The Orange County Water District's Comprehensive Water Resources Management Program

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ABSTRACT

The Orange County Water District in Southern California has developed over several decades a unique and innovative groundwater management control strategy that incorporates proven management policies and state-of-the-art technologies. The regional management program is a model for progressive groundwater management. The evolving management process included the establishment of an institutional framework to gain control of groundwater extractions without the necessity of a formal water rights determination. The program developed a reliable revenue base from which to construct and fund the development of new local water supplies to reduce dependence on imported water supplies and to construct essential water quality enhancement projects. The resulting program includes the construction of groundwater recharge projects, seawater intrusion control barriers, well-head treatment projects, toxic control and response procedures, drought management projects and wastewater recycling projects for landscape irrigation and groundwater recharge.

INTRODUCTION

There is a critical need for additional water supplies in the area of Southern California. The need for new supplies is attributable to rapid population growth, and the environmental and institutional problems that are impacting the area's extensive water importation systems. There is also a need for water supplies of low salinity to off-set the adverse salt balance that exists in the regions groundwater basins.

The State of California and Southern California continue to experience rapid population growth, fueled primarily from population increases from indigenous populations. Estimates of population growth by 2020 are 15,000,000 statewide with one-half of that occurring in Southern California. The state-wide increase is equivalent to the current population of eight western states. Population growth is expected to continue beyond 2020. A state wide population of approximately 50,000,000 is projected by 2050.

The present population of Orange County is about 2,400,000 and has increased tenfold since 1950. Rainfall, even in normal years, averages less than 15 inches (380 mm), and supplemental water supplies are scarcer than ever before.

Major water supply importation projects from outside of Southern California have experienced substantial reduction in firm or dry year yield due to the public trust doctrine which provides project water to meet environment needs during water shortages and due to legal and institutional challenges. The first application of this doctrine impacted the City of Los Angeles Owens Valley importation project. Project water is required to supply Mono Lake in Northern California. Subsequently, the State Water Project developed in the 1970s has also been impacted by the listing of a number of adronomous fish species that use the main water conveyance system linkage in the 400 mile (640 km) transportation system from Northern to Southern California. The projects firm yield has been reduced by about 50%.

The Colorado River which supplies the aqueduct into Southern California has been the primary supplemental water supply source for the area since the 1940s. California has taken in excess of its rights from this supply for a number of years. This surplus water is due to the adjacent states diverting less than their full entitlement of the river. These states, fearful that the continued taking beyond the California right would possibly result in an additional water right, have requested that California cease the over diversions. A plan to reduce the diversion to its right has been developed. It requires California to reduce its take by 800,000 AF (990 Mm^3) from its current level by the year 2016.

In addition, the Orange County Groundwater basin, due to the long term practice of recharging the basin with water supplies containing relatively large amounts of dissolved salts, is experiencing a continual degradation of its supply. The degradation has resulted in a doubling of the area of the basin containing salt concentrations exceeding the secondary public health goal.

THE ORANGE COUNTY GROUND WATER BASIN

The Orange County Ground Water Basin is a large coastal basin located at the southeastern end of the Los Angeles coastal plain. The surface area of the basin encompasses about 230,000 acres (93,000 Ha) and contains 10 to 40 million acre-feet (12,300 to 50,000 Mm^3) of fresh water. While the basin extends to more than 2,000 feet (670 m) from the surface, most of the ground water lies below sea level. The basin is adjacent to the Pacific Ocean but is protected from sea water intrusion by coastal faulting except in two geologic 'gaps' that allow for the invasion of salt water when water levels are below sea level. Usable storage is limited by seawater intrusion and possible subsidence to about 1,000,000 AF (1,233 Mm^3). Further, most of the basin is underlain immediately below the surface by thick clay. This stratigraphic structure protects the basin from accidental waste discharges and leaking underground storage tanks at the surface. Recharge into the regional aquifer is possible only in a small area, about 20,000 acres (8,100 Ha) in area, located in the inland area of the basin.

There are at present about 500 large municipal wells with a capacity of nearly 400,000 afy (490 Mm^3) of annual production capacity.

Two seawater intrusion control facilities have been constructed to block intrusion into the aquifer. The first is the Alamitos Barrier Project, a joint project with the adjacent Los Angeles County. The second project is the Talbert Barrier Project and is located at the mouth of the Santa Ana River. Both projects repel seawater by developing a pressure mound in the aquifer from the injection of water.

The basin is also situated at the lower end of the Santa Ana River watershed (Figure 1). The watershed above Orange County encompasses more than 1,000,000 acres (405,000 Ha) and is drained by the Santa Ana River. The watershed is divided into lower and upper areas, separated by non-water bearing mountains, which are traversed by the Santa Ana River. The upper area contains vast amounts of ground water.

MEETING THE CHALLENGES OF THE PAST

Managing the Basin – The Orange County Water District

Extensive agricultural developments were established in Orange County in the late 1800s. Initially, direct diversions from river provided the needed supply to the orchards. Later, the recharge of the river into the basin supplied well.

Because the flow of the Santa Ana River, the primary source of supply to the groundwater basin, had substantially declined during the period 1900-1930, the Orange County Water District (OCWD) was established in 1933 by a special act of the California Legislature. The legislature gave the district broad authorization to protect the area's rights to the Santa Ana River and to protect and manage the groundwater basin which underlies the major portion of Orange County. The district immediately initiated litigation to secure the water rights to the Santa Ana River. In 1969, the district was finally granted full rights to the river's storm flows and to 42,000 AFY (52 Mm^3/yr) of the base flow, which at that time consisted primarily of rising groundwater.

The OCWD does not provide direct retail water service but functions somewhat as a wholesaler, supplying those agencies that provide retail water service to consumers.

Controlling Overdraft

By the early 1950s, it had become apparent that the reduced flows of the Santa Ana River and the demands on the groundwater basin were causing a significant accumulated overdraft, which in turn was allowing seawater intrusion. After the completion of the Colorado River Aqueduct in the 1940s, there were available ample imported water supplies for replenishing the basin, but the district lacked financial resources to purchase these imported waters; the district's sole source of finance at that time were ad valorem property taxes.

The district's constituents considered a court mandated pumping cutback to balance the extractions with the local yield of the basin. This would mean the establishment of individual water rights through a lengthy and costly process. Instead they chose a management plan that established a uniform fee for the extraction of all waters from the basin. The basin management program contained no restrictions on pumping by individual producers, as no rights to ground water production were determined. The plan was based on the concept of uniformity or equity among producers, regardless of the time or amount of historical use of groundwater. This concept has proven to be successful in preventing water rights disputes and in managing the basin.

The replenishment fee would necessarily be sufficient to purchase imported water supplies in amounts necessary to replace the annual overdraft of the basin and over a specific period, to refill the basin to a level that would prevent the intrusion of sea water into the basin. So in 1956, with an overdraft of 700,000 AF (863 Mm^3), OCWD initiated a program for refilling the basin with relatively inexpensive imported water.

Controlling Seawater Intrusion

The revenues generated by the replenishment, levied on each acre-foot (1,233 m^3) of water extracted from the basin, provided the funds necessary to restore safe levels of basin storage. By 1964, after recharging the basin with large amounts of imported waters, the basin was again full and seawater intrusion was halted.

Because of the likelihood that the imported and local water supplies would be reduced during future dry cycles, a program for conjunctive use of surface and groundwater supplies was established as a basic management strategy. This meant that the basin could not be kept constantly full and that seawater contamination must be controlled, particularly at the two most vulnerable locations, the Alamitos and Talbert Gaps. The Alamitos Barrier was built in 1963 and was supplied with imported water. It is currently being converted to a blend of imported and recycled water supplies. To provide a supply source for the Talbert Barrier, an advanced wastewater treatment plant, Water Factory 21, was built in 1973.

Controlling Extractions

Since, imported water costs were roughly equal to groundwater costs until the 1960's, the amount of extractions from the basin were controlled through voluntary restrictions. However, when import costs accelerated and it became more economical for pumpers to rely on the groundwater basin, pumpers began to shift more heavily to the less expensive groundwater supplies. Consequently, in 1969 the District Act was amended to permit a basin equity assessment (BEA), which allowed OCWD to charge its producers a fee on each acre-foot (1,233 m^3) of water extracted in excess of a specified percentage of total demand. This fee was established as the difference in the cost of groundwater and imported water, thereby removing the incentive to over-produce from the basin. The BEA effectively eliminated any need to adjudicate the Orange County groundwater basin to control extractions.

The district currently limits groundwater production to 75% of each producer's total demand. The district act provides for the establishment of the basin production percentage each year. This allows for a reduced BPP in the event that the production levels were in some way adversely impacting the basin. For example, it would be advisable to reduce extractions in the event that imported water replenishment supplies were curtained so that the basin would be over drafted to a damaging extent if extraction levels continued. Today, about 380,000 AF (470 Mm^3) are extracted each year, but the extraction amounts continue to increase in response to population growth within the area provided that the BBP remains at 75%.

The 1969 amendments to the district act also provide the district the authority to request certain producers to voluntarily extract groundwater at a greater percentage than the BBP. This would be appropriate, for example, if groundwater recharge in a specific area caused water levels to rise too near the surface. The request does not exempt the producer from the BEA. Additionally, the amendments also provide the authority to request specific producers to pump less than the BBP. This authority has frequently been used by the district to reduce extractions from areas near the seawater intrusion facilities during the construction additional barrier facilities. In this instance, the producer is paid by the district the BEA. So, in both instances, the participating agency's water production costs are unchanged by the district's requests.

The BEA has proven to be a useful basin management tool and is consistent with the concept of treating all producers equally.

MEETING THE CHALLENGES OF THE 21ST CENTURY/THE GROUND WATER MANAGEMENT PLAN

With future deficiencies projected for Southern California, due to cutbacks in the supply from the Colorado River and to environmental concerns regarding the Sacramento-San Joaquin Delta and Mono Lake, the district prepared in 1989 a

'Groundwater Management Plan' (GWMP) to meet future needs of the district.`The GWMP assessed the needs and restrictions to make full use of the basin, such as: water contamination plumes, additional groundwater recharge facilities needed to capture the increasing Santa Ana River flows, sea water barrier expansions to allow more use of the basins storage, etc. Four major goals were established; Increasing Basin Water Supplies, Protecting and Enhancing Water Quality, Improving Basin Management, and Improving Constituent Relations. Included in the GWMP was a long range implementation program, including construction on operation costs, to eliminate each impediment. The expected benefits of the management program were also incorporated into the GWMP. The plan received an award from California's leading water organization and has become a model for other groundwater basins planning.

<u>Expanding the Groundwater Recharge System</u>

The Santa Ana River became the central component of future water planning for the district. Projections regarding the Santa Ana River, indicate that its current flow of 150,000 AFY (185 Mm^3/yr) would double by the year 2010 due to a substantial increase in discharges from wastewater treatment plants upstream resulting from population growth. Storm flows were increasing as well, attributable to larger expanses of impermeable surfaces in that growing urban area. Recognizing that these flows could constitute a significant new water supply source, OCWD embarked on an intensive program to expand its capability to capture the river's full flow for basin recharge.

Key to the districts water management program is its extensive artificial recharge system (Figure 2). The district began purchasing vacant land in the 1960s to expand its recharge system, which at that time, included only a, six-mile (9.65 km) reach of the river. The district now owns about 1,600 acres (650 Ha) of land.

The district has relied on the main channel of the Santa Ana River for its central recharge facility. As recharge requirements grew, the district began to acquire vacant lands adjacent or near the river. Sand and gravel were excavated and sold to create deep recharge basins, with depth of 50 ft to 150 feet (15 to 50 m). A piping system was constructed to connect all of these basins with the Santa Ana River. The deep basins account for about ½ of the total recharge system and provided good access to the regional aquifer. In addition, they provide a significant storage capability so that storm flows could be captured for later recharge.

Urbanization adjacent to the district's system has eliminated vacant and inexpensive land. With only expensive and developed land available for purchase to extend the recharge area, enhancement of the existing system became imperative. In 1995 a permanent diversion and dewatering systems were installed in each of the deep basins. This allowed the recharge basins to be emptied and cleaned twice a year without interrupting recharge operations. (Prior operations allowed only a once a year dewatering and cleaning). Increases in percolation rates of as much as 40 percent have been realized, and about 400,000 AFY (500 Mm^3/yr) can now be placed underground.

As the natural flow of the river increased with the advent of wastewater discharges in the upper area, the nutrient and dissolved organics load in the river began to rise. Further, urbanization in the upper watershed, while contributing to increases in storm water flow, resulted in an increase in the silt loading on the recharge system. Consequently, the district began to experience a reduction in the systems recharge rates.

Microorganism growth, encouraged by the high nutrient content, combined with the added silt load, produced a clogging layer at the bottom of each of the deep recharge basins. The formation of this layer caused the rapid reduction in recharge rates.

The Basin Cleaning Vehicle: In the mid 1990s, the district staff conceived a plan to construct an underwater basin cleaning device that would continuously remove the materials that cause and result in the formation of the clogging layer. The device would gently disturb the bottom sediments, using high pressure water jets, which would then be drawn upward into a hood that would allow the sand particles to fall back to the bottom surface under the force of gravity. All other materials, including organic and colloidal materials would be drawn upward into a discharge line. At the surface, the water would be separated from these materials and returned to the recharge basin.

A small-scale basin cleaning device was constructed and pulled across a shallow basin. The result was that the surface of the basin floor that was traversed by the device appeared to be remarkably free of clogging materials. With this apparent initial success, the district contracted to build a full scale, self propelled and GPS guided basin cleaning vehicle (BCV), shown in Figure 3. As with all new inventions, the device was hampered with a multitude of operational problems, from the outset.

After correcting for the deficiencies, which included the refitting of the disturbing mechanism to incorporate mechanical cutting heads that rotate and crush the hardened clogging layer, the refitted device operates as envisioned, returning to the surface the materials that form the clogging layer. Subsequent constant head testing of a basin, with and without the operation of the BCV, showed that the test basin percolation rate of about

4 ft/d (1.2 m/d) could be sustained as compared to the usual percolation loss rate of about 0.05 ft/d (0.015 m/d).

The Constructed Wetlands: The district is also proceeding along another path to aid the fight against clogging and to provide an over all improvement in the quality of the Santa Ana River water. Recognizing that the nutrient content in the Santa Ana River water, especially nitrogen, was not only a potential threat to pubic health since the concentrations occasionally exceed the drinking water standard but also a major factor in growth of microorganisms associated with the clogging of the recharge system, in 1995 the district began to investigate the feasibility of reconstructing some of its lands located in the reservoir area behind Prado Dam. The dam is located about 10 miles (16 km) upstream of the headworks to its recharge system. Of its holdings, about 475 acres (190 Ha) had been constructed into a series of ponds for the purpose of duck hunting. The ponds were fed Santa Ana River water.

After a three year research project conducted by the University of California scientists, the district chose to reconstruct the duck ponds into constructed wetlands that would process about ½ of the river's flow (100 cfs or 2,800 L/s). The research indicated that wetlands, constructed to allow for both aerobic and anaerobic conditions, would be extremely effective in removing nitrates from the river waters. The ponds have now been in operation for several years such that the nutrient removal systems have fully matured. The result is that complete removal of nitrogen is accomplished within a few days of retention in the wetland ponds. While there has been a significant reduction in nitrogen content of the river water, the concentrations are still sufficient to support microorganism growth in the recharge basins. Additional constructed wetlands are in the planning and design phase and the district's goal is to process all of the base flow of the Santa Ana River water through wetlands.

A secondary benefit is provided by the wetlands, i.e., the product water is vastly changed in character. The inflows, as expected, resemble wastewater discharges, but the product water's character resembles more of natural water. The district believes that this is an important issue as all of the river water is eventually used, after recharge, for drinking water.

Increasing Water Supplies

Water Conservation at Prado Dam: OCWD also realized that Prado Dam, which had functioned primarily as a flood control facility, could be effectively operated as an adjunct to the conservation system simply by storing storm water temporarily for later release to the recharge system. An agreement with the U.S. Army Corps of Engineers put in place in the early 1990s provided for a seasonal storage program at the dam. The program allows storm water storage at the close of the storm season, approximately March 1st of each year. The allowed storage amounts are constrained by storage elevations dictated by achieved mitigation for an endangered bird.

Early in the negotiation process, an endangered song bird, the least Bell's Vireo, was listed as an endangered species by both Federal and State agencies. The primary habitat of the migratory bird was found to be in the lower elevations of the reservoir behind Prado Dam. Consequently, the spring time storage of water behind the dam would inundate the bird's critical habitat. This required a mitigation program to be in place prior to the initiation of the conservation program. The district began a program of creating new habitat and the eradication of the bird's predatory enemies. The program has been extremely successful. In 1986, the year the bird was first listed, only 19 pairs were found in the reservoir area. In 2002, more than 300 pairs were present. While it has been difficult to mitigate for the impacts on the species, the resulting water conservation program has resulted in an average annual increase in supplies to the basin of about 10,000 AF (12 Mm^3).

Waste Water Recycling: Recycling of wastewater is given major emphasis in OCWD's program of groundwater management. At the district's Water Factory 21, between 10 and 15 million gallons per day (39 and 59 ML/day) of secondary-treated wastewater is subjected to advanced treatment, including reverse osmosis, before injection into the Talbert Gap barrier system.

Water Factory 21 was constructed in 1975. The facility has produced and injected in the coastal portion of the basin more than 120,000 AF (150 Mm^3) of highly treated wastewater derived the adjacent secondary wastewater treatment plant. The project, first of its kind in the world, uses a high lime pretreatment process and subsequent treatment by either reverse osmosis (RO) or activated carbon filtration. The water is disinfected with chlorine prior to basin injection. However, years of research at the project have resulted in improved RO membranes, using less energy; an alternative membrane based pretreatment process and disinfection without the use of chlorine.

In cooperation with the local sanitation district, OCWD is embarking on the largest indirect potable reuse project in the world. The water will be treated to drinking-water standards, as is that at Water Factory 21.

The Groundwater Replenishment System (GWRS), will replace the existing Water Factory, and incorporate the latest and most cost effective technologies. This 80 million gallon per day (300 ML/d) project will use Microfiltration as the pretreatment process prior to treatment by the 80 mgd (300 ML/d) RO system. Following the RO is a UV disinfection system that is immediately preceded with the addition of hydrogen peroxide. About forty percent of the product water, meeting all drinking water standards, will be injected in to the seawater barrier along the coast. The remaining waters will be transported via a single pipe line extending from the treatment facility, along the Santa Ana River, to the district's recharge system, a distance of about 15 miles (24 km). The $350,000,000 will produce, when operational in 2005, about 75,000 AF (92 Mm^3) of new water supplies for the district and the region. The cost of the water is comparable to the cost of imported supplies. This is due to the use of more cost effective technologies and the use of the basin, in two locations, as a point of constant demand. The combination of the use of the basin as a continuous demand provides for maximizing the production of water and the use of single delivery pipeline minimizes the distribution costs.

The GWRS, while providing the benefit of an additional reliable water supply, also provides an important benefit in basin salinity management, since the product waters are virtually free of dissolved salts. (Small amounts of calcium will be added to stabilize the product water and protect the cement-lined piping system.) As indicated earlier, the district has recharged more than 2,000,000 AF (2,500 Mm^3) of imported Colorado River water with TDS concentration of 600-700 mg/l and 5,000,000 AF (6,200 Mm^3) of Santa Ana River water with slightly less concentration of salts. The effect on the basin has been to triple the area of the basin that contains salt concentrations exceeding the secondary standard for TDS (500 mg/l) since 1954. The concentration of salts creates additional consumer costs as increased use of water softening chemicals and reduced life of home piping and water using devices. The low salinity of the GWRS supplies will nearly curtail the continued salinization of the aquifer.

Fulfilling its commitment to water recycling, the OCWD launched a 7.5 MGD (29 ML/d) reclamation system in the early 1990s for landscape irrigation and industrial applications in the coastal area of the district. The system supplies schools, parks and golf courses through a 40 miles (64 km) piping system. While providing new water supplies for the area, the landscape irrigation project also reduces the groundwater demand along the coast. This lessens the stress on the sea water intrusion control facilities.

Protecting and Enhancing Water Supplies

Toxic Reserve Account: Recognizing that a toxic chemical spill or other waste discharge could rapidly pollute the groundwater basin, the district established a $4,000,000 funding reserve that could be immediately accessed to initiate clean-up operations in the event of a spill which posed an imminent threat to groundwater supplies.

The program placed the district in the primary role of groundwater protection. The advantage of the program is that the district would not have to rely on clean-up actions by others, which were often delayed or contested. The recovery of the district's response expenditures would occur at a latter time.

Contamination Remediation: While the general water quality health of the basin is considered good, there were identified several 'hot spots' of pollutant plumes. Groundwater quality problems resulting from nitrate, salt, selenium and man-made pollutants had shut down about 70 wells in the district. These included a few small areas of volatile organic contamination from prior industrial or military aviation actives and of nitrate concentrations exceeding the public health MCL. The later contamination was due to over application of fertilizers and septic tank usage. In response, the district began a program to build groundwater remediation plants.

In each identified contamination location, a remediation plan was developed. In general, the plans included the construction of a water treatment facility to clean the affected groundwaters. Reverse osmosis and ion exchange technology as well as conventional blending system are in place for reducing nitrates, and TCE is being removed from a polluted aquifer by an air-stripping system. In all cases, in cooperation with the local water retailer, the purified water is introduced into the domestic water system.

The Health and Water Quality Investigation: Because the Santa Ana River is composed mostly of municipal wastewater during low flow conditions and urban and dairy animal runoff during storm events, the district embarked on a multi-disciplinary, multi-year investigation into possible health effects related to this water supply source. The investigation, now in its 6th year, has been guided by a national panel of experts in various scientific fields, including hydrogeology, toxicology, epidemiology, and others. The cost of the investigation has now exceeded $10,000,000. The investigation has been effective in identifying travel times within the aquifer as well as chemical transformations that occur during recharge.

One of the culminating research efforts was the testing of water quality sensitive fish (Medaka) for changes in their endocrine systems when residing in filtered Santa Ana River water as compared to imported water.

Drought Management

The most recent dry year shortage in Southern California occurred during the drought of 1986-1991. During this period, due to significant shortage in deliveries from Northern California, a water shortage developed in the area. Water conservation programs were initiated and imported water supplies were limited. The OCWD responded by increasing the BPP for its constituents. During the last year of the shortage, the BPP was raised to 80%. It was discovered, however, that very few of the district retail agencies possessed sufficient groundwater production capacity to extract at that level.

In response, the district initiated a program to assist local agencies in the development of new, high capacity wells, so that in future water shortage situations, the agencies could respond to higher production percentages from the basin. The conjunctive use well construction program provided large system producers with long term, low-interest financing to construct approximately 20 new wells.

CONCLUSIONS

OCWD has developed unique groundwater management techniques over the last six decades. The district has successfully managed to curtail a large accumulated overdraft without the expenses and complications of a formal groundwater rights determination. The district has also developed a program to not only control, but to manage groundwater extractions from the basin. The control mechanisms are accomplished trough financial incentives rather than regulatory means. Further, the management plan contains a high degree of flexibility that allows the district to respond to changing basin conditions as well as the regions changing water supply situation.

Additionally, the district has embarked on an aggressive program to protect the groundwater basin and to allow for expanded use of the resource. Its Groundwater Management Plan set in motion a comprehensive program to allow for greater use of the basin by its retail customers and to develop new local water supplies to reduce dependence on imported water supplies. When fully implemented, the program will provide the means to continue to produce a large percent of district demand from sources within OCWD. Improved recharge operations, increased storage of storm flows, and expansion of conjunctive use capacity is expected to increase the amount of Santa Ana River water that can be used each year for groundwater recharge. Recycling projects included in OCWD's groundwater management plan will add another block of new supplies annually by the year 2005, and the rapidly expanding groundwater cleanup program will yield additional usable supplies. Finally, the implementation of the GWRS will provide a nearly salt-free ground water recharge supply that nearly eliminates the basins adverse salt balance.

A well-managed regional agency can attain a high level of success through aggressive and innovative programs, particularly when assisted by inter-agency cooperation. The Orange County Water District exemplifies the kind of total water resources management needed for the twenty first century.

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Figure 1
The Watershed

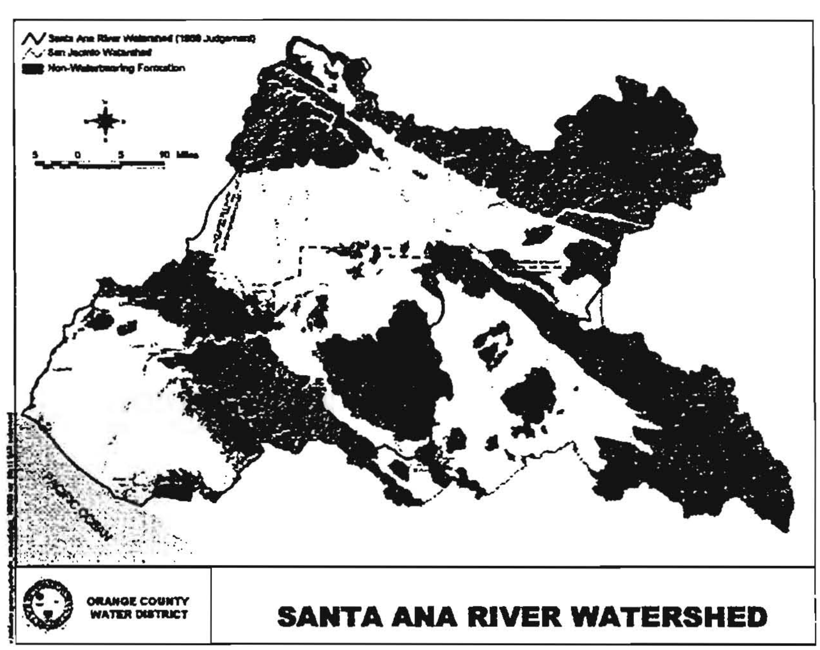

Figure 2
The Recharge
System

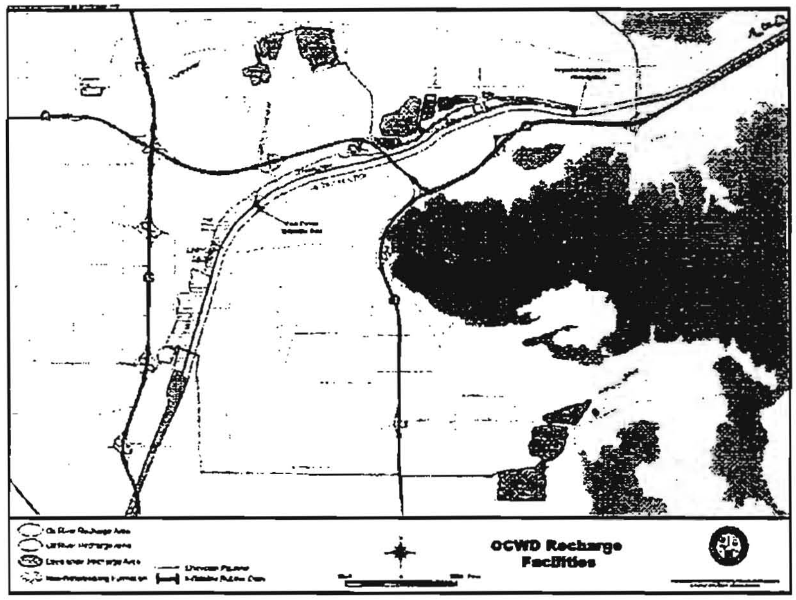

Figure 3
The Basin
Cleaning
Vehicle