DRAFT

UC DAVIS WATER MANAGEMENT PLAN

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LIST OF ACRONYMS

A&E	UC Davis Office of Architects and Engineers
AE	Application Efficiency
ASF	Assignable Square Feet
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
BOD	Biological Oxygen Demand
cfs	cubic feet per second
CRPRC	California Regional Primate Research Center
CVRWQCB	Central Valley Regional Water Quality Control Board
DHS	California Department of Health Services
DOE	Department of Energy
DWR	Department of Water Resources
EC	Electrical Conductivity
EE/CA	Engineering Evaluation/Cost Analysis
EH&S	UC Davis Office of Environmental Health and Safety
EIR	Environmental Impact Report
ELRAT	Environmental Liability Risk Assessment Team
gpm	gallons per minute
IRA	Interim Remedial Action
ISWP	Inland Surface Water Plan
ITEH	Institute of Toxicology and Environmental Health
LEHR	Laboratory for Energy-related Health Research
LRDP	Long Range Development Plan
LTRAS	Long-term Research on Agricultural Sustainability
MCL	Maximum Contaminant Level
mgd	million gallons per day
msl	mean sea level
MPN	Most Probable Number
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
ppm	parts per million
psi	pounds per square inch
SCDS	South Campus Disposal Site
SCWA	Solano County Water Agency
SWRCB	State Water Resources Control Board
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UC	University of California
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
VOCs	volatile organic compounds
WDRs	Wastewater Discharge Requirements
WWTP	Wastewater Treatment Plant

FOREWORD

Virtually every UC Davis activity is critically dependent on water to meet its teaching, research, and public service missions. It is particularly important to recognize that UC Davis research significantly benefits California and to understand how dependent that research is on the availability of adequate water resources. The University's varied research programs explore and seek solutions to problems in agriculture, resource management, the environment, health, medicine, engineering, business, the economy, and public policy. UC Davis scholars also explore the intellectual frontiers of the physical, biological, and social sciences, as well as the humanities. A consistent supply of water of adequate quality is needed to support all of the teaching, research, and public service activities at UC Davis. A Water Management Plan is needed to ensure wise stewardship and economic use of campus and regional water resources. Furthermore, a plan is needed so the Campus can fulfill its responsibility for public trust of natural and renewable resources. The plan presented in this document is designed to set a guiding framework for on-going water resource planning and management. Key issues and opportunities are identified and recommendations are made for a new permanent campus wide management team to focus on water-related issues. Thus, this document should be viewed as the first step in focused planning on campus water resources.

Planning for water resource management is a dynamic process. This fact is well illustrated by the lawsuits and other legal complaints regarding water in and under Putah Creek that have been filed by various Yolo and Solano County public agencies, private land owners, the Putah Creek Council, and UC Davis. In addition, the region sustained six years of drought between 1987 and 1992 and another drought year in 1994. Water resource management must be able to respond to a wide variety of natural, political, and legal events. Thus, the UC Davis Water Management Plan includes a process for regularly reviewing and revising the plan.

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EXECUTIVE SUMMARY

The **UC Davis Water Management Plan** seeks to ensure the campus has sufficient water of adequate quality to fulfill the teaching, research, extension, public service, and land management responsibilities of the campus. The campus must also fulfill its responsibilities for public trust of natural and renewable resources. This plan meets those primary planning goals by providing a framework to guide present and future water development, conservation, disposal, and treatment, and by responding to the increasing water demands for domestic, utility, and field research and teaching uses.

Since the 1994 UC Davis Long Range Development Plan has a planning horizon through the year 2005-06, the Water Management Plan is primarily targeted to that year. However, projections were also made to the year 2046 based on assumptions that: (1) campus growth and development may continue to take place beyond 2005-06 given expected State and regional growth projections; (2) water demands for domestic, utility, field research and teaching uses may change; and (3) technological improvements in water use, conveyance, application, reuse, and drainage will likely occur.

CAMPUS WATER BUDGET

The campus water budget is dependent on the following factors: (1) water supplies including precipitation, groundwater storage and flow, Putah Creek riparian water, water purchased from the Solano Project, and Cache Creek water purchased from the Yolo County Flood Control and Water Conservation District; (2) uses for domestic, utility, and field research and teaching purposes; (3) losses through surface runoff, evaporation, transpiration, and drainage; (4) disposal through storm water drainage and treatment; (5) conservation and reuse; and (6) water quality requirements.

The campus water budget balance is substantially influenced by annual rainfall and can be critically affected by a series of drought years. In the mid-1970s, hydrologic investigations suggested that the groundwater levels at shallow to intermediate depths (i.e., <800 ft. below ground surface)

were declining on the average of approximately 1.0 foot/yr. More recent data including several high rainfall years and the drought 1987-94 drought indicate that campus groundwater levels at shallow to intermediate depths have not declined even though heavy pumping took place during recent years. The extent, recharge rate, and dependability of the deep aquifer is unknown. The campus has successfully managed its water supplies during rainfall-deficient years by achieving a better balance in the use of groundwater and Solano Project water and by substantially improved conservation practices. However, the Davis Campus requires campuswide coordination and comprehensive planning to assure continued successful water management.

WATER DEMAND

UC Davis requires sufficient water of acceptable quality in a timely manner to meet the needs associated with field research and teaching, domestic, and utility uses. Water demand is projected as follows:

Field Research and Teaching Use: Field research and teaching water demand, including substantial additional water needed for new research initiatives, is projected to increase by 1,600 acre-ft/yr by the **year 2005-06**. Examples of new research initiatives might include new aquaculture or fisheries research facilities or greenhouses and research laboratories used for basic, applied, and production-related biotechnology research. Field research and teaching water use is not anticipated to increase beyond 2005-06 volumes unless there is a change in the campus land base or a presently unanticipated program change that has significant water-use implications.

The campus should secure an additional supply of approximately 6,000 acre-ft/yr of high quality surface water to ensure an adequate long-term supply for field teaching and research. This volume of water would include approximately 1,600 acre-ft/yr of increased demand for new research initiatives and approximately 4,400 acre-ft/yr to replace the existing supplies from groundwater and Clear Lake (Table 4-10). The volume of water sought may be reduced if technological advances allow increased use of reclaimed water or if investigation of the groundwater determines that over the long-term these aquifers will continue to be a reliable supply of high quality water.

Domestic Use: Domestic water demand is projected to increase by 3,030 gallons per minute (from 6,670 to 9,700 gpm) to meet hourly peak domestic and fire flow requirements by the year 2005-06. Meeting the hourly peak flow will also satisfy the maximum daily demand of 7,500 gpm and the projected demand of over 1.1 billion gallons/yr (3,430 acre-ft/yr), an increase of 1,080 acre-ft/yr over current use. Domestic water demand is projected to increase an additional 1,300 gpm to 11,000 gpm to meet the hourly peak flow requirements by the year 2046. Meeting the hourly peak flow will also satisfy the maximum daily demand of 8,250 gpm and the projected demand of 1.4 billion gallons/yr (4,300 acre-ft/yr) an increase of approximately 2,000 acre-ft/yr over current use.

Utility Use: Utility system water demand is projected to increase by 655 gpm (from 5,045 to 5,700 gpm) to meet maximum daily flow and backup requirements by the year 2005-06. Meeting the peak flow will also satisfy the projected annual demand of 340 million gallons/yr (1,050 acre-ft/yr), an increase of 125 acre-ft/yr over current use. Utility system water demand is projected to increase an additional 1,425 to 7,125 gpm to meet the maximum daily flow and backup requirements by the year 2046. Meeting the peak flow will also satisfy the projected annual demand of 425 million gallons/yr (1,300 acre-ft/yr) an increase of 375 acre-ft/yr over current use.

The campus should seek to secure a high quality, surface water source of approximately 4,000 acre-ft/yr for domestic and utility uses. This volume would be used to meet the expected increased demand for domestic and utility water of approximately 2,300 acre-ft/yr over the next half century. It would also provide approximately 1,700 acre-ft/yr to reduce the current dependence on groundwater. The volume of surface water sought might be reduced if technological advances allow increased use of reclaimed water and if investigations of the deep aquifer determines that over the long term it will remain a reliable supply of high quality water.

POTENTIAL WATER SOURCES

This Plan identifies a need for additional water to meet the Long Range Development Plan needs through 2006 and anticipates increased water demand by 2046. Campus planners will have to consider both internal and external water sources to meet the projected water demand.

INTERNAL WATER SOURCES

Internal water sources are not likely to meet long-term water demands. Nevertheless, campus planners must carefully assess each potential source by conducting the studies necessary to adequately understand regional aquifers and to stay current with technologies utilized to reclaim and reuse water. The internal water sources are:

Groundwater: The use of additional groundwater to increase campus water supply could be limited by both quantity and quality. Groundwater levels could decline, land subsidence is a possibility, and quality is a problem for some research and industrial-type activities. The extent and recharge rate of the deep aquifer is unknown and the long-term dependability is questionable especially given the likelihood that other water purveyors such as the City of Davis are expected to increase use of this aquifer. The potential for long-term quality changes in the deep aquifer system has not been evaluated, but at best water quality would remain the same and it could potentially decline. The intermediate aquifers will deteriorate by the movement of soluble salts and organic and toxic constituents from ground surface or subsurface sources. Given these unknowns and the likelihood that the water quality will decline at least in the shallow and intermediate aquifers, groundwater is likely not dependable as a long-term solution for increasing the water supply.

Drainage, Storm, and Reclaimed Water: The use of drainage, storm, and reclaimed water has limited potential for providing supplemental water because of limitations on volume, location, time of availability, and the relatively high cost. More important, the strict needs of field teaching and research programs require a water source of extremely high and consistent quality that currently cannot be met by drainage, storm, or reclaimed water.

Putah Creek Riparian Rights: In 1996, the Solano County agencies dropped the Putah Creek water rights adjudication. Therefore, quantification of these rights relative to other riparian water users has not been quantified.

EXTERNAL WATER SOURCES

Water from external sources may be a better option for increasing the campus water supply. There are several alternatives available.

Solano Project Water: Contracting for additional Solano Project water above the current 4,000 acre-ft/yr would be the most desirable for quality purposes, and, if available, might be the least costly. The University initiated negotiations with the Solano Water Agency and Solano Irrigation District in 1992-93 in an effort to obtain additional project water beyond the 4,000 acre-ft/yr currently under contract. Negotiations were terminated by the Solano partners due to reported opposition by other Solano Project member units in Solano County.

Sacramento River Water: This source would appropriate water from the Sacramento River via an application filed by the Yolo County Flood Control and Water Conservation District. The University and the Cities of Davis and Woodland are the intended beneficiaries. For planning purposes, the University identified a need for 6,000 acre-ft/yr for use in its agricultural research program on the Russell Tract and 3,200 acre-ft/yr for domestic use by the year 2046.

Groundwater Recharge from Cache Creek: Development of additional supplies through a Cache Creek Conjunctive Use Project or a Yolo County Conjunctive Use Program. This water source would contribute to the regional groundwater supply.

Purchase Land with Surface Water Entitlement: The University may want to purchase land that has entitlement to surface water from the Solano Irrigation District and good quality groundwater conditions. A land purchase/transfer, in reasonable proximity to the campus, could accommodate field research and teaching. Such a transaction may allow the University to consider selling a portion of Russell Tract land or discharging some of its surface or groundwater into Putah Creek as part of an agreement to provide instream flow in the lower reaches of Putah Creek in return for additional Solano Project water to the University. Any serious consideration of a sale of Russell Tract land must receive early attention given plans for the "Center for the Study of Agriculture and Environment."

Purchasing and Contracting for Water: Some land owners along the Sacramento River and its tributaries have riparian water rights that may be available for purchase or contract on a long-term basis. Although the long-term availability and high conveyance costs of purchasing and/or contracting for water supplies remain open questions, this option should be pursued in cooperation with other Yolo County water jurisdictions.

RECOMMENDATIONS

The following recommendations are intended to assure that the University's surface and groundwater resources are managed through faithful utilization of a sound, integrated, and well-coordinated plan.

MANAGEMENT STRUCTURE

The Campus management structure for water resources should be improved through specific delegation of responsibilities and more effective coordination.

- The Chancellor shall appoint a standing UC Davis Water Management Committee to provide for the oversight of all campus water resource systems and activities including planning, coordination, maintenance, operation, and rehabilitation. The Committee membership shall include representatives of those units that have the most significant water management responsibilities (e.g., Facilities Services, College of Agricultural and Environmental Sciences, Environmental Heath and Safety, Planning and Budget, etc.) and campus community members with general water management expertise.

  The Water Management Committee shall report to the Provost and Executive Vice Chancellor and have oversight responsibility for short- and long-term water resources management. The committee shall provide policy direction to the appropriate campus managers based on Water Management Plan implementation and interpretation. For example, the committee would provide advice and direction for the following areas of responsibility: (1) evaluation and analysis of water systems performance; (2) well location, design, testing, maintenance, rehabilitation, and land subsidence; (3) infrastructure analysis, design, construction, and performance; (4) water quality analysis and assessment; (5) water treatment, disposal, and reuse; (6) remedial and cleanup activities; (7) regional analysis of

surface and groundwater hydrology; (8) compliance with legal requirements and institutional standards; and (9) analysis and interpretation of long-term alternatives for water demand and supply, and disposal.

- The Chancellor shall assign responsibility for the maintenance of the Water Management Plan to the Office of Planning and Budget, in consultation with the Water Management Committee. The plan shall be reviewed every two years and carefully coordinated with all affected campus units and, when appropriate, with local, regional, and state agencies. Any changes/updates to the Plan will be communicated to affected parties. The Office of Planning and Budget will retain technical consultants, as needed, to provide continuity, with responsibilities of oversight evaluation, analysis, interpretation, and recommendations on UC Davis short- and long-term water resources, system needs, entitlements, and their solutions.

- Facilities Services and Environmental Health & Safety will continue to be responsible for operation and maintenance of the campus water system, operational management of the existing water supplies, meeting water quality regulations, and acting as the principal liaison with state and federal regulatory agencies.

- UC Davis will actively participate in regional water planning, especially through the Water Resources Association of Yolo County. The Water Management Committee shall nominate a campus liaison(s) for regional water planning for appointment by the Provost and Executive Vice Chancellor.

WATER SUPPLY

The following recommendations intend to assure that the Campus water supply is adequate to serve teaching, research, public service, domestic, utility, and environmental purposes. The University should:

- Consistently use the entire UC Davis entitlement of Solano Project water;

- Actively pursue all reliable sources of high quality and reliable surface water, including considering purchasing land that has water entitlements to surface water from the Solano Irrigation District;

- Continue to actively protect the University's legal rights to surface water in Putah Creek and the underlying groundwater;

- Plan for negotiation of a continuing contract with the Solano County Water Agency for the University's 4.000 acre-ft/yr Solano Project allocation, and substantially increasing this amount if possible;

- Continue negotiating for appropriated water from the Sacramento River and Cache Creek via Yolo County interests and other regional entities;

- Identify, and seek to be consulted on, proposals regarding the sale and exportation of surface or groundwater from Yolo and Solano Counties that would have an adverse impact on the campus water supplies;

- Conduct a hydrologic analysis to determine the long-term production and water quality trends of the deep groundwater aquifer supplying the deep wells and domestic water;

- Develop and implement a long-term data collection plan designed to monitor groundwater quality and quantity (e.g., depth to water) from the aquifers used by the domestic, utility, and field teaching and research water systems;

- Construct a branch pipeline from the University's existing Solano Project pipeline to the Russell Tract to increase flexibility in utilization of the Solano Project water entitlement each year; and

- Obtain authorization to convey Russell Tract riparian water through this branch pipeline by seeking a Warren Act Contract with the Bureau of Reclamation.

For planning purposes, the campus should continue to seek 6,000 acre-ft/yr for field teaching and research uses at the Russell Ranch and 4,000 acre-ft/yr for domestic use by the year 2046. These volumes are recommended not only to meet anticipated increases in demand due to growth in campus population and programs, but also to ensure a reliable and high quality water supply for teaching and research, to provide for increased management flexibility especially during drought, and to allow for unforeseen demands such as new research initiative, a technology park, and enterprise developments. The volume of surface water sought may be reduced if technological advances allow increased use of reclaimed water and if investigation of the deep aquifer determines that over the long-term it is a reliable supply of high quality water.

DOMESTIC SYSTEM OPERATION AND MAINTENANCE PROGRAM

The domestic water system is used for laboratory purposes, fire protection, landscape irrigation on the west campus, cooling water for the Central Heating and Cooling Plant, and typical domestic purposes. Water is supplied to the system from six wells extending more than 800-1,200 feet below the surface to the deep aquifer of the Putah groundwater basin. The continued effective

operation and maintenance of the domestic system requires implementation of the following recommendations.

- Conduct studies to determine: (1) overall status and response of the deep aquifer system and performance of the deep wells; (2) impact of continued or increased pumping demand; (3) changes in water quality; (4) extent of sanding problems in the deep wells; (5) a rehabilitation/replacement plan for the wells; and (6) number and locations of ongoing domestic system water losses.

- Continue backflow prevention program; replace inaccurate well meters; perform well pump efficiency tests twice per year; and install automatic controls and remote monitoring at a central location on wells and distribution mechanical systems.

UTILITY SYSTEM OPERATIONS AND MAINTENANCE PROGRAM

The utility water system is used for landscape irrigation, greenhouses, and some laboratories. Water is supplied to the system from six wells drilled 300 to 500 feet below ground surface into the shallow/intermediate aquifer. The continued effective operation of the utility system requires implementation of the following recommendations.

- Conduct studies to determine the: (1) scope of work and funds needed to correct existing backflow deficiencies; (2) number and locations of ongoing system water losses; and (3) feasibility of isolating and protecting, at a minimal cost, a portion of the utility system without compromising the overall system integrity.

- Modify campus irrigation schedule to reduce peak and off-peak demand on the system.

- Eliminate present domestic uses of the utility system water.

- Continue the Backflow Prevention Program; replace inaccurate well meters; and perform pump efficiency tests twice per year.

WATER QUALITY AND REGULATORY COMPLIANCE

The existing Environmental/Liability Risk Assessment Team (ELRAT) which meets regularly to review and consider campus-related environmental matters should be formally organized and charged to review new regulations and pending legislation pertaining to all water disposal on the

campus. ELRAT should also review responses and actions pertaining to regulatory inquiries and reports. ELRAT water quality/disposal recommendations should be coordinated with the Campus Water Management Committee as determined appropriate. In addition the University should:

- Continue to ensure that the campus minimum standard for wastewater treatment is in compliance with all applicable laws, regulations, and permits; and continue to strengthen compliance through timely anticipation of the effects of pending rules and regulations and prompt internal reporting within the campus administration.
- Continue programs to clean up groundwater contamination in areas on campus that have already been identified; and develop and actively implement a program to identify and clean up other potential problem areas on University-owned property.
- Review existing groundwater water quality monitoring activities to identify the additional data needed to assure the campus applies procedures that adequately monitor groundwater water quality and trends.
- Continue to work cooperatively with regional water quality regulatory entities.

DRAINAGE AND FLOOD CONTROL

The 1994 UC Davis LRDP eliminated the major drainage improvements that would have been necessitated by the development planned in the 1989 LRDP. However, some changes associated with planned development and anticipated regulatory requirements will be required as follows.

- Increase main pump station capacity to 130 cubic feet/sec to meet capacity requirements and to provide some redundancy for pump failure.
- Maintain the banks on the north fork on-site detention basin.
- Determine if it is necessary to separate drainage from the Cole Facility, areas adjacent to the Veterinary Medical Teaching Hospital and a portion of the Equestrian Center from the general drainage system.
- Provide oil separation for new parking areas.
- Connect new facilities adjacent to Hopkins Tract to the Hopkins drain line; and provide retention basins for major new facilities that cannot be connected to the Hopkins drain line.

- Provide retention basins for new facilities such as Center for Comparative Medicine and California Automobile Research Test Site (CARTS), rather than increasing runoff to the Covell drain.

- Maintain separate drainage for outdoor ½-acre California Regional Primate Research Center field cages from the general drainage system.

- Provide collection and disposal systems, if development occurs, on the south campus west of Old Davis Road in the enterprise or support services zones.

- Provide storm drainage retention ponds for areas of improvement on the Russell Tract.

PUTAH CREEK STEWARDSHIP

The University should continue to pursue Putah Creek instream flows that are adequate for its teaching and research needs and to meet its public trust responsibilities. Simultaneously, the campus should continue to monitor and manage Putah Creek as an important component of its surface and groundwater supplies. Campus actions should include:

- Continue active participation in the legal, regulatory, and political process related to ensuring adequate flows in lower Putah Creek needed to protect groundwater recharge, fish populations, and the aquatic and riparian ecosystems

- Preserve riparian rights to surface water.

- Develop a regional Putah Creek Technical Advisory Committee that is representative of those agencies and constituencies with legitimate interests in the continued health of Putah Creek and surrounding environs.

- Perform a ground level survey of campus irrigation wells, establishing a U.S. Geological Survey benchmark at each site.

WATER CONSERVATION

Water conservation should be a continuing and active goal of the campus. Facilities Services, Agricultural Services, the College of Agricultural and Environmental Sciences, and the School of Veterinary Medicine have special water conservation management responsibilities given their day-to-day management of water supplies in support of the campus academic, domestic, and utility uses.

Facilities Services should continue to expand its conservation efforts and place special emphasis on coordinating additional educational awareness programs. Conservation through education and technological advances will reduce peak and annual water demands.

CONTINGENCY PLANNING

The campus Water Management Committee should supervise development of contingency plans that respond to the following conditions:

- Severe drought created by an annual rainfall of less than 8" in one or more consecutive years and a long-term drought of more than five consecutive years with less than 15" of annual rainfall.
- Interruption and/or destruction of the campus water systems due to major disasters such as earthquakes, fires, or floods.

COORDINATED FUNDING OF WATER PROJECTS

The UC Davis Water Management Committee should develop an integrated and prioritized water resources package of minor and major capital improvement items that should be pursued over the next 10 years. This package should include items recommended for field teaching and research; domestic and utility services; water disposal, treatment, and contamination; water conservation; and hydrologic studies. All items should be analyzed in terms of benefits and costs and prioritized by years over the 10-year period. This package should be reviewed and updated annually.

Chapter 1

INTRODUCTION

The **UC Davis Water Management Plan** seeks to provide sufficient water of adequate quality to fulfill the teaching, research, extension, public service, and land management responsibilities of the campus. The campus must also fulfill its responsibilities for public trust of natural and renewable resources. This plan meets those primary planning goals by guiding present and future water development, conservation, disposal, and treatment, and by responding to the increasing water demands for domestic, utility, and field research and teaching uses.

The UC Davis Water Management Plan provides the most comprehensive analysis of historical use, present status, and future management of campus water resources ever prepared. Yet, the Plan does not attempt to provide definitive solutions for every circumstance, but rather recommends a number of water resource management actions to be pursued in greater depth within the context of the Water Management Plan while also taking into account the rapidly changing political, regulatory, and financial environment. For these reasons, the Plan will have to be regularly updated and the recommended actions carefully reconsidered during each revision.

THE UC DAVIS CAMPUS

UC Davis offers nearly 100 undergraduate majors and more than 70 graduate programs in the College of Agricultural and Environmental Sciences, the College of Engineering, the College of Letters and Sciences, the Division of Biological Sciences, and the Division of Education. In addition, UC Davis has four professional schools: the School of Law; the Graduate School of Management; the School of Medicine; and the School of Veterinary Medicine. The Davis Campus is a community of more than 31,000 persons, consisting of 21,000 students and 10,000 faculty and staff. UC Davis is one of the largest employers in the region, second only to the State of California. The campus directly infuses approximately $300 million into the Yolo County economy and $1.17 billion into the region through wages and benefits, and expenditures by students and visitors.

The Physical Campus: The Davis Campus is physically the largest campus in the UC system, at almost 5,200 acres. For planning purposes the Davis Campus is divided into two major areas, the **main campus** and the **Russell Tract**. The main campus is further subdivided into the central campus, south campus, west campus between Highway 113 and Road 98, and west campus to the west of Road 98 (Figure 1-1).

- The **central campus** is comprised of approximately 840 acres and is located east of Highway 113, north of Interstate 80, south of Russell Blvd, and west of the downtown area of the City of Davis.

- The **south campus** is comprised of approximately 600 acres and is located south of Interstate 80, north of the south fork of Putah Creek and bounded by private property to the east. The area is bisected by the Southern Pacific Railroad tracks and Old Davis Road.

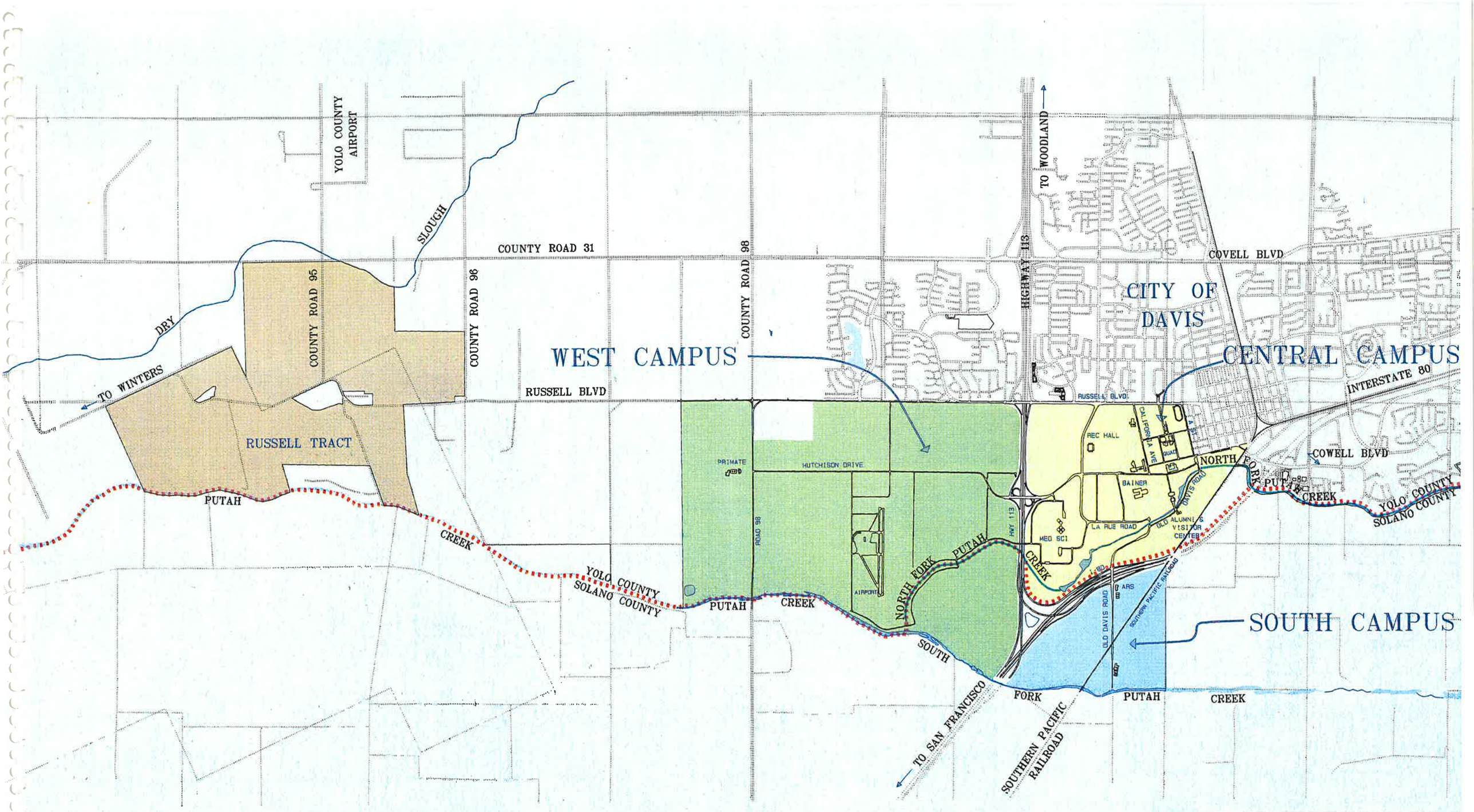
- The **west campus between Highway 113 and Road 98** is the larger section of the west campus and is comprised of approximately 1,700 acres. This part of the campus is bounded by Highway 113 on the east, Road 98 on the west, Putah Creek on the south, and Russell Blvd on the north.

- The **west campus** to the west of Road 98 is comprised of approximately 450 acres. It is bounded by Putah Creek on the south, private property to the west, Russell Blvd to the north, and Road 98 to the east.

- The **Russell Tract** is located approximately 1 ½ miles west of the main campus and is comprised of approximately 1,590 acres. It is bordered roughly by County Road 96 on the east, Putah Creek on the south, Covell Blvd (Road 31) on the north, and Russell Blvd on the northwest.

THE PLANNING PROCESS

Water management is multidimensional and complex requiring planning, design, construction, operation, and maintenance. It must also take into account technological capability, social attitudes, economic realities, political viewpoints, and environmental goals. For these reasons, water management must be proactive, continual, and well coordinated among campus community members and regional agencies. The Water Management Plan Task Force initially developed the overall planning goal and the planning objectives for the plan. The Task Force then identified the planning



DRAFT UC DAVIS WATER MANAGEMENT PLAN

FIGURE 1 - 1

REGIONAL AND LOCAL SETTING

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assumptions that would further guide preparation of the plan. The planning goal, objectives, and assumptions are presented in Chapter 2, Water Management Planning Goal, Objectives, and Assumptions.

CAMPUS WATER SUPPLIES, SYSTEMS, AND DISPOSAL

Planning for the future requires a clear understanding of the present circumstance. Thus, this Plan provides campus planners with an extensive overview of the campus water supplies, the three separate water systems, and wastewater and storm water disposal systems. Regional hydrology information is also provided because it plays such a vital role in plan preparation. Regional hydrology is important because of the geographical location of the campus; campus dependence on both surface and groundwater; the extent and timing of campus water demands, uses, treatment, and disposal; and the occurrence of droughts and floods. The campus water supplies include groundwater from two major aquifer systems and surface water from three sources. The surface water sources are: (1) Putah Creek water pumped at the Russell Tract pursuant to a riparian right; (2) Putah Creek water delivered through a University owned pipeline connected to the Putah South Canal pursuant to a contract with the Solano County Water Agency; and (3) Cache Creek water delivered by the Yolo County Flood Control and Water Conservation District to the Russell Tract. Campus water supplies are distributed through three largely separate systems: domestic, utility, and field research and teaching. The campus operates its own Wastewater Treatment Plant and also must handle water disposal from several other facilities including the Putah Creek Aquaculture Facility and the Institute of Ecology Aquatic Center. A comprehensive overview of Campus Water Supplies, Systems, and Disposal is presented in Chapter 3.

THE WATER MANAGEMENT PLAN

The Plan findings and recommendations are presented in Chapters 4 through 9 addressing the following major topics.

- Chapter 4 presents **Field Teaching and Research Water,** describing current water sources, supply deficiencies, and irrigation infrastructure. The extremely important characteristics of water quality are discussed with reference to suitability of existing and potential sources for all campus water uses. Water demands are projected to the years 2006 and 2046.

- Chapter 5 describes **Domestic and Utility Water Uses** with emphasis on existing sources, users, and infrastructure. Peak hourly demands and annual consumption data are projected to 2006 based on the UC Davis Long Range Development Plan (LRDP) and beyond to the year 2046 based on possible additional growth projections. Four domestic water reuse alternatives are analyzed, including field research and teaching irrigation, landscape irrigation, landscape impoundments, and cooling tower makeup.

- Chapter 6 addresses **Surface Water Management**, including the Solano Project, releases to Putah Creek, and flood control measures. It examines a number of surface water issues affecting future planning including: groundwater recharge, surface water diversions for field research and teaching, municipal, and utility uses; the University's responsibilities for public trust and environmental values. Drainage and flood control measures are assessed in the context of development potential identified in the 1994-2006 UC Davis LRDP.

- Chapter 7 addresses **Water Disposal, Treatment, and Contamination** describing the existing conditions of the wastewater and storm water discharge systems, the influence of Campus landfills, and water quality for both surface and groundwater. This chapter provides a comprehensive description of a complex campus with unique systems and needs. The Wastewater Treatment Plant, septic systems, the Putah Creek Aquaculture Facility, and the Aquatic Center at the Institute of Ecology are carefully examined to assure development of effective and cost-efficient future plans.

- Chapter 8 reviews the progress and status of **Water Conservation** since 1973 and defines a strategy for promoting efficient water management in the context of the longer term, including guidelines for emergency water management efforts in response to droughts.

- Chapter 9 explores **Potential New and Reclaimed Water Sources** based on the predicted need for significant increases in the water supply for both the main campus and the Russell Tract. Internal and external options for additional water are described along with factors that must be considered. A long and costly process must be anticipated given the infrastructure required to import supplemental water, uncertainties associated with water rights, complexities of joint ventures, and the realities associated with environmental values.

Chapter 2

PLANNING GOAL, OBJECTIVES, AND ASSUMPTIONS

PLAN GOAL

To develop and implement a Water Management Plan for UC Davis that will provide sufficient water of adequate quality and reasonable cost and reliability to fulfill the teaching, research, extension, public service, and land management responsibilities of the campus.

PLAN OBJECTIVES

1. Optimize the volume, timing, and quality of water required through good management practices including development and implementation of feasible water conservation technologies.

2. Ensure that water treatment and discharges from the University do not degrade the quality of groundwater, Putah Creek, or storm drainage to levels considered unsafe for the human or natural environment.

3. Protect and develop the University's legal and institutional rights to necessary sources of water, including both water used on campus and adequate in-stream flows in Putah Creek.

4. Achieve the UC Davis management goal consistent with the University's responsibilities and opportunities for water development and management on a regional basis and through joint ventures.

5. Anticipate management scenarios that might be necessary in the event of a major disaster, e.g., earthquake, flood, fire.

6. Recommend actions necessary to implement the plan.

PLANNING ASSUMPTIONS

Numerous explicit and implicit assumptions have been used to prepare the Water Management Plan. Those assumptions presented here potentially affect most aspects of water management planning and were used throughout the report. Planning assumptions specific to particular topics are described in appropriate chapters of the plan.

When it was necessary to make assumptions about future conditions, a worst case scenario was adopted and reflected in the planning assumptions. Worst cases were projections requiring an extreme in planning such as the greatest water supply needed or the maximum need for flood protection. This planning strategy was used to maximize the probability that future conditions would be adequately addressed in the Water Management Plan.

UC Davis Mission

- The overall mission of the University of California will not change substantially between now and the year 2046. The University will continue to serve the state as a center of higher learning and will have obligations for undergraduate, graduate, and professional education, research, and public service.

- The UC Davis campus will continue to support a strong land-based program in education, research, and public service with agricultural and environmental activities making major demands on land and water resources. These programs will remain a vital part of the campus through the year 2046.

Physical Extent of the UC Davis Campus

- The Water Management Plan will fulfill the Planning Goal and Objectives for the existing campus. Subsequent to the completion of the Water Management Plan, plans will be prepared as needed for other holdings administered by the UC Davis campus.

- If the acreage of the campus expands during the next 50 years, the need for water on these lands will be a factor in considering whether to expand and will then be reflected in a future revision of the Water Management Plan.

Climate

- Annual rainfall will continue to be highly variable between years with extended periods of drought and extremely wet years with potential for flooding. The Water

Management Plan will anticipate these periods of excess and deficiency along with extended periods of heat and cold and will incorporate measures to accommodate these fluctuations.

- Climate change due to global warming or other anthropogenic causes will not significantly affect water requirements and supplies through the short-term planning horizon (i.e., 2005-2006).

- Global climate change may affect water requirements and supplies during the 50-year time frame for the Water Management Plan. These changes may make the region more dependent either on imported water or on groundwater. The Water Management Plan will anticipate this potential general drying trend and will incorporate measures to accommodate these potential changes. The exact timing of these effects cannot be predicted accurately, and emphasis will be placed on securing adequate water sources sooner rather than later.

- Global climate change could affect flood control planning and surface water management actions during the 50-year time frame for the Water Management Plan. These changes may result in higher sea levels, increased rainfall, and more flooding. The exact timing of these effects cannot be predicted accurately, and emphasis will be placed on developing sufficiently flexible flood control and surface water management programs.

Major Disasters

- Events such as earthquakes, major power outages, dam breaks, and land subsidence are potential major disasters with small, but finite probabilities of occurrence. The Water Management Plan will include measures necessary to minimize the emergency, temporary, and long-term physical and financial measures required to react to these emergencies.

Regional Setting

- The population of California will continue to increase for the next 50 years.

- Population growth will continue to radiate outward from existing population centers.

- Population growth will occur first along major transportation corridors.

- The corridor between Sacramento and the San Francisco Bay area will a major area of growth between now and 2046.

- The predominant land uses adjacent to UC Davis may be primarily urban by the year 2046.

- As the population grows in Yolo and Solano Counties, the demand for municipal and industrial water will increase, having an impact on both ground and surface water.

- Elevated regional demand for water will generate increased use of groundwater including withdrawals from the deeper aquifers now used by a small number of users. These aquifers are known to be confined and isolated; and the potential for their overdraft is high.

Campus Growth - LRDP Planning Horizon (2005-06)

- Campus population will increase from 21,060 students and 9,550 employees in the 1992-93 academic year to 26,000 students and 12,630 employees in the 2005-06 academic year.

- Campus facilities will increase from a base of 4,745,000 assignable square feet (ASF) in 1993 to a maximum of 6,500,000 ASF in the 2005-06 academic year, depending on funding.

- By the year 2005-06, the central campus (i.e., north of I-80 and east of Highway 113) will be a built landscape consisting of developed and landscaped areas.

- New development on the west and south campus will occur at limited sites adjacent to I-80 and Highway 113 or adjacent to existing development such as around the University Airport and Agricultural Services. For a full description please see the 1994 UC Davis LRDP.

- Development on the Russell Tract will be limited to approximately 20 acres identified for the replacement and relocation of livestock facilities currently on the main campus.

- Except as described above, lands south of I-80, west of Highway 113, and the Russell Tract will remain in current land uses.

Campus Growth - 50-Year Planning Horizon (2046)

- As the state and local population continue to grow through the year 2046, the UC Davis population will likely also grow beyond the targets established in the LRDP.

- Existing agricultural lands on campus will be reduced as the developed portion of the campus expands; impacted research will be accommodated by the Russell Tract.

- Total domestic and utility campus water use in the year 2046 could increase by as much as 25 percent above quantities used in 2005-06. Water for field teaching and research would not increase above 2005-06 volumes unless there is a change in the campus land base.

- Improved technology will allow domestic and utility uses of water currently used for agriculture.

Campus Water Supply, Usage, and Disposal

- Domestic water conservation measures, implemented as LRDP mitigation measures, will result in a net reduction of domestic water use when calculated on a per capita or per square foot basis.

- Pumping costs will continue to increase.

- Surface and groundwater supplies will be managed as an integrated system.

- Highest quality, lowest-cost water will be allocated in support of field research and teaching, e.g., use of Solano Project water for field research, etc.

- Campus development and activities will be planned and managed so they do not degrade surface, ground, treated, or drainage waters either on the campus or in the region.

- Management of all campus water will meet all applicable local, regional, and federal specifications and requirements for water quality.

- Improved technologies, and the economics associated with those technologies, will increase the viability of treating and reusing waste water.

- Putah Creek is an integral part of the campus water system and will become increasingly valuable as an aesthetic, recreational, and scientific resource.

- Withdrawals from the shallow and intermediate aquifers for agricultural uses will decrease as agricultural lands in the region are converted to other uses. Simultaneously, the need for domestic and utility water will increase.

- Elevated campus demand for water will generate increased use of groundwater including withdrawals from the deeper aquifers now used by a small number of users. These aquifers are known to be confined and isolated, and the potential for their overdraft is high.

Regional Coordination/Cooperation

- UC Davis will play a major role in regional water management issues and programs including development of new sources, conservation of existing water supplies, transfers between local users, protection from floods, and coordinated management of groundwater.

- The University will work cooperatively with the Cities of Davis, Woodland, Winters and West Sacramento, Yolo and Solano Counties, and other appropriate public entities.

- The University will continue to pursue actions to protect its legal entitlement to Putah Creek riparian and groundwater recharge rights and to protect appropriate in-stream flow requirements necessary to accommodate field research and teaching programs. The University will also exercise its stewardship of the public trust doctrine as it applies to Putah Creek.

Chapter 3

AN OVERVIEW OF CAMPUS WATER SUPPLIES, SYSTEMS, AND DISPOSAL

Regional hydrology is defined as the distribution, movement, and quality of water on the earth's surface, underground, and in the atmosphere. It defines the physical and biological system within which the plan must be developed consistent with long-range planning goals and prevailing economic, legal, and political constraints. Understanding regional hydrology is an important element of this management plan due to: (1) the geographical location of the campus; (2) the campus's dependence on both surface and groundwater, (3) the extent and timing of campus water demands, uses, treatment, and disposal; and (4) the occurrence of extreme water resources events (i.e., droughts and floods).

The regional hydrology influencing the water resources of the UC Davis campus is dependent on the physiography, surficial geology, and topography of Putah and Cache Creeks and the Sacramento River basin. Coupled with these factors are vegetation and crops, surface land uses, and groundwater movements. Consequently, regional hydrology does not conform to rigidly defined physical, institutional, or political boundaries. The geographical location of the campus is: (1) adjacent to Putah Creek; (2) over groundwater aquifers that are influenced by the runoff of both Putah and Cache Creeks and drawn upon by the City of Davis and other numerous agricultural and domestic water pumpers in all directions; (3) within the surface water drainage and distribution systems originating from Putah and Cache Creeks; and (4) relatively close to the Sacramento River and its contribution to regional water supplies and drainage.

WATER SUPPLIES

Campus water supplies have been developed with a need for high quality and reliable surface and groundwater sources to provide for research, teaching, and domestic and utility water needs. These needs dictate specific timing requirements that do not correlate well with regional hydrologic

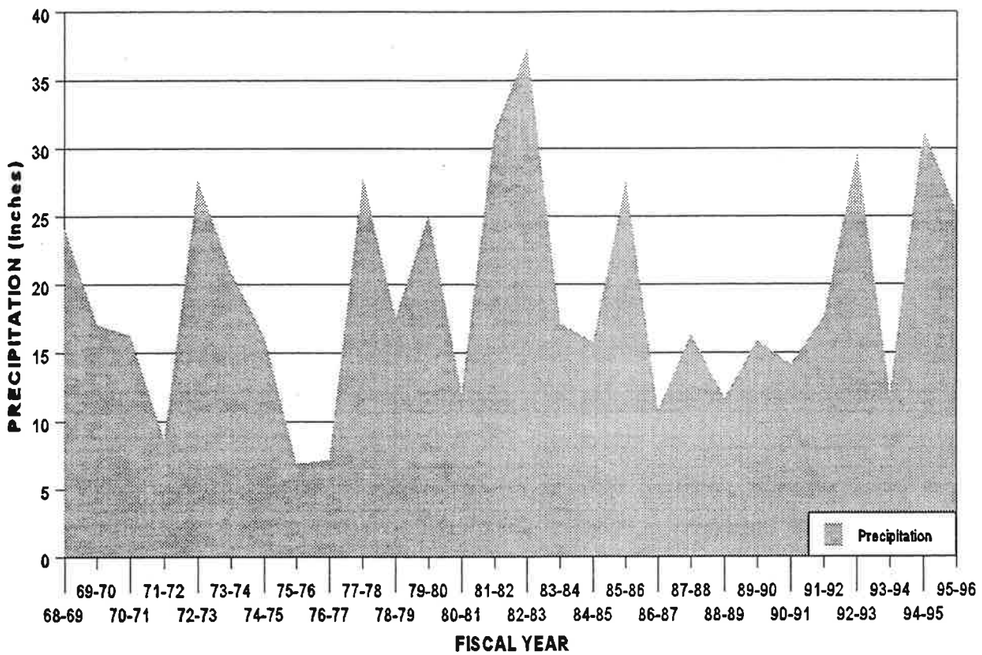


Figure 3-1 - Annual precipitation at the main campus from fiscal year 1968-69 through 1995-96. Precipitation data from the National Oceanic and Atmospheric Administration reference climatological station operated by the UC Davis Department of Land, Air, and Water Resources.

characteristics and climatic of wet winters and dry summers. Also, the potential occurrences climatic extremes such as droughts or floods can affect the reliability of water supplies. The local region is periodically subjected to droughts such as that experienced in 1976-77 and 1989-94 (Figure 3-1). It should be noted that droughts in past centuries have extended over periods longer than any experienced in this century.

SURFACE WATER

Surface water supplying the campus comes from Putah and Cache creeks. Historically, the natural flows in both creeks occurred primarily in the winter months, and during the summer months surface water occurred only in these creeks in isolated pools. A major exception to this general pattern is permanent flows along Putah Creek due to rising groundwater in the vicinity of the Russell Tract. The campus has riparian rights on Putah Creek and the Russell Tract, and along with the

tenant farmer has exercised these rights annually since the campus acquired the Russell Tract in 1991. The volume and duration of water available depends on the seasonal hydrologic conditions and groundwater inflow and outflow.

The University also has riparian water rights for parcels on the main campus that are contiguous to with Putah Creek. The Campus has not recently diverted surface water onto the main campus property from Putah Creek. However, this potential water source could be used in the future if the timing, quality, and volume available were appropriate for beneficial campus uses.

The natural flow of Putah Creek was changed by the completion of Monticello Dam in 1959 and by construction of the Putah Diversion Dam west of Winters to divert water into the Putah South Canal. Rights to the stored water behind Monticello Dam and to the diverted water are held by the U.S. Bureau of Reclamation which sells this Solano Project water to the Solano County Water Agency (SCWA).

The University, as a member unit of the Solano Project, entered into a 40-year contract for the annual purchase of 4,000 acre-ft of Solano Project water from SCWA. To accommodate the delivery of the water to the campus, the University negotiated a right-of-way with private landowners and constructed a pipeline from the Putah South Canal to the main campus. The water is distributed on the campus to various field teaching and research activities. This water is an excellent and generally reliable supply because it has less than 200 parts per million total salts and no undesirable constituents. Reductions in deliveries from the Solano Project can occur during drought conditions.

The campus also uses surface water from Cache Creek at the Russell Tract. Most of the flow in Cache Creek during the spring and summer is controlled by diversions by the Yolo Flood Control and Water Conservation District, which sells and distributes water to agriculturalists through the District's distribution system. The University is a customer of the District and receives water via the Willow Canal, which parallels Putah Creek and terminates on the main campus. The water has limited use on the campus because of the relatively high boron content, weed contamination, and the uncertainty of delivery each year, since amounts for sale are limited and depend on the storage in

Clear Lake. The reliability of delivery was improved somewhat by the District when it constructed the Indian Valley Dam in the late 1960s on a major tributary to Cache Creek.

GROUNDWATER

Groundwater is a vital and important source of water for the campus. The aquifers underlying the campus are alluvial deposits that were generated in the watersheds of Putah and Cache Creeks and the Sacramento River. Eroded material was transported and deposited in the Davis area as the velocity of the water carrying the material decreased. As a result there are multiple layers or strata of sand and gravel that are the major water-producing materials.

Deep gravel and sand aquifers exist between 800-1500 feet below ground surface (bgs). These aquifers are fine in texture, confined by very low permeability clays, and have very limited lateral and vertical recharge. They are identified as "deep aquifers" and are tapped by campus deep wells that supply water for the domestic water system. Static water levels in 1995-96 were approximately 100 feet bgs which was approximately the same depth as in 1981-82. Water from the deep aquifers is lower in total salts (< 250 ppm), higher in sodium (50 to 60%) and higher in temperature by 6 to 8°F than the groundwater pumped from the intermediate depth aquifers.

The "intermediate depth groundwater aquifers" are in the range of 150 to 800 feet bgs. They consist of sand and gravel with lenses of clay between the water-bearing strata. The thickness of good water-bearing aquifers varies from a few feet to 20 feet and more. Most are confined between layers of clay and are not continuous at the same relative depth. The confinement of these materials causes the static water level to rise to within 30 to 60 feet bgs. The pumping level is much lower depending on the volume and rate that water is pumped by the wells.

The intermediate depth aquifers are the source of water for the campus utility wells and wells serving the field teaching and research areas. The water levels of the intermediate aquifers are influenced by local and regional precipitation, runoff, recharge, hydrogeology and pumping. During the 1976-77 and 1989-94 droughts, water levels dropped sharply in intermediate depth wells. However, these water levels rebounded during the normal and above average precipitation years following each drought indicating local recharge of these aquifers. The water quality of the

intermediate aquifers is relatively hard (<600 ppm of calcium), but it has an acceptable level of sodium. The water has a temperature of about 67°F.

There are "shallow depth aquifers" below the campus in the range of 80 to 150 ft. These aquifers have good water-bearing characteristics and are generally unconfined. They provided water from the wells drilled during the 1920s, 1930s, and 1940s, and served domestic and some agricultural uses. These aquifers were inadequate to meet higher capacity demands associated with a growing Campus. Since the 1940s, wells have been drilled into the intermediate depth aquifers to achieve higher production.

CAMPUS WATER SYSTEMS

The campus water system is comprised of three separate supply and distribution systems distinguished by their uses: domestic, utility, and field research and teaching.

DOMESTIC SYSTEM

The domestic system is comprised of six wells with two elevated storage tanks totaling 300,000 gallons and an underground reservoir with a 1,500,000 gallon capacity (Figure 3-2). These six wells pump from the deep aquifer and are capable of a simultaneous production of approximately 5,150 gallons per minute (gpm). The system is used primarily to serve building occupancy requirements and for fire suppression, and it draws from the deep aquifer and provides better water quality than water drawn from the intermediate depth aquifers. Current annual consumption levels are approximately 760 million gallons per year (2,350 acre-ft/yr).

UTILITY SYSTEM

The utility water system consists of six wells drawing water from intermediate depth aquifers which irrigate approximately 980 acres of intensively landscaped areas (Figure 3-3). The six wells are capable of producing approximately 5,000 gpm of simultaneous discharge directly into the distribution system. Despite this seemingly large capacity, the system is frequently depleted during

peak irrigation times. Based on data through 1995, the annual demand on this system is approximately 300 million gallons per year (925 acre-ft/yr). The domestic and utility systems are cross-connected for emergency purposes only and are rarely mixed

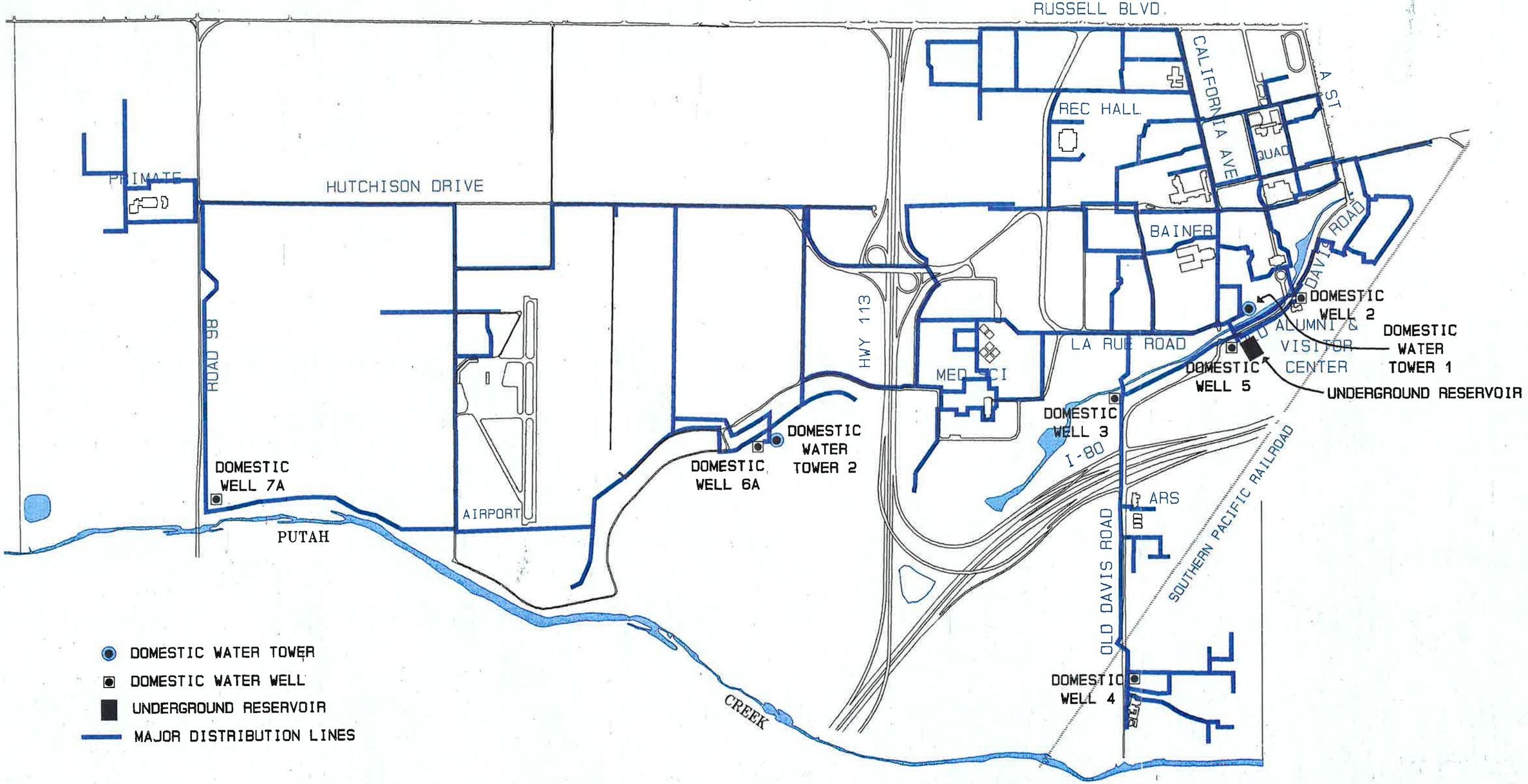
FIELD TEACHING AND RESEARCH SYSTEM

The largest campus water use is irrigation of lands used for field research and teaching. Between 1989 and 1995, the campus used approximately 9,600 acre-ft/yr for field teaching and research uses and for agricultural production at the Russell Tract. A combination of surface water and groundwater supplies are used to meet this demand.

Surface water from the Putah Creek watershed reaches the campus via the Solano Project through an 8¾ mile long, university-owned, 30" pipeline that originates at a turnout on the Putah South Canal. The terminus of the pipeline is a 65 acre-ft, concrete-lined storage reservoir located on the southwest corner of the main campus. This reservoir is recharged when user demand drops below the total volume of water being discharged from the reservoir and supplied directly form the pipeline. The water is then distributed to various field teaching and research areas via a system of pipelines and secondary reservoirs (Figure 3-4).

Surface water from the Cache Creek watershed is delivered to the main campus and the Russell Tract through the Willow Canal operated by the Yolo County Flood Control and Water Conservation District (Figures 3-4 and 3-5). The University owns the canal from the western boundary of the main campus and provides overflow discharge of excess water into Putah Creek near the 65 acre-ft reservoir west of the landfill (Figure 3-4). At the present time, Cache Creek water is used primarily by commercial farmers who lease Russell Tract lands not currently used for field teaching and research uses.

Groundwater for field teaching and research uses is obtained from irrigation wells in the intermediate depth aquifers and range in depth from approximate 300 to 800 feet bgs. The typical design capacity is 1,000 to 1,500 gpm. These wells may directly serve individual parcels, may be blended with other water sources, and may be used to fill the secondary storage reservoirs also connected to the Lake Berryessa supply system (Figure 3-4).



DRAFT UC DAVIS WATER MANAGEMENT PLAN

FIGURE 3 - 2

DOMESTIC WATER SYSTEM

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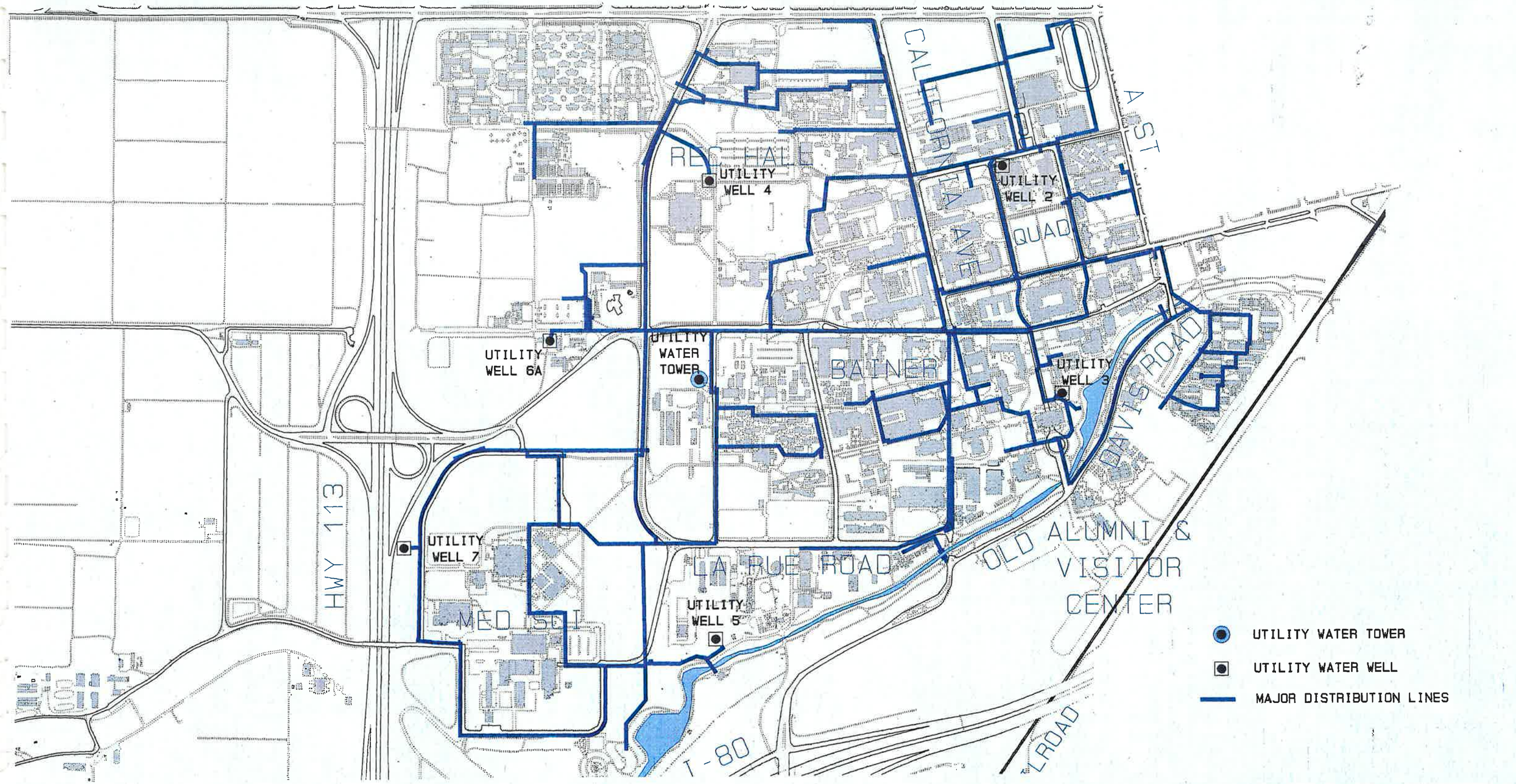

DRAFT UC DAVIS WATER MANAGEMENT PLAN

FIGURE 3 - 3

UTILITY WATER SYSTEM

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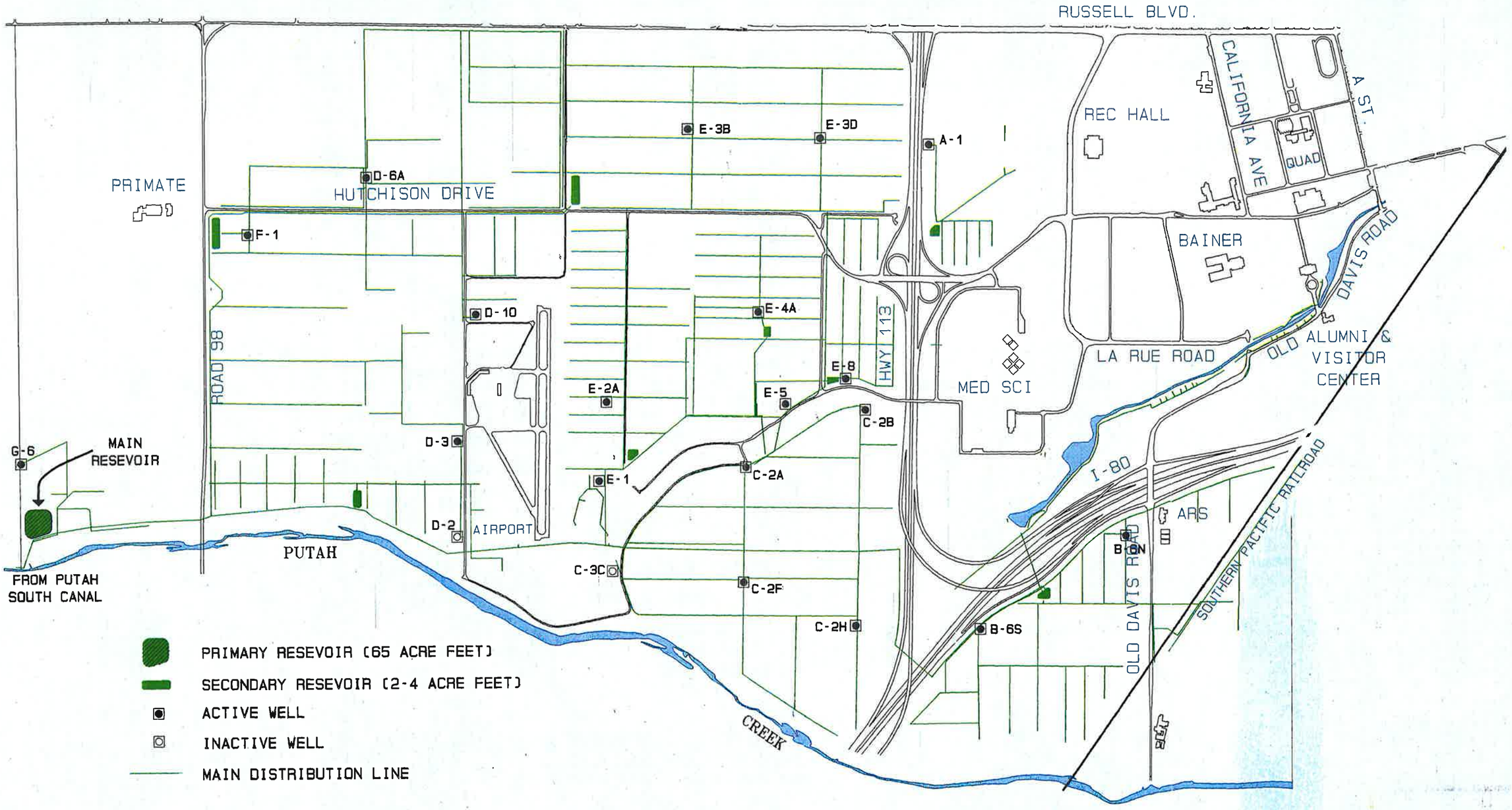

DRAFT UC DAVIS WATER MANAGEMENT PLAN

FIGURE 3 - 4

FIELD TEACHING AND RESEARCH WATER SYSTEM

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COUNTY ROAD 31

DRY SLOUGH

P1

P3

SCHMEISER HOUSE

COUNTY ROAD 95

R2W

P2

DITCH

R1E

COUNTY ROAD 96

RUSSELL BLVD.

RUSSELL BLVD.

RUSSELL BLVD.

H1

FAIRFIELD

L2

J3 UTILITY

KINSELLA LANE

M5

COUNTY ROAD 95A

J3

J1

WILLOW CANAL

K3

WILLOW CANAL

PUTAH CREEK LIFT STATION

PUTAH CREEK

SOLANO COUNTY

YOLO COUNTY

CANAL

PUTAH CREEK DIVERSION POINT

WELL

N

0 1/4 1/2 MILE

DRAFT UC DAVIS WATER MANAGEMENT PLAN

FIGURE 3 - 5

RUSSELL TRACT WATER SUPPLIES

OCTOBER 1997

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Irrigation practices for field teaching and research uses at UC Davis differ greatly from typical commercial farms. For example, the campus has invested in an underground distribution system that loses less water than a typical "open ditch" irrigation delivery method used on most farms. All irrigation on the campus is conducted during daylight hours, typically between 7:00 a.m. and 4:00 p.m. Evening or night irrigation is rare, and is practiced only on alfalfa hay fields or large horse pastures. Demand has outstripped capacity during periods of heavy use. The main supply line and laterals deliver an adequate flow of water, however, problems arise during periods of heavy use when demand from the smaller storage reservoirs exceeds local storage capacity.

WATER DISPOSAL SYSTEMS

WASTEWATER DISCHARGES

Discharge of wastewater from the University to Putah Creek is regulated through National Pollution Discharge Elimination System (NPDES) permits issued by the Central Valley Regional Water Quality Control Board (CVRWQCB). The University currently has NPDES permits to discharge wastewater from the wastewater treatment plant (WWTP), Putah Creek Aquaculture Facility, Institute of Ecology Aquatic Center, USDA Aquatic Weed Control Laboratory, and the Campus Landfill groundwater extraction and treatment system (Figure 3-6). Individual operating permits, effluent discharge limitations, monitoring requirements, and compliance records are discussed in Chapter 7 - Water Disposal, Treatment, and Contamination.

Wastewater Treatment Plant: The campus WWTP has been operational at its current site since 1949. It is located on the central campus south of La Rue Road between Fleet Services and the Cole Facility (Figure 3-6). The WWTP provides secondary treatment of domestic waste generated from most facilities on the central campus and several facilities in the south campus and west campus. Effluent is pumped to a discharge point on the south fork of Putah Creek approximately 100 feet west of Old Davis Road (Figure 3-6). In 1997, the University approved construction of a new WWTP because the existing facility is near capacity. This new WWTP will be located on the south campus (Figure 3-6). The new facility will be able to treat increases in flows, will be more reliable and

efficient, and will treat the effluent to a higher standard than the existing facility. The new plant is expected to be under construction in 1998 and in operation in 1999.

Putah Creek Aquaculture Facility: The Putah Creek Aquaculture Facility is a fish hatchery and aquatic research facility located on the west campus, west of the campus landfill and north of the Putah Creek levee road. Wastewater is discharged into Putah Creek at a point west of Road 98 and south of the landfill (Figure 3-6).

Aquatic Center at the Institute of Ecology: The Aquatic Center at the Institute for Ecology is located on the west campus, adjacent to the north fork of Putah Creek and east of the south end of the University Airport runway. Research at this facility focuses on aquaculture and aquatic systems. Effluent is discharged at three locations: the north fork of Putah Creek adjacent to the Aquatic Center; the south fork of Putah Creek south of Hopkins Road; and into an isolated evaporation/percolation pond west of the Aquatic Center (Figure 3-6).

USDA Aquatic Weed Control Research Laboratory: The USDA Aquatic Weed Control Research Laboratory is located at the intersection of the north and south forks of Putah Creek and is operated by the United States Department of Agriculture on property leased from the University (Figure 3-6). The laboratory was founded in 1963 to conduct research into aquatic plants and to assess the effectiveness and application rates of herbicides to control plant propagation. Fish culture has taken place at the facility since 1985. Wastewater from the greenhouses, laboratory, fish culture canals and headhouse is treated by activated carbon then discharged into two surface impoundments (ponds) for evaporation prior to discharge into the south fork of Putah Creek. A maximum flow of 75,000 gallons per day of treated wastewater is discharged to Putah Creek.

Campus Landfill: In 1995, the University installed a series of extraction wells and treatment units to remediate contaminated groundwater adjacent to the campus landfill. The campus has an NPDES to discharge treated effluent from the groundwater extraction and treatment facility to Putah Creek (Figure 3-6). However, because the University determined it could not economically meet all of the discharge limitations with an on-site treatment system, the treated water is currently being pumped to the campus WWTP. In the future, the University may elect to install additional treatment systems and begin discharging to Putah Creek.

RUSSELL BLVD.
REC HALL
CALIFORNIA AVE
QUAD
A
PRIMATE
HUTCHISON DRIVE
DAM
BAINER
SPAFFORD LAKE
DAVIS ROAD
SLUDGE DRYING PONDS
ROAD 98
CAMPBELL ROAD
HWY 113
ENVIRONMENTAL SERVICES FACILITY
INSTITUTE OF ECOLOGY AQUATICS CENTER
NORTH FORK CUTOFF
MED SCI
LA RUE ROAD
OLD ALUMNI & VISITOR CENTER
WASTE WATER TREATMENT PLANT
LANDFILL EXPANSION
ACTIVE LANDFILL
PUTAH CREEK AQUACULTURE FACILITY
PROPOSED LANDFILL GROUNDWATER TREATMENT OUTFALL
JAMESON POND
AIRPORT
DAM AND WIER
FOREBAY AND PUMPS
I-80
ARBORETUM WATERWAY (STORM WATER DETENTION POND)
ARS
SOUTHERN PACIFIC RAILROAD
OLD DAVIS ROAD
USDA AQUATIC WEED RESEARCH LAB
NEW WASTE WATER TREATMENT PLANT
PUTAH CREEK AQUACULTURE FACILITY AND UNIVERSITY LANDFILL STORM WATER OUTFALL
AIRPORT AREA STORM WATER AND INSTITUTE OF ECOLOGY AQUATIC CENTER OUTFALL
USDA AQUATIC WEED RESEARCH LAB OUTFALL
PUTAH CREEK
SOUTH FORK
CENTRAL CAMPUS STORM WATER OUTFALL
SOUTH CAMPUS STORM WATER OUTFALL
TREATED WASTEWATER OUTFALL
STORMWATER DRAINAGE AREA

N

0 1/2 1 MILE

DRAFT UC DAVIS WATER MANAGEMENT PLAN

FIGURE 3 - 6

MAJOR STORM WATER AND EFFLUENT DISCHARGES

OCTOBER 1997

USER=GDS MULTI=WRI

Septic Systems: Wastewater from buildings at the Russell Tract and most of the west campus except the California Regional Primate Research Center (CRPRC) and several facilities near the University Airport is treated via septic systems. Three structures on the central campus are not served by the WWTP use septic systems. All septic tanks on the campus are serviced by Facilities Services--Mechanical Plumbing Shop. Several abandoned tanks are located on the campus.

Miscellaneous Discharges: A small volume of field irrigation return water and water purged from the west campus water tower every 10-14 days is directed into the Caltrans pond located inside the intersection between I-80 and Highway 113. At the Russell Tract, a small volume of field irrigation return water also enters the slough south of Russell Boulevard and Dry Slough on the northern boundary of the ranch.

MAJOR STORM WATER DISCHARGES

In March 1992, the Campus filed a Notice of Intent with the RWQCB for coverage under the General Industrial Storm Water Permit. The facilities covered under the permit include the Wastewater Treatment Plant, Fleet Services, Unitrans Maintenance, the Campus Landfill, the inactive landfill Cell #3, and the University Airport Maintenance/Repair.

Central Campus: The storm water drainage system for the central campus collects runoff and ultimately discharges it into the south fork of Putah Creek at a point approximately ½-mile west of the Old Davis Road bridge (Figure 3-6). The Arboretum Waterway is a detention basin in this system. Runoff from many storms is retained in the Arboretum Waterway and is disposed of through either evaporation or percolation. Large storms cause the waterway to overflow into the pump pond at the west end of the waterway. Pumps are used to move this runoff south, under I-80 to the south fork of Putah Creek.

South Campus: Storm water runoff on fields west of Old Davis Road accumulates behind berms and roads delineating fields and either evaporates or percolates into the soil. East of Old Davis Road, a ditch drains runoff from Animal Resources Service, Equine Research Laboratory, Oncology, and ITEH into Putah Creek (Figure 3-6). The southern end of the ditch runs adjacent to and possibly

through a portion of an inactive landfill disposal cell. Recent soil sampling in and around the ditch identified potential landfill constituents near the surface.

West Campus: The west campus is not drained by a storm drainage system except in the vicinity of the University Airport and the University Landfill (Figure 3-6). During most storm events, runoff is intercepted by roads that divide the area into fields. These waters either evaporate or percolate on site.

Russell Tract: The Russell Tract is located on the north side of Putah Creek and drainage is to the east and northeast. The ranch does not have a storm drainage system. Most runoff is intercepted by the roads and canals that service the property, forms ponds on the property, and either evaporates or percolates. During some storm events, surface water may flow north into Dry Slough.

Chapter 4

FIELD TEACHING AND RESEARCH WATER

HISTORICAL SETTING

Teaching and research have been conducted on the Davis campus since 1905 when it was called the University Farm. Initially, the University Farm initially consisted of lands east of Highway 113 and north of the former north fork of Putah Creek. Water was supplied through a number of shallow aquifer wells that were either drilled by the University or acquired with the property. As the campus expanded to the south and west, additional wells were acquired and developed.

Provisions for bringing surface water to the Davis area from Cache Creek were ongoing during the early years of the campus. In June 1904, F. E. Russell deeded land to the Yolo County Consolidated Water Company to construct a canal along the north bank of Putah Creek from Winters to Davisville. Similar deeds were given to the water company by George W. Pierce, H. M. La Rue, and Ellen Campbell. Land sought for the canal also was obtained by condemnation as in the case of property owner C. W. Bush, representing the estate of Thomas Hext.

Campus records do not indicate the actual date of canal construction, but it is assumed to have been completed shortly after land acquisition. Documents pertaining to the construction, abandonment, and acquisition by The Regents and repair and maintenance of Willow Canal by the Campus are listed in Appendix C. All these documents are on file in the Shields Library Archives. The completed canal conveyed water from Clear Lake and Cache Creek to the town of Davisville. Between completion of the Willow Canal and the late 1960s, Clear Lake supplied a significant portion of the water used by the University. The most recent record of billing indicates that 1,524 acre-ft were delivered during the 1967 irrigation season at $4.75/acre-ft.

In 1959, the campus began to study the feasibility of bringing a new source of water to the University. The use of Clear Lake water as a supplemental source to groundwater was becoming less desirable. Quality was a problem for many cultivated plants sensitive to boron. Weed seeds and

reliability were also problems. A new source of water during the months of June, July, and August was desired to ensure adequate quality and quantity.

The engineering firm of Stoddard and Karrer of Los Banos was retained to study the feasibility of delivering Solano Project water to the campus. The Campus Committee on Water Utilization provided authorization for the study and worked with Stoddard and Karrer. Through information provided by the committee, it was determined that 11,000 acre-ft were needed annually, based on 4.0 acre-ft/yr on more than 2,750 cultivated acres. This quantity was considered "generous," but justified based on maintaining a balance of soluble salts. The committee calculated that approximately 7,000 acre-ft/yr could be obtained from existing sources and 4,000 acre-ft/yr would be needed from the Solano Project (Lake Berryessa water). Using this information, Stoddard and Karrer prepared cost estimates examining two methods of delivery: (1) increasing releases into Putah Creek and using the creek as a method of conveyance, and (2) constructing an underground pipeline to deliver water from a point of origin at the Putah South Canal. Stoddard and Karrer's final report was completed in September 1961. The capital costs for each method of conveyance were outlined, as were the annual operating expenses. No final recommendation was made at that time because the Solano County Flood Control and Water Conservation District boundaries did not yet extend to the campus and negotiation with the district was necessary.

In December 1962, the campus entered into a contractual agreement with the Solano County Flood Control and Water District (now the Solano County Water Agency). It was agreed that from 1963 to 1968, the University would only be billed for water delivered, up to a maximum of 4,000 acre-ft/yr. The campus began construction of a pipeline to deliver water from the Putah South Canal, and Stoddard and Karrer were selected to engineer the delivery system. For the remainder of the contract (1968 through 1999) the University is to be billed each February for the full 4,000 acre-ft. The contract expires in February 1999, but the University has an option for renewal, subject to renewal of the Master Contract between the U.S. Bureau of Reclamation and SCWA.

THE DAVIS CAMPUS TODAY

The Davis campus encompasses approximately 5,200 acres (Figure 1-1). The main campus, consisting of approximately 3,590 acres, is located along the southwestern boundary of the City of Davis. The main campus currently has approximately 2,000 acres allocated for field teaching and research, with the balance in facilities or non-agricultural open space. Approximately 2 miles west of the main campus is the Russell Tract, approximately 1,590 acres of farmland purchased by The Regents in August 1990. The 1994 UC Davis Long Range Development Plan (LRDP) identified the Russell Tract for field teaching and research and open space. As of 1996, approximately 147 acres had been assigned to the Long Term Research on Agricultural Systems program and is managed by the Sustainable Agriculture Research and Education Program. Capital improvements at the site include a new irrigation delivery system and a well. A field headquarters has also been established. The balance of land remains leased for production farming pending the initiation of new teaching and research activities at the Russell Tract.

CURRENT WATER SOURCES

Main Campus: Water purchased through the Solano Project contract and delivered via the campus distribution system has greatly enhanced the capability for field teaching and research. Past use suggests that of the 2,000 acres assigned for field research, approximately 1,500 acres will be irrigated annually. The 4,000 acre-ft/yr supplied from the Solano Project now constitutes 70-85% of annual irrigation water usage, with the balance provided by groundwater.

The system that supplies water for field teaching and research includes 21 wells in the shallow and intermediate aquifers; 19 of these wells were in active operation in 1996 (Figure 3-4 and Table 4-1). Many of these wells were acquired with the property, including four drilled on the Campbell Tract in 1932. Irrigation needs on the main campus will continue to be met primarily through water delivered from the Solano Project and secondarily from wells. Water from Clear Lake via Cache Creek and Willow Canal has not been used for teaching and research on the main campus since the

Table 4-1 - Inventory of groundwater and surface water supplies on the main campus for field teaching and research

Groundwater Supply	Completed	Depth (ft.)	Design Capacity		Parcels Served[1]
			gpm	cfs	
Well A1	1952	300	2,900	6.4	A1
Well B6N	1964	635	1,300	2.9	B3, B4, B6
Well B6S	1972	500	1,000	2.2	B6, B8, B9
Well C2A	1932	248	1,100	2.4	C2A, C2C, C2D
Well C2B	1932	285	1,215	2.7	C2A, C2B, C2D, C2E
Well C2F	1932	250	650	1.4	C2F, C2G
Well C2H	1932	244	650	1.4	C2G, C2H
Well C3C[2]	1932	270	820	1.8	C3
Well D2[2]	1946	538	1,300	2.9	D2
Well D3	1936	382	1,650	3.7	D4
Well D6A	1936	416	2,500	5.5	D6, D7, F1
Well D10	1939	529	1,400	3.1	D8
Well E1	1993	280	1,000	2.2	Aquatic Center
Well E2A	1948	250	800	1.8	E2A, E2B
Well E3B	1952	240	1,000	2.2	E3
Well E3D	1972	455	1,800	4.0	E3
Well E4A	1956	340	1,000	2.2	E4A, E4B
Well E5	1958	344	650	1.4	E5
Well E8	1972	517	1,400	3.1	E8
Well F1	1955	220	1,300	2.9	F1, D6
Well G6	1962	400	400	0.9	Putah Creek Aquaculture Facility

Surface Water Supply	Origin	Design Capacity	Parcels Served
UCD main delivery pipeline	Berryessa	rated @ 25 cfs	all except A1
UCD main storage reservoir	Berryessa	65 acre-ft	all except A1
UCD secondary reservoirs (8)	Berryessa	25 acre-ft	all

[1] All parcel locations refer to campus Land Assignments Map.
[2] Not in active operation.

Table 4-2 - Inventory of groundwater and surface water supplies at the Russell Tract

Groundwater Supply	Completed	Depth (ft.)	Design Capacity		Parcels Served[1]
			gpm	cfs	
Well H1	unknown	unknown	800	1.8	H1
Well J1	unknown	unknown	743	1.6	J1, H1, ditches, canals
Well J3	1992	399	1,650	3.6	J2, J3
Well J3 - Utility	1947	unknown	unknown	unknown	Landscape, sewer, not potable
Well K3	1980	760	1,100	2.4	K1- K5, L1
Well L2	1948	425	1,037	2.3	L2, L3
Well M5	1947	495	400	0.9	K6
Well P1	1959	512	2,045	4.5	P1
Well P2	1954	450	1,292	2.9	P1, P2
Well P3	1959	672	1,578	3.5	P3, P4
Well R1E	1947	391	950	2.1	R1, P5, M3
Well R2W	1978	764	2,109	4.7	R2, R3

Surface Water Supply	Origin	Design Capacity		Parcels Served
		gpm	cfs	
Willow Canal	Clear Lake	9,000	20.0	All except P1, P3, P4
Putah Creek lift station	Putah Creek	4,190	9.3	H, J, L, M

[1] All parcel locations refer to Russell Tract land assignment map. Water from well J1, Putah Creek and Clear Lake may be commingled and delivered to crops via existing canal and ditch systems. Well J3 drilled by the University in 1992 is dedicated to serving field research in the parcels shown. All other parcels are leased for production farming.

late 1960s, although surplus tailspill is discharged annually on property owned by The Regents and assigned to the Putah Creek Reserve.

Russell Tract: The Russell Tract receives water from three sources: 12 shallow and intermediate aquifer wells with 10 in current operation (Table 4-2, Figure 3-5); Clear Lake via the Willow Canal; and surface diversions from Putah Creek. The majority of water is purchased by the Russell Tract lessee through an annually renewable agreement with Yolo County Flood Control and Water Conservation District and is delivered via the Willow Canal. Wells provide a secondary source, supplementing Clear Lake supplies and providing water to field research. Putah Creek also provides a portion of water delivered to the tract based on riparian water rights, but is limited by the capacity of two lift pumps and water availability in the creek.

SUPPLY DEFICIENCIES

Main Campus: Irrigation records since 1973 indicate water supply has not been a significant problem except during periods of drought. The first drought within this period occurred between 1976 and 1978, and a study of campus water systems was undertaken by Joe Scalmanini, then Associate Development Engineer, UC Davis Department of Land, Air, and Water Resources. Working with the Chancellor's Campus Water Committee, Scalmanini (1978) concluded that regional groundwater was being depleted at the rate of 1.0 ft/yr. The report also projected that water use on the main campus would increase 16% by 1990. Projections of declining groundwater levels and increased water use did not materialize. During the 10 years following the Scalmanini report, rainfall was substantially above normal and groundwater levels increased, reaching levels previously recorded in the late 1950s and early 1960s. Water use declined as open land allocated for production farming was converted to research plots.

The University must be vigilant in its concern about an adequate quantity of high-quality water for long-term teaching and research needs. Water supply concerns should focus on continued delivery of Solano Project water, regional population increases, and drought. In 1992, the sixth consecutive year of a drought, SCWA limited releases from the Solano Project and reduced deliveries to all member units; the campus allocation was reduced by 21.5% during the 1992-93 contract year. Fortunately, conservation of Solano Project water during prior years provided carryover water to meet this deficit.

The University must be alert to the opportunities and the risks associated with the contract renegotiation prior to the February of 1999 expiration for Lake Berryessa water. At this time, the financial terms of the renegotiated contract are uncertain. During 1993 and 1994, legislation that would have transferred the Solano Project including Monticello Dam to Solano County was seriously pursued by the SCWA, but the proposed legislation was not enacted.

Deficiencies related to groundwater supplies are of concern, but must be kept in the context of groundwater use on the Davis campus. The majority of campus irrigation wells tap intermediate depth aquifers, which have been relatively stable over the last 30 years. Therefore, it is concluded

that short-term irrigation demands will be driven by changes in land use. For instance, if a change in land use significantly increases the need for groundwater, the University might find that the shallow or intermediate water aquifers are no longer adequate in terms of supply. Long-term irrigation demands will be driven by changes in land use, a reallocation of resources to municipalities, or new rulings brought about as a result of legislation and water rights adjudication. The impact of these actions is uncertain. In any event, continuing the contract for Solano Project water into the 21st century is vital.

Russell Tract: The Russell Tract does not always have an adequate supply of water to meet the needs of production farming and field research. Production farming is primarily served with Clear Lake water delivered via the Willow Canal and is generally available during the summer months. During drought years, Clear Lake water supplies have been limited or unavailable. During the summer of 1990, no Clear Lake water was delivered to Russell Tract. The following year was slightly better with a release at 35% of normal. These reductions resulted in the fallowing of farmland and rotation to dryland crops with lower revenue potential.

Of the 147 acres currently assigned for teaching and research, approximately 72 require irrigation which is provided from an intermediate aquifer well drilled by the University in 1992. As teaching and research activities expand, additional wells or an alternative surface water supply may be required. Clear Lake water remains unsuitable for crop research due to elevated levels of boron. Clear Lake water also poses problems for research involving aquatic animals. It lacks reliability of delivery, carries a high organic load, and is subject to turbidity. These characteristics make it unsuitable as year-round life support for aquatic animals. Pricing stability of Clear Lake Water must also be considered. Water is sold on a year-to-year basis with no price guarantee. During 1991, a 35%-of-normal supply was provided at $25.00/acre-ft. This is in contrast to a normal year supply in 1989 at $15.00/acre-ft.

Existing groundwater supplies on the Russell Tract have also proven less than desirable. Ten wells serve 1,443 acres of leased farmland through a ditch irrigation system, but capacity is inadequate during periods of drought or when there is a reduction in Clear Lake water. Groundwater

Table 4-3 - Utilization of the main campus irrigation system[1]

Water Supply	Design Capacity (cfs)	Ave. Demand (cfs)	Utilization (%)
Putah South Canal Pipeline[2]	25	21	84
Main reservoir lift pumps	10	10	100
Irrigation wells[3]	54	10	19

[1] Typical summer demand illustrated above.
[2] Reservoir water also supplied from the Putah South Canal Pipeline. Reservoirs supplement pipeline deliveries during the day, and are recharged at night when irrigation activities are reduced.
[3] Includes wells used in irrigation of research crops, does not include wells which support Aquaculture.

quality has generally proven unacceptable for field research in the northern portion of the tract due to high levels of nitrates.

IRRIGATION INFRASTRUCTURE

Main Campus: Solano Project water is delivered to the main campus via a gravity flow pipeline from the Putah South Canal near Winters to the campus' main reservoir (Figure 3-4), a distance of 8.75 miles. The pipeline terminates with a 30" gate valve rated at 25 cubic feet per second (cfs) (Table 4-3). Water reaching the campus is immediately distributed in three directions through a complex irrigation infrastructure designed to serve the needs of small plot research. The system is designed to accommodate irrigation during daylight hours with a minimum of labor.

The first users on the system take water directly from the pipeline, effectively giving them a direct connection to the Putah South Canal. These projects typically require a 24-hour supply and cannot tolerate disruptions in service and presently include the Putah Creek Aquaculture Facility and Rice Research. After delivery to these projects, the remaining water is routed to either the campus distribution system or the main reservoir. The 1996 purchase price for Solano Project water was $4.00/acre-ft. Water is provided to campus users on a recharge basis at $17.90/acre-ft (1995-96 rates). System operation, exclusive of electricity, is approximately $100,000 per year.

On-Campus Deliveries: Water entering the distribution system is passed through four main lateral lines, which cover the west and south campus. These lines were installed as part of the original infrastructure designed by Stoddard and Karrer in the late 1960s. Each line is 18" in diameter and is of asbestos-concrete construction. The laterals provide water to eight aboveground reservoirs having an average storage capacity of 3.0 acre-ft (Figure 3-4). Water entering the reservoirs is generally under pressure of 6.0 to 8.0 pounds/square inch (psi). The pressure of water discharged from the reservoirs is limited to the head in the reservoir, generally 6 feet (less than 3 psi). In some areas where pressure is insufficient to distribute water, connections have been made directly to the laterals and a dedicated line installed to the parcel served.

Discharge lines from the storage reservoirs are a mixture of concrete mortar joint pipe and low head plastic pipe. Efforts are underway to upgrade all supply lines to a minimum 100-foot head plastic pipe. Water reaching cultivated plots is delivered through pasture valves placed on 50-foot to 100-foot spacings. Very little water is lost to evaporation or percolation due to the extensive underground system.

Orders for water delivered from the Putah South Canal are made daily. Although water is taken year round, total demand for field teaching and research usually peaks during the irrigation season starting in April and ending in October (Figure 4-1). More than 80% of the University's contracted supply (4,000 acre-ft) is received during this period.

Unlike the private sector, where irrigation may be conducted on a 24-hour basis, the majority of campus use occurs between 7:00 a.m. and 4:00 p.m. It is not unusual to run the system at full capacity during these hours with water drawn from the main line, the main storage reservoir, and the smaller storage reservoirs. Water control is critical during these periods.

Adjustments must be made daily to keep the system flowing smoothly. During early morning, flow rates are checked and one or two lift stations will be started. These pumps lift water from the main reservoir and inject it into the distribution system. This water is added to that received from the main line. If pressure continues to drop later in the day as more users come on line, wells will be started. In late afternoon, the main line may be further adjusted to increase or decrease flows. Wells

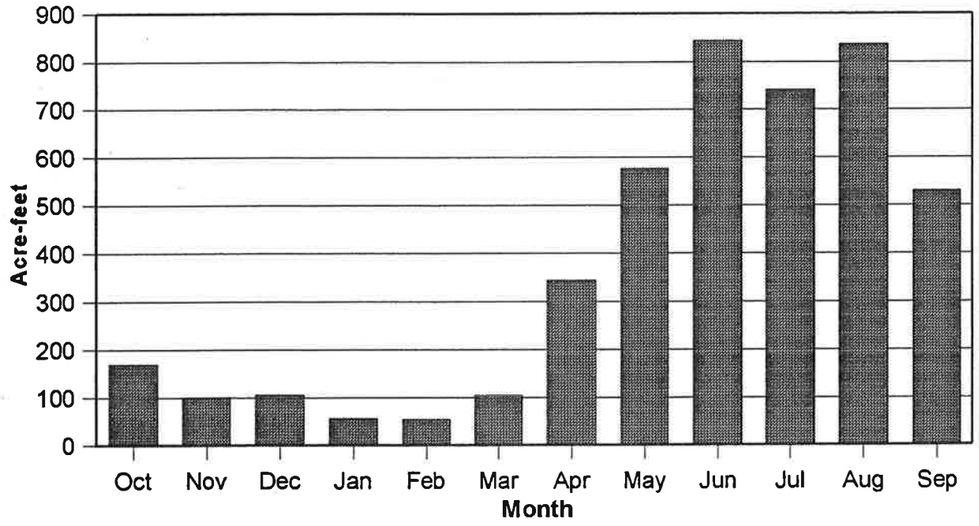

Figure 4-1 - Historical demand for irrigation water on the main campus. Deliveries of both groundwater and surface water averaged over seven hydrologic years listed in Table 4-4. Flows for aquaculture remain at a constant rate throughout the year while field research reflects seasonality of growing season. Approximately 50% of all irrigation water is delivered between July and September.

are shut down by 4:00 p.m. each day. Lift stations keep line pressure at maximum until 12:00 midnight, at which point automatic timers shut them off.

As users come off line in the late afternoon, the distribution system starts to recharge for the following day. The smaller reservoirs continue to fill from water supplied through the main distribution laterals. By 9:00 p.m. the smaller reservoirs are usually charged. From then on, the only incoming flow is from the Putah South Canal, and the majority of this water is diverted directly to refill the main reservoir. Approximately 4.7 cfs is received throughout the night by 24-hour users including Rice Research and the Putah Creek Aquaculture Facility.

On-Campus Backup Systems: Of the 19 active wells described in Table 4-1, 17 backup surface water supplies and two are dedicated to aquatic animals. All of the storage reservoirs may be filled from the wells through various loops in the delivery system. Water released from the reservoirs may be sent anywhere through the delivery system, limited only by gravity. The infrastructure on the main campus includes more than 80 miles of underground lines and over 200

individual turnouts exclusive of the main line connecting the campus to the Putah South Canal. There are only three areas in which backup is marginal or lacking. These include Rice Research, southern portions of F-Tract, and the Putah Creek Aquaculture Facility.

Parcels assigned to Rice Research have no backup in the event of a supply reduction in the main delivery line, because there are no wells or storage reservoirs in the area of Rice Research. F-tract, located between County Road 98 and University Airport, also relies solely on surface water and lacks connections to the groundwater delivery system. In the event of a power outage, the Putah Creek Aquaculture Facility (which uses both surface water and groundwater) has limited backup from a well which may be connected to an emergency generator. In contrast, the Aquatic Center has both an emergency generator to power their well, and a cross connection to the Campus' domestic water supply.

Russell Tract: Adequate Russell Tract infrastructure has been installed on only the 147 acres used by the campus for field research. A network of underground pipelines irrigates 72 one-acre research plots from a single well. There is no backup in the event of mechanical breakdown or failure. Across the remainder of the tract, water is delivered through a series of ditches and applied to the fields with siphon tubes. Two main ditches, the Willow Canal and the Fairfield Ditch, provide the majority of water conveyance on the Russell Tract (Figure 3-5). Both ditches are maintained by the Yolo County Flood Control and Water Conservation District.

HISTORICAL AND CURRENT USE PATTERNS

Main Campus: Detailed records of water use on the main campus are available since 1973 when most of the campus infrastructure was completed and water meters installed. Prior to the 1970s, approximately 1,000 acres of main campus lands were farmed for cash crops, and the revenue was used to pay for capital land improvements such as installation of pipelines and fencing. A marked decrease in use of groundwater occurred as more land was assigned for field teaching and research and the existing irrigation infrastructure was completed.

Overall Main Campus Water Use: Historical water use for seven base years since 1976 is illustrated in Table 4-4. The period reviewed includes wet-year, dry-year, and normal-year conditions. Annual water usage, based on a variety of rainfall conditions, is thought to be a good indicator of future trends. Water used for field teaching and research for seven consecutive years ending September 1995 is presented in Table 4-5. This includes one extremely wet-year and six dry-year conditions, including two years where allocations of Solano Project water were reduced by 21.5% and 13%. When estimating future projections, a distinction must be made between water used for cultivated crops and that used for animal facilities, particularly aquatic animal support due to the relatively large water requirement (See below).

Animal Feed Production: Animal Science is the largest user of water with most used for irrigation of crops grown to feed research animals (Table 4-4). Much of the feed produced by the Animal Science Department supports important research and must meet rigid quality control requirements. For example, about one-third of the alfalfa (100 acres) is cut at a specified degree of maturity to guarantee a prescribed protein content. Premium prices would have to be paid to ensure this kind of quality control in feed purchased on the commercial market. Similarly, it is very difficult to consistently obtain good quality commercial oat hay.

Crops raised for Animal Science herds have also benefited the research programs of Agronomy and Range Science; Land, Air, and Water Resources; and the Division of Biological Sciences. The Agronomy and Range Science and Animal Science Departments have a long history of cooperation. For example, 300 acres of nonirrigated cereal crop production used in Agronomy research are shared with Animal Science.

The Animal Science department conducted a cost analysis of producing animal feed on the main campus in contrast to purchasing animal feed commercially. The analysis included all costs of production incurred by the Agricultural Services Office, e.g., labor, equipment, irrigation water, department management, overhead costs, etc. The only factor not considered was the potential opportunity cost (i.e., what the land could be used for if it were not being used for animal feed production). The department concluded that it saved about $78,000 (in 1990 dollars) by producing animal feed on campus, rather than purchasing it commercially. This savings represented 27.7 % of

Table 4-4 - Historical water usage in acre-feet by campus departments for field teaching and research

LOCATION AND USER	HYDROLOGIC YEAR[1]						
	76-77	79-80	82-83	85-86	88-89	91-92	94-95
Russell Tract:							
LTRAS	n/a[2]	n/a	n/a	n/a	n/a	n/a	65.00
Main Campus:							
Agricultural Engineering	7	12	14	13	47	9	3
Agronomy & Range Science	415	331	354	573	645	484	412
Rice Research	400	367	198	400	651	344	416
Animal Science	1,733	1,425	919	1,512	1,512	1,598	1,686
Putah Creek Aquaculture Facility	2	13	116	685	892	610	548
Aquatics Center	n/a	n/a	n/a	n/a	509	533	667
Animal Resources	82	214	377	308	389	319	255
Botany	0	0	17	15	32	9	0
Entomology	3	2	0	0	0	0	0
Environmental Horticulture	0	149	3	0	0	0	0
Pierce Tract	40	253	0	0	7	52	0
Campus Farming	85	211	0	0	0	0	0
Foundation Plant	119	37	13	24	32	29	54
Foundation Seed	785	207	105	0	0	0	0
Land, Air, & Water Resources	66	92	78	68	67	33	49
Plant Pathology	185	109	102	185	213	216	160
Pomology	219	265	223	246	245	528	179
Student Farm	0	87	43	44	34	30	36
Vegetable Crops	109	71	108	69	173	95	74
Viticulture	446	61	80	2	94	47	30
Wildlife, Fish & Conservation Biology	262	91	97	139	61	77	16
Zoology	19	0	0	0	0	0	0
TOTAL	4,977	3,996	2,849	4,282	5,603	5,011	4,650

[1] The hydrologic year starts on October 1st and ends on September 30th of the following year. Records are based on departmental billings for irrigation water as collected by the UCD Agricultural Services Office. Water used by the Aquatic Center and Putah Creek Aquaculture Facility is in support of aquatic animals, all other use is in support of cultivated crop research.

[2] Records not available, LTRAS not in operation until 1993, Aquatic Center in operation but no records.

[3] Figures include 455 ac-ft /yr as pumped from domestic wells based on estimated average daily flows.

[4] Figure based on metered flows from dedicated well drilled in 1993.

Table 4-5 - Average annual water use (1989-1995) - main campus and Russell Tract[1]

WATER SOURCE	WATER USE (acre-feet)			
	Field Research	**Rice Research**	**Aquaculture**	**Total**
Solano water	2,221	366	493	3,080[2]
Groundwater	1,138	0	695[3]	1,833
Putah Creek	0	0	0	0
Clear Lake	0	0	0	0
Recycled[4]	244	0	0	244
Subtotal	3,603 (70%)	366 (7%)	1,188 (23%)	5,157
			Tenant farmer on Russell Tract	4,443[5]
			Total water use on UC Davis lands	9,600

1 Average annual usage for seven hydrologic years, 1989 through 1995.
2 Average use of Solano Project water during the 1989-95 drought was less than the 4,000 acre-foot contract amount due to efforts to bank water for future years if the drought continued.
3 Groundwater figures shown for Aquaculture include domestic and non-dometic sources.
4 Recycled water is groundwater returned from Aquaculture for use in crop irrigation. Recycling began in 1994.
5 Estimated water use on Russell Tract (See Table 4-9).

the cost of purchasing the same quantity of alfalfa, wheat, and oats on the commercial market. Producing animal feed on campus serves as an important buffer for sharp fluctuations in commercial feed prices. For example, in 1971 the department discontinued its practice of producing animal feed due to relatively low commercial feed prices and a sizable budget cut. Two years later feed prices doubled and seriously affected ongoing research programs. The department immediately restored campus feed production to stabilize support for long-term research and teaching herds.

Aquatic Animal Water Use: The Putah Creek Aquaculture Facility and the Institute of Ecology Aquatic Center use substantial volumes of water and demand is expected to continue increasing (Table 4-5). Historically, Aquatic Center at the Institute of Ecology and the Putah Creek Aquaculture Facility relied primarily on surface water delivered from the Solano Project. As water needs increased, these two programs used increasingly larger portions of the water received under the annual contract. Concern about the amount of Solano Project water being used and certain

quality constraints associated with the Solano Water (temperature fluctuation, super saturation, and turbidity) influenced a shift to groundwater.

In 1986, the Putah Creek Aquaculture Facility was connected to a shallow aquifer irrigation well and water deliveries were divided between groundwater and surface water. In 1994, the Aquatic Center began receiving groundwater pumped from a well drilled specifically for this program, and all connections to Solano Project water were removed. Chlorination of the Campus' domestic wells and the unacceptably high temperature of domestic water required the program to install a dedicated well that draws water from a shallower aquifer. Concurrent to the drilling of the new well, a return system was installed to allow secondary reuse of water for field irrigation; approximately 250 acre-ft/yr was recycled beginning in 1994 (Table 4-5).

Russell Tract: With the exception of 1995 records pertinent to the use of water by LTRAS, historical records of water use on the Russell Tract are unavailable to the University (Table 4-4).

TIMING OF WATER DELIVERIES

Seasonal water demand to the Davis campus follows a pattern typical of private farming. Use usually starts in the latter half of March with preirrigation of spring plantings. Irrigation of pasture and forage crops starts in April with demand peaking June through August (Figure 4-1). Demand remains fairly high throughout the balance of the summer until the first week of October, when the last cutting of alfalfa is removed and Rice Research shuts down operations.

During the late fall and winter months, water use is limited to support for aquatic animals. Although greenhouse operations continue, the amount of water used for cultivated crops during the winter months is minor.

The evaluation of new sources of water to serve the main campus and Russell Tract must carefully consider timing. For example, substantial high quality water supplies for cultivated crops must be available from April through September; needs between October and March can probably

be met through groundwater pumping. In addition, water for aquatic animals must be available year-round.

QUALITY CHARACTERISTICS AND SUITABILITY OF WATER SUPPLIES FOR FIELD RESEARCH

Suitability of irrigation water for crops and ornamental plants can be evaluated by a number of parameters as suggested by Ayers and Westcot (1985) (Table 4-6). These parameters give numerical guidelines to evaluate effects of water salinity, probable effects on infiltration, specific ions toxic to crops, and miscellaneous effects.

EXISTING SUPPLIES

Surface Water: The quality characteristics of existing and potential water sources for field use are presented in Table 4-7. The three surface water supplies available for use include Solano Project, Putah Creek, and Willow Canal. Each of these surface sources are magnesium-calcium bicarbonate-type waters with comparatively low in dissolved mineral contents. Both Solano Project and Putah Creek water are suitable for most crops (Tables 4-6 and 4-7). The only limiting water quality constituent is the 0.71 parts per million (ppm) of boron found in the Solano Project water, which may be marginal for the most boron-sensitive plants (e.g., lemon).

Willow Canal water is similar in quality to Putah Creek water, but contains moderate concentrations of boron (1.86 ppm), an element toxic to boron-sensitive plants including citrus, stone fruits, beans, and some cereal grains (Tables 4-6 and 4-7, Ayers and Westcot, 1985). More complete and updated tables on boron tolerance are provided by Tanji (1990).

Groundwater: The shallow and intermediate aquifers supply the main campus and the Russell Tract irrigation wells. Those on the main campus vary somewhat in chemical quality, but are magnesium-calcium bicarbonate water types, and have about twice the dissolved mineral contents found in surface water supplies. The main campus irrigation waters have varying qualities, but are

Table 4-6 - Water quality characteristics of existing and potential water sources for irrigation

WATER SOURCE	PARAMETER								
	pH	EC mmhos/cm	SAR adjusted	Na meq/L	Cl meq/L	B ppm	Nitrate ppm	Bicarbonate ppm	Source
Surface Water									
Solano Project	8.0	0.38	0.24	0.33	0.47	0.71	0.5	2.7	Klippert[1]
Putah Creek	8.1	0.41	0.60	0.84	0.55	0.49	1.5	3.0	Klippert
Willow Canal	8.4	0.48	1.30	1.60	0.70	1.86	1.0	3.5	Klippert
Irrigation wells, main campus, 19 wells (N=47)									
minimum	7.5	0.57	0.6	1.0	0.6	0.07	1.0	3.6	Klippert
maximum	8.5	1.16	2.3	3.2	1.9	1.09	97.0	10.7	"
mean	8.0	0.88	1.0	1.9	0.9	0.67	23.3	7.0	"
Irrigation wells, Russell Tract, 10 wells (N=11)									
minimum	7.7	0.53	0.9	1.4	0.7	0.41	7.0	3.5	Klippert
maximum	8.5	1.25	1.7	3.4	1.7	1.03	80.0	10.0	"
mean	8.0	0.79	1.2	2.1	1.1	0.73	25.6	5.9	"
Main campus utility wells, intermediate aquifer (N=9)									
minimum	7.3	1.06	1.6	3.1	0.5	0.60	3.2	9.5	Hartline[2]
maximum	7.5	2.01	2.7	6.9	1.8	1.35	7.7	16.4	"
mean	7.4	1.40	2.0	4.5	0.9	0.89	5.7	12.2	"
Main campus domestic wells, deep aquifer (N=8)									
minimum	7.5	0.65	1.3	2.0	0.4	0.44	<0.1	5.4	Hartline
maximum	7.7	0.70	5.6	5.0	0.7	0.88	1.7	6.2	"
mean	7.6	0.67	3.6	4.0	0.6	0.60	0.6	5.7	"
Treated sewage effluent									
	7.4	1.05	3.2	3.8	2.0	0.74	6.6	19.8	Koehler[3]
Putah Creek Aquaculture Facility effluent									
	8.4	0.53	0.61	0.9	0.8	0.45	3.0	3.8	Klippert
Aquatic Center effluent									
	7.7	0.60	0.71	1.22	0.79	0.83	8.0	5.0	Klippert

[1] Manager, Agricultural Services Office
[2] Former acting manager of Physical Plant Utilities Division
[3] Manager, Wastewater Treatment Plant

suitable for most crops (Tables 4-6 and 4-7). The concentrations of boron in certain wells that are nearly 1 ppm or greater are of some concern. The boron content of shallow and intermediate groundwater are higher than Putah Creek water, but less than Willow Canal water.

Table 4-7 - Guidelines for interpretation of water quality for irrigation[1]

Potential Irrigation Problems	Degree of Restriction on Water Use		
	None	**Slight-to-Moderate**	**Severe**
Salinity -affects crop water availability			
Electrical Conductivity (EC_w) - dS/m	< 0.7	0.7 - 3.0	> 3.0
Total dissolved solids (TDS) - mg/L	< 450	450 - 2,000	> 2,000
Infiltration - affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together			
Sodium adsorption ratio (SAR)			
SAR = 0-3 and EC_w	> 0.7	0.7 - 0.2	< 0.2
SAR = 3-6 and EC_w	> 1.2	1.2 - 0.3	< 0.3
SAR = 6-12 and EC_w	> 1.9	1.9 - 0.5	< 0.5
SAR = 12-20 and EC_w	> 2.9	2.9 - 1.3	< 1.3
SAR = 20-40 and EC_w	> 5.0	5.0 - 2.9	< 2.9
Specific Ion Toxicity - affects sensitive crops			
Sodium (Na)			
surface irrigation - SAR	< 3	3 - 9	> 9
sprinkler irrigation - me/L	< 3	> 3	
Chloride (Cl)			
surface irrigation - me/L	< 4	4 - 10	> 10
sprinkler irrigation - me/L	< 3	> 3	
Boron (B) - mg/L	< 0.7	0.7 - 3.0	> 3.0
Miscellaneous Effects - affects susceptible crops			
Nitrates (NO_3) - mg/L	< 5	5 - 30	> 30
Bicarbonate (HCO_3) overhead sprinkling - me/L	< 1.5	1.5 - 8.5	> 8.5
pH		normal range is 6.5 to 8.4	

Reporting Units

Electrical Conductivity is a measure of water salinity, reported in deciSiemens per meter at 25 degrees C, or in millimhos per centimeter (mmho/cm). Both are equivalent.

Total dissolved Solids are reported in milligrams per liter.

SAR is sometimes reported by the symbol Rna. At a given SAR, infiltration rate increases as water salinity increases.

Chloride is reported in milliequivalents per liter. Boron may also be reported in ppm or parts per million.

Nitrates may also be reported in ppm, or parts per million. Both are equivalent.

[1] Adapted from the University of California Committee of Consultants in 1974.

Water samples collected from main campus wells in 1988 showed elevated concentrations of nitrates (Well E4A = 51 ppm, Well A1 = 70 ppm, and Well E5 = 65 ppm). These nitrate concentrations translate into 11.3 to 15.6 mg/L NO_3-N, which is equivalent to 25 to 34 lbs NO_3-N/acre-ft. Subsequent sampling in 1990 and 1994 indicated a significant reduction in these levels. Nitrates in these well waters should continue to be monitored and considered in the fertilization of irrigated croplands. For example, high levels of nitrate may have an impact on the maturation of grapes and sugar beets. The nitrogen contents in the water from those few wells with elevated nitrate levels should be considered a nitrogen credit along with available soil nitrogen when developing fertilizer application rates and could affect some experimental protocols.

Another parameter of concern is carbonates and bicarbonates in irrigation waters. The former is found in waters having pH greater than about 8.2. When waters containing more than 5 meq/L of carbonates are applied by overhead sprinkling systems, the quality of produce such as grapes may be impaired by carbonate deposits similar to scaling on plumbing fixtures.

Nine of ten shallow and intermediate groundwater wells on the Russell Tract have been tested and show qualities similar to those of shallow and intermediate irrigation wells on the main campus. The utility wells that pump from intermediate depth aquifers and the utility reservoir generally have a lower pH and higher salinity, sodium, boron and bicarbonate contents than the irrigation water wells.

POTENTIAL SUPPLEMENTAL ON-CAMPUS SUPPLIES

Three existing, on-campus water sources may have potential as a suitable supplemental water source for cultivated crop research.

Main Campus Utility /Domestic Wells: Utility wells on the main campus draw from the intermediate aquifer and are suitable for most field research uses (Table 4-6). Two exceptions are utility wells 3 and 4, which have boron levels of 1.27 to 1.35 ppm, respectively.

Domestic wells that extract water from the deeper aquifers produce a sodium-bicarbonate, magnesium-bicarbonate-type water that has lower salinity, higher sodium adsorption ratio, lower nitrates, and lower boron contents than the shallow and intermediate irrigation waters. The campus has not used the deep aquifer water for field teaching and research based largely on the research and recommendations of Professor Lloyd Doneen (1955). Using greenhouse experiments, Doneen compared the effects of irrigation using shallow and intermediate well water (30% total sodium cations, 0.45 ppm boron, and 2.2 meq/L residual sodium carbonates) to "new" deeper well water (68% total sodium cations, 0.75 ppm boron, and 3.8 meq/L residual sodium carbonates). The results indicated that when used on Yolo loam soil, deep aquifer water resulted in excessive accumulations of soluble sodium in the soil solution and moderate adsorption of sodium on the soil cation exchange complex. The principal impact of this sodium accumulation was dispersion and reduced infiltration rates, about 0.08 inches/hr as compared to about 0.36 inches/hr of the "new" water amended with 4.7 meq/L of $CaCl_2$. As a result, the "soft" domestic well water from the deep aquifers has not been used extensively for field teaching and research uses.

Recent research indicates that soil permeability of coarser-textured soils is not as heavily impacted as finer-textures soils such as Yolo loam when domestic system water is used for irrigation (Ayers and Westcot 1985, Pettygrove and Asano 1986, Tanji 1990). These studies assessed the sodium adsorption ratio of the deep aquifer water adjusted for lime precipitation (mean $SAR_{adjusted}$ = 3.6) and considered with electrical conductivity (mean EC = 0.67 dS/m [deciSiemens/meter]), and concluded that deep aquifer water would cause only slight to moderate reductions in water infiltration rates (Table 4-6). These findings were based on soil textures that ranged from sandy loam to clay loam with good internal drainage as well as use of normal surface or sprinkler irrigation methods. Deep groundwater is being used successfully by the Department of Environmental Horticulture and in the southern area of the campus (Peter Storey, Facilities Services, pers. comm.), and may be suitable for use for other field teaching and research uses where the soil type is appropriate.

Potential use of the domestic system for field teaching and research is also limited because the water is chlorinated to protect human health. Any future uses of deep aquifer water for crop or animal research must consider the impacts of residual chlorine or include facilities to connect the field

teaching and research water system directly to the deep aquifer wells and bypassing the domestic water system.

Reclaimed Wastewater Effluent: Treated effluent from the campus WWTP is a potential source of water for field teaching and research. However, effluent quality is unsuitable for many research applications due to the high quantity of dissolved minerals compared to the existing or domestic water supplies and may limit its use for research. Furthermore, many field teaching and research projects either require or assume a consistently high quality water supply so that the levels and variability of constituents in the water do not affect the results. Reuse of reclaimed wastewater waters is regulated by Wastewater Reclamation Criteria, California Code of Regulations, Title 22, Division 4, Environmental Health. These regulations dictate how reclaimed water may be used for fodder, fiber and seed crops, orchards and vineyards, pasture for milking cows, and food crops with increasing water quality constraints. Opportunities may exist for use of reclaimed wastewater effluent at limited locations on the campus for field teaching and research, but a new distribution system would be required so it could be delivered to those locations independent of the existing system.

Aquaculture Effluent: Another potential source of water for irrigation of croplands is the effluent from the Aquatic Center and the Putah Creek Aquaculture Facility. Single-pass water discharged by both facilities is of acceptable quality. Effluent discharged by the Aquatic Center is similar to the main campus irrigation wells. Effluent discharged by the Putah Creek Aquaculture Facility reflects a mixture of both groundwater and Solano Project water.

In 1994, the Agricultural Services Office installed a return system capable of delivering effluent from the Aquatic Center to field research crops. During 1994 and 1995, approximately 40% of discharges (approximately 250 acre-ft/yr) were reused in crop irrigation. Future management of this effluent calls for reusing up to 60% of discharges. A return system has also been installed at the Putah Creek Aquaculture Facility to return a portion of groundwater to the Campus' main storage reservoir where it may also be allocated for field research. Record keeping on this return system began in 1996.

QUALITY CHARACTERISTICS AND SUITABILITY OF WATER SUPPLIES FOR ANIMAL SUPPORT

EXISTING SUPPLIES - AQUATIC ANIMAL

Aquatic animal research requires both acceptable water quality and acceptable water temperature. Researchers must be able to duplicate the seasonal fluctuations in temperature that are critical to the sexual maturation of certain species. For example, sturgeon are able to exist in an environment up to 72°F. However, the animal may not progress through the sexual maturation process unless the researcher is able to duplicate temperatures of 60°F as would occur in the animal's natural environment during the winter months. A similar situation exists for catfish.

Groundwater: The Aquatic Center receives all of its water from an intermediate aquifer well. The Putah Creek Aquaculture Facility receives some of its water from a shallow aquifer well. The temperature of water pumped from the deep aquifer ranges between 73°F and 80°F which is unacceptably high and must be chilled prior to use. This is especially critical for trout normally found in an environment ranging from 45°F to 61°F. The temperature of water delivered from the shallow to intermediate aquifer has been measured at 65°F. This water requires less energy to chill and provides a safer living environment. This fact influenced the drilling of a new well (well E1, Table 4-1) for the Aquatic Center in 1993.

Surface Water: Fluctuations in surface water temperature have been problematic for aquaculture research. The Putah Creek Aquaculture Facility relies on groundwater and Solano Project water. Water delivered directly from the Putah South Canal has an acceptable temperature ranging between 50°F and 60°F. However, once stored in campus reservoirs, this water may reach 68°F. In addition, rapid switching between Solano Project water and groundwater is required when the Putah South Canal is shut down for maintenance. This switching produces undesirable temperature fluctuations.

Management and treatment of the water system serving the aquaculture program is also a consideration. Solano Project water delivered from the Putah South Canal is subject to treatments

of copper sulfate by the Solano Irrigation District. This practice, implemented every two weeks during summer months to reduce aquatic weed growth is deadly to fish. Another problem, although less frequent, is super-saturation of oxygen. The cause of this problem has not been determined, but may be linked to water level fluctuations of the Putah South Canal.

EXISTING SUPPLIES - FARM ANIMAL

Water quality guidelines for livestock and poultry uses include monitoring salinity and magnesium levels. These constituents in existing groundwater and Solano Project sources do not approach levels that could cause detrimental effects.

POTENTIAL SUPPLEMENTAL ON-CAMPUS SUPPLIES

Campus domestic and utility wells show potential for use in aquatic animal support. However, beginning in 1994, the Campus implemented a chlorination program of domestic water supply after failing more stringent water quality tests required by the CVRWQCB. Use of this water in aquaculture now requires an expensive filtration system that does not fully eliminate the problem and is not preferred by researchers.

WATER MANAGEMENT OPTIONS

Alternative options for the management of water for field teaching and research are presented in Table 4-8. These options suggest various ways to meet future water demand, and identify estimated costs and environmental benefits of potential short-term (through 2006), long-term (through 2046) and emergency actions. Although not specifically addressed, the cost of pumping is significant and will continue to increase. The options presented are based upon the following considerations, calculations, and assumptions.

TABLE 4-8 - Water management options for field teaching and research

SHORT TERM - YEAR 2006 - The following options assume that the main campus and Russell Tract will continue a crop mix that has water demand equivalent to the present demand.

MAIN CAMPUS

MANAGEMENT OPTION	WATER DEMAND	COST 1990 DOLLARS	ENVIRONMENTAL BENEFITS	IMPLICATIONS
Status quo	5,200 acre-ft/yr	Maintenance $80K/yr	No change	No change
New research initiatives[1]	Up to 2,500 acre-ft/yr	None available	Increased demand for water	Ability of University to continue to fulfill is missing of teaching, research, and public service
Relevel crop lands	Little or no change	$200 per acre	Improved crop yields	Less irrigation labor; less tailwater runoff
Off-hour pumping to save utility costs	No change	Reduce utility costs $9K/yr	Not significant	Reduced energy cost; increased labor cost
Water management training for campus irrigators	5-10% less water use	$500/yr	Water and energy conservation; improved crop yields w/less water use	Reduced energy costs

[1]The timing (long- v. short-term) and location (Main Campus v. Russell Tract) of this water used cannot be predicted now but is placed in this table to identify the potential future need.

RUSSELL TRACT

MANAGEMENT OPTION	WATER DEMAND	COST 1990 DOLLARS	ENVIRONMENTAL BENEFITS	IMPLICATIONS
Status quo	4,500 acre-ft/yr with 60% application efficiency (AE)	$25K/yr for maintenance	no change	no change
Improve water delivery system and upgrade/install wells (e.g., looped main line system, construct reservoir for Solano Project and Clear Lake water); design tailwater return system	Reduce demand to 4,200 acre-ft/yr by improving AE to 65%	$750K to bring Solano Project water to Russell Tract; $500K for reservoir; $400K for looped main line w/o laterals; 6 new wells @ $200,000; and $100K for tailwater return	Water and energy conservation; improved crop yields w/less water use; substituting Berryessa for Cache Creek water improves water quality	Less irrigation labor, potential accumulation of nutrients and pesticides w/tailwater return reservoirs
Off-hour pumping to save utility costs	No change	$5-10K in utility cost savings	Not significant	Small reduction in energy costs; increased labor costs
Water management training for campus irrigators	5-10% less water use	$500/yr	Water and energy conservation; better crop yields w/less water use	Reduction in energy costs

LONG TERM - YEAR 2046 - The following options assume that the main campus will continue a crop mix that has water demand equivalent to the present demand minus water demand associated with moving the animal facilities to the Russell Tract. The Russell Tract will have a crop mix that has water demand equivalent to the water demand on the West Campus, plus the water demand associated with the relocation of animal facilities.

MAIN CAMPUS

MANAGEMENT OPTION	WATER DEMAND	COST 1990 DOLLARS	ENVIRONMENTAL BENEFITS	IMPLICATIONS
Add a tailwater return system to field plots	Reduce demand by 500 acre-ft/yr, improve AE and reduce water demand for some crops	$380K for capital costs; $9,500/yr for utilities and maintenance	Water and energy conservation; preserve soil quality; reallocate high quality water to crops; improve crop yields w/less water use	Recycle lower quality water to forage & other non-research uses; potential accumulation of nutrients & pesticides
Add field by field water measuring devices; pressure control; more refined watering systems; etc.	Reduces water use for some crops through improved irrigation management	$80K for capital costs	water and energy conservation through better management and water use data	Improve planning for water use and energy conservation
Combine the first two options as described above	May increase AE about 5% lowering water demand by 200 acre-ft/yr	$460K for capital costs; $9,500/yr for utilities and maintenance	See first two options above	See first two options above

RUSSELL TRACT

MANAGEMENT OPTION	WATER DEMAND	COST 1990 DOLLARS	ENVIRONMENTAL BENEFITS	IMPLICATIONS
Improve water delivery system incl. laterals, valving, etc. to provide water on demand for intensive plot use	May increase AE by 5% lowering water use by 300 acre-ft/yr	$850K for main lines and laterals; $500K for main reservoir; $2.5 million for 7 small reservoirs; $530K for lift and pressure stations; and $125K/yr for utilities and maintenance	Water and energy conservation; better crop yields w/Less water use	Reduce utility costs; separation of utilities from leased lands; long-term benefits to agriculture from research results
Add a tailwater return system w/multi-use reservoir w/possible winter storage of storm water	Should increase AE by 10% lowering water use by 500 acre-ft/yr	$380K for capital costs; $8500/yr for utilities and maintenance	Water and energy conservation; better crop yields w/Less water use; preserve soil quality; reallocate high quality water	Reduce utility costs; recycle lower quality water for forage & other non-research uses
Add field by field water measuring devices; pressure control; more refined watering systems; etc.	Reduces water use for some crops through improved irrigation management	$80K for capital costs	Water and energy conservation through better management and water use data	Improve planning for water use and energy conservation

WASTE AND STORM WATER REUSE FOR FIELD RESEARCH

MANAGEMENT OPTION	WATER DEMAND	COST 1990 DOLLARS	ENVIRONMENTAL BENEFITS	IMPLICATIONS
Reuse wastewater and storm water for crop irrigation	450 acre-ft/yr from wastewater 780 acre-ft/yr from storm water	$91K for capital costs wastewater reuse $1.6 million capital costs for storm water	Water and energy conservation	Reduce utility costs; reuse governed by California law, Title 22

DROUGHT AND EMERGENCIES

MANAGEMENT OPTION	WATER DEMAND	COST 1990 DOLLARS	ENVIRONMENTAL BENEFITS	IMPLICATIONS
Under mild to moderate drought conditions: conjunctive use of surface water and groundwater; reduce supplies to non-research parcels; terminate rice plots; deficit irrigate pastures	10-20% reduction	Cost to departments to purchase hay or decreased revenue from any leased land or crops sold	Water conservation in time of restricted supply	Loss of research capacity
Under severe drought conditions: conservation targets for all programs; shorten irrigation season; change crop rotations	10-20% reduction	Cost to departments to purchase hay or decreased revenue from any leased land or crops sold	Water conservation in time of restricted supply	Loss of research capacity
Under system failure conditions: interconnect supply lines including connection with domestic water system and sewage effluent	N/A	None available	N/A	Avoid disruption of crop research; short-term reduction of water available for domestic system

ASSUMPTIONS ON FUTURE LAND IMPROVEMENTS AT RUSSELL TRACT

Most of the recommendations for the Russell Tract are made in the context of developing the entire tract for field research. Significant progress has been made in the improvement of approximately 147 acres allocated for LTRAS. In 1992, the southwestern portion of the Russell Tract was improved to allow intensive plot research. The improvements, serving approximately 72 research plots, include an irrigation system with a new well and earthen reservoir, and an underground delivery system. By 1994 approximately $375,000 had been expended for improvements on this site. Short-term future improvements will most likely be linked to expansion of this program.

ASSUMPTIONS ON FUTURE CROP MIXES

Academic field teaching and research programs ultimately establish the requirements for water. The average amount of water required per acre for field teaching and research is not expected to vary significantly over the next decade. Development of animal facilities at Russell Tract would require additional water for waste and sewage removal. The expansion of aquaculture-related facilities would have a major impact on water use (see "Assumptions About Animal Facilities," below). However, overall use may be reduced by development of appropriate wastewater reuse systems (i.e., use of wastewater for irrigation of croplands). Considerations regarding crop mix are described below.

Main Campus: The present crop mix on department-operated farms is a reflection of present and future research interests and needs as envisioned by researchers. Departments in the College of Agricultural and Environmental Sciences do not expect significant changes in crop mix over the next ten years. Consequently, no change in overall water use is expected unless there are improvements in irrigation systems and procedures.

Russell Tract: A large portion of Russell Tract will be leased to commercial growers over the next five to ten years. Crop mix is expected to remain essentially as in the recent past (i.e., alfalfa, wheat, tomatoes, corn, sugar beets, and vine seed).

Future development at Russell Tract is expected to include expansion of the Sustainable Agriculture Research and Education Program and could include alfalfa production for research livestock. No increase in overall water use is anticipated as land use changes from production farming to sustainable agriculture research. The source of water for research is expected to be primarily groundwater and Putah Creek water. Creek water will either be diverted directly from the creek or delivered through a branch pipeline from the Solano Project. Economies in water usage at Russell Tract are possible if improved water delivery and tailwater systems are developed. Calculations for this potential are included in the Table 4-8.

Table 4-9 - Estimated water needs at the Russell Tract for crop research[1]

Crops	Water Applied (in.)	Amount Evaporated[2] (in.)	Available for Crops (ac-ft)	Acres Irrigated (acres)	Total Water (ac-ft)
Alfalfa	52.0	31.2	4.3	443	1918
Cereal grains	13.5	8.1	1.1	200	225
Corn	36.0	21.6	3.0	200	600
Sugar Beets	34.0	20.4	2.8	200	567
Tomatoes	34.0	20.4	2.8	400	1133
			Total	1,443	4,443
	Average water requirement per acre				3.1 ac-ft/ac

[1] Estimated irrigation requirements of the Russell Tract assuming low Irrigation Efficiency (IE=60%) and use of the existing delivery system. Historical records of actual water use are not available. As land is converted from production farming to field research, it is anticipated that the above figures will provide a baseline for water requirements. It is assumed that conversion to research use will be gradually phased in over a number of years. It is also probable that land conversion will take place concurrent with improvements in the irrigation delivery system.

[2] Represents the evapotranspiration rate of applied water from the California Department of Water Resources Bulletin No. 133-3.

ASSUMPTIONS REGARDING CONVERSION OF FARM LAND & ESTIMATION OF IRRIGATION APPLICATION EFFICIENCY

Data are not available to allow direct evaluation of current application efficiency (AE) for either the main campus or the Russell Tract. AE is defined as the amount of water stored in the crop root zone during an irrigation event divided by the total amount applied. Collective experience and judgment of the Water Plan Committee were used to estimate AE to be 75% for main campus and 60% for the Russell Tract. The higher efficiency of main campus water use is associated with pipeline delivery and very limited runoff on the main campus contrasted with open ditches and significant runoff on the Russell Tract. Table 4-9 identifies the estimated water requirements for the Russell Tract assuming a varied crop mix and use of the existing ditch and siphon delivery system. Approximately 3.0 acre-ft/acre will be needed over a growing season.

IDENTIFICATION OF CURRENT WATER DEMANDS

Main Campus: Current water demands for field teaching and research on the main campus are based primarily on past use as illustrated in Table 4-5.

Russell Tract: Current water demand for the Russell Tract is based on 1994 usage as reported by the LTRAS program (Table 4-4) and estimated use on the remainder of the Russell Tract (Table 4-9)

ASSUMPTIONS ABOUT NEW RESEARCH INITIATIVES

When planning for water supplies over a 50-year period, many uncertainties arise regarding the types of field teaching and research programs that may be developed on the campus. In 1946, it would not have been possible for faculty and staff to predict the new technologies and research questions that would face society and campus researchers today. Similarly, predicting the water demands today of new field teaching and research programs and facilities in 2046 is also difficult. Nonetheless, to ensure that the campus is able to maintain its mission of teaching, research, and public service, it is necessary that the University have sufficient flexibility to meet future research demands for water supply in terms of both quantity and quality.

One example of the type of new programs that might increase the need for field teaching and research water is aquaculture and fisheries research. During the 1991-92 and 1994-95 hydrologic years, water use at the Institute of Ecology Aquatic Center and Putah Creek Aquaculture Facility totaled approximately 1,200 acre-ft/yr (Table 4-4). A new Aquatic Facility on either the main campus or the Russell Tract might expand existing facilities and would likely require water year-round, not just during the traditional irrigation season. Using recirculation technology (reuse within the facility) and using discharge water during some seasons for crop irrigation or animal wash down facilities, water demand might increase by several thousand acre-ft without any change in the total acreage devoted to field teaching and research.

Greenhouses and research laboratories used for basic, applied, and production-related biotechnology research are another example of possible teaching and research uses with new water demands that could be placed on the field teaching and research water system. Biotechnology research is an area of major research growth, and the likelihood of increased research and teaching in the field is significant. Many of the possible research questions, especially related to production, could increase water demand.

To ensure that the campus has a reliable, high quality water supply for new field teaching and research initiatives over the next half century, the campus should secure a new, high quality water supply of approximately 1,600 acre-ft/yr to meet potential for increased demand (Table 4-10). This volume should provide sufficient flexibility to meet potential future increases in demand due to new field teaching and research demands that may occur during the planning period.

GENERAL OBSERVATIONS

The amount and cost of water as presented in Table 4-8, Water Management Options for Field Teaching and Research, reflect the fact that more water resources are required per acre of research plot than for the equivalent land area used for commercial farming. Conservation often cannot be practiced during research trials. For example, many research protocols require irrigation practices that are not the most efficient.

An improved crop yield is listed as a potential benefit of most scenarios in Table 4-8 because there are no tailwater return systems presently available and most fields have no drainage provisions to deal with tailwater. As a consequence, irrigators strive to avoid runoff. Water is advanced slowly across the research fields. Thus, water has adequate time to percolate on the head end of the field, but limited time on the tail end. The results of this practice are a lack of uniform irrigation, reasonably low AE, limited crop yield, and often compromised research results.

Table 4-10 - Projected field teaching and research water use and supply balance -- main campus and Russell Tract (2006-2046)

USE/SUPPLY	Volume (ac-ft)	Percentage Use
Projected Use		
Field Research	8,250	73%
Rice Research	500	5%
New research initiatives	2,500	22%
Total Use	11,250	100%
Projected Supplies1		
Solano Project	4,000	36%
Groundwater	3,000	27%
Putah Creek	1,000	9%
Clear Lake	1,400	12%
Recycled	250	2%
Subtotal	9,650	86%
New high quality supply	1,600	14%
Total Supply	11,250	100%

[1] Projected supplies until reliable, high quality surface supplies can be secured to replace the existing groundwater and Clear Lake supplies.

Assumptions:

1. Projected use has have been identified within the context of providing a viable program regardless of site location or availability of an infrastructure.

2. Where possible, programs not requiring a high quality water supply comparable to that now available from the Solano Project will shift to Clear Lake or groundwater supplies.

3. Riparian Rights to Putah Creek Surface Diversions will not be relinquished.

4. The new supply will be high quality water comparable to that now provided by the Solano Project and which is available year round to accommodate changing land use at the Russell Tract from production farming to teaching and research.

5. The campus will also seek to secure a reliable, high quality surface water supply to replace existing groundwater and Clear Lake supplies.

EMERGENCY OPTIONS

The management options for addressing emergency situations are summarized in the last page of Table 4-8. The two types of emergencies addressed are drought and system failure. For the purposes of this report, drought options are categorized as mild to moderate and moderate to severe. The six-year drought, 1987-1992, would be in the moderate drought magnitude.

During mild to moderate drought, a 10-20% reduction in water use can be realized by cutting off water to nonresearch parcels and selectively reducing water supply to research parcels. Specifically, Rice Research plots may be reduced or terminated because the Rice Research is located on gravelly land that is not optimal for rice production given its excessive percolation. Also, pasture lands and alfalfa can be deficit irrigated to save water, without suffering permanent loss of the crop. Deficit irrigation would result in the need to purchase hay from external sources and would result in decreased revenue from any leased land or crops sold.

As drought conditions become moderate with the potential of becoming severe, conservation targets are needed for all departments and programs. The irrigation season can be shortened, crop rotation changed to minimize water demand, and some lands can cease to be irrigated. This case would reduce water demand by 10-20% (the same as that achieved for mild to moderate drought conditions) because the additional demand by crops that are kept in production is expected to offset the savings of water realized by taking crops out of production.

System failure could occur from localized events, such as a construction project accident or an earthquake. The interconnection of supply lines, including interconnections with the domestic water supply and the wastewater treatment plant effluent, could avoid loss of critical crops. One of the more critical needs is to have interconnected supply lines providing water to Putah Creek Aquaculture and Aquatic Center facilities. Increased use of water recirculation would also minimize the impact of system failure on fish facilities.

SUMMARY AND RECOMMENDATIONS

ADDITIONAL DATA NEEDS

Better records of water demand and use would be beneficial for planning and management purposes. Good data are available on a department basis but not on a crop basis. Academic departments should maintain crop plans that incorporate their seasonal water use. Agricultural Services has data on many wells; Environmental Health and Safety (EH&S) has different data on some of the same wells. The existing data bases should be coordinated, and a long-term data collection program designed to monitor groundwater quality and quantity (e.g., depth to water) should be developed and implemented.

The University has a number of detailed reports on file including: the Putah Creek Cone Investigation (Department of Water Resources 1955) containing extensive hydrogeologic data through 1954, the Scalmanini report (1978), and the Nolte and Associates report (1983). These and other reports need to be periodically reviewed and updated to better plan for future water supplies and water quality needs. The controversy associated with downstream releases to Putah Creek, groundwater pumping, and riparian water rights, and the increasing detection of groundwater contamination support the need for better record keeping and water planning.

The acquisition of the Russell Tract makes it even more important for the campus to review, establish, and modify policies for pricing water and related utility costs.

SUPPLY

Two potential campus actions could create the largest demand for supplemental water to support field teaching and research. First, new research initiatives such as biotechnology-related greenhouses and laboratories or new aquaculture or fisheries facilities could significantly increase the demand on the field teaching and research system. The exact demand cannot be determined until new programs or facilities are proposed. Nonetheless, to ensure that the campus has a reliable, high

quality water supply for new field teaching and research initiatives over the next half century, the campus should secure a new, high quality water supply of approximately 1,600 acre-ft/yr to meet potential for increased demand (Table 4-10). This volume should provide sufficient flexibility to meet potential future increases in demand due to new field teaching and research demands that may occur during the planning period.

Second, land improvement on the Russell Tract to support cultivated crop research will require a new, high quality water supply. As land is converted from production farming to field research, total water use is not expected to change significantly, but it will be necessary to acquire higher quality water supplies to replace the existing unacceptable sources. The quality of water from the Solano Project and from Putah Creek is good. The quality of well water is variable and often high in nitrogen or other elements that limit its value for irrigation of many research crops. Clear Lake water delivered via the Willow Canal is a marginal supply source given the high boron and undependable delivery. High quality surface water is most desirable source to ensure a reliable, high quality supply over the long term. Approximately 4,400 acre-ft/yr would be needed for this purpose.

The campus must also actively manage its existing supply of Solano Project water to ensure that the existing quantity and quality will continue to be available for field teaching and research uses. To accomplish this goal, it is essential that the campus beneficially uses the entire annual 4,000 acre-ft/yr Solano Project water entitlement. Campus records indicate that the full annual entitlement of Solano Project water was not used during the 1989-95 drought when water was banked in anticipation of a prolonged drought. This banked water was lost in 1996 and 1997 when Lake Berryessa filled and the reservoir spilled. One element of the water rights licensing process for the Solano Project is an evaluation of the historical use to document that Solano Project water is routinely put to full beneficial use. To ensure that the campus continues to have access to its current supply of Solano Project water, it must establish a record of full use of the 4,000-acre-ft allotment. Establishing this record in non-drought years is especially important in the years leading up to contract renewal and licensing of the Solano Project water rights.

As field teaching and research activities move to the Russell Tract, the campus should develop the infrastructure and take the legal steps needed to deliver a portion of the University's 4,000-acre-ft

Solano Project allotment at to the Russell Tract. One option would be deliver Solano Project water to the Russell Tract via Putah Creek. Another option would be construct a branch line from the existing university pipeline to the Russell Tract. A feasibility study on pipeline delivery alternatives has been prepared by the campus and can be used as a starting point for future detailed studies (Luhdorff and Scalmanini 1994). Any method of delivering Solano Project water to the Russell tract will require approvals by other agencies such as the Bureau of Reclamation and the State Water Resources Control Board (SWRCB) and will also require completing the necessary environmental review.

In 1991 the United States through the Bureau of Reclamation started proceedings to convert its permit for Solano Project water to a licensed water right. On investigation by SWRCB personnel, it was learned that the official place-of-use for project water on the campus had not been amended since the original map was drawn in 1958. Campus land west of the University Airport was acquired after 1960 and was not within the designated place-of-use. Other member units in Solano County also need boundary adjustments as part of the licensing process. Therefore, the University was able to work with the SCWA to include the University's boundary adjustment with the others. The campus Planning and Budget office worked with SCWA so that the Initial Study and Negative Declaration analyzed the effects of the change. The place-of-use issue will be addressed during licensing of the Solano Project water rights, and it is imperative that the campus continue to monitor and promote completion of this permit revision.

QUALITY/SUITABILITY

The quality of additional sources of water for field research continues to be an issue. The best quality water presently available is surface water from the Solano Project. Generally, the second best water quality is well water with shallow and intermediate aquifer water superior to water from the deep aquifer. Clear Lake water delivered via the Willow Canal is marginal for field research and teaching. The Davis Campus should continue efforts to increase its supply of high quality water like currently received from the Solano Project including possibilities like: (1) exchanging Willow Canal water for Putah Creek water; (2) pumping groundwater from wells in exchange for Putah Creek water; or (3) purchasing more Solano Project water. The campus should secure an additional supply

of approximately 6,000 acre-ft/yr of high quality surface water to ensure an adequate long-term supply for field teaching and research. This volume of water would include approximately 1,600 acre-ft/yr of increased demand for new research initiatives and approximately 4,400 acre-ft/yr to October 14, 1997replace the existing supplies from groundwater and Clear Lake (Table 4-10). The volume of water sought may be reduced if technological advances allow increased use of reclaimed water or if investigation of the groundwater determines that over the long-term these aquifers will be a reliable supply of high quality water.

The campus may need to use available freshwater and wastewater supplies to their maximum beneficial uses if demand for water begins to outstrip available water supplies. One option might be to stage water use for multiple purposes based on water quality constraints. For instance, the highest quality source of water would be reserved for drinking water and animal/plant research activities that require water of the highest quality. In the event such high quality water becomes limited, existing water supplies may need to be improved in quality by treatment (i.e., removal of constituents of concern). Water of poorest quality, such as reclaimed wastewater treatment plant effluent, would be used for irrigation of pastures and landscapes and for coolant waters. The vast majority of waters between these two quality extremes are suitable, with some exceptions, for irrigation of agricultural crops. The above scenario requires appropriate "plumbing" for using waters of differing qualities. It is recommended that reuse of wastewater treatment plant effluent receive high priority for feasibility studies.

Groundwater contamination from point (e.g., domestic and utility wastes) and nonpoint (e.g., field teaching and research practices) sources of pollution are of growing concern. There is increasing evidence of contamination of California's groundwater by nitrates, pesticides, dissolved mineral salts, organic solvents, radionuclides and radioactivity, trace elements, and bacteria. The identification, control and remediation of groundwater contaminants are usually difficult and costly. Contamination of groundwater is often not detected for decades and it usually takes years to correct or treat the problem once discovered.

Present water quality analyses of campus groundwater indicate elevated concentration levels of boron and nitrates in some wells. Boron is a naturally occurring geochemical constituent in the

alluvium in Yolo County. Nitrates most probably came from agricultural activities such as fertilization and animal wastes and from other waste disposal practices.

Since the campus is heavily dependent on groundwater that will likely continue to undergo some water quality degradation in the future, early planning of strategies to remediate groundwater pollution should be a high priority. One possibility is to research the potential of using contaminated waters or partially-treated contaminated waters for agricultural and landscape irrigation. Depending on the degree of contamination, many water contaminants can be safely degraded or transformed through physical, biological, and chemical processes operating in the soil-plant-atmosphere continuum.

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Chapter 5

DOMESTIC AND UTILITY WATER USES

EXISTING SOURCES

Water supplied for building and laboratory use and for heating, cooling, and other "industrial" uses on the Davis campus is designated as domestic water. Water supplied for nonagricultural irrigation, greenhouse use, and some laboratories is designated as utility water. Although both uses are served exclusively by groundwater, the different quality requirements of each have resulted in the development of separate systems.

The primary sources of water for the domestic system are deep aquifers, 800-1,500 feet bgs. These aquifers are confined below thick clay beds and have been explored and developed only in the general Davis area within Yolo County. A study of logs of oil and gas wells in the area revealed the presence of the deep aquifers beneath Davis and extending approximately five to seven miles west and north of the city. However, it appears to be blocked by clay deposits to the east and south. Based on drilling logs, these aquifers consist of unconsolidated sand and gravel interspersed with lenses of clay. Little additional information has been developed on the characteristics of the deep aquifer. Well tests in the 1970s determined aquifer transmissivity in the range of 10,000-25,900 gallons/day/foot (gpd/ft) (Scalmanini 1978).

Water for the utility system is supplied by wells completed in intermediate aquifers 150-800 ft bgs. These aquifers are unconfined or semiconfined and are part of a broad geologic plain built mainly by Cache Creek, Putah Creek, and Willow Slough. This plain, called the Lower Cache-Putah Basin, is one of six geohydrologic sub-basins identified as part of an analysis of groundwater in Yolo County. It consists of alluvial fan deposits composed of unconsolidated clay and silt, sand and gravel underlain by some hard silt and clay, and cemented sand and gravel. Well tests in the 1970s determined aquifer transmissivity beneath the campus at about 70,000 gpd/ft (Scalmanini 1978).

Table 5-1 - Domestic well specifications. Locations of domestic wells are illustrated in Figure 3-3.

Well	Date Drilled	Depth (ft)	Gravel Packed	Design Capacity (gpm)	Actual Capacity (gpm)[1]	Pump HP	Comments
DW2	1952	1368	No	400	433	30	Plant efficiency 64.4 rated excellent (10/91)
DW3	1952	1450	No	1000	688	50	Plant efficiency 59.6 rated good (10/91)
DW4	1971	1430	Yes	1200	900	200	Well rehabilitated (4/93), pump rebuilt (9/94)
DW5	1969	1470	No	1300	1100	100	Plant efficiency 66.0 rated good (10/91)
DW6A	1988	1448	Yes	1150	1035	125	Plant efficiency 76.1 rated excellent (10/91)
DW7A	1995	800	Yes	1000	1000	100	Added to system summer 1996

[1] Flow rate based on 1990 PG&E pump test.

DOMESTIC WATER SUPPLY

The University operates six wells exclusively for domestic water supply. All wells are completed in the deep aquifers between 800 and 1,500 ft bgs (Table 5-1). These wells are in various locations across the campus as illustrated in Figure 3-2.

Total pumping capacity of the Domestic System is 5,156 gpm, based upon the most recent Pacific Gas and Electric Company (PG&E) pump test reports conducted winter 1990, daily readings, and the estimated capacity of well 7A which was added to the system in 1996. This is approximately 85% of the original design capacity of 6,050 gpm for the six wells serving the system. An evaluation of DW3 in fall 1993 indicated marginal performance and pump replacement was recommended. DW3 pump assembly was rebuilt with new impellers in summer 1994. Well DW4 was rehabilitated in spring 1993, restoring its capacity from 470 gpm to 900 gpm. Nonetheless, production dropped to below 300 gpm in August 1994. Inspection of the pump assembly revealed excessive wear due to pumping sand which had entered the well. A replacement well pump bowl assembly designed to be resistant to sand, a sand screen to stop or retard sand intrusion, and a sand monitor were installed on DW4 in fall 1994, and the well is observed closely for further signs of deterioration. An evaluation of well DW7 completed in spring 1993 resulted in abandoning that well and constructing a nearby replacement well. The new well (DW7A) is located approximately 500 feet north of the old DW7

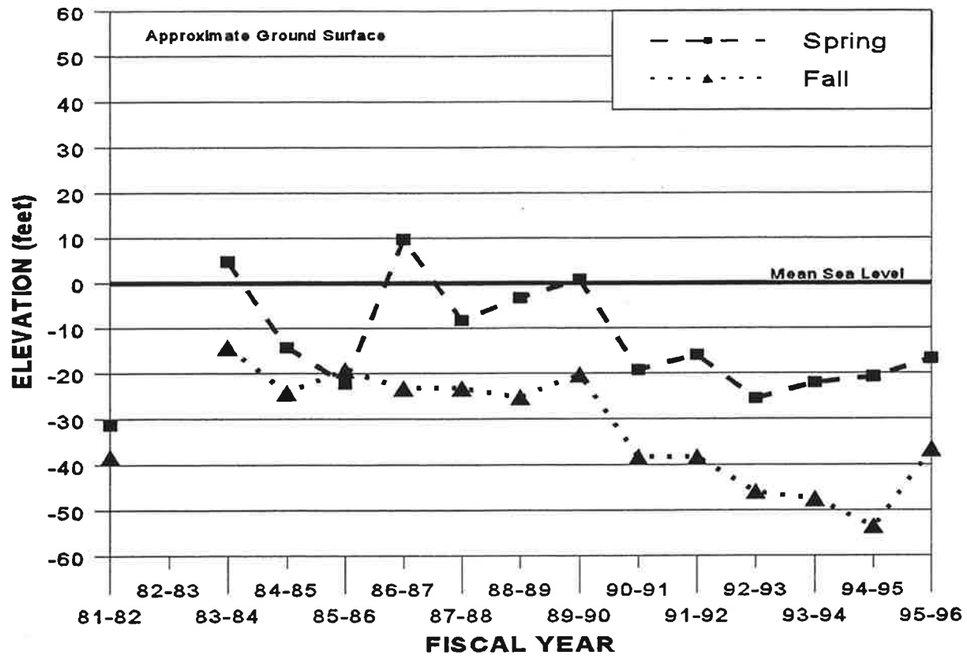

Figure 5-1 - Average spring and fall groundwater elevations relative to mean sea level for domestic wells in deep aquifers (800-1500 ft deep). Ground surface elevation on the central and west campus is approximately 50-60 feet above mean sea level.

well site, was completed to the deep aquifer in summer 1995, and was added to the system in fall 1996.

Water levels in domestic wells have been recorded each spring (late March) and fall (late September) since 1981-82 (Figure 5-1). As expected, the groundwater basin is higher in the spring following the winter rainy season; water levels can be 20-30 feet lower each fall following the dry summer. The existing record of water depths is insufficient to establish long-term trends. However, the average groundwater elevation in spring and fall 1995-96 slightly exceeded the earliest records in 1981-82. An extended 6-year drought beginning with the 1986-87 rainy season resulted in a 20-30 foot drop in overall groundwater elevation from the preceding years. Water levels apparently began to rebound in 1994-95 and 1995-96 following two wet winters at the end of the drought. Similarly, water depths rose following wet winters in 1982-83 and 1985-86. These observations suggest that

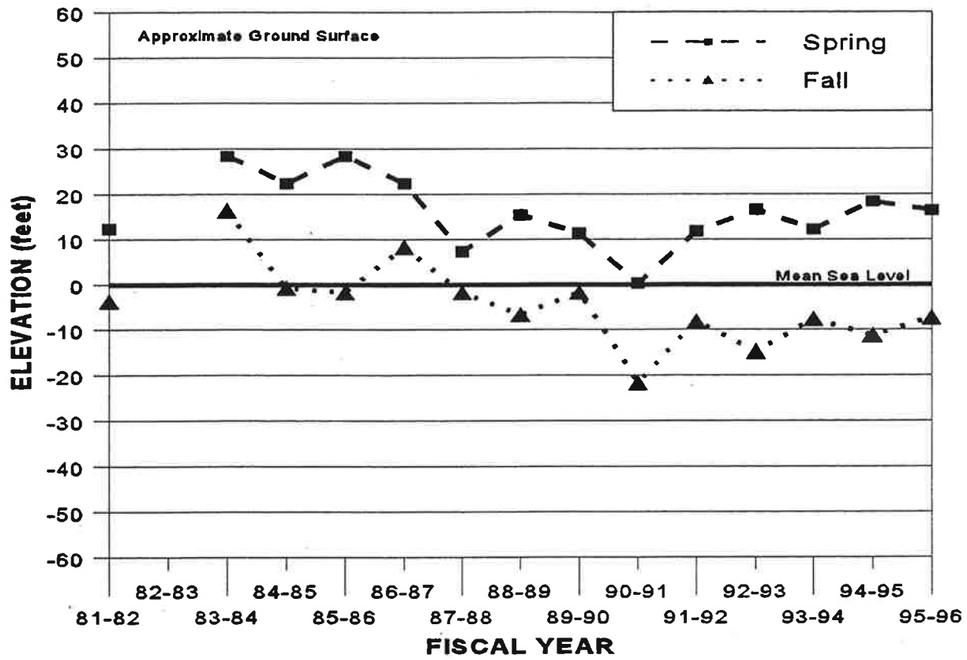

Figure 5-2 - Average spring and fall groundwater elevations relative to mean sea level for utility wells in the shallow and intermediate aquifers (150-800 ft deep). Ground surface elevation on the central campus is approximately 50-55 feet above mean sea level.

at historical pumping rates the aquifers tapped by the domestic wells can recover following extended drought. No statistically valid correlation was found between groundwater elevation and pumping records. This result may mean that the impact due to pumping is less significant than other environmental influences such as precipitation levels.

Available data are insufficient to determine the long-term effects of present and future pumping demands on the deep aquifer system. Therefore, a hydrogeologic study should be conducted to determine the impact of continued or increased pumping demand and to possible changes in water quality.

Table 5-2 - Utility well specifications. Locations of utility wells are illustrated in Figure 3-3.

Well	Date Drilled	Depth (ft)	Gravel Packed	Design Capacity (gpm)	Actual Capacity (gpm)[1]	Pump HP	Comments
UW2	1945	324	No	875	720	75	Plant efficiency 57.4 rated fair (10/91)
UW3	1909	321	No	800	660	75	Plant efficiency 58.6 rated fair (10/91)
UW4	1938	326	No	1,000	565	30	Plant efficiency 67.2 rated excellent (10/91)
UW5[2]	1968	470	Yes	900	1,140	100	Plant efficiency 75.2 rated excellent (10/91)
UW6A[2]	1994	290	Yes	1,000	1,000	100	Added to system Summer 1995
UW7	1951	414	Yes	1,000	960	100	Plant efficiency 65.6 rated good (10/91)

[1] Flow rate based on 1990 PG&E pump test.
[2] Interconnected to domestic system with backflow prevention valves.

UTILITY WATER SUPPLY

Water supplied by the campus utility system is pumped from six wells completed in the intermediate aquifer (Table 5-2). The locations of utility wells are illustrated in Figure 3-3. Total capacity on the Utility System is 5,045 gpm, based on Winter-1990 PG&E pump tests, or about 90% of the original 5,575 gpm design capacity for the six wells serving the system. In 1979, well UW6 was shut down due to poor performance, and the well was officially abandoned in 1986. This well had been a poor producer since its installation in 1969 and had additional problems with high levels of total dissolved solids (TDS). Replacement well UW6A with a designed capacity of 1,000 gpm was developed in summer 1994 and began producing water in spring 1995 (Table 5-2 and Figure 3-3).

Spring and fall water levels in utility wells have been recorded annually since 1981-82 (Figure 5-2). While the recent trend (1983-1994) in the intermediate groundwater levels suggests a decline in groundwater elevations, it should be recognized that the period began with very wet years in 1981-82 and 1982-83 and continued with 8 out of 10 years of below average rainfall (Figure 5-3). Despite this extended drought, spring and fall water levels at the end of the period were approximately the same as the earliest record in 1981-82. Water level hydrographs over a longer period from other wells completed in the general vicinity of the campus suggests those groundwater levels, while lower than in the early 1980's due to drought conditions, are comparable to groundwater levels over the 20-year period preceding the 1976-1977 drought.

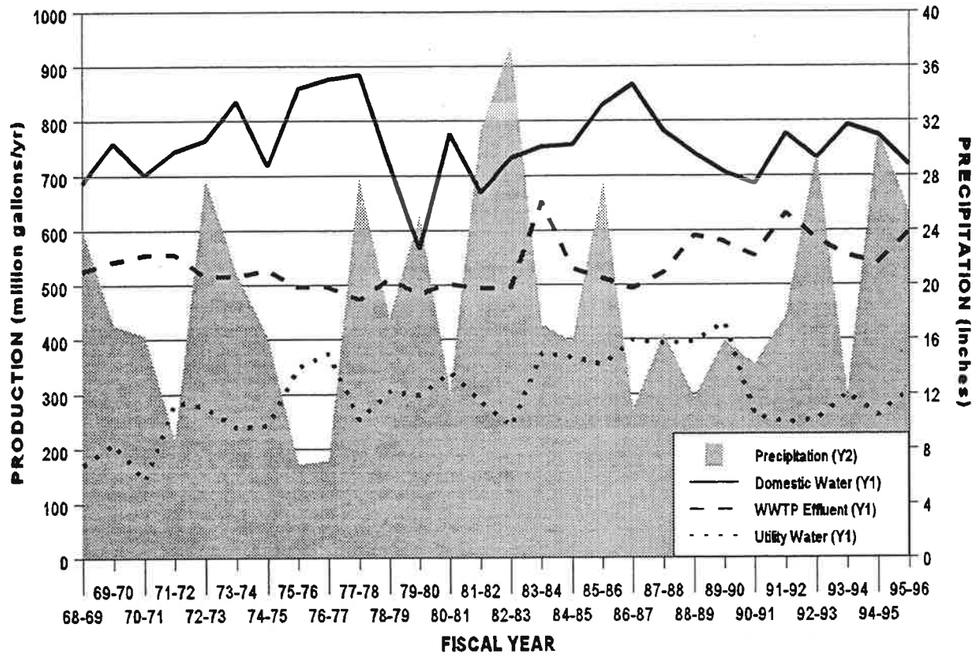

Figure 5-3 - Domestic and utility water production, effluent discharge from the wastewater treatment plant (WWTP), and annual precipitation at the main campus from fiscal year 1968-69 through 1995-96. Precipitation data from the National Oceanic and Atmospheric Administration reference climatological station operated by the UC Davis Department of Land, Air, and Water Resources.

WATER QUALITY

The quality of domestic and utility water is analyzed on a routine schedule according to state and federal standards. Bacteriological analysis of domestic water is conducted weekly by Wastewater Treatment Plant (WWTP) personnel using samples taken from random sites throughout the campus. The results are forwarded to EH&S, and a monthly report is submitted to the California State Department of Health Services (DHS) to demonstrate compliance with state standards. Domestic water is subject to regulation by the U.S. Environmental Protection Agency (USEPA) under the Safe Drinking Water Act as well as by the DHS under the California Safe Drinking Water Act.

Prior to September 1992, the domestic water supply had passed all bacteriological standards. Effective September 1, 1992, a new method of testing for coliform bacteria known as a Coliert test

was put into place by analytical laboratories within the State of California; Coliert is one of several methods of testing bacteriological quality under new regulations. This change was in response to new DHS sampling and testing procedures under Title 22 of the California Code of Regulations to bring the state into compliance with federal guidelines.

Under these new more stringent testing procedures the total coliform bacteria detected in the September 1992 analysis of the campus domestic water supply exceeded applicable standards. In December 1992, the University received a Citation for Noncompliance from DHS for failure to comply with the Maximum Contaminant Level (MCL) for coliform bacteria, known as the Total Coliform Rule. Immediate chlorination of the campus domestic system was ordered by the Office of Drinking Water. An extension for disinfection of the system was granted until the end of 1993 so alternate water supplies could be developed for chlorine sensitive research projects on campus. A dedicated well and pumping plant were installed at the Aquaculture Facility (See chapter 4) and charcoal filters were installed at 20 other locations.

Chlorination of the domestic distribution system began on January 3, 1994. Sodium hypochlorite was initially injected at 0.5 ppm but was reduced to 0.25 ppm when the demand within the distribution system was satisfied and free chlorine was consistently available at user sites. This lower rate of chlorination has been maintained since then and has been proven effective. Facilities personnel monitor the chlorine levels in the water supply as it leaves the underground reservoir and at various locations within the distribution system on a daily basis to ensure a constant residual level of chlorine is maintained.

Chemical and radiological samples are taken every 3 and 4 years respectively, from all active domestic and utility wells for submittal to an independent, certified laboratory. Test results are compiled by EH&S and summarized in an Annual Water Quality Report required by DHS (Appendix D). This report is distributed to campus users and demonstrates that the quality of water supplied to the campus complies with State and Federal primary and secondary drinking water standards.

In addition to state and federally required testing, the University Cooperative Extension Laboratory provides data on metals, nitrates, chlorides, and other dissolved ions to campus

researchers. Samples are drawn weekly at 5 or 6 locations from the distribution systems by WWTP personnel. Sampling locations are rotated weekly to ensure all portions of each system are eventually monitored.

The **domestic water** supply is a sodium-bicarbonate, magnesium-bicarbonate water. It has an EC of about 0.6 mhos and poses a low salinity hazard. Boron and chloride levels are satisfactory for research on most plants. The sodium adsorption ratio is below six. TDS levels in the deep aquifer, the domestic supply, are about half of that found in the shallow and intermediate aquifers which supply utility water. The Annual Water Quality Report submitted to the CVRWQCB in April 1996 is presented in Appendix D.

The **utility water** supply is a calcium-magnesium bicarbonate water, high in both TDS and hardness. It poses a medium salinity problem but can be used for irrigation of moderately salt tolerant crops. Boron levels have decreased over the last ten years and are satisfactory for most crops. Crops that could suffer from the concentrations of boron found in some of the wells are listed by Tanji (1991). Chloride levels are satisfactory for all crops and sodium adsorption ratios are low. Overall groundwater quality from the shallow and intermediate aquifers is good for agricultural uses (Scalmanini 1978). No significant changes in water quality have been detected over the past 20 years, which includes two drought periods and increased local demand on these aquifers. Campus researchers also prefer utility water to domestic water for greenhouse uses because of its hardness (Doneen 1955).

INTERCONNECTIONS BETWEEN SYSTEMS

The utility and domestic systems are operated separately but can be cross-connected under emergency conditions by opening interconnecting valves located at the intersections of Hutchison Drive and California Avenue, California Avenue and Storer Mall, and North and West Quad. These interconnections are not protected by backflow prevention valves. In addition, UW5 and UW6A have been fitted with backflow prevention devices and valves which enable them to discharge directly into the domestic system. This arrangement allows the utility system to back-up the domestic system in case of an emergency but prevents chlorinated domestic water from entering the utility system. The

UW5 connection valve is located south of the Unitrans Maintenance facility. The UW6A connection valve is located on Mini Center Drive north west of the TAPS trailer complex. The domestic system can also be connected to the City of Davis water system via two post-indicator valves; one is located at the intersection of Russell Boulevard and California Avenue and the other on First Street at Aggie Village.

The ability to interconnect systems provides management flexibility for emergencies. However, the interconnections have the potential to create problems for some research applications due to water quality differences between the systems. Connection at UW5 or UW6A is the preferred method to back-up the domestic system. The necessity to back-up the utility system with domestic water is less likely and should only occur as a last resort with prior notice given to research groups.

DIVERSITY AND EXCEPTIONS IN CAMPUS WATER USES

Nearly every campus facility receives domestic or utility water. Domestic water is used primarily to serve the needs of more than 30,000 individuals in approximately 4.5 million assignable square feet (ASF) of academic and administrative facilities, including approximately 2,300 on-campus residents, in approximately 1 million ASF of on-campus housing. Utility water is designated primarily for the nonagricultural irrigation of approximately 300 acres of landscaped areas and is also used in some greenhouses.

Despite these somewhat distinct uses, expediency and insufficient funds during construction have, on occasion, resulted in exceptions to this distinction between uses of the two water systems. These exceptions are of special concern when facilities rely on utility water resources for domestic use. The utility water system is not chlorinated and is not sufficiently protected with backflow prevention devices. This situation was known to exist at the Hunt Hall Tennis Court Drinking Fountain and Head House 20 adjacent to by Hunt Hall, but the situation was remedied by connecting these facilities to the domestic system in 1993 and 1994.

Conversely, domestic water is sometimes used for landscape irrigation. When utility water lines are not available near areas requiring irrigation. This use occurs at the following locations:

- Campus South of I-80 & Old Davis Road
- Campus West of HWY 113
- Far east portion of the arboretum
- Center for Child and Family Studies
- West side of facilities corporation yard
- Voorhies Hall courtyard
- West side of HA2

The use of domestic water for these purposes may present some concern if the deep water aquifer is determined to be less of a renewable resource than the shallow or intermediate aquifers. If it is, the value of the domestic water should be considered when determining the source of water for given applications.

The Aquatic Center at the Institute of Ecology received water from the domestic system until chlorination in 1993 made water from the domestic system unsuitable for aquatic research. In December 1993, a well dedicated to the Aquatic Center was completed. The new well (E1) was designed to produce 1,000 gpm from the intermediate aquifer and is considered a Field Teaching and Research well (Table 4-1). The existing domestic system connection was equipped with a sodium bi-sulfide injection system to neutralize residual chlorine and provides a 300 gpm emergency backup. Domestic water use has been reduced by approximately 153 million gallons/yr (468 acre-ft) by transferring this use from the domestic system to the field teaching and research system.

Chlorination of the domestic water supply also required providing untreated water for fish biology research in the Academic Surge Building. To meet this need, a single purpose well was installed immediately south of this building in 1996. The well is not connected to either the domestic or utility water supply systems, draws from the intermediate aquifer, and has pumping capacity of approximately 50 gal/min.

The domestic system provides water for fire protection with all but two hydrants connected to the domestic supply. Hydrant B-08 at Seed Research and D-12 at Gilmore Hall are connected to the utility water system. If a fire occurred during a power outage in an area served by these hydrants,

there would be no water supply without cross-connecting the domestic system to the utility system. This delay might compromise the Fire Department's ability to quickly respond to such an emergency.

The volume and type of water use within academic and administrative departments is extremely diverse. Quantification according to type of use is not possible due to lack of metering equipment. A distinction must be drawn between water used by building occupants and water used to support the building systems. Specifically, chilled water used for cooling is a large demand that is not controlled by individual departments and users. Total water use for cooling is approximately 31 million gallons/yr (95 acre-ft) at the central plant and 39 million gallons/yr (120 acre-ft) in individual buildings. These values are based on use measurements at the central heating and cooling plant and on relative efficiencies and installed capacity at individual buildings.

EXISTING INFRASTRUCTURE

DOMESTIC WATER SYSTEM

Infrastructure Description: The six domestic wells are connected to a multiple-loop piping distribution system that extends approximately 144,000 linear feet through mains ranging in size from 6" to 14" (Figure 3-2). Service lines ranging in size from ½" to 8" tap off of these mains to serve campus facilities. Storage capacity is provided in two elevated steel storage tanks of 200,000 gallons (Domestic Water Tower #1) and 100,000 gallons (Domestic Water Tower #2), and a 1,500,000 gallon underground reservoir. Domestic Water Tower #1 is located near the intersection of Old Davis Road and California Avenue and controls the operation of four booster pumps in the pump house adjacent to the underground reservoir. Domestic Water Tower #2 is located in the west campus near the sheep barn. Both elevated tanks have a float operated level indicator flags on their bowls. Domestic Water Tower #1 also has a low and high water indicator light at its base and can send signals to the Fire and Police station. The underground reservoir is located immediately adjacent to DW5 and south of Domestic Water Tower #1.

Domestic Water Tower #1 is flushed annually, was relined in 1986, and is in good condition. Domestic Water Tower #2 was relined in 1987 and is also in good condition. Some rusting has

occurred on the exterior of the larger tank indicating the need for an exterior paint inspection. Both tanks are inspected once every five years by an outside contractor

DW2, DW3, and DW5 deliver water directly to the underground reservoir and are controlled automatically by a level monitor in the reservoir. As the level of water drops, the wells are brought on-line successively to maintain storage. Well sequencing can be changed to facilitate system maintenance and overall efficiency. DW4, DW6A, and DW7A discharge directly to the distribution system and are normally manually controlled. If pressure drops below a preset value, pressure sensors start the wells automatically.

The four booster pumps in the pump station adjacent to the underground reservoir are used to pump water from underground storage into the system at the base of Domestic Water Tower #1 to maintain pressure within the distribution system and water level in the tower. The boosters are controlled automatically by a pressure sensor located at the bottom of the tower. As demand outstrips the capacity of the wells discharging directly into the system, water is drawn from the water tower. A drop in pressure triggers the booster pumps to pump water from the underground reservoir. The booster pumps are capable of injecting water at pressures higher than those found in the distribution system so water level in the tower is restored at the same time a system pressure of 60 psi is maintained. This well-reservoir-booster combination can simultaneously meet peak loads, reserve system capacity, and maintain steady state system pressures without surges.

The water tower in west campus was designed to regulate system pressure by controlling well DW6A. A hydraulic problem in the distribution system prevents this from occurring. The tower is connected to the distribution system via a 10" main that ends near the tower. Three smaller distribution lines tee off of it the 10" main and DW6A discharges directly into the 10" main. The tower has an altitude valve at its base that closes when the system pressure approaches a point that would overflow the elevated storage tank. When DW6A is running, back pressure keeps the altitude valve closed, forcing water back into the tower, and causing water in the tower to become stagnant. In the past, bacterial growth was a problem, and the tower was purged every 14 days causing a water loss of nearly 2 million gallons/yr. With the introduction of chlorine to the domestic system, purging the tower is no longer necessary. As part of the project to construct the new Environmental Services

Facility on the west campus, the 10" DW6A discharge main will be extended to a less restrictive point in the distribution system to correct the back pressure situation.

Control System: DW4 on the south campus must be run manually, and its status can be determined only by visual inspection. Similarly, DW6A and DW7A on the west campus are manually controlled without remote status monitoring. Only the central campus wells (DW3, DW4, and DW5) in conjunction with the underground reservoir are controlled automatically. Thus, only the underground reservoir booster pumps are capable of responding automatically to system variations. Overall production and demand must be balanced by manually operating the three wells that pump directly into the system. This method of system control is labor intensive, and may be difficult to achieve with future system changes. Eventually, the three manual wells should be remotely monitored and automatically controlled at a central location.

Emergency operation of domestic wells is via manually controlled stand by engines and generators. Manual control has not been a problem during emergencies because the reserve capacity of the underground reservoir and the automatic engines on the booster pumps are capable of supplying 3,735 gpm which is sufficient to meet short-term emergency demands until production by manually operated wells can be increased.

Existing controls on the underground reservoir currently provide reliable water service to the campus. However, maintenance of this system has become increasingly expensive due to outdated components; the controller is no longer produced and parts are not available. The programming and circuit design of the control system were developed in-house by Facilities Services personnel, are unique to this system, and problems are difficult to diagnose. An attempt to replace the original pneumatic bladder system that controls the booster pumps was initiated in 1988. A programmable controller-based system was installed, but design problems and lack of funding prevented successful completion of the project. The peripheral sensors that provide input to the system have also become problematic. New controls on the entire domestic system are scheduled to be installed by fall 1997. Automatic operation of the system with remote monitoring and control will provide a more efficient, manageable, and reliable system.

Distribution System: Distribution system piping is adequately sized and in good condition. Piping ranges from 2" to 16" in diameter and is made up of a variety of materials including asbestos-cement, cast iron, concrete coated steel, and PVC. Asbestos-cement lines are proving to be more difficult to maintain due to hazards associated with the asbestos content of the pipes. Presently, the campus standard is to install mechanical joint PVC which has proven to be reliable and easy to use and maintain. As new mains are installed, they are disinfected in accordance with the American Water Works Association standards.

Tracer wires are now being installed with new piping to allow easy locating with radio frequency sensing equipment. This improvement speeds response time when underground line must be located to repair water leaks or for new construction.

Leaks have not been a major problem on the system (usually only six main leaks a year). When broken mains do occur, they are repaired, the repair is disinfected with a hypochlorite solution, and service is usually restored within hours. The system probably has a number of small, underground leaks that have never reached the surface. A sonic leak detection survey should be conducted to determine the number and location of such leaks. Surveys of this kind have been conducted in areas such as Petaluma, Poway, and the Serrano Irrigation District, south of Los Angeles. Results have been favorable and show the costs of the survey and associated leak repair are recovered in 1-2 years. The estimated cost for a campus survey is $20-30,000.

Dead-end mains and hydrant runs pose possible pressure losses in high demand times and can cause stagnant, no-flow situations in the vicinity of Animal Resources Service, the CRPRC, and near La Rue Road. Looping these areas back to the system would solve these problems, but to date the costs have not justified these changes to the system. Annual flushing helps clean these lines and is done as part of the hydrant flow testing program conducted by the Fire Department.

Until 1996, the CRPRC on the west campus had been subject to increasing pressure fluctuations. This situation could have become increasingly difficult with the construction of additional field cages that depend on overhead sprinklers to keep occupants cool when temperatures exceed 90°F. The problem was solved by adding DW7A to the system and will be further improved

by local distribution system improvements at the CRPRC included in the Center for Comparative Medicine project currently under construction.

Backflow Prevention: Facilities Services maintains a backflow prevention program on the domestic system to prevent potential contamination of the potable water supply. Backflow prevention valves have been installed on most facilities, separating the water service for domestic and industrial uses. These valves are tested and/or repaired annually as required by the Federal Safe Drinking Water Act of 1974 and Title 17 of the California Administrative Code.

UTILITY WATER SYSTEM

Utility water is distributed via a pipeline network interconnecting six wells and one 100,000-gallon elevated storage tank. All of the wells discharge directly into the system, and their operation is controlled by a pneumatic level sensor in the tank. The tank is equipped with a float-controlled level indicator flag and a low water light that serve as alarms for level and pressure problems.

All of the utility wells receive power from the campus electrical grid. New UW6A was constructed with a diesel generator for back-up power. The other wells are without auxiliary power supplies. This disadvantage prevents using the utility system for anything other than landscape irrigation. All wells must be visually inspected to determine the operational status.

The utility water distribution system serves only the central campus (Figure 3-3) and consists of approximately 52,000 linear feet of mains ranging from 4" to 12" in diameter. Since the system is limited to the central campus, domestic water is used for activities normally supplied by utility water in both the south and west campus areas. If not changed, this limitation in the utility system will require that the domestic water system must provide water for irrigated landscapes as new facilities are developed west of Highway 113 and south of Interstate 80.

The utility system is not considered a potable water supply because backflow protection is incomplete. This factor requires monitoring of actual and potential cross-connections with the domestic system. A complete survey of the utility system is needed to determine the extent of existing protection and where additional valves may be needed. Failure to install backflow valves at

new connections to the utility system could create new potential cross-contamination problems. Incomplete backflow prevention places the quality of domestic water at some risk due to the potential interconnection between the systems under emergency conditions. A safe connection can be made to backup the domestic system with utility water bu using DW5 and DW6A as described above. Backing up the utility system with domestic water requires opening in-ground valves which directly connect the systems without benefit of backflow protection.

CURRENT AND HISTORICAL WATER USE PATTERNS

DOMESTIC SYSTEM

Records on domestic water use are available beginning in 1968 (Figure 5-3). Domestic water consumption generally increased from 1968 until 1978 and then declined dramatically. The sharp drop is likely attributable to water conservation efforts following the 1976-77 drought. Consumption levels rose again between 1980 and 1986 and have declined overall since then. This recent downward trend is most likely due to the extended drought that began in 1986-87, the resulting increased campus and public awareness of the water problems currently facing California and the importance of water conservation, and shifting the Aquatic Center to the Field Teaching and Research water system in December 1993 (See chapter 4).

Domestic water production over the 28-year record was relatively static despite a 62% increase in total ASF in campus administrative and academic buildings and on-campus housing (3.4 million ASF in 1968 to 5.5 million ASF in 1994). Improved water use is attributable to more efficient building designs for facilities constructed in the last two decades and a more aggressive water conservation program established in the late 1970s.

Total campus population, including faculty, students, and staff, increased by 89% between 1968-69 (16,197 individuals) and 1994-95 (30,585 individuals). Consumption per person/day has decreased from 116 gallons to 69 gallons over the last 27 years. According to the U.S. Public Health Service estimates, approximately 15-25 gallons/day can be attributed to individual use. Thus, the majority of domestic use is for research and building mechanical systems.

Table 5-3 - Present and estimated daily and hourly water demands for the domestic and utility water systems.

WATER DEMAND	VOLUME (gallons/min)	
	Maximum Day	Peak Hour
Domestic Water System		
Present capacity	6,670[1]	6,670[1]
Present demand	6,500	8,000
2006	7,500	9,700
2046	8,250	11,000
Utility Water System		
Present capacity	5,045	n/a
Present demand	5,045	n/a
2006	5,700	n/a
2046	7,125	n/a

[1] Does not include 2,140 gpm of standby capacity provided by interconnections to utility wells 5 and 6A.

The volume of effluent produced at the WWTP is not significantly correlated with domestic water production ($r = -0.14$, $P = 0.47$) (Figure 5-3). Lack of correlation is likely due to domestic water uses that do not discharge to the sanitary sewer system. Examples include the CRPRC prior to constructing the west campus wastewater connection in 1995, landscape irrigation on the south and west campus, Environmental Horticulture greenhouses, a number of cooling towers connected to the WWTP in 1996, and former domestic water use at the Aquatic Center.

Meeting peak flow demands, including fire flow requirements, is an important requirement of managing the campus water supply. Domestic water system pumping records indicate a maximum day demand of 2,000 gpm and a peak hour demand of 3,500 gpm under normal conditions. Fire flow requirement is an additional 4,500 gpm and increases maximum day demand to 6,500 gpm and peak hour demand to 8,000 gpm (Table 5-3).

Estimated current capacity of the domestic system assumes 975,000 gallons or 75% of the 1.3 million gallon reservoir will be available to meet projected maximum day and peak hour demands. Using reservoir booster pumps at full capacity for a 4-hour period would require 896,400 gallons (3,735 gpm X 240 minutes) and is within the available reservoir capacity. Domestic wells DW4,

Table 5-4 - Estimated current annual utility water use for landscape irrigation on the central campus. Turf calculations based on a maximum application rate of 1.25" per week.

LANDSCAPE TYPE	VOLUME	
	Million gallons/yr	Acre-ft/yr
Planter Beds	<1	<1
Ground Cover	4	12
Shrubs	10	30
Turf	210	645
TOTAL	224	687

DW6, and DW7A connect directly to the distribution system increasing the 4-hour capacity of the domestic system to 6,670 gpm (3,735 gpm + 2,935 gpm = 6,670 gpm). Thus, the existing configuration of the domestic system can meet the present potential maximum day demand of 6,500 gpm. Interconnections to domestic wells 5 and 6A provide 2,140 gpm of standby capacity that can be used in emergencies to meet the present potential peak hour demand of 8,000 gpm.

UTILITY SYSTEM

The utility system is much smaller and has more limited application than the domestic system, but is more difficult to analyze for consumption trends and causal relationships because individual uses are not metered. Total utility water production has been monitored since 1968 (Figure 5-3). This water is used to irrigate approximately 300 acres of landscaping and several greenhouses within the central campus. Roughly 10-20% of utility water is used for non-irrigation purposes including central campus greenhouses. Total utility water production and annual precipitation since 1968 are inversely correlated ($r_s = -0.45$, $P<0.05$). This relationship is undoubtedly due to higher demand for landscape irrigation during dry years. The correlation probably is not stronger because most rain occurs in the winter when irrigation is already at a minimum, a significant proportion of utility water is not used for landscape irrigation, and the existing landscape irrigation system controller cannot be easily reset to conserve water following short duration storms.

Table 5-5 - Present and estimated annual water demands for the domestic and utility water systems.

WATER DEMAND	VOLUME	
	Million gallons/yr	Acre-ft/yr
Domestic Water System		
Present	760	2,350
2006	1,115	3,430
2046	1,400	4,300
Utility Water System		
Present	300	925
2006	340	1,050
2046	425	1,300

Utility water demand has declined approximately 30% from peak levels in 1989-90 due primarily to changed landscape watering practices. Turf previously was watered until there were no brown spots resulting in some areas receiving twice the necessary water. This policy was changed, and turf areas now receive a maximum of 1.25" of water per week. Total current utility water use for landscape irrigation is presented in Table 5-4. Utility water used for landscape irrigation is expected to increase 1.5-2.0% per year due to new development on the central campus including new athletic fields

The utility system peak hour demand of 5,045 gpm is over 1,500 gpm higher than the domestic system peak (exclusive of fire flow requirements), yet annual utility water production is considerably less than domestic. The high peak utility water demand is due to current policies that focus landscape irrigation to a shorter time to minimize evaporation and to keep irrigated areas available to daytime users. While this is an appropriate policy, the drawback is creating a higher peak demand that could eventually outstrip available capacity. Consequently, a failure of even one well results in the need either to temporarily reduce irrigation or to change irrigation schedules.

DEMAND AND MANAGEMENT ANALYSIS

Projected short-term (year 2006) and long-term (year 2046) water demand and consumption estimates are presented in this section and summarized in Table 5-5.

Table 5-6 - Estimate of domestic water use for campus buildings in 2006 exclusive of off-campus housing.

WATER USE	VOLUME	
	Million gallons/yr	Acre-ft/yr
Average water use - 1993-96	760	2,350
Estimated use for on-campus housing[1]	130	400
Net water use for academic/administrative uses[2,3]	630	1,950
Estimated 2006 water use for academic/administrative uses[2,4]	910	2,800
Estimated 2006 water use for on-campus housing[5]	205	630
Estimated 2006 domestic water use	1,115	3,430
Estimated net increase in domestic water use	355	1,080

[1] Assuming 4,250 on-campus residents in 1995-96 @ 30,700 gal/resident/yr based on metered use at Russell Park and LaRue Park in 1995-96
[2] Includes building use and grounds irrigation on South and West Campus
[3] Avg. use per assignable sq. ft. of buildings = (630 million gal/yr)/4,550,000 sq. ft = 140 gal/sq. ft/ yr
[4] Based on 140 gal/sq. ft./yr x 6,495,740 assignable square feet in 2006
[5] Based on 6,700 on-campus residents by 2006 @ 30,700 gal/resident/yr

SHORT-TERM--DOMESTIC SYSTEM

Annual Consumption: Estimates of future water demand are estimated separately for on-campus housing and for academic and administrative uses due to the different water use patterns in these two distinct types of facilities. The number of on-campus residents is expected to increase by 58% from approximately 4,250 campus residents in 1995-96 (3,230 students and 1,020 dependents) to 6,700[1] in 2006. These estimates do not include approximately 1,450 residents in university-owned housing north of Russell Boulevard who receive domestic water from the City of Davis. The rate of domestic water use at the Russell Park and LaRue Park student housing areas was approximately 30,700 gallons/resident/yr in 1995-96. This value is comparable to expected residential use rates published U.S. Public Health Service (1988). Based on the expected population growth and the existing water use rate, total domestic water use is projected to increase to approximately 205 million gallons/yr (630 acre-ft/yr) due to increased on-campus residents (Table 5-6).

[1]The estimate of on-campus residents in 2006 assumes 25% of the projected enrollment of 26,000 on-campus students will live in university-owned housing and that the number of off-campus, university-owned housing units will not increase. Thus, the number of students housed on-campus will increase by approximately 58% to 5,100 individuals. The number of dependents living on-campus is assumed to rise by a similar proportion to 1,600 individuals.

The 1994 LRDP projected that total ASF for academic and administrative uses would rise from 4,550,000 ASF in 1993[2] to 6,495,740 in 2006, a 43% increase. Domestic water production was approximately 140 gal/ASF/yr over 1993-96. Assuming this use rate in the future, total domestic water demand for academic and administrative uses will be approximately 910 million gal/yr (2,800 acre-ft/yr) in 2006 (Table 5-6).

Total domestic water use will be approximately 1.12 billion gal/yr (3,430 acre-ft/yr) in 2006, an overall increase of approximately 47%.

Peak Hour and Daily Demand: For purposes of this study it was assumed there will be an equivalent relationship between total annual consumption and peak demand. Accordingly, the projected 47% increase in annual consumption by 2006 would increase peak hour and maximum daily demands by the same percentage. Maximum day demand would increase from 2,000 gpm to approximately 3,000 gpm and peak hour demand would increase from 3,500 gpm to approximately 5,200 gpm. Combined with the 4,500 gpm campus fire flow requirement, in 2006 the maximum day demand would be 7,500 and the peak hour demand would be 9,700 (Table 5-3).

In 2006, the required maximum day demand for a 4-hour period would be approximately 1.8 million gallons (7,500 gpm X 240 minutes), and the required peak hour demand for a 4-hour period would be 2.3 million gallons (9,700 gpm X 240 minutes). The reservoir booster pumps used simultaneously with full production from domestic wells 4, 6, and 7A are currently capable of producing approximately 1.6 million gallons in a 4-hour period (6,670 gpm X 240 minutes). Based on these estimates, the domestic water system would not have sufficient pumping capacity to meet either maximum day or peak our demands in 2006. An additional 830 gpm would be needed to meet the maximum day demand and an additional 3,030 gpm would be needed to meet peak hour demand (Table 5-3). Meeting this increased demand could require a combination of new wells, an alternative surface water supply, greater links to the utility system, or reuse of treated wastewater.

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[2]The 1993 estimate of total on-campus building space presented in the 1994 UC Davis LRDP was 4,745,740 ASF. This value included approximately 187,537 ASF for buildings under approved or under construction in 1993 but that were not occupied. For purposes of calculating domestic water consumption, an estimate of 4,550,000 ASF is used in this report to represent space occupied and connected to the domestic water system during 1993-96.

SHORT-TERM--UTILITY SYSTEM

The 1994 LRDP proposed several additions to campus landscaped areas by the year 2006 including 27 acres for new Intramural Sports and Intercollegiate Athletic fields and 23 acres for high density academic and administrative uses. The 1994 LRDP projected that approximately 40 acres of irrigated landscape would be added in support of these developments, a 13% increase over presently irrigated landscape. Current peak demand on the utility water system can be assumed to be at least equal to total system capacity because reserve capacity in the system is currently drawn down during peak irrigation hours. A 13% increase in this peak demand equates to 5,700 gpm, 655 gpm greater than the existing well capacity (Table 5-3). Average annual utility water consumption would increase from approximately 40 million gal/yr (125 acre-ft/yr) (Table 5-5). Meeting this increased demand could require a combination of new wells, an alternative surface water supply, or reuse of treated wastewater.

LONG-TERM--DOMESTIC SYSTEM

Demand and use estimates for 2046 are based on the assumption of a 25% increase after 2006 (See planning assumptions in Chapter 3). The resulting estimated annual use of domestic water is 1.4 billion gal/yr (4,300 acre-ft/yr) with a 11,000 gpm peak hour and an 8,250 gpm maximum daily demand (Table 5-3). These demands are 4,330 gpm and 1,580 gpm, respectively, greater than the current capacity of 6,670. Meeting this increased demand could require a combination of new wells, an alternative surface water supply, greater links to the utility system, or reuse of treated wastewater.

LONG-TERM--UTILITY SYSTEM

Utility water use is also assumed to increase by 25% after 2006. Estimated utility water used in 2046 would be 425 million gal/yr (1,300 acre-ft/yr) a peak demand of 7,125 gpm. This demand is 2,080 gpm more than existing well capacity of 5,045 gpm and will require the addition of two new wells, an alternative surface water supply, or reuse of treated wastewater.

WATER SUPPLY

The campus currently receives 100% of its domestic and utility water supplies from groundwater. Thus, it is limited in its ability to respond to long-term changes in water level and quality. The extent and recharge rate of the deep aquifer are unknown, and the long-term dependability is questionable especially given the likelihood that other water purveyors such as the City of Davis are expected to increase use of this aquifer. The campus lacks the ability to shift to other sources during drought in response to declining water levels and is unable to develop or implement management programs that conjunctively use groundwater and surface water. The water quality of intermediate aquifers will likely deteriorate by the movement of soluble salts and organic and toxic constituents from ground surface or subsurface sources. For these reasons, the campus should seek to secure a high quality, surface water source of approximately 4,000 acre-ft/yr. This volume would be used to meet the expected increased demand for domestic and utility water of approximately 2,300 acre-ft/yr over the next half century. It would also provide approximately 1,700 acre-ft/yr to reduce the current dependence on groundwater. The volume of surface water sought might be reduced if technological advances allow increased use of reclaimed water and if investigations of the deep aquifer determines that over the long term it will remain a reliable supply of high quality water. Using a mixture of groundwater and surface water would provide the campus with increased flexibility during times of drought and would allow long-term conjunctive use of these water supplies. The net result would ensure a dependable, adequate, high quality water supply for the University to ensure its continued ability to meet it mission of teaching research, and public service.

CRISIS SITUATIONS

Drought: The most effective way to deal with drought is to minimize water dependency. A sound water management and conservation plan is an essential component in achieving this goal. Chapter 8 of this plan covers this topic and enumerates a number of actions that can help to minimize water use.

Emergency Measures: A number of measures have been taken to protect the campus' water supply from emergency situations. The most obvious threats stem from well failures that could be

the result of mechanical failure, power outages, earthquakes, or land subsidence. Through the installation of standby engines and generators, the domestic system has been designed to remain at least partially operational under any of these conditions. Facilities Services also maintains a standby crew capable of responding to these types of emergencies as well as to water main breaks.

Domestic Well DW4 has a diesel-powered auxiliary unit for emergency operation. DW6A has a diesel-powered standby generator, and DW5 has a natural gas-powered generator. Booster pumps 3 and 4 have natural gas-powered auxiliary units that allow them to pump from the underground reservoir. Although the wells must be manually started, the emergency booster engines are automatically engaged when a loss of electric power is detected.

In the event of a mechanical failure, reserve capacity in both the underground reservoir and elevated storage tanks could be drawn upon until repairs can be completed. Booster pumps 3 and 4 are capable of pumping 3,670 gpm from the reservoir, thereby maintaining both system pressure and the water level in Domestic Tower #1. DW2, DW3, and DW5 can replenish the reservoir, and DW5 is capable of doing so even in a power outage. Should an earthquake undermine the integrity of the underground reservoir, DW6A and DW4 can pump directly into the system. Both of these wells have diesel-powered backup systems.

The domestic and utility systems can be cross-connected to augment capacity on either system as necessary in an emergency. The benefit of the utility system is lessened, however, by a lack of emergency standby engines. Both systems can be cross-connected to the City of Davis should the need arise.

RECOMMENDATIONS

DOMESTIC SYSTEM

2006 Requirements: Provide an additional 3,030 gpm to meet hourly peak flow requirements of 9,700 gpm by additional and/or replacement wells or by imported surface water.

Meeting the hourly peak flow will also satisfy the maximum daily demand of 7,500 gpm and the projected annual demand of over 1.12 billion gallons/yr (3,430 acre-ft/yr.)

2046 Requirements: Provide an additional 4,330 gpm over present 6,670 gpm capacity to meet hourly peak flow requirements of 11,000 gpm by additional/replacement wells or by imported surface water. Meeting the hourly peak flow will also satisfy the maximum daily demand of 8,250 gpm and the projected demand of 1.40 billion gallons/yr (4,300 acre-ft/yr.).

Replacement, Maintenance and Operations Program:

- Develop a long-term preventative maintenance and replacement program that anticipates an average well life-span of approximately 30 years; with six wells on the system, one well would be replaced approximately every five years.
- Check well meters for accuracy and replace inaccurate meters.
- Continue the Backflow Prevention Program.
- Perform pump efficiency testing semiannually.
- Install automatic controls and remote monitoring at a central location on wells and distribution mechanical systems.

Consultant Studies:

- Conduct a hydrogeologic study to determine overall status and response of the aquifer system, the impact of continued or increased pumping demand, and possible changes in water quality.
- Conduct a sonic leak detection survey to locate system water losses.
- Update analysis of opportunities to use reclaimed water as technology and opportunities change.
- Develop distribution system computer model to facilitate planning for infrastructure, upgrades, and future loads and capacities.

UTILITY SYSTEM

2006 Requirements: Provide an additional 655 gpm to meet peak hourly flow and back-up requirements to 5,700 gpm by additional and/or replacement wells or by imported surface water. Meeting the peak flow will also satisfy the projected annual demand of 340 million gallons/yr (1,050 acre-ft/yr).

2046 Requirements: Provide an additional 2,080 gpm over current capacity to meet peak hourly flow and back-up requirements to 7,125 gpm by additional/replacement wells or by imported surface water. Meeting the peak flow will also satisfy the projected annual demand of 425 million gallons/yr (1,300 acre-ft/yr.).

Replacement, Maintenance and Operations Program:

- Modify irrigation schedules to reduce peak demand constraints.
- Eliminate current domestic uses of utility water.
- Continue backflow prevention program and correct backflow prevention problems.
- Check well meters for accuracy and replace inaccurate meters.
- Buy flow-measuring equipment and perform pump efficiency tests semiannually.

Consultant Studies:

- Perform a study on the utility system to identify the scope of work and funds needed to correct existing backflow deficiencies.
- Perform an economic feasibility study to determine whether portions of the utility system can be isolated from the remainder of the system without compromising overall system integrity. Unprotected segments could then be isolated from the domestic system.
- Conduct a sonic leak detection survey to locate system water losses.

- Update analysis of opportunities to use reclaimed water as technology and opportunities change.

- Develop distribution system computer model to facilitate planning for infrastructure, upgrades, and future loads and capacities.

WATER SUPPLY

The campus should seek to secure a high quality, surface water source of approximately 4,000 acre-ft/yr. This volume would be used to meet the expected increased demand for domestic and utility water of approximately 2,300 acre-ft/yr over the next half century. It would also provide approximately 1,700 acre-ft/yr to reduce the current dependence on groundwater. The volume of surface water sought might be reduced if technological advances allow increased use of reclaimed water and if investigations of the deep aquifer determines that over the long term it will remain a reliable supply of high quality water.

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Chapter 6

SURFACE WATER MANAGEMENT

PUTAH CREEK

EXISTING CONDITIONS

The rugged north coast range is the watershed for Putah Creek and its tributaries. With a point of origin in southern Lake County, the headwaters of Putah Creek are bordered to the southwest by the Mayacmas Mountains and to the northeast by Blue Ridge. This general area is located approximately 40 miles northwest of UC Davis. The creek follows a southeasterly route, leaving the mountains and entering the Sacramento Valley near the foothill town of Winters. From this point eastward, the stream course meanders across the valley floor eastward to the Yolo Bypass where flows are deposited into the Putah Creek Sinks, a depositional area which also provides flood control for the Sacramento River. Under some conditions, Putah Creek flows ultimately joins the Sacramento River. The total length of the stream from the headwaters to the sinks is approximately 50 miles.

Flood Control: Historically, flood waters from Putah Creek dropped their sediment loads near the banks of the stream channel creating natural levees along the creek. As a result, the natural pattern of surface water runoff is away from Putah Creek toward smaller local sloughs to the northeast and southeast then east toward the Sacramento River. The largest local drainage on the campus is Dry Slough which is located north of the Russell Tract and intercepts surface water flows that leave the property. (Figure 1-1). Dry Slough ultimately joins Willow Slough between Woodland and Davis and drains into the Yolo Bypass in eastern Yolo County.

Natural flows through Putah Creek have been altered greatly over the last 120 years. As early as 1871, local residents of Davisville constructed what is now referred to as the south fork of Putah Creek (Figure 1-1). The new diversion was built to reduce flows into the north fork, thereby reducing flooding in town. The original north fork still winds through the campus and was designated

for Open Space Teaching/Research land uses in the 1994 LRDP. On the central campus, this stream course is now the University Arboretum, and the historical channel is the Arboretum Waterway, a pond used by the campus for storm water management.

During the mid-1940s, the Army Corp of Engineers permanently blocked flows into the north fork with the construction of flood control levees on the west and south campus. Starting at the former north fork, the levees line both sides of south fork of Putah Creek east to the Yolo Bypass. Construction of the levees increased the flow capacity of the south fork and eliminated naturally occurring flows into the north fork.

In December 1950, The Regents granted a right-of-way and easement to the Sacramento and San Joaquin Drainage District to build and maintain the north levee (recorded Solano County, Book 586, page 114). In this document, Putah Creek is identified as part of the Sacramento River Flood Control Plan of the California Debris Commission. The State Department of Water Resources (DWR) currently retains authority for the management of the creek and its appurtenances relative to use as a flood control project. This authority provides DWR's Division of Maintenance an easement to maintain the levee roads. It also requires that adjacent landowners seeking to modify the levee or creek file for an encroachment permit.

Water Supply: Putah Creek supplies water to the campus in three ways. First, pumps at the Russell Tract directly divert water from Putah Creek, and this riparian water is applied to field teaching and research uses and for agricultural production (Figure 3-5). The campus also has riparian water rights for some of the lands on the main campus, but these rights have not been exercised in the recent past. Second, upstream storage and diversion of Putah Creek flows also supply the campus with 4,000 acre-ft/yr of high quality water from the Solano Project for use in field teaching and research on the main campus. Lastly, Putah Creek is an important source for water that recharges local groundwater aquifers, and groundwater is the only source of water supply for the campus domestic and utility water systems as well as an important component of the water supply for field teaching and research on the main campus and at the Russell Ranch. (For discussion of water supply management on the campus, please see Chapter 4 - Field Teaching and Research Water, and Chapter 5 - Domestic and Utility Water Uses.)

Solano Project: In 1953, with strong support from Solano County, the U.S. Bureau of Reclamation (Bureau) received funds to plan the system of dams and canals known as the Solano Project. The purpose of the project was to impound and divert flows from Putah Creek for offstream uses. The primary feature of the project was completion of Monticello Dam in 1957 within the rocky narrows known as Devils Gate. The completed dam altered the flow regime of Putah Creek, flooded 27,000 acres of the Berryessa Valley in Napa County, and created Lake Berryessa, with a storage capacity of 1.6 million acre-ft.

With the completion of Monticello Dam, a system was needed to deliver water to the Solano Irrigation District, cities and other users in Solano County, and the UC Davis Campus. To accomplish this, the 33 mile long Putah South Canal was built from Putah Creek to the city of Fairfield. The Putah Diversion Dam was constructed on Putah Creek to raise the elevation of the creek in order to facilitate distribution into the canal. Putah Creek diversions into the Putah South Canal are distributed among eight member units that purchased rights to water following construction of the Solano Project. Water is used by each member unit for agriculture, field research, municipal, and industrial uses. As a member unit, the University receives 4,000 acre-ft annually under a contract due to expire in February 1999. Water received by the University is metered and distributed to departments engaged in field teaching and research. Other member units, and their respective allocations in acre-ft include: Solano Irrigation District, 141,000; Vallejo, 14,750; Fairfield, 9,200; Vacaville, 5,600; Maine Prairie Irrigation District, 15,000; Suisun City, 1,600; California Medical Facility, 1,200. (For discussion of Solano Project water use on the campus, please see Chapter 4 - Field Teaching and Research Water, and Chapter 5 - Domestic and Utility Water Uses.)

Putah Creek Instream Flows: Construction of the Solano Project also created facilities to regulate flows in lower Putah Creek downstream from the Putah Diversion Dam. The original permit conditions for operation of the Solano Project issued by the State Water Rights Board (now the State Water Resources Control Board) required the Bureau to "maintain a permanent live stream at all times as far below the diversion dam as possible, consistent with the purposes of the (Solano) Project and the requirements of downstream users." In March 1969, the Bureau filed a petition with the State Water Rights Board requesting a fixed schedule for releases to Putah Creek. The petition was granted in 1970, and a fixed release schedule that set minimum releases to lower Putah Creek replaced the

Table 6-1 - Existing schedule of minimum releases to lower Putah Creek from the Putah Diversion Dam. Releases are regulated by the Solano Irrigation District as project operator for the Bureau of Reclamation.

MONTH	NORMAL YEAR[1]		DRY YEAR[2]	
	cfs	ac-ft	cfs	ac-ft
August	34	2,090	26	1,598
September	20	1,190	15	892
October	20	1,229	15	922
November	25	1,487	25	1,487
December	25	1,537	25	1,537
January	25	1,537	25	1,537
February	16	920	16	920
March	26	1,598	26	1,598
April	46	2,737	46	2,737
May	43	2,643	33	2,029
June	43	2,558	33	1,963
July	43	2,643	33	2,029
TOTAL (acre-ft)	--	22,169	--	19,249

[1]Normal year = total inflow to Lake Berryessa ≥ 150,000 acre-ft.
[2]Dry year = total inflow to Lake Berryessa <150,000 acre-ft.

previous live stream requirement (Table 6-1). The existing permit includes a lower set of minimum releases in dry years when total inflow into Lake Berryessa is less than 150,000 acre-ft than in normal years when inflow to the lake exceeds this threshold. (Table 6-1). As a result, the lower Putah Creek ecosystem receives approximately 13 percent less water during the driest years. Releases less than the fixed release schedule are also authorized whenever there is a live stream to Old Davis Road and the flow at this point is at least 5 cfs. This alternate permit condition was not implemented until 1994.

The dry year release schedule was first implemented during the 1989-94 drought. The effects of these reduced releases to lower Putah Creek included drying out of long stretches of the creek with concomitant effects on fish populations and the associated aquatic and riparian ecosystems. In 1990,

the Putah Creek Council, a local environmental advocacy group, sued the Solano County Water Agency and Solano Irrigation District for increased flows to lower Putah Creek to protect fish populations under Fish and Game Code Section 5937 and to protect public trust values. At approximately the same time, these two agencies and other Solano Project member units in Solano County filed a lawsuit to adjudicate riparian water rights along lower Putah Creek. Two of the defendants named in the Solano suit were the City of Davis and the University of California. In a countersuit, the City and University raised the same types of issues included in the initial lawsuit filed by the Putah Creek Council. Due to the similarity of the issues raised, all of these court petitions were consolidated in a single action. In 1996, the Solano parties dropped the water rights adjudication, and a trial was held in Sacramento Superior Court on the instream flow and public trust issues.

The final judgment was issued in November 1996. In his ruling, Judge Richard K. Park concluded that:

> "Putah Creek in my opinion is a treasure."
>
> "In my view the amount of additional water reasonably needed to meet what I think are legitimate public trust concerns . . .will not have a significant effect upon the Solano Parties."
>
> " . . . the plain fact of the matter is the 1970 release schedule was never adopted with public trust issues in mind or with Fish and Game [Code] 5937 in mind and for those purposes, therefore, is essentially a shot in the dark."

The flows included in the judgment were based on the biological requirements of the fish and aquatic and riparian ecosystems to ensure their long-term health. The judgment included flow standards to provide adequate water for rearing of resident native fish (Table 6-2) and spawning releases in the late winter and early spring to ensure successful reproduction. These spawning releases included both an initiation release and spawning flows:

> **Spawning initiation:** In every year, a 3-day pulse release from Putah Diversion Dam of 150 cfs for 24 hours on day one, 100 cfs for 24 hours on day two, and 80 cfs for 24 hours on day three. These releases must be made between February 15 and March 31 if uncontrolled spills of this magnitude or greater have not occurred between February 15 and March 31. Compliance Point - Putah Diversion Dam

Table 6-2. Rearing flow releases to lower Putah Creek ordered by the Sacramento Superior Court in November 1996. The existing flow schedule (Table 6-1) remains in effect during the appeal of this judgment.

MONTH	REARING FLOWS[1] (cfs)	
	Minimum Releases	Flow Requirements
October	20	5
November	25	10
December	25	10
January	25	15
February	16	15
March	26	25
April	46	30
May	43	20
June	43	15
July	43	15
August	34	10
September	20	5
Compliance Point(s)	Putah Diversion Dam	Stevenson Bridge Pedrick Road Bridge I-80 Bridge Old Davis Road

[1]In addition to these release and flow standards at compliance points, the Superior Court ruling requires a continuous flow year-round from Old Davis Road to the mouth of Putah Creek in the Yolo Bypass.

> **Spawning flows:** In every year, the spawning initiation releases or uncontrolled spills in lieu of spawning releases described above must be followed by 30 consecutive days of releases sufficient to maintain flows of 50 cfs (mean daily flow; minimum flows always ≥ 90% of the mean daily flow) at each of the compliance points listed below, and then flows ramping down gradually over a 7-day period to the April resident native fish rearing flows of 30 cfs. Compliance Points - Stevenson Bridge, Pedrick Road Bridge, I-80 Bridge, and Old Davis Road

The Solano parties filed an appeal of the judgment. During the appeal, the existing 1970 release schedule remains in effect (Table 6-1). It is anticipated that the Court of Appeals will hear the case in 1998.

UC Davis Putah Creek Riparian Reserve: Putah Creek borders the main campus and the Russell Tract (Figure 1-1). On the main campus, the creek is the southern boundary starting roughly ½-mile west of County Road 98 and extends east to a point approximately ¼- mile east of Old Davis Road opposite the Raptor Center. Total creek frontage on the main campus is approximately 3¾ miles. At the Russell Tract, approximately 1¼ miles of campus property border the creek. On the main campus and the Russell Tract, creek-front property has been designated as the Putah Creek Riparian Reserve and is actively used by the campus for teaching and research purposes based on natural resource values along the creek. In addition, a portion of the reserve south of the University Airport is Camp Putah, a summer environmental teaching camp used the City of Davis. A reserve manager and a campus management committee oversee uses and management of the reserve.

PUTAH CREEK ISSUES AFFECTING FUTURE PLANNING

Instream Flows and Habitat Quality: The University has a long-standing concern about the instream flows in lower Putah Creek to protect the aquatic and riparian ecosystems. This interest involves the maintenance of flows in sufficient amounts during all times of the year to support teaching and research needs and the public trust responsibilities of the University. Although the principal area of teaching and research in fisheries and wildlife habitat, as well as riparian vegetation activities, takes place in and along the creek between the eastern and western boundaries of the campus, the entire length of the creek channel from the Solano Diversion Dam downstream to the Yolo Bypass is a part of the biological and hydrological system. The flow regime necessary to

conduct viable teaching and research programs is critical in terms of maintaining adequate flows, water temperature, and nutrition for biological life. Management of the creek is essential in order to provide for protection of the creek and its native biota. In addition to ensuring adequate flows are present, the campus should work cooperatively with other entities to ensure that maximum benefit is derived from these flows.

Groundwater Recharge: The University's interests in groundwater recharge are twofold. First, there must be adequate releases to satisfy the historic contributions from the creek's streambed to regional groundwater supplies. Second, there must be adequate flows to satisfy any contributions that may serve to recharge local shallow and intermediate aquifers that supply the University wells. Pertaining to regional groundwater supplies, early studies have established that there are gaining and losing reaches of the Creek (V. Scott, pers. comm.). Gaining reaches are those areas that generally have shallow groundwater seeping into the creek. Losing reaches are areas where water is percolating through the streambed and recharging the shallow and intermediate aquifers (located primarily south of the creek). Recharge from the losing reaches, coupled with regional underground flows from the northwest to southeast toward the University's property, provides the principal groundwater source from which the University pumps from wells in the intermediate depth aquifers. Consequently, the University should make sure that the annual release schedule over the long-term is adequate to maintain and protect the natural and historic recharge into the groundwater system on a regional basis. Regarding local Creek recharge directly into aquifers providing water for University wells at shallow and at intermediate depths, an analysis is needed to determine how recharge from Putah Creek contributes to the water supply from these wells.

RECOMMENDATIONS

- Continue active participation in the legal, regulatory, and political process related to ensuring adequate flows in lower Putah Creek needed to protect groundwater recharge, fish populations, and the aquatic and riparian ecosystems

- Preserve riparian rights to surface water.

- Develop a regional Putah Creek Technical Advisory Committee that is representative of those agencies and constituencies with legitimate interests in the continued health of Putah Creek and surrounding environs. The committee should develop a strong position statement to assure the management of Putah Creek supports research, teaching, and public trust and environment values. The Committee shall maintain an inventory of research, teaching, and public service opportunities as identified by the University.

- Perform a ground level survey of campus irrigation wells, establishing a U.S. Geological Survey benchmark at each site. Establish a correlation between past and present water levels and other hydrologic data that are available on a regional basis. Conduct an analysis to determine the connectivity of selected wells to direct recharge from Putah Creek.

STORM DRAINAGE AND FLOOD CONTROL

The local topography at the UC Davis campus and Russell Tract generally slopes away from the natural streambed of Putah Creek. Along the natural channel, Putah Creek is bordered by natural levees that historically formed when the creek flooded. Heavy materials were deposited near the creek, raising the local topography. As a result, storm water runoff on lands adjacent to Putah Creek east of the Coast Range does not flow toward the creek. Instead, lands north of the original channel drain to the east and northeast and lands to the south drain to the east and southeast. The natural course of the creek follows Putah Creek as we know it today from Monticello Dam to the branch point between the north and south forks of the creek near the USDA Aquatic Weed Control Research Laboratory on the west campus (Figure 1-1). From there, the natural path of Putah Creek followed the north fork across the west campus and the Arboretum Waterway through the central campus.

EXISTING INFRASTRUCTURE

Central Campus: The majority of developed campus resources are on the central campus. A system of underground pipes ranging up to 52" in diameter collects storm water from the central

campus and discharges it into the old north fork of Putah Creek which is now the Arboretum Waterway and is a storm water retention pond for the central campus (Figure 3-6). A dam at the east end of the Arboretum waterway prevents storm water from flowing off the campus toward the east, and the waterway has been graded to flow to the west in the opposite direction from the historical slope of the old north fork of Putah Creek. A weir is located in the old stream channel at the west end of the Arboretum Waterway approximately 1,000 feet east of Highway 113.

The weir at the west end of the Arboretum Waterway is used to control the water level in the pond which is normally maintained at an elevation of 39 ft mean sea level (msl). When storm water flows into the Arboretum Waterway, the water level rises in the pond. The Arboretum Waterway can rise to 42 msl with only local street ponding on the central campus. As the water level rises in the Arboretum Waterway, it overtops the weir and flows into the pump pond located north of the weir in the old stream channel. From the pump pond, a pump station moves the storm water to the south fork of Putah Creek through a 54" diameter storm drain (Figure 3-6). The present capacity of the pump station is 53.5 cfs due to the number of installed pumps, but there is space for additional pumps to be installed. The permit for the discharge to Putah Creek allows a maximum flow of 130 cfs, which is the maximum capacity of the 54" diameter line from the pump station to the south fork of Putah Creek. With the present pumping capacity of the pump station at 53.5 cfs and the ability to expand the capacity of the pumping station, there appears to be sufficient flexibility for future development.

In addition to storm water flow form the Arboretum Waterway, the pump pond also receives flow directly via a 42" storm drain serving Health Sciences facilities located west of La Rue Road and south of Hutchison Drive. The pump pond is also connected to the old north fork of Putah Creek on the west side of Highway 113 by a 24" syphon under Highway 113. The west end of the syphon has been raised, and this effectively eliminates flow into the pump pond from west of Highway 113 except during large storms.

For a discussion of water quality in the Arboretum Waterway and storm water discharges to the south fork of Putah Creek, please see Chapter 7 – Water Disposal, Treatment, and Contamination.

West Campus - Highway 113 to County Road 98: This section of the west campus is bounded by Highway 113 on the east, Road 98 on the west, Putah Creek on the south, and Russell Blvd on the north. The entire parcel is owned by The Regents except for approximately 70 acres in the northwest at the intersection of Russell Boulevard and County Road 98 (Figure 1-1) and a single home on the east side of County Road 98 south of Hutchison Drive. The slope is flat and falls from the southwest toward the northeast. This portion of the west campus is approximately 1,700 acres and is used primarily for field teaching and research. A cluster of development is located adjacent to the University Airport along Hopkins Road. The airport and these facilities, cover approximately 446 acres and are drained by a 48" storm water drain that flows directly into Putah Creek near Hopkins Road (Figure 3-6).

The remainder of this portion of the west campus lacks a storm water collection system, and runoff accumulates in individual fields adjacent to field roads where it evaporates or percolates. Large storms may result in shallow overland flows that are intercepted by Russell Boulevard with ponding at the north edge of the campus. Storm water that reaches the North Fork Cutoff forms a pond at the east end of the streambed near Highway 113. A stand pipe at the east end of the cutoff allows flows from greater than a 25-year storm to flow through a siphon under Highway 113 to the pump pond at the east end of the Arboretum Waterway; from here storm water is pumped south to the south fork of Putah Creek. This system for handling runoff from teaching and research fields has created no apparent problems for existing uses on the property.

West Campus - West of County Road 98: The portion of the west campus located west of County Road 98 is bounded by Putah Creek on the south, private property to the west, Russell Boulevard to the north and County Road 98 to the east. This area covers approximately 450 acres, and the natural slope is toward the northeast. The majority of the area is devoted to field teaching and research including agricultural land uses and ecological research by the Department of Wildlife, Fish, and Conservation Biology. The major development in the area is the CRPRC, which has buildings, roadways, service areas, parking, and field cages. The campus landfill is located in the southern portion of this area.

Land north of the campus landfill drains to the north where storm water discharges into the Covell drain at Russell Boulevard. The Covell drain flows northeast through the City of Davis and ultimately discharges into the Yolo Bypass. West of County Road 98 the Covell drain collects water from the campus, the Russell Tract, and other privately-owned property. This reach of the Covell Drain is at capacity and following large storms, runoff forms ponds adjacent to Russell Boulevard including at the intersection of Russell and County Road 98. As a result of this lack of capacity in the regional storm water drainage system, small adjacent sloughs overflow their banks and addition water can backup through the system. As a result, a portion of the land west of County Road 98 is considered to be in the 100-year floodplain as designated by the Federal Emergency Management Agency. There are no flooding problems with major buildings on this part of the campus because they have been constructed above the surrounding area. There are storm water concerns related to periodic flooding of some of the outdoor, ½- acre field cages at the CRPRC.

A new storm water collection system for the campus landfill was installed in 1995. This system is designed to separate noncontact storm water from storm water that comes in contact with the active landfill face. Contact water is minimized by limiting the size of the active landfill face and by application of a soil cover each day. The small amount of contact water is contained at the active face where it is absorbed into the daily fill material and is not allowed to mix with surface runoff that leaves the landfill boundaries. The majority of noncontact water is collected and discharged into an existing pond on the Wildlife, Fish, and Conservation Biology research area west of the landfill. The water then percolates or eventually flows to Putah Creek through the same outfall used for wastewater discharge by the Putah Creek Aquaculture Facility. The remainder of noncontact water that cannot be captured by the storm water system sheet flows into existing drainage ditches on the north and east side of the landfill.

South Campus: The south campus covers approximately 600 acres and has a gentle slope from west to east. The area to the west of Old Davis Road is primarily used for field research, with a few buildings located in the area to provide research support. Storm water on the area ponds locally and either percolates or evaporates and is not discharged from the campus. This method of disposing of storm water is adequate for the existing land uses.

To the east of Old Davis Road, the existing land use is both pasture and low density academic and administrative facilities. Storm drainage from paved areas and buildings north of the railroad tracks is collected by surface drains and is discharged into a ditch adjacent to the tracks. This ditch crosses under the tracks through a 24" pipe that extends east to an open drainage ditch along the eastern campus boundary. Local storm drains on the south side of the railroad tracks also empty into this drainage ditch which ultimately discharges into Putah Creek through a 24" culvert. The culvert's discharge is controlled by a flap gate, as required by the Reclamation Board when the permit to construct the culvert was issued. When the culvert is closed, the drainage basin acts as a retention basin until the water level in Putah Creek drops.

In addition to the major storm water drainage along the eastern campus boarder, there are two additional systems that drain small areas of the south campus directly to Putah Creek. Runoff from the buildings that comprise ITEH and the surrounding parking areas flows into a sump which discharges to a ditch along Old Davis Road and then to Putah Creek. Another discharge point in the South Campus is in the X-Buildings west of the Raptor Center. Storm water runoff from an approximately 1.25 acre area discharges to Putah Creek via a culvert through the levee.

In 1997, the campus approved construction of a new WWTP on a site east of Old Davis Road and south of the railroad tracks. The existing use on the site is pasture. The new WWTP will be constructed so that all storm water from the developed site is returned to the plant and treated as wastewater. Therefore, the new plant will not contribute to storm water runoff from the south campus.

Russell Tract: The Russell Tract does not have a storm drainage system. Storm water collects in or adjacent to canals and field roads causing local ponding. This water either evaporates or percolates. Storm water that leaves the southern portion of the tract is collected by a drainage ditch on the south side of Russell Blvd. This ditch ultimately connects to the Covell drain and reaches the Yolo Bypass. Water that leaves the north portion of the tract is collected by Dry Slough which combines with Willow Slough and also discharges to the Yolo Bypass. Storm water that does leave the Russell Tract flows with the natural topography towards Dry Slough and is not regulated. There are no identified flood problems on the Russell Tract. However, regional flooding occurs in some

wet years when Dry Slough overflows its banks. This flooding occurs north and east of the Russell Tract which is within the Dry Slough drainage (Figure 1-1).

For several years, Yolo County and the City of Davis have been evaluating potential regional flood control solutions. One of the possible designs would divert flows from Dry Slough to Putah Creek; this type of project could include a new drainage facility across the Russell Tract. The 1994 UC Davis LRDP neither incorporated nor excluded this potential option. If Yolo County decides to pursue this alternative, the Campus has requested information on facility design and environmental effects in order to assess impacts on campus program plans for the Russell Tract. In addition, the campus has requested that the county include an evaluation of potential changes to the Putah Creek system of any new drainage solution that incorporates diversion into any part of Putah Creek.

STORM DRAINAGE ALTERNATIVES TO ACCOMMODATE EXPANSION

Central Campus: Most facilities development projected in the 1994 LRDP will be located in the central campus. The majority of new facilities will infill existing developed areas, but there will also be new facilities constructed in the portions of the health sciences area and the area south of the north fork of Putah that had few facilities in 1994. Overall, the existing drainage collection system provides good service to all infill areas and will not need major changes to accommodate new facilities. Development in the health sciences area may require extension of local feeder lines to either the existing drain line in La Rue Road, which connects to a main drain and discharges into the Arboretum Waterway, or to the 42" drain line on the west side of the area that drains into the pump pond. That line was sized in the 1960s for the full development of the health sciences area to Hutchison Drive. There may also be a need to extend the drainage collection system south of the north fork of Putah Creek depending upon the extent and the location of development. Existing parking lots in the area have drainage collection systems that may be of use in accommodating future development.

The detention basin in the Arboretum Waterway in the north fork of Putah Creek and the pump pond are adequately sized and require no modification or expansion except maintenance removal of accumulated sediments to accommodate the proposed LRDP improvements. The pump

station does require the addition of new pumps to expand the pumping capacity beyond the current 53.5 cfs capacity (Morton and Pitalo 1991). In order to maintain the existing levels of water elevation during 10- and 100-year storms, the pump station requires a pumping capacity of 107 cfs which is well within the 130 cfs capacity of the outfall line. The campus will add a new pump to the pump station by the end of the 1997 calendar year.

Several existing storm drainage concerns on the central campus are also in need of attention.

- Several storm events in recent years have surpassed the calculated 100-year storm event for this area of 2.42 inches of rainfall in 24 hours. These storms have caused the entire drainage system to surcharge and backup at low points on the Central campus, with the worst problems located around Briggs Hall and the Hutchison Hall loading dock.

- The Arboretum Waterway banks are subject to erosion and if not adequately maintained could affect the storage capacity on the pond. The entire system of cobbles and wire mesh needs major work as the wire is corroding.

- The quality of drainage would be slightly improved if the drainage from the animal facilities located at the Cole Facility, areas adjacent to VMTH, and a portion of the Equestrian Center are separated from the general drainage.

If additional regulatory requirements impact the overall system, attempts should be made to correct problems at the source rather than treating the entire detention basin output. The Arboretum Waterway detention basin does allow settling and mixing of storm water prior to discharge into the south fork of Putah Creek, resulting in a more uniform quality of storm water discharged from the central campus.

West Campus - Highway 113 to County Road 98: The current water collection system for research fields will be relatively unchanged. The Hopkins Road drain line will remain the only significant collection system. The majority of potential west campus development identified in 1994 LRDP would be in the area served by the Hopkins drain, and these facilities should be connected to the existing drainage system. This system is beginning to approach its capacity and must be evacuated both as new projects are proposed and over the long-term to ensure that adequate capacity is provided for new developments.

For new facilities outside of the Hopkins drainage area, it may be necessary to construct retention ponds to collect storm water and to dispose of the water by evaporation or percolation. The size and location of these ponds will depend on the scale and the location of new projects. For example, the new Environmental Services Facility to be located off Garrod Road near the Agricultural Services office will have on-site retention ponds designed to hold up to a 25-year storm. Drainage from storms of longer frequency will be diverted to the old north fork of Putah Creek and retained west of Garrod Road. Both parts of the system will dispose of storm water runoff via evaporation and percolation.

The majority of the west campus between Highway 113 and County Road 98 will continue to be in field teaching and research use and will have sheet drainage. Water quality of storm drainage in the west campus should remain similar to the existing storm runoff quality. If additional regulations require modifications, it should be done at the source. The majority of runoff from the west area will continue to be locally ponded and either evaporate or percolate.

West Campus - West of County Road 98: This portion of the west campus drains north toward to the Covell drain. Because the existing drain has capacity problems independent of the campus, and there is no plan to solve those problems in the near future, additional development on the campus west of County Road 98 should be planned to maintain or reduce the present level of storm water discharge from the campus. New projects, such as the Center for Comparative Medicine, should be developed with retention ponds to dispose of storm runoff from the project by percolation or evaporation. This will also slightly reduce the existing sheet runoff from this area to the Covell drain. Storm water collection systems would be local in nature and would collect water from specific areas and transport the runoff to retention ponds. It is anticipated that the existing system of surface drains for the majority of the area would be unchanged.

South Campus: Potential development identified in the 1994 LRDP on the east side of Old Davis Road will not change significantly from existing conditions. The existing storm drainage system is adequate and will continue to adequately serve this portion of the south campus. The new WWTP will be built on land east of Old Davis Road, but all storm water from the developed portion of the site will be captured routed through the wastewater treatment facility.

On the west side of Old Davis Road, the 1994 LRDP designated a 12-acre enterprise zone at Interstate 80 for high density academic and administrative uses and a 10-acre support services zone south of the railroad tracks adjacent to the south fork of Putah Creek. Neither area has a drainage system. Options to accommodate the increased runoff from the new facilities on these sites could include: retention ponds, detention ponds with a pump discharge to the south fork of Putah Creek, or detention ponds with a pump discharge to the Arboretum Waterway. The last option has the problem of crossing Interstate 80 and would require double-pumping as the water to the Arboretum Waterway and then to south fork of Putah Creek. Water quality for these new south campus developed areas will be similar to the central campus. As identified in the LRDP EIR, oil separators would be included for drainage from paved areas. If concurrent construction activities on these sites exceed five acres, permits and plans for erosion control during construction will be required. As storm drainage quality requirements change, local treatment or separation at the source may be required. For a discussion of water quality issues associated with the South Campus Disposal Site, please see Chapter 7 - Water Disposal, Treatment and Contamination

Russell Tract: The 1994 LRDP includes the Russell Tract, and all but approximately 20 acres would be used for field teaching and research. The existing drainage pattern from these areas would be unchanged. Support facilities for field teaching and research programs and large animal facilities will be gradually relocated to the Russell Tract. These new facilities should be developed with a system of detention or retention ponds that at a minimum will not increase the runoff from the existing levels and will also reduce the amount of existing sheet runoff.

SUMMARY AND RECOMMENDATIONS

To ensure that the campus continues to have adequate storm water drainage capacity, the campus should prepare a comprehensive drainage and pumpage capacity study that addresses present drainage deficiencies. In addition to this overall review, the campus should implement the following specific actions:

Central Campus

- Increase the capacity of the main pump station as soon as possible to 130 cfs to provide for both an increase in capacity and some redundancy for pump failure. Expected completion is end of calendar year 1997.

- Maintain the banks of the Arboretum Waterway. Cobbles and wire cages need substantial work and sections of the gunite need repair.

- Determine if it is necessary to separate the drainage from the Cole Facility, areas adjacent to VMTH, and a portion of the Equestrian Center from general drainage.

- Provide oil separation for new parking areas and develop a clean out and maintenance program.

West Campus - Highway 113 to County Road 98

- Connect new facilities adjacent to Hopkins Tract to the Hopkins drain line. Evaluate the capacity of this line to accommodate future development.

- Provide retention basins for major new facilities that cannot be connected to the Hopkins drain line.

West Campus to the West of County Road 98

- Do not increase the amount of runoff from the campus to the Covell drain. Provide new retention basins as new facilities, such as Comparative Medicine or California Automobile Research Test Site (CARTS), are added.

- Separate drainage from the ½-acre primate cages from the general drainage.

South Campus

- Provide collection and disposal systems when enterprise zone and support services zone development occurs west of Old Davis Road. Paved areas should have oil separation. Permits and a plan to control erosion during construction will be required for simultaneous construction activities over five acres.

Russell Tract

- As support facilities are added, provide retention ponds to accept the storm drainage from the area of the improvements so that drainage from the Russell Tract will not increase.

Chapter 7

WATER DISPOSAL, TREATMENT AND CONTAMINATION

EXISTING CONDITIONS

MANAGEMENT STRUCTURE

The Office of Environmental Health and Safety serves as liaison between regulators and the University and, in this role, coordinates the interests of several other offices. EH&S also is responsible for coordinating and managing remediation of sites with contaminated groundwater. Facilities Services is responsible for daily operations at the campus landfill, wastewater treatment facilities and cooling towers. Specific departments are responsible for daily operations of their projects and facilities that require waste discharge permits or NPDES permits. The Planning and Budget Office develops campus population projections, sites new facilities, and conducts the environmental review of campus actions. Various offices within Facilities Services conduct studies to determine the adequacy of existing facilities and to identify alternative engineering solutions. The Office of Research works with the faculty to develop research opportunities; on occasion some research projects have potential regulatory implications. Other campus units with an interest in regulatory issues usually are involved with one or more of these offices. Close coordination of all issues regarding wastewater treatment and disposal is essential because all discharges are permitted by the CVRWQCB.

WASTEWATER DISCHARGES AND WATER QUALITY

University wastewater discharges are regulated through NPDES permits issued by the CVRWQCB. The University currently has NPDES permits to discharge wastewater from the WWTP, Putah Creek Aquaculture Facility (Aquaculture Facility) and Institute of Ecology Aquatic Center (Aquatic Center), USDA Aquatic Weed Control Laboratory, and the Campus Landfill groundwater extraction and treatment system. The University is the only permitted point source of wastewater discharge to Putah Creek. The campus has Waste Discharge Requirements (WDRs) for

operation of the campus landfill. However, this permit addresses the protection of groundwater under the landfill. The campus currently has an NPDES General Industrial Storm Water Permit for the existing WWTP and several other facilities that require the implementation of pollution prevention measures. Discharge permits are not required for other campus storm water discharges. All NPDES permits are available for public review at EH&S.

With each NPDES permit for a University discharge, the CVRWQCB issues WDRs specifying operational, monitoring, and reporting requirements for each discharge and that stipulate the quantity and quality requirements of the wastewater that can be discharged. NPDES permits are typically issued for five years. Permit renewal requires the discharger to submit a new Report of Wastewater Discharge. Monitoring requirements and discharge limits have become increasingly stringent.

Water quality objectives included in NPDES permits are currently established on a case-by-case basis because California does not have statewide water quality objectives. In April 1991, the SWRCB adopted a statewide Inland Surface Water Plan (ISWP) with narrative, numeric, and toxicity water quality objectives for toxic pollutants for all California inland surface waters as required by the 1987 amendments to the Clean Water Act. The ISWP was challenged in court soon after its adoption. In March 1994, a final Superior Court decision concluded that the plan was not adopted pursuant to California law, and judgments issued by the Court in July 1994 directed the SWRCB to rescind the plan. California is now without statewide water quality objectives for toxic pollutants, except for those promulgated by the USEPA in December 1992 in the National Toxics Rule. The SWRCB is developing a new ISWP which is scheduled for adoption in 1997. When the new ISWP is adopted, all dischargers will be required to comply with the new standards.

Recent experience in permitting University discharges and the likely adoption of more stringent water quality standards as part of the ISWP suggest that it will be increasingly costly and operationally complex to discharge wastewater. The permitting process will likely take longer and cost more. Furthermore, there is no guarantee that the CVRWQCB will approve new permits to discharge, regardless of the wastewater's characteristics. Monitoring requirements will be more extensive and accordingly expensive. Cumulatively, these changes may create significant constraints on campus operations and research projects that generate wastewater.

Current University discharges are described below with information regarding each facility's compliance status with applicable water quality regulations.

Wastewater Treatment Plant: The WWTP is located on the central campus south of La Rue Road between the Fleet Services and the Cole Facility (Figure 3-6). Effluent is pumped from the WWTP to a discharge point on the south fork of Putah Creek approximately 100 feet west of Old Davis Road (Figure 3-6). Domestic and laboratory wastewater from most facilities on the central campus receive primary and secondary treatment at the WWTP (Figure 3-6). The WWTP also serves several facilities in the South Campus, including Animal Resources Service, Plant Pathology Field Headquarters, ITEH, and Oncology. On the West Campus, effluent from the CRPRC, Division of Agriculture and Natural Resources, and National Grape Importation Facility is routed to the WWTP via the west campus wastewater connection.

The current WWTP treats wastewater with an activated sludge system and a trickling filter system operating in parallel. The trickling filter system was originally constructed in 1949, the activated sludge system was added in 1970, and a dechlorination facility was added in 1988. These major additions to the plant were constructed to accommodate increasing volumes of wastewater generated by the growing campus population and increasingly stringent water quality standards. Biosolids are digested in anaerobic digesters before being trucked to drying ponds immediately south of the CRPRC on the west campus. The dried biosolids are tested to determine appropriate disposal methods. Depending on the test results, the dried biosolids may be disposed of at the campus landfill, at another landfill permitted to accept such wastes, or in accordance with the applicable regulations for use of Class A or Class B biosolids.

The existing NPDES operating permit (Order 92-040) was issued on February 28, 1992 and expired on March 1, 1997. An application to renew this permit is pending before the CVRWQCB. The original plant was required to meet maximum effluent concentrations of 30 mg/L biological oxygen demand (BOD) and 30 mg/L total suspended solids (TSS). The existing NPDES permit stipulates standards established in 1975 that are considerably more stringent, 10 mg/L BOD and 10 mg/L TSS. The current NPDES permit also specifies monitoring and reporting requirements for influent, effluent, and receiving water, and includes biosolids disposal and drying bed specifications,

and reporting and monitoring requirements for biosolids drying beds and biosolids drying bed groundwater. The current permit required the University to develop a pretreatment program and enforcement of local limits to prevent treatment plant upset or bypass to ensure NPDES permit limits are met.

The existing WWTP has a good history of permit compliance. The WWTP has exceeded its effluent limits in only a few isolated instances, and has never exceeded the maximum monthly average for any pollutant more than once in any six-month period. In a staff report presented by Mr. Richard McHenry of the CVRWQCB on January 27, 1995, the compliance record by the WWTP was summarized as follows:

> The University's WWTP has a good record of compliance with waste discharge requirement limits. A review of the WWTP discharger self monitoring reports from January 1993 through September 1994 shows only three instances of noncompliance with Waste Discharge Requirement effluent limitations. In January 1993, the daily maximum chlorine residual limit of 0.1 mg/L was exceeded once with a concentration of 0.2 mg/L. In June 1994, the daily maximum effluent limit for BOD of 25 mg/L was exceeded once with a concentration of 65 mg/L and during the same month the monthly average BOD limit of 10 mg/L was exceeded with an average concentration of 19 mg/L. The sludge disposal ponds have been the source of past odor complaints. Review of chronic toxicity monitoring results show occasional reduced survival to *Ceriodaphnia dubia* (water fleas); however, the problematic constituents should be eliminated through the required nondomestic discharge control program . . .

Sampling results since September 1994 have been similar to those described above. In May 1995, one BOD sample exceeded the maximum weekly average of 15 mg/L with a concentration of 16 mg/L. In that same month, the maximum monthly average limit of 10 mg/L for suspended solids was exceeded with a concentration of 11 mg/L. In June 1996, the daily maximum chlorine residual limit of 0.1 mg/L was exceeded once with a concentration of 1.2 mg/L. These conditions were corrected promptly upon discovery. In addition to the pretreatment program implementation referred to by Mr. McHenry above, the Campus has installed an anoxic selector to reduce concentrations of ammonia, a potential source of toxicity, in the effluent.

The CVRWQCB can issue a Notice of Violation (NOV) any time there is noncompliance with a permit condition. If there is a legitimate reason for the violation (e.g., equipment failure) or reason

to believe that the violation is a one-time circumstance, the CVRWQCB does not normally issue an NOV. If the violation occurs on a regular basis and is considered preventable, the CVRWQCB will issue an NOV. In the last three years, only one NOV has been issued, and the CVRWQCB considers the existing WWTP one of the best operated and maintained plants in the region, and the existing WWTP has an extremely good record of compliance (R. McHenry pers. comm.). The single NOV was for a sewage spill that occurred in an area adjacent to the WWTP used for research by a campus department. In response to this NOV, the department prepared a description of the spill and a workplan to prevent this type of spill from occurring in the future.

The Agency for Toxic Substance and Disease Registry (ATSDR) performed a study of the water, sediment, and aquatic life in Putah Creek in 1996 as part of the ongoing environmental assessment work for remedial actions at the Laboratory for Energy-related Health Research (LEHR) and South Campus Disposal Site (SCDS). This particular investigation was designed to be a screening analysis of fish from Putah Creek to test for the presence of chemical and radiological contaminants. Based on their results, ATSDR has concluded that the concentrations of lead and mercury in some fish may pose a public health risk. The sources of the contaminants were not determined in the study, though both lead and mercury are frequently found in surface waters of the region. The USEPA has agreed to conduct a follow-up study to better define the source(s) of the problem.

Because the WWTP flow rate is below 3 million gallons/day (mgd) and because the University is a single discharger, formal industrial pretreatment standards were not required for the plant before 1992. However, the University maintains numerous laboratories and sources of nondomestic wastewater that could potentially threaten the treatment system and/or receiving stream. As a result, the CVRWQCB required the University to develop a program to prevent treatment plant upset or bypass from nondomestic sources by August 1, 1992. The objectives of this nondomestic discharge control program are. to: (1) identify nondomestic sources of discharge; (2) identify constituents that could cause upset or bypass; (3) develop discharge limits for nondomestic users; and (4) develop a nondomestic monitoring program to enforce limits. The University has identified potentially problematic constituents through an extensive sampling program. Local limits for industrial discharge regulation were submitted for CVRWQCB review on December 28, 1994 and subsequently

approved. The local limits development process involves extensive sampling and analysis of the wastewater system that provides an excellent data base for water quality.

The campus established three priority levels for pollutants of concern to address in the implementation of the pretreatment program (Krieger & Stewart 1995). Five pollutants were identified as having a priority one status: copper, silver, mercury, methylene chloride, and diesel fuel. These are the pollutants on which the Campus is focusing its pretreatment program efforts to identify specific sources and reduce or eliminate discharges to the sanitary sewer. Other pollutants of concern have been detected in Campus wastewater and were assigned priority two or three because they exceeded local limits but have not repeatedly exceeded any applicable standards. These pollutants are proposed to be monitored quarterly so that trends can be identified and it can be determined whether a higher priority status is warranted.

The Campus has proposed several steps or key actions to ensure that local limits are met and the pretreatment program is fully implemented. The key actions being taken to implement the Campus pretreatment program and enforce local limits are:

- education,
- routine and special monitoring,
- responding to exceedances of local limits and repeat violations, and
- follow-up monitoring.

Implementation of the Campus pretreatment program is shared by the Facilities Division--Mechanical Operations and EH&S. Routine and special monitoring programs form the basis for the implementation of the pretreatment program and for meeting local limits. Routine monitoring includes quarterly collection and analysis of WWTP influent, effluent, and collection system samples, and review of these results. Special monitoring involves facility inspection, sample collection on an as-needed basis, laboratory analysis, and review of data. General sources for special monitoring and data review include those listed above for routine monitoring and septic tank waste samples, rinse water from chemical waste storage containers, cooling tower blowdown discharges, and air scrubber discharges. Special monitoring is performed on an as-needed basis.

EH&S and Facilities Services–Mechanical Operations have joint responsibility for implementation of the local limit program. Facilities Services–Mechanical Operations is responsible for the sewer collection system and the WWTP and monitors discharges, collects samples, and maintains records of the system. EH&S is responsible for management of the Campus hazardous waste program, which addresses proper storage and disposal of most of the same chemicals regulated through the pretreatment program. EH&S and Facilities Services–Mechanical Operations collaborate to identify and eliminate discharges of pollutants in exceedance of local limits and review plans and drawings showing proposed facilities that discharge nondomestic wastes to the sewer. In addition, a waste minimization coordinator has been hired to assist the pretreatment program to reduce hazardous wastes and ensure their proper disposal.

The original hydraulic design capacity for the WWTP, including the 1970 expansion, was 4.16 mgd. This rating was based on the more lenient WDRs that were in effect during the 1970s and earlier. With modification of current operational practices and construction of new processes (e.g., polymer addition and/or filtration), the existing WWTP could have the capacity to treat up to 2.0-2.5 mgd on an average monthly basis, although reliability of performance in this range would be a concern. In 1996, the average monthly flow was approximately 1.70 mgd; the higher flows in 1996 reflect new discharges from the campus landfill treatment system and connection of 32 cooling towers. Increased campus population, connecting existing west campus facilities and new facilities, are expected to exceed the estimated dry weather capacity of 2.0-2.4 mgd between 2000 and 2006.

Projected wastewater generation volumes are estimates based on assumptions and regressions applied to projected campus population growth rate, increases in ASF, and per capita flow rates. Although the campus cannot precisely determine when critical thresholds will be crossed, the need for expanded wastewater treatment capacity will continue to increase as the campus grows toward projected. LRDP population and space figures.

Four alternative solutions to increase wastewater treatment capacity were evaluated by HDR Engineering in 1992. These alternatives included:

- Expanding and upgrading the existing treatment facility
- Providing a new treatment facility at a new location
- Pumping the wastewater to the City of Davis treatment plant
- Providing a new wetland treatment facility at a new site

After reviewing this analysis, the campus determined that construction of a new wastewater treatment facility on the UC Davis campus was the most appropriate alternative to replace the aging WWTP. The results of this analysis were reexamined in 1995 by West Yost & Associates. In October 1996, a Draft Environmental Impact Report (EIR) on the project was circulated for public and agency review. The Final EIR was completed and The Regents approved the project in March 1997.

The objectives of the WWTP replacement project are as follows:

- to replace the existing outdated WWTP with a new treatment plant that is more efficient and reliable to operate,
- to replace the existing WWTP with a new design that is sufficiently flexible to meet future stringent discharge permit requirements,
- to protect water quality and aquatic life in Putah Creek,
- to construct the plant near Central Campus yet with minimal conflicts with existing and future uses,
- to locate the plant in an area that allows future expansion, and
- to expand wastewater treatment capacity in a cost-effective manner to accommodate growth anticipated in the 1994 LRDP and to allow for currently unforeseen growth and changes through the 30-year life of the facility.

The new WWTP will be located on the south campus, east of Old Davis Road and south of the Southern Pacific Railroad tracks (Figure 3-6). The new facility will use the same discharge point as the existing WWTP. The new WWTP will use an oxidation ditch treatment process and will have a designed capacity of 2.5 mgd average annual daily flow, 2.7 mgd 30-day average dry weather flow, 2.8 mgd maximum month flow, and 6.25 mgd peak hour wet weather flow. The oxidation ditch treatment process uses an aeration basin for oxidation to reduce the biochemical oxygen demand and nitrification for ammonia removal. Aeration basins would be designed to hold and treat wastewater

for approximately 24 hours while mechanical aerators mix, aerate, and circulate the water. After this treatment, effluent water would be filtered to meet further requirements for suspended solids, and then disinfected and eventually discharged to Putah Creek. Biosolids from the process would be placed in solids storage basins and subsequently placed in drying beds. The dried biosolids would either be applied to land or taken to a landfill for disposal. Construction of the new WWTP plant is expected to begin in March 1998, and treatment of effluent at the new plant is scheduled to begin in November 1999. For more detailed information on the proposed WWTP replacement project, the reader is referred to the reports prepared by HDR Engineering (1992) and West Yost & Associates (1994 and 1995) and to the Draft and Final EIRs (UC Davis 1996 and 1997).

Septic Systems: Wastewater from buildings at the Russell Tract, on the south campus, and on the west campus that are not connected to the WWTP are on septic systems. On the central campus, the following structures use septic systems: South Entrance Information Kiosk, Equestrian Center - C Barn, and the Equestrian Center Trailer. All septic tanks on the campus are serviced on a routine basis by the UC Davis Facilities Services–Mechanical Operations Plumbing Shop. Pumped septage is discharged at the existing WWTP. In addition, TB-174 at Environmental Horticulture has an above ground holding tank that is regularly pumped by Facilities Services–Mechanical Operations Plumbing Shop, and the waste is discharged to the WWTP. Several abandoned septic tanks are located on the campus.

Long-term plans call for existing structures near the west campus wastewater connection system to be connected to the WWTP via that system. New west campus facilities would also be connected to the WWTP including the new Environmental Services Facility and the Contained Research Facility.

Putah Creek Aquaculture Facility: The Aquaculture Facility is located on the west campus, west of the campus landfill and north of the Putah Creek levee road (Figure 3-6). Wastewater is discharged into Putah Creek at a point west of Road 98 and south of the landfill. From 1976 through 1989, research at the facility increased dramatically and water use reached more than 890 acre-ft/yr. Assuming that the water was used at a fairly constant rate and little was lost to either evaporation or percolation, then approximately 2.4 acre-ft/day (800,000 gallons/day) of wastewater

was discharged into Putah Creek. Funding for the facility declined in 1991-92, and effluent discharges also declined to approximately 462,000 gallons/day. Total discharges in 1995 and 1996 were 560 acre-ft and 655 acre-ft, respectively.

WDRs for the Putah Creek Aquaculture Facility are included in Order 94-033 issued by the CVRWQCB on February 25, 1994. The permit includes conditions to limit impacts to the receiving waters of Putah Creek and defines a monitoring and reporting plan. The campus has been reporting data on effluent water quality at the aquaculture facility to the CVRWQCB since December 1990. The results indicate that the effluent is generally in compliance with permit conditions. Possible exceptions are concentrations of iodine and chlorine residual. These constituents are not routinely analyzed with a level of precision that allows comparison to the standards set by the CVRWQCB. However, the results are similar to background samples from Solano Project water and well water prior to entering the aquaculture facility. More detailed analyses are done monthly and are within permit parameters.

Institute of Ecology Aquatic Center: The Aquatic Center is located on the west campus, adjacent to the north fork of Putah Creek and east of the south end of the University Airport runway (Figure 3-6). Water is obtained primarily from a dedicated well that was drilled in 1993 and placed into operation early 1994. Effluent is discharged at three locations. Most of the water used at the Aquatic Center is discharged via a pipe to Putah Creek located south of Hopkins Road (Figure 3-6). Total discharges in 1995 and 1996 were 360 acre-ft and 475 acre-ft, respectively. This water reaches the creek via a pipe from the Aquatic Center facility to Jameson Pond and then from Jameson Pond to the outfall on the north fork of Putah Creek. Effluent is also discharged to the dry north fork of Putah Creek adjacent to the Aquatic Center and either percolates or evaporates. The third discharge is into an isolated evaporation/percolation pond west of the Aquatic Center.

WDRs for the Aquaculture Facility also include the Aquatic Center. (See Putah Creek Aquaculture Facility above). Monitoring and reporting to the CVRWQCB on effluent water quality for the Aquatic Center has been done simultaneously with the aquaculture facility since December 1990. The results indicate that the effluent is generally in compliance with permit conditions. Occasionally, the 24-hour composite sample for suspended matter exceeded the 30-day (20 mg/L)

and 7-day (30 mg/L) average limits. In each case, operational corrections were made in response to these results to bring the discharge into compliance. Like the aquaculture facility, other possible exceedances have been noted for iodine and chlorine. These constituents are not routinely analyzed with a level of precision that allows comparison to the standards set by the CVRWQCB. However, the results are similar to background samples from the Solano Project and well water prior to entering the aquaculture facility. More detailed analyses are done periodically and are within permit limits.

USDA Aquatic Weed Control Research Laboratory: The Aquatic Weed Laboratory is located at the intersection of the north and south forks of Putah Creek (Figure 3-6). USDA operates a collection, treatment, and disposal system for wastewater from the laboratory. Wastewater is generated from a greenhouse, fish holding tanks, aquatic plant culture tanks, an office, and trailers housing a water quality laboratory.

The largest bodies of water at the facility are two large one acre ponds in the stream bed of the north fork just north of the levee that separates the north and south forks. Wastewater from the fish ponds and plant culture tanks is treated through two 2,000-gallon carbon filters and to the ponds for disposal by evaporation/percolation. Aquatic plant culture growth chamber cooling water is discharged to ten small ponds for disposal by evaporation. Wastewater from the greenhouse and laboratory is discharged to two 1,200-gallon holding tanks for disposal by pumping from the tanks and discharge to the WWTP. Domestic wastewater is discharged to a septic tank and leach field system for treatment and disposal. The CVRWQCB regulates this discharge and issued an NPDES permit on June 27, 1995.

Campus Landfill: Groundwater underlying the University's Class III landfill is contaminated with a variety of volatile organic compounds (VOCs), most notably chloroform. Corrective action was initiated in 1995 when the University installed a series of extraction wells and treatment units to remediate contaminated groundwater. The University received a one-year NPDES permit in June 1995 to discharge treated effluent from the groundwater extraction and treatment facility, and a 5-year permit was issued in August 1996. Because the University determined it was not financially feasible to meet all of the discharge limitations with an on-site treatment system, the approximately 180,000 to 230,000 gallons/day are currently treated for VOCs on-site and then pumped to the

campus WWTP for additional treatment. The University may elect to install additional treatment systems and begin discharging to Putah Creek in the future. (Please see Groundwater Contamination - Campus Landfill below for additional discussion of this topic).

Miscellaneous Discharges: A small volume of field irrigation return water is directed from the Campbell Tract on the west campus into the Caltrans pond located inside the intersection between I-80 and Highway 113. Water purged from the west campus water tower every 10-14 days is also directed to this pond. This system has been created at the request of Caltrans to keep water in the pond during the summer and fall. At the Russell Tract, a small volume of field irrigation return water also enters the slough south of Russell Boulevard and Dry Slough on the northern boundary of the Tract. There are no other discharges from field irrigation on either the main campus or the Russell Tract.

STORM WATER DISCHARGES

The water quality of campus storm water discharges are regulated for by permit for several campus facilities classified as industrial activities. On November 16, 1990, the USEPA issued final regulations on storm water discharges associated with industrial activity (Code of Federal Regulations, Title 40, Parts 122, 123 and 124). Subsequently, the SWRCB adopted a General Industrial Storm Water Permit that covers specific industrial activities. This general permit requires industrial dischargers: (1) to eliminate illicit discharges to storm drains, (2) to develop and implement a Storm Water Pollution Prevention Plan, and (3) to monitor discharges to storm water systems. In March 1992, the Campus filed a Notice of Intent for coverage under the General Industrial Storm Water Permit. The facilities covered under the General Industrial Storm Water Permit include the Campus Wastewater Treatment Plant, Fleet Services, Unitrans Maintenance, Airport Maintenance, the Campus Landfill, and Inactive Landfill Cell #3. Notice to terminate coverage of the Campus Landfill under the permit will be pursued due to storm water provisions within the existing landfill WDRs that set stricter requirements and specify a required monitoring and reporting program.

In addition to these permitted storm water discharges, the campus has several non-industrial storm water discharges which do not require discharge permits. Water quality concerns for these storm water discharges are described below.

Central Campus and Arboretum Waterway: The storm water drainage system for the central campus collects runoff and ultimately discharges it into the south fork of Putah Creek at a point approximately ½-mile west of the Old Davis Road bridge (Figure 3-6). The Arboretum Waterway is a detention basin in this system (Figure 3-6). For a detailed discussion of storm water drainage and flood control on the central campus, please see Chapter 6 - Surface Water Management.

The aesthetic qualities of water in the Arboretum Waterway were recognized as poor almost as soon as it was created in 1969. The waterway is a pond with no flow, and receives effluent from the central campus storm drainage system. Thus, it receives runoff from streets and parking lots, building loading docks and service areas, and the campus landscape. Also, facilities such as the Cole Facility (a livestock facility) have the potential to discharge directly to the Waterway via the storm drainage system. An exceedingly large population of ducks and geese forage away from the waterway and bring nutrients back to the system. Occasional low levels of dissolved oxygen have caused fish kills, and duck die-offs occur some summers due to avian cholera. Flushing flows occur only during heavy winter rains.

In 1990, the University commissioned a professor and a graduate student in the UC Davis Civil Engineering Department to characterize problems at the Arboretum Waterway and to develop recommendations. The master's thesis and a report were completed in 1991 (Conners and Darby 1991). Three major findings resulted from the study:

- All constituents of concern were below applicable water quality standards;
- Nutrient loading is the major source of the problems observed in the waterway; and
- Accumulated nutrients and heavy metals in bottom sediments can be released into the water column under some conditions.

The findings of the study were used to develop recommended management actions. The types of actions suggested were divided into four major headings:

- Maintenance actions to reduce the quantity of organic materials reaching the waterway, to control duck and goose populations, and to remove nutrients from the water column.
- Control of inflow water quality through actions to educate the public about the connection between storm drains and the waterway, to educate the campus about proper methods of disposing of hazardous materials, to prevent organic materials from reaching the storm drain system, and to remove key facilities such as confined animal enclosures from the storm drain system.
- Diluting and flushing waterway water with a cleaner source of water during critical times of the year.
- Periodic draining and filling on an annual basis to clean out the system.
- Removal of sediment after draining the waterway and before refilling, an action that could be required every 4-20 years.

Since 1990, the campus has implemented several of the recommended actions. To the degree feasible, Grounds Division minimizes the volume of organic material that reaches the waterway and the use of landscape fertilizers that runoff into the pond. Several campus offices cooperate to periodically reduce the duck populations, and the geese have been removed. Facilities Services–Mechanical Operations working with the University Arboretum designed a stencil and painted all the storm drains on campus to advise potential dumpers that the drains discharge directly to the Arboretum Waterway. Between 1997 and 1999, these two offices will implement a plan to remove sediments that have accumulated in the bottom of the Arboretum Waterway over the last 30 years.

The campus continues to review the report findings and recommendations and implementing some of the maintenance recommendations. The study was prepared with the single objective of improving water quality in the Arboretum Waterway, and treated the entire waterway as a single unit. Other management objectives such as developing different type of environments at various places along the waterway may mean that only a portion of the actions, or that alternative actions, are

implemented. These decisions will be based on land use planning considerations as well as water quality improvement objectives.

South Campus: Storm water runoff from fields west of Old Davis Road accumulates behind berms and roads delineating fields and either evaporates or percolates into the soil. East of Old Davis Road, a ditch along the eastern campus boundary drains runoff from paved areas and buildings at Animal Resources Service, Equine Research Laboratory, ITEH, Oncology, and adjacent research fields and pasture into Putah Creek (Figure 3-6). UC Davis has determined that Inactive Landfill Cell #3 at the South Campus Disposal Site extends further east than previously identified and extends into the drainage ditch along the eastern campus boundary. The University is currently evaluating remediation options to keep storm water from contacting the inactive landfill. Sampling of runoff from this area has not identified constituents from the landfill in the runoff water. Additionally, new information developed during investigation of the old inactive landfill cells near ITEH (formerly LEHR) may require the University to file a new Notice of Intent for a portion of Inactive Landfill Cell #1. The University is currently evaluating this site to determine if storm water can be prevented from leaving this site before applying for coverage.

Runoff from the buildings that comprise ITEH and the surrounding parking areas flows into a sump, which discharges to a ditch along Old Davis Road, then to Putah Creek. Another discharge point in the South Campus is in the X-Buildings west of the Raptor Center. Storm water runoff from an approximately 1.25 acre area discharges to Putah Creek via a culvert through the levee. Recent investigation at the former LEHR site indicates that Inactive Landfill Cell #1 is located beneath these "X-Buildings." Inactive Landfill Cell #1 was identified at depths of 1 to 5 feet bgs, with a soil cover over the fill material. UC Davis is currently evaluating whether a Notice of Intent must be filed for this area.

West Campus: Storm water drainage systems have been developed for facilities around the University Airport and for the campus landfill (Figure 3-6); please see Chapter 6 - Surface Water Management for a description of the storm water drainage system on the west campus. The new Environmental Services Facility for handling hazardous wastes will be located on the west campus to the west of Campbell Road and north of the old North Fork. When construction is completed in

approximately 1998, storm water from this facility will drain to the old north fork of Putah Creek where it will be lost through evaporation and percolation. Design and operation of this drainage facility includes a manually operated drain and an operations protocol to ensure that contaminated water is not accidentally or inadvertently released from the site. An application for an Industrial Storm Water Safety Permit will be submitted to the CVRWQCB for this discharge.

Russell Tract: The Russell Tract does not have a storm drainage system and there are no regulated storm water discharges. Please see Chapter 6 - Surface Water Management for a description of the storm water drainage system on the Russell Tract.

LANDFILLS

Campus Landfill: The Campus landfill is located west of County Road 98 near Putah Creek (Figure 3-6). The CVRWQCB requires a permit that specifies waste discharge requirements for all active landfills. The permit for the Campus landfill was issued by the CVRWQCB in August 1996 (Order No. 96-228). The WDRs in this permit set applicable water quality standards for storm water discharge. In addition, the CVRWQCB Monitoring Reporting Program (MRP No. 96-228) sets standards for testing storm water runoff. Surface water flows must be sampled where they leave the facility boundary during the first storm of the rainy season that produces significant flows and quarterly when water is present. Surface water monitoring reports must be submitted to the CVRWQCB and must include evaluation of potential impacts of the landfill on surface water quality and compliance with the water quality protection standards established by the CVRWQCB. WDR 96-228 requires that the concentrations of specified constituents of concern in waters passing through designated compliance points not exceed the concentration limits established in MRP 94-266. Landfill surface water discharges are also regulated in the campus NPDES General Storm Water Discharge Permit (Permit 5A575009690).

Inactive Landfill: From the 1940s through approximately 1967, campus wastes were disposed in three landfill cells located east of Old Davis Road adjacent to Putah Creek. These cells are under and adjacent to the former LEHR federal Superfund Site. These landfill cells are included in the ongoing effort to characterize groundwater contamination and to develop and implement

remediation strategies. The CVRWQCB does not require a permit to set waste discharge requirements because these inactive cells predate existing regulations. However, the CVRWQCB is actively involved in remediation of the site. No permits are required, but new permits could be required to implement remediation actions (Steve Rosenbaum, personal communication, CVRWQCB). (See groundwater quality section, below, for information on remediation actions at the SCDS.)

GROUNDWATER CONTAMINATION

South Campus Disposal Site: The SCDS is located on the south campus, east of Old Davis Road adjacent to the south fork of Putah Creek. The SCDS includes three inactive landfill cells, and the former UC Davis wastewater treatment plant. The former LEHR site is adjacent to and overlaps the SCDS. LEHR was a facility developed by the Department of Energy (DOE) in conjunction with UC Davis. It was used from 1958 through 1988 to study the health effects of chronic exposures to radionuclides, primarily strontium-90 and radium-226, using beagles to simulate radiation effects on humans. Until 1974, burial trenches at the LEHR/SCDS area were used to dispose of low-level radioactive waste, a method that was acceptable at the time. Three inactive landfill cells not used after 1967 and the old UC Davis wastewater treatment plant closed in approximately 1949 are located east of the former LEHR buildings. LEHR was placed on the National Priorities List (NPL or "Superfund") by the USEPA in May 1994. The LEHR/SCDS area is the focus of ongoing DOE-UC Davis characterization and remediation activities.

Numerous groundwater studies, including a solid waste assessment test (Dames and Moore 1990), have been conducted at LEHR/SCDS, and current estimates are that site characterization is more than 75% complete. Water samples from 25 monitoring wells at the site are analyzed quarterly as part of the characterization. The existing information has revealed the following:

- Elevated levels of nitrate, hexavalent chromium, tritium, carbon-14, chloroform and other VOCs in some monitoring wells;
- Levels of nitrates and hexavalent chromium above MCLs for drinking water in some domestic wells on privately-owned property adjacent to the site; and

- Probable leakage from one or more of the inactive landfill cells.

Elevated concentrations of nitrate in shallow groundwater are common in agricultural areas. In addition, similar elevated levels of hexavalent chromium are found in monitoring wells adjacent to the current campus landfill and are detected in utility water supply wells. Presence of hexavalent chromium and nitrate in monitoring wells up gradient from LEHR/SCDS suggests elevated levels of these compounds may be a regional problem. As a precautionary measure, the DOE has been supplying drinking water to some neighbors since 1989. As site characterization progresses, DOE and UC Davis will be developing site remediation plans. UC Davis has recently initiated an Engineering Evaluation/Cost Analysis (EE/CA) to evaluate and recommend technologies available to remediate the groundwater at the site. The EE/CA proposed an Interim Remedial Action (IRA) consisting of pumping impacted groundwater, treatment to remove VOCs, and reinjection into the shallow aquifer. Implementation of the IRA is expected to begin in Fall 1997.

Campus Landfill: Since the mid-1980s approximately 37 groundwater monitoring wells have been installed in the west campus area down gradient of the former chemical burn trenches at the campus landfill. The results of this sampling and contaminant plume modeling have been used to characterize the nature and distribution of contaminants in groundwater in the vicinity of the campus landfill. Two overlapping plumes with different sources have been identified. The first plume is limited to within 400 feet east of the landfill and is found only in the shallowest water-bearing zone, 35-65 feet bgs. Wells in this zone show contaminants typical of an unlined municipal Class III landfill including elevated TDS, specific conductance, and VOCs such as tetrachloroethane, trichloroethene, and vinyl chloride as well as the atypical VOC chloroform. These results indicate that contaminants from the landfill refuse mass have migrated a relatively short distance during the nearly 30-year history of the landfill.

The second contamination plume is comprised primarily of chloroform and small amounts of carbon tetrachloride. Based on the distribution and constituents in this plume, it appears the plume originates at the old burn trenches located near the former landfill entrance station along County Road 98. This plume is found in the shallowest water-bearing zone (35-65 feet bgs), and the next two water-bearing zones, 65-90 feet bgs and 120-150 feet bgs. Based on present data, this contaminant

plume extends approximately 7,500 feet to the northeast. Contamination in the deepest zone has been detected in five monitoring wells, as a very dilute plume limited to about 1,000 feet down gradient of the former burn trenches at the landfill site. Due to the extremely dilute level of contaminants in the zone (chloroform < 5μg/L) no remedial action other than continued monitoring is planned at this time.

A landfill groundwater cleanup system designed to remediate existing groundwater contamination was installed between April and June 1995. It consists of a series of extraction wells, associated piping, and air-stripping treatment to remove VOCs. After final operational permits were received in July 1995, the system was tested with all discharge water from the testing contained on-site. These tests revealed that hexavalent chromium and TDS were present at levels higher than allowed by the permit for direct discharge to Putah Creek. Thus, additional treatment for these constituents is necessary before this water can be discharged to Putah Creek.

The Campus investigated the options of (1) additional treatment with new facilities on-site and (2) using the existing WWTP prior to discharge to Putah Creek. In June 1995, the campus received a one-year NPDES permit from the CVRWQCB to discharge treated effluent from the groundwater extraction and treatment facility to Putah Creek. In August 1996, a 5-year permit was issued. The cost of installing new treatment equipment at the landfill site was found to be. prohibitive. Treatment at the WWTP was determined adequate to meet discharge requirements so the Campus decided to use the existing WWTP. Pilot testing was conducted for a week to verify that the new discharge would not violate any receiving limitations for the existing WWTP. After successful pilot testing, the cleanup system was placed on-line in October 1995 and now treats 180,000 to 230,000 gallons of groundwater per day. Effluent water quality is sampled regularly to assure discharges meet applicable receiving limits for the WWTP. Regular quarterly groundwater monitoring is also performed to gauge the effectiveness of the cleanup system and thus far it has shown a steady reduction of contaminant levels in the affected area. The University may elect to install additional treatment systems and begin discharging to Putah Creek in the future.

Throughout implementation of the groundwater cleanup program, the Campus worked with the CVRWQCB to ensure compliance with applicable WDRs. On December 6, 1995, the Campus

received a letter from the CVRWQCB stating that the University is in compliance with all WDRs and Orders for this project.

WWTP Biosolids Drying Ponds: Three monitoring wells have been installed at the biosolids ponds for the WWTP (Figure 3-6). Initial findings indicate that high levels of nitrates and salts occur in the area of the ponds; however, the source of these constituents cannot be determined. Salts appear to be the result of agricultural production, and nitrate levels decrease as groundwater moves from southwest to northeast. These constituents are not considered hazardous, and no remediation is required. Additional monitoring wells are planned because one or more of the existing wells may have been damaged during construction activities in the area. The Campus will continue to monitor groundwater in the area and will work with the CVRWQCB to interpret the results and respond accordingly. The Campus connected the CRPRC to the existing WWTP and is in the process of decommissioning the former CRPRC evaporation ponds. In addition, the proposed construction of a new campus WWTP includes decommissioning the biosolids drying ponds.

Pesticide Applicator Site: The Pesticide Applicator site is located on the West Campus, west of Agricultural Services. Shallow groundwater in this area has been impacted by pesticides from a former pesticide loading and washdown facility and rinsewater evaporation bed. Pesticides were released to soil and groundwater, apparently from a sump used to collect pesticide-contaminated rinsewater. The pesticide rinsewater evaporation bed, sump and an underground storage tank were decommissioned and removed in 1987. Contaminated soil around the sump was also removed.

Seven monitoring wells have been installed at the site and are sampled quarterly for organochlorine pesticides, organochlorine herbicides, triazine herbicides and VOCs. Sampling of the wells has identified the presence of pesticides in groundwater near the former sump. Based on monitoring results, the plume of pesticide impacted groundwater extends less than 100 feet from the original source area and no significant migration of contaminants is occurring. VOCs, including chloroform, have been detected in site wells, but there is no known use of VOCs at this facility, and the VOC detections appear to be related to the plume originating at the Campus Landfill.

UC Davis is currently working with the CVRWQCB to determine appropriate response actions to mitigate the groundwater impacts at this site.

RECOMMENDATIONS

The following sections outline management actions that should be included in a campus strategy for wastewater management. Included are recommendations on management structure, regulatory compliance, remediation, monitoring, reclamation, reporting, and coordination.

MANAGEMENT STRUCTURE

The Environmental Liability Risk Assessment Team (ELRAT) is the appropriate body to disseminate information. The chair of ELRAT is the Director of EH&S. The other members include representatives of A&E, Facilities Services–Mechanical Operations, Planning and Budget, the Office of Research, Government and Community Relations, and News Service. ELRAT should review new regulations and pending legislation with the assistance of EH&S and other supporting departments. The review should identify affected campus facilities, outline a coordinated response, and report to appropriate campus offices. Many of the steps are often completed by the time new regulations are promulgated, but formally identifying a group to organize a response will facilitate development of a timely and comprehensive response coordinated among all potentially affected offices.

REGULATORY COMPLIANCE

The minimum standard for wastewater management on the UC Davis campus must be compliance with all applicable laws, regulations, and permits. All facilities requiring permits should have a valid, up-to-date permit at all times. EH&S, with assistance as needed from Government and Community Relations, should continue to coordinate regulatory issues including thorough and timely evaluation of new regulations and pending legislation and coordination with other campus units.

MONITORING

All University-owned properties along Lower Putah Creek are dependent on groundwater. The quality of this water is extremely important to the future of the campus. The campus does not currently have a comprehensive monitoring program to detect regional changes and trends in water quality. To date, water quality data has been collected for three reasons: (1) to comply with regulatory permit requirements, (2) to determine the quality of certain field research, domestic, and utility water supplies, and (3) to characterize groundwater contamination at the LEHR site, campus landfill, and pesticide storage facility. Much of this latter sampling is done as part of regulatory permit compliance. Each of these data gathering efforts is designed to meet specific, limited goals.

A team of experts in water quality and groundwater hydrology should review the existing monitoring activities and identify the additional data needed to adequately monitor regional groundwater quality and trends.

REMEDIATION

The 1994 UC Davis LRDP included the following resource objective regarding remediation of contaminated sites:

> Continue to actively assess the nature and extent of potential soil and groundwater contamination on the campus. Work with appropriate regional, state, and federal agencies to prepare and implement plans for corrective action.

The University must continue programs to clean up groundwater contamination in areas on campus that have already been identified to have a problem. Three sites may require remediation efforts to restore groundwater quality. The LEHR site has been the location of an active UC Davis and DOE program since 1987. This effort will continue through the 1990s and include participation by interested state and federal agencies. The second site is the former Pesticide Applicator Facility, located on the west campus near the University Airport, that was formerly used to wash down pesticide application equipment. Several herbicides and organochlorine pesticides have been detected in groundwater at the site. UC Davis has completed site characterization and a risk assessment and is working with the CVRWQCB to determine

appropriate response actions. The third site is shallow groundwater under the landfill moving in a northeast direction (discussed above under Campus Landfill).

The University should continue to conduct environmental audits to identify other potential problem areas on University-owned properties. These audits should locate and characterize sites that may have been contaminated due to past activities.

For more than 20 years, the aesthetic quality of water in the Arboretum Waterway has been a source of complaints and occasional deaths of fish. While not in violation of any applicable water quality standards and not in need of remediation, the University should develop (1) a preferred long-term management solution, and (2) an implementation strategy to improve water quality in the waterway.

RECLAMATION

Effluent produced at the WWTP is a potential source of water that could be reclaimed for reuse on the campus. The DHS sets standards for reuse of reclaimed water. The general overriding concern is that use of reclaimed water must "fully protect the public health." Beyond this general guidance, the DHS sets restrictions based on the type of treatment and quantity of coliform organisms in the treated effluent.

Effluent from the existing WWTP could be reclaimed for the following uses with relatively few changes in the existing treatment facility.

- Surface irrigation of food crops
- Spray or surface irrigation of vineyards and orchards
- Spray or surface irrigation of fodder, fiber, and seed crops
- Irrigation of pasture for milking animals
- Irrigation of landscapes with restricted public access
- Landscape impoundment
- Groundwater recharge of domestic aquifers
- Creating flow through the arboretum waterway

A study of operations at WWTP in the early 1980s included an analysis of potential reclamation projects on the campus (Nolte and Associates 1983). The report considered field and landscape irrigation, and impoundment alternatives. Most alternatives were not considered economically viable because of the high cost of pumping equipment and pipelines needed to move the treated effluent to research fields in the west campus and landscape areas on the central campus. The only economical alternatives were flood irrigation of alfalfa fields in the south campus and the field between the Arboretum Waterway and Interstate 80. Since this report was prepared, the size of these fields has been reduced.

Most potential campus water reclamation projects using effluent from the WWTP will likely remain prohibitively expensive due to the cost of pumping treated effluent to sites where it might be used and because the cost of field research, domestic, and utility water is relatively low. The campus will be constructing a new WWTP to be online by 2000. The new WWTP will produce a higher quality effluent more suitable for reclamation. Opportunities for water reclamation should be reviewed periodically as new technologies and standards are developed.

Aquatic Center and Putah Creek Aquaculture Facility discharge water is relatively clean and so may be economically used for field irrigation. Construction of a new well for the Aquatic Center in 1993 also included installation of the pipeline connections that now allow the diversion of Aquatic Center discharge water to irrigate teaching and research fields. The effluent from the Aquaculture Facility could also be used for irrigation, but requires installation of the pipeline connections to deliver the discharge water to the fields. Further feasibility studies are required to determine other potential uses of the water discharges from these two facilities.

REPORTING AND COORDINATION

The University should prepare an annual wastewater treatment report summarizing the status of existing permits, related monitoring data, new and continuing issues, actions taken the previous year, trends in water quality, and pending actions. Relevant communications with regulatory agencies should be appended to the report. These reports should be consulted during the updating of the Campus Water Management Plan

Chapter 8

WATER CONSERVATION

This section reviews the progress and status of water conservation at UC Davis since 1973. It also identifies several elements of a strategy to promote efficient water management including guidelines for emergency water management efforts in response to droughts. The overall objective behind the recommendations in this chapter is to promote water conservation as a long-term campus investment. These recommendations are drawn from the collective experience and evaluation of water managers at Agricultural Services and Facilities Services and from recommendations from a report prepared by an undergraduate research course in water conservation (Department of Civil and Environmental Engineering 1992).

It should be noted that the campus differs from a municipal utility in that it does not provide financial incentives for conservation. It is therefore more difficult to hold consumers accountable for water use. Consequently, the campus must rely heavily upon the good faith efforts of employees and students in achieving the 10% reduction goal. A greater burden is also placed upon campus water purveyors (i.e., Agricultural Services and Facilities Services) to meet mandated goals through efficient operation of facilities and infrastructure.

The Davis campus is unique among most other campuses in that it relies heavily upon its own wells for its water supply. This self-sufficiency has placed a greater burden on the campus to protect the water resources for which it is responsible.

1973-1987 ACTIVITIES

The Davis campus has been proactive in energy and water conservation since the energy crisis occurred in the fall of 1973. Efforts at water conservation increased during the 1976-1977 drought. The strategy behind these efforts was to implement the obvious and least costly actions first. As a result, the following items were implemented and have contributed to the success achieved to date:

- Substitute 4 gal/min shower heads for 7 gal/min heads in housing areas.
- Ongoing maintenance programs to repair water leaks.
- Implementing preventative maintenance programs to replace faucet washers.
- Planting new landscaped areas with fescue, Bermuda grass, and drought tolerant plants.
- Increasing reliance on drip irrigation systems in place of traditional spray heads.
- Reducing landscape watering times through installation of timers.
- Reducing turf watering from 2" per week to 1.25" per week.
- Promoting late night or early morning irrigation cycles to reduce evaporation and increase soil penetration.
- Promoting infrequent, deep irrigation cycles to develop stronger, deeper rooted, and more drought-resistant plantings.
- Eliminating washing of walkways, patios, plazas, and driveways except for health and safety reasons.
- Retrofitting low-efficiency irrigation equipment with modern, efficient systems during routine repair and replacement.
- Eliminating single-pass cooling systems when system maintenance dictates replacement.
- Shutting down selected heating, ventilation, and air conditioning systems to minimize cooling tower makeup water.
- Publishing water awareness articles encouraging conservation.

1988-1995 ACTIVITIES

The severity of the 1988-95 drought compelled the campus to explore additional avenues for conservation. A coordinated effort between the agricultural faculty and the Department of Agricultural Services was initiated with the goal of reducing agricultural water use by 20%. Basic techniques for achieving this goal included:

- Temporarily postponing program expansions requiring irrigation water.
- Planting dry land crop species where feasible in rotations.
- Leaving all nonessential parcels out of production.
- Establishing a protocol to identify the role of Agricultural Services in allocating water in the event of rationing.
- Continuing land-leveling operations to capture runoff.
- Relying more heavily on groundwater to preserve surface water supplies delivered under contract.
- Converting one Aquatic Center building to partial recirculation of water.

The Facilities Services Diversion also modified some of its activities to further reduce water consumption. Actions taken included:

- Reducing skimming time on the campus toddler recreation pool to 15 hours/day, 210 days/year.
- Lengthening backwashing cycles for the Hickey Gym pool from weekly to biweekly.
- Increasing water purging cycle on Domestic Water Tower #2 from 10 days to 14 days.
- Adjusting cooling tower cycles of concentration from 4 to 4.5 cycles at the central heating and Cooling Plant.
- Increasing individual building cooling tower and air washer concentration cycles from 2 to 3.
- Continuing a reduction in the number of fire hydrants tested as part of the annual testing program.
- Further reducing landscape irrigation watering.

The results of these efforts were positive. Agricultural use declined 8.5% from the previous year. However, it must be understood that sustained reductions at this level could have severe impacts on academic and research programs. Domestic water use for FY 1990-91 was down 3%

from the previous year and was 7.7% lower than the most recent three-year average. Utility water use declined a remarkable 35.8% below the previous year and was 35.8% lower than the most recent three-year average.

SUMMARY AND RECOMMENDATIONS

MANAGEMENT COMMITMENT

The success of an effective water conservation program is largely dependent upon commitment by top levels of the administration as well as by those units directly responsible for the management of campus water supplies. Specifically, a number of important management actions must accompany the implementation of water conservation alternatives:

- Emphasizing the importance of water conservation to all faculty, staff, and students.
- Relating the importance of campus water conservation to local, regional, and statewide efforts on conservation.
- Setting priorities and guidance for drought-responsive conservation activities that can impact academic and research programs.
- Funding support for infrastructure retrofit projects that decrease water use.

ASSESSMENT OF CURRENT WATER USES AND COSTS

General categories of water use for domestic, utility, and field teaching and research purposes are presented in Chapter 4 - Field Teaching and Research (Tables 4-4 and 4-5) and Chapter 5 - Domestic and Utility Water Uses (Tables 5-4 and 5-6). However, setting priorities for implementing many specific conservation actions requires understanding water use within individual facilities. Existing information on water use in individual buildings is inadequate because of the absence of water meters. Some of the estimates of domestic water use in this plan (e.g., volume of water used for campus residences) and past studies (e.g., Civil and Environmental Engineering 1992) are based either on measurements at only a few campus locations, assumptions about the efficiencies of

mechanical equipment, or assumed general use patterns. This information is then extrapolated to estimate overall campus water use patterns and to identify the potential benefit of specific water conservation measures.

Campus management requires a better understanding of water use within individual facilities to develop and implement the most cost-effective water conservation measures. A water audit should be conducted to obtain data estimating individual facility water use. A complete water audit would map flow rate, flow direction, temperature, and pertinent chemical quality of all water from source, through the on-site processes, machines, and buildings, to evaporation and discharge as waste. Much of this data can be obtained by a walk-through survey of campus buildings.

A complete water audit of the entire campus would be time-consuming and cost-prohibitive. Therefore, it should be limited to facilities known to be heavy users and/or show potential for water-saving opportunities. A consulting firm should be hired to perform a utilities allocation study on major campus buildings with water use a significant component of the study.

RESPONSIBILITIES

Facilities Services, Agricultural Services, the College of Agricultural and Environmental Sciences (CA&ES), and the School of Veterinary Medicine are responsible for day-to-day management of water supplies and deliveries to support campus academic and long range development plans. Each organization is responsible for the following activities regarding their respective water systems:

- Reviewing and monitoring the effectiveness of existing conservation programs.
- Identifying and implementing cost-effective conservation measures.
- Identifying less cost-effective measures that should be implemented as drought responses.
- Setting priorities on measures based upon water savings and cost-effectiveness.
- Providing recommendations for conservation projects that may require capital expenditures.

- Seeking outside funding or rebates to assist with conservation endeavors.

- Providing water conservation project management and coordination among those units responsible for campus water management.

- Developing water conservation standards for new construction, maintenance activities, and equipment purchases by Facilities Services-Mechanical and A&E.

These responsibilities must be faithfully attended to for the campus to reduce future needs for supplemental water and to comply with new laws and regulations that restrict water use for new construction.

EDUCATIONAL AWARENESS PROGRAM

The success of water conservation actions is proportional to the level of support from the campus community. The program will be most successful if students, faculty and staff willingly participate. A key step toward to obtaining this support is an extensive educational awareness program. The DWR has compiled a number of useful ideas for use in such a program. Several of these are described below:

- Publish a letter from the Chancellor indicating support for water conservation. This message can provide background information about the need to conserve water and can stress the importance of individual responsibility as part of a team effort to achieve conservation goals.

- Describe which operations use water and the amount that can be saved by water-conserving actions.

- Use campus publications to communicate policies, programs, ideas, announcements, progress reports, and special achievements.

- Expand the role of safety or energy coordinators in each department to include water conservation.

- Provide custodial staff with water conservation stickers and signs to be placed in labs, bathrooms, kitchens, and dining areas.

- Promote a slogan and/or poster contest. Display the best responses in areas of heavy water use.

- Ask for and promote suggestions from employees at all levels. Recognize or reward individuals or departments that implement a successful water conservation program.
- Publicize drought issues that highlight the sensitivity of precious water resources.
- Provide displays at special events such as the Whole Earth Festival or Picnic Day.
- Distribute water conservation booklets that highlight different aspects of water use for the work site or home.

FIELD TEACHING & RESEARCH WATER CONSERVATION

Specific activities that will help reduce overall consumption by field teaching and research activities that can be undertaken by the CA&ES and Agricultural Services include:

- Postponing program expansions that require irrigation water;
- Planting dryland crop species in rotations where feasible;
- Leaving all nonessential parcels out of production;
- Relying heavily on groundwater early in the season to preserve surface water supplies delivered under contract;
- Minimizing surface runoff; and
- Incorporating recirculation in aquaculture facilities where possible.

DOMESTIC WATER CONSERVATION

Actions that can be implemented by Facilities Services to decrease domestic consumption include:

- Reducing the time of surface level skimming on the campus toddler recreational pool to 9 hours/day, 210 days/year, to produce an annual savings of 1,263 ccf (945,000 gallons);
- Increasing the backwashing cycles for the Hickey Gym pool from weekly to biweekly to achieve an annual savings of 1,043 ccf (780,000 gallons);

- Replacing the 7 gpm shower heads with 4 gpm heads at the Recreation Hall, Recreation Pool, and Hickey Gym to realize an annual savings of 18,591 ccf (13.9 million gallons);

- Increasing the cycles of concentration at the Central Heating and Cooling Plant cooling tower, which would reduce annual makeup water consumption by 1,070 ccf (800,000 gallons);

- Modernizing other, older cooling towers to allow increased cycles of concentration;

- Reducing the number of fire hydrants tested annually by the Fire Department;

- Reducing the normal number of car washes performed at the Central Garage by 25%; and

- Replacing sink faucets in housing units with more restrictive aeration devices.

UTILITY WATER CONSERVATION

Opportunities to reduce utility water consumption are limited due to actions taken since 1990. However, some actions that can be taken by Facilities Services include:

- Reducing water application on turf, planter beds, ground cover, and shrubs from 1.5 to 1.25" per week. (This 17% would reduce annual water consumption by to a 26,512 ccf (19.8 million gallons), but may have a noticeable impact on the campus lawns, as the size and number of dry and brown areas increase);

- Correcting equipment problems and adjusting the 184 irrigation controllers to reduce runoff and increase overall watering efficiency; and

- Adding new control technology to the landscape irrigation system that will use a central computer connected to a weather station. This system will allow adjustments to be made to each system controller according to actual needs derived from data downloaded from the weather station. This central control system will significantly reduce the volume of water required by making daily adjustments of irrigation possible.

WATER REUSE

The total volume of water needed from groundwater and surface water to meet existing and future demand could be reduced through reuse of drainage, storm or reclaimed wastewater. Adapting

these types of water to campus uses could be interpreted as either a form of water conservation or a new water supply. Existing information on various water reuse options is described in Chapter 9 - Potential New and Reclaimed Water Sources.

OTHER OPTIONS

Although substantial progress has been made reducing campus water demand through conservation, the potential for even greater savings still remains. The campus has completed most low cost options. Large capital outlays are now required to make significant progress and have been difficult to justify from a simple payback perspective because water production costs are low. The viability of a project must be compared to the actual value of water quantity and quality which is often dependent upon end use. Different uses may require heating, cooling, cleaning, pumping, chemicals, toxic disposal, and predisposal treatment. The incorporation of costs associated with these uses may still be insufficient to justify a water conservation project.

Several projects for future implementation have been identified and need further study. These include:

Analyze options for replacing single-pass cooling systems: A number of small, single-pass refrigeration units discharge water directly to the sanitary sewer rather than recirculating it. Similarly, water-cooled equipment such as compressors, vacuum pumps, pipette washers, stills, and electron microscopes may discharge directly to the sanitary sewer without recirculation. An inventory of single-pass equipment was conducted by Facilities Services in February 1994. Units were identified in Hunt Hall, Cruess Hall, Plant Pathology Field Headquarters, Wickson Hall, Vet Med-II, Hutchison Hall, Robbins, Hall Head House 001, Briggs Hall, Dairy Barn, TB-174 Primate, Young Hall, Memorial Union, Veihmeyer Hall, Olson Hall, Walker Hall, Old Physics, Everson Hall, Mrak Hall, Environmental Horticulture, Chemistry, Chem Annex, Segundo Hall, Haring Hall, Surge 1, Bainer Hall, Cole B, Med Sci. 1A, Veg Crops Field Head Quarters, and GH 21. It is estimated that these units discharge 150-200 million gallons (450-600 acre-ft) of wastewater per year.

Recent estimates indicate a potential savings of 100-150 million gallons/yr through the replacement of these systems. Many of these units were installed to meet academic research needs and were justified by low installation costs in comparison with available alternatives. Specific possibilities include replacing single-pass water cooled refrigeration units in Segundo, Haring, Hutchison and Storer Halls; ITEH; Environmental Horticulture; and the Memorial Union. Planning and estimating costs for these projects would be approximately $15,000. Construction costs are not ascertainable without a detailed investigation. The Memorial Union project is estimated to be approximately $30,000 and involves the installation of a cooling tower with supply and return piping. Additional annual maintenance costs would accrue, but should be offset by an estimated annual water savings of 5,621 ccf (4.2 million gallons).

Conduct sonic leak detection survey on the water distribution system: Extensive surveys of this kind have been undertaken in areas such as Petaluma, Poway, and the Serrano Irrigation District, south of Los Angeles. Results have been favorable and show that the survey and associated leak repair costs usually have a one- to two-year payback. The cost for such a campus survey would be approximately $23,000.

Use silica dispersant in Central Heating and Cooling Plant cooling towers: This operation change would allow concentrations to be adjusted from 4.5 cycles to 7 cycles. Chemical costs for this type of treatment are estimated to be $15,000 annually. A one-time cost of $8,800 would be necessary to install the mixing and feeding equipment. Annual water savings are estimated to be 2,808 ccf (2.8 million gallons).

Install flush restrictors: The estimated cost for installing flush restrictors on the approximately 3,500 toilets and urinals located on campus is approximately $100,000, but would achieve and annual water savings of approximately 26,740 ccf (20.0 million gallons).

Replace water intensive landscapes: Replacing these types of landscapes with water conserving designs consistent with the LRDP would require a comprehensive study and plan estimated to cost $100,000 to determine the specific projects that would be cost-effective to implement.

Selective installation of water meters: Meters would be added at key locations on the domestic and utility systems to better understand water use patterns and system performance.

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Chapter 9

POTENTIAL NEW AND RECLAIMED WATER SOURCES

The purpose of this chapter is to identify alternative internal and external water sources to meet long-term water supply needs and to emphasize the need for the campus to actively pursue a wide variety of options. Presently available information is inadequate to support recommending one alternative source over another or to recommend specific actions. However, the UC Davis Water Management Committee recommended in this plan should systematically monitor and evaluate possible new sources and develop a long-term solution to meet future needs.

The need for additional water on campus will depend on increased demand due to population growth, development of new facilities, future academic research programs, and the capability of existing sources to supply long-term needs in terms of quantity and quality. Since the campus is dependent in part on supplies external to its boundaries, the long-term continuity of those sources must also be considered. This plan identifies an immediate need for additional water supply by 2006 and long-term needs by 2046. Consequently, water management on the campus must examine both internal and external sources for new water supplies.

Internal options

- Additional groundwater pumping
- Drainage, storm, and reclaimed wastewater
- Putah Creek riparian water

External options

- Solano Project water
- Appropriation from the Sacramento River
- Land transfers and exchanges
- Purchasing and contracting for water

- Groundwater recharge from Cache Creek
- Tehema-Colusa Canal and Colusa Drain

Water conservation does not result in a new supply but may effectively fill that role by lowering the potential growth in demand and reducing the total volume of water needed. Thus, development of new water supplies must always be done within the context of identifying and implementing cost effective water conservation measures. Past and ongoing water conservation programs, and recommendations for new opportunities are described in Chapter 8 - Water Conservation. The success of past measures, at least in part, has resulted in the relatively static production of domestic and utility water on the campus since the late 1960s despite large increases in population and facilities (See Chapter 5 - Domestic and Utility Water Uses). The need for new sources of water will be reduced to the degree water conservation measures are successfully implemented.

Given the assumptions underlying this plan and the resulting anticipated increase in water demand, it is unlikely that the entire future campus water budget can be fulfilled with existing water sources and water conservation. The long lead times needed to identify, acquire, and develop new water sources; to coordinate these options with the various interested government agencies; and to evaluate the various alternative supplies require the campus to continue and sustain recent efforts to evaluate internal and external options. Factors that must be considered for any new potential water source include:

- conveyance options
- cost
- environmental effects
- management capability
- political, legal, and legislative issues
- quality
- quantity
- reliability
- risks
- short- and long-term availability
- timing within and between years
- water rights

INTERNAL OPTIONS

GROUNDWATER

Groundwater from the intermediate aquifer system has been an acceptable source of water and can provide additional supplies. However, there is evidence locally and regionally that groundwater levels could decline, land subsidence is a possibility, and quality is a problem for some research and industrial-type activities. Groundwater obtained from the deep aquifer system is acceptable for domestic purposes, but not for others. The extent and recharge rate of the deep aquifer are unknown and the long-term dependability is questionable especially given the likelihood that other water purveyors such as the City of Davis are expected to increase use of this aquifer. The potential for long-term quality changes in the deep aquifer system has not been evaluated, but at best water quality would remain the same and it potentially could decline. The intermediate aquifers will deteriorate by the movement of soluble salts and organic and toxic constituents from ground surface or subsurface sources. Given these unknowns and the likelihood that the water quality will decline at least in the shallow and intermediate aquifers, groundwater is likely not dependable as a long-term solution for increasing the water supply.

Groundwater underlying University property is part of the common pool used by all other pumpers in and around the campus. No formal determination of the rights to extract this water has been made, but it is possible that, if groundwater levels decline enough to raise questions about damage due to pumping, an adjudication of groundwater rights could occur and the University would be a party to such proceedings. The potential effects on campus water supply are unknown.

DRAINAGE, STORM AND RECLAIMED WASTEWATER

An aggressive water conservation/reuse program has the potential to reduce the need for additional supply by 20-40%, but there are major capital costs and water quality issues associated with most reuse options. In 1983, the campus prepared a study to determine the potential for reusing treated wastewater to reduce demands on freshwater supplies (Nolte and Associates 1983).

The report evaluated four categories of reuse alternatives, including field teaching and research irrigation, landscape irrigation, landscape impoundments, and cooling tower makeup. Some form of advanced treatment would be required to meet reuse requirements for all categories except certain agricultural irrigation alternatives.

Landscape Irrigation: Irrigating campus landscaping is the largest use of utility water. Use of reclaimed water for landscape irrigation is governed by water quality requirements established by DHS and the various chemical and physical parameters that affect plant health, soil suitability, and quality of underlying groundwater. Landscape irrigation with reclaimed water would involve spray irrigation with treated wastewater in areas of relatively high public usage, such as playing fields adjacent to major teaching and recreational facilities. The advanced level of treatment required for this type of reuse substantially mitigates the public health concerns. However, public and social acceptability of landscape irrigation alternatives may not be as great as for those alternatives with less potential for public contact. The estimated reclaimed water costs for landscape irrigation were $267/ acre-ft in 1983 and were considered cost prohibitive.

Use of the existing utility distribution system to deliver reclaimed water for landscape irrigation would be difficult due to the age of the system. This problem is compounded by incomplete records describing system interconnections and service locations which would make isolation of the utility water system extremely difficult in certain central campus areas.

Landscape Impoundments: The Arboretum Waterway is the only landscape impoundment on the Davis campus. It is a retention basin for storm water and aesthetically enhances the arboretum setting. Since additional freshwater is rarely added to the waterway, the impoundment is stagnant most of the year and accumulates nutrients that contribute to the deterioration of water quality. Reclaimed wastewater could be discharged to the impoundment as makeup water and to establish flow. Excess water could be withdrawn from the impoundment for use as landscape irrigation (See above) or discharged to the south fork of Putah Creek using the existing drainage pumping system.

The use of reclaimed water for impoundment purposes is influenced by SDH treatment and water quality requirements. SDH defines the Arboretum Waterway as a nonrestricted recreational impoundment. Because of this classification, water treatment costs make this a cost prohibitive alternative. Additionally, the existing eutrophication problems in the creek could be exacerbated as excess nutrients are a serious water quality problem normally experienced by impoundments supplied with reclaimed water. These nutrients stimulate the growth of aquatic plants and algae, creating unpleasant sight and odor problems and reduced recreational value.

Cooling Water Makeup: The largest single use of cooling water occurs at the Central Heating and Cooling Plant with the remaining demand distributed among several major buildings on the core campus. Water demand is typically highest during summer, concurrent with peak landscape and agricultural irrigation demands. Supplying reclaimed water to satisfy all cooling water demands would require a substantial piping network paralleling the existing domestic water system. Bacteriological water quality and chemical constituents influence the use of reclaimed water for cooling tower makeup. The presence of bacteria and/or nutrients may promote bacterial fouling of heat transfer surfaces and reduce transfer efficiencies. Concentrations of ammonia, chlorides and sulfides are of concern, as is salinity. Wastewater effluent contains higher concentrations of these problem constituents. Removal of these constituents or chemical conditioning is required in order to use reclaimed water. Using reclaimed water for cooling tower makeup was not considered cost effective due to the relatively low water demand and the high costs associated with pretreatment, conditioning, and distribution system piping.

Field Teaching and Research Irrigation: Due to the high cost of treating water to reclamation standards, Nolte and Associates (1983) only evaluated irrigation alternatives that did not require treatment beyond standards required for discharge to Putah Creek. Only one limited application to approximately 100 acres of alfalfa was found to be a viable use of reclamed water for field teaching and research uses. Please see the discussion in Chapter 4 - Field Teaching and Research.

Summary: The potential to reuse treated wastewater is discussed in Chapters 4 and 5 and above. In general, the conclusion for each possible application is that although the potential exists,

either the volume, quality, timing of availability, or cost is a significant limitation. Nonetheless, this possible water source should not be overlooked in the long-term nor during extended droughts. The last comprehensive analysis of potential for reclaimed water use was prepared in 1983, and an updated analysis should be prepared to assess changed conditions and technological advances. This analysis should be reviewed periodically as technological advances occur.

Water discharged from single pass cooling systems and from the Aquatic Center are also potential sources for water reuse (Department of Civil and Environmental Engineering 1992). Single pass cooling water is currently discharged to the campus arboretum, and Aquatic Center water is discharged to Putah Creek. Reuse of both these sources is possible, but these opportunities have not been thoroughly studied. For example, water from both sources could potentially be used for landscape or agricultural irrigation without any treatment. Such reuse projects would reduce flows through the WWTP and the need for utility water pumping. The feasibility of reuse opportunities for cooling water and Aquatic Center discharges should be evaluated to reduce demand on the utility water system and WWTP.

PUTAH CREEK RIPARIAN RIGHTS

Although the campus has riparian rights for essentially all of its property adjacent to the original and improved creek channels, in recent years water has only been diverted and used for beneficial purposes from the creek and applied to lands that are part of the Russell Tract. Riparian water rights at the main Campus have not been exercised in recent times. However, campus planners should continue to be aware of this right should conditions warrant future consideration.

EXTERNAL OPTIONS

Access to external water sources require regional considerations and have received considerable attention in the Yolo County Water Plan Update (Borcalli & Associates 1992a) and the Yolo Solano Supplemental Water Supplies Reconnaissance-Level Investigation of Alternatives (Borcalli & Associates 1992b). The latter was a joint venture between water organizations of Yolo

and Solano Counties. Both reports conclude that long-term urban and agricultural water demand in both counties cannot be sustained without the importation of substantial surface water supplies. The University has participated in discussions regarding the following external sources.

SOLANO PROJECT WATER

Solano Project water is the best quality water to meet current and long-term needs for field teaching and research. Consequently, it is the highest priority source of additional water for the campus. The University initiated negotiations with SCWA and Solano Irrigation District in 1992-93 in an effort to obtain additional project water beyond the 4,000 acre-ft/yr currently under contract. Negotiations were terminated by the Solano partners due to reported opposition by other Solano Project member units in Solano County. This source of water should continue to be pursued, especially if the political atmosphere improves.

APPROPRIATION FROM THE SACRAMENTO RIVER

The Sacramento River is another potential alternative for supplemental water. The Yolo County Flood Control and Water Conservation District took the initiative to file an application for water from the Sacramento River in May 1994. The application included the University and the Cities of Davis and Woodland, without the prior knowledge of these agencies. However, discussions were initiated in the spring of 1995 to clarify legal, physical, and financial participation by all the parties. This supplemental source of water should be pursued. Details are given in a report by Borcalli & Associates (1995) as follows:

> In view of the findings and recommendations from the investigation of supplemental water supplies for Yolo and Solano counties (Table 12, Report No. 12), and recognizing that the competition for reliable water supplies is becoming increasingly more intense throughout California, the Yolo County Flood Control & Water Conservation District filed an application (No. 30358) in May 1994, to appropriate water from the Sacramento River. This application was filed to establish a priority position for the cities of Davis and Woodland, and the University in the water appropriations process. This priority, however, can only be maintained with demonstrated diligence in addressing protests and comments to the application, performing appropriate studies, and formulating a plan to beneficially use the water for which the application was submitted.

The timeliness of filing this application becomes more apparent as other applicants, like Sacramento County (and possibly Solano County), file applications to divert water from the Sacramento River.

Summarized below are pertinent aspects of the application:

Purpose of Use:	Municipal, irrigation and agricultural, fisheries, and aquaculture research
Points of Diversion:	Four points of diversion were identified in the application. One is at the Red Bluff Diversion Dam in Tehema County and the other three are located, east of Woodland and Davis -- one near Conway Ranch's pumping plant, one midway between Interstate 5 and Interstate 80, and one at or near the City of West Sacramento's intake.
Rate of Diversion:	250 cfs
Amount of Diversion:	45,000 acre-ft /yr
Schedule:	Start Work - 1998 Complete Work - 2005 Water Fully Used - 2040
Period of Diversion:	January 1 through December 31
Plan and Purpose of Use:	A portion of the water will be applied directly to beneficial use, for municipal purposes within the cities of Davis, Woodland, and Winters, and or irrigation and agricultural, aquacultural, and fisheries research purposes at the University of California, Davis. The remaining portion of this application is for water that will be used in a conjunctive use program. Under this program, water diverted from the Sacramento River will be used for irrigation on lands within the designated place of use, thereby reducing by corresponding amounts of groundwater that are pumped to irrigate these lands. Similar amounts of groundwater will be pumped by the cities of Davis, Woodland, and Winters for municipal purposes, and by the University of California, Davis, for irrigation and agricultural, aquacultural, and fisheries research purposes. This conjunctive use program will help arrest land subsidence, minimize and mitigate water

quality deterioration, and provide water for increasing municipal, irrigation, and research demands.

LAND TRANSFERS AND EXCHANGES

The University should consider purchasing land within a reasonable distance of the campus that has entitlement to groundwater and to surface water from the Solano Irrigation District. Lands with reliable surface and groundwater of very good quality could accommodate field research and teaching. Such a purchase and transfer of field teaching and research activities would allow the University to consider selling a portion of Russell Tract land. Any plan involving the sale of Russell Tract land must be carefully but promptly considered given Campus plans for "A Center for the Study of Agriculture and the Environment."

PURCHASING AND CONTRACTING FOR WATER

Some land owners along the Sacramento River and its tributaries have riparian water rights that may be available for purchase or contract on a long-term basis. For example, in 1991 Yolo County water purveyors were contacted by agents of land owners on a tributary to the Sacramento River who claimed their clients were interested in selling riparian water rights. Other riparian land owners along the Sacramento River and its tributaries may be interested in a similar arrangement.

The Conway Conservancy Group, a land owner of parcels west and south of Woodland and adjacent to the Sacramento River, was interested in developing its land for a variety of purposes and had indicated an interest in transferring water by contract. The University was contacted by this Group in the summer of 1995. In 1996, PG&E properties placed the Conaway Ranch on the market. A variety of Yolo County groups working with several state agencies made a proposal that included transferring some surface water to the Cities of Davis and Woodland and the University. After reviewing all proposals received, PG&E decided to withdraw the property from the market.

Although the long-term availability and high conveyance costs of purchasing and/or contracting for water supplies remain open questions, this option should be pursued in cooperation with other Yolo County water jurisdictions.

GROUNDWATER RECHARGE FROM CACHE CREEK

The Yolo County Flood Control and Water Conservation District filed an application for diversion of water from Cache Creek for the period of November 1 to March 1 for a maximum of 95,000 acre-ft/yr or an average of 25,000 acre-ft/yr. The purpose is to recharge the groundwater north and south of the Creek in the reach from the Capay Diversion Dam to Moore Dam. This would be a District operation, but dependent on cooperation of land owners along the creek. The direct impact on the University's groundwater supplies would be limited, but the overall recharge would have a positive regional influence and therefore be of some limited benefit to the University.

TEHEMA-COLUSA CANAL AND COLUSA DRAIN

Campus planners must continue to consider the potential of the Tehema-Colusa Canal and Colusa Drain even though neither of these options is considered viable in the near future. The Tehema-Colusa Canal extension was determined not to be feasible by the U.S. Bureau of Reclamation in the 1980's, and Colusa drain water is variable, uncertain in quality, and would require costly treatment.

Chapter 10

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APPENDIX A

USEFUL WATER CONVERSIONS

VOLUME CONVERSIONS

1 cubic foot = 7.48 gallons

100 cubic feet = 1 ccf

1 ccf = 748 gallons

1 ccf = 0.0023 acre-feet

1 acre-foot = 325,851 gallons

1 acre-foot = 43,560 cubic feet

1 acre-foot = 435.6 ccf

1 cubic foot/second (cfs) for 24 hours = 1.98 acre-feet

FLOW CONVERSIONS

1 gpm = 1.0 gallon/minute

1.0 cubic foot/second = 1 cfs

1 cfs = 448 gpm

100 gpm = 0.223 cfs

1 mgy = 1 million gallons per year

PRESSURE CONVERSIONS

1 foot head pressure = pressure from a 12-inch column of water

1 foot head pressure = 0.43 psi

1 psi = 1.0 pounds pressure per square inch

1 psi = 2.32 feet of head pressure

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APPENDIX B

YOLO-SOLANO WATER ORGANIZATIONS

CACHE CREEK CONSERVANCY

ADDRESS: 34490 County Road 25, Woodland, CA 95695

CONTACT: Ann Brice; 661-1070

CENTRAL VALLEY REGIONAL WATER QUALITY CONTROL BOARD (CVRWQCB)

ADDRESS: 3443 Routier Road, Suite A, Sacramento, CA 95827

CONTACT: Richard McHenry (Yolo County); Ken Landau (Solano County)

CITY OF DAVIS PUBLIC WORKS

ADDRESS: 23 Russell Boulevard, Davis, CA 95616

CONTACT: Don Lemmon; 757-5686

CITY OF WEST SACRAMENTO PUBLIC WORKS

ADDRESS: 1951 So. River Road, West Sacramento, CA 95691

CONTACT: Dan Houston

CITY OF WINTERS

ADDRESS: 318 First Street, Winters, CA 95695

CONTACT: 795-2811

CITY OF WOODLAND PUBLIC WORKS

ADDRESS: 300 First Street, Woodland, CA 95695

CONTACT: Gary Wegener; 666-8920

DUNNIGAN WATER DISTRICT

ADDRESS: P.O. Box 84, Dunnigan, CA 95937

CONTACT: Cynthia Peterson; 724-3271

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

ADDRESS: Region 9, Building 205, Presidio of San Francisco, San Francisco, CA 94129

CONTACT: (415) 923-7177

FRIENDS OF CACHE CREEK

ADDRESS: 724 N Street, Davis, CA 95616

CONTACT: Kevin Wolf; (916) 758-4211

NATURAL RESOURCES CONSERVATION SERVICE

ADDRESS: 221 W. Court Street, Woodland, CA 95695

CONTACT: Phil Hogan; (916) 662-2037

PUTAH CREEK COUNCIL

ADDRESS: P.O. Box 743, Davis, CA 95616

CONTACT: Steve Chainey

PUTAH CREEK LANDOWNERS ASSOCIATION

ADDRESS: P.O. Box 705, Winters, CA 95694

CONTACT: Chris Horsley; (916) 795 -2002

SOLANO COUNTY PARKS DEPT. - PUTAH CREEK GREENWAY

ADDRESS: 301 County Airport Road, Vacaville, CA 95688

CONTACT: (707) 795-2990

SOLANO COUNTY WATER AGENCY

(Formerly Solano County Flood Control and Water Conservation District)

ADDRESS: 508 Elmira Road, Vacaville, CA 95687

CONTACT: David Okita, General Manager; (707)451-2852

SOLANO IRRIGATION DISTRICT

ADDRESS: 508 Elmira Road, Vacaville, CA 95687

CONTACT: Robert Isaac, General Manager; (707)448-7347

STATE WATER RESOURCES CONTROL BOARD

ADDRESS: P.O. Box 2000, Sacramento, CA 95812-2000

CONTACT: Ed Anton, Chief, Division of Water Rights; (916) 657-1359

U.S. ARMY CORPS OF ENGINEERS

ADDRESS: 1325 J Street, Sacramento, CA 95814

CONTACT: Alan Oto

U.S. BUREAU OF RECLAMATION

ADDRESS: 7796 Folsom Dam Road, Folsom, CA 95630

CONTACT: Tom Aiken, (916)988-1707

U.S. FISH AND WILDLIFE SERVICE, CENTRAL VALLEY HABITAT JOINT VENTURE PROGRAM

ADDRESS: 2233 Watt Avenue, Suite 375, Sacramento, CA 95825-0509

CONTACT: Dave Paullin; (916) 979-2085

U.S. GEOLOGICAL SURVEY - WATER INFORMATION

ADDRESS: 2800 Cottage Way, Sacramento, CA 95825

CONTACT: Walt Swain; (916) 978-4648, ext. 396

WATER RESOURCES ASSOCIATION OF YOLO COUNTY

ADDRESS: 318 First Street, Winters, CA 95694

CONTACT: Harrison Phipps; (916) 795-0754

WOODLAND CHAMBER OF COMMERCE, WATER COMMITTEE

ADDRESS: 520 Main Street, Woodland, CA 95695

CONTACT: Twyla Thompson

WOODLAND LEAGUE OF WOMEN VOTERS, WATER COMMITTEE

ADDRESS: 1121 West Street, Woodland, CA 95695

CONTACT: Lois Linford; (916) 662-2154

YOLO BASIN FOUNDATION

ADDRESS: P.O. Box 943, Davis, CA 95616

CONTACT: Robin Kulakow; (916) 756-7248

YOLO COUNTY COMMUNITY DEVELOPMENT

ADDRESS: 292 W. Beamer Street, Woodland, CA 95695

CONTACT: Director; 666-8020

YOLO COUNTY FARM BUREAU

ADDRESS: P.O. Box 1556, Woodland, CA 95770

CONTACT: Donna Mast; (916) 662-6316

YOLO COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

ADDRESS: 34274 State Highway 16, Road 94B and Highway 16, Woodland, CA 95695

CONTACT: James F. Eagan, General Manager; (916)662-0265; FAX (916)662-4982

YOLO COUNTY PUBLIC WORKS

ADDRESS: 600 A Street, Room 158, Davis, ca 95616

CONTACT: Tom Mohr; 757-5577

YOLO COUNTY RESOURCE CONSERVATION DISTRICT

ADDRESS: 221 West Court Street, Woodland, CA 95695

CONTACT: Katie Pye; (916) 662-2037

YOLO-ZAMORA WATER DISTRICT

ADDRESS: P.O. Box 176, Yolo, CA 95697

CONTACT: Twyla Thompson; (916) 666-2893

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APPENDIX C

HISTORICAL RECORDS ON WILLOW CANAL

Documents pertaining to the construction, abandonment, and acquisition of Willow Canal by The Regents and to repair and maintenance of Willow Canal by the campus collected by Dave Klippert, Agricultural Services Office, and delivered to Shields Library Archives.

CONSTRUCTION OF WILLOW CANAL

No.	Date	Document Title	No. pages
1.	06/16/04	DEED-F. E. Russell and Wife To Yolo County Consolidated Water Company	2
2.	08/06/04	DEED: H.M. La Rue et al. To Yolo Co. Consolidated Water Company	2
3.	08/08/04	G. W. Pierce, Susan G. Pierce and Eunice Pierce To Yolo County Consolidated Water Company	2
4.	08/11/04	Yolo County Consolidated Water Company, a corporation, Plaintiff vs. C. W. Bush, as Administrator of the Estate of Thomas Hext, deceased, Defendants	2
5.	08/22/04	DEED: Ellen Campbell et al. to Yolo Water Company	2
6.	08/30/27	Clear Lake Water Company, Rules and Regulations	11

Description of Documents 1 Through 6

In 1904, it was proposed by the Yolo County Consolidated Water Company that an irrigation canal be constructed along the north bank of Putah Creek between the towns of Davisville and Winters. The new structure would bring water from Lake County (Clear Lake) to Davisville. Documents Nos. 1 through 5 document the surface adjudication necessary for construction of the canal. Four major landowners provided the necessary easements. One landowner was sued and his land condemned.

The Regents entered agreement with the Yolo County Consolidated Water Company on July 24, 1906. A copy of the agreement has not been discovered. The canal was completed and named the "Willow Canal." It was managed by Yolo County Consolidated Water Company until the mid 1920s when the Clear Lake Water Company took over. Document No. 6 is an operations booklet for customers of the Willow Canal. It was accepted for filing by the California Railroad Commission in 1927. The canal is currently managed by the Yolo County Flood Control and Water Conservation District.

Willow Canal provided a major portion of the irrigation water delivered to the University until 1967. It still provides most of the irrigation water used at the Russell Ranch.

ABANDONMENT OF WILLOW CANAL EAST OF STATION 516, ACQUISITION BY REGENTS

No.	Date	Document Title	No. pages
1.	07/06/50	MEMORANDUM to C.B. Hutchison Re: Davis Water Problem, Proposed Abandonment of Willow Canal by Clear Lake Water Company	2
2.	05/07/51	LETTER to C.B. Hutchison Re: Regents recommendation to execute a contract for purchase of all rights to Canal from Station 516 east	1
3.	06/01/51	CONTRACT Between Clear Lake Water Co. and The Regents of the University of California; continued water deliveries from Willow Canal	6
4.	06/14/51	TRANSMITTAL LETTER from Clear Lake Water Attorney to Ira Smith, UCD	1
5.	06/14/51	TRANSMITTAL LETTER from Clear Lake Water Attorney to P.U.C.	2
6.	06/14/51	TRANSMITTAL LETTER from Clear Lake Water Attorney to UC Berkeley	1
7.	11/29/51 to The Regents	RESOLUTION to transfer all rights east of Willow Canal Station 516	1
8.	12/18/51	DEED: Clear Lake Water Company, a corporation, Grantor, and Regents of the University, a corporation, Grantee	3
9.	00/00/56	AGREEMENT between Clear Lake Water Company and The Regents amending June 1st 1951 Contract, Construction of spillway into Putah Creek	2

Description of Documents 1 Through 9

In 1950, the Clear Lake Water Company proposed to abandon the Willow Canal east of Engineer Station 516 (located at the western edge of the Glide property near the Stevenson Road Bridge). It was thought that the cost of maintaining this section was greater than the revenue received from University water sales. The University filed a protest and eventually entered an agreement with Clear Lake Water Company, whereby the University would fund the maintenance of this section of canal and water would continue to be delivered. This agreement was filed for acceptance with the Public Utilities Commission in June 1951. In late 1951, all rights to the Canal between station 516 and the western property line of the campus were turned over to The Regents.

REPAIR AND MAINTENANCE OF WILLOW CANAL EAST OF STATION 516

No.	Date	Document Title	No. pages
1.	07/30/57	LETTER to L.L. Barley Re: Canal seeping on Pierce property	1
2.	08/30/57	LETTER to C. C. Norris Re: request for emergency repair funding	1
3.	09/18/57	LETTER to Don Gilstrap from Dixwell Pierce, Re: permission to enter Pierce property and make repairs	1
4.	09/18/57	AGREEMENT between Dixwell Pierce, Grantor and Regents, Grantee	2
5.	09/19/57	LETTER to Dixwell Pierce acknowledging authorization to effect repairs	1
6.	10/30/57	LETTER to Dixwell Pierce acknowledging start of repair work	1
7.	11/1/57	AGREEMENT between nieces of Dixwell Pierce and The Regents, Re: excavation of a borrow pit to obtain fill material for additional repairs	1
8.	11/06/57	LETTER to Mrs. M. Worden acknowledging authorization.	1
9.	11/06/57	LETTER to Mrs. C. Celio acknowledging authorization.	1
10.	11/14/57	LETTER to Don Gilstrap from Dixwell Pierce acknowledging start of repairs	1
11.	11/01/82	LETTER from A.G. Shows to J. F. Sullivan, Re: Canal washout on Glide property	1
12.	04/01/90	INVOICE from Yolo County Flood Control and Water Conservation District charging $880.97 for weed control east of Station 516	1
13.	09/00/91	M.O.U. between Yolo County Conservation and Flood Control District and The Regents, Re: maintenance responsibility for Willow Canal east of Station 516	2

Description of Documents 1 Through 13

Since accepting responsibility for the Willow Canal as it lies east of Station 516, there have been three instances of repair or dispute, causing the University to consider a quit-claim deed on the property in 1991. Water from the Canal has not been used for irrigation purposes since 1967. Surplus water from the Canal flows into Putah Creek through a spillway constructed by the University in 1956, located at the southwest corner Davis campus property. An M.O.U. acknowledging this use, and the University's maintenance responsibility, was completed in September 1991.

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UNIVERSITY OF CALIFORNIA, DAVIS

Annual Water Quality Report

April, 1996

The University of California, Davis operates, maintains and monitors the domestic water system for the campus. The Campus water supply complies with state and federal primary drinking water standards.

A new domestic well was drilled in 1995 and will be put into service in 1996.

The table below shows a comprehensive summary of the laboratory test results for the constituents that are regularly monitored in the water supply. The table compares the levels found in the campus domestic water supply with the state and federal primary drinking water standards. The analyses are conducted regularly by a state certified laboratory. In addition to the constituents listed below, we have tested for additional organic chemicals for which the California Department of Health Services and the US EPA have not yet set a standard, and all results were below detection levels.

If you have any questions regarding the domestic water supply, please feel free to call EH&S at 2-1493.

Microbiological Analysis Results

COLIFORM BACTERIA	*Units*	*MCL*	*Range*	*Average*
	% Positive	5	0	0

Chemical Analysis Results

PRIMARY STANDARDS - MANDATORY HEALTH-RELATED STANDARDS

INORGANIC CHEMICALS	*Units*	*MCL*	*Range*	*Average*
Aluminum (Al)	µg/l	1000	<50 - 100	67.2
Arsenic (As)	µg/l	50	2.1 - 5.2	3.94
Asbestos	MFL	7	<.0094 - .0188	0.0113
Barium (Ba)	µg/l	1000	<10 - 110	44.6
Cadmium (Cd)	µg/l	5	<0.10	<0.10
Chromium (Cr)	µg/l	50	<10 - 25	13.8
Flouride (F)	µg/l	1.4-2.4 *	0.13 - 0.16	0.14
Lead (Pb)	µg/l	50	1.0 - 3.6	2.06
Mercury (Hg)	µg/l	2	<0.20	<0.20
Nitrate (NO3)	µg/l	45	1.0 - 3.8	1.78
Selenium (Se)	µg/l	50	<1.0	<1.0
Silver (Ag)	µg/l	100	<10	<10
CLARITY				
Turbidity	NTU	1.00	<0.10 - 0.49	0.302

VOLATILE ORGANICS				
1,2-Dichlorobenzene	µg/l	600	ND	ND
1,1,1-Trichloroethane	µg/l	200	ND	ND
1,1,2,2-Tetrachloroethane	µg/l	1	ND	ND
1,1,2-Trichoroethane	µg/l	32	ND	ND
1,1-Dichloroethane	µg/l	5	ND	ND
1,2-Dichloroethane	µg/l	0.5	ND	ND
1,1-Dichloroethylene	µg/l	6	ND	ND
Cis-1,2-Dichloroethene	µg/l	6	ND	ND
Trans-1,2-Dichloroethene	µg/l	10	ND	ND
Dichloromethane	µg/l	5	ND	ND
1,2-Dichloropropane	µg/l	5	ND	ND
1,3-Dichloropropene	µg/l	0.5	ND	ND
1,4-Dichlorobenzene	µg/l	5	ND	ND
Benzene	µg/l	1	ND	ND
Carbon Tetrachloride	µg/l	0.5	ND	ND
Monochlorobenzene	µg/l	70	ND	ND
Styrene	µg/l	100	ND	ND
Vinyl Chloride	µg/l	0.5	ND	ND
Ethyl Benzene	µg/l	680	ND	ND
Tetrachloroethene	µg/l	5	ND	ND
Toluene	µg/l	150	ND	ND
1,2,4-Trichlorobenzene	µg/l	70	ND	ND
Trichloroethylene	µg/l	5	ND	ND
Trichlorofluoromethane	µg/l	150	ND	ND
Trhchlorotrifluoroethane	µg/l	1200	ND	ND
Xylene (o,p,and m)	µg/l	1750	ND	ND
DISINFECTANT BY-PRODUCTS				
Total Trihalomethanes	µg/l	100	ND	ND
RADIOACTIVITY				
Alpha Activity	pCi/l	15	<1.0	<1.0

SECONDARY STANDARDS (AESTHETIC STANDARDS)

INORGANIC/PHYSICAL				
Chloride (Cl-)	mg/l	500	16 - 29	22.2
Color, Apparent	units	15	<3	<3
Copper (Cu)	µg/l	1000	<10	<10
Foaming Agents (MBAS)	mg/l	0.5	<0.01	<0.01
Iron (Fe)	µg/l	300	<30 - 140	52
Manganese (Mn)	µg/l	50	8.5 - 30	17.92
Odor, Threshold (Ton)	units	3	1.4 - 3	1.96
Sulfate (SO4-)	mg/l	500	29 - 46	36.2
Total Dissolved Solids (TDS)	mg/l	1000	310 - 340	320
Zinc (Zn)	µg/l	5000	<5.0 - 43	16.4
Calcium (Ca)	mg/l	NS	12 - 23	17.6
Hardness	mg/l	NS	83 - 160	120.6
Magnesium (Mg)	mg/l	NS	13 - 26	19.2
pH	units	6.5-8.5	7.6 - 7.8	7.7
Potassium (K)	mg/l	NS	1.6 - 2.5	2.14
Sodium (Na)	mg/l	NS	72 - 90	82

MCL = Maximum allowable Contaminant Level
* = Fluoride standard depends on temperature
MFL = million fibers /liter, MCL for fibers exceeding 10ug in length
NTU = Nephelometric Turbidity Unit
ND = none detected
NS = no standard
µg/l = micrograms per liter
mg/l = milligrams per liter
pCi/l = picoCuries per liter