GRAY WATER PILOT PROJECT

FINAL REPORT

Prepared by

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Office of Water Reclamation

November, 1992

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PREFACE

California just endured six continuous years of drought. This prolonged drought gave us a preview of the future: a future with many more people needing water and at best a constant (possibly diminishing) water supply. As planners and policy makers, we must squarely face the possibility of a tremendous water supply deficit and its attendant problems. To reduce or eliminate the projected water supply shortfalls, water conservation and water recycling must be available options to citizens and decision makers.

Not all types of water use efficiency will find universal acceptance or applicability. Nor will any one method be a panacea to the serious water supply problems we face in the City of Los Angeles, in Southern California--indeed the whole State. Yet, we cannot afford to foreclose any one option a priori, *just because it may be at the leading edge of technology or new to a particular area. The gray water pilot project was launched in this spirit of open-minded attitude towards all water use efficiency techniques, by* ***Councilwoman Joan Milke Flores*** *as part of her 12-point initiative, introduced into the Council Commerce, Energy and Natural Resources Committee, in July 1990.*

EXECUTIVE SUMMARY

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PROJECT OBJECTIVES The pilot project was launched with these primary objectives: (1) to obtain reliable quantitative data from actual use of gray water systems under realistic conditions, and (2) to make recommendations to the City Council based on the findings of the project, for safe use of gray water in the City of Los Angeles.

OVERVIEW The Gray Water Pilot Project consisted of eight gray water test systems installed at residences in the City of Los Angeles, sampled monthly and monitored over a year-long period for safety and water savings. Samples of soils and water were tested at a certified laboratory for indicator bacteria and pathogens (disease organisms), to compare areas receiving gray water with those irrigated with tap water. Twelve monthly sample sets were taken from the each of the eight pilot sites. Each sample was tested for a dozen parameters. The resulting data formed the basis for statistical analyses to determine the significance of differences, between the control areas and the gray-water-irrigated areas. Drip irrigation was the primary method of application of water in all but two of the sites.

FINDINGS Total and Fecal Coliform bacteria and the enterococcus group in control and gray-water irrigated soils fluctuate widely and inconsistently. There appears to be no smooth trend with time or with irrigation treatment. Results of pre-irrigation (baseline) sampling also show great variability among sites, with indicator bacteria counts in the same range as the post-irrigation samples. Therefore, it is not possible to correlate occurrence of indicator bacteria with use of gray water at the pilot sites. It may be that background variation of these bacteria in the soil environment--from domestic and wild animals--overwhelms any contributions from human sources through the gray water distribution system.

The statistical analysis of the data from soil samples indicates a significant difference in the total coliform levels between gray-water-irrigated areas and control areas. This can be attributed to the possibility that gray water contains organic matter which can support growth of soil microorganisms, including coliform bacteria deposited by animals as well as those coming from the gray water sources. However, the statistical tests did not show any significant differences for fecal coliform or for enterococci on the irrigated soils.

Three of the Disease-causing organisms monitored in the sampled soils--Salmonella, Shigella, and Entamoeba histolytica--were negative at all sites in all sampling rounds, in gray water and in soil--both control and gray-water-irrigated. Apparently, neither the gray water nor the soil carried any of these particular organisms. The fact that throughout the year, none of the samples yielded a positive for any pathogens tested is encouraging for the possibility of safe use of gray water--even where total adherence to hygienic handling of the water in not assured.

pH, sodium, chloride, calcium, magnesium and total salts were measured in gray water and in the soil extract to determine if any of the agronomic characteristics of the soil might be affected by gray water irrigation. For the same purpose, sodium adsorption ratio was computed for each sample from the basic data. As expected, sodium and sodium adsorption ratio were both significantly higher in gray-water-irrigated soils than in the control soils. Boron concentrations in the storage tanks and in the soil were measured once, during round 9 sampling. Since boron was not detected in any of the gray water samples, it is not expected to affect boron concentrations in the soil.

CONCLUSIONS From the results presented above, including baseline data, it is clear that backyard soils are contaminated, whether they are in the control areas or in the gray-water-irrigated areas. If these findings can be generalized, the implication is that gray water irrigation--below the surface of the soil--does not by itself elevate the health risks from handling the garden soil, as long as sanitary practices are followed..

It appears that use of gray water at the pilot project sites does not pose a significant risk to the users or the community. Since pilot project sites were controlled, inspected, and repaired as needed, broad generalization of this conclusion may be premature. However, certain more specific generalizations appear inescapable, e. g.:

- Indicator bacteria (total coliform) in the soil seem to increase with gray water application. However, the soil is already so heavily contaminated with animal fecal matter that the additional contribution of gray water may be irrelevant.

- Disease organisms, normally capable of surviving in the soil for a few days, were not present in gray-water-irrigated areas. Neither have these organisms been detected in gray water in storage. This may indicate either an entirely healthy test population (highly unlikely), or a mechanism for deactivation of pathogens. Either way, the results indicate that there may be minimal additional risk of exposure from use of gray water for irrigation of landscaping.

- The water savings potential of a gray water system to an individual home can be significant--about 50 percent of all the water used. However, it is highly unlikely that a large enough number of people will install such systems, because of the maintenance requirements, complications with permitting, and cost. Therefore, gray water cannot be expected to play a significant role in a community's water supply reliability.

RECOMMENDATIONS The following recommendations are based on the findings and conclusions in Sections IV and V.

- Draft ordinance for City Council consideration, to permit gray water systems in the City of Los Angeles, consistent with the systems used in the pilot project and found to be acceptable (in terms of public health protection)

- Maintain an active role in state and local legislation and code changes affecting gray water use.

INTRODUCTION

SECTION I

The six-year drought of 1987-1992 left its palpable impact on the daily life of nearly everyone living in Los Angeles as well as other parts of California. Ordinary people dealt with their water conservation responsibility seriously and successfully, with evident results. Water usage plummeted by as much as 30 percent in many communities. Mandatory conservation is still in effect in some cities in the Northern parts of the State.

In their attempt to cope with the drought, many individuals contacted their representatives on the City Council and the various City Departments to inquire about use of gray water. In response to these inquiries, the gray water pilot project was launched to obtain reliable data about the public health effects, and the possible horticultural effects of irrigation with gray water. The City's elected officials felt that an ordinance permitting use of gray water should be based on sound, credible field data, collected under controlled representative conditions. Available information about gray water at that time was limited to a relatively new permit system in Santa Barbara and San Luis Obispo, and an expired incentive program by the State.

GRAY WATER EXPERIENCE AT OTHER CITIES AND COUNTIES

The City of Santa Barbara and the County of Santa Barbara allowed use of gray water, with a permit, starting in 1989. However, no attempt was made to monitor the performance of the operating systems. Many people in these localities installed systems without a permit and more than a few applied gray water to the surface of the soil, rather than below the ground surface as advised in the guidelines. Thus, the only lesson learned from their experience was that there were no reported health problems associated with gray water systems, even those disregarding safety features of guidelines. This lack of reported cases of disease transmission was not adequate to satisfy public health authorities regarding the *potential* for pathogenic agents to be transmitted via gray water.

Since 1989, numerous other counties and cities have adopted ordinances, guidelines or temporary measures to allow safe use of gray water. The counties currently permitting various forms of gray water systems are: Calaveras, Los Angeles, Mariposa, San Bernardino, San Diego, San Luis Obispo, San Mateo, and Santa Barbara. Some of the Cities now permitting gray water use are: Chula Vista, Pasadena, San Diego, San Luis Obispo, and Santa Barbara. Most of the systems allowed under these guidelines involve below-the-surface application of the gray water. None allow spray or sprinkler application or other uses that involve direct exposure of people to the gray water.

Some communities are contemplating legislation to mandate installation of gray-water-ready plumbing in new housing developments to give future residents an easy choice to use gray water for their landscape irrigation. This is an option with negligible economic impact upon the development and the building industries. Discussions with leaders of these industries indicate that they would welcome any opportunity to extend the available sources of water and postpone the day when water will become the limiting factor to development.

THE ROLE OF THE STATE OF CALIFORNIA IN GRAY WATER

During the earlier drought of 1977-1978, the State provided tax relief to those who chose to install gray water systems. This program recognized the water saving potential of gray water systems, but the incentive was discontinued after the drought. In recent months, other significant statewide gray water-related events have occurred, namely:

- Publication of the State Department of Health Services guidelines for gray water use, in March 1991

- Development of an appendix[1] to the Uniform Plumbing Code by an *Ad Hoc* Committee co-sponsored by the State Department of Water Resources (DWR) and the Department of Health Services (DOHS), and its approval by the International Association of Plumbing and Mechanical Officials (IAPMO) in September, 1992

- Unanimous Approval by the State Legislature of Assembly Bill 3518, introduced by Assembly Member Byron Sher, to facilitate and permit statewide uses of gray water for landscape irrigation below the surface, in single-family residences. The bill was signed by the Governor in July 1992. The same *Ad Hoc* Committee is formulating regulations to implement AB 3518. These regulations will be subjected to a public review process before taking effect, probably in July 1993.

LITERATURE REVIEW

In this section a summary review of the literature on gray water is presented. The objective is (1) to provide the reader background information on gray water, and (2) provide data from other case studies on quality and quantity of gray water for comparison to results of the present study, wherever applicable. Therefore, this review includes definitions, application, characteristics, quantity and barriers and constraints to use of gray water. Although information on treatment of gray water exists (primarily filtration and disinfection) it is not considered here because the pilot project is concerned primarily with <u>use of untreated gray water</u>.

In the limited literature on the subject, gray water is spelled different ways by the authors (with the English "grey", the American "gray", and as one word or two). While all four spellings are considered correct, the present document will use the "gray water" version consistently, unless quoting another source directly.

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[1] The appendix provides a set of "minimum" standards for installation of gray water systems. These standards are set conservatively, because of their newness, allowing only below-ground application of gray water using leach fields similar to on-site disposal leach fields.

Gray Water Definitions

In reference to gray water, depending on the inclusion or exclusion of the kitchen sink wastewater, two definitions of gray water are used in the literature. According to Rose *et al.*(2)[2], "Graywater is defined as all wastewater generated in the household, excluding toilet wastes, and includes wastewater from bathroom sinks, baths, showers, laundry facilities, dishwashers and, in some instances, kitchen sinks". Ingham(9) defines gray water as follows: "Greywater is all waters generated in the household which do not contain toilet wastes". Sherman(5) also excludes kitchen sink wastewater from gray water: "I feel the kitchen sink produces wastes of sufficient strength to be considered black water".

Volume of Gray Water

Volumes of gray water reported in the literature vary from area to area and also vary according to the definition employed for gray water. Data on quantity of gray water from different sources reported in the literature are summarized in Table 1 .

Table 1. Summary of Gray Water Quantity Data from Various Studies

	Source of data*					
	Siegrist	**Rose**	**Boyle**	**Sherman**	**Karpiscak**	**e m r**
Unit generation rate (gpcd)**	20 - 33	29.4-59	21	-	-	45.3***
Ratio to total household wastewater	-	65%	-	70%	69%	53-81%

* Source references are more fully cited in Section VII, by author.
** Gallons per capita per day.
*** Reported figure is the average of data from six different sources.

An estimate of the proportion of black and gray water to total water use in a suburban home is reported as follows: (10)

Toilet	34.1%
Kitchen	12.0%
Bathroom	24.5%
Laundry	23.2%
Miscellaneous	6.2%

Gray Water Quality

Characteristics of household gray water are expected to exhibit considerable variation, both in chemical and microbiological constituents. Variations are caused by factors including individual lifestyles and customs, whether young children are living in the house, whether kitchen sink wastewater is included, type of detergents used, etc. For example, Boyle(4) reported: "If the kitchen sink wastes are excluded, the pollutant concentrations in gray water are significantly

[2] Superscripted numbers in parantheses refer to cited references in section VII.

lower than in total residential waste stream". According to Rose[2], "Total coliform and fecal coliform were low in the graywater from families without children and averaged between 6 and 80 colony forming units (CFU) per 100 ml. In contrast, however, fecal coliform and total coliform counts were significantly higher in graywater from families with young children and averaged $1.5x10^3$ and $3.2x10^5$ CFU per 100 ml, respectively".

Different data are reported in the literature from case studies, indicating wide variation of gray water characteristics. Gray water quality data from several case studies are summarized in Table 2.

Table 2. Physical, Chemical, and Bacteriological Characteristics of Gray Water As Reported by Various Investigators

		Source of data*				
Parameter	**Unit**	**Rose**	**Enferadi**	**Brandes**	**Boyle**	**Sherman**
Turbidity	NTU	20-140	-	-	42-67	-
Phosphate	mg/L	4-35	-	1.4	-	3.4
Sulfate	mg/L	12-40	-	-	0.3-11.9	-
Ammonia	mg/L	0.15-3.2	-	-	0.6-4.5	-
Nitrate nitrogen (N)	mg/L	0-4.9	-	0.12	0.1-0.6	-
Total kjeldhal N	mg/L	0.6-5.2	2-50	11.3	5.7-18.4	1.9
Chloride	mg/L	3.1-12.0	-	-	-	-
Suspended solids	mg/L	-	20-1500	162	36-160	-
BOD	mg/L	-	40-620	149	125-291	33
COD	mg/L	-	60-1610	366	242-622	52
Total dissolved solids	mg/L	-	420-1700	-	686-925	-
Alkalinity	mg/L	149-198	-	-	382	-
Electric conductivity	mho/cm	-	443	-	-	-
Total coliform	MPN/100ml	-	10^2-10^9	$2.4x10^6$	-	
Fecal coliform	MPN/100ml	-	10^1-10^6	$1.4x10^6$	-	-
PH	(none)	5-7	-	6.8	7.1-8.7	-

* Source references are more fully cited at the end of the report, by author.

Data reported from the literature demonstrate consistently that gray water contains a significant concentration of pathogenic indicators and potential pollutants. Gray water may contain microbial agents which represent a public health hazard with unrestricted reuse. Investigators generally warn that these facts should be considered seriously in use of gray water and in selecting the method of gray water application.

Gray Water Uses and Soil Interactions

Gray water can be used for irrigation of trees, shrubs, lawns, landscapes and gardens. Relatively large amounts of gray water may be available to be reused. Gray water reuse as a measure of water conservation can have a role in arid regions. In many cases landscape irrigation may account for 50% of total household water use. According to Roley[11] "Graywater reuse is potentially one of the solutions to the water quantity dilemma". He points out that extensive use of gray water will guarantee a supply of irrigation water to be used on both ornamental and certain edible crops. Rose et al.[2] reported: "In arid regions, all of the household landscape irrigation needs can be met by graywater generated within the household".

Enviro-management & research, Inc., in a report titled *Assessment of on-site wastewater treatment and recycling systems*[10] reported "When graywater is used for irrigation, it helps promote plant growth. Graywater is naturally purified by biological activity in top soil. Soil microorganisms break down organic contaminants (including bacteria, viruses, and biocompatible cleaners) into water soluble plant nutrients. Plant roots take up these nutrients and most of the water".

Gray Water Use Restrictions

Gray water use restrictions arise from health concerns technical and operational restrictions in application of gray water, unsuitability for certain plants, regulatory constraints and public acceptance. One of the most serious concerns in the use of gray water is its microbial content. According to Rose et al[2]. "The presence of *Eschercia Coli* and other enteric organisms in water indicates fecal contamination and possible presence of intestinal pathogens such as Salmonella or enteric viruses. Fecal coliform is a pollution indicator and may be used to assess the relative safety of graywater. Generally, a high fecal coliform count is undesirable and implies a greater chance for human illness to develop as a result of contact during graywater reuse".

In a CCDEH issue paper[3] on graywater use in California, it is reported "These findings demonstrate that a significant quantity of wastewater (an average of 67%) is generated by plumbing fixtures other than the toilet. Assuming discharges from these plumbing fixtures can be diverted into graywater systems, the remaining flow from toilets may be insufficient to carry solids through the sewer collection system. This can result in anaerobic conditions which can damage sewer lines and treatment plants, and make it difficult for treatment plants to comply with discharge requirements. Furthermore, the reduction of up to 67% of flows to the treatment plant represent a similar reduction in the quantity of reclaimed water that will be available after treatment. Losses in the quantity of reclaimed water can adversely impact current and future users of this water". It should be pointed out that gray water use of this magnitude can be expected only if all dwellings in a city install and use gray water system. The concern about loss of reclaimed water would be realistic in a community where the entire flow is currently put to beneficial reclamation and reuse.

Most authors recommend subsurface irrigation with gray water and advise against surface application. This is due to the potential presence of viruses and pathogens in gray water. Also, it is generally recommended[10] that gray water should not come in contact with the edible portion of fruits and vegetables, allowed to collect on the surface of the ground, or to run off the property. Unsuitability of gray water for certain plants is mainly related to the use of detergents and soaps. Some soaps make gray water alkaline[5]. Therefore, gray water may not be effective for subsurface irrigation of acid loving trees or shrubs. In Table 3, suitability of gray water irrigation for selected landscape plants is presented.

Table 3. Suitability of Gray Water Irrigation for Selected Landscape Plant[10]

Suitable	Not suitable	Not suitable
. Ornamental trees and shrubs	. Rhododendrons	. Impatiens
. Flowers and other ornamental	. Bleeding Hearts(Dicentra)	. Hydrangeans
. Ground cover	. Oxalis (Wood sorrel)	. Camellias
. Lawns	. Primroses	. Ferns
. Fruit trees	. Philodendrons	. Foxgloves
	. Azaleas	. Gardenias
	. Violets	. Begonias

Source: Adapted by e.m.r. from the Santa Barbara and San Luis Obispo Gray Water Guidelines

Another limitation to use of gray water for irrigation is its salinity. In particular, water that has been softened has a high sodium content and consequently is far less desirable for irrigation. A high sodium content tends to "seal" the soil with long-term usage[10]. Certain powdered detergents are also reported to contain sodium salts in high concentrations.

PROJECT DESCRIPTION

SECTION II

PROJECT OBJECTIVES

The pilot project was launched with these primary objectives:

1. To obtain reliable quantitative data from actual use of gray water systems under realistic conditions.

2. To make recommendations to the City Council based on the findings of the project, for safe use of gray water in the City of Los Angeles.

3. To publish and disseminate the results of the study to the public through newsletter articles, pamphlets and the media.

PROJECT OVERVIEW

The Gray Water Pilot Project consisted of eight gray water test systems installed at residences in the City of Los Angeles, sampled monthly and monitored over a year-long period for safety and water savings. Samples of soils and water were tested at a certified laboratory for indicator bacteria and pathogens (disease organisms), to compare areas receiving gray water with those irrigated with tap water. Twelve monthly sample sets were taken from the eight pilot sites. Each sample was tested for a dozen parameters. The resulting data formed the basis for statistical analyses to determine the significance of differences, between the control areas and the gray-water-irrigated areas. In addition, periodic interviews with participating home owners and their logs provided data on reliability of systems employed, their maintenance requirements and problems peculiar to gray water systems.

COUNCIL AUTHORIZATION

The City of Los Angeles Council Commerce, Energy and Natural Resources Committee, chaired by Councilwoman Joan Milke Flores, adopted a motion to embark upon a pilot study of gray water use in the City. The Council subsequently affirmed this motion[3] and directed the Office of Water Reclamation to conduct the study and make appropriate recommendations for future legislation to the Council. The work plan, objectives, and scope of the study were based on the discussions of the Council Committee hearings and debate by the full Council.

TASK FORCE

To oversee the project, a task Force was established composed of representatives from the following:

• City Attorney	• Department of Environmental Affairs
• City Administrative Officer, Risk Manager	• Department of Water and Power
• Chief Legislative Analyst	• Mayor's Office
• Department of Building and Safety	• Office of Water Reclamation

The Task Force was kept apprised of the progress of the pilot project through oral and written reports, during the course of the project. This final project report is the end result of the Pilot Project.

PROJECT TEAM

The project team was led by the Office of Water Reclamation, which provided project planning, management, site monitoring, sampling, reporting and recommendations. The Department of Water and Power played a major part in the project by supplying funding for the analysis of samples obtained from project sites, and by supplying water meters for assessing the extent of water conservation achieved at each site. Calscience Laboratories performed the bacteriological and chemical analyses on the samples they received from the field. The following individuals contributed to the project:

[3] Adopted July 31, 1991, Council File Number 87-2121-S21.

• Bahman Sheikh, Director, Office of Water Reclamation	Supervision, Report Preparation
• K. Gary Ghiaey, Office of Water Reclamation	Project Management, Field Sampling, Monitoring, Interviews
• Abbas Amirteymoori, Office of Water Reclamation	Data Analysis, Graphics, Literature Search, Water Savings
• Jerry Gewe, Department of Water and Power	Project Funding
• Amy Chen, Department of Water and Power	Laboratory Liaison
• William Christiansen, Calscience Environmental Laboratories	Laboratory Operations
• Virginia Huang, Calscience Environmental Laboratories	Laboratory Quality Control

FUNDING FOR THE PROJECT

Funding for the Gray Water Pilot Project was provided principally by the City of Los Angeles Department of Water and Power and the Department of Public Works. Major portion of the financial support was derived from the joint sponsorship of the Office of Water Reclamation by these two Departments. Supplemental support, for the laboratory analyses was given by the Department of Water and Power through an ongoing contract with Calscience Environmental Laboratories in Stanton, California.

MATERIALS AND METHOD

SECTION III

TEST SITES

Over thirty families in the City of Los Angeles volunteered the use of their homes for the Gray Water Pilot Project upon learning about the Council's interest in conducting such a study. Because of fiscal constraints, only eight sites could be accommodated by the project. Therefore, a selection protocol and criteria were developed to choose the most appropriate locations. Criteria used in the selection process included the following requirements:

- Site should be within City boundaries.
- Various geographic areas of the City should be represented.
- A range of sizes of homes and sizes of households should be included.
- Both single- and multiple-family dwellings should be included.
- A range of complexity of the drainage systems should be studied.
- Topographic conditions should be varied.
- Both new and pre-existing installations should be investigated.
- A variety of vegetation types should be irrigated.

Furthermore, we required that the owners of the sites indemnify the City of Los Angeles against claims and liabilities and to bear incidental costs associated with the gray water systems installed at their residences. The candidate sites were visited by staff and the owners were interviewed at length. Based on information thus obtained, we selected eight sites and an alternate. A second alternate was added later, when the opportunity for a built-in system--as opposed to retrofits--arose. To protect the privacy of volunteering participants, the specific characteristics of individual sites were not associated with site occupants, owners or addresses. Instead, each site is identified by a number for reporting purposes.

Compliance with Uniform Plumbing Code

All systems designs were reviewed by the Department of Building and Safety for compliance with the Uniform Plumbing Code as adopted by the City. However, inspectors of the Department of Building and Safety reported several technical violations, during the course of the pilot project.

GRAY WATER SYSTEMS

At each of the eight selected sites, a gray water system, usually donated by a manufacturer, was installed, at the expense of the system manufacturer or promoter. A variety of types of systems were installed to maximize the opportunity to learn about the available variety of systems on the market. The original alternate site was a home that has had a gray water system in use for about eleven years. Because one of the main sites failed to function early in the project, the alternate became an active site, for the purposes of sampling and data collection. The failed system was eventually re-configured and stood by as an alternate. In April 1992, a new back-up site was added as a unique opportunity presented itself. This site was a newly designed residence in which the owners were desirous of incorporating gray water separation at three residences from the start. This system was monitored but not sampled since the 8 systems continued to function satisfactorily to the end. The characteristics of the installed systems--some of which are proprietary--are briefly described below.

The Robert Kourik System

Robert Kourik is the author of the Gray Water Handbook, the Drip Irrigation Book, Edible Landscaping and other landscape publications. He sells a mail order gray water system kit for the do-it-yourself weekend plumber. The system consists of a 55-gallon plastic surge tank, flexible tubing, sump pump, bag filter, back-flow preventer, three-way valve and fittings. This system is typically connected to the washing machine discharge line, but also can receive other household gray water. Distribution can be through a subsurface leach field or a buried drip irrigation system. The Kourik system was installed at Site 2[4].

The Agwa System

The Agwa system, designed by Gary Stewart and John and Mark Bozeman, was deployed at two of the pilot sites (Site 4 and Site 6). The system consists of a small receiving tank with a sump pump under the house, 250-gallon storage tank, three-way valve, pumps, an automatically

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[4] Site numbers are keyed to the results of analyses reported in Section IV.

back-washed sand-filter, rigid plastic pipe connections to all household gray water, and a micro-processor that makes all routine decisions and initiates and terminates irrigation. In Site 6, the microprocessor was integrated with the site's pre-existing irrigation controller, to enable potable water irrigation as back-up when/if enough gray water was not available.

The Ted Adams System

Ted Adams is a specialist gray water plumber in Santa Barbara, where gray water use first gained relatively widespread public acceptance. Mr. Adams uses a plastic garbage can with a lockable lid, to which he connects the effluent from washing machines. A sump pump empties the contents through PVC tubing to the irrigation system. Where drip irrigation systems are used, a 200-micron mesh bag filter is affixed to the inlet of the tank to catch lint and other suspended matter from the gray water. This is the simplest, and probably the least expensive of all the systems in the field, and in the pilot project. Ted Adams' apparatus was installed at Site 3 and Site 7.

The WaterSave System

Wayne Stanton and his partners assemble a gray water system that includes two storage tanks, 200-micron mesh bag filter, pump, PVC pipes, three-way valve and other appurtenances. The main features of this system are similar to Robert Kourik's, described above, plus a variable amount of electronic controls. This system was installed at Site 1 and Site 5.

IRRIGATION SYSTEMS

Drip irrigation was the primary method of application of water in all but two of the sites. The type of drip irrigation system used was the tortuous-path emitter systems, which allow for a fairly wide flow path to minimize clogging. Geoflow, a drip irrigation company specializing in underground drip irrigation, donated four of the drip irrigation systems, and provided two others at cost. Two of the drip irrigation systems, in conjunction with the Wayne Stanton System, were by Salco Products, Inc. The latter also supplied drip lines for the latest additional back-up site. The drippers in each system were monitored to assure proper functioning and to prevent clogging.

At site 8, *surface* irrigation with gray water had been practiced for 11 years prior to the pilot project. In order to broaden the range of data applicability, this practice continued after the site became part of the gray water pilot study. Because no alteration to the plumbing system was involved (this system uses gray water from the washing machine discharge pipe), no permits were required and the involvement of the Department of Building and Safety at this site was not necessary. At Site 5, half of the application areas used leach fields and the other half used a drip irrigation system.

ROUTINE USE OF GRAY WATER

Residents at the pilot project sites were given basic information about routine activities involved in the operation of drip irrigation systems. They were forewarned about the potential risks involved in coming in contact with gray water and its microbiological composition. They were trained about changing and cleaning filters, closing off the system and routing gray water to the sewer during rainfall episodes, and other relevant matters. Table 4 provides a summary of site characteristics, type of irrigation system and other relevant information.

Table 4. Characteristics of the Pilot Project Sites

Site	System	Irrigation	Source of Water	Detergent	Animals	Residence
1	WaterSave	leach field, buried drip	all gray water	Oasis	cats	single-family
2	Kourik	buried drip	washing machine	Planet/Oasis	dogs	single-family
3	Ted Adams	buried drip	washing machine	Amway	none/stray	multi-family
4	Agwa	buried drip	wash + 1 bath	Amway	cats	single-family
5	WaterSave	buried drip	all gray water	Oasis	dog, cats	single-family
6	Agwa	buried drip	all gray water	Oasis	dogs	single-family
7	Ted Adams	buried drip	washing machine	powder	none	single-family
8	home-made	surface	washing machine	Oasis	cat	single-family

QUALITY ASSURANCE, PRECAUTIONS AND SAFETY FEATURES

Sampling and Laboratory Analysis

For the results of the study to be reliable, it was critical to incorporate certain precautions to avoid bias on the part of project participants, particularly the laboratory analysts. Therefore, a sample numbering system was adopted that was at once logical and cryptic. The sample numbering protocol was not revealed during the course of the project. It encoded site identity, type of sample, and date using telephone dial correspondence between letters and numbers. An approved quality assurance/quality control procedure was in place at the analytic laboratory, complete with chain-of-custody procedures for sample handling.

Cross Connection Prevention

Cross connection of gray water piping to household potable water lines--usually by mistake, in the course of alteration of the plumbing system--is a risk that cannot be ignored. This risk is present wherever non-potable water lines are placed in the proximity of potable water distribution systems. Precautions were taken at all pilot test sites to minimize the possibility of cross connection between the gray water system and the community water supply system. The following factors are responsible for minimization of the risk of cross connection and its potential impact on community water supplies in these particular systems.

- Professional plumbers performed the alterations, under strict guidelines and inspection.

- Pipes used in gray water systems were generally flexible plastic or color-coded rigid plastic lines, clearly different from the galvanized or copper water lines.

- Pressures employed in gray water distribution systems are typically very low, in the range of 0 to 15 psi, compared to the potable water distribution systems[5] (40 to 100 psi).

- Clear and bold red signs were placed on gray water surge tanks alerting home-owners that the gray water was non-potable and dangerous to drink.

Monthly visits by the project personnel and quarterly inspections by the Department of Building and Safety provided another layer of protection against cross-connection.

SAMPLING PROTOCOL AND PROCEDURES

At the beginning of the pilot project, a rigorous sampling protocol was established, including step-by-step procedures for aseptic sample acquisition, sample handling, transport, labeling, and delivery to the laboratory. The same individual obtained all the samples at all the sites, avoiding cross-contamination of samples, maintaining uniform procedures and constant control of the variables. The sampling activities of the technician was observed and compliance with written procedures was recorded independently.

INTERVIEWS, LOG BOOKS, OBSERVATIONS

Residents at the eight active sites were interviewed at monthly intervals, to obtain qualitative information about their system, satisfaction with its performance, compliance with instructions, difficulties encountered and events that might require servicing or alteration to the system. The residents were also asked to maintain log books in which gray water relevant events would be recorded. Blank forms in binders were provided close to the gray water tank to facilitate logging the events.

Each month, at the time of sampling, project personnel made detailed independent observation of the systems and their irrigation components. Observations were recorded to form a basis of possible explanation of the analytic results. All interview notes, logs and observation notes are maintained at the Office of Water Reclamation. They will remain available for inspection for at least one year.

[5] If a cross-connection did occur, water would flow into the gray water system, not out of it, unless a community water system pressure loss occurred at the same time.

ANALYTICAL PROTOCOL

Samples were analyzed by Calscience Environmental Laboratories in Stanton, California, in accordance with accepted EPA procedures. For each parameter, a description of the analytical procedure employed by Calscience is on file at the Office of Water Reclamation.

RESULTS

SECTION **IV**

BASELINE DATA

Before the start of the study, samples of soils were obtained from all eight sites at locations designated to be irrigated later with gray water. These samples were tested for the same suite of parameters as samples taken in the course of the study. The results are presented in the first table in Appendix A.

ANALYTICAL RESULTS

Raw data from the laboratory testing of samples for different soil parameters were visually compared and evaluated. In parallel, a statistical analysis of the data was also undertaken. The complete set of data from the 12 rounds of sampling, as received from the laboratory is presented in 12 tables in Appendix A. For each site, values obtained for each parameter are compared in various rounds between control- and gray-water-irrigated areas. In addition, at each round of sampling, values of the same parameters are compared across sites for control- and gray-water-irrigated areas. Graphic depictions of these comparisons are presented in Appendix B.

The statistical procedures and data analysis are presented in Appendix C. A summary of the results of statistical comparisons between soils irrigated with gray water and those with tap water appears on Table 5.

Total coliform was significantly higher in gray-water-irrigated soils than in control soils, at the 95 percent level of confidence. On the other hand, fecal coliform--a measure of human fecal contamination--did not appear to be significantly different in the two soils. Sodium concentration and sodium adsorption ratio (SAR) are both significantly higher in gray-water-irrigated soils than in control soils at the 95 percent level of confidence. A weak indication of a minor difference in pH (about 0.14 units) was also observed. All other parameters appear to be similar in gray-water-irrigated and control soils. A more detailed discussion of these results is presented below, for each group of parameters.

Table 5. Summary of Gray Water Project Statistical Analyses

	Mean Difference	Standard Deviation	Number of Data	Standar d Error	Test Statistic	Can Reject* Null Hypothesis?	
Parameter	(Xd)	(s)	(n)	(Xe)	(Xd/Xe)	(@ 90 % Conf.)	(@ 95 % Conf.)
Total Coliform	157,321	610,569	98	61,677	2.55	**Yes**	**Yes**
Fecal Coliform	16,192	376,566	90	39,694	0.41	No	No
Enterococci	19,080	172,509	96	17,606	1.08	No	No
pH	0.14	0.76	96	0.08	1.75	**Yes**	No
Sodium	23.52	98.38	97	9.99	2.35	**Yes**	**Yes**
Chloride	38.09	266.77	94	27.52	1.38	No	No
Calcium	590.73	4,636.96	96	473.26	1.25	No	No
Magnesium	-11.47	231.66	96	23.64	-0.49	No	No
Spec. Conduct.	448.99	3,001.21	90	316.36	1.42	No	No
S. A. R., Calc.	0.33	1.33	94	0.14	2.36	**Yes**	**Yes**

* If the test statistic is larger than 1.66 or smaller than -1.66, then one can say--with 90 % confidence--that the two sets of data are indeed different. If the test statistic is >1.98 or <-1.98, then the same can be said with 95 % confidence. If the test statistic falls outside this range, then observed differences are probably due to chance. The numbers 1.66 and 1.98 are derived from statistical tables based on the statistical design of the project.

Indicator Bacteria

Total and Fecal Coliform bacteria and the enterococcus group in "control"[6] and gray-water irrigated soils fluctuate widely and inconsistently. There appears to be no smooth trend with time or with irrigation treatment. Results of pre-irrigation (baseline) sampling, shown on the first page of Appendix A, also show great variability among sites, with indicator bacteria counts in the same range as the post-irrigation samples. Therefore, it is not possible to correlate occurrence of indicator bacteria with use of gray water at the pilot sites. It may be that background variation of these bacteria in the soil environment--from domestic and wild animals[7]--overwhelms any contributions from human sources through the gray water distribution system.

The statistical analysis of the data from soil samples indicates a significant difference in the total coliform levels--at the 95 percent confidence level--between gray-water-irrigated areas and

[6] "Control" refers to soil samples collected from areas at each site, irrigated with tap water, presumably unaffected by the gray-water system elsewhere on the premises.

[7] The phrase "wild animals" refers mainly to warm-blooded animals such as birds and mammals (including coyotes, raccoons, rats, mice, skunks, etc.)

control areas. This can be attributed to the possibility that gray water contains organic matter which can support growth of soil microorganisms, including coliform bacteria deposited by animals as well as those coming from the gray water sources. However, the statistical tests did not show any significant differences for fecal coliform or for enterococci on the irrigated soils.

In Site 7, there was a consistently lower level of total and fecal coliform bacteria in the control soils than in the gray-water-irrigated soils. Coincidentally, this site does not house any domestic pets. Furthermore, high walls around the site keep neighboring animals and most wild animals--except birds--from visiting and depositing their wastes. This correlation is intriguing. It appears to suggest that in the absence of domestic animals, the garden soil may be "clean" enough to reveal contributions of indicator organisms from gray water irrigation.

In one site, surge tank fecal coliform counts are consistently lower than at other sites. This is the site that has been in operation for about eleven years. The resident at this site has been meticulous and has maintained an exceptionally clean system. The owner completely dries the surge tank after each use of the washing machine to which it is connected. The combination of water source, drying cycles and meticulous operation may account for the extraordinarily low fecal coliform counts in the surge tank at this site. Yet, inspite of these low levels at the surge tank, the soil--control and gray-water-irrigated--at this site is as heavily laden with indicator coliform as the soil at any of the other sites.

Pathogens

Three of the Disease-causing organisms monitored in the sampled soils--Salmonella, Shigella, and Entamoeba histolytica--were negative at all sites in all sampling rounds, in gray water and in soil--both control and gray-water-irrigated. Apparently, neither the gray water nor the soil carried any of these particular organisms. The fact that throughout the year, none of the samples yielded a positive for any pathogens tested is encouraging for the possibility of safe use of gray water--even where total adherence to hygienic handling of the water in not assured.

To explain the complete absence of these pathogens, one might conclude either that (1) none of the residents in any of the test sites shed any of these organisms, or (2) disease organisms that may have been present were deactivated in the detergent-laden environment of the storage tank. In one site, over 20 elderly residents contributed to the gray water system. Interviews with residents at all 8 sites indicated occasional reports of illness in the households. The possibility that a totally healthy population was contributing to the gray water systems is considered to be remote.

Ascaris lumbricoides (common roundworm) turned up positive occasionally during the first three and the last three rounds of sampling . In round 1, Site 6 gray-water-irrigated soil was positive. In round 2, Site 1 soils of both control and gray-water-irrigated areas were positive. In round 2, the control soil from Site 2 was positive. Also in round 2, Site 4 and Site 5 gray water from the surge tank and the gray-water-irrigated soil were positive. In round 3, control soils from Sites 1 and 6 were positive. During the winter and spring, no positive Ascaris was reported at any of the eight sites[8]. The greatest occurrence, at nearly all control sites, occurred in round 12 sampling. There was a scattered pattern of positives in rounds 8 through 12, as

[8] It is not intended to imply that a seasonal correlation with occurrence of Ascaris or its eggs in the soil necessarily exists.

shown on the data sheets in Appendix A. Since no clear correlation with gray water irrigation is evident, it must be concluded that the roundworms were probably not contributed by gray water.

A plausible explanation for the occurrence of Ascaris eggs in these samples--control as well as gray-water-irrigated--is from fecal matter deposited in recent or remote past by domestic animals at the pilot project site residences. Survival of the Ascaris eggs in the soil is relatively long, up to seven years[9]. It may also be possible--though less probable--that at least at site 5 in round 2 sampling someone in the household shed roundworm eggs. Today's hygienic practices make it highly unlikely for most people to become infected with roundworms.

Chemical Parameters

pH, sodium, chloride, calcium, magnesium and total salts were measured in gray water and in the soil extract to determine if any of the agronomic characteristics of the soil might be affected by gray water irrigation. For the same purpose, sodium adsorption ratio was computed for each sample from the basic data. As expected, sodium and sodium adsorption ratio were both significantly higher in gray-water-irrigated soils than in the control soils. This is partially due to the salt content of most of the detergents used in the course of generating gray water. Other laundry additives, such as bleach and water conditioning products may have contributed to the higher sodium levels.

The fluctuation of the concentration of sodium and other salts and a lack of consistency preclude any short-term impacts on the soil characteristics of significance for plant growth. Site 7, the one site that has consistently used regular powder detergents available on the market exhibited acceptable values for sodium, chloride and SAR in the soil.

Boron concentrations in the storage tanks and in the soil were measured once, during round 9 sampling. The results are presented graphically at the end of Appendix B. Clearly, since boron was not detected in any of the gray water samples, it is not expected to affect boron concentrations in the soil. A tabulation of ranges of acceptable values of various chemical parameters for plant growth conditions is presented in Appendix D.

WATER SAVINGS

Water savings from the use of gray water systems was estimated based on the potential demand for gray water use at each site. To estimate the potential demand for gray water, and consequently the amount of water savings, the following methodology was employed:

1- The volume of gray water actually used at each site was measured using a water meter which was installed on the irrigation line.

2- Total volume of water used in each site was calculated by sequential reading of the water meter, simultaneous with the reading of gray water meter, or from the water bills.

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[9] Pettygrove and Asano, 1990, Irrigation with Reclaimed Municipal Wastewater--A Guidance Manual, Lewis Publishers, Inc.

3- Proportion of gray water used is calculated from the two above-mentioned figures.

4- Gray water irrigated areas and total irrigated areas in each site were computed, using on-site measurements of the respective areas. Based on these two figures, the proportion of gray water irrigated areas is calculated. For the purpose of the pilot project, only a small fraction of each site's landscape areas was actually retrofitted for gray-water irrigation.

5- Potential gray water demand (as a fraction of total water use) is calculated by dividing percent of gray water actually used by percent of gray water irrigated areas. This method is based on the assumption that sufficient gray water is available to irrigate the entire landscape areas.

Calculation of water savings indicates that potential demand for gray water ranges from 13 percent to 65 percent, as shown on Table 6. The average potential demand for gray water for all 8 sites is about 46 percent of the total household water use. Potential gray water supply reported in the literature varies from 53 to 81 percent of the total household water use[10]. By comparing the estimated potential demand for gray water (46%) and reported potential supply of gray water, it may be concluded that if the total available gray water is used in a household, the amount of water savings may be about 50 percent, in round numbers. Homes occupied by few individuals and containing large landscaping will not be able to reach this potential savings. Also homes with many occupants and a small area of landscaping cannot achieve these levels of savings.

Table 6. Estimated Potential Gray Water Demand

Site No.	Total Water Use (Gal/Mo)	Gray Water Use (Gal/Mo)	Percent Gray Water Use	Total Landscape Area (sq ft)	Gray water Irrigation Area (sq ft)	Percent Gray Water Irrigated Area (%)	Potential Demand For Use of Gray Water as % of Total Water Use (%)
1	5,920	520	10	2,780	510	18.3	55
2	19,060	410	2.2	8,200	370	4.5	49
3	*	912	--	3,170	460	14.5	--
4	46,660	1,451	3.1	10,100	2,310	22.9	13
5	11,230	680	6.	3,260	410	12.6	43
6	4,240	470	11.	3,280	840	25.6	43
7	11,930	1,120	9.4	4,100	210	5.1	65 (1)
8	*	*	*	*	*	*	*

* No water meter records were obtained from this site.

(1) Since a small area is irrigated with gray water, the measured volume of gray water is more than irrigation requirements at this site. Therefore, the average figure gray water percentage in a typical household is used.

CROSS-CONNECTION

In the systems employed in the pilot study, no cross-connection to a potable system took place. See Section III for precautions employed to minimize the potential for cross connections.

RELIABILITY

The two fully automatic gray water systems by Agwa, performed reliably with practically no input from the residents. The reliability of the manual systems was directly related to the willingness of the residents to maintain the systems. For example, at one site--an apartment building--we expected to encounter technical complications due to the relatively large number of elderly residents in the apartment building using the system. As it turned out, the individual responsible for the laundry facility conscientiously cleaned the filters regularly, resulting in relatively trouble-free operation. When the heavy February rainfalls came, most of the participants promptly shut off their gray water systems, and resumed when the soil became dry again.

In contrast to the apartment building, system failures occurred frequently where maintenance was not a designated function for any one individual. Most system failures recorded occurred as a result of inadequate filter cleaning. These failures resulted in non-performance, i.e., water not being distributed to the irrigation system. This kind of failure--while potentially damaging to vegetation if unchecked for too long--is of no public health significance.

COST

The cost of a gray water system varies greatly with its complexity and capabilities. Approximate price ranges and corresponding capabilities of systems, as suggested by manufacturers and installers are listed below:

$400 to $ 800: This range applies to systems that tap the discharge from the washing machine, only, connected to a low-tech system. The lower end of the price range applies to the do-it-yourself installation, and the upper end to professional installation.

$1,000 to $1,500: In this price range, all gray water tributaries are usually connected to the system. Therefore, it is more labor-intensive and responsive to home-owner installation. The gray water collection and distribution system is still relatively simple and "low-tech", and the total cost depends on the number of gray water sources connected.

$2,500 to $5,000: Gray water systems in this price range are fully automatic, connected to nearly all sources of gray water in the home and possibly backed up by potable water systems for periods when gray water may not be available. The only intervention on the part of the resident is to switch the system off when it is no longer needed during heavy rainfall periods.

MAINTENANCE EFFORT

The extent of maintenance effort required of the resident depends largely on the type of system installed and the frequency of its use. The automated systems, where filter back-wash is performed without resident input on a schedule, require the least effort and cost the most. It is this trade-off that the consumer should understand before selecting which system to purchase.

Systems lacking an automatic filter backwash device require the resident to manually remove and clean both the filter bag and the "Y"-shaped filter. These filters are essential to the operation of systems that rely on a drip irrigation system for application of the gray water to the use areas. If a leach-field disposal system is used, no filters are necessary and maintenance effort is minimal even with the low-tech systems. However, with leach field systems, uniformity of water distribution may be problematic[10]. Furthermore, some local ordinances require frequent application zone changes to minimize the potential for excessive loading of the wastewater disposed in the leach fields.

PERFORMANCE

The gray water systems involved in the pilot project performed well. Where maintenance of the filter was infrequent, clogging of drip irrigation systems occurred, with attendant slow flow and pump damage, at least in one case. A few mechanical problems with valves, pumps and other components--unrelated to the gray water system--were encountered.

ODORS, FLIES, MOSQUITOES

Odors

Odor from gray water systems never permeated outside the enclosed storage tanks. However, the smell became detectable--sometimes pleasantly, other times overwhelmingly--upon removal of the lid. With the lid open, the odor was usually perceptible at a radius of about five feet from the surge tank. Sites using Amway or standard cleaning detergents had a very mild odor, while those using the Oasis or other gray-water specific detergents had a stronger odor. The odor was strongest and least tolerable if gray water had been allowed to reside in the tank for an extended period of time.

Flies, Mosquitoes, Gnats

No flies or mosquitoes were observed or reported at any but one site. The exception was a site where a fish pond receiving tap water is located about ten feet away from the fully enclosed and covered gray water tank. The fish pond has been there for two years, but the resident reported an increase in the number of gnats since the gray water system was installed. It appears that the gnats may have started at the gray water tank and migrated to concentrate around the fish pond.

SURFACE WETTING, PONDING, RUNOFF

Surface wetting and ponding were observed once each at two sites. Soon after they were detected, the malfunctioning components were replaced and the problem was solved. At one site, surface wetting was the result of clogging of the pressure relief valve. At the other site, ponding occurred after the heavy rains of February 1992 caused soil erosion above a segment of shallow-buried drip lines. After the eroded soil was replaced no further ponding was observed. In both cases, the amount of water rising to the surface was minimal and barely detectable.

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[10] Leach fields are typically designed for quick infiltration of water into the soil. They are set deeper than drip systems intended for getting water to the root systems of plants. Leach fields tend to deliver most of the water to one end of the line or the other, depending on the slope of the perforated pipe.

CONCLUSIONS

SECTION **V**

HEALTH-RELATED EFFECTS

From the results presented above, including baseline data, it is clear that backyard soils are contaminated, whether they are from the control areas or from gray-water-irrigated areas. Therefore, the general sanitary practice of washing soiled hands with soap and avoiding direct contact with the dirt in the yard are as valid for sites irrigated with tap water as those irrigated with gray water. If these data can be generalized, the implication is that gray water irrigation--below the surface of the soil--does not by itself elevate the health risks from handling the garden soil, as long as sanitary practices are followed..

It appears that use of gray water at the pilot project sites does not pose a significant risk to the users or the community. Since pilot project sites were controlled, inspected, and repaired as needed, broad generalization of this conclusion may be premature. However, certain more specific generalizations appear inescapable, e. g.:

- Indicator bacteria (total coliform) in the soil seem to increase with gray water application. However, the soil is already so heavily contaminated with animal fecal matter that the additional contribution of gray water may be irrelevant.

- Disease organisms, normally capable of surviving in the soil for a few days, were not present in gray-water-irrigated areas. Neither have these organisms been detected in gray water in storage. This may indicate either an entirely healthy test population (highly unlikely), or a mechanism for deactivation of pathogens. Either way, the results indicate that there may be minimal additional risk of exposure from use of gray water for irrigation of landscaping.

- Individuals assigned the task of cleaning gray water filters--some doing so without protective gloves, in spite of instruction to the contrary--did not report any adverse effects.

- Automated systems do not require handling the filter. The minimal risk of exposure during filter washing and re-installation is absent in automated systems. However, the cost of automated systems is appreciably higher.

- The water savings potential of a gray water system t an individual home can be significant--about 50 percent of all the water used. However, it is highly unlikely that a large enough number of people will install such systems, because of the maintenance requirements, complications with permitting, and cost. Therefore, gray water cannot be expected to play a significant role in a community's water supply reliability. For some individuals, however, a gray water system can spell the difference between a lush landscape and a dry one under drought conditions. It might also mean avoided fines and considerable savings in water costs.

HORTICULTURAL CONSIDERATIONS

It is not possible to observe any important horticultural effects from a one-year test of gray water application on the landscape plants. In the near-term, plant growth has been productive and healthy, probably more due to well-designed irrigation systems and constant availability of water. Any harmful effects would take a number of years to manifest in plant growth impacts. Most of the factors that might bring harm to the soil were monitored and reported. No symptoms of harm to the plants have been observed, even in those sites where regular detergents are being used.

RECOMMENDATIONS

SECTION **VI**

The following recommendations are based on the findings and conclusions in Sections IV and V.

1. Draft ordinance for City Council consideration, to permit gray water systems in the City of Los Angeles, consistent with the models found to be acceptable (in terms of public health protection) the Pilot Project,.

2. Maintain an active role in state and local legislation and code changes affecting gray water use.

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