PROVO RIVER DELTA RESTORATION PROJECT

Riparian Vegetation Technical Memorandum

in Support of the Draft Environmental Impact Statement

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UTAH RECLAMATION MITIGATION AND CONSERVATION COMMISSION

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CENTRAL UTAH WATER CONSERVANCY DISTRICT

JUNE SUCKER RECOVERY IMPLEMENTATION PROGRAM

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INTRODUCTION

The purpose of this memorandum is to describe the current riparian forest along the existing channel and trail of the lower Provo River and provide data that will allow detailed evaluation of the potential effects of the Provo River Delta Restoration Project (project area) on the existing trees along the river. This memorandum discusses the ecology of the dominant riparian trees within the project area, explores the factors affecting their recruitment and survival, and assesses the current conditions in which they grow. An understanding of the current environmental variables within the riparian corridor will allow planners to predict species response to hydrologic changes associated with the project area.

Riparian forests along riverine systems in Utah support several tree species. The riparian forest along the lower Provo River is no different; it supports a mix of native and nonnative species. Cottonwood (*Populus* spp.), willow (*Salix* spp.), and boxelder (*Acer* spp.) are common in transition areas between the river environment and upland areas of the lower Provo River. Each species group is important for wildlife, physical characteristics of the stream and riparian zone, nutrient availability, biological productivity, and natural aesthetics (Molles 2002; Beschta 2003; Cooper and Merritt 2012). Understanding the life history and environmental tolerances of the tree species associated with the lower Provo River is important to evaluate the effects of the proposed project on the existing riparian forest, and to help guide management decisions. While riparian forest along the lower Provo River is not limited to these species groups, cottonwood, willow, and boxelder are the most dominant.

ECOLOGY OF COTTONWOOD, WILLOW, AND BOXELDER SPECIES

Species Descriptions

Cottonwood

Cottonwoods belong to a group of trees known as poplars (*Populus*). Cottonwoods are widespread throughout North America from rapid flowing montane streams at high elevations to the valley floodplains of large, slow, meandering rivers at lower elevations (Braatne et al. 1996). Cottonwoods are dioecious, meaning each tree produces either male or female flowers. These flowers emerge in early spring, prior to leaves, but the flowering period varies with environmental conditions and among species. Pollen is dispersed by wind, and seeds may develop and disperse 3–6 weeks following fertilization (Braatne et al. 1996).

Wind and water are the primary dispersal mechanisms for the fluffy, cotton-like seed. Seed crops are abundant. Female trees produce 25 million seeds per tree annually and seeds are capable of dispersing long distances, although most studies suggest most of the seed crop is deposited relatively close to the mother plant (Braatne et al. 1996; USDA 2001a). Suitable conditions for seed germination include full sunlight and exposed, moist alluvium free of vegetation. Seeds are viable for very short periods. They readily germinate in favorable conditions but successful germination is impeded by dry conditions, vegetated soils, and shade (USDA 2001a).

Once germination is successful, roots establish in freshly deposited silt and sand using anatomically distinct collet hairs (Braatne et al. 1996). Seedling growth is rapid, extending 12–16 inches by the end of the first growing season. Seedling densities can reach up to 4,000 per square meter (Braatne et al. 1996; USDA 2001a). Seedling success is largely dependent on fluvial processes such as flood return intervals. Suitable conditions for establishment occur irregularly at intervals of 5–10 years or longer (Braatne et al. 1996).

Vegetative reproduction in cottonwoods occurs as sprouts emerge from stumps and root crowns as well as the formation of adventitious shoots on roots (suckers) (USDA 2001a). Asexual reproduction takes place when broken crowns or limbs are buried in sediment and develop roots; usually a result of wind storms or flooding events (Braatne et al. 1996; USDA 2001a). This reproduction method is advantageous for revegetation and restoration using cottonwood species. Vegetative reproduction is variable by species. For example, eastern cottonwood (*Populous deltoides*) has a week sprouting response following crown damage (USDA 2001a), while narrowleaf cottonwood (*Populus angustifolia*) relies on sprouting from roots, crowns, and branch fragments as a main regeneration strategy because its window of seed viability is so short(USDA 2001b).

Cottonwood saplings maintain heights of 5–60 cm during the first few years as energy is allocated to root growth. Reproductive maturity is attained at ages of 5–15 years when trees may reach heights of 30–45 feet (Braatne et al. 1996; USDA 2001a). Cottonwoods can reach heights of 60–190 feet, depending on species, and ages range from 30 to 35 years at maturity. Lifespans for cottonwoods are reportedly as long as 100 to 200 years. Stand densities are variable by species. Eastern cottonwood stands may reach densities of 192 mature trees/hectare while Fremont cottonwood is capable of forming stand densities of 400 mature trees/hectare. Regeneration by seed rarely occurs in dense stands due to shading, and riparian cottonwood forests often form linear or crescent shaped strips of even aged trees representing a period of establishment where favorable conditions were present (Braatne et al. 1996).

Water tolerances of cottonwoods depend on the fluvial processes that form the riverine environments where they persist. Generally, cottonwoods are intolerant of drought and shade, but tolerant of brief periods of inundation and siltation (Braatne et al. 1996; USDA 2001a). Drought tolerance is variable by species in mature trees. For instance, both eastern cottonwood and Fremont cottonwood use physiological processes such as rapid closing of stomata to decrease water loss and leaf orientation to minimize heat absorption (Braatne et al. 1996). Seedlings are vulnerable to drought and water deficits until their roots are established enough to reach the water table. Physical scouring from flood events and winter ice can eliminate seedlings and saplings. However, periods of inundation and silt deposition create favorable environments and limit competitors (Braatne et al. 1996).

Three cottonwood species (narrowleaf, Fremont, and eastern) are found along the riparian corridor of the lower Provo River. All three species are native to Utah. The most dominant species is eastern, followed by Fremont, with just a few documented occurrences of narrowleaf. Eastern cottonwood is not typically found west of Texas, with the exception of a population distribution in Utah. Fremont and eastern cottonwood are morphologically similar and are differentiated primarily by leaf and bark color.

Narrowleaf cottonwood is a distinct western species easily differentiated from Fremont and eastern cottonwood by leaf shape and growth habit. However, narrowleaf cottonwood can be difficult to identify among several willow species.

Willow

Willows are a group of shrubs and small trees that belong to the willow family (*Salicaceae*). Willows are widespread throughout North America with more than 100 native species forming dense thickets along streams and bordering wetlands (Sibley 2009). The twigs of these deciduous shrubs are marked by leaf scars late in the growing season after the leaves have fallen (Peattie 1980). Each plant is either male or female, producing elongated, caterpillar-like catkins that contain many flowers (Peattie 1980; USU 2002). Generally, flowers emerge at the same time or just after the leaves in mid-to-late spring but, in the case of coyote willow (*Salix exigua*), flowering may occur throughout the summer. Coyote willow starts to form flower buds prior to the flowering season and may produce flowers at the shoot tips throughout the growing season, but this is temperature dependent (USDA 2006a). Willows produce nectar on disks in the catkins and are primarily pollinated by insects (Peattie 1980; USU 2002).

Willows produce many small seeds winged with tufts of silky white hairs which aid in dispersal (USU 2002; USDA 2006a). Although seed viability is short (usually 1 week), germination readily takes place within 24 hours on a suitable substrate of saturated, freshly deposited alluvium after flood waters from streams and rivers recede. Bebb willow (*Salix bebbiana*), a large shrub willow native throughout the U.S., has been found to have high rates of seed germination (90–100 percent) when conditions where favorable in Alaska (USDA 1992).Willow seeds are typically produced for 1–2 months from late spring to early summer, but seeds are vulnerable to drought and inundation. Thus, the window for seed establishment is narrow due to environmental requirements. Seedling establishment is fairly rapid when successful; coyote willow exhibits annual growth rates of 12 inches in height and 0.1 inch of stem diameter (USDA 2006a).

Willows also reproduce asexually by developing thickets of clones from root sprouts, rooting from broken limbs buried in sediment, and layering when stems are buried in sediment (USDA 2006a; USDA 1992; USDA 2012). Actual methods of vegetative regeneration differ by species and environmental conditions. Peachleaf willow (*Salix amygdaloides*) sprouts from the root crown or stem but does not root sprout and regenerates best in large, open areas recently scoured by seasonal floods (USDA 2012). Bebb willow will regenerate from root fragments and stems when buried in moist soil (USDA 1992). Coyote willow roots will also regenerate when transported by high flows and flood waters. However, the primary mechanism for coyote willow reproduction is developing stems from shoot buds on lateral roots, which grow into extensive colonies as long as a source population is present (USDA 2006a).

Growth characteristics vary by individual willow species. While seedling mortality is unusually high for willows due to temporal and environmental factors in riverine systems, when successful, seedlings exhibit high growth rates compared to other woody species (Karrenberg et al. 2002). Peachleaf willow may develop more slowly than other willow species, can reach heights of 40 feet when mature, and is usually present as a small tree with deeper root penetration than other

species (USDA 2012). Coyote willow commonly grows as a laterally spreading shrub between 6.5–20 feet tall. Individual stems generally persist for 10 years, although some records indicate a lifespan of 20 years. Root sprouts from lateral stems elongate rapidly in coyote willow (USDA 2006a). Bebb willow is longer lived than coyote willow reaching reproductive maturity from 2 to 10 years and producing seed from 10 to 30 years. Crack willow (*Salix fragilis*) is prominent along the lower Provo River and reaches heights of 50–120 feet. This commonly cultivated species was introduced from Eurasia and may present a barrier to native willow development because it produces a shade canopy that hampers competition by other species (Sibley 2009).

Willows are considered pioneering, successional species, which is reflected in their ability to regenerate from shoots and roots, and respond to environmental disturbances such as flood waters, all while maintaining high growth rates (USDA 1992; Karrenberg et al. 2002). Willows can also tolerate anaerobic conditions for prolonged periods by orienting their taproot downward and thickening it with age more than side shoots (Karrenberg et al. 2002). Contrastingly, periods of high flood tend to scour newly established seedlings. Bebb willow will not tolerate inundation above the root crown. Other characteristics of these pioneering species are tolerance to low nutrient levels, intolerance to shade and encroachment by larger floodplain trees and weedy species, the ability to regenerate following fire, frost tolerance, and the ability to occupy some alkaline soils (USDA 2006a; USDA 1992; USDA 2012). While willows generally require moist conditions, some species such as coyote willow are drought tolerant (USDA 2006a).

Three willow species (peachleaf, crack, and coyote) are found along the riparian corridor of the lower Provo River. All three are equally dominant within the riparian corridor. However, they are singularly dominant within individual stands or co-dominant in association with cottonwoods.

Boxelder

Boxelder (*Acer negundo*) is a small-to-large, fast-growing, deciduous tree with an irregular crown. Boxelder is a member of the maple (Aceraceae) family. Boxelder is sometimes referred to as ash leaf maple due to its compound leaf arrangement of 3–5 small, narrow, pointed leaflets (Sibley 2009). This tree is native to the United States, widespread throughout North America, and common on moist sites near lakes and streams (USDA 1988). Boxelder flowers emerge just before the leaves. The tree is dioecious, meaning each tree produces either male or female flowers (USDA 1988; Peattie 1980). Blooms appear in March and April followed by production of large seed crops in fall (Kuhns 1998; USDA 1988). Female trees develop winged samara fruit throughout summer and fall, which is dispersed by wind, birds, and squirrels from September through March. In winter months samaras can be seen skidding across snow fields as they are guided by the wind as far as 100 yards (USDA 1988).

Boxelder produces both from seed and through vegetative reproduction. Seeds will establish in a variety of conditions and soil types from areas of disturbance to areas of moderate cover and competition, but they succeed primarily on moist soil along river banks. The primary reproductive strategy for boxelder is seed, but vegetative reproduction is common when trees are damaged as new shoots sprout on exposed roots following disturbance (USDA 1988).

Although boxelder trees have relatively short life spans, they establish quickly and grow fast. Young shoots can grow 2 feet in one growing season. Although this slows as the trees age, mature boxelders frequently develop clusters of sprouts and grow large burls. Mature boxelders may reach ages of 75–100 years and range in height from large, 25-foot shrubs to 70-foot-tall trees (USDA 1988).

Boxelders are considered weedy by arborists because they grow quickly and vigorously, are tolerant to a variety of conditions, are susceptible to insects, and drop branches and leaves during times of drought (Sibley 2009). Once established, the trees are drought tolerant and will persist in a range of climate extremes. The trees are adapted to a variety of soil textures but grow best in deep, sandy loam or clay loam. Boxelder is moderately shade tolerant and extends itself above the canopy when growing among other trees. However, shade can hinder seedling growth. This species responds positively to disturbance and will regenerate in moist disturbed soil (USDA 1988).

Recruitment Processes

Streamflow regime, together with channel morphology largely controls the composition, distribution, and extent of riparian vegetation on streambank and floodplain areas. Altered flow regimes along with channel incision can limit or prevent recruitment of native woody riparian species, such as cottonwoods, which require specific combinations and sequences of fluvial surfaces and hydrologic patterns for successful seed-based reproduction (Scott et al. 1993, Scott et al. 1999). Specifically, the five conditions that must be met for successful seed-based cottonwood recruitment and sustained health include:

1. Presence of a bare surface at the time of seed dispersal.

2. Transport and deposition of seeds onto the surface.

3. Post-germination decline in water levels at a rate slow enough that seedlings do not desiccate (generally no more than 1 inch per day).

4. Absence of post-germination floods that would scour seedlings.

5. Continued tree root connectivity to the water table, at least annually, following successful recruitment.

Because of these specific requirements, flood magnitude (relative to floodplain surfaces), timing, frequency, peak discharge, recession rate, and water table depth all have the potential to compromise the reproductive success of cottonwoods. Altered hydraulic conditions and flow regimes may tend to instead favor nonnative riparian species such as saltcedar (*Tamarix* spp.), Russian olive (*Elaeagnus angustifolia*) or other undesirable species, which can reproduce and thrive under a wider range of conditions.

Alterations to the timing of flood flows are of particular concern because cottonwoods release seeds for a period of about 1 month (Mahoney and Rood 1998). In the western United States, seed release by eastern cottonwood typically occurs between May and July. The start of seed release is primarily dependent on photoperiod but can vary by 1–2 weeks depending on annual temperature conditions (Mahoney and Rood 1998). This seed dispersal is adapted to coincide with the natural timing of the receding limb of snowmelt-driven spring peak flows, which allows waterborne seeds to be deposited on floodplains and streambanks. When flows remain unaltered, it is relatively rare for a given sequence of annual flow patterns to meet all five of the above requirements. Therefore, successful recruitment is typically not annual.

Willow reproduction and recruitment processes are similar to those of cottonwood in their need for newly scoured soil surfaces to facilitate seed germination. With willows, seasonal flooding often occurs out of step with seed dispersal. Seed dispersal among these species may frequently occur prior to seasonal high flows, causing recently deposited seeds to be swept away in flood waters and mortality of newly germinated seeds and seedlings. Conversely, the timing may coincide with low water or drought conditions following germination, resulting in seedling mortality. As previously discussed, these factors result in a limited window for optimal seedling recruitment for most willow species.

Many willows, including the species documented on the lower Provo River, rely heavily on vegetative reproduction as a means to circumvent hydrologic limitations where flood timing and duration may prevent seedling propagation. As mentioned in the previous section, each willow species utilizes different vegetative reproduction strategies. Some form colony populations with growth from rhizomatous root structures. Some propagate from existing root mass and rooting of downed limbs and branches. Studies of expanding coyote willow colonies have shown that more than 90 percent of individuals resulted from vegetative reproduction (Barnes 1985). Coyote willows, specifically, may revert to this strategy as an adaptation to habitat alteration and disturbance.

Mortality Factors Affecting Riparian Tree Species

Hydrologic Alteration

The need for surface or near-surface hydrology is most often associated with cottonwood and willow seedling recruitment in riparian systems (Mahoney and Rood 1998). Large, mature trees typically have well-developed root structures, which allow them to access deeper water and withstand fluctuating water tables. Research suggests that mature riparian trees and shrubs can access available water as deep as 9.84 feet (Stromberg et al. 1996; Naumberg et al. 2005). This threshold is likely more specific to shrubs and smaller trees such as willows. Fremont cottonwood has been known to grow under conditions where the groundwater may be deeper than 16.4 feet (Lite and Stromberg 2005). However, there is evidence that root mass likely develops in conjunction with water level availability throughout the life of the tree (Shafroth et al. 2000). In other words, a tree that can access water at 3-feet-deep will only develop root structure to that depth. This becomes important when considering reduced groundwater availability to a mature tree.

When addressing cottonwood and willow seedling mortality, a groundwater decline greater than 1 meter will likely result in extensive loss. Consecutive seasons of groundwater decline exceeding 2 meters will likely result in complete seedling mortality as well as water stress and mortality of juvenile trees (Shafroth et al. 2000). While most research in this area concentrates on survivorship of seedlings and young trees, studies report mortality in mature cottonwoods resulting from sudden, permanent groundwater decline of just 1 m, and indicate that an increase in depth to groundwater greater than 2.5–3 meters causes canopy die back in mature adult trees (Scott et al. 1999; Horton et al. 2001). It is evident that the degree of stress and extent of mortality resulting from declining water levels is often dependent upon the rate and extent of decline relevant to established rooting depths of riparian trees within the affected system.

Studies of boxelder trees in riparian systems show an apparent link between distribution of male and female trees dependent upon water availability. The studies note that boxelders react to altered water availability through slowed growth and reduced leaf and flower output. Signs of water stress in boxelders are noted to be excellent early indicators of water stress in riparian forests (Ward et al. 2002).

Soil type, conductivity, and capillary fringe are all variables interacting with declining water levels and associated effects on riparian trees. Soil saturation and soil moisture levels vary by soil type. Soils able to hold water for longer periods following a reduction in groundwater levels will continue to provide hydrologic benefit to riparian vegetation. If riparian trees are rooted in more permeable soils a groundwater decline is likely to have a more immediate impact on tree health and survivorship (Lite et al. 2005). Hydrologic conductivity plays a role in a trees ability to draw moisture up through aerated soils following a decline in groundwater levels.

Soil type affects rooting depth of most tree species both in texture and moisture retention. Studies of wind-downed trees and associated soil types showed that the bulk of root masses for large trees rarely occurred at depths greater than 6.5 feet, with only 5 percent of all trees sampled having root structures deeper than that. The study also showed that trees in well-drained soils rooted deeper than those in organic, moisture-retaining soils (Crow 2005).

Just as too little water availability can lead to tree mortality, so can too much water. Groundwater and surface water increases often result in reduced productivity and mortality in riparian species. Riparian tree species are typically adapted to the brief periods of inundation that result from seasonal floods. However, most cottonwood and some willow species are not well adapted to extended periods of inundation. In observational studies of an altered riparian system in Alberta, Canada, inundated cottonwoods showed signs of stress following the first growing season under the altered conditions and experienced complete mortality following the second growing season. In a similar study of an artificially ponded system in Montana, inundated cottonwoods died quickly following the alteration, while several willow species (including Bebb willow) tolerated and even proliferated under the new conditions (Amlin and Rood 2001). Cottonwood recruitment occurs within the flood zone and requires moist soil conditions for success. However, it is often common to find an elevational distribution of willows closer to a river channel with the potential of experiencing regular surface water increases while cottonwoods persist at a greater distance from river channel influence.

Invasive species encroachment

Competition from nonnative and invasive species is closely tied to altered conditions and disturbance in natural riparian systems. Increases in the presence of invasive species may be directly related to changes in hydrology (Lytle and Merritt 2004). These species are often well adapted to changing conditions and require far more general conditions for reproduction and recruitment. Mortality caused by encroachment of invasive species may result from competition for water, light, and nutrients, but may also result from competition with native species for recruitment surfaces. For example, cottonwood and willows require scoured surfaces and moist soils for seed germination and seedling survivorship. Hydrologic changes that make such surfaces unsuitable for native recruitment provide recruitment opportunities among those invasive species that are able to take advantage of the altered conditions. Subsequently, the establishment of these species in the flood zone alters the surfaces and makes them permanently unsuitable for native recruitment. Eventually, natural recruitment of native riparian tree species becomes unattainable, resulting in an aging and unproductive riparian forest.

Once populations of nonnative species have become established, they quickly become a competing force against native vegetation. Invasive trees such as saltcedar and Russian olive grow and reproduce quickly and prolifically, especially in disturbed conditions. These trees can out-compete native riparian seedlings and juvenile trees for water, nutrients, light, and even space. This causes mortality among native juveniles throughout the infested area. This competition for resources also causes nutrient stress and mortality in mature riparian vegetation. Invasive species infestations are known to destroy entire native riparian corridors. In arid systems with high seasonal temperatures and high soil salinity, alteration of flows and groundwater fluctuations may increase salinity at the surface through increased soil moisture evaporation, creating more favorable conditions for saltcedar colonization.

Herbivory

Riparian tree mortality due to herbivory is more commonly seen in seedling and sapling age classes. Herbivores such as deer, beaver, and insects may cause extensive damage within stands of young cottonwoods and willow. While mortality is unlikely in large, mature trees, trees under stress (e.g., from lack of nutrients, light, or changing hydrologic conditions) may be more susceptible to damage by herbivores. Beaver herbivory is a natural component of a riparian ecosystem. The harvesting of young trees allows regeneration to occur and may appropriately thin a stand. However, beaver populations uncontrolled by predators can cause extensive mortality within a stand. Coyote willow age structure studies show little mortality from beaver herbivory in trees older than 10 years (Ottenbreit and Stanforth 1991).

Age

Over time, lack of natural recruitment within riparian forests leads to an aged forest of older mature trees. In hydrologically altered systems, these trees will probably be from one or two recruitment classes prior to the alteration, resulting in forest composition of same-aged trees. These trees begin to decline in health and vigor as they reach the end of their life span. Age-related mortality of large numbers of trees within single age classes may lead to extensive

decline throughout the forest. In addition, mature cottonwood and willow trees in a hydrologically altered system often become isolated from river flows. The stranded trees and their root systems become singularly dependent upon groundwater availability (Braatne et al. 1996). One physiological response of mature, isolated trees to environmental changes (e.g., drought and extreme heat) is conservation of resources, which may result in lack of leaf and stem production as well as shoot and crown dieback.

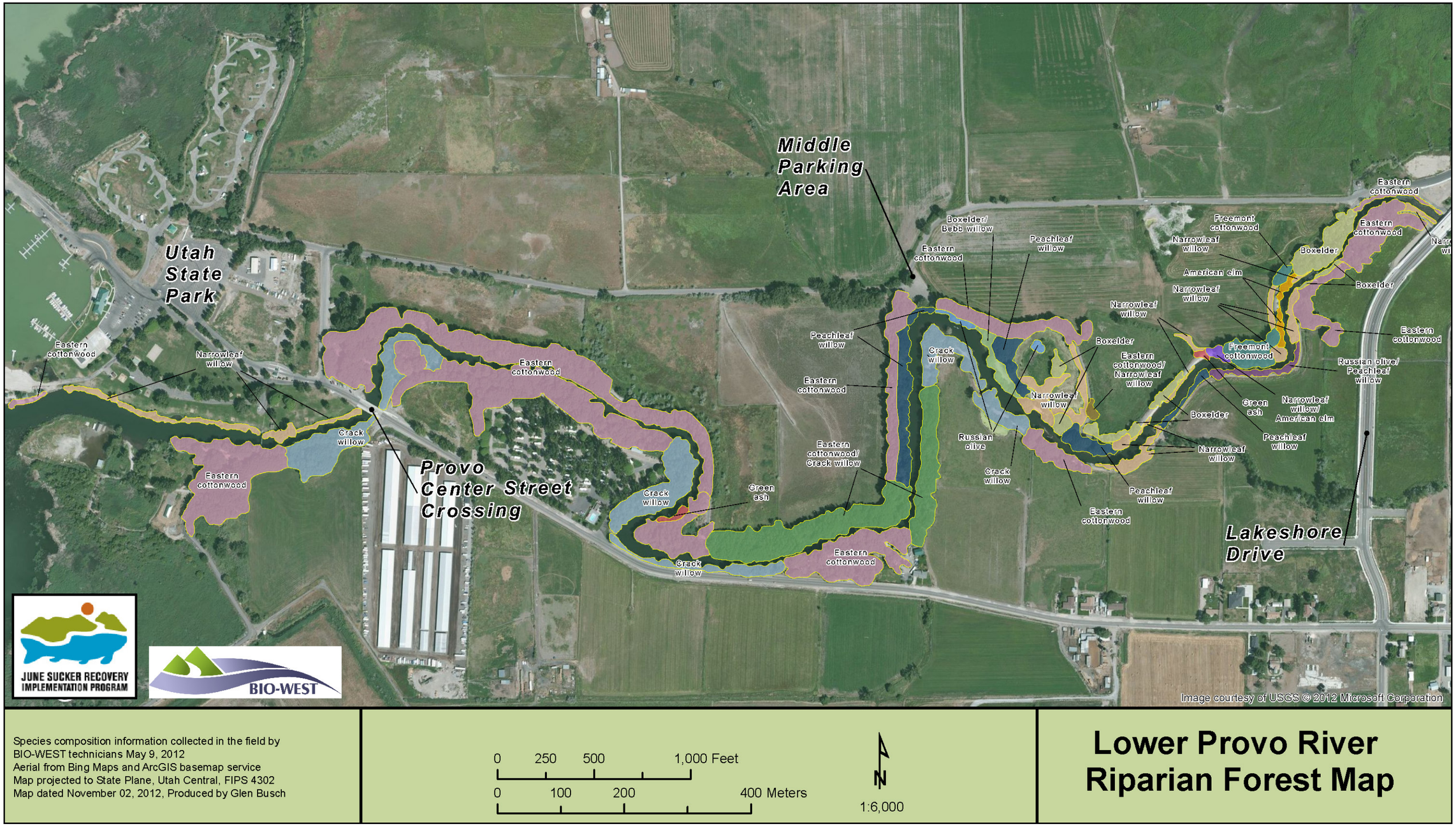
INVENTORY OF TREES AND SHRUBS ALONG THE EXISTING CHANNEL AND TRAIL

Methods

Riparian forest composition along the lower Provo River was inventoried during summer 2012 in the field using base maps (scale: 1 inch=300 feet) prepared with available high-resolution aerial imagery (1-meter resolution or better from ArcGIS online). Riparian forest polygons were assigned to stands where obvious demarcations between communities were found. Species composition was recorded for each polygon by estimating the amount of trees or shrubs of each species per polygon and dividing the number by 100. This resulted in an estimate of species per polygon per area. Each vegetation polygon was then assigned a classification corresponding to the dominant riparian tree species within the polygon. To account for gaps where tree species were not present, bare ground and herbaceous cover were recorded as a percentage of the overall polygon (where appropriate). Tree and shrub species were separated into three categories or canopy layers to account for vertical distribution. Riparian forest polygons were digitized from the field base maps using ArcMap at a scale of 1 inch=800 feet. Field notes were entered into a spreadsheet and joined to the digitized riparian forest polygons.

Results

The riparian forest along the lower Provo River is dominated by eastern cottonwood, crack willow, boxelder, narrowleaf willow, and Fremont cottonwood (Figure 1 and Table 1). Table 2 includes canopy layer terms and definitions. Tree polygons east of the oxbow were generally smaller and more dissected than the larger, more contiguous polygons west of the oxbow. The riparian forest on river right (north) of the lower Provo River is intersected by a recreation trail that parallels the river along its entire length downstream to Utah Lake State Park. Vegetation between the recreation trail and the river generally consists of a moderately diverse collection of mature, native, and nonnative trees. There are some native riparian shrub species in areas with floodplain features (e.g., gravel and sand bars). Occasionally, dense native willow communities can be found in these areas. However, much of this section of the Provo River is incised with steep banks of native soils and fill intermixed with riprap. There is little or no understory or shrub growth.



Species composition information collected in the field by BIO-WEST technicians May 9, 2012
Aerial from Bing Maps and ArcGIS basemap service
Map projected to State Plane, Utah Central, FIPS 4302
Map dated November 02, 2012, Produced by Glen Busch

0 250 500 1,000 Feet
0 100 200 400 Meters
N
1:6,000

Lower Provo River Riparian Forest Map

Figure 1. Lower Provo River tree species polygons.

Table 1. Lower Provo River tree species list.

CODE	GENUS SPECIES	COMMON NAME	NATIVE OR INTRODUCED
ACNE2	*Acer negundo*	box elder	native
ACGR3	*Acer grandidentatum*	bigtooth maple	native
ALIN2	*Alnus incana*	gray alder	native
COSE16	*Cornus sericea*	redosier dogwood	native
ELAN	*Elaeagnus angustifolia*	Russian olive	introduced
FRPE	*Fraxinus pennsylvanica*	green ash	native
HERB	*Various herbaceous understory*	various herbaceous understory	-
JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper	native
PLOC	*Platanus occidentalis*	American sycamore	native
POAN	*Populus angustifolia*	narrowleaf cottonwood	native
PODE3	*Populus deltoides*	eastern cottonwood	native
POFR2	*Populus fremontii*	Fremont cottonwood	native
PRVI	*Prunus virginiana*	chokecherry	native
RHTR	*Rhus trilobata*	skunkbush sumac	native
RICE	*Ribes cereum*	wax currant	native
ROWO	*Rosa woodsii*	Woods' rose	native
SAAM2	*Salix amygdaloides*	peachleaf willow	native
SABE2	*Salix bebbiana*	Bebb willow	native
SAEX	*Salix exigua*	narrowleaf willow	native
SAFR	*Salix fragilis*	crack willow	introduced
SASE10	*Salix ^{x}sepulcralis Simonkai*	weeping willow	introduced
TARA	*Tamarix ramosissima*	saltcedar	introduced
ULAM	*Ulmus americana*	American elm	native
ULPU	*Ulmus pumila*	Siberian elm	introduced

Table 2. Canopy layer definitions.

CANOPY TERMS AND DESCRIPTIONS		
Upper Level	**Mid Level**	**Lower Level**
Trees >15 feet in height	Small trees and shrubs <15 feet but >5 feet in height	Tree saplings and shrubs <5 feet in height

The trail is placed on fill and is commonly referred to as the “north levee and trail.” The vegetation north of the trail is detached from the rest of the riparian forest, and is bordered by agricultural fields and irrigation canals. Narrow strips of mature cottonwood and willow stands have established along the irrigation canals. These linear populations are usually monotypic stands and low in diversity. A second recreation trail circles a pond that may be a remnant oxbow of the river but is now isolated by the main levee and trail. This moderately disturbed area supports a boxelder forest, a mature cottonwood forest, and several dense native willows. In some places the oxbow pond is invaded by nonnative species such as Russian olive and Siberian elm (*Ulmus pumila*). The Utah Lake State Park section on river right contains sparse native willow stands, which are interrupted by developed day-use areas. A map of the vegetation polygons can be found in Appendix A with a data table representing the species and associated percent composition as well as observational notes.

General Riparian Forest Description, River Right

Lakeshore Drive to Oxbow Along River Bank

This section consists mainly of an upper canopy forest with eastern cottonwood, American elm (*Ulmus americana*), and boxelder along the river bank with intermittent but well-established coyote willow. Some tree-sized willows (Bebb willow and peachleaf willow) along with green ash (*Fraxinus pennsylvanica*) and coyote willow make up a small amount of the composition. A few scattered individuals of the invasive tree Russian olive are also present along the bank. The herbaceous layer is variable but in most cases sparse. Where the herbaceous layer is present, it consists primarily of weedy or introduced species such as reed canary grass (*Phalaris arundinacea*) and intermediate wheatgrass (*Thinopyrum intermedium*). Polygon 03 contains Dyer's woad (*Isatis tinctoria*), a noxious weed in the State of Utah (Belliston et al. 2009). Coyote willow and other willows are present wherever there are sandbars, point bars or small streamside shelves. The mid-canopy layer makes up only 10–20 percent of total composition, and evidence of some cottonwood and willow recruitment exists (e.g., the presence of saplings <10 feet high). The upper canopy contains moderate-to-high species diversity in places.

Irrigation Canals Bordering Recreation Path to Oxbow Pond

The north side of the recreation trail is characterized by narrow strips of large, mature cottonwood and willow species, which line irrigation canals and agricultural lands. These communities are dominated by mid-canopy shrubs (e.g., coyote willow), upper canopy Fremont cottonwood, and eastern cottonwood forests. Polygon 02, shown in Figure 1, contains one mature, monotypic Fremont cottonwood stand. Populations lining this canal seem to be homogenous in age structure and species and may have been planted as farmland windbreaks.

Oxbow Area

The pond contains a mixture of open water and islands of vegetation. Riparian communities contained on islands within the pond consist primarily of dense patches of coyote willow bordering the oxbow pond, with a smaller component of Bebb willow. On the northeast edge there is a stand of boxelder with a dense herbaceous understory of reed canary grass. At one point on the north side of the pond there is a stand of Russian olive, which also has a thick reed canary grass understory. Another recreational trail encircles the oxbow pond. Along eastern border of the trail, tree communities consist of a sparse, upper-canopy coyote willow and peachleaf willow forest. To the south there is a mix of upper-canopy trees including boxelder, American elm, peachleaf willow with a shrub layer of coyote willow, Wood's rose (*Rosa woodsii*), and skunkbush sumac (*Rhus trilobata*). To the northeast there is a mature eastern cottonwood forest with a layer of various mid-canopy willow. The willow stands surrounding the oxbow pond may be the most established willow communities along the lower Provo River.

Alligator Park (Big Bend) to Utah Lake State Park

This section of the lower Provo River is more disturbed downstream and is characterized primarily by a mature, even-aged eastern cottonwood/crack willow forest with a subordinate mix of native willows (e.g., peachleaf willow and Bebb willow) and nonnative trees (e.g., saltcedar and Russian olive). The mid-canopy layer along this reach is nearly nonexistent with the exception of a sparse collection of coyote willow, Bebb willow, and green ash. The understory is generally sparse but consists of weedy species such as reed canary grass, brome grasses (*Bromus* spp.), and the State of Utah noxious species whitetop (*Cardaria draba*) in polygon 31.

Utah Lake State Park

Small, narrow strips of riparian forest line the lower portion of the river and are bordered by developed picnic and parking areas. The dominant vegetation in these stands is dense coyote willow at the mid-canopy layer with other native willows interspersed throughout. The upper canopy consists of scattered, younger-aged (<20 feet in height) eastern cottonwood that are sparse and do not comprise more than 25 percent of the overall community.

General Riparian Forest Description, River Left

The riparian forest lining the lower Provo River on the river left (south) bank is intersected by a levee that parallels the river to its outlet at Utah Lake. The south levee is several feet higher (>4,498 feet) and built to a higher standard than the north levee and trail. There is a primitive, two-track dirt road on top of the levee. The bank drops steeply to the river left edge. The levee is immediately bordered to the south by agricultural fields, some private homes, businesses, and Lakeside RV Park and Campground. Development abutting the riparian forest has most likely limited its ability to expand and the forest is reduced to a narrow strip on both sides of the levee. There are a few floodplain features and point bars along the upstream section that support established willow stands.

Lakeshore Drive to Across River from Oxbow Pond

The riparian forest in this section of the lower Provo River is a collection of even-aged, upper-canopy mature species, which are dominated by a mix of native and nonnative trees (e.g., eastern cottonwood, boxelder, Siberian elm, and crack willow). The invasive species Russian olive is also present here. Mid-canopy shrubs and small trees are sparse to nonexistent, with little or no understory species. In some isolated places along river left there are small gravel bars and streamside features that support small native stands of coyote willow and Bebb willow. Occasionally, the native willow peachleaf willow dominates the upper canopy.

Across River from Oxbow Pond to Provo Center Street Crossing

The riparian forest becomes increasingly disturbed in the river left section leading downstream to Utah Lake. The vegetation consists of mature, native and nonnative upper-canopy species including eastern cottonwood, crack willow, boxelder, and peachleaf willow. The introduced

crack willow is increasingly dominant and the trees approach their maximum height of 65 feet (USDA 2006b) in this section. The mid-canopy shrub layer is very sparse or completely absent in most of this section. The small, infrequent shrub layer includes coyote willow, Bebb willow, and the invasive species Russian olive. Along this section the forest is mostly constrained to narrow stands by adjacent agricultural and private development.

Provo Center Street crossing to Levee Road

This section of the riparian forest is a collection of native, introduced, and ornamental vegetation, which is influenced by the construction of levee road leading to the Provo Airport Levee and nearby private property development. The upper canopy is large and even-aged along the north and south sides of the levee road and consists mainly of eastern cottonwood, crack willow, and Bebb willow. Some species, such as Rocky Mountain juniper (*Juniperus scopulorum*) and weeping willow (*Salix* ^{x}*sepulcralis Simonkai*), were most likely planted as ornamentals. The forest becomes sparse as the river flows into Utah Lake, transitioning into herbaceous species dominated by reed canary grass in the private property section. The shrub layer is sparse and consists of small stands of Russian olive.

Stand Age

Tree core samples were collected from three eastern cottonwoods and two Fremont cottonwoods within the riparian corridor. The core samples were removed from the center of the tree trunk at a height of approximately 4.5 feet. The cores were collected in a manner to allow removal of a sample including the center of the tree. Tree growth rings were counted from each core using a stereo microscope. Cottonwoods are fast growing species known to create multiple growth rings within a single growing season. Special care was taken to determine the annual growth ring within each sample; however ages should be considered approximate.

Assessment of the three eastern cottonwood core samples indicates the trees are aged approximately 33, 48, and 51 years. The trees sampled were visually selected to represent the youngest and oldest of the mature tree classes for that species within the riparian corridor. Given the locations of the selected trees, it appears the tree stands increase in age closer to the Utah Lake confluence. The two younger trees were sampled from stands on the river side of the north levee, while the oldest was sampled from the fence line on the far side of the north levee.

There are two stands of Fremont cottonwood within the riparian corridor, each located on the north side of the levee. The two trees sampled are estimated to be 62 and 64 years old. All individuals within each stand appear to be from the same age class. There is no evidence of multiple age classes or any juvenile recruitment within either population. Several scattered Fremont cottonwoods within eastern cottonwood stands also appear to be from the same age class as the sampled Fremont cottonwoods. These observations indicate that the Fremont cottonwoods on the lower Provo River may all be from the same recruitment event. It further indicates that there has either been no subsequent recruitment, or that any recruitment following this class has since been lost. Given the location of these stands, it is likely that these cottonwood stands were isolated from the river by the construction of the levee and trail, preventing any further recruitment. It is also possible that these trees were planted along the levee. The ages of

the mature trees also correspond with levee construction following the flood of record on the lower Provo River, which happened in 1952.

Surface/Groundwater Elevation Interactions along the Existing Channel

The water elevation on Utah Lake is monitored by the Central Utah Water Conservancy District (CUWCD) on the northwest corner of the lake at the Jordan Narrows outlet (Figure 2). BIO-WEST installed a water-level monitoring device at the Utah Lake State Park Marina in 2011 and found that the elevation of the lake on the east side near Provo River outlet is very similar to elevations at the CUWCD monitoring station; unlike Provo Bay, which has been found to be perched approximately 1 foot higher on average than the rest of the lake. Flows in the lower Provo River are monitored by the U.S. Geological Survey (USGS) and CUWCD immediately upstream of the Lakeshore Drive (Figures 3 and 4). BIO-WEST surveyed the channel and floodplain of the lower Provo River in 2010 (Figure 5), and developed a HEC RAS hydraulic model for the purpose of evaluating surface water elevations during different river-flow and lake-level scenarios. This model is functional for the entire project area, from upstream of Lakeshore Drive Bridge to the mouth of Provo River for the existing channel configuration (Figure 6).

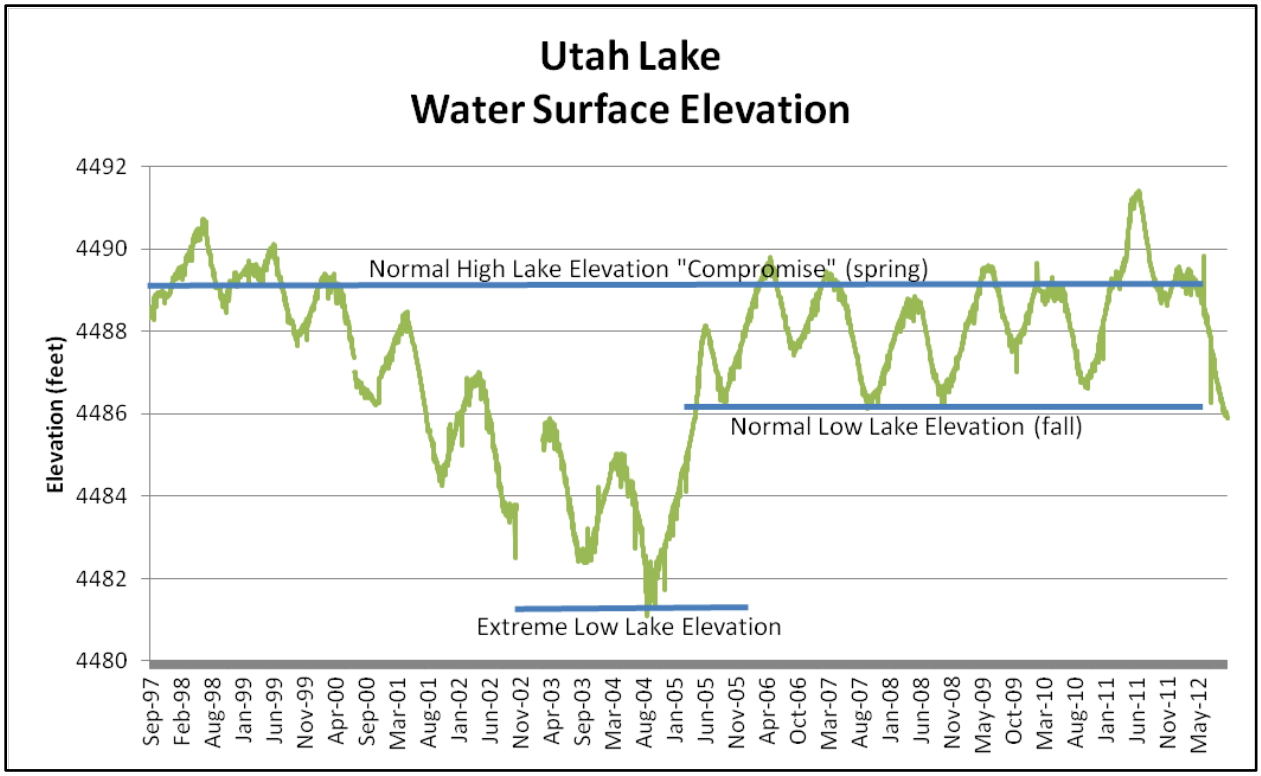


Figure 2. Fifteen years of Utah Lake water-surface elevation data.

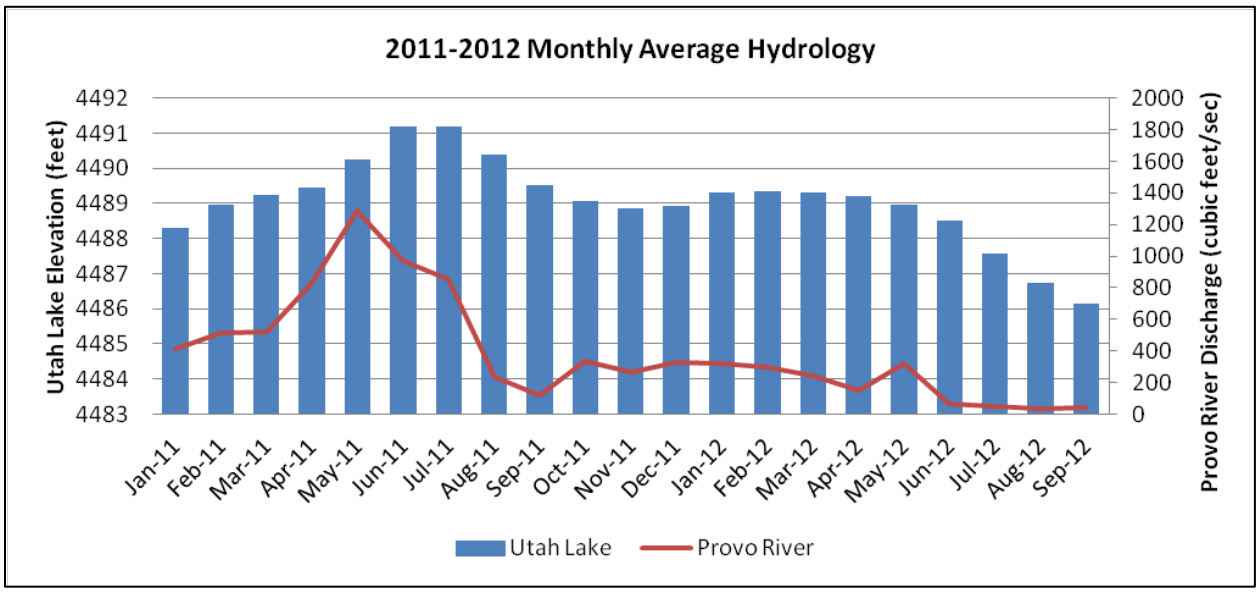


Figure 3. **Monthly average water surface elevation in Utah Lake and flow in the lower Provo River.**

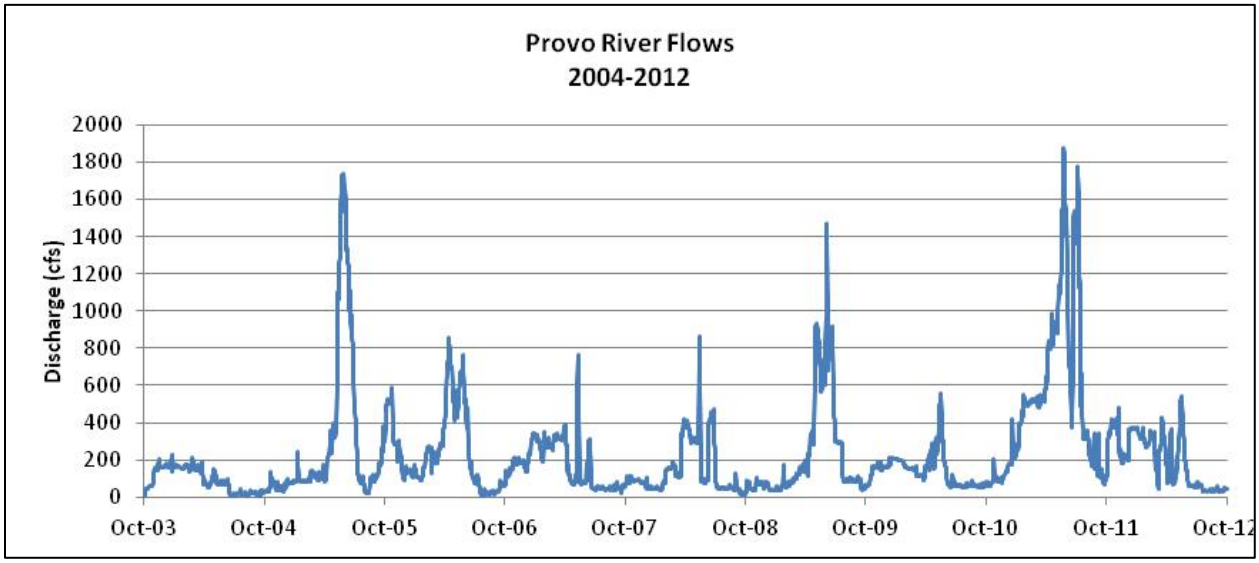


Figure 4. **Nine years of daily average flows in the lower Provo River at the Boat Harbor Drive Gage.**

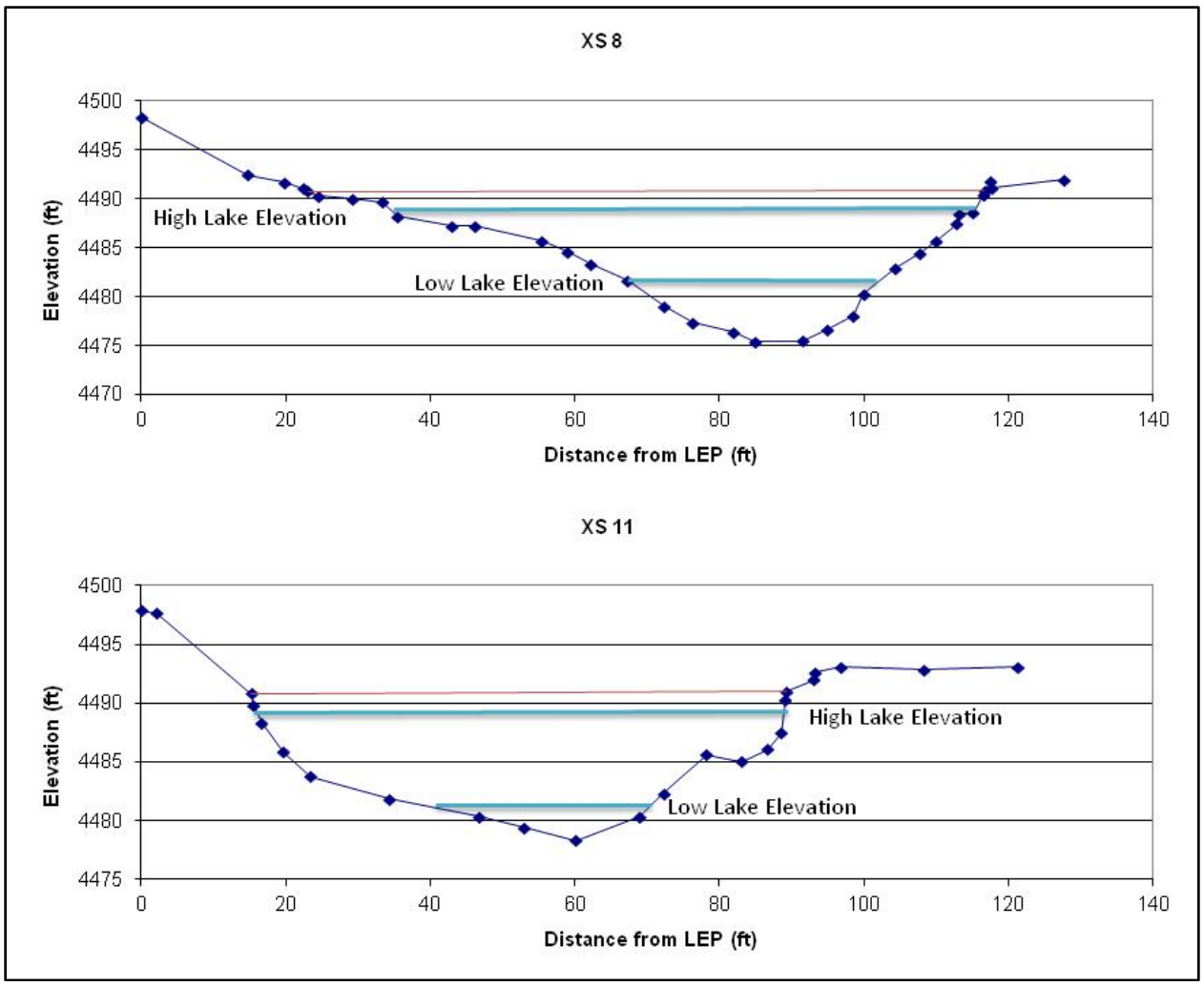


Figure 5. **Cross-section view of the existing lower Provo River channel and the water-surface elevation at high and low levels of Utah Lake. The survey was conducted August 4–5, 2011, when Utah Lake was approximately 4,490.7 feet. Water surface elevations in this part of the channel might remain "perched" and elevated higher than Utah Lake during extreme low lake elevations because of a sand bar that forms at the mouth of the Provo River at an approximate elevation of 4,484 feet, and which at least partially restricts the channel from draining entirely when the lake drops below 4,484 feet. Cross section locations are depicted in Figure 6.**

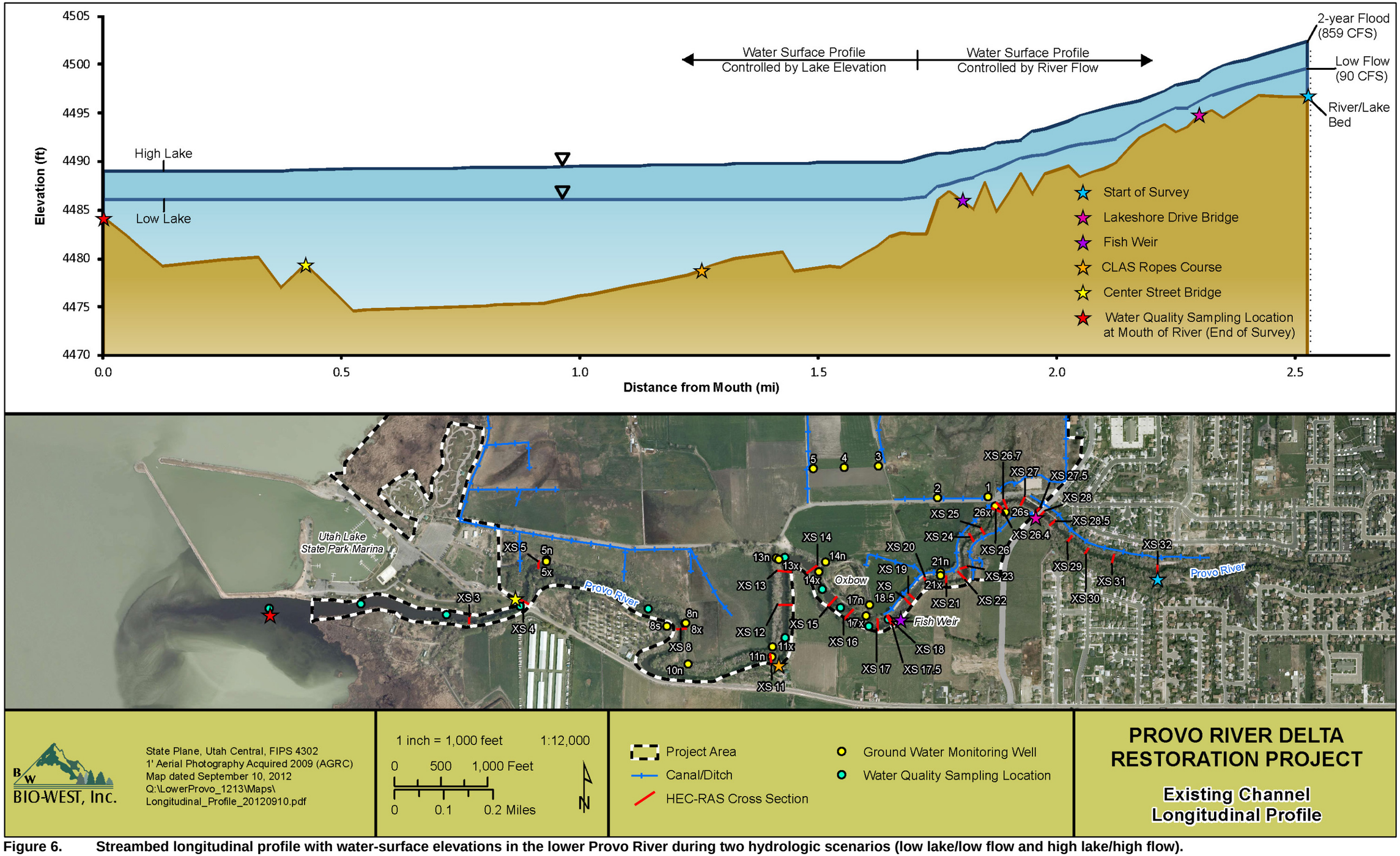


Figure 6. **Streambed longitudinal profile with water-surface elevations in the lower Provo River during two hydrologic scenarios (low lake/low flow and high lake/high flow).**

A series of 21 monitoring wells (piezometers) were installed in April 2012 to determine the current interaction of surface and groundwater elevations in the lower Provo River, and groundwater elevations that likely support the existing riparian forest. The piezometers installed in 2012 were intended to compliment the 10 piezometers north of Boat Harbor Drive installed in 2011 (Figure 7). The purpose of the 2012 piezometers was to collect surface and groundwater elevation data specifically to determine if and where the proposed project would affect the existing trees along the lower Provo River channel and trail. Water-level loggers were installed shortly after the piezometers were drilled, and have been collecting groundwater elevation data every 15 minutes throughout the growing season. Groundwater elevation data was downloaded and corrected periodically during the monitoring period. Barometric pressure corrections are necessary for the raw elevation data. The corrected 15-minute data was then converted into monthly averages for each well.

Monthly average groundwater elevations were then modeled for every square meter of the project area using nearest-neighbor methods (Figure 8). The groundwater elevation profile slopes strongly from east to west on the eastern side of the project area, flattening out to the west, with more than 10 feet difference in water surface elevations from one side of the project area to the other at any time. It is interesting to note that the groundwater elevation on the western portion of the project area is generally lower than Utah Lake. Skipper Bay Dike and other hydrologic alterations effectively keep Utah Lake water from flooding the lower portions of the project area under conditions seen in 2012.

The groundwater elevation data was then converted to “depth-to-groundwater,” which is more relevant to vegetation and their rooting depths (Figure 9). Depth to groundwater was determined by subtracting monthly average groundwater elevation from LiDAR-based digital elevation model (DEM) ground elevations. The results clearly show a seasonal fluctuation in depth to groundwater throughout the project area. The easternmost area north of Provo River maintains the most consistent conditions, with groundwater remaining relatively close to the surface even during the dry summer months. This result is not surprising given the presence of nearby springs and seeps, and the unique characteristics of area peat soils. Depth to groundwater increases more significantly on the southwestern portion of the project area along the existing channel, and north (heading northwest of the big bend, below the oxbow) along one of the old abandoned channels.

The elevation of Utah Lake generally controls the water-surface elevation and wetted perimeter of the existing channel downstream of the Utah Division of Wildlife Resources (UDWR) Fish Weir (Figure 7). The bottom of the channel at the fish weir is 4,487 feet. The fish weir is a local reference of the average extent of slackwater from Utah Lake during the summer, whereas the actual position of the slackwater varies over several hundred feet upstream and downstream of the weir with seasonal and annual fluctuating water levels in Utah Lake (Figure 2).

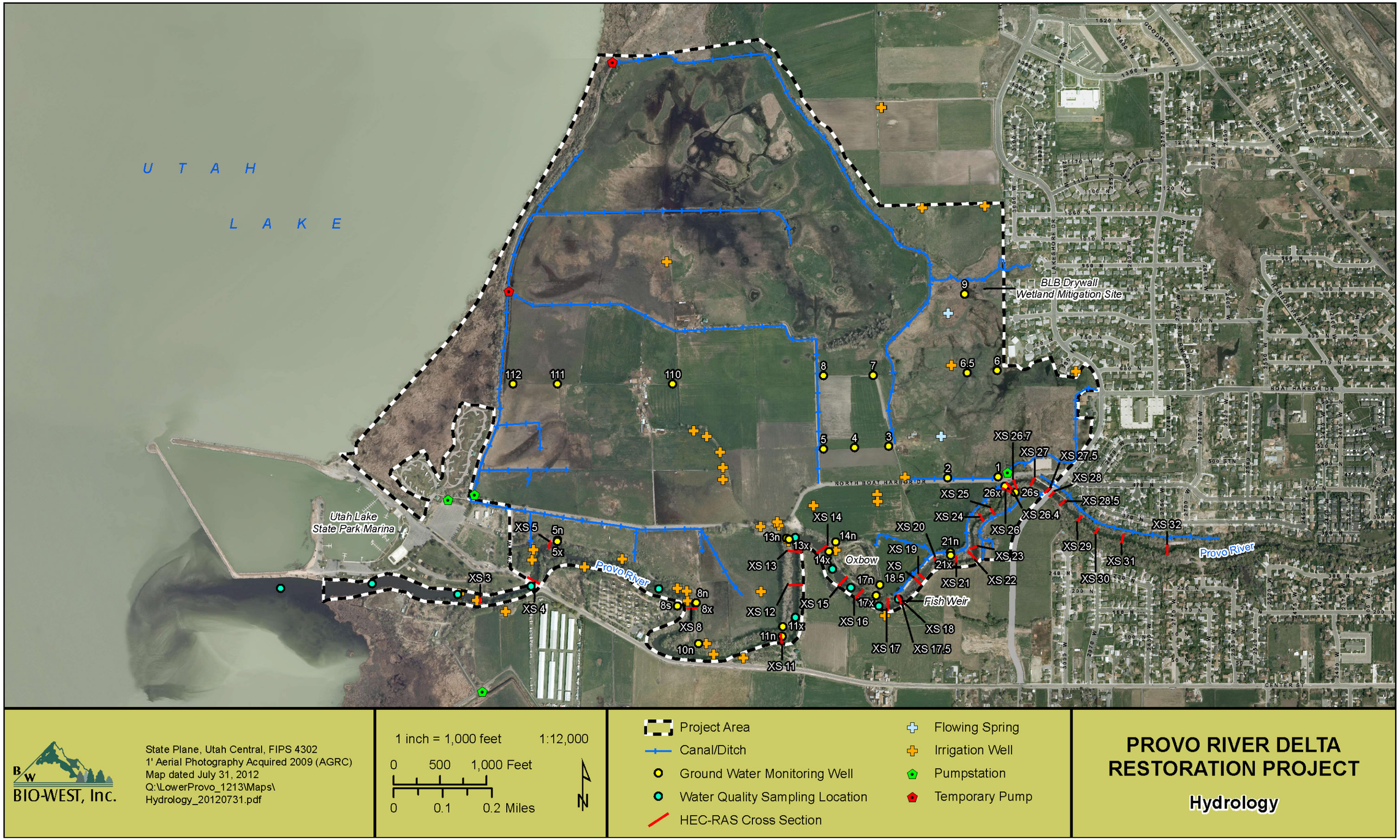


Figure 7. General hydrology map of the project area. Piezometers 1–9 in the eastern portion of the project area were installed in 2011, whereas all other piezometers along the channel and in the western portion of the project area were installed in 2012.

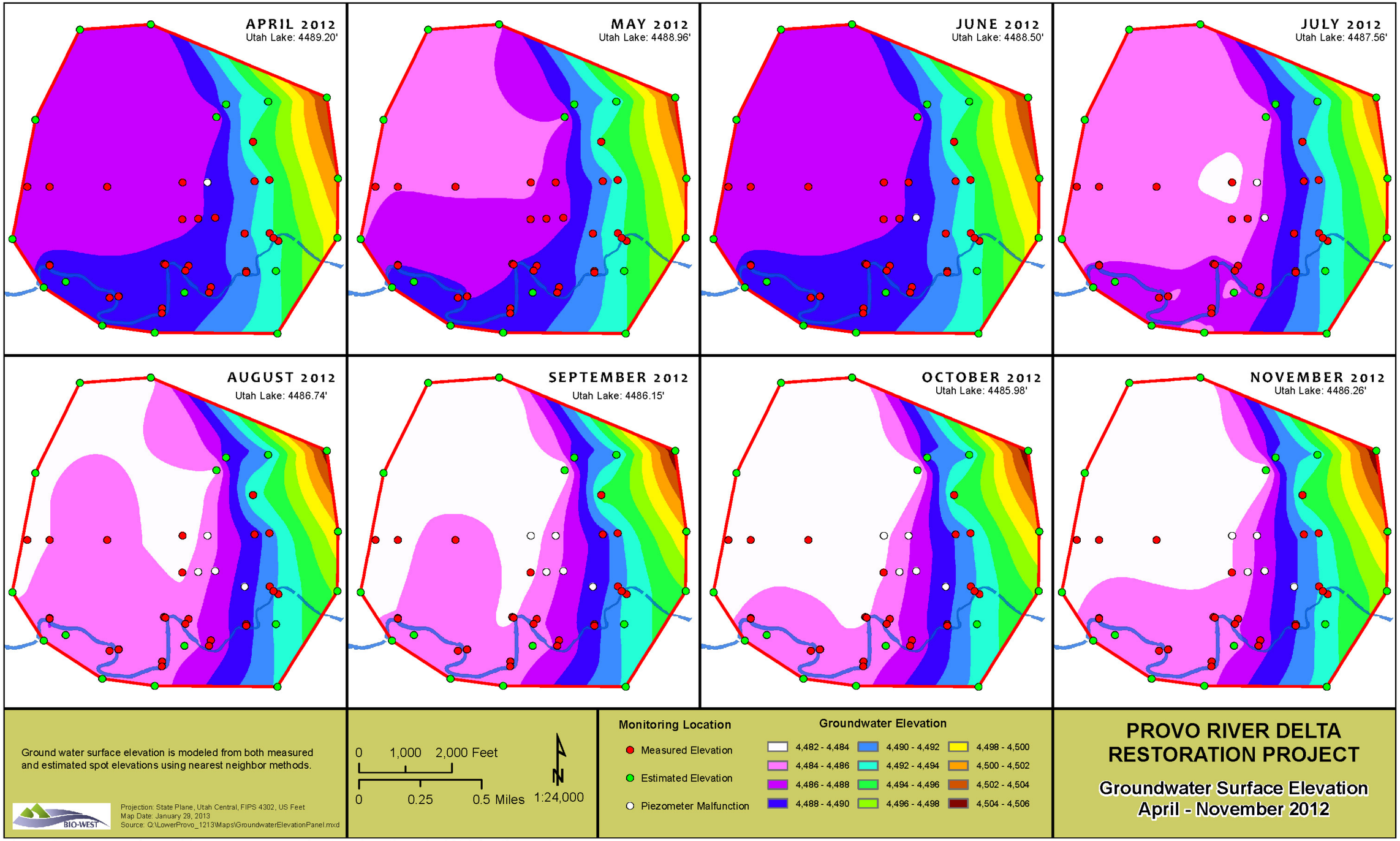


Figure 8. Map of monthly average groundwater elevations in 2012 for the project area.

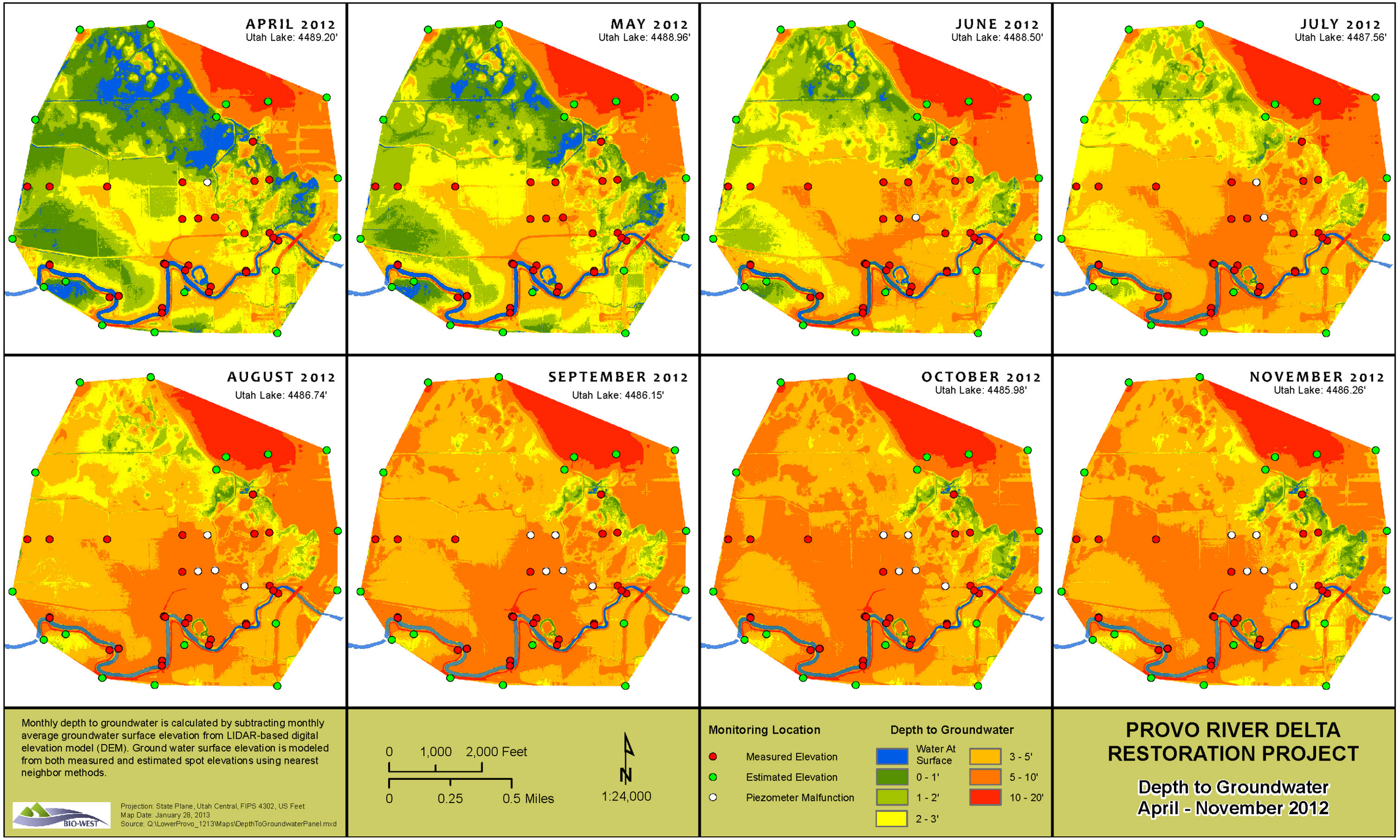


Figure 9. Map of monthly average depth to groundwater in 2012 for the project area.

Surface/Groundwater Interactions from Lakeshore Drive to the UDWR Fish Weir

Flows over the past 10 years in the lower Provo River have ranged from <2 cubic feet per second (cfs) in 2004 to nearly 2,000 cfs in 2011 (Figure 4). Stream discharge in the lower Provo River is the primary driver controlling surface-water elevations and the wetted perimeter in portions of the existing channel upstream of the UDWR Fish Weir (Figure 10). With the existing levees in place, seasonal and annual range in flows causes the water surface or "stage of the river" to fluctuate more than 6 feet during peak flows. Peak flows generally occur in May through June and are fairly short lived, sometimes only lasting a few days.

At high flows, surface water in the channel is nearly 4 feet higher than adjacent groundwater elevations (and the ground outside the levees, for that matter) (Figure 11). This scenario generally indicates a "losing" stream. However, it appears that the levee system effectively prevents water from escaping. The levees are effective in containing nearly all stream discharge within the banks, unless they become overtopped (which occurred in 1983). This portion of the river appears to be a "gaining" reach during moderate and low flows, when groundwater elevations outside the levees are higher than the surface water in the channel within the levees.

Groundwater elevations away from the channel do not seem to be influenced by fluctuating surface-water elevations in the river. The north-to-south groundwater profile (Figure 11) is essentially flat during April–July. Interestingly, the profile changes in late fall, with groundwater elevations increasing with distance from the river and proximity to the peat soils and associated springs/fens. The groundwater recharges back to near the surface in piezometers 6 and 9 during the fall months, at the time of year where the piezometers closer to the channel are at their lowest point of the year.

Surface/Groundwater Interactions from UDWR Fish Weir to the Utah Lake Marina

The groundwater profile slopes slightly away from the existing Provo River channel in the western portion of the project area (Figure 12). Groundwater adjacent to the channel is generally lower than Utah Lake's water surface in the lower portions of Provo River at all times of the year. The groundwater profile indicates that this portion of the river is "losing" water to the adjacent water table. It is interesting to note that water remains "perched" in the channel above the adjacent groundwater during the dry seasons of summer and fall. Permeability of the streambank is very low. The groundwater is generally higher and closer to the surface south of the south levee than it is north of the north levee. The fill makes the south and north levees extend 10 feet and 3.5 feet higher (respectively) than the groundwater during high flow/high lake in 2012.

Figure 10. Photo of surface water elevations in the lower Provo River during an extreme low-flow event in 2004 (<5 cfs in the top photo) and above-normal winter flows in 2010 (173 cfs in the bottom photo). Area shown is above the influence of Utah Lake (just upstream of cross section 26).

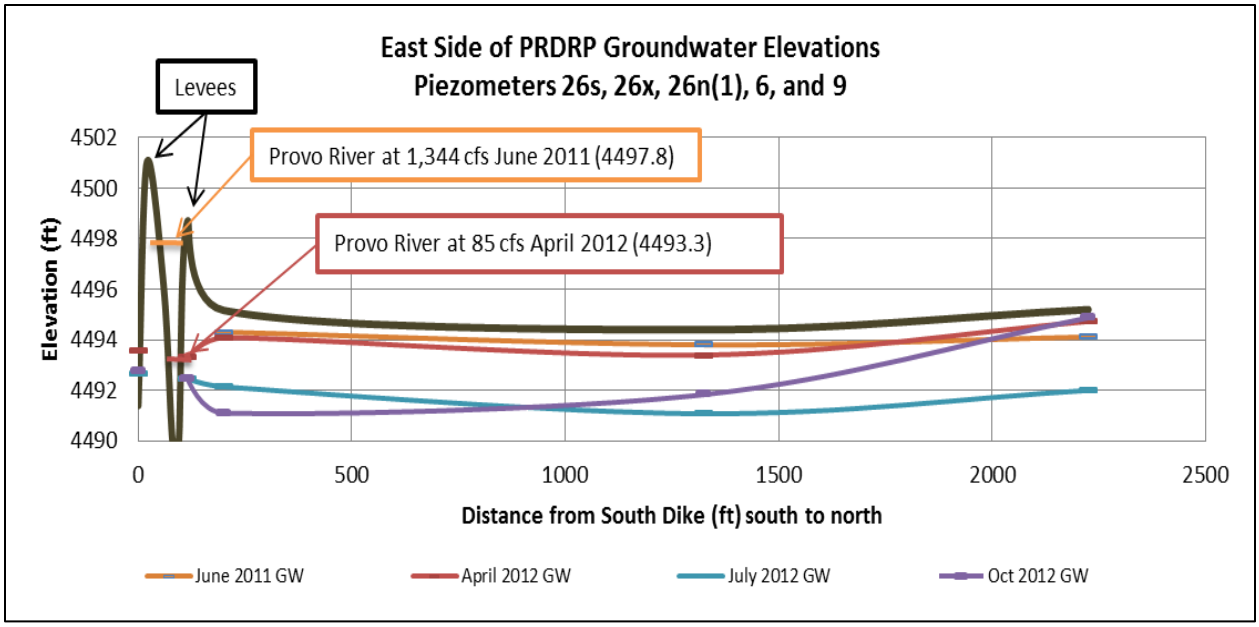


Figure 11. South-to-north profile of monthly average groundwater elevations on the east side of the project area.

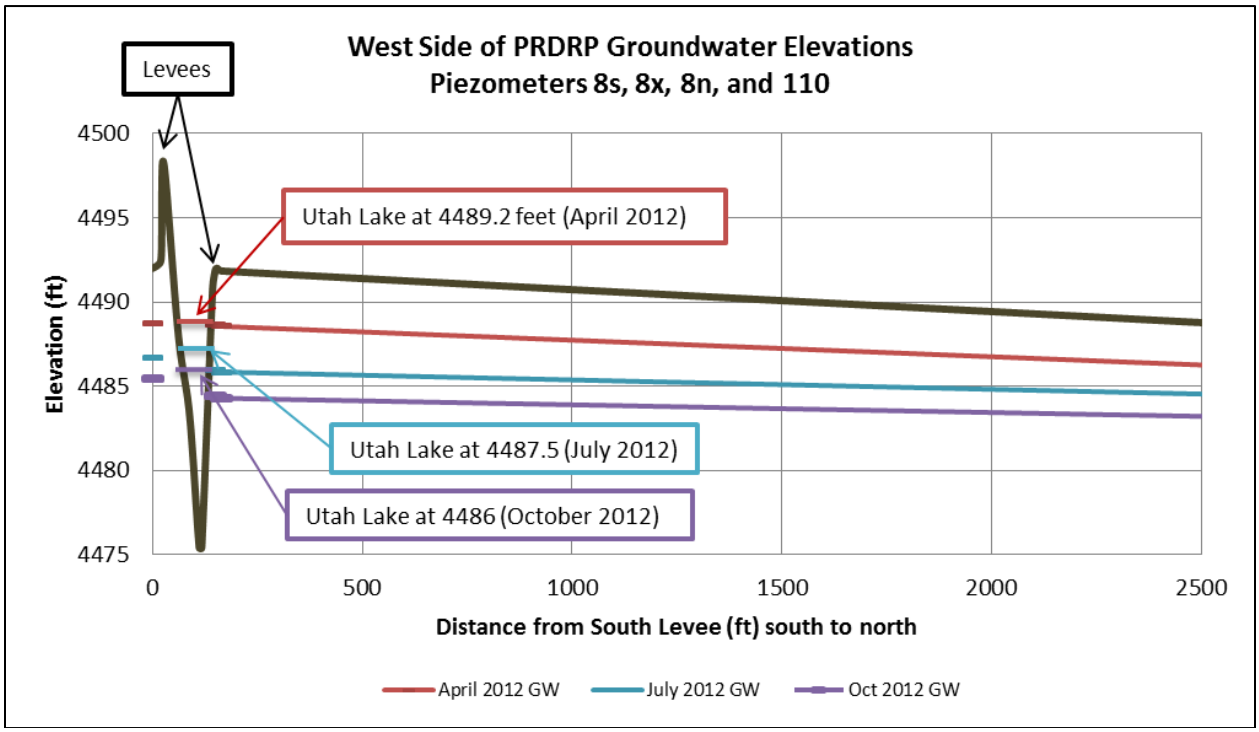


Figure 12. South-to-north profile of monthly average groundwater elevations on the west side of the project area.

Hydrologic Conditions with Potential to Cause Mortality to Existing Trees

Current water-level data as well as surface and groundwater models for the lower Provo River provide spatial information regarding the distribution of groundwater elevations and depth to groundwater within the existing riparian corridor (Figures13 and 14).

Depth to groundwater during April and October illustrate the current maximum seasonal range in groundwater elevations for this part of the project area (Figure 9). Most mature trees along the existing channel are located on surfaces where depth to groundwater is between 2 and 8 feet.

As previously discussed, there is a declining gradient of diversity in riparian tree species along the lower Provo River as it reaches the Utah Lake State Park. Depth to groundwater within the riparian corridor decreases as ground elevation decreases approaching the confluence with the lake. Levees on both sides of the river channel raise the ground elevation and create unvegetated slopes on both sides of the levees. Significant differences in groundwater depths are associated with the height of the levees on each side of the river channel. The trees within the corridor are found on both sides of the levees from the edge of the channel up the levee slope and on the far side of the levee. Depth to groundwater is higher on the levee slopes than at the toe of the slopes. Average depth to groundwater for April 2012 ranged from 0–2 feet at the channel edges, up to 6–8 feet at the levee slopes and trail, and 2–4 feet farthest from the levee. October elevations show an average groundwater decline of 3 feet within portions of the riparian corridor, with a corresponding increase in depth to groundwater.

The depth to groundwater data available to date indicate that most mature trees along the existing riparian corridor are likely rooted to a depth of 8 feet or more when located closest to the levees and within the isolated oxbow. Tree stands located nearest the lake may be rooted at a shallower depth of 6 feet. The existing groundwater fluctuation estimate is important in establishing the history of groundwater availability for these trees and to assess their response to a change in groundwater availability associated with the project area. It is important to note that the drought ending in 2004 (Figure 2), during which Utah Lake water levels dropped to 4,481 feet, did not result in massive mortality of trees in the existing riparian corridor. In addition, most of the trees along the riparian corridor were alive during the floods of 1983–1985, and experienced sustained inundation for more than 2 years (depending on the trees' height position on the levee). It is likely that some of the lower positioned trees died in 1983.

The existing trees have shown resilience to changes in hydrology several times over the past few decades. The 2012 data indicates that in a "normal" year during the growing season the trees in the riparian corridor experience groundwater fluctuations of approximately 3 feet but have experienced decadal fluctuations of more than that. The rate of change affects the ability of the tree to grow new roots at the new ideal elevation.

Efforts to predict the effects of hydrologic changes to trees within the riparian corridor will be addressed following the selection of project alternatives. Groundwater and surface-water modeling will provide the information necessary to assess potential water levels within the riparian corridor and the effect on trees within the existing riparian corridor.

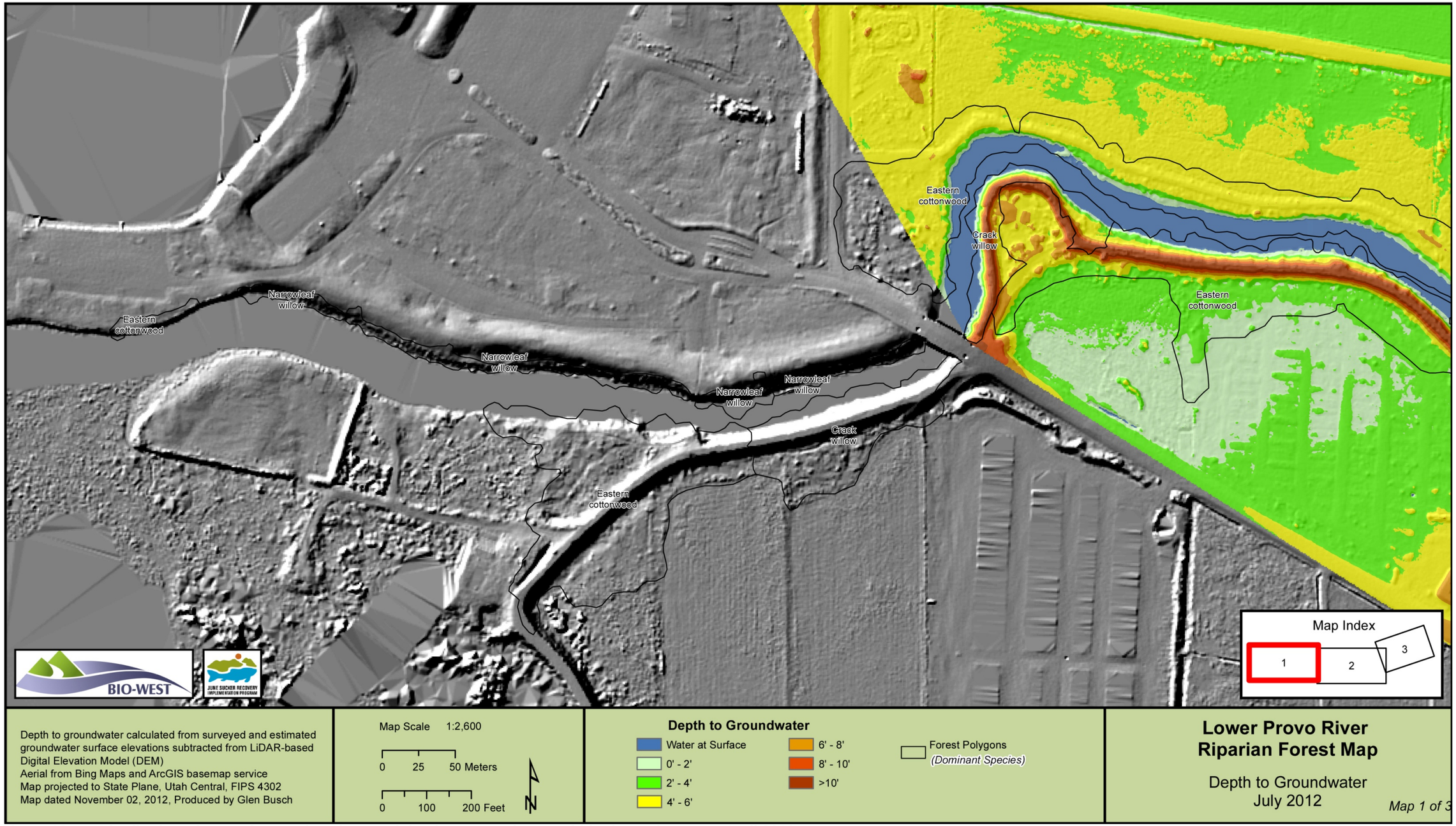


Figure 13a. Distribution of groundwater elevations and depth to groundwater within the project area, April 2012.

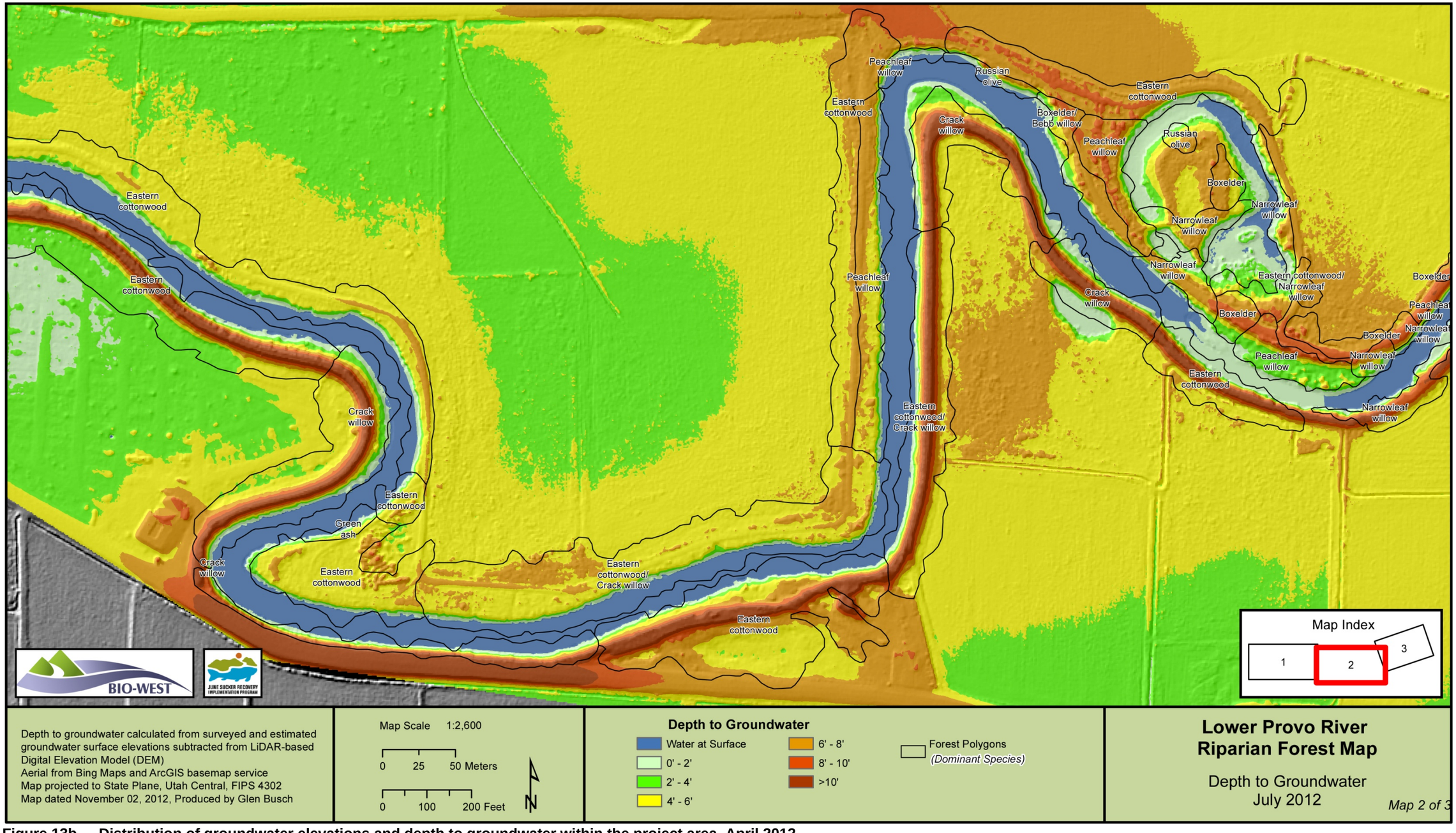


Figure 13b. Distribution of groundwater elevations and depth to groundwater within the project area, April 2012.

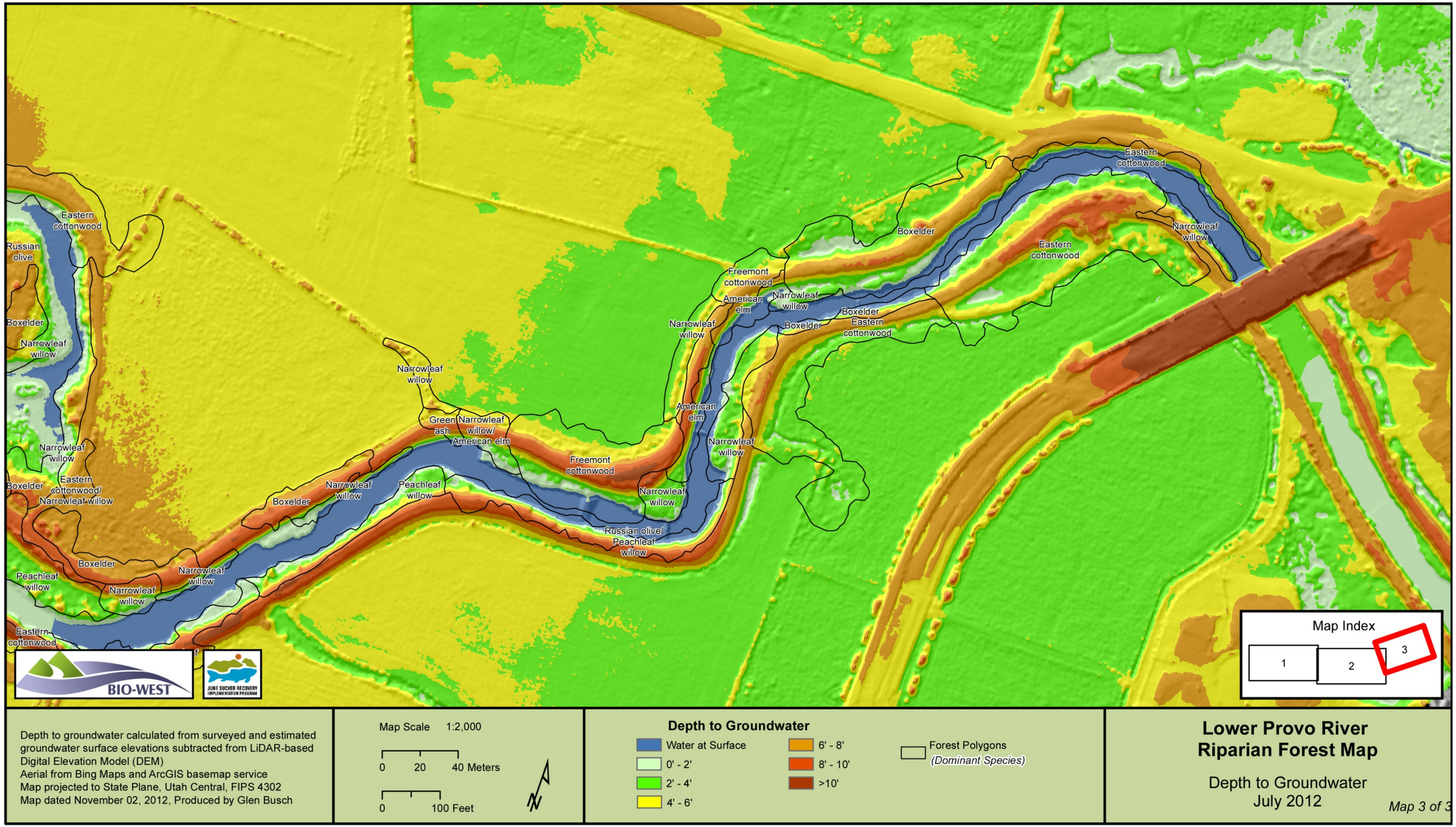


Figure 13c. Distribution of groundwater elevations and depth to groundwater within the project area, April 2012.

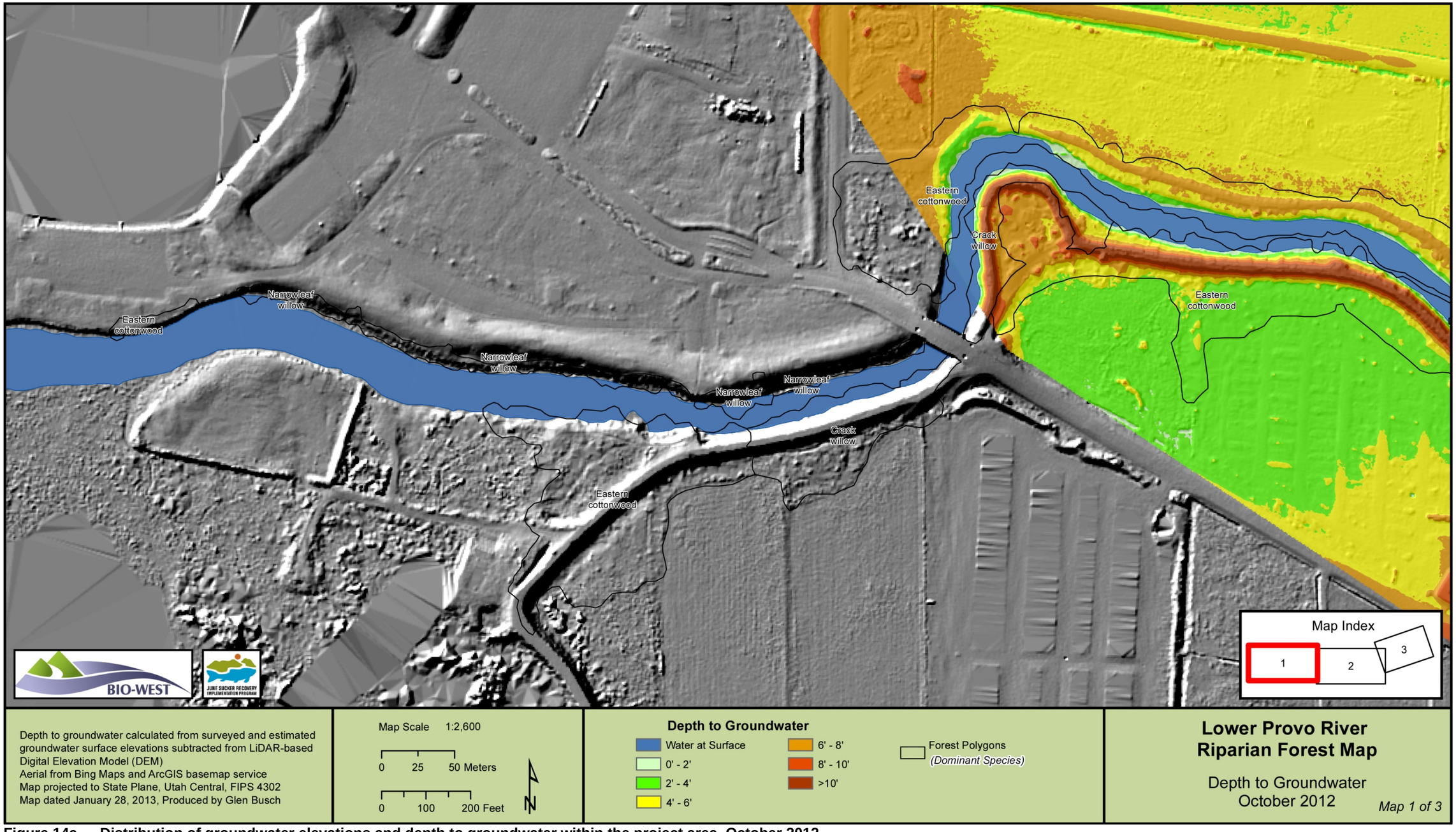
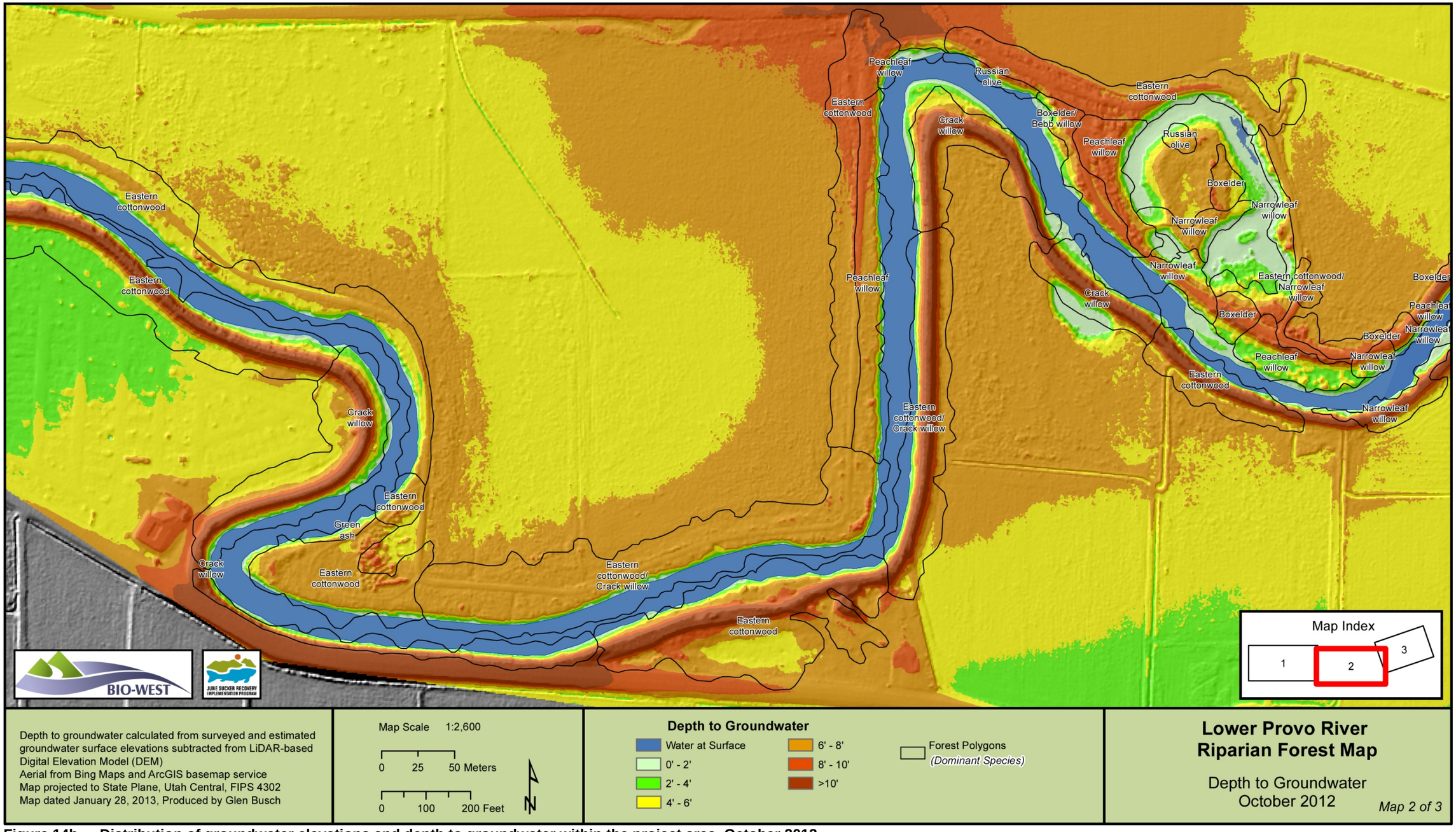


Figure 14a. Distribution of groundwater elevations and depth to groundwater within the project area, October 2012.



Depth to groundwater calculated from surveyed and estimated groundwater surface elevations subtracted from LiDAR-based Digital Elevation Model (DEM)
Aerial from Bing Maps and ArcGIS basemap service
Map projected to State Plane, Utah Central, FIPS 4302
Map dated January 28, 2013, Produced by Glen Busch

Map Scale 1:2,600

0 25 50 Meters

0 100 200 Feet

N

Depth to Groundwater

- Water at Surface
- 0' - 2'
- 2' - 4'
- 4' - 6'
- 6' - 8'
- 8' - 10'
- >10'

Forest Polygons *(Dominant Species)*

Lower Provo River Riparian Forest Map

Depth to Groundwater
October 2012

Map 2 of 3

Figure 14b. Distribution of groundwater elevations and depth to groundwater within the project area, October 2012.

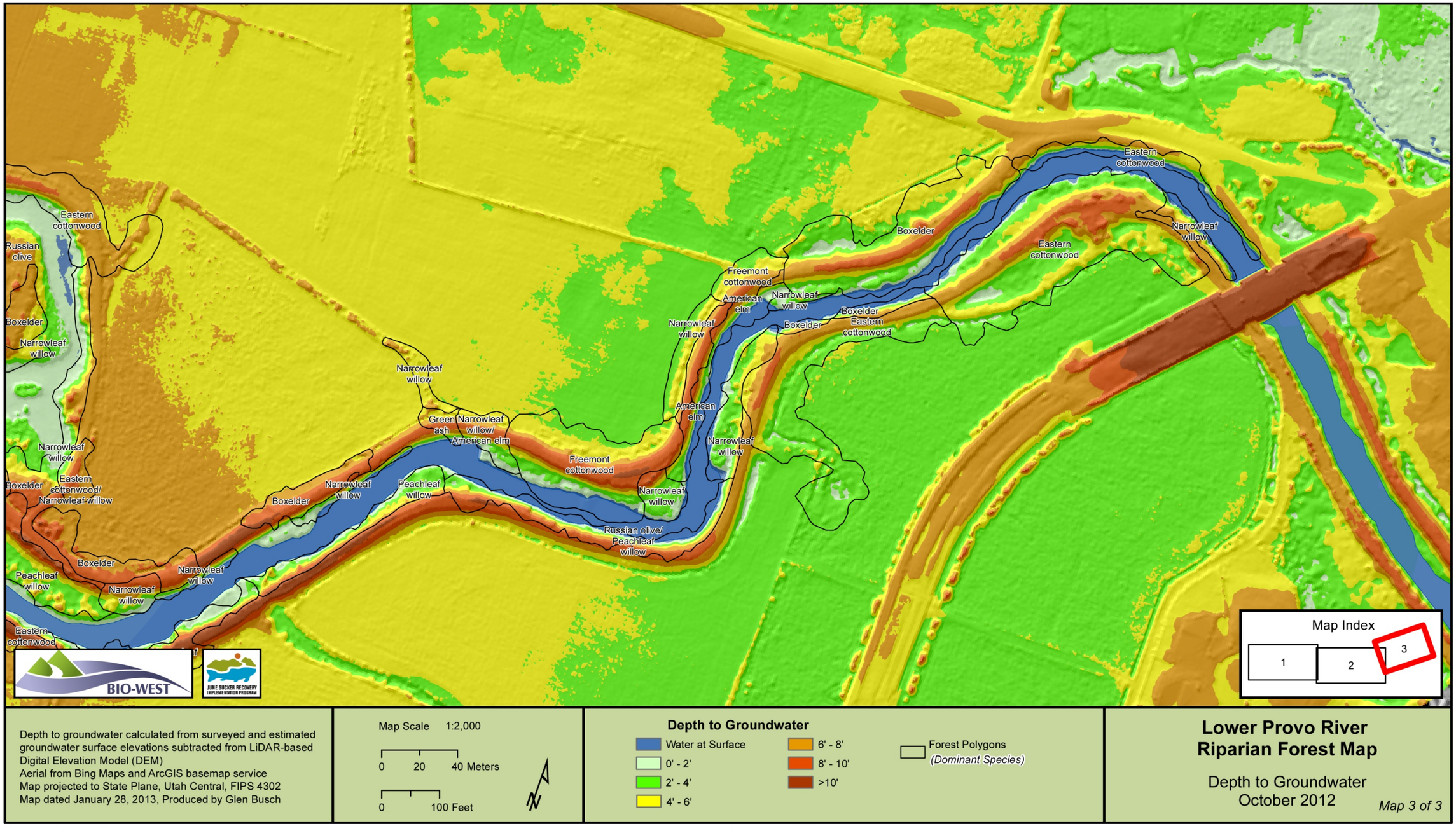


Figure 14c. Distribution of groundwater elevations and depth to groundwater within the project area, October 2012.

SUMMARY

The riparian forest along the lower Provo River is predominantly composed of a mix of native, nonnative, large, mature, even-aged trees with little or no mid-level or lower-level canopy development. This section of the lower Provo River has been the site of various historical uses. The riparian corridor has been altered by levees on both banks of the river, limiting the ability of the river to meander, carry and deposit sediment, and develop floodplain features. The riverine ecosystem has limited hydrologic disturbance regimes, which are important for influencing cottonwood and willow establishment and growth (Beshchta 2003). In addition, nonnative and native ornamental species such as crack willow were likely planted here and have escaped cultivation along the lower Provo River, shifting native species diversity and adding a degree of interspecies competition (Kuhns 1998).

Seasonal change in groundwater elevation is approximately 3 feet. Actual depth to groundwater ranges from 2 to 10 feet along the existing channel, depending on actual cross-sectional position from the river bank to the top of the levee. Riparian vegetation is very limited on the existing steep slopes. Given all available information, and for the purpose of predicting affects to existing trees along the lower Provo River, groundwater elevation alterations of more than 3 feet (higher or lower) compared to existing conditions at any location, is predicted to cause mortality of the mature riparian forest that currently exists along the lower Provo River and trail. If the water table increases in April by more than 3 feet, then mortality by flooding is likely, and if the water table decreases in October by more than 3 feet, then mortality by drought is likely. It is difficult to predict the extent of tree mortality under either scenario. However, research presented in this document indicates that complete mortality of flooded trees is probable, while there may be potential for some trees (likely younger trees) under drought conditions to adapt and survive.

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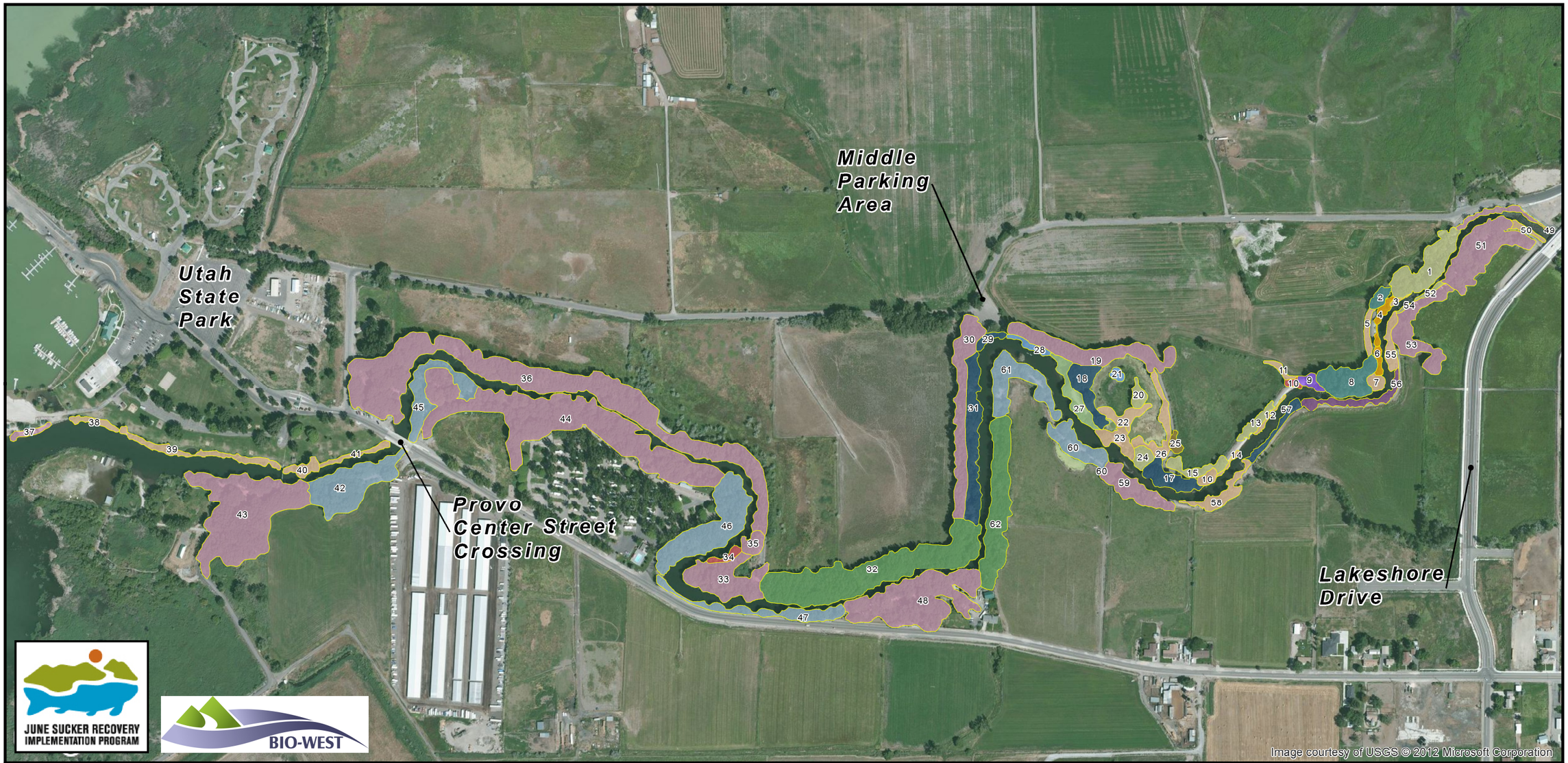
APPENDIX A: MAP OF VEGETATION POLYGONS



Species composition information collected in the field by BIO-WEST technicians May 9, 2012
Aerial from Bing Maps and ArcGIS basemap service
Map projected to State Plane, Utah Central, FIPS 4302
Map dated November 02, 2012, Produced by Glen Busch

0 250 500 1,000 Feet

0 100 200 400 Meters

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1:6,000

Lower Provo River Riparian Forest Map