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Real-Time Water Quality Management in the Grassland Water District

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ABSTRACT

The purpose of the research project was to advance the concept of real-time water quality management in the San Joaquin Basin by developing an application to drainage of seasonal wetlands in the Grassland Water District. Real-time water quality management is defined as the coordination of reservoir releases, return flows and river diversions to improve water quality conditions in the San Joaquin River and ensure compliance with State water quality objectives. Real-time water quality management is achieved through information exchange and cooperation between shakeholders who contribute or withdraw flow and salt load to or from the San Joaquin River. This project complements a larger scale project that was undertaken by members of the Water Quality Subcommittee of the San Joaquin River Management Program (SJRMP) and which produced forecasts of flow, salt load and San Joaquin River assimilative capacity between 1999 and 2003. These forecasts can help those entities exporting salt load to the River to develop salt load targets as a mechanism for improving compliance with salinity objectives. The mass balance model developed by this project is the decision support tool that helps to establish these salt load targets.

A second important outcome of this project was the development and application of a methodology for assessing potential impacts of real-time wetland salinity management. Drawdown schedules are typically tied to weather conditions and are optimized in traditional practices to maximize food sources for over-wintering wildfowl as well as providing a biological control (through germination temperature) of undesirable weeds that compete with the more proteinaceous moist soil plants such as swamp timothy, watergrass and smartweed. This methodology combines high resolution remote sensing, ground-truthing vegetation surveys using established survey protocols and soil salinity mapping using rapid, automated electromagnetic sensor technology. This survey methodology could be complemented with biological surveys of bird use and invertebrates to produce a robust long-term monitoring strategy for habitat health and sustainability.

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CHAPTER 1 INTRODUCTION

1.1 Background

California's Central Valley is the most important wintering area for migratory waterfowl within the Pacific Flyway (Figure 1). However, over 90% of California's wetlands have been eliminated through agricultural expansion and urban development (Campbell, 1988; USFWS, 1999). Historically, much of California's Central Valley was an arid plain dominated by grasses and low shrubs. In the lower-lying areas adjacent to the San Joaquin River large wetland complexes existed. During the wet season, much of the area was transformed into marshes. These wetlands supported an abundance of native vegetation, migratory waterfowl, shorebirds, and other wildlife (Stoddard & Associates, 1986; Campbell, 1988; Isola, 1998).

Figure 1.1 The Pacific Flyway for California waterfowl.

Over time, as more people immigrated to California, land in California was rapidly acquired by settlers. One of California's largest land owners in the early 1900's was the Miller and Lux Cattle Corporation (Miller and Lux). The area encompassing the present day Grassland Basin was once a part of the Miller and Lux land holdings (Grassland Water District, 1986) When Miller and Lux began selling portions of its land holding to market hunters and

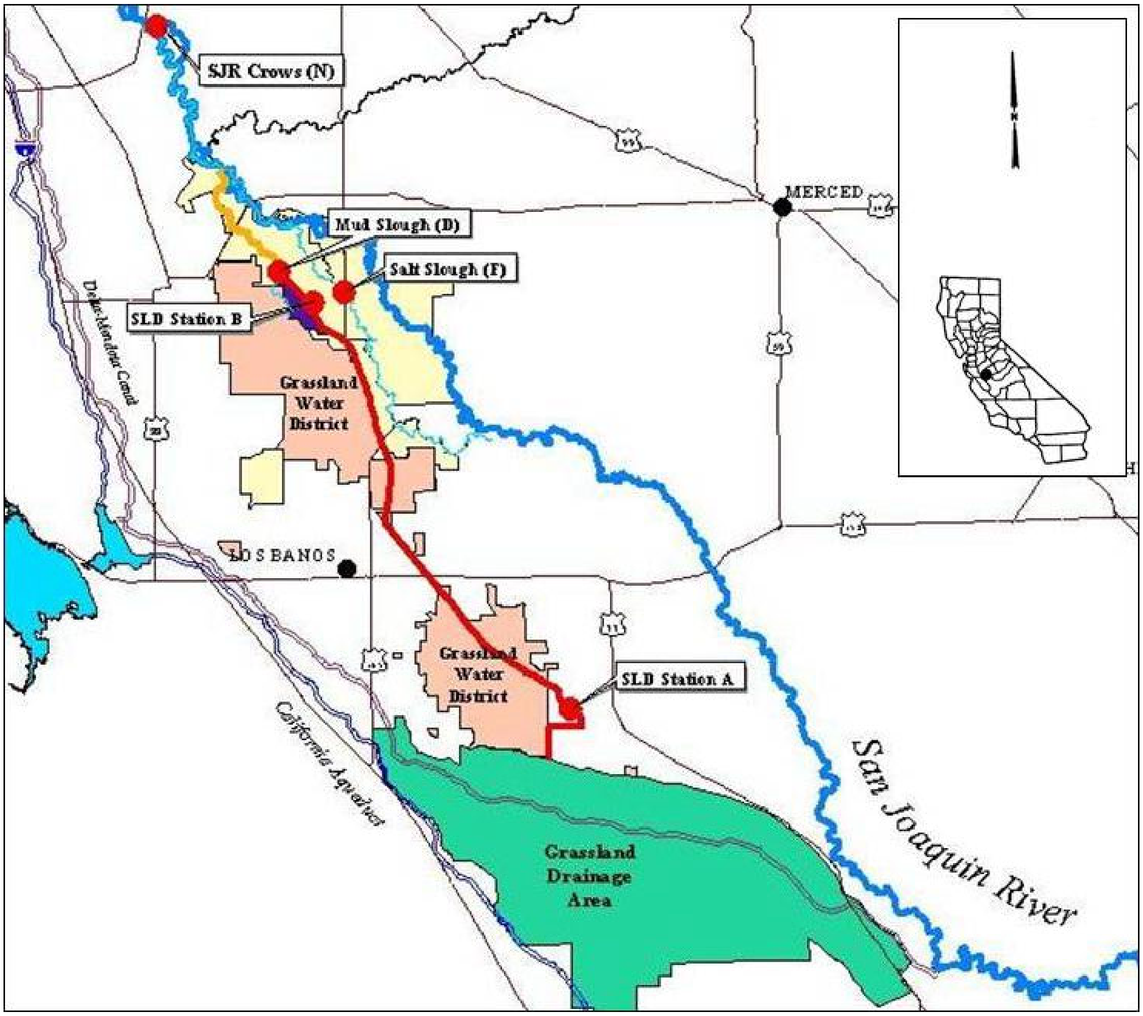


Figure 1.2. The Grassland Ecological Area within the San Joaquin River Basin.

recreational hunters in 1926, the corporation retained most water rights, thus centralizing this vast resource under one entity (Grassland Water District, 1986; Stoddard & Assoc., 1998). In 1939, the U.S. Bureau of Reclamation acquired the water rights from the Miller and Lux Company to develop the Central Valley Project (CVP), which allowed reclamation to expand irrigation service to the southern san Joaquin Valley by trading San Joaquin River water supply with surface water pumpage from the South Delta.. Throughout its history the Grassland Water District GWD has received insufficient water supply to meet demand and to restore the wetlands within the District to a pre-development condition. The problem of in-adequate water supply has been compounded in recent years by concerns over supply water quality and most recently by environmental constraints to salt loading to the san Joaquin River.

1.2 Study Area

The San Joaquin River, flowing northward through California's Central Valley, is a major hydrologic contributor to the Sacramento-San Joaquin Delta. The SJR system, including the river and its associated drainage basin, provides significant social, environmental, and economic benefits (Grassland Water District, 2001). The river system also provides water supply and drainage conveyance for agriculture, wetlands, upland and riparian areas, municipalities and industries. Current uses have resulted in a significant degradation of water quality, the loss of fish and wildlife habitat, a reduction in flood protection capacity, and a shortage of recreational opportunities. The San Joaquin River is a highly constrained system (i.e. over allocated and heavily regulated), hence uncoordinated actions often pit some beneficial uses of the river against others, resulting in deterioration of the overall health of the river system.

The Grassland Water District (GWD) is divided into two major land areas. The Northern Division of the GWD (NGWD) is located roughly between the town of Gustine to the northwest and Los Baños to the south. The San Luis National Wildlife Refuge borders the NGWD to the north and east. The western boundary of NGWD consists of the Volta Wildlife Management Area, uplands and agricultural lands between the towns of Gustine and Los Baños. Henry Miller Road and the town of Los Baños roughly constitute NGWD's southern boundary. The Southern Division of the GWD (SGWD) lies between Los Baños to the northwest and the Fresno County Line to the southeast. Highway 152 and the town of Los Baños border the SGWD to the north. The towns of Dos Palos and South Dos Palos border it to the east, and the southern and western boundary lies roughly along the main canal.

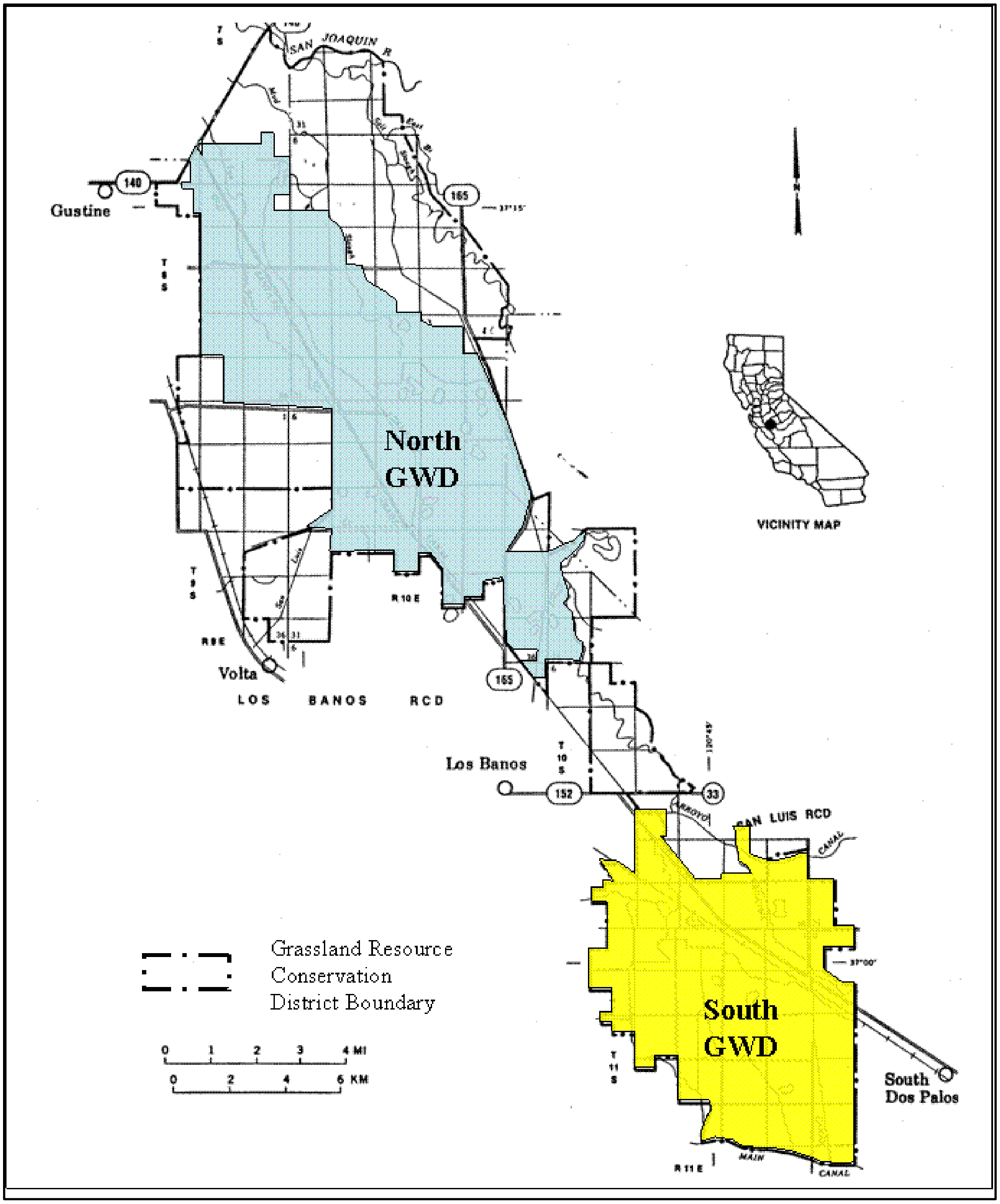


Figure 1.3. Grassland Water District split into Northern and Southern Divisions

1.3 Topography

The topography of the GWD appears flat, with an average slope of less than 2%. There is a general downward slope toward the northeast. The GWD has a peak elevation of 130 feet above sea level at the southern boundary and drops to 74 feet at the northern boundary near the SJR (Stoddard & Assoc., 1986).

1.4 Climate

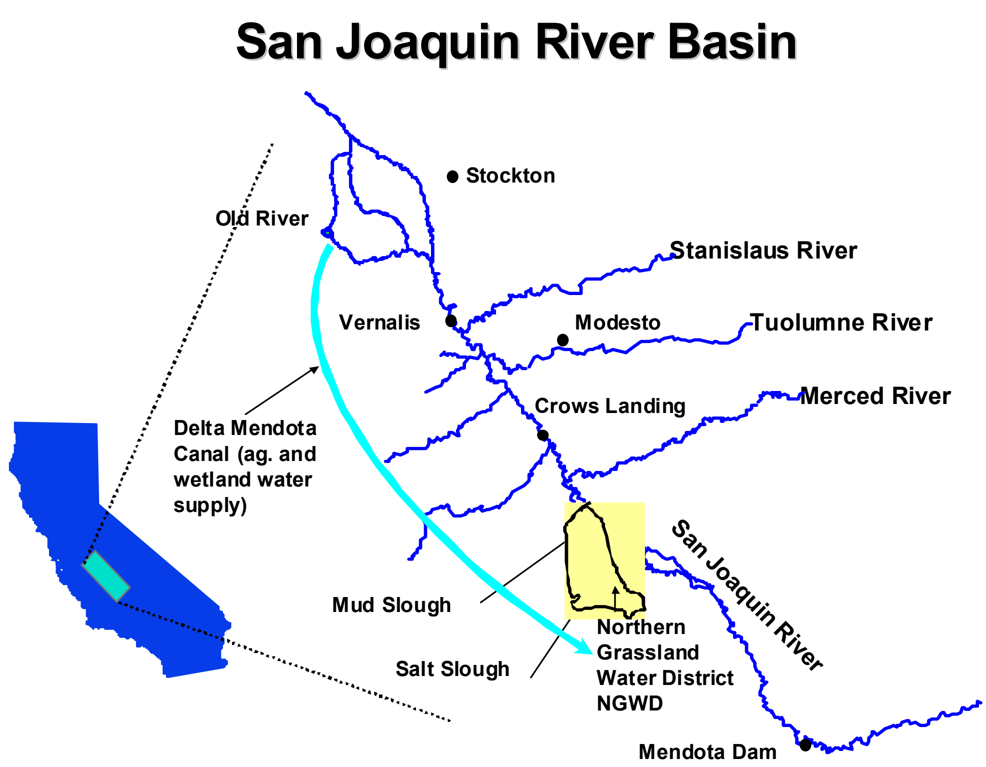
Regional climate in the San Joaquin Valley resembles Mediterranean conditions – warm, dry summers and cool, damp winters (Rundel and Vankat, 1989). During the summer temperatures often exceed 100 degrees Fahrenheit and produce an evaporation potential of 90+ inches per year, although average precipitation at the valley floor is only ten inches (Grassland Water District, 1986). California's precipitation and streamflow are highly variable - climatic anomalies induced by El Nino and la Nina conditions cause extreme events and anomalies in California's weather patterns. California is affected by pressure systems generated over the Pacific Ocean (Kahya and Dracup, 1994; Piechota et al., 1997).

1.5 Hydrology and Hydraulics

Wetland hydrology is dictated by the regional flooding regime. Within the GWD, this regime is managed artificially to maintain standing water from mid-September through mid- to late-April (Grober et al., 1995; Quinn et al., 1997; Quinn and Karkoski, 1998). Historically, floodplain inundation and wetland hydrology was more variable, caused by flood flows in the San Joaquin River resulting from from winter rains and spring snowmelt. Surface and groundwater regional flow in the GWD is from the south-west to the north-east, following the regional topography. The area includes three natural drainages. These drainages are Mud Slough and Los Baños Creek in the northern region and Salt Slough in the southern region. In addition to these historic drainages, there are numerous constructed channels, ditches, drains, culverts, gates, and siphons throughout the GWD.

1.6 Water Supply

The Grassland Water District is the entity responsible for supplying water and drainage capacity to approximately 50,000 acres of privately owned historical wetlands, uplands, and agricultural lands west of the San Joaquin River and uses the River for conveyance of wetland drainage during the spring months (March - May) each year. The GWD, together with the adjacent State and Federal refuges, constitute the largest contiguous wetland complex remaining in the State of California (~160,000 acres) (Grassland Water District, 1986; Shuford et al., 1998). These wetlands are remnants of a much larger wetland complex that extended throughout California's Central Valley. As more and more of California's wetlands are lost to development, this area's value to wildlife increases proportionately (USFWS, 1999). In turn, as the area's wildlife value increases, so must the intensity of wetland management.



San Joaquin River Basin showing Northern Grassland Water District (NGWD) and the two major west-side wetland drainage conveyances Mud and Salt Sloughs. Water supply to agriculture and wetlands in the Grassland sub-basin is provided through pumping from the Sacramento-San Joaquin Delta via the Delta Mendota Canal. Adapted from CRWQCB, 2000.

Figure 1.4. Surface water supply canals and drainage service to Grassland Water District.

The GWD receives most of its water supply from the Central Valley Project (CVP) (Grassland Water District, 1986; Stoddard & Assoc., 1998; Letey, 2001). Canals originating in the Sacramento - San Joaquin Delta now feed an area that once was flooded by the San Joaquin River. Prior to the Central Valley Project Improvement Act (CVPIA) in 1992, the CVP provided the GWD with 50,000 acre feet of water per year--roughly one foot of water per acre per year. In the past, during dry and critically dry water years the GWD often could experience reductions of up to 75% of its annual supply (Grassland Water District, 1986). Hence the GWD was forced to secure necessary maintenance water from local agricultural drainage. These supplies often contained additional pollutants including salts, selenium, and boron. Use of these agricultural return flows ceased in 1985 by mandate after the recognition of selenium toxicosis in migratory waterfowl nesting in what was once Kesterson Reservoir. The selenium issue brought about a significant change in the way environmental water quality was considered in California and helped to bring about one of the largest reforms in water allocation policy in the nation's history.

1.7 Central Valley Project Improvement Act

In October 1992, Congress passed a Western water bill that included, as a major provision, the CVPIA. The CVPIA mandated major changes in the operation of the Central Valley Project (CVP). The CVP was constructed by the U.S. Bureau of Reclamation in 1935 to permit surface water to be diverted from both the Sacramento and San Joaquin Rivers for farmland in the San Joaquin Valley. In addition to supplying agricultural irrigation water, other benefits such as flood control, navigation, power generation, and municipal and industrial water supply were realized by the CVP. Shasta and Keswick dams on the Sacramento River as well as Friant Dam on the San Joaquin River were among the first units built. Canals such as the Friant-Kern, the Madera, the Delta Cross Channel, and the Delta-Mendota Canal were designed to transport and deliver surface water supplies throughout the San Joaquin Valley. With the CVP the origin of water supply for entities such as the Grassland Water District (and later – the State and Federal refuges) was transferred from the Sierra Nevada mountain range and the San Joaquin River to the Sacramento-San Joaquin River Delta and pumped south through the Delta Mendota Canal.

One of the key provisions of the 1992 CVPIA legislation was a recognition that the CVP water allocations to San Joaquin Basin wetlands were inadequate to provide sustainable wetland habitat. Hence the Act dedicated 800,000 acre-feet of water from the CVP primarily for fish and wildlife purposes. A goal of the legislation was to increase wetland supply water from a Level II maintenance allocation to a Level IV optimal allocation. The GWD and the surrounding State and Federal wildlife refuges have been recipients of some portion of this reallocated water supply.

Increased water supply allocations under the CVPIA have improved wildlife habitat but have also resulted in increased seasonal wetland drainage, producing more flow and salt loading to the San Joaquin River. This has, in turn, created opportunities to coordinate the release of seasonal wetland drainage with the assimilative capacity of the San Joaquin River. Coordinated releases of west-side agricultural and wetland drainage with east-side reservoir releases can potentially help to achieve salinity objectives in the main stem of the San Joaquin River and and improve fish habitat in the Sacramento-San Joaquin Delta. Improved scheduling of west-side discharges can assist in avoiding water quality violations and remove an important stressor leading to improvements in the San Joaquin salmon fishery

1.8 Wetland management

Preservation and enhancement of wetlands in California's Central Valley is important to ensuring wildlife and habitat diversity. The regional wetlands are home to millions of waterfowl and shorebirds, a diverse community of moist-soil vegetation, and other common and endangered wildlife (Mason, 1969; Small, 1974; Cogswell, 1977; Grassland Water District, 1986; Stoddard and Associates, 1998; Shuford et al., 1998; Sibley, 2000). Because of the great importance of this wildlife, management practices (BMPs) for wetland management have been developed. Depending on the goals, these BMPs can include grading, discing, mowing, grazing, burning, herbicide application, dry season irrigations, and the timing of wetland flood-up and drawdown. By timing flood-up and drawdown in the San Joaquin Valley, managers mimic the wet/dry seasonal cycle that these historical wetlands once experienced. This seasonal cycle aids life's processes and can be adapted to promote desired species (Frederickson and Laubhan, 1995).

Under "natural" conditions, this diversity would be supported through seasonal flooding and natural disturbances (drought, fire) that historically followed the seasonal cycle. However, due to anthropogenic effects (water projects, agricultural and urban development, etc.), the hydrologic regime that once defined these annual cycles in the Central Valley no longer exists. To mimic these natural processes, research has been undertaken to understand the role of water manipulation, irrigation, waterfowl habitat requirements and both vegetation and waterbird responses to different management techniques. Altering wetland drainage schedules affects the timing and rate of drawdown of wetland ponds and hence the forage value of the wetlands for migrating and wintering shorebirds and waterfowl. Wetland salinity management measures also affect the productivity and diversity of vegetation that can be grown in the watershed (Rosenberg and Sillett, 1991; Mushet et al., 1992).

1.9 Seasonal wetland management

Wetland management, as practiced in California's Central Valley, covers a broad range of activities. These activities may include various intensities of land grading, vegetation discing and burning, the application of herbicides and pesticides, agricultural activities such as grazing cattle or growing rice, and irrigation. Due to anthropogenic alterations in natural hydrology, these wetlands are flooded artificially with Central Valley Project water supplies delivered through GWD canals. The fall flood-up occurs during the months of September and October, and the spring drawdown occurs during the months of February, March, and April.

Wetland drawdowns are timed to make seed and invertebrate resources available during peak waterfowl and shorebird migrations and to correspond with optimal germination conditions (primarily soil moisture and temperature) for naturally occurring moist-soil plants (Smith et al., 1995). Spring drainage that is timed for optimal habitat conditions occurs at a sensitive time for agriculture in the South Delta in that these drainage releases occur during the time crops are being irrigated or the first time and are germinating – potentially affecting crop yields. Studies suggest that approximately 10% of the San Joaquin River's annual flow, and 30% of its annual salt load, passes through wetlands within the Grasslands Basin, which includes the Grassland Water District (Grober et al., 1995; Karkoski et al., 1995; Quinn et al., 1997; Quinn and Karkoski, 1998).

1.10 Moist-Soil Management

The wetland "best management practice" (BMP) specific to this research project focuses on water level manipulation and is most often called "moist-soil management". Moist-soil management refers to a process of water level manipulations to promote productive habitat conditions and beneficial vegetation such as smartweed (*Polygonum punctatum*), watergrass (*Echinochloa crusgalli*), and swamp timothy (*Heleochloa schoenoides*) for foraging

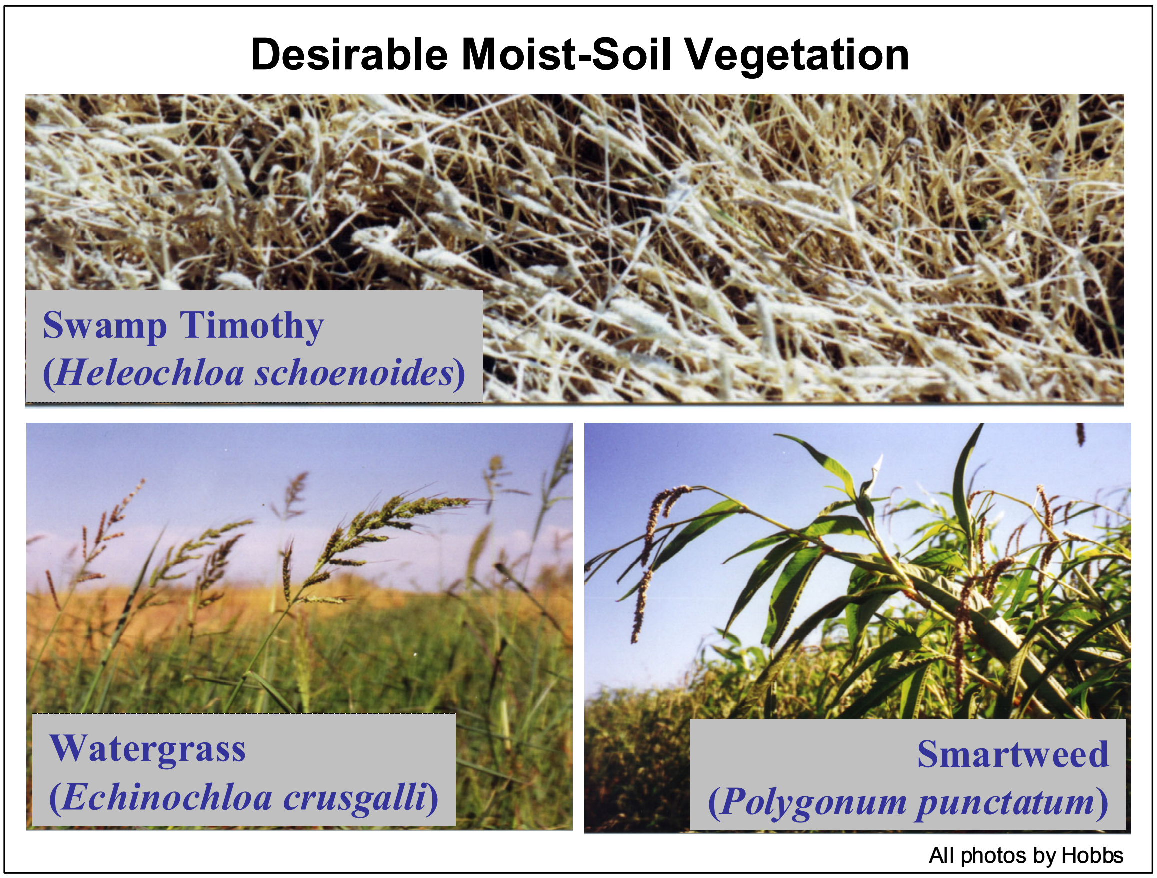


Figure 1.5 Desirable moist-soil plant vegetation.

waterfowl (Figure 1.5). Water-level manipulations include flood-up in the fall and wetland drawdown in the spring, and provide optimal conditions at each stage of vegetation development. In addition to flood-up and drawdown, several summer irrigations are

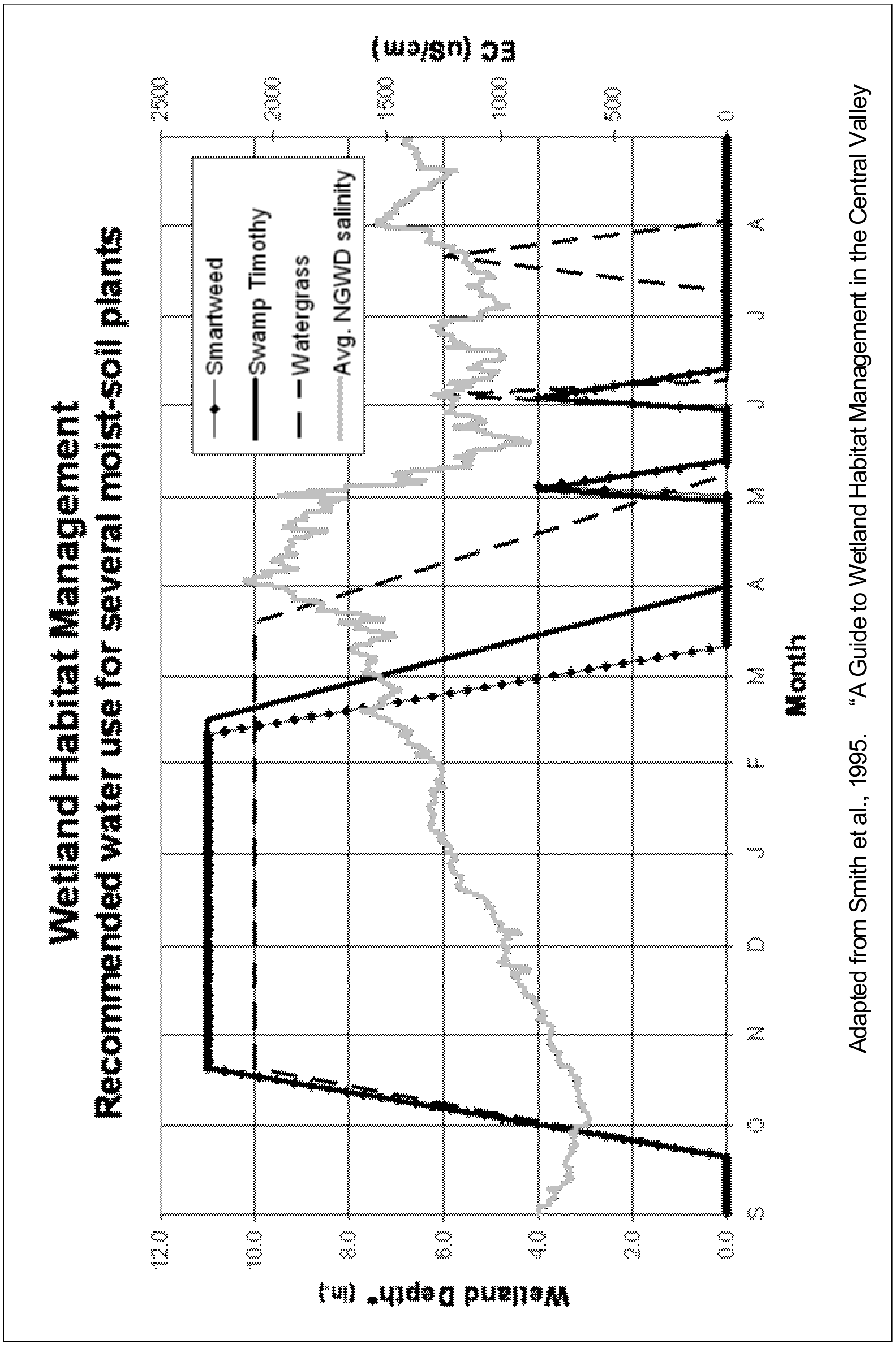


Figure 1.6. Recommended irrigation schedules for certain desirable moist soil plants.

conducted by wetland managers to sustain and improve growth characteristics of the desired vegetation (Figure 1.6). The seeds of moist-soil plants are recognized as a critical waterfowl food source, providing essential nutrients and energy for wintering and migrating birds (Fredrickson and Taylor 1982; Bundy, 1997; Shuford et al. 1998). Not only does the desirable vegetation provide direct nutritional value through consumption, but it also encourages healthy invertebrate populations, a high-protein food source at critical times of the year (Swanson, 1988; Mushet et al., 1992; Smith et al., 1995; Bundy, 1997; Stoddard and Associates, 1998).

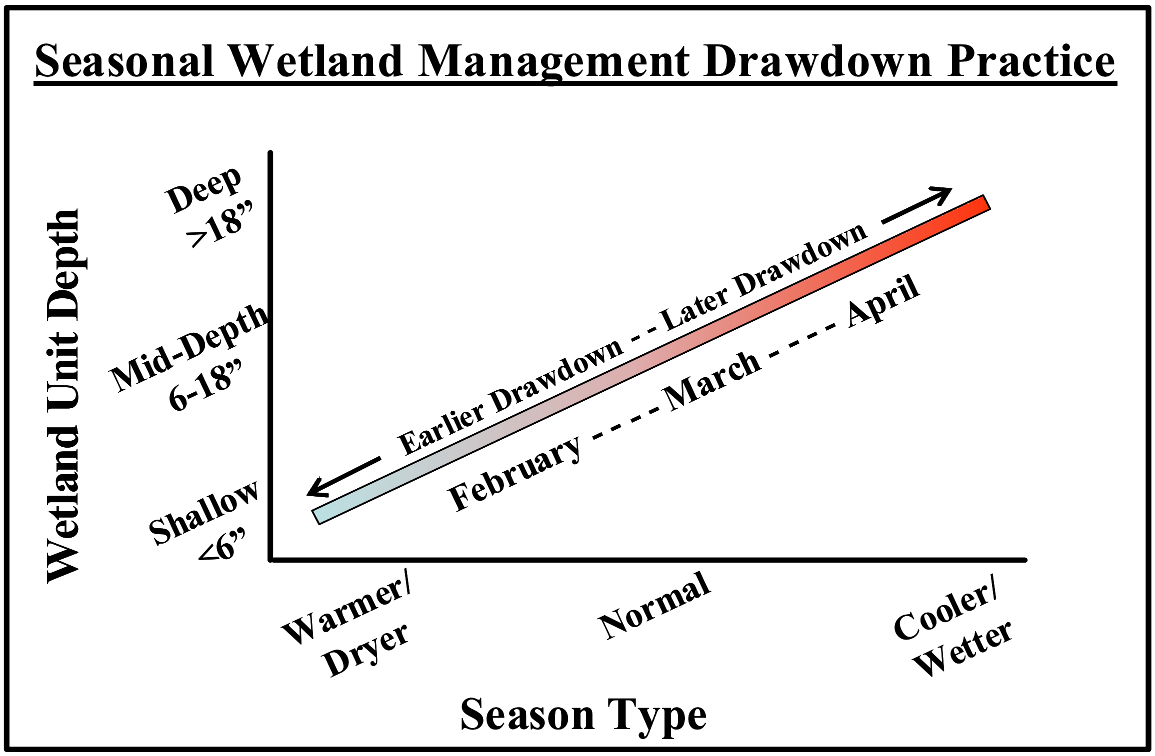


Figure 1.7 Seasonal wetland drawdown practice in the Grassland Water District.

It is generally accepted by wetland managers that during cool wet years, and for wetlands of greater depth, it is better to drain them later because the optimal conditions of soil temperature and soil moisture tend to occur later. Conversely, during warm dry years, and for shallower type wetlands, it is better to drain them earlier because the optimal conditions of soil temperature and soil moisture tend to occur earlier. However, in intensively managed wetland complexes such as the GWD, the heterogeneity of wetland soils, year to year variations in the weather and the complex dynamic ecology of the wetland resource require constant hydrologic manipulation and fine tuning of management decisions by wetland biologists.

1.11 Moist-Soil Vegetation

Many different species of vegetation grow within the GWD. Together they form a mosaic of vegetation communities that provide the habitat required to sustain wildlife. Wetland managers often classify this vegetation, either native or naturalized, into two categories: desirable or non-desirable. Desirable plants include native species that form a healthy mixed marsh or that can provide shelter or food stores to migratory waterfowl and shorebirds. Non-desirable plants are often invasive/introduced species and may consume resources (such as light and soil) that otherwise would go to desirable species.

There are generally three major desirable moist-soil plant communities that are targeted for waterfowl forage potential. These targeted communities are found in a mixed marsh setting and are either dominated by smartweed, swamp timothy, or watergrass. A healthy mixed marsh for the San Joaquin Valley could include several other desirable species such as sprangletop (*Leptochloa fascicularis*), brass buttons (*Cotula coronopifolia*), and alkali heath (*Frankenia grandifolia*). While targeting one of the highly desirable plants in the mixed marsh such as swamp timothy, wetland mangers also promote the other listed species (Smith et al, 1995). Several other acceptable plants work well in a mixed marsh community and can include, but are not limited to, tule or hardstem bulrush (*Scirpus acutus*), cattail (*Typha latifolia*), spikerush (*Haleocharis palustris*), purple ammannia (*Ammannia coccinea*), alkali bulrush (*Scirpus robustis*), fat-hen (*Atriplex patula*), and beggar-ticks (*Bidens spp.*).

The three desirable plants above, swamp timothy, watergrass, and smartweed, have a tendency to grow in large stands, bordered by mixed marsh consisting of desirable plants along with other acceptable plants. As conditions change (drainage plans, for instance), so does the composition of the stands and border areas. Wetland mangers target species by means of water manipulation and other management practices (i.e. flood-up and drawdown plans, disturbance, dry season irrigation, alternative land use).

However, there are several non-desirable plants that tend to establish a stronghold when conditions are not ideal for the more desirable plants. These non-desirable plants include, but are not limited to, aster (*Aster spp.*), cocklebur (*Xanthium strumarium*), salt grass (*Distichlis spp.*), Bermuda grass (*Cynodon dactylon*), and dock (*Rumex spp.*). These species grow in dense stands and can dominate the more desirable wetland species if unchecked (Smith et al, 1995).

1.12 Wetland Management Programs

The wetlands of the GWD are managed from an institutional perspective under different programs to achieve certain policy goals. The nearly 100 individual properties in the GWD are managed to attract waterfowl during the migratory season, particularly during the months when waterfowl hunting occurs (October through January). However, when the hunting season ends, different management strategies are employed. Some waterfowl clubs, during the off-season, provide grazing for cattle. Management of a "cattle club" necessitates early drawdown in late January to early February to promote the emergence of grasses for livestock. Although this management objective is sub-optimal for avian food production in seasonal wetlands, it has benefits for salinity management by allowing salt load to be exported earlier than would be typical in the Basin. More traditional duck clubs, managed specifically for their habitat resource, encourage desirable plant species for food and cover vegetation for migratory waterfowl. This management objective more closely mimics the wet/dry cycle needed to promote desired wetland species, and thus is recognized as being "wildlife friendly" by public, private, and non-profit entities alike (US Department of Agriculture [USDA], the California Department of Fish and Game [DFG], the California Waterfowl Association [CWA], and Ducks Unlimited [DU]).

Two habitat management programs provide funding for wetlands in the Grassland Water District. The Pressley Program is sponsored by the California Department of Fish and Game and Waterbank (soon to be the Conservation Resource Program or CRP) is managed by the

US Department of Agriculture. Both the State and Federal programs promote managing wetlands for optimal habitat conditions while paying the landowner an annual allowance per acre included in the program. Historically, the Pressley Program tends to put slightly more emphasis on over-wintering conditions and food supply for migratory waterfowl, whereas Waterbank emphasizes brood water habitat to provide spring breeding water.

1.13 Impacts of Wetland Management on the San Joaquin River

The wetlands of the GWD are flooded in the fall with water supplied by the Delta-Mendota Canal. These water supplies for the GWD contain varying concentrations of salt, with a dissolved salt concentration (measured as electrical conductivity) in the range of 500 to 1,000 microSiemens per centimeter [uS/cm] (375 to 750 mg/L). As the flooded season progresses, the ponded water increases in salinity as a result of the processes of direct evaporation and evapotranspiration from emergent wetland vegetation as well as through contact with the environment (soil residues, ground water inputs, bird usage, etc.). When the flooded season ends spring releases are discharged into tributaries of the Lower San Joaquin River. These releases, along with agricultural and municipal return flows, contain varying loads of total dissolved solids (TDS) and boron. These constituents have been identified as stressors that lead to frequent exceedance of water quality objectives established for the San Joaquin River by State and Federal agencies (Grober et al., 1995; Quinn et al., 1997).

This spring drawdown in the seasonal wetlands is timed for optimal germination conditions for the most desirable moist-soil vegetation. However, at times these spring releases coincide with higher salt concentrations in the SJR during lower flows and with downstream agricultural withdrawals from the SJR. Peak assimilative capacity typically occurs between the months of January and April. This period is often earlier than the traditional wetland drawdown period (February – April). The response of moist-soil plants and of migratory waterfowl and shorebirds to an altered drawdown regime that would coincide with the highest San Joaquin River assimilative capacity for salt is unknown. Experimentation necessary to determine these impacts will help to identify potential impacts on seed germination rates, waterbird foraging rates, habitat availability, and species diversity and abundance. It is possible that early, experimental drawdown may make food sources available to wildlife without negatively effecting wetland vegetation community and plant species diversity, hence benefiting both wildlife and the health of the San Joaquin River.

1.14 San Joaquin River Management Program

To improve flow and water quality conditions in the San Joaquin River system, the California Department of Water Resources formed the San Joaquin River Management Program (SJRMP), a stakeholder group representing many of the agencies, landowners and other parties interested in improving the San Joaquin River ecosystem. One of the SJRMP's mandates was to reconcile and coordinate the various uses and competing interests along the river. The SJRMP created a number of working subcommittees – one of which was the Water Quality Subcommittee. This subcommittee applied for grants, one of which supported early work on real-time water quality management in the SJR. One of the Water Quality Subcommittee's initial tasks was to develop solutions to address the occurrence of high salinity levels in the lower San Joaquin River at certain critical times of the year such as the onset of pre-irrigation in Delta agricultural lands.

Studies conducted initially under the SJRMP and subsequently by Berkeley National Laboratory, have suggested that wetland drainage from the GWD could be scheduled to coincide with peak assimilative capacity in the San Joaquin River to help improve downstream water quality (Grober et al., 1995; Quinn et al., 1997; Quinn and Karkoski, 1998). Increased surface water supply allocations under the Central Valley Project Improvement Act (CVPIA) have created greater opportunity than existed previously to coordinate the release of seasonal wetland drainage with the assimilative capacity of the San Joaquin River. Coordinated releases will help achieve salt and boron water quality objectives and improve both downstream agricultural draws and fish habitat in the main stem of the San Joaquin River and Sacramento-San Joaquin Delta. Improved scheduling of west-side discharges can assist in avoiding conflict with critical time periods for early season irrigation as well as fish rearing and remove an important stressor leading to improvements in the San Joaquin salmon fishery (Quinn and Delamore, 1994; Grober et al., 1995; Karkoski et al., 1995; Quinn et al., 1997; Quinn and Karkoski, 1998).

The research conducted as part of the "Real-Time Adaptive Wetland Water Quality Management in the Grassland Water District" project focused on better coordinating salt loading from the Grassland Water District with the assimilative capacity for salts in the SJR. To assess the feasibility of such a reconciliation, experiments have been conducted within the 30,000 acres of seasonal wetlands in the Northern Division of the GWD (NGWD). Management of wetland drainage through scheduling of releases to coincide with periods of SJR assimilative capacity can improve the river's water quality. This project provides a systematic data collection program to evaluate the short and long-term consequences of real-time wetland drainage management.

1.15 Coordination between Wetland Management and the San Joaquin River

Management of wetland drainage, through scheduling of releases to coincide with periods of San Joaquin River assimilative capacity, can help improve San Joaquin River water quality and improve compliance with water quality objectives. These objectives were set by the California State Water Quality Control Board (SWQCB) as a result of a lawsuit between the South Delta Water Agency and the USBR that showed the need for salinity objectives to protect south delta agricultural interests. Hence, these objectives were set to protect downstream riparian irrigators who use the San Joaquin River as their sole water supply and to protect the salmon fishery (Grober et al., 1995; Quinn et al., 1997; Quinn and Karkoski, 1998). However, these actions may need to be considered relative to potential biological impacts of changes to traditional wetland management practices. Increased CVPIA water allocations, while increasing the flexibility of the operation of seasonal wetlands and improving the quality of seasonal wetland return flows, also increase the total salt load discharged to the San Joaquin River.

Late season wetland releases (April) containing high salt loads can impact salinity levels in the lower San Joaquin River system. The negative impacts are twofold:

- High salinity releases that coincide with agricultural pre-season irrigation downstream can inhibit germination and reduce crop yields; and
- Salmon can become confused during their annual migration when high flows from sloughs carry high volumes of drainage water.

1.16 Decision Support

Depending on the water year type (wet, normal, dry, etc.), wetland drawdown from the NGWD and adjacent refuges can contribute significant salt load to the SJR. The real-time wetland water quality management project was conceived to complement the salinity assimilative capacity forecasting project led by the SJRMP Water Quality Subcommittee during the 2002 ands 2003 drawdown periods. Since there was no continuous monitoring of salt loads leaving the GWD at the onset of the project, the project required the installation of a series of wetland monitoring stations at the inlet to the NGWD and the multiple drainage outlets from the NGWD. A decision support system (DSS) was developed to help manage this information and readily provide it in a form wetland managers could use. This DSS helps wetland managers to make drawdown scheduling decisions and to manage salt export to coincide with periods of significant San Joaquin River assimilative capacity.

With the installation and operation of the water quality monitoring network, real-time wetland water quality data were collected and the results disseminated and used to calibrate a wetland water quality model (WWQM) developed specifically for this project. The WWQM, which is described in more detail in Chapter 3, was used in conjunction with two-week flow and salinity forecasts for the main stem of the San Joaquin River, to allow the impacts of different wetland drawdown schedules to be simulated and compared. These simulations have allowed GWD staff to play "what-if" games, working through the constraints imposed by the Grassland WD conveyance system while exploring potential benefits to salinity conditions on the San Joaquin River leading to potential long-term improvements in coordination.

A common concern among wetland managers is the impact of potential long-term adjustments to drawdown schedules on the propagation of desirable moist soil plants and the ecological health of the wetland ecosystem. In response to this concern a remote habitat assessment methodology (RHAM) was devised and integrated into the monitoring and assessment program to guide drawdown planning decisions and to ultimately protect the wetland resource. The RHAM uses high-resolution satellite imagery and pattern recognition routines to quantify wetland and upland vegetation. By taking a succession of images, a time series of vegetation conditions can be compiled, and spatial changes in vegetation conditions easily tracked. These long-term changes in vegetation communities can then be related to management decisions to better understand the extent of their impact. The RHAM is discussed in Chapter 4.

1.17 Research Objectives

This CALFED sponsored study had the following objectives:

1. To develop, construct, and maintain a real-time flow and salinity data acquisition network to aid seasonal wetlands drainage management.
2. To develop a wetland water quality model (flow and salinity mass balance) focusing on exports from the Grassland Water District to the San Joaquin River.
3. To experiment with adaptive wetland drawdown schedules to better coordinate salt loading from the Grassland Water District with the assimilative capacity of the San Joaquin River.
4. To develop a habitat assessment methodology for measuring the impacts of changes in seasonal wetland drawdown schedules on moist-soil plant production and habitat health.

1.18 Research Procedures

These objectives are accomplished in this study as follows :

1. To develop, construct, and maintain a real-time flow and salinity data acquisition network to aid seasonal wetlands drainage management.

A real-time wetland water quality network was established to measure flow, salinity (in the form of electrical conductivity, or EC), and temperature at the major inlets and outlets of the North Division of the GWD (NGWD. The main inlet, supplying water to more than 80% of the wetlands in the NGWD, is the Volta Wasteway. The Wasteway fills the San Luis Holding Reservoir that supplies the three main NGWD distribution canals: Mosquito Ditch, Spillway Ditch, and the Melia Ditch. After being diverted from the distribution canals to individual wetland units, wetland drainage is exported through through the main NGWD drainage outlets which include Mud Slough, Los Baños Creek, S-Lake Drain, Hollow Tree Drain, and Fremont Canal. Dataloggers collected data continuously at each of these stations and transmitted the data through phone and satellite telemetry to Berkeley National Laboratory where it was processed, made available on the project website and used to calibrate the WWQM.

2. ***To develop a wetland water quality model (flow and salinity mass balance) focusing on exports from the Grassland Water District to the San Joaquin River***

   The wetland water quality model (WWQM), was constructed using a combination of tools including Microsoft Excel, Microsoft Access, and Environmental Systems Research Institute's (ESRI) ArcGIS. The WWQM accepts daily time step data for water supply and water quality, climate, vegetation indexes, and land use classifications to simulate wetland water and salinity mass balance. The model was manipulated to test different wetland drawdown schedules for salinity discharge to the San Joaquin River. These simulated manipulations, or "games", allowed wetland managers to test the impacts of several different drawdown management schedules on the salinity of the SJR. Alternative wetland drawdown management scenarios include:

   - An early wetland drawdown schedule;
   - A reference management schedule (traditional drawdown);
   - A late drawdown schedule; and
   - A pre-flushing schedule that results in lower salinity drainage later in the season.

3. ***To experiment with adaptive wetland drawdown schedules to better coordinate salt loading from the Grassland Water District with the assimilative capacity of the San Joaquin River.***

   Development of target salt loads and exploration of the means by which these are achieved through adaptive wetland management and drawdown scheduling was accomplished through the use of the WWQM for the spring 2003 drawdown. By modeling the wetland salinity levels and comparing them to SJR assimilative capacity, the model assisted the GWD water master to better coordinate wetland salt loading with the prevailing assimilative capacity of the San Joaquin River.

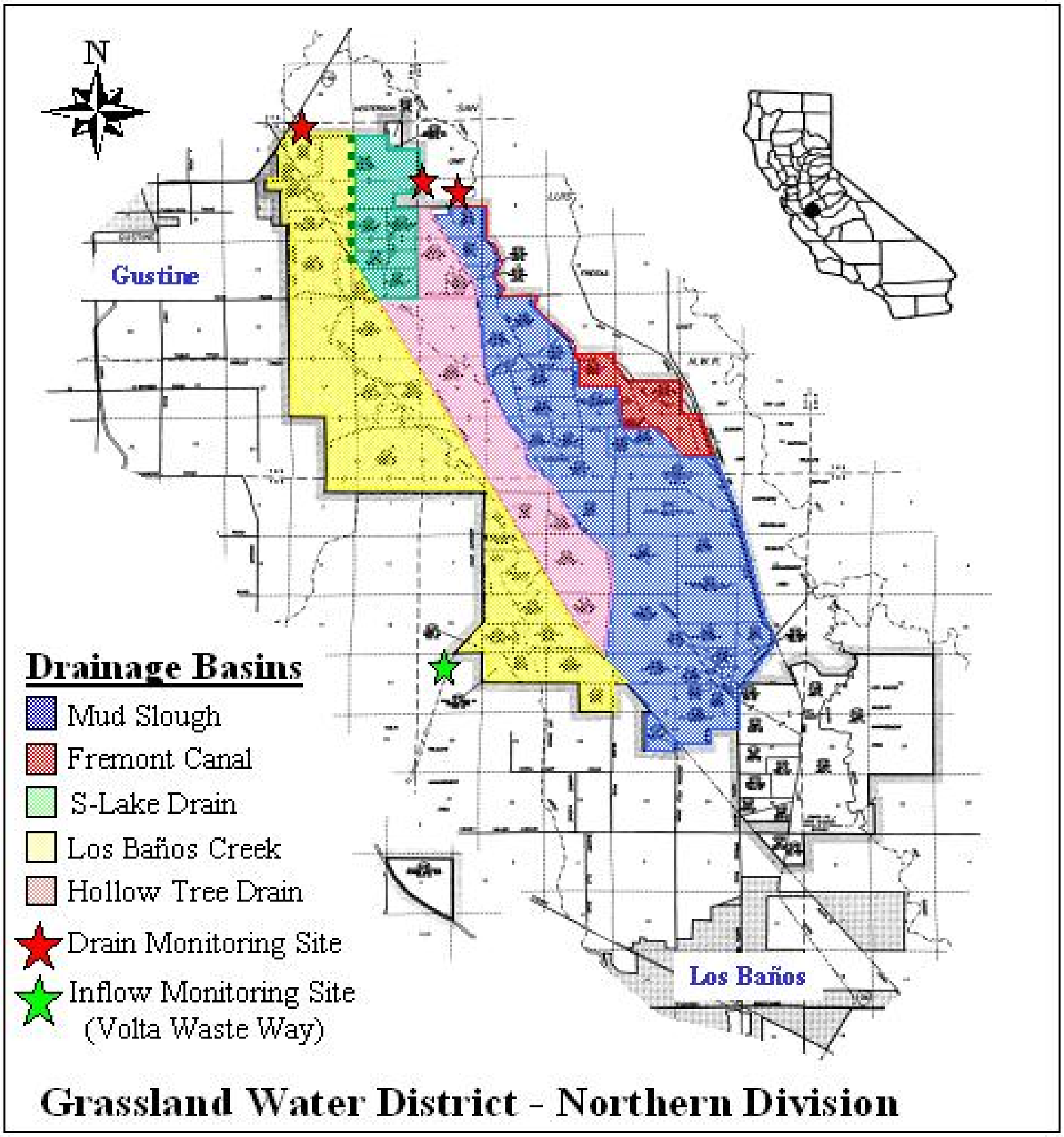


Figure 1.8. Northern Division of the Grassland Water District showing how this area was divided into distinct drainage management areas. Monitoring was designed to provide drainage flow and water quality information for each of these units.

5. ***To develop a habitat assessment methodology for measuring the impacts of changes in seasonal wetland drawdown schedules on moist-soil plant production and habitat health.***

Habitat impact assessment, was accomplished through the development of a remote habitat assessment methodology (RHAM). The RHAM was used to monitor the wetland vegetation communities as a means of assessing long term impacts of salinity management to meet San Joaquin River water quality objectives . The methodology employs remote sensing and pattern recognition technologies. One of these technologies, high-resolution satellite imagery, utilizes multi-spectral digital images of the wetland areas and associated uplands in panchromatic (black and white), red, green, blue, and near-infrared bandwidths. The images are then processed using an image classifier, which separates the different signals and in turn clusters regions with similar attributes. Once calibrated (i.e. which signal represents which type of vegetation), the classifier can provide quantifiable results on where as well as to what coverage and extent these different vegetation communities exist. Each subsequent time this process is repeated, changes from one set of images to another can be assessed, tracked, and quantified.

The habitat-monitoring methodology was designed to answer questions directly related to seasonal wetland management in the GWD. Principally, how do the wetlands respond to timing of wetland drainage that is different from traditional drainage schedules? More specifically, how would the wetlands in the GWD respond to an earlier, or later, than normal drawdown as salinity assimilative capacity in the San Joaquin River requires?

CHAPTER 2 REAL-TIME WETLAND WATER QUALITY MONITORING

2.1 Introduction

The California Regional Water Quality Control Board (CRWQCB) recently announced salinity and boron Total Maximum Daily Loads (TMDL's) for the San Joaquin River – a regulatory procedure to encourage compliance with river water quality objectives. The TMDL requires that all dischargers to the River monitor their drainage return flows as well as the salt loading contained in these return flows (CRWQCB, 2002). The GWD has been recording daily observational flowrate readings and salinity grab samples since the early 1990's. However analysis has shown that continuous data provides a more accurate record of flow and salt loading. To aid in the data collection, organization, and reporting tasks for continuous flow and electrical conductivity monitoring, a real-time wetland water quality network ("network") was developed for the Northern Division of the GWD (NGWD). This real-time data network has been developed using state-of-the-art sensors, datalogging and telemetry equipment to ensure accurate data and convenient access to the data in real-time.

Data obtained by telemetry from the monitoring network has been stored in a project database. GWD staff can access the database to assess conditions without costly and time consuming trips into the field. In addition, the database helps satisfy the Regional Board's data collection requirements, and can be used to develop and calibrate water quality models for meeting water needs, explore salinity trading possibilities, and aid in wetland drainage management.

2.2 Monitoring Parameters

The main objectives of the monitoring program are:

Measure the flow and the salinity of wetland water supply and drainage, and calculate the total salt load entering and leaving the GWD.

Report these data on a real-time basis, through the use of the Internet, to a database capable of advancing wetland modeling efforts and providing decision support to wetland managers allowing them to make timely drainage management decisions.

To accurately measure the flow rate at individual monitoring sites, several methods were employed. These methods depend upon the site characteristics for the individual supply channels, conveyances and drainage outlets and commonly require the development of a relationship between stage and discharge using a flow rating curve or, in instances where velocity is measured directly, between stage and cross-sectional area. In the latter case the cross sectional area of flow is multiplied by the mean velocity to obtain discharge. Direct measurement of velocity, where possible, is valuable, especially in system subjected to seasonal backwater conditions. Under these conditions water backs up in the channel causing high stages that are unrelated to discharge.

Salinity content is estimated by sampling the electrical conductivity of the water. Electrical conductivity (EC), measured in micro-Siemens per centimeter [uS/cm], is a measure of the ions present in the water. The ions consist mainly of Calcium (Ca^{+}), Magnesium (Mg^{+}), Sodium (Na^{+}), and Potassium (K^{+}) cations and Bicarbonate (HCO_3^{-}), Sulfate (SO_4^{-}) and Chloride (Cl^{-}) anions. There is a direct relationship between EC in uS/cm and TDS in mg/L. The flow and EC data can be used for the computation of the total salt loading to and from the GWD. The computation to convert the flow and EC readings in cfs and uS/cm respectively, to total salt load in tons of salt per day [tpd] follows:

$$SaltLoad = M \times Q \times EC \qquad \textbf{(1)}$$

where $\boldsymbol{Q}$ is in cubic feet per second [cfs], *EC* is in microSiemens per centimeter [uS/cm] and $\boldsymbol{M}$ is the ratio of *TDS* [mg/L] to *EC* [uS/cm]. *M* is determined experimentally and is typically 0.75 in the Grassland Basin (California Environmental Protection Agency, 2002). Converting salt load into tons per day [tpd] **Error! Reference source not found.** becomes:

$$SaltLoad[tpd] = \frac{M\left[\frac{mg/L}{uS/cm}\right] \times Q\left[\frac{cu.ft.}{\sec}\right] \times EC\left[\frac{uS}{cm}\right] \times 28.32\left[\frac{L}{cu.ft.}\right] \times 2.2046\left[\frac{lb.}{kg}\right] \times 86{,}400\left[\frac{\sec}{day}\right]}{1{,}000{,}000\left[\frac{mg}{kg}\right] \times 2{,}000\left[\frac{lb}{ton}\right]} \qquad \textbf{(2)}$$

or, simplified, it becomes:

$$SaltLoad[tpd] = Q[cfs] \times EC\left[\frac{uS}{cm}\right] \times 0.002023 \qquad \textbf{(3)}$$

2.3 Monitoring Station Design

Flow transducers and electrical conductivity (EC) sensors were installed at control structures within the NGWD. These sampling devices take measurements every 15 minutes to provide an accurate measurement of salt loading into and out of the NGWD boundary. Flow and EC data at each site are collected on a battery-powered datalogger that communicates through a telemetry system (either telephone or satellite), allowing these data to be accessed 24 hours a day.

At the sites where a simple stage measurement and reliable stage - discharge relationship could be developed, pressure transducers were installed to estimate flows in inlet and drainage channels. Mud Slough at Gun Club Road (MSG) and Los Baños Creek at Highway 140 (LBC) are examples of sites where flow rating curves were used to estimate discharge directly from measured stage in addition to the use of an acoustic velocity sensor. At the MSG site, a pressure transducer was installed within a stilling well. The stilling well allows for minimal noise to be registered by the sensor from occurrences such as pressure variations from velocity changes and turbulence. At the LBC site, Design Analysis H355 Smart Gas bubbler system was used. Depending on the force necessary to push the air through the bubbler apparatus, a pressure value is recorded, converting the reading to a depth measurement. At both these sites the direct stage measurement was redundant used as a secondary estimate and check – often useful if the primary measurement fails or is compromised.

Flow measurements at the inlet site, Volta Wasteway (VWW), and two of the outlet sites, Fremont Canal (FRC) and S-Lake Drain (SLD), were recorded using the same state-of-the-art acoustic velocity transducers used at MSG and LBC These transducers utilize the Doppler principle whereby during operation each transducer produces short pulses of sound at a known frequency along two different axes. Sound from the outgoing pulses is reflected ("scattered") in all directions by particulate matter in the water. Some portion of the scattered energy travels back along the beam axes to the transducer. These return signals have a frequency shift proportional to the velocity of the scattering material. This frequency change (Doppler shift), as measured by the circuitry within the transducer, is proportional to the projection of the water velocity onto the axis of each acoustic beam. By combining data from both beams, and knowing the relative orientation of those beams, the device measures velocity in the two-dimensional plane defined by its two acoustic beams.

When mounted on an underwater structure, these devices measure velocity in a user-programmable sampling volume located up to 75 ft (23 m) from the transducer. A major advantage of this technology is that the transducer never requires calibration because measurements are made in a remote sampling volume free from flow distortion and the velocity data are free from drift. Additionally, Doppler technology has no inherent minimum detectable velocity, performing well at low flows ranging from 0.01 ft/s to 30 ft/s (0.003 m/s to 9.2 m/s) -- velocities often found in wetland slough environments. Data collected by each transducer, which are equipped with two stage measurement sensors, a vertical beam and a pressure are used to calculate the stream cross-sectional area for use in the flow computation. At the Hollow Tree Drain (HTD) monitoring site where a high gradient rendered it unsuitable for either a simple stage measurement or the Doppler system, a ramp weir was designed and installed. The ramp weir, equipped with a pressure transducer, was designed using WinFlume™, which produces an exact rating curve for the dimensions of the weir (Clemmens et. al., 2001)

The location of the monitoring stations-- at all the major inlets and outlets throughout the GWD-- were determined by a global positioning system (GPS) survey and located on the set of GIS maps of the study area. The GIS maps were prepared for locating water delivery and drainage turnouts in the GWD drainage system. These maps also document drainage hydrology within individual wetland basins. These monitoring sites were placed strategically within wetland channels so as to allow computation of salt loads in real-time from different drainage subbasins of the North Grassland Water District (Figure 1.9).

Figure 2.1. - Ramp weir at Hollow Tree Drain showing phases of construction.

Temperature-compensated EC sensors manufactured by Campbell Scientific, Inc. were used to obtain real-time salinity and temperature data at each site. Monthly data quality assurance assessment at each of these sites was performed in accordance with the Project Quality Assurance Plan, developed for the Grassland Bypass Project, to ensure data accuracy and reliability.

2.4 Wetland Monitoring Sites

Four monitoring stations serving five drainage outlets and one supply inlet were constructed to monitor the seasonal wetland discharges and water quality in the NGWD. The inlet station was located on the Volta Wasteway, downstream from the San Luis Holding Reservoir, which supplies more than 80% of the surface water to the NGWD. The five drainage outlet stations are Mud Slough at Gun Club Road (MSG), Fremont Canal at Mud Slough (FRC), Hollow Tree Drain (HTD), S-Lake Drain (SLK), and Los Baños Creek at Highway 140 (LBC). Monitoring stations were co-located where a single gauge house was sufficient to

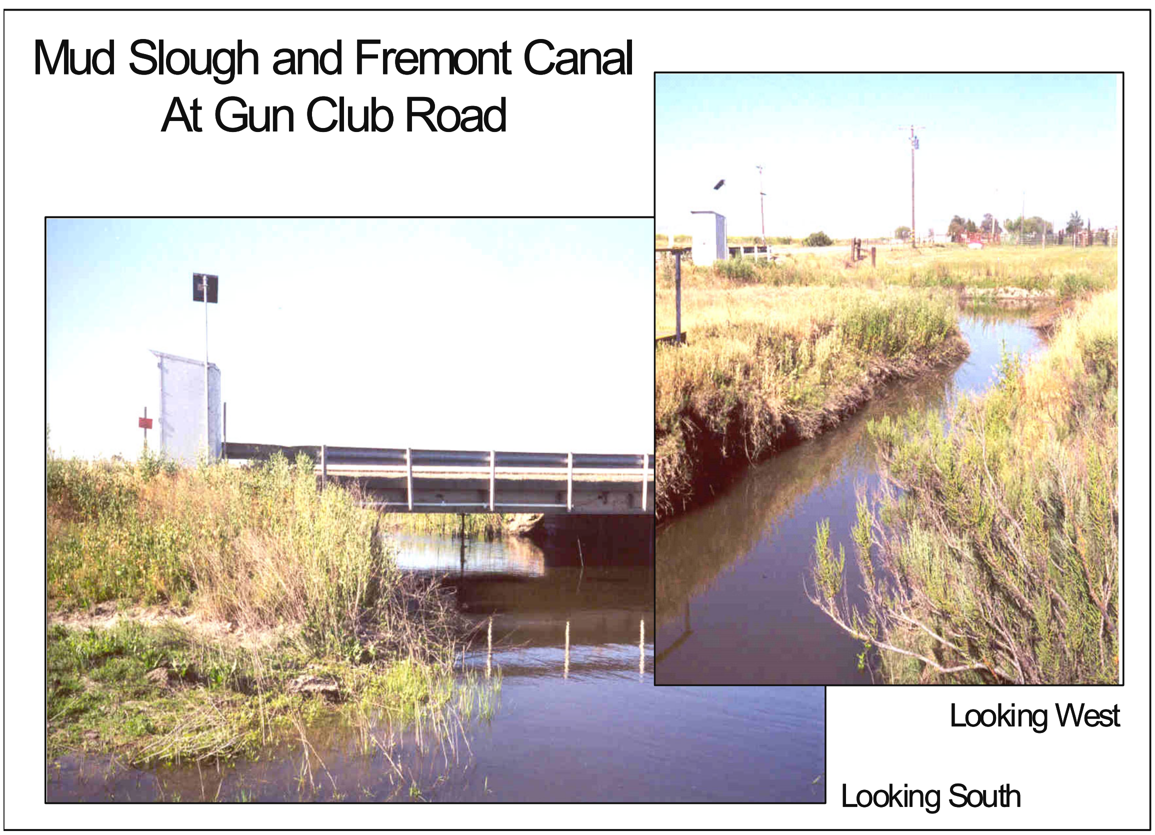


Figure 2.2 - Mud Slough and Fremont Canal monitoring stations.

service flow and water quality sensors from both sites.

2.4.1 Mud Slough at Gun Club Road (MSG)

The monitoring station located on Mud Slough at the Gun Club Road bridge was the first one constructed given its importance as the primary drainage conveyance for GWD. The datalogger at MSG acquires data from sensor arrays at both Mud Slough and Fremont Canal. To calculate drainage discharge , a rating curve was developed that relates stage to cross sectional area of flow. Direct velocity readings were multiplied by the calculated cross sectional area to compute discharge. A Keller pressure transducer was also deployed at MSG and a separate stage-discharge rating developed for this sensor. The reason for this redundant measurement was to provide discharge measurements during low flow episodes when the stage was too low to cover the SONTEK acoustic velocity meter. The SONTEK was mounted approximately 1 foot above the thalweg of the stream channel so as to allow the acoustic beam an unimpeded path across at least 50% of the channel width.

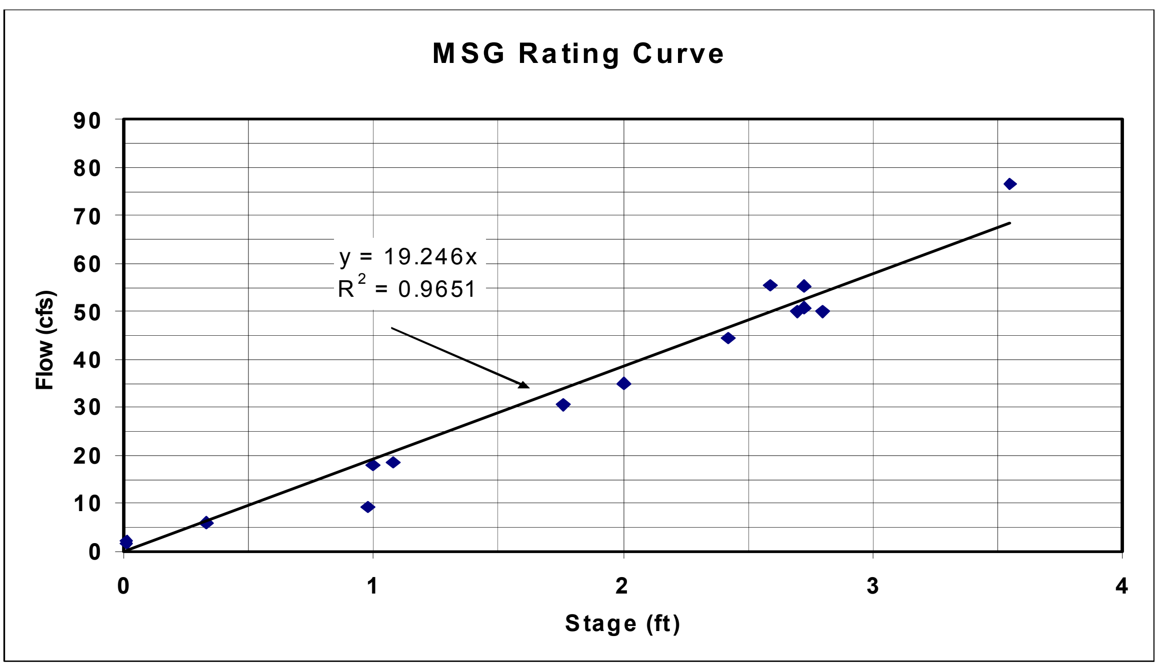


Figure 2.3. - Stage to discharge rating curve for Mud Slough at Gun Club Road (MSG)

The site specifics for the Mud Slough monitoring station are shown below in Table 2.1.

Table 2.1 - Mud Slough monitoring station specifications

Site Summary	Mud Slough accounts for roughly 60% of the discharge from the North Grassland Water District.
Power	Solar Panel with 12-volt battery
Datalogger	CSI 10X Datalogger
EC Sensor	CSI temperature compensated EC probe
Flow Measurement	Mud Slough at Gun Club Road sometimes is affected by a backwater condition cause by high inflow from the Fremont Canal. Use of the SONTEK acoustic sensor at MSG measures velocity directly and can be used to obtain accurate discharge estimates even in backwater conditions.
• Depth	Sontek SL pressure transducer
• Velocity	Sontek SL
Telecommunications	Landline telephone

2.4.2 .Fremont Canal above Mud Slough (FRC)

Fremont Canal and Mud Slough are both monitored using a single datalogger housed in the Mud Slough gauge house. A SONTEK YL is used at this site. This acoustic velocity sensor

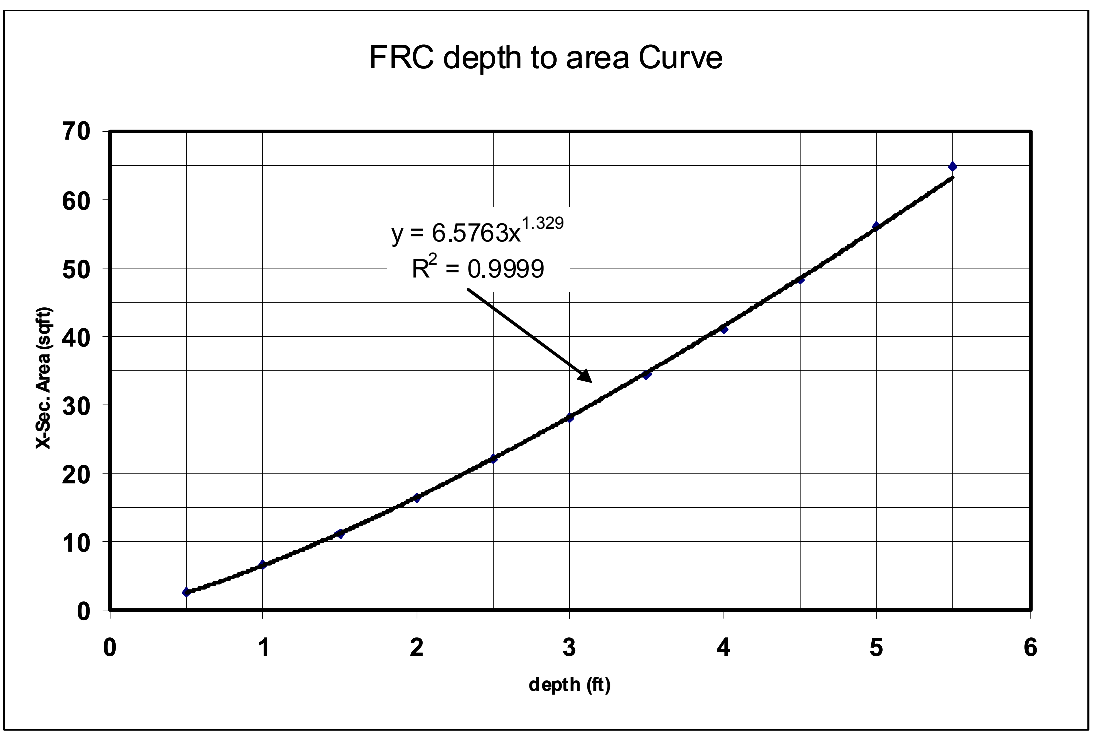


Figure 2.4 - Stage to area curve for Fremont Canal.

measures flow velocity at a point rather than along a path and is suitable for narrow channels where the SONTEK SL's have too short a path length. A flow adjustment is required at this site and other SONTEK acoustic velocity meter sites to account for the location of the sensor at elevations either above or below the 0.6 * depth which is typically used to obtain an average discharge measurement.

The site specifics for Fremont Canal monitoring station are shown below in Table 2.2.

Table 2.2 - Fremont Canal monitoring station specifications

Site Summary	Fremont Canal accounts for roughly 2-3% of the discharge from the North Grassland Water District.
Power	Solar Panel with 12-volt battery
Datalogger	CSI 10X Datalogger
EC Sensor	CSI temperature compensated EC probe
Flow Measurement	Fremont Canal at Mud Slough sometimes can be affected by downstream influences creating a backflow condition. Because of these constraints in this system, it is important to have both a relative depth measurement and a relative velocity measurement. A stage-velocity-discharge rating curve for FRC has been established.
• Depth	Sontek YL pressure transducer
• Velocity	Sontek YL
Telecommunications	Landline telephone

2.4.3 Hollow Tree Drain (HTD)

Hollow Tree Drain is monitored from a gauge house located at the confluence of Hollow Tree Drain and S-Lake Drain. The existing site was poor for both flow and water quality monitoring on account of the highly variable flow, the steepness of the grade and the irregular channel cross section. To obtain good flow and water quality data, a ramp weir was designed and installed during the summer of 2002. The ramp weir was designed using WinFlume™, a commercial water structure design software package. This software requires input of elevations and expected flowrates in order to design suitable flume dimensions. A simple box cross-section was chosen for simplicity of construction with a ramp rising off the flume floor and tapering downstream of the throat of the flume. WinFlume™ produced a stage-discharge rating for the flume. This relationship was applied to the stage measurement obtained from a Keller pressure transducer located in an adjacent stilling well, to estimate discharge. The flume has worked very well since its installation.

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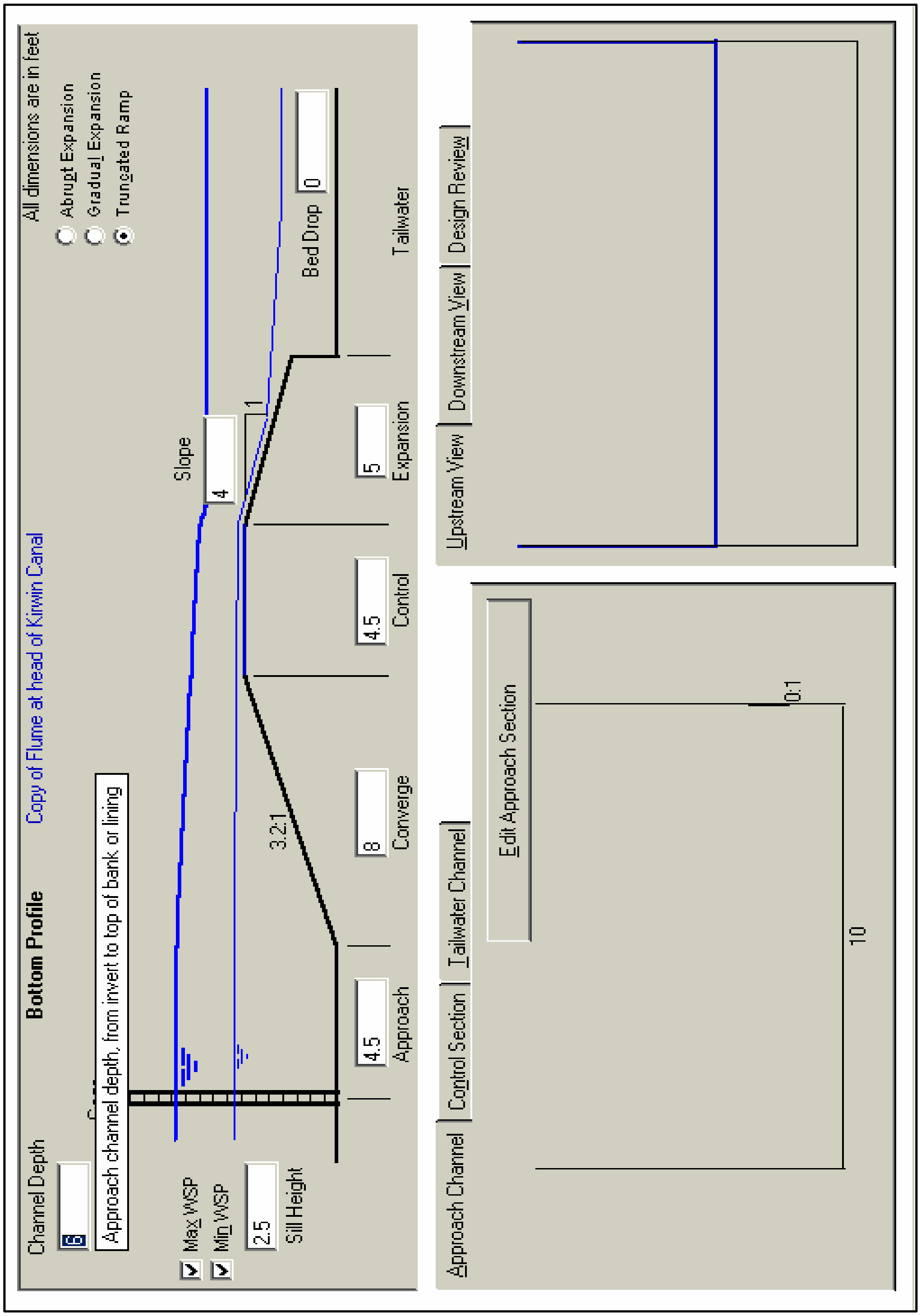


Figure 2.5 Conceptual design of the ramp weir using WinFlume™ (Clemmens et. al., 2001).

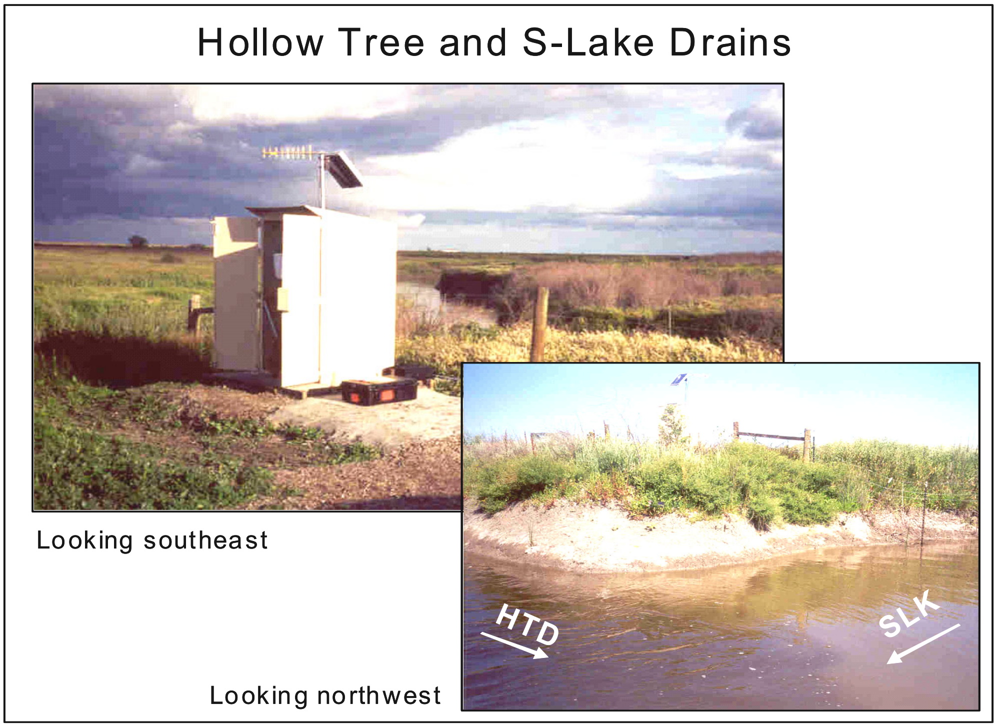


Figure 2.6. Hollow Tree and S-Lake Drain monitoring stations

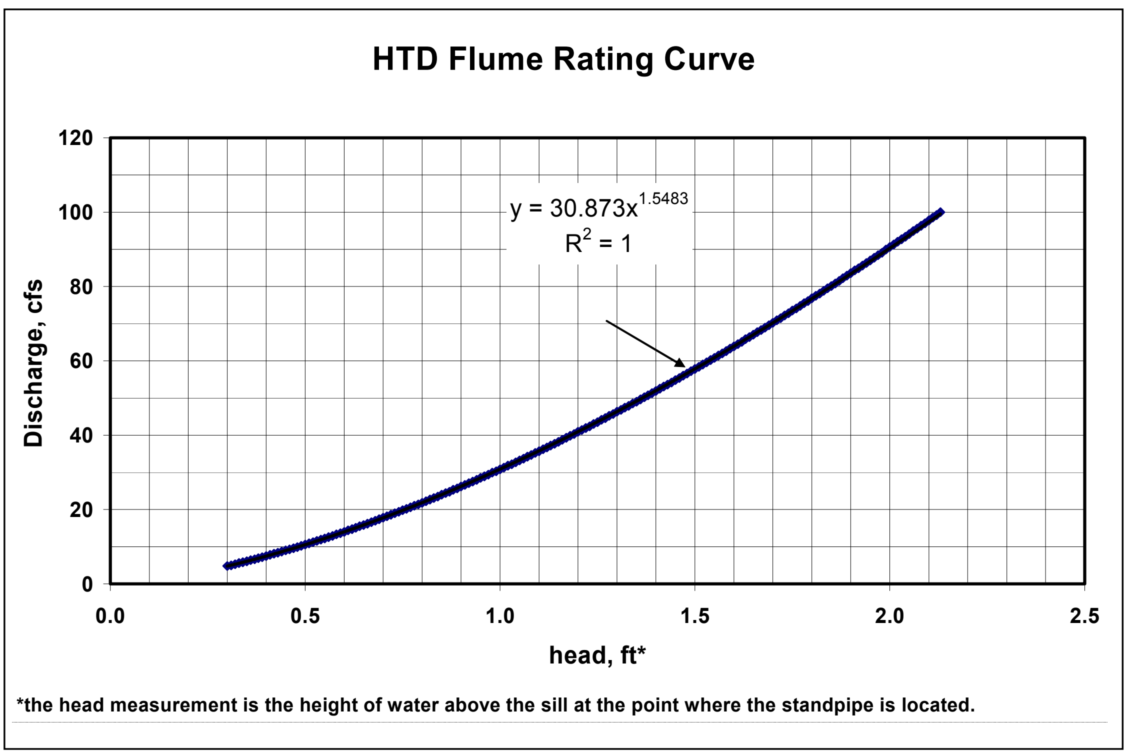


Figure 2.7. Stage to discharge rating curve for the Hollow Tree Drain ramp weir.

The site specifics for Hollow Tree Drain monitoring station are shown below in Table 2.3.

Table 2.3 - Hollow Tree Drain monitoring station specifications.

Site Summary	Hollow Tree Drain at S-Lake Drain accounts for roughly 10% of the discharge from the North Grassland Water District.
Power	Solar Panel with 12-volt battery
Datalogger	CSI 10X Datalogger
EC Sensor	CSI temperature compensated EC probe
Flow Measurement	The portion of the Hollow Tree Drain where the monitoring station is located (at the confluence of HTD and SLK) was steep. As a result, water depth was often shallow making stage and/or velocity measurements extremely difficult. Therefore a ramp-weir type flume was designed and installed along with a n integral stilling well for depth measurements. The flume has a very precise formula relating depth of water above the sill to actual flowrate.
• Depth	Keller Pressure Transducer
• Velocity	n/a
Telecommunications	GOES Telemetry

2.4.4 S-Lake Drain (SLD)

S-Lake Drain shares a gauge house with Hollow Tree Drain. S-Lake Drain is a typical backwater drainage site where the stage is influenced by flow in Hollow Tree Drain. The drainage area served by Hollow Tree Drain is not large and drain flows are sluggish. At time of high flow from Hollow Tree Drain flow can be zero and even negative for short periods at this site. The only means of obtaining good quality data for S-Lake Drain was through the use of a SONTEK acoustic velocity meter. A stage- cross sectional area relationship was established from survey data and was programmed into the SONTEK. Hence discharge was calculated using stage and velocity data and the stage-area rating. The relationship was shown to be quite stable over time and is shown in Figure 2.8.

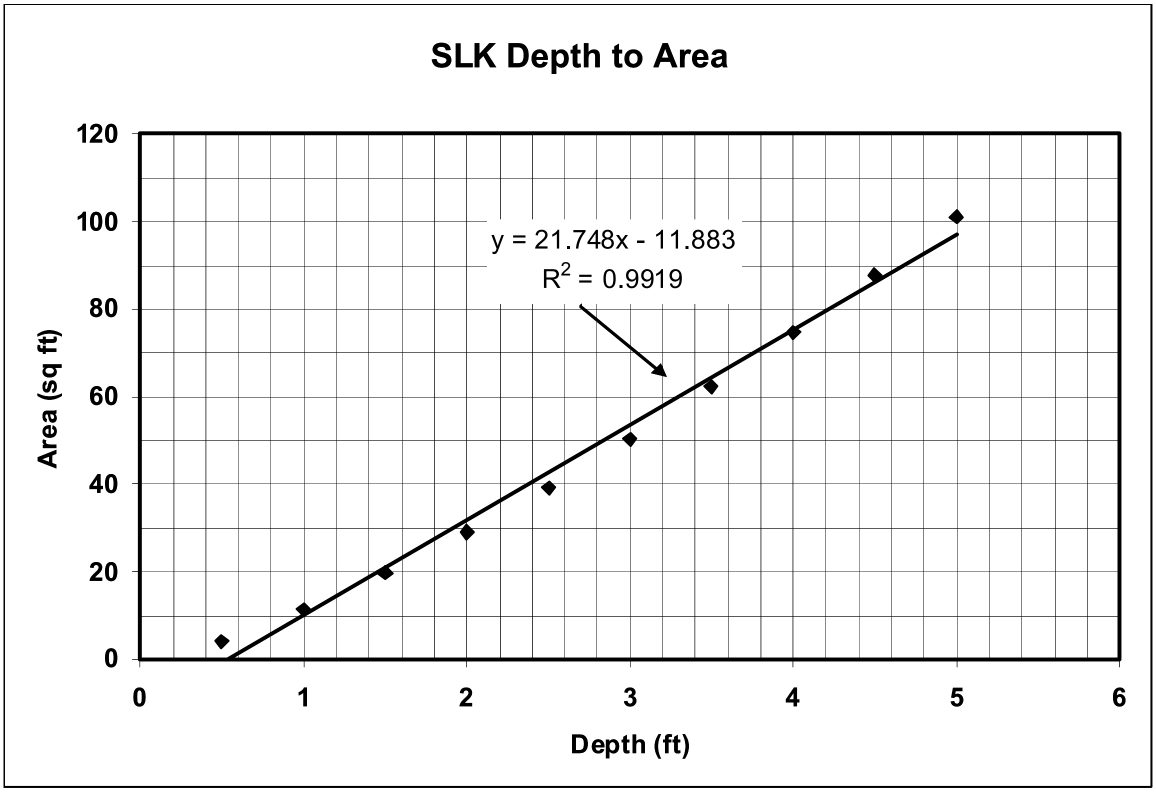


Figure 2.8. Stage-area rating curve for S-Lake Drain.

The site specifics for the S-Lake Drain monitoring station are shown below in Table 2.4.

Table 2.4. S-Lake Drain monitoring station specifications

Site Summary	S-Lake Drain accounts for roughly 10% of the drainage flow from the North Grasslands Water District.
Power	Solar Panel with 12-volt battery
Datalogger	CSI 10X Datalogger
EC Sensor	CSI temperature compensated EC probe
Flow Measurement	S-Lake Drain at Hollow Tree Drain oftentimes is affected by downstream influences, creating a backflow condition. Because of these constraints in this system, it is important to have both a relative depth measurement and a relative velocity measurement. A stage-velocity-discharge rating curve for FRC has been established.
• Depth	Sontek SL pressure transducer and vertical beam
• Velocity	Sontek SL
Telecommunications	GOES Telemetry

2.4.5 Los Baños Creek at Highway 140

The Los Baños Creek at Highway 140 monitoring station was the final station to be constructed. This monitoring station is located in Kesterson Wildlife Refuge. Accordingly,

Figure 2.9. Los Baños Creek at the Highway 140 monitoring station.

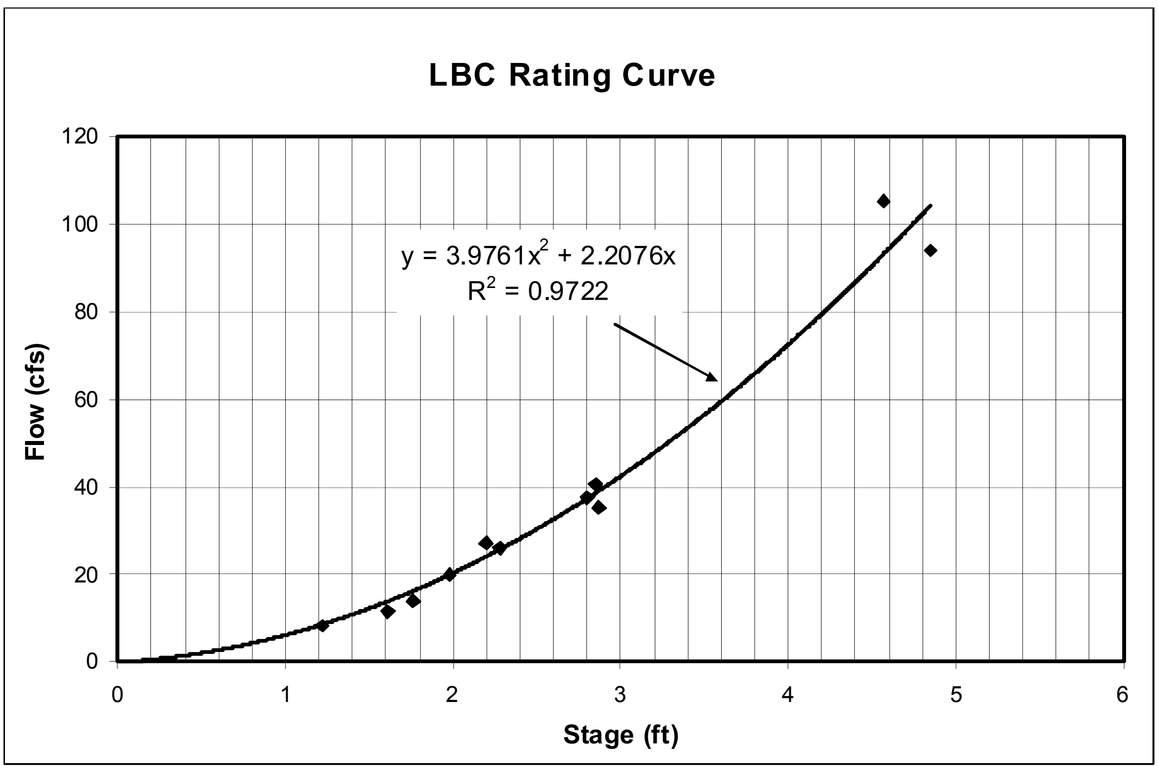


Figure 2.10. Stage - discharge rating curve for Los Baños Creek

special permission was granted for access to the station by the United States Fish and Wildlife Service. The flow at this station is monitored using a Design Analysis Smart Gas System™ air bubbler and a stage to discharge rating curve frequently updated during the project.

The site specifics for Los Baños Creek monitoring station are shown below in Table 2.5.

Table 2.5 - Los Baños Creek monitoring station specifications

Site Summary	Los Baños Creek at Hwy 140 accounts for roughly 30% of the discharge from the North Grassland Water District
Power	Solar Panel with 12-volt battery
Datalogger	CSI 10X Datalogger
EC Sensor	CSI temperature compensated EC probe
Flow Measurement	Los Baños Creek at Hwy 140 is not commonly affected by backwater conditions. A duplicate pressure (bubbler) sensor was located at the site in order to develop and test the reliability of a stage-discharge relationship. The SONTEK deployment was not ideal, being on a shallow bend in Los Banos Creek. However the streambed is stable in this location..
• Depth	Design Analysis Smart Gas Bubbler
• Velocity	n/a
Telecommunications	GOES Telemetry

2.4.6 Volta Wasteway (inlet site)

The Volta Wasteway is the major inlet site to the NGWD, supplying approximately 80% of the surface water. The monitoring station at Volta was difficult to keep operational, as vandalism was a major factor. However, after several design upgrades, the station is now secure (Figure 2.11). The Volta Wasteway is difficult to monitor for flow because it feeds, and is heavily influenced by, the San Luis Holding Reservoir. Backwater conditions are common in the Wasteway and hence a SONTEK velocity sensor was required to obtain a good discharge measurement. As with the previous installations installing a system to record the depth and the velocity requires the use of a stage- cross-sectional area rating curve. The measured stage (SONTEK pressure) defines the cross sectional area which is multiplied with the velocity to give an estimated discharge.

Figure 2.11. Volta Wasteway monitoring station.

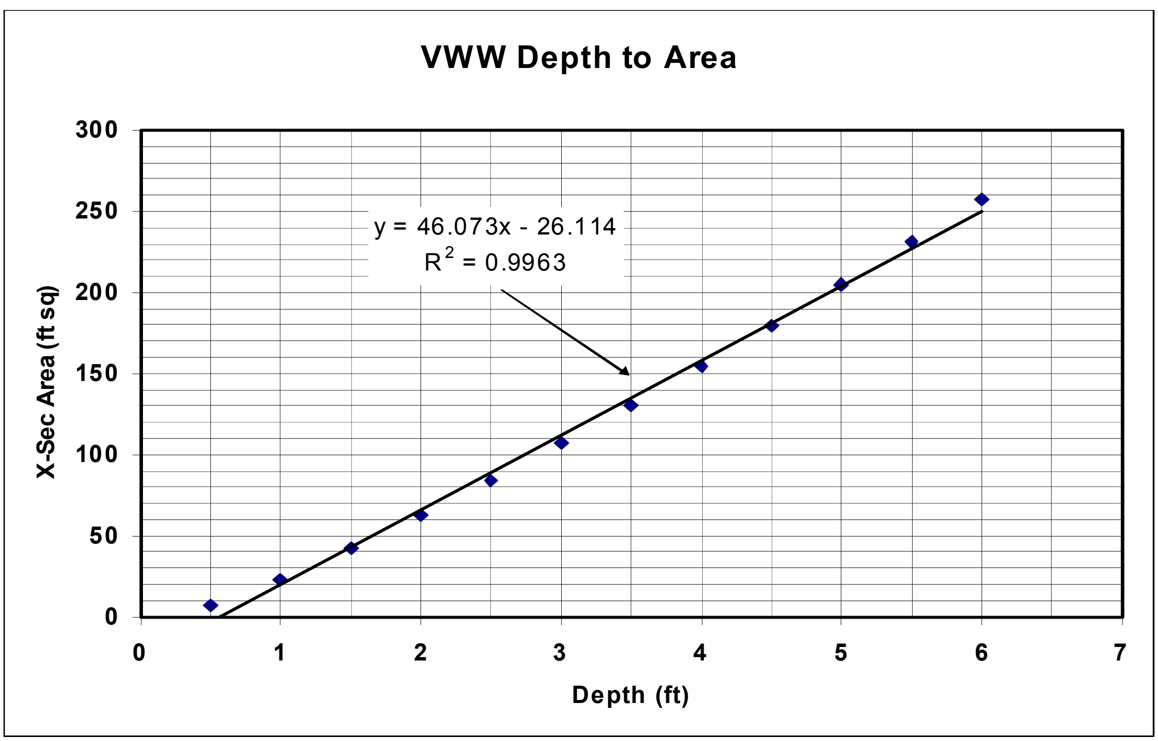


Figure 2.12 Stage - area rating curve for Volta Wasteway.

The site specifics for Volta Wasteway monitoring station are shown below in Table 2.6.

Table 2.6 - Volta Wasteway monitoring station specifications.

Site Summary	Volta Wasteway accounts for roughly 80% of the inflow volume to the NGWD.
Power	Solar Panel with 12-volt battery
Datalogger	CSI 10X Datalogger
EC Sensor	CSI temperature compensated EC probe
Flow Measurement	The Volta Wasteway downstream from the DFG water control structure almost always is affected by backwater conditions from the presence of the San Luis Holding Reservoir located at the end of the Wasteway. Because of these constraints in this system, it is important to have both a relative depth measurement and a relative velocity measurement.
• Depth	Sontek SL pressure transducer and vertical beam
• Velocity	Sontek SL
Telecommunications	GOES Telemetry

2.5 Monitoring Network

The six wetland water quality monitoring stations described above are connected through a real-time network. This network, which comprises the six monitoring stations, a GOES satellite telemetry system, a database, and the Internet - provides real-time data to wetland managers and supplies hydrologic data to a water quality model. The monitoring stations collect and store wetland drainage flow, EC and temperature data. These data are then distributed either via land line to a central database, or through Geostationary Operational Environmental Satellite (GOES) telemetry to the NESDIS data repository in Wallops, Washington. The downloaded information is compiled and error-checked using proprietary data management software and parsed standard report formats. The data are presented on the Internet in graphical and tabular formats. The real-time data is updated weekly, and can be found at http://esd.lbl.gov/people/nwquinn/Grassland_website/grasslandwd/index.html. These data are used in two ways. Their primary use is to help wetland managers monitor and manage salt loads present in seasonal drainage. The data is also useful for calibration of a real-time wetland water quality model developed for the NGWD wetlands. The utility of the model is to develop a better understanding of salinity mass balance in these wetlands – once calibrated the model can assist future scheduling of wetland drainage.

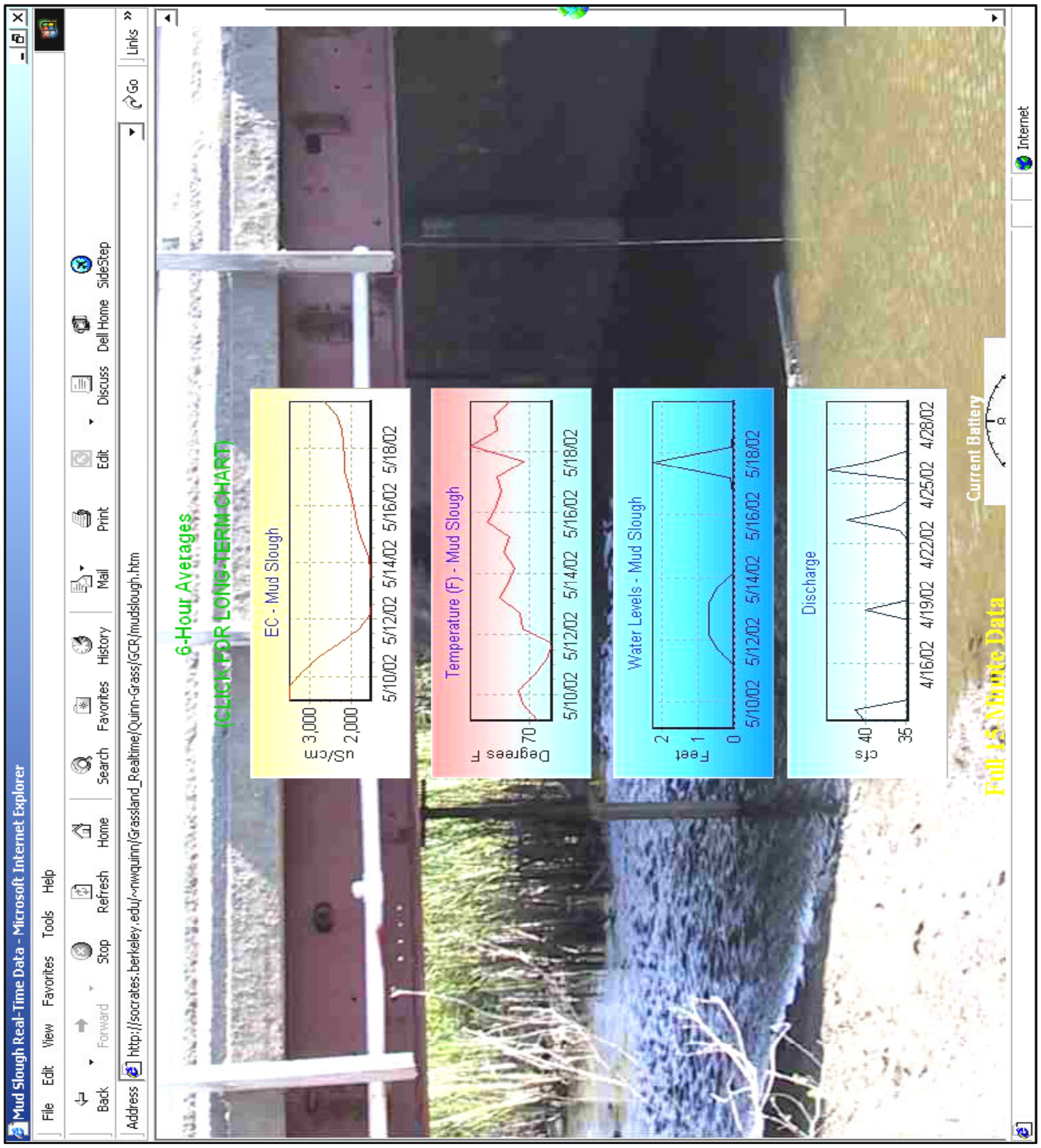


Figure 2.13. Reporting of real-time stage, flow. EC and temperature at the Mud Slough monitoring station in NGWD.

2.6 Discussion

The real-time wetland water quality monitoring project has demonstrated the feasibility of operating and maintaining a network of telemetered flow and water quality stations in drainage canals discharging into the San Joaquin River. In addition to providing continuous real-time flow and water quality data for use in adaptive salinity management the data has also proved useful in the development of a wetland water quality model. This model provides tributary input to the San Joaquin River Input Output Daily Model (SJRIODAY) operated by the SJRMP Water Quality Subcommittee. The SJRMP Water Quality Subcommittee was funded until the year 2002 to enhance the existing network of real-time monitoring stations along the main-stem of the San Joaquin River and to improve the coordination of agricultural return flows and scheduled east-side fish flows (Quinn et al. 1997).

The real-time flow and water quality monitoring data from key locations in the NGWD helps provide decision support to wetland managers scheduling drawdowns and irrigations. Mean daily salinity loading from the NGWD is calculated from the monitoring data and is compared with the daily assimilative capacity determinations on the SJR. The GWD now can evaluate wetland discharge opportunities during the spring months (when the majority of saline discharges from seasonal wetlands occur) and make relevant decisions based upon the real-time data. In addition, this network can provide the backbone for further monitoring efforts to help alleviate other problems within the San Joaquin Basin such as elevated concentrations of nitrates, dissolved organic carbon, and dissolved oxygen.

CHAPTER 3 DEVELOPMENT AND APPLICATION OF A REAL- TIME WETLAND WATER QUALITY MODEL

3.1 Introduction

A wetland water quality model (WWQM) was developed for the seasonal wetlands in the San Joaquin River Basin (SJR). Once developed, it was applied to the wetlands of the Grassland Water District (GWD) as part of the real-time adaptive wetland water quality management research project. The WWQM, a salt and water balance box-type model, utilizes wetland management practices, daily climatic data, land use values, and daily surface water supply data to forecast wetland drainage salinity levels. These forecasts, when used in conjunction with assimilative capacity forecasts for salts in the SJR, can assist wetland managers to better coordinate salt loading from the GWD to the SJR. The main objective of the WWQM is to simulate and forecast seasonal wetland salinity levels for wetlands in the SJR Basin. However, it also has the ability to compare these wetland salt loads with assimilative capacity forecasts for salts in the SJR. This linkage allows the user to estimate the effects of salt loading to the SJR during spring wetland drawdown (February-April), and hence make better decisions regarding salt export.

The WWQM was successfully applied to the seasonal wetlands of the Northern Division of the GWD (NGWD) during the spring 2003 drawdown season. The model was calibrated and validated continually using actual wetland drainage salinity data collected by the monitoring stations in the NGWD. The WWQM resides with the water master of the GWD and is updated weekly or on an “as needed” basis. This application assisted the GWD water master in advising the individual managers of desired drawdown dates to better coordinate salt export from the wetlands.

3.2 Background

The California Regional Water Quality Control Board (CRWQCB) is the policing arm of the U.S. Environmental Protection Agency. The Central Valley Regional Water Quality Control Board regulates water quality in the SJR. Among other constituents of concern, the CRWQCB regulates salinity discharges from point and non-point sources. Using a procedure known as the Total Maximum Daily Load (TMDL), the CRWQCB can allocate the assimilative capacity of a water body such as the SJR for salts and other pollutants among watershed sources in order to maintain water quality. However, if watershed sources develop the ability to better coordinate their pollutant exports through real-time management, more management flexibility is possible. In the case of a traditional TMDL, minimal flexibility is possible and these TMDL's tend to be very restrictive since they are based on a 10% exceedence hydrology and a fixed frequency of violation. However, under real-time management, more salt export would be allowed during periods of high assimilative capacity. Conversely, during periods of low assimilative capacity for salts in the SJR, exports would need to be curtailed. The management of sources of salt load through real-time control requires the development of monitoring systems, more integrative management strategies and coordination with all entities. For the real-time concept to work, releases from west-side agricultural sources and east-side reservoir releases must be coordinated.

3.3 Wetland Management

Wetlands in the SJR Basin seasonally contribute salinity to the SJR because they are flooded in the fall and drawn down in the spring to mimic the natural wet-dry cycle these wetlands once experienced. As the flooded season progresses, the salinity in the wetlands increases. This salinity increase is due to many different factors, foremost among them the quality of the water supply and secondly the further concentration of the salts from evaporative and evapotranspirative losses. Other factors contributing to the salinity increase, but not yet quantified, are groundwater infiltration, bird usage, and water resource management at the regional level. Quantification of these and other possible salinity sources require study outside the scope of this research.

Management of wetland drainage, through scheduling of releases to coincide with periods of SJR assimilative capacity, can help improve SJR water quality. However, these actions may need to be considered relative to potential biological wetland impacts of changes to traditional wetland management practices. Seasonal wetlands in the SJR Basin are intensively managed to provide optimal conditions for waterfowl habitat. One set of wetland "best-management practices" (BMPs) is presented in the publication *A Guide to Wetland*

Habitat Management in the Central Valley (Smith et al., 1995). This guide was produced through a cooperative effort between the California Department of Fish and Game and the California Waterfowl Association. In it water management plans for optimal productivity are presented for three very desirable moist-soil plants – smartweed (*Polygonum punctatum*), swamp timothy (*Heleochloa schoenoides*), and watergrass (*Echinochloa crusgalli*) (Figure 1.6). Using the guide to help direct BMPs, wetland managers conduct drawdown during the months of February through April. In practice, wetland mangers try to drawdown the wetlands earlier when it is unseasonably warm or dry, and try to drawdown their wetlands later in the season when it is unseasonably cool or wet (Table 3.1).

Table 3.1. Wetland Management Decision Tree

Theoretical Decision Tree for Wetland Drainage

Moisture Regime	Temp. Regime	Drawdown Type	SJR Assim. Cap.	Mis-Match?
Very Dry	Cold	Traditional	Early	X
Very Dry	Normal	Traditional	Early	X
Very Dry	Warm	Early	Early	
Dry	Cold	Traditional	Early	X
Dry	Normal	Traditional	Early	X
Dry	Warm	Early	Early	
Normal	Cold	Late	Average	X
Normal	Normal	Traditional	Average	
Normal	Warm	Traditional	Early	X
Wet	Cold	Late	Late	
Wet	Normal	Late	Late	
Wet	Warm	Traditional	Average	

Note: Mis-Match refers to the wetland drawdown type not coinciding with SJR assimilative capacity.

However wetland salinity levels are highest during this wetland drawdown period. In addition, peak assimilative capacity for salts in the SJR typically occurs between the months of January and March (Figure 3.1). This time period is often earlier than the traditional wetland drawdown period (February-April). Hence, the response of wetland habitat

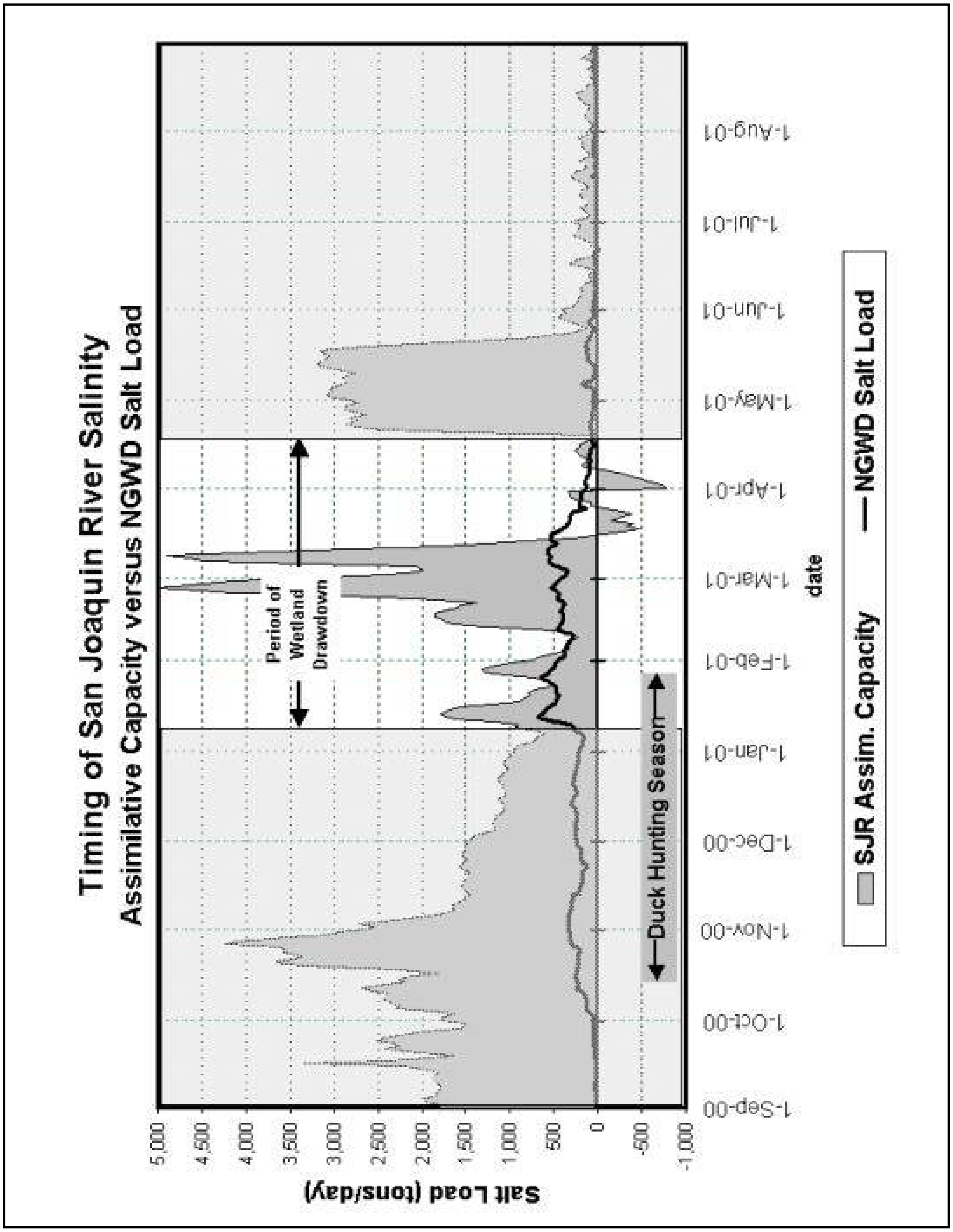


Figure 3.1. Scheduling of San Joaquin River salinity, assimilative capacity versus NGWD salt loading. The majority of NGWD salt load occurs between January and mid-April, coinciding with periods of low assimilative capacity on the San Joaquin River.

conditions to an altered drawdown regime must be assessed. It is possible that early, experimental drawdown may make food sources available to wildlife without negatively affecting the wetland vegetation community and plant species diversity, hence benefiting both wildlife and the water quality of the San Joaquin River.

3.4 San Joaquin River Management

Better coordination of agricultural and wetland releases with reservoir releases of good quality snow-melt water on the east-side of the SJR Basin has been suggested as a means of improving SJR water quality for all beneficial uses (Quinn and Delamore, 1994; Karkoski, Quinn and Grober, 1995; Quinn et al., 1997; Quinn and Karkoski, 1998). Studies have shown positive results of a demonstration project of real-time monitoring and management of agricultural drainage and east-side reservoir releases that forecasts the assimilative capacity for salinity on the SJR (Quinn and Karkoski, 1998) The real-time wetland water quality management project builds upon this program to coordinate seasonal wetland drainage with the assimilative capacity of the SJR.

In 1990, Assembly Bill AB 3603 authorized the creation of the SJRMP, along with an advisory council. The advisory council was required to identify problems facing the SJR system and prepare a plan that would identify solutions for improvement, restoration, and enhancement of the currently degraded conditions. AB 3603 initiated a consensus-based effort to solve water-use problems within the SJR system.

The SJRMP covers a regional area along the SJR from Friant Dam downstream through the northern boundary of the South Delta Water Agency and all other tributaries of the SJR up to the first major dam. The major tributaries are the Merced, Tuolumne and Stanislaus Rivers. Minor tributaries include agricultural returns from the east and west sides, environmental areas such as the Grassland Wetland Area (primarily Mud and Salt Sloughs) as well as smaller creeks like Orestimba Creek.

The SJRMP Water Quality Subcommittee installed and demonstrated a San Joaquin River Real-Time Water Quality Management Network on a pilot scale. This network is used to enable participants to make informed water management decisions regarding the SJR Basin. It integrates the system's water quality monitoring stations, each equipped with water quality and quantity instrumentation, and provides data to a computer model (SJRIO-DAY) that facilitates interpretation of the raw data collected (Quinn, 1997).

The San Joaquin River Real-Time Water Quality Management Program used telemetered stream stage, salinity data and computer models to simulate and forecast water quality conditions along the lower SJR. The primary goal of the program was to eliminate or reduce the frequency of water quality violations, thereby reducing the number and/or magnitude of high quality releases made specifically to meet SJR salinity objectives.

The main objective of the current project was to facilitate the control and timing of wetland and agricultural drainage, in coordination with east-side reservoir operators, to coincide with periods when dilution flow is sufficient to meet Vernalis salinity objectives. By reducing the frequency of violations of Vernalis EC objectives, the project may reduce the number and/or magnitude of high quality releases (e.g., releases of Stanislaus River flows from New Melones Reservoir) performed specifically for meeting Vernalis EC objectives (Quinn and Karkoski, 1998; Grober et al., 1995). Other specific objectives and benefits include a reduction in conflicts between reservoir operators, wetlands managers, and agricultural drainers in meeting Vernalis salinity objectives; improved SJR and Bay-Delta water quality for agricultural, drinking water, industrial, and recreational beneficial uses; expanded and improved monitoring stations with telemetered streamflow, temperature and EC sensors capable of delivering real-time information; and increased understanding and management of activities that affect SJR water quality .

3.5 Previous Modeling Approaches

Watershed modeling is an important tool in integrated basin management. There are an abundance of qualified models developed for hydrologic purposes. However, many do not incorporate adequate water quality components (Arnold et al, 1998). If these watershed models are to be used for environmental applications, water quality along with hydrology must be considered. One of the first salts and water modeling projects utilized dynamic simulation of salinity and other water pollutants such as pesticide residues in the Klamath River Basin, California (Woods and Orlob, 1963). Other early modeling efforts included consumptive use equations for water quality parameters in the Sacramento River Basin,

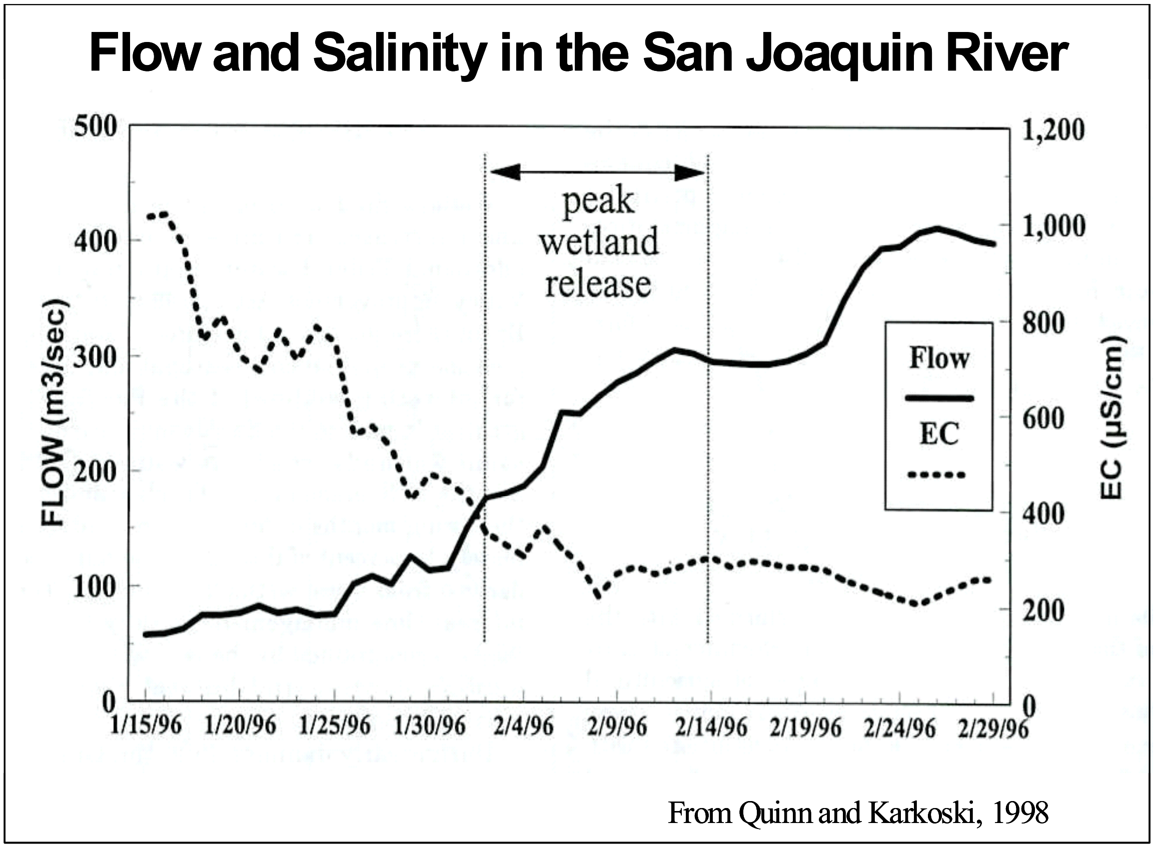


Figure 3.2 Flow and electrical conductivity in the San Joaquin River between January 15 and March 1, 1996.

California (Woods, 1967); linear and multiple regression for salinity impacts on irrigated agriculture in the Lower San Joaquin Basin, California (California Department of Water Resources, 1969); and elemental analyses for salt balances in the Upper Santa Ana River Basin, California (Water Resources Engineers, 1969). Box models for salts and water include mass-balance calculations to estimate TDS and N waste loading from irrigated agriculture (Bay-Valley Consultants, 1974; Tanji, 1977; Aragues et al., 1985); a comprehensive macro-scale simulation/ mathematical model to estimate hydrology and salinity for large catchment basins (U.S. Bureau of Reclamation, 1977) and a dual-type salinity box model for the separate isoclines in the Black Sea (Karaka et al., 1999).

More recently, modeling attempts have focused on entire systems. A basin-scale modeling is described as a water resource planning tool in New Zealand watershed Basins (Cooper and Bottcher, 1993). The model, BNZ (Basin-New Zealand), utilizes algorithms similar to those in CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) developed by the U.S. Department of Agriculture (Knisel, 1980). Several research studies applied dual type box models to describe the layered salinity flux in the Black Sea (Karaka et al., 1999). Recent studies have compared several methods for training artificial neural networks for use in salinity forecasting and other aspects of water resources planning and management.

The literature contains several examples of applying real-time data acquisition to planning and operations modeling. Real-time control of power plant cooling water discharges utilizing optimization models that incorporate stochastic data along with climatic factors were simulated in order to ascertain compliance with temperature standards (Krajewski et al., 1993). A real-time modeling approach was applied to wastewater treatment operations and suggest adaptive management schemes so that facilities' management can better adapt and operate efficiently (Novotny et al., 1992).

In the San Joaquin River Basin, a mass balance model is currently in use to predict the assimilative capacity of the San Joaquin River. This model, the San Joaquin River Input-Output Daily Model (SJRIODAY), calculates daily flows and concentrations of TDS for a 60-mile (96 km) reach of the San Joaquin River from Lander Avenue to Vernalis. Using real-time flow and EC data from five major tributaries and several small tributaries, daily flow calculations are performed using hydrologic routing techniques. The data are used to establish initial conditions for model runs and to generate two-week forecasts of flow and EC (Quinn et al., 1997; Quinn and Karkoski, 1998). The accuracy of the SJRIO forecasts is greatest when east side reservoir releases and estimates of agricultural and wetland releases are available. Through collaboration and a water quality monitoring network, most reservoir releases and the large agricultural entities are tied into the San Joaquin Real-Time monitoring network (Quinn and Karkoski, 1998).

The WWQM created for this project complements this previous work by providing a prediction tool for wetland releases from the GWD. Coordinating the salt load from the NGWD with the SJR's assimilative capacity requires forecast results from SJRIODAY to be used as inputs into the WWQM. The WWQM estimates the salt loads that can be expected from the wetland releases. These values then are compared to the SJR assimilative capacity, providing a quantitative impact assessment tool for managing salinity in the SJR.

3.6 The Wetland Water Quality Model

The WWQM is a salt and water balance box-type model designed to assist coordination of salt loading from regional wetlands the assimilative capacity for salts the San Joaquin River. This box model is similar to other salinity box models (for example, salinity models of the Black Sea) in that it calculates salinity through a weighted contribution from all inputs, outputs and changes in storage (Karaka et al., 1999). However, the unpredictability of managed systems such as the seasonal wetlands in the GWD makes this model more complex than ones used previously. The WWQM somewhat overcomes this through its ability to be updated and calibrated on a daily basis. The WWQM was developed to organize field monitoring data, land use data, and wetland BMPs into a salt and water balance forecasting model. The WWQM continually tracks the weighted flow and salinity contributions into and out of the box (Figure 3.3). The salinity in the box can be calculated at any time using the salt balance equation below :

$$EC_{Dt} = \frac{\left[(D_{t-1} \times EC_{Dt-1}) + (P_t \times EC_{Pt}) + (I_t \times EC_{It}) + (GI_t \times EC_{GIt}) - (E_t \times EC_{Et}) - (ET_t \times EC_{ETt}) - (GO_t \times EC_{GOt}) - (O_t \times EC_{Ot})\right]}{\left[(D_{t-1} + P_t + I_t + GI_t - E_t - ET_t - GO_t - O_t)\right]} \qquad \textbf{(3)}$$

Where EC_{Xt} is the salinity measured as electrical conductivity for parameter X at time t [µS/cm]; D is the end of day depth [in]; P is precipitation [in]; I is inflow [in]; GI is the groundwater inflow seepage [in]; E is the evaporation [in]; ET is the evaporation [in]; GO is the groundwater outflow seepage [in]; and O is the wetland outflow [in].

This model assists wetland managers in their efforts to make timely decisions (i.e. when to begin wetland drawdown) regarding return flows to the SJR. A real-time wetland water quality monitoring network created specifically for this project supplies the data necessary to validate and operate the WWQM. This model was linked with assimilative capacity forecasts for salinity in the SJR. The San Joaquin River Input-Output Daily Model (SJRIODAY) produces weekly assimilative capacity forecasts for salt loads.

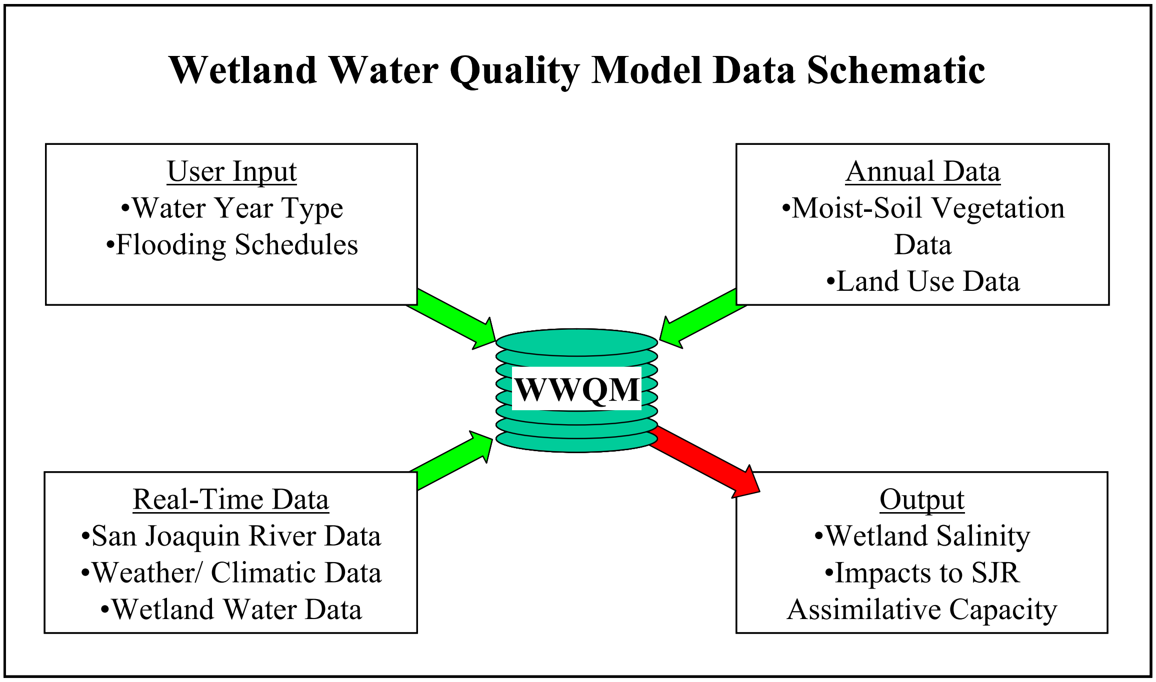


Figure 3.3 . Wetland Water Quality Model (WWDM) data schematic.

The purpose of the model was to predict the quantities and qualities of wetland releases by mimicking the wet and dry seasonal cycle that these wetlands experience. The WWQM required time series data inputs of variables such as inflow volume and water quality, residence time, evapotranspiration, evaporation, precipitation, land use, vegetation types and management strategies. The model tracked salinity changes in each of the wetland basins over the flooded season including drawdown (September through April) and incorporates user-defined schedules for wetland drawdown in the spring months to determine salinity loading to the SJR (Figure 3.1).

Using time series data in conjunction with short and long term weather forecasts, the model was used to predict salinity levels in wetland drainage. The real-time drainage salinity monitoring data at each outlet was used to calibrate the model. Once calibrated, the model simulated different management strategies to produce experimental drainage schedules of salt loading to the SJR. The WWQM, when used along with the SJR assimilative capacity forecasts, can aid wetland mangers to make better drawdown decisions (Grober et al, 1995; Quinn et al, 1997; Quinn and Karkoski, 1998; Quinn, 1999).

3.7 Model Development

The WWQM was developed within Microsoft's™ two database and file systems, Access™ and Excel™. This development scenario was ideal because the Excel™-based user interface is familiar to wetland managers. Moreover, Excel™ allows computation and insertion of logic and is supported by the Access™ database. Access™ has the ability to support Excel™ and the monitoring network constructed specifically for this project, and also readily communicates with ArcGIS™ 8.X, Environmental Systems Research Institute's (ESRI) latest Geographical Information System (GIS) software package. As a model package, it is an integrated database accounting for many of the individual factors (climatic, management, etc.) that effect wetland salinity in the GWD. The model has been designed to perform historic hydrology simulations as well as seasonal "gaming" alternatives. These gaming alternatives include different wetland drawdown protocols such as (a) early drawdown (critically dry to dry year), (b) traditional drawdown (dry to wet year), (c) late drawdown (wet year), and (d) a pre-flushing option to determine the effects of early salt exports while maintaining desired depths within the wetlands.

The WWQM was designed to predict salt loading from seasonal wetlands in the SJR Basin and interact with the California Department of Water Resources' San Joaquin River real-time water quality forecasting model, SJRIODAY (San Joaquin River Input-Output Daily model), introduced above. SJRIODAY provides water quality forecasts of assimilative capacity for salts in the SJR (Figure 3.4). The WWQM uses SJR assimilative capacity forecasts provided by SJRIODAY as a means of estimating allowable wetland discharge. The WWQM has been designed with flexibility to allow for interactions with the next generation of the SJR water quality model, the Delta Simulation Model II (DSM-2).

The WWQM's user interface also resides in the Microsoft Excel™ platform (Figure 3.5) because, as previously noted, there is widespread familiarity with this product among the wetland managers of the GWD. In addition, the model has been designed to allow linkage to GIS software packages such as ARCGIS so results can be viewed and assessed.

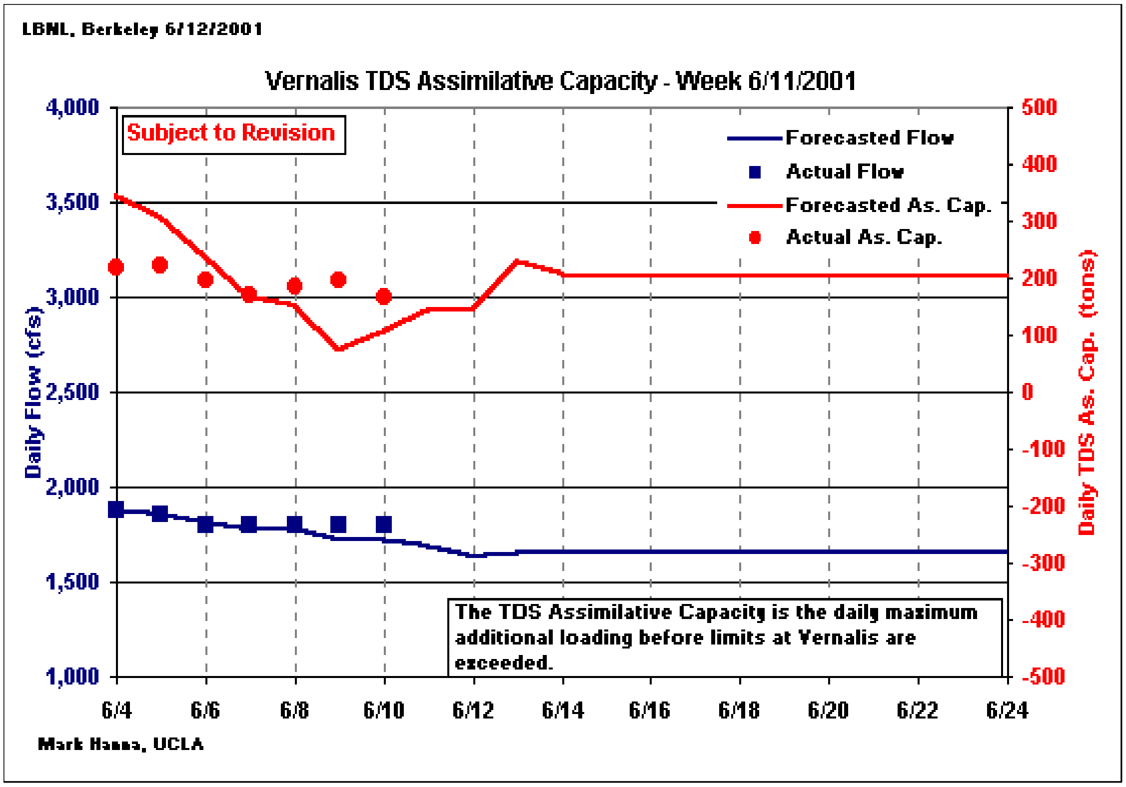


Figure 3.4 Flow and assimilative capacity forecasts on the San Joaquin River for June, 2001 produced by the SJRIODAY Model

The WWQM resides in a file directory called "Model Package" on the computer belonging to the GWD wetland manager. Stored within the directory are several data files required to run the model (Appendix 1 – Wetland Water Quality Model Package). The actual model file, WWQM.xls, contains many links to the various other data files, and constitutes the backbone of the system (Appendix 2 – The Wetland Water Quality Model [WWQM.xls]; and Appendix 3 – Columnar Descriptions of the Wetland Water Quality Model). The two main files that the user needs to run the model are the API.xls (application process interface) and the update.xls files. The API.xls file (Figure 3.5) shows the Wetland Water Quality Model user interface which allows the user to input the necessary parameters such as water year type and expected weather conditions. The user then can perform a rudimentary, fine-tuning calibration operation, and view the results. The user also possesses the ability to run some gaming type scenarios in the API.xls file by changing the water year type and/or simulating a "pre-flush" option of the wetlands themselves.

Generally speaking, there are two different classes of wetlands in the Grassland Water District. Those two wetland classes are:
seasonal wetlands – wetlands that are flooded for a portion of the year
permanent wetlands – wetlands flooded nearly year-round
Within the class of seasonal wetlands, there are three different types of wetlands that could be simulated. These are shallow seasonal wetlands, mid-depth seasonal wetlands, and deep seasonal wetlands. The WWQM was developed to simulate mid-depth seasonal wetlands in particular.

The primary reason mid-depth wetlands were chosen to be modeled is because this is the most popular type of wetland -- estimated at greater than 70 percent of the total seasonal wetland area. Wetland managers try to keep the majority of the ponded area between 10 and 12 inches deep. This is the water depth most preferred by desired waterfowl such as mallards (*Anas platyrhynchos*), green-winged teats (*A. crecca*), northern pintail (*A. acuta*) and other dabbling ducks. Accordingly, waterfowl hunters most commonly want to hunt in these types of wetlands (Frederickson and Taylor, 1982, Grober et al 1995, and Smith et al, 1995).

A secondary reason for the selection of mid-depth wetlands is that the hydrology of mid depth wetlands is much easier to understand. Such understanding leads to more accurate modeling. Shallow wetlands tend to have fluctuating aerial extent because they are more susceptible to daily variations in the weather and, as a result, usually have less defined boundaries. Deep wetlands also provide a challenge because they have less well-defined boundaries, and hence their storage volume (due to bottom undulations) is more variable. When draining deep wetlands can produce much more variability in outflow rates. Mid-depth wetlands, on the other hand, have less variable outflow and better defined boundaries.

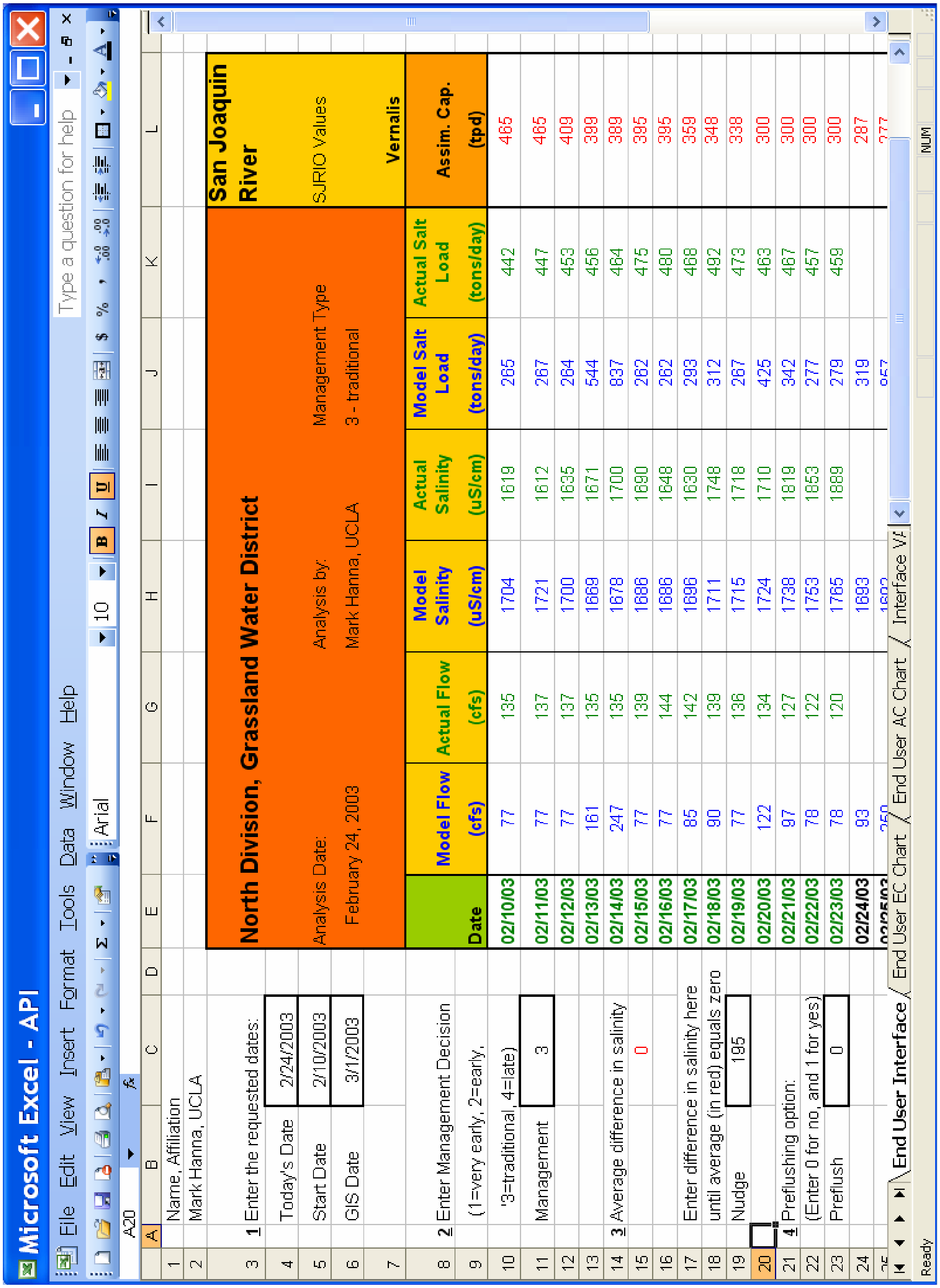


Figure 3.5. Wetland Water Quality Model user interface.

These boundaries, in the form of levies, are designed to keep the entire wetland unit at a chosen depth. Figure 3.6 shows the Salinas Land & Cattle Club, a good example of a mid-depth seasonal wetland unit in the Grasslands Water District.

Figure 3.6. The Salinas Land & Cattle Club, an example of a mid-depth seasonal wetland unit in the Grassland Water District

3.8 Model Components

To track wetland conditions as they progress through the flooded season, and monitor their impacts on the SJR, four different analytical worksheets were created within the WWQM. These four components -- wetland management, wetland hydrology, wetland salinity, and San Joaquin River assimilative capacity -- are discussed below.

3.8.1 Wetland Management

The WWQM's foundation derives from a combination of accepted wetland "best management practices" (BMPs) for seasonal wetlands. The specific BMP used for the seasonal wetland habitat management component is the recommended flooding regime published in “A Guide to Wetland Habitat Management in the Central Valley”. This guide was developed, as noted earlier, through a cooperative effort of the California Department of Fish and Game and The California Waterfowl Association (Smith et al., 1995). For seasonal wetlands in California’s Central Valley, this guide suggests a flooding regime for optimal wetland management for certain moist-soil plants.

3.8.2 Model output parameters

Ai – Target Depth, TD

The model calculates the average depth, or “target depth”, in the wetland unit system based on the management plans named above. The target depth is dictated by date, water year type, and the combination of the wetland percentages delineated as “habitat clubs” (%HC) and “cattle clubs” (%CC). Habitat clubs are those that are managed for habitat throughout the year. Cattle clubs, on the other hand, are flooded during hunting season but drained shortly thereafter in order to graze cattle. The model treats the cattle club exactly like a habitat club during fall floodup and throughout the flooded season. However, no matter the water year type, the WWQM initiates drawdown for cattle clubs on February 1st each year. This target depth, which is a combination of the depth for the habitat clubs (HAB) and cattle clubs (CAT), along with their present percentage of the total land, is the controlling factor during the daily time step process within the WWQM

$$TD_t = (\%HC \times HAB_t) + (\%CC \times CAT_t) \qquad \textbf{(5)}$$

Using the “season type” decision variables within the user interface (Figure 3.5), the end user can shift the wetland management timing curve earlier or later, depending upon the user’s interpretation of the current year type (extremely dry, dry, normal, and wet). This target depth, calculated for a specific wetland system (i.e. shallow, mid-depth, or deep) and water year type, is then compared to the modeled wetland storage depth, *D*, using the water balance formula in Equation 4). This comparison affects the following day’s decisions by either suggesting a need for additional surface water input or that no water is required.

3.9 Wetland Hydrology

Bi – Wetland Storage Depth, D

The hydrologic modeling within the WWQM considers the water cycle (Figure 3.7) and its associated water balance equation. The water balance equation has been arranged to calculate the wetland storage depth, D_t, using the following inputs:

$$D_t = D_{t-1} + \sum_{t=1}^{t} (I_t + P_t + GI_t - E_t - ET_t - O_t - GO_t) \qquad \textbf{(6)}$$

where t is the time step; D_t is the end of period storage depth in the wetland units; I_t is the wetland inflow; P_t is the precipitation that falls within the individual wetland units; GI_t is the groundwater inflow to the individual wetland units; E_t is the direct evaporation from the open water surfaces within each wetland unit; ET_t is the evapotranspiration from the vegetated portions of the wetland units; O_t is the combined wetland outflow and operational spill; and GO_t is the groundwater inflow / outflow. The Wetland Storage Depth, D_t, is calculated by starting each iteration with the results from the previous time step's storage depth, D_{t-1}. The model then adds and subtracts the daily inputs and outputs for the present time, *t*. The inputs are precipitation (P_t), operational inflow (I_t), and groundwater input (GI_t). The outputs are evaporation (E_t), evapotranspiration (ET_t), outflow (O_t) and groundwater outflow (GO_t).

Bii – Precipitation, P

Precipitation data are measured values. The precipitation data come directly from the California Irrigation Management Information System (CIMIS) website, www.cimis.water.ca.gov, operated by the California Department of Water Resources (DWR). CIMIS publishes daily climatic data recorded at many weather monitoring stations across California. All precipitation falling within a wetland unit and its associated uplands is assumed captured within the wetland unit itself. The total volume of rainfall, therefore, is the value of precipitation, measured in inches, multiplied over the land area. The closest CIMIS station is located within the former Kesterson Reservoir north of Los Banos.

Biii – Groundwater Inflow, GI

Lateral groundwater flow and salinity data, if available, can be applied to the WWQM. The WWQM accepts groundwater data through the update files similar to climate and land use data. Since groundwater flux data are not available, the model assumes that groundwater inflows and outflows balance and the net contribution to salt balance is zero.

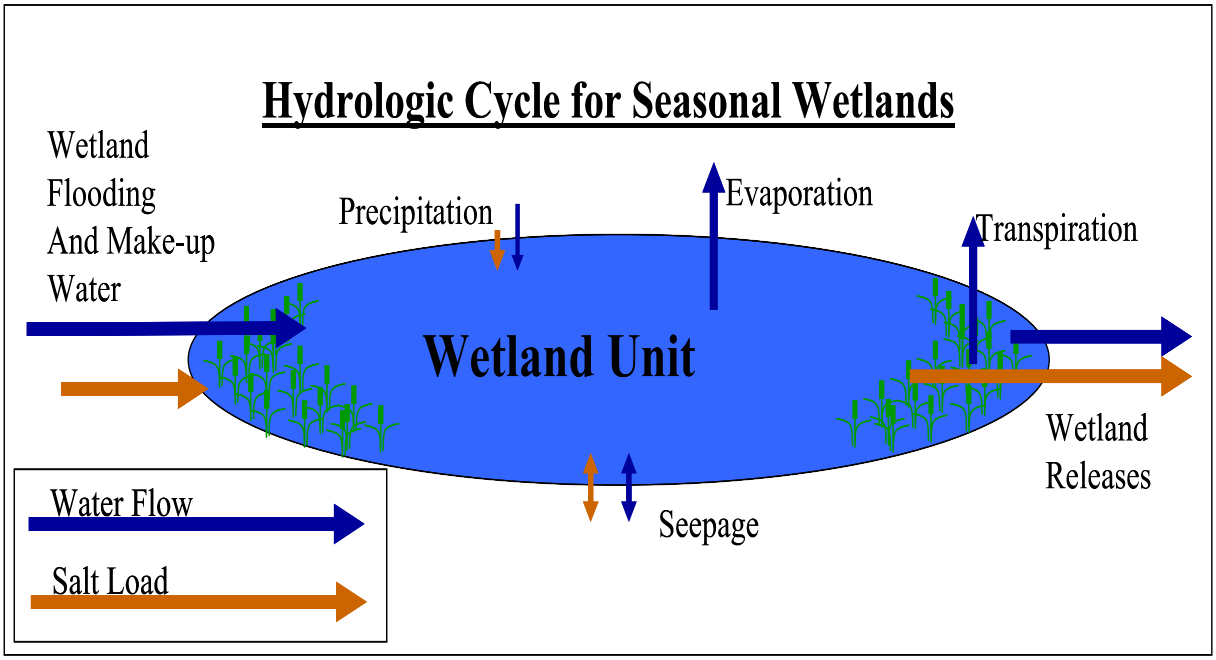


Figure 3.7 – Hydrologic inputs and outputs for seasonal wetlands.

Biv – Surface Water Inflow, I

Surface water inflow is a model calculated value. It represents all water diverted to the wetlands during flood-up, plus make-up and irrigation water. It is the water added seasonal wetlands to maintain their depth at or near management targets, or to provide summer irrigation water. The net inflow is set equal to the difference between the desired depth and the simulated depth, expressed as a volume. The WWQM assumes zero make-up water when simulated depth is greater the management target. Inflow is accounted for in the model in the following manner. If the previous day's End of Day Storage Depth, D_{t-1}, is greater than the current day's target depth, TD_t, then the current day's inflow, I_t, equals zero.

$$\text{If } TD_t > 0, \text{ then} \quad E_t = (\%OW)(E_{pan,\ t}\, K_{p,\ t}) \quad \text{otherwise;} \quad E_t = 0 \qquad \boxed{7}$$

However, within the user interface, the user can request a "preflush" option (Figure 3.5) where the model simulates additional fresh water inputs to help flush out the salts. In this case, where the user has selected a positive, non-zero value in the user interface, I_t is set equal to the user-defined pre-flush value. The default is 0.4 inches for a period of 30 days, yet this can be changed to whatever is desired with the next release of the update.xls file.

Bv – Evaporation, E

Evaporation is a measured value. The evaporation data are measured by monitoring the drop in water elevation in an open pan. This method is called pan evaporation, E_{pan}. This variable comes directly from the CIMIS website, www.cimis.water.ca.gov, operated by DWR, and must be compensated for local precipitation. These data are updated periodically and delivered to the user in the update.xls file. The evaporation data that is downloaded from CIMIS is manipulated for use in the model by multiplying it by the percentage of open water, *%OW*, and by a pan coefficient, K_p. This coefficient is for use in translating corresponding evaporation pan data to the water body of concern.

$$\begin{gathered}\text{If } TD_t > 0\text{, then}\\ E_t = (\%OW)(E_{pan,\ t}\, K_{p,\ t})\\ \text{otherwise;}\\ E_t = 0\end{gathered} \qquad \mathbf{8}$$

Bvi – Evapotranspiration, ET

Evapotranspiration (ET) data are calculated values. Evapotranspiration can be computed in several ways. These options include the Hargreaves method (Hargreaves and Samani, 1985) using temperature as an ET indicator, the Priestley-Taylor approach (Priestley and Taylor, 1972) which uses surface heat flux and large-scale parameters to calculate evaporation and evapo-transpiration, and the Penman-Monteith equation (Monteith, 1965) utilizing many atmospheric components. The Penman-Monteith equation is very robust and is the accepted method if multiple parameters such as vapor pressure, radiation, soil heat flux density, mean daily temperature, and wind speed, are available (Arnold et al., 1998).

CIMIS publishes daily ET data using a modified version of the Penman-Monteith equation for the various climate zones in California. The modification includes a wind function and was developed by the University of California, Davis (CIMIS, 2003). CIMIS publishes the data necessary to calculate reference evapotranspiration, but it also calculates and publishes reference evapotranspiration (ET_o) using the modified version of the Penman-Monteith equation. This daily ET data can be found on the CIMIS website, www.cimis.water.ca.gov, operated by the DWR. For estimating ET_o (ET_{ref}), a modified version of the Penman-Monteith equation (Allen et al., 1999) with some fixed parameters was used (Walter et al., 2000 and Itenfisu et al., 2000.). The equation is written as follows:

$$ET_{ref} = \frac{0.408\Delta(R_n - G) + \gamma \frac{C_n}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d u_2)} \qquad \boxed{9}$$

where Δ is the slope of the saturation vapor pressure at mean air temperature curve [kPa/ ^oC]; R_n is the net radiation [MJ/m^{2}d]; G is the soil heat flux density [MJ/m^{2}d]; γ is the psychrometric constant [kPa/ ^oC]; T is the daily mean temperature [^oC], u_2 is the mean wind speed [m/s]; and e_s-e_a is the vapor pressure deficit [kPa]. C_n and C_d are given specific values depending on the calculation time step and the reference crop, and are 900 and 0.34, respectively (Snyder et al., 2002). The modified Penman-Monteith equation is accepted widely and as such was chosen by DWR for its agricultural water use calculations, and these published daily values of ET_o are used in the WWQM. The ET_o data provided by CIMIS is manipulated for use in the model by multiplying it by a wetland crop coefficient, K_c, the percentage of emergent vegetation, *%EV*, and by an osmotic resistance factor, *R* (Glenn et al, 1995).

If $TD_t > 0$, then,

$$ET_t = (\%EV)(ET_{o,t}\, K_{c,t})\, R \qquad \boxed{10}$$

where *ET* is the total evapotranspiration, *%EV* is the percentage of land covered by emergent vegetation, ET_o is the reference ET published by CIMIS, *Kc* is the crop coefficient, and R is the osmotic resistance factor. The crop coefficient, *Kc*, is used in translating reference evapotranspiration, ET_o, into actual evaporation for the vegetation of concern, in this case, emergent vegetation. Values for the *Kc*'s were taken from the several sources and compiled to create a crop coefficient curve (Snyder et al., 2002; USBR, 1993 - Figure 3.8). Although there was considerable discrepancy between the other sources regarding the magnitude of the seasonal change, there was a general agreement for the seasonal pattern and range (Hargreaves and Samani, 1985; USBR, 1993). This information has been adapted for the WWQM. The formula for the *Kc* as the season progresses is:

$$Kc = 1.05 + \frac{\left[\sin\left((x-135)\times\frac{\Pi}{180}\right)\right]}{5} \quad \textbf{11}$$

where *x* is the julian date. This formula was derived by fitting the sine curve to the interpolated *Kc* curve (Figure 3.8).

Another factor involved in the modeling of ET within the WWQM is salinity effects on plant uptake. Salinity has a marked effect on a plant's ability to take water in through their roots. This phenomenon is referred to as the Osmotic Resistance Factor, *R*. A recent study shows that emergent vegetation is not noticeably affected (*R*=1) when salinities are below 1,460 EC (1,100 mg/L). However, when salinities are in the 4,600 EC range (3,500 mg/L) the growth rate of wetland vegetation decreases to about one-half the normal growth rate (*R*=.5). When salinities reach 8,000 EC (6,000 mg/L) and above, the growth of the vegetation stops altogether (*R*=0) (Glenn et al., 1995). This is incorporated into the model through decision variables, so that if the salinity is below 1460 EC, then evapotranspiration is only a function of the modified Penman-Monteith equation (Equation 9), the *Kc* equation (Equation 11) and the percentage of emergent vegetation (*%EV*) present in the wetlands. The osmotic resistance factor, *R*, comes into effect when the salinity increases above 1,466 EC. When the salinity is below 1,466 EC, *R*=1, but as salinity increases above 1,466 EC, the decision variable includes the formula derived from the emergent vegetation study described above. The formula for calculating *R* is as follows:

If *ECDt* > 1,466, then

R = -0.0002(EC) + 1.2263 **12**

otherwise

$R = 1$

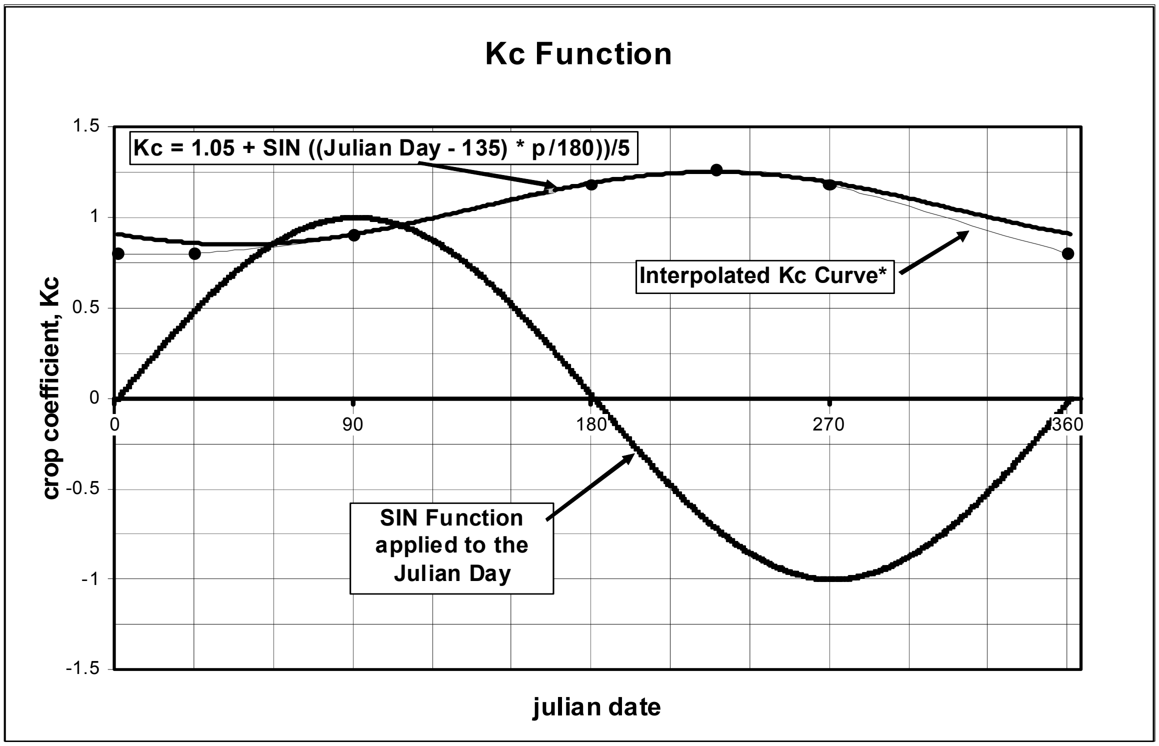


Figure 3.8. The Crop Coefficient, *Kc*, for emergent wetland vegetation in the San Joaquin Valley

Bvii – Surface Water Outflow, O

Surface water outflow is calculated by the WWQM. While the wetlands are flooded, this value is calculated by adding the operational spill, OS_t, to the difference, if positive, between the modeled and target depths (D_{t-1} and TD_t). In other words, if the current day's Target Depth is greater than the previous day's wetland storage depth, D_t, then no major wetland releases will occur, except for operational spill that is automatically released at a rate of 1 cfs per 235 wetland acres.

If $TD_t >= D_{t-1}$, then, **13** $O_t = OS_t$

OS_t = 1 cfs / 235 acres (or 0.1 inches/day) **14**

Otherwise :

If $TD_t < D_{t-1}$, then

$O_t = OS_t + D_{t-1} + TD_t$ **15**

However, if there is a one-fourth inch discrepancy between D_{t-1} and TD_t.

$$D_{t-1} - TD_t, > 0.25, \text{ then}$$
$$O_t = 0.33$$ **16**

The upper limit of 0.33 for O_t is set because there is a maximum outflow capacity of most wetland flow control structures of 3.3 cfs / 235 acres. There is also a depth cutoff of one-fourth inch that functions as the threshold to wetland release prompting the model to stop releasing water from the wetlands.

Bviii – Groundwater Outflow, GO

Groundwater outflow and inflow are predicated on having quantitative regional flow data.

3.10 Wetland Salinity

Ci – Wetland Storage Depth Salinity, EC_D

The wetland salinity for the end of day storage, EC_{Dt}, is calculated on a daily basis by using the box model balancing equation detailed above. The box model uses proportional contributions of all inputs and outputs, along with the water and salts remaining from the previous day, and calculates the overall salinity in the ponded water volume, or end of day storage depth, D_t. The formula used to calculate EC_{Dt} was shown above in.

The WWQM logical expression to calculate is:

$$\text{If } D_t <= 0; \text{ then}$$
$$EC_{Dt} = 0$$
$$\text{otherwise,}$$ **17**

$$\text{If } 0 < D_{t-1} < 1.2\text{”},$$
$$\text{and if } D_t > 0; \text{ then}$$
$$EC_{Dt} = 1.25\ EC_{It}$$ **18**

The assumption that the end of day EC of the depth of water in the wetlands is 1.25 times the EC of the inflow when the wetlands are filling and the depth is between zero and 1.2” comes from field observation of initial floodup in wetland units within the GWD. This is a minimal case. If, however, the wetlands are filling (above the 1.2" level) or are completely full, it follows that:

If $D_{t-1} > 1.2$, then

EC_{Dt} is calculated by : **19**

3.11 San Joaquin River Assimilative Capacity

The SJRMP published weekly assimilative capacity forecasts for salts on the SJR, in tons per day during 2001, 2002 and 2003. Current water quality forecasts are merely straight line projections of current data. The website is http://www.dpla.water.ca.gov/sjd/sjrmp/index.html. These data are downloaded and delivered to the WWQM users through the update.xls file.

3.12 Data updating

Input data are updated and compiled on a weekly or an as-needed schedule into an update spreadsheet, update.xls, and delivered by email to the users of the WWQM.

3.13 Model Outputs

The model outputs for the WWQM are wetland flow and salinity. Flow is a much more difficult parameter to model in this system as there are many different wetland managers making decisions on a day-to-day basis. However, the modeled salinity is less variable and less prone to error.

3.13.1 Wetland Releases - Flow

Total surface water outflow is calculated using the end of day storage depth, D_t, measured in units of inches, into a flowrate, Q_t, measured in units of cubic feet per second [cfs]. This is accomplished by converting the storage depth into the outflow value, O_t, in inches per day using the conversion factor of 0.042014 to get cubic feet per second, per acre. Multiplying this value by the total acreage serviced by the drainage site returns a total flow rate for the entire wetland drainage basin.

Ai – Adjusted Flow, A - Flow

The total simulated surface water outflow needs to be calibrated because the flow calculated by the WWQM consistently underestimates the total flow measured leaving the wetland drainage basins. This is most likely due to groundwater seepage, operational losses, evaporative losses, or a combination of these flows. The calculated flow, $Flow_t$, is corrected to the adjusted flow, $A - Flow_t$, by dividing it by the percentage difference, $Y\%$, between the calculated values and the measured data.

$$A - Flow_t = Flow_t \,/\, Y\% \qquad \mathbf{20}$$

3.13.2 Wetland Salinity, EC_{Dt}

Wetland salinity mass balance model runs rely on the box model developed for the WWQM (Figure 3.3). At any point in time, the model calculates wetland salinity, EC_D [uS/cm], using the proportional contribution salinity balance model presented above.

Bi – Adjusted Wetland Salinity, A-EC_{Dt}

The simulated wetland salinity needs to be adjusted because the salinity calculated by the WWQM also consistently under estimates the salt concentration in drainage outflow. This underestimate is most likely due to groundwater contributions, residual salts, and bird usage, pond short circuiting or a combination of all factors. In general, the assumption that outlet salinity is equivalent to the mean salt concentration in a seasonal wetland is most likely flawed – in many wetlands short-circuiting of flow can occur and the outflow measured salinity will invariably be less than the calculated salinity. The calculated salinity, EC_t, is corrected to the adjusted salinity value, $A - EC_t$, by dividing it by the average percentage difference, $Y\%$, between the calculated and the actual values.

$$A\text{-}EC_{Dt} = EC_{Dt} / Z\% \qquad \mathbf{21}$$

3.14 Model Application

The WWQM was first applied to the NGWD as a management tool for the spring drawdown in 2003. The NGWD encompasses roughly 25,000 acres of wetlands and associated uplands of the 50,000-acre GWD. The 25,000 acres of the NGWD are divided into 70 individually owned and managed wetland units ranging in size from 200 to 2000 acres. During the spring drawdown period discussions took place among the wetland managers as to when drawdown should commence. After the GWD Watermaster, Scott Lower, performed a model simulation on 24 February 2003, and results showed moderately high wetland salinity coupled with high San Joaquin River assimilative capacity, he had justification to call for a seasonal wetland drawdown earlier than normal to begin exporting ponded salts. Another model simulation performed on 24 March 2003 showed that although average wetland salinity concentrations had increased, and SJR assimilative capacity had decreased, there still appeared to be sufficient remaining San Joaquin River assimilative capacity to accommodate the residual salt load in the GWD. As it turned out, an unusually wet April increased San Joaquin River assimilative capacity for the later part of April and early May, so that the necessity of accelerating the typical drawdown schedule was muted. No further action was taken to influence the spring drawdown in 2003.

3.15 Model Input Data Sources

For future simulations using the Grassland Water District WWQM, input data can be organized into into four categories: fixed data, annually invariant data, annually varying data, and real-time (continuous) data. Fixed data, which do not vary with time, include soil properties, land classifications, wetland acreages, drainage basin surface water deliveries and

Table 3.2 NGWD drainage basin specifications.

Drainage Basin	Total Acreage	Wetland Acreage	% Cattle	% Habitat
Mud Slough	10,366	7,925	21%	79%
Hollow Tree Drain	4,150	3,409	0%	100%
S-Lake Drain	1,644	1,390	33%	67%
Fremont Canal	705	461	20%	80%
Los Banos Creek	8,686	8,058	10%	90%
TOTALS	25,551	21,243	14.1%	85.9%

precipitation and evapotranspiration qualities. Annually invariant data, which are static year to year but vary within a given year, include crop coefficients, best management practices, and water table depth. Annually varying data include precipitation, water year classification, air, water, and soil temperatures, and irrigation and wetland flood-up schedules. Real-time (continuous) data include supply water quantity and quality, wetland drainage water quantity and quality, evapotranspiration, precipitation, and San Joaquin River assimilative capacity. Much of the fixed and annually constant data are estimated since intensive monitoring of these wetlands only commenced in water year 2000.

The input data were grouped into the four different WWQM components described above in model development. These components are wetland management, wetland hydrology, wetland salinity, and San Joaquin River Assimilative Capacity.

3.15.1 Wetland Management

The NGWD is subdivided into approximately 70 duck clubs or land and cattle clubs. The private clubs of the GWD range in size from 200 to 2000 acres each. Furthermore, each club is divided into a number of units on the basis of management – uplands, seasonal wetlands, semi-permanent wetlands, and permanent wetlands (Figure 3.6). In addition, some clubs belong to State and Federal habitat programs such as the California Department of Fish and Game's Pressley Program, where land owners get paid a per acre fee for managing their wetlands in a habitat-friendly manner. Other management scenarios can include agricultural activities such as grazing cattle. Other land use data include percent open water and percent emergent vegetation. The wetland units in the NGWD that are solely managed for wetland habitat in the GWD comprise approximately 86% of the wetland acreage, and those that are managed for habitat and cattle grazing comprise the remaining 14% of the wetland acreage.

For modeling purposes, the individual properties, or wetland units, of the NGWD were grouped according to their respective drainage basins. They were then given a land use classification regarding their management practice type, either a habitat club or a cattle club. Each club was assigned a percent open water value and a percent emergent vegetation value, based on satellite imagery vegetation classification. A surface water source ranking also was determined. This surface water ranking depends on how much water re-use is occurring. All of these data are managed in Microsoft Excel™ and Microsoft Access™ database tables so they are able to communicate directly with the WWQM as well as ArcGIS™.

Table 3.3 – Input data for the WWQM

Data Element	Symbol	Units*	Source
Time	t (t-1, t+1)	day	na
Target Depth	TD	inches	Smith et al, 1995
End of Day Storage Depth	D	inches	calculated
Salinity of End of Day Storage Depth	ECD	uS/cm	calculated
Precipitation	P	inches	CIMIS
Inflow	I	inches	calculated
Salinity of Inflow	ECI	uS/cm	network
Evaporation (from open water)	E	inches	calculated
Pan Evaporation	Ep	mm	CIMIS (USDA, Station 5)
Pan Coefficient	Kp	na	USDA, 2000
Evapotranspiration	ET	inches	calculated
Reference Evaporation	ETo	inches	CIMIS
Crop Coefficient	Kc	na	calculated, USBR 1993
Operational Spill	OS	inches	estimated
Outflow	O	inches	calculated
Salinity of Outflow	ECO	uS/cm	calculated
Groundwater Inflow	GI	inches	na
Groundwater Outflow	GO	inches	na
Desired Depth for Habitat Clubs	HAB	inches	Smith et al, 1995
Desired Depth for Cattle Clubs	CAT	inches	estimated
Percentage of open water wetlands	%OW	%	GWD, 2000
Percentage of vegetated wetlands	%EV	%	GWD, 2000
Percentage of wetlands managed as Cattle Clubs	%CC	acres	GWD, 2000
Percentage of wetlands managed under the Habitat Programs	%HC	acres	Cal. DFG, 2001
Osmotic Resistance Factor	R	na	Glenn et al., 1995

*all units in inches or millimeters are counted as "per acre per day"

Ai – Target Depth, TD

Wetland management scenarios within the WWQM follow the two most prevalent management plans in the GWD. These management plans are for :

- habitat clubs-clubs that are managed throughout the year with wetland habitat as their main consideration,
- cattle clubs-clubs that are managed as waterfowl habitat during duck season, and are used for cattle grazing during the non-hunting season, or
- a combination of the two management plans above.

Both of the above management plans are forced using the recommended schedules outlined in Smith et al., 1995. The difference between the habitat and cattle management plans is that although both plans begin floodup at the same time, the cattle club always begins drawdown shortly after the close of duck season. Cattle clubs generally want to experience drawdown earlier than the habitat clubs to promote the growth of grasses for cattle to graze on.

3.15.2. Wetland Hydrology

Bi – Wetland Storage Depth, D

After initial floodup (early to mid-September), the ponds are continually topped-up with a low flow of make-up through each wetland area. The make-up water not only keeps the wetlands "fresh", but also replenishes wetland losses due to direct evaporation, ET, and seepage helps to maintain a desirable depth of between 10 and 12 inches, on average, in a majority of the seasonal wetlands. The WWQM simulates this by continually adding surface water to keep the wetland storage depth, *D*, at the target depth level, *TD*.

Bii – Precipitation, P

Daily data for precipitation, *P*, is readily available from CIMIS. For precipitation in the NGWD, data are downloaded from the CIMIS website for Station 56, Kesterson Reservoir. Kesterson is located just to the northeast of the NGWD, so the data should be representative. These data are delivered to the user in the update.xls file. Precipitation data are downloaded directly into the WWQM from the update.xls file and is applied to the wetlands as a function of total land area.

Biii – Groundwater Inflow, GI

Many wetlands contain soils with low hydraulic conductivity (high clay content), restricting regional groundwater infiltration (Owen, 1995). Regional gradients are shallow after the initial floodup – hence regional groundwater flow is minor compared to the ponded water volume. It has been noted, however, that in the wetlands of the SJR Basin anecdotal evidence of local groundwater flow is evident. Oftentimes, when a wetland has been drained while adjacent wetlands are still flooded, groundwater rises to near the soil surface in the drained wetland. Because the model's wetland boundary uses sub-basins within an entire wetland complex, this "localized' groundwater flow should have little impact on the model's overall results. In addition, this type of seepage more likely has an impact on the summer irrigation season and/or the following season's floodup. Because of a lack of data and understanding, regional groundwater flow was ignored during the 2003 drawdown of the NGWD. However, the WWQM is designed to readily accept groundwater data if available or can be estimated.

Biv – Surface Water Inflow, I

Inflow to the NGWD is supplied through district canals. The WWQM simulates supply for initial wetland floodup in the fall and for make-up water throughout the flooded season. The inflow, *I*, is calculated by comparing the wetland storage depth, *D*, to the target depth, *TD*, and adding water to *D* until it equals *TD*. If *TD* is less than *D*, no inflows are provided.

Bv – Evaporation, E

Because there is no direct evaporation data in close proximity to the NGWD, pan evaporation data was downloaded from the CIMIS website for Station 5, Shafter. Shafter is located south of the NGWD, but is in the same climate zone (zone 10) as signified by the CIMIS website and thus should display similar values to the Los Baños area (CIMIS, 2003). Calculations need to be made to transform the pan evaporation data into wetland. Pan coefficients, K_p, for use in this adjustment range from 0.6 to 1.3. A value of 0.7 is used in the WWQM because it is the most commonly cited in the scientific literature (Veissman and Lewis, 1996; Dingman, 2002). The formula for evaporation per unit area is:

$$E/A = (E_p)(K_p)(\%OW) \quad \boxed{\textbf{22}}$$

where *E* is the calculated evaporation, *A* is the wetland area in acres, E_p is the pan evaporation downloaded from the CIMIS website, K_p is the accepted pan coefficient, and *%OW* is the percentage of open water for the individual wetland units. Pan evaporation data are delivered to the user in the update.xls file.

Bvi – Evapotranspiration, ET

Reference evapotranspiration data, ET_o, is calculated by CIMIS and is downloaded into the WWQM through the update.xls file. To calculate ET_o, CIMIS uses the modified Penman-Monteith equation (CIMIS, 2003). The WWQM uses this published data and applies it to the formula used in the WWQM for evapotranspiration per unit area. This equation is

$$ET/A = (ET_o)(Kc)(\%EV)(R)$$ **23**

where ET is the final evapotranspiration in inches, A is the wetland area in acres, ET_o is the reference evapotranspiration calculated using the crop coefficient Kc, $\%EV$ is the percentage of emergent vegetation, and R is the osmotic resistance factor.

Bvii – Surface Water Outflow, O

Outflow is simulated by the WWQM. While the wetlands are flooded, this value is calculated by adding operational spill, OS_t, estimated at 1 cfs per 233 acres (Lower, 2003; Poole, 2002), to the difference, if positive, between the target depth, TD, and the calculated wetland storage depth, D. For example, if the current day's Target Depth is greater than the previous day's wetland storage depth, D_t, then no wetland releases will occur other than operational spill.

Bviii – Groundwater Outflow, GO

See the Groundwater Inflow section above for a description of the groundwater portion of the WWQM for the GWD.

3.15.3 Wetland Salinity, ECD

The salinity of the wetland storage depth, D, is called the wetland salinity, ECD. It is calculated using the box model formula described in the model development section.

3.15.4 San Joaquin River Assimilative Capacity

San Joaquin River data, including flows, salinity, and assimilative capacity are accessed and downloaded through the California Department of Water Resources' website at:
http://wwwdpla.water.ca.gov/sjd/waterquality/realtime/index.html .
The data are compiled from real-time water quality monitoring stations on the main stem of the SJR. Forecast values are accessed from the same location, but are compiled using the DWR's assimilative capacity forecast model, SJRIODAY (San Joaquin River Input Output Daily model). These data are available to the users in the update.xls file, and populate the user interface for comparison with the forecasted NGWD salinity exports.

3.16 Model Simulations and Model Results

The WWQM was prepared to simulate and forecast operations in the wetlands of the NGWD beginning in September 2002, during fall floodup. All data were inserted into the update file (update.xls) to conform to the model's format and time step. In addition, the real-time monitoring data from the wetlands, as well as for the SJR forecast data for assimilative capacity, required linkages into the model. For graphically viewing the model results, a results table was built into a Microsoft Access™ database. This results table and database provides the application process interface between the Microsoft Excel™ spreadsheet model and ArcGIS, the geographic information system (GIS) chosen for this application. A GIS database was created to provide visual representations of the data such as salinity concentration maps, data tables, and time series graphs, providing the functionality of a graphical user interface for data querying and presentation.

To associate the model with the wetlands of the NGWD, the individual wetland units were arranged into their unique drainage basins. Other associated land use information necessary to operate the model was also supplied. This information includes land area, wetland area, management practices, surface water sources, and percent vegetation versus open water. Each wetland unit was then given a ranking based on the proportion of first use and re-use of surface water supply. This task was performed with several wetland managers and the GWD water master. Each drainage basin then was assigned values from the compilations of the individual wetland unit values for supply ranking, percent vegetation and open water. These drainage basins then were modeled individually within the WWQM.

3.17 Calibration

Objectives for the calibration period were to avoid changing model parameters (such as *ET*, *Kc*, acreages, etc) to best "fit the curve and to simulate salinity concentration build-up as closely as possible. If errors occurred, it was better for the model to over-predict than under-predict, because conservatism in salinity predictions is beneficial to the receiving waters. A third goal was to have the model more closely follow the actual salinity curve during times when wetland drawdown may have been occurring.

A recurring difficulty in modeling seasonal wetlands is that, although there is one water master overseeing the entire GWD, there are at times more than 70 individual wetland mangers making decisions that impact salt concentrations in the wetland management areas. A salt and water balance model cannot uniformly forecast the behavior of all the wetland managers. Calibration runs determined that a correction factor of 0.8 should be applied to modeled EC values to account for a general underestimation of salinity concentrations. This underestimation is likely the result of smaller inflows and outflows that were not modeled, groundwater interactions, salt residues from prior operations, wetland short-circuiting and other factors not accounted for in the model.

Flooded Season 2000 – 2001

During the calibration period, the WWQM closely simulated wetland salinity for the NGWD (Figure 3.9). The year was classified as a dry/normal year even though there was a total of 7.72 inches of rain (Table 3.2). Rainfall of 7.72 inches falls within the range to be classified as a normal year (Table 3.5). The data and early model simulations suggested an early

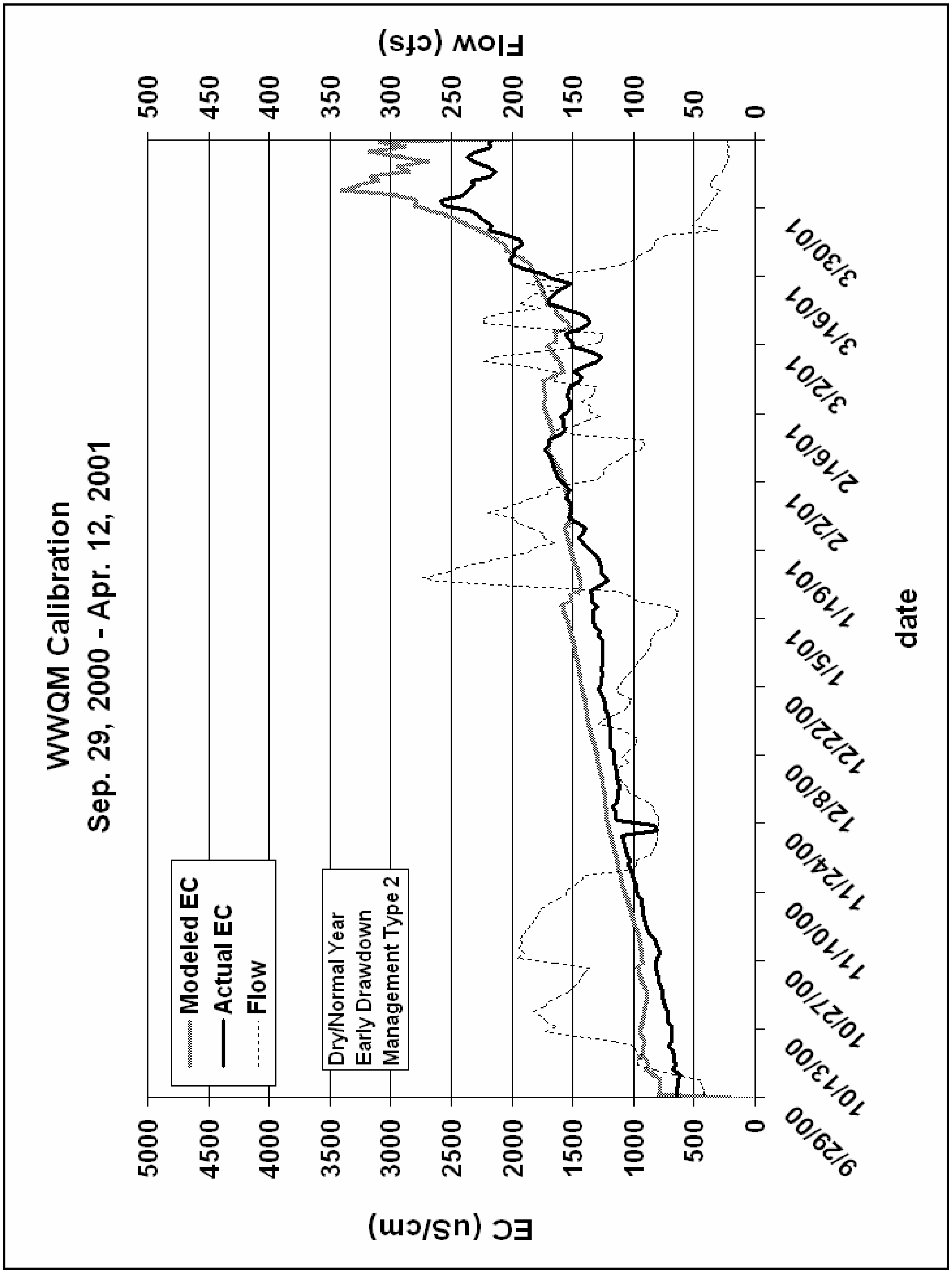


Figure 3.9 Results from WWQM calibration runs for Sep. 29, 2000 to Apr. 12, 2001. Modeled EC shows relatively good agreement with actual EC measurements.

drawdown (Table 3.1) as in dryer years, since soil moisture and temperature optimal for germinating desirable moist-soil vegetation tend to occur earlier. The management classification was set to Early (type 2 in the WWQM). Results showed that, despite an unexpected dip in actual salinity in mid- to late November, the model overestimated the actual salinity on average by 20%. After the November anomalous fall in measured salinity, the model and actual salinity values quickly converged to within 6.8% of each other. The deviation between the model and the actual then increases rapidly at the end of the model season because, when wetland drawdown rates for the NGWD drop below 100 cfs (near the assumed baseflow of 1 cfs / 235 acres), there tends to be a marked increase in model wetland salinity.

Table 3.2 - Annual average rainfall from 1988 to 2003

Water Year[1]	Totals
88-89	6.45
89-90	9.29
90-91	8.35
91-92	9.33
92-93	8.3
93-94	2.27
94-95	13.19
95-96	11.98
96-97	11.68
97-98	21.3
98-99	12.54
99-00	7.8
00-01	7.72
01-02	7.37
02-03	8.26

[1]Water Year is Oct 1-Sep 30

Table 3.3 – Description of water year type.

Year Type	Interval From	Interval To
Critically Dry	below 5.5	
Dry	5.5	7.6
Normal	7.6	11.8
Wet	above 11.8	

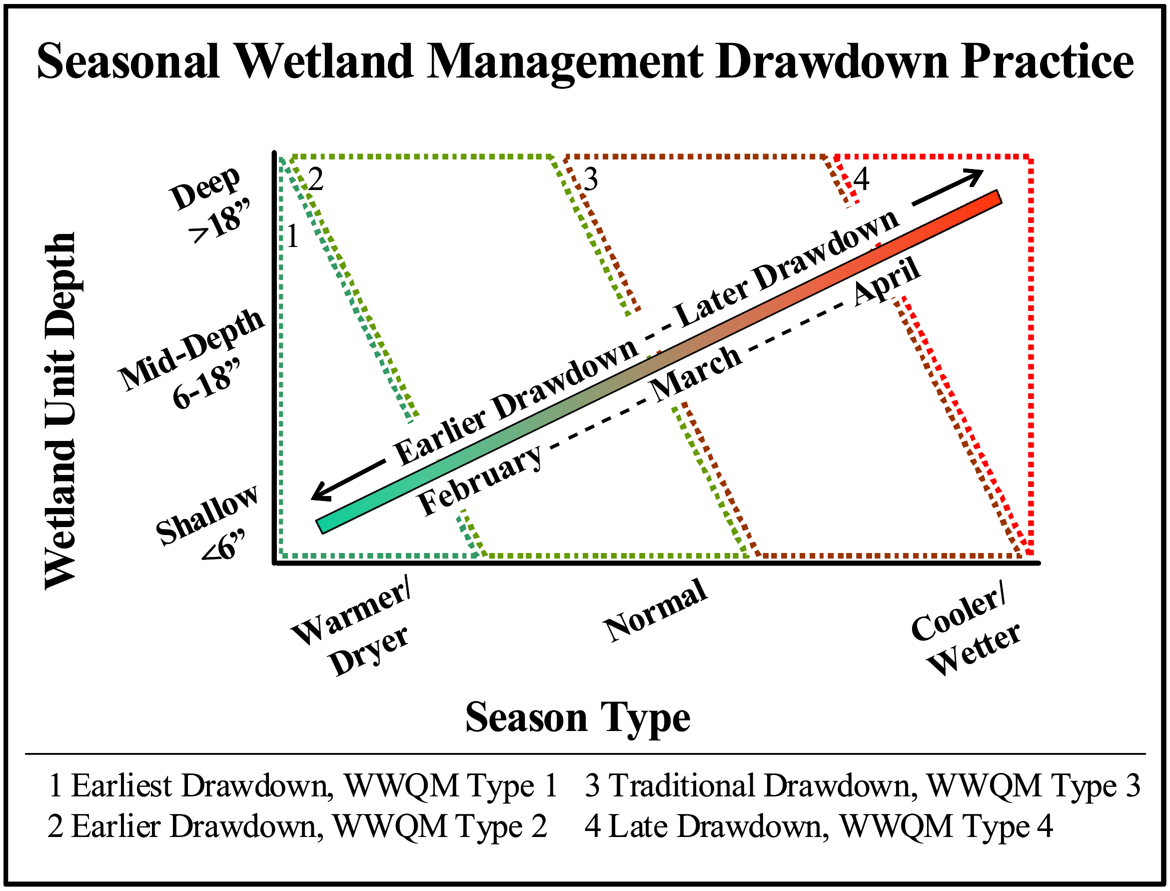


Figure 3.10 Seasonal wetland management practice with year types incorporated.

Although the model consistently overestimated wetland salinity (Figure 3.9), for management purposes the values were acceptable because a slight overestimation adds a factor of safety to the model. Figure 3.11 again shows the propensity for the model to deviate diverge from measured data as salinity increases above 2000 uS/cm.

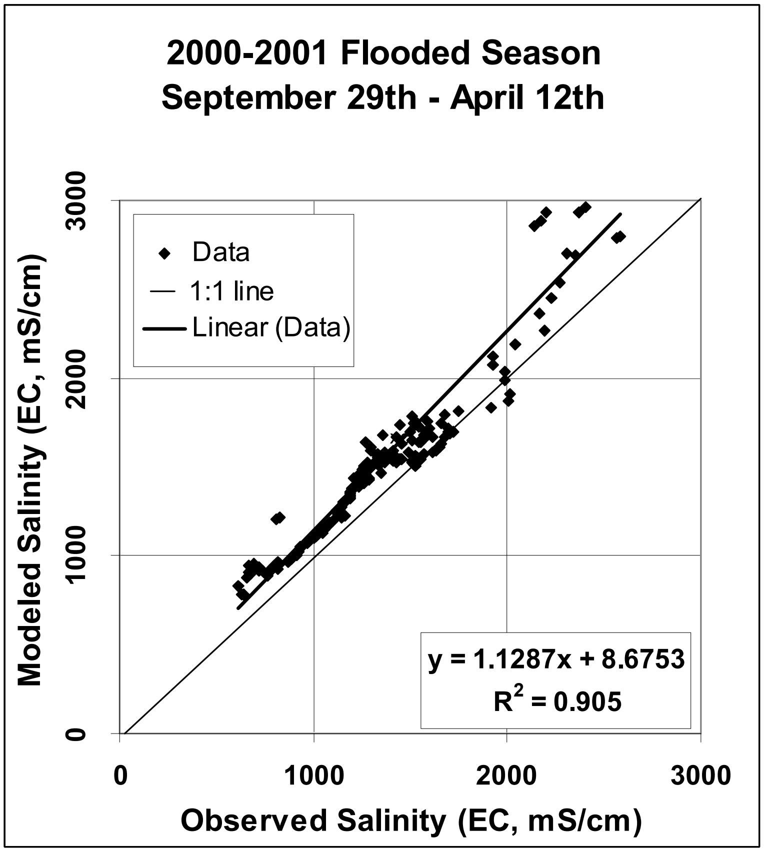


Figure 3.11 Accuracy of modeled versus observed salinity for the 2000-2001 flooded season.

Flooded Season 2001 – 2002

During the second year's validation period, the simulation did not perform as well as during the prior year. Throughout much of the modeled season, the WWQM underestimated the actual salinity. However, by the end of the model season, the modeled salinity was on average below the measured data by only 13% (Figure 3.12). The year was classified a dry year because there was a total of 7.37 inches of rain (Table 3.2). Such a total falls on the high end of the guidelines for a dry year classification (Table 3.3). Because the determination was dry, the management type was set at Very Early (type 1 in the WWQM, Figure 3.10). Results showed that although the model results deviated from measured data, during times of higher flow and during times of increased export, simulated and observed values agree. In addition, during the period of managed drawdown (March), the modeled

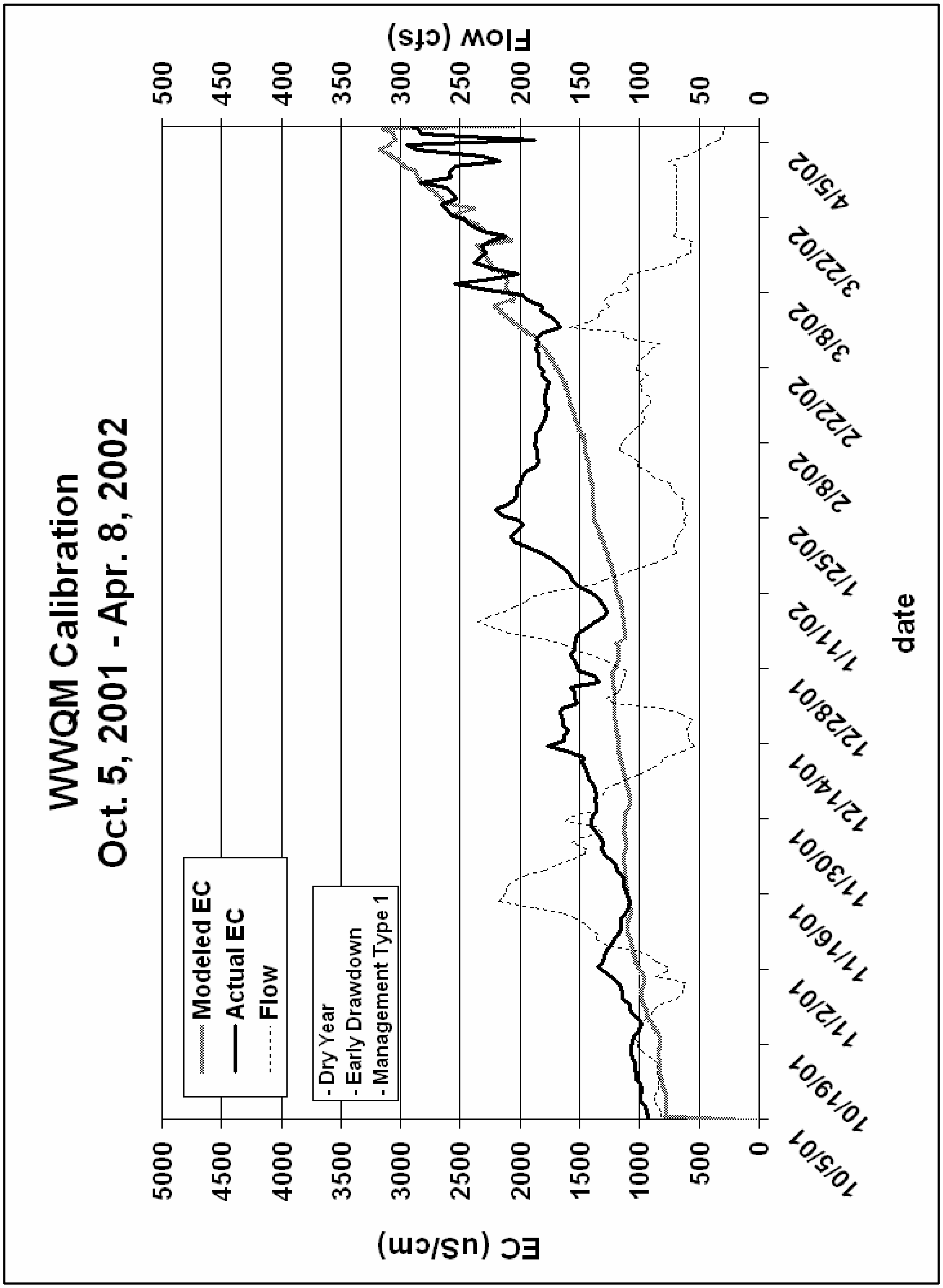


Figure 3.12 – Results from WWQM calibration runs for Oct. 5, 2001 through Apr. 8, 2002. The model underestimates actual salinity by an average of 13%.

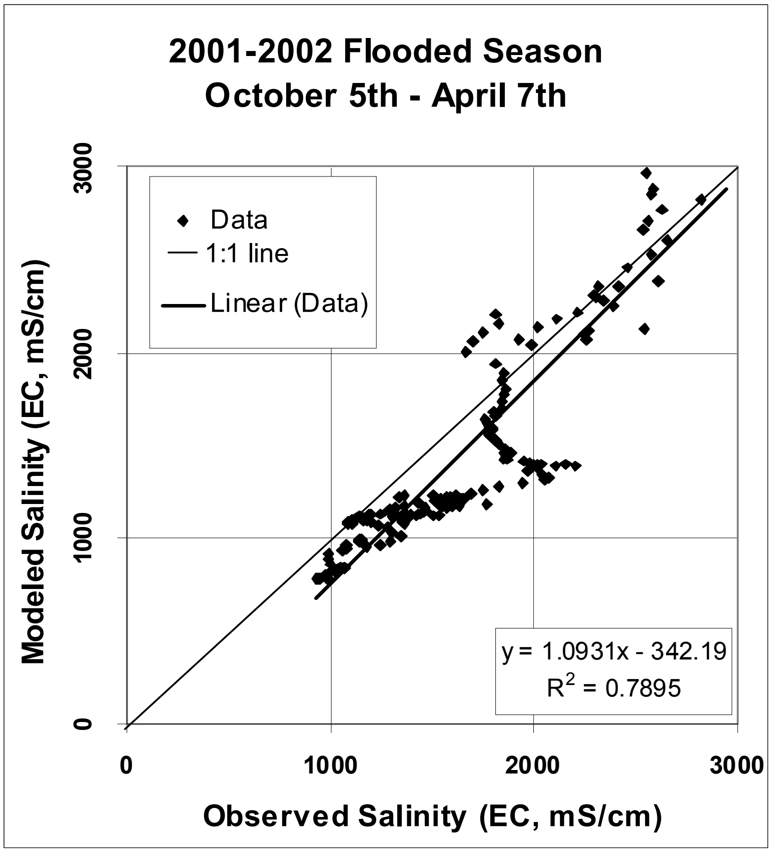


Figure 3.13 Accuracy of modeled versus observed salinity for the 2001-2002 flooded season.

values tracked the actual values very closely (Figure 3.12). Again, when the flows dropped below 100 cfs the model began to deviate more significantly. However, the graphs show that the forecast was valid throughout the period until pond salinity rose above 2,500 EC (Figure 3.13).

3.18 Analysis of Model Results

Flooded Season 2002 – 2003

For the entire model season, the modeled salinity underestimated measured salinity. A user interface was built that incorporated a "nudging" function to address this systematic bias. The nudging function takes the difference in the modeled and actual salinity during the prior two weeks of the model run and shifts the modeled curve upwards or downwards to match the actual wetland salinity data.

During the application year's simulation period, the WWQM once again underestimated the actual salinity. This time it underestimated it by an average of 14.4% (Figure 3.14). The water year type was classified a normal year because, by the time the first model run was performed in late February, almost six inches of rain had fallen and more was forecasted to arrive. Because the determination was for a normal year type, the management type was set at Traditional (type 3 in the WWQM). Results showed that although the model slightly overestimated the actual salinity throughout the year, during the traditional drawdown period (late March to early April), the modeled and observed salinity values had converged (Figure 3.15).

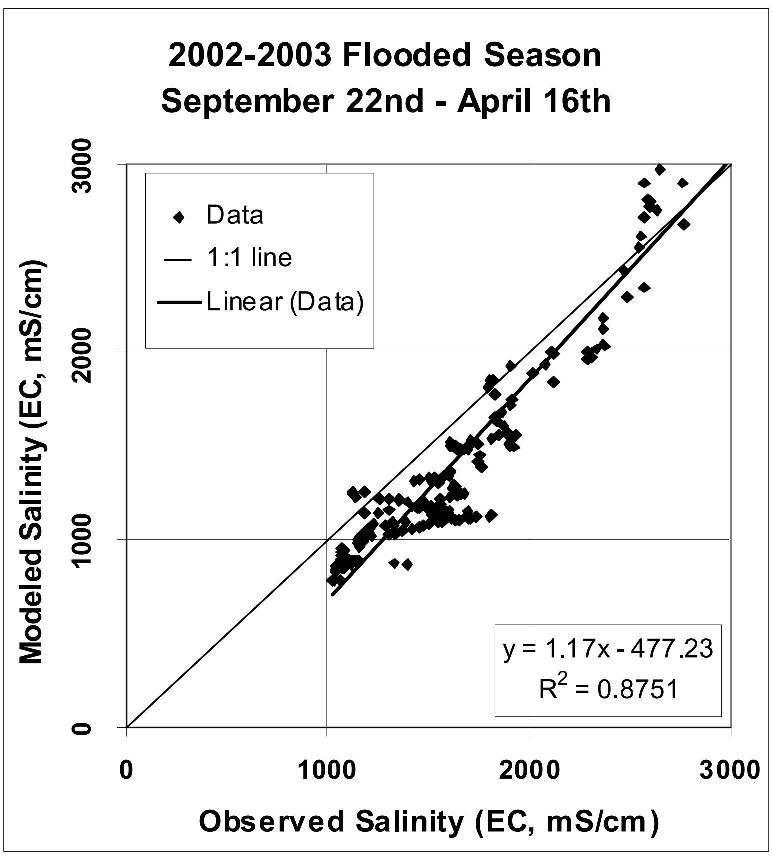


Figure 3.15 - 2002-2003 flooded season scattergram.

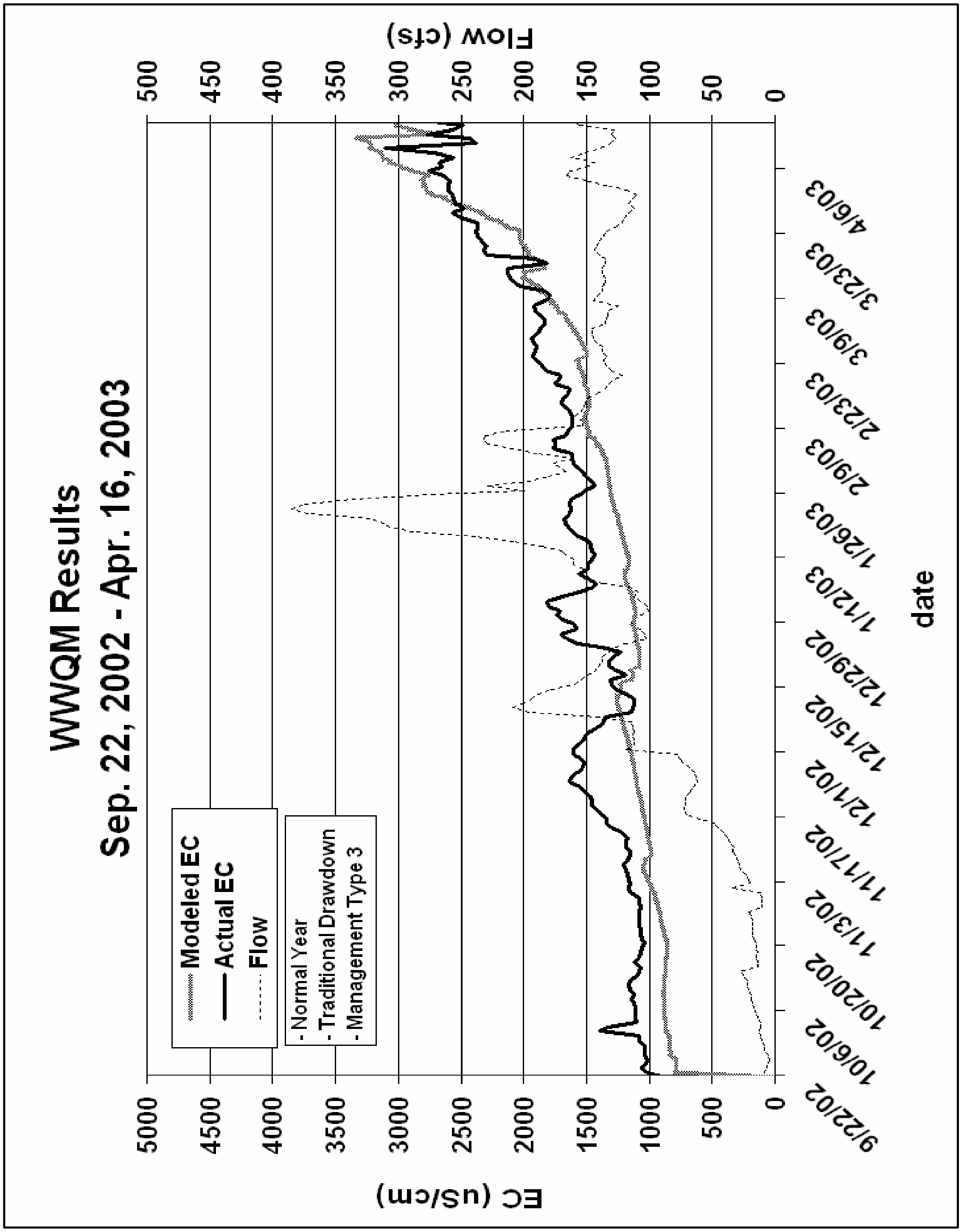


Figure 3.14 Results from WWQM calibration run from Sep. 22, 2002 through Apr. 16, 2003. The model again underestimates actual EC measurements, but by an average of 14%

On 24 February 24 2003, a preliminary model simulation produced a 2-week forecast of the salinity of the NGWD wetlands. After updating the model with data from the real-time wetland water quality monitoring network, the SJRMP, and CIMIS, the model predicted that the wetland salinity would increase from approximately 1800 EC to above 2000 EC in the next two weeks (Table 3.4 and Figure 3.16). In addition, data from the SJRIO2 forecast predicted the assimilative capacity for salts in the SJR should remain acceptable for wetland drawdown for at least one week and peaking in early April (Figure 3.17). These results prompted the GWD to encourage wetland managers to either begin drawdown within five days, or hold off drawdown until a week or two of low assimilative capacities could move through the SJR system (Figure 3.16).

Table 3.4 – Tabular results of February 24, 2003 model application.

North Division, Grassland Water District Analysis Date: February 24, 2003			Analysis by: Mark Hanna, UCLA				San Joaquin River SJRIO Values Vernalis
Date	Model Flow (cfs)	Actual Flow (cfs)	Model Salinity (uS/cm)	Actual Salinity (uS/cm)	Model Salt Load (tons/day)	Actual Salt Load (tons/day)	Assim. Cap. (tpd)
02/10/03	77	135	1751	1619	272	442	465
02/11/03	77	137	1767	1612	275	447	465
02/12/03	77	137	1744	1635	271	453	409
02/13/03	83	135	1715	1671	288	456	399
02/14/03	160	135	1724	1700	559	464	389
02/15/03	77	139	1729	1690	269	475	395
02/16/03	77	144	1726	1648	268	480	395
02/17/03	77	142	1733	1630	269	468	359
02/18/03	77	139	1747	1748	272	492	348
02/19/03	77	136	1748	1718	272	473	338
02/20/03	77	134	1757	1710	273	463	300
02/21/03	77	127	1770	1819	275	467	300
02/22/03	77	122	1782	1853	277	457	300
02/23/03	77	120	1793	1889	279	459	300
02/24/03	87		1728		305		287
02/25/03	250		1729		876		277
02/26/03	250		1747		885		267
02/27/03	160		1767		573		257
02/28/03	77		1786		278		280
03/01/03	77		1806		281		280
03/02/03	77		1830		284		325
03/03/03	77		1855		288		447
03/04/03	77		1871		291		341
03/05/03	77		1900		295		203
03/06/03	77		1930		300		125
03/07/03	77		1959		305		82
03/08/03	77		1987		309		50
03/09/03	77		2021		314		27

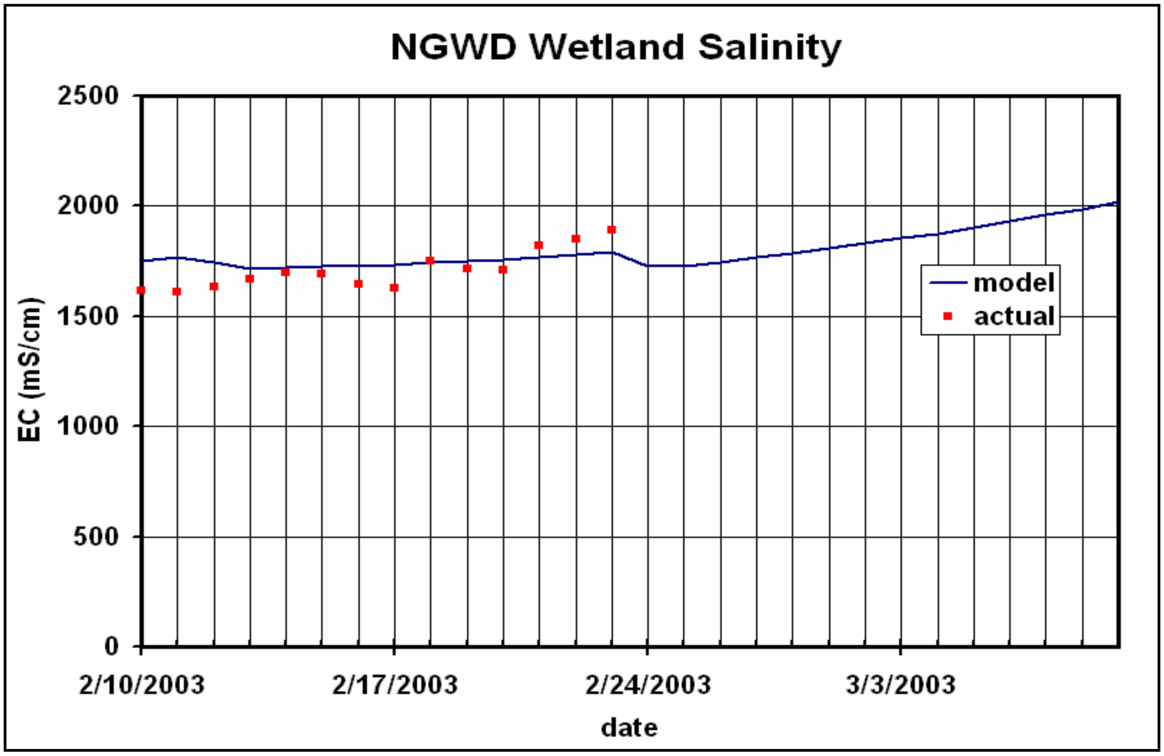


Figure 3.16 Comparison of modeled versus observed EC from February 24, 2003 model application.

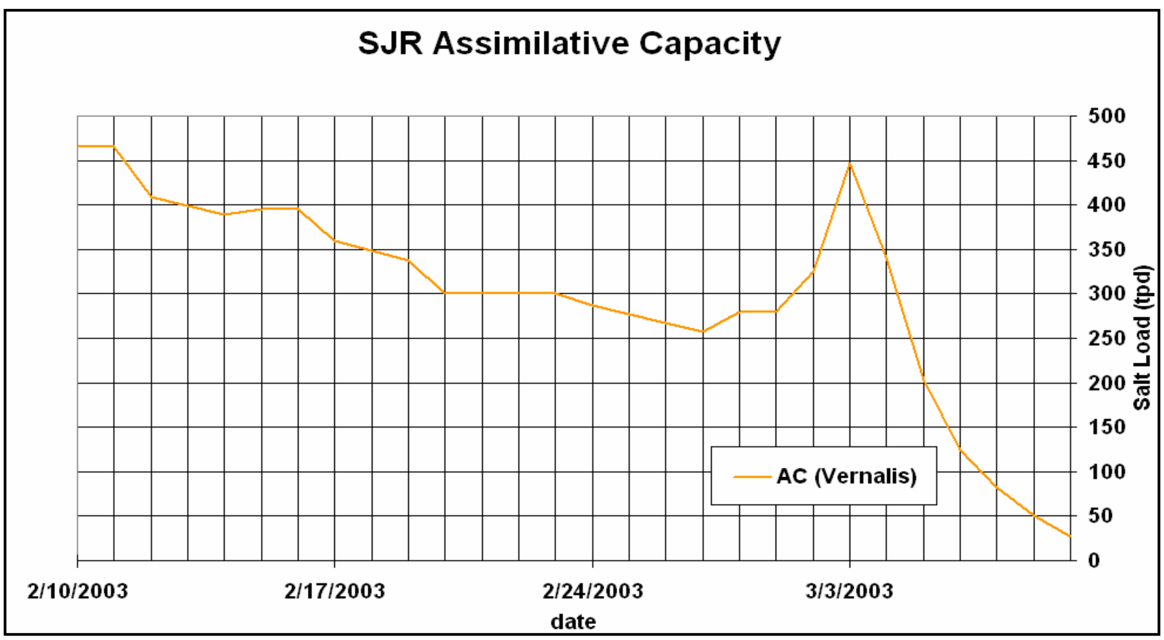


Figure 3.17 Results of SJRIO assimilative capacity forecast incorporating February 24, 2003 model application results.

On 24 March 2003 a second model simulation was performed and again wetland salinities were predicted to increase, this time from 2300 EC to 3000 EC (Table 3 and Figure 3.18). In addition, the SJRIO forecast, published on 24 March, predicted assimilative capacity for salt in the SJR to increase from 140 tons per day to over 200 tons per day in the next two weeks (Figure 3.18). These results prompted the GWD to encourage wetland managers that had not yet completed drawdown to continue to do so through early April, yet by this time most clubs had finished spring drawdow (Figure 3.14).

Table 3.5 - Tabular results of March 24, 2003 model application

North Division, Grassland Water District							San Joaquin River
Analysis Date: March 24, 2003			Analysis by: Scott Lower, GWD				SJRIO Values
							Vernalis
Date	Model Flow (cfs)	Actual Flow (cfs)	Model Salinity (uS/cm)	Actual Salinity (uS/cm)	Model Salt Load (tons/day)	Actual Salt Load (tons/day)	Assim. Cap. (tpd)
03/10/03	77	138	2007	1820	312	508	16
03/11/03	77	131	2037	2019	317	535	16
03/12/03	77	127	2080	2078	323	534	124
03/13/03	77	130	2131	2110	331	555	137
03/14/03	77	128	2127	2123	331	550	134
03/15/03	105	156	2010	2123	428	670	134
03/16/03	250	160	2017	1811	1022	586	135
03/17/03	250	146	2095	1905	1061	563	136
03/18/03	77	141	2182	2296	339	655	136
03/19/03	77	138	2219	2314	345	646	135
03/20/03	77	110	2249	2293	350	510	134
03/21/03	77	100	2268	2339	353	473	134
03/22/03	77	87	2292	2367	356	417	133
03/23/03	77	87	2257	2379	351	419	133
03/24/03	77		2323		361		140
03/25/03	77		2348		365		140
03/26/03	77		2405		374		140
03/27/03	77		2434		378		170
03/28/03	77		2503		389		177
03/29/03	77		2596		404		177
03/30/03	77		2649		412		177
03/31/03	77		2729		424		177
04/01/03	77		2753		428		135
04/02/03	77		2795		435		150
04/03/03	77		2812		437		150
04/04/03	77		2819		438		150
04/05/03	77		3002		467		220
04/06/03	77		3142		488		220

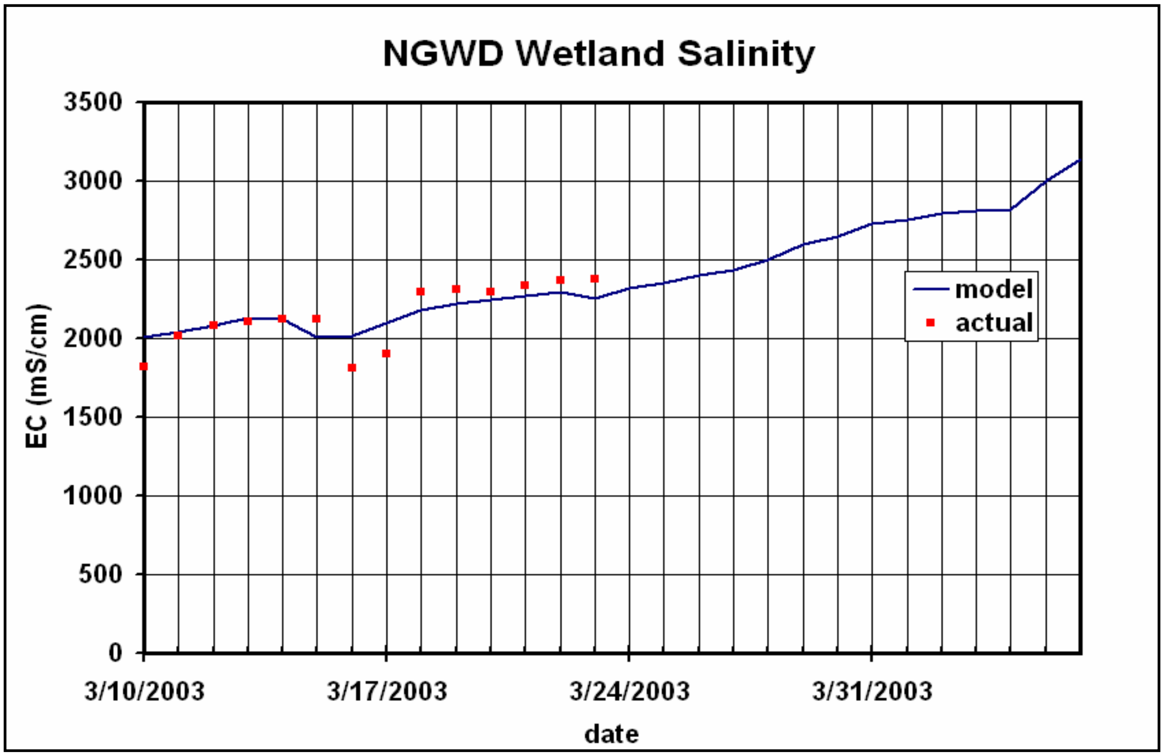


Figure 3.18 Comparison of modeled versus observed EC from March 24, 2003 model application.

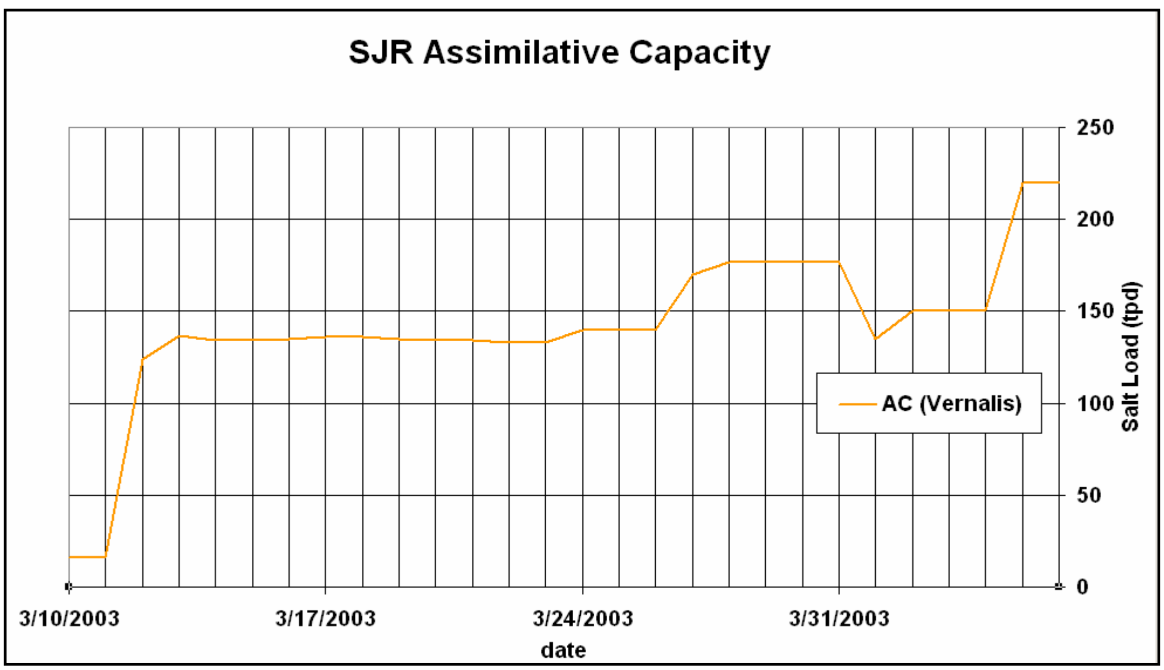


Figure 3.19 Results of SJRIO assimilative capacity forecast incorporating February 24, 2003 model application results

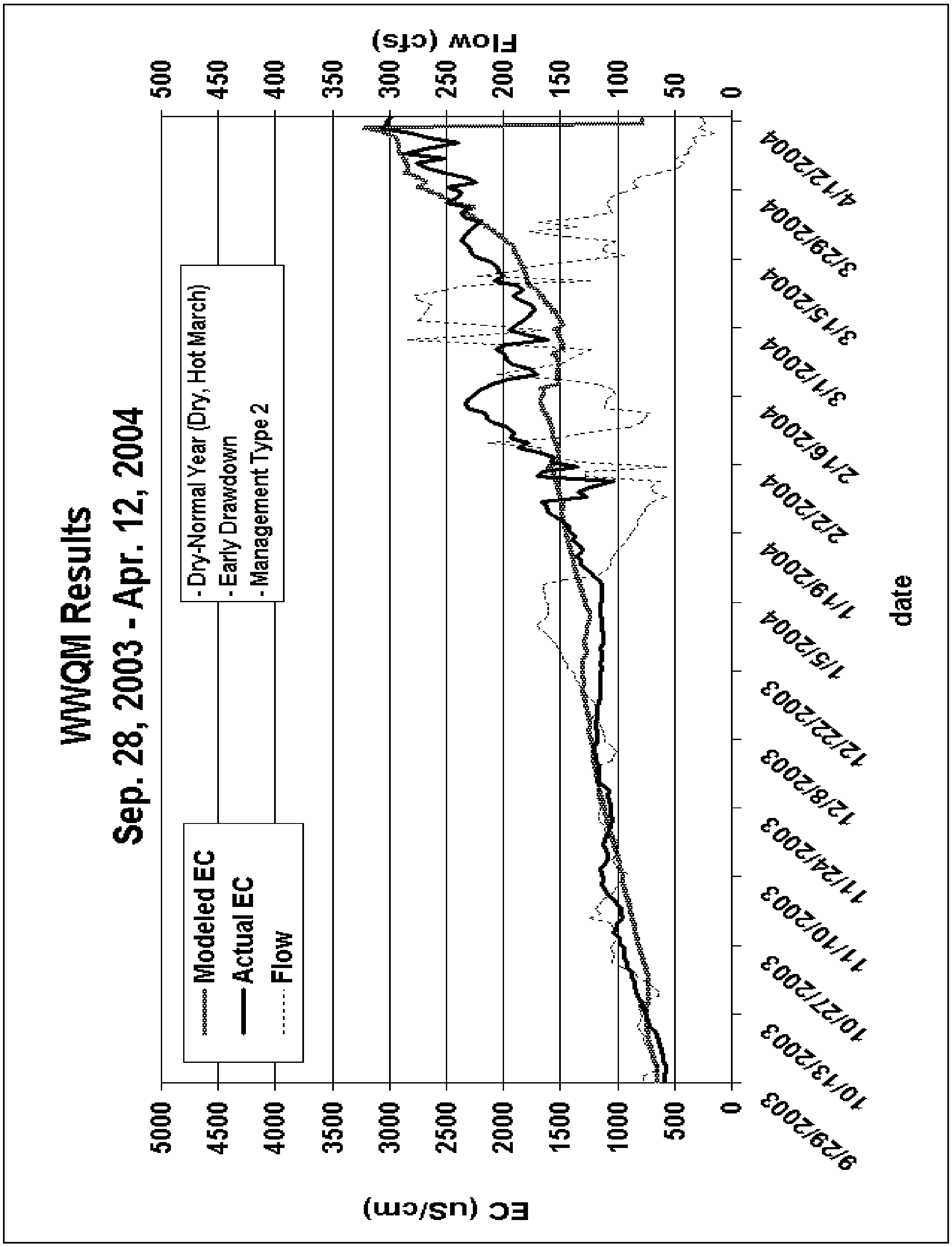


Figure 3.20 Results from WWQM calibration runs for Sep. 28, 2003 through Apr. 12, 2004

Flooded Season 2003 – 2004

During the 2003-2004 flooded season, the model performed similarly to previous years. Due to 7.07 inches of rainfall, 2003-2004 was classified as a dry year and an early drawdown schedule was modeled. On average, the model predicted EC values within 16% of actual values, although the model was more accurate during the first part of the season (Figure 3.20). Between 9/29/03 and 1/21/03, including the flood-up period, modeled values of EC were within 10%, on average, of actual values. This accuracy declined during the second half of the season, where modeled values were within approximately 23% of measured data. However, in contrast to previous years, this error was almost equally positive and negative. Thus, for the 2003-2004 season, the model did not show the same bias towards underestimating EC. In fact, during the important drawdown period, the model overestimated EC, resulting in a conservative estimate of wetland EC concentrations. Although error should be minimized, wetland managers prefer to base management decisions on conservative estimates of EC so as not to exceed the assimilative capacity of the San Joaquin River.

3.19 Discussion

The WWQM provided valuable information that can be used to inform wetland management decisions in the Grasslands Water District. Although daily values of wetland EC include some error, the model does a good job of capturing trends in flow and EC during the flooded season. This information can be very useful to a wetland manager who is trying to determine the appropriate drawdown schedule. In addition, when the WWQM was linked to the SJR forecasting model, SJRIODAY, it becomes an extremely useful tool. The SJRMP produces weekly forecasts of river assimilative capacity and posts them on the Internet at http://wwwdpla.water.ca.gov/sjd/waterquality/realtime/index.html. These data were automatically loaded into the update file that is electronically distributed to users of the WWQM. This linkage of SJRIO assimilative capacity forecasts and the salinity forecasts produced by the WWQM provide decision support to the wetland mangers of the GWD.

A geographical information system was built within ARCGIS™ to complement the WWQM and allow the wetland managers of the GWD to visually analyze salinity concentrations from the seasonal wetlands within the GWD. There is an automatic database link between the WWQM results and the access database that powers the GIS, allowing the most current data to be visualized and archived. Archiving data of the GIS allows good record keeping for review of prior decisions made.

GWD staff will need to work closely with the managers of the individual wetland units to provide information in a timely fashion to reduce the impact of salt export on the SJR. These wetland management decisions will need to be tempered with consideration of any harm management activities might have, but the flexibility demonstrated in the system, no matter how slight, must be used when conditions on the River demand it.

3.20 Future work

Future work should be directed at reducing the error in the modeled values of wetland EC. Although the model includes all of the major flow and salt inputs and outputs, there are a few minor sources and sinks that merit further investigation. For example, some of the minor inflows were neglected or flows were estimated in the model. In addition, as described above, groundwater interactions were neglected in this version of the model (although the model was built to accommodate groundwater data). Although the wetland is most likely in a steady-state relationship with the groundwater for most of the flooded season, and losses of flow and salt to groundwater can therefore be neglected, it is likely that these interactions are significant during flood-up and drawdown. However, including losses to groundwater will result in a decrease in EC concentration and will not address the issue of underestimation. One possible reason for the underestimation of EC concentration in the wetland is the simplification of salt dynamics in the water column as well as interactions at the soil-water interface during flood-up and drawdown. Further research, coupled with applying concepts from existing knowledge, is necessary in order to adequately understand and model these complex processes.

CHAPTER 4 REMOTE SENSING HABITAT ASSESSMENT METHODOLOGY

4.1 Introduction

Assessing the impact of management decisions on intensively managed wetland habitat is an important component of the land management process. Any management decision support system that can impact the wetlands' ecological health and/or distribution of habitat requires a means of estimating these impacts accurately. By combining recent advances in imagery and computing technologies with industry standard environmental survey methods, a Remote Sensing Habitat Assessment Methodology (RHAM), with the capability to accurately and efficiently estimate moist soil plant abundance and habitat quality over large regions, was developed.

The RHAM utilizes very-high-resolution satellite images and pattern recognition data processing tools to identify and characterize various vegetation communities in both temporal and spatial domains. Very-high-resolution commercial satellite data has become increasingly affordable and accessible for scientific applications. Major vendors of commercial satellite imagery now provide customers with the option to task the satellite according to their needs, allowing them collect data for the study site that is on-target, both spatially and temporally. Several commercial image processing packages are available for the analysis and processing of digital satellite imagery. Computing power continues to increase, minimizing the time and labor costs for image analysis. The RHAM takes advantage of the confluence of these technologies to provide a powerful tool for habitat assessment and quantification of land cover in managed wetlands.

Analysis of satellite imagery to evaluate and quantify habitat and land cover in managed wetlands has multiple benefits. Compared to traditional vegetation survey techniques, satellite imagery requires much less time and labor, while covering a larger area. Rather than the exhaustive on-going field effort that would be required to survey a large area such as NGWD, field work is limited to the time necessary to provide calibration for each image. In fact, while satellite imagery can be used effectively to map large or small areas, it becomes increasingly cost effective for larger study sites. Satellite imagery is also temporally flexible; depending on the variables of interest, image collection can be timed to capture different features throughout the growing season. Tracking the changes from one season to the next through the use of multi-temporal imagery can provide valuable feedback to the wetland manager regarding previously made decisions. The satellite imagery is also an unbiased and spatially consistent data source, reducing concerns of consistency between teams of surveyors, or drifts in field methodology and nomenclature during the field season. As an additional benefit, the fact that satellite imagery is an unbiased and standardized data source creates the potential for study sites to be viewed in a broader context, both regionally and worldwide. Finally, the imagery provides an archival data source, which after its initial use, continues to be available as a historical reference, and can be used in later studies, whose needs may not have been foreseen at the time.

4.1.1 Background

For seasonal wetlands in California's Central Valley, management decisions such as scheduling drawdowns and irrigations are made routinely, the timing of which can change from year to year. Habitat assessment is needed to optimize the timing of these changes. Traditional means of habitat assessment such as random sampling or transects for large areas (>1000 acres) are labor intensive (Tatu et al., 1999). In addition, timely data at a high enough resolution is difficult. Moreover, although impact assessment using a fine scale sampling program at the individual pond level could be accomplished, the spatial variations found in larger areas may be missed completely (Link et al., 1994). What is needed is a way to rapidly assess and quantify the various habitat communities at the regional scale, and readily track changes in those communities from year to year (Wiens and Parker, 1995, Shuford et al., 1998; Shuford et al., 1999).

The RHAM was developed for the seasonal wetlands of the Northern Division of Grassland Water District (NGWD) (Figure 4.1) The RHAM performs two major functions for land managers in the NGWD; firstly to catalog the various vegetation communities, both in composition and aerial extent; and secondly to assess changes in these vegetation conditions over time. If the RHAM performs these two functions conjunctively, in both a timely manner and over a large area, it can increase greatly wetland managers' ability to make effective management decisions.

The RHAM was initially developed in 2002. The methodology has evolved since 2002 to create an improved association of data sources, field collection protocols, and analysis techniques. One example is the choice of satellite imagery vendor. Space Imaging's IKONOS imagery was used for the project in 2003. In 2004, this was replaced with DigitalGlobe's QuickBird imagery, a similar satellite data source with higher spatial resolution. The scheduling of image acquisition has also changed. In 2004, imagery was collected and analyzed for April, May, and June, while in 2003, the analysis proceeded from a single May collection date. The scientific protocol for collection of field data remained the same from year to year, but in 2004, a hand-held data acquisition unit replaced clipboard and worksheets in order to standardize and streamline the data collection process. As a final notable difference, field data was collected over a larger area and more diverse range of habitats in 2004, making possible the accurate characterization of a larger range of environments. Experimentation with a variety of parameters in the RHAM has resulted in a robust and repeatable methodology.

4.2 Methods

4.2.1 Data Acquisition – Imagery

The RHAM uses various industry-accepted solutions for data source, data collection, and data analysis and processing. The data source that RHAM has developed around is high-resolution, multi-spectral imagery. High-resolution satellite imagery generally refers to the recent generation of satellite sensors that are capable of a spatial resolution of less than five meters. A high spatial resolution is necessary to capture the spatial variability of small and irregularly shaped vegetation communities typical of NGWD. Multispectral imagery (as distinct from hyperspectral imagery) denotes imagery with a small number of spectral bands (generally three to seven) that provides data in broad bands in the range of visible and infrared light. In this project, the RHAM was developed for imagery having bands in the blue, green, red and near-infrared (NIR) ranges of light. Multiple vendors provide an acceptable digital image product meeting these requirements. This project utilized two different commercial vendors for the 2003 and 2004. Space Imaging's (Thornton, Colorado) IKONOS imagery was selected for the 2003 field season. Digital Globe's (Longmont, Colorado) QuickBird Imagery was utilized in 2004. The two products are similar; the primary difference is that QuickBird imagery has a higher spatial resolution. A comparison of the spectral and spatial characteristics of these two imagery products is given in Table 4.1.

Table 4.1 Comparison of project imagery. IKONOS imagery was used in 2003; QuickBird was used in 2004. The two products cover similar spectra, however QuickBird imagery has a higher spatial resolution, which makes it possible to resolve smaller objects on the ground.

Color/ Band	**IKONOS**	**QuickBird**
Blue	450 – 520 nm	450 – 520 nm
Green	530 – 610 nm	520 – 600 nm
Red	630 – 690 nm	630 – 690 nm
NIR	780 – 900 nm	760 – 900 nm
Panchromatic	500 – 900 nm	450 – 900 nm
Spatial resolution	4 m 1m panchromatic	2.4 m 60 cm panchromatic

For both vendors, the images were delivered in the form of GeoTiffs, which are raster files that have been geo-rectified and are ready for processing. For the QuickBird imagery used in the 2004 RHAM, the imagery was also orthorectified prior to processing, resulting in a more spatially accurate product. Imagery was collected for one date in 2003 (May 20) and for three dates in 2004 (April 26, May 14, and June 19.) Image collection was timed to represent different stages of growth throughout the growing season. The late April image would capture seedlings and perennials in wetland basins, and verdant uplands vegetation. It is believed that the maximum growth period for wetland basins occurs immediately following the first summer irrigation, usually late May to early June (Lower, 2003; Poole, 2003). May imagery was timed to coincide with this maximum growth period, and would capture a mix of inflorescence and mature growth in the wetland basins, and a mix of inflorescence, verdant growth, and seeding in the uplands vegetation. June imagery was designed to capture inflorescence, mature growth, and seeding in the wetlands basin, and seeding and senescence in the uplands vegetation. Figures 4.1 and 4.2 show the project imagery prior to any image processing. A color stretch is performed on the imagery to enhance contrast and ease of viewing. Even without additional processing, considerable difference between the different times in the growing season can be detected with the naked eye.

4.2.2 Data Acquisition – Field Data

For field data collection, the RHAM uses a modification of the California Native Plant Society's (CNPS) Rapid Assessment Protocol (RAP), co-developed by the California DFG (CNPS, 2003). The RAP is accepted widely for similar applications throughout California. The California Native Plant Society, the California Department of Fish and Game, California State Parks, National Parks, other State and Federal agencies, and consulting firms use this methodology to quickly and quantitatively inventory and map vegetation types for several projects throughout California. For example, it is being used in conjunction with a Wildlife Habitat Relationships (WHR) Validation study at Point Reyes National Seashore. It is also being used to inventory and map vegetation for prioritization of conservation sites in the Los Angeles and San Gabriel River watersheds, the San Dieguito River drainage, Napa and Riverside Counties (CNPS, 2003).

The CNPS RAP employs a community-based approach to surveying. In its original format, the CNPS RAP uses a one-page worksheet to rapidly assess large landscapes for a number of important parameters. These parameters include location and distribution of vegetation types and communities, general composition and abundance information on the various plant species, and general site environmental factors. The RAP also provides guidance for identifying the dominant and non-dominant vegetation stands among varying ecosystems, along with varying features such level of community disturbance (CNPS, 2003). The RAP is useful for collecting basic quantitative vegetation and habitat information sufficient for identification and verification of habitats. It can be used for field-based vegetation and habitat mapping and for rapid inventory, validation, and ranking of the full suite of vegetation and habitats in any natural or other management area. Thus, this method can provide wetland and other land use managers with efficient tools for natural resource inventorying and planning (CNPS, 2003).

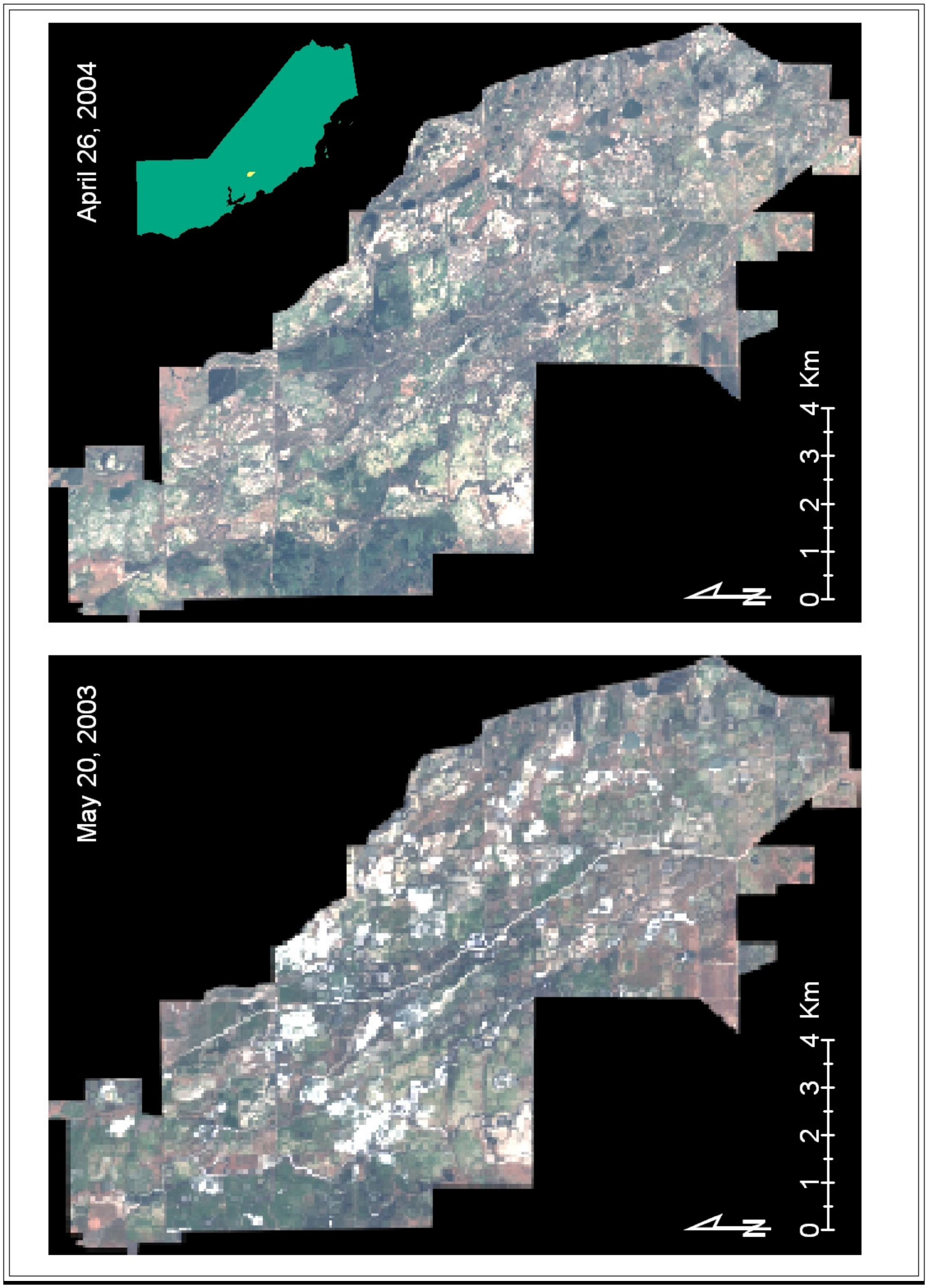


Figure 4.1 Project imagery from May 2003 (IKONOS) and April 2004 (QuickBird). Some areas appear red due to a contrast stretch applied to enhance viewability. White areas on the 2003 image are the result of sun glare on water. Inset shows site location in California.

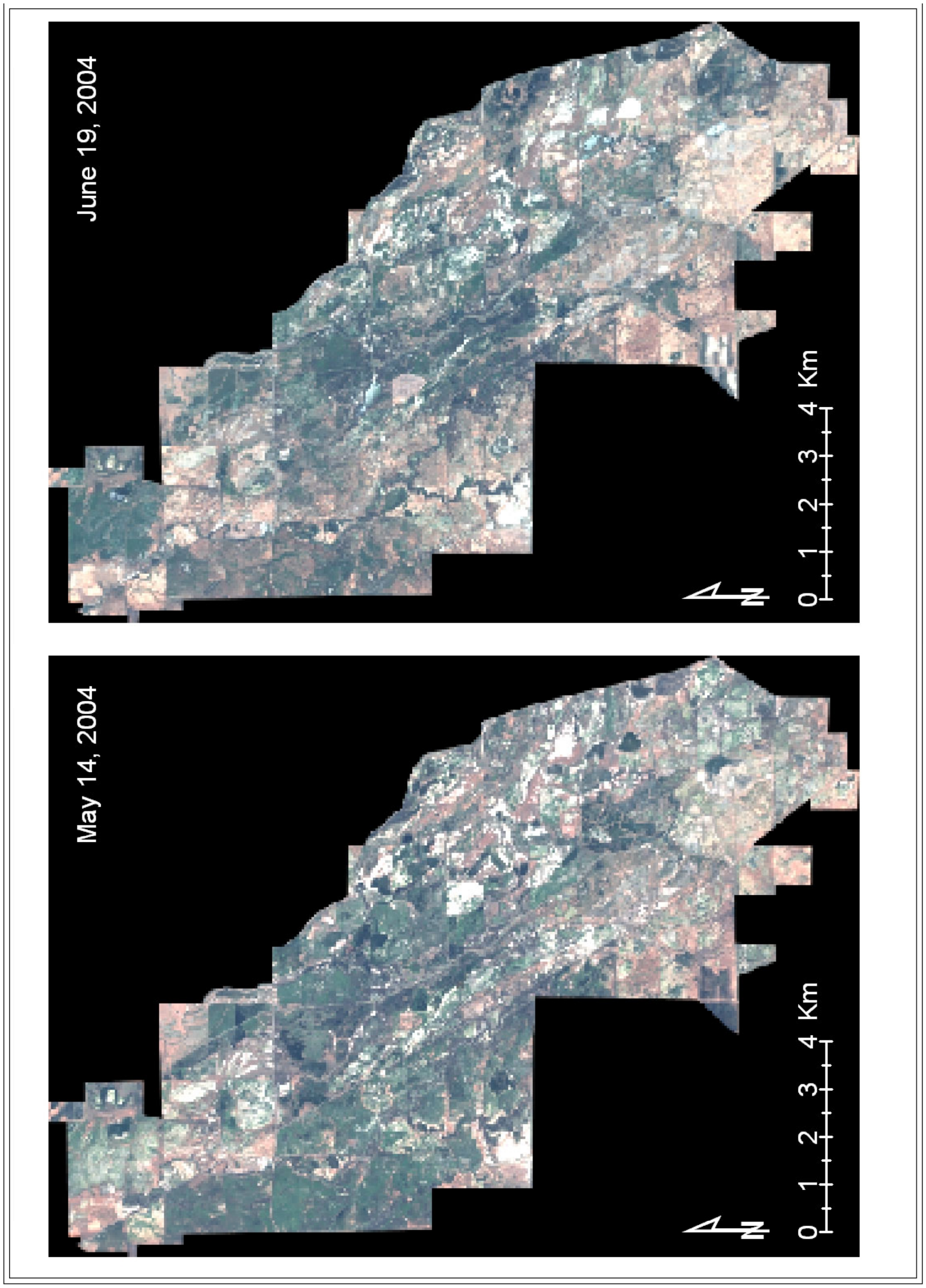


Figure 4.2 Project imagery from May and June (QuickBird). Some areas appear red due to a contrast stretch applied to enhance viewability. The May image appears greener than the June image, due to vegetative senescence already underway in June.

Minor modifications were made to the protocol that reflected the needs and particular focus of the RHAM. For example, in this project's field surveys, field protocols removed the CNPS's emphasis on native species and placed equal weight on cataloging important non-native species. Because of the availability of detailed soils maps for the area, the rather time-consuming soil classification technique used by the RAP was replaced by soil survey data for the purposes of the RHAM. Other minor modifications included the addition of a few new data fields, such as the presence of visible salts, as it was perceived that this could have a significant effect on the spectral response of the pixel. In 2004, the traditional RAP vegetation worksheet was programmed into a hand-held data acquisition system. A Trimble GeoExplorer 3 was programmed with appropriate data fields sufficient to define a community, so that the collection of GPS positions would be automatically tied to attribute data for each plant community. The vegetation database was programmed with predefined pull-down menus wherever possible, in order to standardize and streamline the entry of field data. The development of this computer-based data collection system resulted in a substantial increase in the amount of field data collected in 2004.

4.2.3 Ground Truthing

Ground truthing of the satellite imagery is the process of collecting *in situ* data that tie the spectral values in the imagery to land cover in the real world. Ground truth data may be used both as input to the classification process and, once classification is complete, to check the accuracy of interpretation. Ground truth data was collected during the days shortly before, after, or during the satellite fly-over to ensure maximum correlation between field data and the recorded image. Ground truth data was collected primarily at the Salinas Land and Cattle Club (Salinas Club), a privately owned area of approximately 1,600 acres on the western side of NWGD (Figure 4.4). Additional ground truth data was collected in the San Luis National Wildlife Refuge (SLNWR), a property neighboring the eastern side of NGWD.

In 2003, data was collected using a modified CNPS RAP worksheet to collect 33 ground truth points for the May 20 image. In 2004, the development of a computerized data collection system in 2004 permitted an increase in the number of points collected. For the April 26, 2004 image, 176 ground truth points were collected; for the May 14, 2004 image, 206 ground truth points were collected; and for the June 19, 2004 image, 276 ground truth points were collected. The increasing number of points collected throughout the growing season reflects both an increase in efficiency of data collection and a decrease in the land surface that was flooded. In order to ensure coverage of important species, local refuge managers and wetland biologists assisted in the selection of ground truth locations. Also, to provide for coverage of a range of habitats, ground truth data was collected in all major accessible basins within the Salinas Club and SLNWR. Table 4.2 shows the extensive suite of data collected for one ground truth data point, along with field names from the database and an explanation of each field.

Table 4.2 – Field data from modified CNPS Rapid Assessment Protocol

Attribute Name	Field Entered Data	Explanation
Surveyor	Jos and Sara	personnel performing the survey
Veg_cov	35-50%	bird's eye view of ground cover of viable vegetation
Litter_cov	1-5%	bird's eye view of litter cover
Litter_typ	herbaceous	type of litter, if present
Soil_mois	dry	soil moisture
cracking		soil cracking, if present (low, medium, high)
vis_salt		visible salts, if present (low, medium, high)
Soil_com		soil comment
Shape_1	irregular	shape of vegetation community
Shape_com		shape comment
Size	300-600 sq m	size of vegetation community
Topography	Flat	topography covered by community
Disturb		type of community disturbance, if present
Dist_level		disturbance level, if present
Dist_com		disturbance comment
Com_com		community comment
plant1	cocklebur	species ID of first plant
Growth1	pre-bloom	growth stage of first plant
Health1	good	health of first plant
Per_cov1	35-50%	bird's eye view of ground coverage of first plant
sp_conf1	High	confidence in species ID
sp_com1		species comment
Oth_sp1		text field for field entry of unlisted species ID
Hea_com1		health comment for first plant
plant2	swamp timothy	.
Growth2	pre-bloom	.
Health2	fair	.
Per_cov2	1-5%	
sp_conf2	High	
sp_com2		
Oth_sp2		
Hea_com2		
plant3	bermuda grass	
Growth3	pre-bloom	
Health3	good	
Per_cov3	<1%	
sp_conf3	High	
sp_com3		
Oth_sp3		
Hea_com3		
.		.
.		.
.		.
plant8		attributes for up to 8 species
patch1	scirpus spp	first patch within the community, if present
patch1_com		comment for first patch
patch2	baltic rush	.
patch2_com		.
patch3		.
patch3_com		attributes for up to 3 patches
adjac1	scirpus spp	dominant species of adjacent community, as needed
adj1_com		comment for first adjacent community
adjac2		.
adj2_com		.
adjac3		.
adj3_com		attributes for up to 3 adjacent communities

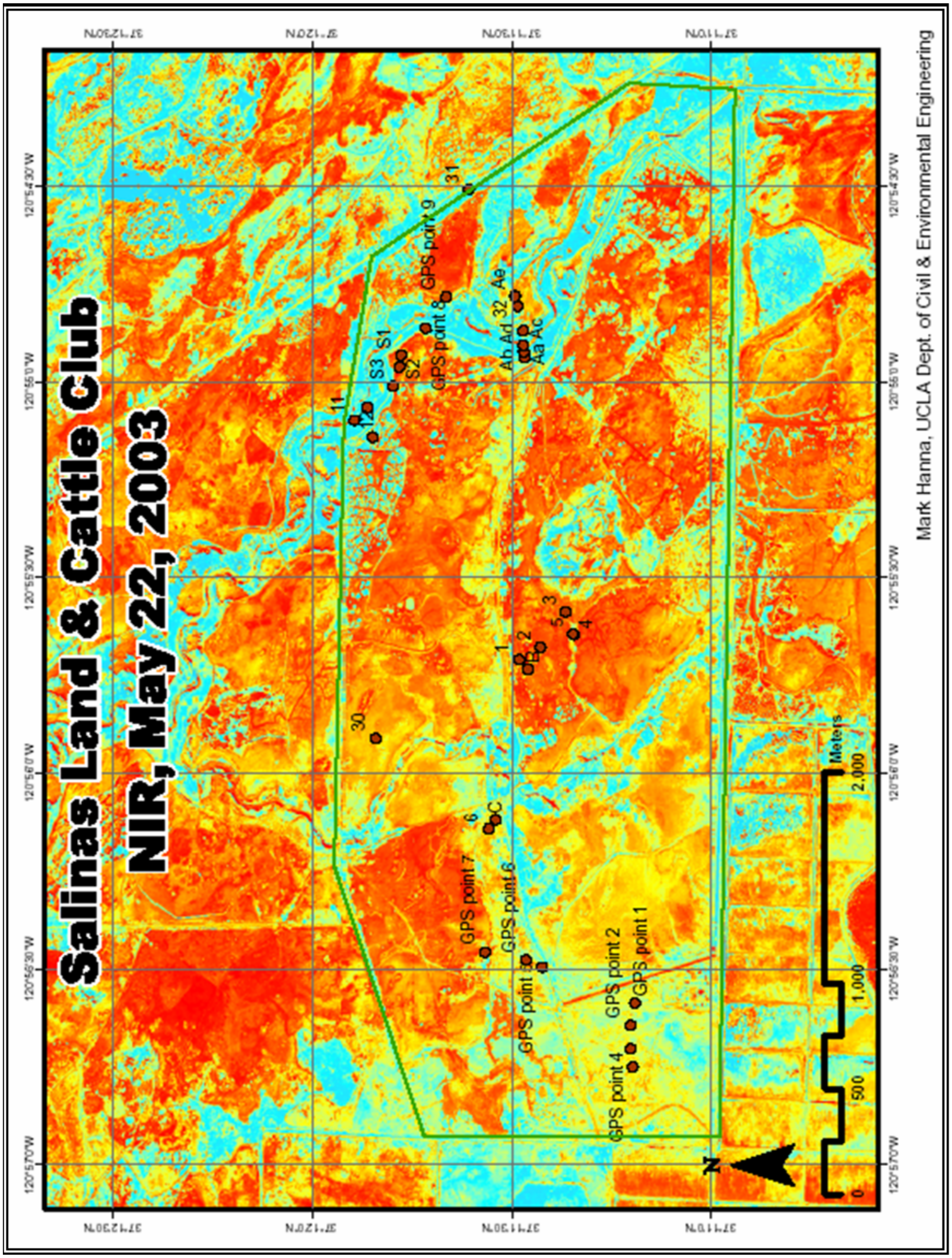


Figure 4.3 2003 Ground truth locations, Salinas Club, Merced County, CA. Field data locations have been overlaid on the near-infrared band of the May 2003 IKONOS imagery. A contrast enhancement has been performed, and regions of verdant vegetation appear red.

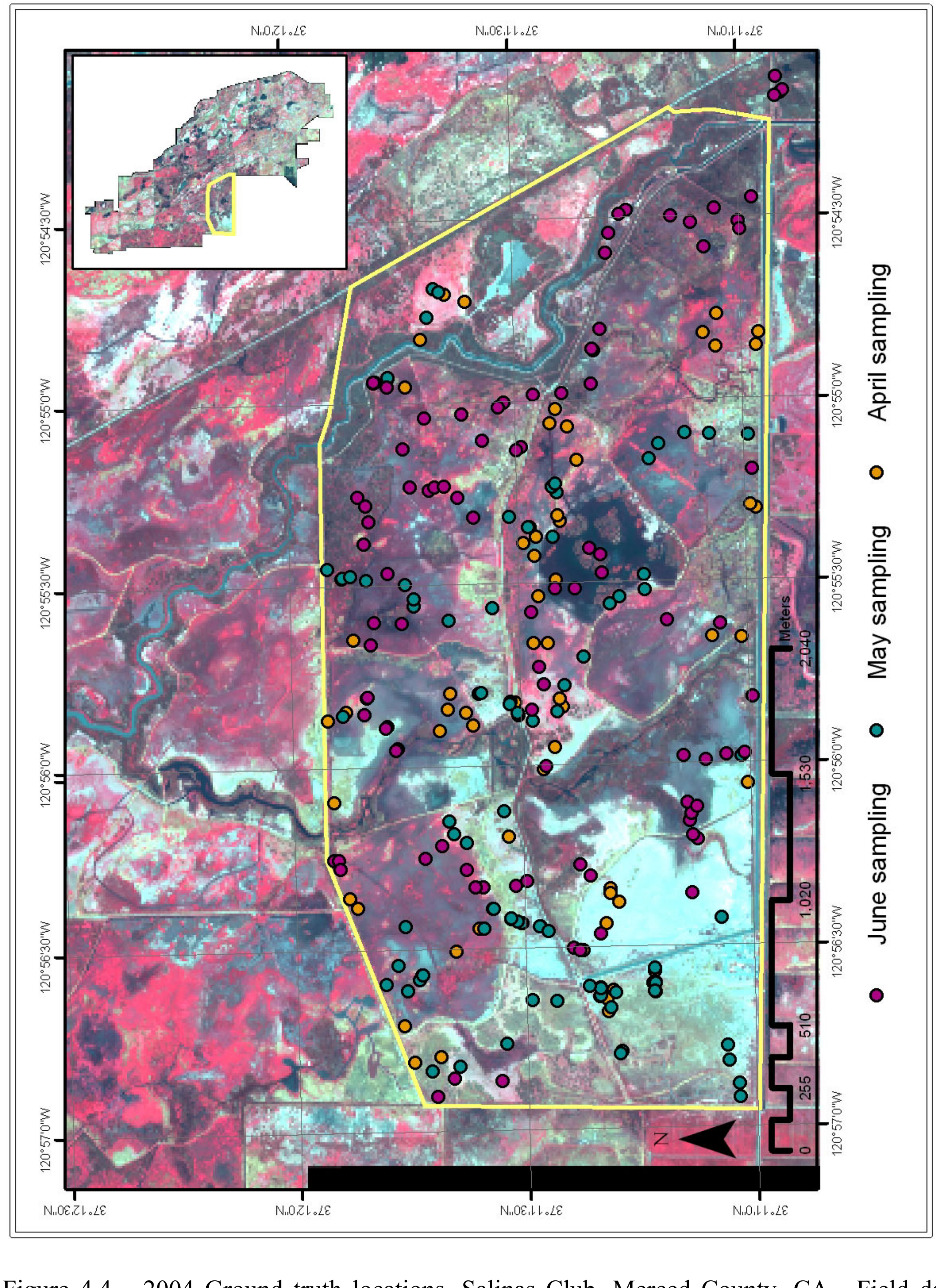


Figure 4.4 2004 Ground truth locations, Salinas Club, Merced County, CA. Field data locations have been overlaid on a false color mapping of the NIR, red, and green bands of May 2004 QuickBird Imagery. Regions of verdant vegetation appear red, water appears dark, and regions of bare, dry soil appear bright.

4.2.4 Image Processing

Image processing and data analysis for the RHAM was performed using commercially available software routines provided by ERDAS Imagine™ Professional. A number of commercial image processing packages are available which perform comparable analyses. A supervised classification technique – whereby data input by an analyst is used to determine seed values for classes - was selected for classification of the images. Maximum likelihood classification is a standard industry algorithm for projects where adequate ground truth data has been collected. This technique requires the input of “training” data, with which software algorithms define statistically-based spectral bounds for each class. Training data is derived from ground truth points; the analyst defines an area around each ground truth point representative of that community of vegetation, and the image processing software compiles a database of the spectral values for that community. Multiple ground truth points are combined into a robust spectral signature for a single land cover class, and this process is repeated until the analyst has created a signature for all desired land cover classes. After all training data has been entered into the spectral signature file, the classification algorithm is implemented. The algorithm uses the defined spectral signatures to extrapolate from the training pixels to all the pixels in the image. This is a very efficient process, resulting in the extrapolation of data from a few thousand pixels to an entire image comprised of tens of millions of pixels. In the end result, every pixel is assigned to a class – the class it is “most likely” to belong to, even if the pixel’s spectral values fall outside the initial seed values for any class.

The start point for classification, a statistical representation of the raw imagery data is shown in Figure 4.5. This figure shows four histograms, one for each spectral band in the imagery for May 14, 2004. The histogram shows the statistical distribution of spectral values. For each band, the spectral values are given on the X-axis, and the number of pixels exhibiting that value is graphed on the Y-axis. Spectral values near the peak of the curve will be represented in the most pixels in the imagery. The histogram describes the statistical distribution of values within a band, but says nothing about the relationships between bands. Therefore, a pixel that is bright (high spectral value) in one band may be dark in another.

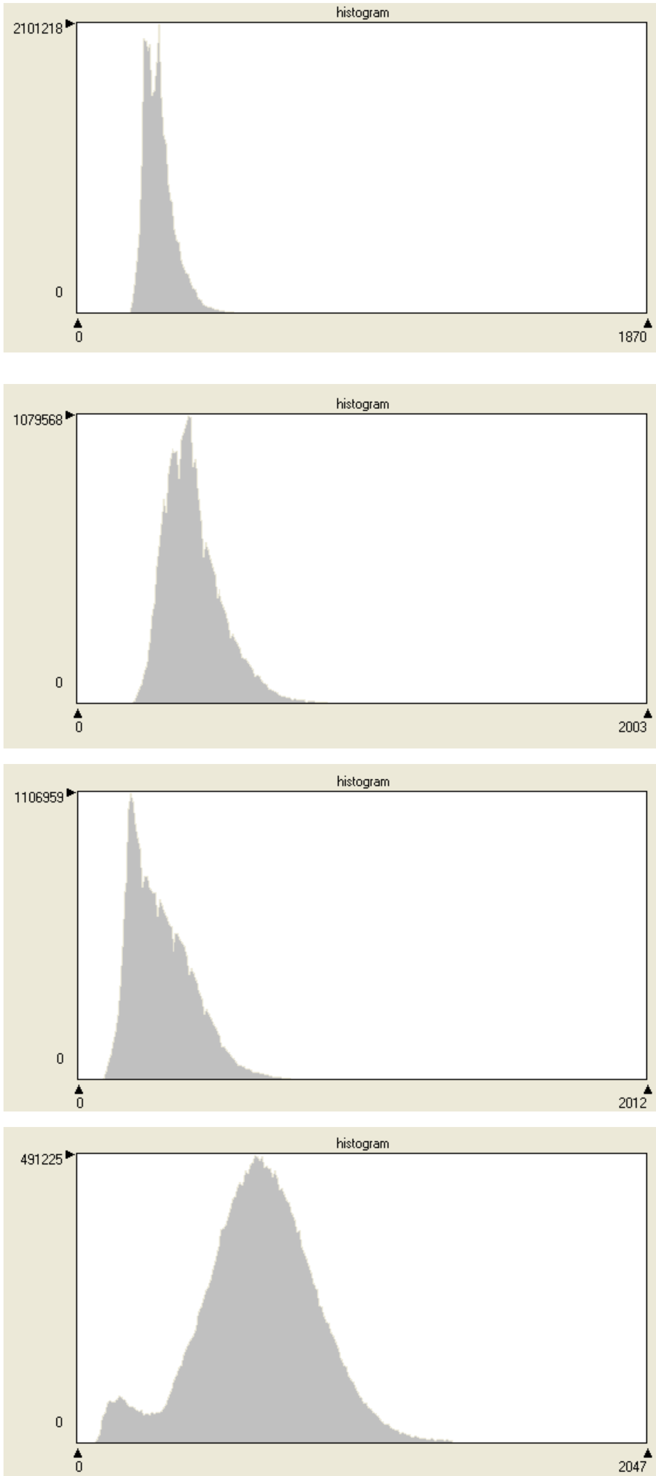


Figure 4.5 Histograms for Bands 1, 2, 3, and 4 (top to bottom) in the May 14, 2004 multispectral imagery. The X-axis displays the spectral value, and the Y-axis displays the number of pixels exhibiting that value in that band. The histograms show the range of spectral values present in the satellite imagery.

An introduction to the relationship between bands is shown in Figure 4.6. Here, the mean values for the training signatures of three land cover classes – buildings, water, and scirpus spp – are shown for the four multispectral bands. Maximum likelihood classification also accounts for the range and variance of spectral signatures, however, it can be seen in this figure that these three classes may be separable based solely on the mean. Scirpus spp and water have similar means in bands 1, 2, and 3, however, scirpus is significantly brighter in band 4, due to the response of chlorophyll in this band. These three land cover classes were chosen for ease of illustration. As a general rule, land cover classes comprised of individual plant species will appear more similar and will be more challenging to separate.

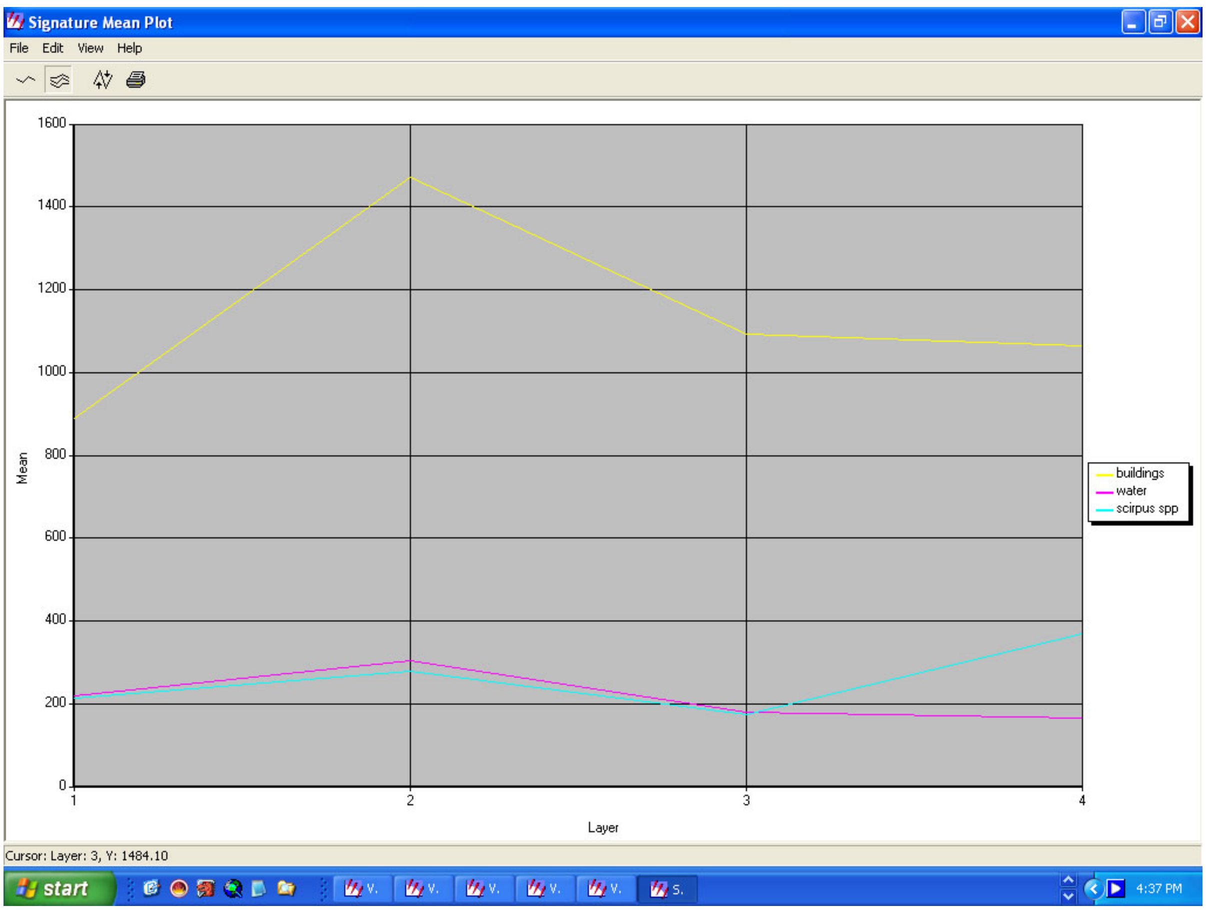


Figure 4.6 Mean values of the training signatures of three land cover classes in the May 14, 2004 imagery. Buildings are considerably brighter in all four bands. Water and scirpus spp take on similar mean values in bands 1, 2, and 3 (blue, green, and red), however scirpus spp is brighter in band 4 (near-infrared.)

An example of creating a single training signature is shown in Figure 4.7, and the final spectral signature file for 2004 is shown in Figure 4.8. Note that the statistical description of each class is too complex to display in this simple view. The color patches and RGB values shown in the signature file correspond to the average tone of that land cover type, as it is displayed in the working window.

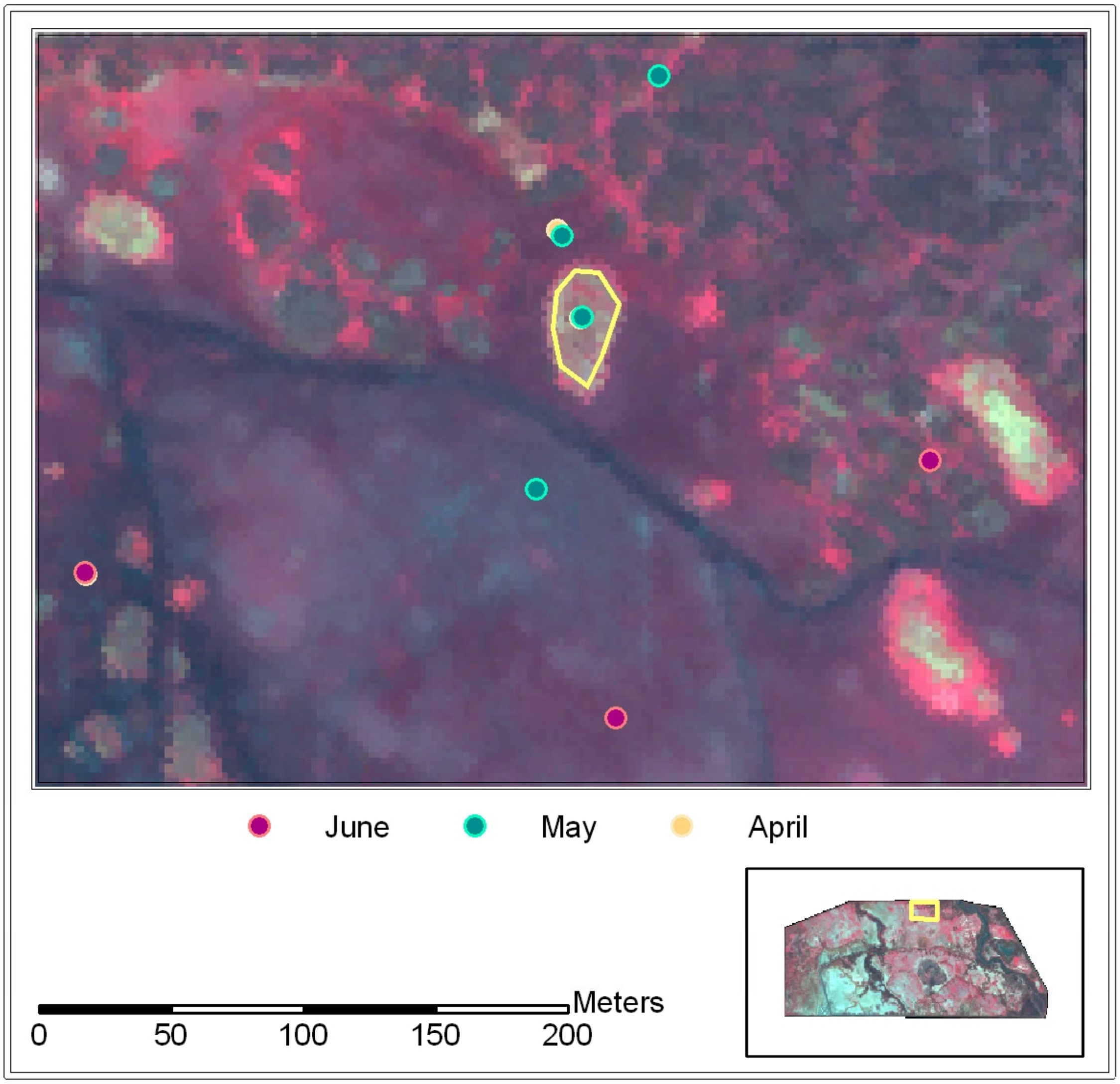
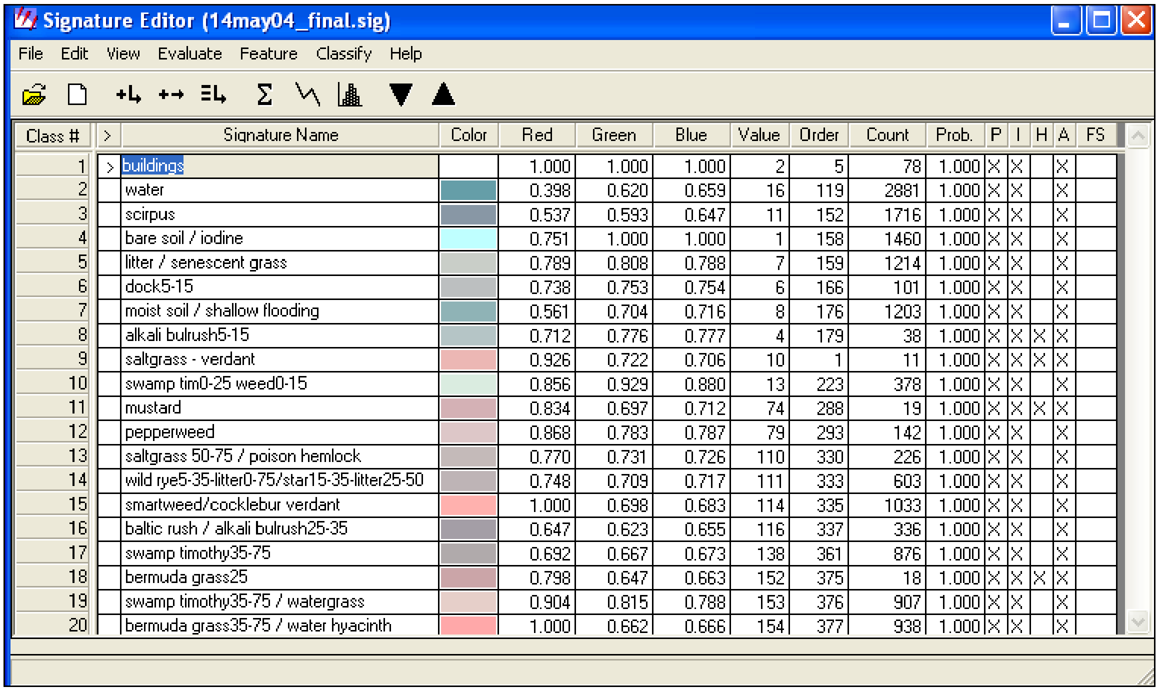


Figure 4.7 Example of training signature delineation. Training signatures are collected in the areas surrounding ground truth points. While the ground truth point represents only a single pixel location, this may be extrapolated to the surrounding area via visual inspection and use of field collected attributes such as community size and shape. It is desirable to maximize the number of pixels included in each spectral signature, as this leads to a more robust statistical description of the class.



Class #	>	Signature Name	Color	Red	Green	Blue	Value	Order	Count	Prob.	P	I	H	A	FS
1	>	buildings		1.000	1.000	1.000	2	5	78	1.000	X	X		X	
2		water		0.398	0.620	0.659	16	119	2881	1.000	X	X		X	
3		scirpus		0.537	0.593	0.647	11	152	1716	1.000	X	X		X	
4		bare soil / iodine		0.751	1.000	1.000	1	158	1460	1.000	X	X		X	
5		litter / senescent grass		0.789	0.808	0.788	7	159	1214	1.000	X	X		X	
6		dock5-15		0.738	0.753	0.754	6	166	101	1.000	X	X		X	
7		moist soil / shallow flooding		0.561	0.704	0.716	8	176	1203	1.000	X	X		X	
8		alkali bulrush5-15		0.712	0.776	0.777	4	179	38	1.000	X	X	X	X	
9		saltgrass - verdant		0.926	0.722	0.706	10	1	11	1.000	X	X	X	X	
10		swamp tim0-25 weed0-15		0.856	0.929	0.880	13	223	378	1.000	X	X		X	
11		mustard		0.834	0.697	0.712	74	288	19	1.000	X	X	X	X	
12		pepperweed		0.868	0.783	0.787	79	293	142	1.000	X	X		X	
13		saltgrass 50-75 / poison hemlock		0.770	0.731	0.726	110	330	226	1.000	X	X		X	
14		wild rye5-35-litter0-75/star15-35-litter25-50		0.748	0.709	0.717	111	333	603	1.000	X	X		X	
15		smartweed/cocklebur verdant		1.000	0.698	0.683	114	335	1033	1.000	X	X		X	
16		baltic rush / alkali bulrush25-35		0.647	0.623	0.655	116	337	336	1.000	X	X		X	
17		swamp timothy35-75		0.692	0.667	0.673	138	361	876	1.000	X	X		X	
18		bermuda grass25		0.798	0.647	0.663	152	375	18	1.000	X	X	X	X	
19		swamp timothy35-75 / watergrass		0.904	0.815	0.788	153	376	907	1.000	X	X		X	
20		bermuda grass35-75 / water hyacinth		1.000	0.662	0.666	154	377	938	1.000	X	X		X	

Figure 4.8 2004 Spectral signature file. Each class is the result of compositing training data for numerous ground truth points. The total number of pixels included in each class is displayed in the "Count" column. The color swatch is derived from the average values of all pixels comprising that class, based on the color mapping used in the display window. Since near-infrared is mapped to red in the display window (as in Figure 4.7), vegetation tends to appear red. The "Red," "Green," and "Blue" columns give the RGB values for the color swatch.

Through a complex process of signature refinement, individual training signatures (Figure 4.7) evolve into the final class signature file that is used to classify the image (Figure 4.8.) The class signatures are based on multiple single signatures added together in proportion to the number of pixels each represents. After signatures are compiled for each class, they are evaluated for separability. There are a number of tools that may be used for this evaluation. Figure 4.9 shows a feature space image for bands 4 (NIR) and 2 (green) and the two-dimensional separability of three classes (scirpus, buildings, and water) within this feature space. Figure 4.10 shows a matrix of separability values for ten land cover classes. Separability here is calculated in all four image bands, using a measure of the spectral distance between classes known as transformed divergence. Transformed divergence ranges in value from 0 to 2000, and values over 1500 are considered to be separable. If classes are insufficiently separable, the analyst may choose to combine classes, to add more training data, or to cull some training data before repeating the evaluation of signature separability.

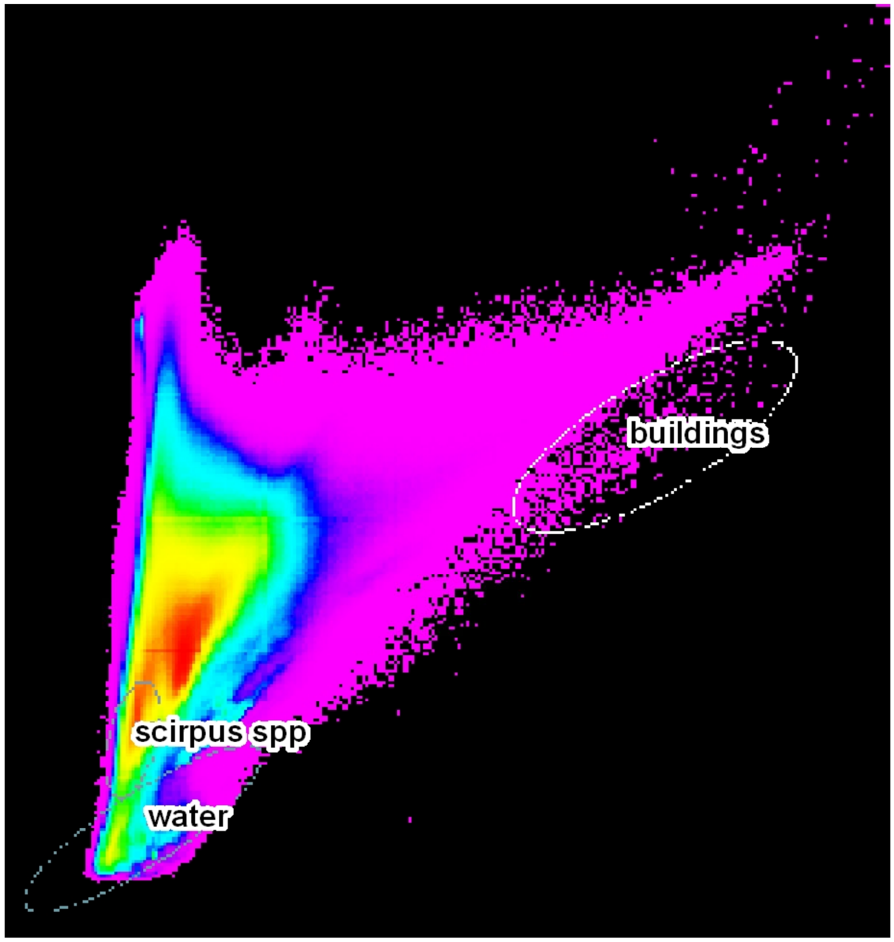


Figure 4.9 Feature space analysis of separability of three land cover classes in bands 2 and 4 of the May 14, 2004 imagery. Band 2 (green) is plotted on the X-axis, and band 4 (near-infrared) is plotted on the Y-axis. The 2-dimensional location of a point on this plot is determined by its spectral value in the two bands. Colors represent the frequency of occurrence of that spectral value combination. Red depicts combinations that occur frequently in the dataset. Violet depicts the combinations that occur least frequently. The class bounds, as determined by training data, of buildings, scirpus spp, and water are plotted on this feature space. The three classes appear to be unambiguously separable in bands 2 and 4. Furthermore, buildings occupy a sector of feature space not represented in too many pixels. Scirpus spp, by contrast, is centered about a red sector. This could indicate either a predominance of scirpus in the image, or a predominance of land cover classes that reflect a signal similar to scirpus spp.

Separability CellArray

Distance Measure: Transformed Divergence
Using Layers: 1 2 3 4
Taken 4 at a time
Best Average Separability: 1982.05
Combination: 1 2 3 4

Signature Name	1	2	3	4	5	6	7	8	9	10
buildings 1	0	2000	2000	1999.96	2000	2000	2000	2000	2000	2000
water 2	2000	0	1999.38	2000	2000	2000	1990.71	2000	2000	2000
scirpus 3	2000	1999.38	0	2000	2000	2000	1998.22	1995.68	2000	2000
bare soil / iodine 4	1999.96	2000	2000	0	1998.01	2000	2000	2000	2000	1871.37
litter / senescent grass 5	2000	2000	2000	1998.01	0	1883.28	2000	1994.58	2000	1578.49
dock5-15 6	2000	2000	2000	2000	1883.28	0	2000	1958.67	2000	1980.31
moist soil / shallow flooding 7	2000	1990.71	1998.22	2000	2000	2000	0	1996.2	2000	1999.97
alkali bulrush5-15 8	2000	2000	1995.68	2000	1994.58	1958.67	1996.2	0	2000	1947.27
saltgrass - verdant 9	2000	2000	2000	2000	2000	2000	2000	2000	0	2000
swamp tim0-25 weed0-15 10	2000	2000	2000	1871.37	1578.49	1980.31	1999.97	1947.27	2000	0

Close

Figure 4.10 Separability matrix showing transformed divergence values for the first ten land cover classes from the spectral signature file. Values over 1900 are considered to indicate excellent separability; values greater than 1700 represent good separability; values greater than 1500 are considered adequately separable. The matrix shows the separability of pairs of classes. For example, the value in row 1 and column 2 would indicate an excellent separability between buildings and water. Classes that are not adequately separable will result in pixels misclassified as the other member of the pair.

4.3 Results

Following the spring 2003 wetland drawdown, the RHAM was applied to North Grassland Water District (NGWD). Maximum likelihood classification was performed on bands 1 (blue) and 4 (NIR) of the 2003 imagery for the Salinas Club. Two bands were selected in order to limit the processing time for classification. Bands 1 and 4 were selected since preliminary analysis indicated that most of the information in the imagery was contained in the spectral values for these bands. The initial classification result for the Salinas Club is shown in Figure 4.11.

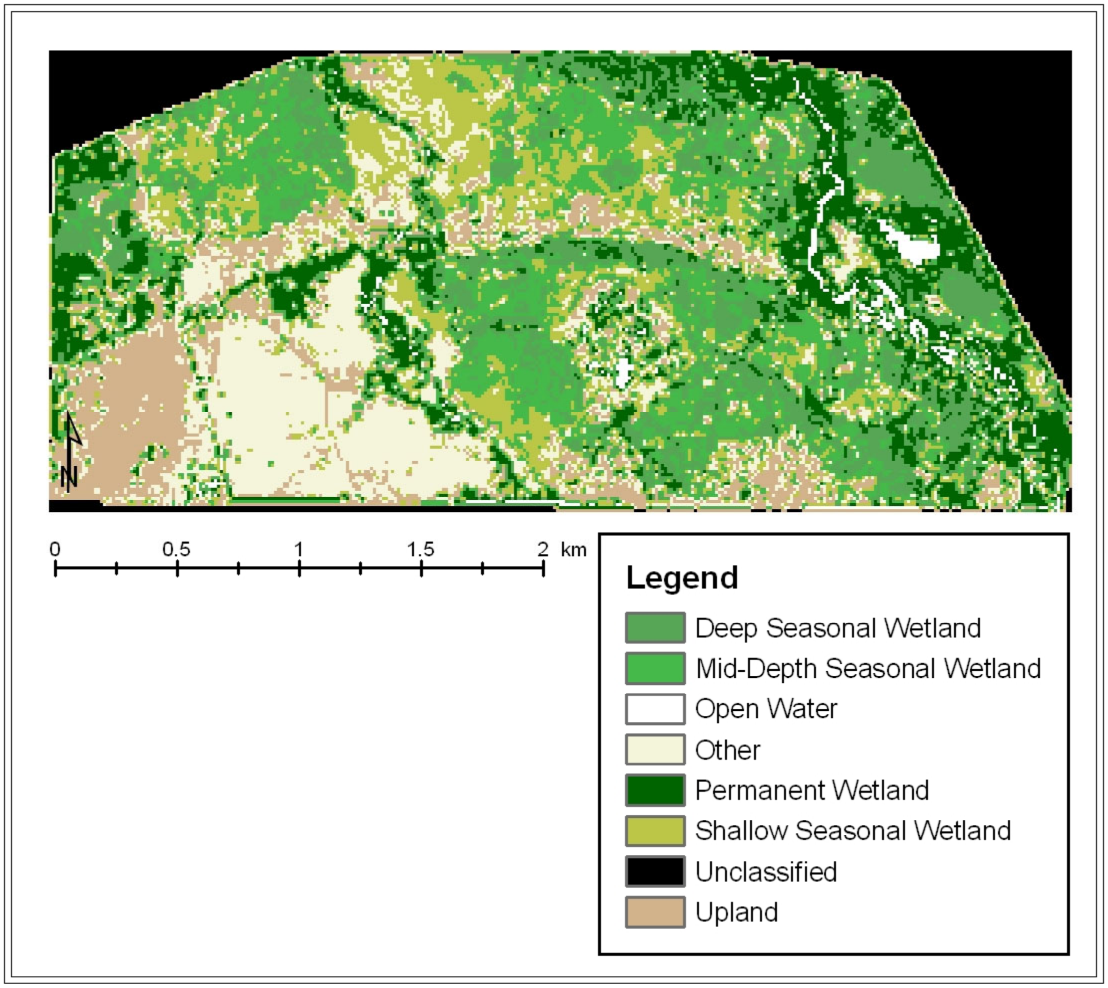


Figure 4.11 2003 maximum likelihood classification result for Salinas Club, Merced County, CA. As expected, the map shows extensive tracts of deep, mid-depth, and shallow seasonal wetlands. The "Other" category includes very shallow seasonal wetlands, salt flats, bare soil, and improvements such as roads and buildings. Unclassified pixels are limited to areas falling outside the study site.

This map was assessed for accuracy through quantitative review by the Salinas Club wetland manager. After several iterations, a final map for the Salinas Club was produced. The spectral signature file used in the final iteration was then applied to the entire NGWD. The result of the maximum likelihood classification of NGWD is shown in Figure 4.12. Reapplying the spectral signature file to the entire NGWD image produced a wetland vegetation and land use map complete with total acreage for each class (Figure 4.13; Table 4.3).

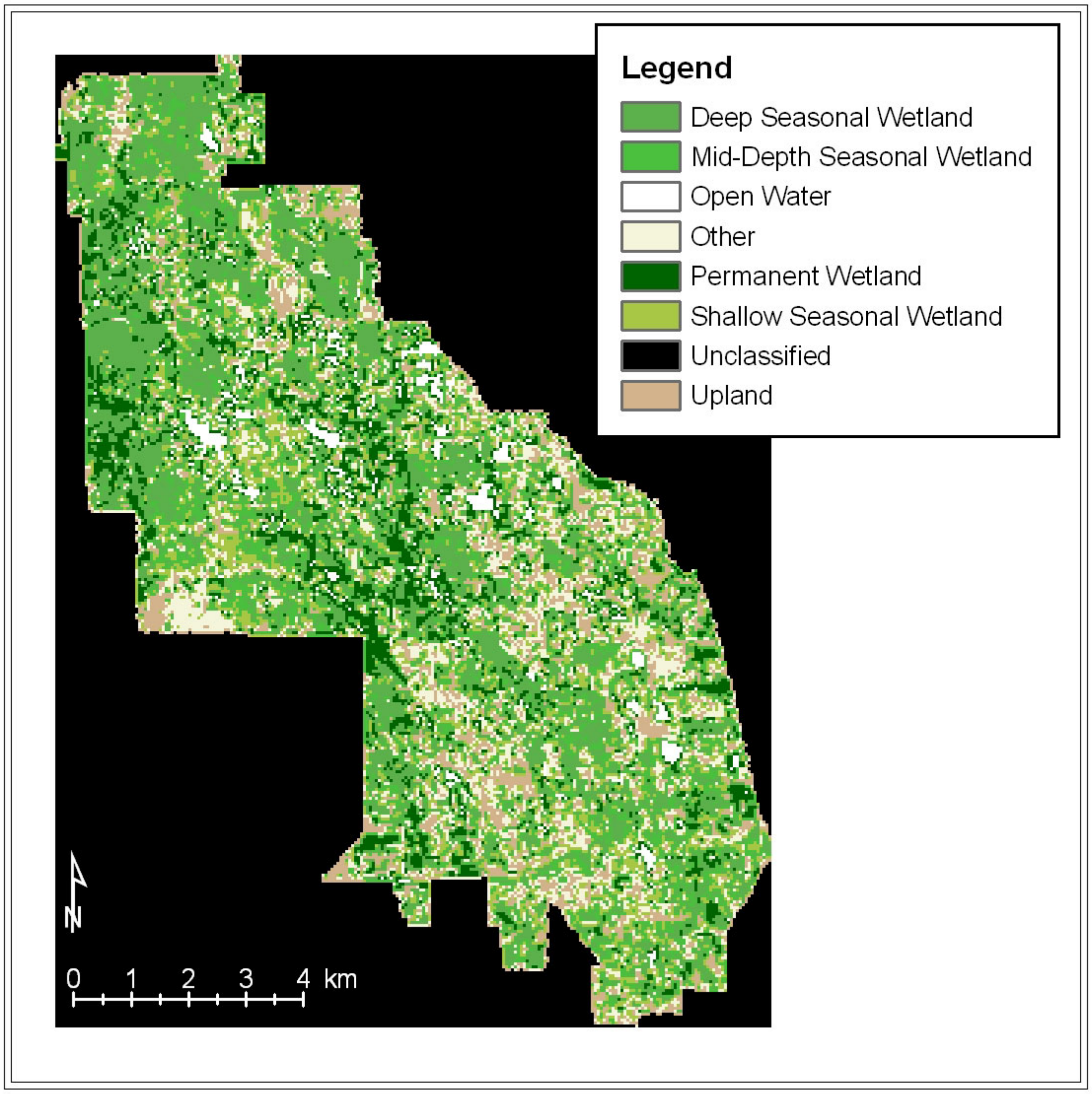


Figure 4.12 2003 maximum likelihood classification of NGWD, Merced County, CA. Classification of the entire area was based on a spectral signature file developed for Salinas Club. The development of the spectral signature file was based on ground truth data at 33 point locations. Using statistically based image processing techniques, this map shows information extrapolated from a few hundred pixels to millions of pixels.

In the final map, the classifications combine similar reflectance signatures. Shallow, mid-depth, and deep seasonal wetlands were grouped into a single classification called "Seasonal Wetlands." The emergent vegetation indicative of semi-permanent and permanent wetlands facilitated their merging into a single classification called "Semi-Permanent to Permanent Wetlands." The uplands and open water classifications were distinct enough on their own, and thus remained as individual classes named "Uplands" and "Open Water." Finally, for purposes of improved accuracy, the three classes for salt flats, bare soil, and improvements, were merged into the single classification called "Other." Performing this process on subsequent images, changes in the aerial extents of the land use classifications can be tracked. Analyzing the changes through comparison with previously made management decisions, impacts may be assigned to various land use activities (Holland, 1986, Fredrickson, 1991).

Of the roughly 25,000 acres in the NGWD, the RHAM estimated that on 20 May 2003, approximately 6,225 acres (25%) were upland, 10,725 acres (43%) were seasonal wetlands, and 4,750 acres (19%) were semi-permanent and permanent wetlands. The remaining 3,400 acres (14%) fall in the open water or "other" categories. Other includes very shallow seasonal wetlands, salt flats, bare soil, and improvements such as roads and buildings. These results are useful as a snapshot in time of the quantity and quality of the habitat in the NGWD.

Table 4.3 Land use acreages for the Salinas Land & Cattle Club and the North Grassland Water District

Wetland Land Use Classification in the Grassland Water District
May 20, 2003

Land Use Category	Salinas Club ~ 1,600 acres		North GWD ~ 25,100 acres	
	acreage	% of total	acreage	% of total
Uplands	325	20%	6225	25%
Seasonal Wetlands[1]	700	44%	10725	43%
Semi-Permanent Wetlands[2]	325	20%	4750	19%
Open Water	50	3%	1700	7%
Other[3]	200	13%	1700	7%

[1]Seasonal Wetlands include shallow, mid-depth and deep wetlands
[2]Semi-Permanent Wetland classification includes permanent and riparian wetlands
[3]The "other" classification includes very shallow seasonal wetlands, salt flats, bare soil, and improvements

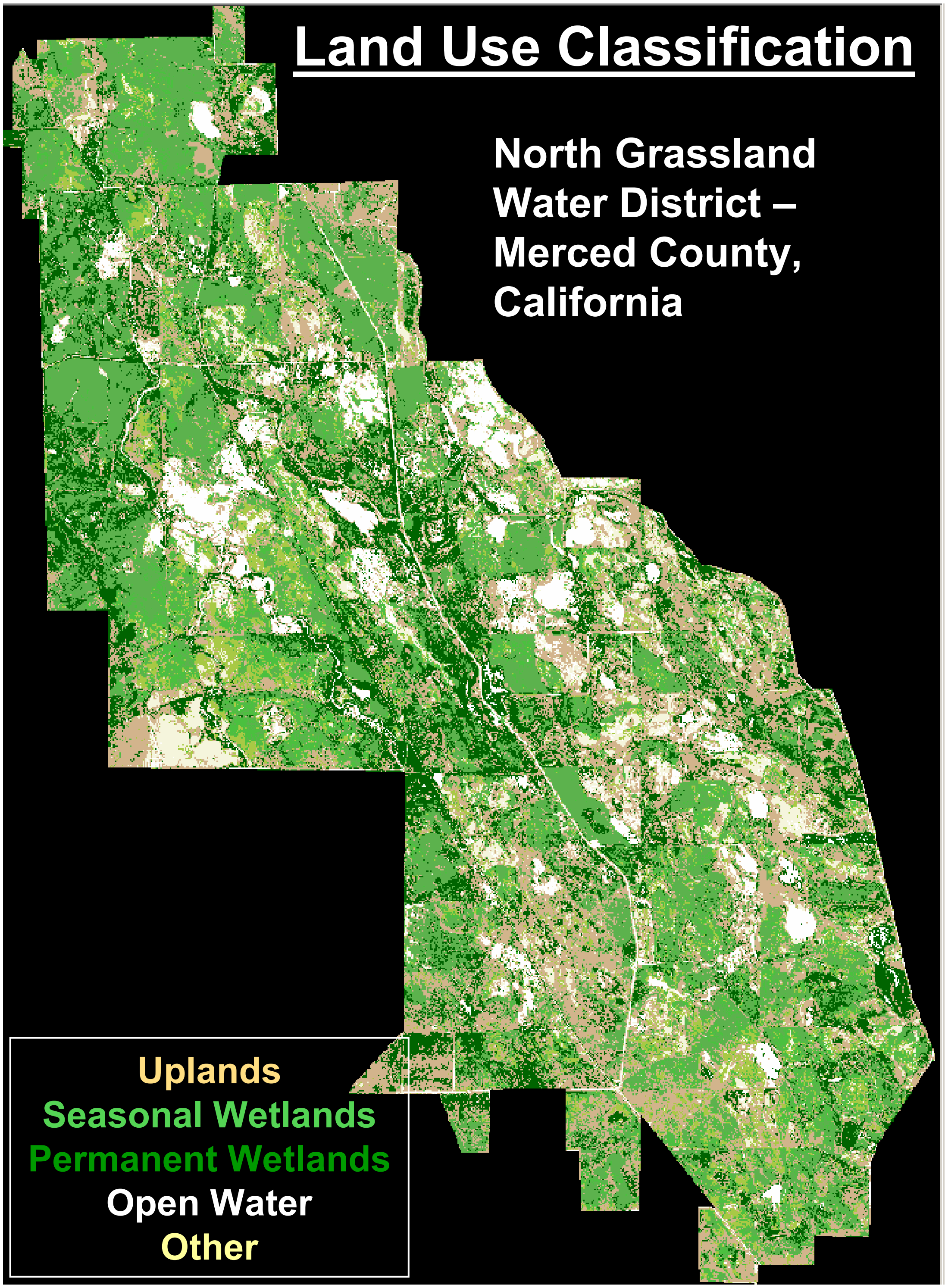


Figure 4.13 Final map showing delineation of entire North Grassland Water District into major land use categories. The map represents the distribution of land use on May 20, 2003.

In 2004, based on the increased quantity of ground truth data, the RHAM was used to derive additional land cover classes from the imagery. Figures 4.14 and 4.15 shows the result of the classification for the April, May, and June images. Additional land cover classes include non-vegetative categories such as "buildings" and "shallow flooding", wetland basin categories such as "scirpus" and "dense swamp timothy", and finally uplands categories such as "mustard" and "pepperweed." Table 4.4 shows the change in distribution of land cover classes across April, May, and June 2004.

Table 4.4 2004 land use percentages for the North Grassland Water District. The table shows significant changes in dominance of certain moist soil plants. Percentages of plant species represent verdant growth only. Plants that are no longer producing chlorophyll will be represented in the litter/senescent grass category, which increases substantially toward the end of the growing season.

Class name	**April 2004**	**May 2004**	**June 2004**
alkali bulrush low density	2.9%	4.2%	4.4%
baltic rush / alkali bulrush high density	0.0%	9.0%	7.7%
bare soil / iodine bush	11.6%	7.1%	9.1%
bermuda grass high / water hyacinth	1.0%	5.9%	5.1%
bermuda grass low density	0.0%	0.8%	0.5%
buildings	0.0%	0.2%	0.0%
litter / senescent grass	10.5%	7.1%	20.2%
mustard	0.0%	0.3%	0.2%
pepperweed	16.7%	4.1%	3.0%
saltgrass high density - verdant	0.1%	1.0%	0.9%
saltgrass high density / poison hemlock	9.4%	6.3%	4.7%
scirpus	1.5%	6.0%	3.3%
shallow flooding	4.7%	2.2%	1.0%
smartweed / cocklebur high density	1.6%	2.7%	0.9%
swamp timothy / alkali weed low density	5.0%	6.8%	11.9%
swamp timothy / alkali weed med density	3.6%	7.8%	2.2%
swamp timothy high density	13.8%	7.3%	2.3%
uplands - creeping wild rye/star thistle	10.2%	12.7%	14.8%
uplands - dock low density	1.3%	3.8%	6.2%
water	6.0%	4.8%	1.5%
TOTALS:	100.0%	100.0%	100.0%

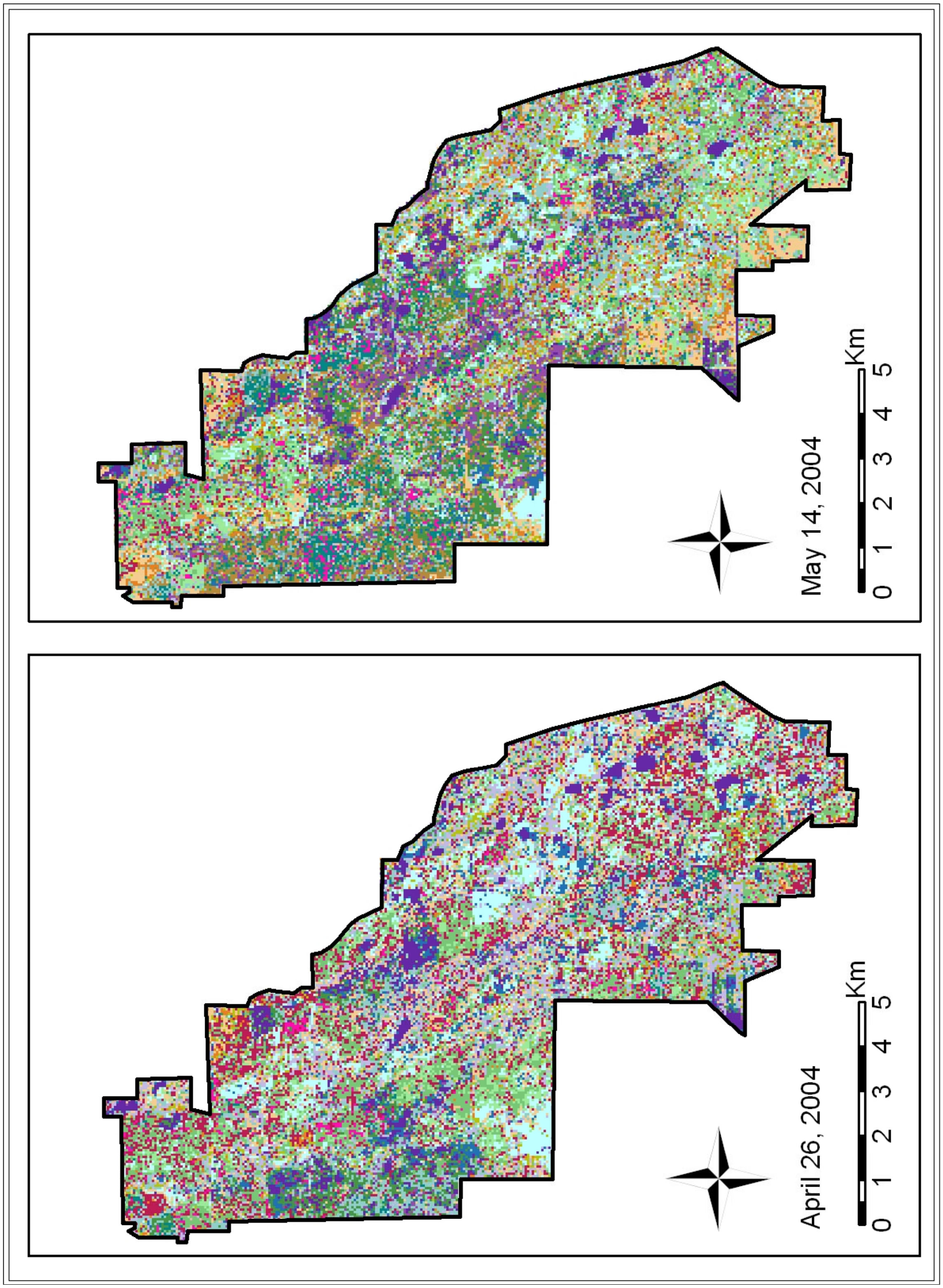


Figure 4.14 April and May 2004 maximum likelihood classification of NGWD. Increasing areas of swamp timothy can be seen near the north and south boundaries of the district.

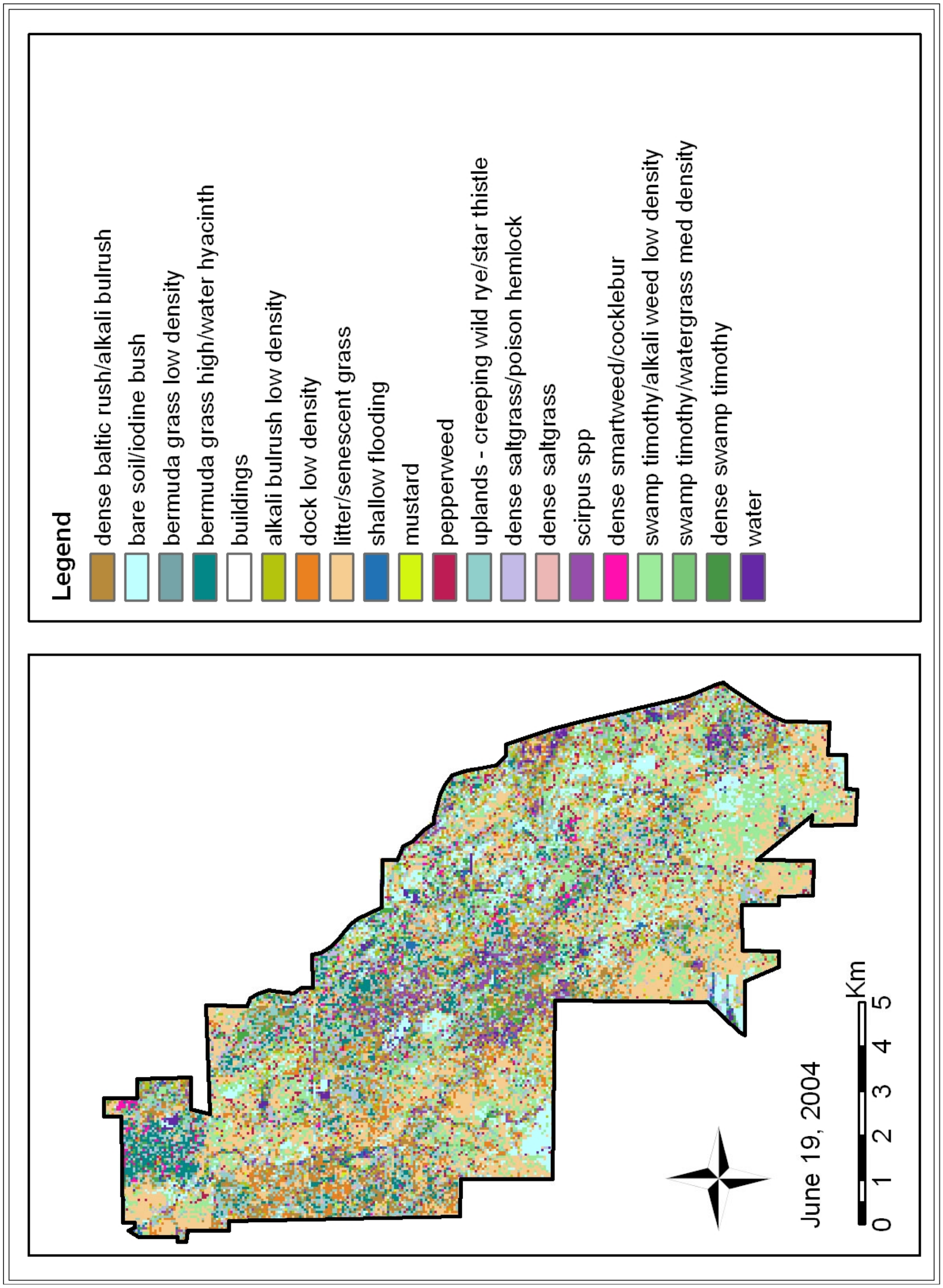


Figure 4.15 June 2004 maximum likelihood classification of NGWD. Decreased verdant swamp timothy and increased litter and senescence indicate a shift toward seed production.

4.3.1 Spectral Analysis Assessment

The table provides reasonable results for the land cover classes. Several notable trends, such as a decrease of open water and an increase in senescent grasses throughout the growing season, provide confidence in the extended application of the spectral signature to the whole of NGWD. The progressive decrease in dense swamp timothy, accompanied by an increase in low and medium density swamp timothy, likely reflects the life stage of the plant. As chlorophyll production wanes, and the plant moves into seeding and senescence, it appears to the satellite to occupy the landscape at a lower density. A few classes, such as pepperweed, show some unexpected variability that could likely be eliminated with continued refinement of the spectral signatures. Continued development of spectral signatures specifically for the months of April and June would also likely improve the accuracy of classification for those months.

Spectral signatures were validated for the 2003 application of the RHAM through a process of comparing land cover classification with the raw imagery from which it was derived. Comparison of the classified imagery with the raw imagery indicated that the extents and locations of known vegetative communities were well-represented. As shown in Figure 4.16 below, the classification does an excellent job of conforming to the boundaries of vegetative communities.

For the 2004 application of the RHAM, accuracy of land cover classes was spot-checked during post-classification assessment using check points reserved from the ground truth data especially for this purpose. During field data processing, ground truth data was divided into subsets characterized by the dominance of an individual plant species or other land cover class. Each ground truth point was then randomly assigned to serve either as a training point or as a check point. Slightly less than half of all field data points were assigned to check point status. Using visual inspection, land cover classes appear to correlate adequately with check points. It would be beneficial to further validate the RHAM by incorporating a quantitative means of assessing accuracy.

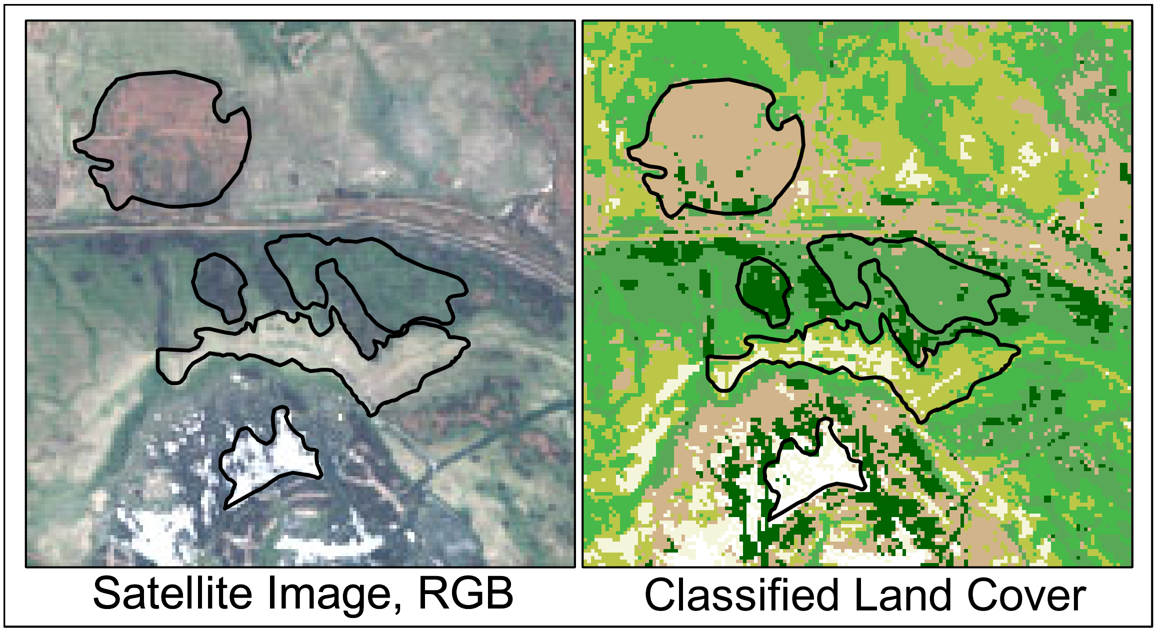


Figure 4.16 Spectral signature validation, 2003 RHAM. Nearly homogenous areas are delineated on the raw imagery and on the classified land cover map. Areas classified as uplands, permanent wetlands, open water, deep seasonal wetlands, and shallow seasonal wetlands all are apparent on the raw imagery.

4.4 Discussion

The RHAM described in this chapter can contribute to resource management programs in the Central Valley of California. Salinity TMDL's and other actions to control salt and nutrient loading from managed wetlands may have an impact on wetland hydroperiod, as drawdown is adjusted to match the San Joaquin River's assimilative capacity. The RHAM provides a tool to assess the long-term impact of these adaptive management strategies on the wetland resource. Results from this methodology may help provide a scientific basis for estimation of water needs of the moist-soil vegetation in managed seasonal wetlands. This research promotes better use of existing water resources to maximize wetland benefit with the possibility of long-term water saving.

From the waterfowl habitat perspective, this methodology has the potential to support the goals of the Central Valley Habitat Joint Venture (CVHJV). The CVHJV was established through a coalition of public, private, and nonprofit organizations to protect and restore wetlands and waterfowl populations in California's Central Valley. Functions of the CVHJV that the RHAM can promote are :

1. Enhancing habitat quality, not just quantity, particularly with regard to winter habitat for feeding birds;
2. Providing guidance for wetland managers on how to maximize productivity of their units;
3. Developing methods to maximize the efficiency of water use and enhance water quality, while concurrently developing realistic guidelines as to how much water is really needed, and when it is needed, for wetland dependent wildlife activities;
4. Providing a decision support tool and evaluation mechanism to promote wetland enhancement efforts of partners in the CVHJV. (The CVHJV has typically focused on acquisition and restoration of wetlands since it has proven difficult to assess or quantify habitat enhancement quantitatively.)

Given the wide range in seed production in Central Valley seasonal wetlands (200-1200 lbs/ac of moist soil seeds) wetland management for waterfowl habitat still appears to be an uncertain science in theory and in practice . The RHAM provides a reliable method that can be used at a valley-wide scale for evaluating management practices (Naylor, 2002, Eadie, 2003). The RHAM can also indirectly assist wetland managers in the more efficient use of water resources by helping to determine water use requirements for moist soil vegetation management.

CHAPTER 5 ESTIMATING SOIL SALINITY IN WETLANDS

5.1 Background

Soil salinity is an important conservation and environmental problem in wetlands of the San Joaquin Basin. Salinity affects plant germination and development, and can lead to significant increases in salt tolerant species' populations, thereby creating imbalances in the wetland ecosystem. Consequently, it can also influence fauna diversity, such as invertebrate, fish, and bird. Thus, it is important to evaluate the extent and variability of soil salinity on those wetlands in order to develop sound planning and management practices for improving long-term habitat health and restoring wetlands.

Measurement methods such as the four-electrode probes and soil sampling are generally applied to determine soil salinity; however, these methods require extensive data collection and laboratory analyses that are very slow, labor-intensive, and expensive. Recently, remote sensing technologies have become easier to use for surveying salt-affected lands. Among those techniques, the electromagnetic induction (EM) method has been very efficient in rapidly collecting salinity information in soil systems (Ceuppens et al., 1997; Hendrickx et al.). Furthermore, the EM technology generally provides better and faster estimates of soil salinity than direct methods (Sudduth et al., 1999). The principle of the EM technique is based on the fact that electrical conductance increases with salinity. The instrument generates a primary electromagnetic field in the soil, which in turn creates a secondary field. The ratio of both fields correlates with the depth-weighted electrical conductivity (EC) in the volume of soil below the EM sensor (Slavish, 1990). Since solid soil particles and rock material have very low EC (McNeill, 1980), the instrument response is primarily influenced by the electrolyte concentration of the soil water, i.e., salinity.

5.2 Objective of the Study

The objective of the study was to assess and map soil salinity in wetlands of the Grassland Water District (Salinas Club) and the San Luis National Wildlife Refuge (NWR), located in the San Joaquin River Basin, using the EM technique.

5.3 Methodology

Soil salinity surveys were conducted in April 2004 on selected lands of the San Luis National Wildlife Refuge (SLNWR), thereafter defined as San Luis Refuge, and the Salinas Club. Maps showing the locations of the surveys are presented in Figures 1 and 2. Two sites were surveyed at each wetland. Selection of the sites was based on representative soil conditions and vegetation population, as well as locations of previous ground plant identification. In June 2003, salinity surveys were also performed at the Salinas Club on the same sites

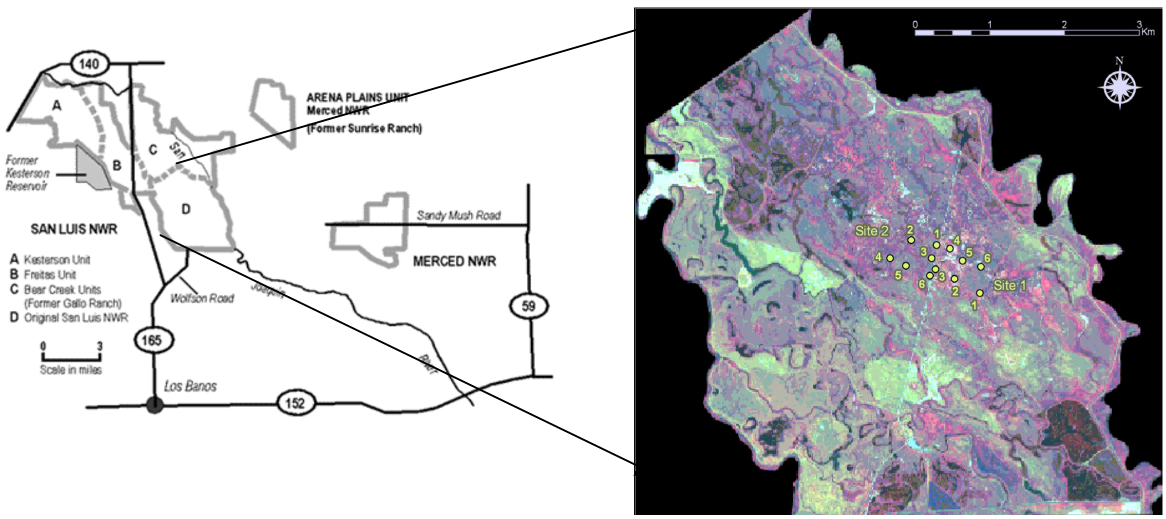


Figure 5.1. Location of sites surveyed at the SLNWR San Luis Unit

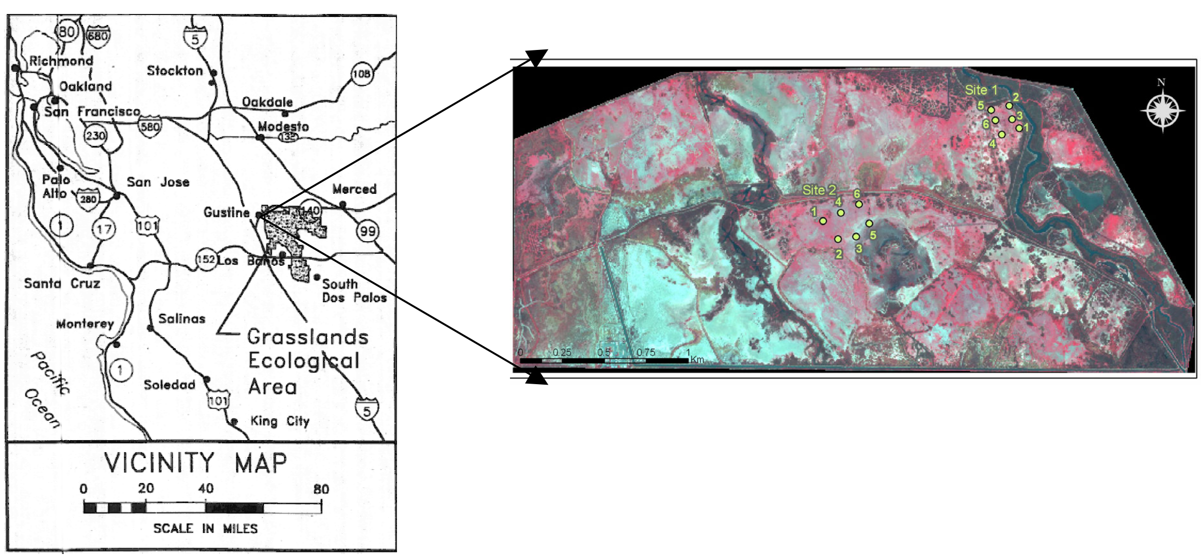


Figure 5.2. Location of sites surveyed at the Salinas Club

The salinity surveys were conducted using a mobilized system available at the California State University, Fresno. This system comprised a geographical positioning system (GPS) and a dual EM-38 meter (Geonics Ltd) placed in a carrier-sled that was attached at the rear of an ATV and operated in both horizontal and vertical modes, providing bulk salinity estimates of both shallow (top 6 inches) and deep (top 6 feet) soils. Such system allowed for rapid salinity measurements (about 2 hours per survey), after initial setup, at both wetlands. The EM and GPS data were collected along transects spaced 150 to 300 ft apart, depending on the extent of vegetation cover, and recorded simultaneously to a laptop computer. After the surveys, the data were analyzed using ESAP (Lesch and Rhoades, 1999) and a soil sampling plan was developed to calibrate the EM data.

Figure 5.3 EM-38 dual mode meter (Geonics Ltd) placed in a carrier-sled that was attached at the rear of an ATV. Horizontal and vertical aligned coupled meters provide sensing of near-surface bulk salinity (top 6 inches) and deeper bulk salinity (up to 6 feet).

For each survey, the sampling plan comprised 6 locations that were spatially representative of the entire survey area. Ground truthing soil sampling was then conducted at each site. Soil samples were collected at 0-6" and 6-12" depths (associated with horizontal and vertical EM-38 alignments of the dual instrument) and then analyzed for EC, moisture, texture, and total dissolved solids (TDS) following standard analytical methods (Rhoades, 1996). Based on the EM data and laboratory analyses, maps of soil salinity were generated for each site surveyed using GIS (Environmental System Research Institute, 1996). The San Luis NWR was included because of the large differences in moist soil plant diversity between the Refuge and the private duck clubs within Grassland Water District

5.4 Results

Table 5.1 presents the EC levels of soils sampled at the San Luis Refuge and Salinas Club. Sampling locations at each site are shown in Figures 5.1 and 5.2. Soil EC at the San Luis Refuge ranged from 0.4 to 19.8 dS/m , indicating a high degree of variability across the surveyed areas. The EC levels were relatively lower at site 1 as compared to site 2. Typically, higher EC values were observed in the first six inches of the soil profile in site 1, which could suggest lower drainage of water. At the Salinas Club, similar variability in the EC data was observed (1.3 to 18.3 dS/m).

Table 5.1. Soil electrical conductivity (dS/m) for samples collected on all surveyed sites.

Sampling location	Depth	San Luis Refuge		Salinas Club	
		Site 1	Site 2	Site 1	Site 2
1	0-6"	12.2	3.34	13.6	4.38
	6-12"	8.69	3.57	14.4	1.34
2	0-6"	3.80	1.86	6.75	5.42
	6-12"	4.31	2.64	5.14	5.24
3	0-6"	2.02	4.21	6.71	18.3
	6-12"	0.42	1.57	4.85	18.2
4	0-6"	2.28	7.54	4.19	3.91
	6-12"	1.31	9.52	5.44	4.37
5	0-6"	1.67	19.8	3.28	8.41
	6-12"	0.94	21.1	1.45	2.21
6	0-6"	1.44	6.63	4.12	4.63
	6-12"	0.65	2.21	3.44	2.31

The texture data indicated that the soils were loamy to clayey. The average EC values of the six samples collected at 0-6" and 6-12" depths in site 2 of the San Luis Refuge and sites 1 and 2 of the Salinas Club were comparable (Table 5.2). Site 1 at the San Luis Refuge exhibited the lowest average EC levels for both depths; all EC data were below 9 dS/m. A high variability in the EC data was observed for all sites and depths, as indicated by the large standard deviations.

Table 5.2. Statistics for EC analyzed on all soil samples collected in 2004.

Site	Depth	Mean	Std. dev.	Minimum	Maximum
SLR, site 1	0-6”	3.90	4.14	1.44	12.2
	6-12”	2.72	3.25	0.42	8.69
SLR, site 2	0-6”	7.23	6.51	1.86	19.8
	6-12”	6.76	7.58	1.57	21.1
SC, site 1	0-6”	6.44	3.8	3.2	13.6
	6-12”	5.79	4.49	1.4	14.4
SC, site 2	0-6”	7.50	5.51	3.90	18.3
	6-12”	5.61	6.33	1.34	18.2

SLR = San Luis Refuge, SC = Salinas Club

Table 5.3 shows the TDS results obtained from the soil analyses conducted on all samples. The TDS values followed the same trend observed with EC. The highest TDS values were observed in site 2 at the Salinas Club.

Table 5.3. Statistics for TDS analyzed on all soil samples collected in 2004.

Site	Depth	Mean	Std. dev.	Minimum	Maximum
SLR, site 1	0-6”	3138	2984	1300	9017
	6-12”	2186	2436	467	6200
SLR, site 2	0-6”	5967	5726	1480	16860
	6-12”	6106	8096	350	21425
SC, site 1	0-6”	5537	4184	1620	12680
	6-12”	5087	4776	1880	14660
SC, site 2	0-6”	6330	4657	2960	14740
	6-12”	4720	5923	1200	16600

SLR = San Luis Refuge, SC = Salinas Club.

These soil laboratory data were used to calibrate the EM measurements and estimate soil salinity over the surveyed areas. For each site, the correlations between measured TDS and calculated conductivity data were above 0.8, suggesting a high degree of survey reliability and accuracy for salinity estimation. The soil salinity levels estimated at 0-6” and 6-12” depths for the surveyed areas in 2004 at the San Luis Refuge are presented in Figures 5.3 and 5.4. The contour maps indicate that the soil salinity levels were generally higher in site 2. Greater salinity was also observed at 0-6" depth as compared to the lower depths for both sites, suggesting that drainage could be poor on those sites. At site 1, the soil salinity was greatest in the western part of the surveyed area, and decreased gradually in a north-west direction. At site 2, salinity was variable across the surveyed area. The greatest salinity problems were encountered in the south and north-east sections. Figures 5.5 and 5.6 show the soil salinity distribution at the two sites surveyed at the Salinas Club in 2004. The salinity levels did not exceed 16 dS/m at those locations

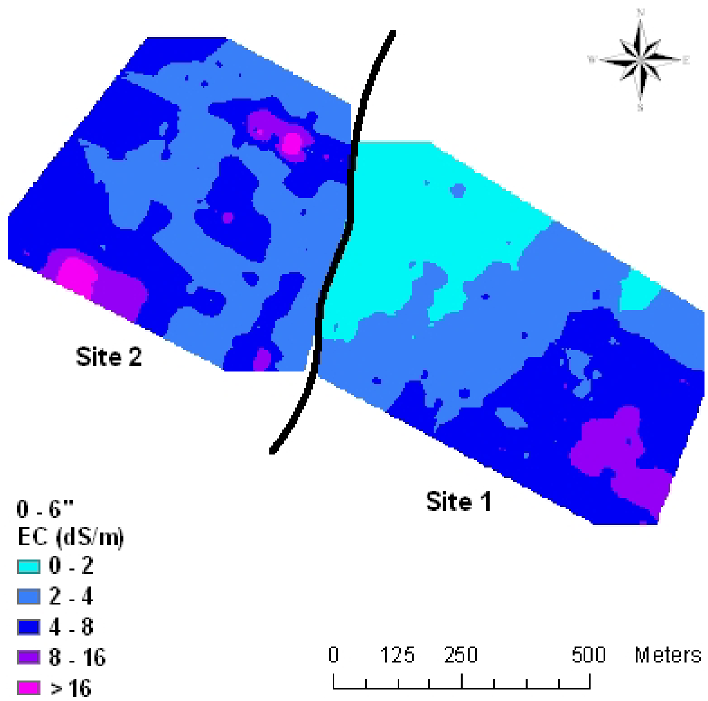


Figure 5.4. Soil salinity estimated at 0-6" depth on two sites surveyed at the San Luis Refuge in 2004

Although the salinity levels were not as variable as those observed at the San Luis Refuge, the salinity distribution was quite different between the 0-6" and 6-12" depths. On both sites, the salinity was higher at the soil surface (0-6"). At site 2, the soil salinity levels remained mostly between 4 to 8 dS/m on surface, indicating low spatial variability in the surveyed area. However, at 6-12" depth, the site exhibited greater spatial variability with salinity values ranging from 0.3 to 15.7 dS/m.

In 2003, salinity surveys were also conducted at the Salinas Club on the same sites. Soil samples were collected at 0-12" for calibration of the EM measurements. Table 5.4 presents the statistics for EC and TDS analyzed on soils collected at the Salinas Club. Compared to 2004, the EC and TDS levels observed the previous years were higher in both sites; however the salinity variability was lower across the surveyed areas.

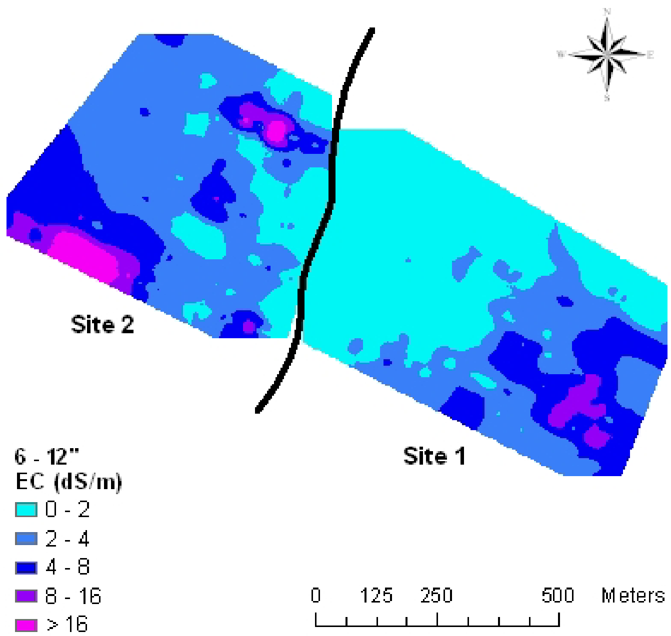


Figure 5.5 Soil salinity estimated at 6-12" depth on two sites surveyed at the San Luis Refuge in 2004

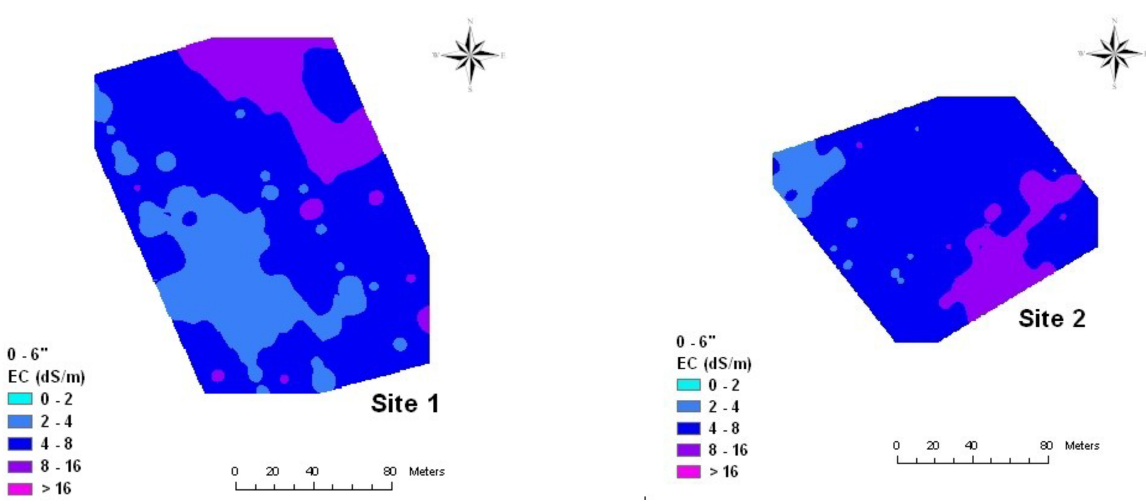


Figure 5.6. Soil salinity estimated at 0-6" depth on two sites surveyed at the Salinas Club in 2004.

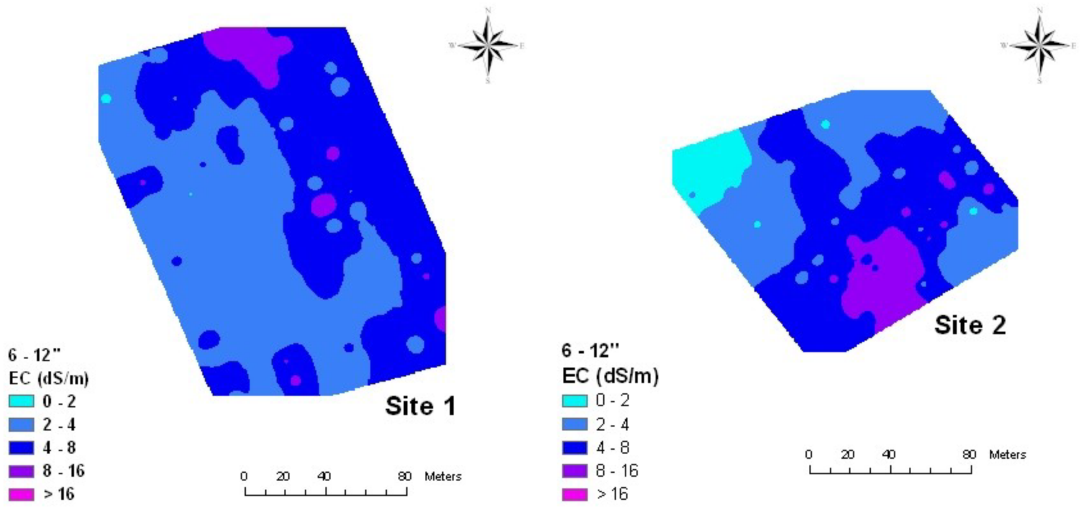


Figure 5.7. Soil salinity estimated at 6-12" depth on two sites surveyed at the Salinas Club in 2004.

Data analyses indicated a high degree of survey reliability and accuracy for predicting salinity levels on both sites. The soil salinity maps generated at each site are presented in Figures 5.7 and 5.8. The mobile system was not used for conducting the 2003 salinity surveys at the Salinas Club; thus, the surveys were performed on smaller areas. Site 1 showed a very uniform salinity pattern, with values ranging from 8 to 16 dS/m. At site 2, a higher salinity variability was observed across the survey area. However, the salinity levels were lower than 8 dS/m in most areas.

Table 5.4. Statistics for EC and TDS analyzed on all soil samples collected in 2003 at the Salinas Club.

Site	**Depth**	**Mean**	**Std. dev.**	**Minimum**	**Maximum**
EC - site 1	0-12"	11.0	2.5	8.4	14.8
EC - site 2	0-12"	4.4	0.8	3.3	5.7
	12-24"	6.7	3.1	2.0	10.6
TDS – site 1	0-12"	9235	2333	6797	12780
TDS - site 2	0-12"	3334	690	2453	4385
	12-24"	5376	2628	1381	8830

SLR = San Luis Refuge, SC = Salinas Club

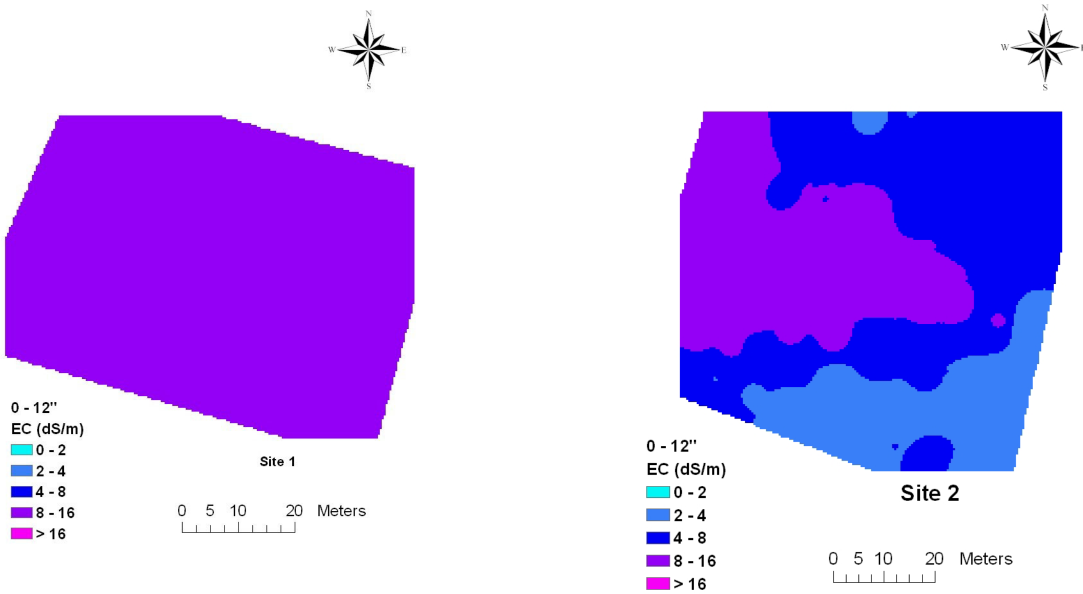


Figure 5.8. Soil salinity estimated at 0-12” depth on two sites surveyed at the Salinas Club in 2003

5.5 Conclusions

The results of the study indicated that the EM technique was very effective to accurately assess soil salinity distribution across the surveyed areas of the San Luis Refuge and Salinas Club wetlands. The soil profile shapes (regular or inverted), indicative of drainage management practices, could be suggested from the salinity surveys and soil sampling at various depths. The EM surveys indicated that the soil salinity levels were relatively high on both wetlands, and particularly at the San Luis Refuge at site 2. Therefore, it is advisable to improve drainage management practices on those wetlands to increase flora and fauna diversity and ameliorate wetland habitat.

The soil salinity survey technique described in this section, when combined with the remote sensing methodology described in Chapter 4 should form the basis of a physically-based (as opposed to biologically based) assessment of baseline conditions in advance of a wetland-wide strategy of real-time management of seasonal drainage. These techniques will allow wetland managers to document any long-term changes in wetland soil salinity conditions and take appropriate management actions to avoid the type of damage to the wetland resource that occurred in the Southern Division of the Grassland Water District. Changes in the health of the wetland resource occurs slowly and insidiously requiring a quantitative approach to assessment. The techniques described in Chapters 4 and 5 should be further refined to improve their accuracy and reduce their cost.

CHAPTER 6 CONCLUSIONS

6.1 Summary

The Real-Time Adaptive Wetland Water Quality Management Research Project was designed to better manage the seasonal wetland drainage contribution to San Joaquin River salinity. To accomplish this project goal decision support tools were developed to improve understanding of seasonal wetland salt mass balance and to assess potential impacts on habitat quality of actions to improve water quality in the San Joaquin River. The tools developed for this project include:

1. A real-time flow and salinity data acquisition network for use in seasonal wetlands;
2. A wetland water quality model focusing on salt exports from the Grassland Water District to the San Joaquin River;
3. Results from theoretical application of adaptive wetland drawdown schedules for better coordination with the salt assimilative capacity of the San Joaquin River.
4. A remote habitat assessment methodology for measuring the impacts of alternative wetland drawdown schedules on moist-soil plant production.

These decision support tools provide a resource to wetland managers to adaptively respond to San Joaquin River salt discharge opportunities while maximizing long-term wetland function and habitat value. Adaptive management can be defined as "changing or altering management decisions based on past or current conditions, either physical or political" (Chess et al., 2000). The Decision Support System (DSS) assists in the computation of GWD wetland water requirements including an estimation of wetland salinity loads in seasonal wetlands. The DSS was designed to interact with the existing SJR water quality forecasting model, SJRIODAY, to allow the partition of assimilative capacity among the wetland releases (Quinn and Hanna, 2003).

Decision Support Systems are becoming more important to ecosystem managers. As the habitat value of the GWD increases so do the impacts of their decisions. As concerns over water quality conditions in the San Joaquin River increase - tools that combine information from several disciplines allow general practitioners to make better informed decisions (Chess et al., 2000; Young et al., 2000). For further details of the decision support system utilizing a former version of the WWQM, see Appendix 4 – Quinn, N. W. T., and W. M. Hanna, 2003.

A decision support system for adaptive real-time management of seasonal wetlands in California. Environmental Modelling and Software, Volume 18, Issue 6.

6.2 GWD –Project Geographic Information System

The results from modeling scenarios were automatically loaded into a Microsoft Access database for use with Geographic Information System (GIS) software. The GIS assists the wetland manager develop salinity forecasts salinities on individual wetlands (Figure 2) allowing drainage from each to be scheduled. Included in the GIS, for each wetland unit, are useful information to the water master. This information includes:

1. the name of the wetland unit;
2. the wetland unit's owner's name and phone number;
3. the location of the wetland unit and its upstream and downstream neighbors;
4. the water supply and drainage canals, including the drainage basin;
5. the total area, total wetland area, and total upland area;
6. the total water and salt remaining on the property;
7. the management goals, either habitat or cattle club;
8. satellite, mapped, and schematic images of the wetland unit; and
9. contact phone numbers where the wetland manager can be reached.

This information will allow GWD staff to quickly ascertain wetlands where salinity is accumulating fastest, whether they will be draining earlier (cattle club) or later (habitat club), what drainage basin this may impact, and who to contact when decisions are made.

6.3 Discussion

The research performed for this project has provided several useful results that can be immediately applied to wetland "best management practices" (BMP). Results from the research have shown that real-time data acquisition is feasible in seasonal wetlands

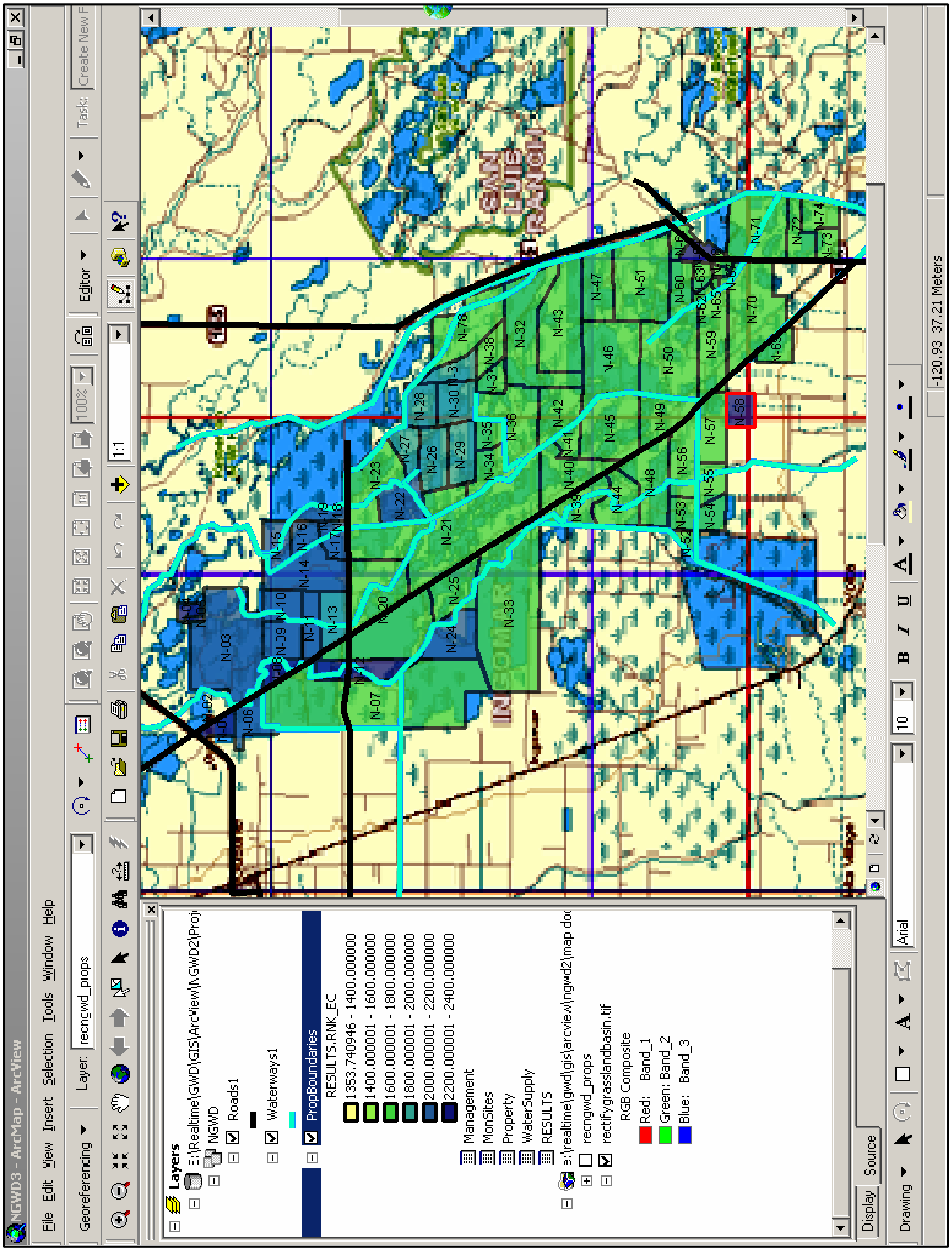


Figure 6.1 Geographical Information System (GIS) for the North Grassland Water District

and can meet regulatory requirements under EPA mandated TMDL's. The same data can also be used to develop and run a wetland water quality model, providing the capability to forecast wetland salinity levels during the drawdown period. These forecasts, when compared to the San Joaquin River assimilative capacity forecasts for salts, can help decision makers adaptively manage salt export. Use of remote sensing techniques to monitor moist soil plant impacts and mobile salinity sensors to map longer term soil salinity impacts – a methodology has been created to aid the development of sustainable best management practices.

Information obtained through this project will be transferable and of significant value to all wetlands in the Grassland Ecological Area including State and Federally managed wetlands. The successful implementation of this combined monitoring, experimentation and evaluation program can provide the basis for adaptive management of wetland drainage throughout the entire 70,000 hectare Grassland Ecological Area. The project will involve local landowners, duck club operators, and managers of State and Federal refuges in the Grassland Basin. Although this pilot project has concentrated on the 20,000 hectares that comprise the GWD, the goal of the project is to disseminate the findings of the project more widely. The Grassland Water District has a successful history of local involvement through the District newsletter high school and college-level educational outreach programs; and "Wild on Wetland" days which educate the public about the benefits and techniques of wetland management.

Currently there are three types of wetland management strategies practiced in the Grassland Water District. These are:

1. Habitat Clubs; Duck Clubs enrolled in the Pressley Program;
2. Cattle Clubs; Duck Clubs that graze cattle in the non-hunting season
3. Clubs that follow a variety of management plans.

Habitat clubs are clubs that are enrolled in a habitat management reimbursement program or manage their lands in a similar manner. An example of a habitat management reimbursement program is the California Department of Fish and Game's Pressley Program.

The Pressley Program pays the landowner approximately $20 per acre for every acre managed under their habitat guidelines. These types of management practices usually promote a later drawdown into late March to early April. Cattle club managers manage their lands in the off-season for cattle grazing. Because of this use, managers tend to drain their wetlands early to promote the growth of grasses. The remaining clubs have no clear goal or precise management strategy. These clubs should be the first priority for applying this DSS to meet their goals, whatever those goals may be. It must be understood that although the GWD is a seasonal contributor of salts to the San Joaquin River, there are other such entities that may also be able to improve their operations.

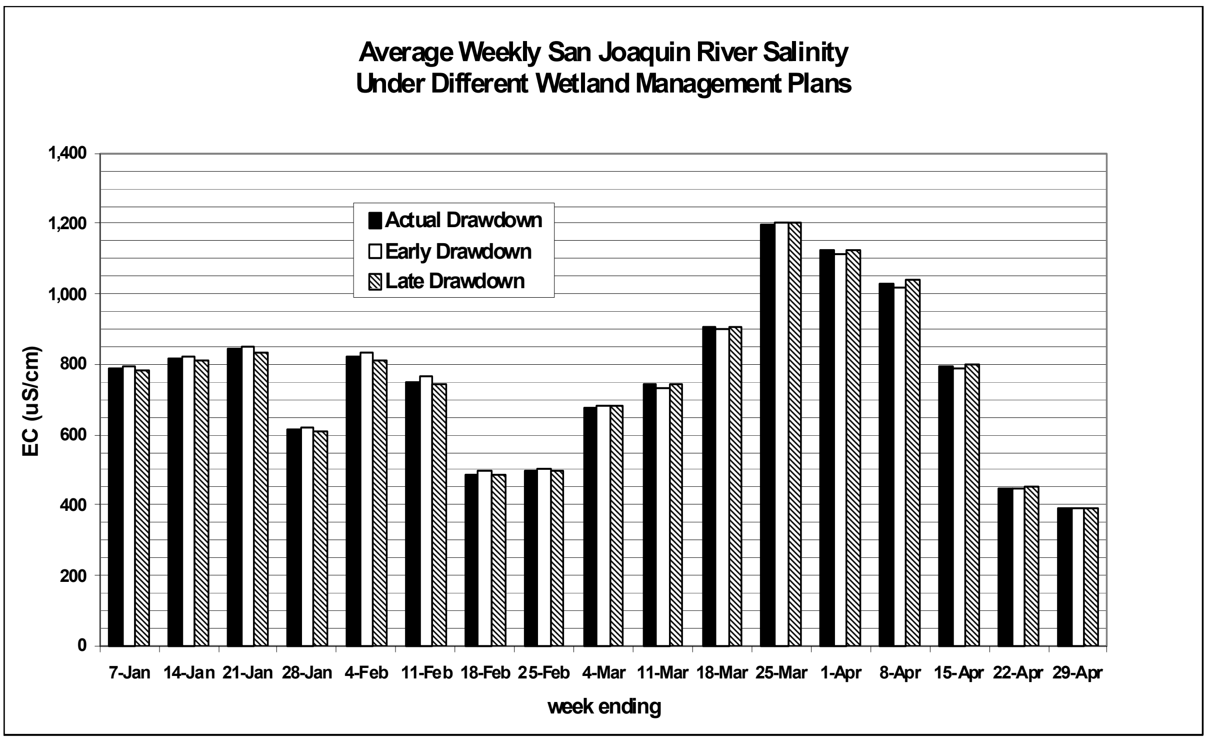


Figure 6.2 Modeled San Joaquin River salinity under different drawdown schedules.

This project has demonstrated the ability to coordinate wetland drainage activities contributing to water quality impairments the San Joaquin River. If a basin-wide effort, combining the activities of environmental, agricultural, municipal and industrial interests is implemented, water quality compliance with environmental objectives in the San Joaquin River is possible.

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8. APPENDICES

APPENDIX 1 WETLAND WATER QUALITY MODEL PACKAGE

The wetland water quality model consists of several interactive spreadsheets that are linked to either the real-time water quality network, or the California Irrigation Management Information System (CIMIS) operated by the California Department of Water Resources (DWR) and the USDA.

WWQM.xls

This is the water and salt balance model that takes all the input data and produces an output estimation of wetland EC. This estimated wetland EC is then read into a results file that uses a water supply source ranking as a multiplier to get the individual wetland units' ECs.

GWD input.xls

This is the main water quality and quantity data file. This file contains daily drainage water quantity and quality, in columnar form, from both the real-time network (updated weekly to biweekly) as well as from GWD daily grab samples (updated monthly to bi-monthly). This file serves as input data for the WWQM.xls. (9/1/95 – present, depending on location).

RESULTS.xls

This is the results file that is the output of the WWQM.xls. It tabulates the GWD ID and the water quality ranking and uses it as a multiplier to estimate (calculate) the individual properties EC from the model results. This file serves as input file populating the fields in the Access Database being read into ArcGIS. ArcGIS takes this information and shades the individual properties according to the estimated EC of the wetlands.

Wetland Habitat Management.xls

This file contains annually static data based on recommendations from the California Water Fowl Association and is adapted from Smith et al. 1995 "A Guide to Wetland Habitat Management in the Central Valley". This file is used as input data to the WWQM.xls. (September 1 – August 31)

AssimCapCalcs.xls

This file contains the actual calculations between the assimilative capacity of the SJR at Vernalis with and without the NGWD input. It also has the ability to load modeled values from both SJRIO and WWQM to produce expected assimilative capacity values for the SJR at Vernalis. This file is from 10/1/98 to present and is updated periodically by request by Ernie Taylor of the California Department of Water Resources at etaylor@water.ca.gov.

API.xls

This file contains the user interface. It has functionality to input the water year type (fore forecasting purposes) and various management scenarios (preflushing, early drawdown, late drawdown). As well, this file accesses the latest SJRIO assimilative capacity forecasts for the San Joaquin River for easy comparison of gaming scenarios.

Update.xls

This file contains the data necessary to run the WWQM. This data included fall under all four categories; static, annually constant, annually varying, and real-time. The file itself is organized in such a way that all necessary data elements are easily updated. For the updates to take effect, the user needs only to move the most recent "update[date].xls" spreadsheet into the proper working directory. Below is a description of the various data available in the update file, organized into separate worksheets. These worksheets are as follows:

Pan and Crop Coefficients – The crop and pan coefficients worksheet contains pan coefficients (Kp) and crop coefficients (Kc) for the calculation of daily evaporation (from open water) and evapotranspiration (from vegetated areas of wetlands).

Flood Schedules – The Flood Schedules worksheet contains the data that drives all surface water flows. These data include wetland habitat management schedules, preflushing option schedules, and inflow EC. The first of this data are the wetland habitat management schedules for the San Joaquin Valley and have been adjusted for four different water type years, very dry, dry, normal, and wet. In addition, this file contains data for wetland habitat management schedules modified for wetland areas under the dual use of running cattle and have been adjusted for the four different water type years, very dry, dry, normal, and wet. This file also includes the data that runs the preflushing option for the WWQM to run different scenarios (see description for API.xls above). Lastly, this file contains the EC values for the delivery water (Inflow EC, see Model Column Description section, below). At present there is no data set on the inflow EC, only a rough profile from sporadic grab samples. The reason for the lack of quality data for the inflow volume and EC is that the Volta Wasteway monitoring station that monitors the delivery water for more than 80% of the NGWD has been repeatedly vandalized since installation.

Station 5, E – The Station 5 worksheet contains daily pan evaporation data for weather station number 5, located in Shafter, California (operated by the USDA). The file gives only estimates because the station is not located within the project area, however it is located within the same type of climate zone as defined by CIMIS. In addition, data is extrapolated every 5 to 15 days as there is no easy way to get the quantity of water added to replenish the pan when levels get low. This file serves as input data for the WWQM.xls. This file can be updated daily from the web at http://www.cimis.water.ca.gov/. (8/31/96 – present)

Station 56, ET, P – The Station 56 worksheet contains daily climate data for weather station number 56, located in Los Baños, California (Kesterson Wildlife Refuge). Data being used from this file include ETo and precipitation to calculate the water and salt balance in the wetland units. This file serves as input data for the WWQM.xls. This file can be updated daily from at http://www.cimis.water.ca.gov/. (8/31/96 – present)

Assumptions – The Assumptions worksheet contains the data assumptions necessary to operate the WWQM. These data include assumptions for groundwater (GW), operational spill (OS), wetland depth (WD), areal precipitation (P), evaporation (E), and evapotranspiration (ET), water balance theory, percent wetland vegetation coverage, and the minimum depth requirements. The assumptions are as follows:

GW – The model is designed to easily incorporate groundwater data as it becomes available. As of now, the model assumes no net groundwater inflow or outflow during a typical season.

OS – The operational spill portion of the model was originally estimated at 1 cfs per 200 acres (or 0.12 inches of water per day per acre)(pers. comm.. Scott Lower, 2002, Tim Taylor, 2000). During the calibration process, this number was updated to 1 cfs per 235 acres (or 0.10 inches of water per day per acre).

D – The assumption is stated that the most recent, accepted guide to wetland management practices for the region, is followed by the wetland managers in the NGWD.

P – The assumption is stated that the precipitation input to the WWQM is that precipitation falling directly onto the wetland area.

E – The assumption is stated that evaporation output from the wetland occurs from the portions of the wetland that are open water (unvegetated areas).

ET – The assumption is stated that evapotranspiration output from the wetland occurs from only the portions of the wetland that are vegetated.

Other – In addition, it is assumed that there are no dissolved solids in E, ET, and P (EC=0.0 mS/cm). That the water balance theory that inflow minus outflow equals the change in storage holds true for these wetlands. The assumptions are made for the percent coverage and percent open water for the wetlands of the NGWD. This value can be greatly improved with further research such as edge detection and pattern recognition techniques applied to aerial photographs. The assumption is made that after the wetland depth drops below a certain level (1.2 in) that drainage stops.

Land Use – The land use worksheet contains data relating to the acreages of the wetlands and the use of those wetlands. Acreages are given for wetland acres, total acres, acres within a specific drainage, and acres managed for solely habitat or for both habitat and raising cattle. This file is a compilation of information from two other spreadsheets, GWD Acreages 12_18_98.xls (from GWD) and pressley.xls (from DFG), as well as discussions with wetland managers. A brief description of the two spreadsheets is below. The GWD Acreages

12_18_98.xls file contains information pertaining to individual properties including GWD ID, Property Name, total acreage, flooded acreage, supply water source, drainage basin, current owner, former owner, federal tract ID, identifier if map is available, water supply quality ranking, and meta data. The pressley.xls file contains information regarding duck clubs participation in the Pressley Program, i.e. clubs that have agreements to manage their lands primarily as wetland habitat. This information includes GWD ID, Property Name, County, Acres under the program, phase of program, funding source, execution date, expiration date, annual budget, contact name, and contact phone.

Metadata – The metadata worksheet contains background information for many of the data contain in the model package, as well as calculations and conversions for the model itself

APPENDIX 2 THE WETLAND WATER QUALITY MODEL (WWQM.XLS)

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
8/31/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00			0	0	12	1192	12	1192
9/1/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	10	1185	10	1185
9/2/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	9	1200	9	1200
9/3/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	9	1122	9	1122
9/4/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1000	8	1000
9/5/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	10	1000	10	1000
9/6/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	900	12	900
9/7/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	14	871	14	871
9/8/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	880	15	880
9/9/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	17	903	17	903
9/10/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	17	741	17	741
9/11/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	747	15	747
9/12/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	700	13	700
9/13/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	700	13	700
9/14/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	10	700	10	700
9/15/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	10	700	10	700
9/16/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	11	700	11	700
9/17/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	700	13	700
9/18/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	719	13	719
9/19/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	26	673	26	673
9/20/2000	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	25	626	25	626
9/21/2000	0.00	0	0	0.36	500	0.32	0.09	0.10	0.10	0	0	0.36	0.36	0.00	90	77	0	0	24	650	24	650
9/22/2000	0.00	0	0	0.71	500	0.29	0.06	0.10	0.10	0	0	0.71	0.71	0.26	90	77	625	781	25	650	25	650
9/23/2000	0.00	0	0	0.81	500	0.29	0.08	0.10	0.10	0	0	1.07	1.07	0.59	90	77	625	781	35	650	35	650
9/24/2000	0.00	0	0	0.83	500	0.13	0.08	0.10	0.10	0	0	1.42	1.42	1.11	90	77	625	781	43	612	43	612
9/25/2000	0.00	0	0	0.66	500	0.17	0.08	0.10	0.10	0	0	1.78	1.78	1.43	90	77	625	781	42	612	42	612
9/26/2000	0.00	0	0	0.71	500	0.14	0.09	0.10	0.10	0	0	2.13	2.13	1.81	90	77	648	810	44	616	44	616
9/27/2000	0.00	0	0	0.68	500	0.22	0.08	0.10	0.10	0	0	2.49	2.49	2.09	90	77	688	860	44	616	44	616
9/28/2000	0.00	0	0	0.76	500	0.30	0.08	0.10	0.10	0	0	2.84	2.84	2.37	90	77	732	915	43	642	43	642
9/29/2000	0.00	0	0	0.83	500	0.22	0.07	0.10	0.10	0	0	3.20	3.20	2.81	90	77	737	921	42	640	42	640
9/30/2000	0.00	0	0	0.74	500	0.13	0.07	0.10	0.10	0	0	3.56	3.56	3.26	90	77	728	910	42	639	42	639
10/1/2000	0.00	0	0	0.65	500	0.14	0.08	0.10	0.10	0	0	3.91	3.91	3.59	90	77	731	914	44	638	44	638
10/2/2000	0.00	0	0	0.68	500	0.16	0.09	0.10	0.10	0	0	4.27	4.27	3.92	90	77	737	921	45	628	45	628
10/3/2000	0.00	0	0	0.71	500	0.20	0.08	0.10	0.10	0	0	4.62	4.62	4.24	90	77	746	932	66	614	66	614
10/4/2000	0.00	0	0	0.74	500	0.29	0.07	0.10	0.10	0	0	4.98	4.98	4.52	90	77	763	954	83	675	83	675
10/5/2000	0.00	0	0	0.81	500	0.11	0.07	0.10	0.10	0	0	5.33	5.33	5.05	90	77	750	937	97	660	97	660
10/6/2000	0.00	0	0	0.64	500	0.20	0.07	0.10	0.10	0	0	5.69	5.69	5.31	90	77	758	947	97	662	97	662
10/7/2000	0.00	0	0	0.73	500	0.32	0.06	0.10	0.10	0	0	6.04	6.04	5.56	90	77	775	969	91	666	91	666
10/8/2000	0.00	0	0	0.84	500	0.12	0.06	0.10	0.10	0	0	6.40	6.40	6.12	90	77	761	952	98	674	98	674
10/9/2000	0.00	0	0	0.63	500	0.20	0.06	0.10	0.10	0	0	6.76	6.76	6.40	90	77	765	957	100	680	100	707
10/10/2000	0.29	0	0	0.71	500	0.36	0.00	0.10	0.10	0	0	7.11	7.11	6.94	90	77	754	942	116	663	116	686
10/11/2000	0.13	0	0	0.53	500	0.33	0.02	0.10	0.10	0	0	7.47	7.47	7.15	90	77	761	951	147	652	147	691
10/12/2000	0.01	0	0	0.68	500	0.32	0.04	0.10	0.10	0	0	7.82	7.82	7.37	90	77	773	966	173	661	173	691
10/13/2000	0.00	0	0	0.81	500	0.20	0.05	0.10	0.10	0	0	8.18	8.18	7.82	90	77	770	962	164	664	164	690
10/14/2000	0.00	0	0	0.71	500	0.10	0.05	0.10	0.10	0	0	8.53	8.53	8.28	90	77	761	951	172	684	172	715
10/15/2000	0.00	0	0	0.60	500	0.05	0.05	0.10	0.10	0	0	8.89	8.89	8.68	90	77	752	941	176	684	176	717
10/16/2000	0.00	0	0	0.56	500	0.09	0.05	0.10	0.10	0	0	9.24	9.24	9.00	90	77	749	936	182	682	182	720
10/17/2000	0.00	0	0	0.60	500	0.12	0.05	0.10	0.10	0	0	9.60	9.60	9.32	90	77	747	934	173	695	173	738
10/18/2000	0.00	0	0	0.63	500	0.02	0.06	0.10	0.10	0	0	9.96	9.96	9.78	90	77	737	921	170	703	170	754

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
10/19/2000	0.00	0	0	0.53	500	0.07	0.05	0.10	0.10	0	0	10.31	10.31	10.09	90	77	734	917	162	699	162	761
10/20/2000	0.00	0	0	0.58	500	0.09	0.05	0.10	0.10	0	0	10.67	10.67	10.42	90	77	731	913	153	726	153	767
10/21/2000	0.00	0	0	0.24	750	0.12	0.09	0.10	0.10	0	0	10.67	10.67	10.36	90	77	746	932	149	726	149	775
10/22/2000	0.00	0	0	0.31	750	0.09	0.08	0.10	0.10	0	0	10.67	10.67	10.39	90	77	758	948	145	736	145	795
10/23/2000	0.00	0	0	0.27	750	0.07	0.05	0.10	0.10	0	0	10.67	10.67	10.45	90	77	767	958	143	762	143	799
10/24/2000	0.00	0	0	0.22	750	0.02	0.05	0.10	0.10	0	0	10.67	10.67	10.49	90	77	772	964	141	772	141	809
10/25/2000	0.00	0	0	0.17	750	0.12	0.03	0.10	0.10	0	0	10.67	10.67	10.41	90	77	783	979	136	750	136	812
10/26/2000	0.73	0	0	0.26	750	0.10	0.00	0.10	0.10	0	0	10.67	10.67	11.19	90	77	751	939	165	777	165	812
10/27/2000	0.00	0	0	0.00	750	0.12	0.02	0.10	0.33	0	0	10.67	10.67	10.72	295	250	761	951	195	771	195	808
10/28/2000	0.19	0	0	0.00	750	0.07	0.02	0.10	0.16	0	0	10.67	10.67	10.67	142	121	757	946	190	792	190	788
10/29/2000	0.10	0	0	0.00	750	0.16	0.01	0.10	0.10	0	0	10.67	10.67	10.49	92	78	763	954	194	795	194	796
10/30/2000	0.00	0	0	0.17	750	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.50	90	77	768	960	192	801	192	811
10/31/2000	0.01	0	0	0.16	750	0.03	0.04	0.10	0.10	0	0	10.67	10.67	10.50	90	77	772	965	193	815	193	828
11/1/2000	0.00	0	0	0.16	1000	0.07	0.03	0.10	0.10	0	0	10.67	10.67	10.47	90	77	783	979	190	857	190	869
11/2/2000	0.00	0	0	0.20	1000	0.05	0.03	0.10	0.10	0	0	10.67	10.67	10.49	90	77	793	991	187	857	187	886
11/3/2000	0.01	0	0	0.18	1000	0.06	0.03	0.10	0.10	0	0	10.67	10.67	10.48	90	77	803	1004	183	883	183	899
11/4/2000	0.00	0	0	0.19	1000	0.05	0.03	0.10	0.10	0	0	10.67	10.67	10.49	90	77	813	1016	180	898	180	911
11/5/2000	0.00	0	0	0.18	1000	0.06	0.03	0.10	0.10	0	0	10.67	10.67	10.48	90	77	823	1029	178	912	178	924
11/6/2000	0.00	0	0	0.19	1000	0.05	0.06	0.10	0.10	0	0	10.67	10.67	10.46	90	77	834	1043	176	911	176	926
11/7/2000	0.00	0	0	0.21	1000	0.03	0.04	0.10	0.10	0	0	10.67	10.67	10.50	90	77	843	1054	170	911	170	929
11/8/2000	0.00	0	0	0.17	1000	0.06	0.04	0.10	0.10	0	0	10.67	10.67	10.47	90	77	853	1066	162	912	162	933
11/9/2000	0.00	0	0	0.19	1000	0.05	0.04	0.10	0.10	0	0	10.67	10.67	10.48	90	77	863	1078	156	935	156	965
11/10/2000	0.00	0	0	0.19	1000	0.05	0.02	0.10	0.10	0	0	10.67	10.67	10.50	90	77	871	1088	154	957	154	977
11/11/2000	0.00	0	0	0.17	1000	0.07	0.03	0.10	0.10	0	0	10.67	10.67	10.46	90	77	882	1102	148	966	148	981
11/12/2000	0.00	0	0	0.21	1000	0.04	0.03	0.10	0.10	0	0	10.67	10.67	10.50	90	77	890	1112	143	992	143	999
11/13/2000	0.12	0	0	0.17	1000	0.08	0.03	0.10	0.10	0	0	10.67	10.67	10.58	90	77	892	1115	139	992	139	1012
11/14/2000	0.01	0	0	0.09	1000	0.12	0.03	0.10	0.10	0	0	10.67	10.67	10.43	90	77	905	1131	105	994	105	1023
11/15/2000	0.00	0	0	0.24	1000	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	911	1138	98	1025	98	1043
11/16/2000	0.00	0	0	0.14	1000	0.06	0.02	0.10	0.10	0	0	10.67	10.67	10.49	90	77	919	1148	98	998	98	1030
11/17/2000	0.00	0	0	0.18	1000	0.02	0.03	0.10	0.10	0	0	10.67	10.67	10.52	90	77	924	1155	86	1019	86	1057
11/18/2000	0.00	0	0	0.15	1000	0.08	0.02	0.10	0.10	0	0	10.67	10.67	10.46	90	77	935	1168	84	1046	84	1059
11/19/2000	0.00	0	0	0.21	1000	0.06	0.02	0.10	0.10	0	0	10.67	10.67	10.48	90	77	944	1180	82	1057	82	1076
11/20/2000	0.00	0	0	0.19	1000	0.09	0.02	0.10	0.10	0	0	10.67	10.67	10.46	90	77	954	1193	80	1059	80	1081
11/21/2000	0.02	0	0	0.21	1000	0.09	0.01	0.10	0.10	0	0	10.67	10.67	10.48	90	77	963	1204	80	1073	80	1097
11/22/2000	0.00	0	0	0.18	1000	0.09	0.01	0.10	0.10	0	0	10.67	10.67	10.47	90	77	973	1216	80	784	80	809
11/23/2000	0.00	0	0	0.20	1000	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	978	1223	79	795	79	823
11/24/2000	0.00	0	0	0.16	1000	0.04	0.00	0.10	0.10	0	0	10.67	10.67	10.52	90	77	982	1228	79	1123	79	1141
11/25/2000	0.00	0	0	0.14	1000	0.02	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	985	1231	79	1134	79	1152
11/26/2000	0.00	0	0	0.13	1000	0.04	0.00	0.10	0.10	0	0	10.67	10.67	10.53	90	77	989	1236	83	1119	83	1150
11/27/2000	0.00	0	0	0.14	1000	0.00	0.01	0.10	0.10	0	0	10.67	10.67	10.55	90	77	990	1237	84	1133	84	1165
11/28/2000	0.00	0	0	0.11	1000	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.56	90	77	991	1239	88	1105	88	1142
11/29/2000	0.06	0	0	0.11	1000	0.05	0.01	0.10	0.10	0	0	10.67	10.67	10.57	90	77	992	1240	97	1090	97	1131
11/30/2000	0.00	0	0	0.10	1000	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.50	90	77	998	1248	104	1097	104	1128
12/1/2000	0.00	0	0	0.17	1250	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1007	1259	105	1097	105	1119
12/2/2000	0.00	0	0	0.16	1250	0.01	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	1013	1266	109	1112	109	1132
12/3/2000	0.00	0	0	0.12	1250	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1021	1276	112	1113	112	1135
12/4/2000	0.00	0	0	0.15	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1028	1285	114	1114	114	1141
12/5/2000	0.00	0	0	0.15	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1035	1294	112	1114	112	1144
12/6/2000	0.00	0	0	0.14	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1041	1302	104	1129	104	1156

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
12/7/2000	0.00	0	0	0.14	1250	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1049	1311	109	1126	109	1155
12/8/2000	0.00	0	0	0.15	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1056	1320	105	1148	105	1163
12/9/2000	0.00	0	0	0.14	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1062	1328	100	1177	100	1192
12/10/2000	0.00	0	0	0.14	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1069	1337	98	1186	98	1190
12/11/2000	0.00	0	0	0.14	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1076	1345	98	1186	98	1192
12/12/2000	0.00	0	0	0.14	1250	0.06	0.02	0.10	0.10	0	0	10.67	10.67	10.49	90	77	1086	1357	104	1179	104	1189
12/13/2000	0.00	0	0	0.17	1250	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1095	1368	110	1182	110	1189
12/14/2000	0.00	0	0	0.16	1250	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1103	1378	129	1167	129	1201
12/15/2000	0.00	0	0	0.16	1250	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1110	1387	125	1159	125	1200
12/16/2000	0.00	0	0	0.15	1250	0.02	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	1115	1394	114	1172	114	1213
12/17/2000	0.01	0	0	0.13	1250	0.01	0.02	0.10	0.10	0	0	10.67	10.67	10.55	90	77	1119	1398	106	1174	106	1233
12/18/2000	0.01	0	0	0.12	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	1123	1403	103	1175	103	1231
12/19/2000	0.01	0	0	0.12	1250	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1129	1411	102	1194	102	1247
12/20/2000	0.00	0	0	0.14	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1134	1418	112	1209	112	1264
12/21/2000	0.00	0	0	0.14	1250	0.06	0.02	0.10	0.10	0	0	10.67	10.67	10.49	90	77	1144	1430	114	1202	114	1283
12/22/2000	0.00	0	0	0.18	1250	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1152	1439	110	1203	110	1270
12/23/2000	0.00	0	0	0.15	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1158	1447	108	1211	108	1269
12/24/2000	0.00	0	0	0.15	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	1162	1453	104	1197	104	1254
12/25/2000	0.00	0	0	0.13	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1167	1459	100	1236	100	1271
12/26/2000	0.00	0	0	0.14	1250	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1174	1468	98	1220	98	1252
12/27/2000	0.00	0	0	0.16	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1180	1476	94	1229	94	1253
12/28/2000	0.00	0	0	0.15	1250	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1187	1483	91	1229	91	1255
12/29/2000	0.00	0	0	0.15	1250	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1194	1492	88	1225	88	1255
12/30/2000	0.00	0	0	0.16	1250	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1200	1500	86	1237	86	1258
12/31/2000	0.00	0	0	0.15	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1205	1507	86	1237	86	1261
1/1/2001	0.00	0	0	0.14	1500	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1215	1519	84	1259	84	1289
1/2/2001	0.01	0	0	0.15	1500	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1224	1530	80	1243	80	1276
1/3/2001	0.00	0	0	0.14	1500	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1234	1543	70	1271	70	1324
1/4/2001	0.00	0	0	0.15	1500	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1244	1555	66	1279	66	1336
1/5/2001	0.00	0	0	0.15	1500	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1254	1567	64	1266	64	1330
1/6/2001	0.00	0	0	0.16	1500	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1264	1580	63	1264	63	1334
1/7/2001	0.00	0	0	0.16	1500	0.05	0.01	0.10	0.10	0	0	10.67	10.67	10.50	90	77	1275	1594	72	1245	72	1297
1/8/2001	0.72	0	0	0.16	1500	0.03	0.01	0.10	0.10	0	0	10.67	10.67	11.25	90	77	1215	1519	97	1265	97	1344
1/9/2001	0.00	0	0	0.00	1500	0.02	0.01	0.10	0.33	0	0	10.67	10.67	10.89	295	250	1218	1523	103	1272	103	1340
1/10/2001	0.47	0	0	0.00	1500	0.05	0.00	0.10	0.33	0	0	10.67	10.67	10.98	290	247	1179	1474	115	1277	115	1347
1/11/2001	0.28	0	0	0.00	1500	0.03	0.01	0.10	0.33	0	0	10.67	10.67	10.90	295	250	1156	1445	196	1221	196	1285
1/12/2001	0.06	0	0	0.00	1500	0.03	0.01	0.10	0.33	0	0	10.67	10.67	10.59	295	250	1155	1443	261	1176	261	1208
1/13/2001	0.00	0	0	0.07	1500	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1162	1452	274	1213	274	1227
1/14/2001	0.00	0	0	0.14	1500	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1170	1463	253	1227	253	1263
1/15/2001	0.00	0	0	0.14	1500	0.05	0.02	0.10	0.10	0	0	10.67	10.67	10.49	90	77	1183	1478	246	1214	246	1271
1/16/2001	0.00	0	0	0.17	1500	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1194	1492	225	1212	225	1282
1/17/2001	0.00	0	0	0.15	1500	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1204	1505	206	1208	206	1295
1/18/2001	0.00	0	0	0.15	1500	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1214	1517	187	1246	187	1333
1/19/2001	0.00	0	0	0.15	1500	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1223	1528	181	1285	181	1370
1/20/2001	0.00	0	0	0.14	1500	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1233	1542	165	1312	165	1415
1/21/2001	0.00	0	0	0.16	1500	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1241	1552	174	1326	174	1447
1/22/2001	0.00	0	0	0.14	1500	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1252	1565	175	1319	175	1417
1/23/2001	0.02	0	0	0.16	1500	0.06	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1263	1579	185	1245	185	1399
1/24/2001	0.33	0	0	0.16	1500	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.85	90	77	1239	1549	195	1312	195	1460

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip inches	GW inches	EC(gw) uS/cm	Op. Inflow inches	EC(if) uS/cm	Evap. (open water) inches	ET (veg. areas) inches	Op Spill inches	Outflow inches	GW inches	EC(gw) uS/cm	Depth (hab) inches	Depth (CC)	End of Day inches	Flow (cfs)	Adj. Flow (cfs)	EC uS/cm	Adj. EC uS/cm	GWD Personnel Q (cfs)	GWD Personnel EC (uS/cm)	Real-Time Network Q (cfs)	Real-Time Network EC (uS/cm)
1/25/2001	0.34	0	0	0.00	1500	0.04	0.02	0.10	0.29	0	0	10.67	10.67	10.85	255	217	1211	1514	199	1424	199	1530
1/26/2001	0.01	0	0	0.00	1500	0.05	0.02	0.10	0.33	0	0	10.67	9.60	10.47	295	250	1218	1523	220	1448	220	1516
1/27/2001	0.00	0	0	0.00	1500	0.04	0.02	0.10	0.20	0	0	10.67	8.53	10.21	179	152	1225	1531	206	1426	206	1511
1/28/2001	0.00	0	0	0.01	1500	0.04	0.02	0.10	0.10	0	0	10.67	7.47	10.06	90	77	1232	1540	194	1414	194	1511
1/29/2001	0.01	0	0	0.01	1500	0.04	0.02	0.10	0.10	0	0	10.67	6.40	9.91	90	77	1239	1549	186	1403	186	1552
1/30/2001	0.00	0	0	0.00	1500	0.04	0.02	0.10	0.10	0	0	10.67	5.33	9.75	90	77	1247	1558	171	1415	171	1540
1/31/2001	0.00	0	0	0.01	1500	0.02	0.02	0.10	0.10	0	0	10.67	4.27	9.62	90	77	1253	1566	170	1428	170	1528
2/1/2001	0.00	0	0	0.00	1750	0.04	0.01	0.10	0.11	0	0	10.67	3.20	9.46	96	81	1260	1575	154	1467	154	1567
2/2/2001	0.00	0	0	0.00	1750	0.04	0.02	0.10	0.10	0	0	10.67	2.13	9.30	90	77	1268	1585	130	1475	130	1617
2/3/2001	0.00	0	0	0.01	1750	0.05	0.03	0.10	0.10	0	0	10.67	1.07	9.14	90	77	1279	1598	124	1510	124	1634
2/4/2001	0.00	0	0	0.02	1750	0.04	0.03	0.10	0.10	0	0	10.67	0.00	8.99	90	77	1290	1612	124	1523	124	1653
2/5/2001	0.00	0	0	0.17	1750	0.05	0.03	0.10	0.10	0	0	10.67	0.00	8.99	90	77	1308	1635	120	1547	120	1661
2/6/2001	0.00	0	0	0.17	1750	0.08	0.04	0.10	0.10	0	0	10.67	0.00	8.94	90	77	1335	1668	112	1546	112	1674
2/7/2001	0.00	0	0	0.22	1750	0.05	0.05	0.10	0.10	0	0	10.67	0.00	8.96	90	77	1360	1700	106	1571	106	1700
2/8/2001	0.00	0	0	0.20	1000	0.06	0.03	0.10	0.10	0	0	10.67	0.00	8.98	90	77	1365	1706	94	1600	94	1723
2/9/2001	0.11	0	0	0.19	1000	0.07	0.01	0.10	0.10	0	0	10.67	0.00	9.09	90	77	1355	1694	91	1567	91	1699
2/10/2001	0.08	0	0	0.07	1000	0.03	0.01	0.10	0.10	0	0	10.67	0.00	9.09	90	77	1349	1686	92	1567	92	1700
2/11/2001	0.21	0	0	0.07	1000	0.04	0.01	0.10	0.10	0	0	10.67	0.00	9.22	90	77	1328	1659	149	1426	149	1612
2/12/2001	0.00	0	0	0.00	1000	0.03	0.02	0.10	0.16	0	0	10.67	0.00	9.02	140	119	1334	1667	163	1407	163	1570
2/13/2001	0.01	0	0	0.04	1000	0.02	0.02	0.10	0.10	0	0	10.54	0.00	8.92	90	77	1338	1672	147	1449	147	1577
2/14/2001	0.00	0	0	0.03	1000	0.05	0.03	0.10	0.10	0	0	10.42	0.00	8.78	90	77	1348	1685	137	1484	137	1582
2/15/2001	0.00	0	0	0.07	1000	0.06	0.02	0.10	0.10	0	0	10.30	0.00	8.66	90	77	1358	1698	128	1507	128	1597
2/16/2001	0.00	0	0	0.08	1000	0.06	0.04	0.10	0.10	0	0	10.18	0.00	8.55	90	77	1370	1713	136	1446	136	1529
2/17/2001	0.00	0	0	0.09	1000	0.04	0.00	0.10	0.10	0	0	10.06	0.00	8.49	90	77	1373	1717	135	1442	135	1519
2/18/2001	0.06	0	0	0.00	1000	0.07	0.02	0.10	0.13	0	0	9.85	0.00	8.33	115	98	1380	1725	143	1445	143	1529
2/19/2001	0.18	0	0	0.00	1000	0.04	0.02	0.10	0.14	0	0	9.65	0.00	8.31	128	109	1363	1704	134	1478	134	1547
2/20/2001	0.00	0	0	0.00	1000	0.02	0.02	0.10	0.30	0	0	9.44	0.00	7.98	267	227	1369	1711	132	1471	132	1538
2/21/2001	0.05	0	0	0.00	1000	0.05	0.02	0.10	0.14	0	0	9.24	0.00	7.81	127	108	1373	1717	131	1452	131	1526
2/22/2001	0.14	0	0	0.00	1000	0.07	0.02	0.10	0.15	0	0	9.04	0.00	7.71	137	117	1368	1710	165	1380	165	1448
2/23/2001	0.40	0	0	0.00	1000	0.06	0.02	0.10	0.22	0	0	8.83	0.00	7.81	197	167	1321	1651	163	1365	163	1432
2/24/2001	0.45	0	0	0.00	1000	0.01	0.01	0.10	0.33	0	0	8.63	0.00	7.91	295	250	1258	1572	164	1339	164	1495
2/25/2001	0.00	0	0	0.00	1000	0.02	0.03	0.10	0.33	0	0	8.43	0.00	7.53	295	250	1267	1584	188	1251	188	1407
2/26/2001	0.00	0	0	0.00	1000	0.04	0.02	0.10	0.33	0	0	8.22	0.00	7.13	295	250	1279	1599	223	1180	223	1297
2/27/2001	0.00	0	0	0.00	1000	0.06	0.04	0.10	0.33	0	0	8.02	0.00	6.70	295	250	1301	1626	214	1156	214	1266
2/28/2001	0.00	0	0	0.01	1000	0.08	0.04	0.10	0.10	0	0	7.81	0.00	6.49	90	77	1326	1658	179	1251	179	1356
3/1/2001	0.00	0	0	0.05	600	0.08	0.03	0.10	0.10	0	0	7.61	0.00	6.33	90	77	1343	1678	144	1461	144	1500
3/2/2001	0.24	0	0	0.03	600	0.04	0.01	0.10	0.10	0	0	7.41	0.00	6.45	90	77	1307	1634	128	1405	128	1506
3/3/2001	0.12	0	0	0.00	600	0.06	0.01	0.10	0.33	0	0	7.20	0.00	6.17	295	250	1299	1623	126	1395	126	1545
3/4/2001	0.21	0	0	0.00	600	0.19	0.01	0.10	0.26	0	0	7.00	0.00	5.92	230	195	1302	1627	126	1350	126	1553
3/5/2001	0.55	0	0	0.00	600	0.04	0.01	0.10	0.19	0	0	6.80	0.00	6.24	167	142	1216	1519	182	1238	182	1429
3/6/2001	0.00	0	0	0.00	600	0.05	0.02	0.10	0.33	0	0	6.59	0.00	5.84	295	250	1231	1539	223	1201	223	1363
3/7/2001	0.00	0	0	0.00	600	0.07	0.04	0.10	0.33	0	0	6.39	0.00	5.40	295	250	1258	1573	223	1222	223	1371
3/8/2001	0.00	0	0	0.00	600	0.08	0.04	0.10	0.19	0	0	6.19	0.00	5.09	167	142	1289	1611	209	1303	209	1452
3/9/2001	0.01	0	0	0.04	600	0.09	0.02	0.10	0.10	0	0	5.98	0.00	4.94	90	77	1309	1636	177	1486	177	1572
3/10/2001	0.00	0	0	0.02	600	0.07	0.04	0.10	0.10	0	0	5.78	0.00	4.75	90	77	1338	1673	193	1469	193	1700
3/11/2001	0.00	0	0	0.04	600	0.08	0.04	0.10	0.10	0	0	5.57	0.00	4.57	90	77	1367	1709	187	1510	187	1695
3/12/2001	0.00	0	0	0.04	600	0.11	0.05	0.10	0.10	0	0	5.37	0.00	4.36	90	77	1409	1761	181	1468	181	1656
3/13/2001	0.00	0	0	0.08	600	0.08	0.05	0.10	0.10	0	0	5.17	0.00	4.21	90	77	1438	1798	156	1448	156	1589
3/14/2001	0.00	0	0	0.05	600	0.09	0.05	0.10	0.10	0	0	4.96	0.00	4.02	90	77	1480	1850	188	1399	188	1512

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
3/15/2001	0.00	0	0	0.17	600	0.08	0.03	0.10	0.10	0	0	4.88	0.00	3.97	90	77	1485	1856	170	1579	170	1679
3/16/2001	0.00	0	0	0.15	600	0.07	0.06	0.10	0.10	0	0	4.80	0.00	3.89	90	77	1501	1877	160	1654	160	1745
3/17/2001	0.00	0	0	0.16	600	0.09	0.05	0.10	0.10	0	0	4.72	0.00	3.82	90	77	1517	1896	124	1806	124	1915
3/18/2001	0.00	0	0	0.17	600	0.10	0.05	0.10	0.10	0	0	4.64	0.00	3.72	90	77	1540	1925	108	1845	108	2004
3/19/2001	0.00	0	0	0.19	600	0.10	0.05	0.10	0.10	0	0	4.56	0.00	3.65	90	77	1558	1948	98	1862	98	2015
3/20/2001	0.00	0	0	0.19	600	0.15	0.05	0.10	0.10	0	0	4.47	0.00	3.54	90	77	1596	1996	95	1821	95	1987
3/21/2001	0.00	0	0	0.23	600	0.13	0.05	0.10	0.10	0	0	4.39	0.00	3.49	90	77	1613	2016	86	1853	86	1988
3/22/2001	0.00	0	0	0.21	600	0.09	0.05	0.10	0.10	0	0	4.31	0.00	3.46	90	77	1619	2024	83	1839	83	1925
3/23/2001	0.00	0	0	0.12	600	0.09	0.05	0.10	0.10	0	0	4.16	0.00	3.33	90	77	1653	2067	82	1812	82	1928
3/24/2001	0.00	0	0	0.12	600	0.10	0.06	0.10	0.10	0	0	4.01	0.00	3.19	90	77	1695	2119	74	1900	74	2038
3/25/2001	0.00	0	0	0.13	600	0.12	0.05	0.10	0.10	0	0	3.87	0.00	3.05	90	77	1749	2187	31	1948	31	2189
3/26/2001	0.00	0	0	0.15	600	0.13	0.07	0.10	0.10	0	0	3.72	0.00	2.90	90	77	1810	2263	51	2027	51	2164
3/27/2001	0.00	0	0	0.17	600	0.12	0.07	0.10	0.10	0	0	3.57	0.00	2.78	90	77	1861	2327	48	2078	48	2232
3/28/2001	0.00	0	0	0.16	600	0.12	0.07	0.10	0.10	0	0	3.42	0.00	2.65	90	77	1920	2400	44	2116	44	2275
3/29/2001	0.00	0	0	0.16	600	0.15	0.08	0.10	0.10	0	0	3.27	0.00	2.49	90	77	2013	2516	42	2167	42	2351
3/30/2001	0.00	0	0	0.20	600	0.13	0.08	0.10	0.10	0	0	3.13	0.00	2.38	90	77	2073	2592	38	2407	38	2562
3/31/2001	0.00	0	0	0.18	600	0.12	0.07	0.10	0.10	0	0	2.98	0.00	2.27	90	77	2132	2665	35	2480	35	2585
4/1/2001	0.00	0	0	0.16	600	0.19	0.07	0.10	0.10	0	0	2.83	0.00	2.07	90	77	2293	2867	32	2288	32	2403
4/2/2001	0.00	0	0	0.23	600	0.35	0.07	0.10	0.10	0	0	2.68	0.00	1.79	90	77	2660	3325	29	2198	29	2368
4/3/2001	0.00	0	0	0.39	600	0.23	0.06	0.10	0.10	0	0	2.53	0.00	1.78	90	77	2649	3311	37	1843	37	2323
4/4/2001	0.00	0	0	0.34	600	0.12	0.06	0.10	0.10	0	0	2.47	0.00	1.84	90	77	2538	3173	35	1859	35	2328
4/5/2001	0.00	0	0	0.23	600	0.12	0.07	0.10	0.10	0	0	2.40	0.00	1.77	90	77	2569	3212	33	1855	33	2191
4/6/2001	0.12	0	0	0.24	600	0.10	0.02	0.10	0.10	0	0	2.33	0.00	1.90	90	77	2351	2939	27	1887	27	2137
4/7/2001	0.04	0	0	0.05	600	0.07	0.04	0.10	0.10	0	0	2.27	0.00	1.78	90	77	2406	3008	25	1980	25	2203
4/8/2001	0.18	0	0	0.11	600	0.08	0.04	0.10	0.10	0	0	2.20	0.00	1.85	90	77	2236	2795	23	2096	23	2311
4/9/2001	0.05	0	0	0.00	600	0.09	0.06	0.10	0.12	0	0	2.13	0.00	1.63	107	91	2398	2997	21	2198	21	2373
4/10/2001	0.00	0	0	0.14	600	0.12	0.07	0.10	0.10	0	0	2.07	0.00	1.48	90	77	2553	3191	22	2082	22	2304
4/11/2001	0.04	0	0	0.24	600	0.06	0.03	0.10	0.10	0	0	2.00	0.00	1.56	90	77	2362	2953	21	2000	21	2175
4/12/2001	0.00	0	0	0.10	600	0.08	0.07	0.10	0.10	0	0	1.93	0.00	1.41	90	77	2492	3116	23	1965	23	2185
4/13/2001	0.00	0	0	0.19	600	0.09	0.07	0.10	0.10	0	0	1.87	0.00	1.34	90	77	2521	3152	21	1952	21	2133
4/14/2001	0.00	0	0	0.20	600	0.11	0.06	0.10	0.10	0	0	1.80	0.00	1.27	90	77	2564	3206	19	1911	19	2129
4/15/2001	0.00	0	0	0.22	600	0.12	0.07	0.10	0.10	0	0	1.73	0.00	1.19	90	77	2623	3278	17	1782	17	1982
4/16/2001	0.00	0	0	0.24	600	0.18	0.08	0.10	0.10	0	0	1.67	0.00	1.07	90	77	750	938	16	1769	16	1952
4/17/2001	0.00	0	0	0.30	600	0.12	0.07	0.10	0.10	0	0	1.60	0.00	1.08	90	77	750	938	17	1774	17	1917
4/18/2001	0.00	0	0	0.24	600	0.19	0.07	0.10	0.10	0	0	1.53	0.00	0.96	90	77	750	938	19	1737	19	1984
4/19/2001	0.00	0	0	0.30	600	0.14	0.04	0.10	0.10	0	0	1.47	0.00	0.98	90	77	750	938	22	1516	22	1713
4/20/2001	0.38	0	0	0.22	600	0.11	0.02	0.10	0.10	0	0	1.40	0.00	1.35	90	77	750	938	24	1304	24	1461
4/21/2001	0.00	0	0	0.00	600	0.08	0.05	0.10	0.31	0	0	1.33	0.00	0.91	273	232	964	1205	24	1198	24	1400
4/22/2001	0.00	0	0	0.18	600	0.12	0.07	0.10	0.10	0	0	1.27	0.00	0.80	90	77	750	938	33	1179	33	1350
4/23/2001	0.00	0	0	0.23	600	0.14	0.08	0.10	0.10	0	0	1.20	0.00	0.72	90	77	750	938	32	1144	32	1331
4/24/2001	0.00	0	0	0.26	600	0.15	0.08	0.10	0.10	0	0	1.13	0.00	0.63	90	77	750	938	31	1071	31	1265
4/25/2001	0.00	0	0	0.28	600	0.18	0.09	0.10	0.10	0	0	1.07	0.00	0.54	90	77	750	938	31	1000	31	1186
4/26/2001	0.00	0	0	0.31	600	0.18	0.10	0.10	0.10	0	0	1.00	0.00	0.48	90	77	750	938	30	1013	30	1235
4/27/2001	0.00	0	0	0.32	600	0.18	0.09	0.10	0.10	0	0	0.93	0.00	0.43	90	77	750	938	26	1119	26	1403
4/28/2001	0.00	0	0	0.31	600	0.18	0.08	0.10	0.10	0	0	0.87	0.00	0.39	90	77	750	938	25	1088	25	1334
4/29/2001	0.00	0	0	0.30	600	0.15	0.10	0.10	0.10	0	0	0.80	0.00	0.34	90	77	750	938	25	1032	25	1202
4/30/2001	0.00	0	0	0.29	600	0.16	0.10	0.10	0.10	0	0	0.73	0.00	0.27	90	77	750	938	24	963	24	1154
5/1/2001	0.00	0	0	0.30	600	0.22	0.13	0.10	0.10	0	0	0.67	0.00	0.13	90	77	750	938	28	914	28	1117
5/2/2001	0.00	0	0	0.39	600	0.20	0.16	0.10	0.10	0	0	0.60	0.00	0.06	90	77	750	938	27	889	27	1093

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
5/3/2001	0.00	0	0	0.68	600	0.20	0.11	0.10	0.10	0	0	0.87	0.00	0.33	90	77	750	938	27	841	27	1064
5/4/2001	0.00	0	0	0.64	600	0.20	0.11	0.10	0.10	0	0	1.13	0.00	0.56	90	77	750	938	24	892	24	1002
5/5/2001	0.00	0	0	1.01	600	0.21	0.10	0.10	0.10	0	0	1.83	0.00	1.16	90	77	750	938	36	918	36	1068
5/6/2001	0.00	0	0	1.02	600	0.22	0.10	0.10	0.10	0	0	2.53	0.00	1.76	90	77	750	938	89	932	89	1000
5/7/2001	0.00	0	0	0.65	600	0.21	0.11	0.10	0.10	0	0	2.80	0.00	1.98	90	77	815	1018	77	939	77	981
5/8/2001	0.00	0	0	0.11	600	0.22	0.11	0.10	0.10	0	0	2.43	0.00	1.66	90	77	996	1245	19	1126	19	1300
5/9/2001	0.00	0	0	0.11	600	0.26	0.12	0.10	0.10	0	0	2.07	0.00	1.30	90	77	1353	1692	30	890	30	1382
5/10/2001	0.00	0	0	0.16	600	0.28	0.11	0.10	0.10	0	0	1.70	0.00	0.97	90	77	1965	2457	16	1119	16	1365
5/11/2001	0.00	0	0	0.17	600	0.24	0.11	0.10	0.10	0	0	1.33	0.00	0.69	90	77	750	938	14	1186	14	1375
5/12/2001	0.00	0	0	0.19	600	0.20	0.07	0.10	0.10	0	0	1.03	0.00	0.51	90	77	750	938	15	1133	15	1414
5/13/2001	0.00	0	0	0.12	600	0.19	0.10	0.10	0.10	0	0	0.73	0.00	0.25	90	77	750	938	21	1107	21	1301
5/14/2001	0.00	0	0	0.13	600	0.20	0.10	0.10	0.10	0	0	0.43	0.00	0.00	90	77	0	0	34	1121	34	1267
5/15/2001	0.00	0	0	0.11	600	0.18	0.09	0.10	0.10	0	0	0.13	0.00	0.00	90	77	0	0	46	1127	46	1284
5/16/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	52	1121	52	1261
5/17/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	46	1176	46	1239
5/18/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	54	1148	54	1181
5/19/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	50	1172	50	1199
5/20/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	62	1161	62	1206
5/21/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	48	1179	48	1256
5/22/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	43	1179	43	1271
5/23/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	39	1167	39	1231
5/24/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	27	1274	27	1347
5/25/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	23	1278	23	1286
5/26/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	16	1300	16	1272
5/27/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	38	989	38	1116
5/28/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	44	1050	44	1037
5/29/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	24	1075	24	1055
5/30/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	24	1067	24	1115
5/31/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	20	1150	20	1207
6/1/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	1162	13	1290
6/2/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	1212	13	1472
6/3/2001	0.00	0	0	0.92	600	0.24	0.13	0.10	0.10	0	0	1.07	0.00	0.44	90	77	750	938	18	1211	18	1449
6/4/2001	0.00	0	0	1.39	600	0.20	0.14	0.10	0.10	0	0	2.13	0.00	1.40	90	77	750	938	18	1247	18	1518
6/5/2001	0.00	0	0	1.35	600	0.25	0.14	0.10	0.10	0	0	3.20	0.00	2.25	90	77	779	974	14	1221	14	1393
6/6/2001	0.00	0	0	1.41	600	0.20	0.13	0.10	0.10	0	0	4.27	0.00	3.23	90	77	781	977	13	1092	13	1289
6/7/2001	0.00	0	0	0.55	600	0.21	0.14	0.10	0.10	0	0	4.40	0.00	3.33	90	77	831	1039	15	1093	15	1330
6/8/2001	0.00	0	0	0.00	600	0.23	0.14	0.10	0.23	0	0	3.73	0.00	2.73	202	172	975	1219	12	1058	12	1321
6/9/2001	0.00	0	0	0.00	600	0.25	0.13	0.10	0.20	0	0	3.07	0.00	2.15	180	153	1211	1514	12	1133	12	1319
6/10/2001	0.00	0	0	0.00	600	0.26	0.14	0.10	0.19	0	0	2.40	0.00	1.56	172	146	1701	2126	13	1185	13	1378
6/11/2001	0.00	0	0	0.00	600	0.24	0.13	0.10	0.18	0	0	1.73	0.00	1.02	158	135	2989	3737	14	1221	14	1221
6/12/2001	0.00	0	0	0.00	600	0.23	0.15	0.10	0.21	0	0	1.07	0.00	0.43	186	158	750	938	12	1175	12	1173
6/13/2001	0.00	0	0	0.25	600	0.22	0.17	0.10	0.10	0	0	0.80	0.00	0.19	90	77	750	938	10	1170	10	1200
6/14/2001	0.00	0	0	0.27	600	0.25	0.13	0.10	0.10	0	0	0.53	0.00	0.00	90	77	0	0	10	1170	10	1221
6/15/2001	0.00	0	0	0.23	600	0.25	0.14	0.10	0.10	0	0	0.27	0.00	0.00	90	77	0	0	9	1194	9	1203
6/16/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	10	1110	10	1142
6/17/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	1117	12	1175
6/18/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	1119	13	1073
6/19/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	1057	15	1157
6/20/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	14	1075	14	1332

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
																			GWD Personnel		Real-Time Network	
Date	Precip inches	GW inches	EC(gw) uS/cm	Op. Inflow inches	EC(if) uS/cm	Evap. (open water) inches	ET (veg. areas) inches	Op Spill inches	Outflow inches	GW inches	EC(gw) uS/cm	Depth (hab) inches	Depth (CC)	End of Day inches	Flow (cfs)	Adj. Flow (cfs)	EC uS/cm	Adj. EC uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
6/21/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	1096	12	1260
6/22/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	11	1109	11	1248
6/23/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1138	8	1211
6/24/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	1129	7	1191
6/25/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	945	7	1241
6/26/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	1236	7	1269
6/27/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	6	1217	6	1267
6/28/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	6	1233	6	1266
6/29/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	6	1233	6	1257
6/30/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	6	1233	6	1249
7/1/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	950	7	973
7/2/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	900	7	927
7/3/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	936	7	964
7/4/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	971	7	1001
7/5/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	957	7	1000
7/6/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	6	1017	6	1075
7/7/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	6	1017	6	1083
7/8/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	1029	7	1090
7/9/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	1029	7	1092
7/10/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	1043	7	1087
7/11/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1050	8	1083
7/12/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1050	8	1086
7/13/2001	0.00	0	0	0.14	600	0.21	0.13	0.10	0.10	0	0	0.17	0.00	0.00	90	77	0	0	8	1050	8	1094
7/14/2001	0.00	0	0	0.29	600	0.23	0.14	0.10	0.10	0	0	0.33	0.00	0.00	90	77	0	0	9	1056	9	1103
7/15/2001	0.00	0	0	0.43	600	0.23	0.12	0.10	0.10	0	0	0.50	0.00	0.00	90	77	0	0	10	1060	10	1107
7/16/2001	0.00	0	0	0.57	600	0.20	0.12	0.10	0.10	0	0	0.67	0.00	0.15	90	77	750	938	9	1078	9	1107
7/17/2001	0.00	0	0	0.57	600	0.18	0.12	0.10	0.10	0	0	0.83	0.00	0.31	90	77	750	938	43	705	43	712
7/18/2001	0.00	0	0	0.55	600	0.18	0.13	0.10	0.10	0	0	1.00	0.00	0.45	90	77	750	938	14	814	14	830
7/19/2001	0.00	0	0	0.56	600	0.20	0.14	0.10	0.10	0	0	1.17	0.00	0.57	90	77	750	938	15	860	15	877
7/20/2001	0.00	0	0	0.58	600	0.19	0.13	0.10	0.10	0	0	1.33	0.00	0.72	90	77	750	938	15	913	15	934
7/21/2001	0.00	0	0	0.57	600	0.19	0.12	0.10	0.10	0	0	1.50	0.00	0.88	90	77	750	938	14	1014	14	1063
7/22/2001	0.00	0	0	0.56	600	0.19	0.13	0.10	0.10	0	0	1.67	0.00	1.01	90	77	750	938	13	935	13	1036
7/23/2001	0.00	0	0	0.56	600	0.21	0.14	0.10	0.10	0	0	1.83	0.00	1.12	90	77	750	938	19	913	19	932
7/24/2001	0.00	0	0	0.59	600	0.22	0.14	0.10	0.10	0	0	2.00	0.00	1.26	90	77	750	938	14	1196	14	1225
7/25/2001	0.00	0	0	0.31	600	0.19	0.13	0.10	0.10	0	0	1.83	0.00	1.15	90	77	933	1167	13	1800	13	1800
7/26/2001	0.00	0	0	0.28	600	0.19	0.13	0.10	0.10	0	0	1.67	0.00	1.02	90	77	750	938	10	2350	10	2350
7/27/2001	0.00	0	0	0.27	600	0.20	0.13	0.10	0.10	0	0	1.50	0.00	0.86	90	77	750	938	10	2500	10	2500
7/28/2001	0.00	0	0	0.29	600	0.21	0.14	0.10	0.10	0	0	1.33	0.00	0.70	90	77	750	938	10	2500	10	2500
7/29/2001	0.00	0	0	0.30	600	0.26	0.15	0.10	0.10	0	0	1.17	0.00	0.49	90	77	750	938	10	2400	10	2400
7/30/2001	0.00	0	0	0.37	600	0.19	0.13	0.10	0.10	0	0	1.00	0.00	0.45	90	77	750	938	9	2100	9	2100
7/31/2001	0.00	0	0	0.27	600	0.18	0.12	0.10	0.10	0	0	0.83	0.00	0.32	90	77	750	938	8	2000	8	2000
8/1/2001	0.00	0	0	0.26	600	0.20	0.13	0.10	0.10	0	0	0.67	0.00	0.14	90	77	750	938	8	1700	8	1700
8/2/2001	0.00	0	0	0.29	600	0.20	0.14	0.10	0.10	0	0	0.50	0.00	0.00	90	77	0	0	7	1600	7	1600
8/3/2001	0.00	0	0	0.29	600	0.20	0.13	0.10	0.10	0	0	0.33	0.00	0.00	90	77	0	0	6	1500	6	1500
8/4/2001	0.00	0	0	0.14	600	0.21	0.12	0.10	0.10	0	0	0.17	0.00	0.00	90	77	0	0	6	1450	6	1450
8/5/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	6	1450	6	1450
8/6/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	5	1400	5	1400
8/7/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	5	1350	5	1350
8/8/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	4	1350	4	1350

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	*inches*	*uS/cm*	*inches*	*uS/cm*	*inches*	*inches*	*inches*	*inches*	*inches*	*uS/cm*	*inches*		*inches*	*(cfs)*	*(cfs)*	*uS/cm*	*uS/cm*	*Q (cfs)*	*EC (uS/cm)*	*Q (cfs)*	*EC (uS/cm)*
8/9/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	5	1300	5	1300
8/10/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	1250	7	1250
8/11/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	1250	7	1250
8/12/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1200	8	1200
8/13/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1100	8	1100
8/14/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	9	1100	9	1100
8/15/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	9	1100	9	1100
8/16/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	10	1163	10	1171
8/17/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	10	1163	10	1164
8/18/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	1208	12	1219
8/19/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	11	1255	11	1266
8/20/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	1250	15	1261
8/21/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	14	1239	14	1246
8/22/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	16	1269	16	1275
8/23/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	1272	18	1272
8/24/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	16	1325	16	1330
8/25/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	17	1268	17	1300
8/26/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	16	1263	16	1298
8/27/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	1220	15	1286
8/28/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	1108	13	1168
8/29/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	16	1047	16	1119
8/30/2001	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	23	1046	23	1118
8/31/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	19	1024	19	1117
9/1/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	1000	7	1000
9/2/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	1000	7	1000
9/3/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	900	8	900
9/4/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	900	8	900
9/5/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	900	8	900
9/6/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	900	12	900
9/7/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	20	900	20	900
9/8/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	26	850	26	850
9/9/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	30	850	30	850
9/10/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	30	850	30	850
9/11/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	25	850	25	850
9/12/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	900	8	900
9/13/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	22	950	22	950
9/14/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	5	950	5	950
9/15/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	11	873	11	992
9/16/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	11	873	11	989
9/17/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	11	873	11	983
9/18/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	11	855	11	970
9/19/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	846	13	959
9/20/2001	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	16	838	16	954
9/21/2001	0.00	0	0	0.36	500	0.18	0.09	0.10	0.10	0	0	0.36	0.36	0.00	90	77	0	0	21	838	21	957
9/22/2001	0.00	0	0	0.71	500	0.18	0.08	0.10	0.10	0	0	0.71	0.71	0.35	90	77	625	781	23	843	23	956
9/23/2001	0.00	0	0	0.72	500	0.16	0.07	0.10	0.10	0	0	1.07	1.07	0.73	90	77	625	781	28	827	28	940
9/24/2001	0.13	0	0	0.69	500	0.16	0.08	0.10	0.10	0	0	1.42	1.42	1.21	90	77	625	781	27	833	27	938
9/25/2001	0.00	0	0	0.56	500	0.17	0.08	0.10	0.10	0	0	1.78	1.78	1.42	90	77	680	850	28	843	28	941
9/26/2001	0.00	0	0	0.71	500	0.14	0.08	0.10	0.10	0	0	2.13	2.13	1.81	90	77	690	862	28	854	28	943

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
9/27/2001	0.00	0	0	0.68	500	0.19	0.09	0.10	0.10	0	0	2.49	2.49	2.12	90	77	714	893	36	858	36	941
9/28/2001	0.00	0	0	0.73	500	0.17	0.09	0.10	0.10	0	0	2.84	2.84	2.49	90	77	722	903	41	859	41	942
9/29/2001	0.00	0	0	0.71	500	0.14	0.08	0.10	0.10	0	0	3.20	3.20	2.88	90	77	723	904	41	859	41	948
9/30/2001	0.00	0	0	0.68	500	0.14	0.08	0.10	0.10	0	0	3.56	3.56	3.23	90	77	726	907	41	859	41	959
10/1/2001	0.00	0	0	0.68	500	0.16	0.10	0.10	0.10	0	0	3.91	3.91	3.55	90	77	735	918	66	809	66	884
10/2/2001	0.00	0	0	0.72	500	0.17	0.09	0.10	0.10	0	0	4.27	4.27	3.91	90	77	740	925	89	754	89	816
10/3/2001	0.00	0	0	0.72	500	0.17	0.09	0.10	0.10	0	0	4.62	4.62	4.26	90	77	744	931	94	815	94	880
10/4/2001	0.00	0	0	0.72	500	0.21	0.08	0.10	0.10	0	0	4.98	4.98	4.59	90	77	753	941	87	848	87	930
10/5/2001	0.00	0	0	0.75	500	0.15	0.07	0.10	0.10	0	0	5.33	5.33	5.02	90	77	747	934	82	855	82	933
10/6/2001	0.00	0	0	0.67	500	0.10	0.06	0.10	0.10	0	0	5.69	5.69	5.42	90	77	740	925	82	848	82	942
10/7/2001	0.00	0	0	0.62	500	0.11	0.06	0.10	0.10	0	0	6.04	6.04	5.77	90	77	737	921	85	848	85	948
10/8/2001	0.00	0	0	0.63	500	0.11	0.06	0.10	0.10	0	0	6.40	6.40	6.12	90	77	734	917	87	853	87	988
10/9/2001	0.00	0	0	0.63	500	0.13	0.08	0.10	0.10	0	0	6.76	6.76	6.44	90	77	735	918	87	853	87	997
10/10/2001	0.00	0	0	0.67	500	0.12	0.06	0.10	0.10	0	0	7.11	7.11	6.82	90	77	732	915	84	877	84	979
10/11/2001	0.00	0	0	0.64	500	0.10	0.06	0.10	0.10	0	0	7.47	7.47	7.20	90	77	728	910	84	877	84	996
10/12/2001	0.00	0	0	0.62	500	0.12	0.08	0.10	0.10	0	0	7.82	7.82	7.52	90	77	728	910	83	889	83	1029
10/13/2001	0.00	0	0	0.66	500	0.11	0.06	0.10	0.10	0	0	8.18	8.18	7.90	90	77	726	907	85	878	85	1028
10/14/2001	0.00	0	0	0.63	500	0.11	0.06	0.10	0.10	0	0	8.53	8.53	8.27	90	77	723	904	85	878	85	1041
10/15/2001	0.00	0	0	0.62	500	0.11	0.06	0.10	0.10	0	0	8.89	8.89	8.61	90	77	722	902	85	866	85	1035
10/16/2001	0.00	0	0	0.63	500	0.14	0.06	0.10	0.10	0	0	9.24	9.24	8.95	90	77	722	902	90	874	90	1054
10/17/2001	0.00	0	0	0.65	500	0.12	0.05	0.10	0.10	0	0	9.60	9.60	9.33	90	77	720	899	97	859	97	1068
10/18/2001	0.00	0	0	0.63	500	0.11	0.05	0.10	0.10	0	0	9.96	9.96	9.70	90	77	717	897	102	868	102	1069
10/19/2001	0.00	0	0	0.62	500	0.09	0.04	0.10	0.10	0	0	10.31	10.31	10.09	90	77	713	891	102	875	102	1057
10/20/2001	0.00	0	0	0.58	500	0.07	0.05	0.10	0.10	0	0	10.67	10.67	10.44	90	77	710	887	105	871	105	1048
10/21/2001	0.00	0	0	0.23	750	0.09	0.05	0.10	0.10	0	0	10.67	10.67	10.42	90	77	721	901	101	841	101	1007
10/22/2001	0.00	0	0	0.25	750	0.10	0.05	0.10	0.10	0	0	10.67	10.67	10.41	90	77	732	915	97	844	97	992
10/23/2001	0.00	0	0	0.25	750	0.11	0.06	0.10	0.10	0	0	10.67	10.67	10.40	90	77	744	930	96	849	96	993
10/24/2001	0.00	0	0	0.27	750	0.09	0.06	0.10	0.10	0	0	10.67	10.67	10.41	90	77	755	944	90	921	90	1061
10/25/2001	0.00	0	0	0.25	750	0.08	0.04	0.10	0.10	0	0	10.67	10.67	10.45	90	77	764	955	88	933	88	1076
10/26/2001	0.00	0	0	0.22	750	0.09	0.04	0.10	0.10	0	0	10.67	10.67	10.43	90	77	773	967	82	941	82	1075
10/27/2001	0.00	0	0	0.24	750	0.11	0.04	0.10	0.10	0	0	10.67	10.67	10.42	90	77	784	979	69	1013	69	1146
10/28/2001	0.00	0	0	0.25	750	0.08	0.04	0.10	0.10	0	0	10.67	10.67	10.45	90	77	792	990	64	1011	64	1144
10/29/2001	0.00	0	0	0.22	750	0.06	0.02	0.10	0.10	0	0	10.67	10.67	10.49	90	77	796	996	63	1041	63	1158
10/30/2001	0.51	0	0	0.18	750	0.01	0.02	0.10	0.10	0	0	10.67	10.67	11.05	90	77	769	962	62	1039	62	1178
10/31/2001	0.00	0	0	0.00	750	0.04	0.04	0.10	0.33	0	0	10.67	10.67	10.65	295	250	775	969	86	1000	86	1244
11/1/2001	0.00	0	0	0.02	1000	0.05	0.04	0.10	0.10	0	0	10.67	10.67	10.48	90	77	782	978	77	1125	77	1295
11/2/2001	0.00	0	0	0.19	1000	0.05	0.03	0.10	0.10	0	0	10.67	10.67	10.48	90	77	792	990	77	1194	77	1352
11/3/2001	0.00	0	0	0.19	1000	0.07	0.04	0.10	0.10	0	0	10.67	10.67	10.46	90	77	804	1005	86	1137	86	1310
11/4/2001	0.00	0	0	0.21	1000	0.02	0.04	0.10	0.10	0	0	10.67	10.67	10.50	90	77	813	1016	92	1159	92	1298
11/5/2001	0.00	0	0	0.16	1000	0.06	0.04	0.10	0.10	0	0	10.67	10.67	10.47	90	77	823	1029	103	1107	103	1278
11/6/2001	0.00	0	0	0.20	1000	0.07	0.04	0.10	0.10	0	0	10.67	10.67	10.46	90	77	835	1043	127	1095	127	1238
11/7/2001	0.00	0	0	0.20	1000	0.07	0.04	0.10	0.10	0	0	10.67	10.67	10.46	90	77	846	1058	136	1085	136	1207
11/8/2001	0.00	0	0	0.21	1000	0.06	0.03	0.10	0.10	0	0	10.67	10.67	10.47	90	77	857	1072	135	1071	135	1181
11/9/2001	0.00	0	0	0.20	1000	0.08	0.03	0.10	0.10	0	0	10.67	10.67	10.46	90	77	869	1086	141	1066	141	1159
11/10/2001	0.33	0	0	0.21	1000	0.09	0.03	0.10	0.10	0	0	10.67	10.67	10.78	90	77	859	1074	146	1047	146	1161
11/11/2001	0.00	0	0	0.00	1000	0.04	0.03	0.10	0.21	0	0	10.67	10.67	10.49	189	161	865	1082	154	1012	154	1154
11/12/2001	0.46	0	0	0.17	1000	0.01	0.00	0.10	0.10	0	0	10.67	10.67	11.01	90	77	840	1051	165	969	165	1116
11/13/2001	0.00	0	0	0.00	1000	0.04	0.02	0.10	0.33	0	0	10.67	10.67	10.62	295	250	845	1057	189	959	189	1089
11/14/2001	0.00	0	0	0.05	1000	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.51	90	77	851	1063	218	939	218	1085

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
11/15/2001	0.00	0	0	0.16	1000	0.05	0.02	0.10	0.10	0	0	10.67	10.67	10.50	90	77	858	1073	214	985	214	1101
11/16/2001	0.00	0	0	0.17	1000	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	865	1081	212	1004	212	1115
11/17/2001	0.01	0	0	0.15	1000	0.04	0.00	0.10	0.10	0	0	10.67	10.67	10.53	90	77	869	1087	211	1003	211	1135
11/18/2001	0.00	0	0	0.13	1000	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	874	1092	204	1041	204	1137
11/19/2001	0.01	0	0	0.13	1000	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	879	1099	195	1042	195	1149
11/20/2001	0.00	0	0	0.14	1000	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	884	1105	179	1071	179	1185
11/21/2001	0.01	0	0	0.14	1000	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	888	1110	167	1093	167	1201
11/22/2001	0.02	0	0	0.13	1000	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.55	90	77	891	1113	156	1104	156	1247
11/23/2001	0.00	0	0	0.12	1000	0.05	0.02	0.10	0.10	0	0	10.67	10.67	10.50	90	77	897	1122	146	1132	146	1295
11/24/2001	0.49	0	0	0.17	1000	0.06	0.01	0.10	0.10	0	0	10.67	10.67	10.98	90	77	873	1091	145	1196	145	1314
11/25/2001	0.00	0	0	0.00	1000	0.04	0.01	0.10	0.33	0	0	10.67	10.67	10.60	295	250	877	1096	157	1203	157	1308
11/26/2001	0.00	0	0	0.06	1000	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	882	1103	149	1209	149	1328
11/27/2001	0.00	0	0	0.15	1000	0.05	0.02	0.10	0.10	0	0	10.67	10.67	10.49	90	77	890	1112	132	1195	132	1357
11/28/2001	0.07	0	0	0.17	1000	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.60	90	77	889	1112	136	1194	136	1403
11/29/2001	0.17	0	0	0.06	1000	0.00	0.01	0.10	0.10	0	0	10.67	10.67	10.72	90	77	880	1100	162	1155	162	1399
11/30/2001	0.00	0	0	0.00	1000	0.03	0.01	0.10	0.16	0	0	10.67	10.67	10.52	139	118	884	1105	157	1160	157	1390
12/1/2001	0.10	0	0	0.15	1250	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.65	90	77	883	1104	137	1189	137	1360
12/2/2001	0.64	0	0	0.01	1250	0.05	0.01	0.10	0.10	0	0	10.67	10.67	11.15	90	77	849	1061	135	1182	135	1362
12/3/2001	0.02	0	0	0.00	1250	0.04	0.02	0.10	0.33	0	0	10.67	10.67	10.77	295	250	852	1065	137	1182	137	1368
12/4/2001	0.00	0	0	0.00	1250	0.03	0.02	0.10	0.21	0	0	10.67	10.67	10.51	186	158	857	1071	131	1182	131	1358
12/5/2001	0.00	0	0	0.15	1250	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.53	90	77	865	1081	128	1193	128	1371
12/6/2001	0.00	0	0	0.13	1250	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	874	1093	119	1206	119	1390
12/7/2001	0.00	0	0	0.16	1250	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	884	1105	110	1225	110	1420
12/8/2001	0.01	0	0	0.15	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	892	1115	99	1224	99	1435
12/9/2001	0.01	0	0	0.13	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	899	1123	89	1235	89	1460
12/10/2001	0.00	0	0	0.13	1250	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	908	1135	82	1245	82	1478
12/11/2001	0.00	0	0	0.16	1250	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	918	1148	79	1280	79	1467
12/12/2001	0.00	0	0	0.16	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	927	1159	64	1451	64	1605
12/13/2001	0.00	0	0	0.15	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	935	1169	54	1465	54	1772
12/14/2001	0.19	0	0	0.14	1250	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.71	90	77	930	1162	58	1391	58	1635
12/15/2001	0.00	0	0	0.00	1250	0.03	0.02	0.10	0.14	0	0	10.67	10.67	10.51	128	109	934	1168	59	1393	59	1634
12/16/2001	0.00	0	0	0.16	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	943	1178	60	1385	60	1596
12/17/2001	0.05	0	0	0.14	1250	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.58	90	77	946	1183	58	1453	58	1640
12/18/2001	0.01	0	0	0.09	1250	0.04	0.00	0.10	0.10	0	0	10.67	10.67	10.53	90	77	952	1190	56	1518	56	1645
12/19/2001	0.01	0	0	0.14	1250	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.57	90	77	956	1194	66	1458	66	1660
12/20/2001	0.11	0	0	0.10	1250	0.05	0.01	0.10	0.10	0	0	10.67	10.67	10.61	90	77	956	1195	81	1467	81	1647
12/21/2001	0.10	0	0	0.06	1250	0.01	0.01	0.10	0.10	0	0	10.67	10.67	10.65	90	77	951	1189	122	1288	122	1521
12/22/2001	0.04	0	0	0.01	1250	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.57	90	77	951	1189	127	1300	127	1546
12/23/2001	0.00	0	0	0.09	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	957	1196	118	1332	118	1542
12/24/2001	0.00	0	0	0.14	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	964	1204	116	1342	116	1576
12/25/2001	0.01	0	0	0.13	1250	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.56	90	77	968	1209	114	1350	114	1343
12/26/2001	0.00	0	0	0.10	1250	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.55	90	77	971	1214	112	1365	112	1368
12/27/2001	0.01	0	0	0.11	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.55	90	77	976	1220	111	1368	111	1510
12/28/2001	0.37	0	0	0.11	1250	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.92	90	77	953	1191	119	1356	119	1524
12/29/2001	0.26	0	0	0.00	1250	0.00	0.00	0.10	0.33	0	0	10.67	10.67	10.85	295	250	934	1168	127	1350	127	1549
12/30/2001	0.11	0	0	0.00	1250	0.01	0.00	0.10	0.28	0	0	10.67	10.67	10.67	254	215	927	1158	142	1371	142	1575
12/31/2001	0.00	0	0	0.00	1250	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.53	91	78	930	1162	154	1344	154	1540
1/1/2002	0.01	0	0	0.14	1500	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	939	1174	163	1335	163	1544
1/2/2002	0.96	0	0	0.12	1500	0.03	0.00	0.10	0.10	0	0	10.67	10.67	11.49	90	77	887	1109	182	1304	182	1533

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
1/3/2002	0.00	0	0	0.00	1500	0.02	0.02	0.10	0.33	0	0	10.67	10.67	11.13	295	250	891	1113	210	1249	210	1510
1/4/2002	0.01	0	0	0.00	1500	0.03	0.01	0.10	0.33	0	0	10.67	10.67	10.77	295	250	893	1116	221	1217	221	1442
1/5/2002	0.00	0	0	0.00	1500	0.02	0.00	0.10	0.20	0	0	10.67	10.67	10.55	183	155	895	1118	235	1166	235	1369
1/6/2002	0.01	0	0	0.12	1500	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.56	90	77	902	1128	227	1166	227	1294
1/7/2002	0.01	0	0	0.11	1500	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	910	1138	214	1188	214	1280
1/8/2002	0.01	0	0	0.12	1500	0.01	0.01	0.10	0.10	0	0	10.67	10.67	10.56	90	77	918	1147	204	1203	204	1296
1/9/2002	0.02	0	0	0.11	1500	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.56	90	77	924	1156	194	1295	194	1327
1/10/2002	0.00	0	0	0.11	1500	0.05	0.01	0.10	0.10	0	0	10.67	10.67	10.51	90	77	935	1169	189	1287	189	1364
1/11/2002	0.00	0	0	0.16	1500	0.02	0.00	0.10	0.10	0	0	10.67	10.67	10.55	90	77	945	1182	172	1283	172	1436
1/12/2002	0.00	0	0	0.12	1500	0.00	0.00	0.10	0.10	0	0	10.67	10.67	10.56	90	77	952	1190	138	1357	138	1535
1/13/2002	0.00	0	0	0.11	1500	0.02	0.00	0.10	0.10	0	0	10.67	10.67	10.55	90	77	959	1199	128	1382	128	1571
1/14/2002	0.00	0	0	0.12	1500	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	968	1209	116	1416	116	1592
1/15/2002	0.00	0	0	0.13	1500	0.02	0.02	0.10	0.10	0	0	10.67	10.67	10.53	90	77	977	1221	104	1418	104	1620
1/16/2002	0.00	0	0	0.14	1500	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	988	1236	87	1498	87	1698
1/17/2002	0.00	0	0	0.15	1500	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1001	1252	79	1553	79	1751
1/18/2002	0.00	0	0	0.16	1500	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	1014	1267	69	1604	69	1826
1/19/2002	0.00	0	0	0.15	1500	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.50	90	77	1027	1284	71	1630	71	1944
1/20/2002	0.00	0	0	0.16	1500	0.05	0.02	0.10	0.10	0	0	10.67	10.67	10.50	90	77	1041	1301	70	1714	70	2055
1/21/2002	0.02	0	0	0.16	1500	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1052	1315	68	1729	68	2075
1/22/2002	0.00	0	0	0.14	1500	0.05	0.03	0.10	0.10	0	0	10.67	10.67	10.49	90	77	1065	1331	66	1677	66	2036
1/23/2002	0.00	0	0	0.17	1500	0.05	0.03	0.10	0.10	0	0	10.67	10.67	10.49	90	77	1080	1350	62	1683	62	1976
1/24/2002	0.00	0	0	0.18	1500	0.05	0.02	0.10	0.10	0	0	10.67	10.67	10.50	90	77	1094	1367	63	1659	63	2012
1/25/2002	0.00	0	0	0.17	1500	0.05	0.02	0.10	0.10	0	0	10.67	10.67	10.50	90	77	1108	1385	60	1779	60	2158
1/26/2002	0.12	0	0	0.02	1500	0.03	0.01	0.10	0.10	0	0	10.67	9.60	10.50	90	77	1102	1377	64	1768	64	2205
1/27/2002	0.00	0	0	0.00	1500	0.02	0.01	0.10	0.23	0	0	10.67	8.53	10.23	207	176	1105	1381	64	1743	64	2106
1/28/2002	0.00	0	0	0.00	1500	0.01	0.01	0.10	0.12	0	0	10.67	7.47	10.09	108	92	1108	1385	63	1752	63	2037
1/29/2002	0.08	0	0	0.00	1500	0.01	0.01	0.10	0.13	0	0	10.67	6.40	10.02	112	95	1103	1378	69	1733	69	2027
1/30/2002	0.00	0	0	0.00	1500	0.03	0.01	0.10	0.21	0	0	10.67	5.33	9.77	184	156	1108	1385	73	1730	73	2025
1/31/2002	0.00	0	0	0.00	1500	0.03	0.01	0.10	0.10	0	0	10.67	4.27	9.62	93	79	1114	1392	75	1729	75	2000
2/1/2002	0.00	0	0	0.00	1750	0.05	0.01	0.10	0.10	0	0	10.67	3.20	9.45	92	78	1121	1401	88	1641	88	1983
2/2/2002	0.00	0	0	0.01	1750	0.03	0.02	0.10	0.10	0	0	10.67	2.13	9.31	90	77	1128	1410	92	1710	92	1958
2/3/2002	0.04	0	0	0.00	1750	0.03	0.02	0.10	0.10	0	0	10.67	1.07	9.20	90	77	1129	1412	102	1659	102	1869
2/4/2002	0.00	0	0	0.00	1750	0.04	0.01	0.10	0.14	0	0	10.67	0.00	9.01	128	109	1136	1420	102	1639	102	1850
2/5/2002	0.00	0	0	0.15	1750	0.05	0.02	0.10	0.10	0	0	10.67	0.00	8.99	90	77	1155	1444	107	1479	107	1861
2/6/2002	0.00	0	0	0.17	1750	0.05	0.02	0.10	0.10	0	0	10.67	0.00	8.99	90	77	1176	1470	117	1625	117	1853
2/7/2002	0.15	0	0	0.17	1750	0.05	0.02	0.10	0.10	0	0	10.67	0.00	9.14	90	77	1179	1474	116	1627	116	1884
2/8/2002	0.06	0	0	0.03	1000	0.06	0.03	0.10	0.10	0	0	10.67	0.00	9.03	90	77	1184	1480	113	1592	113	1864
2/9/2002	0.00	0	0	0.13	1000	0.06	0.03	0.10	0.10	0	0	10.67	0.00	8.97	90	77	1192	1490	108	1604	108	1863
2/10/2002	0.00	0	0	0.19	1000	0.11	0.03	0.10	0.10	0	0	10.67	0.00	8.92	90	77	1207	1508	104	1573	104	1832
2/11/2002	0.00	0	0	0.24	1000	0.07	0.03	0.10	0.10	0	0	10.67	0.00	8.96	90	77	1214	1518	98	1571	98	1809
2/12/2002	0.00	0	0	0.20	1000	0.07	0.03	0.10	0.10	0	0	10.67	0.00	8.97	90	77	1222	1528	95	1579	95	1792
2/13/2002	0.00	0	0	0.09	1000	0.05	0.01	0.10	0.10	0	0	10.54	0.00	8.90	90	77	1227	1534	98	1566	98	1783
2/14/2002	0.00	0	0	0.05	1000	0.05	0.02	0.10	0.10	0	0	10.42	0.00	8.78	90	77	1237	1546	95	1582	95	1767
2/15/2002	0.00	0	0	0.07	1000	0.05	0.02	0.10	0.10	0	0	10.30	0.00	8.67	90	77	1245	1556	91	1608	91	1792
2/16/2002	0.02	0	0	0.07	1000	0.04	0.02	0.10	0.10	0	0	10.18	0.00	8.60	90	77	1249	1561	92	1606	92	1794
2/17/2002	0.07	0	0	0.04	1000	0.07	0.01	0.10	0.10	0	0	10.06	0.00	8.52	90	77	1252	1564	98	1594	98	1785
2/18/2002	0.00	0	0	0.00	1000	0.04	0.03	0.10	0.16	0	0	9.85	0.00	8.29	143	121	1262	1578	98	1576	98	1768
2/19/2002	0.02	0	0	0.00	1000	0.08	0.01	0.10	0.11	0	0	9.65	0.00	8.12	94	80	1273	1591	99	1562	99	1761
2/20/2002	0.00	0	0	0.00	1000	0.05	0.04	0.10	0.11	0	0	9.44	0.00	7.92	98	83	1288	1610	93	1575	93	1811

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
2/21/2002	0.00	0	0	0.01	1000	0.07	0.02	0.10	0.10	0	0	9.24	0.00	7.75	90	77	1301	1627	103	1563	103	1802
2/22/2002	0.02	0	0	0.01	1000	0.09	0.02	0.10	0.10	0	0	9.04	0.00	7.57	90	77	1318	1647	101	1617	101	1848
2/23/2002	0.00	0	0	0.02	1000	0.07	0.04	0.10	0.10	0	0	8.83	0.00	7.37	90	77	1338	1672	98	1653	98	1842
2/24/2002	0.00	0	0	0.04	1000	0.07	0.04	0.10	0.10	0	0	8.63	0.00	7.20	90	77	1357	1696	93	1683	93	1852
2/25/2002	0.00	0	0	0.04	1000	0.08	0.03	0.10	0.10	0	0	8.43	0.00	7.02	90	77	1377	1721	90	1691	90	1864
2/26/2002	0.00	0	0	0.04	1000	0.09	0.03	0.10	0.10	0	0	8.22	0.00	6.83	90	77	1401	1751	83	1672	83	1849
2/27/2002	0.00	0	0	0.05	1000	0.08	0.04	0.10	0.10	0	0	8.02	0.00	6.67	90	77	1423	1779	113	1547	113	1858
2/28/2002	0.00	0	0	0.04	1000	0.10	0.05	0.10	0.10	0	0	7.81	0.00	6.45	90	77	1456	1820	113	1573	113	1808
3/1/2002	0.00	0	0	0.08	600	0.13	0.06	0.10	0.10	0	0	7.61	0.00	6.24	90	77	1491	1863	159	1451	159	1667
3/2/2002	0.00	0	0	0.12	600	0.16	0.04	0.10	0.10	0	0	7.41	0.00	6.06	90	77	1525	1906	141	1549	141	1700
3/3/2002	0.00	0	0	0.13	600	0.14	0.04	0.10	0.10	0	0	7.20	0.00	5.91	90	77	1551	1939	134	1634	134	1753
3/4/2002	0.00	0	0	0.11	600	0.11	0.04	0.10	0.10	0	0	7.00	0.00	5.76	90	77	1576	1970	133	1673	133	1828
3/5/2002	0.00	0	0	0.08	600	0.10	0.04	0.10	0.10	0	0	6.80	0.00	5.60	90	77	1602	2002	125	1549	125	1810
3/6/2002	0.23	0	0	0.07	600	0.04	0.01	0.10	0.10	0	0	6.59	0.00	5.74	90	77	1548	1934	130	1626	130	1928
3/7/2002	0.16	0	0	0.00	600	0.07	0.02	0.10	0.33	0	0	6.39	0.00	5.48	295	250	1533	1917	124	1769	124	1987
3/8/2002	0.00	0	0	0.00	600	0.08	0.04	0.10	0.27	0	0	6.19	0.00	5.09	237	202	1572	1965	109	1958	109	2270
3/9/2002	0.00	0	0	0.04	600	0.10	0.03	0.10	0.10	0	0	5.98	0.00	4.91	90	77	1604	2004	115	1668	115	2548
3/10/2002	0.09	0	0	0.05	600	0.10	0.03	0.10	0.10	0	0	5.78	0.00	4.82	90	77	1610	2013	110	1668	110	2250
3/11/2002	0.00	0	0	0.00	600	0.07	0.04	0.10	0.13	0	0	5.57	0.00	4.57	119	101	1652	2065	108	1642	108	2019
3/12/2002	0.00	0	0	0.04	600	0.17	0.05	0.10	0.10	0	0	5.37	0.00	4.29	90	77	1732	2165	89	1943	89	2215
3/13/2002	0.00	0	0	0.15	600	0.16	0.06	0.10	0.10	0	0	5.17	0.00	4.12	90	77	1787	2233	69	2235	69	2389
3/14/2002	0.00	0	0	0.15	600	0.10	0.06	0.10	0.10	0	0	4.96	0.00	4.00	90	77	1815	2269	68	2253	68	2340
3/15/2002	0.00	0	0	0.19	600	0.10	0.04	0.10	0.10	0	0	4.88	0.00	3.95	90	77	1820	2275	57	2199	57	2294
3/16/2002	0.00	0	0	0.17	600	0.09	0.04	0.10	0.10	0	0	4.80	0.00	3.89	90	77	1830	2287	57	2199	57	2321
3/17/2002	0.52	0	0	0.17	600	0.06	0.00	0.10	0.10	0	0	4.72	0.00	4.41	90	77	1635	2043	56	2195	56	2258
3/18/2002	0.00	0	0	0.00	600	0.09	0.05	0.10	0.33	0	0	4.64	0.00	3.94	295	250	1699	2124	71	2168	71	2115
3/19/2002	0.00	0	0	0.00	600	0.09	0.04	0.10	0.13	0	0	4.56	0.00	3.68	119	101	1764	2205	69	2166	69	2311
3/20/2002	0.00	0	0	0.16	600	0.08	0.05	0.10	0.10	0	0	4.47	0.00	3.61	90	77	1774	2218	69	2166	69	2417
3/21/2002	0.00	0	0	0.16	600	0.12	0.05	0.10	0.10	0	0	4.39	0.00	3.50	90	77	1806	2258	69	2166	69	2461
3/22/2002	0.00	0	0	0.20	600	0.13	0.03	0.10	0.10	0	0	4.31	0.00	3.44	90	77	1824	2280	69	2166	69	2578
3/23/2002	0.13	0	0	0.14	600	0.04	0.03	0.10	0.10	0	0	4.16	0.00	3.53	90	77	1755	2194	69	2166	69	2612
3/24/2002	0.00	0	0	0.00	600	0.10	0.05	0.10	0.18	0	0	4.01	0.00	3.19	163	138	1849	2311	69	2166	69	2653
3/25/2002	0.00	0	0	0.13	600	0.09	0.04	0.10	0.10	0	0	3.87	0.00	3.09	90	77	1877	2346	69	2166	69	2540
3/26/2002	0.00	0	0	0.10	600	0.10	0.05	0.10	0.10	0	0	3.72	0.00	2.94	90	77	1934	2418	69	2166	69	2560
3/27/2002	0.00	0	0	0.13	600	0.12	0.06	0.10	0.10	0	0	3.57	0.00	2.78	90	77	2004	2504	69	2166	69	2628
3/28/2002	0.00	0	0	0.16	600	0.14	0.07	0.10	0.10	0	0	3.42	0.00	2.63	90	77	2078	2597	69	2166	69	2825
3/29/2002	0.00	0	0	0.18	600	0.13	0.06	0.10	0.10	0	0	3.27	0.00	2.51	90	77	2138	2673	69	2166	69	2580
3/30/2002	0.00	0	0	0.17	600	0.13	0.06	0.10	0.10	0	0	3.13	0.00	2.39	90	77	2205	2757	69	2166	69	2590
3/31/2002	0.00	0	0	0.17	600	0.15	0.07	0.10	0.10	0	0	2.98	0.00	2.24	90	77	2305	2882	69	2166	69	2551
4/1/2002	0.00	0	0	0.19	600	0.15	0.07	0.10	0.10	0	0	2.83	0.00	2.11	90	77	2392	2991	76	2492	76	2165
4/2/2002	0.00	0	0	0.19	600	0.16	0.07	0.10	0.10	0	0	2.68	0.00	1.98	90	77	2497	3122	62	2581	62	2320
4/3/2002	0.00	0	0	0.20	600	0.18	0.06	0.10	0.10	0	0	2.53	0.00	1.84	90	77	2629	3286	51	2673	51	2861
4/4/2002	0.00	0	0	0.28	600	0.13	0.05	0.10	0.10	0	0	2.47	0.00	1.84	90	77	2576	3221	43	2591	43	2947
4/5/2002	0.00	0	0	0.23	600	0.11	0.04	0.10	0.10	0	0	2.40	0.00	1.81	90	77	2549	3186	33	2595	33	1878
4/6/2002	0.00	0	0	0.20	600	0.10	0.06	0.10	0.10	0	0	2.33	0.00	1.74	90	77	2562	3202	30	2580	30	2826
4/7/2002	0.00	0	0	0.20	600	0.12	0.06	0.10	0.10	0	0	2.27	0.00	1.67	90	77	2599	3249	29	2597	29	2849
4/8/2002	0.00	0	0	0.22	600	0.16	0.07	0.10	0.10	0	0	2.20	0.00	1.55	90	77	2713	3391	28	2582	28	2964
4/9/2002	0.00	0	0	0.28	600	0.16	0.04	0.10	0.10	0	0	2.13	0.00	1.53	90	77	2679	3349	23	2583	23	2679
4/10/2002	0.00	0	0	0.24	600	0.07	0.07	0.10	0.10	0	0	2.07	0.00	1.54	90	77	2589	3237	27	2481	27	2388

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	*inches*	*uS/cm*	*inches*	*uS/cm*	*inches*	*inches*	*inches*	*inches*	*inches*	*uS/cm*	*inches*		*inches*	*(cfs)*	*(cfs)*	*uS/cm*	*uS/cm*	*Q (cfs)*	*EC (uS/cm)*	*Q (cfs)*	*EC (uS/cm)*
4/11/2002	0.00	0	0	0.18	600	0.14	0.07	0.10	0.10	0	0	2.00	0.00	1.41	90	77	2726	3408	29	2448	29	2454
4/12/2002	0.00	0	0	0.25	600	0.15	0.08	0.10	0.10	0	0	1.93	0.00	1.33	90	77	2800	3500	32	2313	32	2368
4/13/2002	0.00	0	0	0.27	600	0.16	0.08	0.10	0.10	0	0	1.87	0.00	1.27	90	77	2846	3558	38	2168	38	2387
4/14/2002	0.00	0	0	0.28	600	0.17	0.09	0.10	0.10	0	0	1.80	0.00	1.19	90	77	2946	3682	30	2243	30	2360
4/15/2002	0.00	0	0	0.30	600	0.21	0.05	0.10	0.10	0	0	1.73	0.00	1.13	90	77	750	938	22	2293	22	2250
4/16/2002	0.00	0	0	0.30	600	0.16	0.07	0.10	0.10	0	0	1.67	0.00	1.10	90	77	750	938	20	2285	20	2130
4/17/2002	0.02	0	0	0.28	600	0.15	0.05	0.10	0.10	0	0	1.60	0.00	1.10	90	77	750	938	19	2232	19	2244
4/18/2002	0.00	0	0	0.22	600	0.13	0.08	0.10	0.10	0	0	1.53	0.00	1.01	90	77	750	938	20	2073	20	2023
4/19/2002	0.00	0	0	0.25	600	0.16	0.09	0.10	0.10	0	0	1.47	0.00	0.91	90	77	750	938	26	1660	26	2001
4/20/2002	0.00	0	0	0.29	600	0.18	0.08	0.10	0.10	0	0	1.40	0.00	0.84	90	77	750	938	28	1634	28	1966
4/21/2002	0.00	0	0	0.31	600	0.14	0.07	0.10	0.10	0	0	1.33	0.00	0.83	90	77	750	938	34	1553	34	1931
4/22/2002	0.00	0	0	0.26	600	0.17	0.08	0.10	0.10	0	0	1.27	0.00	0.74	90	77	750	938	34	1424	34	2023
4/23/2002	0.00	0	0	0.30	600	0.20	0.09	0.10	0.10	0	0	1.20	0.00	0.64	90	77	750	938	42	1423	42	1548
4/24/2002	0.00	0	0	0.33	600	0.18	0.08	0.10	0.10	0	0	1.13	0.00	0.62	90	77	750	938	39	1322	39	1397
4/25/2002	0.00	0	0	0.30	600	0.18	0.06	0.10	0.10	0	0	1.07	0.00	0.57	90	77	750	938	27	1067	27	1428
4/26/2002	0.15	0	0	0.29	600	0.06	0.05	0.10	0.10	0	0	1.00	0.00	0.79	90	77	750	938	49	886	49	1185
4/27/2002	0.00	0	0	0.01	600	0.07	0.04	0.10	0.10	0	0	0.93	0.00	0.59	90	77	750	938	49	845	49	1352
4/28/2002	0.00	0	0	0.16	600	0.11	0.07	0.10	0.10	0	0	0.87	0.00	0.47	90	77	750	938	47	876	47	1402
4/29/2002	0.02	0	0	0.22	600	0.15	0.04	0.10	0.10	0	0	0.80	0.00	0.41	90	77	750	938	44	910	44	693
4/30/2002	0.00	0	0	0.22	600	0.15	0.05	0.10	0.10	0	0	0.73	0.00	0.33	90	77	750	938	30	1205	30	741
5/1/2002	0.00	0	0	0.25	600	0.09	0.08	0.10	0.10	0	0	0.67	0.00	0.31	90	77	750	938	27	1183	27	736
5/2/2002	0.00	0	0	0.21	600	0.11	0.08	0.10	0.10	0	0	0.60	0.00	0.22	90	77	750	938	25	1240	25	944
5/3/2002	0.00	0	0	0.52	600	0.15	0.08	0.10	0.10	0	0	0.87	0.00	0.41	90	77	750	938	62	840	62	1097
5/4/2002	0.00	0	0	0.57	600	0.16	0.09	0.10	0.10	0	0	1.13	0.00	0.62	90	77	750	938	70	876	70	1123
5/5/2002	0.00	0	0	0.96	600	0.15	0.10	0.10	0.10	0	0	1.83	0.00	1.22	90	77	750	938	69	921	69	1201
5/6/2002	0.00	0	0	0.96	600	0.19	0.11	0.10	0.10	0	0	2.53	0.00	1.78	90	77	782	977	64	979	64	1325
5/7/2002	0.00	0	0	0.62	600	0.19	0.09	0.10	0.10	0	0	2.80	0.00	2.02	90	77	829	1036	60	1076	60	1476
5/8/2002	0.00	0	0	0.07	600	0.16	0.11	0.10	0.10	0	0	2.43	0.00	1.72	90	77	972	1215	63	1120	63	1499
5/9/2002	0.00	0	0	0.05	600	0.17	0.11	0.10	0.10	0	0	2.07	0.00	1.40	90	77	1205	1506	60	1238	60	1626
5/10/2002	0.00	0	0	0.06	600	0.16	0.10	0.10	0.10	0	0	1.70	0.00	1.10	90	77	1555	1943	45	1380	45	1680
5/11/2002	0.00	0	0	0.05	600	0.15	0.10	0.10	0.10	0	0	1.33	0.00	0.79	90	77	750	938	44	1313	44	1747
5/12/2002	0.00	0	0	0.10	600	0.17	0.09	0.10	0.10	0	0	1.03	0.00	0.53	90	77	750	938	40	1334	40	1651
5/13/2002	0.00	0	0	0.10	600	0.22	0.11	0.10	0.10	0	0	0.73	0.00	0.20	90	77	750	938	37	1388	37	1431
5/14/2002	0.00	0	0	0.18	600	0.20	0.11	0.10	0.10	0	0	0.43	0.00	0.00	90	77	0	0	33	1412	33	1343
5/15/2002	0.00	0	0	0.11	600	0.21	0.11	0.10	0.10	0	0	0.13	0.00	0.00	90	77	0	0	31	1390	31	1573
5/16/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	34	1351	34	943
5/17/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	42	1226	42	673
5/18/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	27	1141	27	861
5/19/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	1285	13	1314
5/20/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	1583	12	1938
5/21/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	11	1555	11	1776
5/22/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1619	8	1781
5/23/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1656	8	1752
5/24/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	9	1433	9	1612
5/25/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	16	1206	16	1177
5/26/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	21	1086	21	1010
5/27/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	26	979	26	1025
5/28/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	24	994	24	1326
5/29/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	35	1140	35	1464

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
5/30/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	27	1187	27	1474
5/31/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	21	1238	21	1337
6/1/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	159	1459	159	1789
6/2/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	141	1554	141	1729
6/3/2002	0.00	0	0	0.92	600	0.19	0.12	0.10	0.10	0	0	1.07	0.00	0.51	90	77	750	938	134	1629	134	1563
6/4/2002	0.00	0	0	1.33	600	0.15	0.13	0.10	0.10	0	0	2.13	0.00	1.44	90	77	750	938	133	1683	133	1190
6/5/2002	0.00	0	0	1.31	600	0.26	0.14	0.10	0.10	0	0	3.20	0.00	2.25	90	77	785	981	124	1540	124	1582
6/6/2002	0.00	0	0	1.42	600	0.26	0.15	0.10	0.10	0	0	4.27	0.00	3.15	90	77	799	999	130	1626	130	1583
6/7/2002	0.00	0	0	0.62	600	0.25	0.14	0.10	0.10	0	0	4.40	0.00	3.29	90	77	854	1067	123	1761	123	1719
6/8/2002	0.00	0	0	0.00	600	0.24	0.17	0.10	0.18	0	0	3.73	0.00	2.70	164	139	1018	1272	109	1963	109	1635
6/9/2002	0.00	0	0	0.00	600	0.20	0.16	0.10	0.17	0	0	3.07	0.00	2.16	149	127	1247	1559	114	1658	114	1630
6/10/2002	0.00	0	0	0.00	600	0.20	0.13	0.10	0.20	0	0	2.40	0.00	1.63	183	155	1620	2024	110	1668	110	1603
6/11/2002	0.00	0	0	0.00	600	0.23	0.13	0.10	0.24	0	0	1.73	0.00	1.03	218	185	2975	3719	107	1631	107	1553
6/12/2002	0.00	0	0	0.00	600	0.23	0.13	0.10	0.21	0	0	1.07	0.00	0.45	192	163	750	938	89	1876	89	1523
6/13/2002	0.00	0	0	0.23	600	0.24	0.12	0.10	0.10	0	0	0.80	0.00	0.23	90	77	750	938	68	1979	68	1585
6/14/2002	0.00	0	0	0.23	600	0.21	0.12	0.10	0.10	0	0	0.53	0.00	0.03	90	77	750	938	68	2182	68	1561
6/15/2002	0.00	0	0	0.20	600	0.19	0.12	0.10	0.10	0	0	0.27	0.00	0.00	90	77	0	0	57	2115	57	1675
6/16/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	57	2115	57	1809
6/17/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	56	2109	56	1934
6/18/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	71	2146	71	1962
6/19/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	68	2151	68	1868
6/20/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	67	2149	67	1933
6/21/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	60	2158	60	1779
6/22/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	60	2108	60	1769
6/23/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	57	2082	57	1558
6/24/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	50	1991	50	1488
6/25/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	45	1973	45	1509
6/26/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	34	1996	34	1587
6/27/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	34	1943	34	1528
6/28/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	30	1900	30	1562
6/29/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	28	1861	28	1537
6/30/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	28	1832	28	1566
7/1/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	17	1485	17	1111
7/2/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	1173	13	1104
7/3/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	1183	18	1294
7/4/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	1233	18	1276
7/5/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	14	1275	14	1309
7/6/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	1217	12	1231
7/7/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	16	1094	16	1231
7/8/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	1058	12	1259
7/9/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	1008	12	1330
7/10/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	1050	12	1113
7/11/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	1215	13	1051
7/12/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	1233	12	1227
7/13/2002	0.00	0	0	0.14	600	0.20	0.15	0.10	0.10	0	0	0.17	0.00	0.00	90	77	0	0	10	1170	10	1173
7/14/2002	0.00	0	0	0.29	600	0.22	0.15	0.10	0.10	0	0	0.33	0.00	0.00	90	77	0	0	10	1170	10	1244
7/15/2002	0.00	0	0	0.43	600	0.26	0.14	0.10	0.10	0	0	0.50	0.00	0.00	90	77	0	0	8	1194	8	1334
7/16/2002	0.00	0	0	0.57	600	0.23	0.14	0.10	0.10	0	0	0.67	0.00	0.10	90	77	750	938	10	1190	10	1239
7/17/2002	0.00	0	0	0.61	600	0.22	0.14	0.10	0.10	0	0	0.83	0.00	0.25	90	77	750	938	12	1117	12	1113

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	*inches*	*uS/cm*	*inches*	*uS/cm*	*inches*	*inches*	*inches*	*inches*	*inches*	*uS/cm*	*inches*		*inches*	*(cfs)*	*(cfs)*	*uS/cm*	*uS/cm*	*Q (cfs)*	*EC (uS/cm)*	*Q (cfs)*	*EC (uS/cm)*
7/18/2002	0.00	0	0	0.61	600	0.23	0.14	0.10	0.10	0	0	1.00	0.00	0.38	90	77	750	938	13	1119	13	1030
7/19/2002	0.00	0	0	0.62	600	0.23	0.13	0.10	0.10	0	0	1.17	0.00	0.54	90	77	750	938	15	1030	15	893
7/20/2002	0.00	0	0	0.61	600	0.23	0.14	0.10	0.10	0	0	1.33	0.00	0.67	90	77	750	938	15	1057	15	980
7/21/2002	0.00	0	0	0.62	600	0.23	0.14	0.10	0.10	0	0	1.50	0.00	0.82	90	77	750	938	12	1096	12	1000
7/22/2002	0.00	0	0	0.61	600	0.23	0.13	0.10	0.10	0	0	1.67	0.00	0.97	90	77	750	938	11	1109	11	966
7/23/2002	0.00	0	0	0.61	600	0.30	0.13	0.10	0.10	0	0	1.83	0.00	1.04	90	77	750	938	9	1144	9	1042
7/24/2002	0.00	0	0	0.68	600	0.19	0.13	0.10	0.10	0	0	2.00	0.00	1.30	90	77	750	938	8	1138	8	1122
7/25/2002	0.00	0	0	0.27	600	0.21	0.14	0.10	0.10	0	0	1.83	0.00	1.12	90	77	985	1231	7	1129	7	1300
7/26/2002	0.00	0	0	0.31	600	0.21	0.14	0.10	0.10	0	0	1.67	0.00	0.98	90	77	750	938	7	1200	7	1508
7/27/2002	0.00	0	0	0.31	600	0.21	0.15	0.10	0.10	0	0	1.50	0.00	0.83	90	77	750	938	7	1236	7	1398
7/28/2002	0.00	0	0	0.31	600	0.19	0.13	0.10	0.10	0	0	1.33	0.00	0.72	90	77	750	938	6	1233	6	1335
7/29/2002	0.00	0	0	0.28	600	0.18	0.12	0.10	0.10	0	0	1.17	0.00	0.60	90	77	750	938	6	1233	6	1352
7/30/2002	0.00	0	0	0.26	600	0.16	0.13	0.10	0.10	0	0	1.00	0.00	0.47	90	77	750	938	6	1233	6	1394
7/31/2002	0.00	0	0	0.24	600	0.20	0.14	0.10	0.10	0	0	0.83	0.00	0.28	90	77	750	938	4	1350	4	1603
8/1/2002	0.00	0	0	0.29	600	0.19	0.13	0.10	0.10	0	0	0.67	0.00	0.15	90	77	750	938	5	1000	5	1614
8/2/2002	0.00	0	0	0.28	600	0.21	0.13	0.10	0.10	0	0	0.50	0.00	0.00	90	77	0	0	3	1000	3	1626
8/3/2002	0.00	0	0	0.29	600	0.23	0.13	0.10	0.10	0	0	0.33	0.00	0.00	90	77	0	0	2	900	2	1637
8/4/2002	0.00	0	0	0.14	600	0.18	0.12	0.10	0.10	0	0	0.17	0.00	0.00	90	77	0	0	2	900	2	1649
8/5/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	2	900	2	1660
8/6/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	2	900	2	1672
8/7/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	2	900	2	1684
8/8/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	2	900	2	1695
8/9/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	4	900	4	1707
8/10/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	5	950	5	1718
8/11/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	950	8	1730
8/12/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	1000	13	1741
8/13/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	19	1000	19	1753
8/14/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	21	1000	21	1753
8/15/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	17	1000	17	1716
8/16/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	9	1083	9	1597
8/17/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1081	8	1554
8/18/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	10	1100	10	1342
8/19/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	6	1233	6	1455
8/20/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	1164	7	1446
8/21/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	7	993	7	1413
8/22/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	906	8	1390
8/23/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	6	908	6	1338
8/24/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	5	950	5	1293
8/25/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	4	475	4	1120
8/26/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	5	930	5	1142
8/27/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	925	8	1162
8/28/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	881	8	1087
8/29/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	10	885	10	1089
8/30/2002	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	883	12	1052
8/31/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	13	881	13	1014
9/1/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	767	12	1041
9/2/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	12	767	12	1009
9/3/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	14	764	14	982
9/4/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	720	15	973

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	*inches*	*uS/cm*	*inches*	*uS/cm*	*inches*	*inches*	*inches*	*inches*	*inches*	*uS/cm*	*inches*		*inches*	*(cfs)*	*(cfs)*	*uS/cm*	*uS/cm*	*Q (cfs)*	*EC (uS/cm)*	*Q (cfs)*	*EC (uS/cm)*
9/5/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	17	718	17	939
9/6/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	717	18	906
9/7/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	19	716	19	873
9/8/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	19	716	19	841
9/9/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	21	721	21	817
9/10/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	22	727	22	824
9/11/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	22	727	22	834
9/12/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	25	730	25	837
9/13/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	26	735	26	849
9/14/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	14	786	14	933
9/15/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	14	786	14	963
9/16/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	790	15	972
9/17/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	14	796	14	1000
9/18/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	800	15	1005
9/19/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	800	15	988
9/20/2002	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	17	806	17	983
9/21/2002	0.00	0	0	0.36	500	0.17	0.10	0.10	0.10	0	0	0.36	0.36	0.00	90	77	0	0	18	808	18	875
9/22/2002	0.00	0	0	0.71	500	0.17	0.10	0.10	0.10	0	0	0.71	0.71	0.34	90	77	625	781	18	808	18	1020
9/23/2002	0.00	0	0	0.73	500	0.17	0.09	0.10	0.10	0	0	1.07	1.07	0.71	90	77	625	781	18	700	18	1063
9/24/2002	0.00	0	0	0.72	500	0.15	0.09	0.10	0.10	0	0	1.42	1.42	1.08	90	77	625	781	18	700	18	1028
9/25/2002	0.00	0	0	0.70	500	0.20	0.10	0.10	0.10	0	0	1.78	1.78	1.38	90	77	625	781	19	700	19	1020
9/26/2002	0.00	0	0	0.76	500	0.19	0.09	0.10	0.10	0	0	2.13	2.13	1.75	90	77	665	831	21	700	21	1037
9/27/2002	0.00	0	0	0.74	500	0.15	0.06	0.10	0.10	0	0	2.49	2.49	2.18	90	77	671	839	11	736	11	1039
9/28/2002	0.00	0	0	0.67	500	0.12	0.04	0.10	0.10	0	0	2.84	2.84	2.59	90	77	668	835	10	735	10	1041
9/29/2002	0.00	0	0	0.61	500	0.12	0.07	0.10	0.10	0	0	3.20	3.20	2.91	90	77	675	844	11	736	11	1077
9/30/2002	0.00	0	0	0.64	500	0.13	0.07	0.10	0.10	0	0	3.56	3.56	3.26	90	77	680	850	12	738	12	1080
10/1/2002	0.00	0	0	0.65	500	0.15	0.11	0.10	0.10	0	0	3.91	3.91	3.55	90	77	695	868	34	874	34	1396
10/2/2002	0.00	0	0	0.71	500	0.13	0.10	0.10	0.10	0	0	4.27	4.27	3.93	90	77	700	875	32	878	20	1326
10/3/2002	0.00	0	0	0.69	500	0.12	0.07	0.10	0.10	0	0	4.62	4.62	4.33	90	77	700	875	31	877	21	1102
10/4/2002	0.00	0	0	0.65	500	0.13	0.07	0.10	0.10	0	0	4.98	4.98	4.68	90	77	701	877	33	873	23	1108
10/5/2002	0.00	0	0	0.65	500	0.14	0.07	0.10	0.10	0	0	5.33	5.33	5.02	90	77	704	880	37	862	27	1115
10/6/2002	0.00	0	0	0.67	500	0.14	0.07	0.10	0.10	0	0	5.69	5.69	5.38	90	77	706	883	41	865	28	1109
10/7/2002	0.00	0	0	0.67	500	0.12	0.07	0.10	0.10	0	0	6.04	6.04	5.75	90	77	706	883	42	861	30	1120
10/8/2002	0.00	0	0	0.65	500	0.14	0.07	0.10	0.10	0	0	6.40	6.40	6.09	90	77	708	885	45	861	31	1141
10/9/2002	0.00	0	0	0.66	500	0.15	0.06	0.10	0.10	0	0	6.76	6.76	6.45	90	77	709	886	47	859	33	1124
10/10/2002	0.00	0	0	0.66	500	0.16	0.05	0.10	0.10	0	0	7.11	7.11	6.80	90	77	710	888	46	857	33	1149
10/11/2002	0.00	0	0	0.67	500	0.12	0.05	0.10	0.10	0	0	7.47	7.47	7.20	90	77	708	885	48	850	36	1160
10/12/2002	0.00	0	0	0.63	500	0.07	0.06	0.10	0.10	0	0	7.82	7.82	7.59	90	77	703	879	49	849	38	1152
10/13/2002	0.00	0	0	0.59	500	0.09	0.06	0.10	0.10	0	0	8.18	8.18	7.93	90	77	701	876	54	844	41	1090
10/14/2002	0.00	0	0	0.60	500	0.09	0.05	0.10	0.10	0	0	8.53	8.53	8.29	90	77	699	874	56	841	45	1076
10/15/2002	0.00	0	0	0.60	500	0.10	0.06	0.10	0.10	0	0	8.89	8.89	8.63	90	77	698	873	58	838	48	1068
10/16/2002	0.00	0	0	0.62	500	0.10	0.05	0.10	0.10	0	0	9.24	9.24	8.99	90	77	696	870	70	854	60	1118
10/17/2002	0.00	0	0	0.61	500	0.07	0.05	0.10	0.10	0	0	9.60	9.60	9.38	90	77	692	865	82	840	70	1077
10/18/2002	0.00	0	0	0.57	500	0.07	0.04	0.10	0.10	0	0	9.96	9.96	9.74	90	77	689	861	84	837	72	1071
10/19/2002	0.00	0	0	0.57	500	0.08	0.05	0.10	0.10	0	0	10.31	10.31	10.08	90	77	687	859	83	818	72	1056
10/20/2002	0.00	0	0	0.58	500	0.08	0.05	0.10	0.10	0	0	10.67	10.67	10.44	90	77	685	856	78	810	71	1043
10/21/2002	0.00	0	0	0.23	750	0.08	0.05	0.10	0.10	0	0	10.67	10.67	10.43	90	77	695	869	74	805	70	1055
10/22/2002	0.00	0	0	0.23	750	0.10	0.05	0.10	0.10	0	0	10.67	10.67	10.42	90	77	706	882	67	816	68	1066
10/23/2002	0.00	0	0	0.24	750	0.07	0.04	0.10	0.10	0	0	10.67	10.67	10.46	90	77	714	893	64	805	65	1072

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip inches	GW inches	EC(gw) uS/cm	Op. Inflow inches	EC(if) uS/cm	Evap. (open water) inches	ET (veg. areas) inches	Op Spill inches	Outflow inches	GW inches	EC(gw) uS/cm	Depth (hab) inches	Depth (CC)	End of Day inches	Flow (cfs)	Adj. Flow (cfs)	EC uS/cm	Adj. EC uS/cm	GWD Personnel Q (cfs)	GWD Personnel EC (uS/cm)	Real-Time Network Q (cfs)	Real-Time Network EC (uS/cm)
10/24/2002	0.00	0	0	0.21	750	0.05	0.03	0.10	0.10	0	0	10.67	10.67	10.48	90	77	721	901	60	815	62	1078
10/25/2002	0.00	0	0	0.19	750	0.04	0.04	0.10	0.10	0	0	10.67	10.67	10.49	90	77	727	909	63	819	63	1080
10/26/2002	0.00	0	0	0.18	750	0.05	0.04	0.10	0.10	0	0	10.67	10.67	10.48	90	77	733	917	63	831	63	1077
10/27/2002	0.00	0	0	0.19	750	0.05	0.04	0.10	0.10	0	0	10.67	10.67	10.47	90	77	740	925	67	832	69	1084
10/28/2002	0.00	0	0	0.19	750	0.06	0.04	0.10	0.10	0	0	10.67	10.67	10.46	90	77	748	935	69	834	73	1072
10/29/2002	0.00	0	0	0.21	750	0.07	0.05	0.10	0.10	0	0	10.67	10.67	10.45	90	77	756	946	71	838	76	1080
10/30/2002	0.00	0	0	0.22	750	0.08	0.05	0.10	0.10	0	0	10.67	10.67	10.44	90	77	765	957	76	845	78	1078
10/31/2002	0.00	0	0	0.23	750	0.08	0.05	0.10	0.10	0	0	10.67	10.67	10.44	90	77	774	968	90	847	119	1158
11/1/2002	0.00	0	0	0.23	1000	0.07	0.05	0.10	0.10	0	0	10.67	10.67	10.44	90	77	788	985	107	1115	112	1166
11/2/2002	0.00	0	0	0.22	1000	0.07	0.04	0.10	0.10	0	0	10.67	10.67	10.46	90	77	800	1000	106	1094	112	1155
11/3/2002	0.00	0	0	0.21	1000	0.05	0.03	0.10	0.10	0	0	10.67	10.67	10.48	90	77	811	1014	116	1091	113	1161
11/4/2002	0.00	0	0	0.19	1000	0.06	0.04	0.10	0.10	0	0	10.67	10.67	10.46	90	77	822	1028	115	1065	113	1173
11/5/2002	0.00	0	0	0.21	1000	0.07	0.04	0.10	0.10	0	0	10.67	10.67	10.46	90	77	834	1043	116	1064	113	1186
11/6/2002	0.00	0	0	0.21	1000	0.06	0.03	0.10	0.10	0	0	10.67	10.67	10.48	90	77	845	1056	118	1110	115	1204
11/7/2002	0.52	0	0	0.19	1000	0.03	0.02	0.10	0.10	0	0	10.67	10.67	11.03	90	77	821	1026	142	1094	141	1179
11/8/2002	0.63	0	0	0.00	1000	0.03	0.00	0.10	0.33	0	0	10.67	10.67	11.30	295	250	786	983	206	1108	196	1151
11/9/2002	0.00	0	0	0.00	1000	0.01	0.04	0.10	0.33	0	0	10.67	10.67	10.93	295	250	790	987	214	1107	209	1150
11/10/2002	0.00	0	0	0.00	1000	0.05	0.02	0.10	0.33	0	0	10.67	10.67	10.54	295	250	795	993	206	1146	201	1180
11/11/2002	0.01	0	0	0.13	1000	0.06	0.03	0.10	0.10	0	0	10.67	10.67	10.49	90	77	803	1004	195	1191	194	1180
11/12/2002	0.01	0	0	0.18	1000	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	810	1013	188	1214	189	1172
11/13/2002	0.00	0	0	0.15	1000	0.03	0.03	0.10	0.10	0	0	10.67	10.67	10.50	90	77	818	1022	177	1214	178	1219
11/14/2002	0.00	0	0	0.16	1000	0.02	0.03	0.10	0.10	0	0	10.67	10.67	10.52	90	77	824	1030	157	1260	160	1303
11/15/2002	0.02	0	0	0.15	1000	0.02	0.00	0.10	0.10	0	0	10.67	10.67	10.57	90	77	827	1033	152	1256	154	1341
11/16/2002	0.01	0	0	0.10	1000	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.53	90	77	831	1039	135	1234	149	1340
11/17/2002	0.00	0	0	0.13	1000	0.04	0.03	0.10	0.10	0	0	10.67	10.67	10.50	90	77	838	1048	139	1298	144	1370
11/18/2002	0.00	0	0	0.17	1000	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	845	1056	134	1303	141	1423
11/19/2002	0.00	0	0	0.15	1000	0.02	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	850	1063	132	1333	138	1455
11/20/2002	0.01	0	0	0.14	1000	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	855	1069	121	1397	138	1455
11/21/2002	0.00	0	0	0.13	1000	0.05	0.01	0.10	0.10	0	0	10.67	10.67	10.50	90	77	863	1078	118	1395	132	1478
11/22/2002	0.00	0	0	0.17	1000	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	870	1087	121	1448	127	1507
11/23/2002	0.00	0	0	0.16	1000	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.50	90	77	877	1096	108	1434	119	1550
11/24/2002	0.00	0	0	0.16	1000	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	881	1101	100	1435	102	1635
11/25/2002	0.00	0	0	0.13	1000	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	888	1109	92	1434	104	1620
11/26/2002	0.00	0	0	0.16	1000	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	894	1118	84	1433	107	1569
11/27/2002	0.00	0	0	0.16	1000	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	900	1125	79	1454	115	1525
11/28/2002	0.00	0	0	0.15	1000	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	906	1133	75	1442	112	1520
11/29/2002	0.00	0	0	0.16	1000	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	912	1140	68	1457	107	1539
11/30/2002	0.00	0	0	0.15	1000	0.02	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	915	1144	68	1450	100	1601
12/1/2002	0.00	0	0	0.12	1250	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	923	1154	87	1443	102	1603
12/2/2002	0.00	0	0	0.15	1250	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	932	1166	85	1444	107	1571
12/3/2002	0.00	0	0	0.16	1250	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	942	1178	90	1411	112	1522
12/4/2002	0.01	0	0	0.16	1250	0.03	0.02	0.10	0.10	0	0	10.67	10.67	10.52	90	77	950	1188	91	1427	109	1514
12/5/2002	0.00	0	0	0.14	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	957	1197	95	1394	115	1470
12/6/2002	0.01	0	0	0.13	1250	0.04	0.00	0.10	0.10	0	0	10.67	10.67	10.53	90	77	964	1205	97	1372	138	1402
12/7/2002	0.00	0	0	0.13	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	972	1215	103	1301	147	1359
12/8/2002	0.00	0	0	0.15	1250	0.02	0.02	0.10	0.10	0	0	10.67	10.67	10.53	90	77	980	1224	108	1266	150	1352
12/9/2002	0.01	0	0	0.14	1250	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	987	1234	111	1247	153	1139
12/10/2002	0.00	0	0	0.14	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	995	1244	115	1222	160	1131
12/11/2002	0.01	0	0	0.14	1250	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1002	1253	117	1235	160	1126

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
12/12/2002	0.00	0	0	0.14	1250	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1009	1261	121	1215	167	1122
12/13/2002	0.12	0	0	0.13	1250	0.04	0.00	0.10	0.10	0	0	10.67	10.67	10.65	90	77	1006	1257	159	1211	170	1186
12/14/2002	0.41	0	0	0.02	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.93	90	77	979	1224	187	1240	185	1264
12/15/2002	0.03	0	0	0.00	1250	0.04	0.00	0.10	0.33	0	0	10.67	10.67	10.59	295	250	981	1226	215	1288	208	1303
12/16/2002	0.88	0	0	0.07	1250	0.02	0.01	0.10	0.10	0	0	10.67	10.67	11.41	90	77	926	1157	223	1290	239	1307
12/17/2002	0.29	0	0	0.00	1250	0.01	0.02	0.10	0.33	0	0	10.67	10.67	11.34	295	250	909	1136	225	1276	288	1184
12/18/2002	0.00	0	0	0.00	1250	0.02	0.02	0.10	0.33	0	0	10.67	10.67	10.98	295	250	912	1140	227	1264	307	1250
12/19/2002	0.68	0	0	0.00	1250	0.10	0.01	0.10	0.33	0	0	10.67	10.67	11.22	295	250	876	1095	244	1285	311	1318
12/20/2002	0.30	0	0	0.00	1250	0.04	0.01	0.10	0.33	0	0	10.67	10.67	11.13	295	250	861	1076	289	1256	323	1325
12/21/2002	0.01	0	0	0.00	1250	0.02	0.01	0.10	0.33	0	0	10.67	10.67	10.79	295	250	862	1078	278	1227	372	1286
12/22/2002	0.00	0	0	0.00	1250	0.01	0.02	0.10	0.22	0	0	10.67	10.67	10.54	197	167	865	1081	277	1256	385	1229
12/23/2002	0.01	0	0	0.13	1250	0.02	0.02	0.10	0.10	0	0	10.67	10.67	10.54	90	77	872	1090	273	1283	374	1387
12/24/2002	0.00	0	0	0.13	1250	0.02	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	879	1098	242	1357	336	1567
12/25/2002	0.01	0	0	0.13	1250	0.02	0.00	0.10	0.10	0	0	10.67	10.67	10.55	90	77	884	1105	239	1383	272	1654
12/26/2002	0.00	0	0	0.11	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	892	1114	221	1401	199	1695
12/27/2002	0.00	0	0	0.14	1250	0.04	0.02	0.10	0.10	0	0	10.67	10.67	10.51	90	77	901	1126	209	1434	228	1578
12/28/2002	0.15	0	0	0.16	1250	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.66	90	77	900	1125	201	1525	197	1596
12/29/2002	0.09	0	0	0.00	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.61	90	77	897	1122	190	1552	181	1686
12/30/2002	0.07	0	0	0.05	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.60	90	77	898	1122	175	1572	167	1742
12/31/2002	0.18	0	0	0.07	1250	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.70	90	77	892	1114	161	1614	171	1714
1/1/2003	0.01	0	0	0.00	1500	0.03	0.01	0.10	0.13	0	0	10.67	10.67	10.53	120	102	895	1118	153	1647	176	1803
1/2/2003	0.00	0	0	0.13	1500	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	906	1133	146	1674	161	1811
1/3/2003	0.01	0	0	0.15	1500	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	916	1145	138	1705	189	1700
1/4/2003	0.01	0	0	0.12	1500	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	925	1156	132	1647	208	1547
1/5/2003	0.00	0	0	0.12	1500	0.01	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	934	1167	133	1614	228	1447
1/6/2003	0.00	0	0	0.13	1500	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	944	1180	132	1578	232	1423
1/7/2003	0.01	0	0	0.14	1500	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.56	90	77	952	1190	141	1580	231	1493
1/8/2003	0.00	0	0	0.11	1500	0.02	0.00	0.10	0.10	0	0	10.67	10.67	10.55	90	77	959	1199	150	1521	214	1558
1/9/2003	0.11	0	0	0.12	1500	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.64	90	77	960	1200	153	1487	153	1487
1/10/2003	0.41	0	0	0.02	1500	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.96	90	77	933	1167	153	1492	153	1492
1/11/2003	0.01	0	0	0.00	1500	0.02	0.00	0.10	0.33	0	0	10.67	10.67	10.61	295	250	935	1168	159	1460	159	1460
1/12/2003	0.01	0	0	0.05	1500	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	940	1175	154	1440	154	1440
1/13/2003	0.01	0	0	0.12	1500	0.04	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	950	1188	152	1457	152	1457
1/14/2003	0.01	0	0	0.14	1500	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.56	90	77	958	1198	151	1469	151	1469
1/15/2003	0.00	0	0	0.10	1500	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	967	1208	149	1473	149	1473
1/16/2003	0.02	0	0	0.14	1500	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.55	90	77	975	1219	142	1557	142	1557
1/17/2003	0.00	0	0	0.12	1500	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	984	1229	135	1613	135	1613
1/18/2003	0.00	0	0	0.13	1500	0.00	0.00	0.10	0.10	0	0	10.67	10.67	10.56	90	77	991	1238	132	1648	132	1648
1/19/2003	0.00	0	0	0.11	1500	0.00	0.00	0.10	0.10	0	0	10.67	10.67	10.56	90	77	996	1245	127	1666	127	1666
1/20/2003	0.00	0	0	0.10	1500	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.56	90	77	1002	1252	122	1680	122	1680
1/21/2003	0.00	0	0	0.11	1500	0.02	0.01	0.10	0.10	0	0	10.67	10.67	10.54	90	77	1009	1262	130	1636	130	1636
1/22/2003	0.00	0	0	0.13	1500	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.53	90	77	1019	1274	134	1621	134	1621
1/23/2003	0.00	0	0	0.14	1500	0.03	0.01	0.10	0.10	0	0	10.67	10.67	10.52	90	77	1030	1287	136	1635	136	1635
1/24/2003	0.00	0	0	0.14	1500	0.01	0.00	0.10	0.10	0	0	10.67	10.67	10.55	90	77	1038	1297	134	1626	134	1626
1/25/2003	0.01	0	0	0.12	1500	0.03	0.00	0.10	0.10	0	0	10.67	10.67	10.54	90	77	1045	1307	137	1552	137	1552
1/26/2003	0.00	0	0	0.00	1500	0.05	0.00	0.10	0.13	0	0	10.67	9.60	10.36	115	98	1051	1313	137	1520	137	1520
1/27/2003	0.00	0	0	0.00	1500	0.02	0.01	0.10	0.10	0	0	10.67	8.53	10.24	90	77	1054	1317	142	1433	142	1433
1/28/2003	0.00	0	0	0.00	1500	0.01	0.02	0.10	0.12	0	0	10.67	7.47	10.08	110	94	1057	1322	145	1458	145	1458
1/29/2003	0.01	0	0	0.00	1500	0.05	0.02	0.10	0.12	0	0	10.67	6.40	9.91	104	89	1064	1330	146	1508	146	1508

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip inches	GW inches	EC(gw) uS/cm	Op. Inflow inches	EC(if) uS/cm	Evap. (open water) inches	ET (veg. areas) inches	Op Spill inches	Outflow inches	GW inches	EC(gw) uS/cm	Depth (hab) inches	Depth (CC)	End of Day inches	Flow (cfs)	Adj. Flow (cfs)	EC uS/cm	Adj. EC uS/cm	GWD Personnel Q (cfs)	GWD Personnel EC (uS/cm)	Real-Time Network Q (cfs)	Real-Time Network EC (uS/cm)
1/30/2003	0.01	0	0	0.01	1500	0.04	0.01	0.10	0.10	0	0	10.67	5.33	9.77	90	77	1069	1336	146	1530	146	1530
1/31/2003	0.00	0	0	0.00	1500	0.04	0.00	0.10	0.11	0	0	10.67	4.27	9.63	100	85	1072	1341	135	1574	135	1574
2/1/2003	0.00	0	0	0.00	1750	0.01	0.02	0.10	0.12	0	0	10.67	3.20	9.48	103	88	1076	1345	134	1601	134	1601
2/2/2003	0.00	0	0	0.00	1750	0.04	0.04	0.10	0.12	0	0	10.67	2.13	9.28	110	93	1085	1356	133	1609	133	1609
2/3/2003	0.00	0	0	0.03	1750	0.06	0.02	0.10	0.10	0	0	10.67	1.07	9.12	90	77	1098	1372	132	1613	132	1613
2/4/2003	0.00	0	0	0.04	1750	0.05	0.03	0.10	0.10	0	0	10.67	0.00	8.98	90	77	1110	1387	125	1765	125	1765
2/5/2003	0.00	0	0	0.18	1750	0.06	0.03	0.10	0.10	0	0	10.67	0.00	8.98	90	77	1133	1416	145	1750	145	1750
2/6/2003	0.00	0	0	0.18	1750	0.09	0.02	0.10	0.10	0	0	10.67	0.00	8.95	90	77	1159	1449	142	1756	142	1756
2/7/2003	0.00	0	0	0.21	1750	0.07	0.03	0.10	0.10	0	0	10.67	0.00	8.96	90	77	1186	1483	137	1666	137	1666
2/8/2003	0.00	0	0	0.20	1000	0.06	0.03	0.10	0.10	0	0	10.67	0.00	8.97	90	77	1194	1492	137	1647	137	1647
2/9/2003	0.00	0	0	0.19	1000	0.06	0.03	0.10	0.10	0	0	10.67	0.00	8.97	90	77	1202	1502	135	1611	135	1611
2/10/2003	0.00	0	0	0.19	1000	0.05	0.02	0.10	0.10	0	0	10.67	0.00	8.99	90	77	1207	1509	135	1619	135	1619
2/11/2003	0.00	0	0	0.17	1000	0.11	0.02	0.10	0.10	0	0	10.67	0.00	8.93	90	77	1221	1526	137	1612	137	1612
2/12/2003	0.15	0	0	0.23	1000	0.04	0.00	0.10	0.10	0	0	10.67	0.00	9.17	90	77	1204	1505	137	1635	137	1635
2/13/2003	0.26	0	0	0.00	1000	0.02	0.02	0.10	0.21	0	0	10.54	0.00	9.18	189	161	1179	1474	135	1671	135	1671
2/14/2003	0.00	0	0	0.00	1000	0.03	0.02	0.10	0.33	0	0	10.42	0.00	8.80	290	247	1186	1483	135	1700	135	1700
2/15/2003	0.00	0	0	0.04	1000	0.04	0.02	0.10	0.10	0	0	10.30	0.00	8.69	90	77	1193	1491	139	1690	139	1690
2/16/2003	0.09	0	0	0.05	1000	0.06	0.03	0.10	0.10	0	0	10.18	0.00	8.65	90	77	1193	1491	144	1648	144	1648
2/17/2003	0.00	0	0	0.00	1000	0.04	0.02	0.10	0.11	0	0	10.06	0.00	8.48	101	85	1201	1501	142	1630	142	1630
2/18/2003	0.00	0	0	0.00	1000	0.05	0.03	0.10	0.12	0	0	9.85	0.00	8.28	106	90	1212	1516	139	1748	139	1748
2/19/2003	0.07	0	0	0.01	1000	0.07	0.01	0.10	0.10	0	0	9.65	0.00	8.17	90	77	1216	1520	136	1718	136	1718
2/20/2003	0.00	0	0	0.00	1000	0.02	0.02	0.10	0.16	0	0	9.44	0.00	7.96	143	122	1223	1529	134	1710	134	1710
2/21/2003	0.00	0	0	0.00	1000	0.05	0.02	0.10	0.13	0	0	9.24	0.00	7.76	114	97	1235	1543	127	1819	127	1819
2/22/2003	0.00	0	0	0.00	1000	0.05	0.02	0.10	0.10	0	0	9.04	0.00	7.59	92	78	1247	1558	122	1853	122	1853
2/23/2003	0.00	0	0	0.00	1000	0.03	0.02	0.10	0.10	0	0	8.83	0.00	7.43	92	78	1256	1570	120	1889	120	1889
2/24/2003	0.51	0	0	0.00	1000	0.05	0.02	0.10	0.12	0	0	8.63	0.00	7.74	109	93	1198	1498	116	1928	116	1928
2/25/2003	0.08	0	0	0.00	1000	0.04	0.03	0.10	0.33	0	0	8.43	0.00	7.43	295	250	1198	1497	112	1907	112	1907
2/26/2003	0.00	0	0	0.00	1000	0.05	0.03	0.10	0.33	0	0	8.22	0.00	7.02	295	250	1212	1516	116	1899	116	1899
2/27/2003	0.00	0	0	0.00	1000	0.06	0.03	0.10	0.23	0	0	8.02	0.00	6.70	206	175	1229	1537	113	1919	113	1919
2/28/2003	0.00	0	0	0.01	1000	0.06	0.03	0.10	0.10	0	0	7.81	0.00	6.52	90	77	1245	1557	110	1938	110	1938
3/1/2003	0.00	0	0	0.01	600	0.07	0.03	0.10	0.10	0	0	7.61	0.00	6.34	90	77	1263	1579	117	1889	117	1889
3/2/2003	0.00	0	0	0.02	600	0.08	0.03	0.10	0.10	0	0	7.41	0.00	6.15	90	77	1284	1605	134	1871	134	1871
3/3/2003	0.00	0	0	0.04	600	0.09	0.03	0.10	0.10	0	0	7.20	0.00	5.97	90	77	1306	1633	151	1838	151	1838
3/4/2003	0.00	0	0	0.05	600	0.07	0.02	0.10	0.10	0	0	7.00	0.00	5.82	90	77	1321	1651	166	1834	166	1834
3/5/2003	0.00	0	0	0.02	600	0.07	0.04	0.10	0.10	0	0	6.80	0.00	5.63	90	77	1345	1682	163	1870	163	1870
3/6/2003	0.00	0	0	0.04	600	0.08	0.04	0.10	0.10	0	0	6.59	0.00	5.44	90	77	1372	1715	150	1906	150	1906
3/7/2003	0.00	0	0	0.05	600	0.08	0.04	0.10	0.10	0	0	6.39	0.00	5.26	90	77	1398	1747	144	1916	144	1916
3/8/2003	0.00	0	0	0.05	600	0.08	0.04	0.10	0.10	0	0	6.19	0.00	5.09	90	77	1423	1779	162	1832	162	1832
3/9/2003	0.00	0	0	0.04	600	0.09	0.04	0.10	0.10	0	0	5.98	0.00	4.91	90	77	1454	1817	151	1796	151	1796
3/10/2003	0.00	0	0	0.05	600	0.08	0.04	0.10	0.10	0	0	5.78	0.00	4.74	90	77	1481	1851	138	1820	138	1820
3/11/2003	0.00	0	0	0.04	600	0.08	0.03	0.10	0.10	0	0	5.57	0.00	4.58	90	77	1509	1887	131	2019	131	2019
3/12/2003	0.00	0	0	0.04	600	0.08	0.05	0.10	0.10	0	0	5.37	0.00	4.38	90	77	1548	1935	127	2078	127	2078
3/13/2003	0.00	0	0	0.06	600	0.13	0.03	0.10	0.10	0	0	5.17	0.00	4.17	90	77	1600	2001	130	2110	130	2110
3/14/2003	0.13	0	0	0.09	600	0.11	0.05	0.10	0.10	0	0	4.96	0.00	4.13	90	77	1593	1992	128	2123	128	2123
3/15/2003	0.50	0	0	0.06	600	0.08	0.04	0.10	0.10	0	0	4.88	0.00	4.47	90	77	1472	1839	156	2123	156	2123
3/16/2003	0.09	0	0	0.00	600	0.07	0.02	0.10	0.33	0	0	4.80	0.00	4.14	295	250	1477	1847	160	1811	160	1811
3/17/2003	0.00	0	0	0.00	600	0.09	0.06	0.10	0.19	0	0	4.72	0.00	3.80	166	141	1541	1927	146	1905	146	1905
3/18/2003	0.00	0	0	0.18	600	0.11	0.07	0.10	0.10	0	0	4.64	0.00	3.70	90	77	1571	1964	141	2296	141	2296
3/19/2003	0.00	0	0	0.21	600	0.09	0.05	0.10	0.10	0	0	4.56	0.00	3.67	90	77	1574	1968	138	2314	138	2314

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	inches	uS/cm	inches	uS/cm	inches	inches	inches	inches	inches	uS/cm	inches		inches	(cfs)	(cfs)	uS/cm	uS/cm	Q (cfs)	EC (uS/cm)	Q (cfs)	EC (uS/cm)
3/20/2003	0.00	0	0	0.17	600	0.11	0.05	0.10	0.10	0	0	4.47	0.00	3.58	90	77	1599	1999	110	2293	110	2293
3/21/2003	0.00	0	0	0.19	600	0.11	0.05	0.10	0.10	0	0	4.39	0.00	3.52	90	77	1616	2020	100	2339	100	2339
3/22/2003	0.00	0	0	0.19	600	0.10	0.05	0.10	0.10	0	0	4.31	0.00	3.44	90	77	1635	2044	87	2367	87	2367
3/23/2003	0.03	0	0	0.13	600	0.08	0.02	0.10	0.10	0	0	4.16	0.00	3.41	90	77	1627	2034	87	2379	87	2379
3/24/2003	0.00	0	0	0.04	600	0.10	0.06	0.10	0.10	0	0	4.01	0.00	3.19	90	77	1701	2126	86	2367	86	2367
3/25/2003	0.00	0	0	0.13	600	0.11	0.05	0.10	0.10	0	0	3.87	0.00	3.06	90	77	1746	2183	82	2367	82	2367
3/26/2003	0.00	0	0	0.14	600	0.17	0.05	0.10	0.10	0	0	3.72	0.00	2.87	90	77	1830	2288	84	2490	84	2490
3/27/2003	0.00	0	0	0.19	600	0.11	0.08	0.10	0.10	0	0	3.57	0.00	2.77	90	77	1872	2340	76	2570	76	2570
3/28/2003	0.00	0	0	0.17	600	0.15	0.06	0.10	0.10	0	0	3.42	0.00	2.63	90	77	1945	2432	68	2474	68	2474
3/29/2003	0.00	0	0	0.18	600	0.18	0.06	0.10	0.10	0	0	3.27	0.00	2.47	90	77	2044	2555	58	2550	58	2550
3/30/2003	0.00	0	0	0.22	600	0.15	0.06	0.10	0.10	0	0	3.13	0.00	2.37	90	77	2094	2617	55	2555	55	2555
3/31/2003	0.00	0	0	0.18	600	0.15	0.06	0.10	0.10	0	0	2.98	0.00	2.24	90	77	2177	2721	53	2570	53	2570
4/1/2003	0.05	0	0	0.19	600	0.19	0.03	0.10	0.10	0	0	2.83	0.00	2.16	90	77	2214	2768	50	2715	50	2595
4/2/2003	0.01	0	0	0.14	600	0.09	0.05	0.10	0.10	0	0	2.68	0.00	2.07	90	77	2242	2803	47	2728	47	2602
4/3/2003	0.00	0	0	0.10	600	0.03	0.05	0.10	0.10	0	0	2.53	0.00	1.99	90	77	2248	2810	44	2650	44	2594
4/4/2003	0.07	0	0	0.12	600	0.09	0.03	0.10	0.10	0	0	2.47	0.00	1.97	90	77	2204	2755	43	2643	43	2637
4/5/2003	0.00	0	0	0.09	600	0.10	0.06	0.10	0.10	0	0	2.40	0.00	1.81	90	77	2317	2896	47	2754	47	2759
4/6/2003	0.00	0	0	0.20	600	0.13	0.06	0.10	0.10	0	0	2.33	0.00	1.71	90	77	2380	2975	45	2921	45	2648
4/7/2003	0.00	0	0	0.23	600	0.15	0.06	0.10	0.10	0	0	2.27	0.00	1.63	90	77	2446	3058	44	2835	44	2675
4/8/2003	0.00	0	0	0.26	600	0.15	0.07	0.10	0.10	0	0	2.20	0.00	1.56	90	77	2492	3116	39	2824	39	2554
4/9/2003	0.00	0	0	0.27	600	0.15	0.07	0.10	0.10	0	0	2.13	0.00	1.51	90	77	2517	3146	36	2840	36	2716
4/10/2003	0.00	0	0	0.26	600	0.17	0.07	0.10	0.10	0	0	2.07	0.00	1.44	90	77	2578	3223	35	2900	60	3103
4/11/2003	0.00	0	0	0.28	600	0.17	0.04	0.10	0.10	0	0	2.00	0.00	1.40	90	77	2585	3231	30	3160	60	2376
4/12/2003	0.00	0	0	0.26	600	0.18	0.06	0.10	0.10	0	0	1.93	0.00	1.33	90	77	2654	3318	28	2486	64	2428
4/13/2003	0.30	0	0	0.28	600	0.05	0.05	0.10	0.10	0	0	1.87	0.00	1.71	90	77	2144	2680	29	2507	60	2769
4/14/2003	0.00	0	0	0.00	600	0.03	0.06	0.10	0.26	0	0	1.80	0.00	1.36	233	198	2323	2904	29	2524	57	2570
4/15/2003	0.00	0	0	0.13	600	0.08	0.06	0.10	0.10	0	0	1.73	0.00	1.25	90	77	2407	3008	29	2538	57	2483
4/16/2003	0.05	0	0	0.18	600	0.14	0.05	0.10	0.10	0	0	1.67	0.00	1.19	90	77	2419	3024	29	2588	57	2808
4/17/2003	0.00	0	0	0.18	600	0.09	0.05	0.10	0.10	0	0	1.60	0.00	1.13	90	77	750	938	29	2564	62	2711
4/18/2003	0.00	0	0	0.18	600	0.09	0.08	0.10	0.10	0	0	1.53	0.00	1.05	90	77	750	938	33	2609	63	2633
4/19/2003	0.00	0	0	0.21	600	0.12	0.07	0.10	0.10	0	0	1.47	0.00	0.96	90	77	750	938	35	2557	61	2468
4/20/2003	0.00	0	0	0.24	600	0.09	0.05	0.10	0.10	0	0	1.40	0.00	0.96	90	77	750	938	36	2496	64	2496
4/21/2003	0.02	0	0	0.18	600	0.14	0.06	0.10	0.10	0	0	1.33	0.00	0.86	90	77	750	938	36	2467	68	2430
4/22/2003	0.02	0	0	0.23	600	0.11	0.06	0.10	0.10	0	0	1.27	0.00	0.83	90	77	750	938	35	2340	73	2264
4/23/2003	0.00	0	0	0.20	600	0.11	0.07	0.10	0.10	0	0	1.20	0.00	0.75	90	77	750	938	35	2296	75	2529
4/24/2003	0.06	0	0	0.23	600	0.15	0.03	0.10	0.10	0	0	1.13	0.00	0.76	90	77	750	938	36	2167	73	2484
4/25/2003	0.00	0	0	0.16	600	0.15	0.06	0.10	0.10	0	0	1.07	0.00	0.60	90	77	750	938	34	2112	79	2230
4/26/2003	0.00	0	0	0.25	600	0.13	0.07	0.10	0.10	0	0	1.00	0.00	0.56	90	77	750	938	35	1997	100	2123
4/27/2003	0.00	0	0	0.25	600	0.16	0.08	0.10	0.10	0	0	0.93	0.00	0.46	90	77	750	938	36	1986	102	2280
4/28/2003	0.22	0	0	0.28	600	0.11	0.07	0.10	0.10	0	0	0.87	0.00	0.69	90	77	750	938	32	2031	90	2517
4/29/2003	0.00	0	0	0.00	600	0.14	0.08	0.10	0.10	0	0	0.80	0.00	0.37	92	79	750	938	29	2021	87	2671
4/30/2003	0.00	0	0	0.26	600	0.13	0.08	0.10	0.10	0	0	0.73	0.00	0.32	90	77	750	938	27	2015	81	2791
5/1/2003	0.00	0	0	0.25	600	0.11	0.06	0.10	0.10	0	0	0.67	0.00	0.30	90	77	750	938	27	1974	74	2975
5/2/2003	0.17	0	0	0.22	600	0.09	0.03	0.10	0.10	0	0	0.60	0.00	0.47	90	77	750	938	26	2038	73	2893
5/3/2003	0.42	0	0	0.28	600	0.07	0.02	0.10	0.10	0	0	0.87	0.00	0.97	90	77	750	938	27	1959	73	2646
5/4/2003	0.00	0	0	0.01	600	0.11	0.06	0.10	0.10	0	0	1.13	0.00	0.71	90	77	750	938	37	1992	83	2376
5/5/2003	0.00	0	0	0.87	600	0.12	0.08	0.10	0.10	0	0	1.83	0.00	1.28	90	77	750	938	37	1727	90	2317
5/6/2003	0.00	0	0	0.90	600	0.19	0.09	0.10	0.10	0	0	2.53	0.00	1.79	90	77	783	979	35	1660	91	2248
5/7/2003	0.00	0	0	0.61	600	0.14	0.07	0.10	0.10	0	0	2.80	0.00	2.10	90	77	802	1003	35	1580	104	2008

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip inches	GW inches	EC(gw) uS/cm	Op. Inflow inches	EC(if) uS/cm	Evap. (open water) inches	ET (veg. areas) inches	Op Spill inches	Outflow inches	GW inches	EC(gw) uS/cm	Depth (hab) inches	Depth (CC)	End of Day inches	Flow (cfs)	Adj. Flow (cfs)	EC uS/cm	Adj. EC uS/cm	GWD Personnel Q (cfs)	GWD Personnel EC (uS/cm)	Real-Time Network Q (cfs)	Real-Time Network EC (uS/cm)
5/8/2003	0.00	0	0	0.00	600	0.13	0.08	0.10	0.11	0	0	2.43	0.00	1.78	101	86	915	1143	32	1556	104	1813
5/9/2003	0.00	0	0	0.00	600	0.12	0.09	0.10	0.11	0	0	2.07	0.00	1.47	98	83	1075	1343	26	1508	89	1588
5/10/2003	0.00	0	0	0.00	600	0.14	0.09	0.10	0.11	0	0	1.70	0.00	1.13	100	85	1395	1744	24	1517	102	1676
5/11/2003	0.00	0	0	0.02	600	0.16	0.10	0.10	0.10	0	0	1.33	0.00	0.79	90	77	750	938	24	1508	95	1680
5/12/2003	0.00	0	0	0.10	600	0.16	0.10	0.10	0.10	0	0	1.03	0.00	0.53	90	77	750	938	32	1794	88	1808
5/13/2003	0.00	0	0	0.10	600	0.20	0.11	0.10	0.10	0	0	0.73	0.00	0.22	90	77	750	938	25	1664	75	1673
5/14/2003	0.00	0	0	0.15	600	0.27	0.06	0.10	0.10	0	0	0.43	0.00	0.00	90	77	0	0	23	1589	67	1606
5/15/2003	0.00	0	0	0.11	600	0.17	0.11	0.10	0.10	0	0	0.13	0.00	0.00	90	77	0	0	18	1450	62	1639
5/16/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	16	1413	65	1625
5/17/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	23	1500	58	1492
5/18/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	20	1510	58	1373
5/19/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	1289	61	1413
5/20/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	9	1589	74	1404
5/21/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	17	1612	72	1513
5/22/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	1633	53	1537
5/23/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	30	1527	70	1456
5/24/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	27	1530	57	1368
5/25/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	21	1452	55	1348
5/26/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	15	1473	56	1299
5/27/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	11	1427	58	1292
5/28/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	21	1200	65	1306
5/29/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	38	1029	91	1231
5/30/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1338	84	1264
5/31/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	8	1338	54	1345
6/1/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	1056	60	1313
6/2/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	1056	61	1289
6/3/2003	0.00	0	0	0.92	600	0.28	0.14	0.10	0.10	0	0	1.07	0.00	0.39	90	77	750	938	29	972	68	1289
6/4/2003	0.00	0	0	1.44	600	0.21	0.12	0.10	0.10	0	0	2.13	0.00	1.40	90	77	750	938	36	931	73	1225
6/5/2003	0.00	0	0	1.35	600	0.25	0.12	0.10	0.10	0	0	3.20	0.00	2.28	90	77	773	967	60	962	86	1155
6/6/2003	0.00	0	0	1.39	600	0.22	0.12	0.10	0.10	0	0	4.27	0.00	3.22	90	77	779	974	55	955	83	1196
6/7/2003	0.00	0	0	0.56	600	0.20	0.12	0.10	0.10	0	0	4.40	0.00	3.36	90	77	821	1027	41	937	74	1181
6/8/2003	0.00	0	0	0.00	600	0.20	0.12	0.10	0.25	0	0	3.73	0.00	2.78	226	192	941	1176	38	932	71	1161
6/9/2003	0.00	0	0	0.00	600	0.30	0.13	0.10	0.25	0	0	3.07	0.00	2.11	224	191	1217	1521	34	944	69	1133
6/10/2003	0.00	0	0	0.00	600	0.24	0.11	0.10	0.15	0	0	2.40	0.00	1.60	134	114	1615	2018	31	919	129	1140
6/11/2003	0.00	0	0	0.00	600	0.20	0.11	0.10	0.22	0	0	1.73	0.00	1.08	192	163	2529	3161	32	944	104	1261
6/12/2003	0.00	0	0	0.00	600	0.20	0.11	0.10	0.26	0	0	1.07	0.00	0.50	233	198	750	938	34	929	68	1314
6/13/2003	0.00	0	0	0.18	600	0.19	0.12	0.10	0.10	0	0	0.80	0.00	0.27	90	77	750	938	34	938	58	1191
6/14/2003	0.00	0	0	0.19	600	0.19	0.13	0.10	0.10	0	0	0.53	0.00	0.04	90	77	750	938	34	943	60	1295
6/15/2003	0.00	0	0	0.19	600	0.21	0.13	0.10	0.10	0	0	0.27	0.00	0.00	90	77	0	0	31	958	67	1301
6/16/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	31	937	66	1304
6/17/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	26	925	63	1245
6/18/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	23	937	54	1258
6/19/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	20	930	50	1310
6/20/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	19	924	52	1286
6/21/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	19	905	53	1197
6/22/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	900	65	1024
6/23/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	917	70	1019
6/24/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	917	70	947
6/25/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	18	900	63	1087

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip inches	GW inches	EC(gw) uS/cm	Op. Inflow inches	EC(if) uS/cm	Evap. (open water) inches	ET (veg. areas) inches	Op Spill inches	Outflow inches	GW inches	EC(gw) uS/cm	Depth (hab) inches	Depth (CC)	End of Day inches	Flow (cfs)	Adj. Flow (cfs)	EC uS/cm	Adj. EC uS/cm	GWD Personnel Q (cfs)	GWD Personnel EC (uS/cm)	Real-Time Network Q (cfs)	Real-Time Network EC (uS/cm)
6/26/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	20	960	56	1391
6/27/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	34	903	57	1503
6/28/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	40	860	57	1566
6/29/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	50	772	55	1600
6/30/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	64	784	60	1544
7/1/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	43	750	55	1374
7/2/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	28	800	73	1306
7/3/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	19	800	57	1444
7/4/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	17	800	50	1548
7/5/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	17	800	50	1667
7/6/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	21	800	51	1756
7/7/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	25	800	51	1768
7/8/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	27	800	48	1603
7/9/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	27	800	44	1476
7/10/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	30	800	46	1399
7/11/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	30	800	59	1441
7/12/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	27	800	52	1521
7/13/2003	0.00	0	0	0.14	600	0.21	0.15	0.10	0.10	0	0	0.17	0.00	0.00	90	77	0	0	25	850	49	1504
7/14/2003	0.00	0	0	0.29	600	0.20	0.15	0.10	0.10	0	0	0.33	0.00	0.00	90	77	0	0	23	850	52	1356
7/15/2003	0.00	0	0	0.43	600	0.20	0.15	0.10	0.10	0	0	0.50	0.00	0.00	90	77	0	0	38	850	55	1329
7/16/2003	0.00	0	0	0.57	600	0.21	0.14	0.10	0.10	0	0	0.67	0.00	0.12	90	77	750	938	49	850	65	1188
7/17/2003	0.00	0	0	0.60	600	0.19	0.15	0.10	0.10	0	0	0.83	0.00	0.28	90	77	750	938	51	850	74	1142
7/18/2003	0.00	0	0	0.58	600	0.18	0.14	0.10	0.10	0	0	1.00	0.00	0.44	90	77	750	938	50	850	71	1165
7/19/2003	0.00	0	0	0.57	600	0.17	0.16	0.10	0.10	0	0	1.17	0.00	0.57	90	77	750	938	51	850	75	1093
7/20/2003	0.00	0	0	0.57	600	0.22	0.14	0.10	0.10	0	0	1.33	0.00	0.68	90	77	750	938	45	900	74	1196
7/21/2003	0.00	0	0	0.61	600	0.19	0.14	0.10	0.10	0	0	1.50	0.00	0.85	90	77	750	938	45	900	65	1474
7/22/2003	0.00	0	0	0.58	600	0.19	0.14	0.10	0.10	0	0	1.67	0.00	1.00	90	77	750	938	42	900	65	1329
7/23/2003	0.00	0	0	0.57	600	0.17	0.11	0.10	0.10	0	0	1.83	0.00	1.20	90	77	750	938	41	900	62	1334
7/24/2003	0.00	0	0	0.52	600	0.24	0.14	0.10	0.10	0	0	2.00	0.00	1.23	90	77	750	938	40	1000	62	1319
7/25/2003	0.00	0	0	0.34	600	0.19	0.15	0.10	0.10	0	0	1.83	0.00	1.13	90	77	950	1187	39	1000	55	1328
7/26/2003	0.00	0	0	0.30	600	0.15	0.14	0.10	0.10	0	0	1.67	0.00	1.04	90	77	750	938	39	1000	69	1407
7/27/2003	0.00	0	0	0.25	600	0.20	0.14	0.10	0.10	0	0	1.50	0.00	0.85	90	77	750	938	58	900	86	1291
7/28/2003	0.00	0	0	0.30	600	0.17	0.14	0.10	0.10	0	0	1.33	0.00	0.74	90	77	750	938	52	950	103	1213
7/29/2003	0.00	0	0	0.26	600	0.19	0.13	0.10	0.10	0	0	1.17	0.00	0.58	90	77	750	938	46	1000	101	1152
7/30/2003	0.00	0	0	0.28	600	0.12	0.13	0.10	0.10	0	0	1.00	0.00	0.51	90	77	750	938	21	1250	74	1263
7/31/2003	0.03	0	0	0.21	600	0.20	0.05	0.10	0.10	0	0	0.83	0.00	0.39	90	77	750	938	17	1250	51	1441
8/1/2003	0.00	0	0	0.18	600	0.19	0.10	0.10	0.10	0	0	0.67	0.00	0.18	90	77	750	938	12	1250	41	1445
8/2/2003	0.24	0	0	0.25	600	0.19	0.10	0.10	0.10	0	0	0.50	0.00	0.28	90	77	750	938	6	1250	55	1301
8/3/2003	0.00	0	0	0.00	600	0.20	0.13	0.10	0.10	0	0	0.33	0.00	0.00	90	77	0	0	0	0	61	1249
8/4/2003	0.00	0	0	0.14	600	0.24	0.13	0.10	0.10	0	0	0.17	0.00	0.00	90	77	0	0	0	0	56	1191
8/5/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	59	1239
8/6/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	68	1309
8/7/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	60	1351
8/8/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	47	1338
8/9/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	43	1688
8/10/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	42	1925
8/11/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	40	2047
8/12/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	43	2011
8/13/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	38	2041

Note: Traditional drawdown (Type 3, normal year) selected for entire model run shown.

Time-Step	IN					OUT						Management			MODEL OUTPUT				NGWD COMPOSITE DATA			
Date	Precip	GW	EC(gw)	Op. Inflow	EC(if)	Evap. (open water)	ET (veg. areas)	Op Spill	Outflow	GW	EC(gw)	Depth (hab)	Depth (CC)	End of Day	Flow	Adj. Flow	EC	Adj. EC	GWD Personnel		Real-Time Network	
	inches	*inches*	*uS/cm*	*inches*	*uS/cm*	*inches*	*inches*	*inches*	*inches*	*inches*	*uS/cm*	*inches*		*inches*	*(cfs)*	*(cfs)*	*uS/cm*	*uS/cm*	*Q (cfs)*	*EC (uS/cm)*	*Q (cfs)*	*EC (uS/cm)*
8/14/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	32	2177
8/15/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	34	2196
8/16/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	39	1889
8/17/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	42	1778
8/18/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	43	1776
8/19/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	41	1544
8/20/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	34	1484
8/21/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	36	1578
8/22/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	55	1152
8/23/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	68	903
8/24/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	74	951
8/25/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	71	971
8/26/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	66	945
8/27/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	63	945
8/28/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	65	919
8/29/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	67	897
8/30/2003	0.00	0	0	0.00	600	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	67	850
8/31/2003	0.00	0	0	0.00	500	0.00	0.00	0.00	0.00	0	0	0.00	0.00	0.00	0	0	0	0	0	0	80	863

APPENDIX 3 DESCRIPTION OF THE WETLAND WATER QUALITY MODEL (WWQM.xls)

Column A – Date

The time-step for the WWQM is flexible, and is dependent upon the resolution of the input data. For the purposes of the real-time wetland water quality management project, the model uses a daily time-step. Use of the daily time-step is made possible by the availability of daily values for precipitation, evaporation, and evapotranspiration. In addition, the SJR salinity forecasts are available in a daily time-step format, and the real-time wetland water quality data being collected for this project, taken at 15-minute intervals, is readily averaged for a daily value. Any desired time-step can be easily used, however, all input data must match the model's time-step.

Column B – Precipitation

Precipitation data is a measured value. The precipitation data comes directly from the California Irrigation Management Information System (CIMIS) website, www.cimis.water.ca.gov, operated by the California Department of Water Resources (DWR). CIMIS publishes daily climatic data recorded at many weather monitoring stations across California. The monitoring station providing the precipitation data used in the WWQM is station 56 - Los Baños. This data is delivered to the user in the update[date].xls file.

Column C – Groundwater Input

Although the model has been developed to readily accept groundwater inflow and outflow none was supplied for this project. Many wetlands consist of soils with very low conductivities (clay, silt), so there is little regional groundwater flow into or out of the wetland system (Owen, 1995). It has been noted, however, in the wetlands of the GWD that local groundwater flow is important. Oftentimes, when a wetland has been drained while adjacent wetlands are still flooded, groundwater (usually high in salt content) rises to the surface in the drained wetland. Because the model simulates the entire wetland complex of the NGWD, this "localized' groundwater flow should have little impact on the model's overall results.This type of seepage more likely has an impact on the summer irrigation season and/or the following season's flood-up. This aspect of the model could benefit from additional research.

Column D – Groundwater Input Salinity

Groundwater Input

Column E – Operational Inflow

Operational inflow is a modeled value. It represents all water manually applied by the wetland managers in the form of flood-up, make-up, and irrigation water, and is calculated here. Inflow is the water added to the wetlands to keep their depth at or near management goals, or to provide summer irrigation water. This value is equal to the difference between the desired depth and the actual (modeled) depth, or make-up water, plus some extra for operational spill. The WWQM assumes zero make-up water when modeled depth is greater than management goals. These management goals are the driving force for this calculation and are based upon the assumption that the Guide to Wetland Management (henceforth "the guide") (Smith et. al, 1995) published through a cooperational effort by the California Waterfowl Association and the California Department of Fish and Game, dictates the general management theory that most wetland managers follow. This value is calculated by taking the desired daily wetland depth and comparing it to the end of day depth that the WWQM calculates. For instance, if the model balances all inputs (precipitation, P; groundwater, Gwin; and operational inflow, I) with all ouputs (evaporation, E; evapotranspiration, ET; groundwater, Gwout; operational spill, S; and outflow, O), and outputs a depth of 10 1/2 inches, and the guide calls for a depth of 10 2/3 inches, the model asks for an operational inflow for the following day of 1/6 of an inch. The model has programming in this column to first check if the user has asked for additional inflow by a decision variable in the application process interface contained in the file API.xls. This functionality is installed to allow the user to model the effects of a pre-flushing water management option that could be used to export some of the salts in the wetland prior to drawdown.

Column F – Operational Inflow Salinity

Operational inflow salinity (EC) is an estimated value. Prior to 2003, the EC curve is was estimated using sporadic grab samples taken over the last few years. During 2003 and afterwards, it will be supplied with real-time data. (The real-time monitoring station installed on the Volta Wasteway has never been fully operational because of numerous episodes of vandalism. The Volta Wasteway feeds the San Luis Holding Reservoir, which supplies over 80% of the NGWD). Due to the various uncertainties downstream from the monitoring station, this is another area of study that could help reduce the error in the model. The uncertainties include additional inflow and outflow points, precipitation inputs, evaporation and evapotranspiration outputs, etc.)

Column G – Evaporation

Evaporation data is a measured value. The evaporation data comes directly from the CIMIS website, www.cimis.water.ca.gov, operated by DWR. CIMIS publishes daily climatic data recorded at many weather monitoring stations across California. The monitoring station providing the precipitation data used in the WWQM is station 5 - Shafter. The evaporation data comes from Shafter because it is the nearest location to Los Baños that has a full data set of pan evaporation data that is updated daily. As well, its use is justified because both station 5 and 56 (Los Baños) are located within the same CIMIS climate zone, zone 10 This data is updated periodically and delivered to the user in the update[date].xls file. The evaporation data that is downloaded from CIMIS is manipulated for use in the model by multiplying it by a pan coefficient, Kp.

Column H – Evapotranspiration

Evapotranspiration data is a measured value. The evapotranspiration data comes directly from the CIMIS website, www.cimis.water.ca.gov, operated by DWR. CIMIS publishes daily climatic data recorded at many weather monitoring stations across California. The monitoring station providing the precipitation data used in the WWQM is station 56 - Los Baños. This data is updated periodically and delivered to the user in the update[date].xls file. The evapotranspiration data is calculated by CIMIS using a modified version of Penman's equation. It also includes a wind function developed by the University of California, Davis

(CIMIS, 2003). This data is then manipulated for use in the model by multiplying it by a crop coefficient curve and by an osmotic resistance factor (Glenn et al, 1995).

Column I – Operational Spill

Operational spill data is estimated. It was first assumed to be one cubic foot per second for every 200 acres, however after developing the model it was lowered to one cubic foot per second for every 235 acres (or 0.10 inches of water per day, per acre).

Column J – Outflow

Outflow data is calculated within the model. While the wetlands are flooded, this value is calculated by adding the operational spill to the difference, if positive, of the end of day depth for day t-1 and the desired depth for day t. There is a depth cutoff, however, of ¼ inch, that functions as the threshold prompting the model to quit releasing water from the wetlands.

Column K – Groundwater Output

See description for Column C, "Groundwater Input", above.

Column L – Groundwater Output Salinity

See description for Column C, "Groundwater Input", above.

Columns M and N – Habitat and Cattle Club Wetland Management Depths

The habitat wetland management depth and the cattle club wetland management depth data are adapted from Smith et al. 1995 "A Guide to Wetland Habitat Management in the Central Valley". The difference between the two management scenarios is that the habitat clubs manage for habitat throughout the year, whereas the cattle clubs manage for habitat during the hunting season, but drain their wetlands when duck season ends, allowing grasses to grow for cattle grazing. The habitat clubs and cattle clubs make up approximately 86% and 14% respectively, of the wetland acreage in the NGWD. This data takes the recommended water management (flooding and irrigation) plans for the three main wetland vegetation species targeted by wetland managers such as smartweed (*Polygonum punctatum*),

swamp timothy (*Heleochloa schoenoides*), and watergrass (*Echinochloa crusgalli)* and averages them to get one wetland depth value per day, per management scenario.
These two management scenarios are the driving mechanisms for the WWQM. Depending on user input regarding water year type (very dry, dry, normal, and wet), the data is adjusted for the water year. The calculated end of day storage values (see column O, below) are compared to the sum of 86% of the value for habitat clubs and 14% of the value for cattle clubs (column N), and the following day's inflow is calculated. If the management goal is less than the calculated end of day storage, outflow consists of the difference between those two plus the operational spill (column I), and the following days inflow (column E) is set to zero. If the management goal is greater than the calculated end of day storage, outflow consists of strictly the operational spill, and the difference, or make-up water, is applied in the following days inflow (column E).

Column O – End of day Depth

The end of day depth data are calculated by the WWQM by balancing all water inputs and outputs. These data are used in a comparison to the following day's desired depth, which drives the following day's inflow variable. The end of day depth is calculated in the following manner. Beginning with yesterday's (time t-1) end of day storage and adding and subtracting all inputs and outputs for today (time t=1) to the end of day storage from time t-1, the model calculates wetland depth at the end of time t=1. The model then compares the calculated end of time t=1 storage to the desired depth for time t+1. If the calculated depth for time t=1 is less than the desired depth of time t+1, Inflow for time t+1 is equal to the difference between the calculated depth at time t=1, and the desired depth at time t+1, plus the estimated operational spill volume. Otherwise, if the calculated depth is greater than the desired depth, inflow is equal to zero.

Column P – Flow

This column represents one-half of the results. The flow value is calculated by converting the outflow value, O_t, with units of inches per day, into a flowrate, Q_t, with units of cubic feet per second [cfs]. This is done by multiplying the outflow value by the total wetland acreage and by the conversion factor of 0.042014 [in/day to cfs/acre]. There is a depth cutoff, however, of ¼ inch, that functions as the threshold prompting the model to quit releasing water from the wetlands.

Column Q – Adjusted Flow

This column is available to apply a calibration factor calculated from comparing past results of modeled flow data to actual flow data.

Column R – Salinity (EC)

This column represents the other half of the results. The salinity, or EC, is calculated using a box model routine balancing all salt and water inputs with all salt and water outputs.

Column S – Adjusted Salinity (EC)

This column is available to apply a calibration factor calculated from comparing past results of modeled EC data to actual EC data. Currently, the model has been underestimating the salinity of the wetlands by roughly 80%. This could be attributed to many things, the most important of which could be ground water, residual salts, bird droppings, and an underestimation of inflow EC.

Columns T through W – NGWD Composite Flow and Salinity (EC) Values

These four columns are populated with the flow and EC values from (columns T, U) the GWD staff sampling program and from (columns V, W) the real-time network. These values are updated periodically.

Appendix 4 – Quinn, N. W. T., and W. M. Hanna, 2003

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A decision support system for adaptive real-time management of seasonal wetlands in California

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Abstract

This paper describes the development of a comprehensive flow and salinity monitoring system and application of a decision support system (DSS) to improve management of seasonal wetlands in the San Joaquin Valley of California. The Environmental Protection Agency regulates salinity discharges from non-point sources to the San Joaquin River using a procedure known as the total maximum daily load (TMDL) to allocate the assimilative capacity of the river for salt among watershed sources. Management of wetland sources of salt load will require the development of monitoring systems, more integrative management strategies and coordination with other entities. To obtain local cooperation, the Grassland Water District (GWD), whose primary function is to supply surface water to private duck clubs and manage wetlands, needs to communicate to local landowners the likely impacts of salinity regulation on the long-term health and function of wildfowl habitat. The project described in this paper will also provide this information. The models that form the backbone of the DSS, develop salinity balances at both a regional and local scale. The regional scale concentrates on deliveries to and exports from the GWD while the local scale focuses on an individual wetland unit where more intensive monitoring is being conducted. The design of the DSS is constrained to meet the needs of busy wetland managers and is being designed from the bottom up utilizing tools and procedures familiar to these individuals.

Keywords: Wetlands; Salinity; Real-time monitoring; Assimilative capacity

1. Introduction

The Grassland Water District (GWD) together with the adjacent State and Federal refuges constitute the largest contiguous wetland in the State of California (Fig. 1). The GWD comprises two interconnected units—the northern and southern GWD units—which together provides water to more than 20,000 ha of privately owned wetlands, mostly used as over-wintering habitat for wildfowl on the Pacific Flyway. The Northern GWD (NGWD) is larger in area than the Southern GWD and contains discrete drainage outlets, which provide drainage to distinct subbasins within the NGWD (Fig. 2). For this reason, the NGWD was chosen as the subject of the study described in this paper.

Seasonal wetlands in the GWD are flooded in the fall and drawn-down in the spring to provide habitat for migratory waterfowl, shorebirds, and other wetland-dependent species. Due to alterations in natural hydrology, these wetlands are flooded with Central Valley Project water supplies delivered through GWD canals. In the spring, during the months of March–April, seasonal wetlands are drawn-down to mimic the natural dry cycle of a seasonal wetland. Wetland drawdowns are timed to make seed and invertebrate resources available during peak waterfowl and shorebird migrations and to correspond with optimal germination conditions (primarily soil temperature) to grow naturally occurring moist-soil plants. The seeds of moist-soil plants are recognized as a critical waterfowl food source, providing essential nutrients and energy for wintering and migrating birds (Fredrickson and Taylor, 1982). Optimal timing of wetland flood-up and release has been determined by trial and error for different species of moist-soil plants and for different environmental conditions, although guidelines for these practices are poorly documented.

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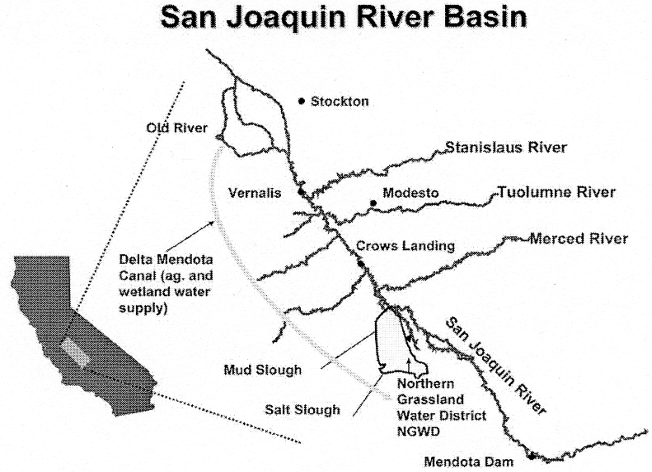

Fig. 1. SJR Basin showing NGWD and the major west-side wetland drainage conveyances Mud and Salt Sloughs. Water supply to agriculture and wetlands in the Grassland subbasin is provided through pumping from the Sacramento—San Joaquin Delta via the Delta Mendota Canal.

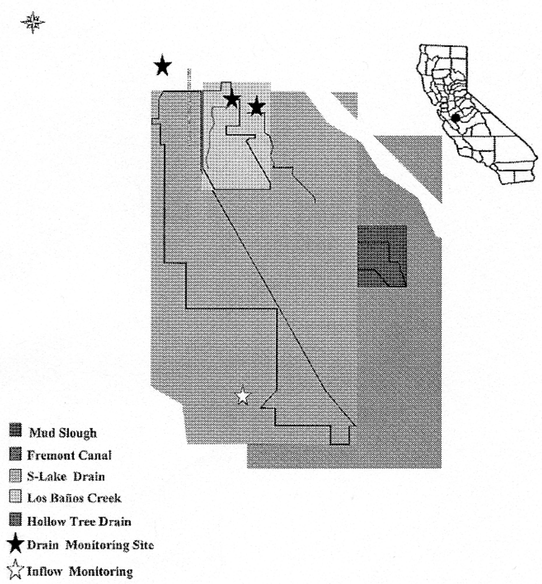

Fig. 2. NGWD showing drainage subbasins and both inflow and drainage monitoring.

2. Wetland management

The seasonal wetlands of the GWD are managed to meet habitat requirements by flooding in the fall and releasing their waters in the spring. Spring releases are discharged into tributaries of the Lower San Joaquin River (SJR). These releases, in combination with agricultural drainage that flows through the GWD, contain varying amounts of total dissolved solids (TDS), boron, and selenium. These constituents have been identified as stressors that lead to frequent exceedance of water quality objectives established for the SJR by state and federal agencies.

Research conducted by Grober et al. (1995) suggests that wetland drainage from the GWD could be scheduled to coincide with peak assimilative capacity in the SJR to help improve downstream water quality (Fig. 3). Assimilative capacity in the SJR occurs during periods when the average electrical conductivity (EC) at Vernalis is below the seasonal running average concentration. Fig. 3 shows that the irrigation season EC objective of 700 uS/cm between April 15 and August 15 each year is frequently violated. Between 1985 and 1998 the EC objective at Vernalis was violated more than 70% of the time.

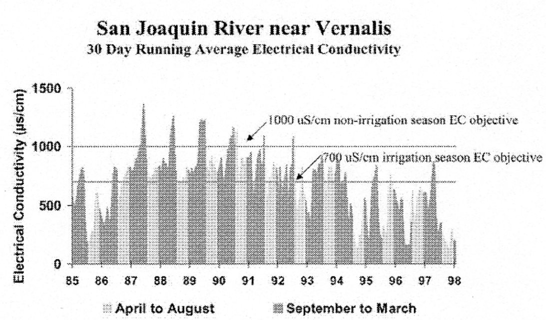

Fig. 3. SJR 30-day running average EC showing periods of assimilative capacity (graph below seasonal objective) and violation (graph above seasonal objective). Over the past 13 years, salinity (EC) objectives have been violated approximately 70% of the time.

Increased water supply allocations ıe Central Valley Project Improvement Act (CVPIA)—environmental legislation that resulted in a large transfer of water between irrigated agriculture and the environment—have created opportunities to coordinate the release of seasonal wetland drainage with the assimilative capacity of the SJR. Coordinated releases will help to achieve salt and boron water quality objectives and improve fish habitat in the main-stem of the SJR and Sacramento—San Joaquin Delta. Improved scheduling of west-side discharges can assist in avoiding critical time periods for fish rearing and remove an important stressor leading to improvements in the San Joaquin salmon fishery. To date, however, no systematic data collection program has been undertaken to evaluate the short- and long-term consequences of real-time wetland drainage management. Drainage monitoring (Fig. 4), undertaken as part of the project described in this paper, has been undertaken to address this deficiency.

Management of wetland drainage, through scheduling of releases to coincide with periods of SJR assimilative capacity, can help to improve SJR water quality. However, these actions may need to be considered relative to potential biological impacts of changes to traditional wetland management practices. Figs. 5 and 6 show how water management for optimal productivity differs between smartweed and water. Peak assimilative capacity typically occurs between the months of January and April. This time period is often earlier than the traditional wetland drawdown period (March–April). Hence, the response of moist-soil plants and of migratory waterfowl and shorebirds to an altered drawdown regime needs to be assessed. This assessment will identify potential impacts to seed germination rates, waterbird foraging rates, habitat availability, and species diversity and abundance. It is possible that early experimental drawdown may make food sources available to wildlife without negatively affecting wetland vegetation

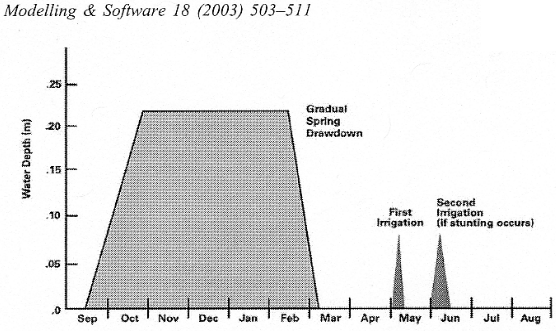

Fig. 5. Wetland flood-up and return flow schedule for smartweed in the Grassland Basin.

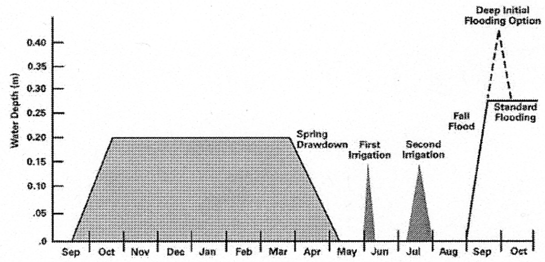

Fig. 6. Wetland flood-up and return flow schedule for watergrass in the Grassland Basin.

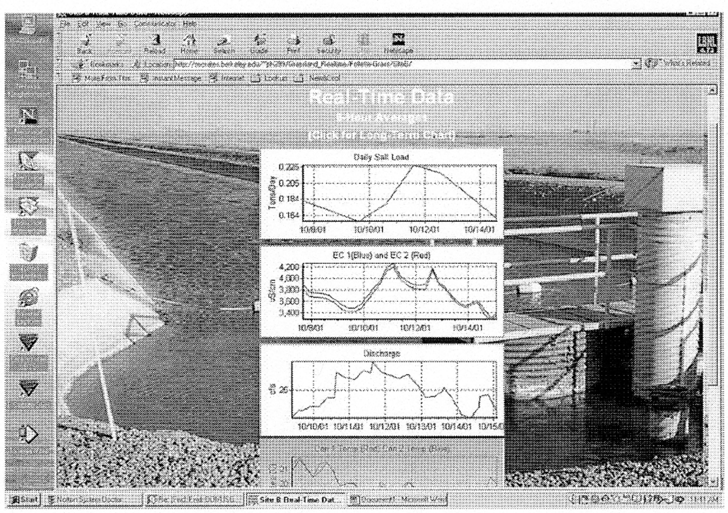

Fig. 4. Example of the real-time data acquisition and reporting system installed at wetland sites and the San Luis Drain. Wetland drainage combines with agricultural drainage in the San Luis Drain (shown above) and the combined flow is discharged to the SJR via Mud Slough.

community and plant species diversity—hence benefiting both wildlife and the health of the SJR. This ongoing research phase of this project will have considerable technology transfer value to other agencies that operate seasonal wetlands and also discharge constituents of concern to the River.

3. Water quality management

As a result of recent landmark environmental legislation that drastically changed water allocations among agricultural, municipal and environmental consumers, increases in water supply have helped to improve the quality of wetland habitat in the Grassland Basin. Additional water allocations, while increasing the flexibility of operation of seasonal wetlands and improving the quality of their return flows, increase the total salt load discharged to the SJR. Exploitation of opportunities to improve coordination of seasonal wetland drainage with the assimilative capacity of the SJR can improve compliance with river water quality objectives (Fig. 3). These objectives were established originally to encourage improvements in the management of agricultural and wetland return flows. These objectives were set to protect downstream riparian irrigators who use the SJR as their sole water supply and to protect the salmon fishery. Wetland releases that contain high salt loads during the months of April coincide with agricultural pre-season irrigation to propagate plant seedlings. Saline water can inhibit germination and reduce crop yields. Salmon can become confused during their annual migration when higher flows emanate from sloughs carrying drainage water than along the main-stem of the SJR.

Better coordination of agricultural and wetland releases with reservoir releases of good quality snowmelt water on the east-side of the San Joaquin Basin has been suggested as a means of improving SJR water quality for all beneficial uses (Karkoski et al., 1995a,b; Quinn and Karkoski, 1998; Quinn et al., 1997). Quinn (1999) described the results of a demonstration project of real-time monitoring and management of agricultural drainage and east-side reservoir releases that forecasts the assimilative capacity for salinity on the SJR (Fig. 7). These forecasts are made weekly based on an analysis of current data at all monitoring stations on a Monday morning in combination with information directly obtained from east-side reservoir operators on the main tributaries, riparian diverters along the main-stem of the SJR and those agricultural drainage districts that continuously monitor their drainage return flows. Wetland real-time water quality management project complements this existing program to coordinate seasonal wetland drainage with the assimilative capacity of the SJR. Since there exists little coordinated monitoring of salt loading leaving the GWD, this project has required the installation of wetland monitoring stations at major drainage outlets from the district (Fig. 2). To allow salt balance modeling, a similar station has been installed at the main GWD inlet at the Volta Wasteway channel. The DSS, described below, was developed to help organize field monitoring data and to allow wetland managers make timely decisions regarding return flows to the SJR. These decisions are aided by the fact that the elements of the DSS will eventually be common for the SJR and wetland salt management projects.

4. Real-time flow and water quality monitoring

Flow transducers and EC sensors have been installed at control structures within the GWD (Figs. 2 and 4). These instruments take measurements every 15 min to provide an accurate measurement of salt loading in to and out of the GWD boundary. Flow and EC data at each site is collected on a battery-powered datalogger that is attached to a phone telemetry system, allowing these data to be accessed 24 h a day.

Flow measurements at the inlet and most of the outlet sites are being made using a state-of-the-art acoustic velocity transducers. These transducers utilize the Doppler principle whereby during operation, each transducer produces short pulses of sound at a known frequency along two different axes. Sound from the outgoing pulses is reflected ('scattered') in all directions by particulate matter in the water. These return signals have a frequency shift proportional to the velocity of the scattering material. By combining data from both beams, and knowing the relative orientation of those beams, the device measures 2D velocity in the plane defined by its two acoustic beams. Each transducer is equipped with two stage measurement sensors, a vertical beam and a pressure sensor which, with information on the stream cross-sectional profile and the velocity, is used in the flow computation.

Temperature-compensated EC sensors are being used to obtain real-time salinity and temperature data at each site. EC is a measure of the TDS, or the presence of ions, in the water. When compensation is made for the water temperature, EC readings provide an accurate count for the salinity in the water. Maps have been prepared locating water delivery and drainage turnouts in the GWD drainage system. These maps will document drainage hydrology within individual wetland basins. The location of the monitoring stations has been determined by Global Positioning System (GPS) survey and located on the set of Geographic Information System (GIS) maps of the study area. These monitoring sites are strategically placed within wetland channels so as to allow computation of salt loads in real-time from different sectors of the GWD.

Real-time flow, EC and temperature data from the

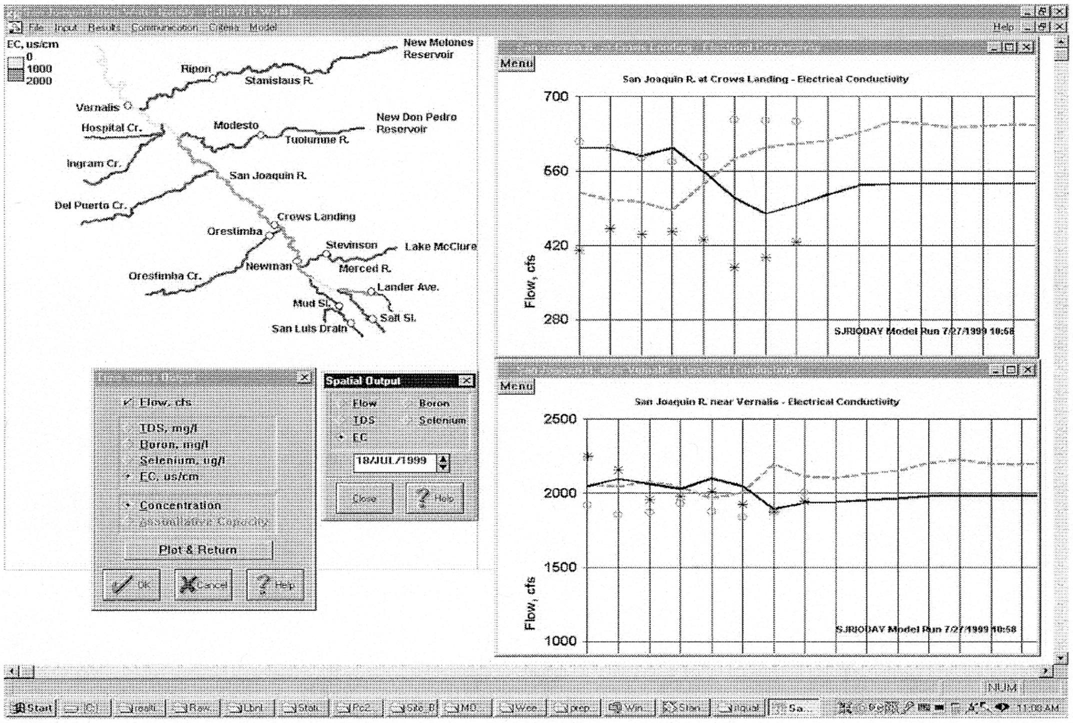

Fig. 7. Graphical user interface for the SJR salinity forecasting model. Wetland drainage enters the SJR through Mud and Salt Sloughs and, when combined with agricultural flows, account for 37% of the salt load in the SJR at Vernalis.

GWD is provided by e-mail and through a website http://socrates.berkeley.edu/~nwquinn/Grassland—Realtime/Quinn-Grass/ as input to the real-time water quality model of the SJR operated by the SJRMP Water Quality Subcommittee (Fig. 7) http://wwwdpla.water.ca.gov/sjd/waterquality/realtime/index.html. The SJRMP Water Quality Subcommittee has been funded to enhance the existing network of real-time monitoring stations along the main-stem of the SJR and to improve the coordination of agricultural return flows and scheduled east-side fish flows (Quinn et al., 1997). Installation of flow and water quality monitoring equipment and cellular telemetry equipment at key locations in the GWD helps to provide wetland and refuge managers the data necessary to make scheduling decisions. Mean daily salinity loading from the GWD is calculated from the monitoring data and is compared with the daily assimilative capacity determinations on the SJR. Wetland discharge opportunities during the spring months, when the majority of saline discharges from seasonal wetlands occur, is evaluated weekly by the project team, cooperatively with the watermaster and district biologist from the GWD.

5. Habitat evaluation

The biological and ecological monitoring and data objectives of the project are to document the effects of changing traditional flood-up and wetland drainage discharge patterns on wetland habitat and bird species (Williams, 1996). Achievement of these objectives will assist in developing adaptive management approaches to optimize wetland habitat conditions while minimizing the negative effects of wetland drainage on the water quality in the SJR.

A program of wetland habitat assessment is proceeding concurrently with the real-time monitoring and water quality management program. Changing the scheduling of wetland drainage to the SJR affects the timing and rate of drawdown of wetland ponds and hence the forage value of the wetlands for migrating and wintering shorebirds and waterfowl. Wetland salinity management measures can also affect the productivity and diversity of vegetation that can be grown in the watershed. The research underway is documenting the impacts of altering traditional wetland management practices and developing guidelines for multi-objective wetland operations including forage production, nesting cover establishment and salinity management. The concurrent program of habitat evaluation and salinity management could lead to optimization of wildlife and environmental benefits to the Grassland Basin and SJR.

Wetland habitat monitoring sites have been randomly chosen from available seasonal wetlands within the GWD. These wetlands correspondingly drain into locations where flow and EC monitoring sites are situated. At all wetland study plots, a paired study design is being used to directly assess differences in traditionally drained wetlands vs. non-traditionally drained wetlands. Biological monitoring is being conducted on adjacent traditionally and non-traditionally drained wetlands. The monitoring includes both a waterbird (waterfowl and shorebirds) usage component and a moist-soil plant production component. The waterbird component measures abundance and diversity and determine time–activity budgets of waterbirds through scan sampling and direct observation to assess foraging potential. The moist-soil plant production component determines the impacts, if any, to the vegetation by assessing changes in total plant biomass, percent coverage, and species composition through grid sampling and aerial photography.

6. DSS design

The rationale for developing a DSS was to provide a set of analytical tools that assist in computation of GWD wetland water requirements, estimation of wetland salinity load in seasonal wetlands and in the selection of best management practices. A requirement of the DSS was that it be simple in design and intuitive, similar to data management tools typically used by the GWD. GWD staffs spend much of their time in the field and do not have large blocks of time that they can devote to learning new software. The DSS was designed to interact with existing SJR water quality forecasting models and software to allow the partition of river assimilative capacity among the wetland releases.

7. Water quality model

The wetland water and salinity model simulates seasonal and permanent wetland management in the GWD and mimics the wet/dry seasonal cycle that these wetlands experience as well as the quantity and water quality of wetland releases. The main objective of the wetland water quality model is to predict the effects of salt loading to the SJR during spring drawdown (January–April). The model incorporates the weekly water use requirements of the major wetland habitat types in the GWD and the adjacent State and Federal refuges. Mapping of the wetland habitat has been limited to date to discriminating open water areas within the wetland complex. Evapotranspiration from moist-soil plants within the GWD is presently estimated and not specifically modeled owing to lack of field data for model calibration. There are no reliable techniques available using remote sensing technology to quantify the areal extent of the major moist-soil plants and other wetland habitat within the GWD. In spite of these limitations the model tracks salinity changes in each of the wetlands over the winter season and incorporates user-defined schedules for wetland drawdown in the spring months. By running scenarios of different weekly wetland fill and release schedules and annual changes in vegetation type and waterbird usage, managers are able to plan operations to minimize water quality impacts on the SJR while maximizing wildlife benefits.

The current model has been developed as a Microsoft Excel spreadsheet on account of the widespread familiarity with this product among wetland managers in the Grassland Basin. The model has been designed to perform historic hydrology simulations as well as seasonal alternatives (along with sensitivity analyses). Seasonal alternatives include different wetland drawdown protocols such as: (a) early drawdown (critically dry to dry year), (b) traditional drawdown (dry to wet year), (c) late drawdown (wet year), and (d) preflushing. The wetland water quality model has been designed to allow easy linkages to popular software packages such as RAISON and ARCVIEW. In addition, the Excel spreadsheet model has been designed to predict salt loading from the NGWD watershed as well to read salt assimilative capacity output directly from the Department of Water Resources' Delta Simulation Model II (DSM-2). First the wetland water quality model provides wetland outflow quantities and salt loads to DSM-2 at Mud and Salt Sloughs for use in its river forecasts and second, the wetland water quality model uses SJR assimilative capacity forecasts provided by DSM-2 as input.

7.1. Input data

Input data for the wetland water quality model fall into four categories; static, annually constant, annually varying, and real-time. Static data, which do not vary with time, include soil properties, land classifications, acreages, drainage basin allocations, and precipitation and ET qualities. Annually constant data, which are static year to year but vary within the year, include crop coefficients (for ET subroutines), best management practices, and water table depth. Annually varying data include precipitation, water year classification, air, water, and soil temperatures, irrigation schedule, and wetland flood-up schedule. Real-time data includes supply water quantity and quality, drainage water quantity and quality, evapotranspiration, precipitation, and SJR assimilative capacity. Much of the static and annually constant data are assumptions, since intensive monitoring in these wetlands only commenced in water year 2000. A typical user will not need modify these data, once measured, except for system changes, calibration, or sensitivity analyses.

7.2. *Model runs*

The model was applied to historical northern GWD drainage data collected during the 1998–1999 water year. The NGWD contains the major drainage outlets to the SJR and, since it is geographically separated from the southern GWD by the city of Los Banos, it can be considered as a hydrologically separate system. During the spring of 1999, NGWD wetland drawdown contributed over 6% of the total salt load in the SJR at the Crows Landing monitoring station, located downstream of the Mud and Salt Slough discharge points, on the SJR. The Mud Slough discharge to the SJR combines flow and salt loads from Mud Slough (north), Fremont Canal, Los Baños Creek, Hollow Tree Drain, and S-Lake Drain. Fremont Canal alone contributes flows and salt loads of approximately 2% of the total wetland acreage in the NGWD (GWD, 2001).

Model simulations have been made, comparing SJR flow and water quality at Crows Landing under several different wetland management plans for the drawdown season between January 1999 and April 1999 (Figs. 8 and 9). The different wetland management plans were simulated using calculated wetland water quality. The salt loads generated from this analysis were compared to river assimilative capacity, estimated by the DSM-2 river hydrodynamic model for the same period. The first step of the model run required developing high and low baseline flow and salt load values for the SJR. The high SJR baseline selected was the actual modeled (DSM-2) salt load at Crows Landing. The low SJR baseline was the salt load at Crows Landing assuming zero contribution of flow and salt load from the NGWD.

Once baseline values were established, the wetland water quality model simulated early and late drawdown release scenarios from the NGWD. For these historical model runs, early and late wetland drawdown scenarios were generated by skewing the actual drainage data by +/−1 standard deviation. To view the impacts of the alternative wetland management plans, the modeled results were added to the low SJR baseline values. Although the actual NGWD salinity contribution to the SJR was roughly 6% during the 1999 wetland drawdown season, effects from altered drawdown schedules are apparent.

7.2.1. *Scenario 1: baseline values: DSM-2 model values (actual) vs. DSM-2 w/o NGWD contribution*

This comparison shows the difference between the actual modeled (DSM-2) SJR qualities and quantities (high baseline) and the SJR had there been no contribution from the NGWD (low baseline).

7.2.1.1. Water quantity Completely removing the NGWD contribution considerably reduced the flow in the SJR at Crows Landing. The reduction in flow ranged from one to almost 11%, with the maximum observed deficit occurring in late March and early April (Fig. 8).

7.2.1.2. Water quality Completely removing the contributions from the NGWD to the SJR had a marked effect by reducing the EC at Crows Landing by more than 4% during peak wetland withdrawals in February and March (Fig. 9). It is interesting to note that during the week ending March 25th, removing the NGWD contribution actually increased the EC of the SJR at Crows

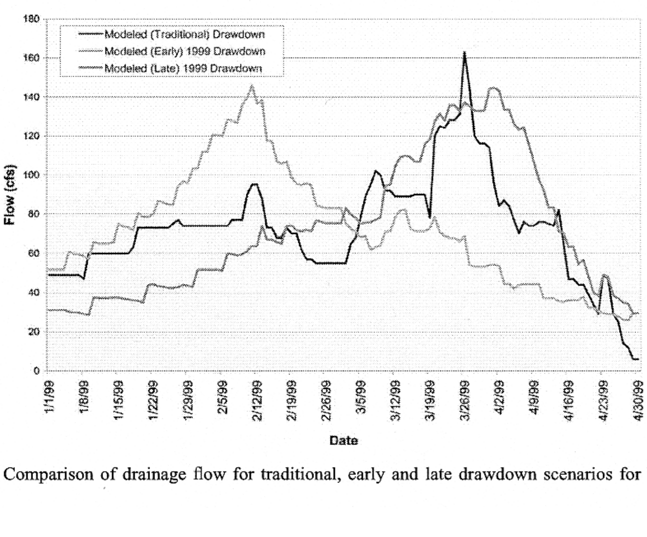

Fig. 8. Comparison of drainage flow for traditional, early and late drawdown scenarios for NGWD.

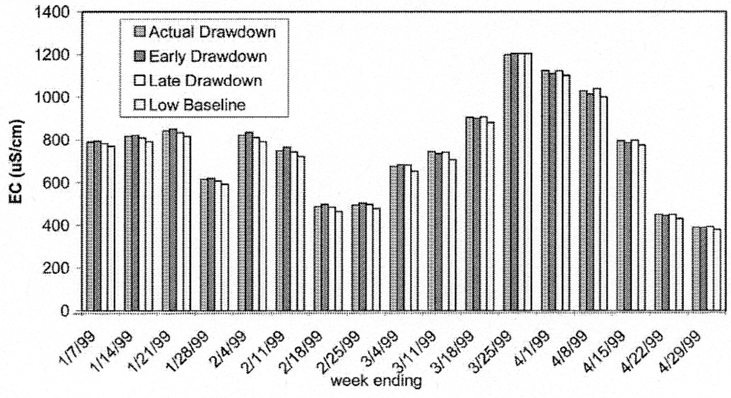

Fig. 9. Average weekly EC at Crows Landing for WY 1999 spring drawdown.

Landing. Further review of the data confirms this, showing that indeed the EC of the SJR was higher during that time than the wetland releases. However, other than that 1 week, removal of the NGWD component decreased the EC, and hence increased the assimilative capacity, of the SJR at Crows Landing.

7.2.2. Scenario 2: wetland water quality model run 1—early wetland drawdown

This comparison is designed to show the difference between the actual modeled (DSM-2) SJR qualities and quantities (high baseline) and the SJR, had there been an early wetland drawdown from the NGWD.

7.2.2.1. Water quantity An early wetland drawdown management plan from the NGWD to the SJR increased the flow in the SJR at Crows Landing during the early months and reduced it in the later months (Fig. 8).

7.2.2.2. Water quality Applying an early wetland drawdown management plan from the NGWD to the SJR had a marked effect by increasing the EC by an average of 1.5% during the early months (January and February) and by reducing the EC by an average of 2.5% in the later drawdown months (March and April)—(Fig. 9).

7.2.3. Scenario 3: wetland water quality model run 2—late wetland drawdown

This comparison shows the difference between the actual modeled (DSM-2) SJR qualities and quantities (high baseline) and the SJR, had there been a late wetland drawdown from the NGWD.

7.2.3.1. Water quantity A late wetland drawdown management plan from the NGWD to the SJR did not have as great an impact on the SJR as did the early drawdown management plan. The late drawdown did decrease the flow in the SJR at Crows Landing during the early months and increased it in the later months, however, on average, it did not change the flows by more than +/−1% (Fig. 8).

7.2.3.2. Water quality Because traditional drawdown management plans tend to be later in the season, applying a late wetland drawdown management plan from the NGWD to the SJR did not have as marked an effect on the water quality of the SJR. The late drawdown decreased the EC by an average of 0.5% during the early months (January and February) and increased the EC by an average of 0.25% in the later drawdown months (March and April)—(Fig. 9).

7.3. Analysis

It was apparent that even though an early withdrawal management plan has the greatest effect on altering the quality of the SJR, this is mainly because wetland managers in the NGWD schedule traditional drawdown later in the season. These simulations will need to be performed on subsequent years to verify the findings from the one drawdown season of 1999.

7.4. Discussion—adaptive management of wetland releases

The overall goal of the project is to provide basic monitoring information and to develop decision support tools to allow wetland managers in the GWD to respond to the long-term challenge of improving water quality while maximizing wetland functions and habitat values. The project considers two levels of monitoring and analysis—the first, at the water district scale, will develop inflow and outflow monitoring and a salinity loading mass balance for the entire North-Grasslands region. The second, conducted at the scale of a single duck club, in this case the most progressive and scientifically managed in the water district, which has designated functional wetland units to attract different bird species and which offers a great diversity of hunting experience. The project is fortunate in having enlisted the cooperation of one of the most innovative wetland managers in the GWD, who has for years been experimenting with different regimes of wetland filling and release—primarily with the objective of optimizing wildfowl habitat under various regimes of water availability and supply water quality. The duck club will benefit by the more intensive level of water flow and quality monitoring while providing the wetland manager a test-bed to observe and evaluate alternative management regimes. More intensive monitoring of a suite of water quality factors is underway at the duck club with including flow, EC, pH, turbidity, dissolved and particulate organic carbon concentrations and biochemical oxygen demand, which provide a comprehensive comparison of management-related impacts.

The synergy between the monitoring and research objectives of our project and the practical aspects of improving wetland function in a climate of increased environmental regulation and control of non-point source discharges provides a unique opportunity for advancement of the art and the science of wildfowl wetland management. By taking this 'pre-emptive' action—the GWD is seen to be proactive in the eyes of the EPA and the Regional Water Quality Control Board (enforcement division for the EPA), which are presently laying the groundwork for salt load allocation and salinity water quality objectives on the SJR.

8. Summary

Information obtained through this project will likely be transferable and of significant value to all wetlands in the grassland ecological area including those wetlands managed by State and Federal wildlife agencies. The successful implementation of this combined monitoring, experimentation and evaluation program will provide the basis for adaptive management of wetland drainage throughout the entire 70,000 ha grassland ecological area. The project will involve local landowners, duck club operators, and managers of State and Federal refuges in the Grassland Basin. Although this pilot project has concentrated on the 20,000 ha that comprise the GWD, the goal of the project is to disseminate the findings of the project more widely. The GWD has a successful history of local involvement through the district newsletter, published monthly; high school and college-level educational outreach programs; and through 'Wild on Wetland' days, which help to educate the public about the benefits and techniques of wetland management.

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