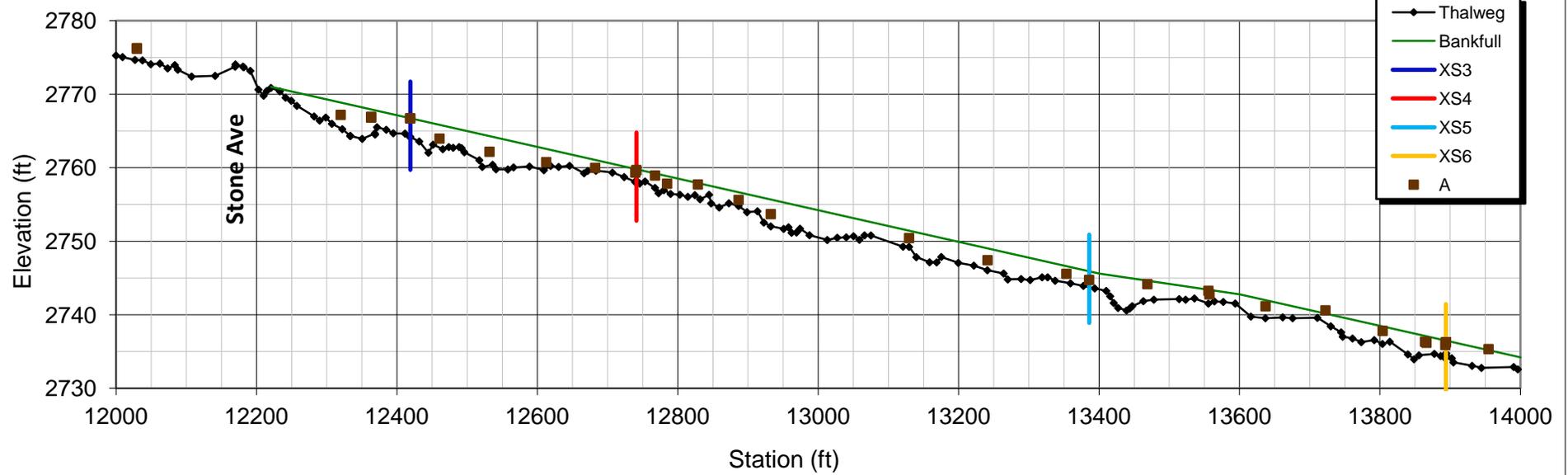




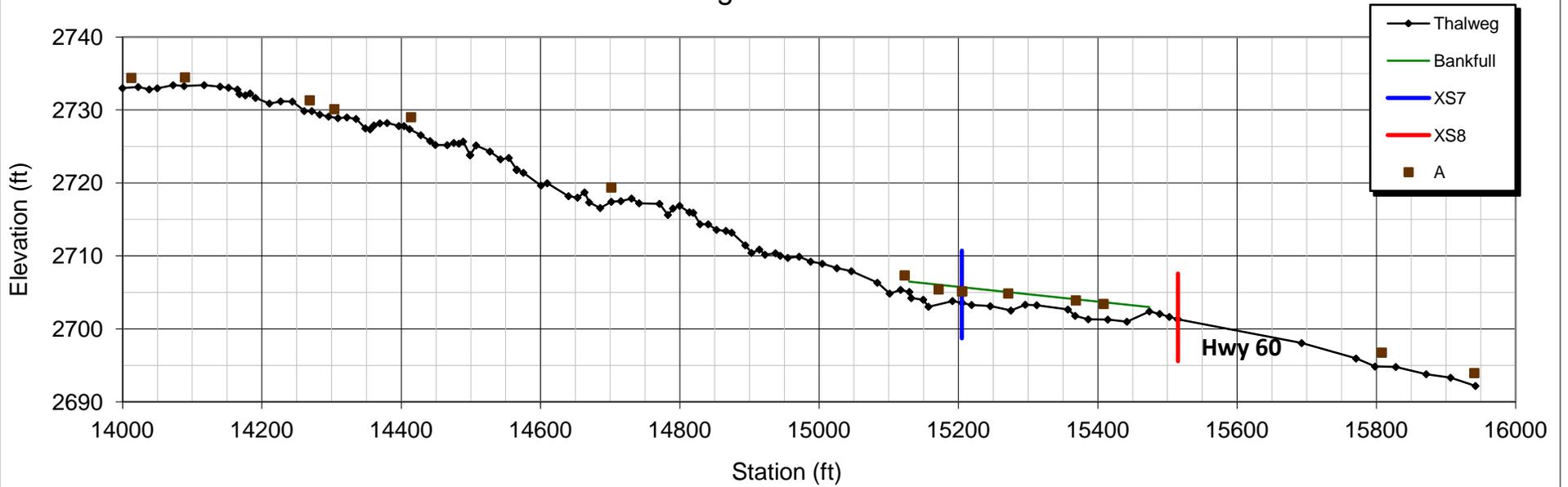
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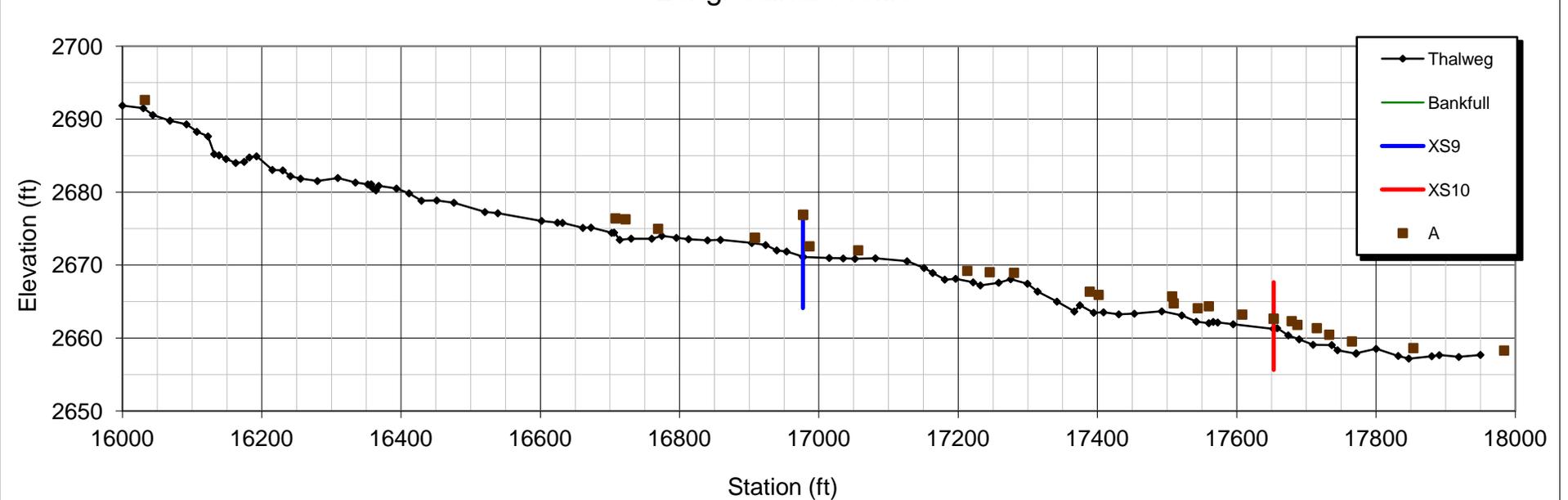
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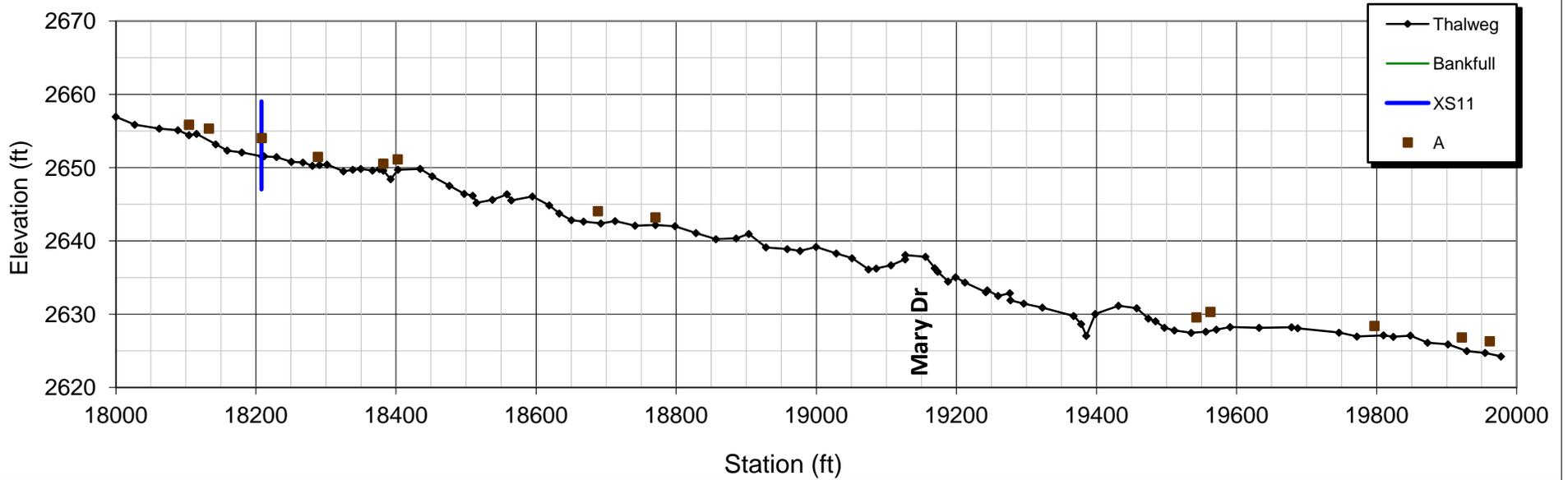
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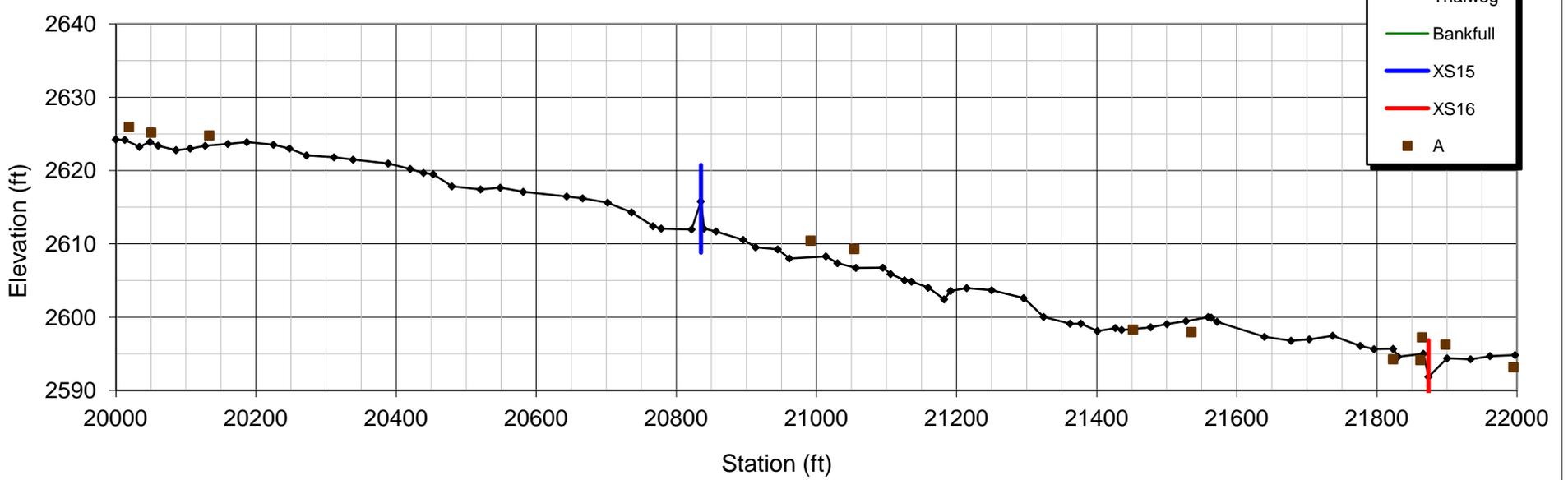
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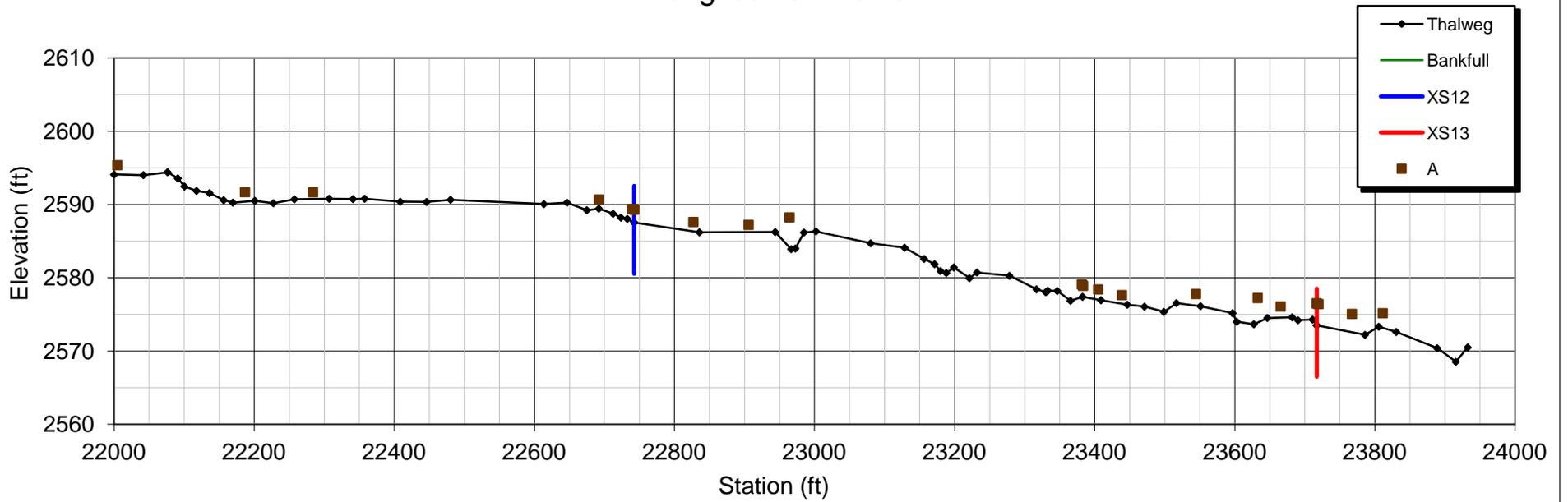
Longitudinal Profile



Longitudinal Profile



Longitudinal Profile



APPENDIX B

Non-Native Vegetation Management Plan

Queen Creek, Superior AZ

Weed Management Guidance Note and Generalized Plan



May 2020

Queen Creek, Superior AZ

Weed Management Guidance Note and Generalized Plan

Submitted to:

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May 2020

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EXECUTIVE SUMMARY

This report provides invasive weed management guidance for the Queen Creek riparian corridor through Superior, AZ. Surveys of Queen Creek found several invasive species, we recommend initially targeting four of these species for treatment: fountaingrass, tamarisk, oleander and tree of heaven.

- Fountaingrass should be spot sprayed annually with herbicide in the spring when plants are rapidly growing. It will likely take several years of annual herbicide treatments to significantly reduce the population of fountaingrass because there is likely a large seedbank from which seedlings will continue to germinate.
- Tamarisk should be chemically treated using a cut stump method in summer or fall when the plant is growing and not water stressed. A single treatment should significantly reduce the existing population. However, tamarisk can resprout and a follow up treatment the next year is recommended.
- Oleander should be chemically treated using a cut stump method. A single treatment will significantly reduce the oleander which should be followed by a second treatment the next year to catch any plants that survive.
- Tree of Heaven should be chemically treated using a basal bark or stem injection method. Like Tamarisk and Oleander, a single treatment will kill most plants and a second treatment the following year should kill any survivors.

Long-term, annual monitoring is needed to monitor target species populations, determine treatment effectiveness and future treatment needs, and to detect new invasions. Fountaingrass and tamarisk likely have significant populations in tributaries to Queen Creek and upstream of Superior which can lead to reinvasion of treated areas.

It is important to only begin treating areas that can continue to be treated until the target populations are under reasonable control. Consider revegetating any larger areas where invasive species have been removed to prevent secondary invasions.

INTRODUCTION

The Town of Superior, in collaboration with several organizations, is working toward enhancing the recreational and natural values within Superior including improving access to trails and enhancing the aesthetic quality of the Queen Creek riparian corridor. A major objective of enhancing the riparian corridor is controlling the invasive plant species along Queen Creek.

This weed management plan was developed to help manage and control invasive plant species found within the Queen Creek corridor. This plan is meant to provide guidance as to which species to target, the methods used to manage them, treatment timing, monitoring and other considerations required for a successful, long-term management program.

PROJECT AREA

The project area includes the Queen Creek riparian corridor in and around Superior, Arizona (Figure 1). Natural Channel Design, Inc. (NCD) has conducted both geomorphic channel assessments and invasive plant surveys within Queen Creek from the water tank (1 mile upstream of Magma Ave) to just downstream of the campground area (Perlite Rd) in 2019 and 2020. This plan covers management of invasive plants observed during these surveys.

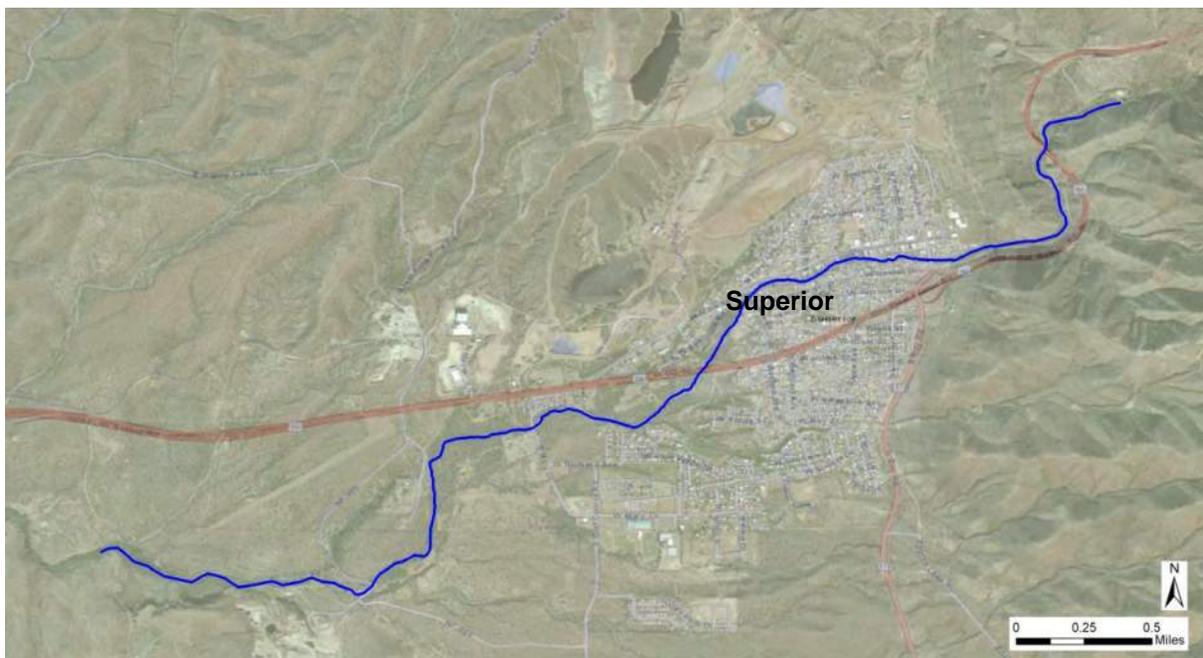


Figure 1. Location of the surveyed Queen Creek corridor through Superior (in blue).

SELECTION OF TARGET SPECIES

Weeds are plants out of place. Even native trees and shrubs can be a nuisance in certain areas. However, many invasive species are highly competitive and utilize disturbed areas to establish themselves and spread to new areas. Those species that are especially adept at occupying and controlling new territory, while out-competing native species are the prime targets for control. It is impossible to control every weed that occurs, therefore, those weed species which have the greatest potential for negative environmental impacts should be the primary targets.

INVASIVE WEED SURVEY RESULTS

Below is list of invasive species found during NCD's stream surveys (Figure 2) as well as those mentioned in WestLand Resources, Inc. (WestLand) draft vegetation assessment and the Town of

Superior’s Waters and Trails Action Plan. WestLand conducted a vegetation assessment in 2019 of the Queen Creek riparian corridor from US 60 to Perlite Road.

- Fountaingrass (*Pennisetum setaceum*)
- Tamarisk or Salt Cedar (*Tamarix sp.*)
- Oleander (*Nerium oleander*)
- Tree of Heaven (*Ailanthus altissima*)
- Giant Reed (*Arundo donax*)
- Mexican Palo Verde (*Parkinsonia aculeata*)
- African Sumac (*Rhus lancea*)
- herbaceous species: (giant or ripgut brome, red brome, Bermuda grass, Lehmann’s lovegrass, London rocket, Asian mustard, Arizona barley, Mediterranean grass, camphorweed)

This is not a static list as new invasive species can show up at any time; therefore, this list should be evaluated every few years. Coordination from time to time with the Tonto National Forest weed specialists will help ensure that managers are kept aware of important new species that have established in the region as well as any new information on treatment strategies that can inform weed management in Queen Creek.



Figure 2. Invasive plant locations found during NCD surveys.

TARGET SPECIES

The Waters and Trails Action Plan identifies three species to target for immediate removal and treatment based on their ability to spread, potential impacts to the stream and/or likelihood of treatment success. These species are:

- **Fountaingrass**
- **Tamarisk**
- **Oleander**

NCD recommends adding an additional target species:

- **Tree of Heaven** (campground area)

Throughout most of Queen Creek, there is only a handful of Tree of Heaven. They do not appear to be spreading and therefore are not a concern at this time. However, in the campground area (where there is perennial water) there are several large, dense infestations that we believe have the potential to spread and we recommend these infestations be targeted for immediate control. This species should continue to be monitored throughout Queen Creek since it has been found to be quite invasive in other areas of Arizona, including along the Verde River.

WestLand also listed African Sumac and Mexican Palo Verde as species of concern for their potential to alter the health of native riparian communities and their ability to impact groundwater. In a recent survey, NCD identified around 25 African Sumac between Magma Avenue and the campground. This species appears to be more weedy than invasive and NCD believes it is not necessary to prioritize it for immediate control. The Mexican Palo Verde is abundant throughout the entire project area and may prove difficult to control. Many weed managers consider this a low priority species.

However, if future enhancements to Queen Creek include adding surface water to a particular reach to improve riparian vegetation, this reach would then be a good location to target removal of these two woody invasive species. Both these species can grow quite large and removing them could make more water available for native species

Giant Reed was only found in a few locations including tributaries to Queen Creek. It does not appear to be spreading within the project area but it is important to monitor this species because it has been found to be highly aggressive in the Verde River riparian corridor.

WestLand also noted that the numerous invasive herbaceous species found in the riparian corridor have the potential to alter the fire regime and threaten the health of native species. They recommend removing seed production and increasing competition through native herbaceous perennial species. The effect these species can have on the fire regime is highly concerning but due to their abundance throughout the region there is not a high likelihood for successful control without enormous long-term effort.

WEED LIFE CYCLES

Understanding a weed's life cycle is important for understanding which control methods will be effective and when to apply them. The descriptions below are simplified but they generally apply to many invasive species.

Annual plants complete their entire life cycle in a single growing season and reproduce only by seed. The general control strategy for annual species is to control them before they set seed. Many annual weeds do not compete well against native vegetation. Many also respond well to repeated mowing which can significantly reduce seed production and the density of an infestation. Mowing in conjunction with seeding native vegetation is often an effective method for replacing very weedy areas with desirable vegetation without the use of herbicide. Herbicide can also be an effective treatment to reduce annual weeds.

Biennial species complete their life cycle in two years. They generally form a rosette in the first year, storing energy in a tap root. The second year they grow, flower, set seed and die. Biennials reproduce by seed, generally producing large quantities that can remain viable for many years, sometimes decades. Most resprout when cut, and consequently, mowing is generally not recommended since they grow back often with more flowers. Repeated mowing will often reduce seed set but not eliminate it. Biennials generally respond well to herbicide and should be treated when they are young and actively growing. The typical strategy for controlling biennial weed infestations is to eliminate the addition of new seed to the existing seedbank by removing or killing plants every year before they flower or set seed. Over time this will eventually deplete the existing seedbank as seeds continue to germinate but are not replaced.

Most herbaceous perennials reproduce by seed and many also reproduce vegetatively through creeping roots. Many resprout when cut. Pulling is often not effective since some roots are usually left behind and may resprout. Herbicide is generally the most effective method of control for herbaceous perennials.

Many woody perennials reproduce primarily by seed but some also reproduce vegetatively from their roots and many tend to resprout vigorously when cut. A common control method for mature trees is a cut stump treatment which involves cutting the tree and applying herbicide to the stump to prevent resprouting. There are several other effective herbicide application methods for larger trees. For smaller trees and shrubs, herbicide can also be applied to the foliage. Pulling of seedlings and young saplings can be effective for many woody perennials. Saplings often resprout if cut or mown.

CONTROL METHODS

A successful weed management program uses a combination of control strategies to reduce the abundance and distribution of target weeds. There are several methods for weed control including mechanical control such as pulling, cutting and mowing; chemical control using herbicide; and competition from desirable vegetation which can prevent reinvasion and help suppress existing weed populations. Ideally, an integrated weed management approach incorporates both active control methods such as herbicides and mechanical removal to provide short-term management and the establishment of competing vegetation as a long-term control strategy.

It is anticipated that efforts to control heavier infestations will take several years of ongoing treatments to be effective. The goal of the multi-year program should be to control target species to the point that expansion or transmissions to other sites is minimal and the site is well established with low maintenance, native species that help prevent further invasion.

Often chemical control is used initially on dense or large infestations. Once populations decline, it's often more effective to remove weeds mechanically. Seeding or planting weedy areas with native vegetation will eventually provide competitive pressure on invasive species as desired vegetation becomes established.

Some other common control methods include prescribed burning, grazing and biological controls (most commonly using insects). The first two are not appropriate or unlikely to be effective in the project area. Tamarisk is the only target species with a biocontrol agent. The tamarisk beetle was first released in western North America in 2001 with a few other releases since then. The beetle has not yet made it to southeast Arizona but in 2019 it had reached the upper reaches of the Gila River in New Mexico and the upper reaches of the Verde River near Cottonwood (see www.riversedgewest.org/services/tamariskbeetle for more information).

CHEMICAL CONTROL

Herbicides can be an appropriate and effective method for treating many weed species. They are widely used and are often the most economic and effective control method. Herbicides are considered safe when used according to the label but they are hazardous chemicals and can have negative effects on humans and the environment. All effort should be made to reduce the amount of herbicide used such as treating younger, smaller plants and spot treating instead of broadcast spraying where appropriate. Spot treatments target individual plants and small patches while broadcast treatments apply herbicides as a complete coverage over larger areas.

There are several issues to consider when deciding to use herbicides and choosing the most appropriate chemical:

- **Timing** – herbicide use should be timed to treat the most vulnerable stage of plant growth and to maximize effectiveness.
- **Selectivity** – some herbicides are selective for certain vegetation types such as broadleaf-specific meaning they generally do not damage grasses or non-specific meaning they kill most plants.

-
- **Pre-Emergent and Post-Emergent Effects** - Pre-emergent herbicides are applied to the soil before the weed germinates; they disrupt germination or kill the germinating seedling. Post-emergent herbicides are usually applied directly to established plants.
 - **Modes of Action** – there are several general mechanisms by which herbicides kill plants, using a combination of herbicides with different modes of action can sometimes provide better control.
 - **Resistance** – invasive weeds can develop resistance to herbicides so avoid actions that promote resistance such as using an herbicide with the same mode of action repeatedly.
 - **Persistence** – some herbicides have a very short half-life meaning they degrade quickly in the environment through chemical degradation, microbial action or sunlight while some have long half-lives and remain present and active for months.
 - **Soil Mobility** – some herbicides bind to soil particles and have little mobility while others move easily through soil to water sources.
 - **Water Contamination** – herbicides can contaminate surface and ground water and care should be taken at sensitive locations. Ensure that chemicals not labeled for aquatic use are not applied directly to or do not drift into water sources.
 - **Toxicity** – herbicides vary in the type and level of hazard they pose to humans and other animals.
 - **Drift** – is the movement of small spray droplets to off-target plants and sites.
 - **Effects on Desirable Vegetation** – care must be taken to minimize effects on desirable vegetation including newly seeded or planted vegetation.

Always refer to the herbicide label for specific directions, application rates and methods, necessary safety precautions, and restrictions on use. It is suggested that large scale herbicide application be completed by trained professionals to improve efficacy and ensure safety protocols are followed.

MECHANICAL CONTROL

Mechanical control consists of pulling, mowing, cutting, or in exceptional cases, tillage, bulldozing, or scraping and burial of the seed bed. Mechanical control is used to eliminate the current year's seed production and to reduce existing weed biomass which shades out desirable species.

Pulling:

Small infestations of plants that are not capable of vegetative reproduction can often be controlled when pulled in early summer or prior to setting seed. However, pulling is not practical for larger infestations or for species that can regrow from root fragments or rhizomes. The easiest time to pull plants is when the ground is moist so that the root can be extracted without causing too much ground disturbance. Many tap-rooted species are effectively removed if cut an inch or two below the soil surface. Weeds pulled before they flower may be left on the ground; however, flowering plants should never be left on the ground because many continue to set seed even when the plant is severed from the root. The flowers should be bagged and disposed of or incinerated if possible.

Mowing and Cutting:

Mowing or cutting is often used to control annual species but is not generally effective on biennial or perennial species since many resprout. Mowing may not eliminate the plants but can significantly reduce seed production of annuals and will remove much of the shading effect on desired vegetation. Mowing usually must be repeated several times in a growing season to significantly reduce seed production. Mowing can also be used effectively when integrated with herbicide treatments.

COMPETING VEGETATION

Ultimately, the establishment of desirable vegetation is the most effective long-term strategy for the sustainable management and control of invasive weeds. Many weeds are dependent on open, disturbed ground to germinate and grow. Providing competition for resources (water, nutrients and sunlight) can suppress invasive species and keep them from becoming established.

TREATMENT RECOMMENDATIONS FOR TARGET SPECIES

FOUNTAINGRASS

Fountaingrass is a fire-adapted perennial grass. It likes disturbed sites and roadsides but also grows in desert shrubland and canyons. It can grow in rock crevices and pavement cracks. Fountaingrass is contributing to the type conversion of shrubland to grassland in some desert regions by facilitating periodic fires which kill the shrubs (DiTomaso et al., 2013). Fountaingrass reproduces by seed which are dispersed by wind and animals. Seeds are thought to survive for 6 years in the soil seedbank. This means that even after treatment, expect germination of fountaingrass from the existing seedbank for several years. Long-term monitoring will be needed since seeds can be brought into the project area from outside through wind, water and animals.

The most effective treatment for fountaingrass in Queen Creek will be spot herbicide application. Herbicide is most effective when applied post-emergence to rapidly growing plants. Hand removal may be an effective method if the entire plant can be uprooted. In the highly rocky terrain in Queen Creek, this would be very difficult or impossible to accomplish, especially with the large number of plants that currently exist. Removal by hand may need to be repeated several times a year at one to two-month intervals.

TAMARISK

Tamarisk species are small trees or shrubs that grow along rivers, lakes, washes and roadsides. Numerous trees along riparian corridors can significantly reduce surface water and water tables. Tamarisks excrete salt which can inhibit native vegetation. Tamarisks survive burning and can introduce fire into ecological communities that are not adapted to wildfire. Tamarisk reproduces by seed which are dispersed by wind and water but do not remain viable for more than a few months (DiTomaso et al., 2013). They also resprout vigorously when cut.

NCD recommends treating tamarisk using a cut stump method which involves cutting down the stem and immediately applying an herbicide to the stump. The cut stump methods work best in summer or fall when the plant is still growing and not water stressed. Foliar application of herbicide also works for smaller, isolated plants. Foliar application should be conducted in late summer or early fall when plants are fully expanded. We do not recommend a foliar application to denser areas of tamarisk in Queen Creek. The denser stands are generally found in a narrow band along the channel edge with a dense stand of mesquite and other native vegetation immediately behind this band. A foliar application increases the risk of herbicide drifting onto nearby native vegetation. Hand pulling can be used to effectively treat new seedlings or very small plants.

The Waters and Trails Action Plan noted that “an impactful program of tamarisk treatment is possible now and will only get more difficult.” The Plan provided some basic tenants for a tamarisk treatment program which also apply to Fountaingrass and include:

- Begin at the farthest upstream location and work downstream
- Focus on clumps and concentrations of tamarisk
- Plan a multi-year program of treatment, re-treatment with quick revegetation and subsequent monitoring
- Utilize certified companies to apply chemical treatments

OLEANDER

Oleander is a large shrub that is toxic in all its parts. It is an attractive flowering ornamental grown across the world in warmer regions. There is little information on how to control oleander, however, an herbicide application using a cut stump method will likely be the most effective method of controlling this species. Check with an experienced herbicide applicator for recommendations on effective treatments.

TREE OF HEAVEN

Tree of Heaven is a fast growing tree with a deep taproot. It likes disturbed places, roadsides, natural areas including riparian areas and woodlands. Tree of Heaven reproduces by seed, which remain viable for about a year, and also vegetatively through a large network of creeping roots which sucker freely.

We recommend either basal bark or stem injection (hack-and-squirt) herbicide treatments for controlling this species. Basal bark treatments are made by applying herbicide directly to the bark of smaller trees and for stem injection, herbicide is added to cuts made in the bark. Basal bark and stem injection work best in late summer or early fall before leaf drop. Foliar application also works well on young trees when leaves have fully expanded. Care must be taken with any foliar application to ensure native vegetation is not harmed. Hand pulling works for seedlings but is not effective once creeping roots have developed (DiTomaso et al., 2013).

GENERAL PRINCIPLES FOR INVASIVE SPECIES CONTROL

The principles listed below are from the Waters and Trails Action Plan and are key to an effective, long-term weed management program so we wanted to reiterate them.

Control is the goal, not eradication

Treatment is focused on limiting the abundance of plants that have a negative impact on the ecosystem, rather than complete removal.

Start with realistic goals and expectations

Experienced restoration ecologists cite how important it is to “bite off what you can chew” and only begin in one year what you can envision continuing in following years.

Have a clear plan for post-removal

Removing nonnative plants creates space for secondary invasives that can be costly and complicated to battle. Steps to monitor and revegetate should be prepared before removal.

Consistency matters

Starting and stopping treatment can lead to genetic resistance to chemical treatments.

Keep it simple

For Superior, focusing on just three species (tamarisk, oleander and fountaingrass) is likely the most feasible and impactful approach. The Early Detection Rapid Response framework has solid principles for catching plants before additional spreading.

Get outside help

Bring in trained and certified contractors for chemical treatment and to tackle other species beyond the three listed above. Certifications required for chemical application can be hard to maintain locally.

ADDITIONAL TREATMENT CONSIDERATIONS

An effective weed management program requires planning for the long-term. The first few years are the most laborious; however, dedicated, successive yearly retreatments should result in a steady decline in weed populations and the effort required for control. Consistent future monitoring is also needed to detect reinfestation of existing weeds or new weed species. Monitoring the Queen Creek project area can be completed in one to two days.

Reasonable control of the existing woody species (Tamarisk, Oleander, and Tree of Heaven) can be expected within a few years. Cut stump treatments are generally very effective but there will usually be some resprouting. Annual monitoring of treated areas is needed for a few years, especially for tamarisk since it is common to see a flush of new seedlings following initial treatments. Fountaingrass will need to be treated annually for several years since this species will continue to germinate from the existing soil

seedbank but we would expect a significant reduction in the number of plants after three years of treatments.

Untreated adjacent lands can continue to re-infest treated areas. Fountaingrass and tamarisk likely have significant populations in tributaries to Queen Creek and fountaingrass likely also has large numbers in the upstream reaches of the watershed. Working to control invasive species on neighboring lands will increase effectiveness of treatments and long-term success of a control program.

DISTURBED AREAS

Weeds are often pioneer species that easily establish on disturbed ground and open, bare areas that lack competitive vegetation. Once weeds become established, they are challenging to control and can inhibit the growth of desirable vegetation. Do not disturb areas and then leave them through a growing season without ensuring there is competing vegetation or a plan to treat the area.

To prevent weed invasions in newly disturbed areas, desired vegetation should be re-established quickly. These areas should be surveyed for invasive plants early in the first growing season following disturbance to ensure a quick response before weeds can become established or begin to build a seed bank.

During the January 2020 Invasive Species and Restoration Site Visit, staff from both the Tonto National Forest and the Gila Watershed Partnership stated they could recommend native seed mixes that would be appropriate for the Superior area. The Gila Watershed Partnership also has a nursery program that provides regionally appropriate, native plant material.

WEED MONITORING

It is important that the project area be surveyed for target and other invasive species regularly. We recommend annual surveys for several years, it may then be appropriate to reduce the frequency to biannual surveys as managers become familiar with weed infestations and as invasive populations decline. Monitoring should be used to:

- Evaluate treatment effectiveness
- Help determine future treatment needs and methods
- Detect new infestations

Treatment methods will change over time and must be adjusted if they are not working adequately or as populations decline. Regular monitoring is critical in evaluating treatment effectiveness and determining appropriate control methods; whether it's deciding to switch to mechanical removal or to return to herbicide treatments if an infestation is getting worse. Also, early detection of new invasions allows for much quicker eradication and more cost-effective treatment.

In addition to general weed surveys, all treated areas should be monitored post treatment to assess the effectiveness of treatment and to determine the need for and type of future treatments. For herbicide treatments in particular, treated areas should be evaluated a few weeks after treatment to ensure that it was effective and thorough.

Weed inventories are easiest to conduct in summer when plants are large and easy to see and identify. However, this late in the growing season is often too late for effective chemical treatment that same year. Late spring or early summer inventories can be useful since early identification allows time to prepare and conduct treatments during that growing season. The downside of an earlier survey is that it is easy to overlook some weeds since they are small and often inconspicuous and identification is more difficult.

TIMING

Timing of control methods is important for maximizing effectiveness. Please note that the timing of treatments and surveys can vary from year to year since precipitation can greatly affect the timing of germination and flowering in Arizona.

In general, it is important to utilize herbicide treatments when plants are young or actively growing and well before most individuals have flowered or set seed. Once seeds have set, mechanical removal of the seed head is needed to ensure loss of the year's seed crop.

HERBICIDE TREATMENT

Spring or early summer is generally the most effective time to chemically treat herbaceous species when plants are young and actively growing. Smaller plants also require less herbicide. Herbicide treatments are more successful when plants are not stressed by lack of precipitation. Timing for woody invasives depends on the species and on the method of application.

MECHANICAL TREATMENT

It's best to pull weeds before they flower or produce seed. It's easiest when the plants are small and when the ground is wet. If plants are flowering then they should be bagged and disposed of. Mow before flowering and seed set. Mowing usually needs to be repeated several times throughout the growing season.

TREATMENT RECORDS

Whenever a treatment is conducted a daily record should be kept in order to record the activity, time, target species and crew size. This information can assist in the development and refinement of future control activities. In addition, if herbicides are utilized, the applicator is required to fill out an herbicide application record to record the date, type of herbicide, amount and rate applied, target species and the total area to which it was applied.

SUGGESTED IMPLEMENTATION STRATEGY

Implementation of the weed management plan may require contracts with outside parties. It is recommended that either town staff or an outside contractor be given responsibility for planning and oversight of treatments. The responsible party should provide site surveys, prescriptions for treatment, and follow-up surveys to ensure successful treatment. Surveys should begin early enough to allow time to contract and schedule the application. Application of herbicides by outside contractors will need to be conducted by licensed applicators. Contracts for those applications should contain maps with acreage to be treated, specify dates for completion of treatment and clauses that include retreatment of areas that are not adequately treated.

Most importantly, funds should be allocated in sufficient amounts to allow effective treatments for several years in a row without interruption. If a needed treatment is skipped or delayed for a growing season and seed set of invasive weeds occurs, the seed bank and therefore the intensive treatment period will likely be extended for several years. If budgets do not allow for treatment of all infestations, it's important to continue treating the budgeted area until adequately controlled before beginning to treat additional areas.

If a knowledgeable town employee is not available to manage the project, a designated employee should work closely with the contractor during the initial implementation phase. This employee should learn to identify the target weed species and become familiar with the plan. Once the initial treatments are done, it may not be necessary to continually hire an outside contractor for weed survey and prescription development.

COST ESTIMATES

Below is an estimate of the cost to treat the target species in the project area. The estimates are based on using a Conservation Crop crew to conduct the treatments. These crews are generally priced on the basis of an 8-person crew for 40 hours which costs around \$7,000. The estimate also assumes that the treatment includes spot herbicide treatments for Fountaingrass, cut stump treatments for Tamarisk and Oleander, and basal bark or stem injection for Tree of Heaven.

For the first year, NCD approximates that Fountaingrass will take one week to treat and the woody species will take three weeks for a total cost of \$28,000. The second year we estimate the fountaingrass will still take a week and the time to treat the woody species should take half the time, for a cost of \$17,500. We estimate the treatment time for third year will take two weeks for a cost of \$14,000.

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