FINAL REPORT FOR FIELD EVALUATION OF PATH TECHNOLOGIES

CHAPMAN COMPANIES RANCHO SAN MARCOS SANTA FE, NEW MEXICO

October 2004

field evaluation

U.S. Department of Housing and Urban Development
Office of Policy Development and Research

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Final Report for Field Evaluation of PATH Technologies

Chapman Companies Rancho San Marcus Santa Fe, New Mexico

NAHB RESEARCH CENTER

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The NAHB Research Center, Inc. is a not-for-profit subsidiary of the National Association of Home Builders (NAHB). The NAHB has over 205,000 members who build more than 80 percent of new American homes. NAHB Research Center, Inc. conducts research, analysis, and demonstration programs in all areas related to home building and carries out extensive programs of information dissemination and interchange among members of the industry and between the industry and the public.

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SUMMARY

This PATH Field Evaluation was initiated as a demonstration of innovative technologies in a new home constructed for Hacienda 2000 Parade of Homes in Santa Fe, New Mexico. Mike Chapman, President of Chapman Companies, has been an active member of the National Association of Home Builders (NAHB) and its committees on research and codes and standards for several years. He has also been interested in promoting the adoption of innovative technologies, particularly with regard to energy efficiency, environmental protection, and water conservation.

The primary goal of this Field Evaluation is to gather relevant design data, installation techniques, cost information, and performance data on technologies that would be useful to any builder integrating the technology into their design. NAHB Research Center staff provided technical assistance, monitoring, data gathering, and evaluated material and installation costs.

Due to water shortages in this area of the country, the selected technologies focused on water conservation. A gray water reuse system was installed, as well as a rainwater collection system. An additional PATH technology incorporated in the house was air admittance valves (AAVs). AAVs are pressure-activated, one-way valves for plumbing drain, waste and vent systems, which allows air in but prevents sewer gas from escaping. AAVs eliminate the need for roof penetrations for plumbing vent pipes and can reduce the material and labor costs for the plumbing vent system.

Evaluation of the rainwater collection system and the gray water system is focused on irrigation water savings for the house, effects of gray water on the soil, and costs of installation. Water flow meters have been installed and hooked up to a data logger so that household water usage and irrigation systems can be determined and analyzed. Activities also include soil and water sampling to measure any contaminants or changes in soil properties.

As of the date of this report, all systems are functioning and appear to be successful in providing irrigation to their respective landscaped areas. Initial observations indicated that modifications and retrofit were needed to improve efficiency and effectiveness, and to make maintenance of the systems easier for the homeowner. Retrofitting of the systems was completed in the summer of 2002. Monitoring and evaluation continued to September 2003.

1.0 INTRODUCTION

Mike Chapman, President of Chapman Companies, has been an active member of the National Association of Home Builders (NAHB) and its committees on research and codes and standards for several years. He has also been interested in promoting the adoption of innovative technologies in housing construction, particularly with regard to energy efficiency, environmental protection, and water conservation.

This PATH Field Evaluation was initiated by Mike Chapman as a demonstration of innovative technologies for a new home constructed for Santa Fe's Hacienda 2000, Parade of Homes, which was held in August 2000. The home, located southeast of downtown Santa Fe, is a single-family detached, 2300 sq. ft. ranch style home, constructed on a slab-on-ground, with 24" deep stem walls. The house is stick framed using 2x6s at 24" on center with R-19 fiberglass batts in the stud cavity, finished on the outside in typical adobe stucco style common in the area. The house uses a natural gas boiler with a plumbing manifold and re-circulating pump for a radiant floor heating system.

Due to water shortages in this area of the country, the main technologies selected focused on water conservation. A gray water reuse system was installed, as well as a rainwater collection system. Other PATH Technologies demonstrated in the house include air admittance valves, radiant floor heating, and energy and water conserving appliances.

The gray water system that was chosen was a packaged system that included a 12-gallon storage tank (also called a surge tank), connected to a centrifugal pump and a sand filter with self-cleaning capabilities. This gray water system uses drain water from only the bathroom sinks, showers and bathtubs. Once the water is collected and filtered, it is pumped out to a mulched garden area.

Along with the gray water, rainwater from the roof is collected and used for irrigation. The water from the roof, a "Pro-Panel" metal roof, was originally diverted into a 600-gallon underground storage tank, where it was stored until water was needed for irrigation. The water was then pumped out to front and rear planting areas, which are separate from the gray water discharge irrigation area. After field observations and analysis of rainfall data, it was decided to increase the size of the rainwater storage tank to 1,200 gallons in order to increase the capacity to capture more of the rainwater from the roof.

By using both the gray water and rainwater collection, Chapman Homes was able to plant certain shrubs and trees, which are not normally provided in a builder's landscape package due to the local government water use restrictions.

The following PATH technologies are being evaluated at the site:

- Gray water reuse and irrigation system
- Rainwater collection and irrigation system
- Air admittance valves (AAVs)

The primary goal of the field evaluation is to gather relevant design data, installation techniques, cost information, and performance data for technologies that builders can integrate into their design. The NAHB Research Center staff provided technical assistance, monitoring, and data gathering, and evaluated material and installation costs.

Activities also included soil sampling to measure any contaminants or changes in soil properties, and collection of water usage data. The final report includes suggestions to facilitate technology acceptance and promote mainstream usage in residential construction.

2.0 PATH TECHNOLOGIES

2.1 Gray Water Reuse and Irrigation System

2.1.1 Design Considerations

Gray water is usually considered as wastewater drained from bathtubs, showers, sinks, dishwashers, and clothes washers. It contains far less organic material than wastewater from toilets, which is called black water, and therefore requires less treatment. By designing a dual plumbing drain system to separate gray water from black water, the gray water can be reused for irrigation, toilet flushing, and exterior washing, resulting in significant water conservation. When planned into new construction, the individual or community wastewater treatment system could be reduced, resulting in cost and space savings.

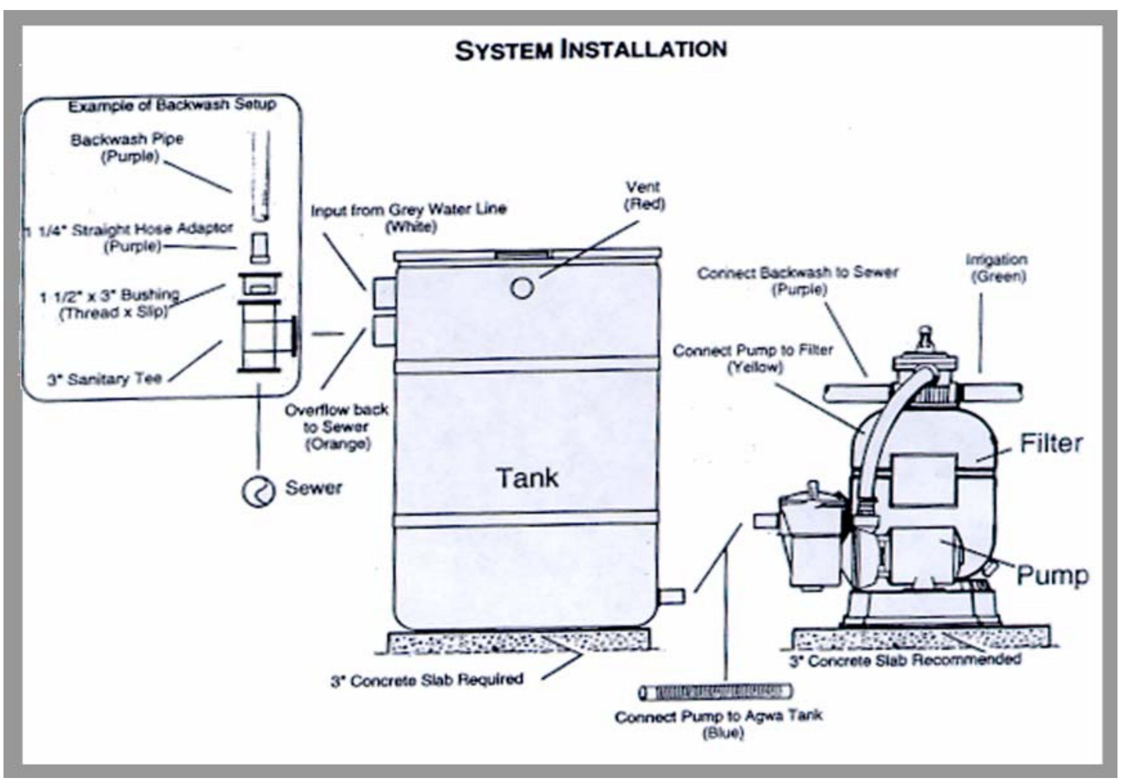

Figure 1 Schematic for gray water system installation

Gray water systems generally consist of a three-way diverter valve, a treatment component (such as a sand filter, surge tank, and bilge pump), dedicated drain system, and irrigation or leaching system. The surge tank cools the water and temporarily holds it back from the drainage hose. Systems can either be custom designed and built, or purchased as a package. Discharge of water can be to planter boxes, drip irrigation systems, water injection systems, leach chambers, irrigated greenhouses, or mulched planting areas. Gray water drain pipes must be installed separately from the normal sewage drain system. The three-way diverter valve allows the gray water to run back into the main sewage system if, for example, the gray water system needs repair.

The gray water system chosen by Chapman Homes is a packaged system purchased from Jade Mountain, Inc. of Boulder, Colorado. The name of the packaged system is the GURU (Gray water Universal Reclamation Unit), Model GFR0012, made by EarthStar Energy Systems. The package included everything needed for a gray water reuse system, ready to be hooked up to the drain and irrigation pipes. The system included a 12-gallon surge tank with a float switch connected to a centrifugal pump, and a sand filter with self-cleaning capabilities.

Operation of the GURU system is simple and straight forward. When the gray water fills the surge tank, a float switch inside the surge tank activates the pump, which then drains the accumulated gray water in the surge tank. The pump sends the gray water to the sand filter, which cleans out dirt, hair, grease and other particles by filtration through a special type of sand (.45-.55 mm pool filter sand). Periodically, the sand filter must be backwashed to remove the accumulated debris and flush it directly to the septic system. The pump with sand filter is similar in operation to those used in some swimming pools. A manual control valve on top of the sand filter allows settings for filter/irrigation, backwash, tank cleaning, and bypass irrigation. There is a pressure gauge on the manual control valve that can be monitored for a pressure decrease that indicates the sand filter needs to be cleaned by backwashing. A regular garden hose can be used to supply clean water for the backwash procedure, as well as to clean the surge tank and the skimmer filter. The self-priming centrifugal pump is a Hayward Power-flo II, 15 amp, 115 volt, 3/4 horsepower with an attached strainer filter on the suction side.

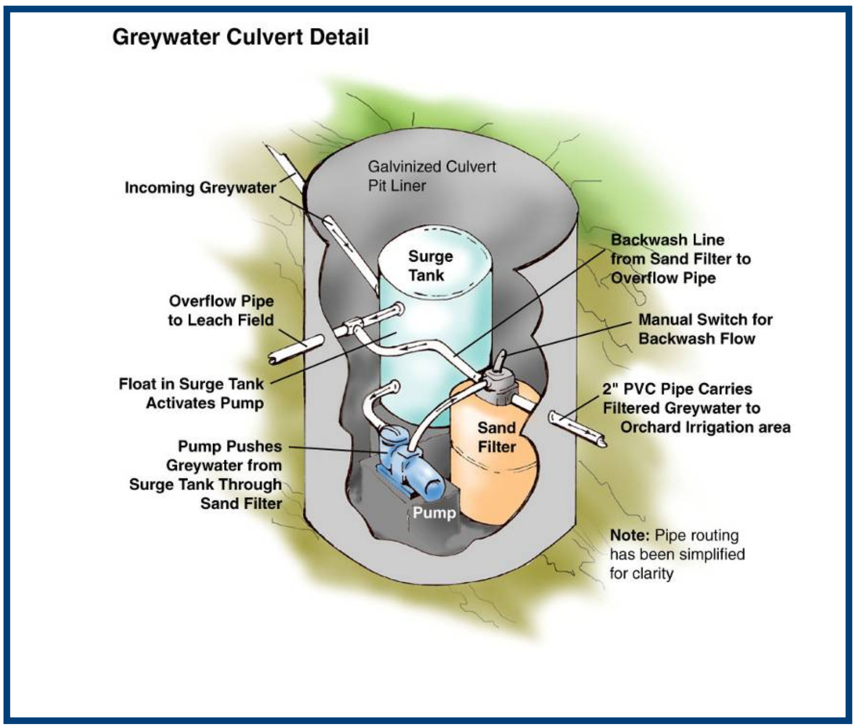

Figure 2 Gray water culvert details

Because of concerns for biological and chemical contamination of the gray water, the builder decided to use the gray water system to drain water from only the bathroom sinks, showers and bathtubs. Dishwasher, kitchen sink, and clothes washer wastewater would require more filtration and treatment to remove suspended solids, organic matter and other contaminants. In some areas, kitchen sinks are not allowed to be hooked up to a gray water system due to the potential for high amounts of organic matter that could be washed into the gray water drain system. Once the gray water is collected and filtered, it is pumped out through an underground 2" pipe to the subsurface portion of a mulched garden area.

2.1.2 Installation

During construction of the house in July 2000, separate pipes for the gray water system were installed and extended outside the house foundation walls to the surge tank. The gray water system package ordered from Jade Mountain was then installed and operational by the August 2000 Santa Fe Parade of Homes. The plumber ran a separate drainpipe system to pick up drain water from two bath sinks, one shower, and two bathtubs. The main drainpipe runs at a 90° angle to the gray water drainpipe and picks up kitchen drains, washer-dryer drain, and all toilets. The layout of the house lends itself well to this design of gray water drainage, since all bathrooms are located along the West side of the house.

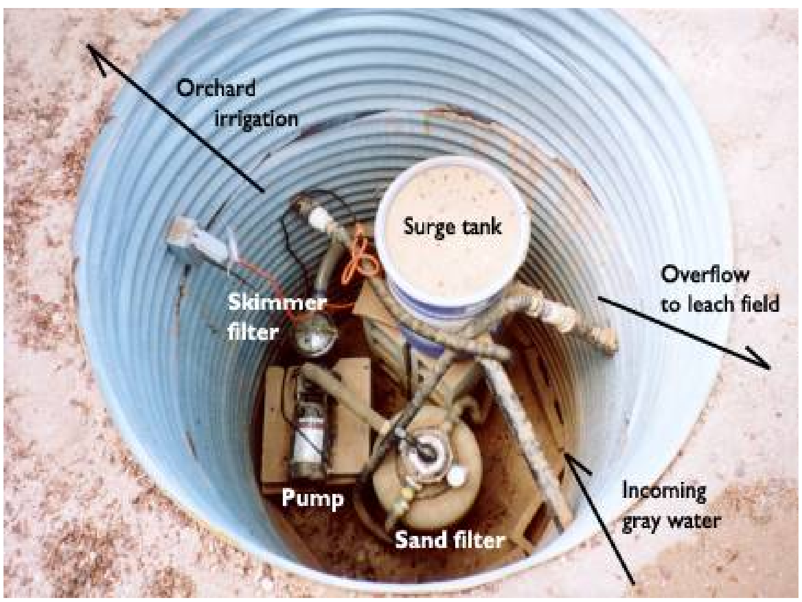

Figure 3 Gray water system installed at the Chapman site

The gray water 2” drainpipe runs under the footing, then underground for about 30’ to a culvert where it terminates into the 12-gallon surge tank. A flexible pipe then runs from the surge tank to a skimmer filter attached to the pump. A float switch inside the surge tank turns on the pump when the surge tank is full. The pump pushes the gray water through the sand filter to a 2” rigid PVC drain pipe that goes to a mulched tree planting area. The mulched tree area contains six fruit trees in a dished out, saucer shaped, planting area with a 6” high earth berm around the perimeter. The berm helps retain any water in the orchard area for percolation and maximum utilization by the tree root system. The area inside the perimeter berm is layered with rough tree bark mulch.

The plumber installed another 2” rigid PVC pipe as an overflow from the top of the surge tank directly to the septic system leach field. In case of servicing needs, the pump can be turned off, and when the surge tank fills, it automatically overflows into the leach field. Normal maintenance of the system is to periodically clean out the skimmer filter and back wash the sand filter every two months. Each winter the system is turned off and started up again in the spring. In the spring of 2002, during start up, the float switch needed repair. Since the repair was completed, the system has been working well.

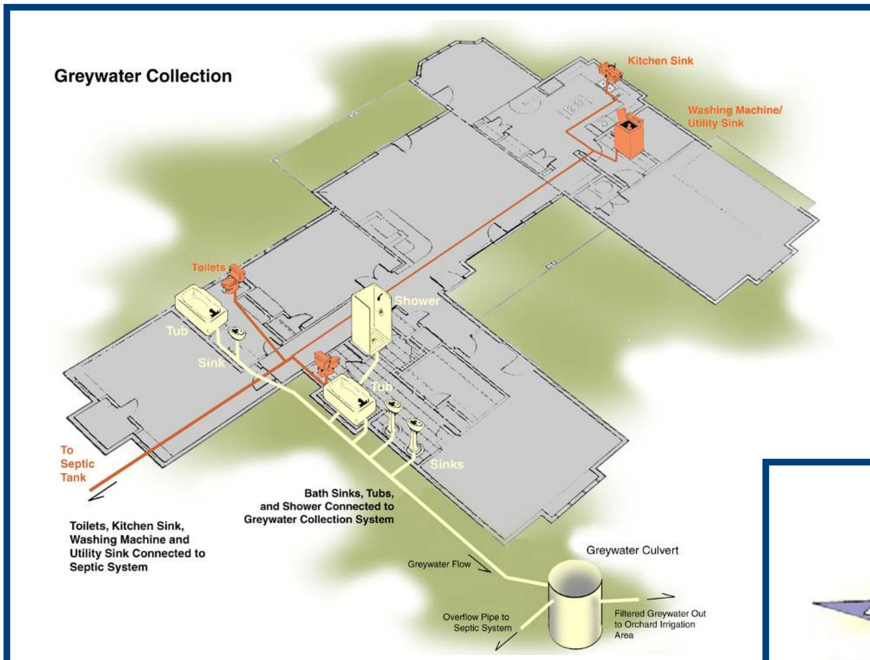

Figure 4 Gray water fixture layout

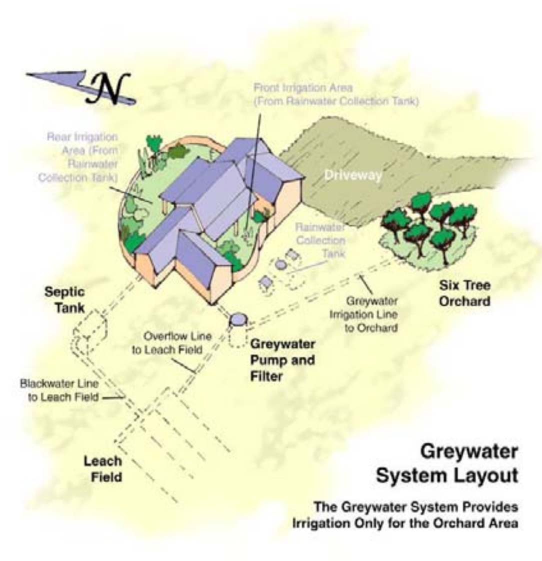

Figure 5 Gray water system layout

2.1.3 Evaluations

Plumbing Subcontractor's Experience

The plumber had installed at least one gray water system prior to this one. He felt that the system was straight forward, and no problems were experienced with the design or installation. He indicated he would have no objection to installing gray water systems in the future. When winter approached, the plumber felt there was a possibility of the pipes and pump freezing. He, therefore, disconnected the gray water system by turning off the pump, which then let the gray water overflow into the leach field from the surge tank.

The plumber told us that if he were to install a gray water system at another house, he would require a maintenance contract with the homeowner, and he estimated that would cost about $50 a month. The plumber felt the average homeowner would not have the ability or the time to perform the required monthly maintenance procedures and if the procedures were neglected, it could lead to clogging of the sand filter and skimmer filter, thereby placing strain on the pump and possibly causing system failure. The maintenance contract would include cleaning the skimmer filter, backwashing the sand filter, checking all connections, and testing the system for proper operation.

Figure 6 Location of the gray water system

Builder's Experience

The builder was very enthusiastic about installing the gray water system. The Santa Fe area receives an average 10 to 12 inches of rain a year, so water conservation is a very important factor in residential development. A typical Southwest region home uses about 50% of its tap water for outside uses, including watering of landscaping. The builder felt that a gray water system would be an excellent way to conserve water by recycling water for landscaping purposes. The builder reports that the idea of a gray water system has been well received by potential buyers.

Figure 7 Gray water outlet located in a mulched area. (Uncovered for photo)

At one point during the fall of 2000, the builder found the system was not working, and upon examination noticed that the skimmer filter was completely clogged with hair and bath oil. Because the accumulation rapidly clogs the filter, the skimmer filter should be cleaned at least once a month.

There was some initial confusion as to whether the sand filter could be backwashed without a separate water supply hooked up to it. A dedicated water supply line can be installed or a garden hose can be brought to the surge tank for the purpose of backwashing the sand filter. The manufacturer requires that fresh water be run into the surge tank during the backwash procedure and a dedicated water supply line for this purpose. The builder felt that a practical way to backwash the filter was to just run bathroom faucets during the backwash procedure, thus supplying a continuous flow of clean water to the sand filter. The homeowner has done this on several occasions, and said that it appeared to be successful.

Homeowner's Experience

The homeowner said that there had been no problems with system functioning. The homeowner was very impressed and happy that her six fruit trees irrigated with gray water were lush and healthy in the middle of a hot and dry desert summer. However, her major concern was maintenance of the pump and filter. Since the pump and filter are located below grade and in a confined space, it was difficult and inconvenient for the homeowner to perform regular maintenance.

In order to access the gray water system, first a heavy and awkward steel lid had to be removed to expose the pit. Then one had to climb down into the confined pit to remove the skimmer filter for cleaning, or to turn the necessary valves to perform the sand filter backwash procedure.

2.1.4 Code Issues

The Santa Fe Health Code officials took an enlightened view of the gray water system as installed on site. The only requirements they specified were to have a sand filter with backwash capability and that the gray water could only be used to irrigate ornamental and fruit trees, not edible nut trees or vegetables. Code officials would not allow a reduction in septic system size because of the gray water system.

Very few states have building codes that allow the use of gray water in any manner. California and Arizona have adopted code provisions that permit the use of gray water under certain specified conditions.

Figure 8 Fruit trees irrigated by the gray water system remain lush and green.

2.1.5 Material and Installation Costs

Cost information for installing the system was collected by the builder and it was estimated the gray water system cost about $2,500 for installing extra drain pipes and the GURU system.

2.1.6 Monitoring

A research and monitoring plan was developed to sample and assess the effects of water discharged from the gray water system to determine if there are any contaminants that would create a risk of damage to trees or shrubs, or create any adverse effect on the soil. Soil samples are taken from the irrigated mulch beds and other areas to determine if unacceptable levels of nitrates, trace elements or other pollutants are present. Soil moisture content of the irrigated area is also evaluated for effectiveness of the total irrigation system.

A water flow meter was installed on the gray water system discharge line leading to the six tree orchard. A sensor on this meter transmits data to an on site data logger, and collects data on flow rate and quantity of gray water pumped to the irrigated area. Total water consumption of the entire house is also monitored by a water flow meter and recorded on the data logger and compared with the amount of gray water discharged to the irrigation area. This comparison should reveal the total amount of tap water saved by using the gray water system for irrigation.

The gray water system was monitored during two seasons starting in June 2002. The first period of monitoring was the period of August 21 through October 31, 2002. The second monitoring period was June 1 through October 31, 2003.

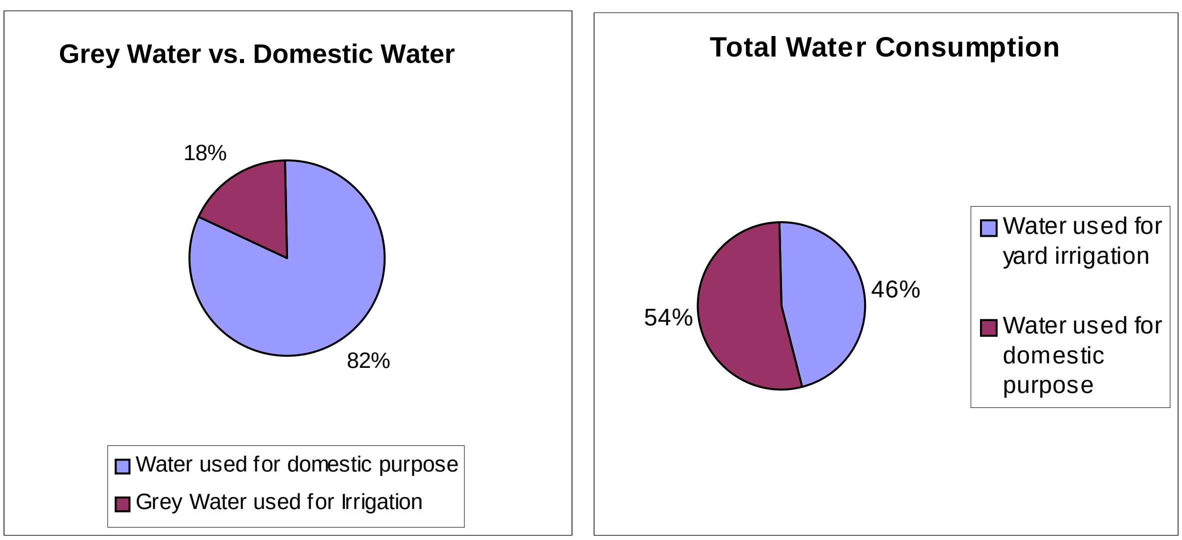

Figure 9 Comparison of water consumption

During the first monitoring period, August through October 2002, total water consumption by the house averaged 162 gallons per day. Of that amount, 37 gallons a day of gray water went to the irrigation of the six-tree orchard. The 37 gallons represents recycled water that normally would have gone directly into the septic system. Instead, the gray water went to irrigate a grove of trees that enhances the beauty of the house and grounds. In the period of August through October 2002 (sixty days), approximately 2,220 gallons of gray water went into the irrigation of the six-tree orchard. Figure 9 illustrates that 18% of the tap water used by the house was recycled into irrigation of the orchard and illustrates the house water used during the first monitoring period for the front and back yard irrigation was 46% of the total household usage. This compares favorably with a household water use study done by American Water Works Association that concluded that, on the average, 50% of all household water usage takes place outside the house.

During the second monitoring period, June through October 2003, 3,973 gallons of gray water went to the orchard irrigation area or about 27 gallons a day.

Soil at the six-tree orchard area was analyzed over two years to determine if there were any deleterious effects on the soil caused by the constant saturation with the gray water. It was felt that using agricultural soil testing methods would give a good indication of any changes in the soil fertility and usefulness. The soil condition parameters that were focused on were the sodium adsorption rate, pH factor, sodium exchange, electrical conductivity, macro nutrient factors – nitrogen, phosphorus, potassium, and also micronutrients and trace elements. Of special concern was the accumulation of salts since this could have serious negative effects on plant material and could cause possible long-term damage to the soil. Soil samples were taken at 6 and 24-inch depths in the irrigated area of the orchard and additional control samples were taken 20 feet from the orchard perimeter. Over a period of two irrigation seasons, ten samples were taken. Samples were sent to the New Mexico State University Soil Testing Laboratory for analysis using generally accepted soil testing techniques. The following table shows the elements tested and types of tests performed by the laboratory.

New Mexico Extension Service Testing Category	Code	Test	Units
Saturated Paste pH	**pH**		
EC -electrical conductivity	**EC**		mmhos/cm
NA - sodium	**Na**	for SAR	meq/L
Ca- calcium	**Ca**	for SAR	meq/L
Mg- magnesium	**Mg**	for SAR	meq/L
SAR -sodium adsorportion rate	**SAR**		
Calculated Exchangable Na %-ESP	**ESP**		
Organic matter	**O.M.**	%	percent
Nitrate-nitrogen	**N**	soil:water extract	ppm

New Mexico Extension Service Testing Category	Code	Test	Units
Bicarbonate phosphorus	**P**	NaHCO3 extract	ppm
K-potassium	**K**	soil:water extract	ppm
Texture estimate		feel	
Micronutrients/Trace Elements			
Iron	**Fe**	DTPA extrac.	mg/kg
Zinc	**Zn**	DTPA extrac.	ppm
Copper	**Cu**	DTPA extrac.	ppm
Manganese	**Mn**	DTPA extrac.	ppm

Soil testing results compared to the control samples showed no major increases in macronutrients, micronutrients, trace elements, or salts. Minor increases in nitrogen, phosphorus, potassium and some trace elements occurred. Slight decreases were recorded in manganese and iron. See Appendix for test results and comparisons.

2.1.7 Conclusions

The gray water system has functioned effectively. It has reliably irrigated the selected area quite well and no major operational problems or other difficulties have surfaced. The gray water system has dependably provided about 30 gallons a day, every day, during the irrigation season.

However, based on observations of the existing set up, some modification of the system is advisable. There is no separate valve to directly shunt the gray water into the septic system and bypass the surge tank, filters, and pump. A diverter valve is recommended and necessary if the system needs servicing or if components need to be replaced. Although operating smoothly throughout the irrigation season, several maintenance functions must be performed on a regular schedule, including cleaning the skimmer filter, backwashing the sand filter, and flushing out the surge tank. The need for placing the pump for easier maintenance by the homeowner was apparent. Several alternative solutions were discussed, including putting the pump and filters above ground in a small shed or engaging in a maintenance contract with a plumbing company.

The gray water system has reliably operated as designed for three years with only some minor adjustments in the first year. The six trees in the orchard are lush and flourishing even though there has been an extreme three-year drought cycle. Gray water that normally would have gone into the septic system has been recycled to enhance the landscaping beauty of the site without using precious well water for irrigation. We feel that the gray water system is a viable and steady source of irrigation water that can significantly reduced the total consumption of household potable water use. We strongly suggest that more research be done and that code issues be examined in more detail.

2.2 Rainwater Collection and Irrigation System

2.2.1 Design Considerations

As drinking water sources shrink and the population increases, interest in harnessing new sources of fresh water to meet rising demand has increased. In some areas, underground fresh water aquifers are being drawn down faster than they can be replenished, and opportunities for new dams are limited. The fresh water problem is particularly severe in the arid regions of the Southwest, where the annual rainfall of 10 to 12 inches comes almost all at once, typically during the period of June through August. In 2002 and again in 2003, the Santa Fe area suffered through extreme drought conditions with an estimated annual rainfall shortage of 4 to 6 inches.

Rainwater harvesting is an excellent method of providing fresh water for a variety of uses. As an example of the potential of capturing rainwater, a 2,500 square foot roof in Santa Fe, New Mexico could collect approximately 18,000 gallons of rainwater in one year through harvesting the typical local annual rainfall. An additional benefit of rainwater collection is that the rainfall collected from the roof does not run off the site as stormwater. Instead, it is returned to the aquifer through slow percolation. This decreases erosion potential, pollution, and could possibly allow for a reduction in stormwater management costs for new development.

A typical rainwater collection system is basic and simple in its operation. Rainwater from the roof is collected into gutters, and the downspout leaders carry it into a storage tank. A simple “first flush” device is recommended to allow the initial rainfall to wash dust and other contaminants from the roof, so that they do not enter the storage tank. A small pump can be hooked up to the storage tank to distribute the water to irrigation areas. If the storage tank is above ground, gravity can distribute the stored rainwater. During dry weather periods, the accumulated rainwater can be used for irrigation, washing, or if properly filtered, even drinking water.

The rainwater harvesting system can be relatively inexpensive. The collection area is the roof, and most homes have an existing gutter/downspout system. The most costly item is the storage tank. Chapman Homes originally chose an underground 600-gallon tank, with roof gutters and downspouts taking the rainfall from the metal roof of the house into the underground tank. A small electric pump lifts the collected rainwater out of the tank and into the irrigation system.

2.2.2 Installation

The rainwater harvesting system was installed in July 2000. Runoff water from the roof flows into the gutters and into downspouts that run into underground leaders, then into a 600-gallon underground plastic storage tank. The tank has a 2-foot

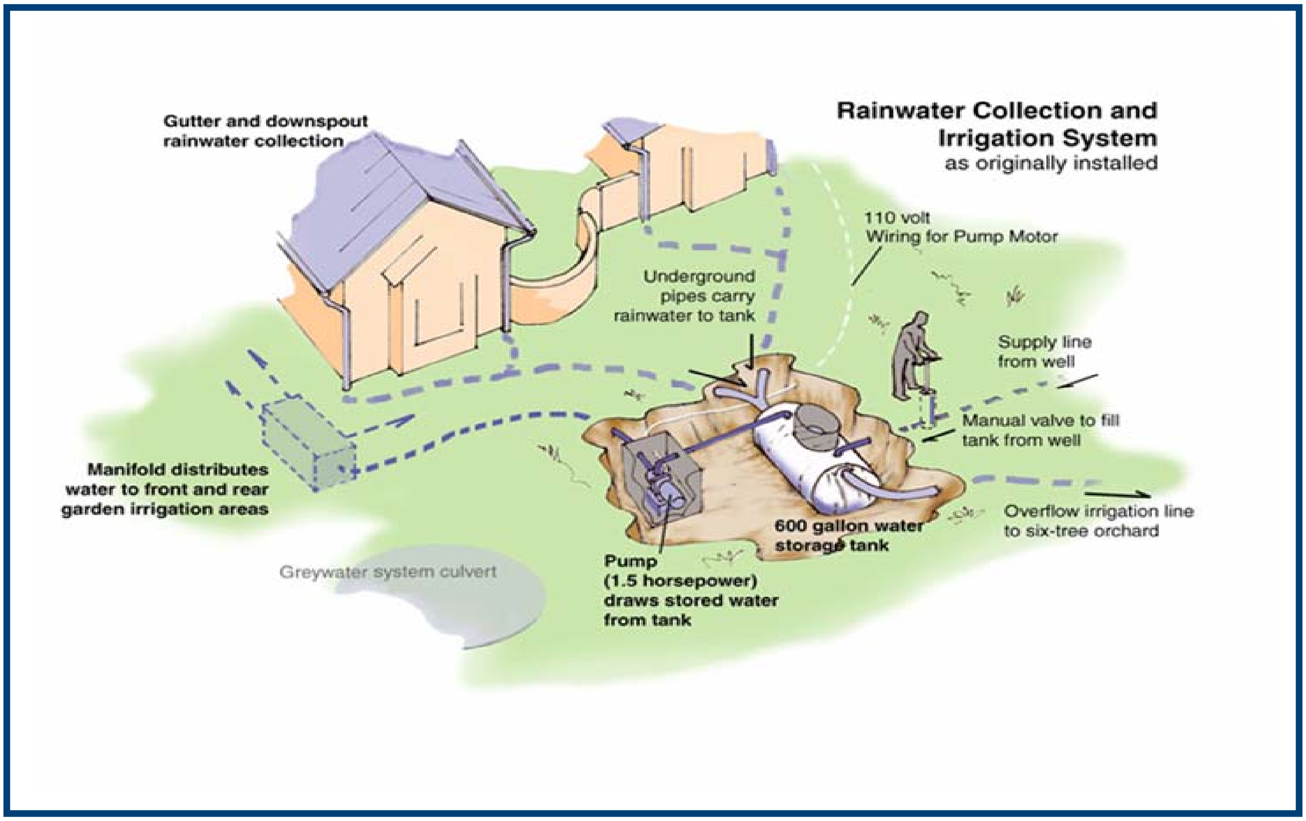

Figure 10 Original installation of rainwater collection system (July 2000)

diameter access hatch on top of the tank, covered by a lid, at grade. There is also an overflow system, using pipe of 6" diameter non-perforated flexible drainpipe that runs from the underground storage tank to the six tree orchard area.

A tap water supply line from the well is hooked up to fill the tank when the tank's collected rainwater is exhausted. There is a manual shut off valve three feet below grade that is accessed by a long T-handle to turn on the tap water to the underground storage tank. A 1.5 horsepower pump, installed next to the underground tank, pulled the water from the tank into an irrigation system that watered a small rear lawn and several shrubs, and the shrubs in the front courtyard. A RainBird E-6 Timer activates the house irrigation system. The irrigation system has four zones: front yard drip irrigation, rear yard drip irrigation, and two pop up sprinkler zones for the rear yard grass lawn. Daily irrigation needs for the landscaped areas were estimated by the landscape irrigation system installer at 150 to 200 gallons a day. The timer provided a heavy watering in the morning for 30 minutes and a short cool-down watering for 20 minutes in the early evening. The timer sequences through each of the four zones in a preset pattern. The timer controlled irrigation system will cycle on even if there was rainfall at the time.

Once the original 600-gallon underground tank filled with rainwater, the pump drew from the tank as the timed irrigation system demanded. When all rainwater in the tank was exhausted, the homeowner would have to turn the T-handle valve on to fill the rainwater storage tank with tap water. This proved to be a cumbersome and inconvenient arrangement for the homeowner.

2.2.3 Evaluation

<u>Builder's Experience</u>

Installation of the tank and other hardware was done by the builder's crew and coordinated with the landscape contractor who installed the irrigation system, the pump, and the plant material. No problems or difficulties were experienced with the installation. The house shares a drilled well with two other lots. When the builder first advertised the house with the rainwater collection system, it generated tremendous interest from prospective buyers and the community. At least one other purchaser has ordered the rainwater collection system in the San Marcos Subdivision. The builder is now offering a rainwater harvesting system as a standard option in new construction.

Figure 11 The rainwater collection tank has a ground level access hatch adjacent to the pump

Figure 12 Front courtyard irrigated from rainwater system

<u>Homeowner's Experience</u>

It appears that the 600-gallon tank was too small. Rainwater collected was quickly used up by irrigation needs. The homeowner needed to fill the tank with tap water about three times a week during the summer months to keep the plants adequately watered. With a potential of capturing approximately 10,000 gallons from the roof area in one year, a larger capacity tank was needed. Also, there was no float switch to start the tap water automatically when the tank was empty, and there was no water level gauge in the tank. Therefore, the homeowner had

Figure 13 Rear yard irrigated from rainwater system

monitor whether the irrigation system was working, or keep looking inside the tank to judge the water level and manually turn on the tap water to the storage tank, which was inconvenient. A float switch to activate the tap water automatically and perhaps a water level gauge should be installed. In addition, the timer system needs to be modified with the addition of a moisture sensor that would prevent the irrigation system from running after a rainfall.

2.2.4. Retrofitting the Rainwater System

In the spring of 2002, a larger underground 1,200 gallon capacity tank was installed. Initially, it was felt that the larger tank should be installed in addition to the existing 600-gallon tank to afford maximum capacity. Historic rainfall data from the National Weather Service for the south Santa Fe area was obtained and placed on a spread sheet. Each rain event and total number of inches of rain on that day from the period of April to October 2001 was recorded and the number of gallons that would be generated from the roof of the Chapman house was then calculated. It was determined that out of forty rain days in that period, only three rain days generated more than 1,200 gallons. By subtracting the daily landscape irrigation use of 200 gallons, there was only one rain day in that period that would theoretically exceed the 1,200 gallon tank capacity. Therefore, the 1,200 gallon tank seemed to be sized reasonably and economically. Winter rainfall was not calculated. Storage tanks are the most expensive component of a rainwater catchment system. By analyzing the amount of rainfall on a daily basis, the storage tank capacity can be selected with greater accuracy.

At the same time the new tank was installed, a solenoid valve and float switch and two water meters to monitor water flow for the evaluation were installed. The solenoid valve was installed on the tap water line going into the 1,200 gallon rainwater storage tank, and connected to a float switch installed inside the rain water tank. When the tank is empty, the float switch activates the solenoid valve, on and tap water flows into the tank. When about 200 gallons has flowed into the tank, the float switch turns off the incoming tap water. Approximately 200 gallons is the landscaping watering requirement for one day. This leaves almost a 1,000 gallon capacity to store incoming rainwater. A back flow preventer was installed on the tap water supply line to prevent any stored rainwater from siphoning back into the main water system. The addition of the float-activated solenoid valve made the entire rainwater/ irrigation operation automatic. The homeowner only has to program and set the timer at the beginning of the irrigation season, and either accumulated rainwater will be pumped to the irrigation system, or if there is no rain, tap water will automatically go into the tank as needed. The irrigation system timer turns the rainwater tank/irrigation pump on as required.

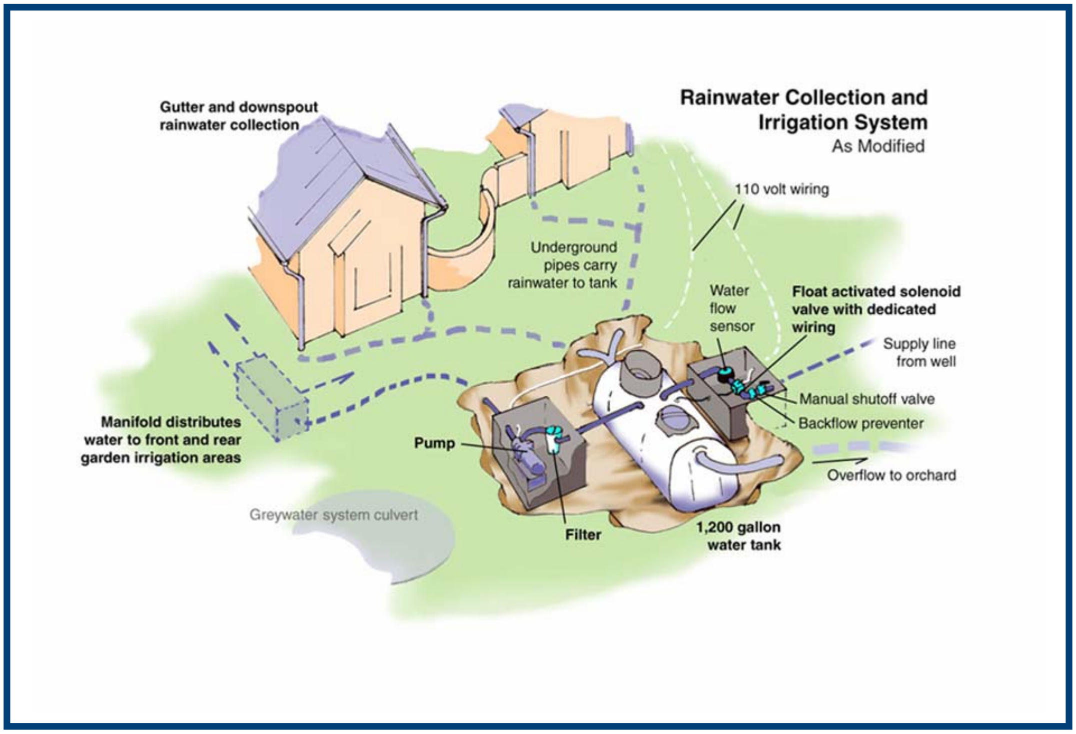

Figure 14 Rainwater collection and irrigation system as modified

Another change made during the rainwater tank replacement was to add a filter on the water line going from the rainwater storage tank to the irrigation pump. Apparently, there was a small filter in the irrigation system that was clogging quite frequently and the addition of a new large size filter should eliminate the clogging problem. This is also a good practice. Should any debris get into the rainwater tank, the filter would prevent damage to the pump as well as the irrigation system.

2.2.5 Material and Installation Costs

Cost information for installing the system was collected by the builder and it is estimated by the builder that the storage tank, pump, underground pipes, and installation labor was $3,000.

2.2.6 Monitoring

A research and monitoring plan was developed to assess the total water used for irrigation and the rainwater collected in the rainwater storage tank. Water meters were installed in the tap water line going to the rainwater tank and on the pump discharge line going to the irrigation system. Both meters transmit data to the on site data logger. The total number of gallons pumped from the rainwater tank and the total number of gallons put into the tank from the dedicated tap water supply line can be monitored. A water meter is installed on the water supply line to the house to collect data on the total amount of water used by the occupants.

A weather station was installed by the Research Center at the site. Wind speed and direction, temperature, relative humidity, and rainfall amount are measured, and that data is sent to the data logger. The recorded rainfall at the site is then compared with the quantity of well water flowing into the rainwater storage tank and the gallons of water that were pumped out of the tank to the irrigation system.

2.2.7 Conclusions

Water supply is becoming a major limiting factor to new house construction throughout the country. Even in areas of high rainfall and large aquifers, new development must typically requires local governmental assessment that adequate water supply and sewer capacity exists for the new development. The consensus is that we are pulling the water supply out of the underground storage aquifers at a much higher rate than natural forces such as rainfall are replenishing the aquifer. Dam construction as a source of relief for the water shortfall problem is limited due to lack of available sites, high cost of construction, environmental concerns and most rivers, particularly in the West, are tapped out.

The rainwater collection system has functioned effectively for three years. The storage system, with few moving parts, has worked well in gathering and storing the rainwater generated from the roof of the house. The only problems encountered were with the irrigation distribution system and these were generally taken care of through adjustments and adding filters.

Data gathered indicates that during the period August through October 2002 approximately 3,800 gallons of rainwater was captured and used for irrigation. This represents approximately 51% of the total irrigation water used and about 22% of the total water used by the household.

During the period June through October 2003 about 4,100 gallons of rainwater was used for irrigation. This represents 15% of the total water used for irrigation and 7% of the total water used by the house. This period was characterized by extreme drought conditions and rainfall was much less then would be typically encountered.

Rainwater is an inexpensive and reasonably reliable source of water that can greatly save on the total consumption of tap water by a household. During the two monitoring periods, a total of 7,986 gallons of captured rainwater was used for irrigation. This is equivalent to thirty-nine days of the house’s landscape needs. Adding the gray water irrigation output during the two monitoring periods brings the total to 14,179 gallons of tap water saved.

One observation that was made is that when designing rainwater capture systems, emphasis should be placed on simplicity to keep the costs down, reduce maintenance, and minimize irrigation distribution problems. For example, using an above ground storage tank and a gravity distribution system would help achieve those goals.

2.3 Air Admittance Valves

2.3.1 Design Considerations

Figure 15 An air admittance valve makes a roof penetration unnecessary

Air admittance vents (AAVs) are pressure-activated one-way valves for plumbing drain, waste and vent systems that allow air in but prevent sewer gas from escaping. Conventional plumbing vents must extend above the roof to minimize odors. AAVs do not need to penetrate the roof, and therefore save labor and material costs. In addition, AAVs do not require lateral branch vent lines, further reducing plumbing labor and material costs. It appears that AAVs offer a significant time and material savings for the plumbing trade. The builder was very interested in using AAVs, since he desired that there be no penetrations to the metal roof.

2.3.2 Code Issues

At the first submittal for Code approval of AAVs, the Santa Fe County mechanical inspector denied the request, citing a local amendment to the Uniform Plumbing Code that did not allow AAVs. The inspector stated that the AAVs might freeze up during the winter and fail to operate as intended. Later, the building inspection department granted a variance since it was an experimental house, with the stipulation that the AAVs be fully exposed to view in the attic for periodic visual inspection.

2.3.3 Evaluation

The project plumber said he had no problems installing the AAVs, and would like to install them on future projects because of the cost savings of not having to run laterals, or install vent pipes through the roof.

2.3.4 Conclusions

AAVs have been installed and are functioning effectively for three years with no problems reported. The goal of providing an alternative to through-the-roof penetrations of roof vent stacks was achieved. However, until the local code is amended, the local code officials will not allow the use of AAVs in the Santa Fe area. This appears to be a major obstacle to widespread acceptance and use of AAVs in local residential construction at this time.

3.0 CONCLUSIONS

An analysis of lessons learned shows that the gray water system worked very well in spite of the maintenance factor and provided a steady and reliable source of daily irrigation water for landscaping plant material. The system could benefit from a valve on the drain line prior to the gray water system that could shunt the gray water into the house septic system leachfield so that maintenance and seasonal shut down functions would be more easily performed.

The rainwater system performed very well in capturing the rainwater from the roof and having it available for irrigation purposes. However, the pump set up seemed to be overly complicated and could be simplified to reduce breakdown potential. Also, having the well water back up supply line going into the tank unnecessarily increased the complexity of the system. This made monitoring the system easier but our recommendation would be to have the well supply go directly to the irrigation system and use the rainwater storage water as it comes available, as a vital and important supplement to the well water. Given the very limited rainfall in that area, storage of rain water will not meet the total landscape water needs on a daily basis. In other geographic areas blessed with more abundant rainfall, this would not be the case.

4.0 REFERENCES

Chapman Companies
404 Brunn School Road A
Santa Fe, NM 87505
505-983-8100
www.chapmanhomes.com

Jade Mountain, Inc. (gray water and rainwater system components)
P.O. Box 4616
Boulder, CO 80306
800-442-1972
www.jademountain.com

Studor, Inc. (Air Admittance Valves)
2030 Main St.
Dunedin, FL 34698
800-447-4721
www.studor.net

NAHB Research Center, Inc.
400 Prince Georges Blvd.
Upper Marlboro, MD 20774
800-638-8556
www.nahbrc.org

APPENDIX A

Figure A1 Steel cover for gray water system underground pit.

Figure A2 Six-tree orchard, irrigated by gray water, is thriving even during extreme drought conditions.

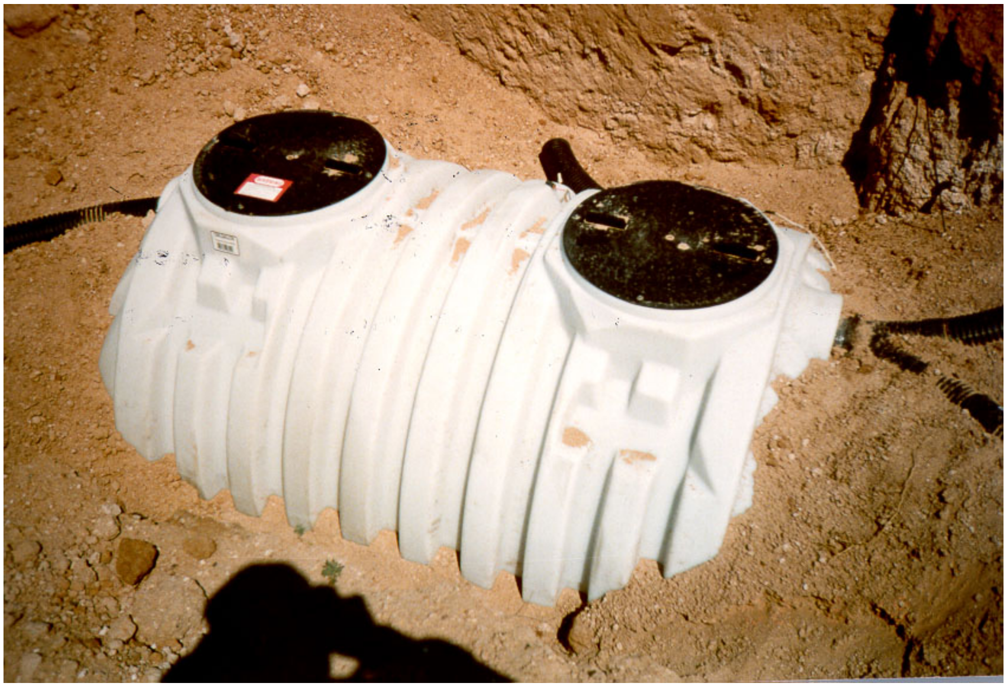

Figure A3 New 1,200-gallon rainwater storage tank. On the right side are the leaders from the roof downspouts. On the left side is the overflow pipe.

Figure A4 Adjusting the float switch in the new rainwater tank.

Figure A5 Inside the house, the research water meter monitors whole house water use.

Figure A6 Tap water supply to the rainwater storage tank showing the research center water meter, solenoid valve, and manual shut off valve.

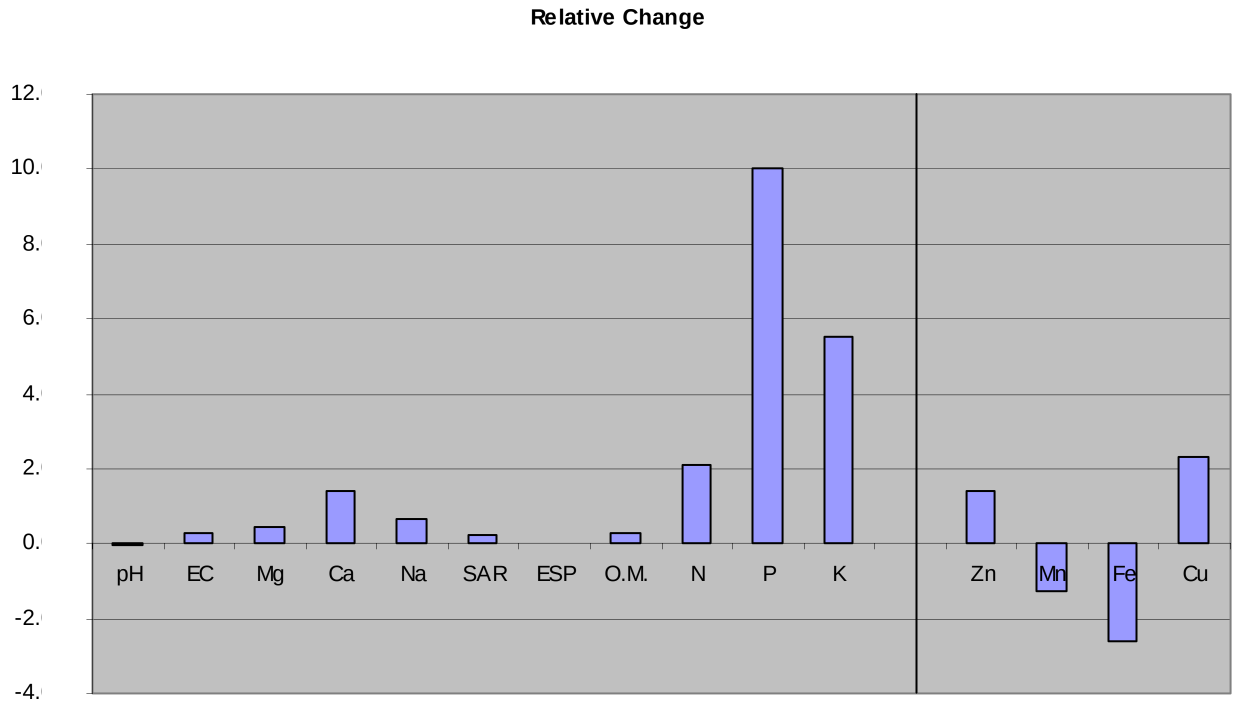

Figure A7 Change in soil conditions at gray water irrigated area

Category	Jun	Jul	Aug	Sep	Oct	Total Gallons Jun - Oct
Total Water Usage	10,440	23,296	8,628	8,737	7,474	**58,577**
Total Domestic Usage	5,173	16,691	2,469	2,627	591	**27,553**
Savings in water due to rainwater harvesting	1,366	133	6,155	285	663	**8,604**
Water saved by using gray water irrigation	712	701	3,160	19	605	**5,199**
TOTAL WATER SAVINGS	**2079**	**834**	**9316**	**304**	**1269**	**13,803**

Figure A8 Summary of Total Water Usage and Savings
June through October 2003

Figure A9 Chart used to size rainwater collection tank

Daily Rainfall Data – April through October, 2001

(rain in inches)

April

Date	6	22	28
Rain	0.26	0.05	0.15
Gallons	496	95	286

May

Date	4	10	13	16	19
Rain	0.90	0.02	0.24	0.01	0.04
Gallons	1718	38	458	19	76

June

Date	7	24	25	26	29
Rain	0.24	0.05	0.03	0.47	0.17
Gallons	458	95	57	897	324

July

Date	1	2	3	12	13	17	24	25	26	27
Rain	0.13	0.25	0.03	0.05	0.40	0.03	0.02	0.01	0.31	0.01
Gallons	248	477	57	95	763	57	38	19	592	19

August

Date	1	5	7	8	9	11	12	14	16	18	28	30
Rain	0.30	0.01	0.01	0.65	0.38	0.10	0.03	0.70	0.39	0.08	0.05	0.26
Gallons	573	19	191	1241	725	191	571	336	744	153	95	496

September

Date	4	16
Rain	0.06	0.26
Gallons	115	496

October

Date	8	9
Rain	0.07	0.07
Gallons	134	134

Monthly Totals

Month	Inches/rain	Gallons
April	0.46	878
May	1.21	2,309
June	0.96	1,832
July	1.24	2,367
August	2.96	5,649
September	0.32	611
October	0.14	267
Total	**7.29**	**13,913**

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