WATER RECYCLING AND WATER REUSE
ASSESSMENT

The University of Georgia
Greenhouse*A*Syst
Publication Series
A Program Designed to Assess
and Manage Issues Involving
Our Natural Resources and
Environment

UNIVERSITY OF GEORGIA
EXTENSION

Table of Contents

The University of Georgia

The Greenhouse*A*Syst Publication Series

A Program Designed to Assess and Manage Issues Involving Our Natural Resources and Environment

Home*A*Syst is a national program cooperatively supported by the USDA Cooperative State Research, Education and Extension Service (CSREES), USDA Natural Resources Conservation Service (NRCS), and U.S. Environmental Protection Agency (EPA).

This publication follows the Farm*A*Syst/Home*A*Syst grower self-assessment model of dividing farming management into a series of issues, dividing each issue into categories, including educational materials, and following up the self-assessment with the development of action plans to address the key areas of concern. Universities that have *A*syst publication series include Oklahoma, Kansas, Texas and Wisconsin. New series have recently been successfully developed at major universities including Orchard*A*Syst and Food *A*Syst.

The Greenhouse*A*Syst publication Series has been developed to assist greenhouse owners with the task of assessing three management issues: Water management, Environmental Risk and Business Profitability. To date, six publications dealing with the water issues are being reviewed and six more are being developed.

The Greenhouse*A*Syst series of publications is a confidential self-assessment program you can use to evaluate your greenhouse business for risks associated with water management issues. Armed with facts and figures, you will then be able to re-evaluate your management strategies and determine ways to conserve water and minimize those risks. By following the guidelines, you will be able to establish a formal company-wide water conservation plan. Implementation of this plan will facilitate more efficient use of resources and impart significant savings in water use, fertilizer and pesticides.

This bulletin will also help you establish a water conservation document you may find useful if and when state or local water authorities develop policies or implement water restrictions. Most water authorities are favorably impressed with businesses that have developed water conservation plans.

Greenhouse*A*Syst risk assessment consists of a series of questions that will walk you through the considerations to be taken into account while evaluating your business. In order to gain the full benefit of the Greenhouse*A*Syst program, we recommend that you use all 12 publications in the series in the following order.

Risk Area	Greenhouse*A*Syst Publication	Suggested Order
Water Source and Expansion	Available	1
Delivery and Technology	Available	2
Water Management	Available	3
Water Quality	Available	4
Water Recycling/Pollution Prevention	Available	5
Water Regulations/Company Policy	In production	6
Fertility Management	In development	7
Operation Safety and Biosecurity	In development	8
Shipping, Transportation and Material Handling	In development	9
Greenhouse Energy Utilization	In development	10
Time and Labor Management	In development	11
Greenhouse Maintenance	In development	12

Water Recycling and Reuse Assessment

Publication #5 in the Series

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WATER USED in a greenhouse is frequently not diverted to collection facilities or recycled. Water and fertilizer solutions that miss the plant containers or eventually drain from the container fall to the floor of the greenhouse to be absorbed into the subsoil. This means that nitrates and phosphorus are being released into the subsoil, which may or may not be moving into the local groundwater supply.

A much better approach, and often a more economically beneficial approach, is to collect and recycle the water that is not used by the plant. There are many considerations involved in water recycling, including how to manage the water quality once the water has been collected. This publication will help you assess the feasibility of water reclamation and recycling in your operation.

Section 1. Greenhouse*A*Syst Risk Assessment Of Water Recycling

The purpose of this section is to assess how recycling water can benefit your business.

Do you recycle any portion of your irrigation water?

If not, there may be potential cost savings and risk reduction from exploring this option.

Can you accurately measure that amount of recycled water?

You should try to determine the amount of recycled water, especially if you've spent the money for water recapture and recycling. This is the type of documentation legislators are interested in.

Could you report with some accuracy how much fresh water you save per year by recycling?

You may find the savings and political benefits from this information to be substantial.

Are your water storage areas covered?

Covered water storage areas reduce disease, algae and contamination risks.

Are there areas of production that would be amenable to recycling?

Outdoor production areas, greenhouses with crops growing on cement flood floors, rolling trays, or ebb and flow systems are excellent candidates for recycling technology.

Do you know how much water you could potentially recycle?

Even saving 15 per cent would be a significant savings and a great position to present to local legislators and water conservation officers.

Have you considered the cost effectiveness of a water recycling system?

The actual dollars saved in water extraction may offset the purchase price of new technology in just a few years. An agricultural economist can help you with the analysis.

Have you assessed the purity of the recycled water you apply to your crops?

Water recycling systems here include sub-irrigation systems such as ebb and flow and capillary mat systems as well as other kinds of irrigation systems that use water recycled from the operation. Issues for recycled water are similar no matter how the recycled water is re-distributed.

Recyling systems may recycle only water leached from production areas, or they may recycle production run-off water as well as storm water runoff from the site. The advantage of using storm water as a part of the recycled water is the dilution it will provide. Because rainfall varies from week to week, however, coping with storm water requires more management effort. Because of the variety of ways that water can be re-used in greenhouses a recycle system design is different for each different operation.

Recycling Water

The advantages of water recycling are many. Recycling is chosen for the two primary reasons of reducing water waste or preventing off-site pollution. For some operations, recycled water is the most economical way to ensure an adequate water supply for all growing seasons. When water is recycled, nutrients and other water additives are recycled, so reduced amounts fertilizers and other chemicals is another advantage of recycle systems.

Disadvantages of water recycling are often very compelling. The cost of storage and additional pumping one disadvantage and, depending on the site, these costs may make some kinds of recycling systems too expensive. However, in many cases, these additional costs may be recovered through water and chemical savings over time.

Using re-cycled water requires more careful management of herbicides and other chemicals (such as systemic pesticides) as well as diseases. The most often cited disadvantage of using recycled water is the increased risk of disease because waterborne pathogens such as *Phytophora* and *Pythium* may be spread. Some operations who use recycled water have installed elaborate water treatment systems to disinfect water, but many companies do not. Often the operations that do not have disinfection systems rely instead on prophylactic fungicide treatment programs to suppress pathogen activity. In many cases, operations with effective disease management programs do not seem to have a higher potential for increased disease development after implementation of a recycling system.

Sub-Irrigation Systems that Recycle Water

The capillary mat system is one way of recycling water. With a capillary mat system, pots with flat bottoms are set onto a capillary mat placed in a shallow pan on benches. The capillary mats must stay continuously saturated and in good contact with the bottoms of pots so that capillary action will draw water from the mats into the potting media. The pots and media must be heavy enough to keep good contact with the capillary mat surface. Benches must be flat and without depressions or high spots, so the mat is evenly wet. A bench with a crowned shape sloping on either side for 1 to 2 inches usually is suitable for preventing wet and dry spots. Typically the mat should be wet 3 to 6 times a day to keep it moist.

One way to keep the mats saturated is to pump water over the mats and allow them to drain at regular intervals. The water applied comes from the drainage water being stored and then re-applied. As water is taken up from the mats into the plant pots, drainage water is supplemented with new water. With capillary mat systems, fertilizer injection is not recommended because this encourages roots to grow into the mats. Fertilizer is better provided through slow release formulations

mixed in the growing media. Perforated black polyethylene sheeting applied over the capillary mat reduces fungal growth and evaporative losses from the mat surface, and prevents root growth into the mat.

Ebb and flow systems require water to be pumped into a shallow tray on benches or across flat floors from a storage tank. The water then flows from the bench tray or floors by gravity back into the storage tank. The flooding stage is usually 6 to 8 inches deep. The flooded condition is maintained until capillary forces move water up to the surface of pots. Then the bench or floor is drained. The benches or floor must be level to slightly sloped to remove the water quickly when the outlet is opened for drainage.

Liquid fertilizers applied in solutions work well in ebb and flow systems, which use less water than capillary mat systems (Dole et al., 1994). Water loss due to evaporation is greatly reduced with ebb and flow (Holcomb et al., 1992).

Recycled water can be used for sprinkler and micro-irrigation water supplies as well as sub-irrigation methods, but with the pressurized systems, the recycled water storage is usually different than for the sub-irrigation systems because the system uses a pressurized water tank.

Design of Water Recycling Storage and Distribution Systems

For successful recycling of water, a system for capturing and carrying runoff and leached water to a suitable storage tank or pond is needed. The extent and complexity of such a system depend on the size of the operation, the topography of the site, and land area available for storage facilities.

For sub-irrigation systems, only leached water from the systems is recycled, so much smaller storage is required. The recycled water is stored in or just outside of the greenhouse and requires only enough volume for one cycle of flow. As this volume is used, it is replaced with fresh water to keep the salts and nutrient concentrations at appropriate levels.

For using recycled water with closed pipe irrigation systems, runoff water from irrigation is captured and carried to one or more centralized storage tanks or ponds. Small operations with limited land space may find closed storage tanks sufficient for recycled water. Larger operations will most likely need open ponds to store the recycled flows.

How many ponds you may require depends on the topography of the growing operation. Conveyance of the water from the greenhouses or outdoor production areas to storage is most economical when gravity is used to move the water. Thus, the storage should usually be at the low points of the site.

Conveyance systems may be closed pipe systems in buried or open channels. From the storage or retention basins, water can be pumped to additional storage basins or tanks at higher points for re-distribution, or pumps from the lower basins may pressurize recycled water to go directly into the irrigation system.

Runoff water treatment can be carried out before the water goes into storage or before it goes into the pressurized irrigation system. Captured runoff is often mixed with fresh water before being re-used.

Implementing a recycle system in an existing nursery may be done in phases over a period of years. Different parts of an operation may be placed under the capture and recycle control, starting with areas of the operation that can most easily be designed and installed, or in areas where water quality problems are the most serious. This allows you to spread out the capital outlay over several years, and adapt and adjust management practices gradually.

Storm water Capture and Recycle Systems

Capturing storm water from greenhouse roofs and from the land areas around the greenhouses is often a part of a recycling system. Storm water at any given site may be more than the storage ponds can handle, particularly if offsite drainage flows through the operation. Consequently storage ponds and tanks that collect storm water must have overflow capability. Such a storage pond should be designed to store what is considered the first flush of a typical storm for the local climate in addition to the amount of water that the operation will recycle from irrigation runoff. Many states define this first flush amount to be 0.5 to 1 inch of rainfall.

Pollutant levels in the first flush are usually the highest for any rain event, but the storm water will be much less concentrated in nutrients than the irrigation runoff that is captured, so storm water dilutes the irrigation runoff water. Discharge of storm water is governed by a different set of permitting regulations than for the normal day-to-day runoff from irrigation, so when storage ponds are created, the discharge water quality from storm events must be considered.

Disease Management and Water Recycling

While water recycling affects all the management components of a greenhouse operation, disease management becomes a critical part of recycling management. A profitable operation will have a workable disease management program before water recycling becomes part of the operation. Some aspects of the disease management program must become more important to ensure the success of a recycling system.

Scout weekly or more often. Sanitize your greenhouse regularly and systematically for disease prevention. Diseased plants are a source of pathogen that can spread to other plants. Pathogens released into drainage water can end up in the captured runoff, so make removing diseased plants as soon as they are spotted a high priority.

Since waterborne pathogens can be dispersed through the runoff, infections can result when this water is reused to irrigate susceptible plants. However, many factors must be present for the infections to occur. Plant susceptibility and age, pathogen concentrations, cultural practices and environmental conditions all contribute to whether disease will take hold at any given time. Consider all of the above factors when making decisions about implementing disease management.

The recycled system affects the relatively high concentration of most waterborne pathogens found in the water that drains from plant pots and the surrounding area. Often, at the point of reuse, the same pathogens have declined to an undetectable level, which is what the system management should do. Natural processes such as microbial and physical degradation are acting within the system to reduce pathogen viability. Pathogen spores tend to settle out in still or slow moving water. Once they have settled to the bottom of a retention basin, unless the bottom is stirred up, they are out of circulation. Larger retention basins and longer retention time for captured water before reuse should promote the breakdown of pathogens in the system.

One exception to the above process is the motile zoospores produced by *Phytophthora*. Its zoospores do not settle; instead they tend to rise to the surface of the water, so drawing recycled water from the middle depth of the storage pond is the best way to avoid spread of both kinds of pathogen spores.

Diluting recycle water is the other major strategy for decreasing disease pathogen concentrations at the point of use. Dilution can come from storm water draining into the storage basin, or from groundwater or surface water pumped into the storage. Dilution can also be handled by mixing fresh and recycled water in the distribution system before it is applied as irrigation water.

Treating Irrigation Water to Remove Plant Pathogens

Several technologies are available to treat recycled water to disinfect the water. These technologies are the same as those recommended for disinfecting surface water for irrigation use. As mentioned above, retention and dilution are the first two practices that reduce pathogen concentrations. If problems are occurring more frequently, some other sanitation practice may be warranted. Options are filtration, chlorination, ozonation and UV treatment.

FILTRATION: Filtration by graded sand media filters reduce fungal spores and nematodes but are not effective against bacteria. Micro-filtration and ultra-filtration use membranes and media with even smaller pore spaces and can remove bacterial propagules, but micro-filters can handle only small amounts of water and they are quite expensive. Filtration is recommended as a pre-treatment for the other sanitation technologies since particulates reduce the efficiency of treatment for chlorination, ozonation and UV light.

CHLORINATION: Chlorination is effective over a wide range of biological agents, works rapidly and is a relatively inexpensive disinfection system that is simple to operate. Chlorination is usually carried out by injecting metered amounts of sodium hypo-

chlorite solution, calcium hypochlorite solution or chlorine gas. The difficulty with effective chlorination is that the amount of chlorine required depends on the impurities, primarily organic matter, in the water. To determine whether chlorination is effective, the residual free chlorine needs to be monitored regularly.

There is a danger of phytotoxicity to plants if the residual free chlorine levels rise too high. Frink and Bugbee (1987) determined that a residual chlorine concentration of 1mg/L or less should not adversely affect plants grown in inert media with overhead irrigation. With peat based media, irrigation water containing as much as 10 mg/L residual chlorine can be applied without phytotoxic effects. Health hazards are a concern and safety precautions that must be taken when handling the chlorination chemicals. Chlorine gas is highly toxic and the most hazardous form of chlorine for use. Sodium hypochlorite burns eyes and skin and, if ingested, causes internal irritation and damage. It is also corrosive and may damage metal parts of irrigation systems. Decomposition of sodium hypochlorite in improper containers may lead to explosion.

OZONE TREATMENT: Ozonation treatment is more expensive in capital and operating costs than other technologies. Ozone is a powerful oxidizing agent that is a most effective biocide on a variety of pathogens. The treatment process consists of bubbling ozone gas through the water to saturate it with ozone, which rapidly breaks down to dissolved oxygen and hydroxyl ions as it reacts with impurities in the water. The disinfective capacity of ozone is affected by organic matter present, water pH, salts (conductivity), and amount and type of iron chelates in the water. Ozonation increases pH. The rate of ozone breakdown increases at high water pH. Effectiveness of the ozone treatment is reduced by organic matter and higher salt concentrations. Some pesticides are removed by ozone treatment.

Ozone is produced chemically by the equipment on site, so the gas itself does not need to be stored. Using oxygen gas increases the amount of ozone produced but does require storing the oxygen gas on site. Excess ozone must be deactivated before it is released to the atmosphere because it is a severe irritant of nasal and throat tissues and poses health risks to workers. The atmospheric ozone level must be monitored to ensure no toxic gas is escaping from the ozone generator. A well-designed ozone treatment system will have automatic alarms that go off when there is an gas leak. Ozone is corrosive to most metals and is toxic to both humans and plants.

ULTRAVIOLET LIGHT: UV light has a low capital cost if the water being treated is of high quality. Poor quality water, however, may require a more expensive UV treatment system. It provides a wide spectrum of biocidal activity. UV light is electromagnetic radiation with a wavelength of 100-400 nm. UV light with wavelengths of 200-280 nm (also known as UV-C rays) kills microorganisms. The effectiveness of UV treatment depends most on the amount of impurities in the water. Pre-filtration is necessary for an optimum UV system. While UV light can pass through 25 cm of pure water, with poor quality water the penetration can be only a few millimeters. Synergistic effects have been observed in combination with UV-ozone treatment systems. These combination systems also break down chemical pollutants.

GOOD SANITATION PRACTICES: Good sanitation practices reduce the amount of pathogens available to be captured in the recycling water systems. Good sanitation practices include decreasing the numbers of pathogens that come into the greenhouse and reducing the chronic levels of pathogens within the greenhouse. Using clean growing media is the first step to good sanitation in an operation. Media direct from a commercial supplier should already be sanitized, but use of topsoils, composts or non-processed amendments in media is different. These amendments have high levels of pathogens and should be heat-pasteurized before use. Any growing media that has spilled or been left out in the open in the greenhouse becomes easily contaminated and must be pasteurized before use.

Careful selection of clean plants and seeds for propagation is the next place to prevent introduction of pathogens into the operation. Inspect any incoming materials for disease symptoms before bringing them into the greenhouse. Destroy questionable material as soon as possible.

Some products used for greenhouse production can spread or contribute to increasing pathogen contact with the crop: floors, reused plastic items, benches and compost piles. Specifically, these are places where pathogens fall and propagate, waiting for a broom or a new use to bring them in contact with plant materials. When sweeping floors, dampen the debris to prevent dust settling on other surfaces. Periodically clean floors with hydrogen peroxide or quaternary ammonium salts solution. Clean any plastic items that are reused with a sodium hypochlorite solution or quaternary ammonium salts solution before reuse. For wood benches, a preservative treatment may be necessary. Another good practice is a chlorine bleach wash of wooden benches between crops. Place compost piles far from greenhouse intake fans and outdoor production areas. Do not situate a compost pile where runoff from the compost pile flows towards production areas. When weather is hot and dry, wetting the compost pile to prevent dust circulation from the pile will keep pathogens from moving with dust.

Greenhouse*A*Syst Assessment of Future Water Use

Instructions for Completing the Risk Assessment

For each subject given in the leftmost column, read through each column and then select the description that best describes your operation. Do not rate practices that do not apply to your operation. Record the risk rating value in column 6 (the rightmost column), and then calculate the overall risk rating for this section at the end of each section. We will use these ratings to assess the overall water related risk of your operation at the end of the document.

	Low-Risk 4	Low-Moderate Risk 3	Moderate-High Risk 2	High Risk 1	Rank Your Site
Water Quality Monitoring — EC	When EC of recycled water is greater than 1.0 mmhos/cm, fresh water is mixed to lower EC for application water to less than 1.0 mmhos/cm.	When EC of recycled water is greater than 1.0 mmhos/cm, it is used for irrigating larger pots only.	EC of recycled water is not adjusted when it is greater than 1.0 mmhos/com.	EC of recycled water is not monitored.	
Water Quality Monitoring — Nitrogen	Nitrogen content of recycled water is monitored and fertilizer applications changed according to the available nitrogen in the water supplied.	Nitrogen content of recycled water is monitored and fresh water is mixed with the recycled water to reduce the nitrogen content before applying to plants.	Nitrogen content of recycled water is monitored but is not diluted nor are fertilizer applications adjusted for nitrogen content of water supply.	Nitrogen content of recycled water is not monitored.	
Watery Quality — Disinfection	All recycled water is disinfected before application to plants.	--------------------	--------------------	Recycled water is not disinfected before application to plants.	
Water Quality — Filtration	All recycled water is stored in a closed or covered tank and filtered to remove suspended solids before pumping into irrigation or watering system.	Recycled water is stored in a pond without cover, and the filtration system is designed to handle organic matter in addition to inorganic suspended solids.	Recycled water is stored in a pond, and the filtration system is often clogged, affecting upstream operating pressures.	Recycled water is not filtered before being pumped into irrigation or watering systems.	
Volume of Recycled Water	Amount of water applied that gets recycled has been measured for most different operating scenarios and is known.	Amount of water that gets recycled has been measured for the highest water use seasons and operating scenarios and is known.	Amount of storage for recycled water is the measure of how much water gets recycled, but change in storage over time is not monitored.	Amount of water that is recycled is during different seasons and is unknown.	

	Low-Risk 4	Low-Moderate Risk 3	Moderate-High Risk 2	High Risk 1	Rank Your Site
Cost and Benefits of Recycled Water	The initial capital and operating costs for use of recycled water have been determined, and the amount of fresh water saved and cost savings of the saved fresh water due to recycling have been determined.	The initial capital and operating costs for use of recycled water have been determined, but the difference in cost of fresh water and recycled water use had not been determined.	The initial capital costs for setting up a recycling system are known, but operating costs of recycled water use have not been determined.	Cost of recycled water use has not been evaluated.	
Surface Water or Recycled Water Disinfection	All surface water and recycled water is disinfected.	--------------------	Only recycled water is disinfected.	None of the surface water supplies are disinfected.	

Ranking Totals	÷	**Total Areas Ranked**	=	**Water Recycling Risk Rating**
____________	÷	________________	=	___________________

Section 2. Greenhouse*A*Syst Risk Assessment Of Pollution Prevention

The purpose of this section is to review just a few of the potential sources of pollution that can come from your operation through the use of water.

Are you aware of any form of pollution coming off your operation's land?

The average businesses fined by local, state and federal regulators usually don't know they were polluting the environment. Unfortunately, telling regulators you did not know will not stop them from placing steep fines on your business. It is always better to know so the problem, if it exists, can be corrected.

How much fertilizer salt is currently under your greenhouse soil?

Phosphates and nitrates may build up in the soil column under certain circumstances. High levels of either nutrient may be an indication of very inefficient use of fertilizers. More efficient use can lead to significant savings and reduced chance of ground water contamination.

Have you tested the soil column immediately underneath your greenhouse for levels of pesticides and herbicides?

These products may also indicate inefficient use and a potential pollution problem.

Have you looked at methods to reduce the off-site release of fertility and pesticide applications?

Reducing the amount of off-target fertilizer will have significant benefits to your business both economically and in the area of risk reduction.

Off-site Water Quality Impacts and Issues

A greenhouse production operation can affect off-site water quality in two primary ways. First, water infiltrates below the soil surface (or below the greenhouse floor), and second, there is runoff both from irrigation and from storm events.

The water that reaches greenhouse floors and infiltrates under outdoor production areas can move to ground water. The potential for impact to ground water is directly related to (1) surface area of your operation, (2) the volumes of water you apply, (3) the pesticides and fertilizers you are applying, (4) the vertical distance of the water table below the production areas, and (5) the soil type below the production areas. Because greenhouse operations are input intensive, the larger the surface area your operation covers, the more area water is infiltrating through. The more efficient the irrigation system and application practices, and the less off-target water applied, then less chemicals and water will infiltrate over the production area. The depth of the water table below the ground surface determines how far infiltrated water has to travel to reach the water table. The soil type and the amount of water applied to the soil determines how fast the water and hence chemicals and nutrients can move to ground water.

Because water table depth may change seasonally, particularly for shallower water tables, take more care to prevent infiltration of water when the water table is higher. Typically, the ground water depth will be shallower in the winter and spring, and deeper in the summer and fall.

Water will move faster into soils with more sand than soils with higher clay content. Remember that in other places where infiltration takes place, plants are taking water out of that soil and preventing movement to the water table. In greenhouse production areas, however, the water that misses containers has no contact with plant roots and has nowhere else to go but down once it infiltrates the soil.

In addition, some of the applied water does not enter the container, or it may spill over the container. This irrigation runoff along with storm water runoff is a potential source for degradation of surface water. The potential for surface water pollution for a greenhouse operation depends on (1) the surface area size of the operation, (2) the volumes of water applied, (3) the pesticides and fertilizers applied, (4) the amount of rainfall and character of the storm events, (5) the amount of on-site capture of runoff for your operation, and (6) any treatment systems for runoff on your operation.

What can a grower do to prevent pollution of ground water and surface water from the operation? More efficient irrigation systems and application practices are the first line of prevention. Irrigation that goes directly into containers with a minimum amount of leaching prevents off-target water. These systems include ebb and flow, capillary mats, flood floor and drip irrigation systems. With all except the drip systems, application water re-circulation is a part of the systems. While drip irrigation does not automatically re-circulate water, it does prevent off target application and minimizes leachate from containers.

Comparing the above systems to any sprinkler or hand watering system, it is apparent that the hand watering or sprinklers have off-target water. Unless you are capturing this off-target water in some way to carry the water to a catch basin, it will either infiltrate into the soil surface or run off. The key to preventing pollution with your operation, no matter what kind of chemicals you use, is preventing off-target water application and increasing re-circulation of leached and off-target water.

Harvesting rain water from the roofs of your structures is another way to prevent runoff, and it offers an alternative water supply source that is relatively clean. Rain water harvesting from roofs is relatively simple. It requires a collection system of gutters, piping and storage. The storage can be a pond, an above-ground tank or a buried tank. Handle the water like any other surface water; it will have suspended solids, but it will have comparatively few suspended solids and does not need to be disinfected.

As an example of the water supply that could come from rain water harvesting, if given a 30-foot by 75-foot floor area structure, for each inch of rainfall, 1400 gallons of water could be collected. In addition, 1400 gallons of runoff have been prevented for each inch of rainfall due to the harvesting of this water. This can really reduce the impact of your operations on surface waters in the area as well as preventing muddy conditions in downstream areas of the operation.

Another important thing to manage correctly

for preventing pollution is your fertilizer regimen. Reducing unnecessary and excessive fertilizer application also prevents unnecessary contamination of water. If the irrigation method creates off-target water, then using slow release fertilizers as much as possible will reduce pollution potential. The slow release fertilizer is less likely to leave the containers without being used by the plants.

In the same manner, careful pesticide management using integrated pest management methods will also prevent pollution by reducing the number of pesticide applications necessary. Growing pest resistant cultivars and biological controls are other options for pest control that may be feasible for an operation.

Cross connection between pipes, wells, fixtures or tanks carrying contaminated water and those carrying potable water should never occur intentionally. This often happens inadvertently when a hose becomes submerged as a tank is being filled. To prevent this kind of accident from occurring maintain an air gap at least 12 inches or 4 times the hose diameter, whichever is more, while filling tanks. Filling water tanks should be constantly monitored to prevent such a situation.

Pollution Prevention With Wells and Pumps

For a growers to minimize their pollution potential, the best power source is electric motors, but this option is not always the most economical choice for certain locations. Pumps can also be powered by diesel, propane, natural gas or gasoline and, in some cases, other alternative energy sources. Electricity also has safety concerns that are not encountered with a combustion engine power supply. If pumps are powered with electricity, be sure that all wiring meets National Electric Code Standards. This is a particular area where safety is a concern because water and metals are both excellent conductors of electricity and the amps required can be considerable for pumping.

When liquid fuels are used, there must be a storage tank to hold the fuel. Storage tanks should be at least 500 feet from any surface water resources. This is to prevent any leakage or spills from flowing into the water. Leak detection and inventory controls are also important. Keeping an eye on the fuel level in the tank and the tank's condition are the key to catching any leaks. Clean up of diesel or gasoline is always costly and not always effective. If there is a leak or spill from a fuel tank, state law requires that the Georgia Environmental Protection Division (EPD) be notified (404-362-2687). Stop the leak as quickly as possible according to the recommendations of the EPD. You are also required to contact the State Fire Marshall at 404-656-9636 within 72 hours of any fires or explosions involving fuel storage tanks.

If you use a deep well turbine, and oil is used as the lubricant, spills, storage and disposal of the waste oil and oil filters can be a concern. Oil filters and used oil can be recycled at a local recycling center. If you do not know where the nearest oil recycling facility is, contact your county extension agent or a local waste disposal service.

For detailed information on procedures for safe handling of chemicals, fertilizers, pesticides, etc., please refer to *Georgia Pest Management Handbook.*

Greenhouse*A*Syst Assessment of Pollution Prevention

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	Low-Risk 4	Low-Moderate Risk 3	Moderate-High Risk 2	High Risk 1	Rank Your Site
		Water Supply from Wells (groundwater)			
Position in Relation to Pollution Sources	Up-slope from all pollution sources with no surface water running into well casing; surface water diverted from well.	Up-slope from most pollution sources. No surface water running into well casing.	Down-slope from many pollution sources, or surface water runoff may enter well.	Low area around casing of well. Surface water runoff from pollution sources runs toward well.	
Meets Drinking Water Well Requirements for Separation Distance from Well Contamination Sources	Meets or exceeds state minimum required separation distances.	Meets most minimum separation distances.	Meets minimum separation distances only for sources required to be at least 100 ft from well.	Does not meet all minimum separation distances for sources required to be at least 100 ft from well.	
Soils Around Well and Their Potential to Protect Groundwater	Fine-textured soils (clay or clay loams); water table or limestone deeper than 20 ft.	Medium-textured soils (silt loam, loam); water table or limestone deeper than 20 ft.	Coarse-textured soils (sands, sandy loams); water table or limestone deeper than 20 ft.	Coarse-textured soils. Water table or limestone shallower than 20 ft.	
Condition of Casing and Well Cap	No holes or cracks visible. Cap (seal) tightly secured. Screened vent.	No defects visible. Well cap vented but not screened.	No holes or cracks visible. Cap (seal) loose.	Holes or cracks visible. Cap (seal) loose or missing. Can hear falling water in well.	
Casing Depth	Cased more than 50 ft below average water level in well.	Cased 31-50 ft below average water level in well.	Cased 10-30 ft below average water level in well.	Cased less than 10 ft below average water level in well or no casing.	
Casing Height above Land Surface	More than 12 inches above grade.	8-12 inches above grade.	At grade or up to 8 inches above grade.	Below grade or in pit or basement. No concrete curbing around well casing.	

	Low-Risk 4	Low-Moderate Risk 3	Moderate-High Risk 2	High Risk 1	Rank Your Site
Concrete Curbing	4-in thick concrete curbing extending at least 2 ft in all directions from well casing and sloping away from casing.	4-in thick concrete curbing extending at least 2 ft in all directions. Curbing may contain cracks but no more than ½ in wide.	4-in thick concrete curbing extends less than 2 ft in all directions. Curbing may contain cracks wider than ½ in and/or water channeling under curbing.	No concrete curbing around well casing.	
Well Age	Less than 20 years old.	21-50 years old.	51-70 years old.	More than 70 years old.	
Well Type	--------------------	Drilled.	Driven-point (sand point) or bored.	Dug well.	
Back Flow Prevention	Anti-siphon devices installed on all faucets with hose connections. No cross connections between water supplies.	Anti-siphon devices installed on some faucets with hose connections.	No anti-siphon devices. Air gap maintained.**	No anti-siphon devices. Air gap not maintained. Cross connections between water supplies.**	
Unused Wells	No unused, unsealed wells.	Unused wells capped and plugged.	Unused well with cover other than properly capped.**	Unused well not covered, capped or protected.**	
Maintenance	Wells are inspected regularly. Leaks are immediately repaired.	Wells are inspected occasionally. Leaks are repaired when needed.	Wells are not inspected with any regularity. Only large leaks are repaired.	Piping or wells are leaking and have not been repaired.	
			Surface Water Supply		
Back Flow Prevention	Anti-siphon devices installed on all faucets with hose connections. No cross connections between water supplies.	Anti-siphon devices installed on some faucets with hose connections.	No anti-siphon devices. Air gap maintained.	No anti-siphon devices. Air gap not maintained. Cross connections between water supplies.	
Maintenance	Piping and connectors are inspected regularly and leaks are repaired immediately.	Piping and connectors are inspected occasionally. Leaks are repaired when needed.	Piping and connectors are not inspected with any regularity. Only large leaks are repaired.	Piping and connectors have leaks that are not being repaired currently.	
Water Supply Protection Equipment	Water source protection equipment is in place directly upstream from pump unit. Inspected before and at the beginning of each use.	Water source protection equipment in place and occasionally inspected.	Incomplete or partial water source protection equipment.	No water source protection equipment in place directly above pump.	

	Low-Risk 4	Low-Moderate Risk 3	Moderate-High Risk 2	High Risk 1	Rank Your Site
Power Units and Pumps for Wells or Surface Water Pumping					
Energy or Fuel Type and Storage	Electric pumps.	Some electric, some petroleum powered with well-maintained secondary containment system for fuel tanks with regular inspection for leaks.	Gas or diesel without secondary containment for fuel tanks, regular inspection of pipes and consistent inventory control.	Gas or diesel without secondary containment and signs of leaks or spills of fuel.	
Runoff Water Quality					
Runoff Water Quality — nitrates	Runoff water has less than 10 ppm nitrate concentration for all test events.	Runoff water has less than 10 ppm nitrate average concentration of all of several test events.	Runoff water is most often less than 10 ppm nitrate concentration.	Runoff water is most often greater than 10 ppm nitrate concentration.	
Runoff Water Quality —soluble phosphorus	Runoff water has less than 0.1 ppm soluble phosphorus concentration for all test events.	Runoff water has less than 0.1 ppm soluble phosphorus concentration average of all of several test events.	Runoff water is most often less than 0.1 ppm soluble phosphorus concentration.	Runoff water is most often greater than 0.1 ppm soluble phosphorus concentration.	
Runoff and Leachate Recycling	90% or more of runoff and leachate from production is recycled.	50-89% of runoff and leachate from production is recycled.	Less than 50% of runoff and leachate from production is recycled.	None of runoff and leachate from production is recycled.	
Fertigation/chemigation — calibration	Injector equipment is calibrated with each change in chemical or change in rate.	Injector equipment is calibrated periodically, at least twice a year.	Injector equipment is calibrated at least once a year.	Injector equipment is calibrated less than once a year.	
Fertigation/chemigation — backflow prevention	For each injector, there is an air-vacuum relief valve upstream from that injector.	For any injector downstream from a pump, there is a check valve and air-vacuum relief valve upstream between the injector and the pump.	--------------------	There is no air-vacuum relief valve or other backflow prevention upstream from injectors.	

Ranking Totals	÷	**Total Areas Ranked**	=	**Pollution Risk Rating**
____________	÷	________________	=	___________________

Summarizing, Evaluating Your Greenhouse*A*Syst Assessment Results and Identifying Action Steps

The purpose of this section is to assist you in summarizing your overall risk to your business from water related issues.

Once you have filled out the sections of risk assessment, you may summarize the results in the table provided below. This will allow you to easily see what areas your company needs to reduce risk in, and where effort needs to be made for improvement. An overall risk value for the company is the last step in the process.

STEP 1. Identify Areas Determined to Be at Risk

Fill in this summary of your Greenhouse* A*Syst Assessment for Your Operation.

Risk Area	Greenhouse*A* Syst Publication	Overall Risk Rating
Water Source	Bulletin 1274	
Delivery and Technology	Bulletin 1275	
Water Management	Bulletin 1276	
Water Quality	Bulletin 1277	
Water Recycling/ Pollution Prevention	Bulletin 1278	
Legislative Awareness/ Company Policy	Bulletin 1279	
Total Overall Risk Level for Water (Average of 6)		

* Bulletins are all Georgia Cooperative Extension bulletins; visit http://www.caes.uga.edu/publications/

Low risk practices (4s) are ideal and should be your goal. Low to moderate risk practices (3s) provide reasonable results and protection. Moderate to high risk practices (2s) provide inadequate protection in many circumstances. High risk practices (1s) are inadequate and pose a high risk for causing environmental, health, economic or regulatory problems.

High risk practices, rankings of "1," require immediate attention. Some may only require little effort to correct, while others could be major time commitments or costly to modify. These may require planning or prioritizing before you take action. All activities identified as "high risk" with a ranking of "1" should be listed in your action plan developed from this assessment. Rankings of "2" should be examined in greater details to determine the exact level of risk and attention given accordingly.

STEP 2. Determine Your Overall Risk Ranking

This value provides a general idea of how your water use practices might be affecting your efficiency of water use and your understanding of proper watering practices and maintaining good water quality in your operations as well as impacts to surface and groundwater.

Water Use Risk Ranking	Level of Risk
3.6 to 4.0	Low Risk
2.6 to 3.5	Low to Moderate Risk
1.6 to 2.5	Moderate Risk
1.0 to 1.5	High Risk

This ranking gives you an idea of how your water use practices might be affecting your business success and conservation of water. This ranking should serve only as a very general guide and not as a precise diagnosis, since it represents the average of many individual rankings.

STEP 3. Transfer Information on Risk to a Formal Plan for Improving Your Water Management and Use Practices.

From the results of this assessment, and after studying the provided guidelines and facts section, outline a plan of changes you want to incorporate into your operations with a timetable on when you will achieve these changes. A plan can always be amended and changed due to new information but, if you do not make a plan with the new knowledge about your own practices that you have gained, then odds of follow-through with real changes is unlikely. The plan outline can be as brief or as detailed as you want to make it. Be sure and note where you need to gather more information or consult with someone in your plan so you will take action only after careful consideration of complex issues.

STEP 4.
Develop A Formal Action Plan.

Simply put, assign specific staff to accomplish specific tasks in a known period of time. If more information is needed to make appropriate decisions, delegate specific fact-finding tasks to personnel best suited to accomplishing the task. Set goals and time lines based upon realistic expenditures of time and resources. Have each individual task written up for the entire team to assess and put into the larger context of the company. A formal action plan form is provided in the Appendix.

STEP 5.
Develop A Company Water Use and Monitoring Policy.

The final step in this process is to sit down with your management team and decide upon how to address your plans. The best method is to establish company water conservation/use policy. By doing so, every new and existing employee will be able to learn and follow your expectations for water management. By developing a policy document, you are also showing legislators and regulators that your company is serious about water management. Such documents will greatly improve how your business is viewed in the community.

STEP 6.
Implement the Policy.

Your policy document stands as a symbol of your commitment to resource preservation. Consistent implementation will yield greater profits and better relations with your community.

References

Dole, J.M., J.C. Coile, and S.L. von Broembsen. 1994. Growth of poinsettias, nutrient leaching, and water use efficiency respond to irrigation methods. *HortScience* 29:858-864.

Georgia Pest Management Handbook. 2004. Cooperative Extension, The University of Georgia College of Agricultural and Environmental Sciences.

Holcomb, E.J., S. Gamez, D. Beattie, and G.C. Elliot. 1992. Efficiency of fertigation programs for Baltic Ivy and Asiatic Lily. *HortTechnology* 2:43-46.

Contacts and Information Sources

Organization/Individual	Responsibilities	Address	Phone Number
Georgia Department of Agriculture, Pesticide Division	Questions regarding anti-siphon requirements for irrigation systems.	Agriculture Building 19 Martin Luther King Jr. Dr. Atlanta, GA 30334	404-656-4958 www.agr.state.ga.us
Geologic Survey Branch Environmental Protection Division	Regulations concerning water well drinking standards.	Georgia DNR 19 Martin Luther King Jr. Dr. Suite 400 Atlanta, GA 30334	404-656-4807 www.state.ga.us/dnr/environ — Geologic Survey Branch
Department of Biological and Agricultural Engineering, University of Georgia	Questions related to well-head protection or ground water on a farm.	Extension Unit Landrum Box 8112, GSU Statesboro, GA 30460	912-681-5653 www.bae.uga.edu
Drinking Water Program Environmental Protection Division	Questions regarding public drinking water.	Georgia DNR 205 Butler St SE Floyd Towers East, Ste. 1152 Atlanta, GA 30334	404-651-5157 www.state.ga.us/dnr/environ — Water Resources Branch
Safe-Drinking Water Hotline U.S. Environmental Protection Agency	General drinking water questions. 8:30 a.m. - 5:00 p.m. EST	401 M Street SW (Mail Code 4604) Washington, DC 20460	1-800-426-4791 www.epa.gov/safewater
U.S. Environmental Protection Agency	General drinking water questions.	U.S. EPA Region IV 61 Forsyth St SW Atlanta, GA 30303	404-562-9424 www.epa.gov/region4
Water Protection Branch Environmental Protection Division	General water quality questions.	Georgia DNR 4229 International Parkway Suite 101 Atlanta, GA 30354	404-675-6240 404-675-1664 www.state.ga.us/dnr/environ — Water Protection Branch
Pollution Prevention Assistance Division	Pollution prevention references	Georgia DNR 7 Martin Luther King Jr. Dr. Suite 450 Atlanta, GA 30334	404-651-5120 1-800-685-2443 www.p2ad.org
Robert A. Aldrich and John W. Bartok Jr.	Greenhouse engineering. NRAES-33	National Resources Agricultural and Engineering Service. 1994	
Karen L. Panter Steven E. Newman Reagon M. Waskom	Pollution Prevention for Colorado commercial greenhouses. SCM-206.	Colorado State University Cooperative Extension	
Sharon L. Von Broembsen Mike Schnelle	Best Management Practices (BMPs) for nurseries to protect water quality. E-951, *Water Quality Handbook for Nurseries.*	Department of Entomology and Plant Pathology Oklahoma State University Cooperative Extension Service	http://zoospore.okstate.edu/nursery/recycling/shy.html

Reagon M. Waskom	Best Management Practices for irrigation practices. XCM 173. August, 1994.	Colorado State University Cooperative Extension
Don Wilkerson	Irrigating Greenhouse Crops. From *Texas Greenhouse Management Handbook.*	Texas Agricultural Extension Service
Don Wilkerson	Treating and recycling irrigation runoff. From *Texas Greenhouse Management Handbook.*	Texas Agricultural Extension Service

Environmental Protection Agency (EPA)
National Service Center for Environmental Publications
U.S. EPA/NSCEP
PO Box 42419; Cincinnati, OH 45242-0419
Phone: 1-800-490-9198 or 1-513-490-8190
M-F 7:30 a.m.-5:30 p.m. EST (www.epa.gov/ncepihom)

Drinking from Household Wells, EPA 570/9-90-013
LEAD In Your Drinking Water, EPA 810-F-93-001
Protecting Our Ground Water, EPA 813-F-95-002
Citizens Guide to Pesticides, EPA

University of Georgia, Cooperative Extension Service
Ag Business Office; Room 203, Conner Hall, UGA
Athens, GA 30602
Phone: 706-542-8999 (http://pubs.caes.uga.edu/caespubs/pubs.html)

Northeast Regional Agricultural Engineering Service, Cooperative Extension
Cornell University
152 Riley-Robb, Ithaca, NY 14853-5701
Phone: 607-255-7654 (www.osp.cornell.edu/vpr/outreach/programs/ageng.html)

Home Water Treatment, NRAES-48. Includes water-treatment basics, physical and chemical treatments, USEPA Primary Drinking Water Standards and health advisories, and pesticide products that contain USEPA drinking-water contaminants. (120 pp.)

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Action Plan Form

Use this action plan form to organize your ideas and to map out the activities necessary to complete your goals. Be sure to make the time frame realistic. Changes in basic resources take time. Please consult the list of references provided if you need additional information to develop this plan.

Area of Concern	Risk Rating	Planned Action	Time Frame	Estimated Cost

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