INYO COUNTY WATER DEPARTMENT
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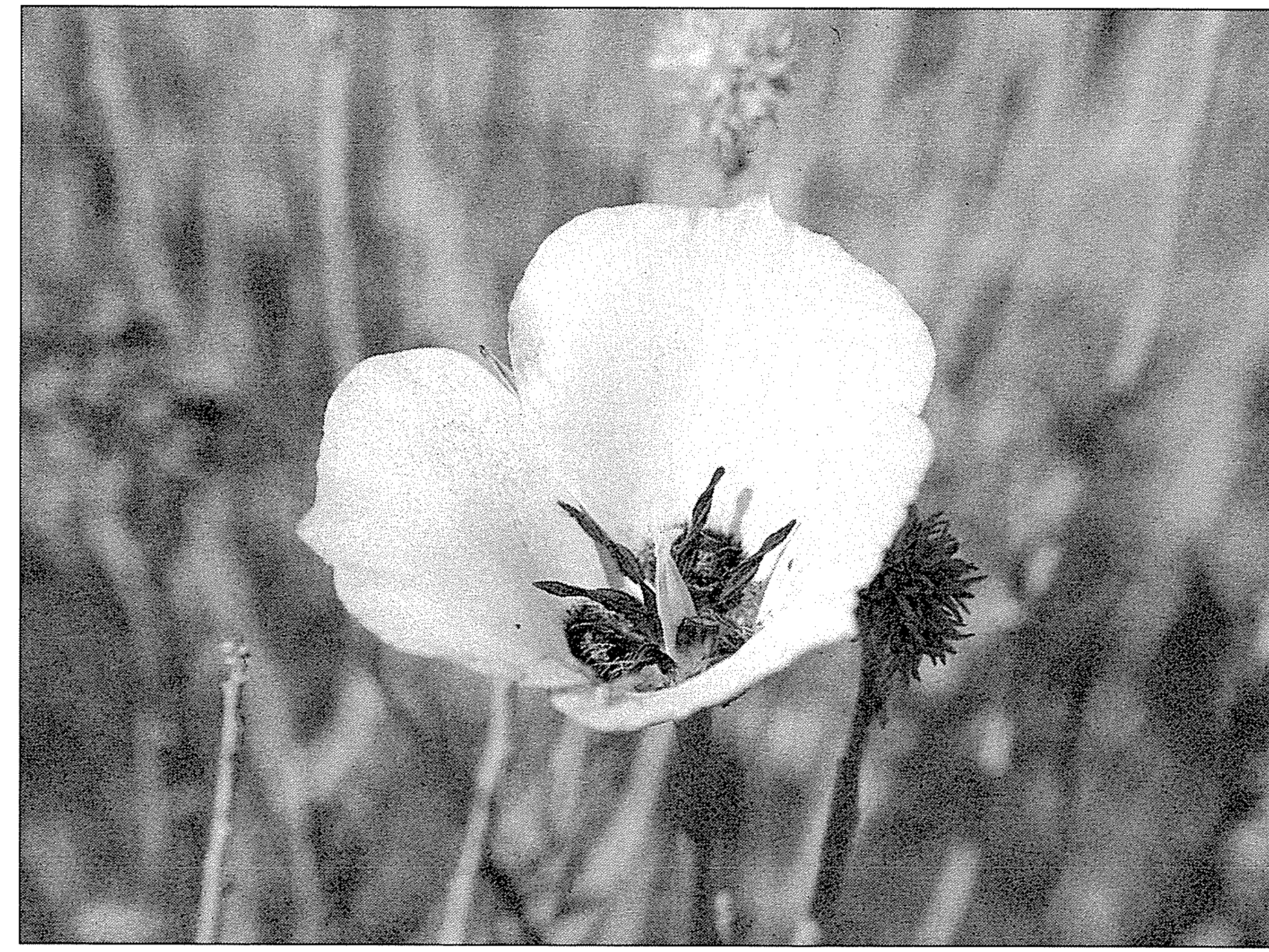
THE OWENS VALLEY

MONITOR



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

1998

The Owens Valley Monitor is the Inyo County Water Department's annual report. The Monitor is a report on monitoring and other work performed by ICWD and the Los Angeles Department of Water and Power. In accordance with the Inyo/Los Angeles water 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.

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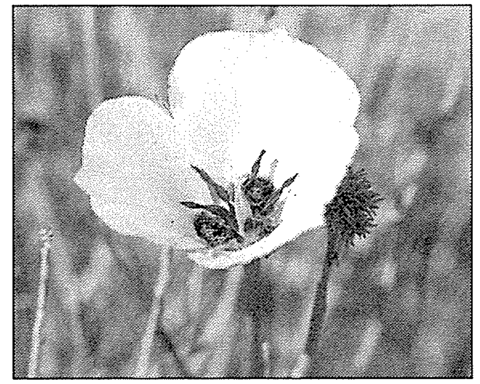

THE OWENS VALLEY MONITOR

This annual report was produced by the Inyo County Water Department 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:

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Front Cover:
Photograph of *Calochortus excavatus* "Inyo County star-tulip," a rare plant that grows in alkaline meadow communities in the Owens Valley and Fish Slough. Photograph by Sally Manning.

Following page:
Billy Lake east of Independence, an element of the Lower Owens River Project. Photogrpah by Leah Kirk

Back cover:
Photograph of waves on Owens Lake taken by T.S. Palmer on an expedition to Death Valley and the Owens Valley in 1891.
(Collection of the Henry E. Huntington Library)

Edited by Leah Kirk
1998 Monitor Design: Wynne Benti

This report is published on recycled paper.

1998 Additions to Inyo County Herbarium

Denise Waterbury, Research Assistant II

Inyo County Water Department's herbarium contains 194 plant species found in the Owens Valley. During 1998, the following species were added to the collection. A complete list is available at the ICWD.

Family/Species	Common Name
BORAGINACEAE	
Pectocarya penicillata	Slender combseed
Tiquilia nuttallii	
BRASSICACEAE	
Hutchinsia procumbens	Meadow mustard
Lepidium dictyotum	
Lepidium fremontii	Desert alyssum
*Lepidium perfoliatum**	Shield cress
CAPPARACEAE	
Cleomella parviflora	Small-flowered stinkweed
CARYOPHYLLACEAE	
Loeflingia squarrosa var. *artemisiarum*	Sage-like loeflingia
FABACEAE	
Lupinus brevicaulis	Sand lupine
HYDROPHYLLACEAE	
Tricardia watsonii	Three hearts
LILIACEAE	
Allium atrorubens var. *cristatum*	Inyo onion
Dichelostemma capitatum	Blue dicks
Zigadenus venenosus var. *venenosus*	Death camas
NYCTAGINACEAE	
Abronia turbinata	Transmontane sand verbena
ONAGRACEAE	
Camissonia parvula	Wiry primrose
OXALIDACEAE	
*Oxalis corniculata**	Creeping woodsorrel
POACEAE	
*Bromus catharticus**	Rescue grass
Panicum capillare	Witchgrass
Spartina gracilis	Alkali cordgrass

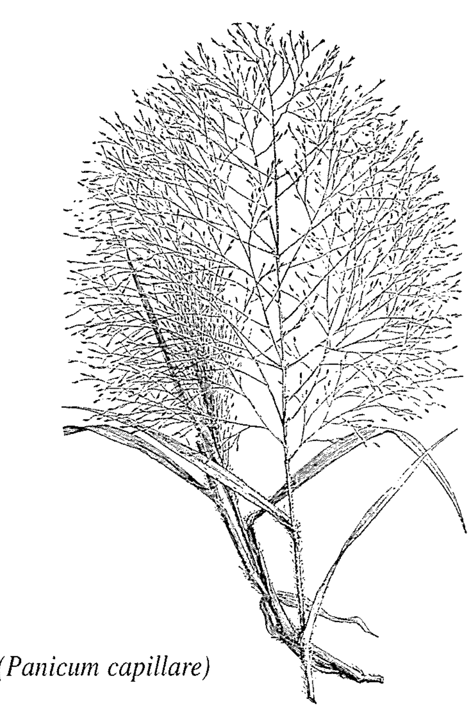
* = non-native species

Family/Species	Common Name
POLEMONIACEAE	
Gilia inyoensis	Inyo gilia
Gilia leptomeria	Sand gilia
Gilia micromeria	Dainty gilia
Linanthus aureus ssp. *aureus*	Golden linanthus
Linanthus parryae	Sand blossoms
POLYGONACEAE	
Centrostegia thurberi	Thurber's spineflower/ Red triangles
SCROPHULARIACEAE	
Mimulus suksdorfii	Suksdorf miniature mimulus
Veronica anagallis-aquatica	

Illustration credits:
Shrubs of the Great Basin, by Hugh N. Mozingo, drawings by Christin Stitter, University of Nevada Press

Intermountain Flora: Vascular Plants of the Intermountain West, U.S.A., published for the New York Botanical Garden by Columbia University Press

Manual of the Grasses of the United States, 2nd edition revised by Agnes Chase, Dover edition of the 1950 publication by the US Department of Agriculture



Witchgrass *(Panicum capillare)*

The Inyo County Water Department

1998 STAFF

Greg James
Director

Soils

Aaron Steinwand
Soil Scientist/
Science Program Coordinator

Vegetation

Sally Manning
Vegetation Scientist

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Research Assistant II

Denise Waterbury
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Christine Hancock
Letty Brown
Richard Kang
White Mountain Research Station
IRT Interns

Hydrology

Randy Jackson
Hydrologist

Robert Harrington
Assistant Hydrologist

David Poe
Summer Hydrologic Technician

Environmental Programs

Brian Cashore
Saltcedar Control Project Coordinator

Irene Yamashita
Revegetation Project Coordinator

Leah Kirk
Lower Owens River/
Environmental Project Coordinator

Chris Howard
GIS/LAN Administrator

Rick Puskar
Saltcedar Research Assistant II

Chuck Spresser
Bruce Cline
Bryan Taylor
Saltcedar Field Assistants

Administrative

Douglas Daniels
Administrative Services Program Administrator

Irene McLean
Administrative Secretary II

Jody Stroud
Account Clerk I

1998 Members Board of Supervisors

Linda Arcularius
Julie Bear
Michael Dorame
Butch Hambleton
Robert Michener

Inyo County Administrator

Rene Mendez

1998 Members Water Commission

Bob Campbell
Teri Cawelti
Ray Gray
Harry Holgate
Scott Kemp
Paul Lamos
David Miller

Owens Valley checkerbloom *(Sidalcea covillei)*. Photograph by Sally Manning

1998 BUDGET

Inyo County Water Department's general operations budget for fiscal year 1997-1998 was $983,223. General operations included ongoing monitoring and management in the Owens Valley and administration.

Of the $983,223, the Los Angeles Department of Water and Power provided $941,745, the county's geothermal trust fund provided $18,515, and the LADWP/ICWD water trust and the previous year's fund balance provided $22,963.

Perspective

Greg James, Director

With the settlement, in mid-1997, of litigation over the 1991 environmental impact report for groundwater management in the Owens Valley, 1998 was the first full year of implementation of the Inyo/Los Angeles water agreement. Carrying out the work in the EIR, the agreement, and an associated Memorandum of Understanding kept the Inyo County Water Department's staff busy throughout the year. To ensure that all of these responsibilities will be met in the coming years, a reorganization of the department was approved by the Board of Supervisors.

Plans for the revegetation of approximately 1,300 acres identified for mitigation in the EIR were developed in large measure due to the efforts our new Revegetation Project Coordinator, Irene Yamashita. Under the tutelage of our new Saltcedar Project Coordinator, Brian Cashore, crews were recruited, materials purchased, and the first major dent was made in the population of saltcedar in the Owens Valley.

Planning for the rewatering of the Lower Owens River moved ahead aided by the capable work of Environmental Project Coordinator, Leah Kirk. (It is now planned that the environmental review of the project will be completed in 2000, and that water will flow in the 60-mile channel by as early as 2001.) The department was immensely aided by the expansion of our Geographic Information System under our new GIS manager, Chris Howard. County Hydrologist, Randy Jackson, with much able help from our new hydrologist, Bob Harrington, greatly advanced our ability to predict water table fluctuations due to groundwater pumping. Our science program has improved with the promotion of Aaron Steinwand to Science Coordinator.

With the invaluable assistance of Inyo County's Congressman, Jerry Lewis, the county obtained an additional $3 million in federal funds for the Lower Owens River Project. These funds, when combined with the $550,000 in federal funds already obtained through the Congressman's hard work, reduced the county's $3.75 million obligation for the project to $200,000. With the help of Congressman Lewis, this remaining obligation may be offset by additional federal funds obtained during 1999.

With regard to groundwater pumping by the City of Los Angeles, under the Drought Recovery Policy adopted by the city and the county during the prolonged drought from 1987 to 1992, groundwater pumping in 1998-99 was again kept low (51,575 acre-feet) in order to promote water table recovery from the declines experienced during the drought. Under this policy, water tables have recovered to pre-drought levels in many areas of the valley, and are expected to rise in the other areas of the valley with the continuation of conservative management in 1999-2000.

Intensive vegetation monitoring throughout the drought period, conducted under the watchful eye of Vegetation Scientist, Sally Manning, documented that vegetation conditions in most of Los Angeles' wellfields, declined below the vegetation baseline

Continued on page 4

Owens Valley Water Management

Inyo County and Los Angeles agreed to a maximum groundwater pumping limit of 64,000 acre-feet for the 1998-1999 runoff year (April 1, 1998-March 31, 1999). An additional amount of groundwater could be pumped by the Los Angeles Department of Water and Power during the winter, if necessary, to prevent the water in the Los Angeles Aqueduct from freezing. Actual pumping was 51,575 acre-feet. The pumping limit was based on predictions of water table responses at 18 indicator wells and in consideration of valleywide vegetation conditions.

Water uses on LADWP's Owens Valley lands for the runoff year were planned at about 92,860 acre-feet. These uses included 44,900 acre-feet for irrigation, 16,800 acre-feet for stockwater, 8,730 acre-feet for LADWP recreation and wildlife projects, and 22,430 acre-feet for enhancement/mitigation projects, including Klondike Lake, Lone Pine Riparian Park, treelots in Independence and Lone Pine, several native pastures and alfalfa fields, and the Lower Owens River rewatering project.

LADWP's April 27, 1998 snow survey reported water content in the Mammoth Pass snowpack as 64.1 inches. The 1998 snowpack varied throughout the Eastern Sierra from 163% of normal at Mammoth Pass to 119% of normal at Rock Creek. Measurements at LADWP's snow survey stations at Big Pine Creek and Cottonwood Lakes were 164% and 183%, respectively.

Runoff in the Owens Valley for April 1998-March 1999 was projected by LADWP at about 603,800 acre-feet or 152% of normal. Recharge to the valley's aquifers for the 1998 water year (October 1, 1997–September 30, 1998) was estimated to be 233,131 acre-feet.

Table 1. Owens Valley Groundwater Pumping (Runoff Year 1998-1999) and Estimated Recharge (Water Year 1998) by Wellfield.

Wellfield	Pumping (acre-feet) April 98-March 99	Est. Recharge* (acre-feet) Oct 97-Sept 98
Laws	483	21,529
Bishop	4,556	54,557
Big Pine	22,645	39,387
Taboose-Aberdeen	547	
Thibaut-Sawmill	12,940	48,218
Independence-Oak	6,692	
Symmes-Shepherd	1,372	
Bairs-Georges	72	50,911
Lone Pine	2,268	18,529
Total	**51,575**	**233,131**

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

Perspective

Continued from page 3

conditions set by the agreement. However, the monitoring has shown conditions improving to equal or greater than baseline conditions with the recovery of water tables combined with the return of average or above precipitation. Similar vegetation recovery is expected in the other areas as water tables return to pre-drought levels.

Despite the demonstrated resiliency of the valley's groundwater dependent vegetation, uncertainty remains as to the ability of the vegetation to repeatedly rebound if future groundwater pumping causes significant fluctuations in water tables. Consequently, in June 1998, the Inyo/Los Angeles Standing Committee agreed to conduct cooperative studies that could affect future groundwater management. The Standing Committee also agreed that, while the cooperative studies are being conducted over a 3 to 5 year period, groundwater pumping will continue to be managed in an environmentally conservative manner. The Inyo/Los Angeles Technical Group is expected to present its recommendations for the cooperative studies and for a conservative groundwater management policy to the Standing Committee in 1999.

In early 1998, Los Angeles proposed expanding its groundwater pumping beyond the Owens Valley floor to Owens Lake. Early in the year, Los Angeles announced that it planned to investigate the feasibility of pumping groundwater from Owens Lake to supply water to its dust abatement program on the lake. Any groundwater pumping by Los Angeles from anywhere in Inyo County is regulated by the agreement. Since Los Angeles has never previously pumped from the lake, a cooperative study was commenced to determine whether groundwater may be safely pumped from under the lake in both the short-term and the long-term.

The county and the city, through the consultant Camp, Dresser & McKee, commenced a workshop process to document the public's concerns regarding the proposed pumping from the lake. The concerns expressed by the public will be used by the county and the city in setting the environmental controls that will govern any pumping from the lake.

Concerns over groundwater pumping were not limited to actual or proposed pumping by Los Angeles during 1998. A private corporation, the Western Water Company, announced its intention to purchase property and/or water rights in the Olancha area. The company wants to pump groundwater and sell it to Los Angeles. Faced with this new situation, in early 1998, the county and Los Angeles agreed that the city would not purchase water extracted or diverted from Inyo County unless the county is satisfied that the purchase will not harm the economy or environment of the county.

In the fall of 1998, the county adopted a comprehensive groundwater management ordinance that regulates water export

Continued on page 5

Reports

Soils

Transpiration coefficients for three Great Basin shrubs. Aaron Steinwand. May 1999.

Vegetation

Results of 1997 vegetation re-inventory. Sally Manning. May 1998. Amended May 28, 1998.

The effects of water table decline on groundwater-dependent Great Basin plant communities in the Owens Valley, California. (in press) In: McArthur, E. Durant; Ostler, W. Kent; Wambolt, Carl L. comps. 1999. Proceedings: Shrubland Ecotones. 1998 August 12-14, Ephraim, UT. Proceedings RMRS-P-000. Ogden, UT: U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Dec. 1998.

Condition of selected vegetation parcels and assessment according to the drought recovery policy. (Draft) Inyo County Water Dept. staff. March 1999.

Quantifying vegetation change in Owens Valley, CA using Spectral Mixture Analysis and the Normalized Difference Vegetation Index. (ms in review) Submitted to: Remote Sensing of Environment. Andrew J. Elmore, John F. Mustard, Sara J. Manning and David B. Lobell. March 1999

Summary of 1998 perennial cover and life form changes in parcels inventoried with line-point transects. Sally Manning. April 14, 1999.

Patterns of vegetation response to groundwater pumping detected with field monitoring and Landsat TM data. Ecological Society of America. Spokane, WA. (abstract submitted and accepted for August 1999 meeting) Sara J. Manning, John F. Mustard and Andrew J. Elmore. January 1999

Precision and accuracy of remotely sensed data for quantitative analysis of vegetation change in a semi-arid region. Ecological Society of America. Spokane, WA. (abstract submitted and accepted for August 1999 meeting) Andrew J. Elmore, John F. Mustard, Sara J. Manning, and David B. Lobell. January 1999

Revegetation plan for impacts identified in the LADWP, Inyo County EIR for groundwater management. Irene Yamashita. May 1998.

Hydrology

Multiple regression modeling of water table response to pumping and runoff. Robert Harrington. November 1998.

Bishop Cone audit for the 1997-1998 runoff year. (Report 98-2) Randy Jackson. September 1999.

Annual pumping plan memorandum report. Randy Jackson. April 1998.

Drought effects to the Thibaut Creek Area: declines in shallow groundwater levels and Thibaut Creek flows to the intake due to drought memorandum report. Randy Jackson. March 1999.

Owens Valley depth to groundwater grid development and integration with Geographic Information Systems: 1985-1997. Chris Howard. October 1998.

Modeling ionic solute transport in melting snow. Water Resources Research, 34, 1727-1736. Robert Harrington and R.C. Bales.

Interannual, seasonal, and spatial patterns of meltwater and solute fluxes in a season snowpack. Water Resources Research, 34, 823-832. Robert Harrington and R.C. Bales. 1998.

Activities

Conferences

Nevada Water Resources Association Meeting, Fall 1998, Las Vegas, Nevada, Randy Jackson.

Nevada State GIS Conference, January 1998, Las Vegas, Nevada, Chris Howard.

Wildland Shrub Symposium: Shrubland Ecotones, Aug. 12-14, 1998, Ephraim, UT, poster presented by Sara J. Manning: The effects of water table decline on groundwater-dependent Great Basin plant communities in the Owens Valley, California.

Professional Soil Scientists Association of California workshop on the preparation of soil monoliths, Aaron Steinwand.

Professional Soil Scientists Association of California Annual Meeting, March 1998, Death Valley, California, Aaron Steinwand.

California Exotic Pest Plant Council (CalEPPC), October 2-3 1998, Ontario, California, Brian Cashore.

Tamarisk Workshop, June 17, Ontario, California, Brian Cashore.

Weed Management Workshop, March 25, 1998, Reno, Nevada, Brian Cashore.

Education

University of California Environmental Biology "Supercourse." Invited instructor and poster judge. Supervised student research projects. Sally Manning.

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

Eastern Sierra Institute Teacher Training Workshop. Lecture, field training and GIS demonstration of ICWD monitoring techniques and results and lead discussion on water resource management. Sally Manning, Denise Waterbury, Derik Olson, and Irene Yamashita.

Tahoe-Baikal Institute. Gave presentation on ICWD history and monitoring (which was simultaneously translated into Russian) and led group in hands-on activities. Sally Manning and Brian Cashore.

Inyo County schools science fair judges: Aaron Steinwand, Chris Howard, Robert Harrington, Brian Cashore.

Edited "Study Guide for the Soil Science Fundamentals Exam," the national exam for certification of professional soil scientists. Aaron Steinwand

Co-leader of Brigham Young University saline and sodic soils fieldrip to Owens Lake, Aaron Steinwand.

Accomplishments

Aaron Steinwand was successfully recertified as a professional soil scientist by the ARCPACS, a national federation of certifying boards for professionals in agriculture, biology, earth, and environmental sciences.

Chris Howard was awarded a grant from the USGS Federal Geographic Data Committee to establish the Eastern Sierra Geospatial Data Clearinghouse at the University of California's White Mountain Research Station.

Figure 8 shows how SMA-derived percent live cover measurements compare to field measurements at the IO1 monitoring site. A seasonal cycle is apparent in the field measurements that were taken more frequently than the satellite measurements. However, for each August measurement between 1991 and 1996 (all of which are concurrent between data sets), the measurements are nearly identical. Error bars, shown in the lower left-hand corner of Figure 8, were derived from our understanding of the method (for SMA) and repeat measurements (for field data).

We have accurately located all of the 33 permanent monitoring sites in each yearly satellite image and have extracted the corresponding live cover estimates. These data can be summarized by comparing each satellite measurement with its concurrent field measurement, as in Figure 8. In addition, our research is concerned with year-to-year changes in percent live cover; therefore, we have subtracted from each measurement the value from the previous year. These respective changes, in the satellite-derived and field-derived data sets, have been plotted against each other in Figure 9. The lines drawn on the plot represent distances of 4.0% and 8.0% from the best fit line and show the precision of this method at the 65% and 95% confidence limits.

Figures 8 and 9 demonstrate the strength of this approach. We have shown that we can measure percent live cover with an uncertainty of just +/-4.0. Our data sets cover the entire Owens Valley, allowing for regional monitoring of vegetation. These data can now be compared with ICWD's GIS data and maps for depth to groundwater, precipitation, soil type, and vegetation community information.

In the future, we hope the results of the remote sensing study will contribute to the development of a tool to predict the effects of drought and groundwater pumping on Owens Valley vegetation on a regional scale.

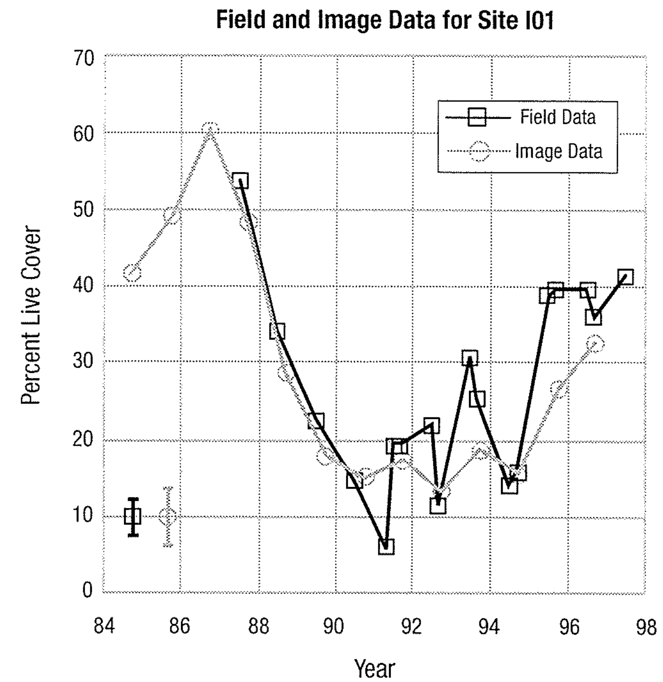


Figure 8. Percent live cover during the last 15 years as measured in the field and from satellite imagery for the I01 monitoring site. Field data were collected several times a year, thus detecting seasonal variation, while the satellite data show just late summer of each year.

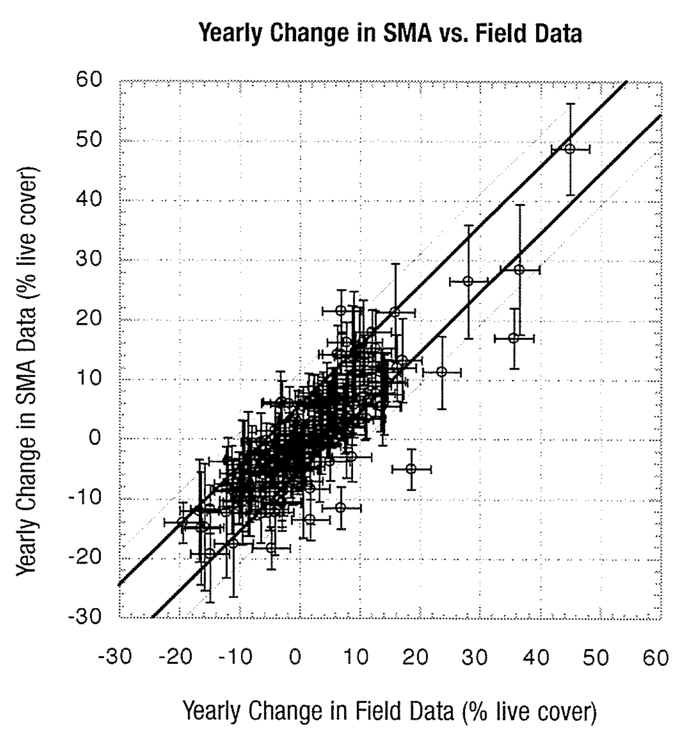
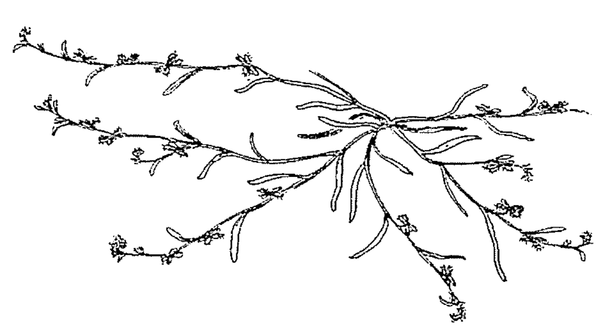


Figure 9. Changes in percent live cover from one year to the next as measured from satellite images (Spectral Mixture Analysis) and in the field show excellent correlation. Heavy and light lines represent one and two standard deviations from the best fit line, respectively.



Slender combseed *(Pectocarya penicillata)*

Groundwater Conditions

Robert Harrington, Assistant Hydrologist
Leah Kirk, Environmental Project Coordinator

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. The Los Angeles Department of Water and Power maintains this network as part of its regular operations. The information collected at these sites helps the Inyo County Water Department 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 or monthly. At a few sites, ICWD and LADWP have installed continuous monitoring devices.

These data are used each year to predict water level changes at selected indicator wells throughout the valley. Multiple linear regression equations developed for these monitoring wells allow ICWD and LADWP to predict the water table response to different groundwater pumping scenarios (see "Predicting Water Table Response to Groundwater Pumping" on page 16).

Under the conservative groundwater management of the Drought Recovery Policy, LADWP's pumping has been relatively low since 1990 and water tables have gradually climbed. In general, water tables continued their upward trend during 1998, due to high recharge and low pumping. Figure 1 shows that as of April 1999, water tables were approaching baseline levels over much of the valley. "Baseline" is the average April water-level from 1985-1987.

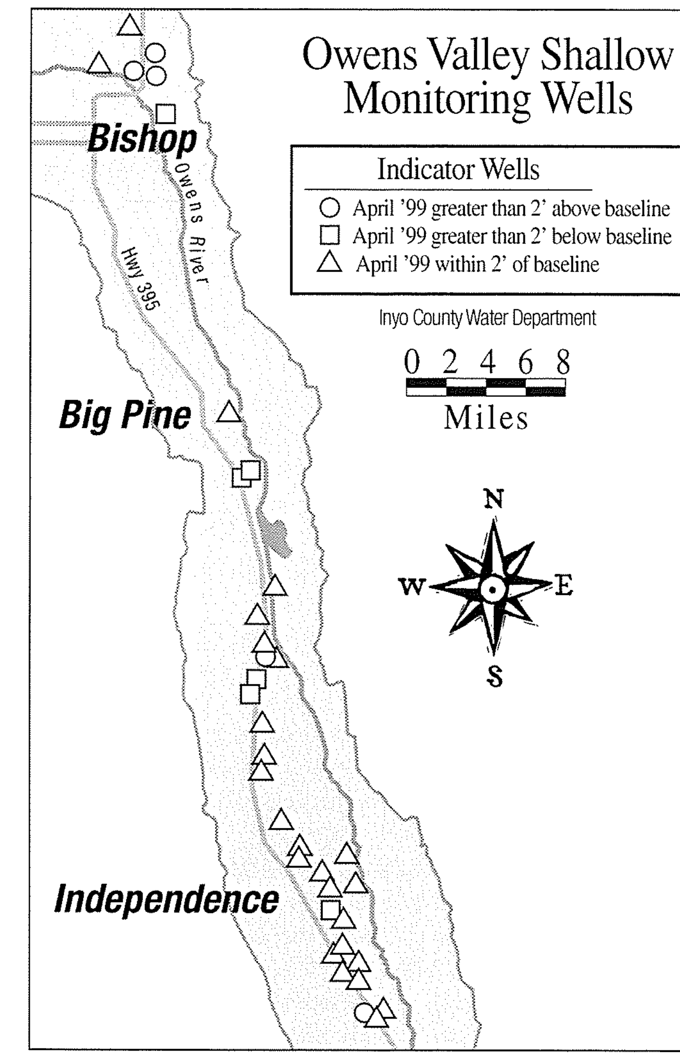


Figure 1. Water levels as of April 1999 in selected shallow monitoring wells relative to baseline groundwater conditions.

Perspective

Continued from page 4

projects, such as the project proposed by the Western Water, through a conditional use permit process. Under the ordinance, a project may not proceed unless the county finds it will not harm the environment or economy of the county.

Although much was accomplished in 1998, many challenges remain. Cooperative studies to improve groundwater management must be identified, agreed upon, and conducted by the county and Los Angeles. A conservative groundwater management policy remains to be agreed upon by the Standing Committee. The environmental "rules" that will govern any groundwater pumping from Owens Lake must be established by the Standing Committee, and it must be determined whether any pumping can take place under the "rules." Western Water's proposed groundwater export project must be evaluated by the Water Department, and decisions must be made by the Inyo County Planning Commission as to whether or not a permit to allow the project to proceed should be issued. The environmental review process for the Lower Owens River Project must be completed before the project can be implemented. These activities and more (and perhaps others yet to be determined) will keep the folks at the Water Department busy in 1999 and during the coming years.

Soil Water Conditions

Aaron Steinwand, Soil Scientist/ Science Coordinator

Each month, the Inyo County Water Department's Derik Olsen and I visit 33 monitoring sites to measure the depth to groundwater and soil water content. The measurements are used to determine whether nearby Los Angeles Department of Water and Power wells can be pumped. This determination includes several factors besides soil water content (precipitation, for example) that may allow a site to be in "on" status even though the water table is not reaching the root zone.

We know that the Owens Valley plant communities that we monitor require periodic connection to the water table for long-term survival and recovery from drought. Through our monthly monitoring, we can easily detect the rise of water above the water table due to capillarity. The soil water and groundwater data show us which monitoring sites have plant root zones connected with the water table and which still need water table recovery. From these observations we can suggest possible reasons for vegetation conditions observed at a particular site and suggest appropriate pumping management.

For simplicity, the wellfield monitoring sites are grouped into three categories to summarize the root zone/water table connection. The connection between the root zone and groundwater is not only related to water table depth. It also depends on the rooting depth of the vegetation and the soil characteristics. For example, in similar soils, a shallower water table is necessary to supply groundwater to grass-dominated sites than shrub-dominated sites because of the shallower roots of the grasses. Similarly, the capillary rise above the water table in a silty soil is much greater than in a sandy soil, allowing plants access to groundwater from greater depths. Brief descriptions of the three categories of root zone/groundwater connection are given below. For management purposes, grass-dominated sites are assigned a root zone of 2 meters; shrub sites are assigned a 4-meter root zone.

- Disconnected: No groundwater is reaching the root zone. Six of the 33 monitoring sites occur in this category. Seven sites were disconnected last year.
- Weakly connected: Groundwater reaches the bottom 0.5 meters of the root zone. Six monitoring sites occur in this category. Nine sites were weakly connected last year.
- Connected: Groundwater extends to the middle of the root zone. Thirteen sites occur in this category. Nine sites were connected last year. All eight control sites located away from the effects of pumping also occur in this category.

Relatively low pumping since 1990 and several high runoff years have promoted substantial water table and soil water recovery from the declines induced by heavy pumping at the onset of the 1987-1992 drought. As of April 1, 1999, the water table was supplying water to the root zone at 19 of the 25 monitoring sites located in wellfields (Figure 2). This compares to about six sites with groundwater in the root zone near the end of the drought in 1992. A few sites, particularly in Laws, Big Pine, and south of Independence, still need additional water table recovery to supply groundwater to the root zone. These areas experienced large water table declines due to pumping and thus had the farthest to recover. The water tables in areas outside the wellfields were not affected by pumping. The root zones at monitoring sites in these areas remained connected to the water table throughout the drought.

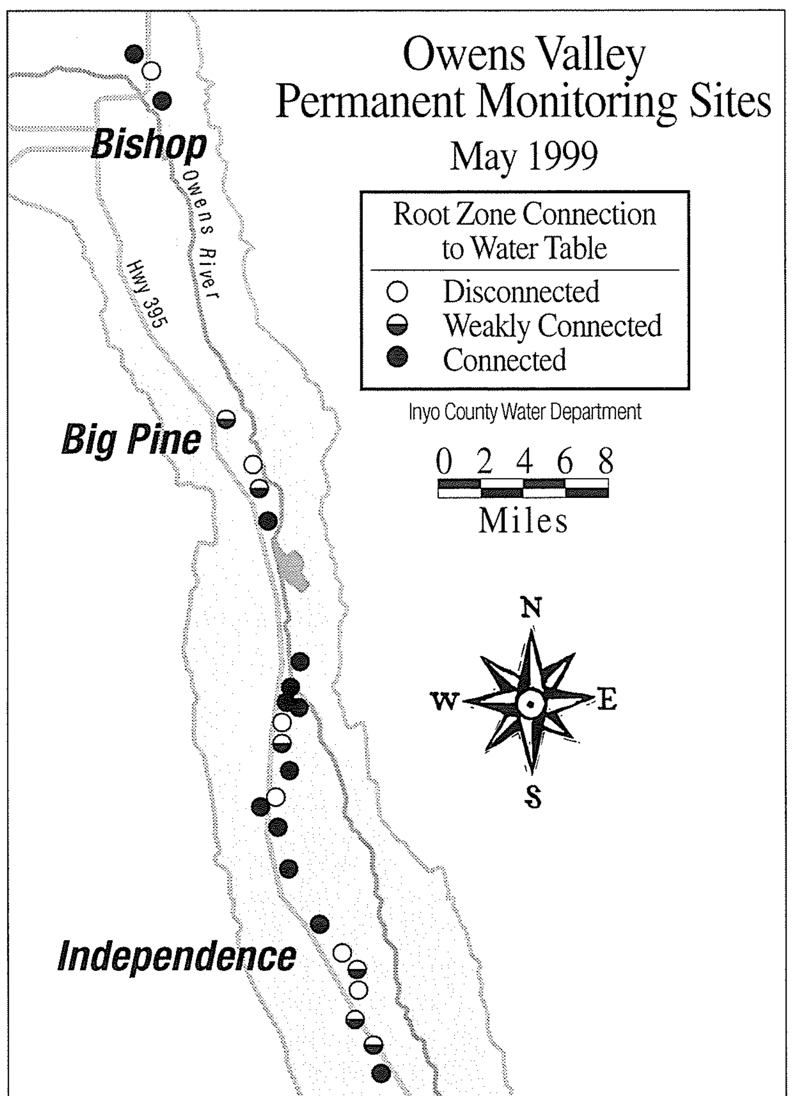


Figure 2. Owens Valley permanent monitoring sites

Characterization of Confining Layer Hydrologic Conductivity and Storage Properties

Purpose: to determine confining layer hydrologic properties to assist groundwater modeling efforts and improve the management of wells sealed to the deep aquifer. Without this information, the magnitude and timing of the effects of pumping deep aquifers will remain difficult to predict. A stepwise approach is proposed starting with analysis of existing data and progressing to low and high intensity field projects, if necessary.

Shallow and Deep Groundwater Geochemistry and the Source of Spring and Seep Water

Purpose: to improve groundwater modeling efforts to predict the effects of distant pumping on springs and seeps. This study will examine the geochemical signatures of springs and seeps and compare them to shallow and deep groundwater samples collected nearby to identify the source of the water.

Application of Canonical Community Ordination to Assess Vegetation Change

Purpose: to apply complex statistical techniques to an extensive dataset of vegetation measurements to quantify the importance of several environmental factors influencing vegetation changes observed in the last decade. To manage groundwater pumping and avoid adverse changes in vegetation, it is imperative to quantify the extent that water table fluctuations and other environmental factors affect vegetation over the long-term.

Inventory and Classification of Riparian Vegetation in the Owens Valley

Purpose: to inventory, classify, and map riparian vegetation on Los Angeles land in the Owens Valley to improve monitoring and management of these areas. To understand and measure groundwater pumping effects on sensitive vegetation requires quantitative data on what vegetation is present and appropriate techniques to monitor it.

Development of a Demographic Model for Nevada Saltbush *(Atriplex torreyi)*

Purpose: to use existing data for Nevada saltbush to develop a model that could allow researchers and managers to predict future population trends based on present conditions. This capability will provide the Inyo/Los Angeles Technical Group advance warning of the gradual conversion of one vegetation type to another, which is not allowed under the agreement.

Development of a Plant Community Dynamics Model for Owens Valley Vegetation

Purpose: to explore options for developing a model to simulate the response of plant communities to different groundwater and vegetation management scenarios. This study will be developed following the completion of an air photo study currently underway.

Remote Sensing Study of Owens Valley Vegetation

Andrew Elmore, Brown University

Over the past two years, scientists at the Inyo County Water Department have been working with researchers at Brown University, Rhode Island, on a remote sensing study of Owens Valley vegetation. This study integrates the ICWD Geographic Information Systems (GIS) database and detailed field measurements with Landsat TM satellite data processed at Brown to analyze changes in vegetation abundance. The purpose of this study is to understand how semi-arid land cover units respond to climatic and anthropogenic forces over a decadal time period at the regional scale. The regional effects of these forces are extremely difficult to measure with field measurements alone. Most of the work completed on this project to date has centered on the validation of remotely derived percent live cover estimates against actual field measurements.

Landsat TM data were used to characterize annual changes in vegetation abundance from 1984 to 1997. Vegetation abundance information is 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 is calculated. This method, called Spectral Mixture Analysis (SMA) is a developing approach that is gaining acceptance in the remote sensing community. More commonly used methods of measuring vegetation abundance from remotely sensed data have been shown to be affected by the background soil color and to saturate at high vegetation abundance. We have shown, however, that SMA has neither of these properties and is highly correlated with field measures of percent live cover.

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Coyote willow *(Salix exigua)*

New Program of Cooperative Studies

Aaron Steinwand, Soil Scientist/ Science Coordinator

Nearly a decade ago, Inyo County and Los Angeles developed the techniques for groundwater and vegetation management that became the basis for the Inyo/Los Angeles water agreement and its technical appendix, the Green Book. At the time, it was recognized that there would be a need for continuing research and cooperative studies to achieve the goals of the agreement. Consequently, the agreement was designed to be flexible to allow adoption of improved techniques. Very few studies were conducted in recent years, however, due in part to litigation over the 1991 environmental impact report for groundwater management in the Owens Valley. Also, during the recent drought, the Green Book's methods were superceded by the goals and conservative management provisions of the Drought Recovery Policy.

The litigation ended in 1997, and the effects of the drought are diminishing in many areas of the valley. The Inyo/Los Angeles Technical Group, therefore, determined it was timely and appropriate to undertake a cooperative study program to investigate several areas of concern regarding the Green Book's methods for managing groundwater pumping. At its June 1998 meeting, the Inyo/Los Angeles Standing Committee concurred and directed the Technical Group to design studies addressing the concerns.

The central question that must be answered to successfully manage groundwater pumping and achieve the goals of the water agreement is: What amount of pumping avoids adverse changes to the vegetation and provides a reliable supply of water for Inyo and Los Angeles? To answer that question, the natural environment must be understood. Briefly, the underlying assumption about the Owens Valley environment is that vegetation conditions are substantially influenced by water table depth and fluctuations. This assumption is supported by multiple lines of evidence that will not be described here. Thus, to include the critical variables affecting the vegetation, pumping decisions should consider the expected water table drawdown and the vegetation's tolerance to water table fluctuations. To accomplish this, the studies proposed by the Inyo County Water Department's scientific staff were directed specifically at improving the tools used to predict the effect of pumping on the water table and at quantifying how Owens Valley plant communities respond when several environmental factors change simultaneously, including water level fluctuations caused by pumping. ICWD has proposed the following studies to improve the methods for managing groundwater in the Owens Valley.

Nevada saltbush *(Atriplex torreyi)*

Development of Hydrological Modeling Tools

Purpose: to improve current hydrological modeling tools used to evaluate the impact of groundwater pumping on depth to the water table. This will provide a method for consistent interpretation of groundwater data and evaluation of management options.

Development of a Model for Predicting Plant Water Use and Soil Water Replenishment

Purpose: to combine information from vegetation, groundwater, precipitation, and soil water monitoring into a model to predict depletion and replenishment of stored soil water above a fluctuating water table. This capability will help protect Owens Valley vegetation by predicting how long soil water will support the vegetation after pumping commences and could provide reliable forecasts of expected pumping yields when evaluating groundwater management strategies.

ET From Groundwater Dependent Plant Communities: Comparison of Micrometeorological and Vegetation-based Measurements

Purpose: to provide direct measurements of evapotranspiration (ET) using micrometeorological methods to corroborate Green Book estimates derived from vegetation transpiration curves. If accurate, estimating ET from simple vegetation measurements offers important advantages for groundwater management. The ET component of the groundwater balance is not well quantified, and results from this study may be applied to improve numerical groundwater models. ET estimates also may be an important component of improved groundwater management strategies.

Vegetation Conditions

Sally Manning, Vegetation Scientist

This issue of the Monitor provides a timely opportunity to discuss what has been observed, measured, and learned about the Owens Valley vegetation. Since the vegetation was inventoried and mapped in the mid-1980s, the Owens Valley environment has progressed through a full cycle, from a wet period, to drought, and back to a wet period. This cycle has allowed the Inyo County Water Department scientists to assess a wide range of vegetation responses to conditions imposed not only by the weather, but also due to pumping during this period. Results will be summarized in general terms; details of the data can be found in the reports listed at the end of this issue.

Water tables were generally high throughout the valley when the Los Angeles Department of Water and Power performed the baseline vegetation inventory during the mid-1980s. Vegetation conditions during that period were therefore the result of a series of wet years (1982-86) and sufficient water provided from groundwater. Other factors influencing the baseline vegetation conditions included site substrate properties (for example soil type), relatively recent land use history, and effects of herbivores (organisms that feed on plants).

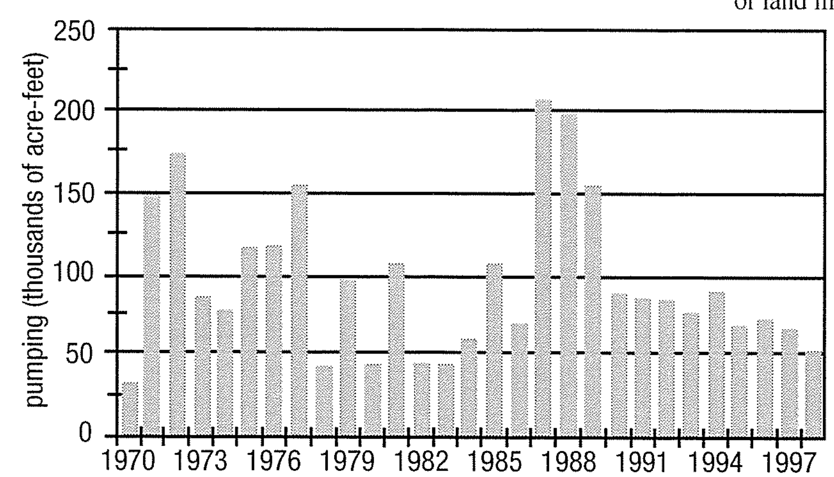


Figure 3. Annual LADWP pumping 1970-1998.

As the inventory was being completed in 1987, there was a dry year and LADWP pumped nearly 210,000 acre-feet. The following year, 1988, was also dry, and pumping again exceeded 200,000 acre-feet (Figure 3). In the fall of 1989, Inyo County and Los Angeles began to apply newly developed groundwater management techniques at then-existing permanent monitoring sites. Because several of the monitoring sites were in soil water deficit at that time, pumping was reduced to 155,000 acre-feet. The heavy pumping during these years, combined with the drought period that lasted well into the 1990s, drove the water tables to significant depths in the wellfield areas. In most of the wellfields, water tables were substantially below baseline levels and plant root zones by 1991.

Because of the drought, LADWP and Inyo County adopted a Drought Recovery Policy. The policy recommended that water tables, soil moisture, and vegetation be allowed to recover. As a result, from 1990 through 1998, annual groundwater pumping ranged between 50,000 and 90,000 acre-feet (Figure 3).

Precipitation in 1993 was above normal, and from 1995 onward, the drought gave way to a series of wet years. Water tables responded to the reduced pumping and increased recharge by rising. By 1998, water tables had returned to baseline (mid-1980s) levels in portions of some wellfield areas. However, although water tables had risen regionally, they remained below baseline levels in large portions of most wellfields.

Patterns of Water Table and Vegetation Response

Since 1991, ICWD has re-inventoried a subset of Owens Valley vegetation parcels in an effort to detect changes in perennial cover and species composition. A vegetation parcel is a unit of land mapped as homogeneous vegetation during the LADWP baseline inventory. The parcels were selected to provide information on vegetation conditions within wellfields and at locations far from the effects of pumping (control areas). Results of each annual inventory were compared with LADWP baseline vegetation conditions.

Before analyzing the vegetation data set for a given year, the best available information on depth to the water table (DTW) is assembled. Methods for assessing the water table conditions beneath a given unit of land area have improved since employing Geographic Information System (GIS) techniques (see past issues of the Monitor). Using data from over 150 test wells located throughout the valley, a spatial statistics routine is run to develop an estimation of the water table depth for all areas being monitored. With this technique, the average DTW beneath a selected vegetation parcel in April of any year from 1985 onward can be estimated. Graphing the estimated DTW during the past 14 years shows a picture of water table fluctuation beneath the parcel, and adding the vegetation data to the same graph allows certain trends in vegetation to be compared with water table conditions.

Three general patterns of water table change and vegetation response were observed in the re-inventory data as of 1998. These patterns were assigned to the categories shown in Table 2.

Table 2. General categories of water table and vegetation response, 1985 through 1998, for Owens Valley vegetation parcels inventoried in 1998.

CATEGORY	DEFINITION
Control	water table beneath parcel has remained relatively constant and was not found to have been affected by groundwater pumping during the drought (see Figure 4A for example)
Wellfield	water table was drawn down due to pumping during the drought and in April 1998 had not risen to the range where it had been during baseline years OR water table had returned to baseline range, but perennial cover was determined to be below baseline level (see Figure 4B)
Recovered Wellfield	water table was drawn down due to pumping during the drought, then had recovered by 1998 or before and has been maintained in the range where it was during baseline years and perennial cover reached baseline levels (see Figure 4C)

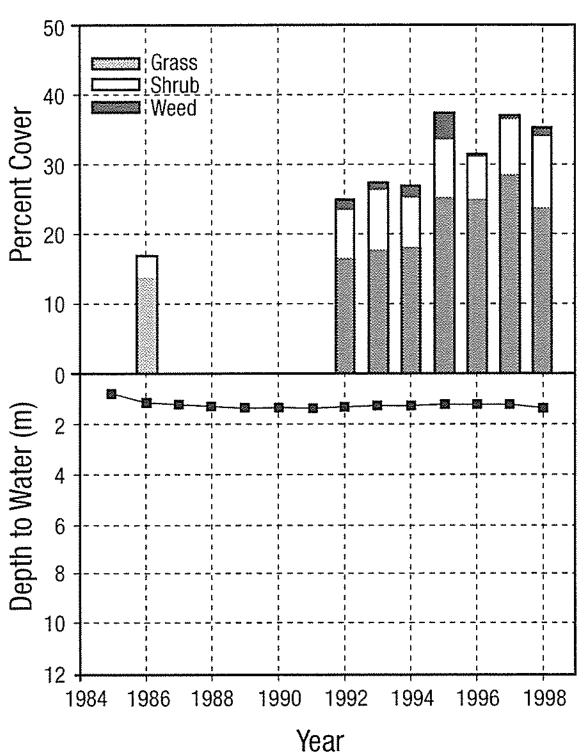


Figure 4A. Big Pine 31

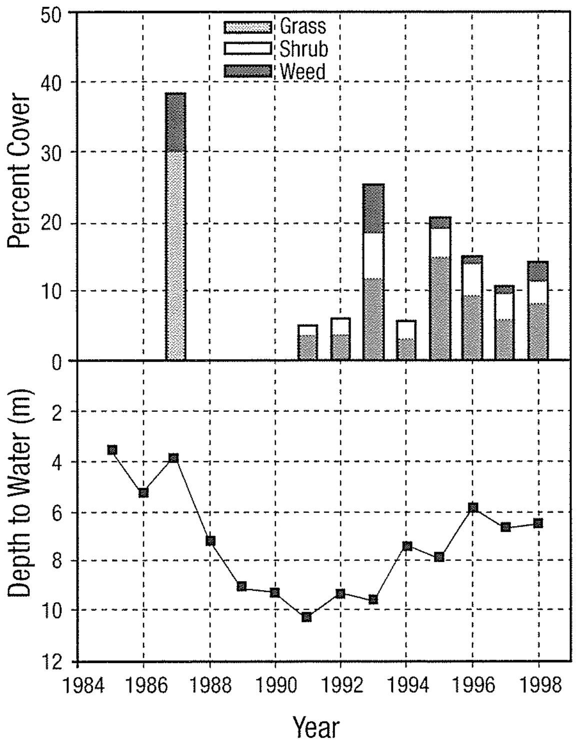


Figure 4B. Laws 85

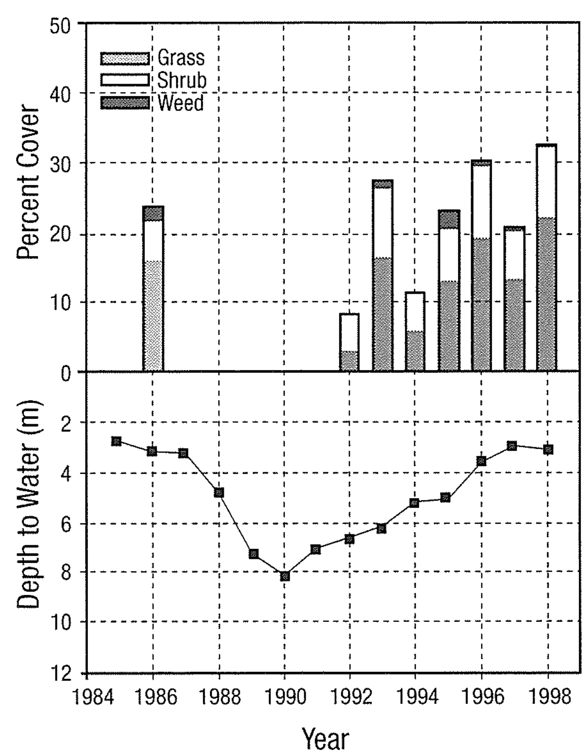


Figure 4C. Blackrock 39

Figure 4. Examples of water table changes, 1985-98, and measured vegetation cover in the years for which field data were collected. (A) A control parcel. Depth to water varied negligibly during and after the drought (1987-92). Vegetation remained very similar to baseline during the drought period but has increased in more recent wet years (1995-98). (B) A wellfield parcel. The water table beneath this parcel was drawn down due to pumping during the drought. Vegetation cover declined below baseline. Neither water table nor vegetation had recovered to baseline levels in this parcel. (C) A recovered wellfield parcel. The water table beneath this parcel was drawn down due to pumping during the drought, but began rising and returned to baseline level. Vegetation cover declined below baseline during the drought, but has since returned to baseline levels.

Owens Lake Groundwater Evaluation

Robert Harrington, Assistant Hydrologist

In July 1998, the Los Angeles Department of Water and Power and the Great Basin Unified Air Pollution Control District signed a Memorandum of Agreement specifying a timetable for implementing dust abatement measures on the Owens Lake playa. The MOA requires that LADWP have 10 square miles of dust abatement measures in place by 2001, with incremental implementation after that. By 2006, LADWP must have attained federal air quality standards. The dust abatement measures identified as being feasible are seasonal shallow flooding, cultivation of salt grass, and spreading of gravel on the playa surface. The first two of these methods require large volumes of water, and LADWP has proposed using groundwater from beneath the Owens Lake to meet part of the water need. Because the Inyo/Los Angeles water agreement applies to any LADWP groundwater extraction in Inyo County, the Inyo County Water Department must evaluate the proposal and determine whether it complies with the agreement.

To conduct the evaluation, Inyo County and LADWP agreed to retain, at LADWP's expense, an independent consultant. The first phase of the evaluation comprises three tasks: (1) solicit input from the public regarding the environmental criteria by which groundwater pumping impacts should be judged, (2) evaluate LADWP's proposed near-term (1999-2001) groundwater pumping at Owens Lake, and (3) prepare a workplan for technical work to be done on the lake for a long-term evaluation of the resource. The execution of the work described in the workplan will be undertaken during a second phase of the evaluation. In September 1998, Camp Dresser& McKee was awarded the contract for the first phase of the evaluation. ICWD is administering the contract.

CDM has sought public input by conducting a series of meetings and interviews, and has worked with ICWD, LADWP, and the public to develop standards and objectives for groundwater pumping. The standards and objectives recommended by the public include protection of non-LADWP wells; protection of springs, seeps, and other water-dependent habitat; and prevention of subsidence near buildings and other infrastructure. CDM will compile the public's recommended standards and objectives, and convey them to the Inyo/Los Angeles Standing Committee in summer 1999.

CDM's work also includes evaluating LADWP's proposal for using water from APCD's wells for a one square mile dust mitigation prototype to be implemented in 1999-2001. Under LADWP's proposal, they will use about 1,400 acre-feet during 1999 and 2,700 acre-feet during 2000 and 2001. Monthly average groundwater production rates would peak at approximately 470 acre-feet per month during late summer. To evaluate the impacts of this initial pumping, CDM is revising an existing groundwater model that was developed by a team of scientists working for APCD. Modifications to the groundwater model include improving the representation of the hydrostratigraphy of the Owens Lake groundwater system, increasing the spatial resolution of the model, and improving the representation of evapotranspiration and spring flow. These modifications will improve the model's ability to predict the effect of the proposed pumping. ICWD, APCD, and LADWP have acted in an advisory and review capacity for the technical aspects of the evaluation. The evaluation will be completed in summer 1999.

The long-term work plan will include recommendations for further work needed at Owens Lake to evaluate the groundwater resources available for LADWP's use in dust mitigation. Components of this work plan will include recommendations for further data collection and groundwater modeling necessary to evaluate the long-term availability of groundwater. The long-term workplan is scheduled to be finalized in late 1999.

Above: Spring mounds at Owens Lake. Photograph by Jim Paulus/APCD

Predicting Water Table Response to Groundwater Pumping

Robert Harrington, Assistant Hydrologist

For the past several years, the Los Angeles Department of Water and Power and the Inyo County Water Department have used forecasts of water table response to pumping to develop and evaluate annual pumping plans. These forecasts are based on multiple linear regression modeling of eighteen shallow monitoring wells that serve as indicators of water table conditions. As specified in the Inyo/Los Angeles water agreement, every April LADWP presents Inyo County with projections of runoff and proposed pumping for the next twelve months. Inyo County evaluates the plan in light of existing and projected vegetation, groundwater, and soil water conditions. To better predict the effects of pumping on water table levels, ICWD improved existing multiple regression models. The improvements were twofold: (1) the number of indicator wells was enlarged by screening all shallow monitoring wells for suitability as indicator wells, and (2) a method of evaluating the uncertainty in the predictions was developed.

The multiple regression models use the relationship between the measured water table fluctuations at monitoring wells and records of pumping and runoff to predict the response of the water table to a given amount of pumping and recharge. ICWD hydrology staff looked at 170 shallow monitoring wells for suitability as indicator wells. The periods of record for the modeled monitoring wells ranged from 6 to 23 years. Multiple regression models were developed for each well and, based on a set of statistical tests, each of these wells was classified as (1) affected by both pumping and runoff, (2) affected by pumping, (3) affected by runoff, or (4) unaffected by either pumping or runoff. Wells affected by pumping and runoff or affected by pumping were regarded as useful for evaluating pumping plans. Other non-statistical criteria, such as distance from LADWP wellfields or proximity to future Lower Owens River Project rewatering areas resulted in a final culling of the set down to 37 wells that appeared useful as indicator wells.

ICWD hydrology staff incorporated statistical methods into the models that provide both predictions of the likliest result and estimates in the uncertainty in that prediction. In the future, we can use such estimates of prediction uncertainty to examine various pumping scenarios, and to evaluate the probability of certain events occurring. For example, when evaluating a pumping plan's effect on vegetation health, we may want to know the probability that the water table will recover to the root zone as well as the likeliest water table elevation. Figure 7 shows the results of simulations of shallow monitoring well 419T, in the Taboose-Aberdeen (TA) wellfield. During the first year of the simulation, various rates of pumping from the TA wellfield are shown along the bottom axis; during the subsequent three years, TA pumping was held at 3,000 acre-feet per year to allow the water table to recover. The vertical axis shows the likelihood that the depth to water (DTW) in the well will not recover to 2.0 meters by the end of the runoff year (starting from a DTW of 1.4 m, approximately the water level extant in April, 1998). The significance of the 2.0 m DTW is that it is the approximate depth of the rooting zone of the vegetation at the site (an alkali meadow). It is clear from Figure 7 that a single year of high pumping from the TA wellfield is likely to affect this site for several years.

In the future, ICWD hydrology staff plans to integrate the multiple regression models with soil water balance models and evapotranspiration models, and to compare them with other hydrologic modeling tools. Integration with soil water balance and evapotranspiration models will be useful for projecting how long a given supply of soil water can sustain healthy native vegetation. A comparison of regression and other hydrologic models will allow ICWD hydrology staff to choose the best predictive tool at a given location for assessing the effects of groundwater pumping.

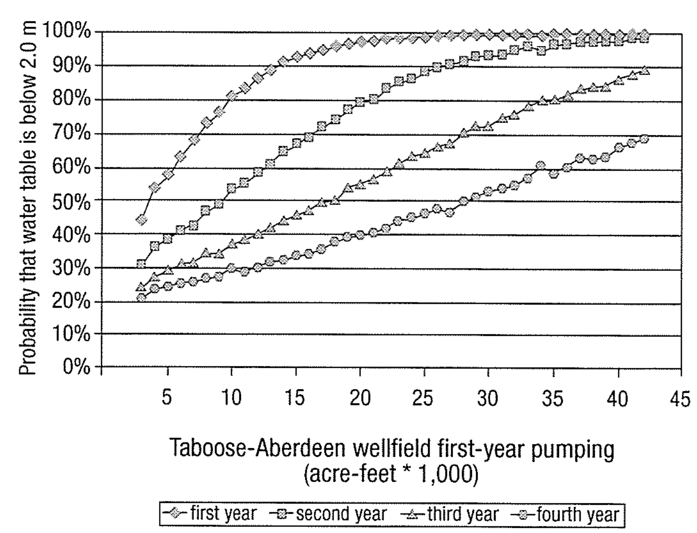


Figure 7. Four-year simulation of water table recovery to 2.0 meters at monitoring well 419T, TA wellfield. Second, third, and fourth year's pumping is held at 3,000 acre-feet/year. 2.0 meters is the approximate rooting zone depth at the site.

Examples of DTW and vegetation data for each of these categories appear in Figure 4. Five 1998 re-inventoried parcels did not fit neatly into any of the above categories. I have recommended that more investigation of the hydrologic data associated with the latter parcels take place.

The general responses of perennial plant cover to water table changes during and after the drought have been as follows:

Control - During the drought, perennial cover remained generally equal to baseline for parcels in this group. Since 1995, cover in the control parcels has increased significantly above baseline levels (Figure 5) and in 1998 it averaged 11% above baseline (Table 3). It is expected that a dry year, like 1999, would bring about a drop in cover, but it is not likely that perennial cover in these parcels would decline below baseline levels.

Wellfield - Perennial cover in the pumped areas declined significantly below baseline levels during the drought years. Although this group's post-drought cover responses have been variable, during the two wettest years, 1995 and 1998, the group showed no statistically significant difference from baseline levels (Figure 5). The data strongly suggest that, without the presence of the water table in the plant root zones in these parcels, a subsequent dry year would result in a decline in average perennial cover to below baseline levels.

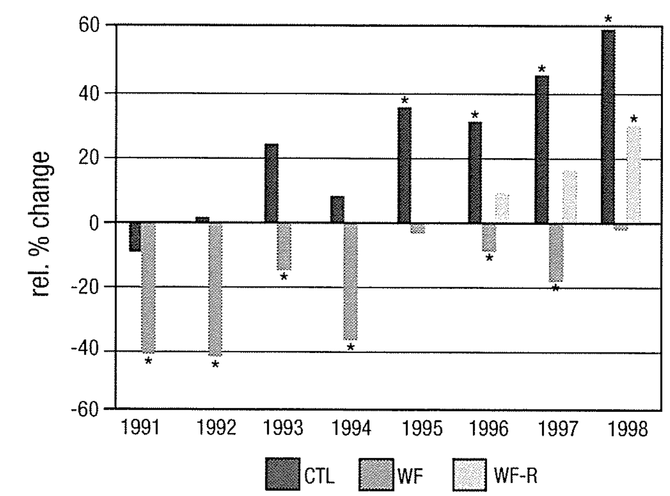


Figure 5. Percent change in perennial cover relative to baseline for re-inventoried parcels in the years and categories shown (CTL = control; WF = wellfield; WF-R = recovered wellfield, the latter category was not created until water tables returned to baseline levels beginning in 1996). Changes that are statistically significantly different from baseline, in either the positive or negative direction, are indicated by asterisks.

Table 3. Some results of monitoring for vegetation changes between LADWP baseline years (1984-87) and 1998 (as measured by ICWD). Asterisks denote statistically significant changes in that category.

	CONTROL (31 parcels)		WELLFIELD (33 parcels)		RECOVERED WELLFIELD (14 parcels)	
	DWP baseline	Inyo 1998	DWP baseline	Inyo 1998	DWP baseline	Inyo 1998
perennial cover	25.63	36.81	26.69	24.40	33.80	41.91*
grass	15.55	19.47	12.88	8.82*	19.07	24.52*
shrub	9.45	13.36*	13.16	14.13	11.40	15.67*
weed	0.68	3.21*	3.78	11.79*	2.24	6.67*

Recovered Wellfield - From 1991 through 1995, this group was indistinguishabe from the wellfield parcels, where perennial cover averaged below baseline level. However, with return of the water table to baseline levels and maintenance of the water table at those levels, this group (14 parcels in 1998) could be separated from the remaining wellfield parcels (Figure 5). Perennial cover in this group had risen an average of 8% above baseline cover in 1998 (Table 2). This increase in cover has not been as great as the increase measured in the control group, but nevertheless it is statistically significant.

The vegetation data also show changes that have occurred in the cover of grass, shrub, and weed species since baseline years. In both control and recovered wellfield areas, shrubs have increased significantly (Table 3). This increase does not indicate a conversion of community type from meadow to scrub as of 1998, because total cover was also higher than baseline in 1998, and grasses had increased to some degree in both of these groups as well. Weed cover was also significantly greater in 1998 than baseline levels in all types of parcels. Weeds are predominantly non-native annual species, but also include some invasive perennial species. The biggest increase in weed cover was measured in the wellfield group which contained nearly 12% cover of weeds in 1998 (Table 3).

The vegetation responses tracked through the drought cycle suggest that in about one-third of the area affected by pumping, both water table and perennial plant cover returned to baseline levels by 1998 (Figure 6). Although not monitored in the past, many of these areas had been affected to some degree by pumping prior to the 1980s. The return of perennial cover and composition following water table recovery is evidence that existing vegetation at these sites is somewhat drought and pumping tolerant. It is not currently understood, however, what the effects of the recent drought cycle will be on the long-term health of the existing vegetation. Changes in shrub cover, increases in weed cover, and other factors such as the age of plants and the ability of the site to recruit new plants will influence the future of the plant communities occupying these areas.

Of greater concern are the remaining two-thirds of the areas affected by pumping where water tables have not returned to baseline levels since the drought ended (Figure 6). Unlike after previous drought cycles and unlike the recovered wellfield areas, the water tables in these areas have not returned to their previous (high) levels, so the vegetation at these sites remains subject to potentially stressful conditions. It is likely that, if another drought begins before the water table recharges soil water in the root zones of the dominant plants at these sites, the risk of permanent adverse vegetation change would increase.

In June 1998, the Inyo/Los Angeles Standing Committee asked the Inyo/Los Angeles Technical Group to recommend a program to manage pumping in a conservative manner while studies concerning groundwater management are conducted. Based on the analysis of the 1998 vegetation and groundwater data, ICWD staff offered the following interpretation of conservative pumping to the Technical Group:

- In wellfield areas where water tables and vegetation cover have returned to baseline levels, manage pumping to maintain water levels; and
- In wellfield areas where water tables and vegetation cover have not returned to baseline levels, manage pumping to promote water levels

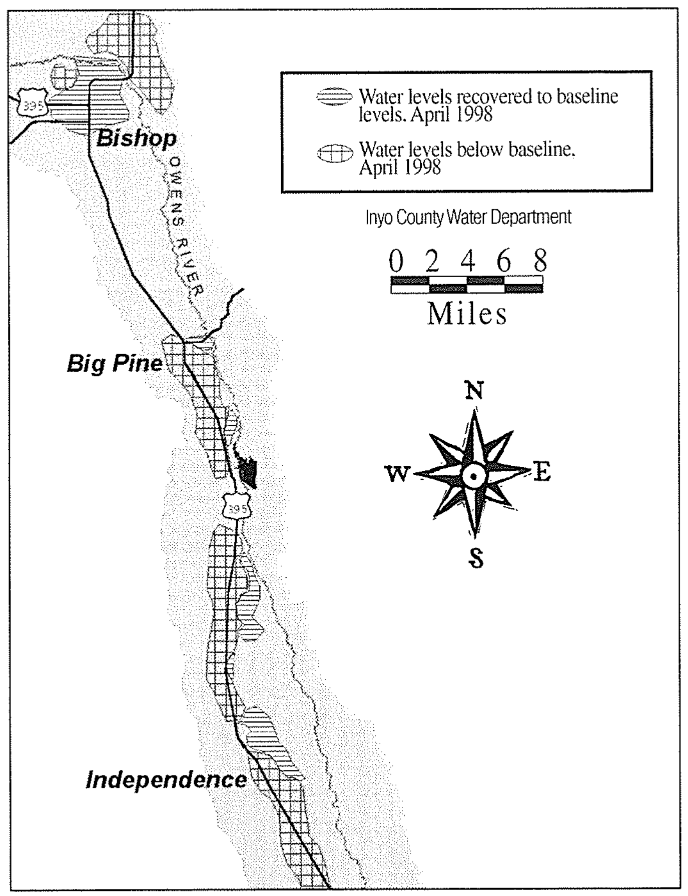


Figure 6. Wellfield areas where water tables returned to baseline levels on or before April 1998 and areas where water tables had not returned to baseline levels. All other regions are control areas, therefore not measurably affected by pumping from 1985 to 1998.

Future Directions

To date, vegetation monitoring has provided sufficient data to allow detection of "certain described decreases or changes" in vegetation as called for in the Inyo/Los Angeles water agreement. As described in this article, the annual vegetation data collected by ICWD have proved useful in analyses of changes in perennial cover on the parcel and wellfield scale. They have also been analyzed to assess changes in plant life form, which reveal whether there have been changes in plant composition.

The data, however, could be used to investigate changes beyond those for which the monitoring program was specifically designed. Several transects are run in parcels each year and all species observed on or near the transects are recorded. All transect locations are accurately recorded using GPS (Global Positioning System). These data can be used in other analyses beyond those described in this article. For example, applying sophisticated statistical analyses to the species and cover data in conjunction with newly developed environmental data sets, such as soils data, might allow an evaluation of more subtle or gradual trends occurring in Owens Valley vegetation. Another application would be remote sensing studies. Using the accurate transect positions, vegetation information can be compared with satellite imagery or other techniques to calibrate the imagery. Once calibrated, the imagery could be used to assess vegetation conditions in areas where field data were not collected. ICWD staff are currently pursuing these two lines of inquiry.

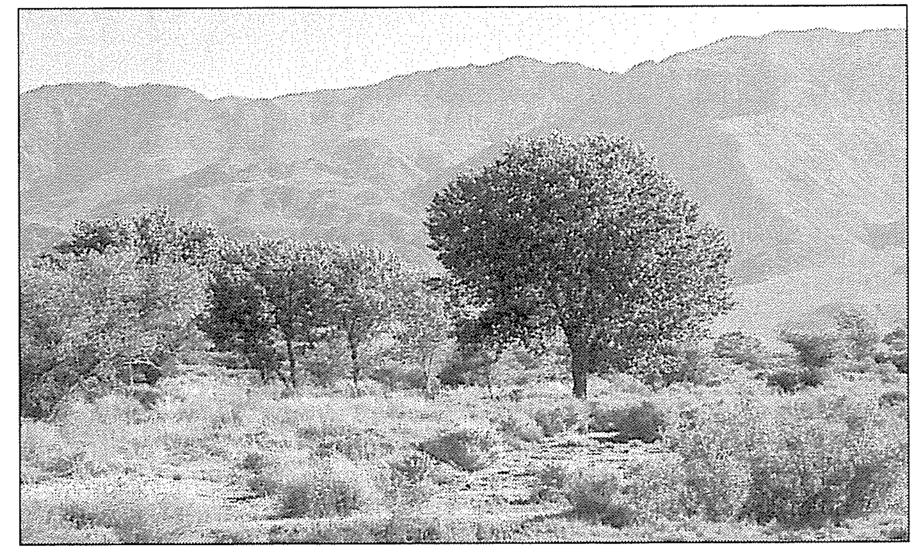
Owens Valley Precipitation

Sally Manning, Vegetation Scientist

1998 was a wet year. ICWD staff continued to collect precipitation data at seven rain gages located in the Owens Valley during the 1998 water year (October 1997 – September 1998). Average precipitation during the period was 7.85 inches, slightly greater than the average for 1995 (Table 4). Because these are relatively new rain gage stations, it is not possible to compare the data directly to a long-term average for the sites at which they are located. At the Bishop airport (not shown in Table 4), the long-term average precipitation was 5.34 inches; the water year total for 1998 was 9.77 inches and the winter amount was 7.57.

Table 4 . Precipitation totals recorded at each of the county rain gages for water years 1993 through 1998. A water year runs from October 1 through September 30.

Rain Gage	Precipitation (inches)					
	1993	**1994**	**1995**	**1996**	**1997**	**1998**
RG-1, east of Fish Slough	5.94	3.40	7.60	4.51	4.66	6.09
RG-2, near Laws	6.29	3.62	7.80	4.55	4.91	7.34
RG-3, southeast of Bishop	7.21	4.34	8.87	4.29	6.85	9.98
RG-4, south of Big Pine	8.29	4.24	9.76	6.85	8.33	8.99
RG-5, near Goose Lake	6.83	2.15	7.07	5.64	7.02	7.47
RG-6, near Blackrock	9.00	2.95	8.67	7.07	8.68	10.01
RG-7, east of Union Wash	5.00	1.61	4.88	2.14	4.35	5.06
Rain Gage Average	**6.94**	**3.19**	**7.81**	**5.01**	**6.40**	**7.85**
Average Precipitation Occurring Oct 1- Apr 15 ("Winter")	**6.85**	**1.81**	**6.76**	**4.45**	**4.67**	**5.81**



Irrigated, "Type E," land in the Owens Valley. Photograph by Leah Kirk

Status:

ESI conducted the bulk of the inventory in the LORP area during the summer of 1998. They will complete the inventory in the northern portion of the Owens Valley in 1999.

Additional Mitigation:

Under the direction of LADWP and the county, ESI will recommend on-site and/or off-site mitigation measures, including mitigation at Hines Spring, to supplement mitigation measures identified in the EIR for impacts to Owens Valley springs. LADWP is to provide 1,600 acre-feet of water per year to supply the recommended measures. The mitigation measures will be implemented by LADWP and maintained by LADWP and/or the county. The measures must be in place by June 2000.

Status:

ESI has initiated its evaluation of potential mitigation sites.

Owens Valley Management Plans:

LADWP, in consultation with the parties to the MOU and others, is to develop management plans for areas of Los Angeles land where problems have been caused by livestock grazing and other uses. Priority will be given to riparian areas, irrigated meadows, and sensitive plant and animal habitats. The plans will provide for the continuation of sustainable uses, including recreation, livestock grazing, agriculture, and other activities and will consider the enhancement of threatened and endangered species habitats.

The planning effort is to begin by 2002, and plans are to be completed no later than 2007. Each plan will contain an implementation schedule and will be implemented in compliance with CEQA.

Status:

ESI has completed draft land management plans for Los Angeles land within the LORP area.

Type E Vegetation:

By December 1999, LADWP and the county are to inventory vegetation identified in the Inyo/Los Angeles water agreement as "Type E,"or irrigated. The data from the inventory will be used as the baseline conditions for management of vegetation under the agreement.

Status:

The inventory is being conducted by Resource Concepts, Inc. under a contract administered by Inyo County and funded by LADWP. Last summer, RCI completed over one-half of the inventory. They will complete the inventory this summer and prepare the final report for the project by the end of the year.

Aerial Photo Analysis:

By June 2000, experts in aerial photography interpretation are to analyze existing air photos of the Owens Valley to:

1. evaluate the merits of using air photos in monitoring vegetation in the valley
2. determine whether the photos can be used to describe vegetation changes that have occurred in the valley
3. determine the feasibility of using air photos to analyze and refine the Owens Valley vegetation map data base
4. recommend how aerial photography or other remote sensing techniques could be used to monitor vegetation conditions and changes. Feasible recommendations will be implemented.

Status:

Ecosat Geobotanical Surveys, Inc., commenced this work last year under a contract administered by Inyo County and funded by LADWP. Ecosat has compiled and evaluated available ground and aerial photography and other data and selected representative areas for intensive analysis. The study is scheduled to be completed by June 2000.

Mitigation Plans for Impacts Identified in the EIR:

The EIR identifies approximately 1,300 acres of land in the Owens Valley that were adversely affected by LADWP water gathering. The EIR provides that these lands will be revegetated with plant species native to the valley. By June 1998, the Technical Group was to complete mitigation plans for the areas.

Status:

See "Owens Valley Revegetation Program" on page 12.

Report on the Status of the Memorandum of Understanding

Leah Kirk, Environmental Project Coordinator

The Owens River Delta. Photograph by Brian Tillemans/LADWP

In the summer of 1997, a Memorandum of Understanding was struck between the California Department of Fish and Game, the State Lands Commission, the Sierra Club, the Owens Valley Committee, the Los Angeles Department of Water and Power, and Inyo County. The MOU resolved the concerns of the organizations and state agencies over the Lower Owens River Project and other provisions of the 1991 environmental impact report for groundwater management in the Owens Valley.

The MOU requires LADWP and Inyo County to implement numerous environmental projects and studies. Here is a summary of MOU projects and accomplishments since the MOU went into effect.

Lower Owens River Project:

This project is a provision of the Inyo/Los Angeles water agreement; it was later identified in the EIR as compensatory mitigation for impacts that occurred between 1970 and 1990. The MOU augments the agreement and the EIR. The LORP consists of:

The Lower Owens River. A 60-mile stretch of the river channel will be rewatered, beginning at the point where the river is diverted to the Los Angeles Aqueduct and ending at Owens Lake. Flows in the river will be approximately 40 cubic feet per second (cfs). In average and above average runoff years, there will be "seasonal habitat flows" of 200 cfs, with lesser flows in drier years.

The Owens River Delta Habitat Area. Some 325 acres of wetlands at the north end of Owens Lake will receive 6-9 cfs annually to provide habitat for shorebirds, waterfowl, and other animals.

Off-River Lakes and Ponds. Existing off-river lakes and ponds in the LORP area will be maintained for fisheries, waterfowl, shorebirds, and other animals.

The 1,500-Acre Blackrock Waterfowl Habitat Area. In average and above runoff years, approximately 500 acres within an overall project area of 1,500 acres will be flooded to provide habitat for resident and migratory waterfowl and other native species. In drier years, a smaller area will be flooded.

Status:

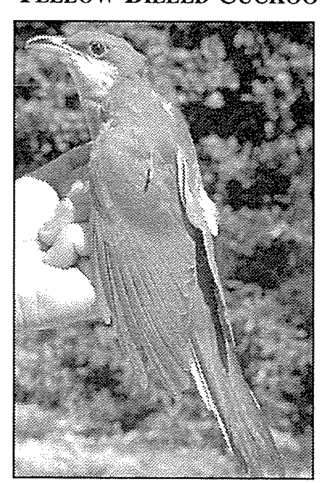
The U.S. Bureau of Reclamation has prepared the preliminary design for a pump system to be located near Owens Lake to carry water from the river to the Los Angeles Aqueduct or to Owens Lake for dust abatement. Final designs and plans for the pump system are expected to be completed in early 2000.

Ecosystem Sciences, Inc. has prepared management recommendations for the project.

Inyo County retained a consultant to assist in complying with environmental laws applicable to the project. A draft EIR for the project should be completed in late 1999 or early 2000.

To date, the county has obtained $3.55 million from the federal government to offset the costs of implementing the project. The county and Los Angeles are each seeking additional federal funds for the project. Flows in the river are planned to begin by 2001.

Yellow-Billed Cuckoo Habitat Evaluation:



Western Yellow-billed Cuckoo. Photo by J.A. Spendelow

Under the direction of LADWP and the county, ESI will evaluate Yellow-billed Cuckoo habitat in woodland areas of Hogback and Baker creeks. ESI will develop habitat enhancement plans for these areas in consultation with LADWP, the lessees for the areas, and the parties to the MOU. The evaluations will be completed by June 2000. Habitat enhancement plans will be implemented as expeditiously as possible.

Status:

ESI is preparing draft habitat enhancement plans, which should be completed by the end of 1999.

Inventories of Plants and Animals at Springs and Seeps:

By June 2000, LADWP and the county must complete an inventory of plants and animals at springs and seeps on Los Angeles land in the Owens Valley.

LADWP Pumping and Uses on the Bishop Cone

Randy Jackson, Inyo County Hydrologist

The Inyo/Los Angeles water agreement requires that any groundwater pumping by the Los Angeles Department of Water and Power be in strict compliance with the provisions of the "Hillside Decree," a 1940 court settlement that precludes LADWP from exporting groundwater from an area surrounding Bishop commonly referred to as the "Bishop Cone." To ensure that LADWP adheres to this requirement, the Inyo County Water Department and LADWP conduct an annual audit of LADWP's groundwater extraction and water uses on Los Angeles land on the Bishop Cone. According to the agreement, in any runoff year, LADWP's groundwater extraction may not exceed the amount of water used on its Bishop Cone lands.

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 Los Angeles 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 land on the Cone during the runoff year.

During the 1997-1998 runoff year (the most recent year for which an audit was done), LADWP groundwater extractions consisted of 10,820 acre-feet of pumped groundwater and 4,721 acre-feet of flowing groundwater from wells adjacent to the Owens River. Uses for the same period amounted to 22,750 acre-feet.

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 and Activities" on page 21).

Table 5. Summary of Bishop Cone audits performed to date.

Runoff Year	Uses on LADWP Land (acre-feet)	Groundwater Extractions (acre-feet)
1995-1996	31,073	9,006
1996-1997	25,098	14,421
1997-1998	22,750	15,541

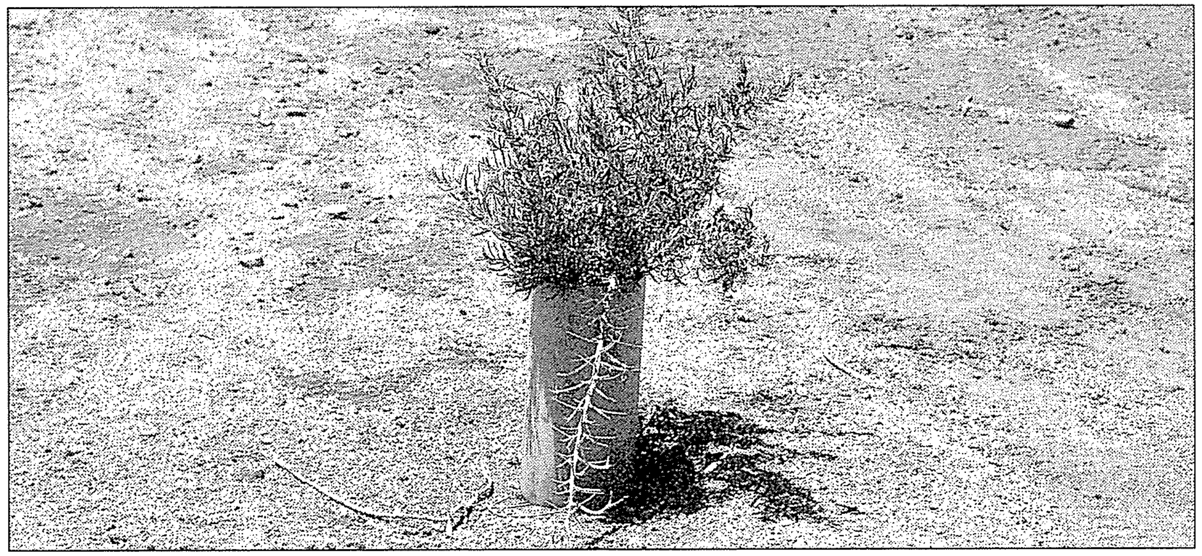
Bishop Cone Private Well Monitoring Program

Randy Jackson, Inyo County Hydrologist

In the summer of 1997, the Inyo County Water Department's hydrology staff set up a monitoring network of privately owned wells located near three proposed Los Angeles Department of Water and Power 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. Monitoring continued during the summer of 1998 as one of the three replacement wells was brought into production. There was no detectable difference in water levels from pre-replacement conditions. Monitoring will continue in 1999 in the portion of the monitoring network linked to the remaining two replacement wells.

The Inyo/Los Angeles 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.

Death camas
(Zigadenus venenosus)



Owens Valley Revegetation Program

Irene Yamashita, Revegetation Project Coordinator

The 1991 environmental impact report for groundwater management in the Owens Valley, commits Inyo County and Los Angeles to establish native vegetation on 1,300 acres at 16 sites in the valley that were affected by the city's water management between 1970 and 1990. This effort became a commitment in June 1997 when the Inyo/Los Angeles water agreement went into effect.

To get the program started, in cooperation with the Los Angeles Department of Water and Power, I developed a mitigation plan that describes each site and sets out goals, strategies, and schedules for establishing native vegetation. The first task of the plan is to protect the sites from disturbance to encourage natural revegetation. Next, revegetation methods will be tested through small-scale plantings before expanding efforts (or plantings) over the entire site.

In 1998, the Inyo County Water Department and LADWP took the initial steps set out in the mitigation plan:

The boundaries of the revegetation areas were established using a global positioning system (GPS) device. This data will be used to construct fences at the sites and to map and track progress over time. LADWP expects to have 10 of the sites fenced by the end of 1999.

Seeds from 20 Owens Valley plant species were collected – the first deposit to the revegetation program's "seed bank." The seeds can be drawn on as needed, allowing flexibility to plan without being dependent on the erratic nature of annual seed production. In the future, the bank will be expanded to include greater species diversity and seed quantities.

Alkali sacaton seeds were collected, and 100-150 plants will be grown out for planting in autumn 1999. The young grasses will be protected with shelters and hand irrigated for one to three years.

A cooperative study was developed to test planting techniques and potential irrigation systems at two revegetation sites, one east of Big Pine and the other south of Independence. A consultant will be retained to conduct the tests.

In addition, monitoring of existing pilot revegetation projects continued in 1998:

1991 and 1996 plantings near Laws were monitored for survival. The 1991 study of fourwing saltbush is now focusing on long-term survival; data will be evaluated after the 2001 growing season. The 1996 planting was intended to increase the species diversity at the site. After two years, the survival rate of this planting is 53%. Six shrub species and two grass species appear to be promising candidates for future revegetation at this site.

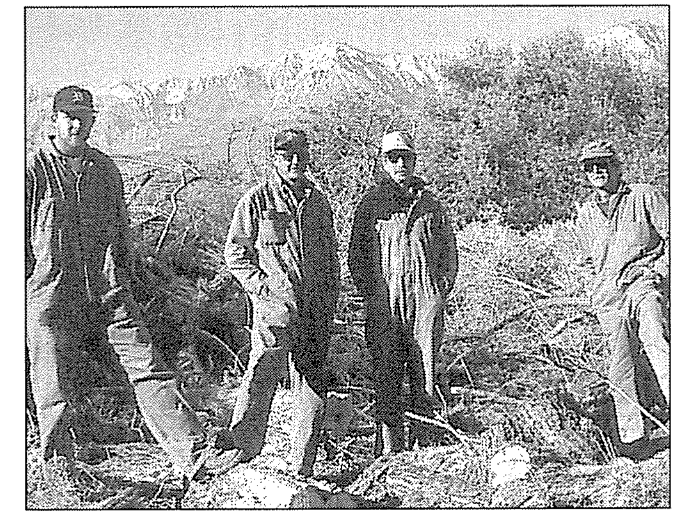
A 1996 test planting near Independence was also intended to examine potential plant species for the area, in addition to testing a planting pattern that could encourage natural recruitment. Thus far, seven shrub species and one grass species appear to be surviving. Plants that have been on the site for two years have a 36% survival rate.

In early 1996, ICWD staff planted cottonwoods, red willow, and birch along a disturbed section of McGee Creek that runs through Millpond Recreation Area. These trees were planted as cuttings, were protected with tree shelters, and have been monitored annually. This minimal input planting technique has had promising results. After two growing seasons, 76% of the cottonwoods and 54% of the willows have survived.

Above: Native black greasewood *(Sarcobatus vermiculatus)*, in a plant shelter at a pilot revegetation project near Independence. Photograph by Irene Yamashita

Saltcedar Control Program

Brian Cashore, Saltcedar Control Project Coordinator



Above: 1998 saltcedar control team members, Bryan Taylor, Chuck Spresser, Bruce Klein, and Rick Puskar. Below: Brian Cashore and Rick Puskar tackle Owens Valley's saltcedar. Top photograph by Brian Cashore. Bottom photograph by Steve Ingram.

When tamarisk or saltcedar was intentionally introduced into the U.S. in the early 1900s it was merely one of many non-native ornamental nursery plants that were transplanted around the globe. What makes non-native invasive plants such as saltcedar different from other introduced species is their ability to take advantage of disturbances to the native plant community to expand their limits. Once established, non-native invasive plants can spread rapidly because of the lack of natural enemies that keep plant populations balanced in their native range. Even though plants, animals, and other natural organisms continually change and expand their territories, the pace of the changes caused by human disturbance is unprecedented.

In the Western U.S., disturbance came in the form of an increasing human population and the water diversions, manipulations, and dam building that resulted. In the Owens Valley, much of the valley floor was disturbed when the Los Angeles Department of Water and Power constructed a series of dikes and basins to contain the abnormally high runoff in the late 1960s. Before that, saltcedar was only a minor component of the valley's plant composition. In 1998, the Inyo County Water Department increased its efforts to curb the spread of saltcedar by hiring a seasonal saltcedar eradication crew and setting up a program of systematic tamarisk control. Three seasonals, Bruce Klein, Chuck Spresser and Bryan Taylor joined Rick Puskar and myself in the effort to contain and control the spread of saltcedar while working towards the denser populations in the central portion of the valley. Though labor intensive, the technique of manually cutting the trees with chainsaws and loppers and immediately treating only the cut stumps with an environmentally safe herbicide is highly effective and less destructive to the landscape than some other forms of invasive plant control. Eventually, other techniques such as controlled burning and biocontrol using insects will be incorporated into the program. At each work site, a data sheet is filled out and the location is recorded using a global positioning system (GPS) so that future monitoring and follow-up treatment can be undertaken.

The saltcedar crew worked on sites from north of Bishop to south of Independence cutting plants ranging in size from 1/4 inch to 18 inches in diameter. Much of the work along the Owens River involved crew members walking along the river banks with chainsaws cutting and treating trees, then meeting our truck at an accessible road downstream. At one irrigated site, the crew worked for 9 days cutting an area of less than 3 acres that produced over 35 cords of cut tamarisk wood, 3 cow carcasses, and countless rat nests. It took a 15-man CDF crew over two weeks to clear and burn the slash at this location.

Because the core area of saltcedar is located within the lower Owens River area, approximately $1 million of a $3 million grant to rewater the river has been allocated specifically for the saltcedar control program. The expanded crew and program will make it possible to increase control efforts prior to the rewatering associated with the Lower Owens River Project.

The end of the 98/99 field season culminated with the taking of Black Rock Springs Hill along the dry river channel near Black Rock Fish Hatchery. Looking north from this vantage point, we saw the dry Owens River bed free of saltcedar trees, ready for the Lower Owens River Project water releases. Looking south, we saw the red bark-tinged hue of a saltcedar-covered landscape, and next season's work.