Runoff Water and Garden Design

A University of California Research Project

Above: Suited to the desert or garden, a native mesquite tree in morning light, Desert Hot Springs, CA

Cover: Details of the Jacobson Garden, Sherman Oaks, CA. Photographs by Chris Reding

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CONTENTS

Introduction

University of California researchers interested in the quality and amount of water flowing off urban landscapes have been studying storm and irrigation runoff from eight single family residential neighborhoods; four in Sacramento County and four in Orange County. Scientists tested for 31 contaminants in the water, from pesticides and nutrients to waterborne microorganisms that can cause disease. The research team also investigated best management practices (BMPs) that could improve runoff water quality and reduce the amount of water that currently runs off the gardens.

To do additional runoff experiments in a controlled setting, a concurrent UC study built three demonstration gardens at UC's Agriculture and Natural Resources South Coast Research & Extension Center in Irvine. The demonstration gardens include a typical lawn-oriented landscape, a low impact garden with mixed Mediterranean plants and efficient irrigation, and a low impact garden which focused on locally appropriate native plants and water saving irrigation.

In short, the study found that runoff water samples from Sacramento and Orange Counties had nutrient concentrations (the amount of a substance in a given amount of water) that raise concerns for eutrophication, *i.e.* the plant and algae consumption of dissolved oxygen in rivers, lakes, and streams. Orange county neighborhoods generated higher nitrate (the form of nitrogen that plants can use) concentrations than the Sacramento sites. Pesticides were also found, some at concentrations high enough to kill creatures at the base of the aquatic food chain. Two pesticides, fipronil and bifenthrin, were detected in virtually every water sample. All runoff samples from each of the four neighborhoods also contained total coliform bacteria, an indicator for disease causing microorganisms such as *Escherichia coli (E. coli*).

Upper image: A typical installation at a study neighborhood's storm drainage network out fall pipe with a green contractor box securing the data collection and water sampling equipment.

Top to bottom: 1. A portion of an Orange County study neighborhood. 2. Lawn irrigation in the desert. 3. Lawn irrigation runoff from a Sacramento County study neighborhood.

Clockwise from top: 1. A jewel-like low to moderate water-using garden in Sherman Oaks (see pages 22-23). 2. A UC Master Gardener's native plant landscape in Orangevale that with grasses and shrubs selected for color and form, achieved a complex garden that evolves over the seasons. 3. A brick on sand patio that percolates water into the soil, in Sacramento (see page 19). 4. A Sacramento homeowner's installation with dry-scape plants and recycled concrete 'flagstone' paving.

There is however, no need for gardens to pollute runoff water. Residential garden designs, such as those on the left, reduce both irrigation runoff and waterborne pollutants. These sustainable landscapes also minimize storm water runoff by percolating water into the soil as much as possible. The gardens are maintained without synthetic fertilizers or pesticides. Compost and humus are used to build healthy, nutrient rich soil. Plants suited to the local climates thrive with low or moderate water that is delivered by efficient irrigation systems. These gardens are green, lush, visually rich, and a pleasure to experience.

After visiting sustainable landscapes around the State, our observations suggest that all existing or new California gardens, from homeowner installations to professionally designed and constructed gardens can reduce water use, minimize runoff, and avoid pollutants. Switching to organic gardening practices and applying integrated pest management methods are basic, low cost steps toward reducing pollution. Simply applying inexpensive mulch to planting beds saves water. Installing rotary irrigation heads and timing water applications to avoid runoff can irrigate gardens more efficiently. Replacing standard irrigation controllers with 'smart' controllers can save additional irrigation water. For even greater performance, grade the garden to slow down water flow, use permeable paving materials, reduce or eliminate lawns, and install plants that are suited to the local climate and soil.

Designing satisfying landscapes that improve the quality and health of our environment can add more meaning and greater intrinsic beauty to the outdoor living places we create and enjoy. Gardening can become a fresh adventure, discovering new plants and creating designs that beautifully fit with local climates and settings.

The following pages describe the UC research findings and present attractive creations by homeowners and professional landscapers that in a variety of ways, help improve water quality and reduce water use.

A Davis mixed-use residential neighborhood drainage that can stop flowing between winter storms yet during the irrigation seasons will have constantly moving water.

Runoff Water Volumes

As attractive as it may look, drainages such as this one on the left can represent excess water flowing off urban neighborhoods, water that is likely carrying pollutants to downstream water bodies. To understand the actual quantity, or volume of water flowing as well as the loading, *i.e.* weight of pollutants within the water, the UC researchers gathered data from each Sacramento study neighborhood every two minutes, twenty-four hours a day, for more than three years.

Working with a subset of this intensive data, they were able to calculate the relative amount of runoff water from both non-storm sources and storm events. For example, the annual dry day water runoff volume measured from the four Sacramento County sites was 4.7 times higher than the total amount of runoff that flowed during rain days.

UC scientists will use the findings from the intensive data to develop a model that given a range of assumptions, can estimate runoff water volumes and pollutant loading. The model would be applicable to residential neighborhoods similar to those in this study, and be useful up to the scale of an urban region, such as Sacramento County.

By using plants adapted to the local climate, permeable paving materials, efficient irrigation systems, and water retaining site grading, gardens can help reduce runoff. Beginning clockwise from the top: 1. A front yard in St. Helena embodies the minimalist gravel landscapes of a Japanese garden, while including olive trees that can grow in stony soil and thrive on little or no dry season irrigation. 2. During the summer, the City of Los Angeles requires homeowners to prevent all irrigation runoff. For a planting bed that borders the sidewalk, this Los Angeles garden uses water efficient plants that can be drip irrigated, avoiding runoff. 3. Originally a front yard planted with turf that sloped to the sidewalk, this Davis home terraced the yard and pulled the lawn away from the property edge. Any over spray or flow from lawn irrigation can be caught by the bordering planter beds. 4. A new garden being installed in an established Sacramento neighborhood grades the slope to the street into three earthen swales that slow down and hold irrigation and storm water. The new plant material that was installed is water efficient and drip irrigated.

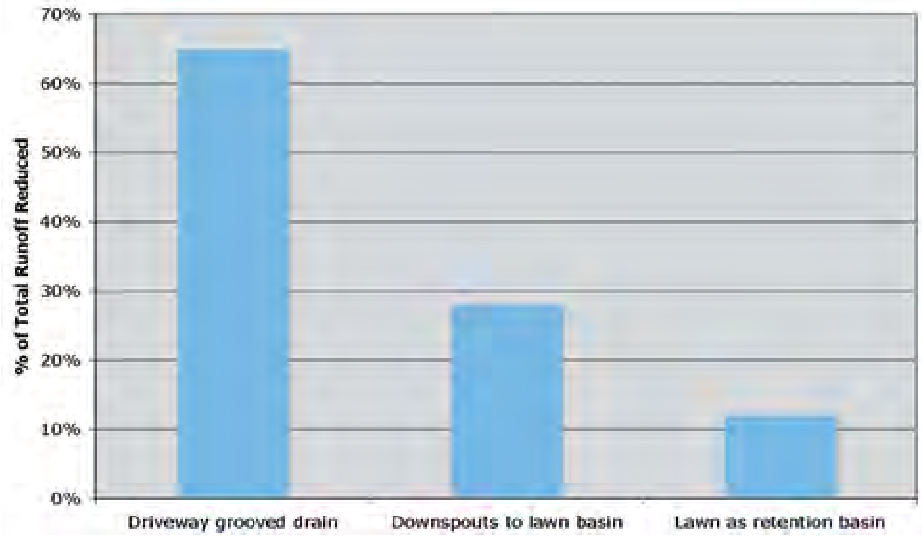
To test how low cost garden modifications could reduce storm water runoff, a study by the USDA Forest Service's Center for Urban Forest Research at UC Davis and the UC Davis Department of Land, Air, and Water Resources made simple alterations to typical Los Angeles residential yard, collected performance data over two years, and developed a model that estimated:

1. A groove cut into the concrete driveway near the sidewalk channelled runoff to a dry well *(i.e.* a four inch diameter gravel filled hole) in the yard and reduced overall storm runoff by 65%.
2. The front lawn was converted into a lawn retention basin that held rainfall and reduced overall runoff by 12%.
3. The roof gutter downspouts were extended to empty into the lawn basin, and overall runoff was reduced by 28%.

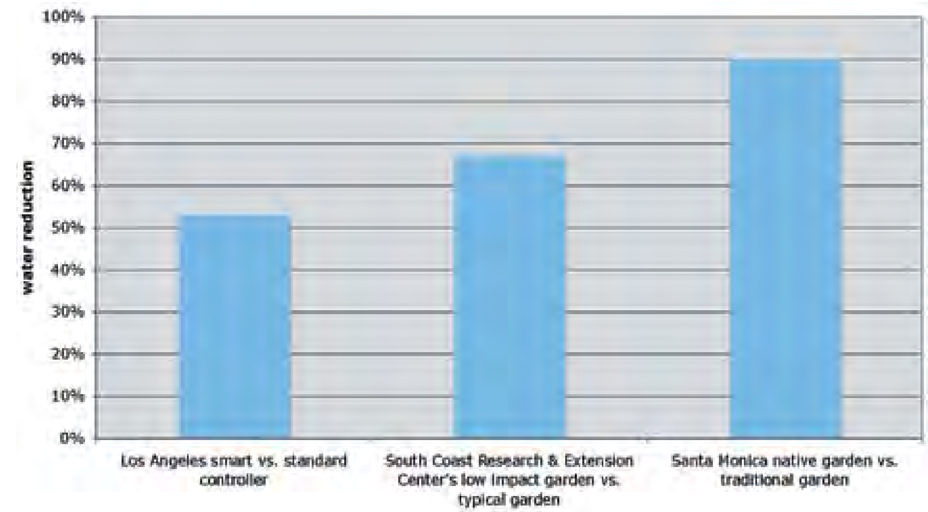
(Note: These results are for loam soil, clay soil is estimated to increase discharge to the street by 63%.)

Better irrigation controllers alone can make a real difference in cutting water use. A smart controller installed by the Center for Urban Forestry Research on a conventional garden in Los Angeles reduced irrigation water by 52%. However, gardens landscaped with local climate adapted plants and efficient irrigation systems can need the least amount of water. At the South Coast Research & Extension Center demonstration gardens, a water conserving Mediterranean plant landscape and heat tolerant turf irrigated by a smart controller used 68% less water than the typical lawn-oriented demonstration garden. To test irrigation water required by a conventional garden and one planted with native plants, the City of Santa Monica landscaped two adjacent, equal sized front yards. Over several years, the City found that the native plant garden used 90% less water than the conventional yard.

REDUCING STORM WATER RUNOFF



REDUCING IRRIGATION WATER

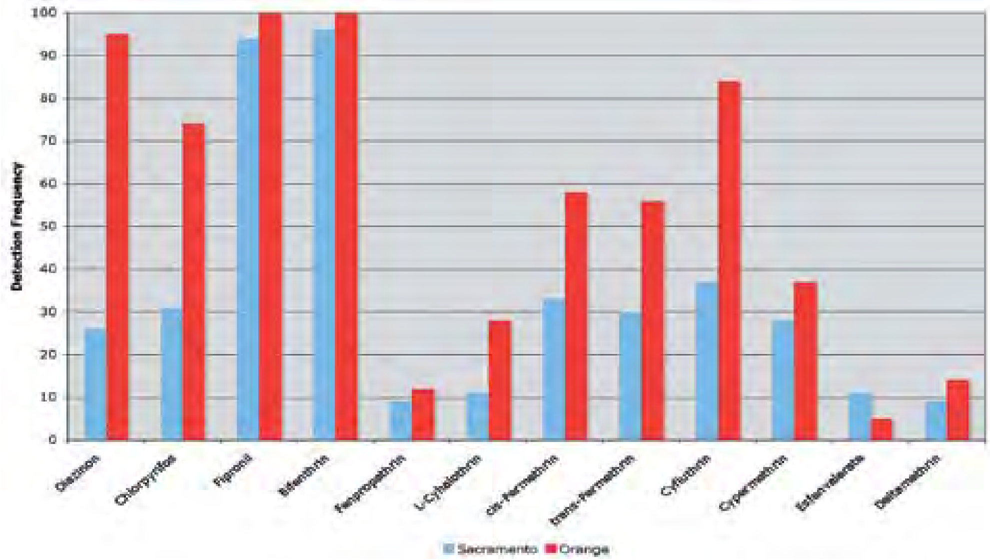


Local climate adapted, water efficient plants can generate vibrant gardens. Clockwise from the top left: 1 & 2. The top two images, from the South Coast Research and Extension Center's low impact Mediterranean plant demonstration garden with heat tolerant turf, needed only 32% of the water used by the Center's lawn-oriented typical demonstration garden. 3. Bottom right: A detail of a Venice parking strip that a resident planted with drought tolerant succulents. 4. A Corona Del Mar homeowner created native plant garden with a visiting butterfly. 5. Fountain grass against a backdrop of Verbena lilicina in a West Marin homeowner designed garden makes a striking color composition.

Pesticides

All the neighborhood runoff samples analyzed by Dr Jay Gan's laboratory at UC Riverside contained traces of pesticides, yet the concentrations (quantities found in the water samples) and the frequency that pesticides were detected varied among the sites and the sample days at each site. Often there were wide swings from low to high concentrations. The median pesticide concentrations in Orange County were many times higher than those in Sacramento County. As per the chart below, the pesticides fipronil and bifenthrin were detected in virtually all water samples. While pesticides were a small component found in the runoff samples, very low concentrations of some pesticides can be highly toxic to aquatic life. For instance, it only takes 78 ng/L (nanograms per liter) of the pesticide bifenthrin to kill 50% of the small freshwater aquatic crustacean *Ceriodaphnia dubia*, once its population has been exposed for 96 hours. A nanogram is 1 trillionth of a gram, hence 78 nanograms are only 0.0000000078 of a gram. Laboratory analyses found that the highest bifenthrin concentrations from the Sacramento County sites varied from 77 ng/L to 670 ng/L.

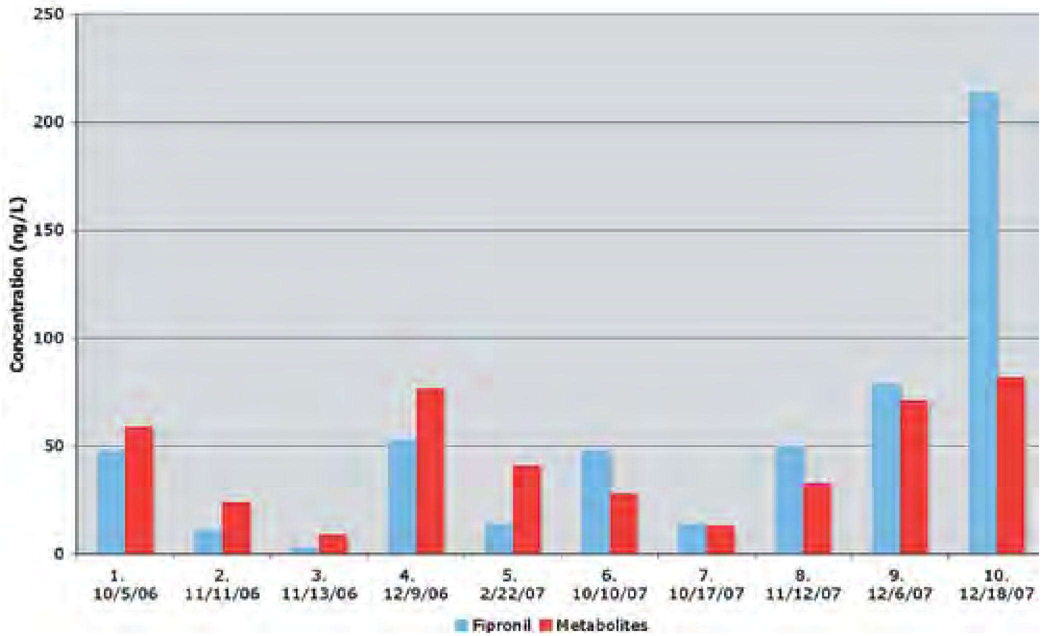
PESTICIDE DETECTIONS IN WATER SAMPLES FROM SACRAMENTO & ORANGE COUNTIES



Above left: Native Douglas iris (Iris douglasiana) growing with a volunteer native witchgrass (Panicum acuminatium), a pleasing and spontaneous plant mix that can occur in an herbicide-free garden.

Healthy plants growing without stress tend to be more resistant to disease and infestation. Clockwise from the top left: 1. An organically maintained, pesticide-free homeowner garden in Corona Del Mar that mixes natives with other plants that are suited to the local climate. 2. The herb garden at the Green Gulch Farm in Muir Beach has been organically maintained for over 35 years. 3. One of the toughest desert trees, this mesquite tree can also thrive in irrigated gardens, such as this dry climate landscape in Desert Hot Springs. 4. A delightfully vibrant and organically maintained display garden requires little irrigation in its foggy coastal climate. Occasional compost and good soil provide sufficient nutrients for the plants. By Flora Farm Landscaping in Half Moon Bay.

FIPRONIL PESTICIDE AND ITS TOXIC METABOLITES IN RUNOFF WATER



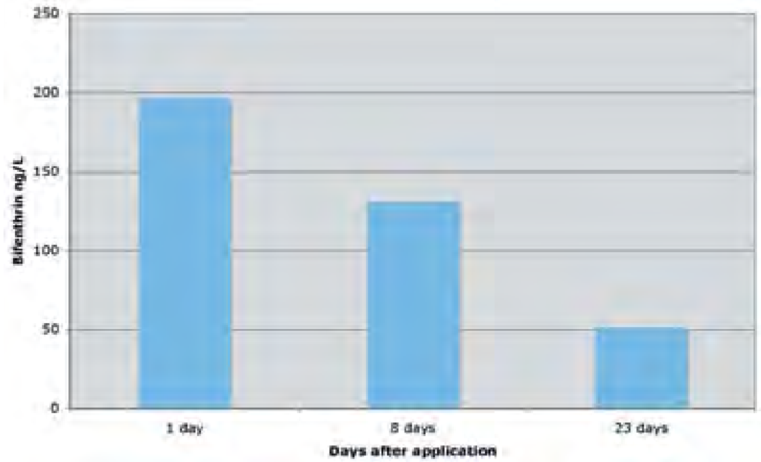
SAMPLING DATE

Pesticides can metabolize (*i.e.* change) into new molecules when exposed in the environment. Dr. Jay Gan's laboratory at UC Riverside looked for metabolites of the pesticide fipronil in ten runoff samples from a Sacramento neighborhood. He found that the fipronil metabolites were present and that their concentrations were sometimes greater than the fipronil.

Not only can the pesticide metabolize, when it does the fipronil metabolites are equally or more toxic than fipronil itself.

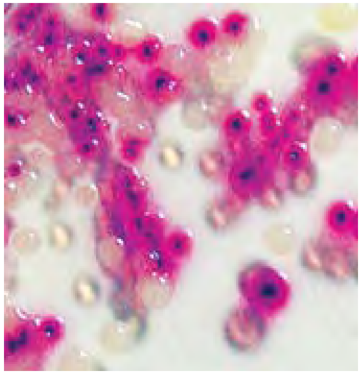
BIFENTHRIN PESTICIDE IN RUNOFF FROM LAWN IRRIGATION

To see if a pesticide applied to a residential lawn will be found in the water after a typical runoff producing irrigation, Dr. Darren Haver of the South Coast Research & Extension Center applied a commercial product containing the pesticide bifenthrin to a demonstration landscape's lawn. The combined fertilizer and pesticide material was placed as per manufacturer's instructions with no spillage onto walks or the driveway. A bifenthrin concentration of almost 200 ng/L was found in runoff from the first irrigation. One week later, the lawn runoff still had enough pesticide to kill 50% of *Ceriodaphnia dubia,* the small crustacean commonly found in lakes, rivers, and streams that is food for fish and other aquatic life.



(bifenthrin applied 10/8/2007)

Integrated pest management (IPM) guidelines stress using the least toxic method possible and applying pesticides only when absolutely necessary. Whether a compact urban garden to an estate landscape, all can be managed with IPM. The gardens at Filoli photographed above, an historic site of the National Trust for Historic Preservation in Woodside, CA, apply IPM practices to their extensive beds. In addition, all green waste is composted and placed back in the gardens and efficient irrigation conserves water. For more IPM information, see the UC IPM web site at www.ipm.ucdavis.edu

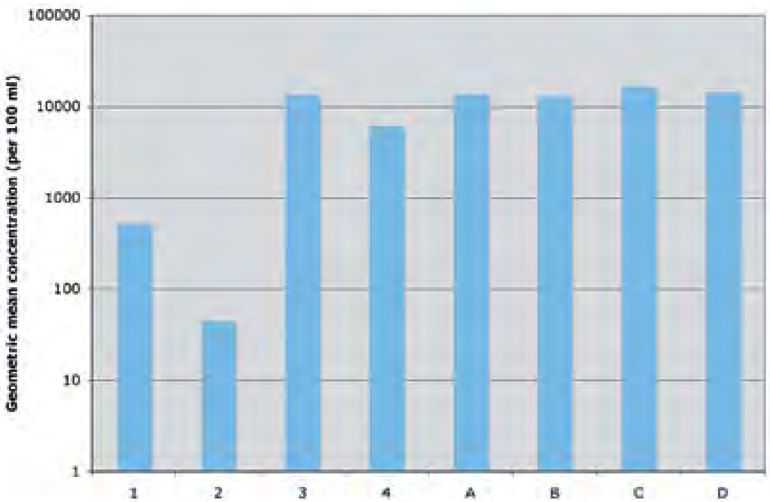


Waterborne Microorganisms

There are many pathogenic microorganisms *(i.e.* microorganisms that can cause disease) that can be transmitted through water. Diseases caused by these microorganisms can range from gastroenteritis *(i.e.* nausea, vomiting, diarrhea, and/or fever) to infectious hepatitis to kidney failure. Pathogenic microorganisms may be present in the feces of humans, pets, birds, and other wild animals, as well as in inadequately composted animal manures and biosolids. This project analyzed water for two pathogenic parasites (*Giardia* and *Cryptosporidium*) and six types of indicator microorganisms (including total coliform bacteria and *E. coli*), whose presence in water suggest that fecal contamination has occurred. The analyses, conducted by personnel in Dr. Marylynn Yates' laboratory at UC Riverside, revealed that indicator microorganisms were routinely present in the runoff water at all sites sampled, with concentrations frequently exceeding the U.S. Environmental Protection Agency's ambient water quality criteria for recreational waters. In addition, concentrations of all indicator microorganisms were generally higher in runoff samples from Orange County than from Sacramento County. *Giardia* or *Cryptosporidium* was detected in three of the fifty-one samples from Sacramento County that were analyzed for parasites. Concentrations of indicator organisms at all sites were typically higher in runoff water generated during storm events than in dry weather runoff water.

Upper left: E. coli colonies growing in the laboratory.

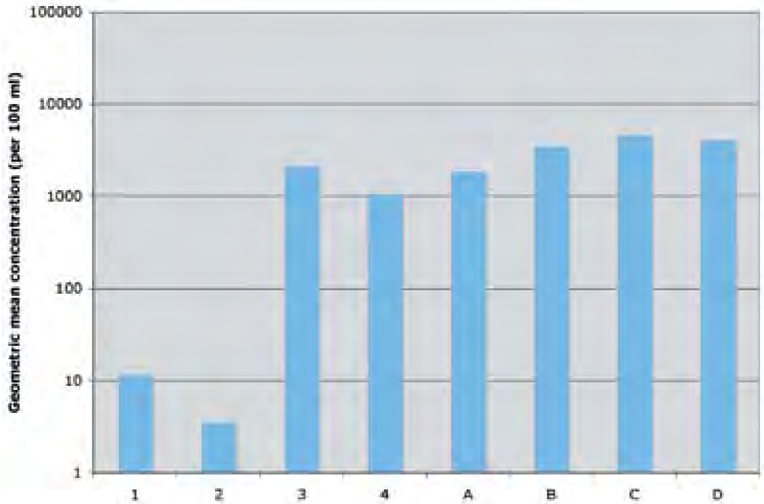
TOTAL COLIFORM BACTERIA IN RUNOFF WATER



Sacramento County sites

Orange County sites

E. COLI IN RUNOFF WATER



Sacramento County sites

Orange County sites




Clockwise from the top: 1 & 2. A stepped shallow lawn placed down slope from a desert garden and to the right, a level North Coast meadow located downs lope from homeowner designed garden beds can slow down water flow, allowing on site treatment of waterborne pollutants. 3 & 4. While coliform bacteria such as E. coli can survive in soil for 60 to120 days, they will die within several to 24 hours on dry surfaces. When dry, the Desert Hot Springs sculptural stone path in the top right image and the outdoor room paved with gravel in the bottom image from a Pacific Palisades home can quickly eliminate coliform bacteria.

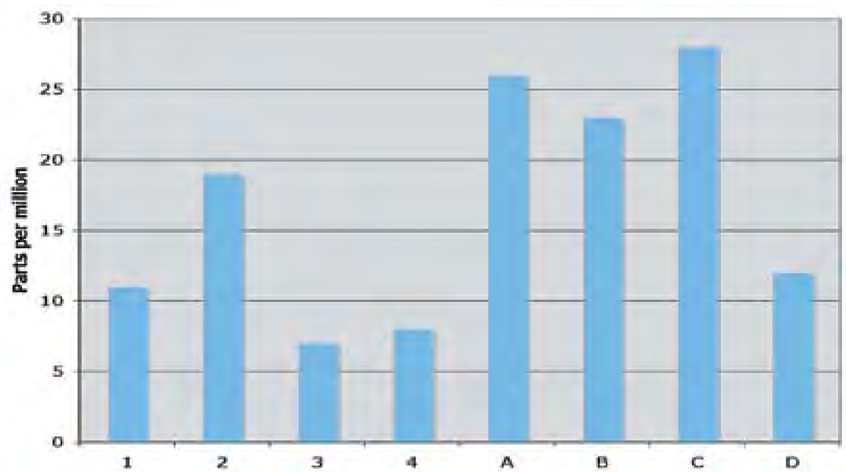
Ferns and forget-me-nots growing wild on the California coast, with nutrients coming from the soil and air only; none from applied fertilizers.

Nutrients

All sampling water from the eight study neighborhoods had the nutrients found in most commercial fertilizers; nitrogen, phosphorous and potassium.

Nitrates are easily leached out of the soil with runoff, or move deeper into the soil. Phosphate on the other hand, binds with soil and does not move in water. However, when runoff water travels across surfaces, it can carry loose soil particles that may be rich in phosphorus and transport it to the downstream water bodies.

HIGHEST NITRATE CONCENTRATIONS IN RUNOFF SAMPLES



Sacramento County Sites Orange County Sites

Eutrophication, the depletion of dissolved oxygen in water, is a primary concern with nutrient pollution. As algae and other water plants grow in nutrient rich water, they consume dissolved oxygen to a point that can threaten the fish and water life that also need the oxygen. (Often referred to as the 'dead zone' effect.) While there are no set standards, the thresholds of concern for eutrophication associated with nitrate and phosphorus concentrations are 0.1 ppm and 0.02 ppm, respectively, or greater.

As per the chart on the left, all of the eight sampling sites had nitrate concentrations that could contribute to eutrophication.

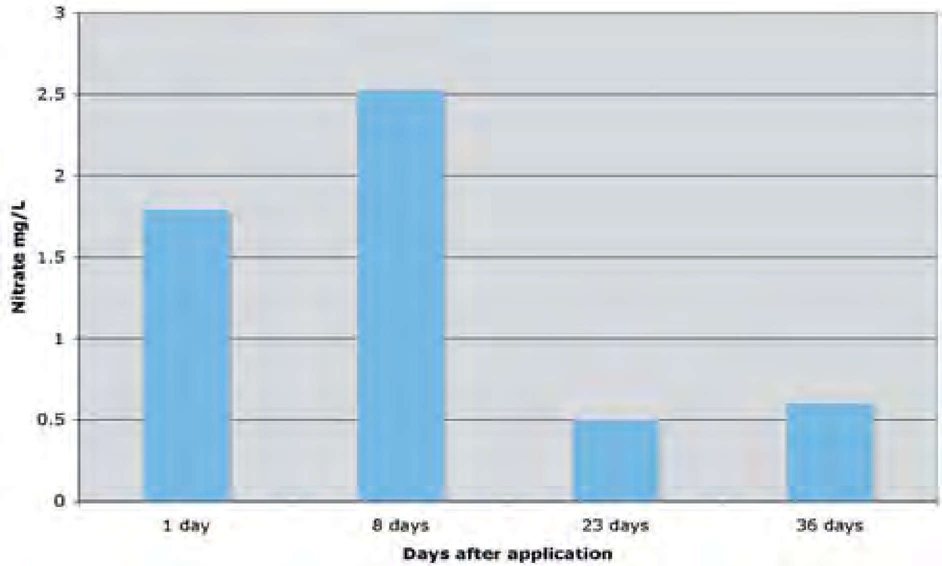
Plants have different survival abilities and strategies that, depending on local growing conditions, can make them beneficial or problematic in gardens. Beginning with the left image and moving clockwise: 1. The palo verde tree is a tough, trouble-free desert plant (and a street tree in Santa Barbara) that needs little water. With small delicate leaves, the tree also uses it's bark to carry out photosynthesis. 2. The particular Agave americana in this image is a 'rescue' plant, saved from road construction by a Los Angeles artist. After breaking through concrete in a yard shared with a auto repair garage, the Agave was planted next to the artist's studio. Within several months the plant was thriving in it's new habitat. Agaves like good drainage, yet need little water. In fact, too much water or fertilizer will shorten the plant's life span. 3. The Ginkgo biloba tree is an ancient survivor from 270 million years ago, when it grew worldwide. In the wild the tree prefers disturbed, moist soils but is moderately drought tolerant and adaptable. Six trees that were growing within 1.2 miles of the blast in Hiroshima are still alive today. 4. Like the Ginkgo tree, the cycad C. circinalis in the bottom right dates from prehistoric times. It has survived for 280 million years without manufactured nutrients, as the species fixes its own nitrogen in association with bacteria that live on its roots. Some cycads thrive in semi-deserts, and can grow on sand or rock. 5. The Cotinus coggygria, a shrub/tree grows best under stress in poor, rocky, or even alkaline soil.

Above: *A teaspoon of good soil containing 100 million to a billion bacteria.*

While many gardeners buy manufactured nitrogen fertilizers, nitrates are also naturally produced in the soil through other processes. Organic gardeners apply humus, compost, and mulch to their garden to feed soil life, and the nitrogen initially contained in the organic matter may be converted to nitrates, the form of nitrogen that plants can use. Nitrogen-fixing bacteria also live on legume roots, forming nitrate-rich nodules that fertilize soil. Soil generated nitrates are formed slowly, and most of the nutrient is taken up by plants as it is produced.

However, applied organic material and animal waste products can still contribute to nitrate contamination in runoff water as both natural and manufactured nitrates are easily leached out by storm or irrigation water. To test for nitrates in lawn runoff, Dr. Darren Haver applied a commercially available fertilizer as per the manufacturer's directions to one of the South Coast Research & Extension Center's demonstration gardens. The turf was then irrigated as per the typical practice for residential lawns and the runoff was collected and analyzed. Nitrate was still present in the runoff 36 days after it was applied.

NITRATE IN LAWN RUNOFF AFTER APPLYING A MANUFACTURED FERTILIZER
(fertilizer applied 10/8/2007)



Clockwise from top: 1. An organically maintained garden in Borrego Springs incorporates local desert plants. With unplanted spaces between vegetation, the garden mirrors the growing patterns of the surrounding desert. The sandy soil exposed between the plants is raked for a refined and texturally rich appearance. 2. A West Marin homeowner designed garden is maintained organically. 3. An Agave americana mixes with bougainvillea, gaura and a fig tree in this organically maintained garden in Pacific Palisades. 4. Fall leaves left in the garden or placed into the compost pile will become food for soil microorganisms.

The above garden has the look of contemporary landscape with a lawn bordered with planting beds. Unlike many gardens of its type, this one is maintained organically without manufactured fertilizers and to rigorous IPM standards. The organically managed garden on the right hand page includes other important sustainable gardening practices, as it is improving its fit with the local climate and reducing irrigation water by eliminating lawns and using gravel paving for outdoor open spaces.

Sacramento Gardens

The gardens on this and the adjacent page are organically maintained, and any water that may runoff the properties would be essentially free of manufactured pesticides or fertilizers. The lush backyard lawn to the left demonstrates that organic methods can produce healthy turf. In addition, this particular lawn is located downslope from the vegetable and ornamental beds, and slows, filters, and absorbs storm and irrigation water before it flows into a creek at the rear of the property. Note the mulch applied to the garden bed, one of easiest and cost effective ways to reduce irrigation water. Native plants, such as California poppies *(Eschscholzia californica)*, Douglas iris, (*Iris douglasiana)*, and coyote bush (*Baccharis pilularis*), along with drought tolerant Mediterranean species, thrive in the garden.

On the right hand page, the landscape feels lush and green, yet there is not one square inch of lawn on the large property. In place of impervious concrete, the driveway, outdoor spaces, and paths are gravel paved. Without thirsty turf, this garden can be very water efficient. To help 'cool' and animate the garden, two recirculating fountains and small reflecting pools provide a counterpoint to the hot and dry Sacramento Valley summer climate.

The gardens above have evolved over the years by the homeowner, a UC Cooperative Extension Master Gardener. Since these photographs were taken, the boxwood borders in the garden bottom right photograph have been replaced with dry-scape plants that have similar water requirements as the drought tolerant olive trees they enclose. For information about sustainable gardening practices suited to your area, contact your county's UC Cooperative Extension Master Gardener program.

From the top left clockwise: 1. The parking strip with Agave americana, the curving leaves of Verbascum bombiciferum, and the branching Acaia craspedocarpa. 2. The tall palms in the court, the bougainvillea in the neighbor's side yard, and the slender green to red leaves of Aeonium arboreum 'blushing beauty" enliven the small entry court. 3. The front garden is layered to open up the entry path, beginning with green/brown aloes beyond the gravel mulch, followed by the sharp grey/green leaves of Yucca rostrata, to the dark green leaves of Agave Salmiana 'green giant' just to the left of the palm trunk. The vertical spires of Verbascum bombiciferum mark the boundary of the garden on the left foreground.

West Hollywood Garden

Landscape Designers: Campion Walker, Barry Campion & Nicholas Walker

Landscape designers Barry Campion and Nicholas Walker worked with dry-scape plants whose striking forms add richness and intrigue to this Southern California garden. Large existing plants, such as the palms in the entry court and the Italian cypress hedge in the backyard, give the landscape an older, established feel. The designers also 'borrowed' color and greenery from plants growing in neighboring yards, adding depth and space to the bungalow-scaled lot. The overall effect is spatially rich and wonderfully complex. Even the narrow parking strip, which is landscaped with succulents and desert-like shrubs, mirrors the garden's delightful character.

Maintained organically, the plants are grouped into two zones that are irrigated once to twice a month during the dry seasons. (Only the areas with roses and bamboo are watered twice a month.) Water is applied in three cycles, each consisting of ten minutes of water followed by one hour of percolation time. With a small recirculating fountain in the entry court and a thin, shaded reflecting pond running parallel to the backyard patio, the garden treats water as the treasured resource that it is.

From the top left clockwise: 1.The colorful green to red leaves of Aeonium arboreum 'Atropurpureum' stand out against the small aquamarine recirculating fountain in the entry court. 2. The entry court wall with red/pink bougainvillea, purple flowers of Duranta erelta and chartreuse green Mexican weeping bamboo Otatea aztelorum provide intense color. 3.The backyard patio viewed from the rear garden. An Aloe hybrid tree on the left and Italian cypress on the right frame the outdoor space. Note the narrow pond that edges the patio. 4. The water loving plants, Pondederia cordata and Iris pseudacorus mark the presence of the pond, lending an oasis accent to the dry-scape garden.

The Jacobson Garden, Sherman Oaks

Landscape architect: Fletcher Studio, David Fletcher

Although the Jacobson home incorporates many forward-thinking ideas including rain water collection with storage for dry season irrigation and a permeable yarrow planted cellular concrete driveway, it is the jewel-like quality of the organically maintained garden that lingers in memory.

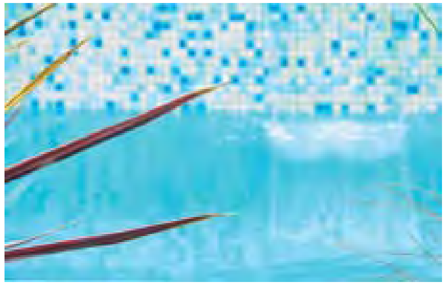
With a spare number of plant choices, it manages to beautifully combine a variety of textures and a soft grey and green palette energized by burgundy New Zealand flax and the aqua water of the pools into a sensual richness. Particularly satisfying is the way that the re-circulating, fountained pools in the front and rear gardens combine with the tapestry of low water plant choices to create a sense of lushness. The garden's quality of being of a singular piece is reflected in the clean modernity of the house with its natural wood and grey-green stucco finishes and large expanses of glass that share the sensibilities of the garden.

The highly permeable driveway, cellular concrete planted with yarrow (Achillea millefolium) can minimize storm water runoff.

The living room's recycled wood/plastic composite deck overlooks the lap pool and a 12 foot wide, jewel-like garden. The garden is hydrozoned for light to moderate water and drip irrigated.

Surrounding the deck and extending to the side yards, Dymondia's silver-green color contrasts with the flax, blends with the stucco walls, and is an attractive low water ground cover. In the foreground, the long stems of cape rush (Chondropetalum tectorum) provides an elegant vertical accent while feather grass (Stipa tenuissima) billows out to the right.

Long narrow leaves of New Zealand flax (Phormium tenax 'Guardsman') on the left over lay the pink flowers of common thrift, Armeria vulgaris. The thin yellow-green leaves of fountain grass (Pennisetum messiacum) adds textural richness to the composition. Each plant tolerates low water.



Left: The dramatic spiked flax leaves hover over Dymondia margaretae, a walkable ground cover.

Mid: A very permeable surface, the cellular concrete and gravel walk leads to the front door.

Right: Flax leaves create a abstract composition when seen against the water and tile. Visible water is a particularly satisfying complement to low water landscapes.

Blue fescue (Festuca glauca) is the primary ground cover in the front yard entry beds. Dasylirion wheeleri, a desert plant, with its lacy tips and the contrasting orange-pink flowers of kangaroo paw (Anigozanthos 'Dusky Chief'), all low water or drought tolerant plants, animate the bed.

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Page 5 bottom left: Dave Roberts
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For more information about the University of California runoff project, go to the California Center for Urban Horticulture's website at ccuh.ucdavis.edu/projects

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