Appendix P. Riparian Vegetation Studies

SUMMARY OF RIPARIAN VEGETATION LITERATURE REVIEW

Introduction

This section summarizes information obtained from published literature and consultants' reports on the ecology of riparian plants in Mono Basin. This information is used in the EIR to support assumptions for assessing impacts on riparian vegetation and evaluating the feasibility of potential mitigation measures.

Growth Patterns of Riparian Species

Black Cottonwood

Habitat and Distribution. Black cottonwood is an obligate riparian species (i.e., it grows only along streams) and requires greater amounts of water than willows (Pezeshki and Hinckley 1988, Patten and Stromberg-Wilkins 1988). Juvenile black cottonwoods on Rush Creek occur mostly in coarse, rocky substrates just beyond channel edges or at the edges of floodplains, reflecting their requirements for both moisture and aeration. On other streams, cottonwood abundance increases with proximity to streams, reflecting their high demands for groundwater (Roe 1958, Patten and Stromberg-Wilkins 1988).

Drought Stress Tolerance. Growth-related indicators of drought stress in cottonwoods include reduced stem radial growth, reduced branch growth and branch or crown dieback, reduced leaf size, increased leaf senescence and loss of leaf area, and reduced seedling abundance (Albertson and Weaver 1945, Smith 1984, Patten and Stromberg-Wilkins 1988, Pezeshki and Hinckley 1988, Rood and Mahoney 1990).

Physiological responses to drought stress in cottonwoods include reduced transpiration, higher leaf temperatures, increased leaf thickness, and reduced size of stomata (leaf pores). Drought-stressed plants may adapt physiologically and morphologically to conserve water, but when these adaptations do not fully offset reduced water availability, leaves lose water potential and wilt or die (Smith 1984, McBride et al. 1989). Black cottonwoods in relatively dry sites may become better adapted to recover from drought stress than trees in relatively wet sites (Schulte et al. 1987).

Male black cottonwoods may more successfully survive periods of drought stress than females; therefore, sex ratios may affect survival and recovery following stress and may be affected by periods of stress (Patten and Stromberg-Wilkins 1988).

Stromberg and Patten (1991) concluded that black cottonwood growth rates on Bishop Creek depended strongly on growing season streamflow volumes.

Root Growth. Although most observations of cottonwood rooting depths and root growth rates have been in species other than black cottonwood, cottonwoods in similar habitats may have similar growth potentials. Fenner et al. (1984) observed Fremont cottonwood root growth up to 6 mm (0.2 inch) per day. Total rooting depth of seedlings reached 72 cm (2.4 feet) at the end of the first summer of their study and reportedly could have grown up to 162 cm (5.3 feet). Ware and Penfound (1949) observed roots 3 m (9.8 feet) deep in 2-year-old cottonwoods in Oklahoma. Dickman and Stuart (1983) observed roots growing 1 m (3.3 feet) or more a year in 3- to 5-year-old poplars in eastern North America. McBride and Strahan (1984) found that root growth in Fremont cottonwoods exceeded that in two willow species.

Fenner et al. (1984) determined that a declining water table promoted deepr root growth. McBride et al. (1989) observed Fremont cottonwood roots following a declining water table. Vertical growth stopped and lateral growth began when the roots reached a stable water table. Groeneveld and Griepentrog (1985) found that roots of juvenile black cottonwood that had adapted to a shallow water table did not elongate when the water table dropped; roots that had not adapted to a shallow water table grew 5 mm (0.2 inch) per day as the water table moved deeper in the soil. Broadfoot (1973) found that cottonwood root growth rates peaked when the water table was 58 cm (1.9 feet) below the ground surface. Robinson (1952) reported that cottonwoods and willows rarely grow where the water table is more than 20 feet deep.

Few observations of total root depth or optimal water table depth have been made for black cottonwood or other riparian species. Observations made at a number of wells in the Owens Valley in 1921 (Ecosat Geobotanical Surveys 1990) suggest that the water table in woody riparian communities is typically 3.9 ± 1.5 feet below the ground surface (see "Water Table Model" below).

Reproduction and Seedling Establishment. Black cottonwood typically reproduces by seed but can also reproduce vegetatively (Patten and Stromberg-Wilkins 1988). Seed maturation, dispersal, and germination is adapted to the timing of high spring flows (Fenner et al. 1985). Seed dispersal in the Lee Vining area typically occurs in June and July. Scouring by floods and ice may promote development of vegetative suckers in cottonwoods (Rood and Mahoney 1990). Stem segments that break off trees may occasionally root and generate new plants in black cottonwood (Galloway and Worrall 1979).

Recruitment occurs episodically following high spring flows; abnormally high summer flows can destroy seedlings (Stromberg and Patten 1989a). Seedlings do not tolerate prolonged flooding, and root growth is promoted by receding water levels; therefore, gradual subsidence of high flows is important for seedling survival and establishment (Fenner et al. 1985). Some cottonwoods require moist conditions at the ground surface for least 1 week to ensure germination and establishment (Moss 1938). Seed viability is short because of their small size (Fenner et al. 1984, Moss 1938). Conditions favoring germination and establishment are normally episodic, occurring at 2- to 10-year intervals. During such years, cottonwoods and willows may germinate successfully for periods of only 2-4 weeks (Rood and Mahoney 1990).

Cottonwood seedlings are generally poor competitors with other plants; therefore, recruitment occurs mostly on open, unvegetated sites with abundant sunlight and constant moisture for the first few weeks of growth (Rood and Mahoney 1990). Mortality of seeds and first-year seedlings most often results from drought or late frosts (Rood and Mahoney 1990, Stromberg and Patten 1989a). Northern cottonwood seedlings survive best on point bars and moist streambanks, where the plants have access to moisture but flooding is avoided (Bradley and Smith 1986, Noble 1987, Wilson 1970).

Quaking Aspen

Habitat and Distribution. Quaking aspen is considered an obligate riparian species in semi-arid regions (Rood and Mahoney 1990), but it occurs on hillsides watered by springs and snowmelt as well as along streams. Quaking aspen is intolerant of shade (Moss 1938). Quaking aspen occurs infrequently in coarse alluvial habitats below the terminal glacial moraines on Mono Lake's tributary streams but is common on all the tributary streams within the terminal moraines.

Drought Stress Tolerance. Indicators of drought stress reported in quaking aspen include reduced growth and reduced seedling abundance (Rood and Mahoney 1990). Quaking aspen may exhibit other growth-related and physiological drought stress indicators similar to those listed above for the closely related black cottonwood.

Root Growth. Quaking aspen seedlings develop extensive lateral root systems with limited tap roots. Extensive clones develop by suckering from lateral roots of a single plant, not by root grafting between separate plants. Mature stands (of one or more clones) are characterized by shallow, spreading, interconnected lateral roots with vertical sinkers descending from the lateral roots. Lateral roots may extend over 100 feet into adjacent open areas; sinker roots have been observed 9 feet deep in well-drained soils. Sinker roots may develop dense mats of fine roots at their lower extremities (Jones and DeByle 1985).

Reproduction and Seedling Establishment. Quaking aspen reproduces mostly by sprouting from the widely spreading lateral roots. Seedling establishment is rare in quaking aspens because seeds are viable for only brief periods and deteriorate rapidly without optimal conditions. Optimal conditions for germination and establishment include adequate drainage; moderate temperature; absence of competing vegetation; and a level, well-watered mineral soil surface. Seedlings are highly sensitive to small soil moisture deficits, and rapid drying of surface soil is the most common cause of seedling mortality (Patten and Stromberg-Wilkins 1988, Moss 1938).

Clonal sprouting is stimulated by heat, light, injury (Schier et al. 1985), and increased streamflows (Patten and Stromberg-Wilkins 1988).

Willows

Habitat and Distribution. The following willows have been reported to occur below the diversion points on Rush, Parker, Walker, and Lee Vining Creeks (Taylor 1982, Patten and Stromberg-Wilkins 1988, Stromberg and Patten 1989d):

- # Coyote willow is common along streambanks and across dewatered floodplains. It is the most abundant and most drought-tolerant of the willows on these creeks.

- # Arroyo, or white, willow was formerly abundant and is now uncommon, but it is reestablishing widely in the rewatered reaches. Arroyo willow is currently the second most common willow in diverted reaches of the creeks, especially on point bars in the lower reaches. In the Owens Valley, it is often associated with western birch.

- # Yellow willow occurs mostly along reaches with little flow, surrounded by sagebrush and often found with Pacific willow. It is more common in the lower than the upper reaches of Rush Creek.

- # Pacific willow is uncommon, occurring mostly in reaches little affected by dewatering. It often occurs with yellow willow along reaches with little flow and surrounded by sagebrush.

- # Red willow is uncommon, but mature plants remain in reaches little affected by dewatering and young plants have established on point bars on lower Rush and Lee Vining Creeks. Red willow is more common in the Owens Valley than in Mono Basin.

Drought Stress Tolerance. Ranking of drought stress tolerance, from most tolerant to least tolerant, is:

- # coyote willo,
- # arroyo willow,
- # yellow willow, and
- # red and Pacific willows.

(Patten 1968, Patten and Stromberg-Wilkins 1988.) Coyote willow's presence on pre-incision floodplain terraces on Rush and Lee Vining Creeks and its dominance in dewatered sections of Parker and Walker

Creeks reflect its tolerance of dewatering compared to other willows. Coyote willow may also be more tolerant of grazing than other willows (Patten and Stromberg-Wilkins 1988).

Although red willow is less tolerant of stress than arroyo willow, it is better adapted to water table decline because it has a more effective root system (Williams and Matthews 1990).

Indicators of drought stress in willows include substantial leaf loss (Smith 1984), low predawn leaf water potential, high leaf temperature, and high transpiration rate (Leighton and Risser 1989).

Root Growth. Willows grown in experimental tanks (McBride et al. 1989) grew roots that followed an artificially receding water table. When water table decline ceased, downward growth stopped and many lateral roots were produced. Red willow and sandbar willow, closely related to coyote willow) developed fibrous root systems with many lateral roots (McBride et al. 1989). Root growth rates in sandbar willow and red willow were less than that in Fremont cottonwood (McBride and Strahan 1984).

Reproduction and Seedling Establishment. Coyote willow reproduces vigorously from both seeds and sprouts. Coyote willow is regenerating more than other willow species on Rush Creek (Stromberg and Patten 1989d). Patten (1986) observed that strong willow survival and growth was associated with sandy substrates. McBride and Strahan (1984) found that willows established best where the surface sediment size averaged less than 2 mm; cottonwoods established more often where the surface sediment size averaged 2-20 mm.

Arroyo willow requires abundant subsurface moisture throughout summer for seedlings to survive and establish. Other willows require at least temporarily saturated soils (Stromberg and Patten 1989a).

Mountain Rose

Habitat and Distribution. Mountain rose is a facultative riparian species that tolerates a wide range of soil moisture conditions. It tolerates both full sun and shade (Patten and Stromberg-Wilkins 1988). It grows most vigorously on well-watered streambanks with topsoil but also persists in former riparian areas now dominated by sagebrush. Mountain rose also invades areas where willows or cottonwoods have died or become decadent from dewatering (Stromberg and Patten 1989d).

Drought Stress Tolerance. Mountain rose is apparently much more tolerant of drought stress than willows or cottonwoods because it invades or persists in areas where obligate riparian plants have died. Like garden roses, however, mountain rose grows best with an ample water supply. No specific studies of drought stress tolerance in mountain rose are available.

Root Growth. No observations of mountain rose root growth are available.

Reproduction and Seedling Establishment. Mountain rose spreads vegetatively by root sprouts and also reproduces by seed. Fruit and seed production is abundant on the tributary streams, where large numbers of seeds are dispersed by robins and other birds (Patten and Stromberg-Wilkins 1988, Stromberg and Patten 1989d).

Mountain rose abundance on the tributary streams is highly correlated with woody litter abundance, indicating that organic matter from woody litter may promote rose germination and establishment (Patten and Stromberg-Wilkins 1988).

Buffalo Berry

Buffalo berry is a facultative riparian species in Mono Basin, occurring near streams and on the drier edges of floodplains. On Rush Creek, it tends to occur on the silty soils of raised terraces (Patten and Stromberg-Wilkins 1988, Stromberg and Patten 1989d).

Buffalo berry reproduces by seed and by clonal sprouting. Reproduction by both means has been observed on Rush Creek in response to rewatering (Patten and Stromberg-Wilkins 1988, Stromberg and Patten 1989d).

Jeffrey Pine

Jeffrey pine is a facultative riparian species in Mono Basin; in some areas, it is restricted to the streamside riparian strip and in other areas is a widespread upland forest tree. In both settings, it is intolerant of floods and requires well-drained soils. Its seedlings do not compete well with other species (Patten and Stromberg-Wilkins 1988).

Stumps of Jeffrey pines have been observed in the active channel of the West Walker River north of Pickle Meadows (Stine pers. comm.). These pines evidently established on the riverbanks when flows were lower and may have died in response to increased flows and drowning of their roots.

Conclusions Regarding Growth of Riparian Vegetation

Effects on Individuals

Individual riparian plants respond to drought stress through physiological and morphological adaptations such as the following:

- # stomate size (affecting CO_2 exchange and water loss);
- # transpiration rate and leaf shape (affecting leaf temperature and water uptake);
- # leaf orientation, size, thickness, and hairiness (affecting energy gain); and
- # growth rate (affecting root-shoot ratio and dormancy period).

Individuals of different species and sometimes of different populations in the same species differ in their capacity to tolerate drought stress without substantial dieback, reproductive failure, or mortality. Adult riparian plants are more tolerant of drought stress than young plants.

Roots can grow vertically to follow a receding water table, but root growth will not keep pace with a water table that recedes too rapidly.

Effects on Populations

Although willows and cottonwoods may be severely depleted by prolonged dewatering, they have strong potential to recolonize riparian areas. The following conditions are necessary for natural recolonization:

- # overbank flows coinciding with seed dispersal,
- # gradually receding flows following seed dispersal,
- # accessible groundwater during periods of high water demand, and
- # predominantly sandy or gravelly substrates for seedlings.

The availability of these conditions largely determines the rate and distribution of vegetation recovery from seeds.

Recruitment of new stands of willows and cottonwoods is intermittent, limited to years when moisture conditions are optimum. Prolonged periods of stress during which seedlings do not establish, however, can alter the age distribution of an existing population.

Substantial changes in channel or floodplain morphology (e.g., incision, lateral erosion, topsoil removal, or channel abandonment) may locally alter the long-term potential for riparian vegetation to reoccupy areas where prediversion riparian vegetation was abundant.

Changes in flow or other factors that reduce sand and gravel bar formation can reduce riparian vegetation recruitment by retarding development of favorable seedling sites.

RIPARIAN VEGETATION MAPPING

Methods

Vegetation Mapping

Jones & Stokes Associates prepared detailed maps of prediversion (1940) and existing (1989) riparian vegetation on the diverted segments of Rush, Lee Vining, Parker, and Walker Creeks. Prediversion vegetation was mapped using black-and-white aerial photographs taken in December 1929 and June 1940. No direct field verification of prediversion vegetation was possible; however, limited information on vegetative composition and condition was available from ground-based photographs, recollections of individuals who lived in the area at the time, written field notes from C. H. Lee, and the remains of formerly vigorous vegetation. Existing vegetation was mapped using color aerial photographs taken in August 1987 (Rush Creek only) and July 1990 (all creeks). Field surveys were conducted in summer and fall 1990 and 1991 to verify existing vegetative composition and condition.

Vegetation was mapped as polygons having generally uniform composition and condition. Composition was defined in terms of dominant woody species. Condition was characterized in terms of cover class, vigor, vegetative layering, and response to rewatering. All riparian vegetation was mapped on detailed topographic maps (scale = 1:1,200; contour interval = 2 feet) prepared from May 1991 aerial photographs.

The maps of prediversion and existing riparian vegetation were used to determine how riparian vegetation had changed after 50 years of diversions and to determine where riparian vegetation was already responding favorably to recent rewatering.

Composition. Dominant species and overall composition were characterized using the vegetation classification described in Appendix F.

Cover Class. Areas with less than about 10% vegetative cover (woody or herbaceous) were mapped as unvegetated. Areas with over 10% cover of herbaceous plants but less than 10% cover of woody plants were mapped as herbaceous vegetation. Areas with over 10% cover of woody plants were mapped as forest/woodland or scrub vegetation. Cover classes of woody vegetation were mapped as follows:

- class 1 = 10-25% cover,
- class 2 = 25-50% cover,
- class 3 = 50-75% cover, and
- class 4 = 75-100% cover.

Riparian Vigor. Three broad categories were used to describe overall community vigor for forest/woodland and scrub vegetation types. "Establishing" polygons were those in which the cover by seedlings and saplings of woody plants exceeded cover by mature plants. "Mature" polygons were those in which cover by mature plants exceeded cover by woody seedlings and saplings and cover by live stems and branches exceeded cover by dead wood. "Decadent" polygons were those in which cover by dead wood (usually cottonwood and willow) exceeded cover by live branches and stems of the same species. Vigor was not assessed for herbaceous vegetation types or individual plants.

Vegetative Layering. Four generalized vegetative layers were recognized in vegetated areas:

- layer A = groundcover (herbaceous plants only, mostly under 1 foot tall);
- layer B = low shrubs and tree saplings (mostly 1-4 feet tall);
- layer C = tall shrubs and short trees (mostly 4-12 feet tall); and
- layer D = tall trees (mostly over 12 feet tall).

Vegetation polygons were characterized in terms of the number of different layers present. Layers with less than about 10% cover were not counted. Herbaceous vegetation types, by definition, had only one layer present (layer A). Woody vegetation types could have one to four layers present, although tall trees (layer D) were present only in forest/woodland vegetation.

Acreage. Riparian vegetation polygon sizes were measured manually using an electronic planimeter, except for existing vegetation on Rush Creek below The Narrows, which was measured digitally using ArcInfo (GIS software). Minimum polygon sizes were influenced by patch isolation and density. Isolated patches of dense vegetation were mapped down to about 0.05 acre. Contiguous polygons of sparse to dense vegetation were generally at least 0.2 acre in size. Measured acreages were compiled in a database from which tables were prepared summarizing acreages by stream, reach, and habitat type.

Total mapped acreages for each reach varied slightly between the 1989 and 1940 maps. These discrepancies resulted from minor errors in the manual planimetry process. To eliminate these discrepancies, the mean of the 1940 and 1989 acreages was calculated for the entire mapped area on each stream. Each polygon acreage was multiplied by a correction factor (one for the 1940 data set and another for the 1989 data set) to obtain the same total for each year.

The corrected riparian vegetation acreages were considered accurate to approximately ±5%. In evaluating differences between 1940 and 1989 acreages, differences of less than 5% were considered undetectable; differences of 5-10% were considered detectable, but slight; differences greater than 10% were considered readily detectable.

Responses to Rewatering

The effect of recent court-ordered streamflows was assessed for each mature woody riparian vegetation polygon mapped on each stream. Four qualitative levels of response to rewatering were recognized.

Response level 0 was "no response," indicated by no establishment of new plants and no increased growth of mature trees that had survived dewatering.

Response level 1 was "slight response," indicated by sparse establishment of new seedlings, saplings, or suckers (with some searching needed to find them) or increased growth of mature survivor trees (if present).

Response level 2 was "moderate response," indicated by the presence of numerous new seedlings, saplings, and suckers (easily found in moderate numbers) and increased growth of mature survivor trees (if present).

Response level 3 was "strong response," indicated by an abundance of new seedlings, saplings, and suckers (dominant visually and in percent cover) and vigorous growth of mature survivor trees (if present).

These observations were used to develop estimates for minimum responses to alternatives under which flows would be similar to or greater than recent actual flows. These observations were also used to help evaluate the reliability of the riparian width, cottonwood growth, and water table depth models for predicting prediversion and point-of-reference conditions.

Results

Vegetation Mapping

Figures P-1 through P-8 show the extent and type of prediversion and point-of-reference riparian vegetation on Rush, Parker, Walker, and Lee Vining Creeks.

Tables P-1 through P-8 list prediversion and point-of-reference riparian vegetation acreages by habitat type and reach for each creek.

Responses to Rewatering

Tables P-9 through P-12 summarize observed responses of the riparian vegetation to rewatering as of summer 1991.

DESCRIPTIONS OF RIPARIAN VEGETATION BY REACH

Prediversion Conditions

Rush Creek

Reach R0 (above Grant Lake Reservoir). Despite highly variable water elevations during the 1920s and 1930s (eroded shorelines are visible well above the lake surface in the January 1930 aerial photograph), some patches of floating or emergent vegetation were present. These "plant beds" described by Vestal (1990, Court Testimony, Vol. I-XVIII) most likely occurred in the gently sloping shallows at the south end of the lake.

Above the spillway elevation of the 1926 dam, the 1929-1930 aerial photographs show riparian vegetation dominated by willows and cottonwoods, with scattered conifers (probably mostly lodgepole pines), small meadows, and probably some quaking aspens from the high water level of the lake to about 0.8 mile upstream. From this point to beyond the current south end of the lake, the vegetation appears to have been dominated by quaking aspens with scattered conifers.

Reach R1a (Grant Lake Dam to Mouth of Return Ditch). Prediversion aerial photographs indicate that the upper third of this reach supported a narrow stand (up to about 50 feet wide) of cottonwoods, quaking aspens, and willows that was apparently tall, dense, and nearly continuous in the 1930s. Quaking aspens occurred along the Grant Lake reservoir spillway in the uppermost portion of this reach. The photographs also indicate a wider zone (100-150 feet wide) of sparser vegetation in this reach, probably dominated by scattered clumps of willows.

The middle third of the reach appears to have supported narrower and less continuous riparian vegetation. The lower third of the reach supported dense strands of cottonwood forest, willow scrub, and quaking aspens on both sides of the channel and A-Ditch forebay. Riparian vegetation at the bottom of the reach was about 400 feet wide.

Reach R1b (Return Ditch). This channel was constructed shortly before 1940 and supported no riparian vegetation.

Reach R2a (Mouth of Return Ditch to Base of Moraine). This reach passes through a narrow ravine (100-500 feet wide at its rim) in the lowest of the Pleistocene moraines on Rush Creek. Riparian vegetation was confined to narrow strips along the banks and lower slopes of the channel. The upper quarter of the channel supported about 1.2 acres of willow scrub, mostly on the right bank of the stream. One minor overflow channel between this reach and the major overflow channel to the east (reach R2b below) supported about 1.1 acres of dense mountain rose.

The lower three-quarters of this reach supported about 6.5 acres of cottonwood forest, willow scrub, conifer-broadleaf forest with Jeffrey pines, and small quaking aspen groves. The riparian zone was mostly 70-150 feet wide.

Reach R2b (A-Ditch Supply Channel). Beginning in the early 1900s, this natural overflow channel east of reach R2a was regulated as a supply channel for the A-Ditch. The A-Ditch originated midway along this channel at about the 7,010-foot elevation and carried irrigation water eastward to Pumice Valley from before 1920 (when hydrographic records begin) every year until 1948, then intermittently until 1970.

In 1940, vegetation above the A-Ditch intake included willows and quaking aspens along the channel; quaking aspen groves with scattered willows on the hillside west of the channel; and small, linear meadows. Vegetation below the A-Ditch intake included a dense strip of willow scrub along the channel and meadows west of the channel.

Quaking aspens on the hillside west of the channel were associated with springs, possibly fed by water from the main channel of Rush Creek. The meadows were also partially supported by the springs but had probably been enlarged by irrigation from the springs and the overflow channel.

Reach R3 (Base of Moraine to Old Highway Bridge). Approximately 23 acres of cottonwood-willow forest and willow scrub lined the banks and floodplain of this reach in a riparian zone mostly 200-400 feet wide. Jeffrey pines were widely scattered throughout most of the cottonwood-willow forest and were locally dominant over about 1.0 acre near the upper end of this reach. Several small patches of willows or buffalo berry occurred on locally moist sites near but above the floodplain in this reach. The B-Ditch intake was located on the right side of the creek about 1,400 feet above the old highway bridge. Riparian vegetation appears to have been absent from about 600 feet above to 400 feet below the old highway bridge.

Reach R4 (Old Highway Bridge to Mouth of Parker Creek). Riparian vegetation was absent from one or both sides of the creek from the old highway bridge to U.S. Highway 395 (U.S. 395). Below U.S. 395, narrow but nearly continuous strips of willow scrub and cottonwood woodland occurred on both sides of the creek. The riparian zone was mostly 100-150 feet wide, and about 49% of the vegetation had less than 50% cover. Pines were widely scattered throughout the reach but were not dominant in any portion of the reach. One small stand of quaking aspens grew above the right bank of the stream near the middle of this reach.

Stine (1991) notes that, in the 1930s, Rush Creek was relatively dry from the B-Ditch intake to springs near The Narrows. Irrigation diversions above this reach, particularly during the Dust Bowl drought, may have caused some decline in riparian vegetation cover and vigor in this reach before 1940.

Reach R5 (Mouth of Parker Creek to The Narrows). Riparian vegetation was intermittent along Rush Creek for about 700 feet below the confluence with Parker Creek, alternating from one side of the creek to the other. From about 700 feet below Parker Creek to The Narrows, riparian vegetation was mostly continuous on both sides of the creek. Cottonwood-willow woodland and willow scrub were dominant over about 9.6 acres in a riparian zone averaging about 200-250 feet wide.

Charles Lee, a consulting hydrologist working for LADWP in the 1930s, visited Rush Creek near the confluence with Walker Creek on March 23, 1934. His notes record watercress "along margins of Walker and Rush Creeks and seepages entering . . . 6 inches to 1 foot above stream level." Lee also noted "big seepage flow into Rush Creek from both sides appreciably increasing flow" to 6-8 cubic feet per second (cfs) at The Narrows (Stine 1991).

Reach R6 (The Narrows to the Ford). The bottomlands of Rush Creek were characterized by extensive riparian forests, abundant springs at the bases of cliffs, and extensive wet meadows. Riparian vegetation and spring-fed vegetation in this reach were more extensive than in any other stream reach of comparable length in Mono Basin.

The farthest downstream stand of Jeffrey pines on Rush Creek was at the cliff base on the right side of the stream from The Narrows to near the "Big Wash" that enters the bottomlands from Pumice Valley about 2,500 feet below The Narrows. These trees were large and old (Vestal 1990, Court Testimony, Vol. I, pp. 251-252; Stine 1991).

From The Narrows to Big Wash and from the lower meadows to the ford, woody riparian growth was relatively dense, with extensive patches with over 75% cover on both sides of the stream. From Big Wash to the lower meadows, woody riparian vegetation was more patchy, with many small wooded areas separated by small meadows or gravel bars, many larger patches of sparse cover, and some large patches of dense cover. In all these areas, the vegetation was mostly cottonwood-willow forest and willow scrub.

Three major meadow areas occurred on the left side of Rush Creek in this reach. The uppermost meadows, from about 300 to 2,000 feet below The Narrows, were partially separated from Rush Creek by a large island of sagebrush scrub and were mostly 10-15 feet above the nearest elevation of the stream. These meadows appear to have been watered not by groundwater associated with Rush Creek but by springs fed by groundwater recharge at Cain Ranch and along Walker and Bohler Creeks.

The middle set of meadows, from about 2,000 to 4,000 feet below The Narrows, were adjacent to Rush Creek and mostly 2-10 feet above the nearest elevation of the stream. These meadows were probably supported partly by groundwater associated with Rush Creek and partly by groundwater seepage through the Bohler Creek delta deposits.

The lower meadows, from about 1,700 to 4,300 feet above the ford, were mostly less than 5 feet above the nearest elevation of the stream. The lower meadows were described by Charles Lee in his March 1934 notes as "swampy" with "springs and seepages all along [the stream] margin and cut meander channels" (Stine 1991). The lower meadow was irrigated during the 1930s with Rush Creek water diverted from the middle meadows area into the "Indian Ditch." This ditch ceased operation shortly after 1940 (Stine 1991).

Patches of meadow fragmented by narrow corridors of cottonwood-willow forest occurred along the right side of Rush Creek from about 3,000 to 4,800 feet below The Narrows, or just below Big Wash. These meadows were low on the floodplain and within a few feet of the nearby streambanks.

Additional springs and seeps occurred near the base of the high bluffs on the right side of the bottomlands, mostly from Big Wash to the lower end of the lower meadows (about 1,700 feet above the ford). Some of these springs are identified on a map from the Aitken case of 1931-1933 (Stine 1991). The springs are evident on the 1930 and 1940 aerial photographs as lines of dense willow thickets above the edge of the floodplain. Vestal recalled that the biggest springs issued from "around the downstream end of the big wash" (Stine 1991). Lee noted watercress along the margins of Rush Creek wherever he saw the creek in the bottomlands on his March 23, 1934 visit. A substantial portion of the water flowing from these springs originated from Rush Creek water diverted to irrigate Pumice Valley via the A- and B-Ditches (Stine 1991).

Small, scattered patches of cattail or bulrush probably occurred near the springs on the right side of the creek and along abandoned or subsidiary channels. Remnants of such vegetation are evident today but were not mentioned in the recollections or notes of persons present in the 1930s.

Reach R7 (the Ford to County Road). This reach was dominated by dense thickets of willow scrub and cottonwood-willow forest. Photographs from the bluffs overlooking the riparian thickets show several small, interconnected ponds among patches of willows, cottonwoods, and possibly quaking aspens, with wide, thick mats of what appear to be watercress. Few unvegetated or sparsely vegetated sand or gravel bars are visible in prediversion aerial photographs. A meadow of approximately 4.9 acres occurred immediately below the ford, and another of about 2.3 acres occurred above the Clover Ranch buildings. The Rush Creek Fish Hatchery was located on the right side of the creek near the middle of this reach.

Reach R8a (County Road to 1940 Lakeshore). The reach from County Road to the lakeshore (at elevation 6,417.5) was approximately 2,200 feet long in 1940. Willow scrub characterized the floodplain for half this distance, from County Road to about elevation 6,420. Meadows occurred between the willow scrub and the lakeshore.

Reach R8b (1940 Lakeshore to 1989 Lakeshore). This reach (approximately 2,200 feet long) was beneath the surface of the lake in 1940.

Parker Creek

Reach P0 (above Diversion). Riparian vegetation above the present location of the LADWP diversion pond was similar to current vegetation in the area. Willow scrub with several scattered pines (similar to that in upper reach P1) occupied the lower 0.2 mile of the reach. The remainder of the reach was dominated by conifer-broadleaf forest with quaking aspens and pines.

Reach P1 (Diversion to Base of Moraine). Parker Creek occupied two roughly parallel channels in this reach. The north channel (the main Parker Creek channel) supported approximately 7.5 acres of woody riparian vegetation, of which nearly all was willow scrub. The south channel (commonly called "South Parker Creek" but incorrectly identified as the main "Parker Creek" on the 1953 and 1986 U.S. Geological Survey [USGS] topographic maps) appears to have been a natural overflow channel and used as part of the irrigation system. South Parker Creek supported about 7.0 acres of woody riparian vegetation, of which about 6.5 acres was willow scrub. All this vegetation appears in the 1929-1930 and 1940 aerial photographs to have relatively dense, vigorous canopies; however, sheep grazing probably suppressed establishment of young willows during much of the early 1900s.

Reach P2 (Base of Moraine to Cain Ranch Road). About 61% of all the woody riparian vegetation in reaches P1-P4 occurred in this reach. Willow scrub occupied about 35 acres, most or all of which was not stressed by drought; however, sheep grazing probably suppressed recruitment of young plants as in reach P1. Small patches of conifer-broadleaf woodland, non-native cottonwoods, and mixed riparian scrub each occupied about 0.5 acre in this reach.

Reach P3 (Cain Ranch Road to U.S. 395). This reach supported approximately 2.5 acres of willow scrub in a narrow, nearly continuous strand similar to that in the middle of reach P2. A few scattered buffalo berries were probably also present.

Reach P4 (U.S. 395 to Rush Creek). The upper 0.5 mile of this reach supported about 1.6 acres of coyote willow scrub in a narrow, nearly continuous strand. About 2.6 acres of buffalo berry grew in a locally wide portion of this reach just below U.S. 395. Based on prediversion aerial photographs, the willows and buffalo berries appear to have had relatively dense canopies and predominantly live stems.

The lowest 0.2 mile of Parker Creek supported about 1.4 acres of willow and 0.3 acre of conifer-broadleaf forest. As today, this vegetation was associated with springs along lower Parker Creek that appear to have been fed by groundwater recharge and irrigation on Cain Ranch.

Walker Creek

Reach W0 (above Diversion). Immediately above the current aqueduct road, three narrow strips of willow and mixed riparian scrub converged through the meadow toward the downstream end of the quaking aspen grove. The middle strip followed the active main channel of the stream. The two lateral strips were associated with irrigation channels (which might have followed former natural channels). Above the present location of the diversion pond, the dense groves of tall quaking aspen and lodgepole pine were essentially the same as they are today.

Reaches W1 and W4 (Diversion to Cain Ranch Road, Main and Secondary Channels). These reaches supported the majority of woody riparian vegetation on Walker Creek, about 19 acres on the main channel and about 15 acres on the secondary channel. Most was willow scrub dominated by coyote willow and probably subdominated by mountain rose. Several patches of mixed riparian scrub dominated by buffalo berry, two small quaking aspen groves, and a few small stands of Jeffrey pine were also present. Based on aerial photographs, all this vegetation appears to have been in good condition, but willow reproduction may have been limited, as described above for Parker Creek.

Additional riparian vegetation (not mapped for this EIR) occurred north of Walker Creek along irrigation channels fed by Bohler Creek and perhaps in lesser part by the secondary channel of Walker Creek.

Large areas of sagebrush scrub were present in these reaches, particularly along the secondary channel at the base of the moraine between Walter and Bohler Creeks. Areas of meadow upslope from and within the sagebrush areas had probably been created through many years of flood irrigation on sagebrush-covered slopes.

Reaches W2 and W5 (Cain Ranch Road to U.S. 395, Main and Secondary Channels). These reaches are transitional between the narrow riparian strand surrounded by sagebrush of the preceding reach and the larger riparian patches surrounded by meadow of the following reaches. The upper halves of both channels supported small, scattered strips of willow scrub surrounded by meadow. The lower halves supported continuous to slightly interrupted strips of willow scrub surrounded by sagebrush scrub or irrigated pasture. The 3.7 acres of woody vegetation appear to have been in good condition.

Reach W3 (U.S. 395 to Rush Creek). The upper 0.7 mile of this reach supported about 5.9 acres of coyote willow scrub in a narrow but nearly continuous strand. Based on prediversion aerial photographs, the willows appear to have had relatively dense canopies and predominantly live stems.

The lowest quarter mile of Walker Creek supported about 4.6 acres of willow scrub and 0.9 acre of quaking aspen forest. As today, these quaking aspens were associated with springs in and along lower Walker Creek that appear to derive their flow largely from irrigation on Cain Ranch. The springs may also have temporarily received water from irrigation on several acres on the ridge between Walker and Bohler Creeks, just west of The Narrows.

Lee Vining Creek

Reach L0 (above Diversion). The site later occupied by the diversion dam and pond supported the same type of conifer-broadleaf forest and meadow that was present above and below the diversion site. Elden Vestal (1990, Court Testimony, Vol. I, p. 241) recalled a "grove of lodgepole pines and some of considerable size, well in excess of 20 inches . . . in diameter" at the site of the diversion dam. Vegetation above the diversion pond was probably essentially the same as it is today.

Reach L1 (Diversion to Highway 120). Riparian vegetation in this reach was essentially the same as that of today, dominated by lodgepole and Jeffrey pines and quaking aspens, with willows along the streambanks and meadow margins. Vestal (1990, Court Testimony, Vol. I, p. 240) described the vegetation as dense and noted the presence of moss-covered banks in some areas.

Reaches L2a (Highway 120 to U.S. 395) and L2b (U.S. 395 to 0.45 Mile below U.S. 395). These reaches are the steepest portions of Lee Vining Creek below the diversion. In reach 2a, riparian vegetation was confined to a narrow zone by canyon walls and morainal bluffs. The vegetation was mostly conifer-broadleaf forest. White fir and mountain mahogany added to the diversity of riparian vegetation in this reach. From the present location of the Highway 120 crossing to about 0.3 mile downstream on the east side of the creek was an overflow channel supporting a moderately dense strand of Jeffrey pine.

In reach 2b, Jeffrey pines were common among the cottonwoods, willows, and quaking aspens. Quaking aspens watered by hillside seepage occurred on bluffs on both sides of the creek in this reach. The lower end of reach 2b is at the bottom of the existing (1989) stand of riparian forest below U.S. 395.

Reaches L3a (0.45 Mile below U.S. 395 to Big Bend) and L3b (Big Bend to County Road). Vegetation on the broad, low-gradient floodplain in this reach was mostly black cottonwood-willow community, with patches and strands of conifer-broadleaf vegetation where Jeffrey pines grew. Quaking aspen was probably common among the cottonwoods. Riparian plants such as creek dogwood and bitter cherry (which remain only in sites above reach 3) and water birch (no longer present anywhere on Lee Vining Creek) were probably occasional to locally common in these reaches.

Groundwater seepage supported woody riparian vegetation at several locations on bluffs on either side of the floodplain. Quaking aspen forest and willow scrub occurred at the base of the bluff on the east side of Lee Vining Creek at County Road. A narrow strand of willow scrub occurred along the west side of the floodplain from about 0.1 to 0.5 mile above County Road. About 2.3 acres of riparian vegetation (mostly willow scrub) occurred on the high bluffs below the present location of the sewage ponds.

Evidence of these conditions is provided by dead wood and remnant vegetation visible in the area today and by photographs and recollections from prediversion times. Some pines are clearly identifiable in the winter 1929-1930 aerial photographs, primarily by their shadows, but most are not readily distinguishable from the deciduous trees in these images. A Burton Frasher photograph of the downstream reach of Lee Vining Creek taken from the hillside above Lee Vining in the late 1920s shows a multilayered canopy of tall deciduous trees with patches and strands of conifers along most of this reach. A more distant view of Lee Vining Creek's riparian zone from the Mono Inn area (Frasher Foto No. 8039) also shows scattered pines from County Road at least as far upstream as the high bluffs. Range vegetation survey data on an aerial photograph printed in Taylor (1982) indicate that quaking aspen was a dominant species throughout much of the Lee Vining Creek riparian zone.

Vestal recalled a "good distribution" of Jeffrey and lodgepole pines among cottonwoods along Lee Vining Creek near the town of Lee Vining and continuing along both sides of the stream to just above County Road. Vestal also recalled that quaking aspens were more common along Lee Vining Creek than Rush Creek and that water birch was a common constituent of the riparian vegetation on Lee Vining Creek (Stine 1991).

Reach L3c (County Road to 1940 Lakeshore). The reach from County Road to the lakeshore (at elevation 6,417.5) was approximately 0.2 mile long in 1940. Approximately 4.3 acres of cottonwood-willow woodland and forest existed along the creek, and a narrow strip of willows existed at the base of the hill east of the County Road crossing. Irrigated pastures and lake-fringing meadow vegetation occupied all unwooded ground above the beach. In the winter 1929-1930 aerial photographs, three narrow ponds (totaling about 0.5 acre) are evident behind lakeshore berms in meadows between the lake and the downstream end of the riparian forest. These ponds are not visible in the June 1940 photographs.

Little site-specific information is available on the condition of vegetation in this reach. Available photographs include the winter 1929-1930 and summer 1940 aerial photographs, a photograph taken at or near the County Road crossing by Joseph Dixon on July 14, 1916 (photograph no. 2176), and a Burton Frasher photograph from the late 1920s or early 1930s in which Lee Vining Creek vegetation is visible from the Mono Inn area (Frasher Foto No. 8039). All these photographs indicate a relatively tall, multi-layered, and dense canopy in this reach.

Wayne McAffee recalled collecting worms for sale as fishing bait on a regular basis near the mouth of Lee Vining Creek in the late 1920s (McAffee 1990, Court Testimony, Vol. II, p. 413). Woody Trihey interpreted this as indicating "very deep deposits of sandy loam soil" resulting from abundant leaf litter and organic material in the floodplain (McAffee 1990, Court Testimony, Vol. II, pp. 678-679). Vestal recalls no Jeffrey pines below County Road on Lee Vining Creek (Stine 1991).

Reach L3d (1940 Lakeshore to 1989 Lakeshore). This reach was beneath the surface of the lake in 1940 and supported no riparian vegetation.

Point-of-Reference Conditions

Rush Creek

Reach R0 (above Grant Lake Reservoir). Above the current spillway elevation of Grant Lake reservoir, the cottonwood-willow, quaking aspen, and conifer-broadleaf vegetation on Rush Creek is essentially the same as it was in 1940.

Woody riparian vegetation that was to be inundated along approximately 1.5 miles of Rush Creek by the enlargement of Grant Lake reservoir was felled and burned by LADWP in summer and fall 1940 (Vestal 1990, Court Testimony, Vol. I-XIII; Stine 1991). No riparian scrub or forest remains today. The inundated channel is periodically exposed when water levels fall in Grant Lake reservoir. Weedy grasses and forbs have established in some areas, but this section is an eroded and essentially unvegetated reservoir drawdown zone. No significant patches or beds of floating or emergent vegetation occur around the margins of Grant Lake reservoir.

Reach R1a (Grant Lake Dam to Mouth of Return Ditch). The upper third (1,100-1,300 feet) of this reach was eliminated by 1940-1941 construction of the existing Grant Lake Dam. An estimated 2-3 acres of riparian vegetation were eliminated along the main channel and spillway. The bottom end of this reach was filled to prevent water flowing out of the return ditch from forming a long backwater up the former stream channel.

Only about 1.6 acres of mature woody willow and mixed riparian scrub remain, mostly in the lower third of the remaining reach. Most is in poor condition with little canopy cover, stressed by dewatering, invaded by upland plants, and without an herbaceous groundcover. Another 1.6 acres of mostly dead or severely stressed willow and cottonwood-willow vegetation remains along the dry channel.

Reach R1b (Return Ditch). The Return Ditch is lined by sagebrush and rabbitbrush scrub and supports essentially no woody riparian vegetation. Only a few small, isolated willows are present. Seepage is insufficient to support riparian plants or significant meadow areas outside the ditch.

Reach R2a (Mouth of Return Ditch to Base of Moraine). This relatively narrow, steep section of Rush Creek supports about 6.0 acres of willow and mixed riparian scrub, cottonwood-willow, quaking aspen, and conifer-broadleaf vegetation in relatively good condition. Except where the channel has been disturbed at the mouth of the Return Ditch, canopy cover, plant vigor, and riparian plant diversity are relatively high in all vegetation types and are similar to prediversion conditions. Several factors have probably favored survival of riparian vegetation in this area, including substrates that minimize loss of streamflow, presence of seeps or colluvial aquifers, shading by steep slopes, and inaccessibility for tree harvesting.

Reach R2b (A-Ditch Supply Channel). Water was diverted from Rush Creek to the A-Ditch every year from before 1920 to 1948. The A-Ditch was again used almost continuously from 1952 to 1959 and intermittently through the 1960s. No water has been diverted to the A-Ditch for irrigation since October 1969. Natural overflows into the A-Ditch supply channel may have occurred during some unregulated high runoff events.

Approximately 5.6 acres of mature quaking aspen forest and willow scrub occur along this channel or on nearby hillsides. Most of this good-quality vegetation occurs along the middle third of this reach, supported by springs and soil moisture that are probably fed by seepage from Rush Creek. The adjacent spring-watered meadows are heavily grazed.

Approximately 1.7 acres of mostly decadent willow and mixed riparian scrub occur along the lower third of this channel. Many formerly vigorous willows are now dead or have a few live stems competing for water with drought-stressed mountain rose.

Reach R3 (Base of Moraine to Old Highway Bridge). Between 1940 and 1989, vegetation in this reach was affected by logging, irrigation diversions, and severe floods in addition to dewatering. Many of the largest and most accessible Jeffrey pines were logged by the Inyo Lumber Company in 1940-1942 (Vestal 1990, Court Testimony, Vol. I-XVIII; Stine 1991). Water was diverted from Rush Creek via the B-Ditch to irrigate pastures in Pumice Valley almost every year from before 1920 to 1967. Severe floods altered the path of Rush Creek in the lower 1,600 feet of this reach and eroded away the first 500 feet of the B-Ditch in 1967.

From the base of the moraine to about 1,600 feet above the old highway bridge, the riparian zone remains mostly 200-400 feet wide, but the vegetation has become patchy and varies greatly in condition. Overall condition is good, with about 33% of the 25.7 woody riparian acres having over 50% cover and about 14% having measurable cover of tall shrubs and short trees. Plant density and vigor have improved significantly in this reach since minimal flows were restored in 1985 (Patten and Stromberg-Wilkins 1988).

The severely scoured lower 1,600 feet of this reach is mostly unvegetated floodplain. Only a few very small patches of mature or establishing riparian scrub or woodland occur in this area. A few patches of sagebrush scrub, some with dead wood from former riparian forest, occur on islands that were not stripped of topsoil during the 1967 and 1969 floods. Establishment of new riparian and upland plants is severely suppressed in the lower portions of this reach by herds of sheep crossing Rush Creek.

Reach R4 (Old Highway Bridge to Mouth of Parker Creek). Riparian vegetation declined substantially in this reach during the 1950s, 1960s, and 1970s because of diminishing releases from Grant Lake reservoir and the absence of significant flow from springs.

Riparian vegetation is mostly absent from the old highway bridge to U.S. 395. Below U.S. 395, scattered small remnants of the 1940 riparian vegetation persist and narrow strips of willow and cottonwood seedlings are evident along the channel edges and on a few small islands in the channel.

Reach R5 (Mouth of Parker Creek to The Narrows). Riparian vegetation declined in this reach during the same period as in reach R4. Gravel mining began midway between Parker Creek and The Narrows in the 1960s, resulting in some localized loss of woody riparian vegetation. The 1967 and 1969 floods caused severe scouring and channel realignment throughout this reach, resulting in the loss of most of the remaining cottonwood-willow woodland and willow scrub.

Most of the existing woody riparian vegetation in this reach consists of young, vigorous willows and cottonwoods in intermittent strips 10-20 feet wide along both sides of the channel. Several widely scattered individuals or small clumps of mature cottonwoods survive throughout the cobble- and gravel-covered floodplain. Most of these trees have a few small suckers nearby but have improved only slightly since rewatering. A few small patches of relatively dense and vigorous willows occur in and around the quarries, evidently where water seeps from the cliffs. Overall response to rewatering has been negligible, except within a few feet of the main channel.

Reach R6 (The Narrows to the Ford). Riparian vegetation persisted with relatively minor losses in this reach until the early or mid-1960s because springs contributed significantly to surface water and groundwater in the riparian zone. The floods of 1967, 1969, and the early 1980s caused severe scouring and moderate to deep channel incision throughout this reach, resulting in the direct loss of much streamside vegetation and permanently lowered water tables in most of the remaining vegetated area.

Grazing has continued throughout the periods of dewatering and rewatering in this reach. Grazing has been heavier on the west side of the stream, which is easily accessible and has more meadows; the east side is less accessible and has less herbaceous forage.

This reach still contains the largest areas of live riparian vegetation on Rush Creek. The vegetation that suffered least from dewatering includes about 6.8 acres of dense willow scrub and mixed riparian scrub in good condition on slopes above the creek on the west side of The Narrows. About 5 acres of dense willow scrub remain at the cliff-base seeps on the east side of the creek from Big Wash to the lower end of the lower meadows, much of which appears moderately to severely stressed by reduced springflow.

Mature willow and mixed riparian scrub is scattered throughout another 75 acres of the bottom-lands. The most vigorous of this vegetation is located between the stream and the middle meadows; most of the rest contains abundant dead wood and excessive amounts of rose, indicating several years of drought stress. Only about 2.0 acres of cottonwood-willow vegetation remain in this reach.

"Decadent" riparian vegetation occupies about 23 acres in this reach. These areas contain more dead than live wood (often enough to make walking difficult), little or no live cottonwood or willow, and larger amounts of rose and upland vegetation than were present before dewatering.

Establishing riparian vegetation occupies about 6.0 acres on gravel bars wetted by the stream along the existing active channel. Most areas of willow and cottonwood seedlings of saplings occur in the middle third of this reach.

The meadows on the west side of the creek are still present but have all declined as a result of reduced groundwater and continued grazing. The upper meadows cover about 6.8 acres, the middle meadows about 7.7 acres, and the lower meadows about 10.1 acres. Meadows on the east side of the creek below Big Wash are small and scattered.

Unvegetated floodplains are locally prominent where floods removed topsoil, channel incision and lateral cutting were severe, and subsidiary channels were abandoned after the main channel incised.

Reach R7 (the Ford to County Road). Riparian vegetation declined in this reach at the same time and under the same influences described for reach R6. Riparian vegetation characteristics in this reach are similar to those in reach R6, but the incised channel is deeper (8-10 feet in the vicinity of the former Clover Ranch meadows) and wider (up to 300 feet in several locations). Mature woody riparian vegetation is mostly mixed riparian scrub (6.7 acres), with a few small areas dominated by willows (7.0 acres). Decadent riparian vegetation occupies 12 acres, all several feet above the existing low flow channel. Willows and cottonwoods are establishing on about 1.5 acres of gravel bar near the middle of the reach. Meadows are no longer present.

Reaches R8a (County Road to 1940 Lakeshore) and R8b (1940 Lakeshore to 1989 Lakeshore). The reach from the lakeshore to County Road is approximately 0.8 mile long (August 1989). It was severely scoured and deeply incised during the floods of the late 1960s and early 1980s.

No mature riparian vegetation is present in this reach. Seedlings and young saplings of coyote willow have established extensively over approximately 25 acres of gravel bar habitat, mostly from about 400 to 2,200 feet above the lakeshore.

Outside the channel, widely scattered individuals of coyote willow or black cottonwood occur on some of the higher terraces that were formerly active floodplains. A patch of coyote willows occurs at a seep on the east side of the creek approximately 550-850 feet from the lakeshore. Above the 1940 lake elevation, several clumps of dead willows are scattered among sagebrush and rabbitbrush scrub beyond the edges of the incised channel.

Parker Creek

Reach P0 (above Diversion). Willow scrub dominates the riparian vegetation for about 0.2 mile above the diversion pond. Several Jeffrey and lodgepole pines also are scattered through this area. From about 0.2 mile above the diversion pond to near the Parker Creek campground, the riparian vegetation is predominantly conifer-broadleaf forest dominated by quaking aspens and pines.

Reach P1 (Diversion to Base of Moraine). Parker Creek occupies two roughly parallel channels in this reach. Combined, they support about 30% of the existing woody riparian vegetation below the LADWP diversion. The main Parker Creek channel (i.e., the north channel) supports approximately 6.3 acres of woody riparian vegetation, of which nearly all is willow scrub. South Parker Creek (i.e., the south channel) supports about 8.9 acres of woody riparian vegetation, of which about 90% is willow scrub. The riparian zone (both channels combined) is up to 600 feet wide in the upper half of this reach.

Some of the vegetation in this reach appears to be moderately stressed by drought, although significant amounts of water were conveyed through riparian areas in this reach before being diverted for meadow irrigation.

Reach P2 (Base of Moraine to Cain Ranch Road). Over 60% of the woody riparian vegetation on the diverted section of Parker Creek occurs in this reach. Willow scrub occupies about 30 acres, much of which is moderately to severely stressed by dewatering and grazing (the willows are mostly old plants with much dead wood, sparse canopies, and abundant competing mountain rose). Small patches of conifer-broadleaf woodland, non-native cottonwoods, and mixed riparian scrub also occur in this reach (less than 0.5 acre each). The riparian zone varies from 100 to 400 feet wide in this reach.

Reach P3 (Cain Ranch Road to U.S. 395). The stream channel in this reach is bordered almost entirely by meadow and sagebrush scrub. Only about 0.4 acre of willow scrub persists near the ranch buildings at the upper end of this reach.

Reach P4 (U.S. 395 to Rush Creek). The upper 0.5 mile of this reach has relatively few scattered, drought-stressed coyote willows. About 0.9 acre of stressed buffalo berry and 1.0 acre of meadow persist from about 250 to 1,000 feet below U.S. 395.

The lowest 0.2 mile of Parker Creek supports about 1.3 acres of mixed riparian scrub (mostly rose) and conifer-broadleaf forest (Jeffrey pines and black cottonwood). This vegetation is moderately stressed by dewatering but has persisted because of springs fed by groundwater from Parker Creek and irrigation on Cain Ranch.

Walker Creek

Reach W0 (above Diversion Site). Immediately above the aqueduct road is the LADWP diversion pond and adjacent disturbed ground that is unvegetated or supports weedy upland plants. Above the diversion pond, Walker Creek supports a large and continuous stand of dense quaking aspen woodland and small meadows in excellent condition. The forest flora is diverse, the vegetation is multilayered, no obvious drought stress is evident, and livestock grazing has not been severe. About 0.6 mile above the diversion pond, the quaking aspen forest shifts to conifer-hardwood forest dominated by quaking aspen and lodgepole pine.

Reaches W1 and W4 (Diversion to Cain Ranch Road, Main and Secondary Channels). These reaches still support the majority of woody riparian vegetation on Walker Creek, about 19 acres on the main (south) channel and about 13 acres on the secondary (north) channel. The coyote willow scrub is generally co-dominated by mountain rose and the mixed riparian scrub is dominated by mountain rose or buffalo berry. Two small quaking aspen groves and a few small stands of Jeffrey pine also persist. Most of this vegetation is in highly stressed condition, as described for Parker Creek. Additional riparian vegetation (not mapped for this EIR) occurs north of Walker Creek along irrigation channels watered mostly by Bohler Creek.

Large areas of sagebrush scrub are still present in these reaches. Meadow occurs in several areas that were dominated by sagebrush in 1940.

Reaches W2 and W5 (Cain Ranch Road to U.S. 395, Main and Secondary Channels). As noted under "Prediversion Conditions", these reaches are transitional between the broad, level pastures of Reaches W1 and W4 and the incised canyon of Reach W3. The main channel supports meadow vegetation throughout the reach and several scattered, mostly solitary willows and buffalo berries in stressed condition. The secondary channel supports remnants of willow shrub in stressed condition, with sparse canopies and many dead stems.

Reach W3 (U.S. 395 to Rush Creek). From U.S. 395 to the spring-fed quaking aspen and willow stands, about 4.8 acres of willow and mixed riparian scrub in narrow, fragmented strips are present. Many coyote willow and buffalo berry shrubs have sparse canopies and many dead stems resulting from several years of drought stress. Little or no reproduction of woody riparian plants is evident.

The lowest quarter mile of Walker Creek supports about 5.0 acres of mixed riparian and willow scrub and two small patches of quaking aspen forest. These quaking aspens are supported by springs along lower Walker Creek that continued to flow because of groundwater recharge by irrigation on Cain Ranch, even after the channel was dewatered.

Lee Vining Creek

Reach L0 (above LADWP Diversion Dam). The diversion pond, dam, and adjacent disturbed slopes occupy about 2.1 acres of reach L0. For more than 2 miles above the diversion pond, the riparian vegetation is dominated by quaking aspens and Jeffrey and lodgepole pines, with occasional cottonwoods and willows. The vigor of the plants and the condition of the riparian community is generally high in this reach.

Reach L1 (LADWP Diversion Dam to Highway 120). Vegetation along the stream in this reach is generally a high-quality stand of pines and quaking aspens (about 13.1 acres), containing many tall trees, intermittent willow shrubs along the banks, and a well-developed herbaceous layer. About 5.2 acres of meadows and 3.7 acres of willow scrub supported by shallow groundwater occur on the left side of the stream within 1,400 feet of the diversion dam. Additional meadows irrigated by the O-Ditch occur further upslope, closer to the highway. The vigor of the plants is high and little grazing occurs in this reach.

Reach L2a (Highway 120 to U.S. 395). Construction of the new Highway 120 partially filled and prevented the stream from entering the overflow channel on the right side of the creek just below the Highway 120 culvert. Riparian vegetation along the overflow channel decreased in area and density, particularly in its upper half. Scattered Jeffrey pines remain, but few or no willows persist.

Riparian vegetation (about 14 acres) on the main channel of this steep, narrow reach is essentially the same as in prediversion times. It is predominantly conifer-broadleaf forest dominated by quaking aspens (mostly in the upper half), cottonwoods (mostly in the lower half), and Jeffrey pines. Willows are scattered along the reach. In the lower half of the reach, white firs, creek dogwood, and bitter cherry are locally numerous among the other trees. The vigor of the plants is high and no grazing occurs in this reach.

The riparian zone is mostly 100-150 feet wide in Reach L2a, but it widens to about 300 feet from 800 to 1,200 feet upstream from U.S. 395. Jeffrey pine forest with an understory of upland rather than riparian plants occurs on higher slopes outside the riparian corridor.

Reach L2b (U.S. 395 to 0.45 Mile below U.S. 395). Vegetation in this reach is similar to that in the lower part of reach 2a but has a greater proportion of cottonwoods and quaking aspens than conifers and a greater average width (250-300 feet) because the canyon is wider. Both sides of the canyon support intermittent quaking aspen stands in this reach (about 4.4 acres), probably associated with seepage from the canyon sides. This reach ends where existing quaking aspen stands on the right side of the stream end.

Reach L3a (0.45 Mile below U.S. 395 to Big Bend). Woody and herbaceous riparian vegetation declined rapidly in this reach during the 1950s and early 1960s. Young cottonwoods and willows occur only in narrow, discontinuous strips along the banks of the main channel and near the middle of several subsidiary channels, including portions of the historical main channel. Older cottonwoods that have survived dewatering despite injuries from drought stress occur in the upper half of this reach in subsidiary channels on the right side of the floodplain. A narrow (4-12 feet wide) but locally vigorous strand of mountain rose occurs along both sides of a subsidiary channel just west of the older cottonwoods.

Unscoured surfaces within the floodplain are dominated by sagebrush. Scattered mountain rose occurs in some locations, especially where the trunks (mostly fallen) of long-dead cottonwoods and pines are present.

The steep bluffs below Lee Vining's wastewater treatment ponds support large stands of cottonwood and willow. Most of this vegetation is vigorous and clearly supported by seepage from the ponds. Vegetation immediately below the southernmost pond, which appears to have been unused for several years, is stressed from lack of water.

Reach L3b (Big Bend to County Road). Woody and herbaceous riparian vegetation declined rapidly during the 1950s in this reach, especially in the upper half. The existing main channel in this reach is wide, resulting from severe lateral erosion during the 1969 floods.

Woody riparian vegetation is essentially absent from the upper half of this reach. Sagebrush and scattered rose cover uneroded surfaces in the floodplain, and dead tree trunks are locally common. Scattered herbaceous vegetation (mostly saponaria and other weeds) is establishing on gravelly and cobbly surfaces within the wide channel above the summer flow.

In the lower half of this reach, the main channel supports widely scattered individuals and small clusters of young, vigorous cottonwoods and willows. Most of these plants have probably grown from seed since 1986, when flows became continuous in this reach. Some may have grown vegetatively from plants whose roots survived the dewatering and floods or from tree or shrub fragments introduced from upstream during the 1969 floods. A few Jeffrey pine seedlings have also established in this area.

Patches of locally dense herbaceous vegetation (mostly lupine, saponaria, wormwood, rushes, and grasses) occur on gravel bars in the existing main channel, historical main channel, and other subsidiary channels wetted by groundwater in this reach.

Portions of the historical main channel and other areas not stripped of topsoil during the 1969 floods are vegetated mostly with sagebrush rather than riparian plants. Mountain rose is often common among the sagebrush where woody riparian vegetation formerly grew. Formerly irrigated meadows on the west side of the floodplain have reverted to sagebrush scrub. A few healthy lodgepole pines remain at the former meadow margins.

Outside the floodplain, a stand of quaking aspens persists at the base of the bluff east of the County Road crossing. Mixed riparian scrub (rose) climbs part way up the bluffs on the right side of the creek near the middle of the reach. These areas are probably supported more by groundwater seepage and snowmelt than streamflows.

Reach L3c (County Road to 1940 Lakeshore). About 250 feet below County Road, the channel divides, with the main channel following the right side of the floodplain and a secondary channel following the left edge of the floodplain.

In the upper half of this reach, young cottonwoods and willows are locally numerous in the floodplain, as they are in the lower half of reach L3b. Outside the floodplain, several white cottonwoods and Lombardi poplars (both non-native), black cottonwoods, Jeffrey pines, and thickets of mountain rose occur on the left side of the creek near County Road.

In the lower half of this reach, a few young black cottonwoods are scattered on the scoured floodplain between the main and secondary channels, but overall, the floodplain is only sparsely vegetated.

Scattered willow and cottonwood seedlings and forbs (mostly lupine, wormwood, and saponaria) occur in a band mostly 1-3 feet wide along the banks of the main channel.

Reach L3d 1940 Lakeshore to 1989 Lakeshore. This 1,800-foot-long reach emerged as the lake level dropped after 1940. The upper half of the reach is very cobbly, without topsoil, and mostly un-vegetated. Scattered willow and cottonwood seedlings and forbs occupy a strip 1-3 feet wide along the banks of the main channel. A few small patches of mature willow occur at the edge of the floodplain in sites not scoured by the 1969 floods.

Dense thickets of willow saplings and forbs mostly sweet-clover occupy about 5 acres in the flood-plain from 300 to 800 feet above the lakeshore. This vigorous young growth is supported by streamflow in several small channels, abundant shallow groundwater, and one or more small springs. Small amounts of topsoil are developing from trapping of sediments and organic materials among this vegetation.

Outside the current floodplain, a more mature stand of coyote willow occupies approximately 2 acres on a terrace west of the creek. The oldest of these willows probably date from 1971 or 1972, the first 2 years after ground occupied by these willows was above the lake level.

Lakeshore meadow vegetation dominated by salt grass, rushes, and bulrushes occupies about 3 acres of the wave-cut shoreline at the mouth of the creek.

RIPARIAN VEGETATION WIDTH MODEL

Methods

Taylor (1982) developed a model that relates streamflow to riparian zone width on eastern Sierran alluvial streams. The model is a simple linear regression equation based on measured riparian strip widths (from aerial photographs) and stream gage data from several eastern Sierran streams.

Taylor (1982) found this model to explain 67% of the variance in riparian strip width and recommended its use in assessment of the impacts of proposed streamflow diversions on riparian vegeta-tion. Such use requires an assumption that vegetation impacts of changes in streamflow in a given stream system are predictable from study of smaller or larger stream systems. The model also makes use of an "incision index" that is not precisely defined and might not adequately account for the effects of stream incision along Rush and Lee Vining Creeks.

Jones & Stokes Associates used this model to preliminarily assess the potential for recovery of riparian vegetation under different streamflow alternatives on the tributary streams. Riparian vegetation widths were calculated in a spreadsheet using mean annual streamflows predicted by the Los Angeles

Aqueduct Monthly Program (LAAMP) operations model for each alternative (Chapter 3A, "Hydrology") and gradient, incision index, and elevation values measured from 7.5-minute USGS topographic maps. Riparian widths were calculated for numerous points on each stream and average widths were calculated for each stream segment.

Results

Table P-13 lists the results of the model for selected points on Rush Parker, Walker, and Lee Vining Creeks. The approximate prediversion (1940) and point-of-reference (1989) widths of the riparian zone at each point are listed for comparison with the results of the model.

The following limitations of the model were considered in interpretation of the results of these analyses.

- The model is not valid for predicting riparian zone widths at mean annual streamflows higher than those included in Taylor's (1982) regression analysis, or above approximately 60 cfs.

- Topography controls riparian zone width more than streamflow does in most locations along all the modeled streams. The model is most reliable where a stream occupies a single channel over relatively uniform alluvium, is not gaining flow from springs, and is not confined in a canyon or against bluffs.

- Comparisons of existing or prediversion riparian widths may be misleading because they do not account for changes in vegetation condition.

Rush Creek

The model was run for the segment of Rush Creek from the base of the moraine to Mono Lake (reaches R3-R8). The segment from the dam to the base of the moraine was not modeled because of geomorphological conditions that do not fit the model's assumptions.

The model predicts riparian widths averaging about 70-80 meters (230-260 feet) under the No-Restriction Alternative. These results are inaccurate because flows are actually 0 cfs throughout most years. The LAAMP model's calculation of 25.3 cfs mean annual flow under this alternative results from averaging of infrequent and very large uncontrolled spills.

The model predicts riparian widths of:

100-110 meters (330-360 feet) under the 6,372-Ft Alternative;
125-130 meters (410-425 feet) under the 6,377-Ft Alternative; and
140-145 meters (460-475 feet) under the 6,383.5-Ft Alternative.

Higher flow alternatives could not be modeled because the model is not calibrated for mean annual flows over about 60 cfs. Had the model been calibrated for such flows, the higher alternatives would have resulted in successively greater widths.

Above The Narrows, actual widths in 1989 and 1940 were generally narrower than those predicted under the 6,372-Ft Alternative. Properly calibrated and applied, the model should not predict widths exceeding actual prediversion widths as frequently as it does. Possible reasons for these results are that the model may not be accurately calibrated for this area, it may not adequately account for topographic and geomorphic influences on riparian vegetation, and the calculation of mean annual flow may be excessively influenced by infrequent high flows.

Below The Narrows, actual widths in 1989 were scattered in their relationships to widths predicted under the alternatives because reductions in riparian zone width during the diversion period were highly variable in this area. Actual widths in 1940 were generally greater than widths predicted under the 6,383.5-Ft Alternative. Some of the prediversion riparian zone width was sustained by spring runoff, as well as streamflow.

Parker Creek

The model was run for all segments from the LADWP diversion point to Rush Creek (reaches P1-P4). The model was difficult to apply to reaches above U.S. 395, because the flatness of the terrain made the incision index difficult to measure.

The model predicts riparian widths ranging from 0-6 meters (0-20 feet) under the 6,372-Ft Alternative to 20-29 meters (66-95 feet) under the No-Diversion Alternative. The greatest widths are predicted in reach P2, where the terrain is flattest and actual widths in 1940 and 1989 were greatest.

Actual widths in 1940 and 1989 were closest to those predicted for the No-Diversion Alternative.

Walker Creek

The model was run for all segments from the LADWP diversion point to Rush Creek (reaches W1-W5). The incision index was difficult to measure above U.S. 395, as described for Parker Creek.

The model predicts no riparian vegetation under the No-Restriction Alternative through the 6,410-Ft Alternative and only 3-8 meters (10-26 feet) of riparian width under the No-Diversion Alternative. These results are clearly inaccurate, because actual widths in 1940 and 1989 were substantially greater than those predicted for the No-Diversion Alternative. Reasons for the model's inaccuracy on Walker Creek are not readily apparent.

Lee Vining Creek

The model was run for the segment of Lee Vining Creek from U.S. 395 to Mono Lake (reaches L2b-L3d). The segment from the diversion dam to U.S. 395 was not modeled because of geomorphological conditions that do not fit the model's assumptions. The segment from U.S. 395 to 0.5 mile below the highway (reach L2b) may only marginally meet the model's geomorphological assumptions.

The model predicts riparian widths averaging about 45-55 meters (150-180 feet) under the No-Restriction Alternative. As in the modeling of Rush Creek, these results are inaccurate because flows are actually 0 cfs throughout most years. The LAAMP model's calculation of 19.0 cfs mean annual flow under this alternative results from averaging of large, infrequent, uncontrolled spills.

The model predicts riparian widths ranging from 100-110 meters (330-360 feet) under the 6,372-Ft Alternative to 140-150 meters (460-490 feet) under the 6,410-Ft Alternative. The No-Diversion Alternative was not modeled because of limits on model calibration.

Actual widths in 1989 were generally closest to those predicted under the No-Restriction Alternative. Although a mean annual flow of 19 cfs does not accurately represent conditions that would occur under that alternative, 19 cfs does approximate flows that have occurred in Lee Vining Creek since the mid-1980s. Actual widths in 1940 were generally between those predicted for the No-Restriction and 6,372-Ft Alternatives.

Conclusions

The results of the riparian width model appear to be generally plausible for scattered locations on Rush Creek below The Narrows, and possibly Lee Vining Creek. In these areas, the model predicted widths generally within or near the range of prediversion conditions.

On Rush Creek, the model predicts riparian width increases of about 19% between the 6,372-Ft Alternative and the 6,377-Ft Alternative, and increases of about 11% between the 6,377-Ft Alternative and the 6,383.5-Ft Alternative. These comparisons appear to be within reason, but probably overestimate the actual potential for the riparian zone to widen in many areas, because of topographic factors (see "Groundwater Depth Model").

On Lee Vining Creek, the model predicts increases of about 15%, 10%, 4%, and 8%, respectively, for the intervals between the 6,372-Ft, 6,377-Ft, 6,383.5-Ft, 6,390-Ft, and 6,410-Ft Alternatives. These comparisons also appear to be within reason. Whether they represent high or low estimates of the potential for change is uncertain.

The results of the model appear to be implausible (i.e., substantially wider or narrower than under prediversion conditions) for all of Rush Creek above The Narrows, scattered locations on Rush Creek below The Narrows, all of Parker and Walker Creeks, and possibly Lee Vining Creek. The reasons for implausible results may include influences from groundwater from sources other than the stream channels, the presence of multiple channels, inaccurate input data, or inapplicability of conditions on measured streams to these particular streams.

COTTONWOOD GROWTH MODEL

Methods

Stromberg and Patten (1990, 1992) developed regression equations that relate streamflow to black cottonwood growth rates on Rush and Lee Vining Creeks. Six different regression equations (nonlinear univariate, linear univariate, and bivariate equations based on annual flows and summer flows) were developed from stream gage records and tree ring analysis for each of seven cottonwood populations.

Jones & Stokes Associates used the nonlinear univariate models based on annual flow to predict potential cottonwood growth rates under different streamflow alternatives on the tributary streams. (Annual flows generally explained more variance than summer flows; nonlinear equations generally explained more variance than linear equations; and univariate equations are more reliable than bivariate equations for predicting growth in future years, although bivariate equations sometimes explained more variance for past years.)

These models are valid over the range of streamflow values used to derive the models (0-222 cubic hectometers [hm^3] for Rush Creek and 0-80 hm^3 for Lee Vining Creek). Cottonwood growth rates were calculated in a spreadsheet using mean annual streamflows predicted by LAAMP for each alternative (Chapter 3A, "Hydrology").

Vigor was assessed using the assumption that growth rates less than 1 mm/year reflect declining vigor leading to tree death, growth rates of 1-2 mm/year reflect low vigor, and growth rates above 2 mm/year reflect high vigor (Stromberg and Patten 1992). Potential growth rates and vigor levels were calculated and graphed for each sample site.

Results

Table P-14 lists the results of the model for selected points on Rush and Lee Vining Creeks. Models were not developed for Parker and Walker Creeks, where cottonwoods are nearly absent.

The model predicts annual radial growth increments (i.e., tree ring widths) based on streamflow. Average growth rates were correlated with canopy vigor as follows (Stromberg and Patten 1992a):

- >2.0 mm/year: high canopy vigor (no significant drought stress and no harm to the trees);
- 1.5-2.0 mm/yr: lower canopy vigor (drought stress evident, but not lethal to the trees); and
- <1.5 mm/yr: severe stress or tree death (from sublethal to lethal drought stress).

Rush Creek

For both channel-side sites, the model predicts high canopy vigor (2.0-3.2 mm average growth) under all alternatives, even under the No-Restriction Alternative. Growth rates would increase proportionately with higher flows. These results suggest that any of the alternatives would provide favorable conditions for riparian vegetation; however, channel-side trees may not reliably indicate the effects of the alternatives throughout the riparian zone. Although channel-side trees may survive and grow under any alternative that provides water consistently, floodplain trees may require higher than average flows to ensure vigor.

For the floodplain site, the model predicts lower canopy vigor (1.6-1.8 mm average growth) under the 6,383.5-Ft through No-Diversion Alternatives and severe stress or tree death (1.1-1.5 mm average growth) under the No-Restriction through 6,377-Ft Alternatives.

Lee Vining Creek

For the two channel-side sites, the model predicts high canopy vigor (3.4-9.3 mm average growth) under all alternatives, including the No-Restriction Alternative. At Site LV1c, the model predicts that growth rates would increase proportionately with higher flows. At Site LV2c, the model predicts declining growth at higher flows. Two of these predictions, high canopy vigor under the No-Restriction Alternative, and declining growth at Site LV2c under mean annual flows higher than 42 cfs, are counterintuitive and probably inaccurate. These predictions suggest that growth rates in the relatively young trees at Site LV2c, which grew mostly under point-of-reference conditions, cannot be reliably extrapolated to the full range of alternatives in the EIR.

For the floodplain site above U.S. 395 (Site LV0f), the model predicts severe stress or tree death (0.8-1.3 mm average growth) under all alternatives, with tree death most likely under the No-Restriction and 6,372-Ft Alternatives. The prediction of near-lethal conditions for all alternatives appears inconsistent with the presence of mature cottonwoods in a site where the channel was not incised and where colluvial groundwater may have buffered the effects of streamflow diversions. The predicted growth rates may be reliable, but they are not accurately correlated with canopy vigor for this group of trees.

For the floodplain site above County Road (Site LV2f), the model predicts high canopy vigor (2.1-2.7 mm average growth) under all alternatives, including the No-Restriction Alternative. The result for the No-Restriction Alternative is again counterintuitive and suggests the same unreliability described for the Site LV2c model.

Conclusions

On Rush Creek, the model for the floodplain site is probably the best of the three models for predicting the effects of each alternative on vegetation throughout the riparian zone. On Lee Vining Creek, none of the models is clearly reliable for predicting both the range of expected growth rates and the associated levels of canopy vigor under the full range of alternatives.

While the models may be useful for predicting the effects of some alternatives at the specific sites sampled, the results cannot be extrapolated to sites without live, mature cottonwoods. Sites where the forest had died were not modeled. Cottonwoods that had survived many years of stream dewatering have in some cases been sustained by unmeasured sources of groundwater other than the stream. Many factors have caused geographical and temporal variations in streamflows on Rush Creek so that correlations between release flows and tree growth rates may be inaccurate for some periods, particularly at sites below The Narrows.

The models cannot predict the distribution of woody riparian vegetation under the alternatives and are limited in their ability to predict vigor; therefore, they are not used quantitatively in the impact assessment. The evidence that mean annual streamflow can substantially influence cottonwood growth and vigor was assumed to be valid and was considered qualitatively in the impact assessment.

WATER TABLE MODEL

Introduction

A site-specific water table depth model was developed by SWRCB consultants for Rush, Parker, Walker, and Lee Vining Creeks to predict the extent of primary woody riparian habitat for various levels of summer streamflow. The model was made possible by the acquisition of detailed topographic information and several groundwater profiles along these streams.

The model has the advantage of employing the actual spatial relationships from section to section along these particular stream systems, allowing direct estimation of water table depths and riparian suitability rather than relying upon streamflow-habitat correlations involving other streams. Accuracy of the model, considered good overall, can be improved principally through acquisition of additional water table profile data but also through increase of the density of topographic sampling.

The results of the model are relative increases or decreases of primary riparian habitat for various streamflows. The model neglects the presence of any zones of shallow groundwater flow derived from sources other than streamflow.

Model Elements

The model has five key elements:

detailed topographic mapping,
water table profiles and streamflow responses,
water table boundary conditions,
stage discharge relationships, and
water table depth requirements of woody riparian vegetation.

The model combines observations of water table profiles with channel loss inferences from synoptic flow studies to estimate the configuration of the continuously varying water table along each stream. It uses observed relationships between streamflow releases and stream stage, and between changes in stream stage and water table depths, to allow depiction of water table elevations for various summer streamflows under the alternatives.

This water table elevation model is then compared to the detailed topographic elevation data to yield water table depths for each streamflow. After selection of the maximum depth of water table generally needed for the vigorous growth of woody riparian vegetation, an acreage of "primary riparian habitat" is then estimated for each stream reach under each alternative. These five key elements and their information sources are described in the following sections.

Fluvial Topography

Detailed topographic mapping of the stream corridors using a contour interval of 2 feet was developed from aerial photography and ground reference-point surveys performed in 1991 (Aerial

Photometrics 1991). Coverage also included distributary channels and floodchannels. The photos were taken after local snowmelt and before leafing on May 6, 1991. For this project, photogrammetric contours were used in the form of CAD-generated maps at a scale of 1 inch = 100 feet; because they exist in electronic digital format they can also be processed numerically or printed at any map scale.

This topographic data provides a detailed picture of the configuration of the fluvial system. Based on spot checks by SWRCB consultants, it appears to accurately depict the relative elevations of floodplain areas with respect to adjacent stream elevations. (Floodchannel elevations are less reliable, however, and require field evaluation.) The mapped terrain configuration, if compared to a model of groundwater elevation, is sufficiently detailed to distinguish small changes in shallow groundwater zones for different water table elevations.

Water Table Profiles and Streamflow Responses

Observations. In the spring of 1991, five piezometer arrays were installed along the tributary streams by SWRCB subcontractors for purposes of characterizing water table profiles and identifying responses to changing streamflow. Water table elevations and some stream surface elevations were monitored continuously with data loggers, and the changes over the 1991 snowmelt period were observed (Balance Hydrologics 1993).

Observations of water table responses to changes in streamflow lead to the conclusion that changes in streamflow water surface elevation are almost always rapidly followed by similar changes in water table elevation (Figures P-9, P-10, and P-11). These observations underscore the highly permeable nature of the fluvial substrates and the overriding importance of stream stage to nearby water table elevations. This relationship also allows a simple geometric approach to modeling the alternatives.

Water table elevation observations also corroborate earlier conclusions of synoptic flow studies that the tributary streams are generally losing flow to a deeper water table. The profiles for Parker and Walker Creeks where they pass over alluvial fan and Pleistocene delta material show downward sloping water tables perpendicular to the streams of about 2-3% slope when corrected for local stream geometry (Figures P-12 and P-13). Readings of piezometers on Rush Creek above U.S. 395 also indicate streamflow loss, but apparently with much less water table slope.

Observations in the Rush Creek bottomlands, however, indicate only a very slowly losing or equilibrium condition, with water table profiles almost level away from the stream (Figure P-14). Both bottomland profiles show this condition, but one of them appears to have had an amplified response to changes in stream stage (Figure P-15). This apparent phenomenon is probably the result of the piezometer being located just downstream of a major stream bend, where site-specific factors mask typical responses.

Extrapolations. The sample size of this water table depth information is obviously small. Gathering similar information at several other locations would greatly enhance the predictive capability of this model.

Extrapolation of these observations to water table profiles through all stream reaches is somewhat subjective, but it can be guided by results of synoptic flow measurements by DFG contractors (California Department of Fish and Game 1991, 1992a, 1992b, 1993). Relative rates of streamflow loss should be proportional to groundwater slopes, according to D'Arcy's law. Based on the piezometer profiles and this information, water table slopes for particular stream reaches were estimated for model use (Table P-15).

Water Table Boundary Conditions

Analysis of stream configuration and piezometer data shown in Figures P-12, P-13, and P-14 demonstrates the complexity of water table surfaces near the meandering streams. The observations could be reconciled, however, with a simple geometric model of the water table at greater distances from the streams, sloping uniformly away (and down-profile) from the stream as shown.

In the model, as in most groundwater flow models, the downward-sloping water table is imposed as a boundary condition, requiring a specific water table depth at a specific, relatively-large distance from the general trend of the watercourse, corresponding to the estimated perpendicular water table slope (Table P-15). The water table depths in the near-stream locations as dictated by the sequence of stream centerline elevations are required to transition smoothly to the boundary conditions (as shown, for example, on Figures P-12, P-13, and P-14).

The process to establish the "stream trend" and therefore the locations to impose the boundary conditions required the use of averaging algorithms to remove the meander of the actual stream. The steps to accomplish this using an appropriate visual approach are described in the "Methods" section below.

Stage-Discharge Relationships

Stream stage in relation to flow releases from the diversion structures provides an essential tie from flow releases of the alternatives to water table depths. Stage-discharge data were obtained directly or derived from reports of DFG contractors cited above. In some cases, the derivation required use of Manning's law to estimate streamflow from cross-sectional area and shape, channel slope, and roughness characteristics. In all cases, averaging of data from several sections was required, but significant differences between distinct reaches were retained.

The stage-discharge data for each creek were compiled in such a manner as to facilitate assessment of particular streamflows (the July-August average streamflow release projected for each alternative by the

LAAMP model). Fortunately, most of the published stage-discharge data is in terms of release flows at the diversions.

To represent the range of alternatives but to keep the task manageable, two reference flow releases for each stream were established for evaluation (Table P-16). They were chosen to encompass the range of streamflows of interest. The model results for these two reference conditions were then linearly interpolated to the intermediate July-August flows of the alternatives. Some loss of accuracy occurs with this interpolation approach, but the increased accuracy obtained by employing more model runs is not needed for the purposes of this assessment.

Water Table Depth Requirements of Woody Riparian Vegetation

To employ the model, it is necessary to make a general estimate of the maximum depth of groundwater needed to sustain woody riparian vegetation during the growing season, but this need not be a precise estimate. The model is intended to estimate relative changes in riparian habitat from point-of-reference conditions, which it can do adequately if the same depth estimate is applied to all alternatives and scenarios.

Information about direct observations of groundwater depths under various plant communities is scarce. Fortunately, such data was collected in the Owens Valley in 1921 (Ecosat Geobotanical Surveys 1990) from an array of observation wells drilled for this purpose. Woody riparian communities had a water table at an average depth of 3.9 feet. The standard deviation of the observations was ±1.5 feet. This suggests that a "primary riparian habitat" can be assumed to have a shallow water table throughout the growing season at a depth of up to 3.9 + 1.5 feet, or about 5 1/2 feet.

Methods

The methods used to construct and execute the model were a combination of computerized and manual techniques, although the entire model could be computerized. Stream trends in plan view were established manually, and manual topographic cross-sections were used as a basis for manual generation of water table profiles. The development of the profile of the stream trend and the model output calculations were accomplished using computerized spreadsheets. The steps of the entire procedure can be summarized as follows:

1. Manually draw stream centerlines along the photogrammetrically-derived topographic maps.

2. Manually draw smooth curve in plan view to approximate a smooth stream trend, changing directions slowly.

3. Identify points along the stream centerlines at 2-foot elevation increments from contour crossings.

4. Project each of these stream centerline points onto the vertical surface along the stream trend at the same elevation. Measure horizontal distances between each projected point and enter elevations and stream-trend distances into a database.

5. Develop a stream trend profile point corresponding to each projected stream centerline point by computing the vertical coordinate of a point on a line representing a least-squares fit of the seven nearest projected stream centerline points.

6. Manually generate topographic cross-sections every 500 feet in the Rush and Lee Vining Creek bottomlands and every 1,000 feet elsewhere.

7. Locate each corresponding stream trend point in each cross-section, using both the offset distance from the stream centerline and the elevation obtained in item 5 above. From this trend point, drawn lines using the selected groundwater slopes (Table P-15) to represent the trend groundwater profile at each location.

8. Beginning at the stream, superimpose an estimated groundwater profile on the section beginning at the specified stage offset above or below the stream centerline (Table P-16) and, through smooth transitions, becoming asymptotic with the trend groundwater profile several hundred feet from the stream. Repeat for two stream stages corresponding to the evaluation streamflows.

9. Locate and measure all portions of the section where the estimated groundwater profile is less than 5 1/2 feet from the topographic profile. Repeat for the two evaluation streamflows.

10. Multiply the section lengths of this primary riparian habitat by the intersectional distance and combine all sections in a reach to estimate acreages of habitat for the two evaluation streamflows.

11. Using linear interpolation, estimate from the reference data the primary riparian habitat acreages corresponding to the average growing season streamflow for each of the alternatives.

12. For the higher lake level alternatives, subtract acreages in the lower reaches of Rush and Lee Vining Creeks to account for submergence of point-of-reference vegetation by the normal highstands of the lake:

    - 6,372-Ft Alternative: 6,378 feet, 0 acres submerged.
    - 6,377-Ft Alternative: 6,383 feet, 9 acres submerged.
    - 6,383.5-Ft Alternative: 6,389 feet, 18.5 acres submerged.
    - 6,390-Ft Alternative: 6,397 feet, 29 acres submerged.

- # 6,410-Ft Alternative: 6,415 feet, 36 acres submerged.
- # No-Diversion Alternative: 6,436 feet, 42 acres submerged.

13. Compare derived primary habitat acreages for each stream reach with prediversion and point-of-reference acreages from the mapping program. Screen the model results against the known acreages according to the following criteria:

    - # where the model acreage lies between prediversion and point-of-reference acreages (which was the case for most of the reaches), accept the model acreage;

    - # where the model acreage exceed the prediversion acreage (which occurred only where the water table profile was not directly observed), use the prediversion acreage; and

    - # where the model acreage is less than the point-of-reference acreage (which occurred in one reach), use the point-of-reference acreage.

    Treat the results as the maximum potential acreages of riparian habitat over the long term if streamflows remained at the point-of-reference levels. These acreages could remain vegetated with xeric plant communities (i.e., sagebrush scrub) for long periods of time until optimum conditions for recruitment occurred or intervention (through overflow channel watering or planting and irrigating) occurred.

14. For minimum potential acreages, generally use the point-of-reference condition.

15. Apply the percentage increases in riparian habitat for each reach under each alternative, as obtained in step 11, to both the maximum and minimum point-of-reference scenario acreages. Allocate increases to both woody riparian and meadow/ wetland acreages according to the point-of-reference ratio of these types.

Table P-17 shows acreages of the important parameters in steps 13-15 by stream reach for each alternative except the No-Restriction Alternative.

Results

The range of estimated riparian vegetation increases due to stage effects from the point of reference under the alternatives (except the No-Restriction Alternative, which cannot be modeled) for Rush and Lee Vining Creeks combined is 8 acres (for the 6,372-Ft Alternative) to 30 acres (for the 6,410-Ft Alternative). These acreage increases are not substantial, being 2-8% of the point-of-reference acreages along these streams. Based on stage effects alone, an estimated difference of 31 acres of primary riparian habitat separates the lowest streamflow (6,372-Ft) alternative and the No-Diversion Alternative:

- # 12 acres on Rush Creek,
- # 7 acres on Lee Vining Creek,
- # 8 acres on Parker Creek, and
- # 4 acres on Walker Creek.

These increases in riparian acreage resulting from streamflow changes are more than offset by decreases caused by newly established willow-covered floodplains near the mouths of Rush and Lee Vining Creeks being submerged by the rising lake. If the lake rose to the level of the No-Diversion Alternative, about 30 acres of riparian vegetation on Rush Creek and 12 acres on Lee Vining Creek would be lost.

No estimates have been made of the extent of shallow water table associated with the north (overflow) channel of Walker Creek. It is assumed that with continued blockage of this channel inlet and substantial reduction of irrigation below the Lee Vining conduit a shallow water table supporting the existing riparian vegetation along this channel will be lost. In the model context, this loss would be compensated by expansion of woody riparian vegetation along the entire main channels of Walker and Parker Creeks once meadow irrigation and grazing were largely curtailed.

The combined effects of these factors, as represented by the results of the water table model, are presented in Table 3C-14 and Figure 3C-11 of Chapter 3C.

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