Chapter 2. Existing Conditions in the Yolo Bypass

This chapter presents background information about existing conditions in the Bypass. Specifically, this chapter focuses on current land and water uses and historic and recent hydrologic and hydraulic conditions. Information in this chapter has been prepared largely as a compendium to information presented in the 1994 suitability analysis document (Chapter 1) (Jones & Stokes Associates 1993), although some general background information from that document has been used in the following sections. Hydrologic data discussed in this chapter should be considered as an extension of the body of knowledge and understanding of the Bypass. Throughout the project, the Working Group has expressed considerable interest in gaining a better understanding of how, when, and why water flows through the Bypass. This chapter does not focus on existing habitat conditions in the Bypass because this information has already been extensively discussed in the 1994 Suitability analysis document and in the CALFED ERPP document (Chapter 1).

The reader should note that the area known as the "Yolo Basin" is a large geographic feature that was formed through thousands of years of geologic and hydrologic changes. The Bypass is a subset of the Yolo Basin and, as previously described, is a massive, leveed flood conveyance facility.

Soils and Landforms

Almost all the landforms in the Yolo Basin are composed of sediment from alluvial deposition and range in size from gravel to clay. The creation of most landforms in the Yolo Basin has occurred in the Holocene, the last 10,000 years since the end of the Tioga period of glaciation. The periods of deposition correlate with periods of glaciation in the Sierra Nevada, the rise and fall in sea level, and climatic change. The landforms in the Yolo Basin include:

- the floodplains and natural levees along the Sacramento River;
- the floodplain distributary deltas of Cache and Putah Creeks;
- the edges of the young alluvial fans of Cache and Putah Creeks, stretching from the Coast Range foothills to the edge of the Yolo Basin; and
- the creek basins and intermediate and high basin rims in the Yolo Basin and around its borders (Figure 2-1).

The alluvial fans, natural levees, and floodplains are composed of coarse sediment deposited by the flowing water of periodic overbank flooding of the Sacramento River and Putah and Cache Creeks. The basins and basin rims are composed of fine sediment deposited by the ponded water of rainfall, flood overflows, and the sinks of Cache and Putah Creeks.

The soils of the Bypass formed in alluvial parent material and are associated with the landforms described above. A detailed description of soil types can be found in Appendix C; a simplified presentation is shown in Figure 2-2. Hydric soils (Appendix C and Figure 2-3) are soils that have the morphological features currently accepted as defining wetlands. Although many of these areas no longer qualify as wetlands because the hydrology has been altered and the vegetation removed, wetland soil characteristics remain, indicating the former extent of wetlands. Presence of these soils indicates that the Bypass was either entirely wetland or included portions of wetlands before reclamation and settlement.

AGRICULTURAL AND MANAGED WETLANDS LAND AND WATER USE

This section describes land and water use in the Bypass. It was developed largely from interviews in May and June 2000 with landowners and land managers with operations in the Bypass and from input from the entire Working Group, as well as from existing data sources. As described in Chapter 1, for organizational purposes, the Bypass is discussed as having northern and southern areas (Northern Bypass and Southern Bypass). The I-80 causeway marks the boundary between these two portions. Most of the land holdings in the Bypass are private. However, there are some publicly owned lands. The agricultural land holdings are generally large properties managed by highly experienced owner farmers and tenant farmers. The managed wetlands (private duck clubs and public properties) are operated to support waterfowl, upland game birds, and numerous other avian and terrestrial wetland species.

One of the goals of the Working Group and one of the purposes of this document is to identify opportunities and constraints related to habitat-enhancement strategies. The goal includes an attempt to identify these opportunities and constraints while maintaining desired existing agricultural and managed wetland (private duck clubs and public properties) operations. Possible strategies may include the movement of water on to and off of certain parcels of land for habitat enhancement, modification of existing canals to improve habitat quality, or changes to existing management practices that would improve habitat without adversely affecting existing land uses and water delivery.

Detailed characterization of the entire Bypass is beyond the scope of this project. However, information about certain areas allows general statements to be made about conditions throughout the Bypass, including those areas for which information is currently scarce. This section includes maps that show land use, infrastructure, and irrigation patterns in the Bypass. Descriptions of infrastructure maintenance programs, effects of floods, and water availability and delivery are also included. Descriptions of flooded conditions in this section are not meant to imply that complete or catastrophic flooding of all lands in the Bypass occurs on a regular basis. Depending on incoming flows from a variety of sources, some lands are flooded frequently, while others are rarely flooded. An in-depth discussion of Bypass flood hydrology is presented later in this chapter.

Agricultural Land Use and Production

Northern Bypass

Historically, rice, corn, tomatoes, melons, and safflower have been the predominant crops grown in the Northern Bypass. Because of colder temperatures and stronger delta winds in the Southern Bypass, rice does not grow as well south of I-80 as it does north of I-80; however, wild rice has been found to produce well south of the interstate (Figure 2-4). In the last 5–10 years, corn and safflower crops have been planted in place of tomatoes because tomato crops do not tolerate spring flooding. The Bypass has been flooded during April and May in 3 of the last 6 years, and the prolonged periods of late spring flooding since the late 1980s and early 1990s have made tomato farming uneconomical.

Soils in the Northern Bypass are generally more productive than in the Southern Bypass (excluding the areas around the historical Putah Creek Sink, as described below). North of I-5, the soils are good throughout the Bypass. Farther south but still north of I-80, soil quality is better on the east side of the Bypass. To the west, the soils have a high clay content and therefore have poorer quality than in the eastern areas, a possible result of materials deposited in the prehistoric Yolo Basin by floodwaters from the Sacramento River and its tributaries (Jones & Stokes 1993). Flooding in the Bypass does not appear to significantly affect soil conditions, although some limited erosion (8–10 inches deep) has been detected around structures such as fence posts and pump stations following floods, and laser-leveled fields have been disturbed. However, flood events may also level some fields by filling in low spots with sediment that has been eroded from higher ground, thus also potentially improving soil quality.

Southern Bypass

In the Southern Bypass, crop farming is concentrated in the northern and northwestern area near Putah Creek and I-80. Crop patterns are determined by soil quality, slope of fields, elevation, and temperatures.

In general, soils in the eastern and central areas of the Southern Bypass have a higher clay content than the western side of the Bypass. These areas are also very flat. Crops in these areas include corn, milo, safflower, beans, and sudan grass. As mentioned above, temperatures are generally too cold south of I-80 for growing domestic rice crops. Wild rice crops have done well in this area, but productivity is limited by wind shatter, foraging by birds, and, currently, a small market demand for this crop.

On the western side of the Southern Bypass, soils subject to Putah Creek sediment deposits are high quality and very productive. These high-quality soils are also at higher land elevations than those in the eastern area of the Bypass. Farmers in this area indicate that fields above the 15-foot contour interval on the U.S. Geological Survey (USGS) quadrangle maps flood less frequently and are, therefore, less risky to farm. Crops on high-quality soils and at high elevations near Putah Creek are dominated by tomatoes (Martinez pers. comm.). Tomato production in these fields has not been severely affected by flooding in recent years and, therefore, has not declined to the extent seen in the Northern Bypass.

In addition to growing crops, some landowners also derive income from livestock grazing operations, particularly in the more southern end of the Bypass.

Agricultural Water Use, Sources, and Delivery

Northern Bypass

Irrigation water sources in the Northern Bypass include the Knights Landing Ridge Cut, Cache Creek, and Willow Slough to the west and the Sacramento River and Tule Canal to the east. Rainfall runoff and irrigation tailwater from adjoining cropland is also pumped through the East Bypass Levee in the northernmost area of the Bypass. Irrigation water is pumped from groundwater wells at various locations. Major water sources and canals in the Northern Bypass are shown on Figure 2-4. As previously stated, much of the information provided herein is based on personal interviews with Bypass water users. Water use and delivery in the Bypass depends on a complex and evolving set of conditions. Therefore, the following information and associated maps should be considered as an informative but not necessarily exhaustive summary of these conditions.

Water coming in through the Knights Landing Ridge Cut is dammed as it enters the Bypass and is diverted to the north and south. During high flows, water overtops the small dam and follows a shallow floodway channel southeast toward the Tule Canal. This floodway helps control small nuisance spring flooding from the Knights Landing Ridge Cut. The dam is also used to back water up as far upstream as College City in Colusa County for irrigation pumping (Jenness pers. comm.). For crop irrigation in the Bypass north of the Knights Landing Ridge Cut outfall, water is gravity fed north through a canal approximately 1 mile along the West Bypass Levee, lifted through pumps, and gravity fed across the Bypass to the east. The water is lift-pumped to irrigate fields and gravity fed to the south along this east-west canal.

In the northeast area of the Northern Bypass, tailwater from fields to the north and outside of the Bypass (between the Bypass and Sacramento River levees) is brought into the Tule Canal through the East Bypass Levee by lift pumps and a screw gate–controlled pipe. This water is used to irrigate Bypass fields north of the Knights Landing Ridge Cut inlet when flow from the Knights Landing Ridge Cut is too low to divert by gravity to the north (as previously discussed). Fields from south of the Knights Landing Ridge Cut inlet to the City of Woodland's former settling ponds are irrigated from the north-south canal adjacent and parallel to the West Bypass Levee and from several small cross canals branching off of this north-south canal. Water flows by gravity south from the Knights Landing Ridge Cut dam and is lift-pumped into fields and cross canals. Tailwater from these fields drains east to the Tule Canal.

During periods of low flow, Cache Creek does not carry surface water to the Bypass. It dries in summer months upstream of the Cache Creek Settling Basin. Any flows entering the settling basin during these drier summer periods come from groundwater recharge captured by the creek channel and agricultural tailwater delivered to the creek channel (Regional Water Quality Control Board 2000). During normal and high flows in the late fall and winter (associated with storm runoff from seasonal storms), Cache Creek enters the Northern Bypass through a concrete culvert in the West Bypass Levee in the southeast corner of the Cache Creek Settling Basin, just north of I-5. This water flows east by gravity to the Tule Canal through a small canal that runs across the City of Woodland's former settling ponds, north of I-5 and the Yolo Shortline railroad trestle (Figure 2-4).

During high events (historically during late fall or winter), when the settling basin is at capacity, Cache Creek water flows into the Bypass over a large, concrete "step ladder" spillway structure built into the West Bypass Levee immediately north of the previously described concrete culvert (further discussion of Cache Creek hydrology is presented later in this chapter). During these events (and when the Bypass is not inundated), some of the water is diverted by a gated diversion structure, located north of the Yolo Shortline Railway, into the Conaway Canal, where it flows south by gravity.

The Conaway Canal carries Conaway Ranch's Sacramento River water diversion west, through a siphon under the Sacramento River Levee and under the East Bypass Levee and Tule Canal (Hall pers. comm.). The Conaway Canal extends across the Bypass just north of I-5 from the Sacramento River to near the West Bypass Levee. At the West Bypass Levee, the Conaway Canal turns and extends south (adjacent and parallel to the West Bypass Levee) toward I-80, feeding several cross canals along the way. The fields between I-5 and I-80 are irrigated from these cross canals. Tailwater from these fields drains east to the Tule Canal. Water from Willow Slough flows directly into the Conaway Canal.

Fields just north of I-80 are irrigated with water from the Conaway and Tule Canals. Because of the flatness of the land, Tule Canal water can be moved by one or two pump stations to the west side of the Bypass when needed. Tailwater from this area drains eastward back to the Tule Canal.

Southern Bypass

Major water sources and canals in the Southern Bypass are shown on Figure 2-5. Much of the information provided herein is based on personal interviews with Bypass water users. Water use and delivery in the Bypass depends on a complex and evolving set of conditions. Therefore, the following information and map should be considered as an informative but not necessarily exhaustive summary of these conditions.

The Toe Drain (Figure 2-5) (named the Tule Canal north of I-80) is the main water source for farming operations in the Southern Bypass. The water elevation in the Toe Drain is affected by the Delta tide as far north as I-80 and fluctuates between 3 and 7 feet at the Lisbon gage (0–4 feet above sea level). A few hundred feet north of this gage, the Lisbon Weir blocks the lower part of the channel and limits the range of tidal fluctuation upstream of the weir. The main part of the weir consists of a rock mound reinforced on the downstream side with sheet piling. A relatively new segment of the weir consists of vertical steel panels held in place by piers. The weir operates passively by impounding upstream inflow and tidal water at a minimum elevation equal to the weir crest elevation (2.5 feet above sea level), which provides higher and more stable water levels for upstream diversion pumps yet still allows inflow of tidal water. At high tide, the weir is completely submerged, and at low tide the drop in water level across the weir is up to 2.5 feet.

The pool of water impounded by the Lisbon Weir is used to irrigate fields north of Putah Creek. The water backs up out of the Toe Drain into an east-west trending canal located upstream of Lisbon Weir. About three-quarters of the way across the Bypass from the Toe Drain, a large pump station delivers water from this canal to fields north, west, and south (between I-80 and Putah Creek) via canals. The canal heading west also delivers water to fields west of the Bypass via a gated pipe through the West Bypass Levee and pumping stations and distribution laterals outside the Bypass. Tailwater from this area drains into Putah Creek (Schmid pers. comm.).

A southern extension of the east-west canal extends south to Putah Creek at a pool created by a small flashboard checkdam located 1 mile west of the Toe Drain within the Bypass. This canal can convey water in either direction, allowing either Putah Creek water or Toe Drain water to be used to irrigate fields over a broad area north and south of Putah Creek.

Putah Creek water supply is limited after May of each year (Schmid pers. comm.); however, south of Putah Creek, other irrigation sources include tailwater from drainage districts and Reclamation District (RD) 2068 and groundwater from various locations within the Bypass (Martinez pers. comm.).

In the south end of the Southern Bypass, substantial areas are supplied by networks of cooperatively managed canals and pump stations using the Toe Drain as a water source. In the southernmost reaches of the Bypass, water is also pumped from Cache Slough and Prospect Slough (not shown on Figure 2-5) for delivery through surface channels. Along the southwestern edge of the Bypass, groundwater provides a reliable water supply. Groundwater use increases generally from south to north, with limited use in the most southern reach (approximately Yolo CR 155) to more significant use in areas closer to but south of Putah Creek (Hardesty pers. comm.).

Flooding Impacts to Agricultural Operations

As previously stated, late spring flooding in the Bypass has a significant detrimental effect on farming operations. Floods affect crops in a variety of ways. Floods in April–June can damage or destroy crops planted during dry periods in March–May. When this flooding happens, it is usually too late to replant those fields with a different crop. Floods can also erode planting beds and furrows. If the ground remains too wet to work until May or June, the shortened season results in limited crop options and decreased yields.

The maintenance of infrastructure, including roads, canals, drainage ditches, diversion structures, pumps, and wells, is done on an as-needed basis, often in response to flood damage. Roads are sometimes eroded and require regrading or rebuilding. Some canals and ditches fill with sediment deposited from floods and require periodic excavation to maintain necessary flow capacity. Canals oriented north-south are parallel to the floodflow direction and, therefore, generally do not disrupt flow patterns. They exhibit less damage than east-west canals. East-west trending canals often create eddies and other hydraulic disturbances that can cause erosion and deposition of sediments and deposition of flood debris, such as tree limbs, agricultural vegetation, and irrigation pipes, in fields and canals. Such debris conditions necessitate extensive cleanup efforts. According to several landowners and tenants, debris deposition is a larger problem in the Southern Bypass than in the Northern Bypass; however, this difference has not been formally documented in any previous studies. It has also been reported by some Working Group members that the southwest edge of the Bypass generally does not suffer from significant sediment deposition on open farm/pasture ground and associated canals, except in areas where flow patterns are interrupted, such as adjacent to and downstream of interior cross levees and channels within the Bypass.

Other structures potentially affected by flooding include irrigation pumps and electrical switch boxes. Some of these features are temporarily installed for the growing season and removed each fall; others are permanent structures built at an elevation above the Bypass design flood stage. Nonetheless, these permanent structures are at risk of inundation or damage by floodwaters.

Climate and hydrology data from DWR are used to various degrees by Bypass farmers to predict late-season flood risk. In the Northern Bypass, the levels of Clear Lake (the source of Cache Creek) and the Knights Landing Ridge Cut are watched to assess the likelihood of flooding from these sources. In recent years, some farmers have felt that the risk of flooding was high if annual rainfall totals were near to or above average. However, some farmers believe this information is of limited practical use because even if late-season flooding is likely, crops must still be planted for economic reasons. Therefore, crop planting becomes a gamble that flooding will not occur.

Some landowners feel that reservoir operations of the state and federal water projects have shifted in recent years to focus on water supply rather than flood control. These landowners believe that reservoirs are being filled for water supply too early in the season, thereby reducing their capacity to control late season storms. If and when these storms occur, reservoir releases are increased and the Bypass floods, even though it may have been dry for the previous few weeks or more.

Managed Wetland Land and Water Use

Over the past 50 or more years, some parcels in the Bypass have been managed as private wetlands, largely for the purpose of supporting waterfowl hunting (duck clubs). These clubs are generally concentrated in the Southern Bypass, south of the Lisbon Weir. A few smaller duck clubs are located north of I-80. Most of these clubs are owned or rented by members who pay a fee for the right to hunt on club land. Some clubs allow nonmembers to hunt by paying a seasonal fee or by leasing blinds on club land. In addition to these privately owned wetlands, the DFG owns and manages the 3,660-acre Yolo Wildlife Area and also holds conservation easements on an additional 1,525 acres of the duck clubs to ensure that they are maintained as wetland habitats. The USFWS also holds conservation easements on 4,467 acres of duck clubs and other private lands (different from those held by the DFG) to ensure their protection.

The general management practice for duck clubs is to allow hunting on the land during the waterfowl season (generally mid-October through mid-January) and either farm the land or manage it fully as wetland during the off season. Wild rice is the dominant crop grown in the Southern Bypass duck club fields. The annual growing season for wild rice extends from April to October or November.

Duck clubs that are not farmed are managed as wetlands throughout the year. This habitat includes a mixture of open water and upland cover areas. Target plant species, such as native grasses, tules, swamp timothy, smart weed, and watergrass, are grown in fields and provide food and cover for waterfowl and other birds. These plant species, along with problem vegetation, such as cocklebur, clover, and knuckleweed, are managed through periodic flooding, disking, mowing, and burning. Of increasing concern in the Bypass is a non-native vegetation—the water hyacinth. Water hyacinth is a completely waterborne plant that pioneers rapidly and aggressively. Herbicide use (RoundUp) and seeding in fields and waters is limited.

As previously discussed, several of the duck clubs have conservation easements held by the DFG and USFWS (as described in greater detail later in this chapter). These programs pay landowners to maintain certain lands as wetland habitats.

Under the state's Presley Program or Wetland Easement Program, detailed wetland management agreements are developed that mandate the timing of flooding, drawdown, irrigation, soil disturbance, and maintenance of semiopen water "brood" habitat for resident waterfowl species. These agreements are assessed and sometimes modified by DFG biologists in the spring of each year. Generally speaking, the lands under state easements are flooded from September or October through April of the following year, with additional late spring or summer irrigation periods. These programs allow flexibility in habitat management design from year to year, allowing several wetland properties to be managed in concert with each other. The lands under the state's Presley Program and Wetland Easement Program are diverse, productive wetlands managed under the close observation of wetland biologists.

The federal Waterbank Program follows similar steps, but it has less habitat management flexibility. Under the Waterbank Program, private wetlands are flooded from September or October through approximately July 15 of each year. As with the state programs, this flooding is done to provide spring habitat for waterfowl and other water birds, specifically brood habitat for resident species. Nesting for various species occurs from late April through June of each year.

Following the Waterbank Program flood season, fields are drained or flooded for various periods to create cover areas and open water, respectively. Water depths in ponds vary from 3–4 inches to 2–3 feet. Water is constantly circulated through the ponds to maintain water quality. Some ponds are flooded again approximately 1 month before the beginning of hunting season. Not all ponds are flooded initially, although generally all the ponds are flooded by the end of November.

Water sources for clubs in the Southern Bypass include the Toe Drain, RD 2068, and wells. The water flow and local reuse of the water is controlled by a variety of ditches, canals, pumps, and gates. For clubs adjacent to the Toe Drain (south of the Lisbon Weir) water is pumped out of the

Toe Drain and gravity fed to the west through canals. Water for ponds is drawn from these canals by gravity and lift pumps. Screw and flap gates are used to control flow in and out of the ponds. Tailwater from ponds circulates through other ponds or drains directly back to canals that drain east to the Toe Drain.

Flooding Impacts to Managed Wetlands

Flooding of the Bypass can affect private and public managed wetland operations in similar but seasonally different ways than it affects farmers. Floods damage infrastructure, and managers have to perform maintenance similar to that done by farmers. Ditches and canals sometimes fill with sediment and need to be excavated to maintain flow capacity. In addition, debris deposited on fields needs to be removed; roads, field levees, gates, pipes, and pumps may need to be repaired. Permanent structures, such as pump stands and club houses, can also be damaged by high water. Significant flooding during the hunting season (mid-October to mid-January) can make it dangerous or impossible to hunt in the duck clubs, resulting in lost hunting time and subsequent lost revenues for private hunting operations. As flooding periods increase, hunting opportunities decrease and the result is an economic impact to the property owners. Lastly, floods and their timing affect plant species composition and wetlands and may adversely affect waterfowl, pheasants, and other nesting birds.

Natural Gas Land Use

Land management for waterfowl and natural gas operations are very compatible throughout the Sacramento Valley. At the southern end of the Bypass, the Rio Vista gas field is one of the most productive in Northern California. The Yolo Wildlife Area sits above the Todhunter gas field, and there are active gas wells on the Conaway Ranch property in the Bypass. These fields are all mature and have been declining in production for the last several decades. However, new seismic imaging exploration techniques and record prices have brought about new exploration and development activities that suggest that the Bypass will continue to be natural gas-producing area.

STATE AND FEDERAL LAND MANAGEMENT IN THE YOLO BYPASS

Although the majority of lands within the Bypass are privately owned, several thousand acres are owned, managed, or under easements through state and federal agencies. Table 2-1 presents these agencies, the types and acreage of land they manage, the types of management practices employed on these lands, and the historical and future land uses of these properties. The following text provides a description of these programs.

United States Fish and Wildlife Service

Conservation Easement Program

The USFWS provides a one-time payment (based on approximately 40–60% of the appraised fee title value) to purchase the future development and agricultural rights, the right to flood the property, and place some restrictions on grazing. Landowners (and their future assignees) agree not to alter existing topography; not to grow or cultivate agricultural crops; and not propose activities, including the construction of levees and installation of new water control structures, that would adversely affect the use of the easement lands as habitat suitable for migratory birds.

In any year that the landowner does not abide by the management guidelines prescribed in the easement agreement, the USFWS has at its sole discretion the nonexclusive right and option—but not the obligation—to implement those prescribed activities.

Easement provisions do not usually prohibit hunting or the continuing operation of a hunting, fishing, and recreational club on the easement lands, providing such activities are in accordance with all applicable state and federal laws regulating hunting and fishing on privately owned lands. Landowners may take actions to operate and improve the lands as waterfowl habitat and operate and improve their facilities and operations, including building or relocating hunting blinds, excavating channels to blinds, irrigating vegetation, and planting approved trees and vegetation.

The USFWS does not purchase the right for public access to the easement lands, nor does it restrict grazing or controlled fire programs conducted to enhance migratory bird habitat. The easement interests acquired by the United States become a component part of the National Wildlife Refuge System and subject to the laws and regulations pertaining to the National Wildlife Refuge System that are applicable to the easement interests that were acquired.

In addition to the conservation easement program, the USFWS provides free technical assistance (e.g., wetland habitat management, riparian restoration, control burning, water management efficiency) to landowners. However, money for operation and maintenance of the property is not provided through this easement program.

Partners for Fish and Wildlife Program

Through its Partners for Fish and Wildlife Program, the USFWS provides shared cost funding (via a competitive application system) to landowners for wildlife habitat/facility enhancement. Through the execution of a Wildlife Extension Agreement, the landowner joins as a participant in a wildlife management program and grants to the USFWS the authority to complete wildlife habitat development or to personally carry out wildlife management activities with financial or material support. The terms of the agreement are in effect for 10 years. At the end of the term, the wildlife habitat development becomes the property of the landowner.

Table 2-1. State and Federal Land Management in the Yolo Bypass

Agency	Conservation Easement Acreage (Approximate)	Fee Title Acreage (Approximate)	Physical Characteristics	Current Use	Recent Historical Use	Potential Future Use	Management Practices
U.S. Fish and Wildlife Service (USFWS)	4,467 (with potential for additional 870)	None	Managed seasonal wetland with some semipermanent and permanent wetland interspersed with mostly unmanaged upland habitat	Mostly duck hunting	Irrigated grazing pasture and some food crops	Same as present	Annual artificial flooding with spring drawdown to encourage annual moist plant germination
California Department of Fish and Game		3,660	Flat terrain with slope to the east of approximately 8.5 feet across the Bypass; only relief is from canals and levees				Wetland management
California Department of Fish and Game	1,525		Managed seasonal wetland with associated upland grassland	Duck hunting	Duck hunting; some grazing	Duck hunting	Wetland management
Reclamation Board (Sacramento–San Joaquin Drainage District)	None	1,600 (subject to USFWS conservation easement	Grassland with trees; flooding when Fremont Weir spills; dry in summer	Leased to individuals for pheasant hunting; spoil pile storage for levee repair	None; no agricultural use	Possible open-to-public hunting	None
City of Woodland	None	460	Grassland in flood zone	Sanitary sewer-treated effluent and storm drainage conveyance	Wastewater effluent holding ponds	Productive agricultural use	None

Natural Resources Conservation Service

Wetlands Reserve Program

The NRCS administers the Wetlands Reserve Program (WRP), a voluntary program offering landowners the opportunity to protect, restore, and enhance wetlands on their property. The program consists of permanent conservation easements, 30-year easements, or 10-year wetland restoration agreements. The WRP offers payment based on the agricultural value for wetlands that have previously been drained and converted to agricultural uses. WRP pays up to 100% reimbursement for restoration costs and, in the case of the permanent conservation easement, the legal costs to establish the easement. The landowner retains control of access (no public access is required); the landowner maintains ownership of the land and has the right to hunt, fish, trap, and pursue other appropriate recreational uses. The land, including any easement, can be sold. The program does not fund any operations and maintenance costs.

The USDA requires that the easement area be maintained in accordance with WRP goals and objectives for the duration of the term of the easement, including the restoration, protection, enhancement, maintenance, and management of wetland and other land functions and values. In addition, the easement grants to the United States through the NRCS the following rights:

the right of access to the easement area;

the right to permit compatible uses of the easement area, including such activities as hunting and fishing, if such use is consistent with the long-term protection and enhancement of the wetland resources for which the easement was established;

all rights, title, and interest in the easement area subject to compatible uses reserved to the landowner; and

the right to perform restoration, protection, enhancement, maintenance, and management activities in the easement area.

Water Bank Program

NRCS also administers the Water Bank Program, which includes the following objectives:

preserve, restore, and improve habitat in important migratory bird nesting and breeding areas;

benefit other wildlife resources;

preserve and improve wetlands of the nation;

enhance and maintain the natural beauty of the landscape; and

promote comprehensive and total water management planning.

Under the Water Bank Program, eligible persons in selected areas that have eligible wetlands may enter into 10-year agreements. Landowners receive annual payments for the conservation and protection of wetlands from drainage, filling, flooding, or other land use practices that would destroy the wetland character and value to nesting waterfowl. Water Bank Program agreements have provisions for renewal for additional 10-year periods upon agreement by all parties.

Generally, under the Water Bank Program, at least 20% of the area must be designated wetlands. In the Central Valley, water must remain on the designated wetland from January 1 through July 15 of each year to provide adequate brood habitat for waterfowl and other wildlife. If adequate nesting cover is not present, practices such as seeding may be required to establish or improve the nesting habitat on adjacent lands.

Erosion and sediment control measures to prevent damage to the wetland and adjacent lands may be necessary. Designated wetland areas should be managed to prevent excessive encroachment by tules and other emergent vegetation that reduces open water area and limits access to cover by young ducks. Water Bank Program lands can only be grazed by livestock as a marsh management tool to improve or maintain viable habitat. These lands cannot be used as a source of agricultural irrigation water.

Conservation Reserve Program

NRCS has recently introduced the Conservation Reserve Program (CRP), which will pay landowners (on a per-acre basis) for entering into a 10-year agreement to follow a management plan that enhances wildlife values on their property. Many of the landowners whose Water Bank Program contracts have expired are expected to place their wetlands into the Conservation Reserve Program

Conservation Reserve Enhancement Program

The Conservation Reserve Enhancement Program (CREP) is a recent initiative that has been established as part of the CRP. CREP expands CRP effectiveness through more focused community-based, local participation planning and design efforts. In California, CREP is focused on restoring upland habitat in the Sacramento Valley through a pilot program developed by the DFG and the USDA Farm Services Agency (FSA). Specifically, the primary objectives of Sacramento Valley CREP are to:

coordinate and partner federal and nonfederal resources to address specific conservation needs and

provide upland nesting habitat and spring and summer wetlands needed by waterfowl, pheasants, shorebirds, and neotropical songbirds through the development of native grasslands and other wildlife grass mixes.

Additional shallow water and small brood pond habitats will also be developed.

FSA and DFG have targeted a total of 10,000 acres in Butte, Colusa, Glenn, Placer, Sacramento, Solano, Sutter, Yolo and Yuba Counties that are in need of wildlife habitat restoration efforts. The local FSA office will administer the CREP, with technical advice being provided by the NRCS, based on biological information provided by DFG and the USFWS. Land eligibility requirements are the same as they are for CRP. Land must have been owned or operated by an applicant for the previous 12 months, must qualify as irrigated cropland, and must have been planted to crops in 2 of the last 5 years. The land must be physically and legally capable of being planted in a normal manner. Participating landowners will be paid an annual rental rate of $160 per acre for rice crop fields and $100 per acre for all other planted crops.

California Department of Fish and Game

Presley Program

In response to the loss of wetland habitat quality and quantity in California, the California Legislature passed the California Waterfowl Habitat Preservation Act of 1987. The Act established the California Waterfowl Habitat Program, or Presley Program, a multifaceted wetland incentive program that involves private landowners and was designed to improve habitat for waterfowl. Consistent with its primary waterfowl habitat objectives, the program also endeavors to enhance habitat for shorebirds, wading birds, and other wetland-dependent species. The DFG administers this program.

Under the Presley Program, economic incentives are provided to landowners who agree to manage their properties in accordance with a wetland management plan developed cooperatively by wetland biologists of the DFG's Presley Program and the landowner. The Presley Program Standard Agreement is a nonnegotiable state contract that must be signed by all program participants. The site-specific management plans provide an immediate and long-term wetland management direction for the property. Management plans typically require landowners to implement "moist-soil management" practices, such as timely spring drawdowns, spring and summer irrigations, and pond-bottom disking, as needed. These landowner requirements, once adopted, are not optional. Failure to implement required items will result in the withholding of all or a portion of the incentive payment.

NATURAL VEGETATION AND WETLANDS IN THE YOLO BYPASS

The following section describes the natural vegetation communities that are commonly found in the Bypass. Although these habitats are not the dominant land features in the Bypass, all the following habitats do exist in some measure and could be enhanced in appropriate areas of the Bypass. The primary source of the following information is the 1994 Yolo Basin Suitability Analysis document, with additional updates and input from DFG Yolo Wildlife Area staff and other private land stakeholders.

Riparian Habitats

In the project area, riparian habitats are typically linear and are associated with river and stream channels, canals, and ditches. In the Bypass, most of the mixed riparian habitat is located near the Sacramento River, near the Fremont Weir, in the vicinity of the Sacramento Weir, and lining the Tule Canal near the I-5 causeway. South of I-80, riparian habitats are found along Putah Creek, the tidal sloughs surrounding Little Holland Tract and Liberty Island, and along the length of the Toe Drain. A large percentage of California's wildlife species commonly use riparian habitats. Historically, mixed riparian forests support the densest and most diverse wildlife communities in the project area. Statewide, lowland riparian woodlands support approximately 55 mammal, 150 bird, and 50 reptile and amphibian species (Mayer and Laudenslayer 1988).

The large trees in riparian forests of the Bypass provide nesting structures for larger birds, such as hawks, owls, American crows, great egrets, and great blue herons. The open forest canopy also provides hunting perches for aerial foraging and hunting birds, such as red-tailed kites, yellow-rumped warblers, and black phoebes. Woodpeckers, wood ducks, bats, raccoons, and other animals use tree cavities for nesting, shelter, and other uses.

Mixed riparian forests typically support lush vegetation, with cottonwood, willow, sycamore, valley oak, Oregon ash, and black walnut dominating the overstory layer. Saplings of canopy trees, black willow, box elder, wild grape, blackberry, California rose, and poison oak are common midstory species, and understory vegetation is typically dense.

Willow scrub, another form of riparian habitat, supports overstories from 10 to 40 feet tall and is dominated by willows, including black willow and red willow; it may also support scattered cottonwoods. Willow scrub typically grows in dense clumps and provides cover for many wildlife species. Many small mammals and birds feed on willow seeds, and young willow shoots are a favored food of beavers. Large numbers of insects are associated with dense willow thickets. Consequently, these thickets sometimes support high densities of migratory and resident insectivorous birds. Willows also provide perches and cover for species that forage near water (e.g., black-crowned night herons, snowy egrets, belted kingfishers, black phoebes, and several species of swallows and bats) (Jones & Stokes Associates 1990).

Nonwoody riparian habitat is dominated by false bamboo, cocklebur, weedy annual grasses, sedges, rushes, mustard, sweet clover, thistle, and other exotic agricultural weeds. This community is typically associated with ditches, canals, and disturbed portions of drainage courses (Jones & Stokes Associates 1990). Nonwoody riparian communities provide breeding or foraging habitat for savannah sparrows, house finches, American goldfinches, California ground squirrels, gopher snakes, and pond turtles (Jones & Stokes Associates 1990).

Valley Oak Woodland

Valley oak woodlands and savanna are associated with the highest floodplain terraces, where flooding is least frequent and is of the shortest duration. In Yolo County, conversion to agricultural or urban uses has occurred on a greater percentage of historical valley oak groves than on any other type of riparian vegetation community (Jones & Stokes Associates 1990).

Approximately 70 acres of valley oak woodland or savanna remain in the project area. These relict forests are fragmented and small. This community is largely confined to areas adjacent to the Sacramento River, such as downstream of the Fremont Weir, but some small stands are scattered near the southern end of the Toe Drain (Jones & Stokes Associates 1990).

This community typically supports a sparse to dense canopy, consisting of valley oak trees occasionally interspersed with black walnuts. The midstory is sparse, consisting of saplings, wild grape, poison oak, elderberry, and blackberry, and the understory is typically dominated by lush grasses or sedges (Jones & Stokes Associates 1990). Sycamores are a component of valley oak stands located in or near the Bypass in the vicinity of Fremont Weir.

It is questionable whether valley oaks are able to establish new seedlings and, therefore, sustain existing stands under current conditions and land uses. Statewide surveys have shown that few valley oaks were established over the last 75–125 years. Potential factors affecting oak establishment are thought to include altered patterns of wildfire, competition with exotic annual grasses, lowered groundwater tables, and livestock grazing (Pavlik et al. 1991). The direct loss of valley oaks coupled with an apparent lack of regeneration in existing valley oak stands has become a statewide concern in recent years.

Uplands

Upland habitats are composed of vegetation types that are not classified as wetland, riparian, or agricultural. Generally speaking, uplands are composed of the previous year's crop remains, exotic and native grasses, agricultural weeds, sedges, and rushes. These areas are used by many species associated with grasslands and other open habitats. Seed-eating birds, such as ring-necked pheasants, savannah sparrows, white-crowned sparrows, and house finches, frequently forage in these areas because annual plants typically produce large quantities of seed. Rank growths of herbaceous vegetation also provide ideal conditions for voles and other small mammals. Consequently, raptors that prey on rodents, including black-shouldered kites, northern harriers, kestrels, red-tailed hawks, and Swainson's hawks, frequently forage in these areas. Uplands provide nesting cover for mallards, gadwall, meadowlarks, and northern harriers.

Open Water

Open water habitats are provided by lakes, ponds, flooded oxbows, rivers, streams, and canals. Open water habitats lack emergent vegetation but may support floating or submergent aquatic plants. Open water areas provide habitat for a large and diverse cross section of water bird species. Larger bodies of water, such as Grays Bend (adjacent to the Fremont Weir), Green's Lake (south of I-80) (Figures 2-4 and 2-5), the numerous ponds in the Yolo Wildlife Area, and certain sections of Cache and Prospect Sloughs, provide loafing habitat for large populations of birds. Water birds forage on submerged aquatic plants, small fish, and invertebrates associated with open water areas. Open water in canals and large drainage ditches also provides brood habitat for ducks.

Natural and Managed Wetland Habitats

Freshwater marshes develop on fine-textured soils that are permanently saturated or inundated. Marshes are dominated by dense stands of tule and cattail and typically support some verbena, smartweed, sedges, and rushes (Jones & Stokes Associates 1990). Most of the freshwater marshes in the project area are on private property.

Marshes provide important wintering habitat for ducks, geese, and swans. During spring and early summer, these wetlands provide critical duck brood habitat, which is generally lacking throughout most of the project area. Marshes are also used by many other species of wildlife, including grebes, ibis, herons, egrets, bitterns, coots, shorebirds, rails, raptors, muskrats, raccoons, opossums, and beavers. Upland species, such as ring-necked pheasants, forage and take cover at the margins of wetlands. Garter snakes, Pacific treefrogs, and bullfrogs are common reptile and amphibian inhabitants (Jones & Stokes Associates 1990).

Managed Wetlands

Wetlands maintained by private owners and DFG are important water bird use areas in the Bypass. These wetlands provide roosting and foraging habitat for migrating and wintering shorebirds, ducks, geese, swans, white pelicans, double-crested cormorants, and other water birds. Managed wetlands are maintained with an artificial hydrology. Water levels are manipulated to produce such annual plants as swamp timothy, watergrass, and several species of sedges and rushes. Water levels are also manipulated to control the proliferation of tules and cattails. Many private wetland owners control vegetation by grazing or mowing during the summer months to create open areas. Seasonal wetlands are typically flooded from September or October through April, with periodic late spring or summer irrigations. Many ponds are drawn down throughout the spring months to provide a diversity of habitats. Some managers grow rice and wild rice as agricultural crops and flood them during winter months to provide waterfowl habitat. Although highly modified from natural conditions, flooded rice fields function as seasonal wetlands and provide an important supplement to natural marshes as a source of feeding or resting habitat for water birds.

Mudflats are a condition associated with seasonal wetlands or agricultural fields that have prolonged inundation in spring and are exposed as water recedes. Spring mudflat habitat fluctuates annually in response to hydrologic conditions. When the Bypass floods in late winter, this habitat becomes abundant as water recedes. This habitat is rare in years that the Bypass does not flood. In summer, mudflats become vegetated with annual grasses and forbs, such as swamp timothy, watergrass, smartweed, and cocklebur (Jones & Stokes Associates 1990). Mudflats are the favored foraging sites for sandpipers, plovers, avocets, stilts, and other shorebird species. Thousands of shorebirds may use exposed and shallow flooded mudflats in the project area. Shorebirds are present all year. Their numbers increase during their spring and fall migration. Presence of mudflats is essential for shorebird migration.

YOLO BYPASS FLOOD HYDROLOGY AND CONVEYANCE

The frequency, duration, and timing of flood inundation in the Bypass largely determine the viability of agriculture and the potential for restoring wetland and other habitats. This section describes the role of the Bypass in the Sacramento Valley flood control system and the historical patterns of inundation. The relative importance of various sources of floodwaters is identified, and potential trends toward increased or decreased flooding in the Bypass are evaluated.

History and Design of the Yolo Bypass

The Bypass is the largest feature of the FCP (Figure 1-2). In addition to 980 miles of levees along the Sacramento, Feather, and American Rivers and a number of smaller creeks and rivers, the FCP includes three flood relief structures and five overflow weirs that shunt excess flows from the main Sacramento River channel into the Butte Basin and two flood bypasses (Sutter and Yolo). Runoff from the entire Sacramento Valley watershed reaches the Delta via the lower Sacramento River and the Bypass. The design capacity of the Bypass (500,000 cfs at the southern end) is approximately 4.5 times greater than the capacity of the lower Sacramento River, and, consequently, the Bypass is relied on as the principal means of draining the valley during major floods.

The Bypass is approximately 41 miles long and is bounded on the east side and along most of the west side by levees constructed by the USACE. Construction of the levees began in 1917, and the Fremont and Sacramento Weirs (the two spillways that release water from the Sacramento River into the Bypass) were built in 1924 and 1917, respectively. The height and grade of the levees are designed to match the calculated water-surface profile of the design flow, with an extra allowance for freeboard. An 8-mile segment along the western boundary of the Bypass between the South Fork of Putah Creek and 1 mile north of CR 155 has no levee. The natural ground elevation in this area is close enough to the design flood stage that a levee was considered unnecessary.

The conveyance capacity of the southern half of the Bypass was decreased by construction of the Ship Channel along the eastern edge of the Bypass. This channel was completed in 1963. Dredged material excavated during construction of the 30-foot-deep channel was used to build a second levee along the west side of the channel. This interior levee extends from near the I-80 causeway to the southern tip of Prospect Island. The second levee is classified as a navigation levee and is not constructed or maintained to flood control levee standards. However, because it is higher than the original federal flood control levee on the east side of the channel, it constitutes the new east levee of the Bypass for practical purposes.

Various berms and interior levees also partially obstruct the conveyance of floodflows within the Bypass. Land grading within the Bypass is restricted by the Reclamation Board. However, interior or restricted-height levees have historically been allowed within the Bypass to prevent inundation of selected areas from tidal fluctuations and small floods, but the height of those levees, most of which existed when the Bypass was constructed, is limited to minimize flow obstruction during large floods. The heights of these levees were approved on a case-by-case basis. Examples of interior levees include the north levees of Liberty Island and Little Holland Tract, the north and east levees of Egbert Tract, and the levee on three sides of the Mound Ranch (an approximately half-section area adjacent to the West Bypass Levee of the Bypass north of Liberty Island). Other major earthen berms, more or less perpendicular to flow, include the berms that support about half of the length of the I-80 causeway and the nearby Southern Pacific Railroad causeway and portions of the embankment for the abandoned Sacramento Northern Railroad line that cuts diagonally across the Bypass a few miles to the south. The entire lengths of the I-5 and railroad causeways in the Northern Bypass are elevated on pilings that do not significantly obstruct flows.

Floodflows in February 1986 and January 1997 approximately equaled the capacity of the Bypass, and a frequency analysis of peak flows has revealed that both of those floods approximately corresponded to 70-year events (U.S. Army Corps of Engineers 1991; Harris pers. comm.). A 70-year flood is a flood magnitude that has a probability of 1/70 (0.014) of being equaled or exceeded in any year. Water levels were 2–4 feet above the design water surface in some locations and only 2–3 feet below the top of the east flood control levee of the Bypass (U.S. Army Corps of Engineers 1996). In 1986, 1995, and 1997, flooding inundated areas west of the Bypass boundary along the unleveed segment in the Southern Bypass (Hardesty pers. comm.). Some docks in the Port of Sacramento at the northern end of the Ship Channel were only 6 inches above the water surface during the January 1997 flood (Tavana pers. comm.). In spite of these large flood events, none of the Bypass levees have ever failed. However, several Bypass levees have incurred significant damage from wave fetch and other causes during the recent flood events. This damage has included levee slippage and creation of erosion shelves where waves have repeatedly set against the interior levee slopes while the Bypass is inundated.

Floodway Restrictions on Land Use

As previously stated, land use within the Bypass is restricted by easements held by the Reclamation Board. In addition to granting the state the right to inundate the land with floodwaters, the easements preclude landowners from building structures or berms or growing vegetation that would significantly obstruct floodflows. Although the easement language varies slightly from parcel to parcel, it typically states that grantees shall keep the premises free of timber, brush, and tules, which will obstruct the free flow of water over said land. Reclamation Board regulations regarding vegetation and vegetation maintenance standards for floodways and bypasses throughout the state include the following (CCR Title 23, Section 131 [g]):

Invasive or difficult-to-control vegetation, whether naturally occurring or planted, that impedes or misdirects floodflows is not permitted to remain on a berm or within the floodway or bypass.

The Reclamation Board may require clearing or pruning of trees and shrubs planted within floodways in order to minimize obstruction of floodflows.

Section 136 of the regulations includes the following regulations specifically for the Yolo and Sutter Bypasses:

The planting of vegetation or the impoundment of water shall not be permitted in any area where there could be an adverse hydraulic impact.

The planting of vegetation is generally permitted for the development of native marsh, riparian vegetation, and wetlands.

The depth of ponded water must be controlled to prevent the growth of unauthorized vegetation that could adversely affect the operation of the flood control project.

No permanent berms or dikes are permitted above natural ground elevation without a detailed hydraulic analysis, except where otherwise expressly provided for in reservations contained in easement deeds to the Sacramento and San Joaquin Drainage District.

Required maintenance may include removal, clearing, thinning, and pruning of all vegetation directly or indirectly resulting from the permitted project.

State Easements in the Yolo Bypass

Through Working Group meetings, it has become evident that many landowners in the Bypass have little or no knowledge of the parameters expressed in state easements regarding the Bypass. Often, copies of easements did not change hands during the sale of the land to new owners.

Without this information, many landowners have been unaware what specific restrictions are in place on their lands. Many landowners expressed concerns that changes in the management of upstream reservoirs, the construction of the Ship Channel levee, and upstream urbanization have affected and will continue to affect the duration, stage, and frequency of floodwaters in the Bypass. As a result of these concerns, the Working Group felt it was important to research the easement language regarding the Bypass. Because of budget constraints, it was not possible for the project team to conduct an exhaustive analysis of all Bypass easements. However, the team did review numerous easements that were specifically distributed by age and location throughout the Bypass to assess whether differences exist in easement language.

It is important to note that the information presented in this section was not prepared by attorneys and is based on a review of the plain language of the easements. This section should not be interpreted as legal advice. Readers are encouraged to seek the advice of counsel on all legal matters, including the interpretation of easements.

Variation in Easement Format. The earliest recorded flowage easement for the Bypass was 1916 and the latest was 1994. Before the 1970s, easement structure (format of the language) varied from one contract to the next, with the most significant variation occurring before the 1940s. During the 1940s, contract structure became more consolidated to three or four formats, where before that time the structure seemed to depend on the individual situation for which the easement was drawn up. It was not until the 1970s that the structure of the contract became standardized. Even though it took many years to standardize the structure and the contract language prior to this time is not consistent, the basic restrictive parameters of each contract appear to be the same.

Language. As mentioned above, the specific wording from one contract to the next has varied over time. However, these contracts have certain language that appears to make broad restrictions on the lands and allowances for flood inundation of lands.

Early easements appear to allow the Reclamation Board or representatives of the Reclamation Board to maintain the land to make it more conducive for accommodating floodwaters. Later easement wording is more specific to allow the Reclamation Board or representatives of the Reclamation Board to enter the parcel to clear obstructions to floodwaters that are natural or artificial and lists obstructions such as tules, building structures, and ditches.

Easements have evolved over the years from being vague to more specific and from having a variety of formats to having a standardized format. They appear to lack time-specific language that would limit the duration and time of year that floodwaters can inundate lands in the Bypass. They also appear to extend in perpetuity. There is some question as to how far west some easements extend and whether lands located in the unleveed western edge of the Bypass (south of Putah Creek) have been and will continue to be subject to flooding that has not been addressed by easements.

Historical Inundation of the Bypass

The DWR maintains a gaging station at the Lisbon Weir that has recorded water levels in the Toe Drain in the southern part of the Bypass since water year 1935. These records reveal the historical magnitude, frequency, duration, and timing of inundation of the Bypass. The gage datum is a USACE datum, which is 3 feet below mean sea level. Water level at the gage site is tidally influenced and fluctuates between 3 and 7 feet above the USACE datum during low-flow periods. Flow is contained within the channel of the Toe Drain up to a stage of 11.5 feet above the datum. Figure 2-6 shows the periods during which the stage exceeded 11.5 feet during water years 1935–1999, specifically as measured at the Lisbon gage. Inundation occurred in 46 of the 65 years (71% of the years), and the inundation years are scattered fairly uniformly throughout the period of record. However, the record number of successive years without inundation (6 years) and the record number of successive years with inundation (also 6 years) both occurred within the past 14 years.

The cumulative seasonal duration of inundation ranged from 0 to 135 days, as shown in the first graph in Figure 2-7, for each year during 1935–1999. The maximum stage recorded each year at the Lisbon gage is shown in the second graph of Figure 2-7. The stage during the February 1986 flood (27 feet above the USACE datum) slightly exceeded the stage during the January 1997 flood (27 feet), but both of those stages were 2.5 feet higher than the maximum stage in any other year. There is a slight correlation between maximum stage and the duration of inundation for small floods but not for large ones, as shown in Figure 2-8. Because it is critical to avoid flood stages higher than the design stage, additional reservoir releases during major floods are accommodated to the extent possible by increased duration rather than increased release rate.

For farmers, the timing of inundation is more critical than its duration. Inundation in autumn or late spring has much greater adverse impacts on agriculture than midwinter inundation. The earliest recorded inundation began on October 14, 1962, when many summer crops remained unharvested. The impending flood prompted farmers south of I-5 to hastily construct setback interior levees parallel to the Tule Canal in an unsuccessful attempt to limit inundation to a narrow strip along the east side of the Bypass (Dudley pers. comm.). This early flood was highly unusual; in all other years, inundation did not occur earlier than November 18. In spring, inundation later than May 10 occurred in only four of the years of record. Three of those years were in the late 1990s, however, prompting speculation that hydrologic conditions or reservoir operating rules have changed. The latest recorded inundation ended on June 10, 1998. This event can be attributed to exceedingly wet spring weather, which contributed to a new record for the greatest number of days of rain during the water year in Sacramento. The unusual storm in June dropped substantial amounts of rain onto an existing heavy snowpack. The June 1998 flood event significantly damaged crops and equipment in the Bypass, which resulted economic impacts to the farming and private wetland communities.

Trends in Inundation

The two largest floods on record and the largest number of successive years of inundation all occurred within the last 15 years, prompting speculation that the climate has been changing, upstream urbanization has increased runoff rates, or flood operations at upstream reservoirs have changed. Historical time series of inundation duration, peak flows, and annual discharge were evaluated to determine whether the suspected changes have, in fact, occurred. Casual inspection of Figure 2-7 does not reveal an obvious trend in either inundation duration or maximum stage, in spite of the relatively recent occurrence of the two record stages. A linear regression analysis confirmed that neither data set has a trend slope greater than zero at even a 60% confidence level.

The possibility of a long-term climate change was investigated by plotting the annual unimpaired runoff in the Sacramento Valley, also known as the "four rivers index". To develop the index value for each year, unimpaired runoff in four major rivers (Sacramento, Yuba, Feather, and American) are adjusted to remove the effects of storage changes, diversions, and evaporation in upstream reservoirs. The resulting runoff values for water years 1906–1999 are shown in Figure 2-9. No persistent long-term trends are evident in the data. A statistical analysis of the data reportedly indicated that the variability of runoff has been greater during the last 30 years than during the preceding 30 years (Dettinger et al. 1995). To determine whether changes in reservoir operations might have changed the routing of floodwaters to the Bypass, the relationship between the duration of inundation in the Bypass and unimpaired runoff was plotted. The results are shown in Figure 2-10, with values for the recent series of wet years labeled individually. These recent years clearly follow the same relationship that existed in prior years. Therefore, technical analysis indicates that any changes in reservoir operations that might have been implemented in recent decades do not appear to have altered the basic relationship between rainfall runoff and inundation in the Bypass. It is very important to note that these technical assumptions are not shared by several landowners in the Bypass and that these landowners believe that further analysis of related data is necessary to resolve these issues.

The only major reservoir that has experienced a significant change in flood operations in recent years is Folsom Reservoir. A reevaluation of the relative costs and benefits of flood control and water-supply operations following the February 1986 flood led to a decision to increase the amount of storage volume dedicated to flood control from 400,000 acre-feet (af) to a variable volume between 400,000 and 670,000 af (Jones & Stokes 2000). This increase in storage volume decreases the peak outflow during major floods, thereby decreasing the maximum flood stage in the Bypass during those events. The additional flood-storage capacity also provides more flexibility to adjust the timing of controlled storage releases in such a way that the combined peak outflow from all of the major Sacramento Valley reservoirs is decreased during moderate flood events. Technical analysis indicates that seasonal flood-storage-capacity curves, objective releases, outlet capacities, and other elements of flood management operations at other major reservoirs in the Sacramento River watershed have not changed in recent years (Pineda and Hinajosa pers. comms.). However, as previously stated, several landowners in the Bypass do not share these technical assumptions.

Sources of Inundation

The principal inflows to the Bypass are the Fremont and Sacramento Weirs, Knights Landing Ridge Cut, Cache Creek, Willow Slough, and Putah Creek. The relative importance of each of these inflows as sources of flooding can be identified by comparing the timing and magnitude of their historical flows with the timing and magnitude of inundation at the Lisbon gage. Maximum daily flows at Fremont and Sacramento Weirs are plotted above the number of days of inundation at the Lisbon gage for each year during water years 1935–1999 in Figure 2-11, and a similar plot comparing Cache Creek and Putah Creek flows with inundation duration is shown in Figure 2-12. During the period of overlapping record (1947–1998), the years with spills at the Fremont Weir corresponded almost exactly with the years in which there was flooding at the Lisbon gage, and there was a rough correlation between the magnitude of the maximum daily weir flow and the duration of inundation. In contrast, spills over the Sacramento Weir were much smaller and less frequent. Although all of the years with Sacramento Weir spills were also flood years at the Lisbon gage, there was little additional correlation between the data sets.

Further confirmation of the dominant role played by Fremont Weir spills in causing inundation in the Bypass is revealed by a comparison of the timing of individual spill events at the weir and inundation events at the Lisbon gage. Figure 2-13 shows the periods of spills at the Fremont Weir in each year during water years 1935–1999. Detailed comparison of this chart with the corresponding chart of inundation events at the Lisbon gage (Figure 2-6) reveals an almost perfect correspondence between individual spills and individual inundation events. As would be expected, the onset of inundation typically lags a day or two following the onset of spills over the weir, and inundation often lingers 5–10 days after weir spills have ceased. Brief spill events at the weir often do not result in flood stages at the Lisbon gage, which is a predictable result of the large storage capacity of the Bypass.

The relative contributions of the six potential sources of flood inflow can also be identified from continuous hydrographs of daily flows. Development of daily flow timeseries for each of the tributaries during water years 1968–1998 is described in the next section (“Low-Flow Hydrology”), and selected results are presented here. Figure 2-14 shows hydrographs of daily flows during 1995–1998, when hydrologic conditions were relatively wet. Inflows from Fremont and Sacramento Weirs are shown in the top hydrograph, Knights Landing Ridge Cut and Cache Creek are in the second hydrograph, Willow Slough and Putah Creek are in the third hydrograph, Bypass flow at I-5 is in the fourth hydrograph, and the hourly stage at Lisbon Weir is in the bottom hydrograph. The Y axis scales are set to display the full range of flows that occurred during the 4-year period. Note that the Y axis scales for the weir and I-5 flows are about 12 times larger than the Y axis scales for the local tributaries. Figure 2-15 shows the same hydrographs with the Y axis scales expanded ten-fold so that small floods and low flows can be seen more easily.

A comparison of the Fremont and Sacramento Weir hydrographs reveals that Sacramento Weir spills have only occurred during periods when Fremont Weir is already spilling. The Sacramento Weir spills are also consistently of shorter duration and smaller magnitude than the Fremont Weir spills. These relationships are true throughout the complete 1968–1998 analysis period for daily flows. Thus, Sacramento Weir does not cause inundation in the Bypass at times when the Bypass is not already inundated by spills at Fremont Weir.

The hydrodraphs also reveal that major high-flow events in the four local tributaries also coincide with periods of spill at Fremont Weir. By the same token, high-flow events in the tributaries also tend to coincide with one another. This high degree of correlation simply reflects the regional nature of large storms that produce floods. Runoff from the local tributaries are much smaller in magnitude than spills from Fremont and Sacramento Weirs (note that the Y axis on the hydrographs for the weirs spans a range six times larger than the Y axis scale for the hydrographs for the westside tributaries). Among the tributaries, Knights Landing Ridge Cut and Cache Creek contribute substantially more inflow than Willow Slough and Putah Creek. Knights Landing Ridge Cut inflows are typically 30–50% as large as Cache Creek inflows during large floods, but the two sources are more nearly equal during small floods.

The high degree of regulation of Putah Creek (Lake Berryessa holds more than four times the average annual runoff from the drainage area above it) results in infrequent high-flow events that tend to occur in sequences of wet years when the reservoir fills and spills, such as 1995–1999. In contrast, the relatively small, low-elevation, unregulated watershed of Willow Slough generates a relatively large number of small runoff peaks.

The four local tributaries are capable of causing localized inundation within the Bypass in years when Fremont and Sacramento Weirs do not spill. Figure 2-16 shows hydrographs during 1987–1990, when hydrologic conditions were dry and the weirs did not spill. The Y axis scales are the same as the enlarged scales used in Figure 2-15. Runoff events in the westside tributaries are considerably smaller than events that coincide with weir spills. The maximum combined inflows from Knights Landing Ridge Cut and Cache Creek during nonweir-spill periods were about 5,000 cfs in January 1981 and January 1988. The maximum inflows from Willow Slough and Putah Creek were about 1,500 cfs and 1,200 cfs, respectively, in January 1985 (not shown). The magnitude of Willow Slough inflow, during small flood events when Lake Berryessa is not spilling, often exceeds the magnitude of Putah Creek flows.

Overall, spills over the Fremont Weir are clearly the principal source of floodwater during major inundation events in the Bypass. However, other tributaries are capable of independently generating small inundation events that can locally flood agricultural fields along the canals that convey tributary flows across the Bypass to the Tule Canal or Toe Drain. The effects of other tributaries on inundation was investigated by comparing the magnitude of peak flows in those tributaries with stage increases at the Lisbon gage during periods when Fremont Weir was not spilling. For example, Figure 2-17 shows daily flows in Cache Creek (first graph) aligned with the corresponding hourly stage at the Lisbon gage (second graph) during water year 1988, a year in which no spills occurred at the Fremont or Sacramento Weirs. Two runoff events in early December and early January generated peak flows of 3,600 cfs and 2,700 cfs, respectively. These local runoff events increased stage at the Lisbon gage by approximately 1.5 feet over the high end of the normal tidal range. The hourly water levels fluctuate between stages of 3–7 feet above the USACE datum, and the sinusoidal effect of monthly lunar cycles can be seen (in Figure 2-17, the black lines extending down to the X axis are errors in the data set). Tabulating Cache Creek maximum flows and Lisbon stage increases for several similar events resulted in the plot shown in Figure 2-18, which demonstrates that stage at the Lisbon gage increases by about 1 foot for every 2,000 cfs of flow in Cache Creek. The actual increase in flow at the Lisbon gage probably exceeded the inflow from Cache Creek because other local tributaries presumably generated inflow during the same storm events.

The perception among some landowners that flooding from Cache Creek has increased in the past 10 years appears to reflect the wet conditions that prevailed during that decade. There has been no change in Cache Creek watershed conditions or reservoir-flood operations. The largest Cache Creek flow recorded that occurred in the absence of a simultaneous spill at Fremont Weir (about 5,000 cfs) could have caused isolated flooding areas of the Bypass where Cache Creek flows travel to the Tule Canal. However, these flows (5,000 cfs) would not have caused widespread inundation throughout the Bypass. Construction of the Cache Creek settling basin and subsequent raising of its outlet spillway also reportedly affected the distribution of flooding on nearby lands.

Sediment Erosion and Deposition

Erosion and deposition of sediment along the Bypass is not routinely measured but reportedly occurs in various areas. Landowners participating in the Working Group have also reported scour and deposition problems along irrigation canals oriented in an east-west direction, perpendicular to floodflows. Current velocities during floods are large enough to scour the upstream banks of the earthen canals and deposit sediment in or immediately downstream of the canals. One farmer reported that silt deposited on his fields during floods improved the soil texture relative to the underlying native clay loam soil (Schmid pers. comm.). Landowners have also reported that sediment deposited during floodflows and nonfloodflows commonly clogs pump intakes at various locations.

Currents and wave actions cause local scour along the face of the navigation levee on the east side of the Southern Bypass, where the Bypass narrows and the levee deflects the predominant direction of floodflow. Erosion of the West Bypass Levee immediately downstream of the interior levees surrounding the Mound Ranch was sufficiently severe that riprap was planned to have been placed on the Bypass levee slope to maintain its structural integrity. To date, this work has not been completed because of the possibility of Giant Garter snake habitat and potential impact concerns.

The USGS has monitored suspended sediment concentrations in the Bypass in recent years as part of a larger water-quality investigation. These data revealed that suspended sediment concentrations in the Toe Drain rise to a peak near the tail end of a Bypass inundation event (Department of Water Resources 1999). This peak probably results from a shift in dominant current direction during the receding phase of flooding. In full flood, water flows parallel to the longitudinal axis of the Bypass and sediment transport are in the same direction. As the flooding recedes, water begins to flow eastward toward the Toe Drain, which conveys the residual floodwaters to the Delta. This shift in flow direction is accompanied by an influx of suspended sediment into the Toe Drain.

LOW-FLOW HYDROLOGY

In the absence of spills at the Fremont and Sacramento Weirs, the hydrology of the Bypass is dominated by inflows from Knights Landing Ridge Cut, Cache Creek, Willow Slough, and Putah Creek. Base flow discharges from these tributaries may be important sources of water for irrigation supply and the maintenance of aquatic and riparian habitats along the waterways. Moderate or high flows from the tributaries can cause localized flooding and could potentially be used to create floodplain habitat in years without spills at the weirs. A complete set of measured or estimated daily inflows to the Bypass during water years 1968–1998 was developed to assess the timing and magnitude of inflows from the different sources and their respective contributions to water supply and flooding. The 1968–1998 period was selected because it follows the construction of most of the major reservoirs in the Sacramento River watershed and because it includes two droughts and two periods of unusually wet conditions.

Inflows from Cache Creek, Fremont Weir, and Sacramento Weir are gaged, and the data can be used without adjustment. There are substantial periods of missing records for the Fremont Weir, so flows during those periods had to be estimated. Inflows from the other tributaries were estimated by a variety of methods involving subtraction or addition of flows at upstream gages, watershed runoff correlations based on rainfall and drainage areas, and adjustments for seepage losses. The procedures used to develop the daily inflow timeseries for each tributary are described below.

Development of Daily Inflow Data for 1968–1998

Fremont Weir

Spills over the Fremont Weir were gaged by the USGS during water years 1968–1975 and by the DWR during 1984–1998, although data for water years 1984–1995 were not readily available. Fremont Weir spills were found to be closely correlated to flows in the Sacramento River at Verona, immediately downstream of the Fremont Weir. The relationship between Fremont Weir spills and flows at Verona, during the periods for which weir flows were gaged, is shown in Figure 2-19 and was used to estimate daily Fremont Weir flows during 1976–1995. The data are grouped into subsets of the period of record to demonstrate that the relationship varies slightly with time, presumably in response to changes in riverbed configuration or updates of the rating curve for the gage. Nevertheless, the relationship is well defined and fairly stable. The following function fits the data well and was used to estimate Fremont Weir spills during water years 1976–1995:

$Q_F = 0.06\,(Q_V - 56000)^{1.5}$ if $Q_V > 56000$
$Q_F = 0$ if Q_V # 56000

where

Q_F = Fremont Weir spill (cfs)
Q_V = Sacramento River flow at Verona (cfs)

Sacramento Weir

Spills at the Sacramento Weir were gaged by the USGS during water years 1968–1998, and records were complete. These data were used directly in the analysis.

Putah Creek

The stream gage on Putah Creek closest to the Bypass is the South Fork Putah Creek near Davis gage, located at Old Davis Road, approximately 7 miles upstream of the West Bypass Levee. However, the period of record covers only water years 1970–1981, with a number of gaps. The only continuous set of daily flow data for lower Putah Creek during 1968–1998 is the release and spill data for Putah Diversion Dam, located at Lake Solano, 22 miles upstream of the West Bypass Levee. Putah Diversion Dam is a small rediversion dam located 7 miles downstream of Lake Berryessa, a large reservoir impounded by Monticello Dam. Flows between Putah Diversion Dam and the Bypass are affected by seepage losses, tributary inflows, evapotranspiration, and channel storage.

Seepage and evapotranspiration losses are a function of groundwater level, weather conditions, and, to a lesser extent, streamflow. Based on an extensive analysis of flow gains and losses completed by Putah Creek interests, it is reasonable for the purposes of this Bypass analysis to simply assume a constant net flow loss of 25–30 cfs along the 22-mile reach of lower Putah Creek. Tributary inflow from Dry Creek and other minor drainage areas increases small flood peaks in the creek, whereas channel storage tends to diminish small flood peaks. The net result of these effects can be estimated by comparing daily flows at Putah Diversion Dam and Old Davis Road during the period of overlapping record for those two gages. This comparison indicated that inflow from Putah Creek to the Bypass could reasonably be divided into three categories. During periods when flows at Putah Diversion Dam consist entirely of scheduled water-rights releases, inflow to the Bypass equals the releases minus the net flow losses along the channel. During periods when there is active rainfall runoff but no spill from Lake Berryessa, inflow to the Bypass equals two times the gaged flow at Putah Diversion Dam minus net flow losses. When Lake Berryessa is spilling, inflow to the Bypass essentially equals the gaged flow at Putah Diversion Dam minus net flow losses.

This analysis leads to the following function that covers all three flow conditions:

Conditions 1 (scheduled releases only) and 3 (Lake Berryessa spill)

$Q_{YB} = \max(Q_{PDD} - 30, 0)$

Condition 2 (active rainfall runoff)

If: 1) $Q_{PDD} > 60$ (to eliminate scheduled release-only condition), and
2) $Q_{BER} < 900$ (to eliminate Lake Berryessa spill periods), and
3) $Q_{INT} > 100$ (to eliminate noise in the interdam runoff estimates)

Then: $Q_{YB} = \max[(Q_{PDD})(2) - 30, 0]$

where

Q_{PDD} = Putah Creek flow at Putah Diversion Dam (cfs)
Q_{BER} = Outflow from Lake Berryessa (releases plus spills)(cfs)
Q_{INT} = Rainfall runoff from the interdam reach between Lake Berryessa and Putah Diversion Dam (see Willow Slough calculations below)(cfs)
Q_{YB} = Putah Creek outflow to Bypass (cfs)

For consistency, this equation was used to estimate Putah Creek outflow to the Bypass throughout the 1968–1998 analysis period.

Willow Slough

Flows in Willow Slough were not gaged at any time during 1968–1998. For this analysis, daily flows were estimated by correlation with gaged runoff in the interdam reach of Putah Creek, adjusted for drainage area size.

The Willow Slough watershed consists of 55 square miles of upland watershed on the easternmost slopes of the Coast Ranges that drains into sloughs and crosses an additional 136 square miles of flat valley floor terrain before discharging into the Bypass. The topography, soils, and annual rainfall in the upper part of the watershed are essentially the same as in the interdam reach of Putah Creek (Goodridge 1993). Therefore, runoff from the upper watershed can be estimated by multiplying the interdam runoff by the ratio of the drainage areas (55 $miles^2$/41 $miles^2$ = 1.34). Two previous studies have estimated the additional amount of runoff that derives from the valley floor part of the watershed. For an investigation of flood problems along Chickahominy Slough (part of the Willow Slough watershed), the U.S. Soil Conservation Service (1969) estimated that two-thirds of the runoff originated in the upland part of the watershed. The upland part constituted one-third of the total watershed, which indicates a unit runoff four times greater than on the valley floor. An uncalibrated HEC-1 rainfall-runoff model developed by Borcalli & Associates, Inc., for the Willow Slough watershed management plan indicated that the percentage of runoff contributed by the upper part of the watershed increases with storm magnitude (Jones & Stokes Associates 1996). For a 2-year event, the sum of peak flows from upper watershed creeks (1,140 cfs) equaled 55% of the peak flow at Highway 113 (7 miles upstream of the Bypass; drainage area 164 miles^2). For a 10-year event, upper watershed runoff (4,190 cfs) was 83% of the peak flow at Highway 113. Note that peak flows in the upper watershed creeks where they reach the valley floor would often not be simultaneous and that summing them ignores this nuance. This may explain why the unit runoff in the upper watershed is slightly less than 3 times greater than valley floor unit runoff for a 2-year event and 10 times greater for a 10-year event. Inverting these percentages yields the ratio of Highway 113 peak flow to upper watershed peak flow, which decreases from 1.82 for a 2-year event to 1.20 for a 10-year event. A straight-line function between those two points is as follows:

$$\text{Ratio} = (-0.000203)\,(\text{upper watershed peak flow}) + 2.05$$

Finally, runoff at Highway 113 needs to be increased to reflect the additional 27 square miles of drainage area between there and the Bypass. A simple ratio of total drainage areas overlooks the relatively high proportion of runoff from the upper watershed but is probably adequate for the purposes of this investigation because the increase in total area is small. The ratio is 191 miles^2/164 miles^2 = 1.16.

Combining the three steps in converting Putah Creek interdam runoff to Willow Slough outflow to the Bypass leads to the following equation:

$$Q_{WS} = 1.16\{[1.34\ Q_{INT}]\ [(-0.000203\{1.34\ Q_{INT}\} + 2.05)]\}$$

where

Q_{WS} = Willow Slough outflow to the Bypass (cfs)

This is a nonlinear function that simplifies by combining terms to:

$$Q_{WS} = -0.000423\ (Q_{INT})^2 + 3.19\ Q_{INT}$$

A weakness of this methodology is that the two previous studies focused on relatively large peak floodflows, whereas a continuous timeseries of daily flows is needed for this investigation. A potential source of error is that peak flows are often several times greater than mean daily flow for the same day in watersheds of this size and type. Thus, using the results of a peak flow analysis to develop mean daily flows could lead to erroneously high flows. Also, the floodflow analysis did not consider seepage gains and losses along the creek channel, which can greatly alter low flows. A final source of error stems from the estimates of runoff in the interdam reach. This runoff was calculated by subtracting Lake Berryessa outflow from Lake Solano inflow. Lake Solano inflow is not gaged but is calculated by the U.S. Bureau of Reclamation (BOR) as the residual in the daily water balance for Lake Solano. Because of errors in other terms in the water balance and lags caused by the routing time for runoff and Lake Berryessa releases, the estimated runoff from the interdam reach is often negative. All negative values were set to zero for this analysis, but the accuracy of low-flow estimates for Willow Slough is undoubtedly poor. The relative accuracy of flows during typical rainfall-runoff events is probably better, however, and those are the events of primary interest in this investigation.

Cache Creek

The USGS operated a gage on Cache Creek near Yolo (13 miles upstream of the West Bypass Levee of the Bypass) throughout the 1968–1998 analysis period. Records for the gage are complete. There are no significant tributaries or diversions downstream of the gage, and the data were used without modification in the analysis.

Knights Landing Ridge Cut

Knights Landing Ridge Cut is an artificial overflow channel that connects the lower end of the Colusa Basin Drain to the Bypass. The Colusa Basin Drain is a canal that conveys irrigation and drainage water for a distance of 70 miles along the west side of the Sacramento River between Stony Creek and Knights Landing (Figure 1-2). Under low-flow conditions, the drain discharges to the Sacramento River through a set of gates that are operated to maintain a relatively constant water level elevation of 25 feet above the USACE datum on the upstream (drain) side. This elevation is high enough to create ponding along the entire length of the Knights Landing Ridge Cut, thereby allowing farmers to easily access the water for irrigation. A berm is constructed at the Bypass end of the Knights Landing Ridge Cut every spring to prevent the ponded water from flowing into the Bypass. Flows from the Colusa Basin Drain through the gate to the Sacramento River are gaged by DWR. When Sacramento River stage exceeds 25 feet, the gates close and flow in the drain is shunted through the Knights Landing Ridge Cut to the Bypass. These overflows are not gaged.

Daily flows through the Knights Landing Ridge Cut were estimated by extrapolating gaged runoff from part of Colusa Basin Drain's tributary area to its entire watershed. The drain intercepts all of the small creeks flowing from the easternmost slopes of the Coast Ranges between Stony Creek and Knights Landing. The total watershed area tributary to the drain is 130 $miles^2$. DWR operates a second gage about halfway down the drain, where it crosses Highway 20. The drainage area upstream of this gage is 108 $miles^2$. The topography, geology, and annual rainfall in the ungaged part of the watershed are very similar to the corresponding characteristics of the gaged part, so during periods of significant rainfall (days with greater than 0.3 inches of rain at Colusa) runoff from the entire watershed was estimated by multiplying gaged flows at Highway 20 by the drainage area ratio (1.21). No adjustment to the Highway 20 flows was made during periods of little or no rainfall. Flow through the Knights Landing Ridge Cut was estimated by subtracting gaged outflow to the Sacramento River from the estimated total flow arriving at the lower end of the drain.

Figure 2-20 shows gaged flows at Highway 20 and at the outlet gate to the Sacramento River during water year 1996. The two hydrographs demonstrate how flow through the outlet gates drops to zero when the gates close during large storm events. During the summer and fall months, flow at Highway 20 approximately equaled the release to the Sacramento River, suggesting that irrigation diversions and return flows are approximately balanced along the lower half of the drain.

The method mentioned above results in sporadic low flows throughout the dry season as a result of imbalances between diversions and return flows along the lower part of the drain and inaccuracies in the gage records. In reality, most of these flow fluctuations are absorbed by storage changes in the drain and Knights Landing Ridge Cut, although some flow is passed through the impoundment at the Bypass end of the Knights Landing Ridge Cut and allowed to flow across the Bypass to the Tule Canal. Errors in estimated flows during moderate to large rainfall-runoff events are undoubtedly more accurate (as a percentage of total flow) than errors in estimated low flows.

HYDROLOGY CONCLUSIONS

The previous hydrologic analysis was conducted at the request of the Working Group so that they could better understand the impacts and implications of flows from the numerous tributaries to the Bypass. Ensuing discussions based on the presented data resulted in a variety of opinions amongst the Working Group stakeholders regarding the hydrology of the Bypass. Preeminent in these discussions have been the issues of upstream reservoir management and upstream urbanization that would potentially result in floodwaters entering the Bypass in excess of what was historically planned for. In the context of the technical data previously presented, several stakeholders that have an intimate historical knowledge of the Bypass remain unconvinced that conditions in the Bypass have not dramatically changed over time with regard to flood frequency, duration, and stage. Therefore, it is important to note that for the purpose of this document, no consensus conclusion can be reached by the Working Group regarding these flood impact issues. Nonetheless, the following is a summary of specific hydrologic conclusions that can reasonably be made about the Bypass.

- Construction of the Ship Channel has likely impacted the flow capacity of the Bypass, although no historical technical analysis was conducted to confirm this conclusion, and no mitigation was performed as a result of channel construction.

- Interior levees and berms located perpendicular to floodflows, including those associated with highways and railroads, likely cause partial obstructions to floodflows.

- The design flood capacity of the Bypass is at or slightly less than a 70-year flood event and recent extreme flood events in 1986 and 1998 have encroached into the design freeboard of the system.

- The east and west levees incur erosional damage caused by wind-borne wave fetch when the Bypass is inundated adjacent to the levees.

- Inundation of the Bypass occurred in 46 of 65 years (71% of the years from 1935–1999), and the inundation years are scattered fairly uniformly throughout the period of record.

- The record number of successive years without inundation (6 years) and the record number of successive years with inundation (also 6 years) both occurred in the 14-year period from 1986 and 2000.

In all but one event, inundation of the Bypass has occurred no earlier than November 18.

Inundation later than May 10 occurred in 4 of the of 65 years record. Three of those years were in the late 1990s, the latest occurring on June 10, 1998.

A statistical analysis of flow data reportedly indicates that the variability of runoff from the Yuba, Feather, Sacramento, and American River watersheds has been greater during the last 30 years than during the preceding 30 years (Dettinger et al. 1995).

During the period of overlapping record (1947–1998), the years with spills at the Fremont Weir corresponded almost exactly with the years in which there was flooding at the Lisbon gage, and there was a rough correlation between the magnitude of the maximum daily weir flow and the duration of inundation.

All of the years with Sacramento Weir spills were also flood years at the Lisbon gage.

Sacramento Weir spills have only occurred during periods when Fremont Weir is already spilling. The Sacramento Weir spills are also consistently of shorter duration and smaller magnitude than the Fremont Weir spills. Thus, Sacramento Weir does not cause inundation in the Bypass at times when the Bypass is not already inundated by spills at Fremont Weir. It should be, noted however, that the Sacramento Weir is an operated facility, rather than a grade-controlled structure like the Fremont Weir. Furthermore, this summary does not necessarily account for the specific impacts of American River flows.

Putah and Cache Creeks, Willow Slough, and the Knights Landing Ridge Cut are capable of causing localized inundation within the Bypass in years when Fremont and Sacramento Weirs do not spill.