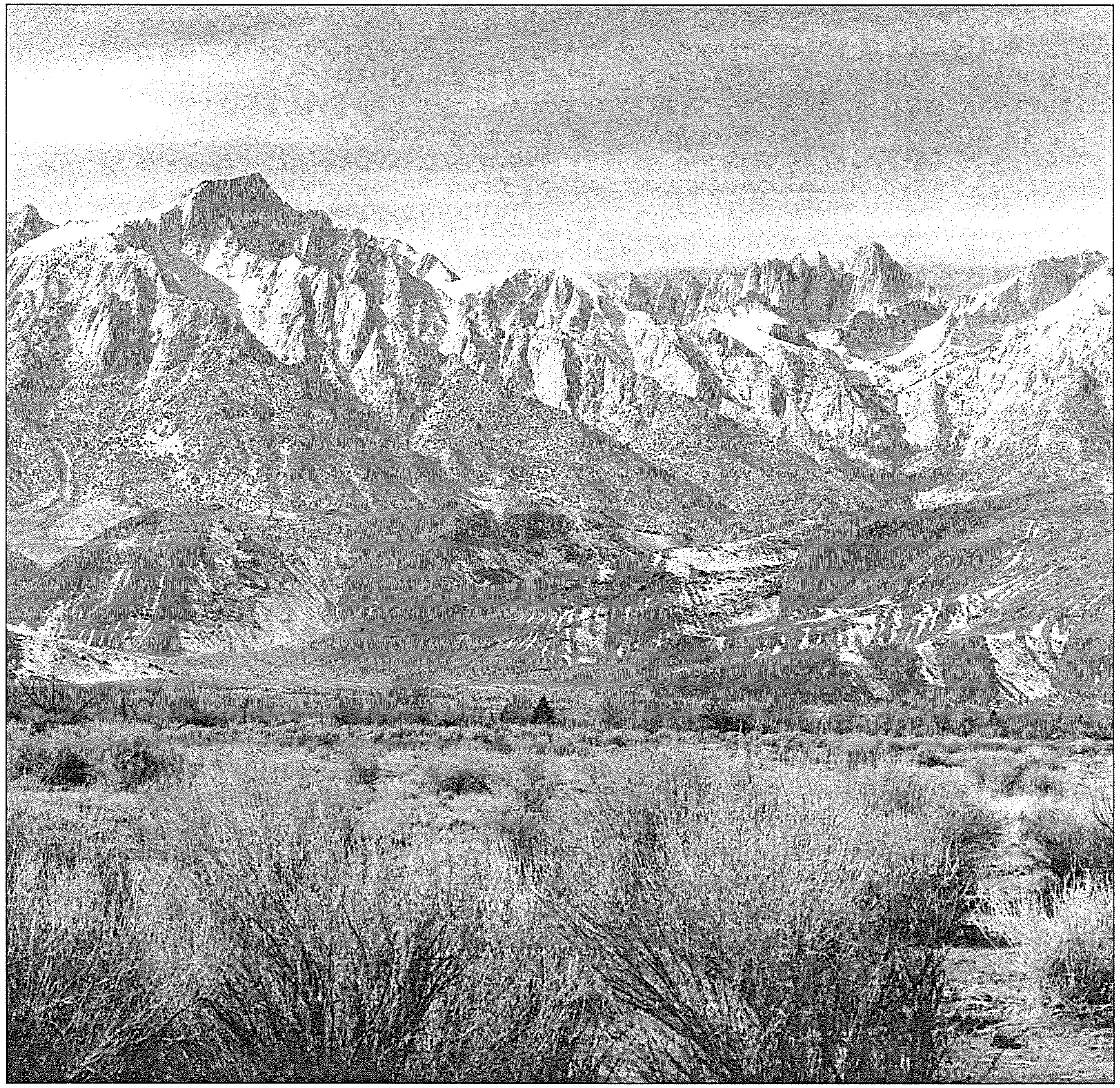

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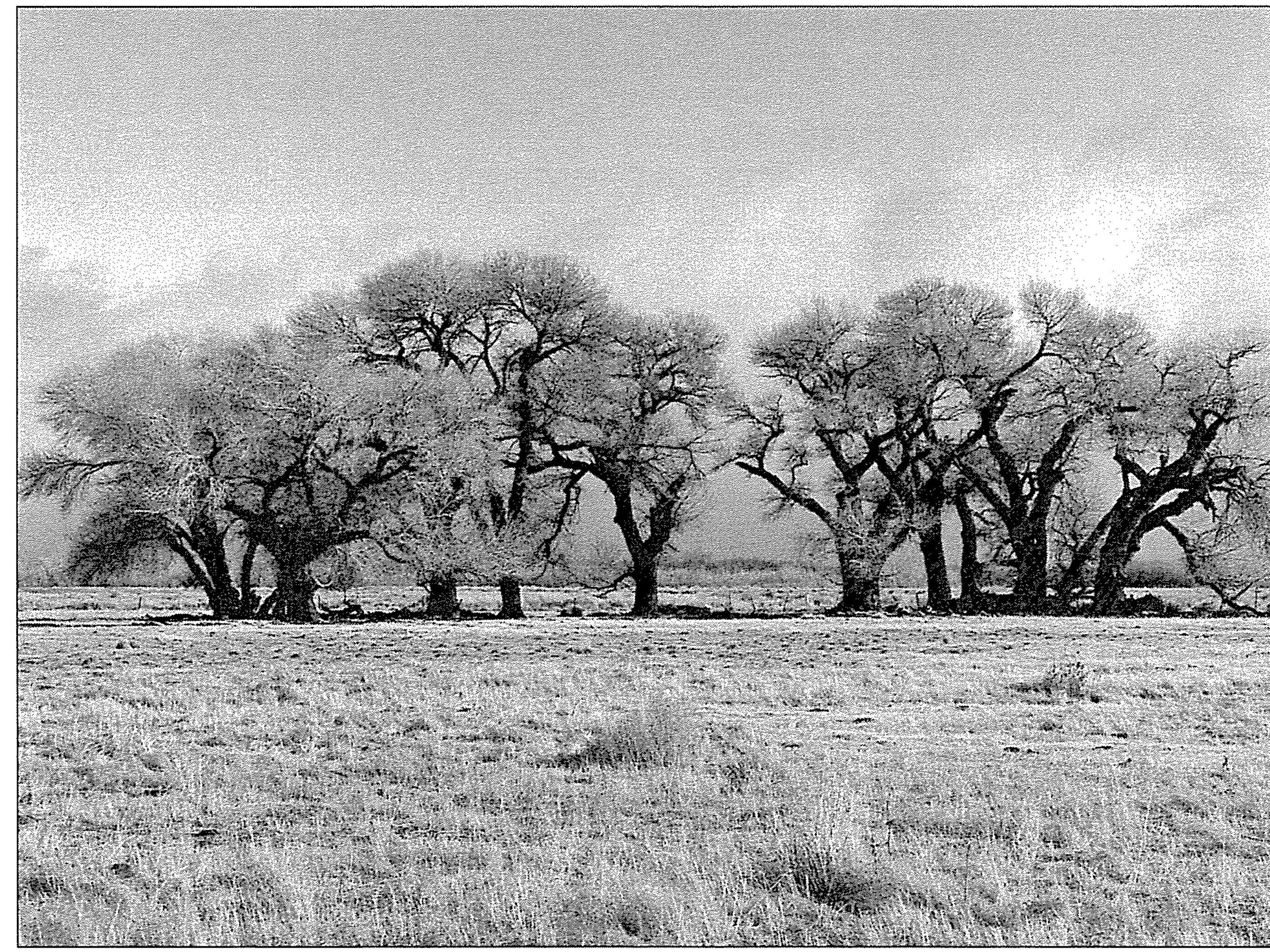
THE OWENS VALLEY

MONITOR



INYO COUNTY WATER DEPARTMENT'S ANNUAL REPORT
ON ACTIVITIES AND CONDITIONS IN THE OWENS VALLEY

1997

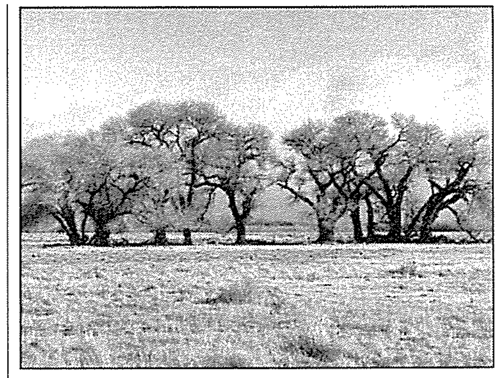
INTRODUCTION

The Owens Valley Monitor is the Inyo County Water Department's (ICWD) annual report. The Monitor is a report on monitoring and other technical work performed by ICWD staff and the Los Angeles Department of Water and Power (LADWP).

In accordance with a cooperative Owens Valley water management agreement, ICWD and LADWP monitor water activities in the valley and their effects on groundwater levels and vegetation.

The two agencies also conduct scientific research on methods of improving water management.

TABLE OF CONTENTS



THE OWENS VALLEY MONITOR

This annual report was produced by the Inyo County Water Department (ICWD) in Bishop, California.

The ICWD also produces a newsletter called the Owens Valley Water Reporter. The newsletter covers the activities of the ICWD and water issues in the Owens Valley and the Eastern Sierra. If you would like to receive the newsletter and the annual report, let us know:

Phone: (760) 872-1168
FAX: (760) 873-5695
E-mail: inyowaterdept@telis.org
Web: http://www.sdsc.edu/Inyo/inyohpg.htm
Write: Inyo County Water Department
163 May Street
Bishop, CA 93514

Front Cover:
Cottonwood trees in the Owens Valley
Photograph by Leah Kirk, ICWD

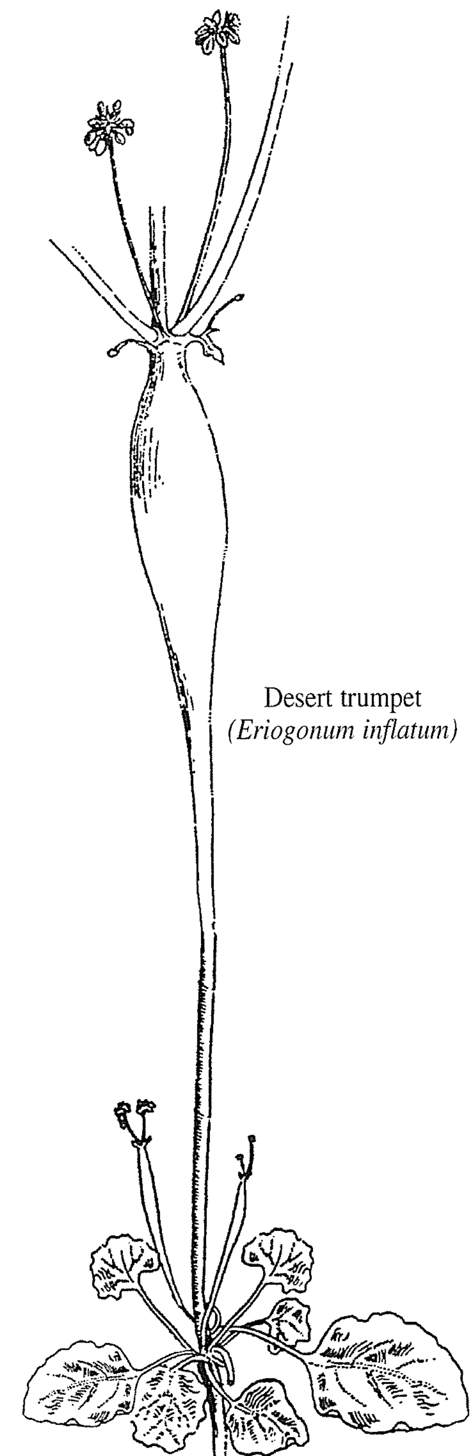
Back cover:
Lone Pine Peak, the Whitney Crest and Mt. Whitney. Photograph by Bill Fettkether, courtesy China Lake NAWS.

1997 Monitor Design: Wynne Benti

This report is published on recycled paper.

1997 ADDITIONS TO INYO COUNTY HERBARIUM

Denise Waterbury maintains ICWD's herbarium, which contains various plant species found in the Owens Valley. During 1997, the following species were added to the collection. A complete list is available at the ICWD.



Desert trumpet
(Eriogonum inflatum)

Family/Species	**Common Name**
ASCLEPIADACEAE	
Asclepias erosa	Desert milkweed
ASTERACEAE	
Baccharis salicifolia	Mulefat/Water wally
Chrysothamnus albidus	White-flowered rabbitbrush
Chrysothamnus nauseosus ssp. consimilis	Nevada rabbitbrush
Chrysothamnus nauseosus ssp. hololeucus	White-leaf rabbitbrush
Hymenoclea salsola	Burrobush
Tetradymia axillaris var. longispina	Longspine horsebush
Tetradymia stenolepis	Mojave cottonthorn
Xylorhiza tortifolia	Mojave aster
BORAGINACEAE	
Cryptantha circumsissia	Capped cryptantha
Cryptantha pterocarya	Wing-nut forget-me-not
*Myosotis scorpioides**	Forget-me-not
BRASSICACEAE	
*Descurainia sophia**	Flixweed
*Sisymbrium altissimum**	Tumble-mustard
CYPERACEAE	
Scirpus americanus	Three-square
FABACEAE	
Prosopis pubescens	Screw-bean mesquite
GENTIANACEAE	
Centaurium exaltatum	Four-petal centaurium
LAMIACEAE	
Salvia columbariae	Chia
PLANTAGINACEAE	
*Plantago major**	Common plantain
POACEAE	
*Bromus madritensis ssp. rubens**	Red brome
*Bromus tectorum**	Cheatgrass
*Schismus arabicus**	Arabian schismus
POLYGONACEAE	
Eriogonum inflatum	Desert trumpet
*Rumex crispus**	Curly dock
SALICACEAE	
Salix goodingii	Valley willow
SOLANACEAE	
Nicotiana attenuata	Coyote tobacco
Solanum americanum	Small-flowered nightshade
*Solanum rostratum**	Buffalo berry

* = non-native species

THE INYO COUNTY WATER DEPARTMENT

1997 ICWD STAFF

Greg James
Director

VEGETATION

Sally Manning
Vegetation Scientist

Irene Yamashita
Supervising Research Assistant

Brian Cashore
Supervising Research Assistant

Derik Olson
Research Assistant

Denise Waterbury
Research Assistant

Stephanie Frei
Summer Research Assistant

Richard Potashin
Summer Research Assistant

HYDROLOGY

Randy Jackson
Hydrologist

Rick Puskar
Hydrologic Technician

David Poe
Summer Hydrologic Technician

SOILS

Aaron Steinwand
Soil Scientist

ADMINISTRATIVE

Douglas Daniels
Fiscal Operations Supervisor

Irene McLean
Secretary, Receptionist

Leah Kirk
Environmental Specialist

Chris Howard
Geographic Informationn Systems Specialist

Research assistant, Richard Potashin, 1,381 transects later.

ICWD'S BUDGET

Inyo County Water Department's general operations budget for fiscal year 1996-97 was $970,461. General operations included ongoing monitoring and management in the Owens Valley and administration.

Of the $970,461, the Los Angeles Department of Water and Power provided $919,250 the county's geothermal trust fund provided $20,000, and the LADWP/ICWD water trust and the previous year fund balance provided $19,607.

INYO COUNTY BOARD OF SUPERVISORS

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INYO COUNTY WATER COMMISSION

Bob Campbell
Ray Gray
Harry Holgate
Scott Kemp
David Miller

INYO COUNTY ADMINISTRATOR

Rene Mendez

1997-1998 PUMPING PROGRAM

Leah Kirk, ICWD Environmental Specialist

Inyo County and Los Angeles agreed to a maximum groundwater pumping limit of 70,000 acre feet for the 1997-1998 runoff year (April 1, 1997 - March 31, 1998). An additional amount of groundwater could be pumped by the Los Angeles Department of Water and Power (LADWP) during the winter, if necessary, to prevent the water in the Los Angeles Aqueduct from freezing. Actual pumping by LADWP during the period was 66,910 acre-feet. Table 1 shows a breakdown by wellfield of the actual pumping from April 1997 through March 1998 compared with estimated groundwater recharge for October 1996 through September 1997. LADWP annual pumping and the percent of normal runoff for 1987 to the present is shown in Figure 1.

Each year, the Inyo/Los Angeles Technical Group develops an annual pumping program based on projected runoff and groundwater recharge, and on measurements of vegetation conditions, soil water, and water table levels. Since 1990 and the adoption by the county and city of a Drought Recovery Policy, pumping has been managed with the aim of raising water table levels. Water tables had declined in 1987 and 1988 due to high pumping and drought. These two years were followed by several years of continued drought, low groundwater recharge, and reduced groundwater pumping by LADWP.

In developing the 1997-1998 pumping program, the Inyo County Water Department (ICWD) and LADWP used multiple linear regression equations developed for 18 monitoring wells in the Owens Valley to predict water table responses to different amounts and distributions of groundwater pumping. The pumping limit was based on these predictions and in consideration of valley-wide vegetation conditions. Table 2 shows water levels at the 18 monitoring wells in 1987 and since 1990, with the predicted response at the wells to 70,000 acre-feet of pumping during 1997-1998.

Total Owens Valley water uses for the runoff year were about 93,000 acre-feet. These uses included about 47,000 acre-feet for irrigation, about 16,000 acre-feet for stockwater, about 8,000 acre-feet for LADWP recreation and wildlife projects, and about 22,000 acre-feet for enhancement/mitigation projects. LADWP installed the E/M projects in the 1980s by agreement with Inyo County. They include Klondike Lake, Lone Pine riparian park, treelots in Independence and Lone Pine, several pastures and alfalfa fields, and the Lower Owens River Rewatering Project.

Table 1. Owens Valley groundwater pumping and estimated recharge by wellfield.

Wellfield	Pumping (acre-feet) Apr 97-Mar98	Est. Rechg.* (acre-feet) Oct 96-Sep 97
Laws	2,951	16,698
Bishop	10,820	48,409
Big Pine	24,654	33,173
Taboose-Aberdeen	1,072	
Thibaut-Sawmill	18,043	40,736
Independence-Oak	6,825	
Symmes-Shepherd	1,499	
Bairs-Georges	48	43,319
Lone Pine	998	16,123
Total	**66,910**	**198,458**

***Estimated recharge does not account for losses due to outflow or evapotranspiration.**

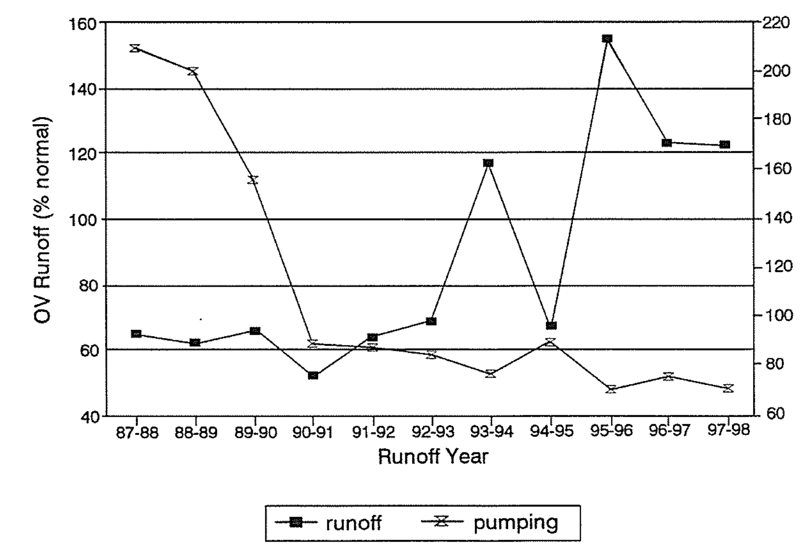


Figure 1. Owens Valley runoff and pumping 1987-1998

Table 2. Predicted water levels at 18 Owens Valley indicator wells based on 70,000 acre-feet of pumping. (All values are in feet).

Wellfield	Well	1987	1990	1991	1992	1993	1994	1995	1996	1997	Predicted 1998	Predicted Recovery
Laws	436T	7.2	D19.0	D19.0	D19.0	18.5	14.7	15.4	10.9	12.7	10.5	2.3
	492T	32.3	D62.2	57.7	51.3	50.5	41.9	44.5	37.5	40.1	35.1	4.9
Big Pine	425T	14.3	26.0	26.5	26.6	26.2	24.3	24.1	21.9	20.5	20.0	0.5
	426T	11.4	19.2	D19.7	D19.7	D19.7	19.0	19.0	16.5	15.3	11.5	3.8
Taboose-Aberdeen	418T	8.3	18.9	18.8	17.8	16.8	15.2	14.6	12.9	11.7	9.6	2.2
	419T	6.5	26.4	25.0	21.8	18.8	15.6	14.5	11.9	10.1	5.8	4.4
	421T	34.3	53.6	50.6	47.5	45.2	42.5	42.0	38.6	37.1	33.3	3.8
	502T	7.6	D16.0	D16.0	D16.0	15.7	13.4	13.2	12.0	10.6	6.7	3.9
Thibaut-Sawmill	415T	18.5	34.2	32.8	33.1	32.4	28.4	29.6	21.4	20.1	24.7	-4.6
Independence-Oak	407T	7.2	19.6	18.0	16.9	15.4	15.6	14.2	13.3	12.1	12.5	-0.4
	408T	3.0	10.9	9.1	9.3	8.3	7.5	6.6	5.7	3.2	4.1	-0.9
	409T	17.4	25.9	19.1	19.4	17.4	13.0	15.4	9.0	4.7	7.3	-2.6
Symmes-Shepherd	401T	17.5	28.2	26.4	25.0	24.4	23.8	23.3	21.6	20.8	19.5	1.2
	403T	6.1	14.9	12.9	11.4	10.5	11.0	11.0	10.3	9.1	7.5	1.6
	404T	3.8	9.3	7.8	7.4	6.3	7.2	6.3	6.2	5.7	4.2	1.5
	447T	23.0	55.8	51.3	47.5	46.4	45.1	46.3	43.7	40.3	35.4	4.9
Bairs-Georges	398T	5.6	13.4	10.5	7.5	5.4	5.9	5.2	4.3	4.4	4.7	-0.3
	400T	6.6	7.7	7.1	6.8	6.3	6.6	6.1	6.0	6.1	6.1	-0.1

*D = Dry

Owens Valley Monitoring and Management

Throughout the year, ICWD and LADWP monitor the vegetation, groundwater, and soil water in the Owens Valley. This monitoring is required in the long-term water agreement between Inyo County and Los Angeles.

The purpose of the monitoring is to document the valley's environmental response to groundwater pumping and other LADWP water management activities and to guide groundwater management decisions. The agreement requires that LADWP pumping be managed to avoid significant decreases or changes in vegetation and to avoid groundwater mining (depletion of water in the aquifer that exceeds replenishment from recharge over a 20-year period).

ICWD and LADWP have established 22 permanent monitoring sites that are linked to nearby LADWP pump-equipped wells. Eight additional monitoring sites are located outside the range of drawdown of the wells. These sites serve as controls for comparison with the pumping-affected sites. Each monitoring site contains a 100-meter vegetation transect and equipment used to measure soil water and groundwater levels.

Under the agreement, LADWP wells linked to monitoring sites are automatically turned off based on the information collected at the sites. Wells are turned off on July 1 or October 1 if the soil water cannot meet the vegetation's estimated water needs. These wells can only be turned back on when soil water recovers to the amount required by the vegetation at the time the wells were turned off.

Since 1990, however, pumping has been managed according to the Drought Recovery Policy. Under this policy, some wells linked to monitoring sites with adequate soil water have not been operated in order to allow the water table to recover.

Of LADWP's 102 production wells, 60 are linked to monitoring sites. Two of these are exempt from the turn-off provisions during the irrigation season only. Another 22 wells are exempt from being turned off because they are the sole supply for town water systems, fish hatcheries or irrigation, or because they are not located in areas of groundwater-dependent vegetation. An additional 20 wells are not linked to monitoring sites: 11 wells in the Bishop area, 5 wells near Laws, 1 well in the Bairs-Georges wellfield that supplies Diaz Lake, 1 residential well in Big Pine, and 2 residential wells in Independence.

The following articles describe ICWD and LADWP projects and monitoring results related to the hydrology, soil water, and vegetation of the Owens Valley.

Reports

Hydrology

Evaluation of the linkage of enhancement/mitigation wells 380 and 381 to the TS4 monitoring site (Memorandum Report). Randy Jackson. January 1997

Green Book analysis of drought effects on shallow groundwater levels from 1988 through 1996 in Owens Valley, Inyo County, California (Report 97-1). Randy Jackson. June 1997.

Lower Owens River planning study: Water quality in selected off-river lakes and one on-river pond in the Lower Owens River Enhancement/Mitigation Project, July 1996 through June 1997 (Report 97-2). Randy Jackson. August 1997.

Bishop Cone audit for the 1996-1997 runoff year (Report 98-1). Randy Jackson. March 1998

Soils

Evaluation of methods to calculate vegetation water requirements for the Owens Valley, California. Aaron Steinwand. February 1998.

Vegetation

Line point data analysis, 1996: Overview. Sally Manning. March 1997. 46 p.

Monitoring results of four revegetation treatments on barren farmland in the Owens Valley, California — 1996 progress report. Irene Yamashita. May 1997

Using plant shelters to increase plant establishment: Second annual report. Irene Yamashita. May 1997.

Germination of Owens Valley seeds: 1996 final test results. Denise Waterbury, Sally Manning and Irene Yamashita. August 1997. 18 p.

Plant communities of LADWP land in the Owens Valley: An exploratory analysis of baseline conditions. Sara J. Manning. November 1997. 160 p.

Activities

Accomplishments

Dr. Aaron Steinwand earned certification as a Certified Professional Soil Scientist from ARCPACS, a federation of national certifying boards in agriculture, biology, earth, and environmental science.

Dr. Steinwand was also granted membership in the Professional Soil Scientists Association of California.

Brian Cashore was hired as ICWD's Saltcedar Control Project Coordinator.

Conferences

Nevada State GIS Conference, January 1997, Reno, Nevada, Chris Howard.

Changing Water Regimes in Drylands, June 9-13, 1997. Sponsored by Desert Research Institute. Tahoe City, California. Sally Manning presented a poster: A decade of monitoring vegetation response to groundwater pumping in the Owens Valley, California. Sara J. Manning and Aaron L. Steinwand.

Changing Ecosystems: Natural and Human Influences, Ecological Society of America 1997 Annual Meeting, August 10-14, 1997. Albuquerque, New Mexico. Sally Manning.

Workshop for Proper Functioning Condition of Riparian Areas, U.S. Dept. of Interior, September 3-4, 1997. Bishop, California. Brian Cashore.

Federal Geographic Data Committee Conference, September 1997, Tempe, Arizona, Chris Howard.

California Exotic Pest Plant Council (CalEPPC), October 1997. Concord, California. Brian Cashore.

Soil Science Society of America Annual Meeting, October 26-31, 1997. Anaheim, California. Aaron Steinwand presented a poster: Soil water and vegetation monitoring network for groundwater management in the Owens Valley, California, A.L. Steinwand and S.J. Manning. Agronomy Abstracts, p. 287. ASA, Madison, Wisconsin.

COMDEX, November 1997, Las Vegas, Nevada, Chris Howard.

Education

University of California Environmental Biology "Supercourse." Invited instructor. Sally Manning.

Home Street School Inventor's Fair. Judge. Sally Manning.

Eastern Sierra Institute Teacher Training Workshop. Field demonstrations of vegetation inventory techniques and discussions on water resource management. Sally Manning, Denise Waterbury, Irene Yamashita, Derik Olson, Brian Cashore.

Elderhostel. Invited instructor. Sally Manning.

Water Education Foundation. Hosted fieldtrip. Greg James, Randy Jackson, Sally Manning, Aaron Steinwand.

Inyo County schools science fairs judges: Brian Cashore, Aaron Steinwand, Denise Waterbury.

Groundwater Use by Nevada Saltbush

Aaron Steinwand, ICWD Soil Scientist

Last year, ICWD soil and vegetation staff completed a project begun in 1995 to investigate groundwater uptake by Nevada saltbush. This species was chosen for the study because it is groundwater dependent and it is a dominant component of many plant communities in well field areas.

At three sites located near Independence ICWD staff monitored groundwater depth, soil water, precipitation, leaf area, and plant transpiration. Two sites, one with a shallow (1.5m) and one with an intermediate (5.8m) water table, were established in 1995. Another site with a deep water table (>8.5m) was established in 1996. ICWD vegetation staff visited the sites every three weeks during the growing season to measure the amount of water transpired by the plant leaves and the number or area of leaves present at each site. Soils staff monitored depth-to-groundwater and soil water biweekly throughout the year. Monitoring in 1995 began in early summer, missing the first half of the growing season. The lack of early growing season data prevents comparison with the later years; consequently, data from 1995 are not presented.

Although only preliminary analyses have been completed, several trends were clear. At the shallow and intermediate sites, leaf area was similar, and the total amount of water transpired in 1996 and 1997 was about two to three times the average annual precipitation (Table 6). Most of the water transpired was groundwater. We also observed groundwater use by Nevada saltbush throughout the growing season, even when soil water from winter precipitation was available.

At the deep water table site, however, leaf area was much lower and total water use was less than or equal to average annual precipitation. Decreased transpiration by the leaves also contributed to lower total water use. In 1997, the plants clearly restricted transpiration in late May after the soil water derived from winter precipitation was exhausted. We also observed this in 1996, but to a lesser degree. The vegetation at this site responded to extended periods without groundwater partly by reducing transpiration and to a greater extent by dropping leaves and dying back to levels sustainable by precipitation alone.

One important result for the monitoring and management program was that a larger than expected quantity of water was transpired by plants when groundwater was available. This observation prompted a review of current methods to estimate transpiration for well on/off status calculations. The results of that analysis are summarized earlier in this report.

Table 6. Total growing season transpiration measured in the field (T_a) and transpiration estimates using the proposed Kc method and the current method. †

Site	Year	T_a	T_a (Kc est)	T_a (Current est)
		cm		
Shallow	1996	32.2	28.3	11.7
	1997	28.5	29.6	12.1
Intermediate	1996	42.7	48.4	15.2
	1997	40.3	38.4	16.5
Deep	1996	11.4	15.4	7.8
	1997	5.7	13.2	6.7

†: Growing season was inferred to be March 26 to Oct. 15 each year.

Owens Valley Precipitation

Sally Manning ICWD Vegetation Scientist

To augment Owens Valley precipitation measurements made by LADWP, ICWD installed and now monitors seven rain gages. The purpose of this monitoring program is to obtain more comprehensive data on valley-floor precipitation, so gages were situated in places where there are no LADWP gages. These gages have been continuously checked since October 1, 1992, the beginning of the 1993 water year.

ICWD rain gage data show that for the five years of record, highest annual precipitation occurred in 1995 (Table 3). The 1951– 97 average annual rainfall recorded at the Bishop airport is 5.4 inches; against this standard, 1993, 1995 and 1997 were above-normal years.

Precipitation in the Owens Valley typically falls during the cooler winter months, prior to the vegetation growing season. The long-term average annual pattern observed at the Bishop airport shows 4.5 inches (83%) of the annual precipitation falling from October through April. For comparison, Table 3 also shows the average Owens Valley precipitation that fell prior to each of the five growing seasons. From this perspective, both 1996 and 1997 were average years in terms of pre-growing season cumulative precipitation, although overall they were above-average years. This is one of several ways to analyze precipitation and its effect on Owens Valley plant growth.

Table 3. Precipitation totals recorded at each of the county rain gages for water years 1993 through 1997 (a water year is October 1 – September 30).

Rain Gage	Precipitation (inches)				
	1993	1994	1995	1996	1997
RG-1, near Five Bridges	5.94	3.40	7.60	4.51	4.66
RG-2, near Laws	6.29	3.62	7.80	4.55	4.91
RG-3, southeast of Bishop	7.21	4.34	8.87	4.29	6.85
RG-4, south of Big Pine	8.29	4.24	9.76	6.85	8.33
RG-5, near Goose Lake	6.83	2.15	7.07	5.64	7.02
RG-6, near Blackrock	9.00	2.95	8.67	7.07	8.68
RG-7, southeast of Independence	5.00	1.61	4.88	2.14	4.35
Owens Valley Average	**6.94**	**3.19**	**7.81**	**5.01**	**6.40**
Avg. Precipitation Occurring Oct 1 - Apr 15 ("Winter")	**6.85**	**1.81**	**6.76**	**4.45**	**4.67**

Snowpack and Runoff

Randy Jackson, ICWD Hydrologist

LADWP's April 9, 1997 snow survey reported water content in the Mammoth area snowpack of 51.5 inches. The 1997 snowpack varied throughout the Sierra from 121% of normal at Mammoth Pass to 84% at Rock Creek. Measurements at LADWP's stations at Big Pine Creek and Cottonwood Lakes were 84% and 112%, respectively.

Runoff in the Owens Valley for April 1997 – March 1998 was projected by LADWP at about 486,000 acre-feet or 122% of normal. This was similar to the estimated runoff for April 1996 – March 1997 of 123%.

Groundwater Monitoring

With a network of over 1,000 surface water and groundwater measuring stations, the Owens Valley may be the most intensively monitored watershed in the country. LADWP maintains this network as part of its regular operations. The information collected at these sites helps ICWD and LADWP to understand the valley's hydrology and to manage LADWP's groundwater pumping.

During the course of each year, groundwater levels are measured at about 700 monitoring wells throughout the Owens Valley. Depending on their location, monitoring wells are checked annually, semi-annually, quarterly, or monthly. At a few sites, ICWD and LADWP have installed continuous monitoring devices.

LADWP provides ICWD with monthly reports showing the amount of groundwater pumped and water level readings taken during the month. ICWD's GIS Specialist uses the 100-200 shallow well water level measurements taken valley-wide by LADWP each April to develop groundwater contour maps (see GIS article on page 21). These maps are used by the vegetation staff to evaluate the effects of groundwater pumping on Owens Valley vegetation.

In addition, data collected by both ICWD and LADWP are used each year to predict water level changes at 18 monitoring wells throughout the valley. Multiple linear regression equations developed for these 18 wells allow ICWD and LADWP to predict the water table response to different groundwater pumping scenarios (see Table 2).

Tests of LADWP Deep Wells

In 1997, the Inyo/Los Angeles Technical Group initiated a study of two LADWP wells in the Big Pine and Thibaut-Sawmill wellfields and continued an existing study of two more wells in the Thibaut-Sawmill wellfield. The aim of the studies was to determine whether the wells affected water table levels at the permanent monitoring sites to which they are linked. If no effects could be detected, the study results would be used to establish a more appropriate method for managing pumping from these wells.

The wells under study are perforated only below significant confining layers that separate the shallow aquifer from the deep aquifer. The wells are sealed at the confining layer to prevent vertical flow down the borehole. LADWP constructed the wells in the 1980s, with the approval of Inyo County, in an attempt to reduce or eliminate the effects of groundwater pumping on vegetation. Other LADWP wells are perforated in both the shallow and deep aquifers and can have dramatic effects on water table levels. Linking the operation of these wells to the permanent monitoring sites is appropriate because effects of the wells on water tables, soil water, and vegetation can be measured at the monitoring sites. But wells that pump only from deep aquifers may have no measurable effects at the permanent monitoring sites. The monitoring sites may not be effective tools for managing pumping from these wells.

To evaluate the effects of the four wells, ICWD and LADWP staff measure water levels in the deep and shallow aquifers before, during, and after pumping to observe the responses at the permanent monitoring sites and at other observation wells within a two-mile radius of the pumped wells. Wells 375, in the Big Pine wellfield, and 382, in the Thibaut-Sawmill wellfield, were turned on in November 1997. Wells 380 and 381, in the Thibaut-Sawmill wellfield, were turned on in early April 1997; they were also operated from October 1996 through February 1997.

Preliminary results of the study showed that pumping from the wells in the short term did not affect the water tables at the monitoring sites to which they are linked. Pumping from all four of the wells lowered water levels in the deep aquifers to various degrees, depending on pumping rates, proximity to the pumping wells, and aquifer characteristics. Figure 2 shows hydrographs of representative shallow monitoring wells near the linked monitoring sites and deep monitoring wells near the pumped wells.

Pumping from well 382 was discontinued on April 21, 1998. Pumping from well 375 was discontinued on June 16. Wells 380 and 381 were turned off in April 1998.

Once the pump tests are completed and all of the data are collected and analyzed, the Technical Group will recommend how groundwater pumping from the four wells should be managed in the future.

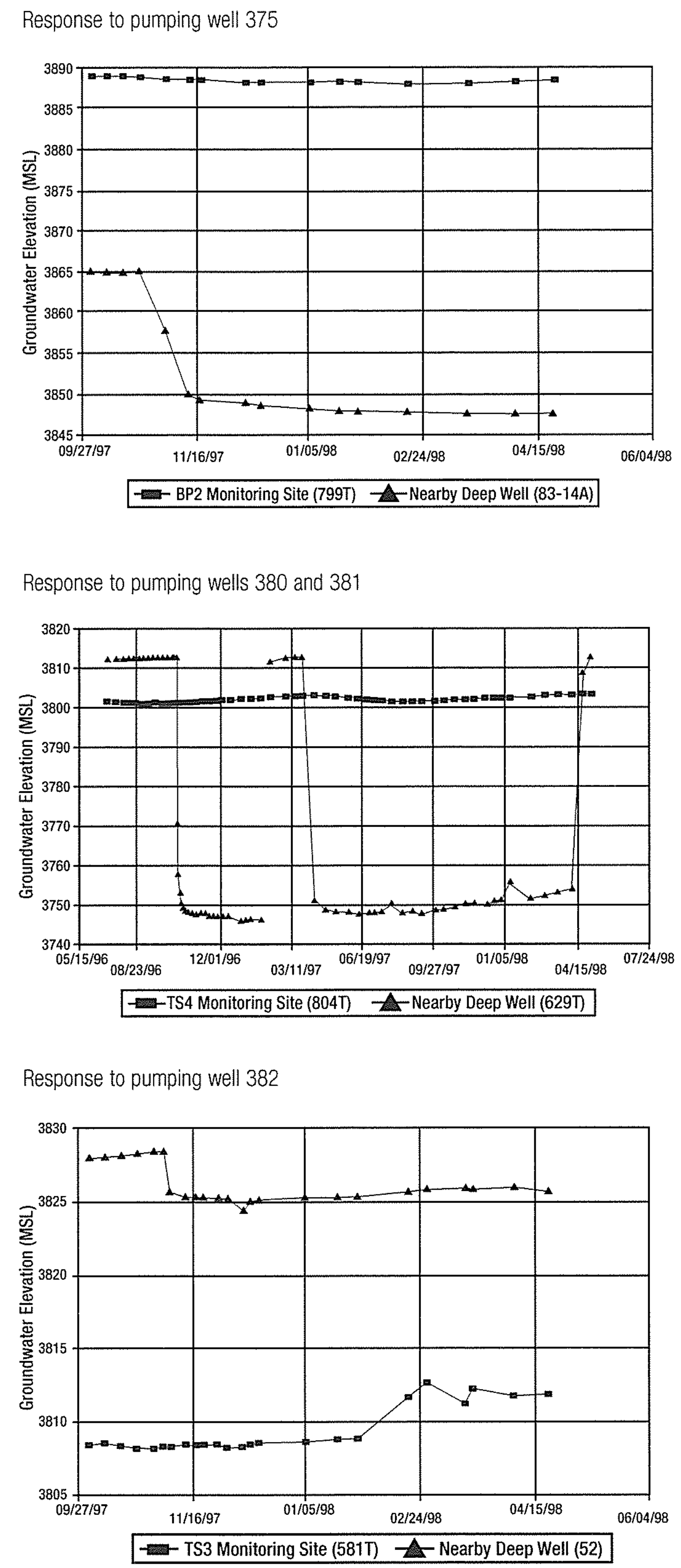
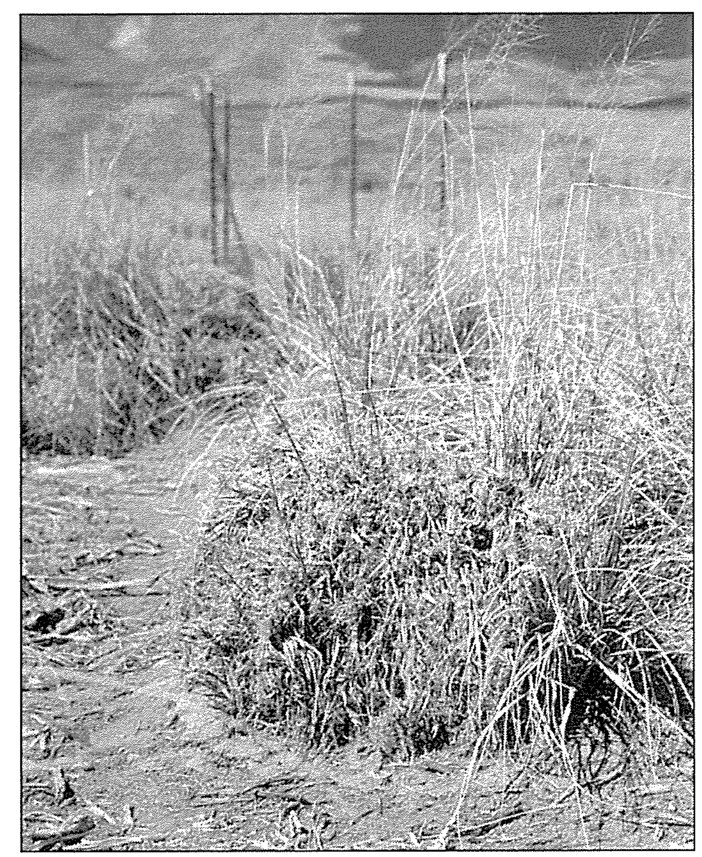


Figure 2. Shallow and deep groundwater response to pumping from four LADWP wells.

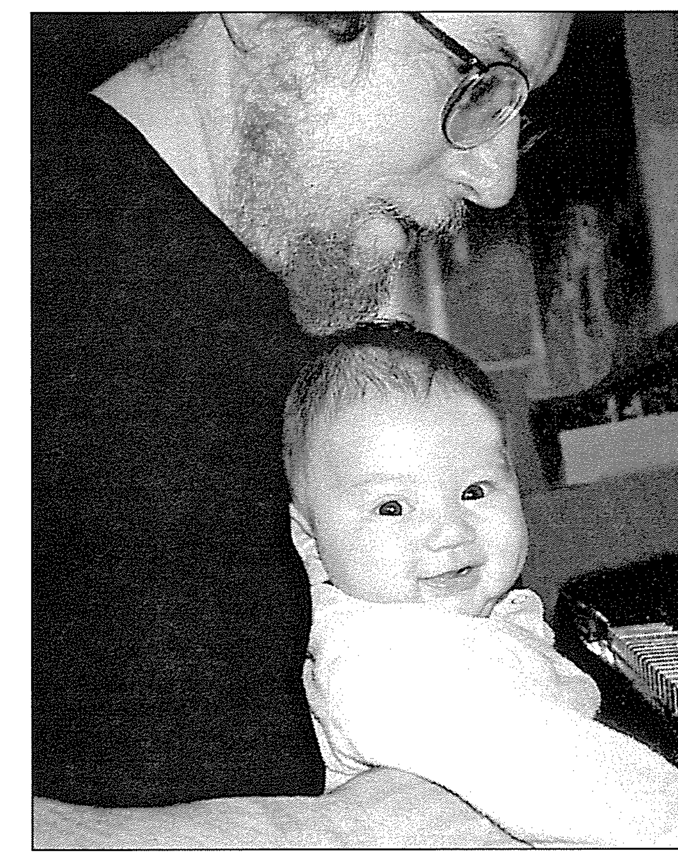
(Figure 12). Vegetation abundance information will be extracted from the imagery by assuming every pixel is a mixture of vegetation, soil, and shade; using this mixture model, the fraction of vegetation in each pixel will be calculated. Once the images are validated using the ICWD field measurements, the remotely sensed data can be combined with the existing GIS database to classify land cover change and response across the valley.

The Brown University research group consists of John F. Mustard, Professor of Geology; Steven P. Hamburg, Associate Professor of Environmental Studies and Biology; and Andrew J. Elmore, Graduate Student in Geology. Dr. Mustard earned his Ph.D. in Geology from Brown University in 1990 and stayed on as a post doc, becoming a professor in 1996. Dr. Hamburg earned his Ph.D. from Yale University and became a professor at Brown in 1994. Andrew Elmore began his Ph.D. program in the fall of 1997, after earning a Bachelor degree of Applied Physics at Purdue University. John A. Grant, Professor of Earth and Atmospheric Science at Buffalo State College, NY is also a member of this project. Dr. Grant earned his Ph.D. in Geology at Brown University in 1991. He will add a Geomorphology and Hydrology component to the story, by studying the groundwater and process geomorphology in the Owens Valley. This project draws upon the wealth of data collected in the valley over the years and the expertise of the scientists and technicians working in Inyo County.

New Sprouts



Pumping and drought during the period from 1987-1994 took its toll on groundwater dependent plant species in susceptible areas throughout the valley. However, thanks to conservative pumping and a series of wet years since 1990, the water table returned to plant root zones resulting in the rejuvenation of plants such as this alkali sacaton (*Sporobolus airoides*). This bunchgrass was believed to be dead, but in 1997 green sprigs emerged from long-dormant buds buried in its depths.



On January 29, 1998, at 9:07 p.m., Claire Sumiko Jellison was born. This was momentous because Claire is the daughter of ICWD's Irene Yamashita and husband Bob Jellison. Claire weighed in at 8 pounds 13 ounces and 21.5 inches. At last count, she was 14 pounds 7 ounces and 23.75 inches. Here Claire is shown at her daily piano lesson with dad. We are told she favors Beethoven's "Für Elise."

Owens Valley Remote Sensing Study

Andrew Elmore, Brown University

In February 1997, ICWD learned that a NASA grant proposal to perform a remote sensing study of the Owens Valley was awarded funding. The proposal had been submitted by Dr. John Mustard, a geologist at Brown University. This article summarizes that proposal.

At Brown University, we are interested in the response of vegetation in semi-arid environments to climate variability and water-use policy. Climate variability can have significant effects on the availability of water to semi-arid ecosystems. This stress may be compounded where surface water is diverted or groundwater is extracted for urban and irrigation uses. The distinct land cover units of semi-arid systems (riparian, phreatophyte, and desert shrub communities) show complex response to climatic and anthropogenic stress based on their drought tolerance. The overall purpose of this study is to understand how semi-arid land cover units respond to these driving factors over the course of a decade.

The Owens Valley was chosen for this project because it contains an ideal set of conditions for studying the responses of semi-arid vegetation to outside forces. From 1987 to 1992 the valley was subjected to a pronounced drought, while annual rainfall was above average before and after the drought. Drought conditions may have been compounded in some parts of the valley by groundwater pumping for export and local irrigation. Initial studies showed distinct drops in vegetation abundance in a variety of regions in the valley. Since 1992, increased precipitation and reduced groundwater pumping has resulted in positive vegetation response in some areas.

These conditions and responses are documented in a substantial data base gathered over the past decade by ICWD and LADWP. A wealth of information exists on key surface (vegetation cover, species composition, and plant recruitment) and subsurface (depth-to-groundwater and soil moisture) parameters, all maintained in a Geographic Information System. Although these data are of high quality, they are limited in scope and scale, which limits the feasibility of making regional assessments of changes. In the Owens Valley, a regional view is a fundamental perspective that is lacking in the current understanding of response to the driving forces of drought and human resource use.

Using these field measurements for validation, the study will utilize satellite imagery to gain a regional view of ecosystem responses. The imagery is produced by a satellite-borne remote sensing instrument, the Landsat Thematic Mapper (TM). The Landsat TM has been recording images of the Owens Valley every 20 days for the past 15 years. The images have a spatial resolution of 30m X 30m. These satellites collect the most useful wavelengths for measurement of vegetation abundance.

Landsat TM data will be used to characterize yearly changes in vegetation abundance from 1984 to 1997

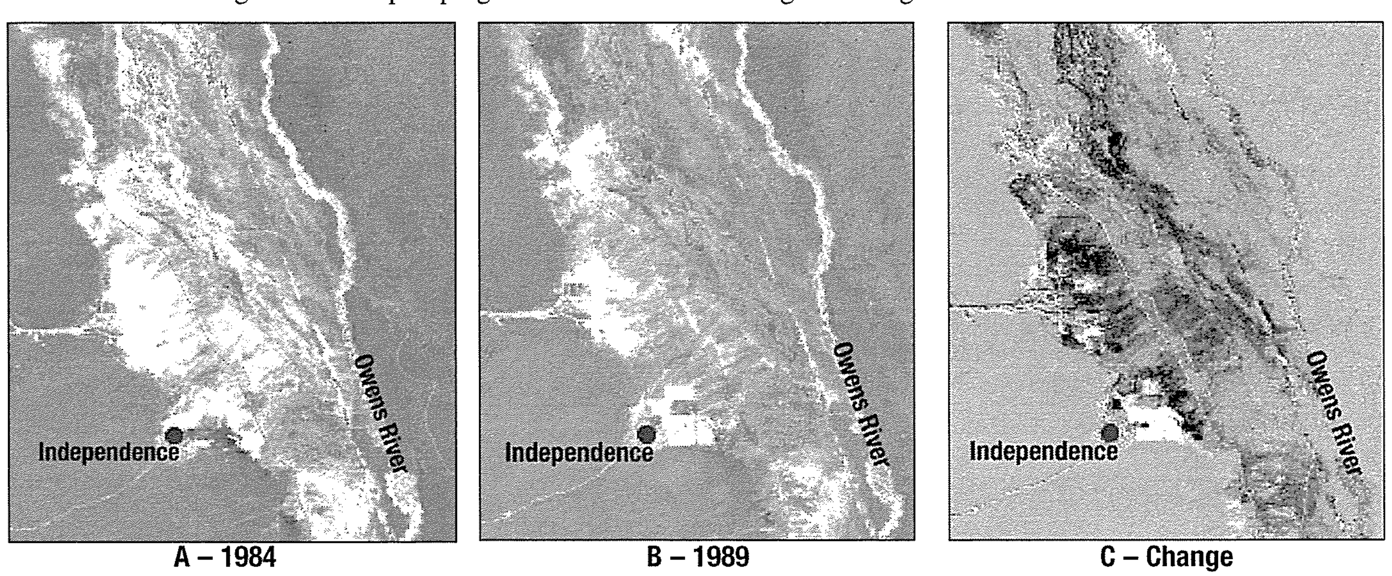


Figure 12. Vegetation change images can be formed by subtracting one year's vegetation image from another. This black-and-white example from the Independence area shows (A) 1984 vegetation abundance, (B) 1989 vegetation abundance, and (C) the difference between the two scenes. In image (C), vegetation decreases can be seen as dark areas, vegetation increases are bright, and areas with little to no change are a neutral gray. In the actual study, color imagery will be used.

Audit of Uses & Pumping on the Bishop Cone

The Inyo County/Los Angeles water agreement requires that ICWD and LADWP jointly conduct an annual audit of LADWP groundwater extraction and water uses on Los Angeles-owned land on the Bishop Cone. According to the agreement, in any year, LADWP's groundwater extraction may not exceed the amount of water used on its Bishop Cone lands.

Audits conducted for runoff years 1995-96 and 1996-97 showed that water uses on 3,728 acres of LA-owned land were 31,073 acre-feet and 25,098 acre-feet, respectively. In contrast, LADWP groundwater extractions for the two time periods were 9,006 acre-feet and 14,421 acre-feet.

The agreement defines water uses as the quantity of water supplied to Los Angeles land on the Bishop Cone, including conveyance losses (i.e., water seepage from canals and ditches), less any return flow to the LA Aqueduct system. Uses include irrigation, stockwater and recreation. Groundwater extraction is defined as the sum of all groundwater pumped by LADWP on the Bishop Cone plus the amount of artesian water that flowed out of uncapped wells on Los Angeles-owned land on the Cone during the runoff year.

During the 1995-1996 runoff year, LADWP groundwater extractions consisted of 4,283 acre-feet of pumped groundwater and 4,723 acre-feet of artesian flow. Pumped groundwater made up 9,870 acre-feet of the 1996-1997 LADWP groundwater extractions, with 4,551 acre-feet of the total derived from flowing wells.

LADWP collects the pumping and surface water information at mutually agreed upon measuring stations and provides the data to the county. ICWD performs the audit and reports on the water uses and groundwater extractions on the Bishop Cone (see "Reports & Activities" on page 25).

Bishop Cone Private Well Monitoring Program

In the summer of 1997, ICWD hydrology staff set up a monitoring network of privately owned wells located near three LADWP replacement wells on the Bishop Cone. The private well network, established in anticipation of the construction of the replacement wells, provided baseline information on water levels at the private wells. As monitoring continues, ICWD hydrology staff will be able to identify any variations in water levels at the private wells caused by pumping from the three replacement wells. LADWP proposed constructing the wells to replace three old wells on the Bishop Cone that no longer functioned properly.

The water agreement requires that LADWP groundwater pumping be managed to avoid causing significant adverse effects to water quality or water levels in privately owned wells in the Owens Valley. Any such effects must be promptly mitigated by LADWP. Mitigation could include: discontinuing pumping from LADWP wells to allow water table recovery near the affected private well; setting the pump deeper in the casing of the private well; deepening or replacing the private well; compensating the well owner for the cost of additional power if water table decline results in a significant pump lift.

The private wells were identified using the Inyo County Assessor's parcel list and ICWD's GIS. ICWD's David Poe, a summer employee, gathered all of the data then canvassed potentially affected Bishop area neighborhoods to find willing participants for the monitoring network. A total of 19 private well owners chose to participate in the program. During the summer of 1997, water levels at the private wells were measured every two weeks. From September 1997 to January 1998 the wells were checked monthly. Beginning in January, water levels will be measured every other month. More frequent measurements will resume when LADWP begins operating the replacement wells in the summer of 1998.

Lower Owens River Project Water Quality Study

From July 1996 to June 1997, ICWD hydrology staff collected water quality measurements at five sites within the Lower Owens River Project area. The data were collected to provide a baseline characterization of water quality at three off-river lakes, one on-river pond, and a Los Angeles Aqueduct spillgate that is the water supply for several existing off-river lakes. The work was conducted in conjunction with other planning studies. The project will rewater approximately 60 miles of the Lower Owens River and supply water to Owens Valley lakes and wetlands.

Each month during the study, ICWD staff measured dissolved oxygen, turbidity, pH, electrical conductivity, and temperature. Measurements were taken at South Twin Lake, Goose Lake, and Billy Lake, at Lone Pine Pond on the Owens River, and at the Blackrock spillgate along the aqueduct.

The data collected during the study indicate that water quality in the off-river lakes and at the spillgate was consistent with warm water aquatic habitats. However, Lone Pine Pond was found to have low concentrations of dissolved oxygen in the summer. For short periods of time in the summer, the measured dissolved oxygen was low enough to be potentially lethal to warm water game fish.

The study is described in a report, available at ICWD(see "Reports and Activities" on page 25).

It is one of four studies related to the Lower Owens River Project conducted by ICWD's hydrology staff. The previous work concerned water quality, flows, and losses in the river channel. The results of these studies will be incorporated into management plans and an environmental impact report describing the Lower Owens River Project.

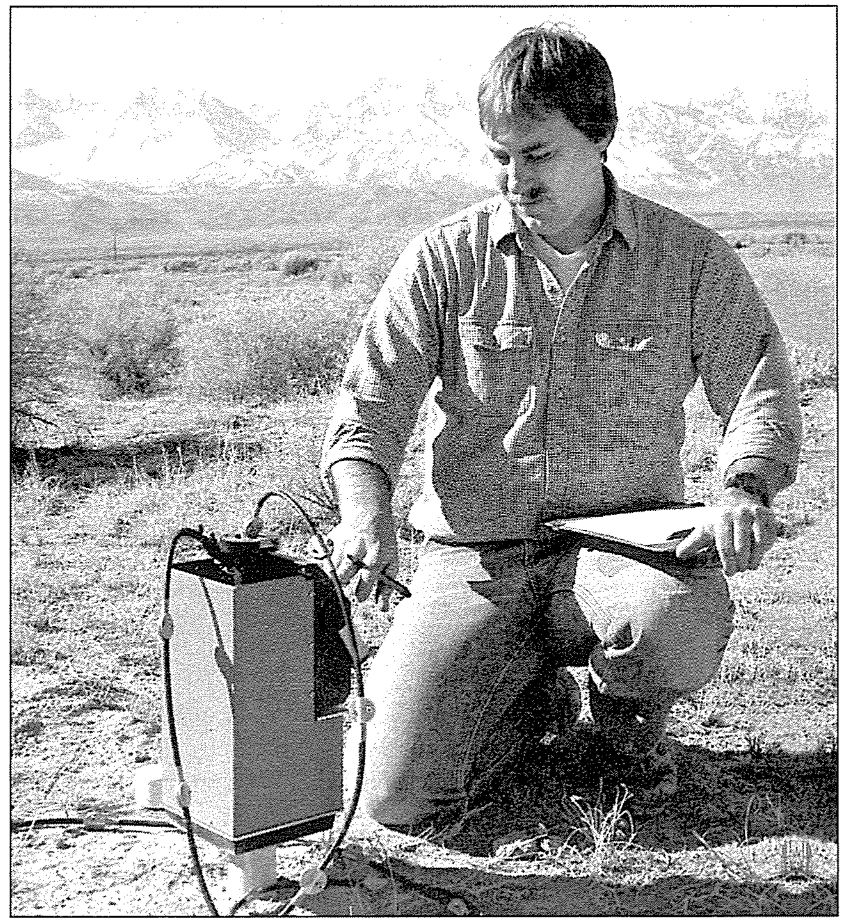
Monitoring Site Soil Water Status

Aaron Steinwand, ICWD Soil Scientist

In October 1996, five of the 22 permanent monitoring sites linked to LADWP wells were in surplus status. The soil water at these sites was sufficient to meet the estimated water requirements of the vegetation, and therefore the wells linked to the sites could be operated in accordance with the water agreement. Precipitation and a rising water table during the following winter and spring (December 1996 – April 1997) increased the available soil water to surplus status at seven additional monitoring sites.

On July 1, 1997, one of the twelve sites in surplus status went into deficit status (insufficient soil water to meet estimated plant needs). Another monitoring site went into deficit on October 1, leaving ten sites in surplus status compared with five at the same time in 1996. Since then, five more sites gained enough soil water from February 1998 snow and rain to exceed the vegetation water requirements.

Under the Drought Recovery Policy agreed upon by Inyo County and Los Angeles, some wells linked to monitoring sites in surplus status are not being operated to allow water table recovery.



Aaron Steinwand uses a neutron probe to measure soil water.

Refinement of Vegetation Transpiration Estimates

Aaron Steinwand, ICWD Soil Scientist

The strategy used by LADWP and ICWD to manage groundwater pumping is based on the soil-plant water balance. Well operation is halted if the available soil water is insufficient to meet projected vegetation water requirements (VWR) at the associated permanent monitoring sites. The VWR approximates the amount of water transpired by the vegetation when adequate soil water is available. Basing the VWR on the water transpired by well-watered vegetation increases the likelihood that managed pumping will not endanger vegetation survival.

In 1997, ICWD initiated a review of the current procedures to estimate VWR. The review was prompted by results from a research project begun in 1995 to evaluate groundwater uptake by Nevada saltbush. In that study, the annual amount of water transpired by Nevada saltbush was greater than the VWR predicted by the current technique.

The current method to estimate VWR was developed initially to determine the water-use categories (Type A, B, C) assigned to vegetation parcels mapped during the 1984-87 inventory. Apparently, the method was developed shortly after the mapping was completed and later it was adopted to calculate VWR at the permanent monitoring sites when they were installed. The primary flaw with this method is its reliance on vegetation cover measurements to account for leaf abundance. Calculating transpiration from vegetation measurements requires an estimate of the total area of leaves at a site. Vegetation cover measured with the standard point-intercept method represents the area of land shaded by leaves, but it does not account for layering of leaves in plant canopies or for understory plants. To remedy this problem, a new method was

Geographic Information Systems

Chris Howard, ICWD GIS Specialist

1997 was the fourth year ICWD has used Geographic Information Systems (GIS) to monitor, manage, and analyze spatial data. Examples of spatial information used by ICWD include the locations of rain gages, wells, and monitoring sites. In a GIS, spatial information is stored in a layered structure. The primary benefit of using GIS, as opposed to paper maps, is the improved speed and accuracy of viewing and analyzing different information layers. For example, ICWD uses GIS to assist in determining the relationship between groundwater pumping and vegetation conditions (Figure 11).

During 1997, significant progress was made on groundwater layer development. Since 1991, ICWD has used Surfer (by Golden Software) to develop depth-to-water contours from the network of hundreds of observation wells in the Owens Valley. An interpolation model called "kriging" was applied to depth-to-water data to develop a valley-wide estimation of depth-to-water in the shallow aquifer. Surfer provided this estimate in the form of a gridded layer where each grid cell was assigned a depth-to-water value. Contours were created from the gridded layers for each of the Owens Valley USGS quadrangles.

ICWD identified that the Surfer depth to groundwater layers would be useful in a GIS format for multilayer, spatial analyses. After researching the current technologies of groundwater modeling and GIS capabilities, we found no existing methodology to integrate Surfer grids into a GIS format, so we developed a new process with the assistance of Team Engineering and Sierra Hermitage. Through this effort, a protocol was developed for converting the Surfer depth-to-water layers into GIS-compatible layers.

As of December 1997, the conversion of the Surfer groundwater grid layers had been started. Groundwater layers for every year since 1985 should be converted from Surfer to GIS layers in 1998.

Also during 1997, ICWD's Derik Olson began entering into the GIS the agricultural status of Los Angeles land in the Owens Valley in 1924, 1944, and 1980. For each of these years it is noted whether the land was cultivated, irrigated, or abandoned. This information had been compiled on paper several years ago by ICWD staff. Once in the GIS, the information can be integrated with maps of the valley's soils, vegetation parcels, depth-to-water, and other data.

Other GIS Projects in 1997:
- Prepared Bishop Cone exhibit maps.
- Prepared maps in support of Bureau of Reclamation pumpback station siting.
- Integrated well locations for entire Owens Valley into GIS.
- Provided GIS support for annual vegetation inventory.
- Provided GIS support for well assessment on the Bishop Cone.

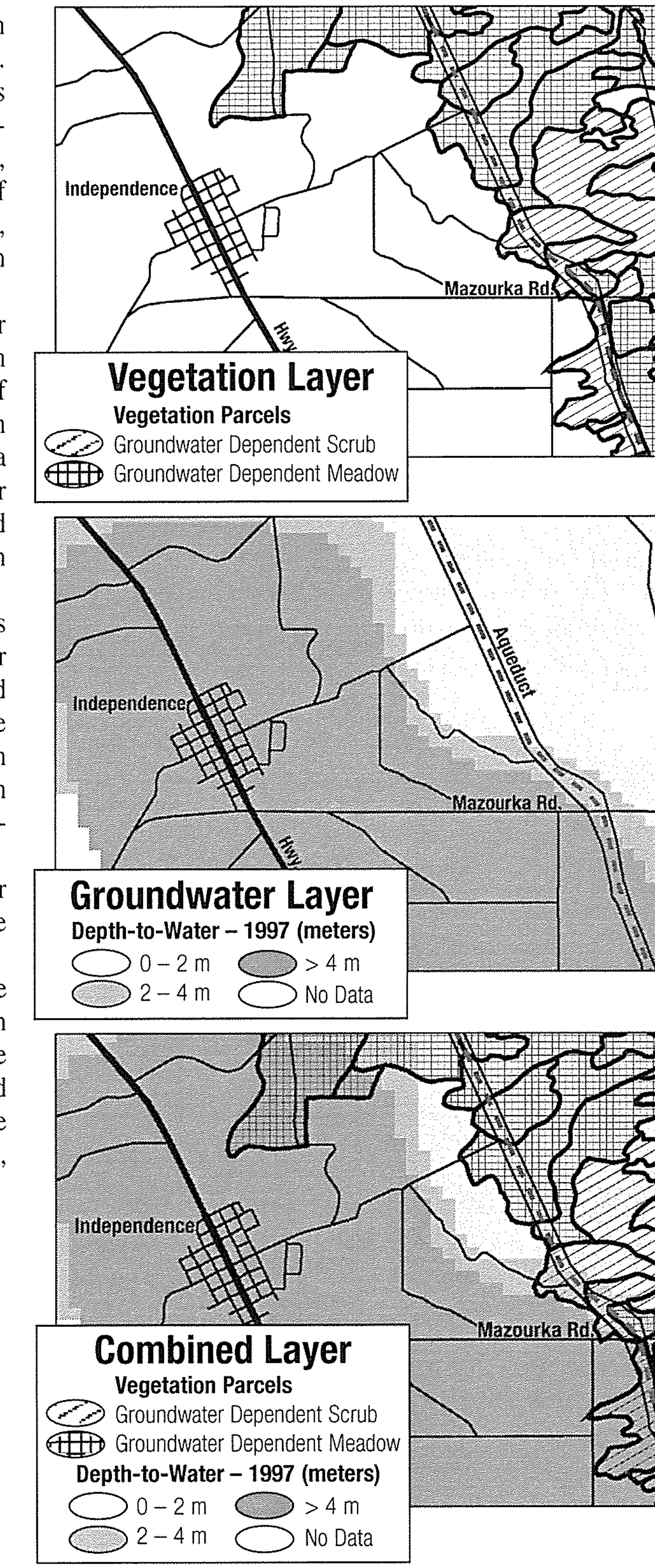


Figure 11. Examples of GIS layers for the Independence area.

SALTCEDAR CONTROL PROGRAM

Brian Cashore, ICWD Saltcedar Control Project Coordinator

Saltcedar. Tamarisk. *Tamarix ramosissima.* Ornamental shrub? Weed?

After three years of part-time and preliminary saltcedar eradication work in the Owens Valley, ICWD has initiated a saltcedar control program. The program was made possible by funding provided by LADWP under the long-term water agreement. This funding provides $750,000 over the first three years of the program and $50,000 per year thereafter for maintenance.

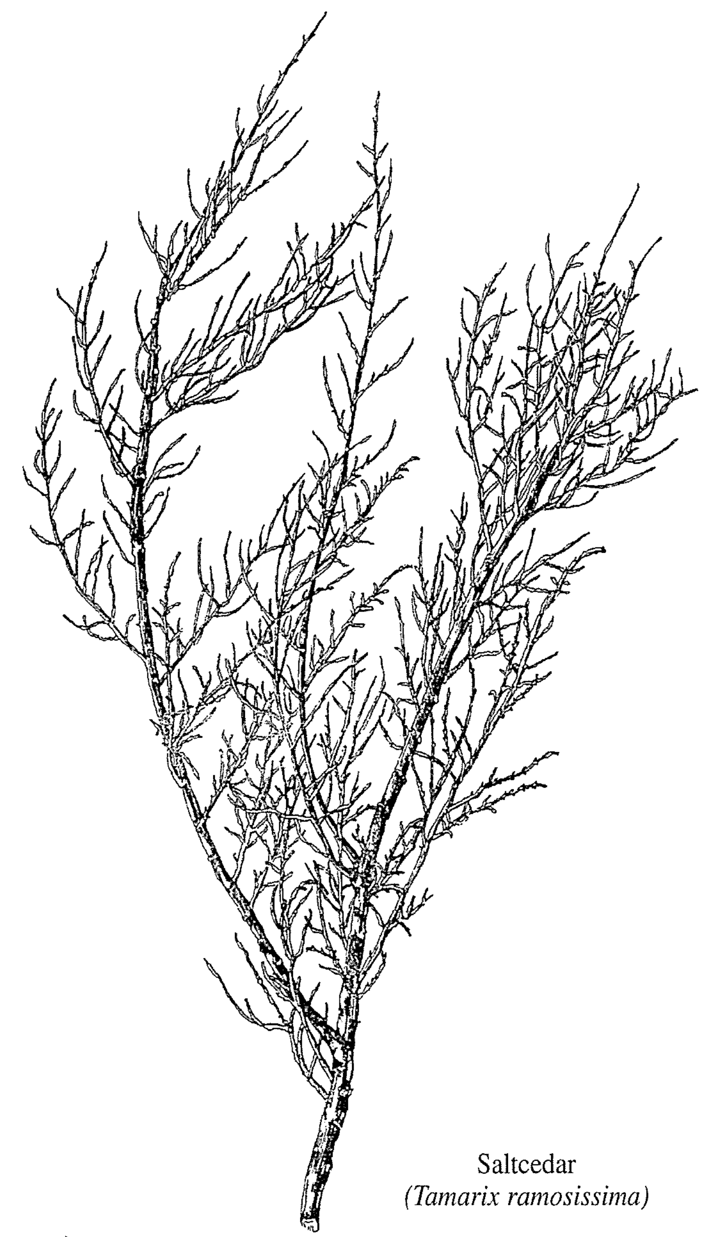
Why do these non-native shrubby plants need to be controlled? Though intentionally introduced from Europe and Asia into the U.S. in the early 1900's, saltcedar has been expanding its range in the Owens Valley since the late 1960's. And in many areas of the valley, it has succeeded. In the valley, as elsewhere in the western U.S., this species does not thrive without human help. It benefits from disturbance in the form of dams, diversions, floods, fires, and water table fluctuations, which stress native species and provide conditions that suit saltcedar.

Once established, saltcedar can out-compete stressed native plants and cover large areas of formerly native habitat. Though plants have pioneered new areas for eons, the pace of this human assisted take-over can surpass the abilities of native plants, animals, and insects to adapt. The result is a less productive and less diverse environment. In riparian areas in the Southwest where this has occurred, entire ecosystems have been displaced, and flood and fire frequencies have risen dramatically. To stem this spread, our goal is to gradually restore disturbed, weedy areas to a more stable natural state.

Before the water agreement's funding became available, ICWD staff initiated a program to attempt to curb the spread of saltcedar in the Owens Valley. In this fledgling program we used various tools and techniques to determine what worked best in the valley. The experience gained through the pilot program will form the basis for the fully-funded saltcedar control program.

In 1997, ICWD attempted to curb the spread of saltcedar by removing isolated outlying populations in riparian, spring, and disturbed moist areas. Sites at Hogback Creek, Oak Creek, Calvert Slough, Owens River, Klondike Lake, the Laws area, and springs west of Independence were cleared using a cut-stump treatment. This entails cutting saltcedar plants at the base, using a chainsaw, lopper, or ax, and applying a systemic herbicide to the cut stump. Future work may include the use of fire, mechanical removal, inundation, and the use of insect predators.

In the next year, we will delineate saltcedar populations using a Global Positioning System and will incorporate the information into ICWD's Geographic Information System database. This tool will give us the ability to track the effectiveness of the treatments, a vital part of any successful weed control program.



Saltcedar
(Tamarix ramosissima)

As the saltcedar control program gets underway, ICWD's Rick Puskar and I, along with the California Department of Forestry crews and others, will continue working to contain the spread of this opportunistic plant in the Owens Valley.

developed that utilizes leaf area index data (LAI). LAI is a measure of the total leaf area which can be used directly to calculate VWR.

The new method was adopted from common techniques used in agriculture. In irrigation scheduling, daily transpiration is estimated from a crop coefficient (Kc) and measurements of potential evapotranspiration (ETp). The Kc for a particular plant species is the fraction of ETp actually transpired. ETp is commonly defined as the water used by a dense stand of grass or alfalfa. It has proven to be a useful standard to compare soil water use for different locations, weather conditions, and plant species, and it is widely applied for soil water management.

Crop coefficients for common crops and some native species are available from published studies, but previously, they have not been prepared for Owens Valley species. The Kc values developed to estimate VWR were calculated using transpiration and LAI measurements from the 1984-87 Inyo/Los Angeles cooperative studies database and ETp estimates obtained from the California Irrigation Management Information System (CIMIS). CIMIS maintains a meteorological station in Bishop to provide data to local irrigators. Curves were fit to the Kc data to allow calculation of transpiration for each day of the year (Figure 3). Transpiration for the growing season can be determined by summing the daily values.

Two simple comparisons were completed to test the performance of the Kc procedure. In the first comparison, the Kc method yielded transpiration estimates much closer to the measured values for Nevada saltbush at the uptake sites than the current method (see Table 6 on page 24). Overestimation of transpiration by the Kc method at the deep water table site was expected because the method assumes sufficient soil water or groundwater is available for uptake. This assumption is included in the current method as well but is not evident because of the low values this method gives. In the second comparison, VWR was calculated with both methods using monitoring site data collected in 1994 and 1995. Results from the two methods correlated well, but the Kc method produced VWR values about 2.5 times greater than the current procedure. Adopting the Kc method would result in VWR estimates that more accurately represent actual vegetation water requirements but, compared with the current methods for managing pumping, pumps may be turned off sooner and/or remain off longer.

The flaws in the current transpiration estimation methods also occur in the water-use category assignments (Type A, B, C) for vegetation parcels on the 1984-87 maps. Fortunately, the water-use estimates can be recalculated using modified Kc procedures prepared during this analysis. This may change the classification for some vegetation parcels if adopted.

The proposed Kc method offers several advantages and eliminates several unjustified assumptions present in the current method. The Kc values were developed from the same database as the current method and are easily adapted to our mid-summer vegetation measurements. Additional analyses on the cooperative study database are still in progress, however, to further refine the VWR estimates. These analyses will be completed in 1998.

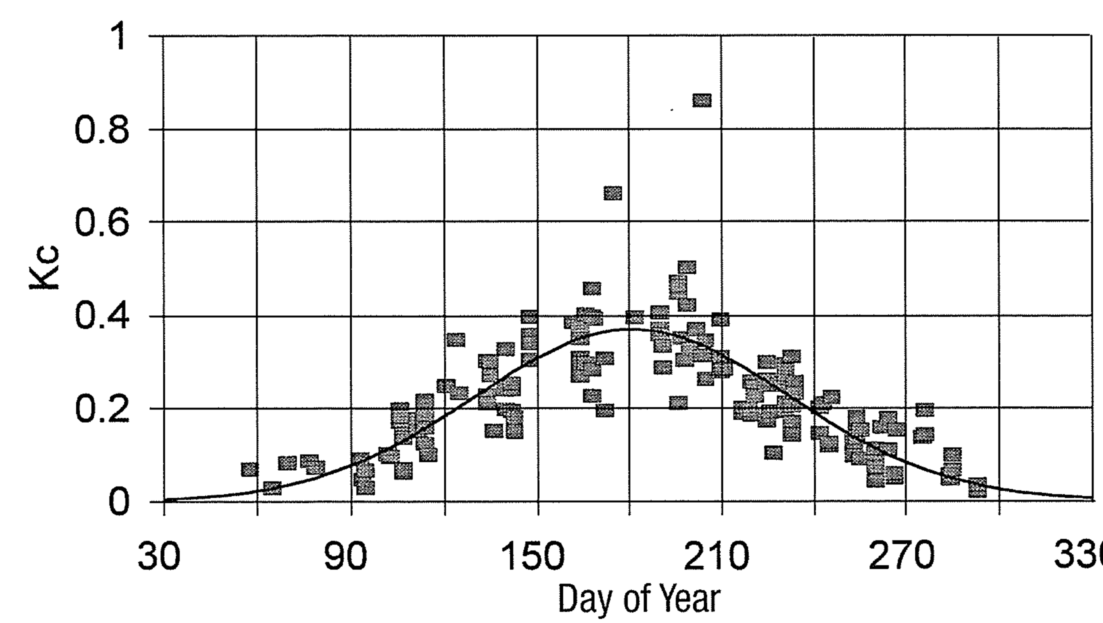


Figure 3. Nevada saltbush transpiration coefficient data and fitted curve.

Monitoring Site Conditions

Aaron Steinwand and Sally Manning

The soil water/vegetation monitoring program for managing groundwater pumping was established during the first four years (1987-1990) of the six year drought. By 1990, 33 permanent monitoring sites had been instrumented. Twenty-two of these were located near and were linked to LADWP wells. The status of these wellfield sites determines whether the linked wells are allowed to operate.

Management during the drought

The soil water and vegetation conditions at the monitoring sites reflect events that occurred at the beginning of the drought. Before the monitoring program was fully in place, high pumping in 1987-89 lowered the water table below the rooting zone at many of the wellfield sites. Because it was not replenished either from precipitation or groundwater, soil water decreased as plants continued to transpire during succeeding growing seasons. Half the monitoring sites had entered off status by 1990. Unfortunately, by that time, the water table was too deep in portions of the wellfields for timely water table recovery that would replenish soil water. Los Angeles and Inyo County subsequently adopted the Drought Recovery Policy, which reduced pumping until water tables and vegetation recovered. The long drought extended the recovery period, but the recent wet years and restricted pumping have produced various amounts of water table recovery.

Although we continue to calculate the monitoring site status as data are collected, because of the Drought Recovery Policy, the status of the site ("on" or "off") does not reflect actual well operation. Wells linked to all sites in off status remain off (except for occasional testing purposes), but many wells linked to sites in on status have not been operated. Furthermore, monitoring site status does not directly indicate whether groundwater is reaching the plant root zone. The calculations that determine whether a monitoring site is in on or off status include several factors, precipitation for example, that may allow a site to be in on status even though no groundwater is reaching the root zone. The rise of water above the water table due to capillarity is easily detected, however, by our soil monitoring techniques. Using the soil water and groundwater data, we determine which monitoring sites are connected to the water table and which are not. By relating soil water data to vegetation conditions, we have begun to see trends and can suggest possible reasons for vegetation changes that we have measured.

Soil water conditions

The connection between the root zone and groundwater is not simply a function of water table depth; it also depends on the rooting depths of the species present at the site and soil characteristics. For example, in similar soils, a shallower water table is necessary to supply groundwater to grass-dominated sites than to shrub-dominated sites because grasses have shallower roots. Similarly, the capillary rise above the water table in a silty soil is much greater than in a sandy soil, allowing plants in silty soils access to groundwater from greater depths. The monitoring sites are grouped into three categories described below, and displayed in Figure 4. For management purposes, grass-dominated sites are assigned a root zone of 2m and shrub-dominated sites are assigned a 4m root zone.

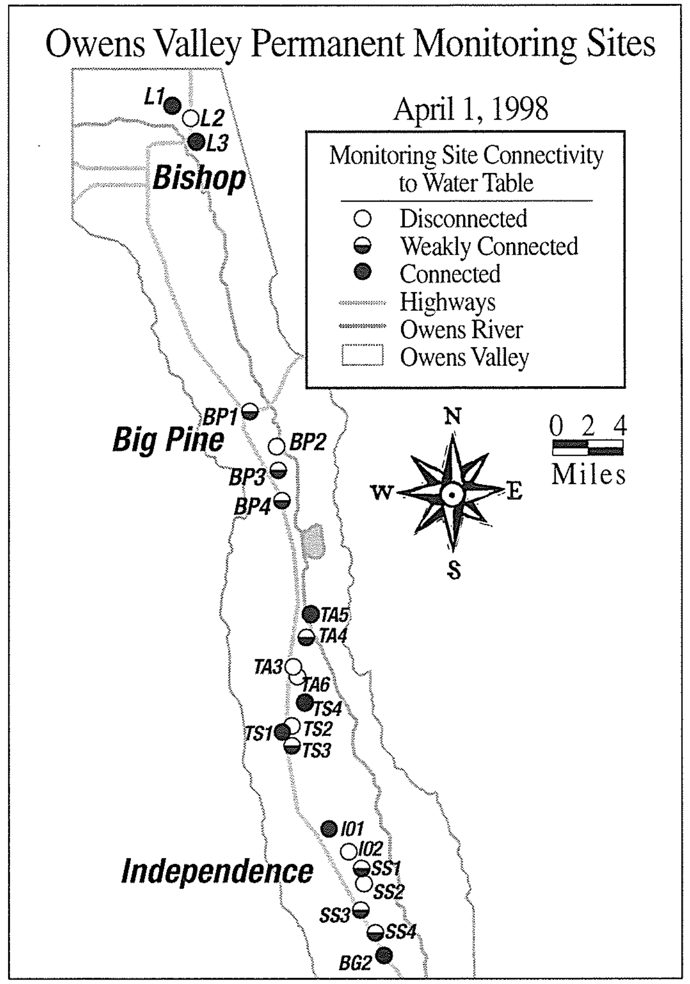


Figure 4. Owens Valley Permanent Monitoring Sites

The wellfield monitoring sites can be grouped into three categories to summarize the soil water and groundwater connection. Representative hydrographs from monitoring sites in the three categories are shown in Figure 5.

1. Disconnected: No groundwater is reaching the root zone. Seven sites occur in this category.

2. Weakly connected: Groundwater has entered the bottom 0.5m of the root zone. Eight sites occur in this category.

Owens Valley Revegetation Program

Irene Yamashita, ICWD Supervising Researcher

When the water agreement became final in June 1997, Inyo County and Los Angeles became formally responsible for meeting a requirement in the 1991 EIR to revegetate approximately 1,000 acres in the Owens Valley with native plants. The land was identified in the EIR as requiring mitigation for impacts of water export that occurred between 1970 and 1990. A native plant revegetation plan is being completed for these areas and is scheduled to be released to the public in June 1998. In anticipation of this work, several years ago ICWD began testing methods of reestablishing native plants on barren lands in the valley.

Laws revegetation study

Since 1991, ICWD has been monitoring the success of a native plant revegetation project in the Laws area in which 400 fourwing saltbush shrubs were planted. During five years of monitoring we observed that mortality decreased annually. If healthy plants are transplanted and care is taken to promote their development during the first three years after planting, very high survival rates may be expected at this site. In 1997, we began to focus on the long-term survival and recruitment of the planted shrubs occurring within this study site. This monitoring will continue on an annual basis, and the results will be analyzed every five years.

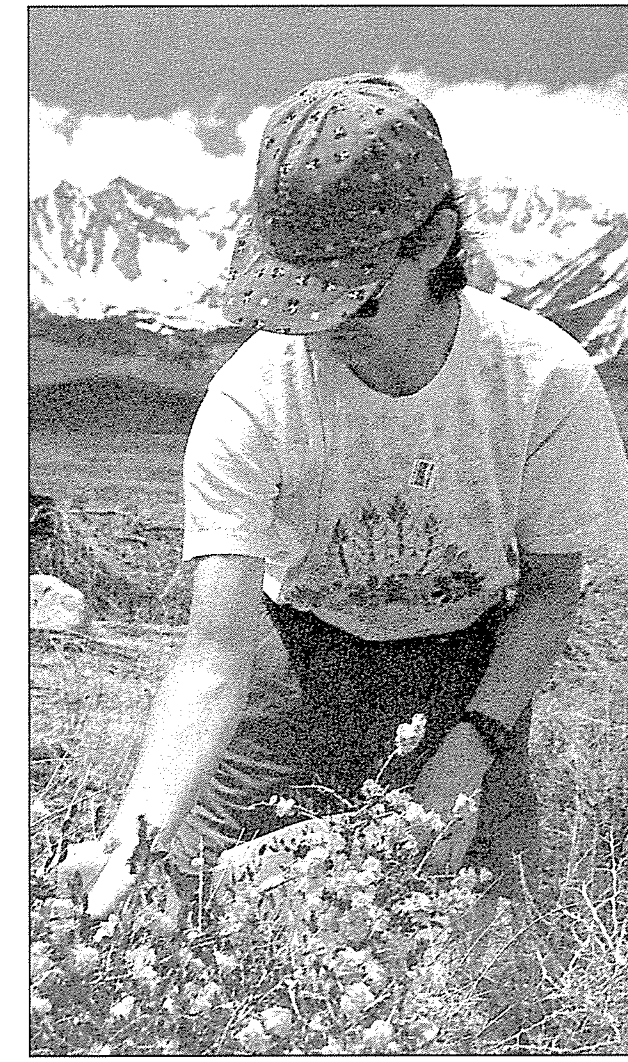
In November of 1996 ICWD planted 88 plants at the Laws revegetation site to increase the variety of species providing seed to the site and to observe species survival. Five new species were planted: Nevada ephedra, winterfat, allscale, shadscale, and budsage. Five additional species were added during 1997 to replace dead fourwing saltbush plants. These included Indian ricegrass, saltgrass, desert needlegrass, Parry's saltbush, and hopsage.

The plants were watered with two liters of water once a month from April through September. After one year, overall survival was 62%. None of the desert needlegrass survived.

Independence revegetation site

In 1996, LADWP constructed an exclosure southeast of Independence. ICWD staff planted native containerized plants in the autumn of that year. Plants were concentrated in three sets of three rows each, with ten meters between sets. This scheme was used to observe whether natural recruitment would occur in the space between sets. The sets of transplanted shrubs and grasses will contribute a ready seed source from a variety of species and could potentially provide some wind protection.

The planting consisted of 138 plants of nine species: winterfat, greasewood, allscale, shadscale, fourwing saltbush, sagebrush, budsage, desert olive, and alkali sacaton. Plants used in this study were smaller and younger (nine months to two years) than in the Laws revegetation study. The plants were irrigated with two liters of water once a month from April through September. After one year, overall



Irene Yamashita collects seeds of native plants for revegetation program.

survival was 49%. None of the budsage survived through the first year.

Millpond tree planting

Since 1996, ICWD has worked on the restoration of riparian vegetation along a stretch of McGee Creek at Millpond Recreation Area west of Bishop. Cuttings or "poles" of willow trees, cottonwoods, and birch were planted and protected with tree shelters in 1996, with an overall survival rate of 86%. In the autumn of 1996, seven dead trees were replaced with rooted willow cuttings remaining from the spring planting.

In 1997, monitoring revealed an overall survival rate of 75%. Survival rates were highest for cottonwoods (89%), followed by willows (71%). None of the birch cuttings survived. Six of the dead trees were replaced by container plants; two of the replacements were birch trees that were started from seed. We will continue to monitor the survival of the transplants in 1998.

this community as it exists in the Owens Valley.

Like Alkali Meadow, Desert Sink Scrub tends to occur on the valley floor. As its name suggests, it tends to occur in places where water collects in barren slick spots during wet periods. Vegetation cover is sparse, averaging about 14%. Although water may be readily accessible beneath the surface, it is likely that soil characteristics at or near the surface preclude new plant establishment or encroachment into the slick spots, and thus, plant cover remains low.

A variety of groundwater-dependent plant species typically inhabit these communities, with the proportion of grass to shrub being about equal. Often, dominance within a Desert Sink parcel is shared by 3-5 species, typically including alkali sacaton, greasewood, saltgrass, shadscale, Parry's saltbush, and/or rabbitbrush. This community shares species with both Alkali Meadow and Greasewood Scrub, and although Desert Sink might be viewed as transitional between the two, its high species diversity relative to the other two communities confounds attempts to describe a smooth transition from one to the other.

Parry's saltbush
(Atriplex parryi)

Conclusion

The report contains other findings concerning the characteristics of Owens Valley plant communities. True to scientific investigation, however, the analysis raised additional questions and pointed to many new avenues of inquiry. These will be pursued as time and priorities allow.

Riparian Monitoring

Brian Cashore

Owens Valley streamside habitats are so strongly influenced by stream flow that they are invariably different from the surrounding uplands. Unlike their upland counterparts, riparian areas support an abundance and variety of life forms — from microbes to humans.

The diverse and structurally complex riparian habitats thrive on and are the result of dynamic natural forces. Floods, droughts, and seasonal variations in stream flow or groundwater levels act on riparian areas to alter vegetation, move debris, or change channel structure. Long-term monitoring of riparian sites must be capable of tracking these "normal" processes and conditions and detecting human-caused changes along a given stream reach.

In the Inyo County/Los Angeles water agreement riparian vegetation is designated as "Type D." A goal of the agreement is to manage LADWP's groundwater pumping and surface water conveyance to avoid causing significant decreases or changes in vegetation. The technical appendix to the agreement, the Green Book, requires Inyo County and Los Angeles to develop appropriate procedures and techniques to monitor and manage riparian vegetation. To this end, a pilot riparian monitoring program was initiated in 1996 and was continued in 1997.

In July 1997, LADWP's Paula Hubbard and I revisited locations set up for riparian monitoring in 1996.We visited 11 permanent transects on four Owens Valley creeks: Birch, Baker, Taboose, and Shepherd. At each site, we ran a vegetation transect, measured the channel cross section, photographed permanent points, listed plant species, and measured flow, depth, channel substrate, and tree canopy. These techniques, and perhaps other approaches such as remote sensing, will be applied to the creeks and riparian areas in and around the Owens Valley in the future.

Over time, Inyo County and LADWP will expand the riparian monitoring program to cover all riparian areas on Los Angeles land in the valley. The data gathered through the program will be used to identify trends and judge the relative health of the streams. The information will also help us to distinguish between natural changes in these dynamic systems and changes caused by groundwater and surface water management.

3. Connected: Groundwater extends at least to the middle of the root zone. Seven sites occur in this category. Five sites have had water table recovery or were located near water spreading areas; two sites were never dry. All eight control sites would also occur in this category, but they are not shown in Figure 4.

Two-thirds of the sites had at least some groundwater in the root zone in 1997. The most recent changes were: soil water at BP3 (4m root zone, weakly connected) increased slightly due to groundwater recovery beginning in October, and IO1 (2m root zone) changed from weakly connected to well connected in December.

Vegetation Conditions

In general, we have observed that vegetation conditions generally follow the trends in the groundwater-soil water fluctuations. But an understanding of the relationship between the vegetation and groundwater and soil water is complicated because each monitoring site has unique soil and vegetation conditions. The history of percent live plant cover is presented in the graphs in Figure 6. Vegetation cover typically increased at the sites where water tables entered the root zone. As the water table rose, the magnitude of the vegetation response varied, partly due to the particular mixture of grasses and shrubs present at the sites. At grass-dominated sites, total cover often increased greatly because deeper-rooted shrubs flourished before the grass root zone above 2m was wetted. Sites L1, BP1, TA6, TS1, and TS3 (Figure 6) all showed this response to some degree.

Vegetation at many sites has not yet recovered to pre-drought levels. At most of the weakly connected sites, however, the vegetation cover has increased since the dry years of the early 1990s, and the cover is at or just below the initial conditions. Examples are TS3, BP4, and IO1 (Figure 6). It is expected that vegetation at these sites will continue to improve. At sites that are not receiving groundwater, plant cover typically remains below baseline and fluctuates with precipitation; cover increases following wet winters and declines after dry ones. This pattern is evident for L2, IO2, SS1, and SS2 (Figure 6).

It is more difficult to use the permanent monitoring site data to generalize about the sites currently containing ample groundwater within the root zone because of the various ways water reached the root zone at sites within this category. Vegetation at sites that have never dried, for example TA5, has remained stable or increased slightly due to increased precipitation following the drought. A similar pattern has occurred at some of the control sites: BC1, BC2, and TSC, for example (Figure 6). Some sites that have reconnected by water table rise, for example L3, BP1 and TS1, showed dramatic increases in total vegetation cover from the low point in the early 1990s. This vegetation pattern has also been observed at some control sites, such as BC3 and TAC.

As of April 1998, the water table was supplying water to the root zone at 15 of the 22 well field sites. Plentiful winter precipitation, minimal pumping, and above-normal predicted recharge should continue to produce soil water and vegetation recovery at all 22 sites in 1998.

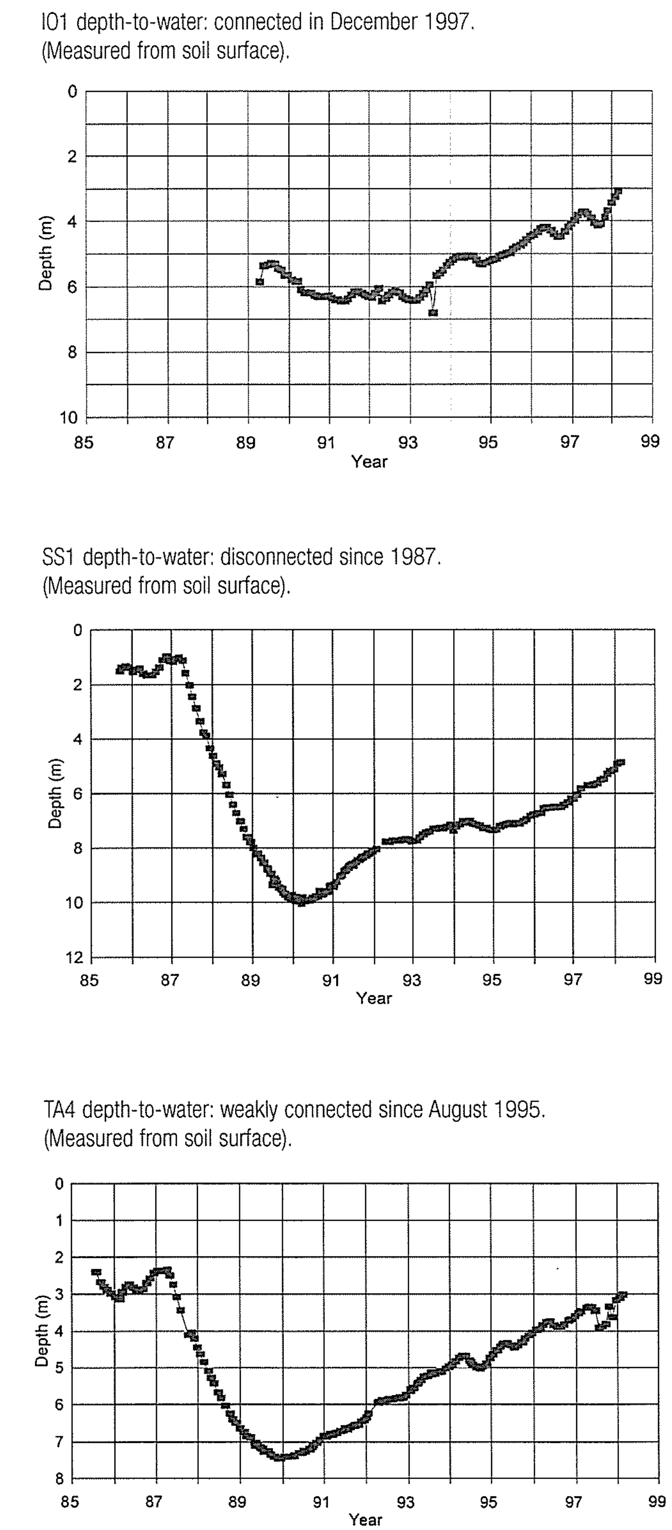


Figure 5. Hydrographs from three Owens Valley monitoring sites representing the three categories of connection between the plant root zone and groundwater.

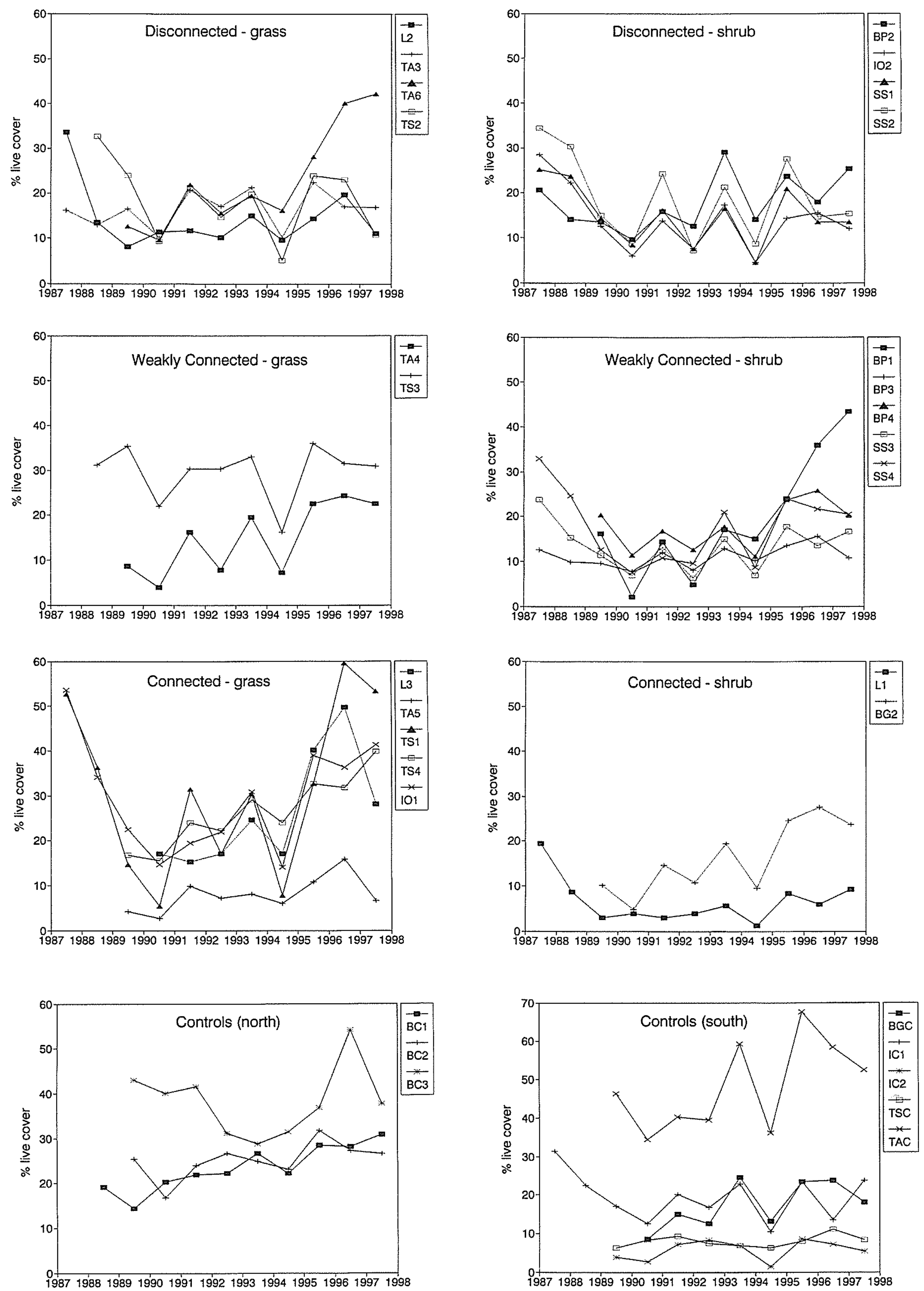


Figure 6. Plant cover at permanent monitoring sites, 1987-1997.

Report on Owens Valley Plant Communities

Sally Manning, ICWD Vegetation Scientist

Because an understanding of the characteristics of the Owens Valley vegetation is critical for responsible management, it is important to continue to expand our knowledge of the vegetation. One of my goals for 1997 was to consolidate and report on some analyses I had performed using the LADWP baseline vegetation data (collected 1984-1987). The baseline has proven invaluable in monitoring vegetation change over time, but salient features of the plant communities had not been rigorously evaluated. In the report, entitled "Plant communities of LADWP land in the Owens Valley: An exploratory analysis of baseline conditions," I presented results of my analyses of the baseline data.

Some interesting insights emerged. Perhaps the most useful information for management purposes was the characterization of depth to the water table beneath various plant communities during the baseline period. Using the best data I had available, I averaged the depth-to-water beneath all parcels that were classified as the same plant community. Results are summarized in Figure 10.

Tamarisk Scrub parcels exhibited the shallowest depth-to-water. This was not surprising because these weed-dominated parcels tend to occur adjacent to open water in disturbed places.

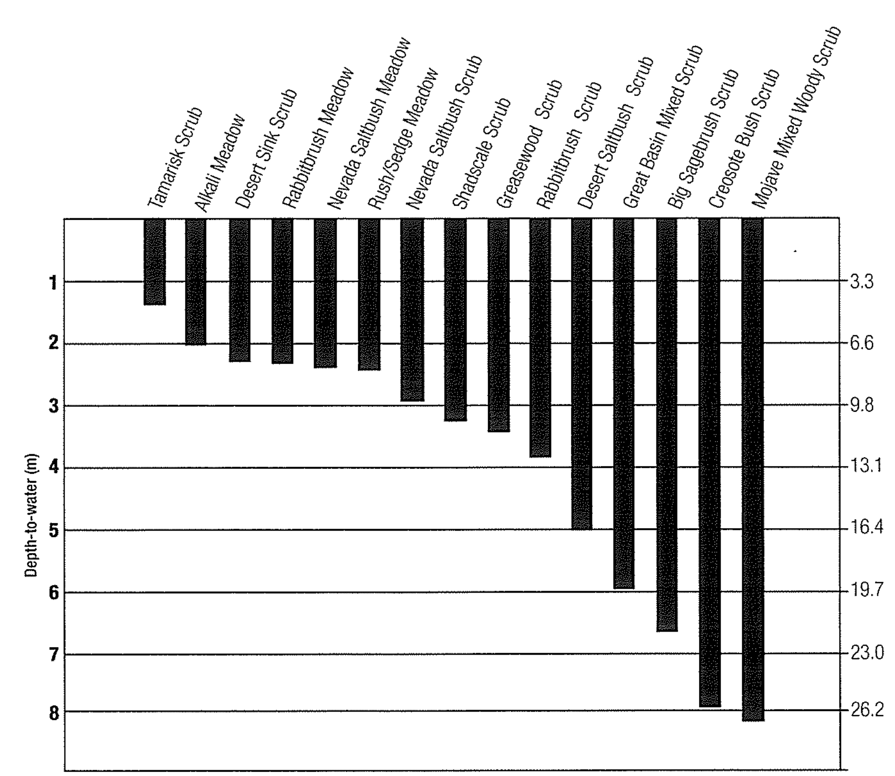


Figure 10. Average depth-to-water for the Owens Valley plant communities during baseline years.

The next five communities in Figure 10 all showed an average baseline water table depth less than 2.5m (8 feet). These communities — Alkali Meadow, Desert Sink Scrub, Rabbitbrush Meadow, Nevada Saltbush Meadow, and Rush/Sedge Meadow — included all the grass-dominated communities I evaluated. This finding was consistent with previous studies which had shown that the two dominant native perennial grass species in the valley, saltgrass *(Distichlis spicata)* and alkali sacaton *(Sporobolus airoides)*, effectively root to about 2m. One surprise, however, was that the community called Desert Sink Scrub exhibited a water table depth in the "meadow" community range. More about this below.

The scrub communities dominated by groundwater-dependent shrubs all had average depth-to-water ranging from 3 to 4m (Figure 10). They were: Nevada Saltbush Scrub, Greasewood Scrub and Rabbitbrush Scrub. Previous studies had shown that the effective rooting depth for many of the shrubs inhabiting these communities was about 4m (13 feet), so these findings also were in agreement. Average depth-to-water beneath Shadscale Scrub parcels was 3.25m. Shadscale *(Atriplex confertifolia)* is not known to be a groundwater-dependent species, so further investigation into the characteristics of this Owens Valley plant community might be warranted.

The last five communities shown in Figure 10 are not characterized by groundwater-dependent species, and their depth-to-water values averaged beyond 5m (16.4 ft). These communities tend to occur on alluvial fans or high terraces in the Owens Valley.

Desert Sink Scrub

Many of the findings that emerged from this analysis were consistent with existing knowledge. However, the community called Desert Sink Scrub in the baseline vegetation data proved to be an anomaly in several ways. Besides having a depth-to-water in the range of most Owens Valley meadow communities, the characteristics of and plant species present in the Desert Sink parcels did not correspond with previous descriptions of this community in the scientific literature. However, no existing plant community description could be found that would adequately describe

Shrub Recruitment

Sally Manning, ICWD Vegetation Scientist

Recruitment is the germination and subsequent establishment of new plants in an area. During 1997, I continued to monitor shrub recruitment, survival, and growth at the 33 permanent monitoring sites. Attempts to monitor recruitment commenced in 1989, but the methods were not standardized until 1993.

Before 1991, I observed no new shrub seedlings at the monitoring sites. Following the March rains of 1991, numerous nevada saltbush *(Atriplex torreyi* = ATTO*)* seeds germinated at many of the monitoring sites. ATTO also germinated in relatively large quantities following the winters of 1993 and 1995. Very little new recruitment was recorded in 1992, 1996, or 1997. No 1994 recruits were observed.

As of late summer 1997, survival of the 1991 ATTO seedlings was 6.2% overall (Table 5). The highest survival rates have occurred at the monitoring sites located in meadow communities, where ATTO appears to be invading. More specifically, highest survival of 1991 ATTO recruits (11.5%) has been in the meadow sites located in LADWP wellfields that have experienced water table draw-down below the root zone followed by water table recovery to at least the shrub root zone (4 m) in 1995 or after. This occurred at TS1, which had the greatest number of 1991 ATTO survivors (70) and at TS3 (40) and BP1 (32).

At monitoring sites where groundwater reached the shrub root zone, growth of the 1991 ATTO plants has been dramatic. For example, at TA6, soil water has begun reaching the shrub root zone. The five 1991 ATTO shrubs at this site appear full grown and they are reproductively mature. At another site, TA3, (located approximately 0.5 miles from TA6), there have been a fair number of 1991 ATTO survivors, but the water table has not quite reached the lower part of the shrub root zone. At this site, the 1991 recruits appear small and frail, and very few have produced flowers. Growth of one representative 1991 ATTO recruit from each of the two sites appears in Figure 9.

Overall survival of the numerous ATTO seedlings that germinated in 1995 has been 13.6% (Table 5). This is about equal to the second-year survival rate of the 1991 ATTO recruits, but note that there are over four times more 1995 ATTO plants. So far, survival of the 1995 ATTO seedlings has been highest at the meadow sites, both control and wellfield. The 1995 cohort has experienced a different set of environmental conditions than the 1991 ATTO cohort. For the 1995 group, higher annual precipitation and higher water tables have prevailed. These favorable conditions may promote ATTO seedling survival and thus alter the vegetation characteristics at the meadow sites.

Table 5. Some recruitment results for *Atriplex torreyi* (ATTO).

COHORT	# Surviving 8/91	8/92	8/93	8/94	8/95	8/96	9/97	% overall
1991 ATTO	4167	891	621	452	296	276	260	6.2
wf scr	1524	194	59	35	13	13	11	0.7
ctl scr	548	54	29	17	15	14	14	2.6
wf mdw	1911	600	513	379	248	232	220	11.5
ctl mdw	184	43	20	21	20	19	15	8.2
1993 ATTO	-	-	696	23	12	11	8	1.1
wf scr	-	-	601	2	0	0	0	0
ctl scr	-	-	40	3	2	2	2	5.0
wf mdw	-	-	32	14	8	8	6	18.8
ctl mdw	-	-	23	4	2	1	0	8.7
1995 ATTO	-	-	-	-	19852	5616	2691	13.6
wf scr	-	-	-	-	11380	2642	1075	9.4
ctl scr	-	-	-	-	3019	580	311	10.3
wf mdw	-	-	-	-	5236	2279	1232	23.5
ctl mdw	-	-	-	-	217	115	73	33.6

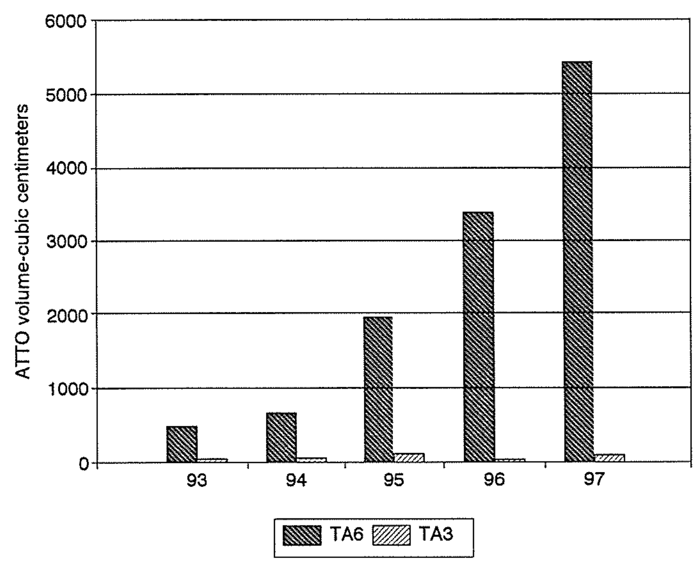


Figure 9. Representative ATTO growth at TA6 (where the water table has entered the shrub root zone) and TA3 (where the water table remains beyond the shrub root zone).

Vegetation Monitoring Overview

Sally Manning, ICWD Vegetation Scientist

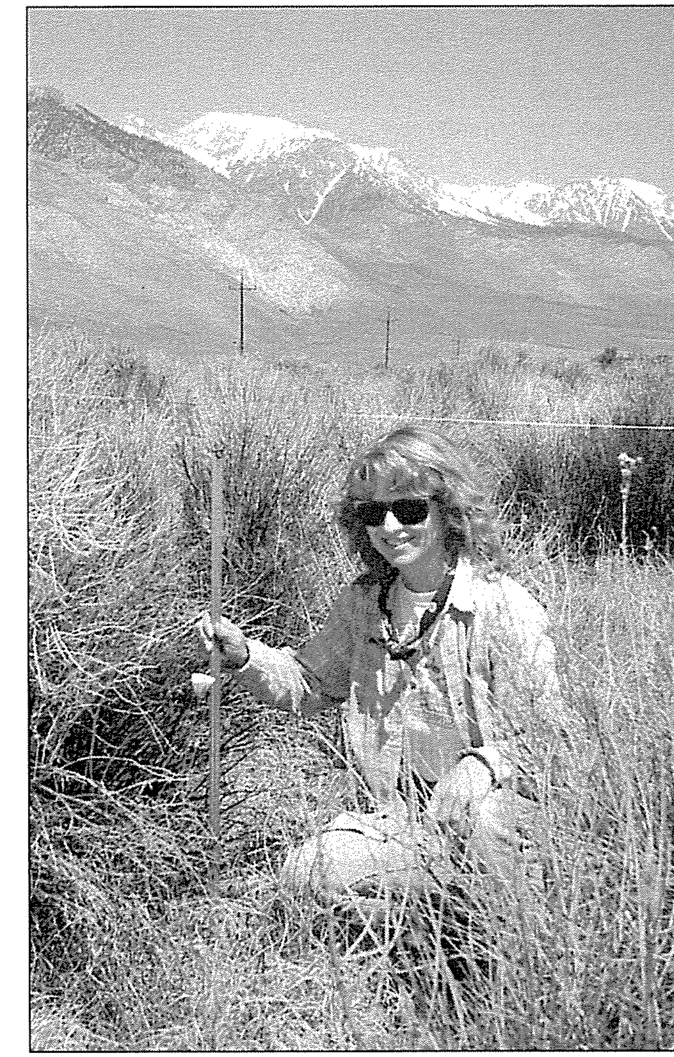
Because the water agreement mandates no significant adverse changes in Owens Valley vegetation caused by pumping or surface water management practices, vegetation monitoring is a cornerstone of the Water Department's operations.

Ongoing monitoring of vegetation conditions occupies the majority of the vegetation staff's time. We are responsible for collecting plant cover information from 33 permanent monitoring sites. We also spend a significant amount of time adding to the information we gather at the permanent sites by inventorying vegetation conditions at many other sites throughout the valley during the summer. Organizing field crews, collecting and tallying the data, and analyzing the results keep the staff busy.

But many other activities vie for our time. The vegetation staff annually visits a number of rare plant sites to collect data and make assessments, and we painstakingly track new shrub recruitment at the permanent monitoring sites and other locations. In conjunction with LADWP, we have initiated a fledgling riparian monitoring program. To date, we have been involved in all aspects of the revegetation efforts called for in the EIR, such as monitoring ongoing pilot projects, implementing new projects, experimenting with seed collection and plant propagation techniques, reporting on results, and devising new plans for revegetation.

Until the long-term agreement became final in June 1997, we also maintained a moderate level of activity studying and treating saltcedar and other weeds. Saltcedar control has since become an independent program. At the end of 1997, we acquired the rain gage monitoring program which, due to time constraints, the County Hydrologist was unable to continue.

Although the demands of field work, meetings, and routine data analysis can be great, one goal of the vegetation staff is to continue to learn everything we can about the Owens Valley plant species, the natural conditions that maintain them, and the responses of these species to LADWP's groundwater and surface water management. This is achieved through research efforts, both in the field and "from the books." With Aaron Steinwand, ICWD's Soil Scientist, we researched Nevada saltbush water use and evaluated this species' response to altered water table conditions. I performed an exploratory analysis of the baseline vegetation data in an attempt to better understand vegetation conditions as they existed prior to the water agreement and to compare the Owens Valley information with other vegetation classification efforts statewide. One exciting research project that was launched late in 1997 was the collaboration with Brown University on a remote sensing study of Owens Valley using ICWD ground truth data in conjunction with Landsat satellite imagery. All these projects are discussed elsewhere in this issue of the MONITOR.



Sally Manning measuring *Calochortus excavatus*, one of the Owens Valley's rare plants.

The vegetation staff is also involved in — and has contributed to — other ICWD activities, such as an air photo study, a type E vegetation inventory, a biological inventory of Owens Valley springs and seeps, and Lower Owens River Project issues involving plants. We will continue to be involved with these and other future projects.

The vegetation staff members have become proficient in using the Global Positioning System, regularly use the Geographic Information System, and continue to add to our knowledge of the Owens Valley flora. We attend relevant workshops and conferences to hone our skills, and we often are called upon to share our knowledge with other organizations and individuals.

Vegetation Inventory and Conditions

Sally Manning, ICWD Vegetation Scientist

As part of an ongoing program to assess vegetation conditions and plant responses to water table levels valley-wide, ICWD inventoried 86 vegetation parcels throughout the valley during the summer of 1997. ICWD staff ran a total of 1,381 transects in vegetation parcels from Laws to Lone Pine. We compared conditions in these 86 parcels to data contained in the baseline vegetation inventory. This baseline inventory, conducted between 1984 and 1987 by LADWP, serves as the reference for vegetation change under the long-term agreement.

The 86 parcels were divided into two primary groups: control and wellfield. Thirty parcels were located in control areas, far from the influence of groundwater pumping. The remaining 56 parcels were categorized as "wellfield." These parcels lie within areas subject to water table decline caused by pumping from LADWP wells. In most cases, the water table declined beneath these parcels because of heavy pumping during 1987-1989, a period of severe drought. Since that time, because of reduced pumping and some high runoff years, the water table under most of the wellfield areas has begun to climb.

In 1997, I estimated that the water table had returned to the approximate level where it had been during baseline years in 22 of the 56 well field parcels. Therefore, these 22 parcels were categorized as "recovered wellfield" (wf-r). Compared with 1996, the number of parcels in this category increased, indicating a gradual increase in groundwater elevation. Still, in 1997 the water table under 34 parcels, although increasing, had not returned to the baseline year depth.

Areas where the water tables have recovered include areas adjacent to the Owens River in Laws, near the junction of highways 395 and 168 at Big Pine, near the Blackrock rest stop, south of Lone Pine, and other scattered areas. Water tables have not fully recovered in most of the Laws area, east and southeast of Big Pine, near Aberdeen, near the Blackrock fish hatchery, or south of Independence between highway 395 and the LA Aqueduct.

Perennial Cover: Change From Baseline

The 1997 perennial cover relative to 1984-1987 baseline conditions was similar to results obtained in 1996. This may have been because of the similarity of climatic and environmental conditions between the two years. The results are summarized in Table 4 and Figure 7. Control parcels (ctl) maintained statistically significant ($p<0.05$) higher cover than baseline, and as a group, achieved the highest cover measured to date. When it is stated that a change is statistically significant at $p = 0.05$, this means that there is a 95% chance that the statement "there is no measurable change" can be rejected. This is standard data analysis procedure.

Wellfield parcels (wf) again showed depressed cover relative to baseline. On average, cover was 18.6% below baseline. This decrease was statistically significant.

Denise Waterbury fully equipped to begin another day in the field running transects.

Perennial cover in the recovered wellfield parcels (wf-r) was not statistically different from baseline. Although as a group they averaged 16% higher cover, this increase was not statistically significant. Sixteen of the 22 parcels in this group increased in perennial cover by various amounts, but 6 declined. The net result was that the increases did not outweigh the decreases and therefore the change relative to baseline was not statistically significant. This result was consistent with results obtained in 1996.

Plant Composition

Besides evaluating the vegetation conditions in terms of perennial cover, the data can be tabulated and compared in many ways. One method I have chosen is to group the species into life form categories. The three simple categories I used were grasses, shrubs and weeds. "Grass" is composed primarily of native, perennial grasses, but includes grass-like plants as well. "Shrub" includes woody native species. "Weed" includes all non-native species, both annual and perennial, as well as some invasive native species.

Figure 8 shows the results of this analysis. In the figure, I show the average grass, shrub, and weed composition for the 86 parcels inventoried in 1997. The graph displays the information for the three management categories (a - 30 control parcels, b - 34 well field parcels, and c - 22 recovered well field parcels) in three time periods: baseline, 1992, and 1997.

Table 4. Average percent change in perennial cover relative to baseline conditions for parcels re-inventoried 1991-97. Numbers in bold indicate changes that are statistically significant.

From baseline year to:	ctl	# parcels	wf	# parcels	wfr	# parcels
1991	-8.4%	9	**-40.8%**	21	-	
1992	+0.9%	50	**-41.8%**	49	-	
1993	+23.8%	24	**-14.8%**	36	-	
1994	+7.5%	24	**-36.9%**	36	-	
1995	**+35.6%**	30	-3.5%	39	-	
1996	**+30.8%**	41	**-9.0%**	42	+9.1%	14
1997	**+45.4%**	30	**-18.6%**	34	+16.0%	22

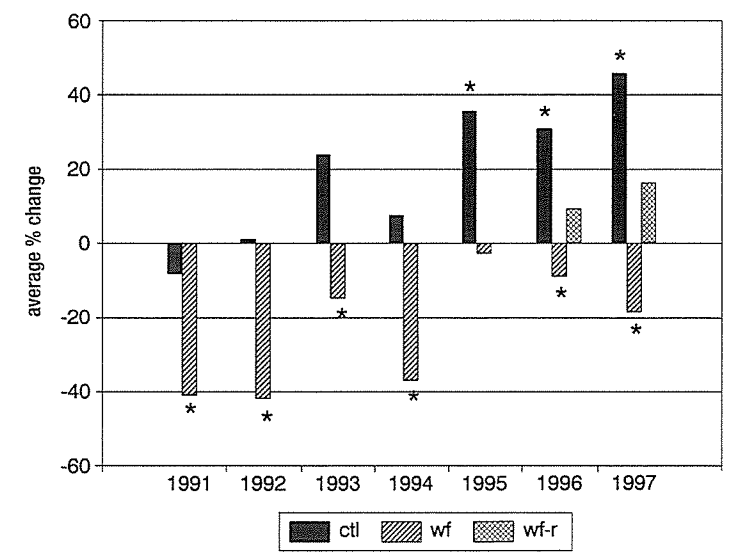


Figure 7. Graph of data from Table 4. Bars show the magnitude and direction of change from baseline (0%) and statistically significant changes are marked with an asterisk.

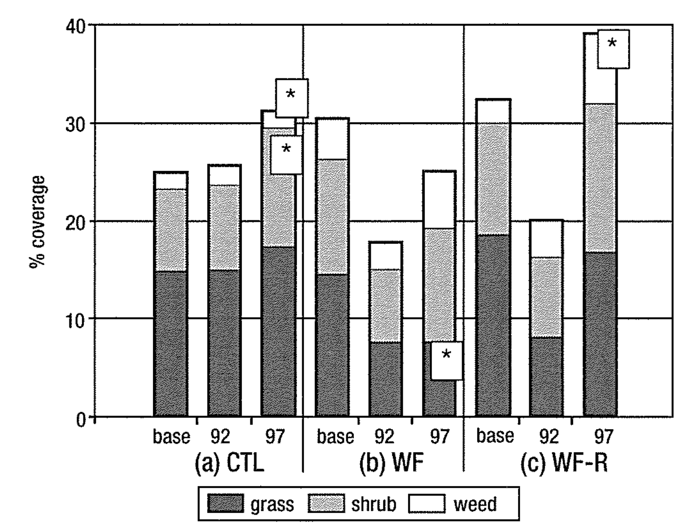


Figure 8. Average percent cover by plant life form for plants in (a) control, (b) wellfield, and (c) recovered wellfield parcels during baseline year (base), 1992 and 1997. Asterisks in 1997 denote significant changes from baseline for the life form indicated.

Grass cover has been consistent in the control parcels (Figure 8a), where water tables have been unaffected by pumping. Even though the period from baseline through 1992 was a drought, grass cover apparently did not respond to the drought and remained at about 15%. Since the drought ended, there has been a small increase in average grass cover (Figure 8a, "97"), but this was not statistically significant. In the well field parcels (Figure 8, b and c), grasses responded to the combination of drought and pumping (from baseline year to 1992) by declining. Since 1992, lack of water table recovery (Figure 8b, "97") appears to account for the continued suppression of grass cover; the average wf grass cover was 7.7% in 1997, down significantly from the 14.5% baseline. However, where the water table has recovered (Figure 8c, "97"), grass cover has returned approximately to baseline conditions (from 18.6% to 16.8%).

Shrubs account for the majority of increased cover in the control parcels. Since 1992, shrub cover has increased and, relative to baseline, this has been a significant increase (from 9.1 % to 12.1 %) (Figure 8a). Shrub cover in the wellfield parcels has remained relatively constant (Figure 8b). In the recovered wellfield parcels, shrub cover has shown an average increase (from 11.4% baseline to 15.0% in 1997), but this increase was not statistically significant (Figure 8c). Results from control parcels suggest that the increase in shrub cover at recovered wellfield sites is a trend that will continue.

As in 1996, weeds have increased, on average, in all parcels. This increase has been statistically significant in the control and recovered wellfield parcels (Figure 8a and c, respectively). Between baseline year and 1997, average weed cover went from 0.7% to 1.6% in the control parcels; from 4.1 % to 5.7% in the wellfield parcels; and from 2.1 % to 7.1 % in the recovered wellfield parcels.

Conclusion

The recovered wellfield sites appear to be on the rebound, but they do not yet compare to the controls. Precipitation during 1995 appeared to boost cover in the control areas, and that increased cover has been maintained by a combination of favorable precipitation and relatively constant water table conditions. Cover in the wellfield parcels also benefited from 1995 precipitation, and in that year perennial cover in these parcels returned to baseline levels. Since 1995, however, that level of cover has not been maintained in parcels where the water table has not recovered. In parcels where the water table has recovered, perennial cover appears to be holding at baseline level. It is likely that, due to reduced pumping and favorable precipitation, the wf-r parcels will, like the control group, soon exceed baseline conditions. One potential threat to their continued improvement, however, may be the increase in weeds that could compete with shrubs and grasses and thus retard the continued increase in perennial plant cover in the future.