Chapter 3

RESIDENTIAL WATER CONSERVATION BY EFFICIENT UTILIZATION OF RAINFALL AND REDUCTION OF LANDSCAPE WATER REQUIREMENTS

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Can residential water consumption in Berkeley be reduced? Utilizing collected and stored rooftop rainfall for exterior purposes and integrating drought resistant or native vegetation are methods that may reduce the water requirements of individual dwellings as well as conserve the water available to the community. The potential for rooftop rainwater collection from the typical Berkeley home is determined in this paper.

Urbanization challenges the natural resources and physical environment of an area by altering the magnitude, process, and content of surface runoff (Dunne and Leopold, 1979). The development of impervious structures, such as asphalt roads and driveways, sidewalks, parking lots, and roofs, reduces land permeability and natural recharge infiltration. Stream sedimentation and storm flow runoff increase as well (Feth, 1973). Less water is contained in the soil, and nonproductive uses replace naturally occurring vegetation. Plant transpiration is reduced and the moisture content in air is decreased (Black, 1982).

Dry summers and wet winters characterize the Mediterranean climate of the San Francisco Bay Area. The normal average rainfall in Berkeley is 23.2 inches per year (National Weather Service, 1983). Variability of rainfall within and between seasons is typical and may cause water storage and supply problems under extreme conditions due to the constraints of the East Bay Municipal Utility District (EBMUD) system. The EBMUD system enforces regulations regarding water consumption that suffice for the survival requirements of water users and conserve the available water resource during drought periods. A supplementary water source for plants in the Bay Area is provided by the condensation of fog.

Methods Used for Determining RUnoff Collection Capabilities

It is necessary to calculate the size of the typical home in Berkeley in order to determine the potential for rainfall collection. In Berkeley sixty percent of single family detached residential units are one-story structures and forty percent are two- or more story homes. The average home of 1450 square feet is located on a 5,000 square foot lot (Berkeley Board of Realtors, 1983). The landscaped area can be calculated by assuming the land not occupied by the residential structure is garden space and subtracting the area of the home from the property area. This calculation yields a 3550 square foot garden area for the typical Berkeley residence but neglects areas covered by exterior structures not attached to the housing unit, including garages, decks, or pathways.

The sample for this study consists of thirty homes without swimming pools or attached annexes, such as garages or cabanas, apparent on the property. The runoff from the sample homes could draind directly off the housing structure into a storage. Homes with attached annexes would require either separate or connecting runoff collections systems and could complicate the proposed system.

Sanborn Maps were used to calculate roof areas as a comparison with the Berkeley Board of Realtor's figures and to determine the volume of water which falls as precipatation on the typical home in Berkeley. Aerial photographs would not provide accurate representations of the desired information because the photographic angle could create image distortion. Sanborn Maps feature one-dimensional outlines of the developed and undeveloped land in Berkeley, including parks, commercial businesses, schools, and residences. The maps picture only residential homes, not walkways, driveways, or decks.

The home and property perimeters of the residential units in the sample were measured and the average area was calculated. The measurement of the features on the map probably was somewhat inaccurate because the texture of the map paper was distinctly warped and distorted the images. The results obtained are constrained by the arbitrary selection process and limited sample size.

The area of the average residence in the sample was 1600 square feet, the average lot was 5265 square feet, and the average garden was 3665 square feet. The percent idfference between the values calculated from the map and the values obtained from the Berkeley Board of Realtors was approximately ten percent for home size, five percent for property size, and three percent for landscaped area. Since these values are relatively small, the dimensions obtained from the Berkeley Board of Realtors can be considered fair and accurate standard values and are used to calculate various dimensions of the following water collection system.

Collection Capabilities of the Runoff Storage System

The proposed process of water collection consists of filter screens, gutters, downspouts and rain diverters. Filter screens resting on top of gutters block debris from entering the gutter system. The runoff flows through the gutters lining the perimeter of the roof to downspouts. The capacity of runoff from the typical Berkeley residence is sufficiently contained by two downspouts located at diagonally opposing corners. Plastic rain diverters connect downspouts to a water storage container located adjacent to one of the downspouts. A pump attached to the tank removes the collected runoff and supplies a drip irrigation or other landscape watering system with moisture.

The gutter system potentially can collect nearly 21,000 gallons of rooftop runoff per year from a typical Berkeley residence. The yield can be calculated by multiplying the area of the average home by the normal rainfall:

$$\begin{aligned} \text{Volume/Year} &= \text{Residential Area} \times \text{Normal Annual Precipitation} \\ &= 1450 \text{ feet}^2 \times 23.2 \text{ inches/year} \times 1 \text{ foot/12 inches} \\ &= 2803 \text{ feet}^3\text{/ year} \times 7.48 \text{ gallons/feet}^3 \\ &= 20{,}969 \text{ gallons/year} \end{aligned}$$

The cost of a runoff collection system for the average residence is shown in Table 1. The subtotal value (A) represents the cost of the plastic rain diverters that complete the system for homes equipped

Material	Cost per Foot	Estimated Feet per Item	Quantity	Total Cost
Rain Diverter I	$0.17	10	1	$ 1.70
Rain Diverter II	$0.17	86	1	$ 14.65
Subtotal (A)				$ 16.35
Filter	$0.13	153	1	$ 19.89
Gutter	$0.13	153	1	$ 76.50
Downspout	$0.80	10	2	$ 16.00
Total (B)				$128.74

Table 1: Estimated Cost of Materials Used in Water Collection System

with filters, downspouts, and gutters. The total amount (B) represents the cost of purchasing all the elements in the system. Plastic gutters and galvanized downspouts were recommended because of the material's durability, low cost, and light weight (Ace Hardware Company, 1983). For single-story homes, ten foot long downspouts should satisfactorily connect the gutter to the storage tank. Rain Diverter I connects from the downspout adjacent to the runoff storage tank to the storage tank. Rain Diverter II, the length of two sides of the home plus an additional ten feet to extend to the tank, connects the other downspout to the tank. Most healthy, dedicated adults should be capable of properly installing the system. The cost of labor is not included.

Evaluation of Runoff Storage Containers

Polyvinyl plastic cistern tanks and home-made closed-brick storage containers are viable alternative ways in which to store the runoff. The size of the tank should be large enough to collect a significant amount of runoff. However, collecting the maximum volume of rooftop runoff would require either a large land area, defeating the intended purpose of the collected runoff because the landscape would be replaced by the storage tank, or a high, cylindrically-shaped container. A 21,000 gallon cylindrical runoff container might be hazardous during an earthquake.

Commercial cisterns range in volume capacity and price from 100 gallons at $175.95 to 6000 gallons at $5333.95 (Truitt and White Lumber Company, 1983). A square-shaped 6000 gallon capacity brick runoff storage container has sides 9'3" in length. "Porta Costa Red Common Brick" of dimensions 8" x 3 3/4" x 2½" is recommended because of its suitability for a runoff storage container and for its low cost (Truitt and White Lumber Company, 1983). Mortar can be made by combining certain proportions of lime, cement, sand, and water. Premixed, dry, packaged mortar is recommended because of convenience and ease of preparation. Six-mil strength polyethylene sheeting seals the top of the container and minimizes the contained runoff's exposure to pollutants. Table 2 summarizes the total cost of developing the storage container.

Material	Cost per unit	Units	Cost
Brick	$0.31/brick	1600 bricks	$495.00
Mortar	$2.99/bag·35 bricks	46 bags	$137.54
Polyethylene sheeting	$0.45/foot	25 feet	$ 11.25
Total (D)			$644.79

Table 2: Cost of Building a Brick Runoff Storage Container

The cost of constructing the described storage container is $4689.16 less than the cost of purchasing the 6000 gallon commercial cistern. In fact, the brick container costs only twelve percent of the cost of the cistern.

The 6000 gallon tank provides storage of a reasonable volume of runoff. When the container is filled, additional runoff could drain off the roof by disconnection of the rain diverter from the tank. The minimum amount of rainfall necessary to fill a 6000 gallon tank can be calculated as follows:

$$\text{Rainfall/year} = (\text{Volume/year})/\text{Residential Area}$$
$$= (6000 \text{ gallons/year})/1450 \text{ feet}^2$$
$$= 4.14 \text{ gallons/year feet}^2 \times 1 \text{ foot}/7.48 \text{ gallons} \times 12 \text{ inches}/1 \text{ foot}$$
$$= 6.64 \text{ inches/year}$$

The rainfall has surpassed this amount throughout the recorded levels of rainfall in Berkeley (see paper by Lawler, this report). Capacity storage would be guaranteed by the collection of the normal annual rainfall in Berkeley.

Quality of Rooftop Rainwater Runoff

The form of runoff from a roof probably is neither pure rainwater nor potable water. Traces of debris collected on a roof, including soot, twigs, shingles, tar, leaves, insects, larvae, and guano, are likely components of the runoff. These substances in runoff most likely are not harmful for vegetation or other purposes where potability is not crucial. In fact, some of the elements in the debris may provide nutrients to the soil.

Since the runoff may collect in the tank for several months before use, the tank should be closed in order to minimize the possible accumulation of pollutants. The quality of runoff presumably would be subpotable and may decrease with storage time. Collected runoff could be stored indefinitely, although the water might stagnate without filtration. Runoff stored in a closed container from the rainy season to the watering period should be safe to use for watering environmentally adapted plants. Water remaining in the container at the end of the watering period should be drained from the tank, allowing fresher runoff collection from the oncoming rainy season.

Determination of Gallons and Cost of Water Conserved

Purchasing 6000 gallons of water from EBMUD at $0.38 per 750 gallon unit costs $3.04 (Lara, pers. comm., 1983). There are 18,996 single family detached residential units in Berkeley (Census, 1980). Assuming the cost of water and the number of household units are constant, 114 million gallons of water and $57,748 can be saved in one year by homeowners if every home utilized the described storage system. In twenty years 2.28 billion gallons of water and $1,154,960 can be saved.

Gross per capita consumption of water from EBMUD in 1982 was 175 gallons per day, or nearly 64,000 gallons per year (EBMUD, January 1983). The average residential occupancy of 2.11 in Berkeley (Census, 1980) yields the gross consumption per household of 369 gallons per day and 134,685 gallons per year. Landscape watering accounted for half of the residential water consumption, or approximately 64,340 gallons per year. Installing the water storage system could diminish the amount of water purchased for landscape purposes by almost ten percent with no landscape alteration.

Evaluation of Drip Irrigation for Landscape Watering Purposes

Drip irrigation provides an effective method for efficient watering by reducing the water requirements of a garden by fifty percent (Sunset, 1977). The typical drip-irrigated Berkeley garden would require only 32,170 gallons of water per year. Almost twenty percent of the necessary landscape water could be stored in the 6000 gallon tank.

The drip irrigation system essentially pumps water from the storage tank through polyethylene tubing. The water is distributed from emitters located along the tubing and mist sprayers attached to the ends of the tubes. Holder stakes extend select emitters. The runoff is widely dispersed around the garden by drip irrigation; pooling of the runoff and concentrating possible harmful substances dissolved in the water, and additional attraction of flies and mosquitoes are thereby avoided. Drip irrigating eliminates dragging heavy hoses around the garden. The emitters in the system simultaneously water many plants. The emitters permit slow and frequent watering at the base of plants. Only a small area of soil is moistened and a minimal amount of water is lost by evaporation, spray, and runoff (Sunset, 1977). Plant stress related to water search and weeds sprouting between desired plants is reduced by water flowing directly to desirable foliage. Vegetation adapted to sprinkler systems or hose watering may not survive the transition to drip irrigation. Trees and shrubs previously irrigated with large volumes of water may not adapt quickly to the drip irrigation system providing considerably smaller volumes of water to root systems. Established root systems may already range deep and wide and may not receive enough water from the emitters soaking only tiny root portions.

A drip irrigation system can pump between one-half gallon to four gallons of runoff per hour. The system could run from two months to sixteen and one-half months pumping 6000 gallons of stored runoff. Since drip irrigation is not constantly required, especially in an environment adapted to drought conditions, a surplus of water should be available in the storage container. The extra stored runoff could be used liberally for exterior watering purposes not requiring potable water, such as washing and cleaning pathways or cars.

The Carefree Company manufactures a "Drip Mist" drip irrigation kit which retails for $13.95 (Truitt and White Lumber Company, 1983). The kit includes materials to assemble a drip irrigation system and is less expensive than individually purchasing essential components included in the kit.

Polyethylene tubing is recommended because of its low cost and functionality (John Hollenbeck Associates, 1983). Table 3 is a breakdown of the cost of a drip irrigation system for a 3550 square foot area. Less tubing is necessary for watering a drought-resistant garden than a nonadapted garden. The location of the tubes can be shifted, allowing the same length of tubing to water a more extensive area. The cost of the drip irrigation system for a nonadapted garden is approximately sixty percent more than the cost of developing a drip irrigation system for a drought-resistant garden.

Material	Cost per Unit	Units (E)	Cost (E)	Units (F)	Cost (F)
Tubing					
1/4"	$0.08/foot	500	$40.00	300	$24.00
1/8"	$0.06/foot	200	$12.00	80	$ 4.80
Emitters	$1.89/3	47	$29.61	25	$15.75
Mist Sprayers	$1.89/3	8	$ 5.04	8	$ 5.04
Holder Stakes	$1.09/8	16	$ 2.18	8	$ 1.09
Mounting Clips					
1/8"	$1.09/15	15	$ 1.09	8	$ .58
1/4"	$1.29/15	15	$ 1.29	8	$ .58
Connectors					
T	$1.99/5	16	$ 6.37	9	$ 3.58
L	$1.09/3	9	$ 3.27	5	$ 1.82
Straight	$1.45/5	9	$ 2.61	5	$ 1.45
Total			$103.46		$58.69

Table 3: Cost of Drip Irrigation Systems for a Nonadapted Garden (E) and a Drought Resistant Garden (F)

Reducing Landscape Water Requirements by Planting Adapted Vegetation

A garden composed of drought-resistant or native plants adapted to the Mediterranean climate of the San Francisco Bay Area requires little summer water and could further reduce landscape water consumption (James and Andrews, 1978). A few plants suggested for establishing a low water use garden are (EBMUD, 1983):

Trees - Ceratonia siliqua (Carob)
Pinus contorta (Shore Pine)
Pistacia chinensis (Chinese Pistache)

Shrubs - Ceanothus (Julia Phelps)
Dendromecon harfordii (Island Bush Poppy)
Rhus ovata (Sugar Bush)

Groundcover - Arctostaphylos uva-ursi 'Point Reyes' (Kinnikinnick)
Ceanothus gloriosus (Anchor Bay)
Fragaria chiloensis (Coast Strawberry)

The plants were selected for their suitability to the dry California summers and low water requirements. Many of these plants ordinarily receive more water than they need in order to thrive. One light irrigation per week is sufficient for many of the plants listed, including Frageria chiloensis and Rhus ovata. Ceanothus gloriosus is representative of plants that cannot tolerate water during the summer and cannot be planted with shrubs and trees requiring irrigation at that time (Deering, 1955; Lenz, 1977). A book concerning native California plants or drought-resistant plants should be consulted to select actual plants and determine the most ideal situation for their successful growth.

Conclusion

This paper estimates the total cost of developing a water collection system with or without an established gutter sytem. The storage of runoff in commercially-made cisterns or in constructed brick tanks is examined as well. Lastly, a drip irrigation system for nonadapted or drought-resistant gardens is evaluated. The most probable situation is of a gutter-lined residence (A) with a brick storage tank (D) and nonadapted garden requiring a drip irrigation system (E). The total initial cost would be $764.56 for the system, plus approximately $40.00 for a pump to obtain the runoff from the tank (Ace Hardware Store, 1983). If all the elements involved in this sytem last fifteen years, then the cost of the complete system per year is less than $55.00

Collecting water runoff for landscape watering and exterior purposes is an efficient method of water conservation. Integrating the described system could provide satisfaction to the individual for being conservational and reducing the water bill, decrease the water requirements of the city and create a surplus of water for dry years, and minimally decrease revenue to the utility company. However, the image of the storage tank may be undesirable. Furthermore, initial cost of the described storage system is high relative to the low cost of water as well. The storage container could easily be camouflaged by vegetation. Developing a drought-resistant garden would minimize summer landscape water requirements as well as provide ornamental decoration.

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