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Increasing Fort Ord groundwater supply by use of recharge basins

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Increasing Fort Ord Groundwater Supply by Use of Recharge Basins

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Abstract

Currently there is a shortage of water in Monterey County. The Monterey Peninsula Water Management District, which serves central Monterey County, is in the process of finding a water source to provide an extra 10,730 acre-feet of water per year to its constituents, an amount the State Water Resources Control Board determined was being over-pumped from the Carmel River by the California-American Water Company (SWRCB, 1995). In north Monterey County, the Marina Coast Water District is trying to solve the problem of saltwater intrusion in the aquifers that they pump on Fort Ord (MCWRA, 2004).

Many solutions for these problems are being discussed, especially the prospect of a desalination plant in either Sand City or Moss Landing (MPWMD, 2004). The Marina Coast Water District currently operates a desalination plant but it is not capable of providing enough water to the district to ease the pumping of the wells on Fort Ord (MCWD, 2004). One solution that is being widely used around the world, but not locally, is rainwater harvesting.

Rainwater harvesting is the capture of rainwater from roofs and roads (Texas Guide to Rainwater Harvesting, 2004). Once captured, the water can then be stored in cisterns or allowed to recharge the groundwater for future use (Centre for Science and Education, 2004). To calculate the amount of water that can be captured, the catchment area (roofs, etc) is multiplied by the amount of rainfall for that area. That total is then multiplied by a runoff coefficient, called an SCS Curve Number, which adjusts the total runoff available by taking infiltration, evaporation and error in the design of the system into account (Viessman, et al, 2003).

The amount of runoff that can be captured from the impervious surfaces of Fort Ord is 9665 acre-feet during an average rainfall year, 20240 acre-feet during a wet year, and 4420 acre-feet during a dry year. By simply capturing water from the housing areas and schools on Fort Ord during average, wet and dry years, 4600, 9640 and 2100 acre-feet per year, respectively, can be captured. This water can then be allowed to recharge the groundwater on Fort Ord, where it can not only help increase the water supply, but fill the aquifers to help stop the migration of saltwater intrusion.

Introduction

The current providers of water to the residents of the greater Monterey Peninsula area are the California-American Water Company (Cal-Am), whose resource, although a private company, falls under jurisdiction of the Monterey Peninsula Water Management District (MPWMD) and the Marina Coast Water District (MCWD) (MPWMD, 2004). The boundary of the Monterey Peninsula Water Management District can be seen in Figure 1 (MPWMD, 2004).

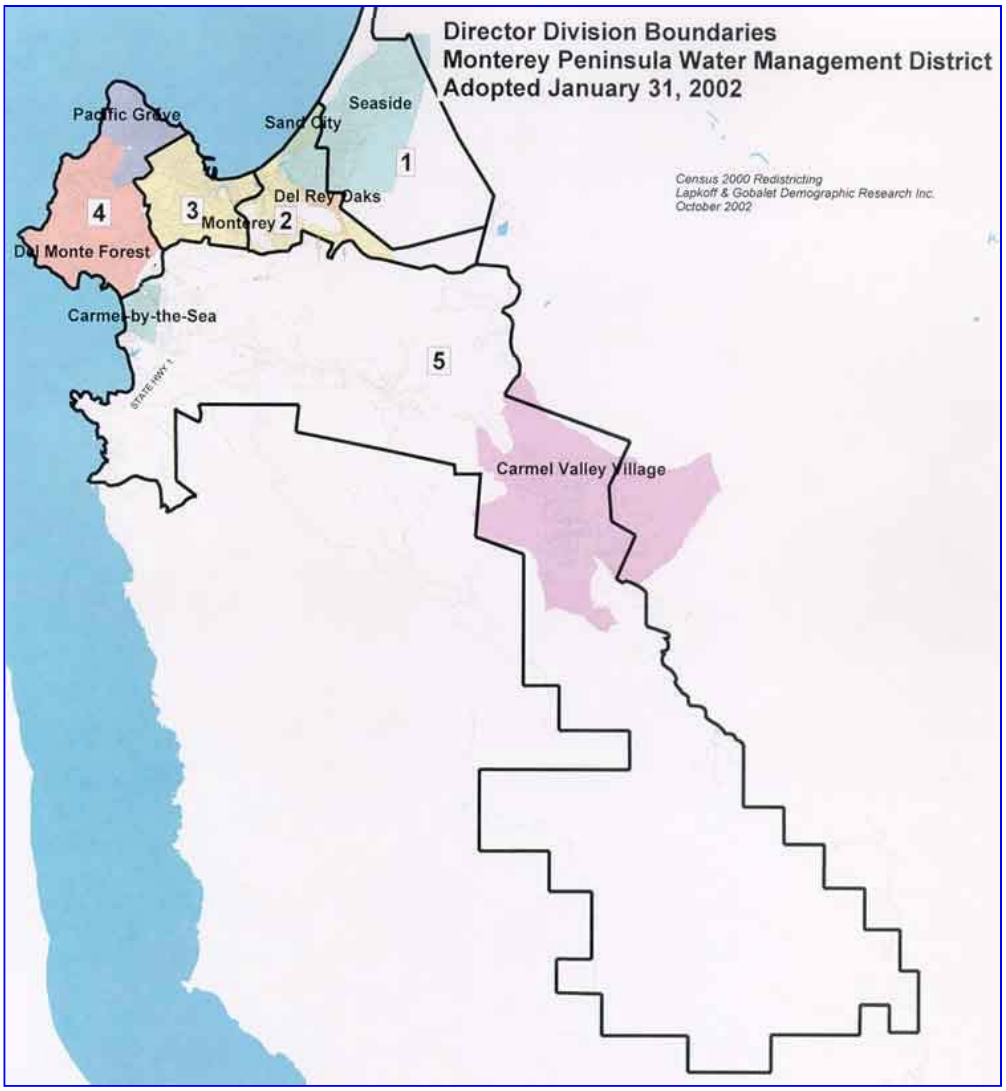

Figure 1. Monterey Peninsula Water Management District Boundary Map

The water for the MPWMD is provided from Cal-Am pumps along the Carmel River in Carmel Valley, Ca (MPWMD, 2004). Once a braided system that spread from valley wall to valley wall, the river is now a single channel system that runs the length of the valley floor to the Pacific Ocean (Kondolf & Curry, 1986). The discharge of the river is also controlled by two upstream dams, the San Clemente Dam and the Los Padres Dam, both of which are located near the community of Cachagua, Ca (Figure 2) (Monterey County, 2004).

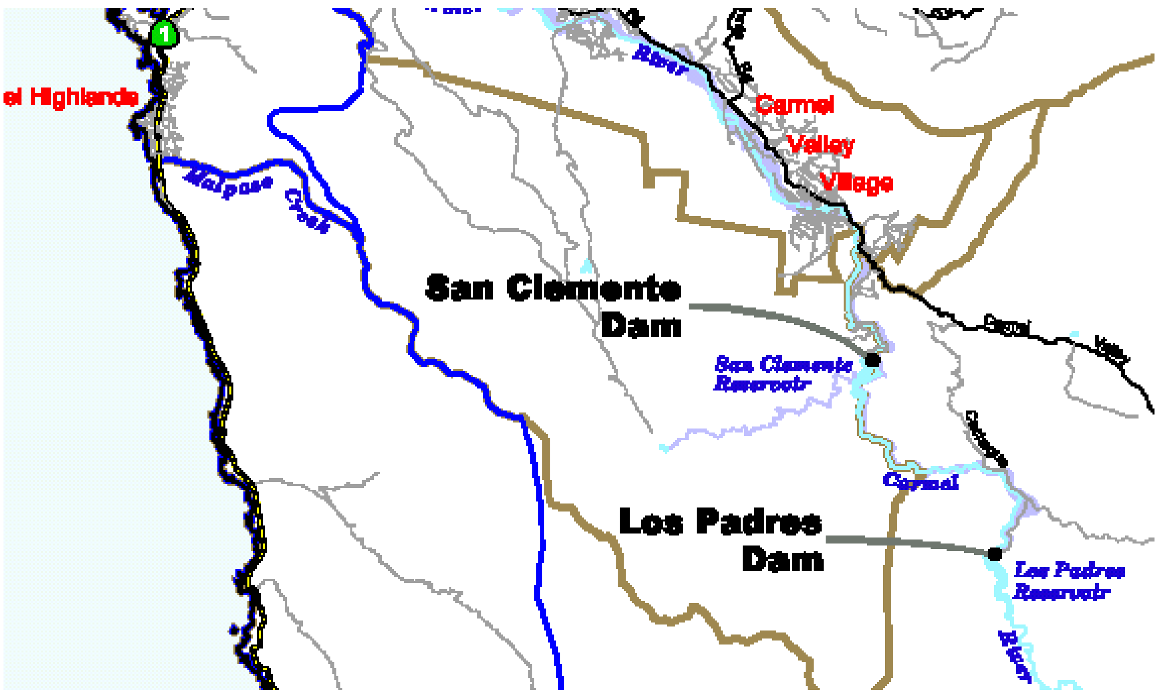

Figure 2. Location of San Clemente and Los Padres Dams on the Carmel River

In the late 1960's riparian vegetation in the watershed began to die in the Garland Park and Robinson Canyon areas near wells (Figure 3)(Kondolf & Curry, 1984). The Carmel Valley Property Owners Association hired a consultant who concluded that withdrawal from the wells led to the death of the riparian vegetation, however when Cal-Am hired their own consultant, he reported that the withdrawal from the wells only speeded up the ‘natural succession’ of the plants (Kondolf & Curry 1984). Finally, in July 1995, in the landmark California Water Rights Decision 1632 and State Water Resources Control District Order WR 95-10, the connection between the groundwater being pumped by Cal-Am and the water in the channel of the river was confirmed (SWRCB, 1995). It was determined that the riparian vegetation was disappearing due to the over-pumping of the river system by Cal-Am (MPWMD, 2004). In WR 95-10, the State Water Resources Control Board determined that Cal-Am was over drafting water from the river at 10,730 acre-feet per year (SWRCB, 1995).

Figure 3. Location of Garland Ranch Regional Park on the Carmel River (MSN, 2004)

This decision led to an expanded effort to find water for the Monterey area. At the time the MPWMD had plans to build a new dam on the Carmel River, slightly downstream of the Los Padres Dam (MPWMD, 2004). Named "the New Los Padres Dam" and referred to as "Plan A", the new structure was set to be able to contain 24,000 acre-feet of water and would completely engulf the existing Los Padres Dam (MPWMD, 2004). Concerns over environmental and aesthetic impacts of the new dam caused for its implementation to be rejected by Monterey County voters in 1995 (MPWMD, 2004). The idea of a dam was not completely dismissed by politicians and board members for almost ten years, but has recently been determined to be an obsolete project to obtain more water (MPWMD, 2004). However, though very unlikely, the Cal-Am Water Company, if they desired, could build the dam as a privately owned structure, using company profits and passing the cost onto the same voters who originally rejected it (Curry, 2003).

For many years, there were two alternative plans to the new dam. The first plan was a small desalination plant in Sand City that would produce enough water to compensate for the 10,730 acre-feet being over-drafted by Cal-Am, and allow for a small amount of growth (MPWMD, 2004). This plant would have been owned and operated by the MPWMD, which is an elected board, effectively meaning that Monterey County voters would be able to be part of the decision-making regarding the operation of the plant. While this was a popular option for those concerned with the yet unknown repercussions of desalination plants (both in the health of the ocean and in terms of growth on land), many in Monterey, including those in hospitality and local politics favor what is called "Plan B" (Sand City, 2004).

"Plan B" also contains a desalination plant (MPWMD, 2004). However, this plant would be much larger in size and therefore have the potential to produce much more potable water (MPWMD, 2004). This large, centralized plant will be located in Moss Landing, Ca and be used to provide water to not only the area surrounding the city of Monterey, but also all of Monterey County, which stretches from Moss Landing in the north to San Luis Obispo County in the south and from the Pacific Ocean in the west to as far east as King City (Figure 4) (MPWMD, 2004). The original concept of this plant had one tremendous strength: that it will utilize energy from neighboring Duke Energy, thus making the project extremely cost effective (Figures 5 and 6) (MPWMD, 2004). One major drawback is that the plant will be owned by Cal-Am, leaving Monterey County voters unable to control its operation or cost (MPWMD, 2003). The second part of "Plan B" involves pumping water from the Carmel River to the Seaside Basin on Fort Ord where it will be stored until there is a shortage of water (MPWMD, 2004).

On March 31, 2004, the Monterey Peninsula Water Management District voted to discard the plans for the Sand City plant after studies determined that the plant would only be able to produce approximately 9,000 acre-feet of water per year (Hennessey, 2004). Additionally, the small north county water district, the Pajaro-Sunny Mesa Community Services District, has purchased the original site for the Moss Landing plant (Hennessey, 2004). The water board voted 5-2 to wait three to four months before the discussing where the new location of the plant should be (Hennessey, 2004).

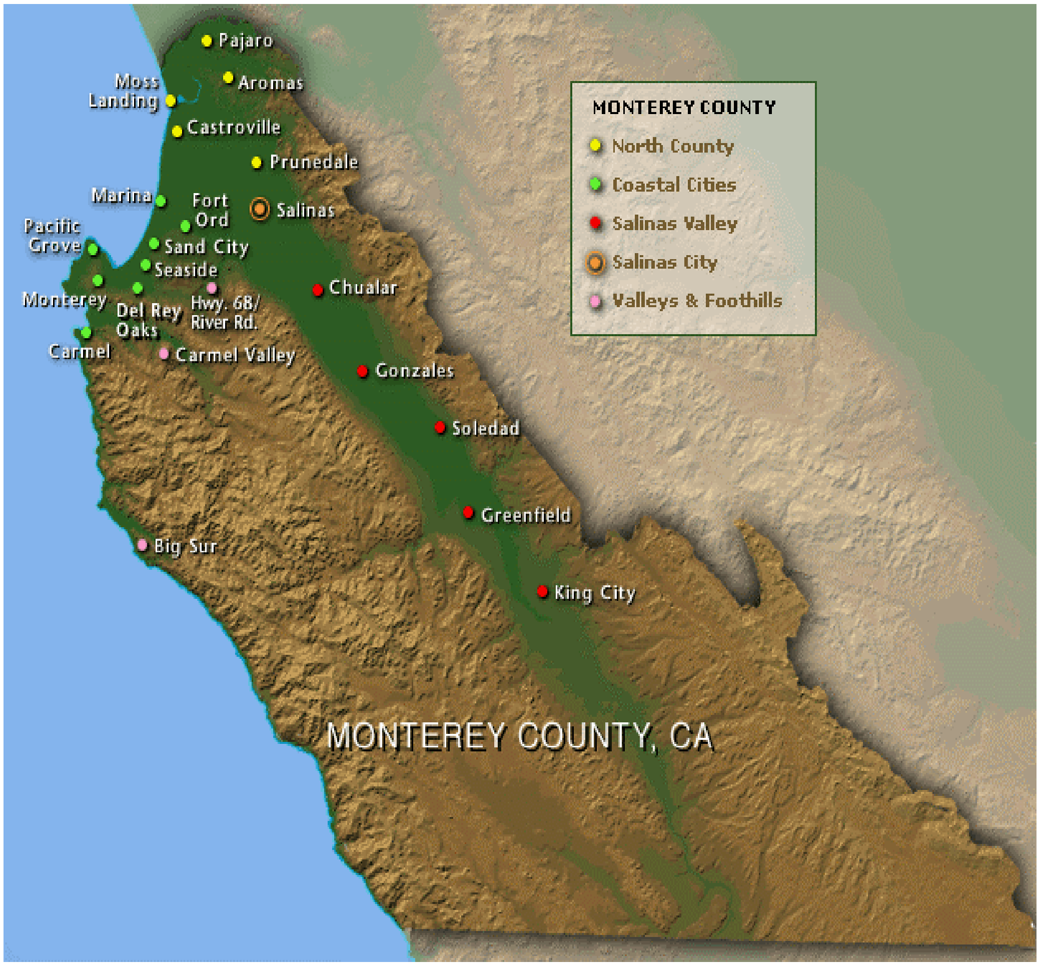

Figure 4. Map of Monterey County


Figure 5. Aerial View of Moss Landing. Original site for desalination plant is in the center of the page


Figure 6. Duke Energy, the proposed neighbor to the original Moss Landing desalination plant

The water that is distributed by the Marina Coast Water District is provided through pumping of groundwater out of the Salinas Basin on Fort Ord (MCWD, 2004). The water is being pumped out of the aquifers at a much higher rate than it is being re-charged, which has led to salt water intrusion to occur in the A, Upper and Lower 180', and 400' aquifers (figures 7 and 8), rendering these aquifers unable to provide potable water (MCWRA, 2004). Drilling wells into deeper aquifers does not seem to alleviate this problem – many of the aquifers, though considered confined are being found to have holes in their aquitards (solid barriers between underground aquifers), allowing salt water to flow freely into them (Teraszki, 2003). Also, as wells are drilled deeper, they come in contact with more saline water (Environment Canada, 2004).

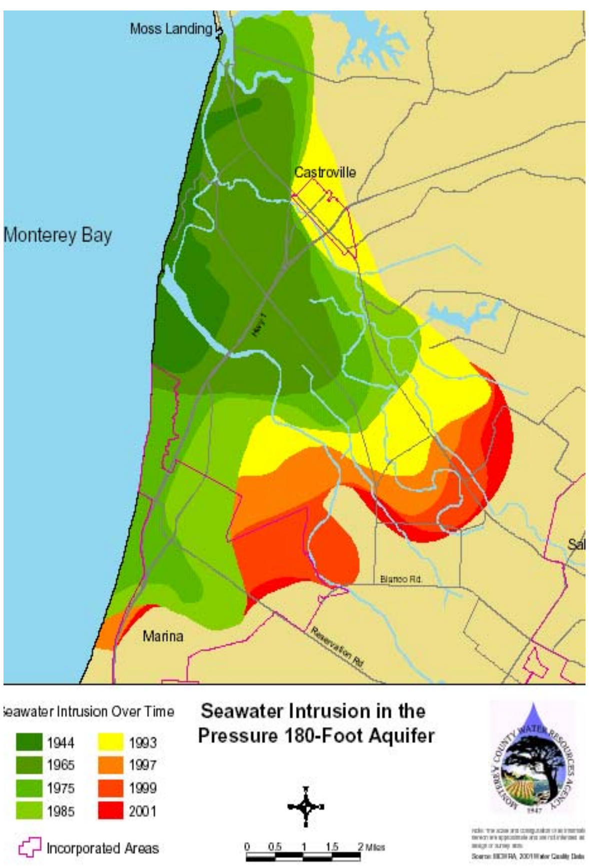

Figure 7. Saltwater Intrusion in the 180' Aquifer (MCWRA, 2004)

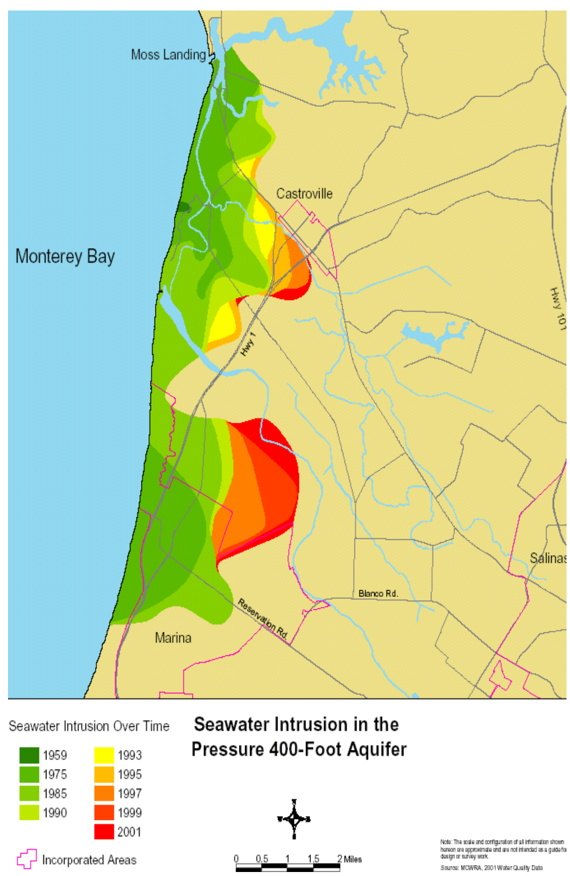

Figure 8. Saltwater Intrusion in 400'Aquifer (MCWRA, 2004)

In an effort to ease the pumping of groundwater from Fort Ord, MCWD has installed a small desalination plant (MCWD, 2004). Because of it's small size, that plant can only produce 13% of the water needed by MCWD, even when running at full operation (MCWD, 2004). MCWD has recently begun a process to renovate and update their desalination plant in an effort to be able to produce more water at a lower cost.

Another option, which has yet to be explored by either district, is the harvesting of water on Fort Ord. Water harvesting is the process of collecting rainwater that would otherwise runoff the surface and not recharge a surface reservoir (such as a lake or river) or the groundwater (Texas Guide to Rainwater Harvesting, 2004). The water that is collected can then be used to either recharge the groundwater or stored for use in the immediate future as a resource for flushing toilets or landscaping (Centre for Science and Environment, 2004). If the water that is captured is to be used as drinking water, the filtration system through which it passes needs to be very high quality, as the water will often contain contaminants from the roofs and roads on which it fell (Centre for Science and Environment, 2004).

The first step to rainwater harvesting is to determine the catchment area, or the area where the rain that will be gathered will fall. In general, this is an impervious area over which water will runoff and can be redirected for storage (Texas Guide to Rainwater Harvesting, 2004). On Fort Ord, the two main areas for catchment are roofs and streets. Because of the differences in physical structure and contaminants, these two catchment areas need to be discussed separately.

When using a roof for a catchment area, it is necessary to have rain gutters and a conduit, or downspout, to gather and transport the water from the roof to the ground (United Nations Environment Programme, 2004b). The most common sized gutters are 1 inch per every 100 square feet of roof and 4 inch downspouts (Montana State University, 2004). Fortunately, most roofs are already equipped with this hardware, easing the work and cost necessary to implement such a program. It is also highly recommended that a coarse mesh filter be placed at the head of the conduit to prevent large pieces of debris from contaminating the water (Centre for Science and Education, 2004).

The next component in many rainwater-harvesting systems is a first flush device. This part of the system will allow for a certain amount of water from the first rains of the season to be diverted away from the water supply that is being gathered (Texas Guide to Rainwater Harvesting, 2004). This is important because the water from the first flush will have the highest amount of contaminants, and by eliminating that water from the supply immediately, you decrease the amount of filtration needed to properly clean the water for use (Texas Guide to Rainwater Harvesting, 2004). This can be achieved by either having a turning valve that allows a certain amount of water to flow through before beginning the diversion into a storage container or through a separate downspout (Texas Guide to Rainwater Harvesting, 2004). Approximately 10 gallons of water for every 1000 square foot catchment area will flow into a separate pipe with a sealed top that is attached to the gutter and downspout system. Once this pipe is full, the remaining water will then flow into a storage container (Texas Guide to Rainwater Harvesting, 2004). The first flush water can easily be stored in a separate container to be analyzed by the Monterey Bay Sanctuary Citizen Watershed Monitoring Network and the Coastal Watershed Council, two groups who collaborate to study the contaminant levels of first flush rains throughout Monterey and Santa Cruz counties (Coastal Watershed Council, 2004).

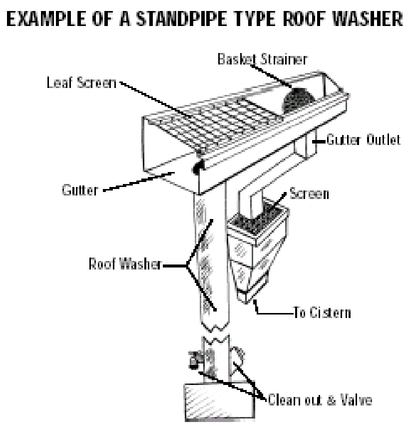

Figure 9. Example of a First Flush Filter (Texas Guide to Rainwater Harvesting, 2004)

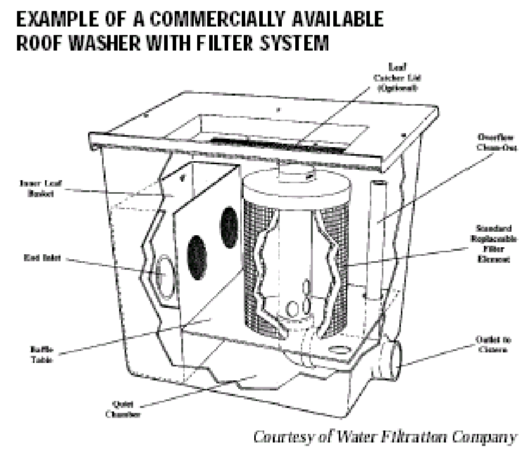

Figure 10. Example of a First Flush Filter (Texas Guide to Rainwater Harvesting, 2004)

The water that makes it past the first flush device must then be filtered to remove contaminants. Simple filters include a charcoal filter, a slow sand filter, and a mixed media, also called a Dewas (named for the area in India where it was designed), filter (Centre for Science and Environment, 2004). These filters are very simple, using layers of pebbles, sand and charcoal to filter out debris and dirt from the water supply (figures 11, 12 and 13). Figure 14 illustrates a commonly used downspout filter designed by the German company WISY (Rainwater Harvesting Systems Ltd, 2004).

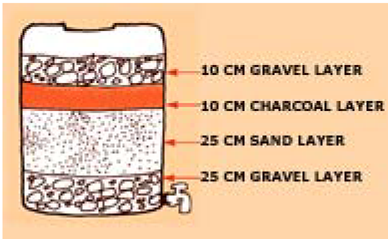

Figure 11. Charcoal filter (Centre for Science and Environment, 2004)

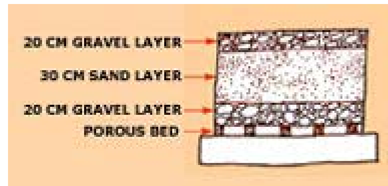

Figure12. Sand Filter (Centre for Science and Environment, 2004)

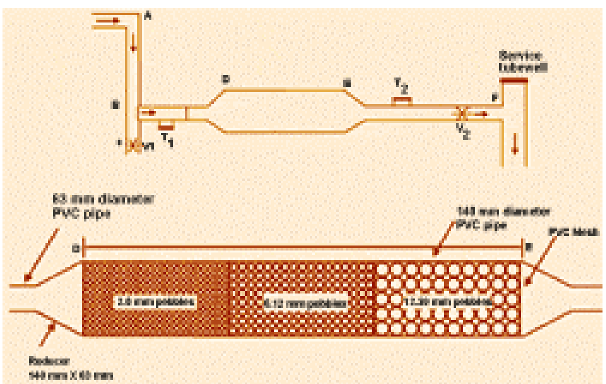

Figure 13. Dewas Filter (Centre for Science and Environment, 2004)

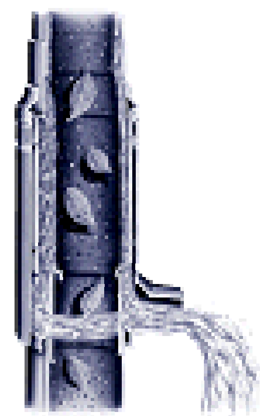
Figure 14. WISY downspout filter (Rainwater Harvesting Systems, Ltd, 2004)

For large roofs in countries such as India, a larger filter system designed by R. Jeyakumar is used to filter out dirt and debris (Centre for Science and Environment, 2004). This larger mixed media filter consists of circular chambers of sand, gravel and then pebbles. After the water is filtered through these chambers, it spills into a storage container where it can be chlorinated or ozonated to remove biological contaminants (figure 15) (Centre for Science and Environment, 2004). For individual consumers of harvested rainwater, there is also the option to disinfect the water coming into their tap through a charcoal or reverse osmosis filtration system (Texas Guide to Rainwater Harvesting, 2004). Table 1 includes a synopsis of different filtration types and their features, which are published in the Texas Guide to Rainwater Harvesting (2004).

For larger, more contaminated areas, such as Fort Ord, more complex filtration and purification of the water is needed. This is due to the fact that the California Health and Safety Code, under the Toxic Injection Well Control Act of 1985, does not permit the deliberate recharge of uncontaminated groundwater with potentially contaminated surface water, such as would be collected from the rainwater harvesting systems and potentially diverted to recharge basins on Fort Ord (California Health and Safety Code, 2004).

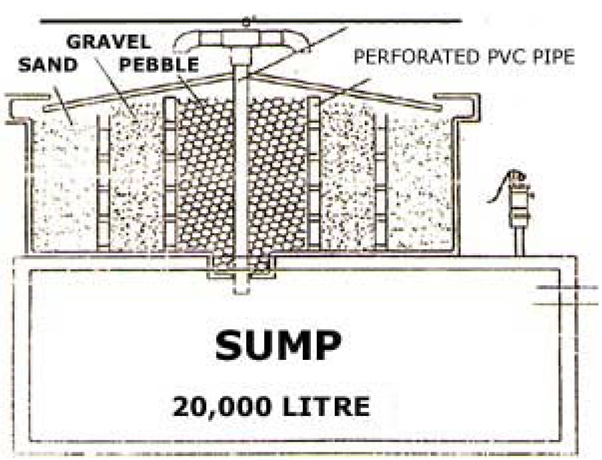

Figure 15. R. Jeyakumar filter (Centre for Science and Environment, 2004)

Table 1. Filtration Types

METHOD	LOCATION	RESULT
SCREENING		
Strainers and Leaf Screens	Gutters and Leaders	Prevent leaves and other debris from entering tank
SETTLING		
Sedimentation	Within Tank	Settles particulate matter
FILTERING		
In-Line/Multi Cartridge	After Pump	Sieves sediment
Activated Charcoal	At Tap	Removes chlorine
Reverse Osmosis	At Tap	Removes contaminants
Mixed Media	Separate Tank	Traps particulate matter
Slow Sand	Separate Tank	Traps particulate matter
DISINFECTING		
Boiling/Distilling	Before Use	Kills microorganisms
Chemical Treatments (Chlorine or Iodine)	Within Tank or At Pump (liquid, tablet or granule)	Kills microorganisms
Ultraviolet Light	Ultraviolet light systems should be located after the Activated carbon filter before trap	Kills microorganisms
Ozonation	Before Tap	Kills microorganisms

Once the water has been initially filtered, it must be diverted into a storage container. The largest and most readily available storage container is the earth's groundwater system. Groundwater recharge is a natural function of the water cycle (Ritter, et al, 1995). After water falls to the ground in the form of precipitation, it will then move in several different pathways (Figure 16) (Viessman, et al, 2003). The first is infiltration into the soil. After the soil becomes fully saturated, the water will then form rills, which will then become part of surface flow (Viessman, et al, 2003). This surface flow can drain into a puddle, a river, a lake, or any other type of reservoir (Viessman, et al, 2003). Once in these reservoirs, the standing water will then slowly infiltrate the soil, recharging the groundwater (Goudie, 1981). The surface water and the groundwater are truly one water: any change in the amount of surface water will change the infiltration to groundwater, and any removal of groundwater will lower the level of the surface water as it replaces the water that was just pumped out (Sax, 2003). When water doesn't have the opportunity to act in this fashion due impervious cover in the watershed, it can be directed to do so from a rainwater harvesting system through a recharge basin (Viessman, et al, 2003).

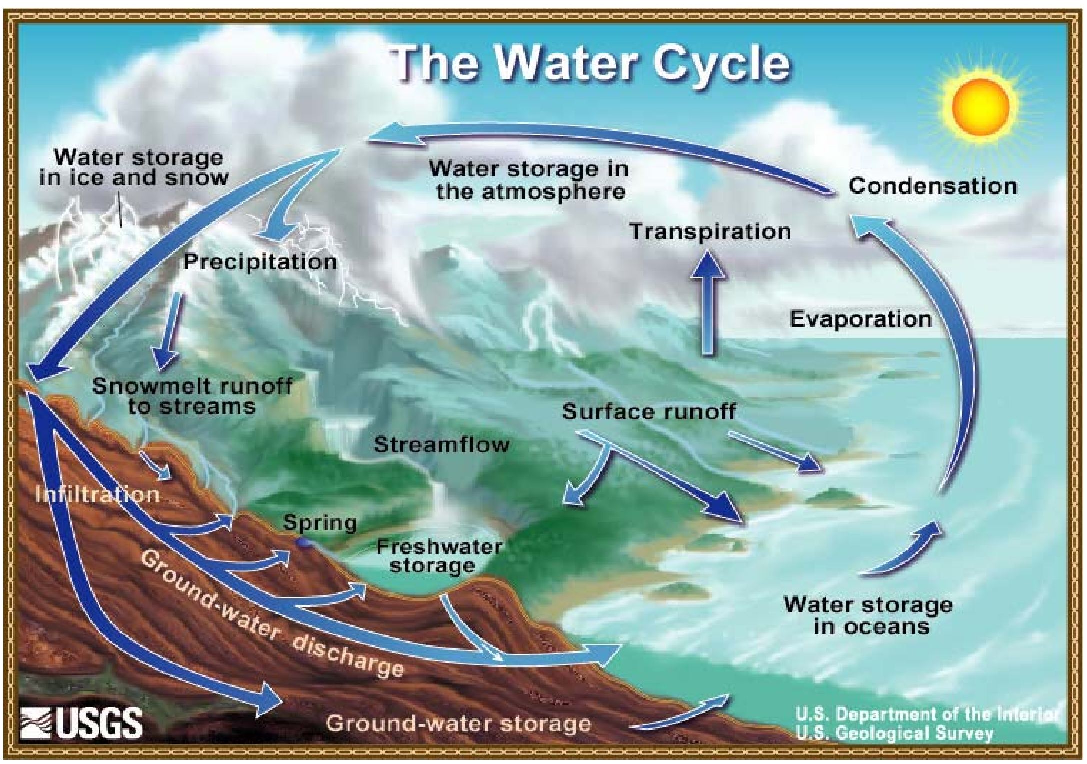

Figure 16. The Water Cycle (USGS, 2004)

A recharge basin is an artificially dug basin that is covered in riprap (granite blocks) in order form pools of standing water (Goudie, 1981). The riprap forms as a defense against erosion of the surrounding soils, so that they do not cause the basin to fill with sediment and overflow, and thus flood surrounding areas. As the water is allowed to sit in the recharge basin, it is able to infiltrate the soil, and increase groundwater levels (Goudie, 1981). Water can then be stored in the groundwater system for future use, at which time it can be pumped to the surface through wells.

Other options for storage include many types of above and below ground storage tanks or cisterns (Texas Guide to Rainwater Harvesting, 2004). These tanks can be attached to a rainwater harvesting system either before or after filtration. For individual use a cistern would be attached after filtration to ensure that as much debris as possible would be removed from the water before it is sent through pipes into a residence (Centre for Science and Environment, 2004). However, for a large, public areas such as Fort Ord, where water needs to be more thoroughly treated than can be done with simple filters, a cistern can be directly attached to a downspout (provided a coarse mesh filter is in place to remove large pieces of debris). Water can then be transported by truck to the local treatment facility for proper cleaning before it is put into the water supply for that particular community. Table 2 illustrates different material that can be used for creating cisterns (Texas Guide to Rainwater Harvesting, 2004).

Table 2. Storage Container (Cistern) Types

MATERIAL	FEATURE	CAUTION
PLASTICS		
Garbage Cans (20-50 gallon)	Commercially available, inexpensive	Use only new cans
Fiberglass	Commercially available, alterable and moveable	Degradable, requires interior coating
Polyethylene/Polypropylene	Commercially available, alterable and moveable	Degradable, requires exterior coating
METALS		
Steel Drums (55 gallon)	Commercially available, alterable and moveable	Verify prior use for toxics, corrodes and Rusts, small capacity
Galvanized Steel Tanks	Commercially available, alterable and moveable	Possible corrosion and rust
CONCRETE AND MASONRY		
Ferrocement	Durable, immoveable	Potential to crack and fail
Stone, Concrete Block	Durable, immoveable	Difficult to maintain
Monolithic/Poured in Place	Durable, immoveable	Potential to crack
WOOD		
Redwood, Douglas Fir, Cypress	Attractive, durable	Expensive

When considering collecting water from roads and storm drains, the removal of contaminants becomes a much greater concern (Centre for Science and Environment, 2004). Simple filtration methods described above are not enough to remove such harmful toxins as gasoline and oils (Centre for Science and Environment, 2004). In order to remove these chemicals, the pipes that carry the water from the streets need to be diverted to carry the water to a treatment facility where contaminants can be removed. When used in conjunction with harvesting roof water, the amount of water moving through the storm drains should be drastically decreased.

In many areas in the United States and throughout the world rainwater harvesting has been very successful and is now an everyday part of life (Texas Guide to Rainwater Harvesting, 2004). In Europe and North America small systems have been built by individual homeowners to increase their water supply and decrease their dependence on their municipal water source (Envireau Rainwater Management, 2004). In Oregon, one homeowner built a system that is able to capture 3600 cubic feet/year of rainwater (Ersson, 2004). This water is used for all daily functions from September to June, when the weather dries and municipal water is once again used (Ersson, 2004).

In Gansu, China where the climate is extremely arid and groundwater supplies were diminished, rainwater harvesting became essential to residents (Changemakers, 2004). In 1995, the Gansu Research Institute for Water Conservation provided 2000 + households with $50 each to be able to purchase all of the necessary components of a rainwater harvesting system (Changemakers, 2004). By 2002 tremendous results had been seen, including a 20-40% increase in crop yield and an increase in per capita income from $100 per year to $182 per year (Changemakers, 2004). In terms of labor saved, the installation of these systems has saved 70 water fetching labor days per family per year (Changemakers, 2004). After the success of Gansu, rainwater harvesting systems were installed throughout China. By 2001, there were 12,000,000 cisterns and recharge ponds in China, which provide water for over 36,000,000 people (Changemakers, 2004).

Many countries around the world not only use rainwater harvesting systems as a means to provide water to their citizens, but have made policies regarding doing so (Centre for Science and Environment, 2004). In many Caribbean islands, such as Barbados and the United States Virgin Islands, rain water harvesting systems are required on most, or all, new buildings (United Nations Environment Programme, 2004b). In addition all new buildings in Belgium must have a rainwater harvesting systems installed for use in flushing toilets and for external water supply (Canadian Water and Wastewater Association, 2004). Perhaps the most extensive existence of rainwater harvesting systems is in India, where the climate is dry and most of their water comes from monsoons (Centre for Science and Environment, 2004). Many regions and cities has government regulations on where systems must exist, some of which are more restrictive than others. For example, in New Delhi all buildings with a catchment area greater than 100 square meters built after June 2001 must have an attached system (Centre for Science and Environment, 2004). Table 3 illustrates government requirements for rainwater harvesting systems per region (Centre for Science and Environment, 2004). The areas in the table refer to catchment size.

Table 3. Rainwater Harvesting System Requirements

Region Name	New Buildings	Existing Buildings	Land Plots
Indore	> 250 square m	n/a	n/a
South Delhi	All	All	All
New Delhi	>100 square m	n/a	> 1000 square m
Kanpur	>1000 square m	n/a	n/a
Hyderabad	>300 square m	n/a	n/a
Tamil Nadu	All	All	n/a
Haryana	All	n/a	n/a
Rajasthan	>500 square m	> 500 square m	> 500 square m
Mumbai	> 1000 square m	>1000 square m	>1000 square m
Gujarat	All Government	All Government	n/a

Though there are no laws forbidding the use of rainwater in the United States as there are in some African countries, such as Uganda or Kenya, there is very little policy or financial incentives to promote it either (United Nations Environment Programme, 2004a). One exception is that the state of California does have a tax credit for having cisterns in operation (Canadian Water and Wastewater Association, 2004). With the lack of water in the United States West reaching an almost critical point, it becomes imperative that local or state governments consider the positive effects that rainwater harvesting systems can have on their water supply.

These successes with rainwater harvesting can be applied locally to alleviate the stress in finding a new water source. Systems could be attached to every home or business in the county to be reused in that home or business. However, taking into consideration the large area of Fort Ord and the great proportion of which is impervious cover, harvesting water from this site alone may help to provide a large amount of water needed by the county to either replace the 10, 730 acre-feet per year that Cal-Am can no longer pump or limit the amount of salt water intrusion in north Monterey County.

Methods

To determine the amount of water that can be captured by rainwater harvesting, the size of the developed area on Fort Ord needs to be determined. The total size of Fort Ord is approximately 28,000 acres (MACTEC, 2004). However, a great portion of this land is undeveloped as part of the Bureau of Land Management Lands. The number of developed acres of land can be determined using GIS data provided by the environmental engineering firm MACTEC on their website for the cleanup of Fort Ord. On this site is a GIS data set regarding parcel maps for Fort Ord, which includes parcel size and land use. Using this information, it can be determined which parcels would contribute to the runoff on Fort Ord and which ones wouldn't. Parcels that are categorized as parks or BLM lands are not included in the data as they are able to naturally process their rainfall and do not significantly contribute to the runoff on Fort Ord.

Once the size of each of the parcels with impervious cover has been determined, the annual precipitation on Fort Ord needs to be calculated. This was done using historical precipitation data for Monterey (data for Fort Ord was unavailable) provided by the Western Regional Climate Center (2004). Historical data from 1941- 2003 was used to determine rainfall for an average year (19.58 inches), a dry year (8.95 inches) and a wet year (41.01 inches) to illustrate the potential for rainwater harvesting through varying degrees of precipitation.

The area of Fort Ord is then multiplied by precipitation to calculate the total amount of water that is falling into the Fort Ord system and could potentially be harvested. Because some of the precipitation that falls will infiltrate into the surface and some will runoff, the ratio that will runoff is determined using an SCS (Soil Conservation Service) composite curve number (Viessman, et al, 2003). While SCS curve numbers are designed to determine runoff in areas with rainfall patterns consistent with the United States East Coast, it is a reference tool that is nonetheless helpful (Curry, 2004).

To calculate an SCS composite curve number, the proportion of impervious area to non-impervious area is determined. In the case of Fort Ord, many of these parcels have an equal amount of housing, roads or other structures, as they do parks, lawns and open space. An SCS composite curve number is calculated by dividing the area of each parcel into its respective land use and then multiplying that area by the appropriate SCS curve number (Viessman, et al, 2003). Each area within the parcel is calculated by the same means and then summed to get an SCS composite curve number (Viessman, et al, 2003). For example, the SCS number for concrete is 100 and the SCS number for parks is 39. If 50% of the parcel is concrete (.5*100 = 50) and 50% of the parcel is park or lawn (.5*39 = 19.5), then we have a composite number of 69.5, which can then be rounded to 70, and applied to the entire parcel.

Each parcel of land will have it's own SCS curve number assigned to it, consisting of 70 in housing areas and 90 in well developed areas. Although the SCS Curve number for roofing and concrete is 100, rainwater harvesting manuals suggest using a number of 90 to compensate for losses due to evaporation and general collection as well as the material over which the rain passes (Texas Guide to Rainwater Harvesting, 2004). If an SCS Curve number cannot be ascertained from the GIS parcel information, a curve number of 70 will be used so as not to overestimate the amount of water that can be captured from that parcel. Because the SCS number represents a percentage, when used in calculations, they will be expressed as .7 and .9 respectively. This SCS curve number will then be multiplied by the total precipitation (precipitation * area) for each parcel to determine the amount of water that will be available for capture for later use.

Results

Figure 17 is the parcel map provided by MACTEC (2004) that has been used to determine acreage and land use in the parcels on Fort Ord. The parcels were analyzed separately and then grouped together based on land use. Table 4 illustrates the types of land uses and the amount of runoff that can be captured during an average, wet, and dry rain-fall year. The regions where the different land uses are located have been drawn on the map.

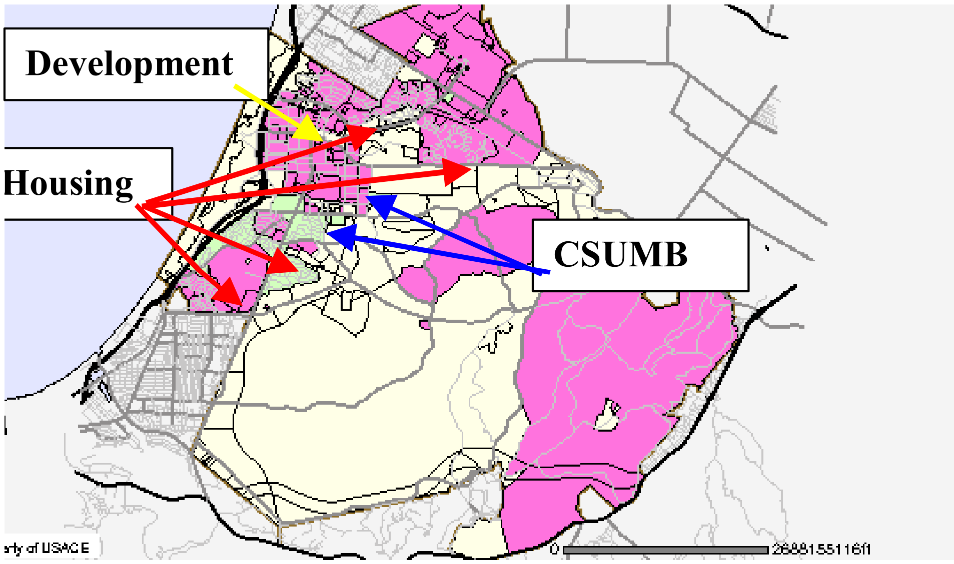

Figure 17. Parcel Map of Fort Ord

Table 4. Potential Runoff for Different Land Use on Fort Ord

Category	Runoff Avg. Year (Acre-Feet/Year)	Runoff Wet Year (Acre-Feet/Year)	Runoff Dry Year (Acre-Feet/Year)
Housing	4025.496745	8431.339198	1840.050861
CSUMB (non-housing)	408.5187517	855.6360575	186.7335458
Schools (non-CSUMB)	169.4381407	354.885503	77.45001833
Buildings	778.6376316	1630.844192	355.9145456
Roads	945.615121	1980.5759	432.2398025
Development	2484.929618	5204.645741	1135.859044
Misc.	851.1458633	1782.711535	389.0579917
Total	**9663.7819**	**20240.6381**	**4417.305809**

As the above table illustrates, the total amount of runoff that can potentially be captured on Fort Ord using a rainwater harvesting system is approximately 9,700 acre-feet of water during an average rainfall year, 20,000 acre-feet during a wet year and 4,400 acre-feet during a dry year. In each case, the bulk of the runoff available comes from areas of housing on Fort Ord, which includes CSUMB housing, public housing, and current and abandoned military housing in Stillwell, Patton, Hayes, Fitch and Marshall housing communities, providing 4000, 8400, and 1800 acre-feet per year respectively for average, wet and dry years.

The schools on Fort Ord, including CSUMB, UC system extension schools and public middle and elementary schools could provide approximately 600 acre-feet of water for an average year, 1,200 acre-feet during a wet year and 250 acre-feet during a dry year. Lone standing buildings that are not a part of housing or school campuses also have the ability to provide for a large amount of water. During an average year buildings such as the Department of Defense building and the Astronomy Center are able to provide a combined 800 acre-feet of water. During a wet year that number rises to over 1,600 acre-feet and during a dry year it falls to 350 acre-feet per year.

Roads and areas that do not fit into the other categories (labeled as miscellaneous) each provide approximately 10 % of the water that can potentially be harvested on Fort Ord. Roads can provide 950 acre-feet of water during an average year, 2,000 acre-feet during a wet year, and 400 acre-feet of water during a dry year. Miscellaneous areas, such as business parks, can provide 850 acre-feet of water during an average year, 1800 acre-feet of water during a wet year, and 400 acre-feet of water during a dry year.

After housing, the single largest source for captured runoff is the areas marked as development. These areas are on the southwest region of Fort Ord, running next to Highway One and 12th Street. During an average rainfall year approximately 2500 acre-feet of water runs off these parcels. During a wet year, that number can rise to 5200 acre-feet and can fall to 1100 acre-feet during a dry year.

Discussion

While the areas of impervious cover on Fort Ord have the capability to provide almost 10,000 acre-feet of water during an average year, in the interest of water quality, water should only be gathered from housing and schools. Together, these two land uses provide almost half (48%) of the water that can be captured on Fort Ord, and are likely to be the least polluted, not only from everyday chemicals and debris like oils and gasoline, but from the remnants from military use, such as lead paint and other toxins, that are expected to be found in higher quantities on both roads and in the areas labeled 'development'.

The 4600 acre-feet of water that can be captured from housing and schools on Fort Ord is more than enough to replace the approximate 2,200 acre-feet of water per year that the Marina Coast Water District currently pumps to provide water for the city of Marina (MCWD, 2001). In addition to Marina, MCWD also provides water for Fort Ord. Although the amount that can be pumped from the aquifers has been set by the Fort Ord Reuse Authority under a September 1993 agreement between the Monterey County Water Resource Agency and the federal government at 6,600 acre-feet per year, this amount has not yet been reached (MCWD, 2001). Therefore, the remaining water that can be gathered from rainwater harvesting can be used to provide water for Fort Ord.

The primary reason why MCWD should have priority over MPWMD for this resource is that the issues surrounding the district, especially regarding Fort Ord, are more pressing. Saltwater intrusion has been occurring for over 50 years, and as of 2001, the overall Salinas Groundwater Basin was being over drafted by 17,000 acre-feet per year (MCWD, 2001). Used in conjunction with the current practice of using recycled water on golf courses and farms, rainwater harvesting could help reduce or even eliminate overdraft, which would mitigate the problem of saltwater intrusion. In addition, water treatment facilities for Fort Ord already exist within the Marina Coast Water District, and the means of introducing the water captured from the rainwater harvesting system can be achieved through simple recharge basins and pumped out through existing wells. Lastly, the bulk of the growth in the area surrounding the city of Monterey is occurring on Fort Ord as new development projects are taking place, and water supplies for this area will need to increase.

Because the majority of the rain on Fort Ord is seasonal, rainwater harvesting manuals suggest that the water that is captured be used for groundwater recharge (Centre for Science and Education, 2004). Because all of the water comes within a short period of time, storage tanks would need to be extremely large to hold the majority of the water that can be gathered for the whole year at once (Centre for Science and Education, 2004). Recharging the groundwater would also help to raise aquifer levels, even if temporarily. In addition, any excess water that is recharged but not pumped out of the aquifers will aid in slowing saltwater intrusion in the basin.

The potential for rainwater harvesting on Fort Ord should serve as an example to surrounding cities. If the limited housing on Fort Ord has the capability to provide so much water for consumptive use, cities such as Monterey or Salinas should consider how much water could possibly be provided for their communities by installing rainwater harvesting systems. By possibly introducing these systems to building codes to provide water for consumers, if only for use in toilets or landscaping, these cities could reduce their dependence on their current water sources and potentially ease the environmental damage that is occurring in their respective watersheds.

While the benefit of rainwater harvesting systems is clear, further research needs to be completed to assess the cost of implementing such a program on Fort Ord. Initially, this would be high as the bulk of the costs associated with such a project occur with the purchase of cisterns, filters and piping, however afterwards the remaining costs is simply associated within maintenance. As for whether the costs of maintaining these systems is comparable to desalination or other possible projects is currently unknown, however what is known is that Monterey County has a problem of lack of water and rainwater harvesting is one possible solution.

One last concern is for the quality of the water that would continue to runoff of Fort Ord through storm drains into Monterey Bay. Because of the high levels of contaminants in the water, its release into the bay violates the Clean Water Act (USEPA, 2004). Studies need to be done to determine how to initially reduce the contaminants in the water from Fort Ord, possibly through clean up of current and former military lands. In addition, it is imperative that there be a focus on treating the water from the storm drains before it can spill into the sanctuary.

Conclusion

Rainwater harvesting systems have been used throughout the world for centuries to gather water for use within homes and municipalities. There are current examples of success with these systems in many parts of the world, including China, India and within the United States. With the current research into alternative water sources for Monterey County taking place, rainwater harvesting is a viable option, which should be looked into. By simply attaching rainwater harvesting systems to housing areas and schools on Fort Ord, 4600 acre-feet of water can be captured for use by the Marina Coast Water District to allocate to consumers in Marina and on Fort Ord. Also, the addition of this captured water into the groundwater on Fort Ord has the potential to alleviate the saltwater intrusion that is migrating through the 180' and 400' aquifers.

Acknowledgements

In completing this capstone report, I would like to give thanks to Dr. Robert Curry and Dr. Douglas Smith for the amazing classes they have taught at CSUMB and the way they teach students to look at the physical world in a practical and social way. Thank you to Dr. Lars Pierce, who has always been extremely supportive and knowledgeable. Thank you to fellow CSUMB graduate Michael Bogan for the inspiration to care about water and how it is allocated. To William Woodworth for being dedicated to the capture of rainwater on Fort Ord for many, many years. And finally, thank you to Joshua Choate for supporting me through this long process.

Appendix A. Runoff Potential for Parcels on Fort Ord

Parcel Name	Acreage	SCS #	Runoff Avg. Year (Acre-Feet/Year)	Runoff Wet Year (Acre-Feet/Year)	Runoff Dry Year (Acre-Feet/Year)
Abrams Housing	46.21	0.7	52.77952167	110.5458725	24.12547083
Abrams Housing	1.224	0.7	1.398012	2.928114	0.63903
Abrams Housing	175.7	0.7	200.6786833	420.318325	91.73004167
Abrams Housing / Housing Authority	7.136	0.7	8.150501333	17.071096	3.725586667
Abrams Housing / Housing Authority	1.447	0.7	1.652715167	3.46158575	0.755454583
Abrams Housing / Interim	2.23	0.7	2.547031667	5.3347175	1.164245833
Abrams Housing / Peninsula Outreach	2.342	0.7	2.674954333	5.6026495	1.222719167
Army Maintenance Center	35.49	0.7	40.535495	84.9009525	18.5287375
Army Reserve Center	9.842	0.7	11.24120433	23.5445245	5.138344167
Astronomy Center	1.581	0.9	2.3216985	4.86276075	1.06124625
Barloy Canyon Road - south	7.251	0.9	10.6480935	22.30226325	4.86723375
BOQ (bachelor officers quarters)	29.625	0.7	33.8366875	70.87040625	15.46671875
Brostrom Housing	52.11	0.7	59.518305	124.6601475	27.2057625
Building 4419, 4420, 4421, 4423 / Surplus II	4.648	0.7	5.308790667	11.119178	2.426643333
Building 4448 / Surplus II	0.115	0.7	0.131349167	0.27510875	0.060039583
Building 4448 / Surplus II	1.485	0.7	1.6961175	3.55249125	0.77529375
Building 4458 / Surplus II	1.178	0.7	1.345472333	2.8180705	0.615014167
Building 4550 / Surplus II	0.318	0.7	0.363209	0.7607355	0.1660225
Building 4560 / Surplus II	0.295	0.7	0.336939167	0.70571375	0.154014583
Building 4885 - part	0.959	0.7	1.095337833	2.29416775	0.500677917
Business Park / Light Industrial / Office Park / Re	3.925	0.7	4.483004167	9.38958125	2.049177083
Business Park / Light Industrial / Office Park /	35.202	0.7	40.206551	84.2119845	18.3783775
Business Park / Light Industrial / Office Park / R	5.574	0.7	6.366437	13.3344015	2.9100925
Business Park / Light Industrial / Office Park / R	28.363	0.7	32.39527317	67.85138675	14.80784958
Business Park / Light Industrial / Office Park / R	5.193	0.7	5.9312715	12.42295425	2.71117875
Business Park / Light Industrial / Office Park /	3.341	0.7	3.815978833	7.99250725	1.744280417
Cable TV area	0.27	0.7	0.308385	0.6459075	0.1409625
Campus addition / Surplus II	9.23	0.7	10.54219833	22.0804675	4.818829167
Campus addition / Surplus II	3.733	0.7	4.263708167	8.93026925	1.948937083
Campus addition / Surplus II	48.82	0.7	55.76057667	116.789645	25.48810833
Campus addition / Surplus II	23.539	0.7	26.88546117	56.31117275	12.28931958
Campus addition / Surplus II	12.465	0.7	14.2371075	29.81939625	6.50776875
Campus Housing / Schoonover	407.313	0.7	465.2193315	974.3945243	212.6513288
Central Campus	90.733	0.7	103.6322082	217.0560193	47.37018708
Central Campus	126.794	0.7	144.8198803	303.3229465	66.19703417
Central Campus	6.522	0.7	7.449211	15.6022545	3.4050275
Childcare Center	6.147	0.7	7.0208985	14.70516075	3.20924625
CID Building	1.6	0.7	1.827466667	3.8276	0.835333333
Coe Avenue Triangle	2.108	0.7	2.407687333	5.042863	1.100551667
Commercial area / Fitch Housing / Marshall Housing	512.174	0.7	584.9880703	1225.248252	267.3975092
Corporation yard	10.607	0.7	12.11496183	25.37459575	5.537737917

Parcel Name	Acreage	SCS #	Runoff Avg. Year (Acre-Feet/Year)	Runoff Wet Year (Acre-Feet/Year)	Runoff Dry Year (Acre-Feet/Year)
DBRAC / DPW / Police	0.937	0.7	1.070210167	2.24153825	0.489192083
Development	67.858	0.9	99.649473	208.7142435	45.5496825
Development / mixed use	13.392	0.9	19.666152	41.190444	8.98938
Development / mixed use	13.324	0.9	19.566294	40.981293	8.943735
Development / mixed use	63.075	0.9	92.6256375	194.0029313	42.33909375
Development / mixed use	23.728	0.9	34.844568	72.981396	15.92742
Development / mixed use	33.59	0.9	49.326915	103.3144425	22.5472875
Development / mixed use	12.202	0.9	17.918637	37.5303015	8.1905925
Development / mixed use	71.035	0.9	104.3148975	218.4859013	47.68224375
Development / mixed use	14.696	0.9	21.581076	45.201222	9.86469
Development / mixed use	108.311	0.9	159.0547035	333.1375583	72.70375875
Development / mixed use	3.214	0.9	4.719759	9.8854605	2.1573975
Development / mixed use	9.968	0.9	14.638008	30.659076	6.69102
Development / mixed use	29.335	0.9	43.0784475	90.22712625	19.69111875
Development / mixed use	2.135	0.9	3.1352475	6.56672625	1.43311875
Development / mixed use	46.607	0.9	68.4423795	143.3514803	31.28494875
Development / mixed use	7.541	0.9	11.0739585	23.19423075	5.06189625
Development / mixed use / Surplus II	11.651	0.9	17.1094935	35.83556325	7.82073375
Development / mixed use ASP	58.834	0.9	86.397729	180.9586755	39.4923225
Development / mixed use-ac limit	36.445	0.9	53.5194825	112.0957088	24.46370625
Development / mixed use-ac limit	17.731	0.9	26.0379735	54.53612325	11.90193375
Development / mixed use-ac limit	255.336	0.9	374.960916	785.349702	171.39429
Development / mixed use-ac limit	129.308	0.9	189.888798	397.719081	86.797995
Development / mixed use-ac limit	54.42	0.9	79.91577	167.382315	36.529425
Development / mixed use-ac limit / historic distr	85.312	0.9	125.280672	262.398384	57.26568
Development mixed use / retail / Surplus II	37.359	0.9	54.8616915	114.9069443	25.07722875
Development / mixed use	45.659	0.9	67.0502415	140.4356693	30.64860375
Development / mixed use	1.135	0.9	1.6667475	3.49097625	0.76186875
Development / mixed use-ac limit	41.673	0.9	61.1968005	128.1757298	27.97300125
Development / mixed use-ac limit	24.543	0.9	36.0413955	75.48813225	16.47448875
Development area - northeast area	269.81	0.9	396.215985	829.8681075	181.1099625
Development area - south	39.153	0.9	57.4961805	120.4248398	26.28145125
Development area - south	0.487	0.9	0.7151595	1.49789025	0.32689875
Development mixed use / retail / Surplus II	16.16	0.9	23.73096	49.70412	10.8474
Development Park area	12.586	0.9	18.482541	38.7113895	8.4483525
DOD Center	24.253	0.7	27.70096817	58.01923925	12.66208708
East of 2nd Avenue	34.387	0.7	39.27568517	82.26230075	17.95287958
Expansion Area 3B	332.835	0.7	380.1530425	796.2245288	173.7676063
Facilities Engineer Area	18.394	0.7	21.00901367	44.0030465	9.603200833
Fredericks Housing - peanut	20.28	0.7	23.16314	48.51483	10.58785
Hayes Housing	106.945	0.7	122.1490142	255.8391763	55.83420208
Hayes Housing / Stilwell Housing	199.02	0.7	227.31401	476.105595	103.905025
Hayes Housing 2K	14.814	0.7	16.920057	35.4387915	7.7341425
Housing future	82.87	0.7	94.65135167	198.2457575	43.26504583

Parcel Name	Acreage	SCS #	Runoff Avg. Year (Acre-Feet/Year)	Runoff Wet Year (Acre-Feet/Year)	Runoff Dry Year (Acre-Feet/Year)
Housing future	105.569	0.7	120.5773928	252.5474403	55.11581542
Housing future	92.295	0.7	105.4162725	220.7927138	48.18568125
Housing Single Family Dwelling	0.551	0.7	0.629333833	1.31812975	0.287667917
Housing Single Family Dwelling low density	156.654	0.7	178.924977	374.7555315	81.7864425
Housing Single Family Dwelling low density	209.323	0.7	239.0817532	500.7529468	109.2840496
Housing Single Family Dwelling low density	218.441	0.7	249.4960288	522.5654823	114.0444054
Housing Single Family Dwelling low density	58.598	0.7	66.92868233	140.1810655	30.59303917
Housing Single Family Dwelling low density	138.81	0.7	158.544155	332.0682225	72.4703875
Housing Single Family Dwelling low density	134.154	0.7	153.226227	320.9299065	70.0395675
Housing Single Family Dwelling low density	265.795	0.7	303.5821892	635.8480888	138.7671396
Housing VOQ (visiting officers quarters)	0.844	0.7	0.963988667	2.019059	0.440638333
Housing VOQ (visiting officers quarters)	0.27	0.7	0.308385	0.6459075	0.1409625
Housing VOQ (visiting officers quarters)	0.26	0.7	0.296963333	0.621985	0.135741667
Law School / Surplus II	3.141	0.7	3.5875455	7.51405725	1.63986375
Legal Assistant School / Surplus II	3.497	0.7	3.994156833	8.36569825	1.825725417
Lexington Court Housing	7.961	0.7	9.092788833	19.04470225	4.156305417
Lift Station # 31	0.137	0.9	0.2011845	0.42137775	0.09196125
Lift Station # 96	0.098	0.9	0.143913	0.3014235	0.0657825
Lightfighter Lodge	3.035	0.7	3.466475833	7.26047875	1.584522917
Maintenance Buildings	7.556	0.7	8.630211333	18.075841	3.944861667
Maintenance Center / Surplus II	2.807	0.7	3.206061833	6.71504575	1.465487917
Maintenance Center / Surplus II	13.077	0.7	14.9361135	31.28345325	6.82728375
Maintenance Center Building 4885 Phase I	7.051	0.7	8.053417167	16.86775475	3.681209583
Maintenance Center Building 4885 Phase II	4.866	0.7	5.557783	11.6406885	2.5404575
Maintenance Center Building 4900	8.024	0.7	9.164745333	19.195414	4.189196667
Marina Park offices	8.468	0.7	9.671867333	20.257573	4.421001667
Martinez Hall	3.607	0.7	4.119795167	8.62884575	1.883154583
National Guard	5.165	0.7	5.899290833	12.35597125	2.696560417
National Guard	0.407	0.7	0.464861833	0.97364575	0.212487917
Normandy Road - part	0.784	0.9	1.151304	2.411388	0.52626
Normandy Road - part / Gigling Road	2.33	0.9	3.421605	7.1664975	1.5640125
Office Park	3.06	0.7	3.49503	7.320285	1.597575
Office Park	25.385	0.7	28.99390083	60.72726625	13.25308542
Office Park / Transit Center	3.781	0.7	4.318532167	9.04509725	1.973997083
Office Park / Transit Center	15.559	0.7	17.77097117	37.22101775	8.123094583
Officers' Club	2.208	0.7	2.521904	5.282088	1.15276
Oil Well Rd	29.029	0.9	42.6290865	89.28594675	19.48571625
Park Visitor Center	65.878	0.7	75.24365567	157.5966455	34.39380583
Park Visitor Center	28.743	0.7	32.8292965	68.76044175	15.00624125
Patton Housing	0.093	0.7	0.1062215	0.22247925	0.04855375
Patton Housing	11.236	0.7	12.83338467	26.879321	5.866128333
Patton Housing	3.483	0.7	3.9781665	8.33220675	1.81841625
Patton Housing	2.306	0.7	2.633836333	5.5165285	1.203924167

Parcel Name	Acreage	SCS #	Runoff Avg. Year (Acre-Feet/Year)	Runoff Wet Year (Acre-Feet/Year)	Runoff Dry Year (Acre-Feet/Year)
Patton Housing - lower	2.377	0.7	2.714930167	5.68637825	1.240992083
Patton Housing - lower	2.241	0.7	2.5595955	5.36103225	1.16998875
Patton Housing - lower	26.243	0.7	29.97387983	62.77981675	13.70103292
Patton Housing - upper	9.972	0.7	11.389686	23.855517	5.206215
Preston Housing	153.765	0.7	175.6252575	367.8443213	80.27814375
Preston Housing / Shelter Plus	64.183	0.7	73.30768317	153.5417818	33.50887458
Public facilities / institute / Surplus II	98.89	0.7	112.9488617	236.5696025	51.62882083
Railroad Spur Intermodal Transportation	6.647	0.7	7.591981833	15.90128575	3.470287917
Railroad Spur Intermodal Transportation 8th Street	2.966	0.9	4.355571	9.1226745	1.9909275
Railroad Spur Intermodal warehouses	10.567	0.9	15.5176395	32.50145025	7.09309875
Red Cross buildings	0.0138	0.7	0.0157619	0.03301305	0.00720475
ROW	3.861	0.9	5.6698785	11.87547075	2.59169625
ROW / Coe Avenue - south	5.096	0.9	7.483476	15.674022	3.42069
ROW / Reservation Road - south	5.416	0.9	7.953396	16.658262	3.63549
ROW / 6th Avenue / 8th Street Road	8.651	0.9	12.7039935	26.60831325	5.80698375
ROW / 8th Street	18.923	0.9	27.7884255	58.20241725	12.70206375
ROW / Barloy Canyon Road	6.092	0.9	8.946102	18.737469	4.089255
ROW / Barloy Canyon Road	0.011	0.9	0.0161535	0.03383325	0.00738375
ROW / Blanco Road	0.551	0.9	0.8091435	1.69473825	0.36985875
ROW / Blanco Road	9.692	0.9	14.232702	29.810169	6.505755
ROW / Booker Street / Patton - lower	31.193	0.9	45.8069205	95.94186975	20.93830125
ROW / Business Park / Light Industrial / Office Pa	7.673	0.9	11.2678005	23.60022975	5.15050125
ROW / Chapel Hill Road	0.994	0.9	1.459689	3.0572955	0.6672225
ROW / development / mixed use / Surplus II	30.109	0.9	44.2150665	92.60775675	20.21066625
ROW / Fremont	2.409	0.9	3.5376165	7.40948175	1.61704125
ROW / Gigling Road	4.419	0.9	6.4893015	13.59173925	2.96625375
ROW / Gigling Road	2.345	0.9	3.4436325	7.21263375	1.57408125
ROW / Housing future Singe Family Dwelling medium	0.07	0.9	0.102795	0.2153025	0.0469875
ROW / Housing future Singe Family Dwelling medium	4.907	0.9	7.2059295	15.09270525	3.29382375
ROW / Housing future Singe Family Dwelling medium	97.065	0.7	110.8644075	232.2037463	50.67601875
ROW / Imjin Road	198.218	0.7	226.3979923	474.1870105	103.4863142
ROW / Imjin Road	72.598	0.7	82.91901567	173.6725655	37.90220583
ROW / Imjin Road - northeast	3.561	0.9	5.2293285	10.95274575	2.39032125
ROW / Intergarrison Road	16.782	0.9	24.644367	51.6172365	11.2649175
ROW / Intergarrison Road	5.399	0.9	7.9284315	16.60597425	3.62407875
ROW / Intergarrison Road	7.755	0.9	11.3882175	23.85244125	5.20554375
ROW / Intergarrison Road - part	0.155	0.9	0.2276175	0.47674125	0.10404375
ROW / Martinez Hall	8.431	0.9	12.3809235	25.93164825	5.65930875
ROW / mid Intergarrison Road	9.265	0.9	13.6056525	28.49682375	6.21913125
ROW / middle Imjin Road	0.465	0.9	0.6828525	1.43022375	0.31213125
ROW / Monterey Road - south	3.227	0.9	4.7388495	9.92544525	2.16612375
ROW / Normandy - Parker Flats	25.495	0.9	37.4394075	78.41624625	17.11351875
ROW / North of Hwy 68	14.703	0.9	21.5913555	45.22275225	9.86938875
ROW / North South Road	6.226	0.9	9.142881	19.1496195	4.1792025

Parcel Name	Acreage	SCS #	Runoff Avg. Year (Acre-Feet/Year)	Runoff Wet Year (Acre-Feet/Year)	Runoff Dry Year (Acre-Feet/Year)
ROW / North South Road	1.014	0.9	1.489059	3.1188105	0.6806475
ROW / Reservation Road	4.118	0.9	6.047283	12.6659385	2.7642075
ROW / Reservation Road	10.396	0.9	15.266526	31.975497	6.978315
ROW / Reservation Road	17.024	0.9	24.999744	52.361568	11.42736
ROW / Reservation Road - north	21.058	0.9	30.923673	64.7691435	14.1351825
ROW / Reservation Road - north	9.171	0.9	13.4676135	28.20770325	6.15603375
ROW / retail	2.217	0.9	3.2556645	6.81893775	1.48816125
ROW / retail	5.211	0.9	7.6523535	16.02773325	3.49788375
ROW / road	49.172	0.9	72.209082	151.240779	33.006705
ROW / road	47.573	0.9	69.8609505	146.3226548	31.93337625
ROW / road	1.298	0.9	1.906113	3.9923235	0.8712825
ROW / road	2.241	0.9	3.2909085	6.89275575	1.50427125
ROW / road	13.749	0.9	20.1904065	42.28848675	9.22901625
ROW / road	2.246	0.9	3.298251	6.9081345	1.5076275
ROW / road	10.464	0.9	15.366384	32.184648	7.02396
ROW / road	10.584	0.9	15.542604	32.553738	7.10451
ROW / road	1.11	0.9	1.630035	3.4140825	0.7450875
ROW / south development area	4.433	0.9	6.5098605	13.63479975	2.97565125
ROW / South of Hwy 68	0.791	0.7	0.903453833	1.89226975	0.412967917
ROW / South of Hwy 68	11.534	0.7	13.17375033	27.5922115	6.021709167
ROW / South reserve	25.728	0.7	29.385664	61.547808	13.43216
ROW / South reserve	14.011	0.7	16.00289717	33.51781475	7.314909583
Satellite Campus	3.024	0.7	3.453912	7.234164	1.57878
Satellite Campus	33.12	0.7	37.82856	79.23132	17.2914
Satellite Campus	2.371	0.7	2.708077167	5.67202475	1.237859583
Satellite Campus	5.473	0.7	6.251078167	13.09278425	2.857362083
Satellite Campus	6.536	0.7	7.465201333	15.635746	3.412336667
School Fitch Middle	1.326	0.7	1.514513	3.1721235	0.6922825
School Hayes	4.85	0.7	5.539508333	11.6024125	2.532104167
School Marshall	40.104	0.7	45.805452	95.938794	20.93763
School Patton	15.129	0.7	17.2798395	36.19235025	7.89859875
School site – future	10.671	0.7	12.1880605	25.52769975	5.57115125
School Stilwell	19.106	0.7	21.82223633	45.7063285	9.974924167
Site 33	12.941	0.7	14.78077883	30.95810725	6.756280417
Site 35	15.112	0.7	17.26042267	36.151682	7.889723333
Site 35A	2.169	0.7	2.4773595	5.18879025	1.13239875
Site 35B	14.478	0.7	16.536289	34.6349955	7.5587225
South Campus	11.953	0.7	13.65231817	28.59456425	6.240462083
Stilwell Housing	3.619	0.7	4.133501167	8.65755275	1.889419583
Thorsen Village Housing	90.492	0.7	103.356946	216.479487	47.244365
Transit Center Building 2058	101.751	0.7	116.2166005	243.4138298	53.12250125
University Campus	23.881	0.7	27.27608217	57.12932225	12.46787208
Veterans Clinic	4.552	0.7	5.199142667	10.889522	2.376523333
Veterinary Clinic etc	7.188	0.7	8.209894	17.195493	3.752735

Parcel Name	Acreage	SCS #	Runoff Avg. Year (Acre-Feet/Year)	Runoff Wet Year (Acre-Feet/Year)	Runoff Dry Year (Acre-Feet/Year)
Visitor Center / business park	6.087	0.7	6.9523685	14.56162575	3.17792125
Warehouse Building 2434	5.611	0.7	6.408697167	13.42291475	2.929409583
Warehouse Building 2988 and Building 2990	273.286	0.7	312.1381597	653.7684335	142.6780658
Total	**7841.1178**		**9663.78187**	**20240.63813**	**4417.305809**

References	
PPT for Average Year (in)	19.58
PPT for Wet Year (in)	41.01
PPT for Dry Year (in)	8.95

Citations

California Environmental Protection Agency. 2004. http://www.calepa.ca.gov/

California Health and Safety Code. 2004. Chapter 6.5, *Hazardous Waste Control*. Article 5.5, *The Toxic Injection Well Control Act of 1985*. http://www.dtsc.ca.gov/LawsRegulationsPolicies/hs_code.html

California State Water Resources Control Board. 1995. Water Rights Decision WR-95. http://www.waterrights.ca.gov/hearings/WaterRightOrders/WRO95-10.pdf

California State Water Resources Control Board. 2004. http://www.swrcb.ca.gov

Canadian Water and Wastewater Association. 2004. Rainwater Harvesting and Grey Water Reuse. http://www.cmhc-schl.gc.ca/publications/ en/rh-pr/tech/03-100-e.htm

Centre for Science and Education. 2004. http://www.rainwaterharvesting.org

Changemakers. 2004. Water Journal Case Study – Rainwater Harvesting in China. http://www.changemakers.net/journal/03july/gansu.cfm

Coastal Watershed Council. 2004. http://www.coastal-watershed.org

Curry, Robert. 2003. Lecture presented in ESSP 387: Water Resource Assessment, Law and Policy. California State University, Monterey Bay.

Curry, Robert. 2004. Personal Communication.

Envireau Rain Water Management. 2004. Rainwater Harvesting Case Studies. http://www.envireau.co.uk/rainwater_harvesting_casestudies.htm

Environment Canada. 2004. Groundwater Quality. http://www.ec.gc.ca/water/en/manage/qual/e_grdwtr.htm

Ersson, Ole. 2004. Oregon Rainwater Harvesting and Purification System. http://users.easystreet.com/ersson/rainwatr.htm

Goudie, A. 1981: The Human Impact: Man's Role in Environmental Change. MIT Press, Cambridge, Mass.

Hennessey, Virginia. "Water Board Drops Plans for Desal Plant in Sand City," Monterey Herald. 02 April 2004.

Kondolf, M.G and R.R. Curry. 1984. The Role of Riparian Vegetation in Channel Bank Stability: Carmel River, California in Warner, Richard E. and Kathleen M. Hendrix, editors. *California Riparian Systems: Ecology, Conservation and Productive Management*. Berkeley. University of California Press.

Kondolf, M.G. and R.R. Curry. 1986. Channel Erosion Along the Carmel River, Monterey County, California. Earth Surface Processes and Landforms 11:307-319

MACTEC. 2004. Former Fort Ord Cleanup. www.fortordcleanup.com

Marina Coast Water District. 2001. Urban Water Management Plan. http://www.mcwd.org/mcwd_uwmp.pdf

Marina Coast Water District. 2004: www.mcwd.org

Montana State University. 2004. Rainwater Harvesting Systems for Montana. http://www.montana.edu/wwwpb/pubs/mt9707.html

Monterey County. 2004. Dam Inundation. http://www.co.monterey.ca.us/gpu/news/hs-10 dam inundation countywide e-size.pdf

Monterey County Water Resources Agency. 2004. http://www.mcwra.co.monterey.ca.us/

Monterey Peninsula Water Management District. 2003. Autumn Report. http://www.mpwmd.dst.ca.us/newsltr/2003fall/Page1-AutumnNewsletter.pdf.

Monterey Peninsula Water Management District. 2004. http://www.mpwmd.dst.ca.us/

MSN. 2004. Microsoft Maps. http://www.mappoint.msn.com

Rainwater Harvesting Systems Ltd. 2004. http://www.rainharvesting.co.uk/index.htm

Ritter, D. et al. 1995. Process Geomorphology. WCB/McGraw-Hill, Boston, Mass.

Sand City. 2004. The City of Sand City. http://www.sandcity.org/water/

Sax, Joseph. We Don't Do Groundwater: A Morsel of California Legal History. 6 University of Denver Law Review 269. Spring 2003.

Teraszki, Mike. 2003. Lecture presented in ESSP 387: Water Resource Assessment, Law and Policy. California State University, Monterey Bay.

Texas Guide to Rainwater Harvesting. 2004. www.twdb.state.tx.us/publications/reports/RainHarv.pdf

United Nations Environment Programme. 2004a. Framework for Inclusion of Rainwater Harvesting in National Water Legislation in Sub Saharan Africa. http://www.unep.or/jp/ietc/Focus/RWH2.asp

United Nations Environment Programme. 2004b. Rainwater Harvesting from Rooftop Catchments in *Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean*. http://www.oas.org/usde/publications/Unit/oea59e/ch10.htm

United States Environmental Protection Agency. 2004. http://www.usepa.gov

United States Geological Survey. 2004. http://www.usgs.gov

Viessman, W. et al. 2003. Introduction to Hydrology. Pearson Education Inc. Upper Saddle River, NJ.

Western Regional Climate Center. 2004. http://www.wrcc.dri.edu/