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An Integrated Building Water Management Model for Green Building

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An Integrated Building Water Management Model for Green Building

by

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of the requirements for the degree of
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Department of Civil and Environmental Engineering
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ABSTRACT

The U.S. Green Building Council (USGBC) is the developer of the Leadership in Energy and Environmental Design (LEED™) green building scoring system. On first inspection of LEED points, few address water efficiency. However, water management encompasses other points beyond the Water Efficiency (WE) category. In general, the industry is apt to take a somewhat compartmentalized approach to water management. The use of alternative water sources or the reuse of wastewater significantly complicates the water budget picture. A total water management systems approach, taking into consideration water from various sources, both inside and outside the building, should be implemented in order to devise a strategy for optimal reduction of potable water consumption and wastewater generation. Using the STELLA software to create an integrated building water management (IBWM) model provides stakeholders with a tool to evaluate potential water savings under dynamic conditions for a specific project site. Data collection for IBWM model calibration also shows that water consumption trends are unique to each project, and using LEED assumptions about water usage can overestimate or underestimate potential water savings.

CHAPTER 1:

INTRODUCTION

Increased population accompanied by other water stressors is putting stress on the world’s water supply. In the United States, buildings utilize large amounts of potable water, as well as discharge wastewater and contribute to pollutant loadings through stormwater runoff. As our population increases and spreads out, our demand for water also increases and our infrastructure also spreads. Increased stress on water resources, both in terms of decreasing quantity and quality, leads to growing interest in more efficient water uses. Through the implementation of water management strategies, such as water reclamation, conservation, or decentralized water reuse, the issues associated with increased water demand may be alleviated.

Similarly, water cannot be infinitely pumped from potable sources to meet community demands. Sustainable solutions are required that meet current and projected demand as well as preserve natural and human cycles. One way to determine impacts from possible solutions that aim to alleviate the disparity between supply and demand is the creation and implementation of a systems model. Models are currently used by planning and regulatory agencies to predict future water demand and decision-making outcomes.

The objective of this study is to develop a dynamic systems model capable of analyzing the interaction among different water supplies and demands in the building environment. Current models rely on static assumptions about individual usage and water supply; but occupancy, climate, and fixture usage are all fluctuating variables that vary over time. A model capable of evaluating water changes over time will better predict the overall impacts of preferred water management strategies.

CHAPTER 2:

BACKGROUND

Green Building and LEED

The building industry significantly impacts the human and natural environments. Buildings account for a substantial portion of electricity consumption, greenhouse gas emissions, material use, waste output, and potable water consumption. Forty percent of the extracted materials in the United States are consumed by the construction industry; and poor reuse and recycling processes result in 145 million tons of waste, the majority being from demolition (Kibert, 2005). The planning and development of building sites individually and in relationship to each other also puts a strain on resources and the environment. Transportation within the built environment consumes energy and increases air pollution (Kibert, 2005). Further effects of buildings in the United States are outlined in Table 1.

TABLE 1: Percent of resources used and waste produced from the building sector.

Building usage	**Percent of total**
Total energy	36%
Electricity consumption	65%
Greenhouse gas emissions	30%
Raw materials	30%
Waste output	65%
Potable water consumption	12%

*Percentages taken from the USGBC, 2007.

In response to impacts from the building industry, a green building movement emerged. Building "green" involves the use of two main concepts: sustainability and integrated design. These concepts are quintessential in the planning of a green building and are also necessary when designing any project. Sustainability requires developers to examine the entire lifetime of the project. The same is true of an integrated design process. The "green" process requires both ideas to fuse, resulting in streamlined construction and leading to savings in water, energy, and costs.

Savings occur in all sectors when building green. The initial building costs can be no more than those of a conventional structure; but because a green building is more efficient, savings continue throughout the entire lifetime of the structure. In addition to environmental and economic benefits, green buildings also enhance the comfort and health of occupants by improving air quality, thermal conditions, and the overall work environment.

In the United States there are nonprofit organizations that promote sustainability and green design such as the U.S. Green Building Council (USGBC). The USGBC consists of more than 9,000 organizations and 75 regional chapters including a chapter for the Florida Gulf Coast (USGBC, 2007). All sectors share a common goal to transform the building market.

TABLE 2: Growth of USGBC membership and LEED projects.

Year	**2002**	**2003**	**2004**	**2005**	**2006**
LEED projects (millions of square feet)	80	141	180	500	642
USGBC membership	2370	3532	4970	5882	7600

*Data taken from the USGBC, 2007.

Leadership in Energy and Environmental Design (LEED)

In order to define and promote green buildings, the USGBC created the Leadership in Energy and Environmental Design (LEED) rating and certification system. Participation in LEED is completely voluntary, and programs are available for all building types including new commercial construction, existing building operations, homes, neighborhood development, schools, and retail structures (USGBC, 2007). LEED rating systems set a standard that defines green building based on building type. Points are awarded in seven major categories inherent in green building. The point breakdown for LEED 2009 for New Construction and LEED 2009 for Existing Building: Operations and Maintenance is given in Table 3.

TABLE 3: Breakdown of LEED 2009 credits by category in the New Construction (NC) and Existing Building: Operations and Maintenance (EBOM) rating systems.

LEED Category	**Possible Points out of 110**	
	NC 2009	**EBOM 2009**
Sustainable Sites	26	26
Water Efficiency	10	14
Energy and Atmosphere	35	35
Materials and Resources	14	10
Indoor Environmental Quality	15	15
Innovation and Design Process	6	6
Regional Priority Credits	4	4

*Information compiled from LEED 2009 checklists.

Water Dimensions in LEED Certification

On first inspection of LEED NC 2009 points and categories, only 10 of the 110 points pertain to water. Although Water Efficiency is one of the smallest categories in terms of points, water management affects each of the seven categories in the LEED system. Figure 1 shows how water is linked to LEED categories through environmental quality, energy, and materials.

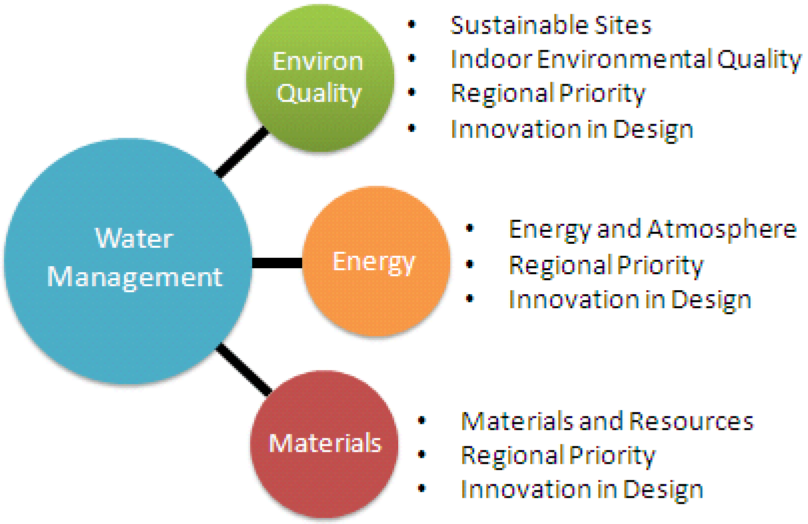


FIGURE 1: The effect of water management on LEED categories.

Both indoor and outdoor environments benefit from integrated water management. Efficient water practices take into account stormwater management that preserves local hydrology and protects the natural cycle. Preserving green space within a building site is one way to accomplish responsible stormwater management. Responsible water management increases water efficiency while maintaining an agreeable aesthetic to the building site (Peretti and La Rocca, 2000).

Sustainable water reuse is a central theme in green building; water is a finite resource intrinsically linked to energy. Energy is required to pump and move water throughout the building system. Additional energy is consumed by treatment processes that result in water which meets acceptable quality standards.

Various water strategies can be implemented to increase water use efficiency. Technologies such as water cisterns or membrane bioreactors (MBRs) require initial manufacturing and replacement parts throughout the operational lifetime of the system. Appropriate materials for use in water applications are chosen for the technology to be successful. However, there is also an intrinsic energy and water cost in the transportation and manufacturing of these products. In the end, water is a universal connector, and all related aspects must be considered in green building.

Specific points directly related to water are outlined in Table 4. The goal of Water Efficiency is to reduce the inflow of water through the system, and the goal of Sustainable Sites is to control the outflow. LEED outlines the points attainable through conservative water practices in these two categories, as well as the Innovation in Design sector.

TABLE 4: LEED 2009 NC credits that are directly related to water management.

LEED Credit	Possible Points
Sustainable Sites	**6 Points**
SS Credit 5.1: Site Development – Protect or Restore Habitat	1 Point
SS Credit 5.2: Site Development – Maximize Open Space	1 Point
SS Credit 6.1: Stormwater Design – Quantity Control	1 Point
SS Credit 6.2: Stormwater Design – Quality Control	1 Point
SS Credit 7.1: Heat Island Effect – Non-Roof	1 Point
SS Credit 7.2: Heat Island Effect – Roof	1 Point
Water Efficiency	**10 Points**
WE Prerequisite 1: Water Use Reduction – 20% Reduction	Required
WE Credit 1: Water Efficient Landscaping	2 to 4 Points
Reduce potable water use by 50%	2 Points
Reduce potable water use by 100%	4 Points
WE Credit 2: Innovative Wastewater Technologies	2 Points
Reduce potable water use by 50% or treat 50% of wastewater	
WE Credit 3: Water Use Reduction	2 to 4 Points
Reduce potable water use by 30%	2 Points
Reduce potable water use by 35%	3 Points
Reduce potable water use by 40%	4 Points
Energy and Atmosphere	**2 Points**
EA Credit 3: Enhanced Commissioning	2 Points
Innovation in Design	**5 Points**
ID Credit 1: Innovation in Design	1 to 5 Points
Regional Priority	**1 Point**
WE Credit 2: Innovative Wastewater Technologies	

The Sustainable Sites category stresses the importance of protecting or maximizing green space in order to protect habitat for local plants and wildlife and decrease the heat island effect (USGBC, 2006). Increased green space on a building site can also provide economic incentives in the form of increased property values and reduced resource use from a more compact structure design (USGBC, 2006). Both the quantity and quality control of stormwater address runoff limitations. Restricting the amount of stormwater runoff from urban development prevents erosion of stream channels and disruption of the hydrologic cycle. Further protection of the natural hydrologic cycle is maintained through pollution control. Stormwater treatment methods include constructed wetlands and natural filters. Although heat island effect points are not directly linked to water management, the strategies used to control stormwater runoff coincide with the strategies that decrease the urban heat island effect. By using vegetation or permeable materials, the heat absorption caused by impervious surfaces, such as pavement and rooftops, can be reduced.

All points in the Water Efficiency category are achieved through water management strategies. By using conservation measures or technologies to treat and reuse wastewater within the building (whether greywater, blackwater, or both), overall potable water use is reduced. Treated effluent from systems is often used in flushing toilets or offsetting irrigation demands because these sources do not need high-quality potable water.

Enhanced commissioning is affected in the Energy and Atmosphere category because installation of systems, such as the MBR, can be considered major mechanical system. As such, its performance should be verified and submetered to ensure proper operation.

Additional points are available in the Innovation in Design and Regional Priority categories. Projects that exceed the basic requirements set by LEED or incorporate additional innovative technologies can receive additional points toward certification. Building-scale MBR plants represent an innovative technology used for water reuse. It is possible to treat and reuse all wastewater within the building, thereby closing the water loop and creating a structure that is closer to attaining independence from municipal potable supply. The newly formed Regional Priority category adds an additional achievable point to credits that are important to the geographical region of the project. For Tampa, an additional credit is available for achieving Water Efficiency credit 2.

Water Management Options

As population increases, so does the consumption of water resources. Water demand is further altered by additional stressors such as land use, urbanization, and climate change (Zimmerman *et al.*, 2008). How each stressor relates to another form a complex web, and it is not clear how a change in one stressor will ultimately affect the others (Zimmerman *et al.*, 2008). When designing a system, certain stressors, such as population and urbanization projections are included in the preliminary evaluation. However, other stressors, most notably climate change, are often overlooked.

An integrated systems approach to building water management allows for the best allocation of potable water drawn from the municipal supply. These options include practices that regulate the inflow of water and recycling of water throughout the building system, but also decrease the outflow of water through efficient wastewater and infiltration processes. Management encompasses all aspects of the water cycle, from start to finish. Conventional water allocation is compared to the appropriation of water in a green building in Figure. 2.

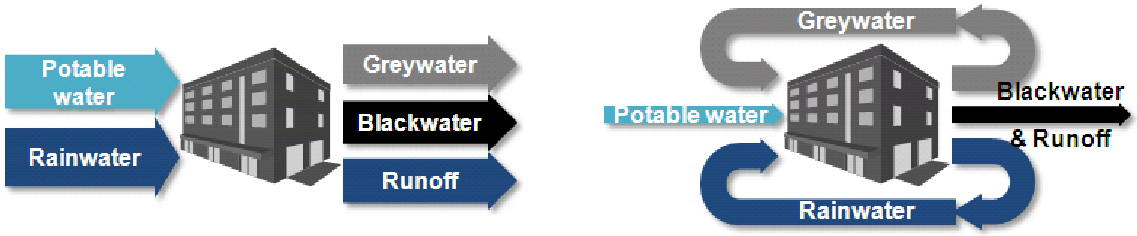


FIGURE 2: Water flow in a conventional structure (left) vs. a green building (right).

In addition to engineering, a technology must also overcome issues such as social acceptance, education, cost, and ease of use (Lazarova *et al*., 2001). The preceding considerations can be categorized as sustainability indicators. All sustainable water projects must overcome the same obstacles in order to succeed. The slow push towards alternative water supplies has caused an increase in the use of "sustainable" technologies; for example, the membrane bioreactor (MBR), rainwater cistern, and reclaimed water distribution. Although each technology is proven to decrease potable water demand, the sustainability of each option depends on the aforementioned indicators.

Integrating cultural and social aspects into water management is also crucial in large scale management projects. An integrated approach needs to take all tradeoffs, such as the social, cultural, and technical into account in order to be successful (Pahl-Wostl et al., 2008). Doing so encompasses all stakeholders, whether managers or residents, into the larger water management process (Pahl-Wostl et al., 2008). Often overlooked is the need for a change in a general population's belief and behavior in order for a strategy to succeed (Pahl-Wostl et al., 2008). For example, water conservation efforts are achieved when human behavior is modified through education and participation. A study conducted in Jordan evaluated the affects of implementing greywater reuse in residences (Al-Jayyousi, 2004). The results showed that the low-income families saved money and gained awareness about the importance of water conservation and water quality from a hands-on perspective. It is not enough to solve problems through the sole use of technology. Forgetting the human side of water management can result in local water disputes that are socio-culturally based or lead to water projects that succeed on paper, but fail in practice.

Conservation

The leading option for water management is conservation. Common tactics include the implementation of water-conserving fixtures such as low-flow water closets and waterless urinals to reduce the demand for potable water. Although the Energy Policy Act (EPAct) of 1992 already sets maximum values allowable by water fixtures (Table 5), green buildings often implement hardware that goes beyond the set requirements. For example, water closets are mandated to use no more than 1.6 gallons per flush (gpf); however, there exists high-efficiency toilets (HETs) that use less than 1.3 gpf. Low-flow options are also available for other fixtures such as showerheads and faucets. Sensors and aerators installed in faucets can further reduce water use.

TABLE 5: Maximum requirements for plumbing fixtures defined by the EPAct of 1992.

Plumbing fixture	**Maximum requirement**
Water closets	1.6 gallons (6 liters) per flush
Urinals	1.0 gallon (3.8 liters) per flush
Showerheads	2.5 gallons (9.5 liters) per minute at 80 psi (550 kPa) 2.2 gallons (8.5 liters) per minute at 60 psi (410 kPa)
Faucets	2.5 gallons (9.5 liters) per minute at 80 psi (550 kPa) 2.0 gallons (7.8 liters) per minute at 60 psi (410 kPa)
Replacement aerators	2.5 gallons (9.8 liters) per minute
Metering faucets	0.25 gallons (0.98 liters) per cycle

*Unless otherwise noted, flow rates are at a pressure of 80 psi. Fixture requirements compiled from Kibert, 2005.

Conservation requires knowledge about current water use patterns, and resolution is critical when applied to water monitoring. Water companies and utilities keep track of water pulled from wells and additional sources, but they also measure water used by individual residences and buildings to better evaluate where water is going. Water use can be assessed further through submetering. Submetering provides better resolution regarding water usage. Often buildings only meter water entering the building system, but water submetering can aid water conservation measures by providing information on the amount of water used and when water is used for various fixtures and applications (Tamaki *et al*., 2001). The routes of water must be known first before conservation measures can be taken. The University of São Paulo in Brazil utilized submetering to reduce water consumption (Tamaki *et al*., 2001). With this information, water reduction amounts can be estimated based on various possible water management strategies such as low-flow fixtures, water reuse technologies, or irrigation sensors. Anomalies in water usage on campus can be isolated and addressed with greater speed because of increased resolution due to added meters (Tamaki *et al*., 2001).

Education is a major component of conservation, and submetering provides detailed information about water usage that can be used to educate users about the importance of proper water management. The University of South Florida campus in Tampa meters water usage for the entire campus and has submeters on many campus buildings. The impact education has on water conservation was made evident by a student initiative that monitored fourteen residence halls over a time period of two months. Student residents were educated about energy and water conservation, as well as given incentives to decrease their usage. The result was a 20% decrease in overall energy usage based on decreased usage of cold and hot water (Cox and Joustra, 2008). Submetering allowed usage by individual residence halls to be measured and evaluated. Like the University of São Paulo, the University of South Florida is also capable of pinpointing abnormalities in campus water usage and fixing the issue.

Recycling/Reuse

The quality of water is of great importance when determining where it will be discharged or reused. In a sense, all water is reused. Water discharged upstream is used as a drinking water source for populations downstream, and water discharged into larger water bodies is recycled in the aquatic system. Wastewater is often defined as water that has been contaminated or polluted, but the definition of contamination is up for interpretation. All water contains some form of impurities, but regulations set contaminant levels that label water as polluted. While water remains a pure substance, it is the impurities within it that need to be removed in order to improve the level of quality.

All wastewater can potentially be recycled within a building system (Boehler *et al*., 2007). Wastewater exiting the building generally falls under one of two streams: greywater or blackwater. Greywater consists of water from sinks, showers, and other low-strength sources. Blackwater contains higher amounts of organic material and exits from toilets and urinals. Toilet flushing can make up 35% of overall water consumption, but utilizing alternative sources such as rainwater can help offset the potable cost (Cheng, 2003). Kitchen wastewater can be grouped into either category; it does not come into direct contact with human excrement, but does have a high organic loading. Greywater reuse systems have been shown to be economically feasible and offset potable water consumption (Ghisi and Ferreira, 2007). Because water recycling has associated human and ecological risks, political regions often have unique sets of guidelines that outline appropriate approaches to ensure safety (Anderson *et al*., 2001). Water can be treated for reuse on-site using technologies such as the membrane bioreactor or off-site at municipal wastewater treatment facilities.

Membrane Bioreactor

Membrane bioreactors (MBRs) operate using both biological treatment methods as well as permeable membranes which provide an absolute barrier and prevent solids within the influent water from passing to the effluent. MBRs differ from traditional wastewater treatment systems in that secondary clarification and tertiary treatment solutions are replaced by the membrane, providing an opportunity to decrease the overall area, as well as resources required for treatment. Several variations of the MBR exist; namely aerobic and anaerobic MBRs, and those which may utilize the membranes in submerged or external applications.

MBRs are assumed to be suitable for use in a sustainable water management plan because they allow production of high-quality effluent which can be used for greywater and blackwater reuse applications. Since they are compact, MBRs can then be implemented in proportionally smaller systems while still maintaining effluent quality. However, pitfalls also exist; the most significant of which is the issue of fouling which reduces and may eventually prevent flow through the membrane. Fouling significantly affects the sustainability of membranes because it not only requires increased energy consumption associated with necessary increases in pressure over time, but it also shortens the useful life of a membrane, requiring premature replacement and thus an added cost.

MBRs occupy less space than other conventional treatment processes and have been utilized in structures such as the Solaire Apartments (General Electric, 2007) and the Helena Building (Dynatec, 2006) in New York City where the system provides recycled water for toilet flushing, irrigation, and cooling. The appeal of implementing MBRs in green buildings is the ability to produce high-quality water which can be reused on-site, thereby reducing the demand and cost for municipal potable water (GE, 2010).

Atasoy *et al*. (2007) investigated the performance of MBR technology treating separate greywater and blackwater streams from campus lodgings. Treated effluent from both sources of wastewater proved to be adequate for re-use applications such as toilet-flushing or irrigation. Neither effluent detected total coliforms. Permeate from treated greywater contained lower pollutant concentrations due to the lower beginning concentrations in the feed water. Greywater is often targeted for reuse over blackwater because it is easier to treat and has a high generation rate within buildings (Atasoy *et al*., 2007).

The emergence of the MBR package plant has made it easier to integrate this technology in high-performance urban buildings where time, installation, and limited footprint are crucial (Sorgini, 2004). The systems are shipped wire, piped, and tested ready-to-go; they are inclusive systems containing everything from backwater tanks and air supply systems to instrumentation and controls (Sorgini, 2004). High-quality effluent produced by the packaged MBR meets agency standards for reuse and treated wastewater (Sorgini, 2004). MBR operations can be computer-controlled, minimizing the need for an operator to always be present (GE, 2010).

Reclaimed Water

An important resource from wastewater treatment is the water itself. Reclaimed water is an example of recycling and reuse, techniques also implemented toward solid waste management. Through the treatment process, water is removed from the waste stream, and the use of reclaimed water offsets demand for finite potable water resources.

Highly treated reclaimed water can be delivered to the building site from a regional or satellite wastewater treatment facility. Although normally associated with irrigation, the applications of reclaimed water extend to other nonpotable uses such as cooling towers and toilet flushing, similar to the uses for greywater. Florida contains an extensive reclaimed water program, and the cost for reclaimed water is generally less than that for potable water.

Green Roof

Another technology available for offsetting stormwater runoff is the green roof. A green roof consists of a water-proof root containment system, drainage, and a plant growing medium (Green Roofs, 2005). The green roof is often used as an example of integrated design in sustainable construction because of how it affects the building system. Benefits are seen in water management, energy efficiency, and air quality. A green roof mitigates runoff quantities through water retention by plants and substrate (VanWoert *et al*., 2005). This method also increases the quality of water leaving the green roof, protecting the environment from high pollutant loads. Insulation and evaporation allow a green roof to even out building temperatures over time. In addition to reducing heat outdoors, vegetative roofs may also have positive impacts on the indoor conditions of the building while providing an aesthetically pleasing environment for workers and guests. Although these and other benefits exist, there is hesitation to install green roofs. Policy changes and incentives could help increase the prevalence of this technology (Carter and Fowler 2008). Green roofs are included in best management practices (BMPs) defined by the Clean Water Act (CWA) that meet stormwater management guidelines; Section 319 of the CWA has funded at least twelve green roof projects to treat nonpoint pollution sources (Carter and Fowler 2008). In general, green roofs are encouraged according to local and federal policy, but the extent of encouragement varies. Certain areas like Toronto mandate that green roofs be implemented when feasible, whereas other cities do not mention the option in local codes and regulations. Green roof subsidies dependent on unit area are offered in other parts of the world, but not in the United States; however, grants awarded to green roof construction projects are found in Chicago (Carter and Fowler 2008) and other governed areas. The creation of incentives based on roof size or expansion of existing grants could increase green roof area and have a beneficial effect on urban stormwater management.

In addition to water management, green roofs can also achieve LEED points in other non-water-related categories. A green roof has the ability to reduce the energy demand building by maintaining a reasonable temperature within a building (Oberndorfer *et al*., 2007). Points for energy reduction are awarded in the Energy and Atmosphere category of the LEED system. Points may also be awarded to green roofs in the Materials and Resources category. Green roofs often extend the lifetime of the roof. Using local plants and materials gains LEED NC points for Regional Materials (MR Credits 5.1 and 5.2) and Rapidly Renewable Materials (MR Credit 6).

Low Impact Development

Undeveloped green spaces perform important functions in both the natural and built environment, such as stormwater mitigation, local temperature control, and air quality modification. Often human development and implementation of green space work against one another; increased human development often results in a decrease in green areas due to the land demanded for an increased built environment. Established urban green spaces are also threatened by local growing populations. Drivers of human development such as demographics, economics, scientific innovation, and socio-cultural processes affect urban development, and therefore, also affect the green spaces associated with development (James *et al*., 2009).

In the Leadership in Energy and Environmental Design (LEED) green building certification system established by the U.S. Green Building Council (USGBC), protection of green space is an integral part of sustainable design. LEED provides multiple credits related to green space. The Sustainable Sites category stresses the importance of protecting or maximizing green space in order to protect habitat for local plants and wildlife and decrease the heat island effect (USGBC, 2006). Increased green space on a building site can also provide economic incentives in the form of increased property values and reduced resource use from a more compact structure design (USGBC, 2006). Utilization of green space plays a major role in water management due to its positive effects on stormwater retention, treatment, and possibility of reuse.

Although green space function may be well recognized, integration of green spaces into the planning, design, and management processes is lacking (James *et al*., 2009). Local development requirements contain ordinances for building projects. These include required green areas and plantings in parking lots or specified green perimeters around buildings to be incorporated during the planning and design stage. However, best management strategies for green areas are generally unknown. The Florida Parks Department has a more detailed management plan which was implemented to preserve their parks. Those management strategies include the removal of invasive plant species, habitat restoration, prescribed burning, and constant monitoring and inventory. Although these strategies exist to keep parks in an “original” natural state, they are not perfect. For example, the chosen original state used as the park benchmark depends on many factors and cannot be definitively determined. For instance prescribed burning is often actually performed during unnatural fire seasons in order to protect nearby human developments. James *et al*. (2009) acknowledges the holes in green space research and suggests an integrated framework with special focus placed on green space management and green space behavior as a result of social, demographic, and environmental change. Management, whether focused on water, green space, or another entity, requires integration of the possible effects due to changes in social, cultural, environmental, and additional factors in order to be successful and sustainable.

One method to decrease stress on the sewer system is to decrease runoff through low impact development (LID). Low Impact Development is “a new, comprehensive land planning and engineering design approach with a goal of maintaining and enhancing the pre-development hydrologic regime of urban and developing watersheds" (Low Impact, 2005) Quantity control of stormwater can best be attained by limiting the impervious surfaces on site, a LID strategy. More green space allows more water to infiltrate, reducing excessive stormwater flows and pollution that can travel within these flows. LID practices not only created aesthetically pleasing green areas, but also increase local property values which resulted in an increase in property taxes collected by the local government. In the end the LID projects can make more money than they cost to execute, strengthening the business case for environmentally sustainable practices. A cost-benefit analysis can determine economic gains.

Native Landscaping

Choosing the most appropriate vegetation beforehand results in less maintenance, water, and energy needed in the long-run. In drought-prone regions, such as Florida, utilizing native plants and vegetation for outdoor landscaping (xeriscaping) is an advantageous practice. Choosing the proper plants and implementing other drought management techniques, such as soil and water management, provides resiliency to changes over time (Rockström, 2003).

The application of wireless or wired sensors can also aid in reducing the water requirement for landscaping. In an Australian study, wireless sensors were used to measure soil moisture, temperature, and humidity so that irrigation efficiency could be improved (McCulloch *et al.*, 2008). Soil moisture sensors were placed at three different soil depths to best model moisture patterns in both time and space around plant root structures. Previous studies used moisture, temperature, and humidity data to predict plant disease outbreaks.

Water Modeling

Models allow individuals to better predict future needs and how to achieve those goals. Benefits of utilizing a model include analyzing solutions that can waste less energy, such as reduced energy from pumping less potable or wastewater to and from buildings. Model analysis can also result in economical benefits due to the decrease in energy used for improved management practices. However, in order for model analysis and management practices based on that analysis to be successful, education of stakeholders is necessary. Dynamic modeling of a system should be built at the proper scale, whether individual or community-based, with all stakeholders in mind.

An integral part of utilizing a model for policy changes or decision-making is education and public involvement (Stave 2003). A model cannot be successful if the information it provides is not explained to and understood by planners, policymakers, and members of the community. Models can easily become complex in order to accurately simulate programmed conditions. The challenge is to simplify inputs and outputs so that anyone can understand the underlying concepts and reasoning behind the results. In a Las Vegas water management case, public forums allowed participants to suggest possible ways to meet increasing water demand and to witness how their proposed policies affected the point where demand exceeded supply (Stave 2003). Some participants believed restricting hotel water usage would lower demand substantially, but the model showed the audience that reducing residential demand would have a higher impact. With policies such as conservation, successful results occur when the community is actively involved and understands the consequences of their choices.

A life cycle assessment performed on Australia's largest water service provider included considerations, such as operations and maintenance of the system (Lundie *et al*., 2004). Energy and chemical usage were prevalent throughout the water processes.

Different scenarios utilizing different technologies were evaluated based on how resource utilization and environmental impact differed from a baseline case. Strategic planning was used for determining improvement options in the Australian water system. The same life cycle analysis steps are included water use and reuse modeling. Building owners need to choose appropriate technologies if successful water reuse is going to be achieved. They must also consider the materials involved in implementing the chosen technology. The financial cost due to maintenance and level of education needed by operators are two additional factors to contemplate. An important, but often overlooked step is what happens to the technology when its usable life ends. Conventional management discards and replaces old technology, but if end-of-life is considered before implementing a system, a technology that can be reused, recycled, or deconstructed in a sustainable manner can be chosen from the start.

Available urban water use models include Aquacycle (Mitchell, 2005) and House Water Expert (Maheepala, 2007). Both models originate in Australia and evaluate the water balance of both the interior and exterior of the urban environment. Rainwater and wastewater are considered alternative water sources for reuse within the system. House Water Expert (HWE) focuses on residential water consumption (Maheepala, 2007). Users build their home in the program interface by specifying the home area, green space, paved spaces, home features (swimming pool, spa, shed, etc.), water fixtures both indoors and out, and the frequency that each fixture is used by household members. The choice of collecting rainwater in a storage unit or treating wastewater for reuse is available. Each action changes the amount of total water consumed, wastewater generated, and stormwater generated listed at the top of the interface. Users are also provided with a results tab where a breakdown of water use is provided including sources of incoming water, water disposal values, usage for the household, usage per individual, usage per appliance, and outdoor water usage (Maheepala, 2007).

Climate data is built into the program; users choose from a set of weather stations available in Australia to mimic the climate of their region. HWE is a good educational tool because the intuitive nature of the program is applicable to a wide audience (Mitchell *et al*., 2004). However, calculations are static. End results are given as an average use per day or over the year. In addition to a single residence, Aquacycle also contains the ability to expand the water balance up to a community or regional level and has specific files for climate data that can be altered by the user (Mitchell, 2005). The total area included in the model is called the catchment and can be divided into no more than 50 clusters, where each cluster is divided into uniformly spaced blocks (Last and Mackay, 2007). Outputs of the program include daily, monthly, and annual water usage. The outdoor water parameters are more detailed in Aquacycle than in HWE; they include inflow and infiltration, leakage in pipes, and groundwater recharge. However, evaluation of the program found that Aquacycle contained discrepancies with runoff calculations (Last and Mackay, 2007).

CHAPTER 3:

RESEARCH MOTIVATION

The LEED rating system clearly states the objective for each point, and there are numerous technologies and methods available to utilize in order to reach each goal. However, the process is abstract. Analysis of water use requires knowledge of both initial and final water values, but those values are dependent on the water management option that has been implemented. Everything is relative; an integrated building water management (IBWM) is needed to provide measurable value to each alternative

The challenge is to give meaning to LEED requirements and evaluate the impact of different water management alternatives. There are many techniques that affect water flows in a building system, but the magnitude of impact is also of great importance. For example, the use of potable water can be lowered by installing toilets that use fewer gallons per flush (gpf) or by installing sinks that use fewer gallons per minute (gpm). The effect of each option is already given: the demand for potable water will decrease; however, the magnitude of that decrease is unknown in each case. A quantitative decision-making tool, taking into account various options for water conservation and reuse, is needed. By assigning values to the unique options, the impact of different methods can be measured with respect to the system and to each other.

The movement of water throughout a system is an observable event; flows and volumes are measurable and verifiable. Hence, a model was chosen as the best medium by which to sort the information and serve as a decision-making tool. Adaptability to numerous flow setups, such as low-flow fixtures and various water sources, allows for each option affecting water use to be considered. All conceptualized aspects are networked using the *Systems Thinking Experimental Learning Laboratory with Animation* (STELLA) visual modeling software (ISEE Systems) to form a coherent system. STELLA was chosen as the development tool for the model due to its visual mapping, simulation features, and user-friendly interface. Utilizing STELLA provides a built-in dynamic aspect to the IBWM model, allowing trends in water demand and supply to be simultaneously plotted.

The objectives of this study are:

- Develop a dynamic integrated building water management (IBWM) model for the building water cycle. The model must be customizable and able to track water quantities and flows over time.
- Check assumptions and calculations defined by Leadership in Energy and Environmental Design (LEED) green building rating systems. LEED outlines assumptions about water consumption to use when calculating water savings in green buildings. This project will measure water consumption at a local school and compare measured values with LEED values.
- Calibrate and test the IBWM model to verify performance. Using a local school as a test site, measured consumption will be used to calibrate the IBWM model.
- Determine whether STELLA can be used as a teaching tool about the building water cycle.

CHAPTER 4:

INTEGRATED BUILDING WATER MANAGEMENT MODELING

Overview

Development of the first version of the IBWM was based on a generic commercial building, but with the Patel Center for Global Solutions at the University of South Florida in mind. The initial version of the IBWM model (Version 1) was developed from the conceptual volumes and flows of water in a building system. The control volume includes the building and adjacent landscaping. Runoff was considered a major area within the framework; and as such, a green roof option and low impact development (LID) strategies, such as limited impervious surfaces, were included for analysis. Equations and assumptions were developed intuitively. Because of this, the validity of the numerical results may be questioned; however, the model succeeded at tracking the various flows and maintaining a mass balance, as well as providing comparable outcomes for different water management options. Equations and assumptions are estimated values with the exception of mandated flows given in the Energy Policy Act of 1992.

The second and current version of the model was developed to accommodate the water flows and management options of a local children’s school. Version 2 borrowed heavily from Version 1 because the water mapping is essentially the same; water is still taken from the same sources (potable water, recycled water) and delivered to the same sinks (toilets, irrigation). New equations and assumptions were taken directly from the LEED NC Reference Manual so that attainable LEED points for the project could be determined from the improved model. Although the assumptions may not accurately represent the water usage for a specific building, this model allows users to alter the assumptions to values they feel more accurately portray water usage for their particular site. Sectors of the model not included in the Reference Manual, such as green roofs or cooling, are generally turned off in the Version 2 framework because 1) they do not contribute to attainable LEED credits and 2) acceptable equations and assumptions for these sectors have not been developed. However, these sectors are built-in and prepared to be linked when proper assumptions can be established. The current IBWM model consists of various flows and volumes that can be separated into individual sectors.

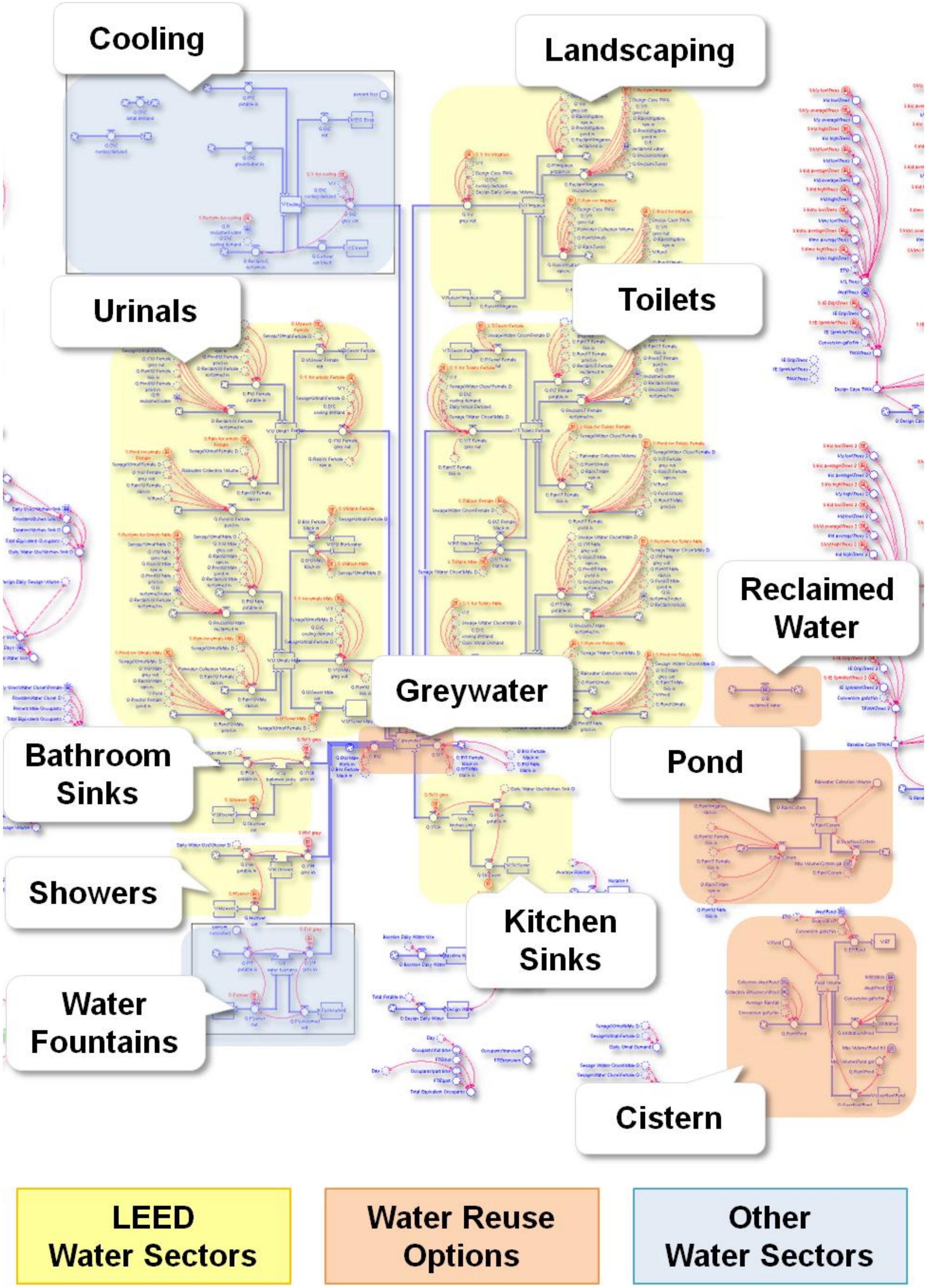


FIGURE 3: IBWM modeling framework using STELLA.

Full-Time Occupant Equivalent

For water fixtures within a building, water demand is directly linked to hours of occupancy. In order to account for the various time periods each individual spends in the building, each time period is normalized to an 8-hour workday. This results in a full-time occupant equivalent (FTE) value that describes building occupancy and can be used to determine the water fixture demand by the occupants. A full-time employee working an 8-hour workday is given a value of 1.0. The value given to an individual working for a different period of time is determined by dividing the hours worked by the 8-hour average workday. Students carry an FTE value of 1.0 in the LEED for Schools rating system. The total FTE calculation is as follows:

$$\mathrm{FTE} = \sum \left(\mathrm{N}_i \times \frac{\mathrm{t}_i}{\mathrm{t}_{\mathrm{full}}} \right) \tag{1}$$

N_i = Number of employees working i hours

t_i = Average daily number of hours worked

t_{full} = Full-time average daily number of hours worked (8 hours)

The FTE value is used to calculate baseline and demand water flows for toilets, urinals, bathroom sinks, kitchen sinks, and showers.

Irrigation

Irrigation around a building can create the single largest water demand for the site. Choosing native or adaptive plants through xeriscaping practices greatly reduces or eliminates the demand for water sources in addition to natural rainfall. Rainwater harvesting from either a conventional or green roof provides additional support for irrigation. Water caught via low impact development (LID) design practices can be stored in a retention pond and pumped as demand dictates, although filtration may be necessary to prevent possible clogging of the piping system. In addition to cooling and toilet flushing, both reclaimed water and greywater are applicable for irrigational purposes. The sum of all inflows for irrigation is the total flow for irrigation.

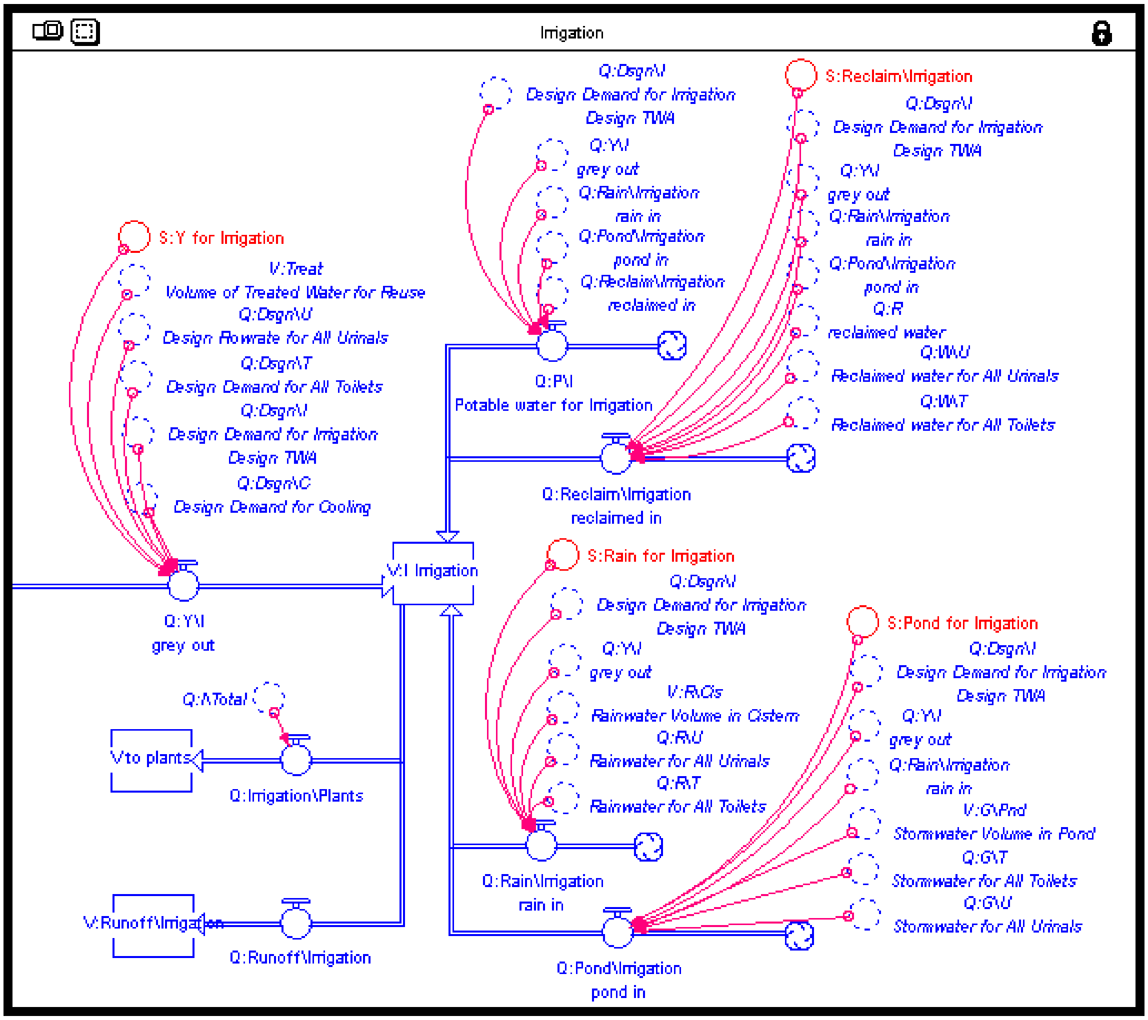


FIGURE 4: Detail model framework for the irrigation sector.

The stock in the center of the irrigation portion of the model represents the landscaping within the building site. There is no accumulation of volume in this stock; all water sources are applied to irrigation and then are either used by the plants or exit as runoff.

Therefore, the sum of all inflows must equal the sum of all outflows. This balance is represented as:

$$\Sigma Qin - \Sigma Qout = 0 \qquad (2)$$

$$Q_P^I + Q_Y^I + Q_W^I + Q_R^I + Q_G^I - Q_{run}^I - Q_{plants}^I \qquad (3)$$

Q_P^I = Flow of potable water to irrigation (gal/day)

Q_Y^I = Flow of treated greywater to irrigation (gal/day)

Q_W^I = Flow of reclaimed water to irrigation (gal/day)

Q_R^I = Flow of collected rainwater to irrigation (gal/day)

Q_G^I = Flow of collected stormwater to irrigation (gal/day)

Q_{Run}^I = Flow leaving irrigation as runoff (gal/day)

Q_{plants}^I = Flow of water used by irrigated plants (gal/day)

Calculations for irrigation are applied to month of July according to the LEED Reference Manual. The underlying assumption is that the amount of water demanded in July is the highest value of the year and will represent the greatest gap in water availability and water need. However, summer months can also be times of plentiful rainfall, reducing the irrigation demand for other water sources. The IBWM model has the capability of running water calculations over a year-long period to better estimate water requirements and determine whether the July scenario provides the worst-case irrigation water demand scenario. The water demand for irrigation depends on landscape factors specific to individual plantings, the evapotranspiration rates for the region, the efficiency of the irrigation system, and implementation of alternative water sources.

The Landscape Coeeficient (K_L) is used to calculate the amount of water lost through evapotranspiration. This value depends on 1) the landscape species, 2) the microclimate, and 3) the planting density. Values for each factor are given in Table 6. The formula is given as:

$$K_{L,i} = k_{s,i} \times k_{d,i} \times k_{mc,i} \tag{4}$$

$k_{s,i}$ = Species factor for vegetation type i (%)

$k_{d,i}$ = Density factor for vegetation type i (%)

$k_{mc,i}$ = Microclimate factor for vegetation type i (%)

The species factor (k_s) accounts for the species of plants being used. The factor can be high, average, or low depending on the plants chosen. The average k_s value is 0.5 (50%). If a plant does not require irrigation, the k_s is 0, and the resulting K_L is 0. The density factor (k_d) accounts for the number of plants and total leaf area in a given landscape. An average k_d is given to areas where trees shade 60% to 100% (or groundcover shades 90% to 100%) of the landscaped area. Where shading is less than these percentages, the k_d value is lower. Higher densities have higher k_d values. The microclimate factor (k_{mc}) accounts for temperature, wind, and humidity. The average k_{mc} value is 1.0 and is given to areas where landscape evapotranspiration is unaffected by buildings and pavements. Landscaped areas near reflective surfaces or exposed to windy conditions have higher k_{mc} values. Low k_{mc} values are given to shaded areas and those protected from wind.

TABLE 6: Landscape factor values for calculating the landscape coefficient.

Vegetation Type, *i*	**Species Factor (k_s)**			**Density Factor (k_d)**			**Microclimate Factor (k_{mc})**		
	Low	**Avg**	**High**	**Low**	**Avg**	**High**	**Low**	**Avg**	**High**
Trees	0.2	0.5	0.9	0.5	1.0	1.3	0.5	1.0	1.4
Shrubs	0.2	0.5	0.7	0.5	1.0	1.1	0.5	1.0	1.3
Groundcover	0.2	0.5	0.7	0.5	1.0	1.1	0.5	1.0	1.2
Mixed: trees, shrubs, groundcover	0.2	0.5	0.9	0.6	1.1	1.3	0.5	1.0	1.4
Turfgrass	0.6	0.7	0.8	0.6	1.0	1.0	0.8	1.0	1.2

*Coefficients compiled from the LEED NC Reference Guide (USGBC, 2009).

After the landscape coefficient has been calculated, the water requirement can be determined from this value and the evapotranspiration rate for the area.

$$ET_{L,i} = ET_0 \times K_{L,i} \tag{5}$$

$ET_{L,i}$ = specific evapotranspiration rate for vegetation type *i* (in/day)

ET_0 = reference evapotranspiration rate (in/day)

$K_{L,i}$ = landscape coefficient for vegetation type *i* (%)

The reference evapotranspiration rate (ET_0) is the amount of water required to grow a reference plant in inches per time. This value can be found in regional agricultural data. However, extensive values could only be found for areas in Texas. This model uses these values as assumptions. Summing the reference evapotranspiration rate for all plant types on the building site (turfgrass, groundcover, shrubs, trees, and mixed) results in the total reference evapotranspiration rate for all landscaping:

$$ET_L A_{Tot} = \Sigma(ET_{L,i} \times A_i) \tag{6}$$

$$= ET_{L,Tre}\, A_{Tre} + ET_{L,Shr}\, A_{Shr} + ET_{L,Grd}\, A_{Grd} + ET_{L,Mix}\, A_{Mix} + ET_{L,Trf}\, A_{Trf} \tag{7}$$

$ET_L A_{Tot}$ = specific evapotranspiration rate for all irrigation multiplied by the total area (in-ft^2/day)

$ET_{L,Tre}$ = evapotranspiration rate for trees (in/day)

A_{Tre} = Area taken up by trees (ft^2)

$ET_{L,Shr}$ = evapotranspiration rate for shrubs (in/day)

A_{Shr} = Area taken up by shrubs (ft^2)

$ET_{L,Grd}$ = evapotranspiration rate for groundcover (in/day)

A_{Grd} = Area taken up by groundcover (ft^2)

$ET_{L,Mix}$ = evapotranspirtation rate for mixed areas of trees, shrubs, and groundcover (in/day)

A_{Mix} = Area taken up by mixture of trees, shrubs, and groundcover (ft^2)

$ET_{L,Trf}$ = evapotranspiration rate for turfgrass (in/day)

A_{Trf} = Area taken up by turfgrass (ft^2)

The above value ($ET_L A_{Tot}$) represents the total water demanded by the vegetation as a volume, but does not include the efficiencies of the installed irrigation system. The total irrigation water demand that incorporates these efficiencies is calculated as:

$$Q_{Base}^{I} = (ET_L A_{Tot} / IE) \times CE \times CF \quad (8)$$

Q_{Base}^{I} = Baseline case water flow demanded for irrigation (gal/day)

$ET_L A_{Tot}$ = Site-specific water demand (in-ft^2/day)

IE = Irrigation efficiency (%)

CE = Controller efficiency (%)

CF = Conversion factor (0.6223 gal/ft^2/in)

The irrigation efficiency (IE) depends on the type of irrigation system used for each landscaped area. Values are given in Table 7. The controller efficiency (CE) is only applicable if there is a percent reduction in water use from weather-based controllers or moisture sensor-based systems. Documentation must support this number if used. In this model, controller efficiency is not included and is therefore assumed to be 1.

TABLE 7: Irrigation efficiency (IE) values.

Irrigation Type	**IE**
Sprinkler	0.625
Drip	0.90

*Irrigation efficiencies taken from the LEED NC Reference Manual (USGBC, 2009).

The above calculated value is considered as the baseline case when sprinklers are used for irrigation and there are no alternative water sources. In the baseline case, the total water allocated (TWA) for irrigation is the same as the total potable water allocated (TPWA) because all water used is from a potable source.

The design case water demand for irrigation is calculated in the same manner as the baseline case. However, the design case allows to alternative water sources to be included in the equation so that the potable water demand may be reduced.

$$Q_{Dsgn}^{I} = [(ET_{L}A_{Tot} / IE) \times CE \times CF] - Q_{Y}^{I} + Q_{W}^{I} + Q_{R}^{I} + Q_{G}^{I} \qquad (9)$$

Q_{Dsgn}^{I} = Design case water flow demanded for irrigation (gal/day)

Q_{Y}^{I} = Flow of treated greywater to irrigation (gal/day)

Q_{W}^{I} = Flow of reclaimed water to irrigation (gal/day)

Q_{R}^{I} = Flow of collected rainwater to irrigation (gal/day)

Q_{G}^{I} = Flow of collected stormwater to irrigation (gal/day)

Values for alternative water depend on the water management options chosen for a project. Figure 5 shows the possible water sources for irrigation in the IBWM model. The chosen sources in the model represent common alternative water methods and may be altered to fit additional sources not specifically represented.

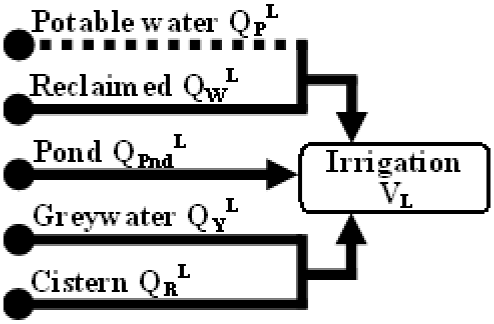


FIGURE 5: Water sources for irrigation in the IBWM model.

The previous calculations provide daily water flow rates. The IBWM model sums flows over a specified time period (default time period set to 365 days or one year). Cumulative volumes are tracked during the time period and final values are displayed at the end according to the following equations:

$$V_{Base}^{I} = \int_0^t Q_{Base}^{I} dt \tag{10}$$

$$V_{Dsgn}^{I} = \int_0^t Q_{Dsgn}^{I} dt \tag{11}$$

V_{Base}^{I} = Baseline case water volume for irrigation (gal)

V_{Dsgn}^{I} = Design case water volume for irrigation (gal)

t = time period (days)

Q_{Base}^{I} = Baseline case water flow demand for irrigation (gal/day)

Q_{Dsgn}^{I} = Design case water flow demand for irrigation (gal/day)

The percent reduction in overall water for irrigation depends on the total water allocated for both the baseline and design cases. The percent reduction in potable water depends only on the potable water used for the baseline and design cases. As mentioned before, the potable water used in the design case is the same as the total water used for the design case. The equations are:

$$P_{Tot}^{I} = \left(1 - \frac{V_{Dsgn}^{I}}{V_{Base}^{I}}\right) \times 100 \tag{12}$$

$$P_{P(Tot)}^{I} = \left(1 - \frac{V_{P(Dsgn)}^{I}}{V_{Base}^{I}}\right) \times 100 \tag{13}$$

P_{Tot}^{I} = Percent reduction in total water use for irrigation (%)

$P_{P(Tot)}^{I}$ = Percent reduction in potable water use for irrigation (%)

$V_{P(Dsgn)}^{I}$ = Volume of potable water used for irrigation (gal)

Bathroom Sinks

A detailed view of the portion of the model involving bathroom sinks is shown below in Figure 6. The bathroom sinks stock does not accumulate volume; therefore, the volume within the stock is 0. The only inflow is assumed to be potable water because of the possibility of human consumption. Water exiting from bathroom sinks is sent directly to the sewer in the baseline case. The model provides the opportunity for greywater exiting the fixtures to be routed to treatment before being reused within the building.

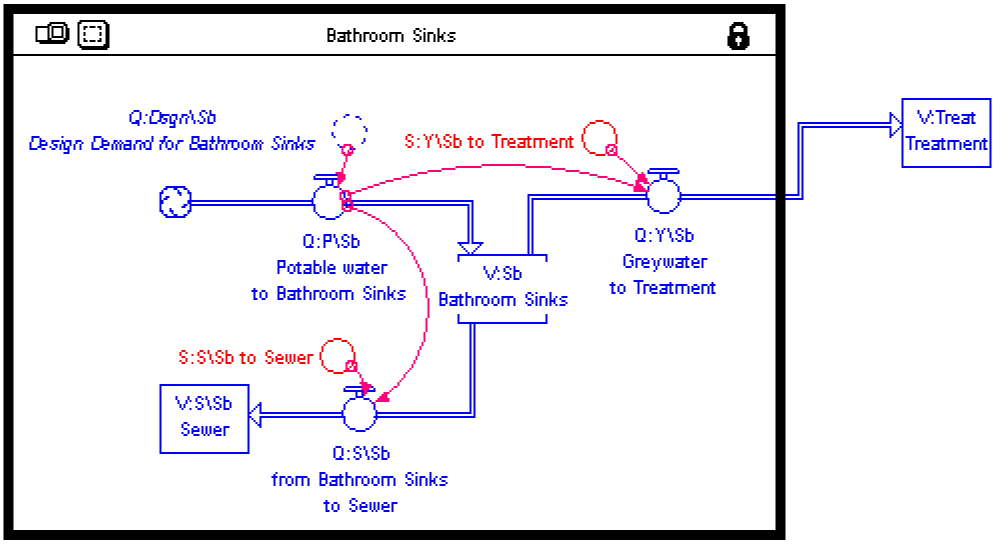


FIGURE 6: Detail model framework for the bathroom sink sector.

Because there is no accumulation in the bathroom sink stock, the difference between all inflows and all outflows must be 0:

$$\Sigma Q\text{in} - \Sigma Q\text{out} = 0 \qquad (14)$$

$$Q_P^{Sb} - Q_S^{Sb} - Q_Y^{Sb} \qquad (15)$$

Q_P^{Sb} = Flow of potable water to bathroom sinks (gal/day)

Q_S^{Sb} = Flow to sewer from bathroom sinks (gal/day)

Q_Y^{Sb} = Flow of greywater from bathroom sinks to treatment (gal/day)

The baseline and design case total water demand for bathroom sinks depends on the FTE defined by the building occupants, number of times each occupant uses the fixture, the flow rate of the fixture, and the duration of the usage application:

$$Q_{Base}^{Sb} = FTE \times N_A^{Sb} \times Q_A^{Sb(Base)} \times t_A^{Sb(Base)} \quad (16)$$

$$Q_{Dsgn}^{Sb} = FTE \times N_A^{Sb} \times Q_A^{Sb(Dsgn)} \times t_A^{Sb(Base)} \quad (17)$$

Q_{Base}^{Sb} = Baseline case water flow for bathroom sinks (gal/day)

Q_{Dsgn}^{Sb} = Design case water flow for bathroom sinks (gal/day)

N_A^{Sb} = Number of bathroom sink applications (uses/person/day)

$Q_A^{Sb(Base)}$ = Baseline case flow rate of bathroom sink application (gpm)

$Q_A^{Sb(Dsgn)}$ = Design case flow rate of each bathroom sink application (gpm)

$t_A^{Sb(Base)}$ = Baseline case duration for each bathroom sink application (sec)

$t_A^{Sb(Base)}$ = Design case duration for each bathroom sink application (sec)

The only variables that change between the baseline and design cases are the flow rate of the fixture and the duration of the event. In order to reduce the water demand, water-saving fixtures must be implemented. Possible values for the previous equations are given in Table 8.

TABLE 8: Flow rate, duration, and uses per day for bathroom sinks.

Bathroom Sink Fixture Type	**Flow Rate** (gpm)	**Duration** (sec)		**Uses/Day**			
		Non-residential	Residential	FTE	Transient	Retail Customer	Residential
Conventional	2.5	15[1]	60	3	0.5	0.2	5
Low-flow	1.8	15[1]	60	3	0.5	0.2	5
Ultra low-flow	0.5	15[1]	60	3	0.5	0.2	5

[1] If an autocontrol system is used, the duration is 12 seconds.

Summing the daily flows over a defined time period (in number of days) results in overall baseline case and design case volumes:

$$V_{Base}{}^{Sb} = \int_0^t Q_{Base}{}^{Sb} dt \tag{18}$$

$$V_{Dsgn}{}^{Sb} = \int_0^t Q_{Dsgn}{}^{Sb} dt \tag{19}$$

$V_{Base}{}^{Sb}$ = Baseline case water volume for bathroom sinks (gal)

$V_{Dsgn}{}^{Sb}$ = Design case water volume for bathroom sinks (gal)

t = time period (days)

$Q_{Base}{}^{Sb}$ = Baseline case water flow demand for bathroom sinks (gal/day)

$Q_{Dsgn}{}^{Sb}$ = Design case water flow demand for bathroom sinks (gal/day)

Water demand for both the baseline case and design case comes only from a potable source. Therefore, the percent reduction in overall water use and percent reduction in potable water use are equal:

$$P_{(Tot)}{}^{Sb} = P_{P(Tot)}{}^{Sb} = \left(1 - \frac{V_{Dsgn}{}^{Sb}}{V_{Base}{}^{Sb}}\right) \times 100 \tag{20}$$

$P_{Tot}{}^{Sb}$ = Percent reduction in total water use for bathroom sinks (%)

$P_{P(Tot)}{}^{Sb}$ = Percent reduction in potable water use for bathroom sinks (%)

Kitchen Sinks

A detailed view of the portion of the model involving bathroom sinks is shown below in Figure 7. Like the bathroom sinks, the kitchen sinks stock does not accumulate volume; therefore, the volume within the stock is 0. The only inflow is assumed to be potable water because of the possibility of human consumption. Water exiting from bathroom sinks is sent directly to the sewer in the baseline case. The model provides the opportunity for greywater exiting the fixtures to be routed to treatment before being reused within the building.

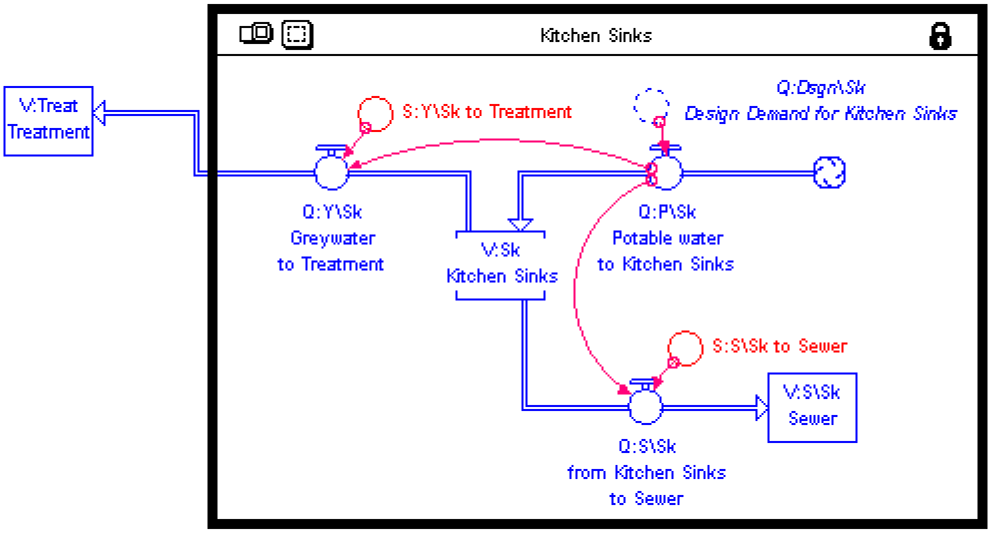


FIGURE 7: Detail model framework for the kitchen sink sector.

Because there is no accumulation in the kitchen sink stock, the difference between all inflows and all outflows must be 0:

$\Sigma Qin - \Sigma Qout = 0$ (21)

$Q_P^{Sk} - Q_S^{Sk} - Q_Y^{Sk}$ (22)

Q_P^{Sk} = Flow of potable water to kitchen sinks (gal/day)

Q_S^{Sk} = Flow to sewer from kitchen sinks (gal/day)

Q_Y^{Sk} = Flow of greywater from kitchen sinks to treatment (gal/day)

The baseline and design case total water demand for kitchen sinks depends on the FTE defined by the building occupants, number of times each occupant uses the fixture, and the flow rate of the fixture. The duration in both cases is the same.

$Q_{Base}^{Sk} = FTE \times N_A^{Sk} \times Q_A^{Sk(Base)} \times t_A^{Sk}$ (23)

$Q_{Dsgn}^{Sk} = FTE \times N_A^{Sk} \times Q_A^{Sk(Dsgn)} \times t_A^{Sk}$ (24)

Q_{Base}^{Sk} = Baseline case water flow for kitchen sinks (gal/day)

Q_{Dsgn}^{Sk} = Design case water flow for kitchen sinks (gal/day)

N_A^{Sk} = Number of kitchen sink applications (uses/person/day)

$Q_A^{Sk(Base)}$ = Baseline case flow rate of each kitchen sink application (gpm)

$Q_A^{Sk(Dsgn)}$ = Design case flow rate of each kitchen sink application (gpm)

t_A^{Sk} = Duration for each kitchen sink application (sec)

The only variable that changes between the baseline and design cases is the flow rate of the fixture. In order to reduce the water demand, water-saving fixtures must be implemented. Possible values for the previous equations are given in Table 9.

TABLE 9: Flow rate, duration, and uses per day for kitchen sinks.

Kitchen Sink Fixture Type	**Flow Rate** (gpm)	**Duration** (sec)		**Uses/Day**			
		Non-Residential	Residential	FTE	Transient	Retail Customer	Residential
Conventional	2.5	15	60	1	0	0	4
Low-flow	1.8	15	60	1	0	0	4

Summing the daily flows over a defined time period (in number of days) results in overall baseline case and design case volumes:

$$V_{Base}{}^{Sk} = \int_0^t Q_{Base}{}^{Sk} dt \quad (25)$$

$$V_{Dsgn}{}^{Sk} = \int_0^t Q_{Dsgn}{}^{Sk} dt \quad (26)$$

V_{Base}^{Sk} = Baseline case water volume for kitchen sinks (gal)

V_{Dsgn}^{Sk} = Design case water volume for kitchen sinks (gal)

t = time period (days)

Q_{Base}^{Sk} = Baseline case water flow demand for kitchen sinks (gal/day)

Q_{Dsgn}^{Sk} = Design case water flow demand for kitchen sinks (gal/day)

Water demand for both the baseline case and design case comes only from a potable source. Therefore, the percent reduction in overall water use and percent reduction in potable water use are equal:

$$P_{(Tot)}^{Sk} = P_{P(Tot)}^{Sk} = \left(1 - \frac{V_{Dsgn}^{Sk}}{V_{Base}^{Sk}}\right) \times 100 \qquad (27)$$

P_{Tot}^{Sk} = Percent reduction in total water use for kitchen sinks (%)

$P_{P(Tot)}^{Sk}$ = Percent reduction in potable water use for kitchen sinks (%)

Showers

A detailed view of the portion of the model involving showers is shown below in Figure 8. The center shower stock does not accumulate volume; therefore, the volume within the stock is 0. The only inflow is assumed to be potable water. Water exiting from bathroom sinks is sent directly to the sewer in the baseline case. The model provides the opportunity for greywater exiting the fixtures to be routed to treatment before being reused within the building.

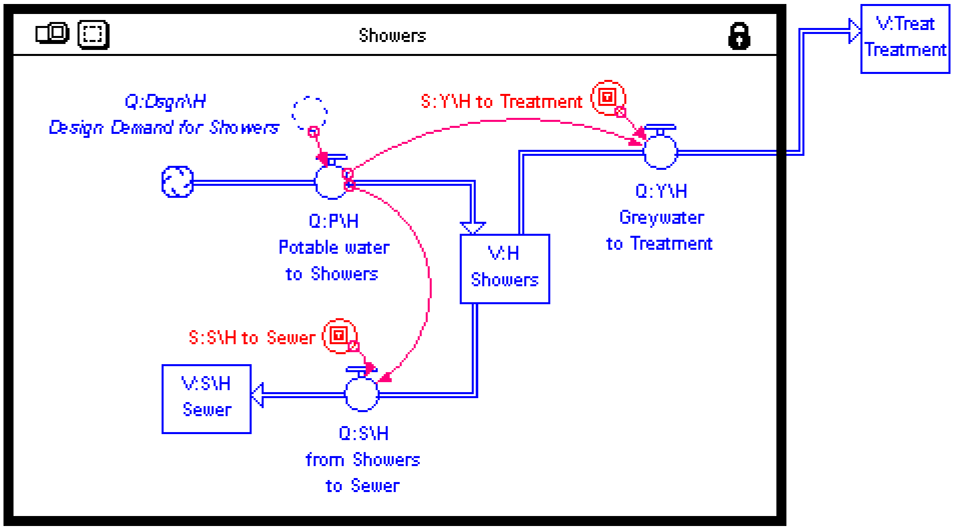


FIGURE 8: Detail model framework for the showers sector.

Because there is no accumulation in the shower stock, the difference between all inflows and all outflows must be 0:

$$\Sigma Q_{in} - \Sigma Q_{out} = 0 \quad (28)$$

$$Q_P^H - Q_S^H - Q_Y^H \quad (29)$$

Q_P^H = Flow of potable water to showers (gal/day)

Q_S^H = Flow to sewer from showers (gal/day)

Q_Y^H = Flow of greywater from showers to treatment (gal/day)

The baseline and design case total water demand for showers depends on the FTE defined by the building occupants, number of times each occupant uses the fixture, and the flow rate of the fixture. The duration in both cases is the same.

$$Q_{Base}^H = FTE \times N_A^H \times Q_A^{H(Base)} \times t_A^H \quad (30)$$

$$Q_{Dsgn}^H = FTE \times N_A^H \times Q_A^{H(Dsgn)} \times t_A^H \quad (31)$$

Q_{Base}^H = Baseline case water flow for showers (gal/day)

Q_{Dsgn}^H = Design case water flow for showers (gal/day)

N_A^H = Number of shower applications (uses/person/day)

$Q_A^{H(Base)}$ = Baseline case flow rate of each shower application (gpm)

$Q_A^{H(Dsgn)}$ = Design case flow rate of each shower application (gpm)

$t_A^{H(Base)}$ = Duration for each shower application (sec)

The only variable that changes between the baseline and design cases is the flow rate of the fixture. In order to reduce the water demand, water-saving fixtures must be implemented. Possible values for the previous equations are given in Table 10.

TABLE 10: Flow rate, duration, and uses per day for showers.

Shower Fixture Type	**Flow Rate** (gpm)	**Duration** (sec)		**Uses/Day**			
		Non-Residential	Residential	FTE	Transient	Retail Customer	Residential
Conventional	2.5	300	480	0.1	0	0	1
Low-flow	1.8	300	480	0.1	0	0	1

Summing the daily flows over a defined time period (in number of days) results in overall baseline case and design case volumes:

$$V_{Base}{}^{H} = \int_0^t Q_{Base}{}^{H} dt \tag{32}$$

$$V_{Dsgn}{}^{H} = \int_0^t Q_{Dsgn}{}^{H} dt \tag{33}$$

$V_{Base}{}^{H}$ = Baseline case water volume for showers (gal)

$V_{Dsgn}{}^{H}$ = Design case water volume for showers (gal)

t = time period (days)

$Q_{Base}{}^{H}$ = Baseline case water flow demand for showers (gal/day)

$Q_{Dsgn}{}^{H}$ = Design case water flow demand for showers (gal/day)

Water demand for both the baseline case and design case comes only from a potable source. Therefore, the percent reduction in overall water use and percent reduction in potable water use are equal:

$$P_{(Tot)}{}^{H} = P_{P(Tot)}{}^{H} = \left(1 - \frac{V_{Dsgn}{}^{H}}{V_{Base}{}^{H}}\right) \times 100 \tag{34}$$

$P_{Tot}{}^{H}$ = Percent reduction in total water use for showers (%)

$P_{P(Tot)}{}^{H}$ = Percent reduction in potable water use for showers (%)

Toilets

There are numerous alternative water sources that can be applied to flushing toilets because water for sewage conveyance does not need to be of high quality (potable water). The source flows and sink flows from toilet fixtures for the IBWM model are shown in Figure 9. Alternative sources of water include recycled greywater from sinks and showers, collected rainwater, collected stormwater, or reclaimed water. Water used for flushing is sent directly to the sewer in the baseline scenario. For the design case, blackwater exiting the fixtures can be sent to treatment for use as a separate possible recyclable source within the building. The toilets are split into two sections for male and female. The separation is necessary because the number of applications for a male and female toilet differ if urinals are present in the building. The number of applications for a male toilet will be less due to utilization of urinals.

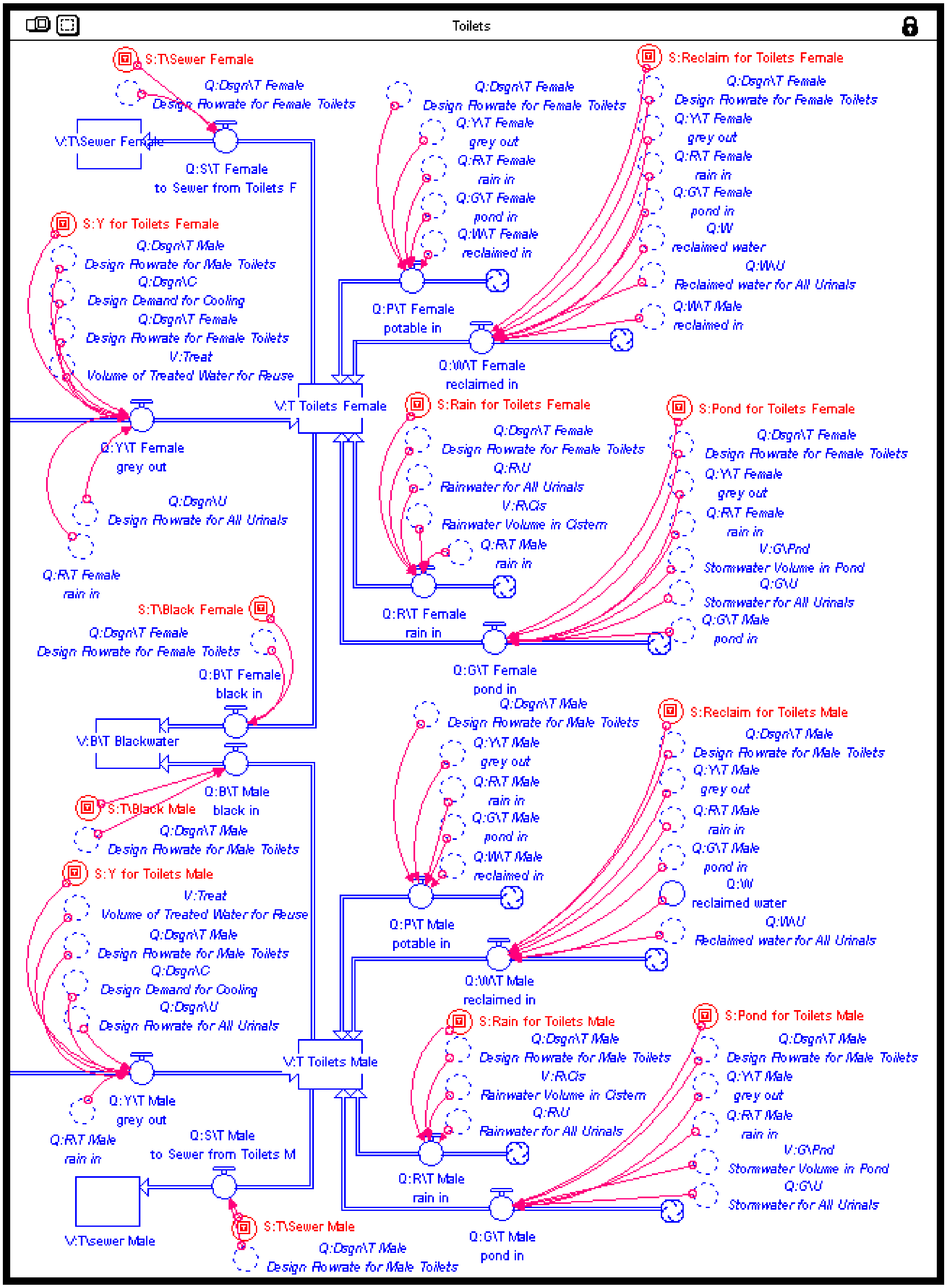


FIGURE 9: Detail model framework for the toilets sector.

There is no accumulation in the toilet stocks. As a result, the difference between all inflows and all outflows must be 0:

$$\Sigma Qin - \Sigma Qout = 0 \qquad (35)$$

$$Q_P^T + Q_Y^T + Q_W^T + Q_R^T + Q_G^T - Q_S^T - Q_B^T \qquad (36)$$

Q_P^T = Flow of potable water to toilets (gal/day)

Q_Y^T = Flow of treated greywater to toilets (gal/day)

Q_W^T = Flow of reclaimed water to toilets (gal/day)

Q_R^T= Flow of collected rainwater to toilets (gal/day)

Q_G^T = Flow of collected stormwater to toilets (gal/day)

Q_S^T = Flow to sewer from toilets (gal/day)

Q_Y^T = Flow of blackwater from toilets to treatment (gal/day)

Water demanded for the flushing of toilets depends on the number of occupants in the building (FTE), the usage of each occupant, and the gallons required for each toilet application. Water demand can be decreased by installing toilet fixtures that use fewer gallons per flush.

$$Q_{Base}^T = FTE \times N_A^T \times V_A^{T(Base)} \qquad (37)$$

$$Q_{Dsgn}^T = FTE \times N_A^T \times V_A^{T(Dsgn)} - Q_Y^T - Q_W^T - Q_R^T - Q_G^T \qquad (38)$$

Q_{Base}^T = Baseline case water flow for all toilets (gal/day)

Q_{Dsgn}^T = Design case water flow for all toilets (gal/day)

N_A^T = Number of toilet applications (uses/person/day)

$V_A^{T(Base)}$ = Baseline case volume of each toilet application (gpf)

$V_A^{T(Dsgn)}$ = Design case volume of each toilet application (gpf)

The only variable that changes between the baseline and design cases is the flow rate of the fixture. In order to reduce the water demand, water-saving fixtures must be implemented or alternative water sources must be used to offset the potable supply. Possible values for the previous equations are given in Table 11.

TABLE 11: Volume per event and uses per day for toilets.

Toilet Fixture Type	Flow Rate (gpf)	Uses/Day							
		FTE		Transient		Retail Customer		Residential	
		M	F	M	F	M	F	M	F
Low-flow	1.6	1	3	0.1	0.5	0.1	0.2	5	5
High-efficiency	1.28	1	3	0.1	0.5	0.1	0.2	5	5
Ultra low-flow	0.8	1	3	0.1	0.5	0.1	0.2	5	5
Composting	0	1	3	0.1	0.5	0.1	0.2	5	5

M = Male; F = Female

Summing the daily flows over a defined time period (in number of days) results in overall baseline case and design case volumes:

$$V_{Base}^{T}=\int_0^t Q_{Base}^{T}\,dt \tag{39}$$

$$V_{Dsgn}^{T}=\int_0^t Q_{Dsgn}^{T}\,dt \tag{40}$$

V_{Base}^{T} = Baseline case water volume for toilets (gal)

V_{Dsgn}^{T} = Design case water volume for toilets (gal)

t = time period (days)

Q_{Base}^{T} = Baseline case water flow demand for toilets (gal/day)

Q_{Dsgn}^{T} = Design case water flow demand for toilets (gal/day)

The percent reduction in overall water for toilet flushing depends on the total water allocated for both the baseline and design cases. The percent reduction in potable water depends only on the potable water used for the baseline and design cases. The equations are:

$$P_{Tot}^{T}=\left(1-\frac{V_{Dsgn}^{T}}{V_{Base}^{T}}\right)\times 100 \tag{41}$$

$$P_{P(Tot)}{}^{T} = \left(1 - \frac{V_{P(Dsgn)}{}^{T}}{V_{Base}{}^{T}}\right) \times 100 \tag{42}$$

$P_{Tot}{}^{T}$ = Percent reduction in total water use for toilets (%)

$P_{P(Tot)}{}^{T}$ = Percent reduction in potable water use for toilets (%)

$V_{P(Dsgn)}{}^{T}$ = Volume of potable water used for toilets (gal)

Urinals

The same framework used for toilets holds true for that of urinals within the model. The alternative water sources available are the same: recycled greywater from sinks and showers, collected rainwater, collected stormwater, or reclaimed water. In the baseline case, flushed water is sent to the sewer. The design case allows blackwater leaving the urinals to be reused for other applications. The urinals are split into male and female sections. If urinals are installed in the building, there will be a water demand in the male section. There will not be a demand in the female section.

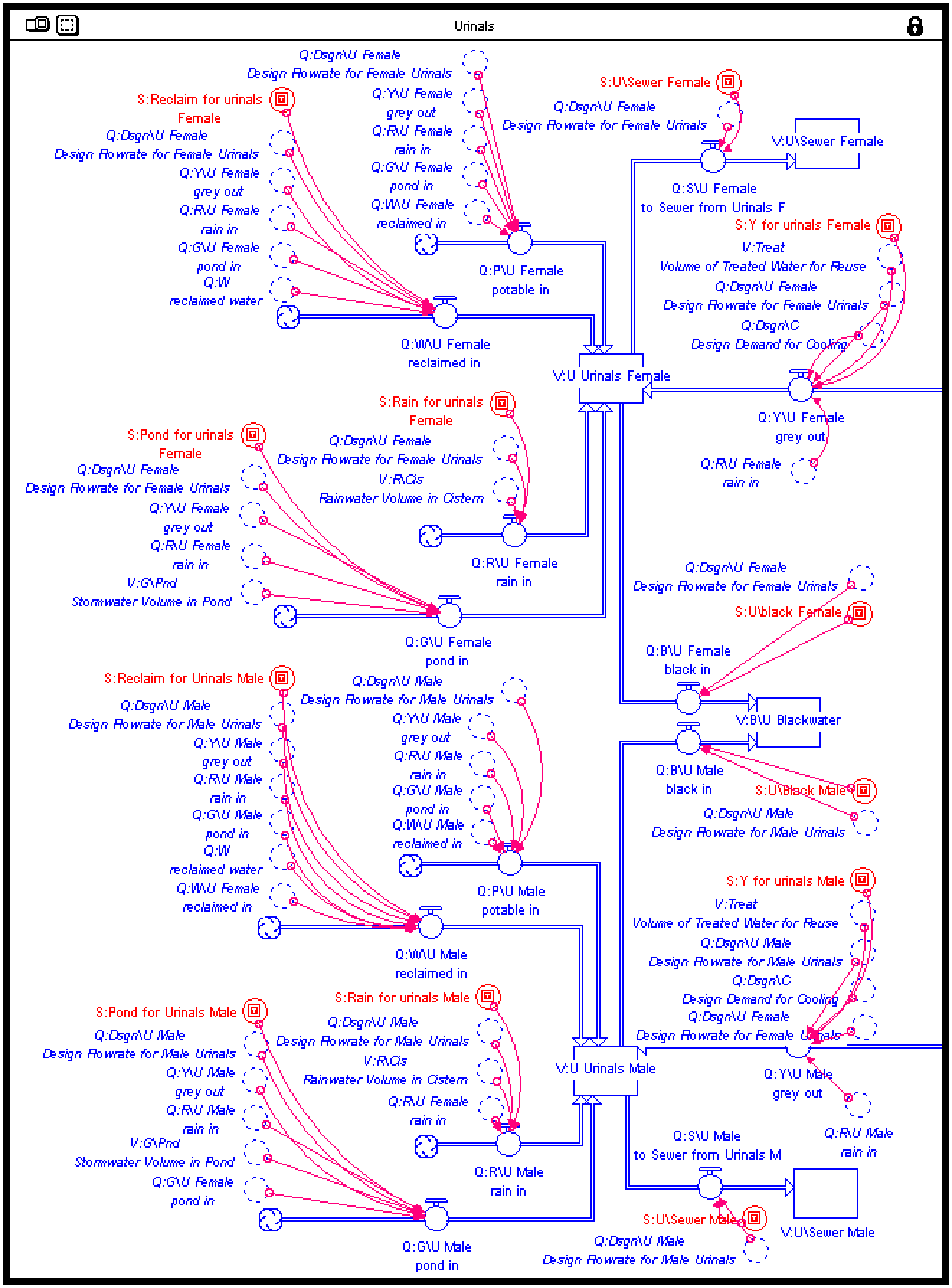


FIGURE 10: Detail model framework for the urinals sector.

There is no accumulation in the urinals stocks. As a result, the difference between all inflows and all outflows must be 0:

$$\Sigma Qin - \Sigma Qout = 0 \tag{43}$$

$$Q_P^U + Q_Y^U + Q_W^U + Q_R^U + Q_G^U - Q_S^U - Q_B^U \tag{44}$$

Q_P^U = Flow of potable water to urinals (gal/day)

Q_Y^U = Flow of treated greywater to urinals (gal/day)

Q_W^U = Flow of reclaimed water to urinals (gal/day)

Q_R^U= Flow of collected rainwater to urinals (gal/day)

Q_G^U = Flow of collected stormwater to urinals (gal/day)

Q_S^U = Flow to sewer from urinals (gal/day)

Q_Y^U = Flow of blackwater from urinals to treatment (gal/day)

Water demanded for the flushing of urinals depends on the number of occupants in the building (FTE), the usage of each occupant, and the gallons required for each urinal application. Water demand can be decreased by installing urinal fixtures that use fewer gallons per flush.

$$Q_{Base}^U = FTE \times N_A^U \times V_A^{U(Base)} \tag{44}$$

$$Q_{Dsgn}^U = FTE \times N_A^U \times V_A^{U(Dsgn)} - Q_Y^U - Q_W^U - Q_R^U - Q_G^U \tag{46}$$

Q_{Base}^U = Baseline case water flow for all urinals (gal/day)

Q_{Dsgn}^U = Design case water flow for all urinals (gal/day)

N_A^U = Number of urinal applications (uses/person/day)

$V_A^{U(Base)}$ = Baseline case volume of each urinal application (gpf)

$V_A^{U(Dsgn)}$ = Design case volume of each urinal application (gpf)

The only variable that changes between the baseline and design cases is the flow rate of the fixture. In order to reduce the water demand, water-saving fixtures must be implemented or alternative water sources must be used to offset the potable supply. Possible values for the previous equations are given in Table 12.

TABLE 12: Volume per event and uses per day for urinals.

Urinal Fixture Type	**Flow Rate** (gpm)	**Uses/Day**					
		FTE		**Transient**		**Retail Customer**	
		M	**F**	**M**	**F**	**M**	**F**
Conventional	1.0	2	0	0.4	0	0.1	0
Low-flow	0.5	2	0	0.4	0	0.1	0
Waterless	0	2	0	0.4	0	0.1	0

M = Male; F = Female

Summing the daily flows over a defined time period (in number of days) results in overall baseline case and design case volumes:

$$V_{Base}^{U}=\int_0^t Q_{Base}^{U}dt \qquad (47)$$

$$V_{Dsgn}^{U}=\int_0^t Q_{Dsgn}^{U}dt \qquad (48)$$

V_{Base}^{U} = Baseline case water volume for urinals (gal)

V_{Dsgn}^{U} = Design case water volume for urinals (gal)

t = time period (days)

Q_{Base}^{U} = Baseline case water flow demand for urinals (gal/day)

Q_{Dsgn}^{U} = Design case water flow demand for urinals (gal/day)

The percent reduction in overall water for urinal flushing depends on the total water allocated for both the baseline and design cases. The percent reduction in potable water depends only on the potable water used for the baseline and design cases. The equations are:

$$P_{Tot}^{U}=\left(1-\frac{V_{Dsgn}^{U}}{V_{Base}^{U}}\right)\times 100 \qquad (49)$$

$$P_{P(Tot)}{}^{U} = \left(1 - \frac{V_{P(Dsgn)}{}^{U}}{V_{Base}{}^{U}}\right) \times 100 \qquad (50)$$

$P_{Tot}{}^{U}$ = Percent reduction in total water use for urinals (%)

$P_{P(Tot)}{}^{U}$ = Percent reduction in potable water use for urinals (%)

$V_{P(Dsgn)}{}^{U}$ = Volume of potable water used for urinals (gal)

Cooling Tower

There are five possible water sources for a cooling tower. It is assumed that recycled water sources are sought first, such as recycled greywater and reclaimed water. Rainwater stored in a cistern and stormwater collected in a pond provide two additional water sources. Potable water is only extracted as needed. The cooling volume requires replenishment due to evaporation, drift, and bleed-off. Drift occurs when water droplets exit the tower by air flow and represents from 0.05 to 0.2 percent of the system's flow rate (Bracciano, unpublished). Evaporation within the tower increases the concentration of dissolved solids; therefore, water from the tower is drained, or bled-off, to return the concentration to a safe and reasonable value.

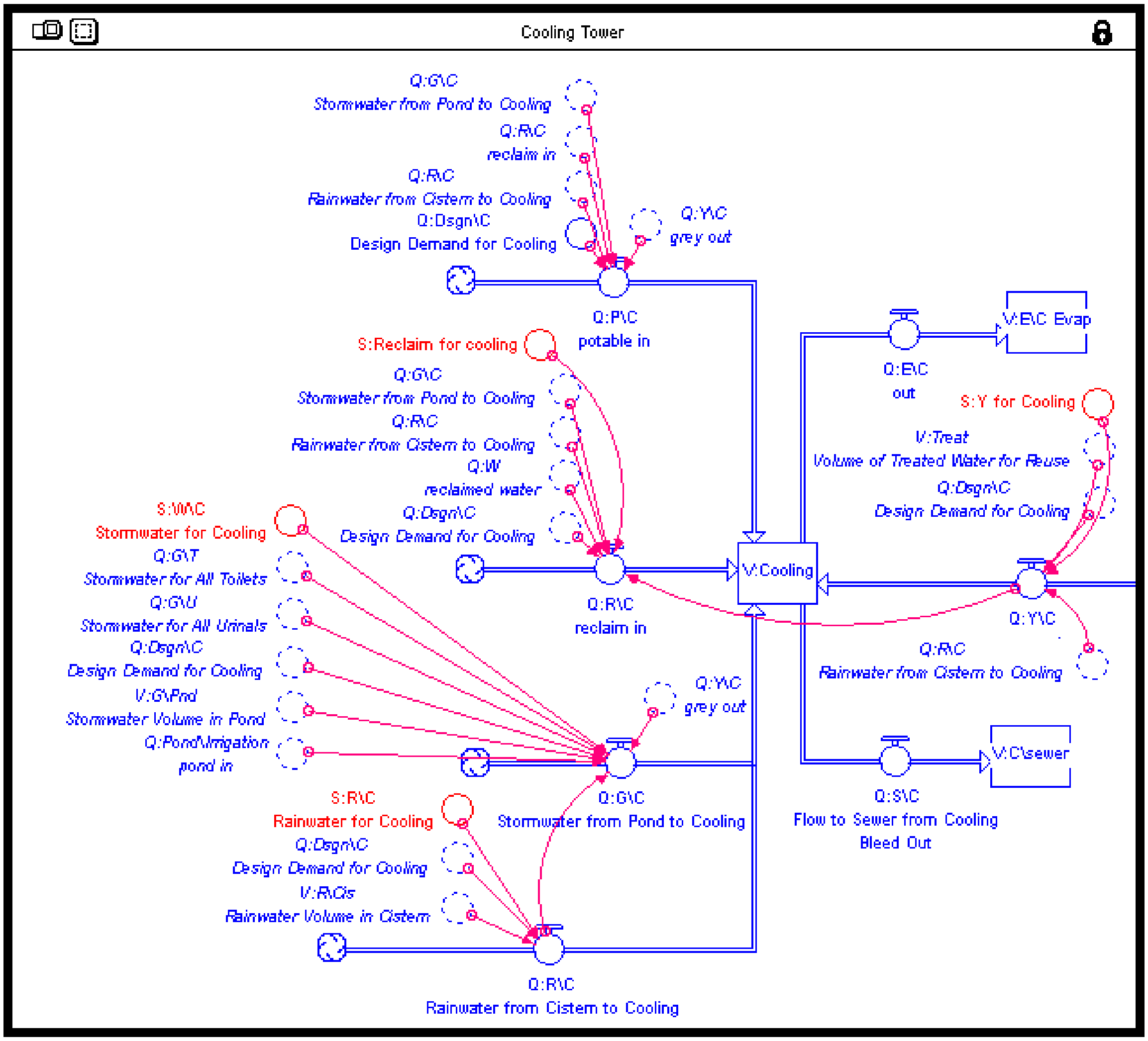


FIGURE 11: Detail model framework for rainwater collection.

Water lost in the cooling volume through evaporation and bleed out must be made up from other sources. As a result, the difference between all inflows and outflows is 0.

$$\Sigma Q\text{in} - \Sigma Q\text{out} = 0 \tag{51}$$

$$Q_P^C + Q_Y^C + Q_W^C + Q_R^C + Q_G^C - Q_S^C - Q_E^C \tag{52}$$

Q_P^C = Flow of potable water to cooling tower (gal/day)

Q_Y^C = Flow of treated greywater to cooling tower (gal/day)

Q_W^C = Flow of reclaimed water to cooling tower (gal/day)

Q_R^C= Flow of collected rainwater to cooling tower (gal/day)

Q_G^C = Flow of collected stormwater to cooling tower (gal/day)

Q_S^C = Flow to sewer from cooling tower as blowdown (gal/day)

Q_E^C = Flow of evaporation lost from cooling tower (gal/day)

The percent reduction in overall water needed for cooling is calculated using both the baseline and design cases. The percent reduction in potable water depends only on the potable water used for the baseline and design cases. The equations are:

$$P_{Tot}^{C}=\left(1-\frac{V_{Dsgn}^{C}}{V_{Base}^{C}}\right)\times 100 \tag{53}$$

$$P_{P(Tot)}^{C}=\left(1-\frac{V_{P(Dsgn)}^{C}}{V_{Base}^{C}}\right)\times 100 \tag{54}$$

P_{Tot}^C = Percent reduction in total water use for cooling (%)

$P_{P(Tot)}^C$ = Percent reduction in potable water use for cooling (%)

$V_{P(Dsgn)}^C$ = Volume of potable water used for cooling (gal)

Green Roof

A green roof, containing native and drought-tolerant landscaping, should only require natural rainfall for sustainable maintenance. Of this rainfall, between 70% and 90% is lost through evapotranspiration (ET) in the summer, 25% to 40% in the winter. The remainder can exit the subsystem as runoff which can be collected in a cistern for irrigation use. If the maximum volume of the cistern is exceeded, the excess flow is directed to the storm sewer.

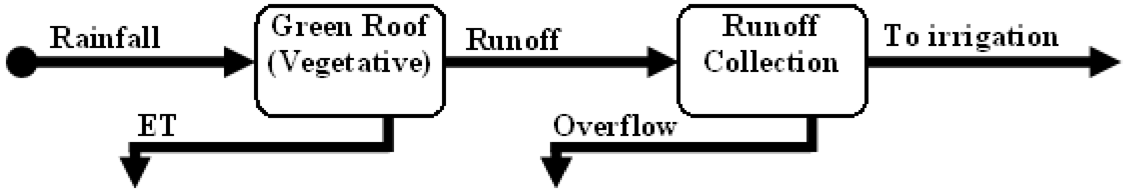


FIGURE 12: Sources and sinks for green roof.

If a green roof is implemented on the building and required irrigation, the demand can be included in the irrigation section of the IBWM with the other landscaping. Potential rainwater capture can be added to the rainwater collection sector of the model by implementing override values in the interface section.

Rainwater Collection

A rainwater collection system typically consists of a rain barrel or cistern to store water, a first flush system to prevent debris from entering the storage container, and piping to both collect and distribute the stored water. Systems often utilize roof areas and gutters for collection. Rainwater enters the storage unit from the collection area, and a portion of the rainwater volume is rejected in the first flush system prior to entering collection. If the maximum storage volume is exceeded, an overflow pipe directs excess water out of the collection system.

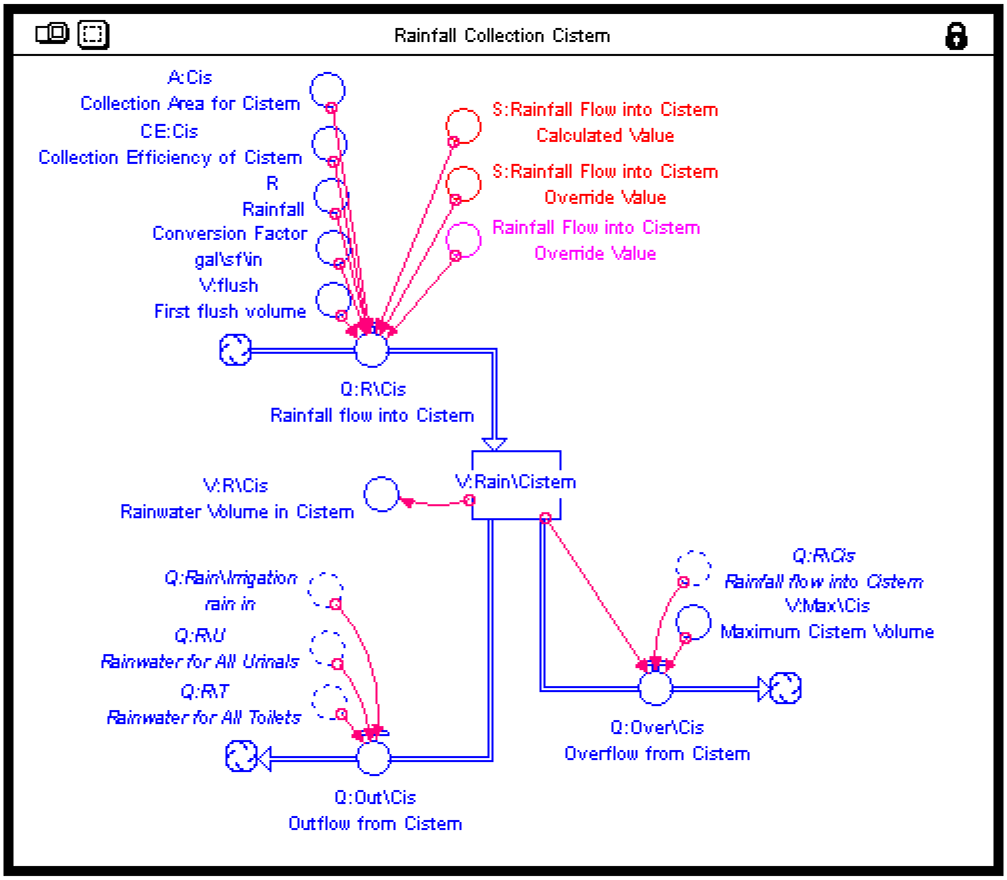


FIGURE 13: Detail model framework for rainwater collection.

For the rainwater collection system, the central collection volume can carry a storage volume. Therefore, the difference between all inflows and outflows is not necessarily 0. In this case, the difference in flows results in an accumulation of volume in the stock.

$$V_R^{Cis} = \int_0^t \left(Q_R^{Cis} - Q_{Out}^{Cis} - Q_{Over}^{Cis}\right) dt \qquad (55)$$

V_R^{Cis} = Volume of rainwater in the cistern (gal)

t = time period (days)

Q_R^{Cis} = Flow of rainwater into the cistern (gal/day)

Q_{out}^{Cis} = Flow of water out of the cistern to meet water demands (gal/day)

Q_{over}^{Cis} = Overflow from cistern (gal/day)

The amount of rainwater collected by the cistern depends on the rainfall, collection area, amount of water in the first flush, and the efficiency of the overall system:

$$Q_R^{Cis} = A^{Cis} \times R \times CE^{Cis} \times CF - V_{flush} \tag{56}$$

Q_R^{Cis} = Flow of rainfall into the cistern (gal/day)

A^{Cis} = Collection area for rainfall collection into the cistern (ft^2)

R = Rainfall (in)

CE^{Cis} = Collection efficiency of the cistern system (%)

CF = Conversion factor (0.6223 $gal/ft^2/in$)

V_{flush} = Volume of the first flush (gal)

Rainwater in the cistern can be used for cooling tower makeup water, toilet flushing, urinal flushing, or irrigation in the IBWM model.

Stormwater Collection

The stormwater collection system in the IBWM model has a similar setup as the rainwater collection system. Collected stormwater is directed to a storage pond and used to offset potable water use in the building system. Additional losses from the pond include evaporation and infiltration of stored water. If water entering the pond exceeds the maximum storage volume, excess water is directed to an overflow.

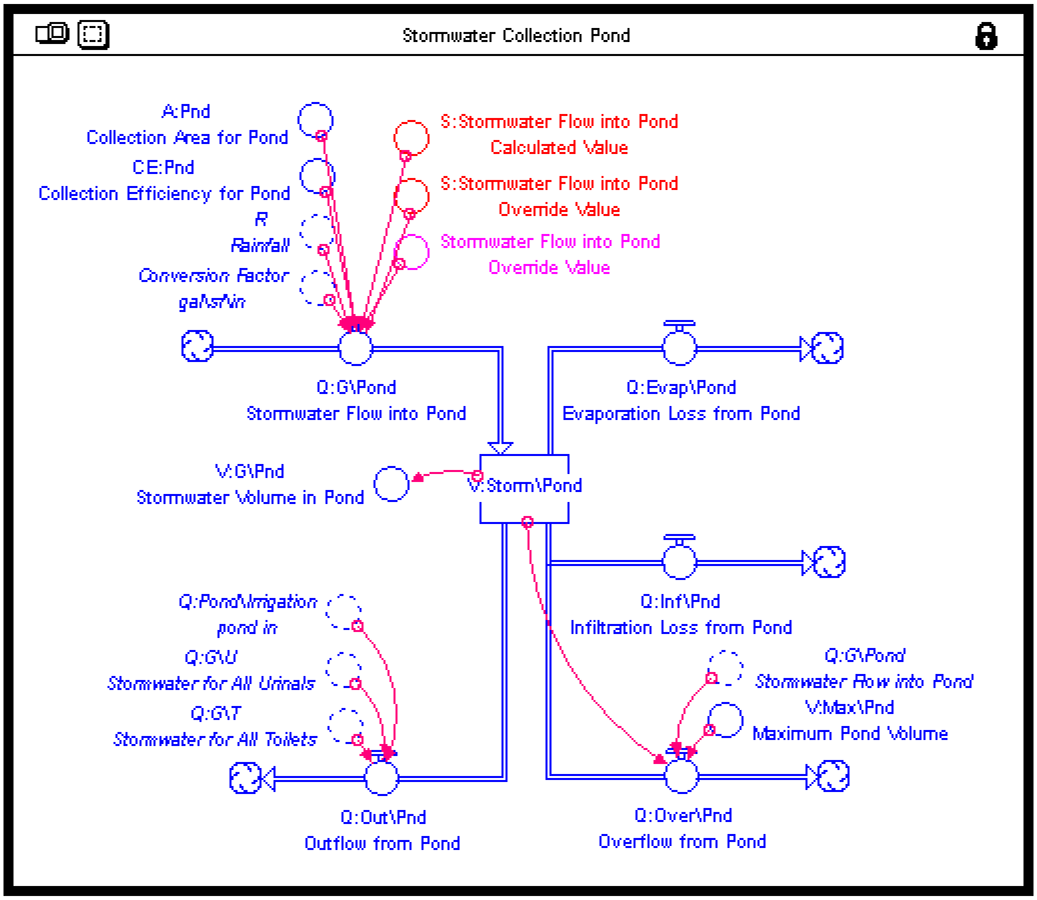


FIGURE 14: Detail model framework for stormwater collection.

The central collection volume in the stormwater sector can carry a storage volume. In this case, the difference in flows results in an accumulation of volume.

$$V_W^{Pnd} = \int_0^t \left(Q_W^{Pnd} - Q_{Out}^{Pnd} - Q_{Over}^{Pnd} - Q_E^{Pnd} - Q_{Inf}^{Pnd} \right) dt \qquad (57)$$

V_W^{Pnd} = Volume of stormwater in the pond (gal)

t = time period (days)

Q_W^{Pnd} = Flow of stormwater into the pond (gal/day)

Q_{out}^{Pnd} = Flow of water out of the pond to meet water demands (gal/day)

Q_{over}^{Pnd} = Overflow from pond (gal/day)

Q_E^{Pnd} = Evaporation loss from the pond (gal/day)

Q_{Inf}^{Pnd} = Infiltration loss from the pond (gal/day)

The amount of rainwater collected by the pond depends on the rainfall, collection area, and the efficiency of the overall system:

$$Q_W^{Pnd} = A^{Pnd} \times R \times CE^{Pnd} \times CF \qquad (58)$$

Q_W^{Pnd} = Flow of stormwater into the pond (gal/day)

A^{Pnd} = Collection area for stormwater collection into the pond (ft^2)

R = Rainfall (in)

CE^{Pnd} = Collection efficiency of the pond system (%)

CF = Conversion factor (0.6223 $gal/ft^2/in$)

Stormwater in the cistern can be used for cooling tower makeup water, toilet flushing, urinal flushing, or irrigation in the IBWM model.

CHAPTER 5:

MODEL SIMULATIONS

Assumptions

A sample run of the IBWM model for a hypothetical green office building in Tampa, FL was conducted using the following assumptions.

FTE

The full-time occupant equivalent (FTE) is calculated assuming that the office building employs 85 full-time workers and 30 part-time workers. The total FTE is calculated as 100.

TABLE 13: FTE calculations for sample model simulation.

Occupant Type	Number	Average Hours Worked per Day	Weight	FTE
Full-time	85	8	1.0	85
Part-time	30	4	0.5	15
Total	**115**			**100**

Irrigation

The assumptions for landscaping around the office building are given in Table 14 below. All landscape factors are assumed to be average values. Sprinklers are used to provide water to the plants, yielding an irrigation efficiency (IE) of 0.625. The water consumption required to irrigation incorporates the average evapotranspiration rate averaged from data collected for Odessa, FL from 2004 to 2006 (USGS, 2010).

TABLE 14: Irrigation parameters for sample model simulation.

Vegetation Type	**Area** (ft^2)	**Landscape Factors**			**IE**
		k_s	k_d	k_{mc}	
Trees	200	0.5	1.0	1.0	0.625
Shrubs	0	0.5	1.0	1.0	0.625
Groundcover	200	0.5	1.0	1.0	0.625
Mixed	150	0.5	1.0	1.0	0.625
Turfgrass	5000	0.5	1.0	1.0	0.625

Fixtures

The green office building contains toilets, urinals, bathroom sinks, kitchen sinks, and showers for employees. The baseline parameters for these fixtures are based on the LEED values and are provided in Table 15.

TABLE 15: Baseline fixture parameters for sample model simulation.

Fixture	**Volume or Flow Rate**	**Duration**	**Uses per Day**	
			Male	**Female**
Conventional toilet	1.6 gpf	n/a	1	3
Conventional urinal	1.0 gpf	n/a	2	0
Bathroom sink	2.5 gpm	15 sec	3	3
Kitchen sinks	2.5 gpm	15 sec	1	1
Shower	2.5 gpm	300 sec	0.05	0.05

Rainfall Collection

In this scenario, the feasibility of a rainwater collection system is being evaluated. The building has a total roof collection area of 10,000 square feet. The collection efficiency of the system is 90%, and the first flush volume is 5 gallons for every 500 square feet of catchment area. If all 10,000 square feet of catchment are utilized, the first flush volume is 100 gallons. The cistern volume can be varied. Daily rainfall values collected by a personal weather station in Lutz, FL (KFLLUTZ5) for 2009 were used for the simulations (Ferguson, 2010).

Wastewater Treatment

Another option available for the building is wastewater treatment and reuse. The wastewater reuse technology can store up to 5,000 gallons of water for use in the building. Water can be collected from sinks, showers, toilets, and urinals, and be used for irrigation or sewage conveyance.

Model Runs

The IBWM model was run using different scenarios. Each model run lasted a full year from June 1 to May 31. Percent reductions in both total water and potable water were determined from the LEED baseline case. The scenarios analyzed by this IBWM simulation are:

- Scenario 1: Conservation measures are in place. The building installs toilets that use 1.28 gpf, urinals that use 0.5 gpf, and sinks with 1.8 gpm flow rates.
- Scenario 2: The same conservation measures mentioned in Scenario 1 are in place, as well as low-flow showerheads that use 1.8 gpm. Aerators are installed on bathroom sinks to reduce the duration from 15 seconds to 12 seconds. Drip irrigation is installed for all landscaping, changing the irrigation efficiency from 0.625 to 0.90.
- Scenario 3: All conservation measures mentioned above are in place. Greywater from kitchen sinks, bathroom sinks, and showers are used to flush toilets.
- Scenario 4: All conservation measures are still in place. Greywater from kitchen sinks, bathroom sinks, and showers is used for flushing urinals first and then toilet flushing.
- Scenario 5: All conservation measures are in place. Greywater from kitchen sinks, bathroom sinks, and showers is used for irrigation.

- Scenario 6: All conservation measures are in place. Greywater from kitchen sinks, bathroom sinks, and showers is used for flushing urinals and toilets. Rainwater is collected in a 5000 gallon cistern for irrigation use.
- Scenario 7: Same as Scenario 6, but the cistern size is 1000 gallons.

The percent savings in total water consumption and percent savings in potable water consumption for each water sector are give in Tables 16 and 17, respectively. The overall total water savings and potable water savings for each scenario is presented in Figure 15.

TABLE 16: Percent savings in total water consumption for each water sector.

	Toilets	**Urinals**	**Bathroom Sinks**	**Kitchen Sinks**	**Showers**	**Irrigation**	**All**
Baseline	0	0	0	0	0	0	0
Scenario 1	20	50	28	28	0	0	16
Scenario 2	20	50	42	28	28	31	31
Scenario 3	20	50	42	28	28	31	31
Scenario 4	20	50	42	28	28	31	31
Scenario 5	20	50	42	28	28	31	31
Scenario 6	20	50	42	28	28	31	31
Scenario 7	20	50	42	28	28	31	31

TABLE 17: Percent savings in potable water consumption for each water sector.

	Toilets	**Urinals**	**Bathroom Sinks**	**Kitchen Sinks**	**Showers**	**Irrigation**	**All**
Baseline	0	0	0	0	0	0	0
Scenario 1	20	50	28	28	0	0	16
Scenario 2	20	50	42	28	28	31	31
Scenario 3	82	50	42	28	28	31	48
Scenario 4	20	100	42	28	28	31	48
Scenario 5	20	50	42	28	28	83	48
Scenario 6	66	100	42	28	28	99	74
Scenario 7	66	100	42	28	28	88	69

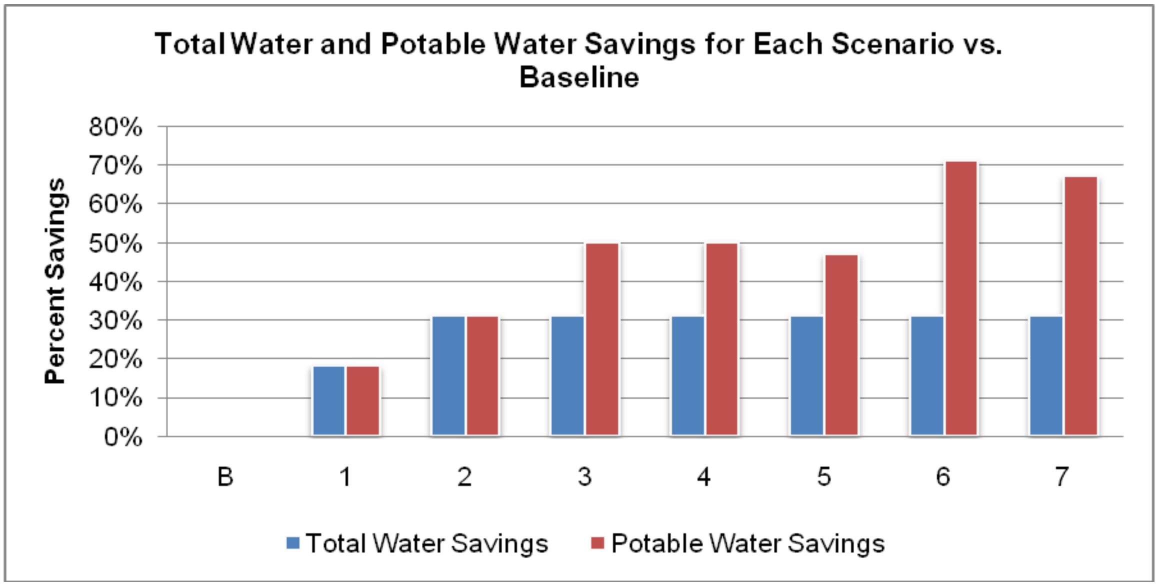


FIGURE 15: Overall total water and potable water savings for each simulation scenario.

The total water savings only depends on conservation measures taken in the building. The conservation measures in the form of low-flow fixtures are the same for scenarios 2 through 7, and these scenarios have the same percent savings in total water consumption. However, the implementation of alternative water sources changes the amount of potable water saved in each scenario. Simply changing the source of water to meet demand will not affect the overall amount of water savings; changing the water source substitutes potable water with an alternative point of supply.

The IBWM model differentiates between total water reduction and potable reduction and presents these values to the user. LEED currently awards points for reducing the use of potable water; however, future editions will address the reduction of total water demand. The IBWM model also provides users with a breakdown of where water is being used for the building site. This provides users with the ability to see which fixtures or water sectors are putting the most stress on the building's water cycle. Table 18 shows the percent of total water used by each fixture or irrigation output by the model. Again, scenarios 2 through 7 have the same values because water to meet demand is only being substituted; the amount of water still needed for each fixture does not change.

TABLE 18: Percent of total water going to each sector for simulation.

	Toilets	Urinals	Bathroom Sinks	Kitchen Sinks	Showers	Irrigation
Baseline	27.27	8.52	15.98	5.33	5.33	37.59
Scenario 1	25.87	5.05	13.64	4.55	6.32	44.58
Scenario 2	31.59	6.17	13.33	5.55	5.55	37.80
Scenario 3	31.59	6.17	13.33	5.55	5.55	37.80
Scenario 4	31.59	6.17	13.33	5.55	5.55	37.80
Scenario 5	31.59	6.17	13.33	5.55	5.55	37.80
Scenario 6	31.59	6.17	13.33	5.55	5.55	37.80
Scenario 7	31.59	6.17	13.33	5.55	5.55	37.80

Resolution

The IBWM model can show trends on an annual, monthly, or daily scale. Figure 16 plots the percent reduction in potable water consumption for the parameters set in scenario 7. The percent reductions shown are calculated as an annual average, monthly average, and daily average.

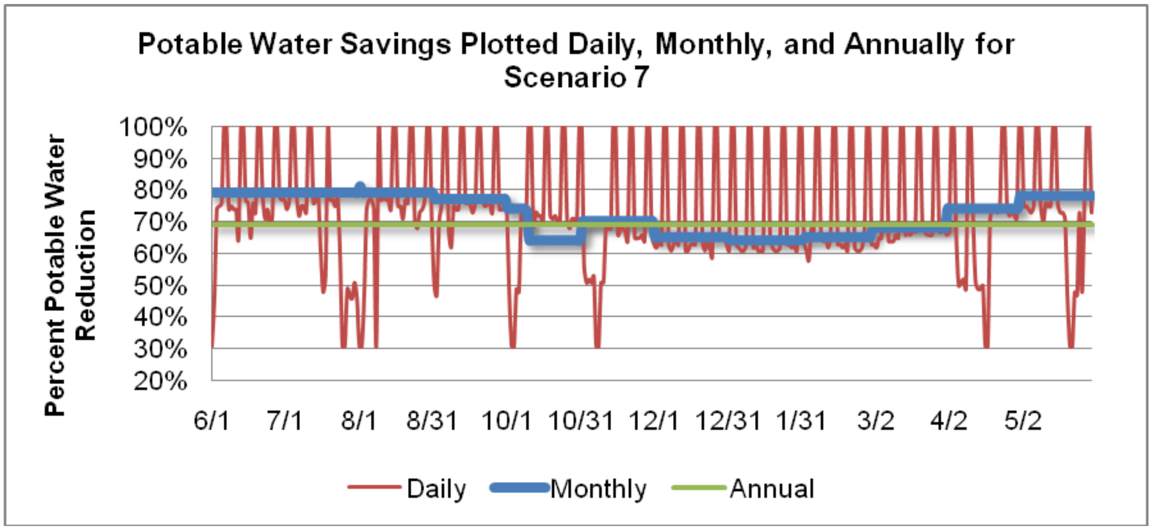


FIGURE 16: Potable water reduction for scenario 7 plotted annually, monthly, and daily.

The average annual potable water reduction for scenario 7 is 69%. The figure above shows that the percent savings by month and day varies due to the change in rainfall and evapotranspiration, the main variables affecting irrigation. The plot supports the LEED suggestion of analyzing water consumption over the entire year. However, providing resolution down to the monthly or daily level allows users to evaluate how the effects of water management are dynamic with respect to time. This also shows model users when an assumed water reduction is not being met.

Plotting daily water consumption captures trends such as workday consumption vs. weekday consumption, and seasonal changes for irrigation. Figure 17 presents the daily water consumption for irrigation, sewage conveyance, water fixtures, and the total building over the simulation year for scenario 7.

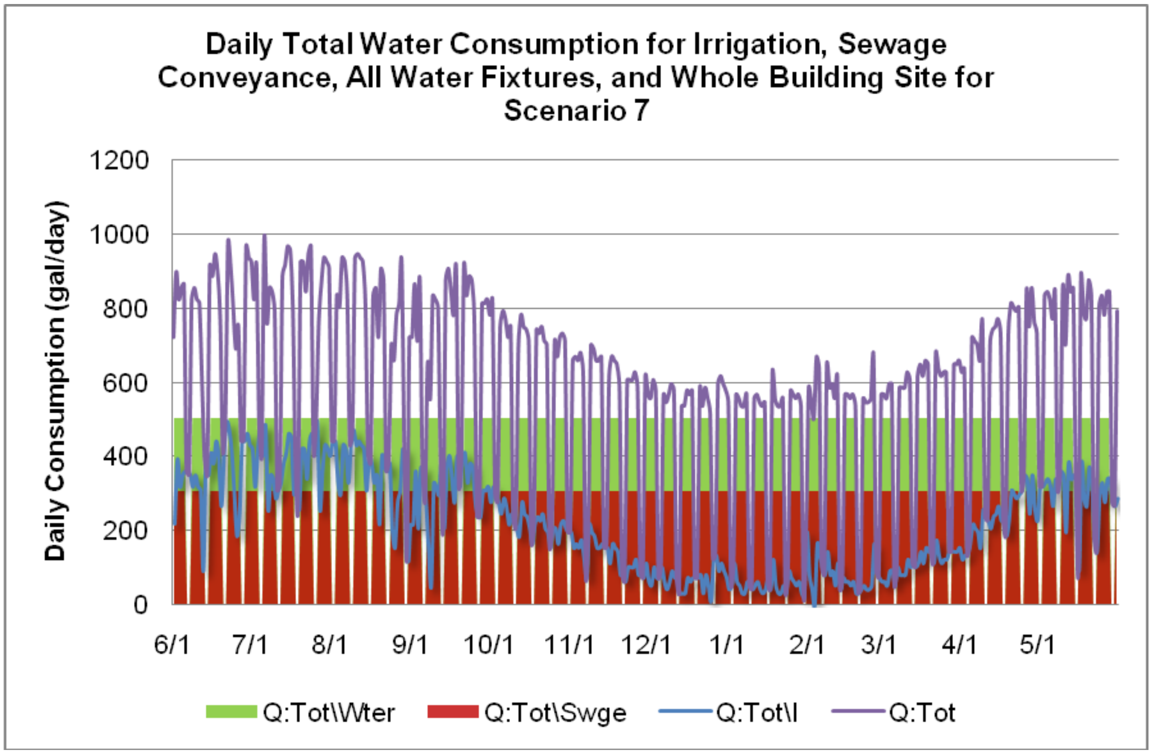


FIGURE 17: Daily water consumption breakdown for scenario 7.

The trends in interior versus exterior water consumption for the building are seen in the above figure. The colored bars represent interior water usage by building fixtures. Water consumption by all fixtures is around 504 gal/day (306 gal/day for toilets and urinals) when the building is occupied during the weekdays; interior consumption goes to zero during the weekends when the building is not occupied. Total water consumption for the site is the sum of the demand by all water fixtures and irrigation. The graph shows that irrigation drives the changes in overall demand; more water is consumed in the summer when irrigation demand is high, while less water is consumed in the winter when irrigation demand is low.

July Baseline Case

LEED calculations for water fixtures use an annual average; however, the landscaping portion of LEED NC allows projects to calculate potable water savings by using the month of July as the baseline. The underlying assumption is that evapotranspiration is highest in July; and therefore, the water required for irrigation will be the highest and will be harder to meet with alternative water sources. Figure 18 plots the amount of water required for irrigation based on the irrigation parameters given earlier in Table 14. Also graphed is the available rainwater for collection each month assuming a collection area of 2000 square feet. The rainwater and evapotranspiration values are average values for the Lutz, Florida area and are provided in Table 19.

TABLE 19: Rainfall and reference evapotranspiration (ET_0) used for Figure 18.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rain	2.92	2.08	1.80	3.59	3.36	5.40	8.59	5.98	4.98	2.34	1.02	1.82
ET_0	0.86	1.00	1.77	2.88	3.66	4.21	4.52	4.14	3.66	2.91	1.74	1.01

*Rainfall values are an average of KFLLUTZ5 data (2007-2009) and NWS normal values
*Reference ET values are an average of USGS data (2004-2006) for Odessa, FL

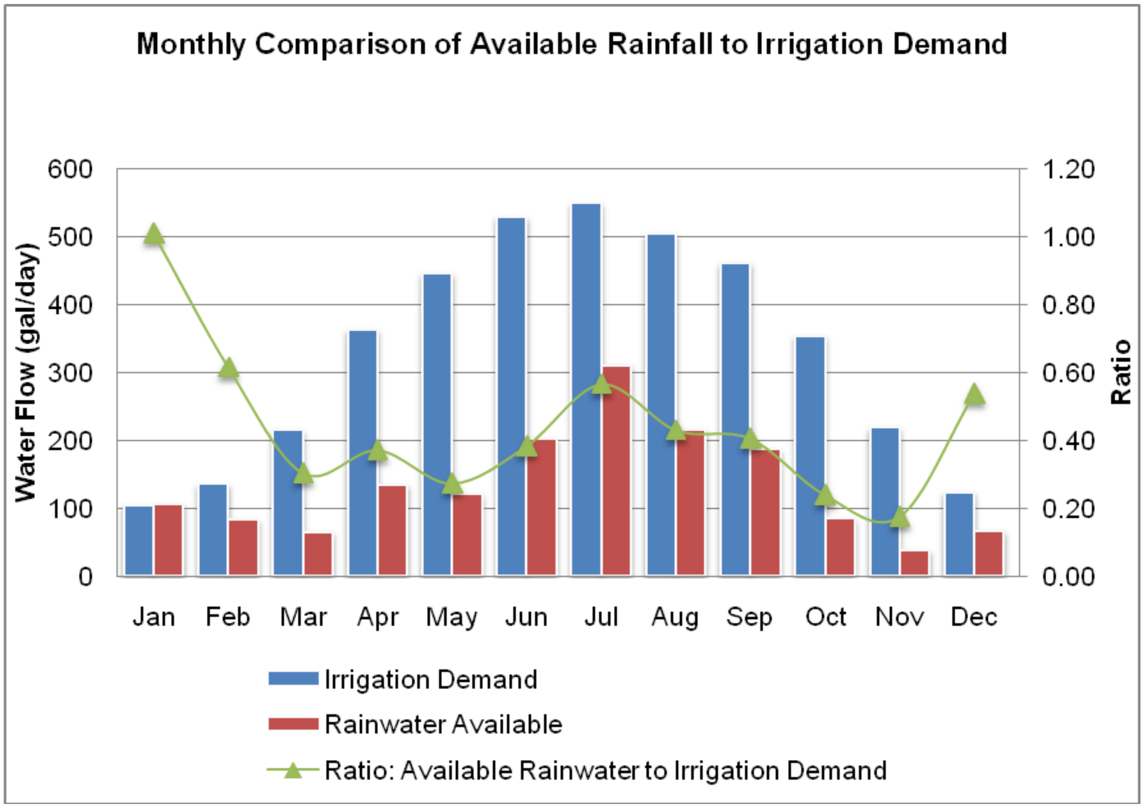


FIGURE 18: Monthly comparison of available rainfall to irrigation demand.

The triangles define the ratio of available rainwater to the irrigation demand for each month; higher ratios indicate that rainwater can meet more of the demand. If all rainwater is applied for irrigation, the ratio becomes the percent potable water savings.

November actually provides the worst-case month to offset potable water for landscaping because it has the lowest ratio of 0.17. Although July has the highest demand for irrigation, there is also a fair amount of rainfall available to offset potable water. The ratio for July is 0.56; if all rainwater is collected and applied to irrigation, 56% of potable water would be saved. However, the annual average ratio is 0.40 or 40% possible potable water savings. In this scenario, the July baseline assumption overestimates the potential potable water reduction by 16 percentage points.

TABLE 20: Irrigation demand, rainwater supply, and ratio of supply to demand.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Demand (gal/day)	104	135	215	362	445	528	549	503	460	353	218	123	**333**
Supply (gal/day)	105	83	65	134	121	202	310	216	186	84	38	66	**134**
Ratio (%)	100	61	30	37	27	38	56	43	40	24	17	54	**40**

The difference in this scenario affects Water Efficiency credit 1: Water Efficient Landscaping. The July baseline calculates a 56% potable water reduction, which would earn the project two points for exceeding the 50% reduction threshold. However, measuring the reduction over the year would show that the average savings of 40% does not meet the 50% goal. The end result is that the building is perceived as more water-efficient than it really is. Doing so not only overestimates water savings, but also the potential economic savings and payback associated with it.

CHAPTER 6:

LEARNING GATE COMMUNITY SCHOOL

Overview

Part of the Hillsborough County School District, Learning Gate Community School is an environmentally-themed K-8 charter school. The school began as a private institution in 1983 and was charted in 2000 with an approximate student body of 500. Their educational programs integrate the natural world into teaching activities and subjects. Learning Gate Community School is registered for LEED Platinum certification. Newly constructed modular buildings on the campus have achieved platinum certification in the LEED for Schools rating system.

Learning Gate provides an optimal test site for water budget analysis because of the extensive planning and technologic implementation exercised in order to preserve water on campus. To collect rainwater, there are two cisterns for the new buildings, totaling 10,000 gallons. Collected water from cisterns is used to flush toilets in the new buildings which are already plumbed for this purpose. The school is also investigating whether it is feasible to collect additional rainwater in two retention ponds located on the north side of the campus. Currently the ponds collect stormwater runoff for the school which quickly infiltrates and recharges the groundwater supply. Therefore, any retention attempt would require that the ponds be lined to halt the high infiltration that occurs naturally. Learning Gate intends to implement an on-site natural wastewater treatment system (Eco-Machine) where all wastewater generated on campus will be sent for treatment and reused to supplement the toilet-flushing need. Recycled water can also be used to supplement the campus demand or to sustain a fish or plant crop within the Eco-Machine. All the aforementioned technologies provide excellent educational opportunities for students to learn and be a part of the water treatment and reuse process.

The study area for this project consists of one newly constructed modular classroom building that contains a mix of fourth and fifth grade students. Each class has approximately 22 occupants, and the building contains two classrooms.

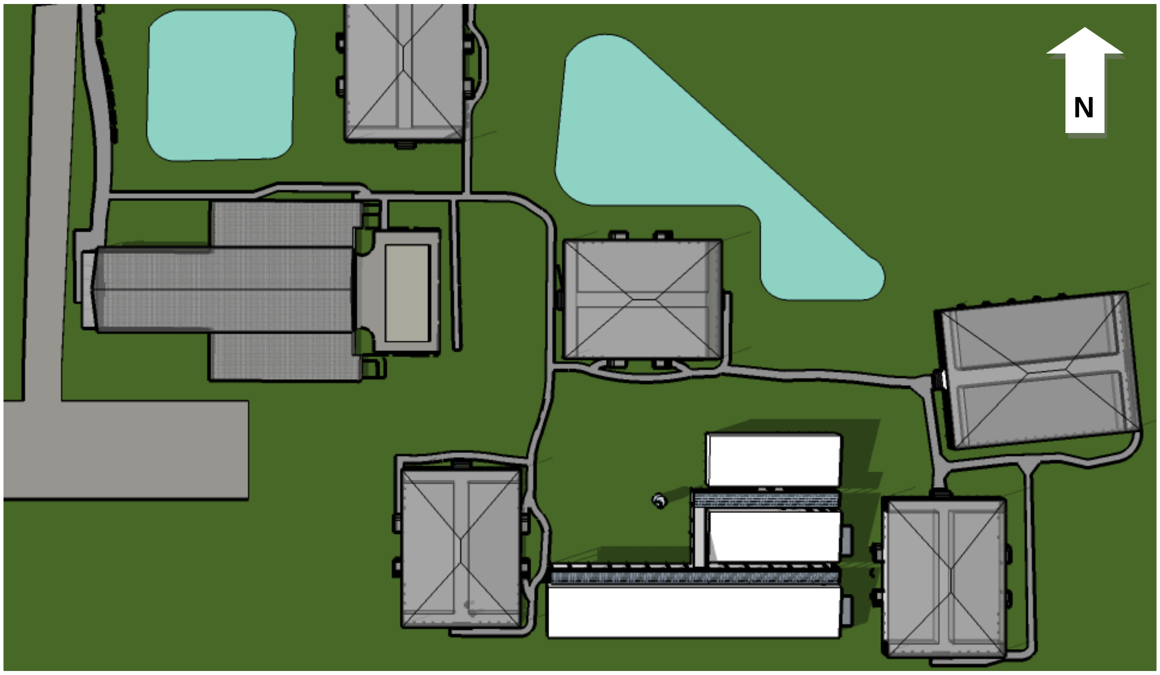


FIGURE 19: Aerial view of Learning Gate campus.

Wetlands area behind campus

Northwest stormwater pond

Decking made of recycled plastic

Munters air conditioning unit for green classrooms

Interior of green classroom

Vegetable garden on campus

FIGURE 20: Pictures of Learning Gate campus.

Rain barrels collecting condensate

Recycling bins

Compost bin on campus

Pervious parking outside the main building

FIGURE 21: Pictures of Learning Gate campus (cont.).

Rainwater Collection System

The newly constructed modular classrooms on the south side of the campus have low-flow toilets and sinks installed with automatic sensors. The automatic sensors are manufactured by Zurn and are battery-powered. Faucets can only be operated by tripping the sensor; however, toilets have a manual button in addition to the sensor.

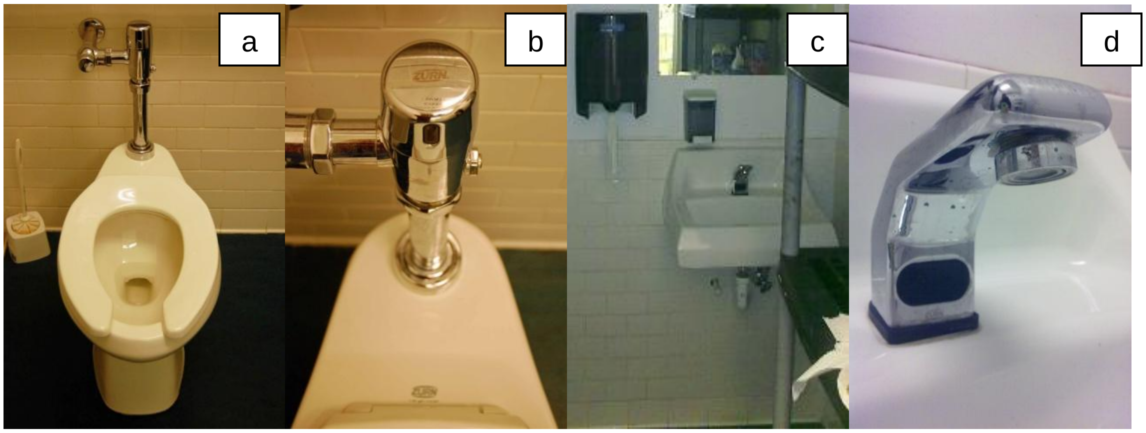


FIGURE 22: Photos of bathroom fixtures: (a) 1.28 gpf toilet, (b) detail view of sensor and manual button, (c) lavatory, and (d) detail view of faucet sensor.

Toilets utilize stored rainwater for flushing. Rainwater is directed to the gutter system by the angled roofs of the two smaller classroom buildings. Downspout pipes are covered with angled screens to keep debris from entering the storage bladders (10,000 gallon capacity) located under the classroom buildings, and water passing by chlorine tablets provides disinfection. A 600 gallon equalization tank provides rainwater to the toilets. In the event of decreased rainwater storage, potable water is added to the system from the school well. An overflow pipe releases excess water during high intensity rainfall events.

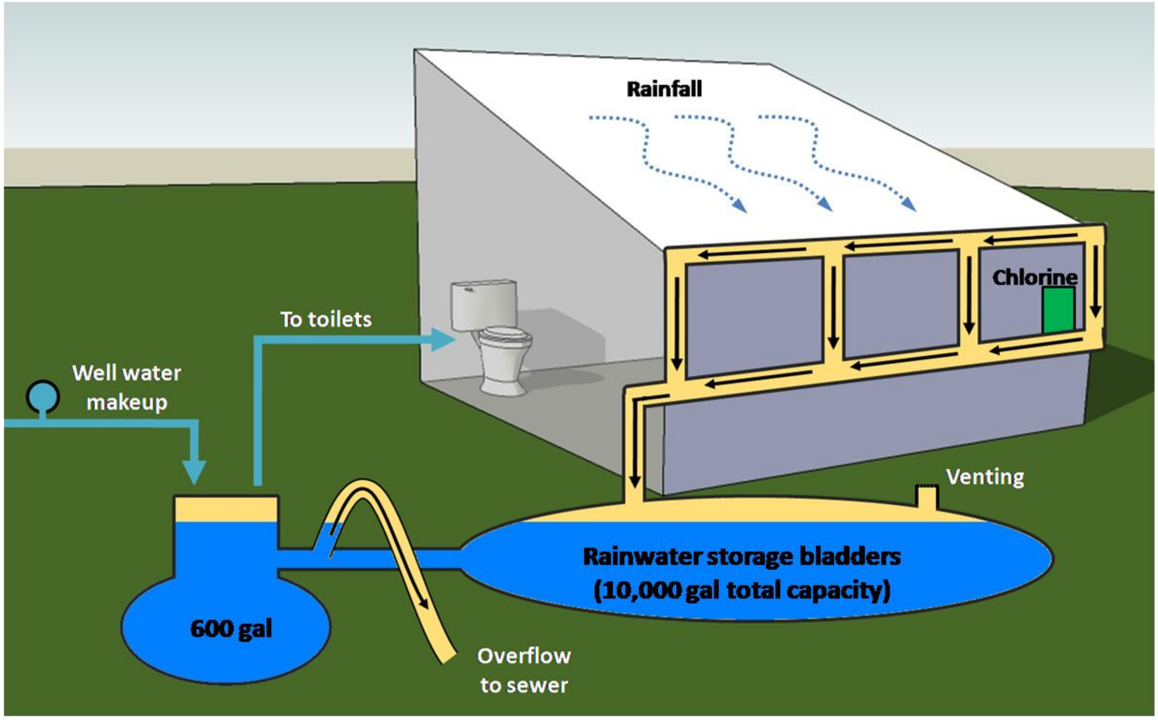


FIGURE 23: Overview of the rainwater collection system at Learning Gate.

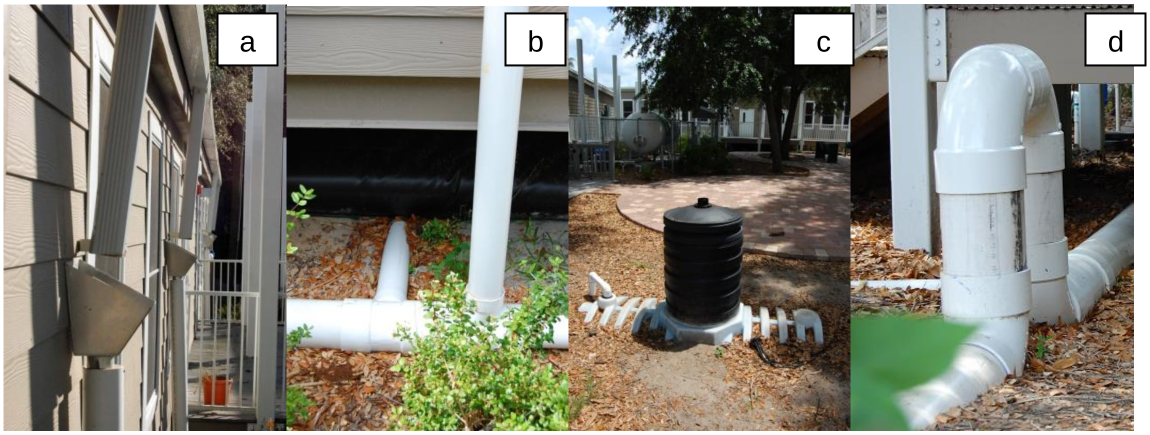


FIGURE 24: Photos of the rainwater collection system at Learning Gate: (a) gutter piping, (b) storage bladder beneath building, (c) equalization tank, and (d) overflow pipe.

Data Collection Equipment

In order to acquire data on water usage for model calibration, sensors were installed on water lines in two of the LEED certified modular buildings. Each building is approximately 1910 square feet (27.3’ x 70’) and contains two classrooms with two bathrooms in between them. Each bathroom contains one toilet and one sink.

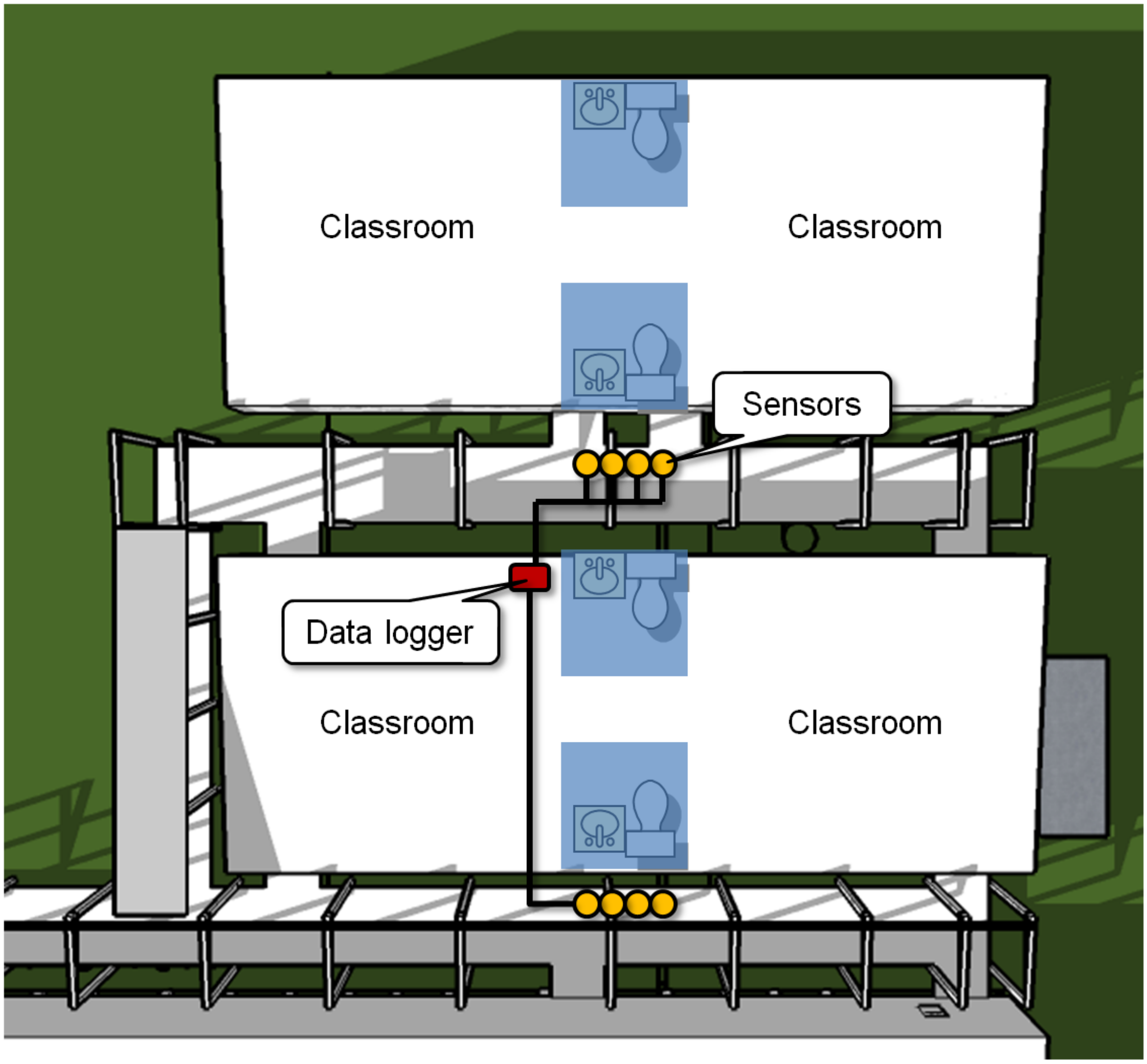


FIGURE 25: Aerial view of classrooms and sensor equipment location.

The water line to each toilet has a 1” diameter, and the water line to the sinks has a ¾” diameter. Each pipe was fitted for a paddlewheel flow sensor (FPB151 series 4-20 mA polypropylene sensor from Omega Engineering, Inc.). Each sensor was calibrated and programmed to the conditions listed in Table 21.

TABLE 21: Parameters for installed sensors.

Sensor Location	**Pipe Diameter**	**Flow Units**	**K-Factor**	**Output Signal**		**Avg.**	**Sens.**
				4 mA	**20 mA**		
Toilet line	1”	gpm	352.44	0 gpm	15 gpm	0	0
Sink line	¾”	gpm	545.14	0 gpm	10 gpm	0	0

All sensors are programmed so that output amperage values are related to water flow in gallons per minute (gpm). An output of 4 mA corresponds to a flow rate of 0 gpm. For toilets, an output of 20 mA corresponds to a flow rate of 15 gpm. For sinks, an output of 20 mA corresponds to a flow rate of 10 gpm. The relationship between output amperage and flow rate is linear. The K-factor defines the number of pulses per volume unit. The K-factors are 352.44 pulses per gallon for the toilet sensors and 545.14 pulses per gallons for the sink sensors as defined by tables supplied by the sensor manufacturer. Both averaging and sensitivity values are set to 0 so that data is collected as it happens and without bias.

FIGURE 26: Installed water sensors under decking.

Sensors are hardwired to the HOBO U30-ETH Ethernet communications data logger (from the Onset Computer Corporation). Four 24 V direct current (DC) power supplies provide power to all eight sensors; two sensors share each power supply.

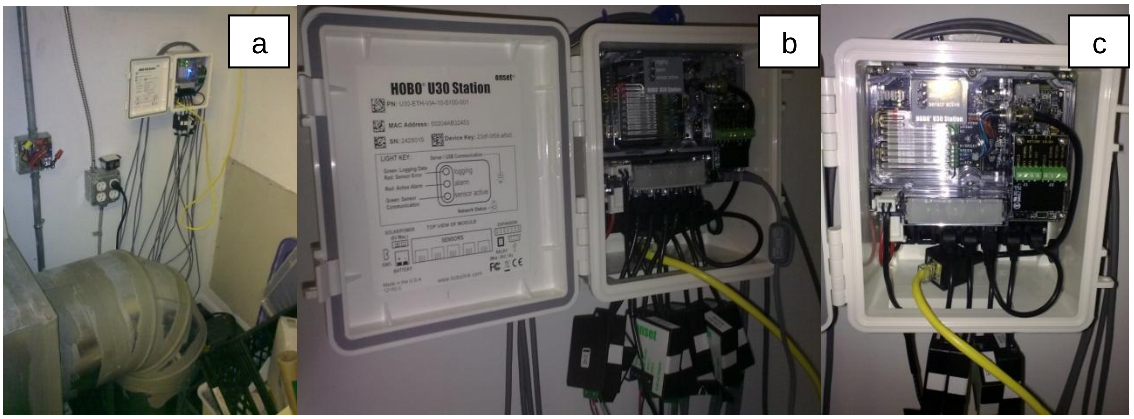


FIGURE 27: HOBO data logger: (a) location in classroom closet, (b) sensor connections, and (c) detail inside view.

Data is logged at an interval of once every second through an ethernet connection at Learning Gate and saved to the Onset-hosted webserver HOBOlink.com. The public link for this project can be found at: https://www.hobolink.com/p/d2199c59fe86b5f1e570197760be4b5e.

Learning Gate Data

Resolution of Data

Raw data from the HOBO data logger is given as a flow rate logged at each second. From this data, the volume of each fixture usage event and the time at which it occurred can be determined. The resolution provides insight into individual usage patterns for students within the classrooms.

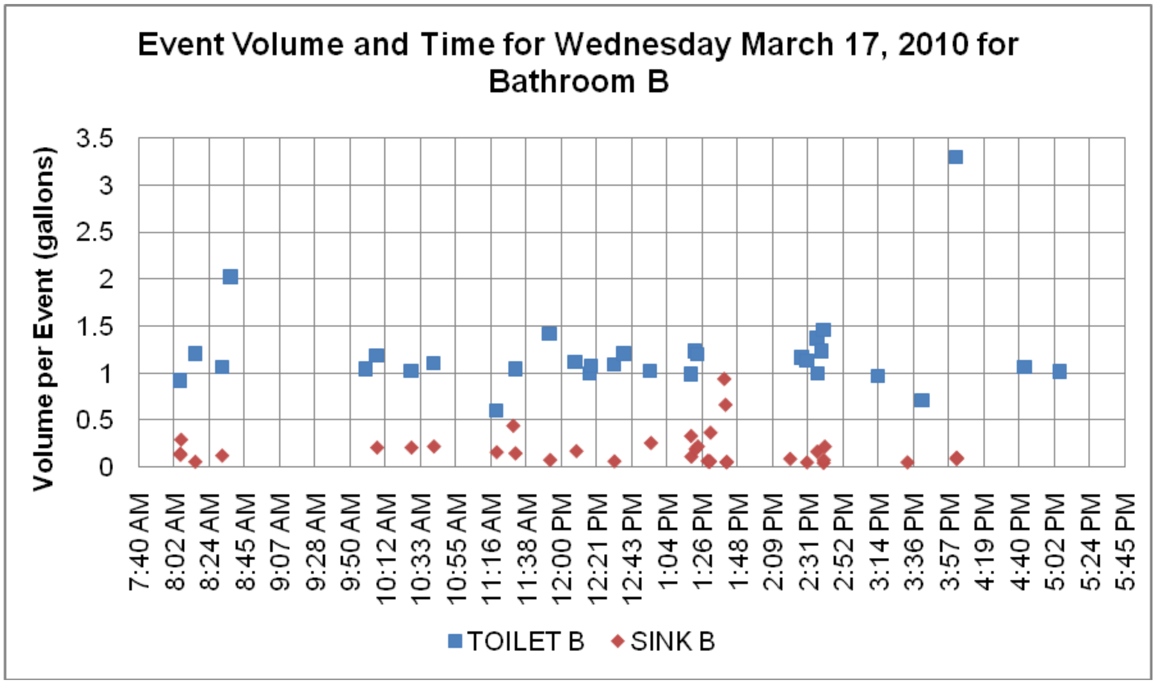


FIGURE 28: Event volume and time of event for bathroom B (3/17/10).

The figure above shows the compiled data for one bathroom during one day. Each square represents the volume for each toilet use at a specific time, and each diamond represents the volume for each bathroom sink use. Bathroom sink applications generally occur right after toilet uses. Bathroom activity can be split into morning, midday, and afternoon sections. Morning use is clustered around the beginning of the school day as students arrive to class. The highest period of usage is between 10:00 AM and 1:30 PM and coincides with the period before, during, and right after lunch. The third cluster of activity is seen at the end of the school day when students are released from class.

Utilizing the detailed data for both bathrooms on the same day provides an estimation of the number of fixture uses per event. The assumption is that one toilet flush and one sink use occurs for each trip to the bathroom or event. However, in reality the number of times a fixture is used during one event can be greater than once, as seen in the data compiled in Table 22.

TABLE 22: Statistical values for the number of times each fixture is used per event.

	Mean	**Median**	**Minimum**	**Maximum**	**Std. Dev.**	**Events**
Toilet Uses	1.1	1	1	2	0.27	78
Sink Uses	1.6	1	1	6	1.05	81

*Data is from both bathroom A and bathroom B on 3/17/10.

Clustered uses were assumed to be part of a larger event. Toilets were generally flushed once per visit, although some events contained two separate flush events. Multiple sink uses per visit were more common due to the automated faucet sensor. Removing hands from under the faucet causes the water flow to cease until tripped again.

Since the beginning and end date for each event is logged, the duration and flow rate for the sinks can be estimated. Table 23 includes the average event duration and flow rate for bathroom sinks from 163 events. Distribution curves are provided in Figures 29 and 30.

TABLE 23: Statistical values for sink flow rate and duration per event.

	Mean	**Median**	**Minimum**	**Maximum**	**Std. Dev.**	**Events**
Flow rate (gpm)	1.07	1.08	0.443	1.75	0.333	163
Duration (sec)	12	10	4.0	51	7.74	163

*Data is from both bathroom A and bathroom B on 3/17/10.

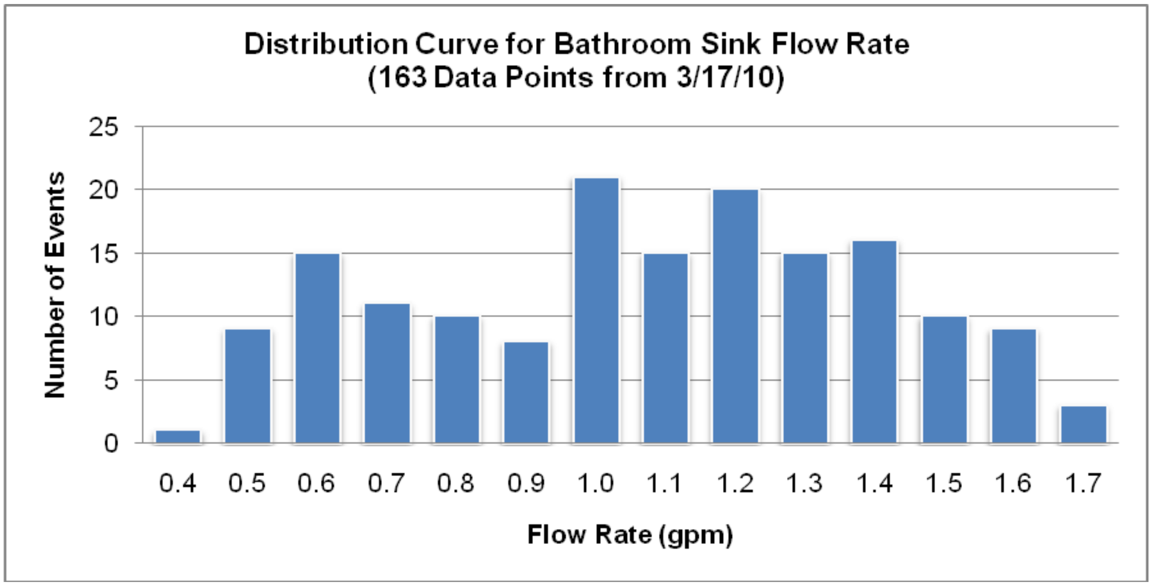


FIGURE 29: Distribution curve for bathroom sink flow rates (3/17/10).

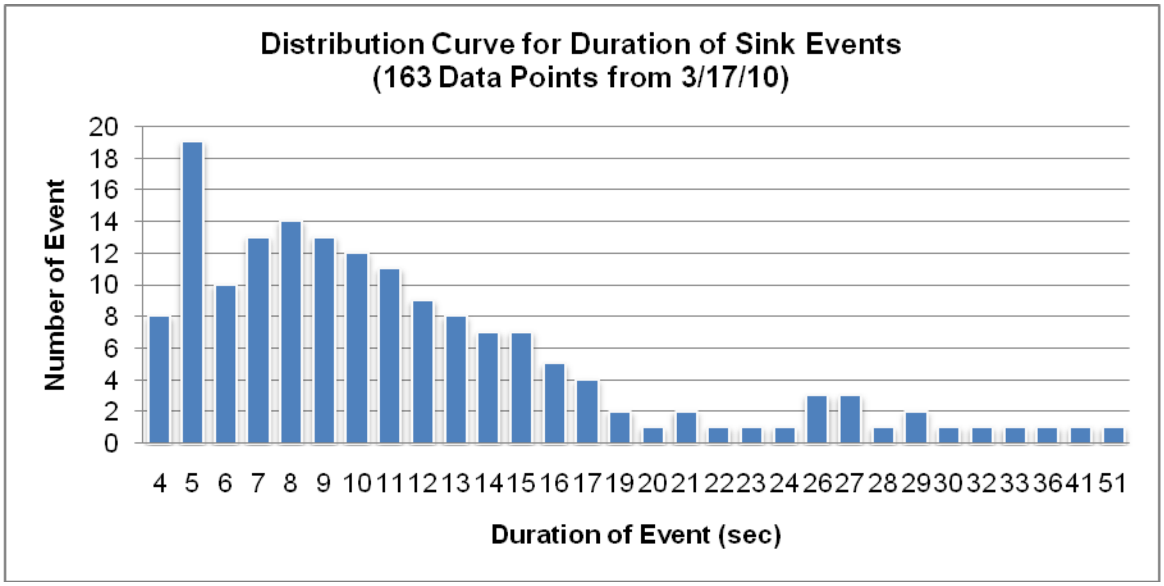


FIGURE 30: Distribution curve for bathroom sink duration (3/17/10).

Without the high resolution from the sensors and logger, information on usage within the individual event context would not be possible.

Fixture Data

Data collected over multiple days provides an improved picture of water usage in the classrooms. The distribution of event volumes for both toilets and bathroom sinks is shown in Figures 31 and 32. Both figures include fixture events from February 18, 2010 through May 10, 2010. Events less than 0.05 gallons assumed to be a result of interference from the sensors and were omitted from the data set.

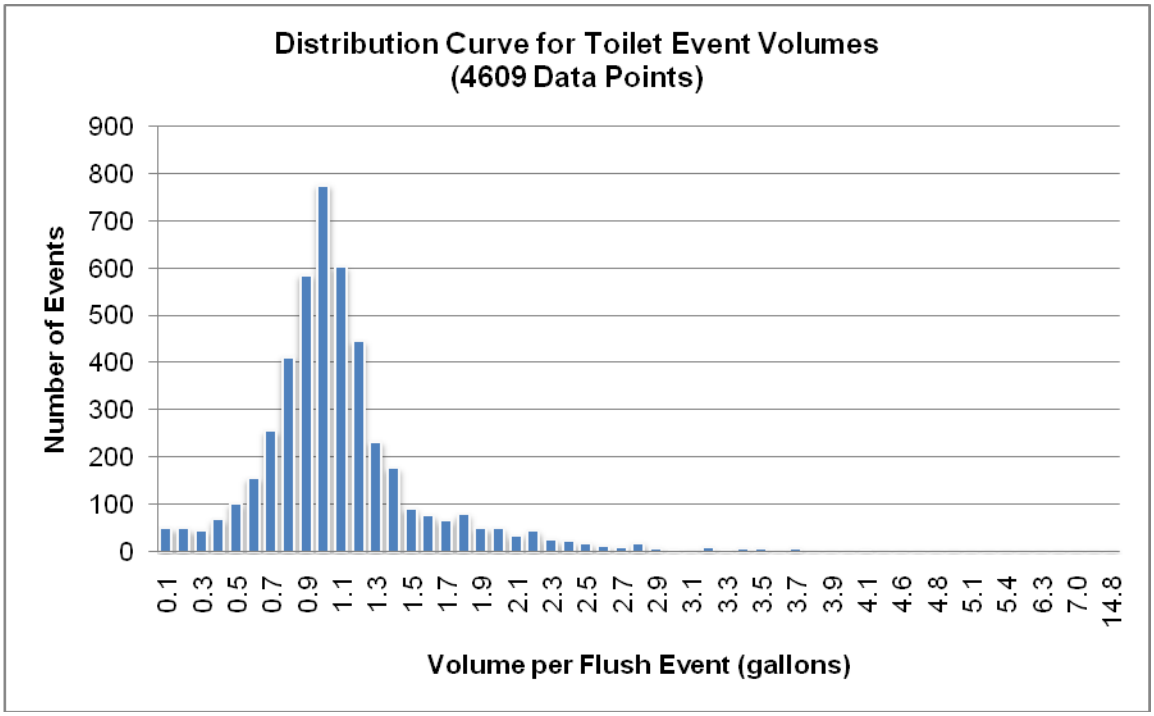


FIGURE 31: Distribution curve for toilet event volumes from 2/18/10 to 5/10/10.

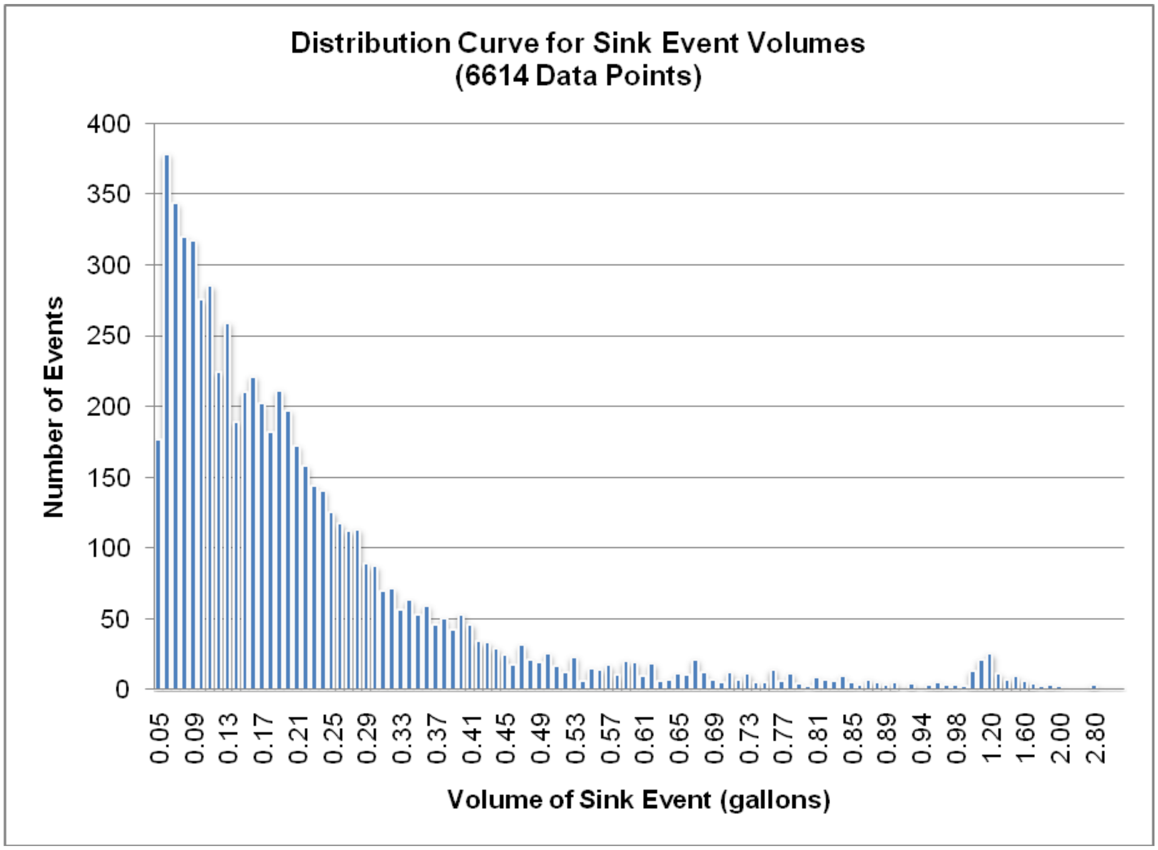


FIGURE 32: Distribution curve for sink event volumes from 2/18/10 to 5/10/10.

Event volumes for each toilet use follow a normal distribution curve. The average volume per flush of 1.12 gpf is less than the rated 1.28 gpf of the toilet fixtures, but within the 0.61 gpf standard deviation. The average volume for each sink use is 0.23 gallons with a standard deviation of 0.24 gallons. The resulting curve does not follow a normal distribution. However, previous distribution curves for sink duration and flow rate have trends closer to that of a normalized curve.

From the same data set, the number of times each fixture is used can be calculated. Table 24 shows the average number of uses per day for toilets and sinks.

TABLE 24: Fixture uses per day from 2/17/10 through 5/10/10 for weekdays only.

	Toilets			Sinks		
	A	B	All	A	B	All
Mean	25.8	33.2	29.5	55.3	30.8	43.1
Median	24.0	33.5	29.0	48.5	29	38.5
Minimum	5.0	17	5.0	23	5.0	5.0
Maximum	57	60	60	147	96	147
Std. Dev.	9.6	7.4	9.3	26.6	15.3	24.9
Count	52	52	104	52	52	104

Data on fixture uses per day changed dramatically from day to day. During the 52 weekdays evaluated, uses for toilets ranged from 5 to 60 per day, and uses for sinks ranged from 5 to 147 per day. No trend between number of fixture uses and day of the week was observed for weekdays.

Table 25 shows the average number of uses per day per person for each fixture assuming that the study building has 44 occupants.

TABLE 25: Fixture use per student per day for weekdays (2/17/10 - 5/10/10).

Fixture	Mean	Median	Minimum	Maximum	Std. Dev.	Count
Toilets	1.34	1.32	0.73	2.66	0.349	52
Sinks	1.96	1.76	0.86	4.36	0.738	52

Like the overall uses per day, the number of uses per student per day contained a relative range of values. The LEED assumption that students use each fixture (toilet and bathroom sink) three times per day is higher than the values calculated in this study.

Interpretation of Data

The data on fixture water use from the Learning Gate bathrooms shows a range of values as seen in the distribution curves. Factors such as equipment calibration, programmed time steps for data collection, and how each fixture is activated result in a series of observed numbers that do not match up to the expected values.

The calculated flow rate for the bathroom sinks is calculated by dividing the total volume for each sink event by the duration. The HOBO data logger is able to take a reading once every second; however, a sink may be activated or deactivated anywhere within that second. For an average duration length of 12 seconds, this provides decent room for error, as the duration may be underestimated by up to one second or overestimated up to one second, causing the flow rate to follow the same trend. The flow rate should be standard for each sink because they are automated, and individuals do not have control of the faucet. On the other hand, duration is expected to vary because it depends on how long an individual holds their hand over the sensor to prolong activation.

The data collected on the volume per flush for toilets was unexpected. The expected value from the toilet manufacturer is 1.28 gpf. Although the average is slightly less at 1.12 gpf, events were observed from 0.1 gpf up to 14.8 gpf. Like the sinks, it is possible that the data logger does not capture the entire event with a resolution of one data point per second. However, this would not cause the drastic range of values. Also like the sinks, the toilets contain an automated feature; and it was assumed that this would result in a more uniform flush volume. The culprit behind the erratic flush volume can be traced back to the manual button provided on each toilet. By overriding the automatic flush mechanism by utilizing the manual button, various flush volumes occur. Figure 33 shows the effect of the manual button on flush volumes when different forces are applied to the button.

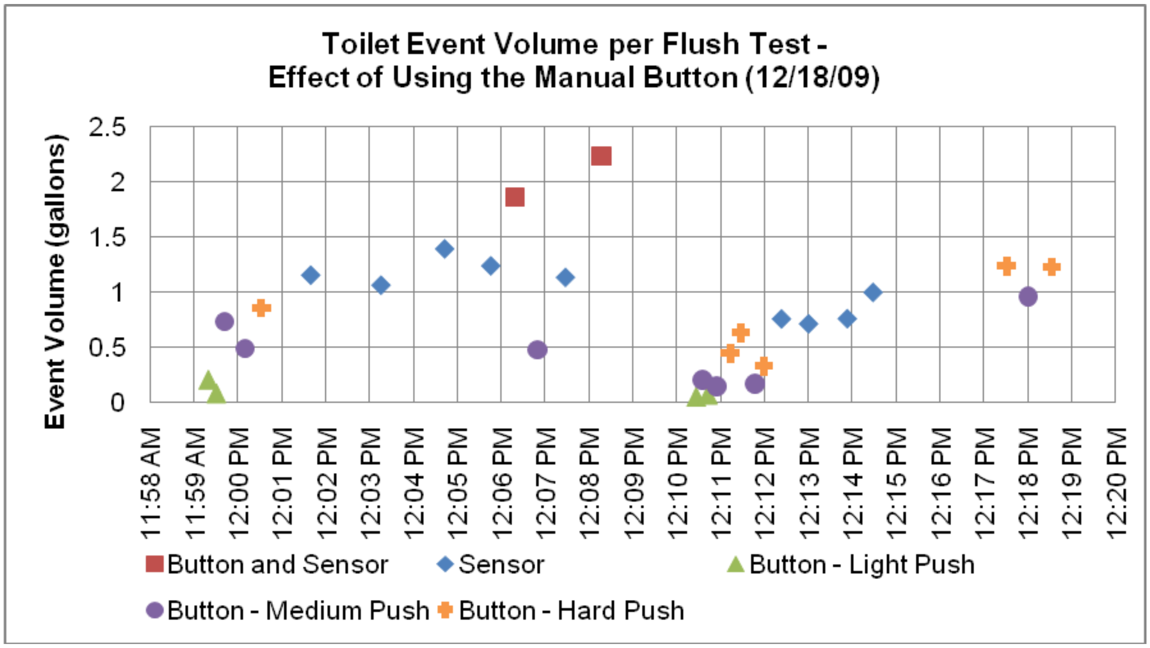
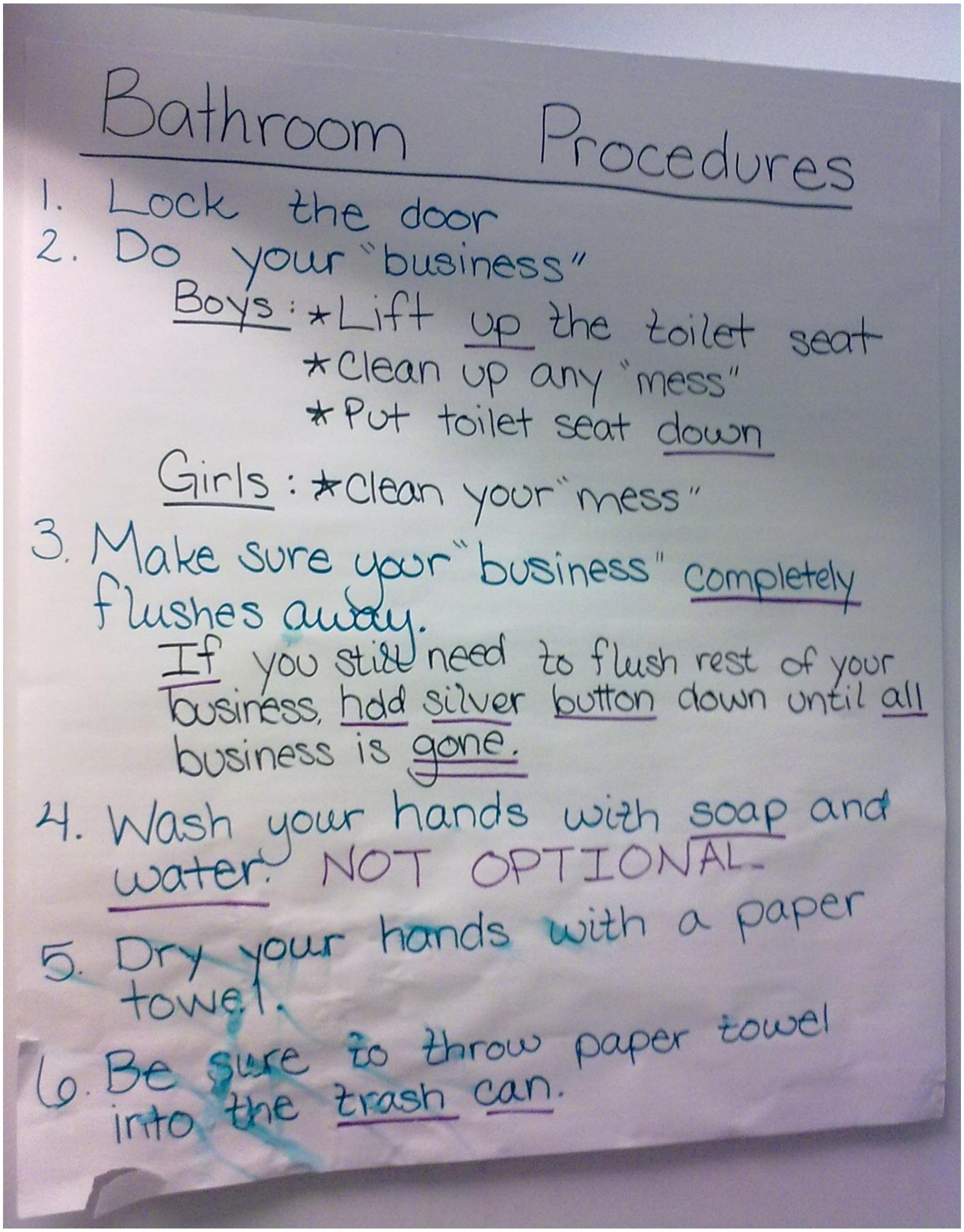


FIGURE 33: Effect of using the manual flush button on toilet flush volumes.

The test shows that using the manual flush button can create a flush volume of nearly any value. Pushing the button lightly resulted in some flushes being near the lower-end threshold of 0.05 gallons, whereas holding the manual button down can result in an infinite flush volume as water continues to flow until the button is released. This can explain the 14.8 gpf event observed in the data. The test also showed that there is a delay between the time the automatic sensor is tripped and the time the toilet is flushed, which makes it possible for a user to press the manual button thinking the sensor has not been activated. Doing this can cause a double flush; the sensor activates a new flush while the one activated by the manual button is still occurring. The resulting value is higher than that of a normal automated flush volume.

Evidence that students are using the manual button over the automated flush system was found on one of the bathroom doors (Figure 34). Students are encouraged to hold the button down to clear the toilet.



Bathroom Procedures

1. Lock the door
2. Do your "business"

Boys: *Lift up the toilet seat
*Clean up any "mess"
*Put toilet seat down

Girls: *Clean your "mess"

3. Make sure your "business" completely flushes away.

If you still need to flush rest of your business, hold silver button down until all business is gone.

4. Wash your hands with soap and water. NOT OPTIONAL.
5. Dry your hands with a paper towel.
6. Be sure to throw paper towel into the trash can.

FIGURE 34: Bathroom procedures posted on bathroom door.

LG STELLA Model

The IBWM model utilizing the STELLA software is set up to represent the study classroom building. Toilets and bathroom sinks are the only fixtures included in the water budget. Sources of water used to meet these demands come from collected rainwater or potable water from the on-site well. The duration of each model run is for an entire year starting July 1 and ending June 30.

The STELLA model has a built-in Monte Carlo Simulation function that allows users to input average values and their corresponding standard deviations to create random runs. Using the parameters listed in Table 26, the Learning Gate IBWM model was run 4000 times to produce the distribution of annual water demand values plotted in Figure 35.

TABLE 26: Parameters used in the STELLA runs for water demand in study building.

	Toilets		**Sinks**		
	Volume per Event (gpf)	**Uses per Student per Day**	**Flow Rate (gpm)**	**Uses per Student per Day**	**Duration (sec)**
Mean	1.12	1.34	1.07	1.96	12
Std. dev.	0.611	0.349	0.333	0.738	7.74

The large standard deviation values for the bathroom sink duration per event, number of sink uses per student per day, and toilet volume per flush caused some values chosen in the random STELLA drawing to be negative. As a result, the annual water demand was calculated as zero for 70 out of 4000 runs. This indicates that the additional data on the variables in Table 26 should be analyzed to evaluate whether the range of values for each parameter can be minimized.

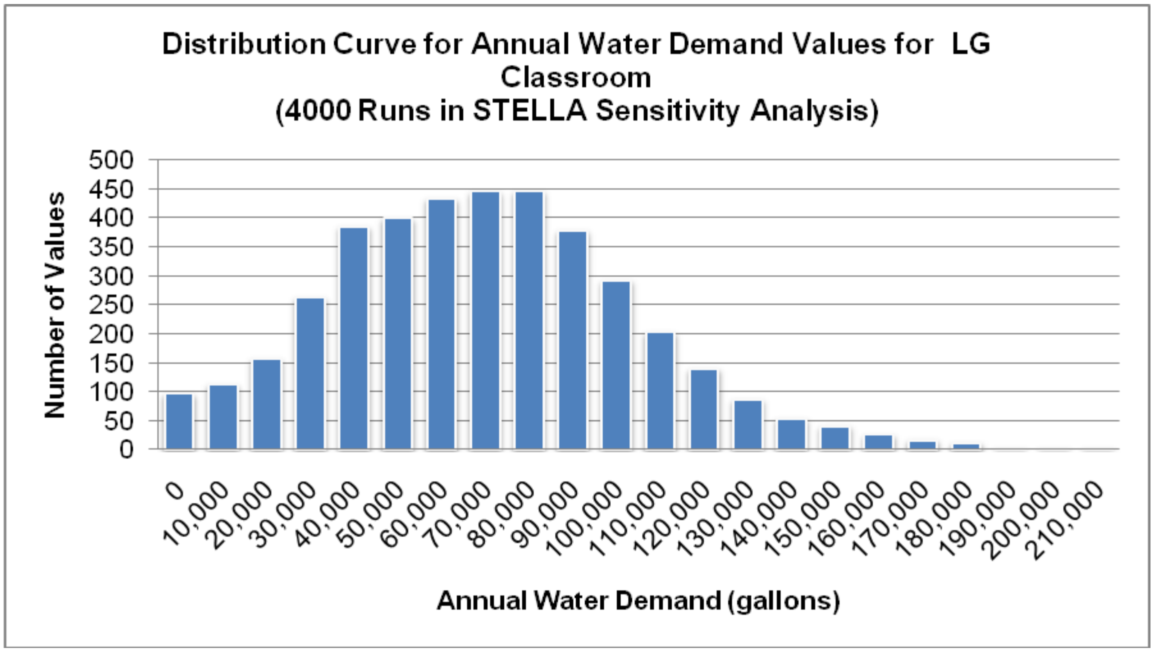


FIGURE 35: Distribution curve for the annual water demand for the Learning Gate classroom study.

For the distribution curve above, the average annual water demand is approximately 69,600 gallons for the classroom building. The average annual water demand is approximately 70,800 gallons if the 70 events with no demand listed are omitted.

The STELLA software also has the ability to create a distribution for the possible water supply. For the Learning Gate classroom scenario, the total rainfall available for collection was determined from 4000 runs. The average rainfall value was calculated from three years of measured data (KFLLUTZ 2007-2009) for Lutz, FL and the normal values from the National Weather Service. These values are shown in Table 27.

TABLE 27: Annual rainfall for Lutz, Florida.

	2007[1]	**2008**[1]	**2009**[1]	**Weather**[2]	**Mean**
Rainfall (in)	36.67	42.64	51.39	44.77	43.87

[1] Annual rainfall compiled from KFLLUTZ5.
[2] Annual average rainfall from NWS.

The mean value for the data in the previous table is 43.87 inches with a standard deviation of 6.07 inches. These values were used to create the distribution curve in Figure 36 for the rainfall available for collection from the classroom building, assuming a 90% collection efficiency and roof collection area of 1910 square feet.

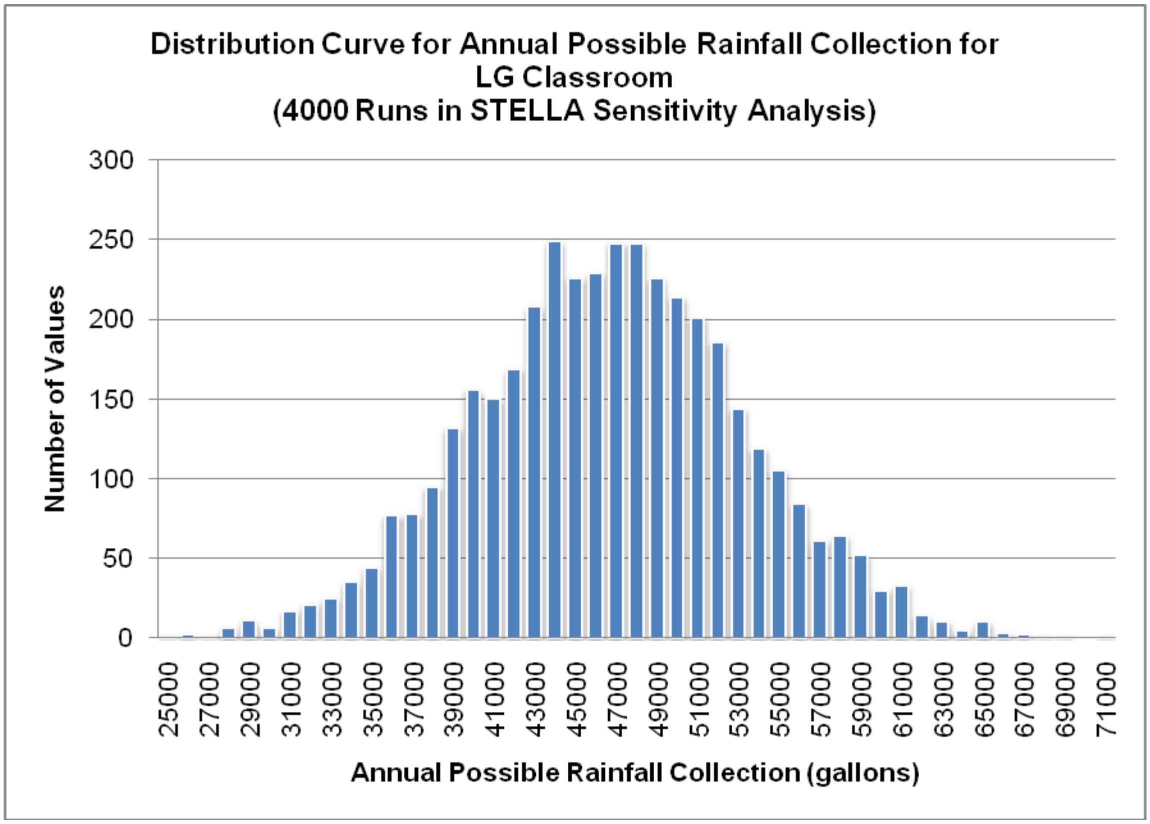


FIGURE 36: Distribution curve for the annual water supply for the Learning Gate classroom study.

The average volume of rainfall available for collection from the STELLA runs is 46,700 gallons. The standard deviation is 6600 gallons.

The probability of meeting annual water demand with a selected water supply can be evaluated by compiling both the demand and supply distributions.

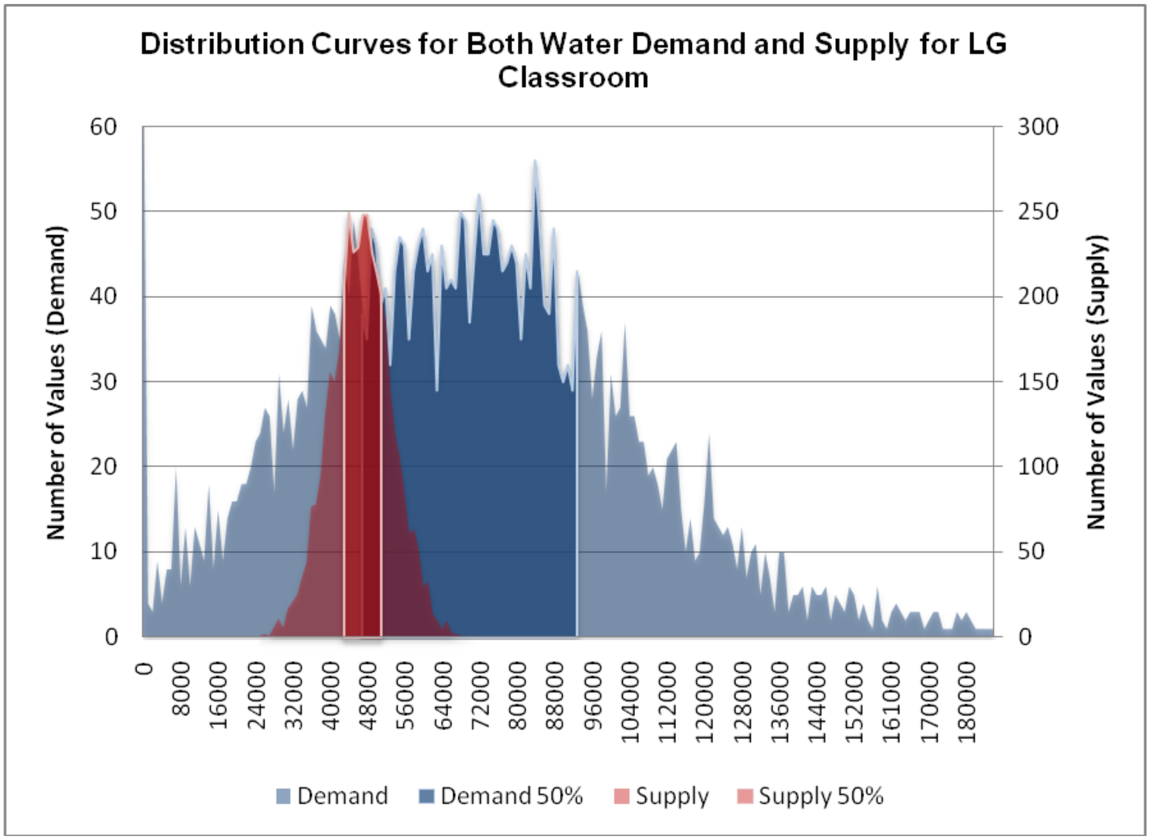


FIGURE 37: Distribution curves for both the annual water demand and supply for the Learning Gate classroom study.

The range of values for the annual rainfall supply is much smaller than that of the annual water demand. Water demand depends on multiple variables that contain a range of possible values. The end result is a broadly distribution of annual water demand. From the distribution plots, it is unlikely that collected rainfall can meet all of the water demand.

Calibration

LEED reference manuals outline assumptions on individual water usage in order to estimate water savings; however, the question remains about whether these assumptions provide accurate results. Answering this question also provides the opportunity for model calibration and defends calibration as an important step in determining potential and accurate water savings. Table 28 below describes the baseline and design parameters used to evaluate water savings for the Learning Gate classroom study. These values will be used in the STELLA IBWM model.

TABLE 28: IBWM model parameters for the LG classroom study using LEED assumptions.

Fixture	**Volume or Flow Rate**		**Duration**		**Uses per Day**	
	Base	**Design**	**Base**	**Design**	**Base**	**Design**
Toilet	1.6 gpf	1.28	n/a	n/a	3	3
Sink	2.5 gpm	1.0	15 sec	12 sec	3	3

LEED assumes baseline fixture ratings of 1.6 gpf for toilets and 2.5 gpm for sinks, as well as usage rates of three uses per day per person for each. The baseline duration of each sink event is set at 15 seconds. For this run, the design fixture ratings are set at 1.28 gpf for toilets and 1.0 gpm for sinks in order to represent the expected water use for each fixture in the building bathrooms. The duration for each bathroom sink event is set to 12 seconds because LEED assumes this set duration if automatic sensors are used, as is the case in the Learning Gate classrooms. The IBWM model was run from February 18, 2010 to May 10, 2010, and the cumulative design water demand for this period is plotted against the measured actual water use in the classrooms in Figure 38.

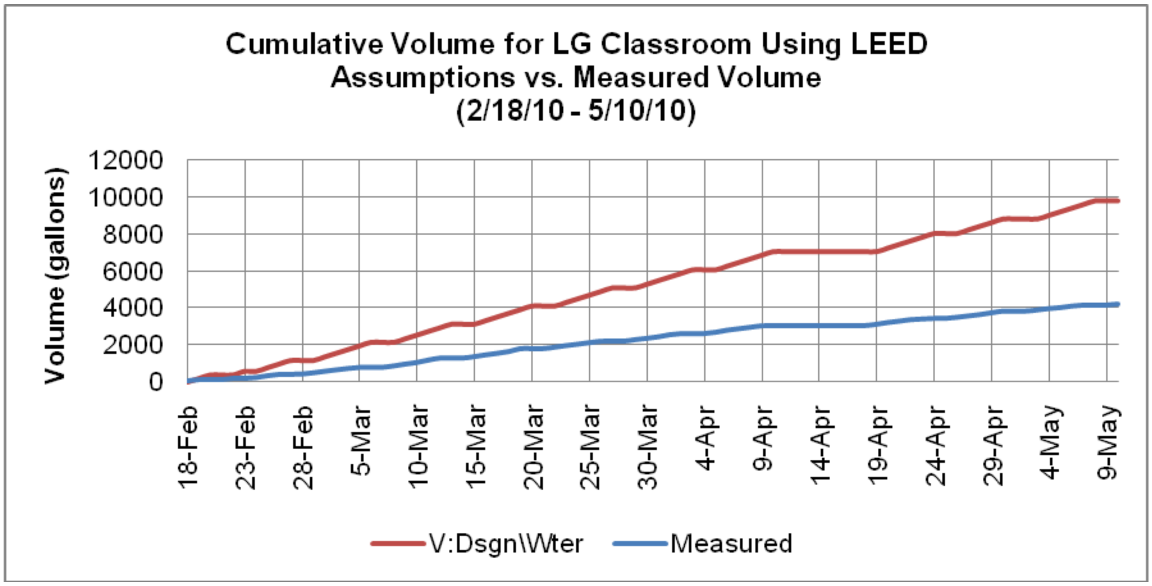


FIGURE 38: Cumulative water demand volume for LG study using LEED assumptions vs. measured values.

The above figure shows that the LEED assumptions used for the design water demand have overestimated the measured water usage of the building. This is expected because the LEED assumptions for fixture uses per person per day are much higher than the rates observed at the study site.

A second IBWM model run was conducted using the parameters in Table 29. These values use the same LEED assumptions for baseline fixture use, but replace design and personal fixture usage per day values with those calculated from the sensor data.

TABLE 29: IBWM model parameters for the LG study using measured values.

Fixture	Volume or Flow Rate		Duration		Uses per Day	
	Base	Design	Base	Design	Base	Design
Toilet	1.6 gpf	1.12	n/a	n/a	1.34	1.34
Sink	2.5 gpm	1.07	15 sec	12 sec	1.96	1.96

For this run, the fixture design volume for each toilet flush is slightly less than what the fixture is rated for and the flow rate of the bathroom sinks is slightly more. The number of times each person uses each fixture per day is less than the LEED-assumed value of three times per day.

The results of the IBWM model run are shown in Figure 39. The cumulative design water demand volume using calibrated values is compared to measured water use in the classroom building during the defined time period.

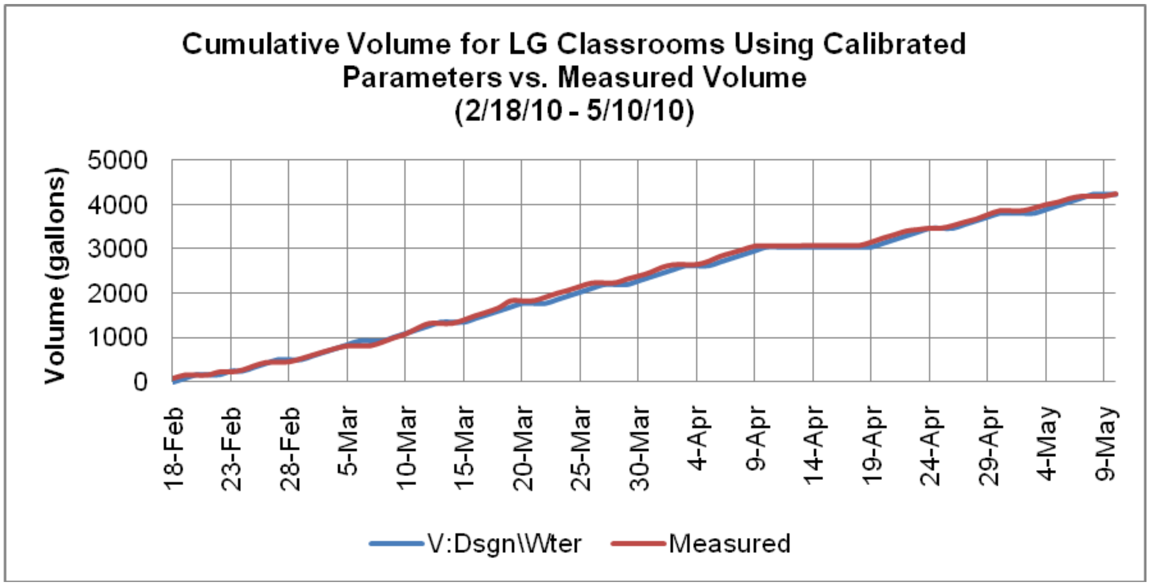


FIGURE 39: Cumulative water demand volume for LG study using calibrated assumptions vs. measured values.

Using the calibrated values, the IBWM model run closely followed the measured water usage in the classroom building. Flat areas on the graph show times where volume is not accumulating and represent weekends or vacation time when the classrooms were not occupied.

The classroom building used for these IBWM model runs contains a rainwater collection system to offset the potable water demand of the toilet and was included in the model runs. The collection area was set to the roof area of 1910 square feet with a collection efficiency of 90%. The storage area was 5000 gallons. (The rainwater collection system at Learning Gate has a total of 10,000 gallons split between two buildings.) Daily rainfall amounts were input from documented values. The resulting water reduction percentages are plotted in Figure 40 for the model run using LEED assumptions and the model run using calibrated values. The percent reduction in total water demand and percent reduction in potable water demand are included.

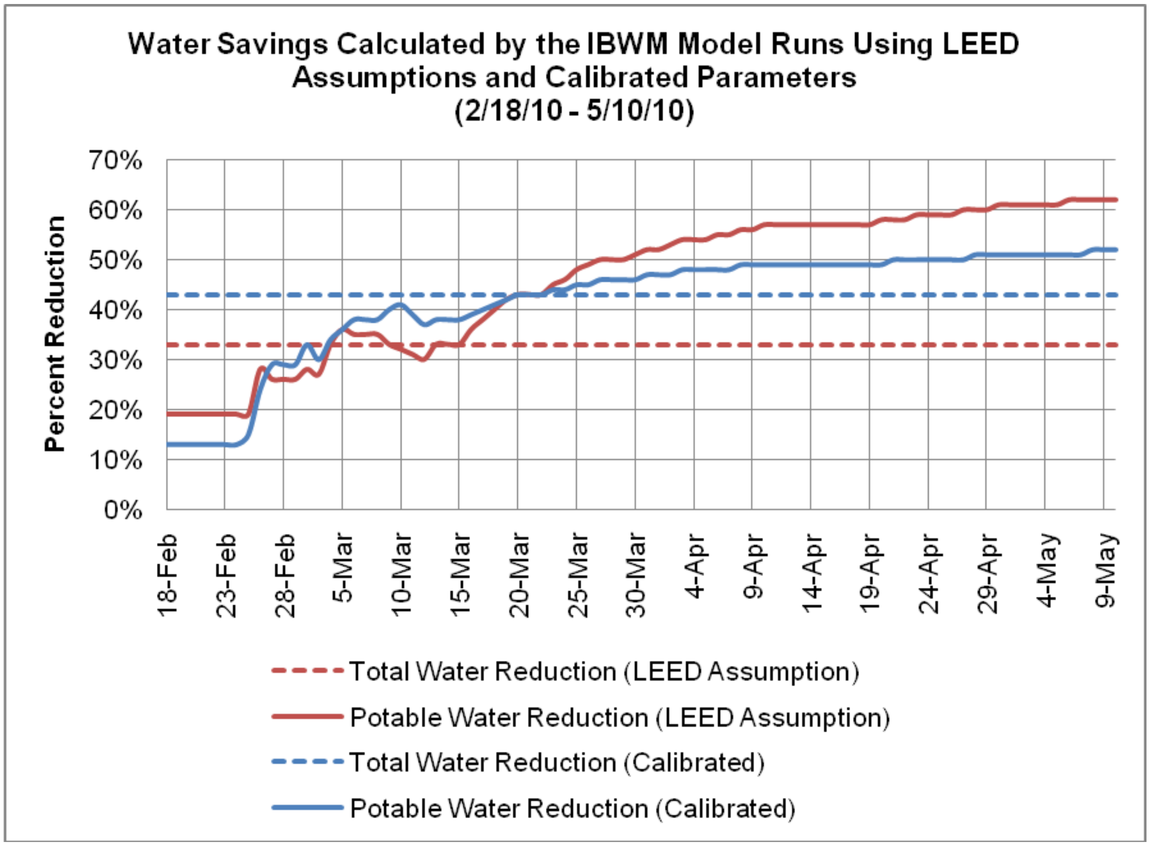


FIGURE 40: Water savings based on IBWM model runs using LEED assumptions and calibrated values.

The percent reduction in total water is constant throughout the model runs for both scenarios. This is because the amount of total water saved depends on conservation.

Substituting some of the overall water needed with rainwater does not change the total amount of water still required for the fixtures. Reduction values for total water are a result of the low-flow toilets and sinks installed in the bathrooms. Potable water reduction is dependent on the rainwater used. As a result, the percent reduction changes as available rainwater changes.

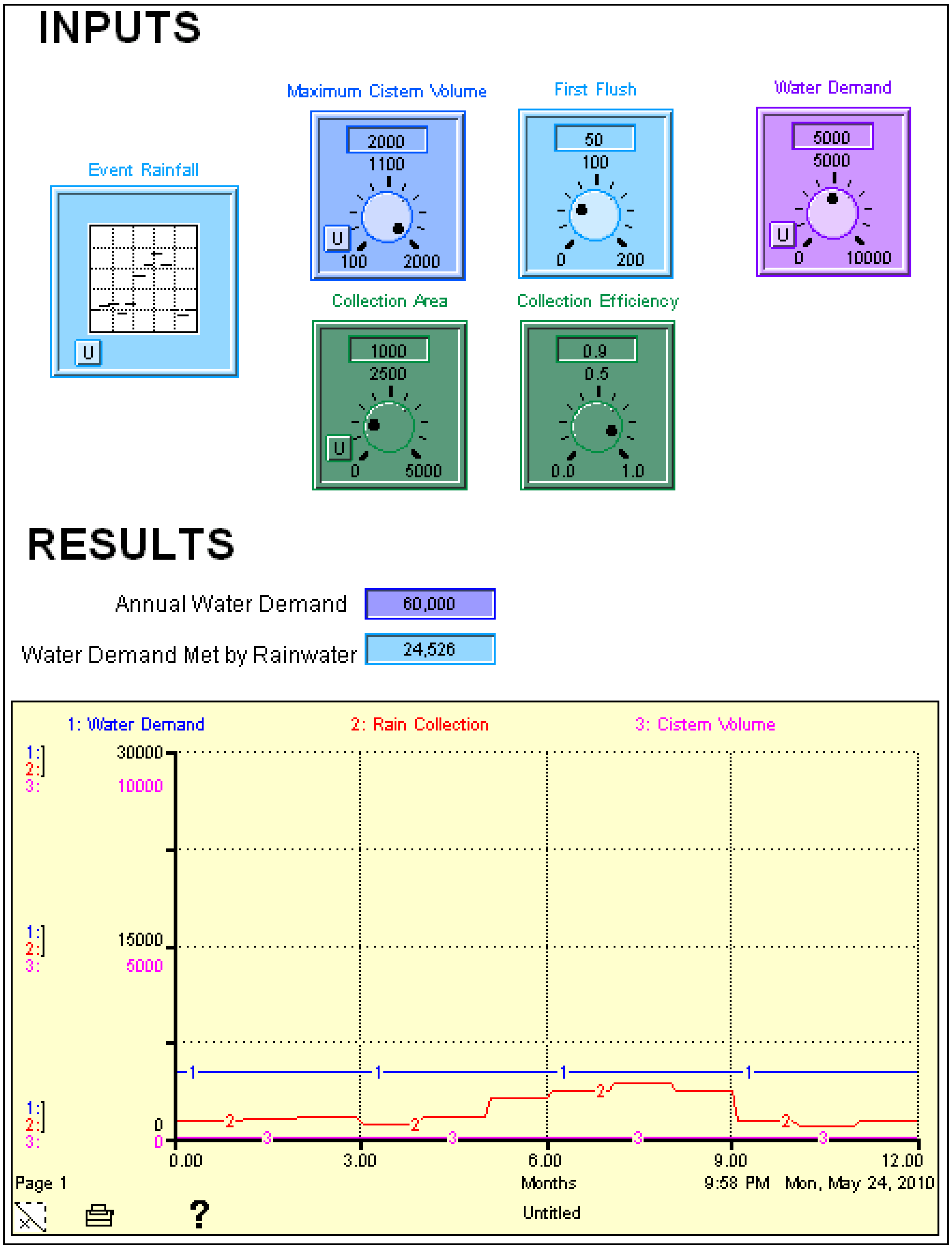
The figure above shows that the LEED assumptions underestimate the total water savings, but overestimate the potable water reduction. The pairs of values each differ by about 10 percentage points. The LEED assumptions underestimate the total water reduction in this case because of the decreased gallons per flush value (1.28 gpf vs. 1.12 gpf). Another reason is the assumption that each fixture is used three times per occupant, when data shows they are used fewer times. Having fewer events causes the water savings per event to hold more weight. The difference in events per occupant per day also affects the potable water savings. Now the LEED assumption overestimates the savings because the ratio of water demand for toilets to water demand for sinks has decreased. Using the LEED assumptions, water needed for toilets is heavily weighted; but if the volume per flush and number of flushes is decreased, the weight of the toilet sector also decreases compared to the sink sector which has not changed as much between the two scenarios.

Education

Part of the project objectives is to develop an IBWM model that is a user-friendly tool for evaluating water management. In order to determine whether STELLA is an appropriate platform for the IBWM model, students at Learning Gate were introduced to the program and given the opportunity to play with different model scenarios over a three day period from May 24 through May 26, 2010. Lessons took place during four 7th grade computer classes held daily. Approximately 75 students in the 7th grade took part.

An overall introduction to modeling was conducted on the first day, focusing on how the STELLA program can build relationships in a thought experiment. Students followed the sample model provided online through NetSim (isee systems, 2010) entitled “Mystery on the Island of Borneo.” The model asks the user to think how bubonic plague, falling roof beams, and dying fish may be linked on the island. Users are able to follow the creation of a STELLA model that shows the relationships between each of the three unexplained mysteries and the thought process behind the answer. The program teaches students how one question leads to a chain of questions that eventually trace back to the answer and how everything is interconnected. This exercise also linked back to a book the students had read *Who Killed Cock Robin?*. Both the book and STELLA model pose a question with the answer linked to DDT in the environment.

On the second day, students were asked to define words related to rainwater catchment: rain barrel, cistern, first flush system, rainwater, potable water, greywater, and blackwater. Although the computer room is located in the new classroom complex where rainwater collection is implemented, most students were unfamiliar with the system. After explaining the components of a typical system, the students were provided with a worksheet showing a classroom and asked to draw a rainwater collection system used to flush the toilet within the building. The following components were to be included: cistern, overflow pipe, first flush system, piping for rainwater to toilets, and potable make-up water for toilets. From the picture, students mapped out the same rainwater collection system as a STELLA model schematic. The goal of the exercise was to have students follow the thought process for building a STELLA model by turning a tangible system into a computer model. Once complete, the students were given time to play with a STELLA model of the rainwater collection system. Students were asked a series of questions that required them to change the collection area, cistern size, and monthly rainfall in the model interface.


INPUTS

Event Rainfall

Maximum Cistern Volume: 2000

First Flush: 50

Water Demand: 5000

Collection Area: 1000

Collection Efficiency: 0.9

RESULTS

Annual Water Demand: 60,000

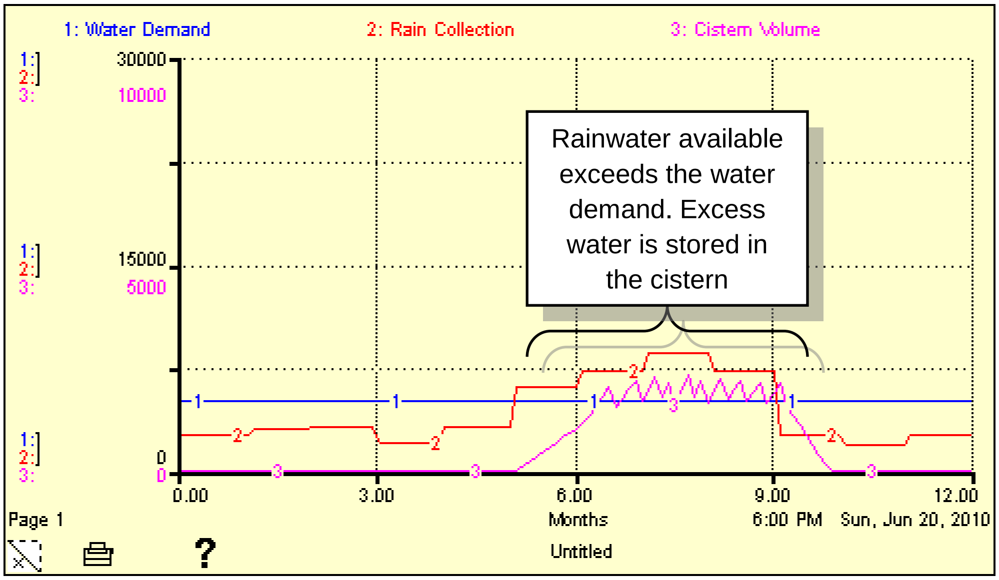
Water Demand Met by Rainwater: 24,526

FIGURE 41: STELLA rainfall model interface.

Students enjoyed playing with the STELLA model and creating the output graph. In the end, students could:

- Easily change the input parameters of the model and run the model.

- Evaluate the effects of changing collection area and cistern size. Increasing the collection area provides more rainwater capture, but the cistern must be large enough to store the water.
- View the effect that changing rainfall has on rainwater collection. Students were given drought-year monthly rainfall totals and asked to determine the new parameters they would need to use to still meet the toilet-flushing water demand.
- Understand the meaning of the different plots on the graphical output device. When the rainfall collection line is beneath the water demand line, there is not enough rainwater to meet demand, and the cistern is not storing water because it is all being used. When the rainfall collection line exceeds the water demand line, there is more water available than demanded; and storage in the cistern occurs.



Rainwater available exceeds the water demand. Excess water is stored in the cistern

FIGURE 42: Output graph from STELLA rainwater model.

On the third day of STELLA lessons, the students were given extra time to answer questions from the rainwater model. Once completed, they were given an additional worksheet that asked questions about the IBWM model created for the entire campus. The objective of the worksheet was to evaluate how well the students could maneuver through the IBWM model developed for this project. Not all students were able to complete the assignment, but beneficial feedback was collected from those who had time to work through the overall model. The version provided to the students would consistently freeze during model runs; this information resulted in the creation of the current IBWM model that is not plagued by the same problem. Additional comments about the preliminary model interface include:

- Busy interface with too many variable inputs on each page.
- Lack of run button in an easily accessible area.
- Insufficient explanation of input variables and associated terms.
- Additional instructions required.
- Additional work on aesthetics.
- Helpfulness of the existing “undo” button on input tables.
- Worked well and good layout.
- Useful program that is easy to work.

Comments were used to create the current version of the IBWM model that eliminates most of the negative aspects regarding model runs and framework. Feedback about the user interface will be used to construct an appealing and user-friendly design for the final model product.

The education session undertaken at Learning Gate showed that students can understand the concepts behind STELLA modeling and water management. Although problems were faced with the previous version of the IBWM model used for the lessons, all students had a good grasp of the rainwater collection model. The future use of the STELLA IBWM model as both an educational and decision-making tool is affirmed by the actions of the 7th grade students over the three day evaluation period. If the students can actively comprehend the processes of the model, then it follows that an IBWM model using STELLA can be utilized by a wide audience.

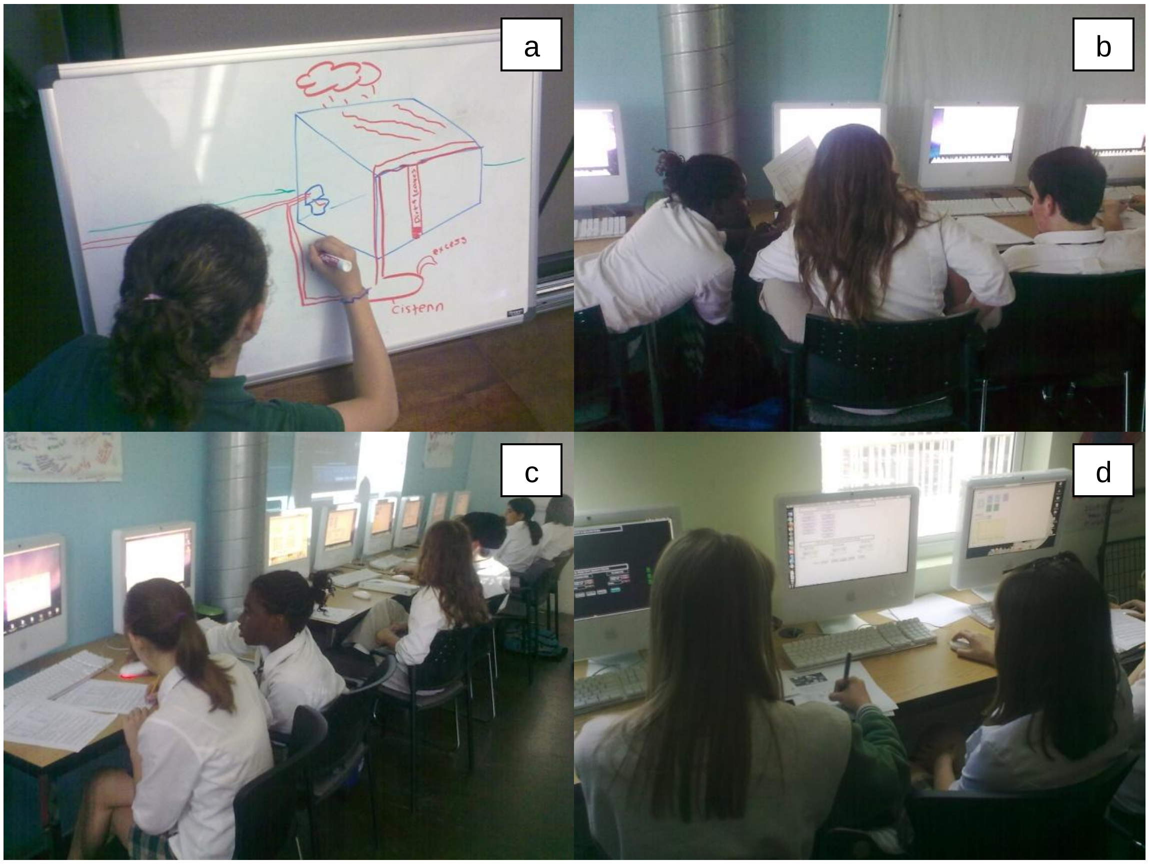


FIGURE 43: Students during the STELLA lessons at Learning Gate: (a) drawing a rainwater collection system, and (b-d) using models to analyze water saving scenarios.

CHAPTER 7:

CONCLUSION

Overview

Water conservation and reuse are often compartmentalized; each water-saving technique is advised in place of another. However, an integrated approach evaluates the outcomes of different water management techniques or more importantly a combination of techniques. This information is crucial to making decisions based on water use, and these decisions are made by individuals involved in the construction of both green and conventional buildings. Sustainable design calls for a change in thinking methods; it requires an integrated approach. As such, the STELLA integrated water budget management (IBWM) model incorporates the integration of creative and innovative water management techniques with common methods for conservation to better educate its users.

The research and discoveries made in the green building industry affect the builders and users of building projects. The STELLA model provides users with the ability to analyze the effects that different water management options have on a building's water budget. The conceptualized flows and volumes are assigned concrete values that can then be tracked using tables and graphs. Results estimate the best courses of action to take in order to gain LEED points toward accreditation However, the system's generic framework allow it to be applied to other structures and totally closed systems; e.g., a space station. Therefore, the model has as many applications as can be imagined by its users. The model also serves as a teaching tool. Educators can utilize the model to teach students about the importance of water as a natural resource, cause and effect, and mass balance.

Future Work

With the model, users can track changes in water consumption due to variations in seasonal demand, building occupancy, and occupant behavior. Model parameters are derived from literature review, historical data of university water usage and consultation with building superintendents. However, smart sustainable design requires the fusion of related dimensions in order to perform a more complete system analysis. Mapped water flow represents only one dimension within the system. A second dimension is defined by *energy* (*E*) usage. Water and energy share a close bond, referred to as *watergy*. Heating and treating water requires energy values that can be defined and integrated into the IBWM-QEC model. Treating water to higher quality standards requires more energy; and more energy has a higher associated cost. Therefore, water *quality* (*Q*) and *costs* (*C*) construct a third and fourth dimension to the model. Integrating all four dimensions establishes a sustainable and unique approach to overall building hydraulic design, and an IBWM-QEC model provides a single platform where each aspect is defined and allowed to interact.

The advanced IBWM-QEC model can be a powerful tool for designers and managers to examine scenarios for reducing water consumption and wastewater output, while providing users with an understanding of building water integration. The finished product is anticipated to be adopted for use by the USGBC as a tool to be used with future versions of LEED. The STELLA modeling software is widely available and can therefore be used by other planning agencies and researchers to determine feasible water reuse and efficiency projects. Additionally, the model can be further developed for use in real-time applications. For example, if sensors are incorporated within a building, the model can run simulations from the web using the real-time data. By inputting collected data, the model can help make future predictions regarding the water budget. Also, it should be noted that although the IBWM-QEC model is intended for tracking water in individual buildings, the model can be modified and adapted for multiple building or community-level modeling, thereby expanding the applications to other sectors such as neighborhood development. The ease of use of STELLA also makes it a great educational tool for teaching water conservation and reuse. The water budget model and the water usage data can be made available on the internet so that students and the public can learn about and appreciate water conservation and reuse in a sustainable framework such as a green building.

CHAPTER 8:

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APPENDICES

Appendix A: STELLA IBWM Model Variables by Sector

Irrigation

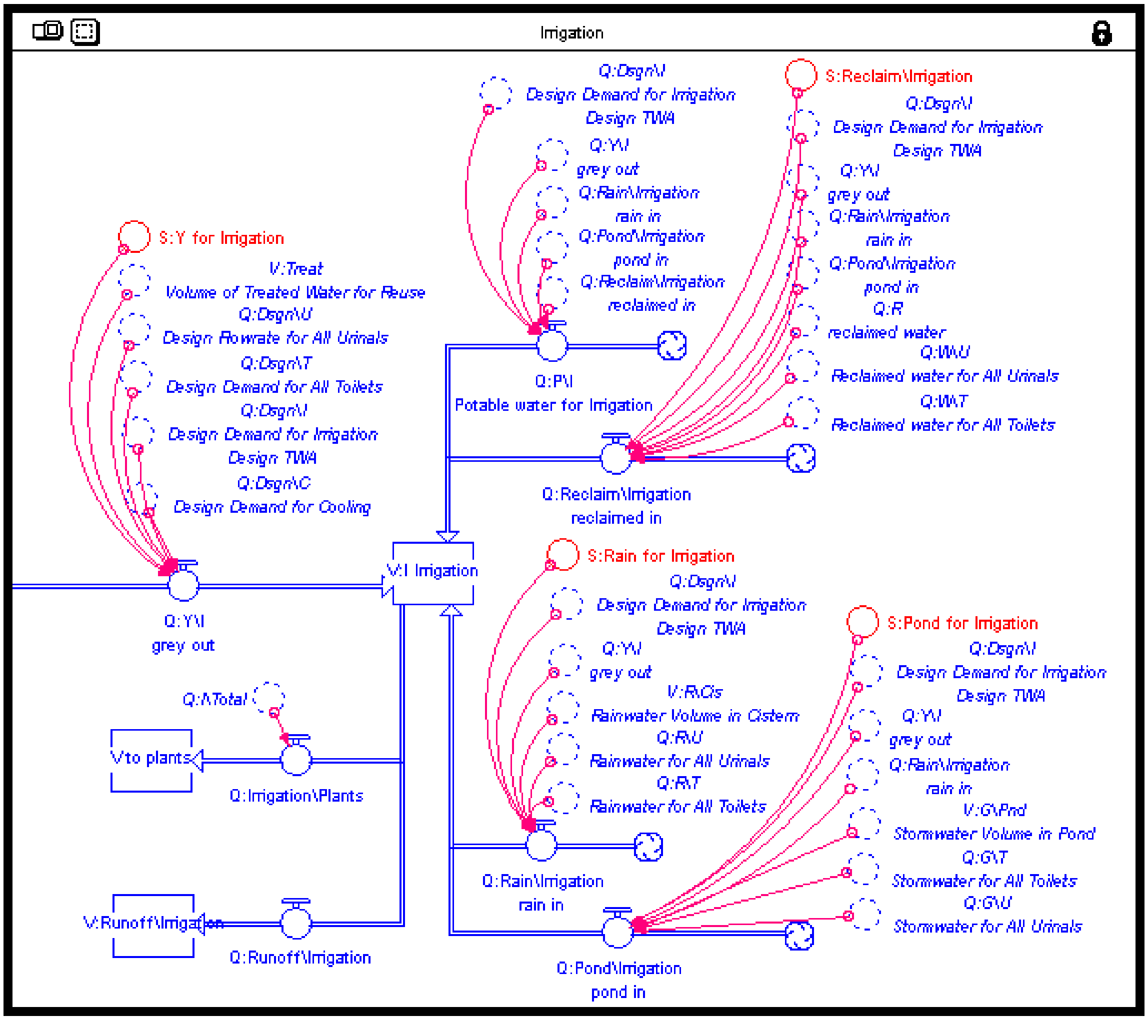

FIGURE A1: Detail view of the IBWM model irrigation section.

TABLE A1: Variables in the irrigation section of the IBWM model.

Notation in Model	Variable	Description	Units or Value
Q:Dsgn\C	Q_{Dsgn}^{C}	Design demand flow for cooling	gal/day
Q:Dsgn\I	Q_{Dsgn}^{I}	Design demand flow for irrigation	gal/day
Q:Dsgn\T	Q_{Dsgn}^{T}	Design demand flow for toilets	gal/day
Q:Dsgn\U	Q_{Dsgn}^{U}	Design demand flow for urinals	gal/day
Q:G\T	Q_{G}^{T}	Flow of stormwater to toilets	gal/day
Q:G\U	Q_{G}^{U}	Flow of stormwater to urinals	gal/day
Q:I\Total	Q_{Total}^{I}	Total water flow allocated for irrigation	gal/day
Q:Irrigation\Plants	Q_{Plants}^{I}	Flow of water utilized by plants	gal/day

Appendix A (Continued)

TABLE A1 (Continued).

Notation in Model	**Variable**	**Description**	**Units or Value**
Q:Pond\Irrigation	QGI	Stormwater flow for irrigation	gal/day
Q:R	QW	Total available flow of reclaimed water	gal/day
Q:R\T	QRT	Flow of rainwater for toilets	gal/day
Q:R\U	Q_R^U	Flow of rainwater for urinals	gal/day
Q:Rain\Irrigation	Q_R^I	Flow of rainwater for irrigation	gal/day
Q:Reclaim\Irrigation	Q_W^I	Flow of reclaimed water for irrigation	gal/day
Q:Runoff\Irrigation	Q_{Run}^I	Flow of runoff water from irrigation	gal/day
Q:W\T	Q_W^T	Flow of reclaimed water for toilets	gal/day
Q:W\U	Q_W^U	Flow of reclaimed water for urinals	gal/day
Q:Y\I	Q_Y^I	Flow of greywater to irrigation	gal/day
S:Pond for Irrigation	-	Switch to turn on stormwater source flow for irrigation	1
S:Rain for Irrigation	-	Switch to turn on rainwater source flow for irrigation	1
S:Reclaim\Irrigation	-	Switch to turn on reclaimed water flow for irrigation	1
S:Y for Irrigation	-	Switch to turn on greywater flow for irrigation	1
V:G\Pond	V_G^{Pond}	Volume of stormwater in the storage pond	gal
V:R\Cis	V_R^{Cis}	Volume of rainwater in the cistern	gal
V:Runoff\Irrigation	V_{Run}^I	Volume of runoff from irrigation	gal
V:Treat	V^{Treat}	Volume of treated greywater available for reuse	gal
V to plants	V_{Plants}^I	Volume of water going to plants	gal

Bathroom Sinks

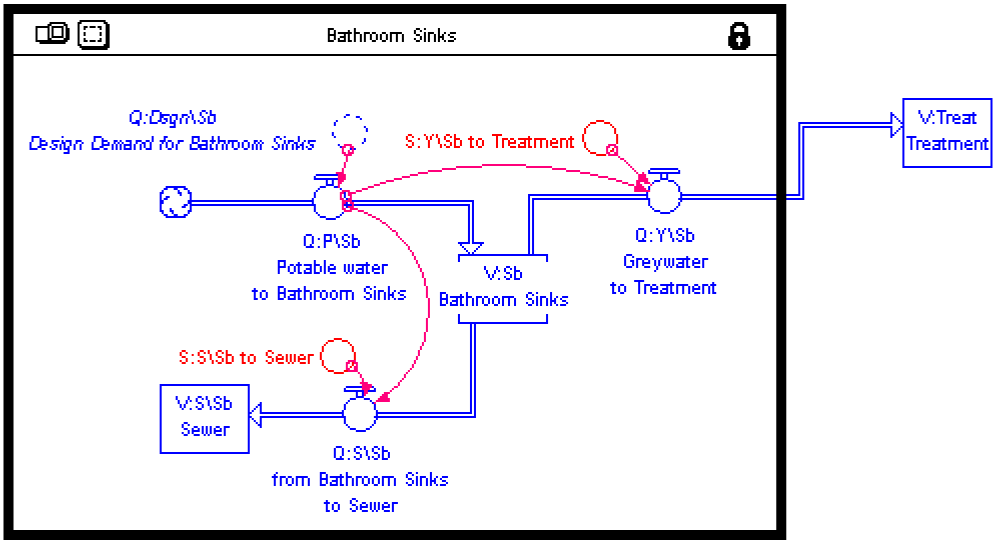

FIGURE A2: Detail view of the IBWM model bathroom sink section.

Appendix A (Continued)

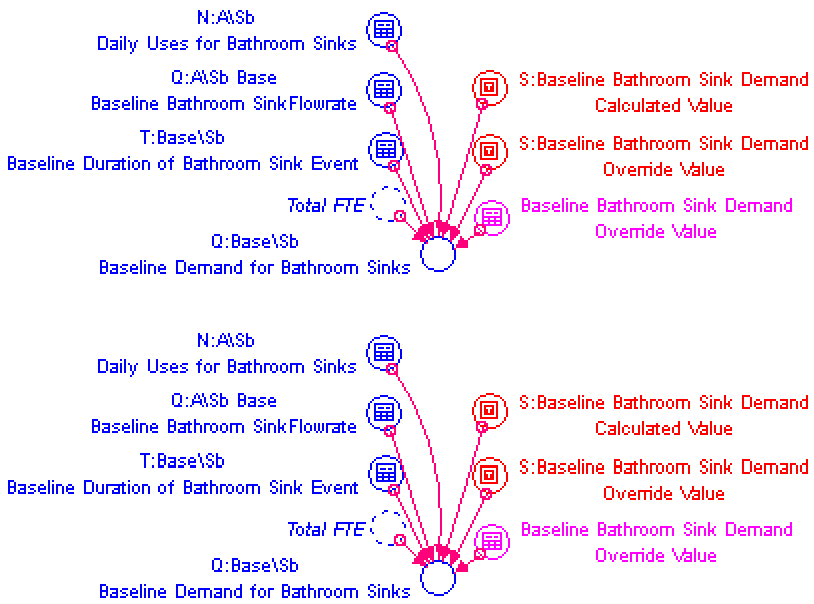

FIGURE A3: Baseline (top) and design (bottom) components for bathroom sinks in the IBWM model.

TABLE A2: Variables in the bathroom sink section of the IBWM model.

Notation in Model	Variable	Description	Units or Value
Q:Dsgn\Sb	Q_{Dsgn}^{Sb}	Design demand flow for bathroom sinks	gal/day
Q:P\Sb	Q_{P}^{Sb}	Design potable water demand for bathroom sinks	gal/day
Q:S\Sb	Q_{S}^{Sb}	Flow to sewer from bathroom sinks	gal/day
Q:Y\Sb	Q_{Y}^{Sb}	Greywater flow from bathroom sinks to treatment for reuse	gal/day
S:S\Sb	S_{S}^{Sb}	Switch to turn on sewer flow from bathroom sinks	1
S:Y\Sb	S_{Y}^{Sb}	Switch to turn on greywater reuse flow from bathroom sinks	1
V:S\Sb	V_{S}^{Sb}	Volume of water entering sewer from bathroom sinks	gal
V:Sb	V^{Sb}	Volume of water in bathroom sinks	gal
V:Treat	V^{Treat}	Volume of water in treatment for reuse	gal
Baseline Bathroom Sink Demand Override Value	Q_{Base}^{Sb}	Override value for baseline water demand for bathroom sinks if imbedded model calculations are not used	gal/day
N:A\Sb	N_{A}^{Sb}	Number of applications of bathroom sinks	uses/person/day
Q:A\Sb Base	$Q_{A}^{Sb(Base)}$	Baseline flow rate for each bathroom sink application	gpm
Q:Base\Sb	Q_{Base}^{Sb}	Baseline water demand for bathroom sinks	gal/day
S:Baseline Bathroom Sink Demand Calculated Value	-	Switch to use model calculations for baseline water demand for bathroom sinks	1

TABLE A2 (Continued).

Notation in Model	**Variable**	**Description**	**Units or Value**
S:Baseline Bathroom Sink Demand Override Value	-	Switch to use the override value for baseline water demand for bathroom sinks	1
T:Base\Sb	t_{Base}^{Sb}		sec
Total FTE	FTE	Full-time occupant equivalent	people
Design Bathroom Sink Demand Override Value	Q_{Dsgn}^{Sb}	Override value for design water demand for bathroom sinks if imbedded model calculations are not used	gal/day
N:A\Sb	N_{A}^{Sb}	Number of applications of bathroom sinks	uses/person/day
Q:A\Sb Dsgn	$Q_{A}^{Sb(Dsgn)}$	Design flow rate for each bathroom sink application	gpm
Q:Dsgn\Sb	Q_{Dsgn}^{Sb}	Design water demand for bathroom sinks	gal/day
S:Design Bathroom Sink Demand Calculated Value	-	Switch to use model calculations for design water demand for bathroom sinks	1
S:Design Bathroom Sink Demand Override Value	-	Switch to use the override value for design water demand for bathroom sinks	1
T:Dsgn\Sb	t_{Dsgn}^{Sb}		sec
Total FTE	FTE	Full-time occupant equivalent	people

Kitchen Sinks

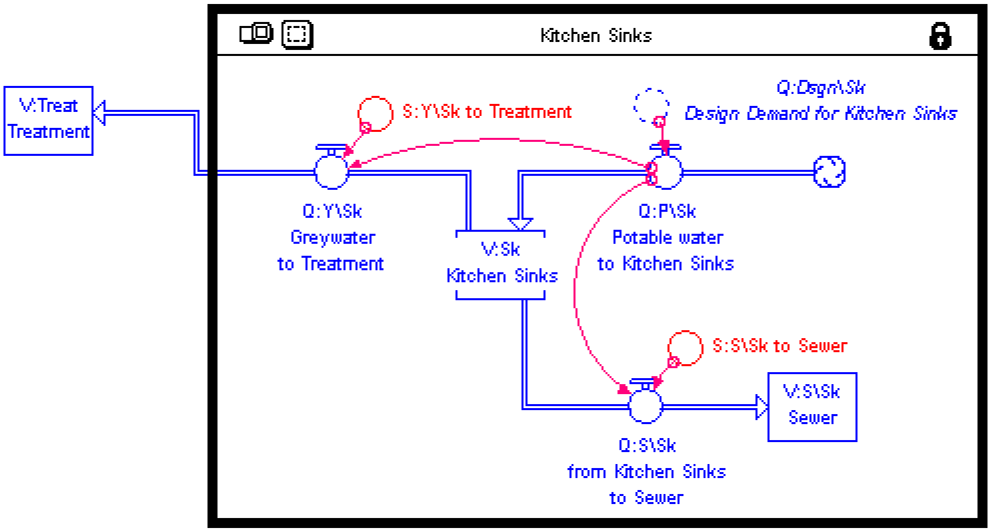

FIGURE A4: Detail view of the IBWM model kitchen sink section.

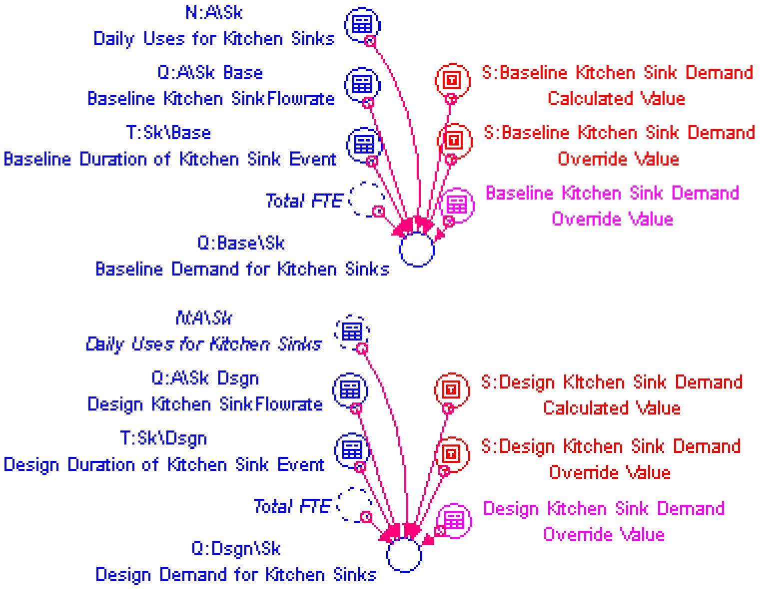

FIGURE A5: Baseline (top) and design (bottom) components for kitchen sinks in the IBWM model.

TABLE A3: Variables in the kitchen sink section of the IBWM model.

Notation in Model	**Variable**	**Description**	**Units or Value**
Baseline Kitchen Sink Demand Override Value	Q_{Base}^{Sk}	Override value for baseline water demand for kitchen sinks if imbedded model calculations are not used	gal/day
Design Kitchen Sink Demand Override Value	Q_{Dsgn}^{Sk}	Override value for design water demand for kitchen sinks if imbedded model calculations are not used	gal/day
N:A\Sk	N_A^{Sk}	Number of kitchen sink applications	uses/person/day
Q:A\Sk Base	$Q{:}_A^{Sk(Base)}$	Baseline kitchen sink flow rate	gpm
Q:A\Sk Dsgn	$Q_A^{Sk(Dsgn)}$	Design kitchen sink flow rate	gpm
Q:Base\Sk	Q_{Base}^{Sk}	Baseline demand flow for kitchen sinks	gal/day
Q:Dsgn\Sk	Q_{Dsgn}^{Sk}	Design demand flow for kitchen sinks	gal/day
Q:P\Sk	Q_P^{Sk}	Flow of potable water to kitchen sinks	gal/day
Q:S\Sk	Q_S^{Sk}	Flow of water to the sewer from kitchen sinks	gal/day
Q:Y\Sk	Q_Y^{Sk}	Flow of greywater collected from kitchen sinks	gal/day
S:Baseline Kitchen Sink Demand Calculated Value	-	Switch to use model calculations for baseline water demand for kitchen sinks	1
S:Baseline Kitchen Sink Demand Override Value	-	Switch to use the override value for baseline water demand for kitchen sinks	1
S:Design Kitchen Sink Demand Calculated Value	-	Switch to use model calculations for design water demand for kitchen sinks	1
S:Design Kitchen Sink Demand Override Value	-	Switch to use the override value for design water demand for kitchen sinks	1

Appendix A (Continued)

TABLE A3 (Continued).

Notation in Model	Variable	Description	Units or Value
S:S\Sk	-	Switch to direct water from kitchen sinks to sewer	1
S:Y\Sk	-	Switch to collect greywater from kitchen sinks for reuse	1
T:Sk\Base	t_{Base}^{Sk}	Baseline duration for kitchen sink application	sec
T:Sk\Dsgn	t_{Dsgn}^{Sk}	Design duration for kitchen sink application	sec
Total FTE	FTE	Full-time occupant equivalent	people
V:S\Sk	V_S^{Sk}	Volume of water directed to sewer from kitchen sinks	gal
V:Sk	V^{Sk}	Volume of water in kitchen sinks	0
V:Treat	V^{Treat}	Volume in water for treatment for reuse	gal

Showers

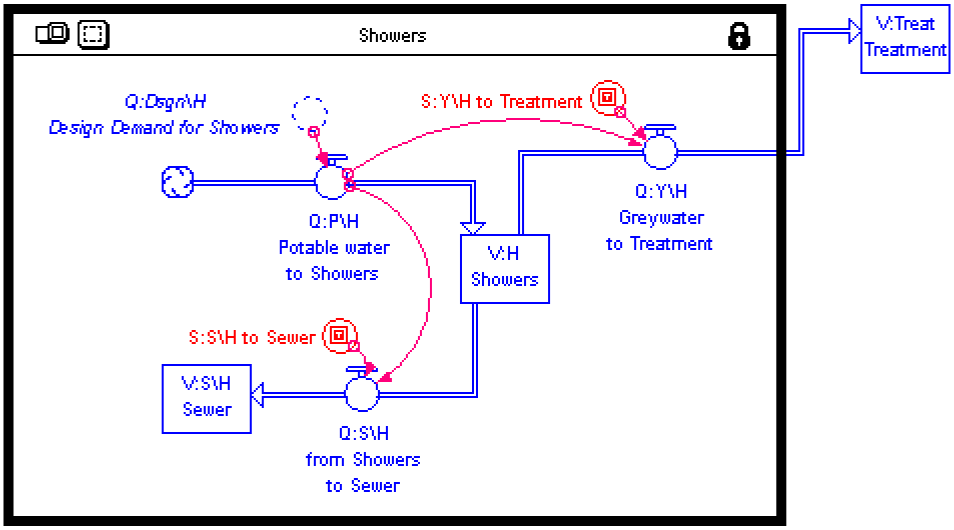

FIGURE A6: Detail view of the IBWM model shower section.

Appendix A (Continued)

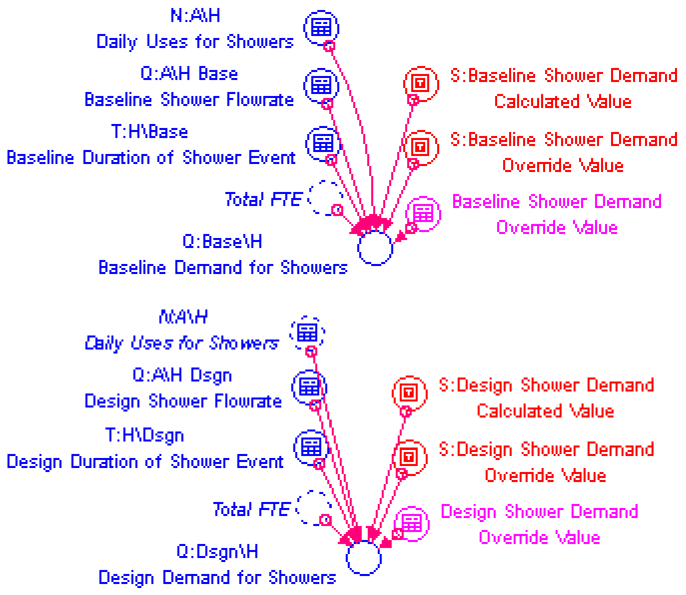

FIGURE A7: Baseline (top) and design (bottom) components for showers in the IBWM model.

TABLE A4: Variables in the shower section of the IBWM model.

Notation in Model	**Variable**	**Description**	**Units or Value**
Baseline Shower Demand Override Value	Q_{Base}^{H}	Override value for baseline water demand for showers if imbedded model calculations are not used	gal/day
Design Shower Demand Override Value	Q_{Dsgn}^{H}	Override value for design water demand for showers if imbedded model calculations are not used	gal/day
N:A\H	N_{A}^{H}	Number of shower applications	uses/person/day
Q:A\H Base	$Q:_{A}^{H(Base)}$	Baseline shower flow rate	gpm
Q:A\H Dsgn	$Q_{A}^{H(Dsgn)}$	Design shower flow rate	gpm
Q:Base\H	Q_{Base}^{H}	Baseline demand flow for showers	gal/day
Q:Dsgn\H	Q_{Dsgn}^{H}	Design demand flow for showers	gal/day
Q:P\H	Q_{P}^{H}	Flow of potable water to showers	gal/day
Q:S\H	Q_{S}^{H}	Flow of water to the sewer from showers	gal/day
Q:Y\H	Q_{Y}^{H}	Flow of greywater collected from showers	gal/day
S:Baseline Shower Demand Calculated Value	-	Switch to use model calculations for baseline water demand for showers	1
S:Baseline Shower Demand Override Value	-	Switch to use the override value for baseline water demand for showers	1
S:Design Shower Demand Calculated Value	-	Switch to use model calculations for design water demand for showers	1
S:Design Shower Demand Override Value	-	Switch to use the override value for design water demand for showers	1

TABLE A4 (Continued).

Notation in Model	Variable	Description	Units or Value
S:S\H	-	Switch to direct water from showers to sewer	1
S:Y\H	-	Switch to collect greywater from showers for reuse	1
T:H\Base	t_{Base}^{H}	Baseline duration for shower application	sec
T:H\Dsgn	t_{Dsgn}^{H}	Design duration for shower application	sec
Total FTE	FTE	Full-time occupant equivalent	people
V:S\H	V_{S}^{H}	Volume of water directed to sewer from showers	gal
V:H	V^{H}	Volume of water in showers	0
V:Treat	V^{Treat}	Volume of water in treatment available for reuse	gal

Appendix A (Continued)

Toilets

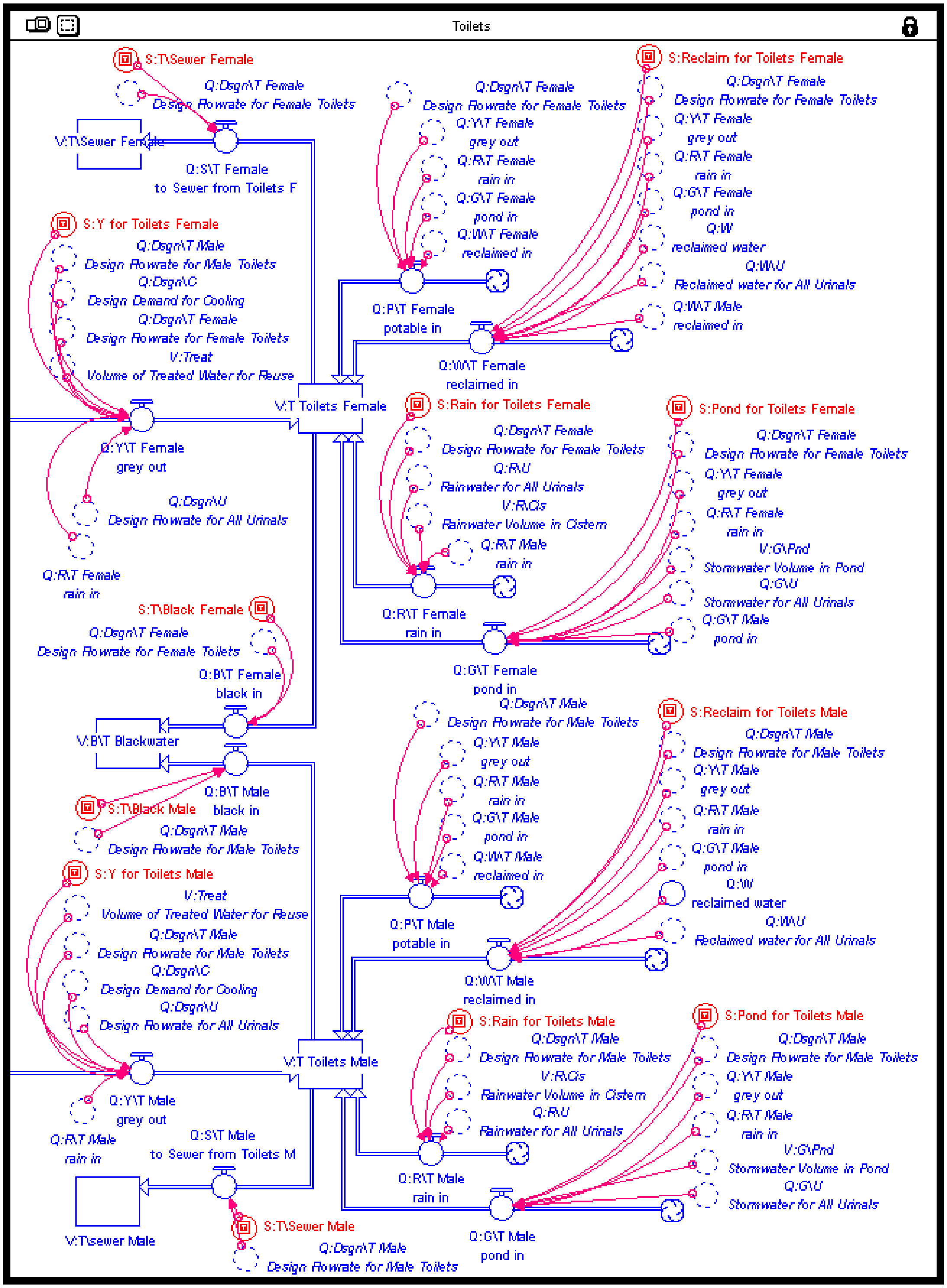

FIGURE A8: Detail view of the IBWM model toilets section.

Appendix A (Continued)

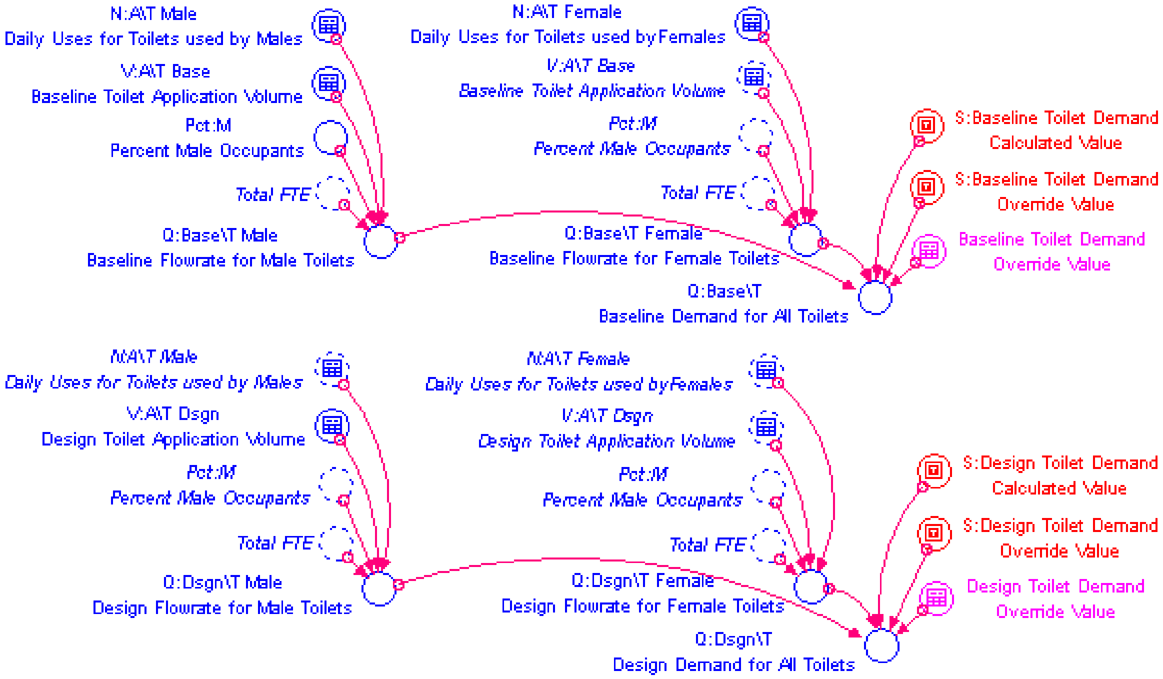

FIGURE A9: Baseline (top) and design (bottom) components for toilets in the IBWM model.

TABLE A5: Variables in the toilet section of the IBWM model.

Notation in Model	Variable	Description	Units or Value
Baseline Toilet Demand Override Value	Q_{Base}^{T}	Baseline demand flow for all toilets	gal/day
Design Toilet Demand Override Value	Q_{Dsgn}^{T}	Design demand flow for all toilets	gal/day
N:A\T Female	$N_{A}^{T(F)}$	Daily applications of female toilets	uses/person/day
N:A\T Male	$N_{A}^{T(M)}$	Daily applications of male toilets	uses/person/day
Pct:M	P^{M}	Percent of occupants that are male	-
Q:Base\T	Q_{Base}^{T}	Baseline demand flow for all toilets	gal/day
Q:Base\T Female	$Q_{Base}^{T(F)}$	Baseline demand flow for female toilets	gal/day
Q:Base\T Male	$Q_{Base}^{T(M)}$	Baseline demand flow for male toilets	gal/day
Q:Dsgn\C	Q_{Dsgn}^{C}	Design demand flow for cooling	gal/day
Q:Dsgn\T	Q_{Dsgn}^{T}	Design demand flow for all toilets	gal/day
Q:Dsgn\T Female	$Q_{Dsgn}^{T(F)}$	Design demand flow for female toilets	gal/day
Q:Dsgn\T Male	$Q_{Dsgn}^{T(M)}$	Design demand flow for male toilets	gal/day
Q:Dsgn\U	Q_{Dsgn}^{U}	Design demand flow for all urinals	gal/day
Q:G\T Female	$Q_{G}^{T(F)}$	Flow of stormwater to female toilets	gal/day
Q:G\T Male	$Q_{G}^{T(M)}$	Flow of stormwater to male toilets	gal/day
Q:G\U	Q_{G}^{U}	Flow of stormwater to all urinals	gal/day
Q:P\T Female	$Q_{P}^{T(F)}$	Flow of potable water to female toilets	gal/day
Q:P\T Male	$Q_{P}^{T(M)}$	Flow of potable water for male toilets	gal/day

TABLE A5 (Continued).

Notation in Model	**Variable**	**Description**	**Units or Value**
Q:R\T Female	$Q_R^{T(F)}$	Flow of rainwater to female toilets	gal/day
Q:R\T Male	$Q_R^{T(M)}$	Flow of rainwater to male toilets	gal/day
Q:R\U	Q_R^{U}	Flow of rainwater to all urinals	gal/day
Q:S\T Female	Q_S^{T}	Flow of water to the sewer from female toilets	gal/day
Q:S\T Male	$Q_S^{T(M)}$	Flow of water to the sewer from male toilets	gal/day
Q:W	Q_W	Total flow of available reclaimed water	gal/day
Q:W\T Female	$Q_W^{T(F)}$	Flow of reclaimed water to female toilets	gal/day
Q:W\T Male	$Q_W^{T(M)}$	Flow of reclaimed water to male toilets	gal/day
Q:W\U	Q_W^{U}	Flow of reclaimed water to all urinals	gal/day
Q:Y\T Female	$Q_Y^{T(F)}$	Flow of greywater for female toilets	gal/day
Q:Y\T Male	$Q_Y^{T(M)}$	Flow of greywater for male toilets	gal/day
S:Baseline Toilet Demand Override Value	-	Switch to use the override value for baseline water demand for toilets	1
S:Design Toilet Demand Calculated Value	-	Switch to use model calculations for design water demand for toilets	1
S:Design Toilet Demand Override Value	-	Switch to use the override value for design water demand for toilets	1
S:Pond for Toilets Female	-	Switch to direct stormwater to female toilets	1
S:Pond for Toilets Male	-	Switch to direct stormwater to male toilets	1
S:Rain for Toilets Female	-	Switch to direct rainwater to female toilets	1
S:Rain for Toilets Male	-	Switch to direct rainwater to male toilets	1
S:Reclaim for Toilets Female	-	Switch to direct reclaimed water to female toilets	1
S:Reclaim for Toilets Male	-	Switch to direct reclaimed water to male toilets	1
S:T\Black Female	-	Switch to direct water from female toilets to treatment for reuse	
S:T|Black Male	-	Switch to direct water from male toilets to treatment for reuse	1
S:T\Sewer Female	-	Switch to direct water from female toilets to sewer	1
S:T\Sewer Male	-	Switch to direct water from male toilets to sewer	1
S:Y for Toilets Female	-	Switch to reuse greywater for female toilets	1
S:Y for Toilets Male	-	Switch to reuse greywater for male toilets	1
Total FTE	FTE	Full-time occupant equivalent	people
V:A\T Base	$V_A^{T(Base)}$	Baseline volume per toilet application	gpf
V:AT Dsgn	$V_A^{T(Dsgn)}$	Design volume per toilet application	gpf
V:B\T	V_B^{T}	Volume of blackwater for reuse from all toilets	gal
V:G\Pnd	V_G^{Pnd}	Volume of stormwater in the collection pond	gal
V:R\Cis	V_R^{Cis}	Volume of rainwater in the cistern	gal
V:T\Sewer Female	$V_S^{T(F)}$	Volume of water into sewer from female toilets	gal
V:T\Sewer Male	$V_S^{T(M)}$	Volume of water into sewer from male toilets	gal
V:T Toilets Female	$V^{T(F)}$	Volume of water in female toilets	0
V:T Toilets Male	$V^{T(M)}$	Volume of water in male toilets	0
V:Treat	V^{Treat}	Volume of water in treatment available for reuse	gal

Urinals

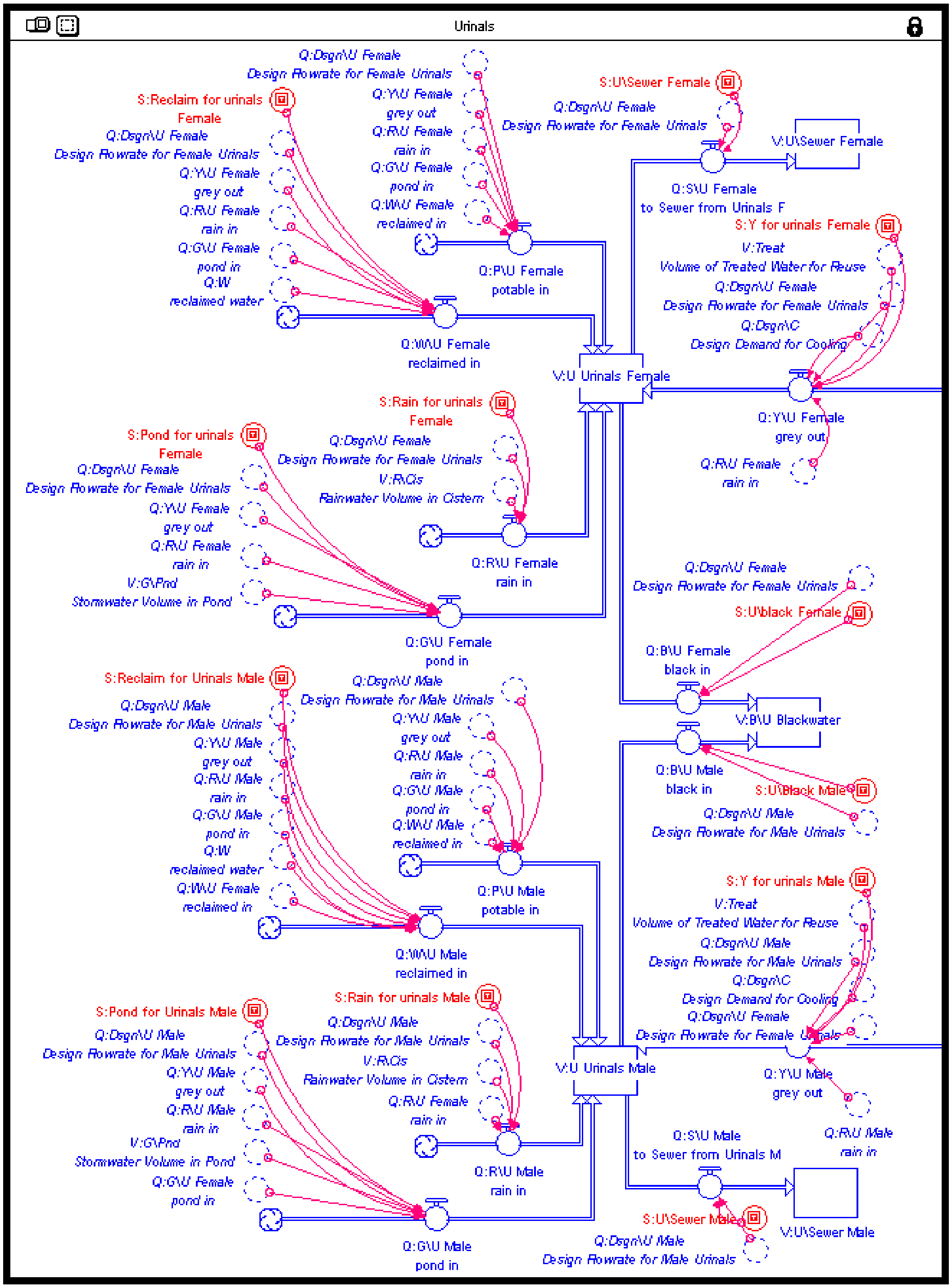

FIGURE A10: Detail view of the IBWM model urinals section.

Appendix A (Continued)

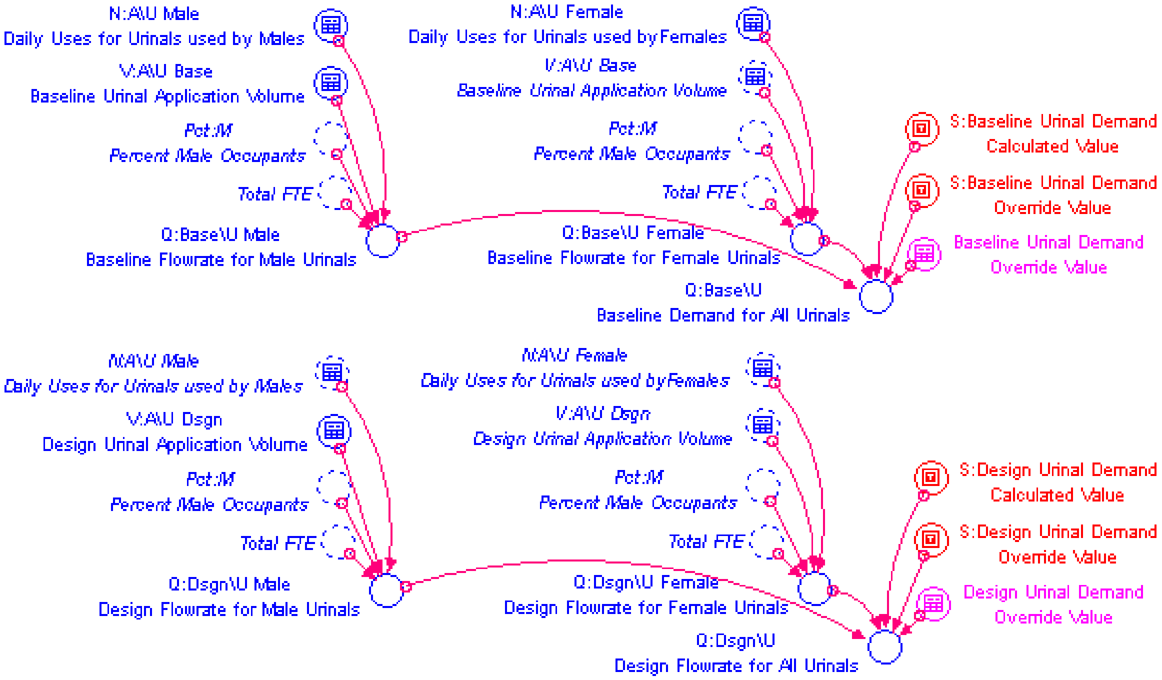

FIGURE A11: Baseline (top) and design (bottom) components for urinals in the IBWM model.

TABLE A6: Variables in the urinal section of the IBWM model.

Notation in Model	Variable	Description	Units or Value
Baseline Urinal Demand Override Value	Q_{Base}^{U}	Baseline demand flow for all urinals	gal/day
Design Urinal Demand Override Value	Q_{Dsgn}^{U}	Design demand flow for all urinals	gal/day
N:A\U Female	$N_{A}^{U(F)}$	Daily applications of female urinals	uses/person/day
N:A\U Male	$N_{A}^{U(M)}$	Daily applications of male urinals	uses/person/day
Pct:M	P^{M}	Percent of occupants that are male	-
Q:Base\U	Q_{Base}^{U}	Baseline demand flow for all urinals	gal/day
Q:Base\U Female	$Q_{Base}^{T(F)}$	Baseline demand flow for female urinals	gal/day
Q:Base\U Male	$Q_{Base}^{T(M)}$	Baseline demand flow for male urinals	gal/day
Q:Dsgn\C	Q_{Dsgn}^{C}	Design demand flow for cooling	gal/day
Q:Dsgn\U Female	$Q_{Dsgn}^{U(F)}$	Design demand flow for female urinals	gal/day
Q:Dsgn\U Male	$Q_{Dsgn}^{U(M)}$	Design demand flow for male urinals	gal/day
Q:G\U Female	$Q_{G}^{T(F)}$	Flow of stormwater to female urinals	gal/day
Q:G\U Male	$Q_{G}^{T(M)}$	Flow of stormwater to male urinals	gal/day
Q:G\U	Q_{G}^{U}	Flow of stormwater to all urinals	gal/day
Q:P\U Female	$Q_{P}^{T(F)}$	Flow of potable water to female urinals	gal/day
Q:P\U Male	$Q_{P}^{T(M)}$	Flow of potable water for male urinals	gal/day
Q:R\U Female	$Q_{R}^{T(F)}$	Flow of rainwater to female urinals	gal/day

Appendix A (Continued)

TABLE A6 (Continued).

Notation in Model	**Variable**	**Description**	**Units or Value**
Q:R\U Male	$Q_R{}^{T(M)}$	Flow of rainwater to male urinals	gal/day
Q:R\U	$Q_R{}^{U}$	Flow of rainwater to all urinals	gal/day
Q:S\U Female	$Q_S{}^{T}$	Flow of water to the sewer from female urinals	gal/day
Q:S\U Male	$Q_S{}^{T(M)}$	Flow of water to the sewer from male urinals	gal/day
Q:W	Q_W	Total flow of available reclaimed water	gal/day
Q:W\U Female	$Q_W{}^{T(F)}$	Flow of reclaimed water to female urinals	gal/day
Q:W\U Male	$Q_W{}^{T(M)}$	Flow of reclaimed water to male urinals	gal/day
Q:W\U	$Q_W{}^{U}$	Flow of reclaimed water to all urinals	gal/day
Q:Y\U Female	$Q_Y{}^{T(F)}$	Flow of greywater for female urinals	gal/day
Q:Y\U Male	$Q_Y{}^{T(M)}$	Flow of greywater for male urinals	gal/day
S:Baseline Urinal Demand Calculated Value	-	Switch to use model calculations for baseline water demand for urinals	1

Appendix A (Continued)

Cooling Tower

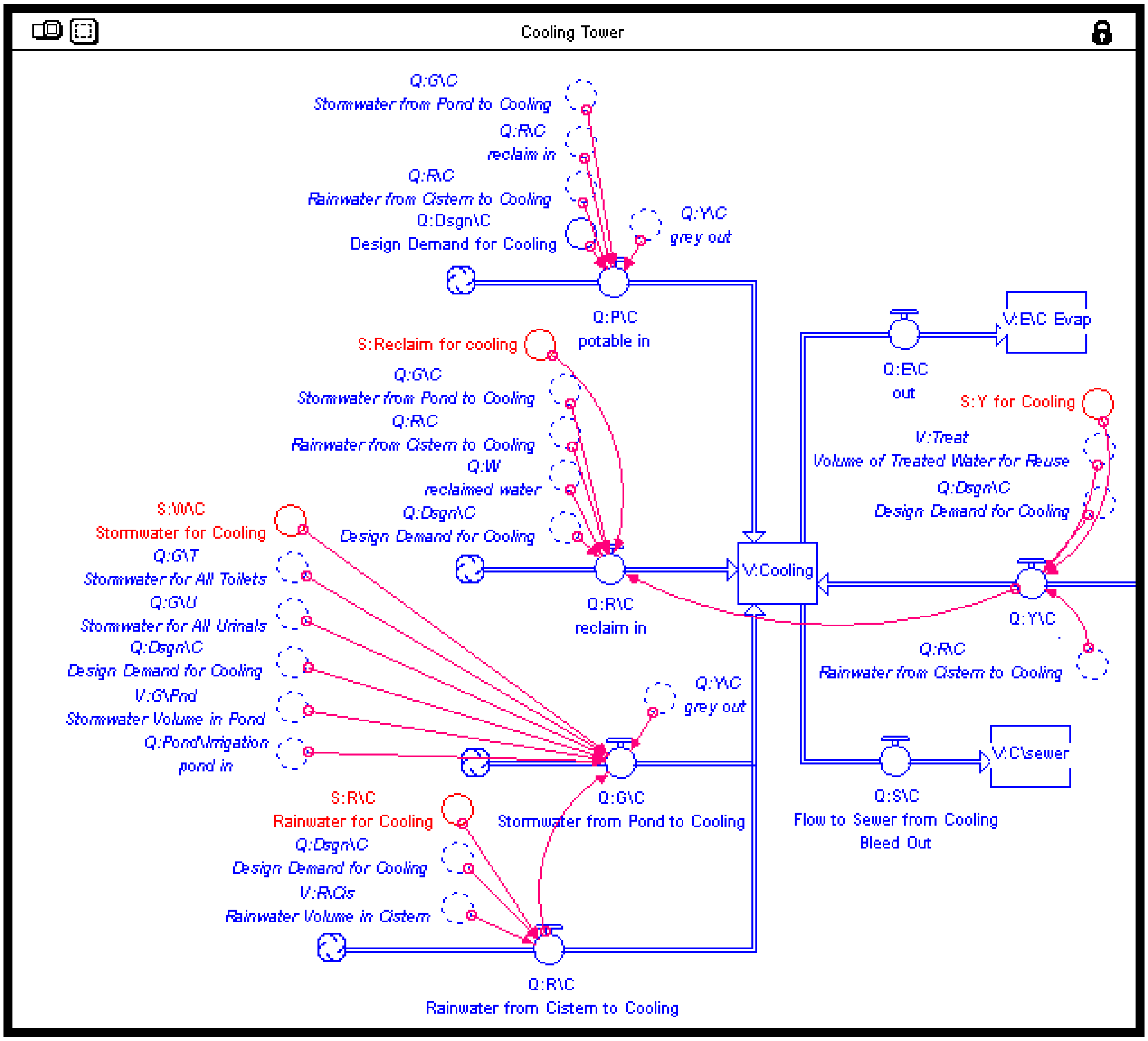

FIGURE A12: Detail view of the IBWM model cooling section.

TABLE A7: Variables in the cooling section of the IBWM model.

Notation in Model	Variable	Description	Units or Value
Q:Dsgn\C	Q_{Dsgn}^{C}	Design demand flow for cooling	gal/day
Q:E\C	Q_{E}^{C}	Flow lost through evaporation from cooling	gal/day
Q:G\C	Q_{G}^{C}	Flow of stormwater for cooling	gal/day
Q:G\T	Q_{G}^{T}	Flow of stormwater for toilets	gal/day
Q:G\U	Q_{G}^{U}	Flow of stormwater for urinals	gal/day
Q:P\C	Q_{P}^{C}	Flow of potable water for cooling	gal/day

TABLE A7 (Continued).

Notation in Model	Variable	Description	Units or Value
Q:Pond\Irrigation	Q_G^I	Flow of stormwater for irrigation	gal/day
Q:R\C	Q_R^C	Flow of rainwater for cooling	gal/day
Q:R\C reclaim in	Q_W^C	Flow of reclaimed water for cooling	gal/day
Q:S\C	Q_S^C	Flow of water bled out to sewer from cooling	gal/day
Q:W	Q_W	Total available flow of reclaimed water	gal/day
Q:Y\C	Q_Y^C	Flow of greywater for cooling	gal/day
S:R\C	-	Switch to direct rainwater to cooling	1
S:Reclaimfor cooling	-	Switch to direct reclaimed water to cooling	1
S:W\C	-	Switch to direct collected stormwater to cooling	1
V:C\sewer	V_S^C	Volume of water directed to sewer from cooling	gal
V:Cooling	V^C	Volume of water in the cooling tower	gal
V:E\C	V_E^C	Volume of water lost through evaporation from cooling	gal
V:G\Pnd	V_G^{Pnd}	Volume of stormwater available in the pond	gal
V:R\Cis	V_R^{Cis}	Volume of rainwater available in the cistern	gal

Rainwater Collection

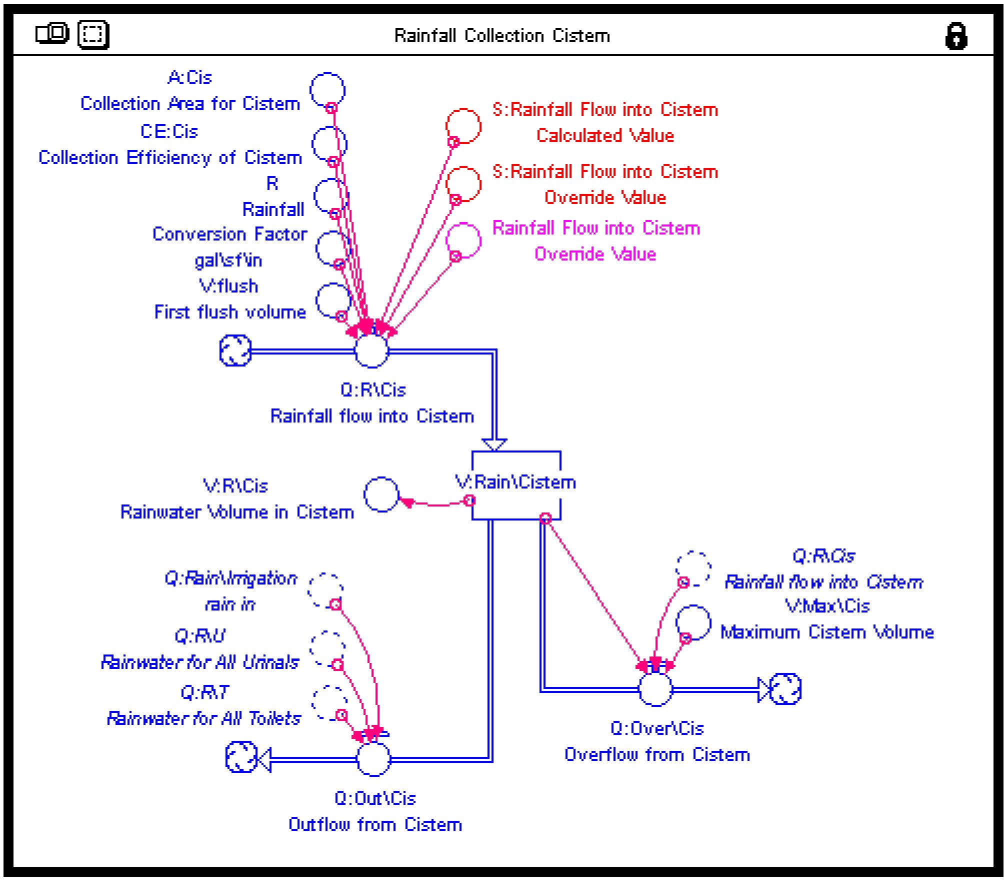

FIGURE A13: Detail view of the IBWM model rainwater collection section.

TABLE A8: Variables in the rainwater collection section of the IBWM model.

Notation in Model	**Variable**	**Description**	**Units or Value**
A:Cis	A^{Cis}	Collection area for the cistern	ft^2
CE:Cis	CE^{Cis}	Collection efficiency of the cistern collection system	-
Conversion Factor	CF	Conversion factor	0.6223 $gal/ft^2/in$
Q:Out\Cis	Q_{Tot}^{Cis}	Total outflow to all fixtures from cistern	gal/day
Q:Over\Pnd	Q_O^{Pnd}	Overflow from cistern	gal/day
Q:R\Cis	Q_R^{Cis}	Flow of rainwater into the cistern	gal/day
Q:R\T	Q_R^T	Flow of rainwater to toilets	gal/day
Q:R\U	Q_R^U	Flow of rainwater to urinals	gal/day
Q:Rain\Irrigation	Q_R^I	Flow of rainwater to irrigation	gal/day
R	R	Rainfall	in/day
Rainfall Flow into Cistern Override Value	Q_R^{Cis}	Flow of rainwater into the cistern	gal/day

TABLE A8 (Continued)

Notation in Model	Variable	Description	Units or Value
S:Rainfall Flow into Cistern Calculated Value	-	Switch to use model calculations to determine rainwater flow into cistern	1
S:Rainfall Flow into Cistern Override Value	-	Switch to use override value to determine rainwater flow into cistern	1
V:flush	V^{flush}	Volume of the first flush	gal
V:Max\Cis	V_{Max}^{Cis}	Maximum cistern volume	gal
V:R\Cis	V_R^{Cis}	Volume of rainwater in the cistern	gal
V:Rain\Cistern	V_R^{Cis}	Volume of rainwater in the cistern	gal

Stormwater Collection

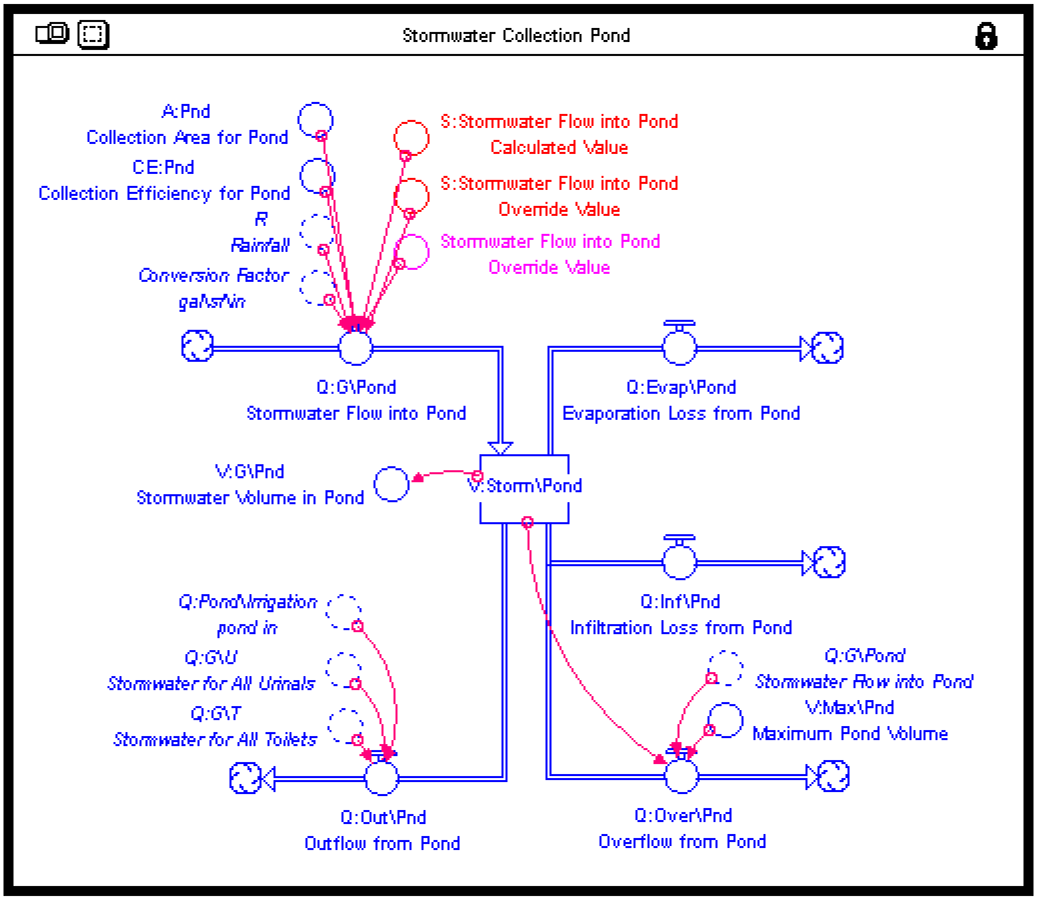

FIGURE A14: Detail view of the IBWM model stormwater collection section.

TABLE A9: Variables in the stormwater collection section of the IBWM model.

Notation in Model	**Variable**	**Description**	**Units or Value**
A:Pnd	A^{Pnd}	Collection area for the pond	ft^2
CE:Pnd	CE^{Pnd}	Collection efficiency of the stormwater collection system	-
Conversion Factor	CF	Conversion factor	0.6223 $gal/ft^2/in$
Q:Evap\Pond	Q_E^{Pnd}	Flow lost through evaporation from the pond	gal/day
Q:G\Pond	Q_G^{Pnd}	Flow of stormwater into the pond	gal/day
Q:G\T	Q_G^T	Flow of stormwater for toilets	gal/day
Q:G\U	Q_G^U	Flow of stormwater for urinals	gal/day
Q:inf\Pnd	Q_{Inf}^{Pnd}	Flow lost through infiltration from the pond	gal/day
Q:Out\Pnd	Q_{Tot}^{Pnd}	Total flow to all fixtures from pond	gal/day
Q:Over\Pnd	Q_O^{Pnd}	Overflow from stormwater pond	gal/day
Q:Pond\Irrigation	Q_W^I	Flow of stormwater for irrigation	gal/day
R	R	Rainfall	in/day
S:Stormwater Flow into Pond Calculated Value	-	Switch to use model calculations to determine flow of stormwater into pond	1
S:Stormwater Flow into Pond Override Value	-	Switch to use override value for flow of stormwater into pond	1
Stormwater Flow into Pond Override Value	Q_G^{Pnd}	Flow of stormwater into the pond	gal/day
V:G\Pnd	V_G^{Pnd}	Volume of stormwater in the pond	gal
V:Max\Pnd	V_{Max}^{Pnd}	Maximum volume of the stormwater pond	gal
V:Storm\Pond	V_G^{Pnd}	Volume of stormwater in the pond	gal

Appendix B: STELLA IBWM Model Equations

```
Design_TWA(t) = Design_TWA(t - dt) + (Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA) * dt
INIT Design_TWA = 0
INFLOWS:
Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA =
(S:Design_Irrigation_Demand_Calculated_Vlaue*(TWA\Groundcover+TWA\Mixed+TWA\Shrubs+TWA\Trees+TWA\Turfgr
ass))
+
(S:Design_Irrigation_Demand_Override_Value*Design_Irrigation_Demand_Override_Value)
Total_Rainfall(t) = Total_Rainfall(t - dt) + (Rainfall_Flow_In) * dt
INIT Total_Rainfall = 0
INFLOWS:
Rainfall_Flow_In = Q:R\Cis_Rainfall_flow_into_Cistern
V:Baseline_TPWA_2(t) = V:Baseline_TPWA_2(t - dt) + (Q:Base\I_Baseline_Demand_for_Irrigation_TPWA__and_TWA) *
dt
INIT V:Baseline_TPWA_2 = 0.0000000000000001
INFLOWS:
Q:Base\I_Baseline_Demand_for_Irrigation_TPWA__and_TWA =
(S:Base_Irrigation_Demand_Calculated_Vlaue*(TPWA\Groundcover_2+TPWA\Mixed_2+TPWA\Shrubs_2+TPWA\Trees_
2+TPWA\Turfgrass_2))
+
(S:Base_Irrigation_Demand_Override_Value*Baseline_Irrigation_Demand_Override_Value)
V:BaseTotal(t) = V:BaseTotal(t - dt) + (Q:Base\Total) * dt
INIT V:BaseTotal = 0.0000000000001
INFLOWS:
Q:Base\Total = Q:Base\Total_Baseline_Total_Water_Use_All_Potable_Water
V:Base\H(t) = V:Base\H(t - dt) + (Q:Base\H) * dt
INIT V:Base\H = 0.0000000000000001
INFLOWS:
Q:Base\H = Q:Dsgn\H_Design_Demand_for_Showers
V:Base\I(t) = V:Base\I(t - dt) + (Q:Base\I) * dt
INIT V:Base\I = 0.0000000000000001
INFLOWS:
Q:Base\I = Q:Base\I_Baseline_Demand_for_Irrigation_TPWA__and_TWA
V:Base\Sb(t) = V:Base\Sb(t - dt) + (Q:Base\Sb) * dt
INIT V:Base\Sb = 0.0000000000000001
INFLOWS:
Q:Base\Sb = Q:Base\Sb_Baseline_Demand_for_Bathroom_Sinks
V:Base\Sk(t) = V:Base\Sk(t - dt) + (Q:Base\Sk) * dt
INIT V:Base\Sk = 0.0000000000000001
INFLOWS:
Q:Base\Sk = Q:Base\Sk_Baseline_Demand_for_Kitchen_Sinks
V:Base\Swge(t) = V:Base\Swge(t - dt) + (Q:Base\Swge) * dt
INIT V:Base\Swge = 0.0000000000001
INFLOWS:
Q:Base\Swge = Q:Base\Swge_Basline_Sewage_Conveyance
V:Base\T(t) = V:Base\T(t - dt) + (Q:Base\T) * dt
INIT V:Base\T = 0.0000000000000001
INFLOWS:
Q:Base\T = Q:Base\T__Baseline_Demand_for_All_Toilets
V:Base\U(t) = V:Base\U(t - dt) + (Q:Base\U) * dt
INIT V:Base\U = 0.0000000000000001
INFLOWS:
Q:Base\U = Q:Base\U_Baseline_Demand_for_All_Urinals
V:Base\Wter(t) = V:Base\Wter(t - dt) + (Q:Base\Wter) * dt
INIT V:Base\Wter = 0.0000000000001
INFLOWS:
Q:Base\Wter = Q:Base\Wter_Baseline_Water_Use_for_Fixtures_All_Potable_Water
V:B\T_Blackwater(t) = V:B\T_Blackwater(t - dt) + (Q:B\T_Male_black_in + Q:B\T_Female_black_in) * dt
INIT V:B\T_Blackwater = 0
INFLOWS:
Q:B\T_Male_black_in = S:T\Black_Male*Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets
Q:B\T_Female_black_in = S:T\Black_Female*Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets
V:B\U_Blackwater(t) = V:B\U_Blackwater(t - dt) + (Q:B\U_Male_black_in + Q:B\U_Female_black_in) * dt
INIT V:B\U_Blackwater = 0
```

```
INFLOWS:
Q:B\U_Male_black_in = S:U\Black_Male*Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals
Q:B\U_Female_black_in = S:U\black_Female*Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals
V:Cooling(t) = V:Cooling(t - dt) + (Q:Y\C_grey_out + Q:P\C_potable_in + Q:R\C_reclaim_in +
Q:G\C_Stormwater_from_Pond_to_Cooling + Q:R\C_Rainwater_from_Cistern_to_Cooling -
Q:S\C_Flow_to_Sewer_from_Cooling_Bleed_Out - Q:E\C_out) * dt
INIT V:Cooling = 0
INFLOWS:
Q:Y\C_grey_out = IF ( Q:Dsgn\C_Design_Demand_for_Cooling > Q:R\C_Rainwater_from_Cistern_to_Cooling )
   THEN
      IF (V:Treat_Volume_of_Treated_Water_for_Reuse ) > Q:Dsgn\C_Design_Demand_for_Cooling -
Q:R\C_Rainwater_from_Cistern_to_Cooling
         THEN ( Q:Dsgn\C_Design_Demand_for_Cooling - Q:R\C_Rainwater_from_Cistern_to_Cooling )*S:Y_for_Cooling
      ELSE (V:Treat_Volume_of_Treated_Water_for_Reuse)*S:Y_for_Cooling
ELSE 0
Q:P\C_potable_in = Q:Dsgn\C_Design_Demand_for_Cooling - Q:Y\C_grey_out -
Q:R\C_Rainwater_from_Cistern_to_Cooling - Q:G\C_Stormwater_from_Pond_to_Cooling - Q:R\C_reclaim_in
Q:R\C_reclaim_in = IF (Q:Dsgn\C_Design_Demand_for_Cooling > ( Q:Y\C_grey_out +
Q:R\C_Rainwater_from_Cistern_to_Cooling + Q:G\C_Stormwater_from_Pond_to_Cooling ) )
   THEN
      IF ( ( Q:Dsgn\C_Design_Demand_for_Cooling - Q:Y\C_grey_out - Q:R\C_Rainwater_from_Cistern_to_Cooling -
Q:G\C_Stormwater_from_Pond_to_Cooling ) > Q:W_reclaimed_water )
         THEN (Q:W_reclaimed_water*S:Reclaim_for_cooling)
      ELSE ( (Q:Dsgn\C_Design_Demand_for_Cooling - Q:Y\C_grey_out - Q:R\C_Rainwater_from_Cistern_to_Cooling -
Q:G\C_Stormwater_from_Pond_to_Cooling )*S:Reclaim_for_cooling )
ELSE 0
Q:G\C_Stormwater_from_Pond_to_Cooling = IF ( Q:Dsgn\C_Design_Demand_for_Cooling > ( Q:Y\C_grey_out +
Q:R\C_Rainwater_from_Cistern_to_Cooling) )
   THEN
      IF ( ( Q:Dsgn\C_Design_Demand_for_Cooling - Q:Y\C_grey_out - Q:R\C_Rainwater_from_Cistern_to_Cooling ) > (
V:G\Pnd_Stormwater_Volume_in_Pond - Q:G\U_Stormwater_for_All_Urinals - Q:G\T_Stormwater_for_All_Toilets -
Q:Pond\Irrigation_pond_in ) )
         THEN ( ( V:G\Pnd_Stormwater_Volume_in_Pond - Q:G\U_Stormwater_for_All_Urinals -
Q:G\T_Stormwater_for_All_Toilets - Q:Pond\Irrigation_pond_in )*S:W\C_Stormwater_for_Cooling )
      ELSE ( ( Q:Dsgn\C_Design_Demand_for_Cooling - Q:Y\C_grey_out - Q:R\C_Rainwater_from_Cistern_to_Cooling -
Q:G\U_Stormwater_for_All_Urinals - Q:G\T_Stormwater_for_All_Toilets - Q:Pond\Irrigation_pond_in
)*S:W\C_Stormwater_for_Cooling )
ELSE 0
Q:R\C_Rainwater_from_Cistern_to_Cooling = IF ( V:R\Cis_Rainwater_Volume_in_Cistern >
Q:Dsgn\C_Design_Demand_for_Cooling )
    THEN ( Q:Dsgn\C_Design_Demand_for_Cooling*S:R\C_Rainwater_for_Cooling )
ELSE ( V:R\Cis_Rainwater_Volume_in_Cistern*S:R\C_Rainwater_for_Cooling )
OUTFLOWS:
Q:S\C_Flow_to_Sewer_from_Cooling_Bleed_Out = 0
Q:E\C_out = 0
V:C\sewer(t) = V:C\sewer(t - dt) + (Q:S\C_Flow_to_Sewer_from_Cooling_Bleed_Out) * dt
INIT V:C\sewer = 0
INFLOWS:
Q:S\C_Flow_to_Sewer_from_Cooling_Bleed_Out = 0
V:Dsgn\H(t) = V:Dsgn\H(t - dt) + (Q:Dsgn\H) * dt
INIT V:Dsgn\H = 0.0000000000000001
INFLOWS:
Q:Dsgn\H = Q:Dsgn\H_Design_Demand_for_Showers
V:Dsgn\I(t) = V:Dsgn\I(t - dt) + (Q:Dsgn\I) * dt
INIT V:Dsgn\I = 0.0000000000000001
INFLOWS:
Q:Dsgn\I = Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA
V:Dsgn\Sb(t) = V:Dsgn\Sb(t - dt) + (Q:Dsgn\Sb) * dt
INIT V:Dsgn\Sb = 0.0000000000000001
INFLOWS:
Q:Dsgn\Sb = Q:Dsgn\Sb_Design_Demand_for_Bathroom_Sinks
V:Dsgn\Sk(t) = V:Dsgn\Sk(t - dt) + (Q:Dsgn\Sk) * dt
INIT V:Dsgn\Sk = 0.0000000000000001
INFLOWS:
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Q:Dsgn\Sk = Q:Dsgn\Sk_Design_Demand_for_Kitchen_Sinks
V:Dsgn\Swge(t) = V:Dsgn\Swge(t - dt) + (Q:Dsgn\Swge) * dt
INIT V:Dsgn\Swge = 0
INFLOWS:
Q:Dsgn\Swge = Q:Dsgn\Swge_Design_Sewage_Conveyance
V:Dsgn\T(t) = V:Dsgn\T(t - dt) + (Q:Dsgn\T) * dt
INIT V:Dsgn\T = 0.0000000000000001
INFLOWS:
Q:Dsgn\T = Q:Dsgn\T__Design_Demand_for_All_Toilets
V:Dsgn\Total(t) = V:Dsgn\Total(t - dt) + (Q:Dsgn\Total) * dt
INIT V:Dsgn\Total = 0.0000000000001
INFLOWS:
Q:Dsgn\Total = Q:Dsgn\Total_Design_Total_Water_Use_All_Water
V:Dsgn\U(t) = V:Dsgn\U(t - dt) + (Q:Dsgn\U) * dt
INIT V:Dsgn\U = 0.0000000000000001
INFLOWS:
Q:Dsgn\U = Q:Dsgn\U_Design_Flowrate_for_All_Urinals
V:Dsgn\Wter(t) = V:Dsgn\Wter(t - dt) + (Q:Dsgn\Wter) * dt
INIT V:Dsgn\Wter = 0
INFLOWS:
Q:Dsgn\Wter = Q:Dsgn\Wter_Design_Water_Use_for_Fixtures_All_Water
V:E\C_Evap(t) = V:E\C_Evap(t - dt) + (Q:E\C_out) * dt
INIT V:E\C_Evap = 0
INFLOWS:
Q:E\C_out = 0
V:H_Showers(t) = V:H_Showers(t - dt) + (Q:P\H_Potable_water_to_Showers - Q:S\H_from_Showers_to_Sewer -
Q:Y\H_Greywater_to_Treatment) * dt
INIT V:H_Showers = 0
INFLOWS:
Q:P\H_Potable_water_to_Showers = Q:Dsgn\H_Design_Demand_for_Showers
OUTFLOWS:
Q:S\H_from_Showers_to_Sewer = Q:P\H_Potable_water_to_Showers*S:S\H_to_Sewer
Q:Y\H_Greywater_to_Treatment = Q:P\H_Potable_water_to_Showers*S:Y\H_to_Treatment
V:I_Irrigation(t) = V:I_Irrigation(t - dt) + (Q:Y\I_grey_out + Q:Rain\Irrigation_rain_in + Q:Pond\Irrigation_pond_in +
Q:Reclaim\Irrigation_reclaimed_in + Q:P\I_Potable_water_for_Irrigation - Q:Runoff\Irrigation - Q:Irrigation\Plants) * dt
INIT V:I_Irrigation = 0
INFLOWS:
Q:Y\I_grey_out = IF (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
(Q:Dsgn\T__Design_Demand_for_All_Toilets+Q:Dsgn\U_Design_Flowrate_for_All_Urinals) ) >
Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA
  THEN ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA*S:Y_for_Irrigation )
ELSE ( ( V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
(Q:Dsgn\T__Design_Demand_for_All_Toilets+Q:Dsgn\U_Design_Flowrate_for_All_Urinals) )*S:Y_for_Irrigation )
Q:Rain\Irrigation_rain_in = IF ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA > Q:Y\I_grey_out )
  THEN
    IF ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA - Q:Y\I_grey_out ) > (
V:R\Cis_Rainwater_Volume_in_Cistern - Q:R\U_Rainwater_for_All_Urinals - Q:R\T_Rainwater_for_All_Toilets )
      THEN ( ( V:R\Cis_Rainwater_Volume_in_Cistern - Q:R\U_Rainwater_for_All_Urinals -
Q:R\T_Rainwater_for_All_Toilets )*S:Rain_for_Irrigation )
    ELSE ( ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA - Q:Y\I_grey_out )*S:Rain_for_Irrigation )
ELSE 0
Q:Pond\Irrigation_pond_in = IF ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA > ( Q:Y\I_grey_out +
Q:Rain\Irrigation_rain_in ) )
  THEN
    IF ( ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA - Q:Y\I_grey_out - Q:Rain\Irrigation_rain_in ) > (
V:G\Pnd_Stormwater_Volume_in_Pond - Q:G\U_Stormwater_for_All_Urinals - Q:G\T_Stormwater_for_All_Toilets ) )
      THEN ( ( V:G\Pnd_Stormwater_Volume_in_Pond - Q:G\U_Stormwater_for_All_Urinals -
Q:G\T_Stormwater_for_All_Toilets )*S:Pond_for_Irrigation )
    ELSE ( ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA - Q:Y\I_grey_out - Q:Rain\Irrigation_rain_in -
Q:G\U_Stormwater_for_All_Urinals - Q:G\T_Stormwater_for_All_Toilets )*S:Pond_for_Irrigation )
ELSE 0
Q:Reclaim\Irrigation_reclaimed_in = IF ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA > ( Q:Y\I_grey_out +
Q:Rain\Irrigation_rain_in + Q:Pond\Irrigation_pond_in ) )
  THEN
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        IF ( ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA - Q:Y\I_grey_out - Q:Rain\Irrigation_rain_in -
Q:Pond\Irrigation_pond_in ) > ( Q:W_reclaimed_water - Q:W\U_Reclaimed_water_for_All_Urinals -
Q:W\T_Reclaimed_water_for_All_Toilets) )
            THEN ( Q:W_reclaimed_water - Q:W\U_Reclaimed_water_for_All_Urinals -
Q:W\T_Reclaimed_water_for_All_Toilets )*S:Reclaim\Irrigation
       ELSE ( ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA - Q:Y\I_grey_out - Q:Rain\Irrigation_rain_in -
Q:Pond\Irrigation_pond_in - Q:W\U_Reclaimed_water_for_All_Urinals - Q:W\T_Reclaimed_water_for_All_Toilets
)*S:Reclaim\Irrigation )
ELSE 0
Q:P\I_Potable_water_for_Irrigation = Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA-Q:Y\I_grey_out-
Q:Rain\Irrigation_rain_in-Q:Pond\Irrigation_pond_in-Q:Reclaim\Irrigation_reclaimed_in
OUTFLOWS:
Q:Runoff\Irrigation = 0
Q:Irrigation\Plants = Q:I\Total
V:P_Dsgn\H(t) = V:P_Dsgn\H(t - dt) + (Q:P_Dsgn\H) * dt
INIT V:P_Dsgn\H = 0
INFLOWS:
Q:P_Dsgn\H = Q:P\H_Potable_water_to_Showers
V:P_Dsgn\I(t) = V:P_Dsgn\I(t - dt) + (Q:P_Dsgn\I) * dt
INIT V:P_Dsgn\I = 0
INFLOWS:
Q:P_Dsgn\I = Q:P\I_Potable_water_for_Irrigation
V:P_Dsgn\Sb(t) = V:P_Dsgn\Sb(t - dt) + (Q:P_Dsgn\Sb) * dt
INIT V:P_Dsgn\Sb = 0
INFLOWS:
Q:P_Dsgn\Sb = Q:P\Sb_Potable_water_to_Bathroom_Sinks
V:P_Dsgn\Sk(t) = V:P_Dsgn\Sk(t - dt) + (Q:P_Dsgn\Sk) * dt
INIT V:P_Dsgn\Sk = 0
INFLOWS:
Q:P_Dsgn\Sk = Q:P\Sk_Potable_water_to_Kitchen_Sinks
V:P_Dsgn\Swge(t) = V:P_Dsgn\Swge(t - dt) + (Q:P_Dsgn\Swge) * dt
INIT V:P_Dsgn\Swge = 0
INFLOWS:
Q:P_Dsgn\Swge = Q:P_Dsgn\Swge_Sewage_Conveyance_from_Potable_Water
V:P_Dsgn\T(t) = V:P_Dsgn\T(t - dt) + (Q:P_Dsgn\T) * dt
INIT V:P_Dsgn\T = 0
INFLOWS:
Q:P_Dsgn\T = Q:P\T_Potable_water_for_All_Toilets
V:P_Dsgn\Total(t) = V:P_Dsgn\Total(t - dt) + (Q:P_Dsgn\Total) * dt
INIT V:P_Dsgn\Total = 0
INFLOWS:
Q:P_Dsgn\Total = Q:P_Dsgn\Total_Design_Total_Water_Use_Potable_Water
V:P_Dsgn\U(t) = V:P_Dsgn\U(t - dt) + (Q:P_Dsgn\U) * dt
INIT V:P_Dsgn\U = 0
INFLOWS:
Q:P_Dsgn\U = Q:P\U_Potable_water_for_All_Urinals
V:P_Dsgn\Wter(t) = V:P_Dsgn\Wter(t - dt) + (Q:P_Dsgn\Wter) * dt
INIT V:P_Dsgn\Wter = 0
INFLOWS:
Q:P_Dsgn\Wter = Q:P_Dsgn\Wter_Design_Water_Use_for_Fixtures_Potable_Water
V:Rain\Cistern(t) = V:Rain\Cistern(t - dt) + (Q:R\Cis_Rainfall_flow_into_Cistern - Q:Out\Cis_Outflow_from_Cistern -
Q:Over\Cis_Overflow_from_Cistern) * dt
INIT V:Rain\Cistern = 0
INFLOWS:
Q:R\Cis_Rainfall_flow_into_Cistern =
(S:Rainfall_Flow_into_Cistern_Calculated_Value*(R_Rainfall*A:Cis_Collection_Area_for_Cistern*CE:Cis_Collection_Effici
ency_of_Cistern*Conversion_Factor_gal\sf\in - V:flush_First_flush_volume))
+
(S:Rainfall_Flow_into_Cistern_Override_Value*Rainfall_Flow_into_Cistern_Override_Value)
OUTFLOWS:
Q:Out\Cis_Outflow_from_Cistern =
Q:Rain\Irrigation_rain_in+Q:R\T_Rainwater_for_All_Toilets+Q:R\U_Rainwater_for_All_Urinals
Q:Over\Cis_Overflow_from_Cistern = IF ( V:Rain\Cistern < V:Max\Cis_Maximum_Cistern_Volume )
   THEN ( 0 )
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ELSE ( Q:R\Cis_Rainfall_flow_into_Cistern )
V:Runoff\Irrigation(t) = V:Runoff\Irrigation(t - dt) + (Q:Runoff\Irrigation) * dt
INIT V:Runoff\Irrigation = 0
INFLOWS:
Q:Runoff\Irrigation = 0
V:Sb_Bathroom_Sinks(t) = V:Sb_Bathroom_Sinks(t - dt) + (Q:P\Sb_Potable_water_to_Bathroom_Sinks -
Q:S\Sb_from_Bathroom_Sinks_to_Sewer - Q:Y\Sb_Greywater_to_Treatment) * dt
INIT V:Sb_Bathroom_Sinks = 0
INFLOWS:
Q:P\Sb_Potable_water_to_Bathroom_Sinks = Q:Dsgn\Sb_Design_Demand_for_Bathroom_Sinks
OUTFLOWS:
Q:S\Sb_from_Bathroom_Sinks_to_Sewer = Q:P\Sb_Potable_water_to_Bathroom_Sinks*S:S\Sb_to_Sewer
Q:Y\Sb_Greywater_to_Treatment = Q:P\Sb_Potable_water_to_Bathroom_Sinks*S:Y\Sb_to_Treatment
V:Sk_Kitchen_Sinks(t) = V:Sk_Kitchen_Sinks(t - dt) + (Q:P\Sk_Potable_water_to_Kitchen_Sinks -
Q:Y\Sk_Greywater_to_Treatment - Q:S\Sk_from_Kitchen_Sinks_to_Sewer) * dt
INIT V:Sk_Kitchen_Sinks = 0
INFLOWS:
Q:P\Sk_Potable_water_to_Kitchen_Sinks = Q:Dsgn\Sk_Design_Demand_for_Kitchen_Sinks
OUTFLOWS:
Q:Y\Sk_Greywater_to_Treatment = Q:P\Sk_Potable_water_to_Kitchen_Sinks*S:Y\Sk_to_Treatment
Q:S\Sk_from_Kitchen_Sinks_to_Sewer = Q:P\Sk_Potable_water_to_Kitchen_Sinks*S:S\Sk_to_Sewer
V:Storm\Pond(t) = V:Storm\Pond(t - dt) + (Q:G\Pond_Stormwater_Flow_into_Pond - Q:Out\Pnd_Outflow_from_Pond -
Q:Over\Pnd_Overflow_from_Pond - Q:Evap\Pond_Evaporation_Loss_from_Pond -
Q:Inf\Pnd_Infiltration_Loss_from_Pond) * dt
INIT V:Storm\Pond = 0
INFLOWS:
Q:G\Pond_Stormwater_Flow_into_Pond =
(S:Stormwater_Flow_into_Pond_Calculated_Value*(R_Rainfall*A:Pnd_Collection_Area_for_Pond*CE:Pnd_Collection_Effi
ciency_for_Pond*Conversion_Factor_gal\sf\in))
+
(S:Stormwater_Flow_into_Pond_Override_Value*Stormwater_Flow_into_Pond_Override_Value)
OUTFLOWS:
Q:Out\Pnd_Outflow_from_Pond =
Q:G\T_Stormwater_for_All_Toilets+Q:G\U_Stormwater_for_All_Urinals+Q:Pond\Irrigation_pond_in
Q:Over\Pnd_Overflow_from_Pond = IF ( V:Storm\Pond < V:Max\Pnd_Maximum_Pond_Volume )
   THEN ( 0 )
ELSE ( Q:G\Pond_Stormwater_Flow_into_Pond )
Q:Evap\Pond_Evaporation_Loss_from_Pond = 0
Q:Inf\Pnd_Infiltration_Loss_from_Pond = 0
V:S\H_Sewer(t) = V:S\H_Sewer(t - dt) + (Q:S\H_from_Showers_to_Sewer) * dt
INIT V:S\H_Sewer = 0
INFLOWS:
Q:S\H_from_Showers_to_Sewer = Q:P\H_Potable_water_to_Showers*S:S\H_to_Sewer
V:S\Sb_Sewer(t) = V:S\Sb_Sewer(t - dt) + (Q:S\Sb_from_Bathroom_Sinks_to_Sewer) * dt
INIT V:S\Sb_Sewer = 0
INFLOWS:
Q:S\Sb_from_Bathroom_Sinks_to_Sewer = Q:P\Sb_Potable_water_to_Bathroom_Sinks*S:S\Sb_to_Sewer
V:S\Sk_Sewer(t) = V:S\Sk_Sewer(t - dt) + (Q:S\Sk_from_Kitchen_Sinks_to_Sewer) * dt
INIT V:S\Sk_Sewer = 0
INFLOWS:
Q:S\Sk_from_Kitchen_Sinks_to_Sewer = Q:P\Sk_Potable_water_to_Kitchen_Sinks*S:S\Sk_to_Sewer
V:Treat_Treatment(t) = V:Treat_Treatment(t - dt) + (Q:Y\Sb_Greywater_to_Treatment + Q:Y\H_Greywater_to_Treatment
+ Q:Y\Sk_Greywater_to_Treatment - Q:Y\T_Male_grey_out - Q:Y\T_Female_grey_out - Q:Y\C_grey_out - Q:Y\I_grey_out
- Q:Y\U_Male_grey_out - Q:Y\U_Female_grey_out) * dt
INIT V:Treat_Treatment = 0
INFLOWS:
Q:Y\Sb_Greywater_to_Treatment = Q:P\Sb_Potable_water_to_Bathroom_Sinks*S:Y\Sb_to_Treatment
Q:Y\H_Greywater_to_Treatment = Q:P\H_Potable_water_to_Showers*S:Y\H_to_Treatment
Q:Y\Sk_Greywater_to_Treatment = Q:P\Sk_Potable_water_to_Kitchen_Sinks*S:Y\Sk_to_Treatment
OUTFLOWS:
Q:Y\T_Male_grey_out = IF ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets > Q:R\T_Male_rain_in )
   THEN
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    IF (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Design_Flowrate_for_All_Urinals ) > Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets -
Q:R\T_Male_rain_in
        THEN ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets - Q:R\T_Male_rain_in )*S:Y_for_Toilets_Male
    ELSE (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Design_Flowrate_for_All_Urinals)*S:Y_for_Toilets_Male
ELSE 0
Q:Y\T_Female_grey_out = IF ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets > Q:R\T_Female_rain_in)
  THEN
    IF (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Design_Flowrate_for_All_Urinals - Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets ) >
Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets - Q:R\T_Female_rain_in
        THEN ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets - Q:R\T_Female_rain_in
)*S:Y_for_Toilets_Female
    ELSE (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Design_Flowrate_for_All_Urinals -
Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets)*S:Y_for_Toilets_Female
ELSE 0
Q:Y\C_grey_out = IF ( Q:Dsgn\C_Design_Demand_for_Cooling > Q:R\C_Rainwater_from_Cistern_to_Cooling )
  THEN
    IF (V:Treat_Volume_of_Treated_Water_for_Reuse ) > Q:Dsgn\C_Design_Demand_for_Cooling -
Q:R\C_Rainwater_from_Cistern_to_Cooling
        THEN ( Q:Dsgn\C_Design_Demand_for_Cooling - Q:R\C_Rainwater_from_Cistern_to_Cooling )*S:Y_for_Cooling
    ELSE (V:Treat_Volume_of_Treated_Water_for_Reuse)*S:Y_for_Cooling
ELSE 0
Q:Y\I_grey_out = IF (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
(Q:Dsgn\T__Design_Demand_for_All_Toilets+Q:Dsgn\U_Design_Flowrate_for_All_Urinals) ) >
Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA
  THEN ( Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA*S:Y_for_Irrigation )
ELSE ( ( V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
(Q:Dsgn\T__Design_Demand_for_All_Toilets+Q:Dsgn\U_Design_Flowrate_for_All_Urinals) )*S:Y_for_Irrigation )
Q:Y\U_Male_grey_out = IF ( Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals > Q:R\U_Male_rain_in )
  THEN
    IF (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals ) > Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals -
Q:R\U_Male_rain_in
        THEN ( Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals - Q:R\U_Male_rain_in )*S:Y_for_urinals_Male
    ELSE (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals)*S:Y_for_urinals_Male
ELSE 0
Q:Y\U_Female_grey_out = IF ( Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals > Q:R\U_Female_rain_in )
  THEN
    IF (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling) >
Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals - Q:R\U_Female_rain_in
        THEN ( Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals - Q:R\U_Female_rain_in
)*S:Y_for_urinals_Female
    ELSE (V:Treat_Volume_of_Treated_Water_for_Reuse -
Q:Dsgn\C_Design_Demand_for_Cooling)*S:Y_for_urinals_Female
ELSE 0
V:T\Sewer_Female(t) = V:T\Sewer_Female(t - dt) + (Q:S\T_Female_to_Sewer_from_Toilets_F) * dt
INIT V:T\Sewer_Female = 0
INFLOWS:
Q:S\T_Female_to_Sewer_from_Toilets_F = S:T\Sewer_Female*Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets
V:T\sewer_Male(t) = V:T\sewer_Male(t - dt) + (Q:S\T_Male_to_Sewer_from_Toilets_M) * dt
INIT V:T\sewer_Male = 0
INFLOWS:
Q:S\T_Male_to_Sewer_from_Toilets_M = S:T\Sewer_Male*Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets
V:T_All_Toilets(t) = V:T_All_Toilets(t - dt) + (Q:W\T_Reclaimed_water_for_All_Toilets + Q:Y\T_Greyater_for_All_Toilets +
Q:P\T_Potable_water_for_All_Toilets + Q:R\T_Rainwater_for_All_Toilets + Q:G\T_Stormwater_for_All_Toilets -
Q:B\T_Blackwater_for_Reuse_from_All_Toilets - Q:S\T_Water_to_Sewer_from_All_Toilets) * dt
INIT V:T_All_Toilets = 0
INFLOWS:
Q:W\T_Reclaimed_water_for_All_Toilets = Q:W\T_Female_reclaimed_in+Q:W\T_Male_reclaimed_in
Q:Y\T_Greyater_for_All_Toilets = Q:Y\T_Female_grey_out+Q:Y\T_Male_grey_out
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Q:P\T_Potable_water_for_All_Toilets = Q:P\T_Female_potable_in+Q:P\T_Male_potable_in
Q:R\T_Rainwater_for_All_Toilets = Q:R\T_Female_rain_in+Q:R\T_Male_rain_in
Q:G\T_Stormwater_for_All_Toilets = Q:G\T_Female_pond_in+Q:G\T_Male_pond_in
OUTFLOWS:
Q:B\T_Blackwater_for_Reuse_from_All_Toilets = Q:B\T_Female_black_in+Q:B\T_Male_black_in
Q:S\T_Water_to_Sewer_from_All_Toilets =
Q:S\T_Female_to_Sewer_from_Toilets_F+Q:S\T_Male_to_Sewer_from_Toilets_M
V:T_Toilets_Female(t) = V:T_Toilets_Female(t - dt) + (Q:Y\T_Female_grey_out + Q:P\T_Female_potable_in +
Q:W\T_Female_reclaimed_in + Q:G\T_Female_pond_in + Q:R\T_Female_rain_in -
Q:S\T_Female_to_Sewer_from_Toilets_F - Q:B\T_Female_black_in) * dt
INIT V:T_Toilets_Female = 0
INFLOWS:
Q:Y\T_Female_grey_out = IF ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets > Q:R\T_Female_rain_in)
  THEN
    IF (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Design_Flowrate_for_All_Urinals - Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets ) >
Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets - Q:R\T_Female_rain_in
      THEN ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets - Q:R\T_Female_rain_in
)*S:Y_for_Toilets_Female
    ELSE (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Design_Flowrate_for_All_Urinals -
Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets)*S:Y_for_Toilets_Female
ELSE 0
Q:P\T_Female_potable_in = Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets - Q:Y\T_Female_grey_out -
Q:R\T_Female_rain_in - Q:G\T_Female_pond_in - Q:W\T_Female_reclaimed_in
Q:W\T_Female_reclaimed_in = IF ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets > ( Q:Y\T_Female_grey_out
+ Q:R\T_Female_rain_in + Q:G\T_Female_pond_in ) )
  THEN
    IF ( ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets - Q:Y\T_Female_grey_out - Q:R\T_Female_rain_in -
Q:G\T_Female_pond_in ) > ( Q:W_reclaimed_water - Q:W\U_Reclaimed_water_for_All_Urinals -
Q:W\T_Male_reclaimed_in ) )
      THEN ( Q:W_reclaimed_water - Q:W\U_Reclaimed_water_for_All_Urinals - Q:W\T_Male_reclaimed_in
)*S:Reclaim_for_Toilets_Female
    ELSE ( ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets - Q:Y\T_Female_grey_out -
Q:R\T_Female_rain_in - Q:G\T_Female_pond_in - Q:W\U_Reclaimed_water_for_All_Urinals - Q:W\T_Male_reclaimed_in
)*S:Reclaim_for_Toilets_Female )
ELSE 0
Q:G\T_Female_pond_in = IF ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets > ( Q:Y\T_Female_grey_out +
Q:R\T_Female_rain_in ) )
  THEN
    IF ( ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets - Q:Y\T_Female_grey_out - Q:R\T_Female_rain_in )
> ( V:G\Pnd_Stormwater_Volume_in_Pond - Q:G\U_Stormwater_for_All_Urinals - Q:G\T_Male_pond_in ) )
      THEN ( ( V:G\Pnd_Stormwater_Volume_in_Pond - Q:G\U_Stormwater_for_All_Urinals - Q:G\T_Male_pond_in
)*S:Pond_for_Toilets_Female)
    ELSE ( ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets - Q:Y\T_Female_grey_out -
Q:R\T_Female_rain_in - Q:G\U_Stormwater_for_All_Urinals - Q:G\T_Male_pond_in )*S:Pond_for_Toilets_Female )
ELSE 0
Q:R\T_Female_rain_in = IF ( V:R\Cis_Rainwater_Volume_in_Cistern - Q:R\U_Rainwater_for_All_Urinals -
Q:R\T_Male_rain_in > Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets )
  THEN ( Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets*S:Rain_for_Toilets_Female )
ELSE ( V:R\Cis_Rainwater_Volume_in_Cistern - Q:R\U_Rainwater_for_All_Urinals - Q:R\T_Male_rain_in
)*S:Rain_for_Toilets_Female
OUTFLOWS:
Q:S\T_Female_to_Sewer_from_Toilets_F = S:T\Sewer_Female*Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets
Q:B\T_Female_black_in = S:T\Black_Female*Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets
V:T_Toilets_Male(t) = V:T_Toilets_Male(t - dt) + (Q:P\T_Male_potable_in + Q:R\T_Male_rain_in + Q:Y\T_Male_grey_out
+ Q:G\T_Male_pond_in + Q:W\T_Male_reclaimed_in - Q:B\T_Male_black_in - Q:S\T_Male_to_Sewer_from_Toilets_M) *
dt
INIT V:T_Toilets_Male = 0
INFLOWS:
Q:P\T_Male_potable_in = Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets-Q:Y\T_Male_grey_out-
Q:R\T_Male_rain_in-Q:G\T_Male_pond_in-Q:W\T_Male_reclaimed_in
Q:R\T_Male_rain_in = IF ( V:R\Cis_Rainwater_Volume_in_Cistern - Q:R\U_Rainwater_for_All_Urinals >
Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets )
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   THEN ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets*S:Rain_for_Toilets_Male )
ELSE ( V:R\Cis_Rainwater_Volume_in_Cistern - Q:R\U_Rainwater_for_All_Urinals )*S:Rain_for_Toilets_Male
Q:Y\T_Male_grey_out = IF ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets > Q:R\T_Male_rain_in )
  THEN
    IF (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Design_Flowrate_for_All_Urinals ) > Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets -
Q:R\T_Male_rain_in
      THEN ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets - Q:R\T_Male_rain_in )*S:Y_for_Toilets_Male
    ELSE (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Design_Flowrate_for_All_Urinals)*S:Y_for_Toilets_Male
ELSE 0
Q:G\T_Male_pond_in = IF ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets > ( Q:Y\T_Male_grey_out +
Q:R\T_Male_rain_in ) )
  THEN
    IF ( ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets - Q:Y\T_Male_grey_out - Q:R\T_Male_rain_in ) > (
V:G\Pnd_Stormwater_Volume_in_Pond - Q:G\U_Stormwater_for_All_Urinals ) )
      THEN ( ( V:G\Pnd_Stormwater_Volume_in_Pond - Q:G\U_Stormwater_for_All_Urinals
)*S:Pond_for_Toilets_Male)
    ELSE ( ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets - Q:Y\T_Male_grey_out - Q:R\T_Male_rain_in -
Q:G\U_Stormwater_for_All_Urinals )*S:Pond_for_Toilets_Male )
ELSE 0
Q:W\T_Male_reclaimed_in = IF ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets > ( Q:Y\T_Male_grey_out +
Q:R\T_Male_rain_in + Q:G\T_Male_pond_in ) )
  THEN
     IF ( ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets - Q:Y\T_Male_grey_out - Q:R\T_Male_rain_in -
Q:G\T_Male_pond_in ) > ( Q:W_reclaimed_water - Q:W\U_Reclaimed_water_for_All_Urinals ) )
       THEN ( Q:W_reclaimed_water - Q:W\U_Reclaimed_water_for_All_Urinals )*S:Reclaim_for_Toilets_Male
    ELSE ( ( Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets - Q:Y\T_Male_grey_out - Q:R\T_Male_rain_in -
Q:G\T_Male_pond_in - Q:W\U_Reclaimed_water_for_All_Urinals )*S:Reclaim_for_Toilets_Male )
ELSE 0
OUTFLOWS:
Q:B\T_Male_black_in = S:T\Black_Male*Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets
Q:S\T_Male_to_Sewer_from_Toilets_M = S:T\Sewer_Male*Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets
V:U\Sewer_Female(t) = V:U\Sewer_Female(t - dt) + (Q:S\U_Female_to_Sewer_from_Urinals_F) * dt
INIT V:U\Sewer_Female = 0
INFLOWS:
Q:S\U_Female_to_Sewer_from_Urinals_F =
S:U\Sewer_Female*Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals
V:U\Sewer_Male(t) = V:U\Sewer_Male(t - dt) + (Q:S\U_Male_to_Sewer_from_Urinals_M) * dt
INIT V:U\Sewer_Male = 0
INFLOWS:
Q:S\U_Male_to_Sewer_from_Urinals_M = S:U\Sewer_Male*Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals
V:U_All_Urinals(t) = V:U_All_Urinals(t - dt) + (Q:W\U_Reclaimed_water_for_All_Urinals +
Q:P\U_Potable_water_for_All_Urinals + Q:R\U_Rainwater_for_All_Urinals + Q:G\U_Stormwater_for_All_Urinals +
Q:Y\U_Greywater_for_All_Urinals - Q:S\U_Water_to_Sewer_from_All_Urinals -
Q:B\U_Blackwater_for_Reuse_from_All_Urinals) * dt
INIT V:U_All_Urinals = 0
INFLOWS:
Q:W\U_Reclaimed_water_for_All_Urinals = Q:W\U_Female_reclaimed_in+Q:W\U_Male_reclaimed_in
Q:P\U_Potable_water_for_All_Urinals = Q:P\U_Female_potable_in+Q:P\U_Male_potable_in
Q:R\U_Rainwater_for_All_Urinals = Q:R\U_Female_rain_in+Q:R\U_Male_rain_in
Q:G\U_Stormwater_for_All_Urinals = Q:G\U_Female_pond_in+Q:G\U_Male_pond_in
Q:Y\U_Greywater_for_All_Urinals = Q:Y\U_Female_grey_out+Q:Y\U_Male_grey_out
OUTFLOWS:
Q:S\U_Water_to_Sewer_from_All_Urinals =
Q:S\U_Female_to_Sewer_from_Urinals_F+Q:S\U_Male_to_Sewer_from_Urinals_M
Q:B\U_Blackwater_for_Reuse_from_All_Urinals = Q:B\U_Female_black_in+Q:B\U_Male_black_in
V:U_Urinals_Female(t) = V:U_Urinals_Female(t - dt) + (Q:W\U_Female_reclaimed_in + Q:P\U_Female_potable_in +
Q:G\U_Female_pond_in + Q:R\U_Female_rain_in + Q:Y\U_Female_grey_out -
Q:S\U_Female_to_Sewer_from_Urinals_F - Q:B\U_Female_black_in) * dt
INIT V:U_Urinals_Female = 0
INFLOWS:
Q:W\U_Female_reclaimed_in = IF (Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals > (
Q:Y\U_Female_grey_out + Q:R\U_Female_rain_in + Q:G\U_Female_pond_in ) )
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  THEN
    IF ( ( Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals - Q:Y\U_Female_grey_out - Q:R\U_Female_rain_in -
Q:G\U_Female_pond_in ) > Q:W_reclaimed_water )
      THEN (Q:W_reclaimed_water*S:Reclaim_for_urinals_Female)
    ELSE ( (Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals - Q:Y\U_Female_grey_out -
Q:R\U_Female_rain_in - Q:G\U_Female_pond_in )*S:Reclaim_for_urinals_Female )
ELSE 0
Q:P\U_Female_potable_in = Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals - Q:Y\U_Female_grey_out -
Q:R\U_Female_rain_in - Q:G\U_Female_pond_in - Q:W\U_Female_reclaimed_in
Q:G\U_Female_pond_in = IF (Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals > ( Q:Y\U_Female_grey_out +
Q:R\U_Female_rain_in ) )      THEN (
     ( IF ( ( Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals - Q:Y\U_Female_grey_out -
Q:R\U_Female_rain_in ) > V:G\Pnd_Stormwater_Volume_in_Pond )
         THEN (V:G\Pnd_Stormwater_Volume_in_Pond*S:Pond_for_urinals_Female)
         ELSE ( (Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals - Q:Y\U_Female_grey_out -
Q:R\U_Female_rain_in )*S:Pond_for_urinals_Female ) ) )
   ELSE 0
Q:R\U_Female_rain_in = IF ( V:R\Cis_Rainwater_Volume_in_Cistern >
Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals )
   THEN ( Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals*S:Rain_for_urinals_Female )
ELSE ( V:R\Cis_Rainwater_Volume_in_Cistern*S:Rain_for_urinals_Female )
Q:Y\U_Female_grey_out = IF ( Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals > Q:R\U_Female_rain_in )
  THEN
    IF (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling) >
Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals - Q:R\U_Female_rain_in
      THEN ( Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals - Q:R\U_Female_rain_in
)*S:Y_for_urinals_Female
    ELSE (V:Treat_Volume_of_Treated_Water_for_Reuse -
Q:Dsgn\C_Design_Demand_for_Cooling)*S:Y_for_urinals_Female
ELSE 0
OUTFLOWS:
Q:S\U_Female_to_Sewer_from_Urinals_F =
S:U\Sewer_Female*Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals
Q:B\U_Female_black_in = S:U\black_Female*Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals
V:U_Urinals_Male(t) = V:U_Urinals_Male(t - dt) + (Q:Y\U_Male_grey_out + Q:G\U_Male_pond_in + Q:R\U_Male_rain_in
+ Q:W\U_Male_reclaimed_in + Q:P\U_Male_potable_in - Q:S\U_Male_to_Sewer_from_Urinals_M -
Q:B\U_Male_black_in) * dt
INIT V:U_Urinals_Male = 0
INFLOWS:
Q:Y\U_Male_grey_out = IF ( Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals > Q:R\U_Male_rain_in )
  THEN
    IF (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals ) > Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals -
Q:R\U_Male_rain_in
      THEN ( Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals - Q:R\U_Male_rain_in )*S:Y_for_urinals_Male
    ELSE (V:Treat_Volume_of_Treated_Water_for_Reuse - Q:Dsgn\C_Design_Demand_for_Cooling -
Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals)*S:Y_for_urinals_Male
ELSE 0
Q:G\U_Male_pond_in = IF (Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals > ( Q:Y\U_Male_grey_out +
Q:R\U_Male_rain_in ) )
  THEN
    IF ( ( Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals - Q:Y\U_Male_grey_out - Q:R\U_Male_rain_in ) > (
V:G\Pnd_Stormwater_Volume_in_Pond - Q:G\U_Female_pond_in ) )
      THEN ( ( V:G\Pnd_Stormwater_Volume_in_Pond - Q:G\U_Female_pond_in )*S:Pond_for_Urinals_Male)
    ELSE ( (Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals - Q:Y\U_Male_grey_out - Q:R\U_Male_rain_in -
Q:G\U_Female_pond_in )*S:Pond_for_Urinals_Male )
ELSE 0
Q:R\U_Male_rain_in = IF ( V:R\Cis_Rainwater_Volume_in_Cistern - Q:R\U_Female_rain_in >
Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals )
   THEN ( Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals*S:Rain_for_urinals_Male )
ELSE ( V:R\Cis_Rainwater_Volume_in_Cistern - Q:R\U_Female_rain_in )*S:Rain_for_urinals_Male
Q:W\U_Male_reclaimed_in = IF (Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals > ( Q:Y\U_Male_grey_out +
Q:R\U_Male_rain_in + Q:G\U_Male_pond_in ) )
  THEN
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        IF ( ( Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals - Q:Y\U_Male_grey_out - Q:R\U_Male_rain_in -
Q:G\U_Male_pond_in ) > ( Q:W_reclaimed_water - Q:W\U_Female_reclaimed_in ) )
           THEN ( Q:W_reclaimed_water - Q:W\U_Female_reclaimed_in )*S:Reclaim_for_Urinals_Male
       ELSE ( (Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals - Q:Y\U_Male_grey_out - Q:R\U_Male_rain_in -
Q:G\U_Male_pond_in - Q:W\U_Female_reclaimed_in )*S:Reclaim_for_Urinals_Male )
ELSE 0
Q:P\U_Male_potable_in = Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals - Q:Y\U_Male_grey_out -
Q:R\U_Male_rain_in - Q:G\U_Male_pond_in - Q:W\U_Male_reclaimed_in
OUTFLOWS:
Q:S\U_Male_to_Sewer_from_Urinals_M = S:U\Sewer_Male*Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals
Q:B\U_Male_black_in = S:U\Black_Male*Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals
V_to_plants(t) = V_to_plants(t - dt) + (Q:Irrigation\Plants) * dt
INIT V_to_plants = 0
INFLOWS:
Q:Irrigation\Plants = Q:I\Total
UNATTACHED:
Cooling_Demand_Flow = 0
UNATTACHED:
Q:W = Q:W_reclaimed_water
A:Cis_Collection_Area_for_Cistern = 2000
A:Pnd_Collection_Area_for_Pond = 0
Area\Groundcover = 20000
Area\Groundcover_2 = 20000
Area\Mixed = 60000
Area\Mixed_2 = 60000
Area\Shrubs = 0
Area\Shrubs_2 = 0
Area\Trees = 40000
Area\Trees_2 = 40000
Area\Turfgrass = 80000
Area\Turfgrass_2 = 80000
Baseline_Bathroom_Sink_Demand_Override_Value = 50
Baseline_Irrigation_Demand_Override_Value = 50
Baseline_Kitchen_Sink_Demand_Override_Value = 50
Baseline_Shower_Demand_Override_Value = 50
Baseline_Toilet_Demand_Override_Value = 50
Baseline_Urinal_Demand_Override_Value = 50
CE:Cis_Collection_Efficiency_of_Cistern = 0.9
CE:Pnd_Collection_Efficiency_for_Pond = 0.9
Conversion_Factor_gal\sf\in = 0.6223
Conversion_gal\sf\in = 0.6223
DAYS = TIME
Design_Bathroom_Sink_Demand_Override_Value = 50
Design_Irrigation_Demand_Override_Value = 50
Design_Kitchen_Sink_Demand_Override_Value = 50
Design_Shower_Demand_Override_Value = 50
Design_Toilet_Demand_Override_Value = 50
Design_Urinal_Demand_Override_Value = 50
FTE:Full_FTE_Value_for_Full_time_Occupants = Ocp:Full_Full_time_Occupants*Percent_FTE_for_Full_time_Occupants
FTE:Other_1_FTE_Value_for_Occupants = Ocp:Other_1_Number_of_occupants*Percent_FTE_for_Other_Occupants_1
FTE:Other_2_FTE_Value_for_Occupants = Ocp:Other_2_Number_of_occupants*Percent_FTE_for_Other_Occupants_2
FTE:Part_FTE_Value_for_Part_time_Occupants =
Ocp:Part_Part_time_Occupants*Percent_FTE_for_Part_time_Occupants
FTE:_Constant =
FTE:Full_FTE_Value_for_Full_time_Occupants+FTE:Other_1_FTE_Value_for_Occupants+FTE:Other_2_FTE_Value_for
_Occupants+FTE:Part_FTE_Value_for_Part_time_Occupants
IE\Sprinkler\Groundcover = 0.625*S:IE\Sprinkler\Groundcover
IE\Sprinkler\Groundcover_2 = 0.625*S:IE\Sprinkler\Groundcover_2
IE_Drip\Groundcover = 0.9*S:IE_Drip\Groundcover
IE_Drip\Groundcover_2 = 0.9*S:IE_Drip\Groundcover_2
IE_Drip\Mixed = 0.9*S:IE_Drip\Mixed
IE_Drip\Mixed_2 = 0.9*S:IE_Drip\Mixed_2
IE_Drip\Shrubs = 0.90*S:IE_Drip\Shrubs
IE_Drip\Shrubs_2 = 0.90*S:IE_Drip\Shrubs_2
```

Appendix B (Continued)

IE_Drip\Trees = 0.90*S:IE_Drip\Trees
IE_Drip\Trees_2 = 0.90*S:IE_Drip\Trees_2
IE_Drip\Turfgrass = 0.9*S:IE_Drip\Turfgrass
IE_Drip\Turfgrass_2 = 0.9*S:IE_Drip\Turfgrass_2
IE_Sprinkler\Mixed = 0.625*S:IE_Sprinkler\Mixed
IE_Sprinkler\Mixed_2 = 0.625*S:IE_Sprinkler\Mixed_2
IE_Sprinkler\Shrubs = 0.625*S:IE_Sprinkler\Shrubs
IE_Sprinkler\Shrubs_2 = 0.625*S:IE_Sprinkler\Shrubs_2
IE_Sprinkler\Trees = 0.625*S:IE_Sprinkler\Trees
IE_Sprinkler\Trees_2 = 0.625*S:IE_Sprinkler\Trees_2
IE_Sprinkler\Turfgrass = 0.625*S:IE_Sprinkler\Turfgrass
IE_Sprinkler\Turfgrass_2 = 0.625*S:IE_Sprinkler\Turfgrass_2
k\d_average\Groundcover = 1.0*S:k\d_average\Groundcover
k\d_average\Groundcover_2 = 1.0*S:k\d_average\Groundcover_2
k\d_average\Mixed = 1.1*S:k\d_average\Mixed
k\d_average\Mixed_2 = 1.1*S:k\d_average\Mixed_2
k\d_average\Shrubs = 1.0*S:k\d_average\Shrubs
k\d_average\Shrubs_2 = 1.0*S:k\d_average\Shrubs_2
k\d_average\Trees = 1.0*S:k\d_average\Trees
k\d_average\Trees_2 = 1.0*S:k\d_average\Trees_2
k\d_average\Turfgrass = 1.0*S:k\d_average\Turfgrass
k\d_average\Turfgrass_2 = 1.0*S:k\d_average\Turfgrass_2
k\d_high\Groundcover = 1.1*S:k\d_high\Groundcover
k\d_high\Groundcover_2 = 1.1*S:k\d_high\Groundcover_2
k\d_high\Mixed = 1.3*S:k\d_high\Mixed
k\d_high\Mixed_2 = 1.3*S:k\d_high\Mixed_2
k\d_high\Shrubs = 1.1*S:k\d_high\Shrubs
k\d_high\Shrubs_2 = 1.1*S:k\d_high\Shrubs_2
k\d_high\Trees = 1.3*S:k\d_high\Trees
k\d_high\Trees_2 = 1.3*S:k\d_high\Trees_2
k\d_high\Turfgrass = 1.0*S:k\d_high\Turfgrass
k\d_high\Turfgrass_2 = 1.0*S:k\d_high\Turfgrass_2
k\d_low\Groundcover = 0.5*S:k\d_low\Groundcover
k\d_low\Groundcover_2 = 0.5*S:k\d_low\Groundcover_2
k\d_low\Mixed = 0.6*S:k\d_low\Mixed
k\d_low\Mixed_2 = 0.6*S:k\d_low\Mixed_2
k\d_low\Shrubs = 0.5*S:k\d_low\Shrubs
k\d_low\Shrubs_2 = 0.5*S:k\d_low\Shrubs_2
k\d_low\Trees = 0.5*S:k\d_low\Trees
k\d_low\Trees_2 = 0.5*S:k\d_low\Trees_2
k\d_low\Turfgrass = 0.6*S:k\d_low\Turfgrass
k\d_low\Turfgrass_2 = 0.6*S:k\d_low\Turfgrass_2
k\L_Groundcover = ET\0*(k\s_low\Groundcover+k\s_average\Groundcover+k\s_high\Groundcover)*(k\d_low\Groundcover+k\d_average\Groundcover+k\d_high\Groundcover)*(k\mc_low\Groundcover+k\mc_average\Groundcover+k\mc_high\Groundcover)
k\L_Groundcover_2 = ET\0*(k\s_low\Groundcover_2+k\s_average\Groundcover_2+k\s_high\Groundcover_2)*(k\d_low\Groundcover_2+k\d_average\Groundcover_2+k\d_high\Groundcover_2)*(k\mc_low\Groundcover_2+k\mc_average\Groundcover_2+k\mc_high\Groundcover_2)
k\L_Mixed = ET\0*(k\s_low\Mixed+k\s_average\Mixed+k\s_high\Mixed)*(k\d_low\Mixed+k\d_average\Mixed+k\d_high\Mixed)*(k\mc_low\Mixed+k\mc_average\Mixed+k\mc_high\Mixed)
k\L_Mixed_2 = ET\0*(k\s_low\Mixed_2+k\s_average\Mixed_2+k\s_high\Mixed_2)*(k\d_low\Mixed_2+k\d_average\Mixed_2+k\d_high\Mixed_2)*(k\mc_low\Mixed_2+k\mc_average\Mixed_2+k\mc_high\Mixed_2)
k\L_Shrubs = ET\0*(k\s_low\Shrubs+k\s_average\Shrubs+k\s_high\Shrubs)*(k\d_low\Shrubs+k\d_average\Shrubs+k\d_high\Shrubs)*(k\mc_low\Shrubs+k\mc_average\Shrubs+k\mc_high\Shrubs)
k\L_Shrubs_2 = ET\0*(k\s_low\Shrubs_2+k\s_average\Shrubs_2+k\s_high\Shrubs_2)*(k\d_low\Shrubs_2+k\d_average\Shrubs_2+k\d_high\Shrubs_2)*(k\mc_low\Shrubs_2+k\mc_average\Shrubs_2+k\mc_high\Shrubs_2)
k\L_Trees = ET\0*(k\s_low\Trees+k\s_average\Trees+k\s_high\Trees)*(k\d_low\Trees+k\d_average\Trees+k\d_high\Trees)*(k\mc_low\Trees+k\mc_average\Trees+k\mc_high\Trees)

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k\L_Trees_2 =
ET\0*(k\s_low\Trees_2+k\s_average\Trees_2+k\s_high\Trees_2)*(k\d_low\Trees_2+k\d_average\Trees_2+k\d_high\Trees
_2)*(k\mc_low\Trees_2+k\mc_average\Trees_2+k\mc_high\Trees_2)
k\L_Turfgrass =
ET\0*(k\s_low\Turfgrass+k\s_average\Turfgrass+k\s_high\Turfgrass)*(k\d_low\Turfgrass+k\d_average\Turfgrass+k\d_high
\Turfgrass)*(k\mc_low\Turfgrass+k\mc_average\Turfgrass+k\mc_high\Turfgrass)
k\L_Turfgrass_2 =
ET\0*(k\s_low\Turfgrass_2+k\s_average\Turfgrass_2+k\s_high\Turfgrass_2)*(k\d_low\Turfgrass_2+k\d_average\Turfgrass
_2+k\d_high\Turfgrass_2)*(k\mc_low\Turfgrass_2+k\mc_average\Turfgrass_2+k\mc_high\Turfgrass_2)
k\mc_average\Groundcover = 1.0*S:k\mc_average\Groundcover
k\mc_average\Groundcover_2 = 1.0*S:k\mc_average\Groundcover_2
k\mc_average\Mixed = 1.0*S:k\mc_average\Mixed
k\mc_average\Mixed_2 = 1.0*S:k\mc_average\Mixed_2
k\mc_average\Shrubs = 1.0*S:k\mc_average\Shrubs
k\mc_average\Shrubs_2 = 1.0*S:k\mc_average\Shrubs_2
k\mc_average\Trees = 1.0*S:k\mc_average\Trees
k\mc_average\Trees_2 = 1.0*S:k\mc_average\Trees_2
k\mc_average\Turfgrass = 1.0*S:k\mc_average\Turfgrass
k\mc_average\Turfgrass_2 = 1.0*S:k\mc_average\Turfgrass_2
k\mc_high\Groundcover = 1.2*S:k\mc_high\Groundcover
k\mc_high\Groundcover_2 = 1.2*S:k\mc_high\Groundcover_2
k\mc_high\Mixed = 1.4*S:k\mc_high\Mixed
k\mc_high\Mixed_2 = 1.4*S:k\mc_high\Mixed_2
k\mc_high\Shrubs = 1.3*S:k\mc_high\Shrubs
k\mc_high\Shrubs_2 = 1.3*S:k\mc_high\Shrubs_2
k\mc_high\Trees = 1.4*S:k\mc_high\Trees
k\mc_high\Trees_2 = 1.4*S:k\mc_high\Trees_2
k\mc_high\Turfgrass = 1.2*S:k\mc_high\Turfgrass
k\mc_high\Turfgrass_2 = 1.2*S:k\mc_high\Turfgrass_2
k\mc_low\Groundcover = 0.5*S:k\mc_low\Groundcover
k\mc_low\Groundcover_2 = 0.5*S:k\mc_low\Groundcover_2
k\mc_low\Mixed = 0.5*S:k\mc_low\Mixed
k\mc_low\Mixed_2 = 0.5*S:k\mc_low\Mixed_2
k\mc_low\Shrubs = 0.5*S:k\mc_low\Shrubs
k\mc_low\Shrubs_2 = 0.5*S:k\mc_low\Shrubs_2
k\mc_low\Trees = 0.5*S:k\mc_low\Trees
k\mc_low\Trees_2 = 0.5*S:k\mc_low\Trees_2
k\mc_low\Turfgrass = 0.8*S:k\mc_low\Turfgrass
k\mc_low\Turfgrass_2 = 0.8*S:k\mc_low\Turfgrass_2
k\s_average\Groundcover = 0.5*S:k\s_average\Groundcover
k\s_average\Groundcover_2 = 0.5*S:k\s_average\Groundcover_2
k\s_average\Mixed = 0.5*S:k\s_average\Mixed
k\s_average\Mixed_2 = 0.5*S:k\s_average\Mixed_2
k\s_average\Shrubs = 0.5*S:k\s_average\Shrubs
k\s_average\Shrubs_2 = 0.5*S:k\s_average\Shrubs_2
k\s_average\Trees = 0.5*S:k\s_average\Trees
k\s_average\Trees_2 = 0.5*S:k\s_average\Trees_2
k\s_average\Turfgrass = 0.7*S:k\s_average\Turfgrass
k\s_average\Turfgrass_2 = 0.7*S:k\s_average\Turfgrass_2
k\s_high\Groundcover = 0.7*S:k\s_high\Groundcover
k\s_high\Groundcover_2 = 0.7*S:k\s_high\Groundcover_2
k\s_high\Mixed = 0.9*S:k\s_high\Mixed
k\s_high\Mixed_2 = 0.9*S:k\s_high\Mixed_2
k\s_high\Shrubs = 0.7*S:k\s_high\Shrubs
k\s_high\Shrubs_2 = 0.7*S:k\s_high\Shrubs_2
k\s_high\Trees = 0.9*S:k\s_high\Trees
k\s_high\Trees_2 = 0.9*S:k\s_high\Trees_2
k\s_high\Turfgrass = 0.8*S:k\s_high\Turfgrass
k\s_high\Turfgrass_2 = 0.8*S:k\s_high\Turfgrass_2
k\s_low\Groundcover = 0.2*S:k\s_low\Groundcover
k\s_low\Groundcover_2 = 0.2*S:k\s_low\Groundcover_2
k\s_low\Mixed = 0.2*S:k\s_low\Mixed
k\s_low\Mixed_2 = 0.2*S:k\s_low\Mixed_2
k\s_low\Shrubs = 0.2*S:k\s_low\Shrubs
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k\s_low\Shrubs_2 = 0.2*S:k\s_low\Shrubs_2
k\s_low\Trees = 0.2*S:k\s_low\Trees
k\s_low\Trees_2 = 0.2*S:k\s_low\Trees_2
k\s_low\Turfgrass = 0.6*S:k\s_low\Turfgrass
k\s_low\Turfgrass_2 = 0.6*S:k\s_low\Turfgrass_2
N:A\H_Daily_Uses_for_Showers = 0.05
N:A\Sb_Daily_Uses_for_Bathroom_Sinks = 3
N:A\Sk_Daily_Uses_for_Kitchen_Sinks = 1
N:A\T_Female_Daily_Uses_for_Toilets_used_byFemales = 3
N:A\T_Male_Daily_Uses_for_Toilets_used_by_Males = 1
N:A\U_Female_Daily_Uses_for_Urinals_used_byFemales = 0
N:A\U_Male_Daily_Uses_for_Urinals_used_by_Males = 2
Ocp:Full_Full_time_Occupants = 50
Ocp:Other_1_Number_of_occupants = 0
Ocp:Other_2_Number_of_occupants = 0
Ocp:Part_Part_time_Occupants = 20
P:Base\H_Vol_Percent_of_All_Water_for_Showers = (V:Base\H/V:BaseTotal)*100
P:Base\I_Vol_Percent_of_All_Water_for_Irrigation = (V:Base\I/V:BaseTotal)*100
P:Base\Sb_Vol_Percent_of_All_Water_for_Bathroom_Sinks = (V:Base\Sb/V:BaseTotal)*100
P:Base\Sk_Vol_Percent_of_All_Water_for_Kitchen_Sinks = (V:Base\Sk/V:BaseTotal)*100
P:Base\Total =
P:Base\H_Vol_Percent_of_All_Water_for_Showers+P:Base\I_Vol_Percent_of_All_Water_for_Irrigation+P:Base\Sb_Vol_
Percent_of_All_Water_for_Bathroom_Sinks+P:Base\Sk_Vol_Percent_of_All_Water_for_Kitchen_Sinks+P:Base\T_Vol_Pe
rcent_of_All_Water_for_Toilets+P:Base\U_Vol_Percent_of_All_Water_for_Urinals
P:Base\T_Vol_Percent_of_All_Water_for_Toilets = (V:Base\T/V:BaseTotal)*100
P:Base\U_Vol_Percent_of_All_Water_for_Urinals = (V:Base\U/V:BaseTotal)*100
P:Dsgn\H_Vol_Percent_of_All_Water_for_Showers = (V:Dsgn\H/V:Dsgn\Total)*100
P:Dsgn\I_Vol_Percent_of_All_Water_for_Irrigation = (V:Dsgn\I/V:Dsgn\Total)*100
P:Dsgn\Sb_Vol_Percent_of_All_Water_for_Bathroom_Sinks = (V:Dsgn\Sb/V:Dsgn\Total)*100
P:Dsgn\Sk_Vol_Percent_of_All_Water_for_Kitchen_Sinks = (V:Dsgn\Sk/V:Dsgn\Total)*100
P:Dsgn\Total =
P:Dsgn\H_Vol_Percent_of_All_Water_for_Showers+P:Dsgn\I_Vol_Percent_of_All_Water_for_Irrigation+P:Dsgn\Sb_Vol_
Percent_of_All_Water_for_Bathroom_Sinks+P:Dsgn\Sk_Vol_Percent_of_All_Water_for_Kitchen_Sinks+P:Dsgn\T_Vol_P
ercent_of_All_Water_for_Toilets+P:Dsgn\U_Vol_Percent_of_All_Water_for_Urinals
P:Dsgn\T_Vol_Percent_of_All_Water_for_Toilets = (V:Dsgn\T/V:Dsgn\Total)*100
P:Dsgn\U_Vol_Percent_of_All_Water_for_Urinals = (V:Dsgn\U/V:Dsgn\Total)*100
P:Pot\All_Water_Vol_Percent_Red_in_Potable_Water_for_All_Sectors = 1-(V:P_Dsgn\Total/V:BaseTotal)
P:Pot\H_Vol_Percent_Red_in_Potable_Water_for_Showers = 1-(V:P_Dsgn\H/V:Base\H)
P:Pot\I_Flow_Percent_Red_in_Potable_Water_for_Irrigation = IF (Q:Base\I=0)
    THEN 0
ELSE (1-(Q:P_Dsgn\I/Q:Base\I))
P:Pot\I_Vol_Percent_Red_in_Potable_Water_for_Irrigation = 1-(V:P_Dsgn\I/V:Base\I)
P:Pot\Sb_Flow_Percent_Red_in_Potable_Water_for_Bathroom_Sinks = IF (Q:Base\Sb=0)
    THEN 0
ELSE (1-(Q:P_Dsgn\Sb/Q:Base\Sb))
P:Pot\Sb_Vol_Percent_Red_in_Potable_Water_for_Bathroom_Sinks = 1-(V:P_Dsgn\Sb/V:Base\Sb)
P:Pot\Sk_Vol_Percent_Red_in_Potable_Water_for_Kitchen_Sinks = 1-(V:P_Dsgn\Sk/V:Base\Sk)
P:Pot\Swge_Vol_Percent_Red_in_Potable_Water_for_Swge_Conveyance = 1-(V:P_Dsgn\Swge/V:Base\Swge)
P:Pot\T_Flow_Percent_Red_in_Potable_Water_for_Toilets = IF (Q:Base\T=0)
    THEN 0
ELSE (1-(Q:P_Dsgn\T/Q:Base\T))
P:Pot\T_Vol_Percent_Red_in_Potable_Water_for_Toilets = 1-(V:P_Dsgn\T/V:Base\T)
P:Pot\U_Vol_Percent_Red_in_Potable_Water_for_Urinals = 1-(V:P_Dsgn\U/V:Base\U)
P:Pot\Wter_Flow_Percent_Red_in_Potable_Water_for_Water_Fixtures = IF (Q:Base\Wter=0)
    THEN 0
ELSE (1-(Q:P_Dsgn\Wter/Q:Base\Wter))
P:Pot\Wter_Vo_Percent_Red_in_Potable_Water_for_All_Water_Fixtures = 1-(V:P_Dsgn\Wter/V:Base\Wter)
P:Total\All_Water_Vol_Percent_Red_in_Total_Water_for_All_Sectors = 1-(V:Dsgn\Total/V:BaseTotal)
P:Total\All_Watr_Flow_Percent_Red_in_Total_Water_for_All_Sectors = IF (Q:Base\Total=0)
    THEN 0
ELSE (1-(Q:Dsgn\Total/Q:Base\Total))
P:Total\H_Flow_Percent_Red_in_Total_Water_for_Showers = IF (Q:Base\H=0)
    THEN 0
ELSE (1-(Q:Dsgn\H/Q:Base\H))
```

```
P:Total\H_Vol_Percent_Red_in_Total_Water_for_Showers = 1-(V:Dsgn\H/V:Base\H)
P:Total\I_Flow_Percent_Red_in_Total_Water_for_Irrigation = IF (Q:Base\I=0)
    THEN 0
ELSE (1-(Q:Dsgn\I/Q:Base\I))
P:Total\I_Vol_Percent_Red_in_Total_Water_for_Irrigation = 1-(V:Dsgn\I/V:Base\I)
P:Total\Sb_Flow_Percent_Red_in_Total_Water_for_Bathroom_Sinks = IF (Q:Base\Sb=0)
    THEN 0
ELSE (1-(Q:Dsgn\Sb/Q:Base\Sb))
P:Total\Sb_Vol_Percent_Red_in_Total_Water_for_Bathroom_Sinks = 1-(V:Dsgn\Sb/V:Base\Sb)
P:Total\Sk_Flow_Percent_Red_in_Total_Water_for_Kitchen_Sinks = IF (Q:Base\Sk=0)
    THEN 0
ELSE (1-(Q:Dsgn\Sk/Q:Base\Sk))
P:Total\Sk_Vol_Percent_Red_in_Total_Water_for_Kitchen_Sinks = 1-(V:Dsgn\Sk/V:Base\Sk)
P:Total\Swge_Flo_Percent_Red_in_Total_Water_for_Sewage_Conveyance = IF Q:Base\Swge=0
    THEN 0
ELSE (1-(Q:Dsgn\Swge/Q:Base\Swge))
P:Total\Swge_Vol_Percent_Red_in_Total_Water_for_Swge_Conveyance = 1-(V:Dsgn\Swge/V:Base\Swge)
P:Total\T_Flow_Percent_Red_in_Total_Water_for_Toilets = IF (Q:Base\T=0)
   THEN 0
ELSE (1-(Q:Dsgn\T/Q:Base\T))
P:Total\T_Vol_Percent_Red_in_Total_Water_for_Toilets = 1-(V:Dsgn\T/V:Base\T)
P:Total\U_Flow_Percent_Red_in_Total_Water_for_Urinals = IF (Q:Base\U=0)
    THEN 0
ELSE (1-(Q:Dsgn\U/Q:Base\U))
P:Total\U_Vol_Percent_Red_in_Total_Water_for_Urinals = 1-(V:Dsgn\U/V:Base\U)
P:Total\Wter_Fl_Percent_Red_in_Total_Water_for_All_Water_Fixtures = IF (Q:Base\Wter=0)
    THEN 0
ELSE (1-(Q:Dsgn\Wter/Q:Base\Wter))
P:Total\Wter_Vo_Percent_Red_in_Total_Water_for_All_Water_Fixtures = 1-(V:Dsgn\Wter/V:Base\Wter)
Pct:M_Percent_Male_Occupants = 0.5
Percent_FTE_for_Full_time_Occupants = T:Full_Average_hours_per_day/8
Percent_FTE_for_Other_Occupants_1 = T:Other_1_Average_hours_per_day/8
Percent_FTE_for_Other_Occupants_2 = T:Other_2_Average_hours_per_day/8
Percent_FTE_for_Part_time_Occupants = T:Part_Average_hours_per_day/8
Q:A\H_Base_Baseline_Shower_Flowrate = 2.5
Q:A\H_Dsgn_Design_Shower_Flowrate = 2.5
Q:A\Sb_Base_Baseline_Bathroom_SinkFlowrate = 2.5
Q:A\Sb_Dsgn_Design_Bathroom_SinkFlowrate = 2.5
Q:A\Sk_Base_Baseline_Kitchen_SinkFlowrate = 2.5
Q:A\Sk_Dsgn_Design_Kitchen_SinkFlowrate = 2.5
Q:Base\H_Baseline_Demand_for_Showers =
((Total_FTE*N:A\H_Daily_Uses_for_Showers*(T:H\Base_Baseline_Duration_of_Shower_Event/60)*Q:A\H_Base_Baseline_Shower_Flowrate)*S:Baseline_Shower_Demand_Calculated_Value)
+
(Baseline_Shower_Demand_Override_Value*S:Baseline_Shower_Demand_Override_Value)
Q:Base\Sb_Baseline_Demand_for_Bathroom_Sinks =
((Total_FTE*N:A\Sb_Daily_Uses_for_Bathroom_Sinks*(T:Base\Sb_Baseline_Duration_of_Bathroom_Sink_Event/60)*Q:A\Sb_Base_Baseline_Bathroom_SinkFlowrate)*S:Baseline_Bathroom_Sink_Demand_Calculated_Value)
+
(Baseline_Bathroom_Sink_Demand_Override_Value*S:Baseline_Bathroom_Sink_Demand_Override_Value)
Q:Base\Sk_Baseline_Demand_for_Kitchen_Sinks =
((Total_FTE*N:A\Sk_Daily_Uses_for_Kitchen_Sinks*(T:Sk\Base_Baseline_Duration_of_Kitchen_Sink_Event/60)*Q:A\Sk_Base_Baseline_Kitchen_SinkFlowrate)*S:Baseline_Kitchen_Sink_Demand_Calculated_Value)
+
(Baseline_Kitchen_Sink_Demand_Override_Value*S:Baseline_Kitchen_Sink_Demand_Override_Value)
Q:Base\Swge_Basline_Sewage_Conveyance =
Q:Base\T__Baseline_Demand_for_All_Toilets+Q:Base\U_Baseline_Demand_for_All_Urinals
Q:Base\Total_Baseline_Total_Water_Use_All_Potable_Water =
Q:Base\I_Baseline_Demand_for_Irrigation_TPWA__and_TWA+Q:Base\Wter_Baseline_Water_Use_for_Fixtures_All_Potable_Water
Q:Base\T_Female_Baseline_Flowrate_for_Female_Toilets =
Total_FTE*N:A\T_Female_Daily_Uses_for_Toilets_used_byFemales*V:A\T_Base_Baseline_Toilet_Application_Volume*(1-Pct:M_Percent_Male_Occupants)
```

Q:Base\T_Male_Baseline_Flowrate_for_Male_Toilets =
Total_FTE*N:A\T_Male_Daily_Uses_for_Toilets_used_by_Males*V:A\T_Base_Baseline_Toilet_Application_Volume*Pct:M_Percent_Male_Occupants
Q:Base\T__Baseline_Demand_for_All_Toilets =
((Q:Base\T_Female_Baseline_Flowrate_for_Female_Toilets+Q:Base\T_Male_Baseline_Flowrate_for_Male_Toilets)*S:Baseline_Toilet_Demand_Calculated_Value)
+
(Baseline_Toilet_Demand_Override_Value*S:Baseline_Toilet_Demand_Override_Value)
Q:Base\U_Baseline_Demand_for_All_Urinals =
((Q:Base\U_Female_Baseline_Flowrate_for_Female_Urinals+Q:Base\U_Male_Baseline_Flowrate_for_Male_Urinals)*S:Baseline_Urinal_Demand_Calculated_Value)
+
(Baseline_Urinal_Demand_Override_Value*S:Baseline_Urinal_Demand_Override_Value)
Q:Base\U_Female_Baseline_Flowrate_for_Female_Urinals =
Total_FTE*N:A\U_Female_Daily_Uses_for_Urinals_used_byFemales*V:A\U_Base_Baseline_Urinal_Application_Volume*(1-Pct:M_Percent_Male_Occupants)
Q:Base\U_Male_Baseline_Flowrate_for_Male_Urinals =
Total_FTE*N:A\U_Male_Daily_Uses_for_Urinals_used_by_Males*V:A\U_Base_Baseline_Urinal_Application_Volume*Pct:M_Percent_Male_Occupants
Q:Base\Wter_Baseline_Water_Use_for_Fixtures_All_Potable_Water =
Q:Base\Sb_Baseline_Demand_for_Bathroom_Sinks+Q:Base\Sk_Baseline_Demand_for_Kitchen_Sinks+Q:Base\T__Baseline_Demand_for_All_Toilets+Q:Base\U_Baseline_Demand_for_All_Urinals+Q:Dsgn\H_Design_Demand_for_Showers
Q:Dsgn\C_Design_Demand_for_Cooling = 0
Q:Dsgn\H_Design_Demand_for_Showers =
((Total_FTE*N:A\H_Daily_Uses_for_Showers*(T:H\Dsgn_Design_Duration_of_Shower_Event/60)*Q:A\H_Dsgn_Design_Shower_Flowrate)*S:Design_Shower_Demand_Calculated_Value)
+
(Design_Shower_Demand_Override_Value*S:Design_Shower_Demand_Override_Value)
Q:Dsgn\Sb_Design_Demand_for_Bathroom_Sinks =
((Total_FTE*N:A\Sb_Daily_Uses_for_Bathroom_Sinks*(T:Dsgn\Sb_Design_Duration_of_Bathroom_Sink_Event/60)*Q:A\Sb_Dsgn_Design_Bathroom_SinkFlowrate)*S:Design_Bathroom_Sink_Demand_Calculated_Value)
+
(Design_Bathroom_Sink_Demand_Override_Value*S:Design_Bathroom_Sink_Demand_Override_Value)
Q:Dsgn\Sk_Design_Demand_for_Kitchen_Sinks =
((Total_FTE*N:A\Sk_Daily_Uses_for_Kitchen_Sinks*(T:Sk\Dsgn_Design_Duration_of_Kitchen_Sink_Event/60)*Q:A\Sk_Dsgn_Design_Kitchen_SinkFlowrate)*S:Design_KItchen_Sink_Demand_Calculated_Value)
+
(Design_Kitchen_Sink_Demand_Override_Value*S:Design_Kitchen_Sink_Demand_Override_Value)
Q:Dsgn\Swge_Design_Sewage_Conveyance =
Q:Dsgn\T__Design_Demand_for_All_Toilets+Q:Dsgn\U_Design_Flowrate_for_All_Urinals
Q:Dsgn\Total_Design_Total_Water_Use_All_Water =
Q:Dsgn\I_Design_Demand_for_Irrigation_Design_TWA+Q:Dsgn\Wter_Design_Water_Use_for_Fixtures_All_Water
Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets =
Total_FTE*N:A\T_Female_Daily_Uses_for_Toilets_used_byFemales*V:A\T_Dsgn_Design_Toilet_Application_Volume*(1-Pct:M_Percent_Male_Occupants)
Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets =
Total_FTE*N:A\T_Male_Daily_Uses_for_Toilets_used_by_Males*V:A\T_Dsgn_Design_Toilet_Application_Volume*Pct:M_Percent_Male_Occupants
Q:Dsgn\T__Design_Demand_for_All_Toilets =
((Q:Dsgn\T_Female_Design_Flowrate_for_Female_Toilets+Q:Dsgn\T_Male_Design_Flowrate_for_Male_Toilets)*S:Design_Toilet_Demand_Calculated_Value)
+
(Design_Toilet_Demand_Override_Value*S:Design_Toilet_Demand_Override_Value)
Q:Dsgn\U_Design_Flowrate_for_All_Urinals =
((Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals+Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals)*S:Design_Urinal_Demand_Calculated_Value)
+
(Design_Urinal_Demand_Override_Value*S:Design_Urinal_Demand_Override_Value)
Q:Dsgn\U_Female_Design_Flowrate_for_Female_Urinals =
Total_FTE*N:A\U_Female_Daily_Uses_for_Urinals_used_byFemales*V:A\U_Dsgn_Design_Urinal_Application_Volume*(1-Pct:M_Percent_Male_Occupants)
Q:Dsgn\U_Male_Design_Flowrate_for_Male_Urinals =
Total_FTE*N:A\U_Male_Daily_Uses_for_Urinals_used_by_Males*V:A\U_Dsgn_Design_Urinal_Application_Volume*Pct:M_Percent_Male_Occupants

```
Q:Dsgn\Wter_Design_Water_Use_for_Fixtures_All_Water =
Q:Dsgn\H_Design_Demand_for_Showers+Q:Dsgn\Sb_Design_Demand_for_Bathroom_Sinks+Q:Dsgn\Sk_Design_Dema
nd_for_Kitchen_Sinks+Q:Dsgn\T__Design_Demand_for_All_Toilets+Q:Dsgn\U_Design_Flowrate_for_All_Urinals
Q:I\Total =
Q:Pond\Irrigation_pond_in+Q:P\I_Potable_water_for_Irrigation+Q:Rain\Irrigation_rain_in+Q:Reclaim\Irrigation_reclaimed_
in
Q:P_Dsgn\Swge_Sewage_Conveyance_from_Potable_Water =
Q:P\T_Potable_water_for_All_Toilets+Q:P\U_Potable_water_for_All_Urinals
Q:P_Dsgn\Total_Design_Total_Water_Use_Potable_Water =
Q:P\I_Potable_water_for_Irrigation+Q:P_Dsgn\Wter_Design_Water_Use_for_Fixtures_Potable_Water
Q:P_Dsgn\Wter_Design_Water_Use_for_Fixtures_Potable_Water =
Q:P\H_Potable_water_to_Showers+Q:P\Sb_Potable_water_to_Bathroom_Sinks+Q:P\Sk_Potable_water_to_Kitchen_Sin
ks+Q:P\T_Potable_water_for_All_Toilets+Q:P\U_Potable_water_for_All_Urinals
Q:W_reclaimed_water = 0
Rainfall_Flow_into_Cistern_Override_Value = 50
S:Baseline_Bathroom_Sink_Demand_Calculated_Value = 1
S:Baseline_Bathroom_Sink_Demand_Override_Value = 1
S:Baseline_Kitchen_Sink_Demand_Calculated_Value = 1
S:Baseline_Kitchen_Sink_Demand_Override_Value = 1
S:Baseline_Shower_Demand_Calculated_Value = 1
S:Baseline_Shower_Demand_Override_Value = 1
S:Baseline_Toilet_Demand_Calculated_Value = 1
S:Baseline_Toilet_Demand_Override_Value = 1
S:Baseline_Urinal_Demand_Calculated_Value = 1
S:Baseline_Urinal_Demand_Override_Value = 1
S:Base_Irrigation_Demand_Calculated_Vlaue = 1
S:Base_Irrigation_Demand_Override_Value = 1
S:Design_Bathroom_Sink_Demand_Calculated_Value = 1
S:Design_Bathroom_Sink_Demand_Override_Value = 1
S:Design_Irrigation_Demand_Calculated_Vlaue = 1
S:Design_Irrigation_Demand_Override_Value = 1
S:Design_KItchen_Sink_Demand_Calculated_Value = 1
S:Design_Kitchen_Sink_Demand_Override_Value = 1
S:Design_Shower_Demand_Calculated_Value = 1
S:Design_Shower_Demand_Override_Value = 1
S:Design_Toilet_Demand_Calculated_Value = 1
S:Design_Toilet_Demand_Override_Value = 1
S:Design_Urinal_Demand_Calculated_Value = 1
S:Design_Urinal_Demand_Override_Value = 1
S:FTE:Constant = 1
S:FTE:Varying = 1
S:IE\Sprinkler\Groundcover = 1
S:IE\Sprinkler\Groundcover_2 = 1
S:IE_Drip\Groundcover = 1
S:IE_Drip\Groundcover_2 = 1
S:IE_Drip\Mixed = 1
S:IE_Drip\Mixed_2 = 1
S:IE_Drip\Shrubs = 1
S:IE_Drip\Shrubs_2 = 1
S:IE_Drip\Trees = 1
S:IE_Drip\Trees_2 = 1
S:IE_Drip\Turfgrass = 1
S:IE_Drip\Turfgrass_2 = 1
S:IE_Sprinkler\Mixed = 1
S:IE_Sprinkler\Mixed_2 = 1
S:IE_Sprinkler\Shrubs = 1
S:IE_Sprinkler\Shrubs_2 = 1
S:IE_Sprinkler\Trees = 1
S:IE_Sprinkler\Trees_2 = 1
S:IE_Sprinkler\Turfgrass = 1
S:IE_Sprinkler\Turfgrass_2 = 1
S:k\d_average\Groundcover = 1
S:k\d_average\Groundcover_2 = 1
S:k\d_average\Mixed = 1
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S:k\d_average\Mixed_2 = 1
S:k\d_average\Shrubs = 1
S:k\d_average\Shrubs_2 = 1
S:k\d_average\Trees = 1
S:k\d_average\Trees_2 = 1
S:k\d_average\Turfgrass = 1
S:k\d_average\Turfgrass_2 = 1
S:k\d_high\Groundcover = 1
S:k\d_high\Groundcover_2 = 1
S:k\d_high\Mixed = 1
S:k\d_high\Mixed_2 = 1
S:k\d_high\Shrubs = 1
S:k\d_high\Shrubs_2 = 1
S:k\d_high\Trees = 1
S:k\d_high\Trees_2 = 1
S:k\d_high\Turfgrass = 1
S:k\d_high\Turfgrass_2 = 1
S:k\d_low\Groundcover = 1
S:k\d_low\Groundcover_2 = 1
S:k\d_low\Mixed = 1
S:k\d_low\Mixed_2 = 1
S:k\d_low\Shrubs = 1
S:k\d_low\Shrubs_2 = 1
S:k\d_low\Trees = 1
S:k\d_low\Trees_2 = 1
S:k\d_low\Turfgrass = 1
S:k\d_low\Turfgrass_2 = 1
S:k\mc_average\Groundcover = 1
S:k\mc_average\Groundcover_2 = 1
S:k\mc_average\Mixed = 1
S:k\mc_average\Mixed_2 = 1
S:k\mc_average\Shrubs = 1
S:k\mc_average\Shrubs_2 = 1
S:k\mc_average\Trees = 1
S:k\mc_average\Trees_2 = 1
S:k\mc_average\Turfgrass = 1
S:k\mc_average\Turfgrass_2 = 1
S:k\mc_high\Groundcover = 1
S:k\mc_high\Groundcover_2 = 1
S:k\mc_high\Mixed = 1
S:k\mc_high\Mixed_2 = 1
S:k\mc_high\Shrubs = 1
S:k\mc_high\Shrubs_2 = 1
S:k\mc_high\Trees = 1
S:k\mc_high\Trees_2 = 1
S:k\mc_high\Turfgrass = 1
S:k\mc_high\Turfgrass_2 = 1
S:k\mc_low\Groundcover = 1
S:k\mc_low\Groundcover_2 = 1
S:k\mc_low\Mixed = 1
S:k\mc_low\Mixed_2 = 1
S:k\mc_low\Shrubs = 1
S:k\mc_low\Shrubs_2 = 1
S:k\mc_low\Trees = 1
S:k\mc_low\Trees_2 = 1
S:k\mc_low\Turfgrass = 1
S:k\mc_low\Turfgrass_2 = 1
S:k\s_average\Groundcover = 1
S:k\s_average\Groundcover_2 = 1
S:k\s_average\Mixed = 1
S:k\s_average\Mixed_2 = 1
S:k\s_average\Shrubs = 1
S:k\s_average\Shrubs_2 = 1
S:k\s_average\Trees = 1

S:k\s_average\Trees_2 = 1
S:k\s_average\Turfgrass = 1
S:k\s_average\Turfgrass_2 = 1
S:k\s_high\Groundcover = 1
S:k\s_high\Groundcover_2 = 1
S:k\s_high\Mixed = 1
S:k\s_high\Mixed_2 = 1
S:k\s_high\Shrubs = 1
S:k\s_high\Shrubs_2 = 1
S:k\s_high\Trees = 1
S:k\s_high\Trees_2 = 1
S:k\s_high\Turfgrass = 1
S:k\s_high\Turfgrass_2 = 1
S:k\s_low\Groundcover = 1
S:k\s_low\Groundcover_2 = 1
S:k\s_low\Mixed = 1
S:k\s_low\Mixed_2 = 1
S:k\s_low\Shrubs = 1
S:k\s_low\Shrubs_2 = 1
S:k\s_low\Trees = 1
S:k\s_low\Trees_2 = 1
S:k\s_low\Turfgrass = 1
S:k\s_low\Turfgrass_2 = 1
S:Pond_for_Irrigation = 1
S:Pond_for_Toilets_Female = 1
S:Pond_for_Toilets_Male = 1
S:Pond_for_urinals_Female = 1
S:Pond_for_Urinals_Male = 1
S:Rainfall_Flow_into_Cistern_Calculated_Value = 1
S:Rainfall_Flow_into_Cistern_Override_Value = 1
S:Rain_for_Irrigation = 1
S:Rain_for_Toilets_Female = 1
S:Rain_for_Toilets_Male = 1
S:Rain_for_urinals_Female = 1
S:Rain_for_urinals_Male = 1
S:Reclaim\Irrigation = 1
S:Reclaim_for_cooling = 1
S:Reclaim_for_Toilets_Female = 1
S:Reclaim_for_Toilets_Male = 1
S:Reclaim_for_urinals_Female = 1
S:Reclaim_for_Urinals_Male = 1
S:R\C_Rainwater_for_Cooling = 1
S:Stormwater_Flow_into_Pond_Calculated_Value = 1
S:Stormwater_Flow_into_Pond_Override_Value = 1
S:S\H_to_Sewer = 1
S:S\Sb_to_Sewer = 1
S:S\Sk_to_Sewer = 1
S:T\Black_Female = 1
S:T\Black_Male = 1
S:T\Sewer_Female = 1
S:T\Sewer_Male = 1
S:U\black_Female = 1
S:U\Black_Male = 1
S:U\Sewer_Female = 1
S:U\Sewer_Male = 1
S:W\C_Stormwater_for_Cooling = 1
S:Y\H_to_Treatment = 1
S:Y\Sb_to_Treatment = 1
S:Y\Sk_to_Treatment = 1
S:Y_for_Cooling = 1
S:Y_for_Irrigation = 1
S:Y_for_Toilets_Female = 1
S:Y_for_Toilets_Male = 1
S:Y_for_urinals_Female = 1

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S:Y_for_urinals_Male = 1
Stormwater_Flow_into_Pond_Override_Value = 50
T:Base\Sb_Baseline_Duration_of_Bathroom_Sink_Event = 15
T:Dsgn\Sb_Design_Duration_of_Bathroom_Sink_Event = 15
T:Full_Average_hours_per_day = 8
T:H\Base_Baseline_Duration_of_Shower_Event = 300
T:H\Dsgn_Design_Duration_of_Shower_Event = 300
T:Other_1_Average_hours_per_day = 0
T:Other_2_Average_hours_per_day = 0
T:Part_Average_hours_per_day = 4
T:Sk\Base_Baseline_Duration_of_Kitchen_Sink_Event = 15
T:Sk\Dsgn_Design_Duration_of_Kitchen_Sink_Event = 15
Total_FTE = FTE:_Constant*S:FTE:Constant+FTE_Varying*S:FTE:Varying
TPWA\Groundcover_2 =
k\L_Groundcover_2*Area\Groundcover_2*Conversion_gal\sf\in/(IE_Drip\Groundcover_2+IE\Sprinkler\Groundcover_2)
TPWA\Mixed_2 = k\L_Mixed_2*Area\Mixed_2*Conversion_gal\sf\in/(IE_Sprinkler\Mixed_2+IE_Drip\Mixed_2)
TPWA\Shrubs_2 = k\L_Shrubs_2*Area\Shrubs_2*Conversion_gal\sf\in/(IE_Drip\Shrubs_2+IE_Sprinkler\Shrubs_2)
TPWA\Trees_2 = k\L_Trees_2*Area\Trees_2*Conversion_gal\sf\in/(IE_Drip\Trees_2+IE_Sprinkler\Trees_2)
TPWA\Turfgrass_2 =
k\L_Turfgrass_2*Area\Turfgrass_2*Conversion_gal\sf\in/(IE_Sprinkler\Turfgrass_2+IE_Drip\Turfgrass_2)
TWA\Groundcover =
k\L_Groundcover*Area\Groundcover*Conversion_gal\sf\in/(IE_Drip\Groundcover+IE\Sprinkler\Groundcover)
TWA\Mixed = k\L_Mixed*Area\Mixed*Conversion_gal\sf\in/(IE_Sprinkler\Mixed+IE_Drip\Mixed)
TWA\Shrubs = k\L_Shrubs*Area\Shrubs*Conversion_gal\sf\in/(IE_Drip\Shrubs+IE_Sprinkler\Shrubs)
TWA\Trees = k\L_Trees*Area\Trees*Conversion_gal\sf\in/(IE_Drip\Trees+IE_Sprinkler\Trees)
TWA\Turfgrass = k\L_Turfgrass*Area\Turfgrass*Conversion_gal\sf\in/(IE_Sprinkler\Turfgrass+IE_Drip\Turfgrass)
V:A\T_Base_Baseline_Toilet_Application_Volume = 1.6
V:A\T_Dsgn_Design_Toilet_Application_Volume = 1.6
V:A\U_Base_Baseline_Urinal_Application_Volume = 1
V:A\U_Dsgn_Design_Urinal_Application_Volume = 1
V:flush_First_flush_volume = 0
V:G\Pnd_Stormwater_Volume_in_Pond = V:Storm\Pond
V:Max\Cis_Maximum_Cistern_Volume = 1000000
V:Max\Pnd_Maximum_Pond_Volume = 1000
V:R\Cis_Rainwater_Volume_in_Cistern = V:Rain\Cistern
V:Treat_Volume_of_Treated_Water_for_Reuse = V:Treat_Treatment
ET\0 = GRAPH(TIME)
(0.00, 0.00), (3.10, 0.00), (6.20, 0.00), (9.30, 0.00), (12.4, 0.00), (15.5, 0.00), (18.6, 0.00), (21.7, 0.00), (24.8, 0.00), (27.9,
0.00), (31.0, 0.00)
FTE_Varying = GRAPH(DAYS)
(0.00, 100), (1.00, 100), (2.00, 100), (3.00, 100), (4.00, 100), (5.00, 0.00), (6.00, 0.00), (7.00, 100), (8.00, 100), (9.00,
100), (10.0, 100), (11.0, 100), (12.0, 0.00), (13.0, 0.00), (14.0, 100), (15.0, 100), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00),
(19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.00), (26.0, 0.00), (27.0, 0.00), (28.0,
0.00), (29.0, 0.00), (30.0, 0.00), (31.0, 0.00), (32.0, 0.00), (33.0, 0.00), (34.0, 0.00), (35.0, 0.00), (36.0, 0.00), (37.0, 0.00),
(38.0, 0.00), (39.0, 0.00), (40.0, 0.00), (41.0, 0.00), (42.0, 0.00), (43.0, 0.00), (44.0, 0.00), (45.0, 0.00), (46.0, 0.00), (47.0,
0.00), (48.0, 0.00), (49.0, 0.00), (50.0, 0.00), (51.0, 0.00), (52.0, 0.00), (53.0, 0.00), (54.0, 0.00), (55.0, 0.00), (56.0, 0.00),
(57.0, 0.00), (58.0, 0.00), (59.0, 0.00), (60.0, 0.00), (61.0, 0.00), (62.0, 0.00), (63.0, 0.00), (64.0, 0.00), (65.0, 0.00), (66.0,
0.00), (67.0, 0.00), (68.0, 0.00), (69.0, 0.00), (70.0, 0.00), (71.0, 0.00), (72.0, 0.00), (73.0, 0.00), (74.0, 0.00), (75.0, 0.00),
(76.0, 0.00), (77.0, 0.00), (78.0, 0.00), (79.0, 0.00), (80.0, 0.00), (81.0, 0.00), (82.0, 0.00), (83.0, 0.00), (84.0, 0.00), (85.0,
0.00), (86.0, 0.00), (87.0, 0.00), (88.0, 0.00), (89.0, 0.00), (90.0, 0.00), (91.0, 0.00), (92.0, 0.00), (93.0, 0.00), (94.0, 0.00),
(95.0, 0.00), (96.0, 0.00), (97.0, 0.00), (98.0, 0.00), (99.0, 0.00), (100, 0.00), (101, 0.00), (102, 0.00), (103, 0.00), (104,
0.00), (105, 0.00), (106, 0.00), (107, 0.00), (108, 0.00), (109, 0.00), (110, 0.00), (111, 0.00), (112, 0.00), (113, 0.00), (114,
0.00), (115, 0.00), (116, 0.00), (117, 0.00), (118, 0.00), (119, 0.00), (120, 0.00), (121, 0.00), (122, 0.00), (123, 0.00), (124,
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0.00), (135, 0.00), (136, 0.00), (137, 0.00), (138, 0.00), (139, 0.00), (140, 0.00), (141, 0.00), (142, 0.00), (143, 0.00), (144,
0.00), (145, 0.00), (146, 0.00), (147, 0.00), (148, 0.00), (149, 0.00), (150, 0.00), (151, 0.00), (152, 0.00), (153, 0.00), (154,
0.00), (155, 0.00), (156, 0.00), (157, 0.00), (158, 0.00), (159, 0.00), (160, 0.00), (161, 0.00), (162, 0.00), (163, 0.00), (164,
0.00), (165, 0.00), (166, 0.00), (167, 0.00), (168, 0.00), (169, 0.00), (170, 0.00), (171, 0.00), (172, 0.00), (173, 0.00), (174,
0.00), (175, 0.00), (176, 0.00), (177, 0.00), (178, 0.00), (179, 0.00), (180, 0.00), (181, 0.00), (182, 0.00), (183, 0.00), (184,
0.00), (185, 0.00), (186, 0.00), (187, 0.00), (188, 0.00), (189, 0.00), (190, 0.00), (191, 0.00), (192, 0.00), (193, 0.00), (194,
0.00), (195, 0.00), (196, 0.00), (197, 0.00), (198, 0.00), (199, 0.00), (200, 0.00), (201, 0.00), (202, 0.00), (203, 0.00), (204,
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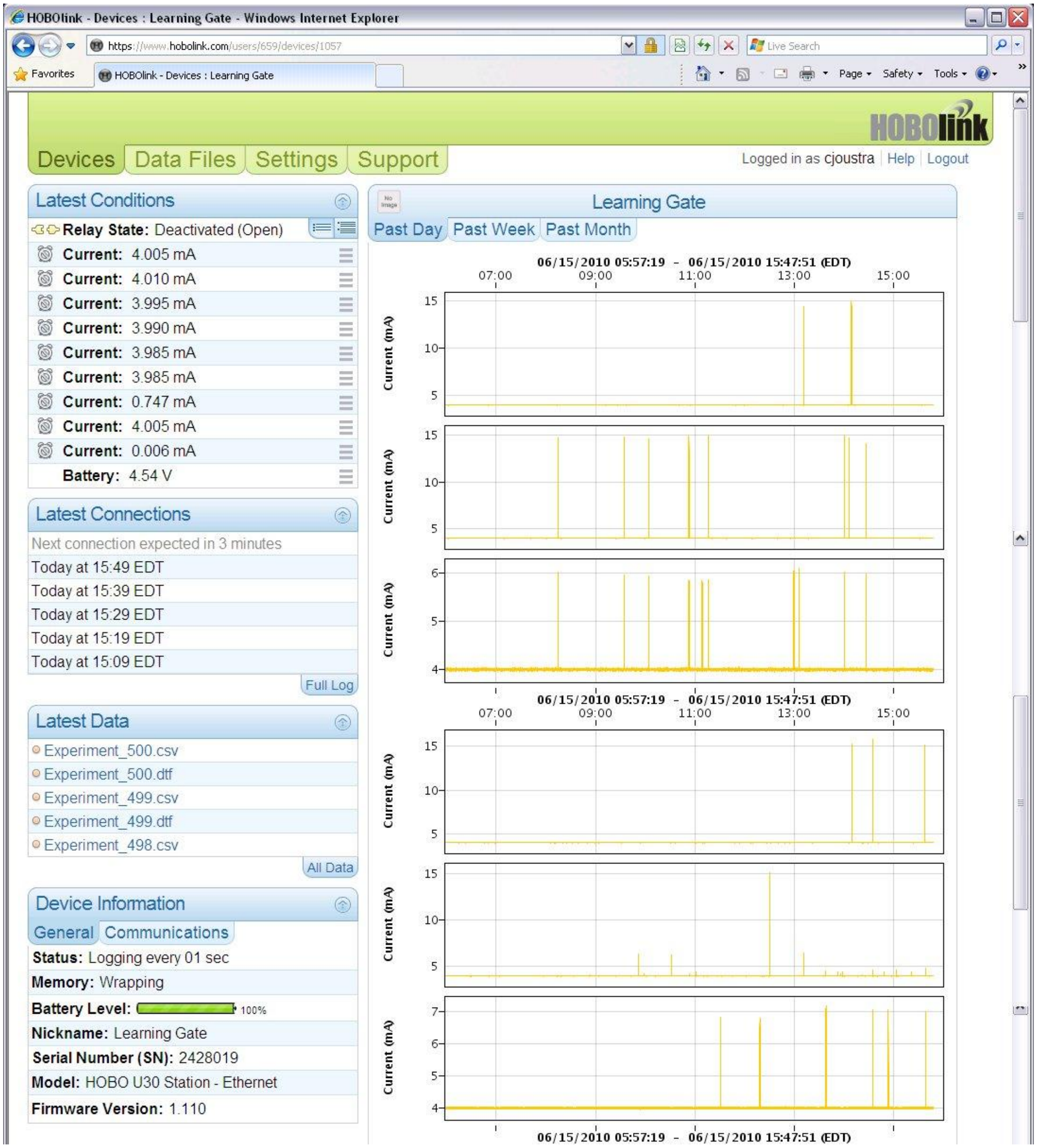
0.00), (205, 0.00), (206, 0.00), (207, 0.00), (208, 0.00), (209, 0.00), (210, 0.00), (211, 0.00), (212, 0.00), (213, 0.00), (214, 0.00), (215, 0.00), (216, 0.00), (217, 0.00), (218, 0.00), (219, 0.00), (220, 0.00), (221, 0.00), (222, 0.00), (223, 0.00), (224, 0.00), (225, 0.00), (226, 0.00), (227, 0.00), (228, 0.00), (229, 0.00), (230, 0.00), (231, 0.00), (232, 0.00), (233, 0.00), (234, 0.00), (235, 0.00), (236, 0.00), (237, 0.00), (238, 0.00), (239, 0.00), (240, 0.00), (241, 0.00), (242, 0.00), (243, 0.00), (244, 0.00), (245, 0.00), (246, 0.00), (247, 0.00), (248, 0.00), (249, 0.00), (250, 0.00), (251, 0.00), (252, 0.00), (253, 0.00), (254, 0.00), (255, 0.00), (256, 0.00), (257, 0.00), (258, 0.00), (259, 0.00), (260, 0.00), (261, 0.00), (262, 0.00), (263, 0.00), (264, 0.00), (265, 0.00), (266, 0.00), (267, 0.00), (268, 0.00), (269, 0.00), (270, 0.00), (271, 0.00), (272, 0.00), (273, 0.00), (274, 0.00), (275, 0.00), (276, 0.00), (277, 0.00), (278, 0.00), (279, 0.00), (280, 0.00), (281, 0.00), (282, 0.00), (283, 0.00), (284, 0.00), (285, 0.00), (286, 0.00), (287, 0.00), (288, 0.00), (289, 0.00), (290, 0.00), (291, 0.00), (292, 0.00), (293, 0.00), (294, 0.00), (295, 0.00), (296, 0.00), (297, 0.00), (298, 0.00), (299, 0.00), (300, 0.00), (301, 0.00), (302, 0.00), (303, 0.00), (304, 0.00), (305, 0.00), (306, 0.00), (307, 0.00), (308, 0.00), (309, 0.00), (310, 0.00), (311, 0.00), (312, 0.00), (313, 0.00), (314, 0.00), (315, 0.00), (316, 0.00), (317, 0.00), (318, 0.00), (319, 0.00), (320, 0.00), (321, 0.00), (322, 0.00), (323, 0.00), (324, 0.00), (325, 0.00), (326, 0.00), (327, 0.00), (328, 0.00), (329, 0.00), (330, 0.00), (331, 0.00), (332, 0.00), (333, 0.00), (334, 0.00), (335, 0.00), (336, 0.00), (337, 0.00), (338, 0.00), (339, 0.00), (340, 0.00), (341, 0.00), (342, 0.00), (343, 0.00), (344, 0.00), (345, 0.00), (346, 0.00), (347, 0.00), (348, 0.00), (349, 0.00), (350, 0.00), (351, 0.00), (352, 0.00), (353, 0.00), (354, 0.00), (355, 0.00), (356, 0.00), (357, 0.00), (358, 0.00), (359, 0.00), (360, 0.00), (361, 0.00), (362, 0.00), (363, 0.00), (364, 0.00), (365, 0.00)
R_Rainfall = GRAPH(TIME)
(0.00, 0.00), (8.10, 0.00), (16.2, 0.00), (24.3, 0.00), (32.4, 0.00), (40.5, 0.00), (48.6, 0.00), (56.7, 0.00), (64.8, 0.00), (72.9, 0.00), (81.0, 0.00)

Appendix C: HOBOLink Website



Learning Gate

Latest Conditions

Relay State: Deactivated (Open)
Current: 4.005 mA
Current: 4.010 mA
Current: 3.995 mA
Current: 3.990 mA
Current: 3.985 mA
Current: 3.985 mA
Current: 0.747 mA
Current: 4.005 mA
Current: 0.006 mA
Battery: 4.54 V

Latest Connections

Next connection expected in 3 minutes
Today at 15:49 EDT
Today at 15:39 EDT
Today at 15:29 EDT
Today at 15:19 EDT
Today at 15:09 EDT

Latest Data

- Experiment_500.csv
- Experiment_500.dtf
- Experiment_499.csv
- Experiment_499.dtf
- Experiment_498.csv

Device Information

Status: Logging every 01 sec
Memory: Wrapping
Battery Level: 100%
Nickname: Learning Gate
Serial Number (SN): 2428019
Model: HOBO U30 Station - Ethernet
Firmware Version: 1.110

FIGURE C1: HOBOLink website for Learning Gate.

Appendix D: Data Output Logged by HOBO Data Logger and HOBOlink

Table D1: Raw data from sensors in mA.

Time, Eastern Daylight Time	Current, mA	Current, mA	Current, mA	Current, mA	Current, mA	Current, mA	Current, mA	Current, mA
	Toilet A	Toilet B	Sink A	Toilet C	Sink B	Sink C	Toilet D	Sink D
3/15/2010 9:08:41	3.995	4.01	3.995	3.971	3.99	3.995	0.909	4
3/15/2010 9:08:42	3.995	4.005	3.985	3.98	3.976	3.99	0.85	3.985
3/15/2010 9:08:43	4.015	3.98	3.98	3.98	3.98	3.98	0.786	4.015
3/15/2010 9:08:44	4.02	3.976	3.971	3.995	3.99	3.985	0.821	3.995
3/15/2010 9:08:45	3.995	4	4.005	4	4	3.995	0.771	3.99
3/15/2010 9:08:46	3.99	3.99	3.99	3.995	3.995	3.99	0.87	3.971
3/15/2010 9:08:47	3.995	3.99	3.985	3.98	3.985	4	0.796	4.005
3/15/2010 9:08:48	4.005	3.995	3.971	4	3.976	3.99	0.791	3.99
3/15/2010 9:08:49	3.985	4.01	3.99	4.005	3.98	3.99	0.816	3.971
3/15/2010 9:08:50	3.99	3.985	3.99	3.976	3.976	3.99	0.747	4
3/15/2010 9:08:51	3.995	4	4	3.976	3.985	3.99	0.791	3.976
3/15/2010 9:08:52	3.99	4	3.995	4	3.976	3.985	0.806	4.005
3/15/2010 9:08:53	3.995	3.99	4	3.99	3.976	3.985	0.811	3.99
3/15/2010 9:08:54	4	3.98	4.015	3.99	3.976	3.98	0.826	3.971
3/15/2010 9:08:55	3.985	3.99	3.99	3.976	3.99	3.99	0.801	4.01
3/15/2010 9:08:56	3.985	4.01	4.01	3.985	3.976	3.99	0.821	3.98
3/15/2010 9:08:57	3.985	3.985	3.99	3.985	4.01	3.99	0.836	3.985
3/15/2010 9:08:58	3.985	3.995	3.976	3.971	3.995	3.99	0.776	3.99
3/15/2010 9:08:59	3.985	3.99	3.985	3.99	3.98	3.98	0.776	3.985
3/15/2010 9:09:00	3.99	4.015	4.005	4.005	3.971	3.966	0.816	3.99
3/15/2010 9:09:01	3.985	3.995	3.976	3.985	3.985	3.995	0.806	4.01
3/15/2010 9:09:02	3.99	4.01	3.98	3.985	3.985	3.99	0.796	3.99
3/15/2010 9:09:03	3.99	3.995	3.98	3.985	3.99	3.98	0.826	4
3/15/2010 9:09:04	3.995	3.98	3.99	3.985	3.99	4	0.757	3.985
3/15/2010 9:09:05	4.005	3.99	3.995	3.971	3.966	3.995	0.836	4
3/15/2010 9:09:06	3.995	3.995	4.01	3.98	3.995	3.99	0.762	3.98
3/15/2010 9:09:07	3.98	4.005	4	3.976	3.995	3.995	0.796	3.985
3/15/2010 9:09:08	3.98	4	3.99	4.005	3.976	3.98	0.786	3.99
3/15/2010 9:09:09	3.995	4.005	3.976	3.99	3.995	4.005	0.836	4.02
3/15/2010 9:09:10	4.005	3.99	3.98	3.985	3.985	3.995	0.836	4.005
3/15/2010 9:09:11	3.98	3.995	4.015	4	3.976	3.98	0.786	4
3/15/2010 9:09:12	4.005	4.025	3.985	3.99	3.995	3.98	0.796	3.995
3/15/2010 9:09:13	3.995	4.015	3.99	3.99	3.966	3.99	0.845	3.99
3/15/2010 9:09:14	3.99	4.005	3.976	3.995	3.98	3.995	0.781	3.99
3/15/2010 9:09:15	3.985	4	3.995	3.99	3.985	4	0.84	3.966
3/15/2010 9:09:16	3.99	3.995	3.985	3.98	3.985	3.985	0.86	3.985
3/15/2010 9:09:17	3.976	4.01	3.985	3.99	3.99	3.98	0.821	4.01
3/15/2010 9:09:18	3.995	3.99	3.976	3.976	4	3.98	0.776	3.985
3/15/2010 9:09:19	4	4.005	3.985	3.98	3.976	3.976	0.821	4.005
3/15/2010 9:09:20	3.985	3.985	3.961	3.976	3.98	3.99	0.855	3.99
3/15/2010 9:09:21	3.971	3.995	4	4.005	3.995	3.99	0.845	3.985

Appendix E: Filtered Event Data from Bathrooms A and B (3/17/10)

Table E1: Events for bathrooms A and B on 3/17/10.

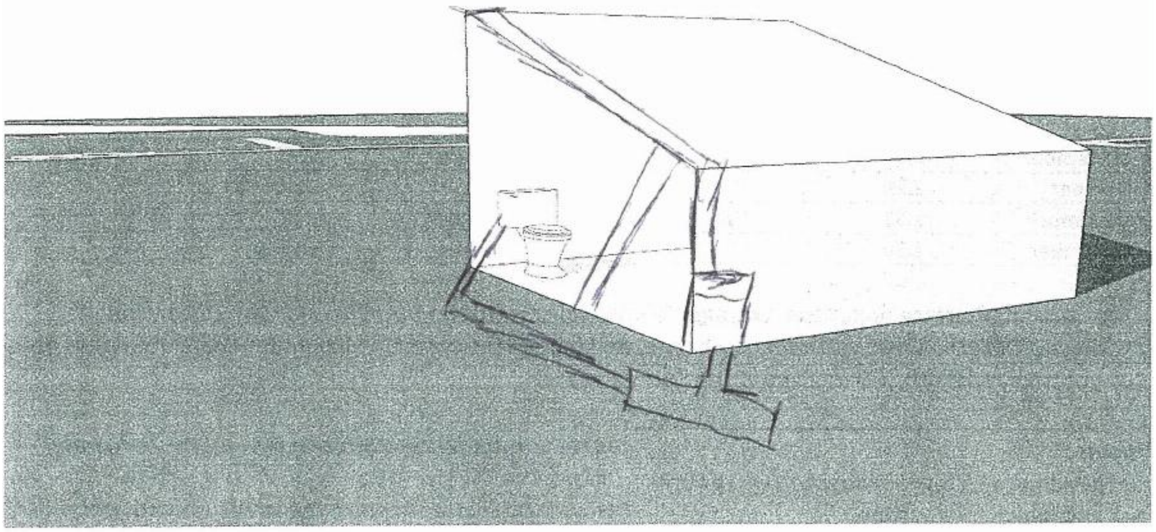
Start Time	End Time	Duration	Volume	
2:37:25 AM	**2:37:35 AM**	**10**	**1.027**	**Toilet A**
6:57:49 AM	**6:58:01 AM**	**12**	**1.016**	**Toilet B**
8:06:11 AM	**8:06:24 AM**	**13**	**0.919**	**Toilet B**
8:06:42 AM	8:06:58 AM	16	0.297	Sink B
8:15:31 AM	**8:15:43 AM**	**12**	**1.209**	**Toilet B**
8:32:00 AM	8:32:08 AM	8	0.128	Sink B
9:01:44 AM	**9:01:51 AM**	**7**	**0.443**	**Toilet A**
9:08:45 AM	9:08:51 AM	6	0.070	Sink A
10:41:43 AM	**10:41:55 AM**	**12**	**1.103**	**Toilet B**
11:20:07 AM	**11:20:16 AM**	**9**	**0.605**	**Toilet B**
11:20:20 AM	11:20:30 AM	10	0.164	Sink B
11:31:45 AM	**11:31:56 AM**	**11**	**1.042**	**Toilet B**
11:52:38 AM	**11:52:54 AM**	**16**	**1.417**	**Toilet B**
12:08:13 PM	**12:08:27 PM**	**14**	**1.120**	**Toilet B**
12:09:10 PM	12:09:21 PM	11	0.176	Sink B
12:17:35 PM	**12:17:46 PM**	**11**	**0.998**	**Toilet B**
12:32:11 PM	**12:32:23 PM**	**12**	**1.089**	**Toilet B**
12:38:14 PM	**12:38:28 PM**	**14**	**1.205**	**Toilet B**
12:54:17 PM	**12:54:30 PM**	**13**	**1.021**	**Toilet B**
1:19:15 PM	**1:19:27 PM**	**12**	**0.991**	**Toilet B**
1:21:52 PM	**1:22:07 PM**	**15**	**1.234**	**Toilet B**
1:29:54 PM	1:29:59 PM	5	0.073	Sink B
1:30:49 PM	1:30:54 PM	5	0.061	Sink B
1:39:08 PM	1:39:59 PM	51	0.941	Sink B
1:41:13 PM	1:41:17 PM	4	0.059	Sink B
2:20:18 PM	2:20:26 PM	8	0.094	Sink B
2:27:15 PM	**2:27:26 PM**	**11**	**1.168**	**Toilet A**
2:30:26 PM	**2:30:39 PM**	**13**	**1.130**	**Toilet A**
2:36:38 PM	**2:36:54 PM**	**16**	**1.371**	**Toilet A**
2:39:44 PM	**2:39:56 PM**	**12**	**1.234**	**Toilet A**
2:40:45 PM	**2:40:58 PM**	**13**	**1.463**	**Toilet A**
3:14:05 PM	**3:14:16 PM**	**11**	**0.970**	**Toilet A**
3:32:18 PM	3:32:23 PM	5	0.057	Sink B
3:41:15 PM	**3:41:27 PM**	**12**	**0.714**	**Toilet A**
4:02:00 PM	**4:02:28 PM**	**28**	**3.300**	**Toilet A**
4:43:54 PM	**4:44:08 PM**	**14**	**1.065**	**Toilet A**
5:05:52 PM	**5:06:04 PM**	**12**	**1.017**	**Toilet A**

Appendix F: Student Worksheet on Rainfall Collection at Learning Gate

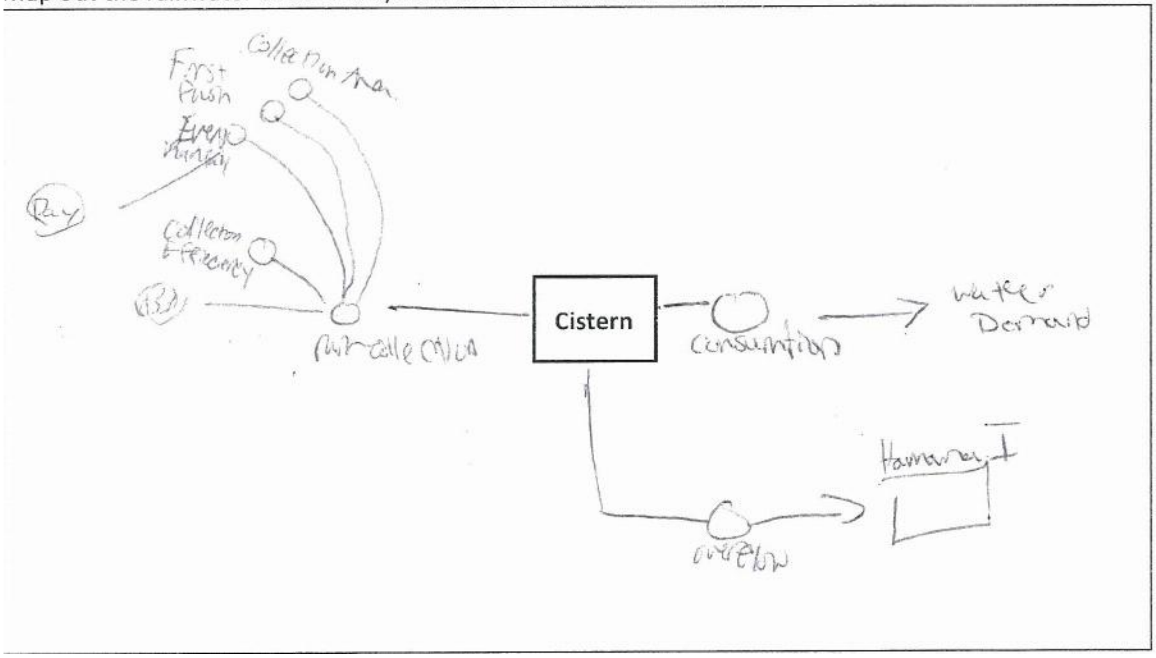
Rainfall Collection at Learning Gate

The new classrooms at Learning Gate use rainwater for flushing. A model can be used to determine how much drinking water (potable water) can be saved by using rainwater. Before building the STELLA model, the features of a rainwater collection system need to be listed. In the image below, create a diagram of a rainwater collection system that is used to flush toilets. Include the following:

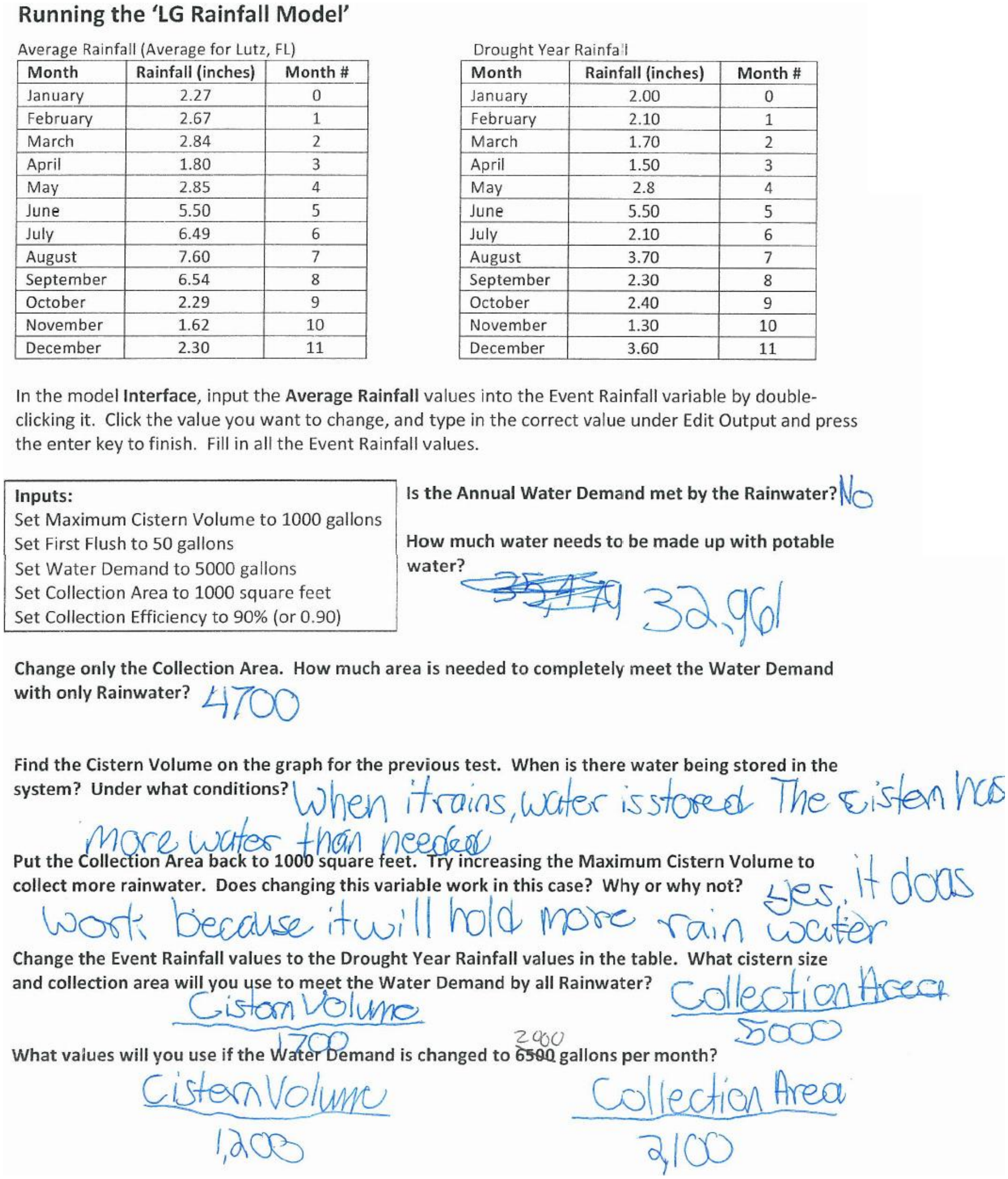
- Rainfall path
- Cistern under building
- Storage overflow pipe
- Pipe to bring rainwater to toilets
- First flush system
- Potable water to toilets (for when there is not enough rainwater)



Map out the rainwater collection system as a STELLA model schematic:



Appendix F (Continued)



Running the 'LG Rainfall Model'

Average Rainfall (Average for Lutz, FL)

Month	Rainfall (inches)	Month #
January	2.27	0
February	2.67	1
March	2.84	2
April	1.80	3
May	2.85	4
June	5.50	5
July	6.49	6
August	7.60	7
September	6.54	8
October	2.29	9
November	1.62	10
December	2.30	11

Drought Year Rainfall

Month	Rainfall (inches)	Month #
January	2.00	0
February	2.10	1
March	1.70	2
April	1.50	3
May	2.8	4
June	5.50	5
July	2.10	6
August	3.70	7
September	2.30	8
October	2.40	9
November	1.30	10
December	3.60	11

In the model **Interface**, input the **Average Rainfall** values into the Event Rainfall variable by double-clicking it. Click the value you want to change, and type in the correct value under Edit Output and press the enter key to finish. Fill in all the Event Rainfall values.

Inputs:
Set Maximum Cistern Volume to 1000 gallons
Set First Flush to 50 gallons
Set Water Demand to 5000 gallons
Set Collection Area to 1000 square feet
Set Collection Efficiency to 90% (or 0.90)

Is the Annual Water Demand met by the Rainwater? No

How much water needs to be made up with potable water?
~~35,479~~ 32,961

Change only the Collection Area. How much area is needed to completely meet the Water Demand with only Rainwater? 4700

Find the Cistern Volume on the graph for the previous test. When is there water being stored in the system? Under what conditions? When it rains, water is stored The cisten has more water than needed

Put the Collection Area back to 1000 square feet. Try increasing the Maximum Cistern Volume to collect more rainwater. Does changing this variable work in this case? Why or why not? yes, it does work because it will hold more rain water

Change the Event Rainfall values to the Drought Year Rainfall values in the table. What cistern size and collection area will you use to meet the Water Demand by all Rainwater?

Cistom Volume
1700

Collection Area
5000

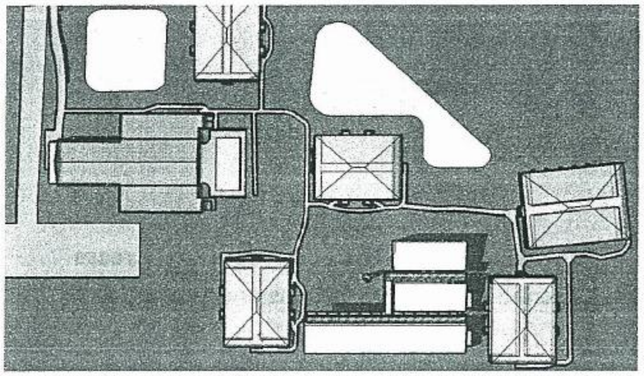
What values will you use if the Water Demand is changed to 2900 ~~**6500**~~ **gallons per month?**

Cistern Volume
1,200

Collection Area
2,100

Appendix G: Student Worksheet on Learning Gate School Model

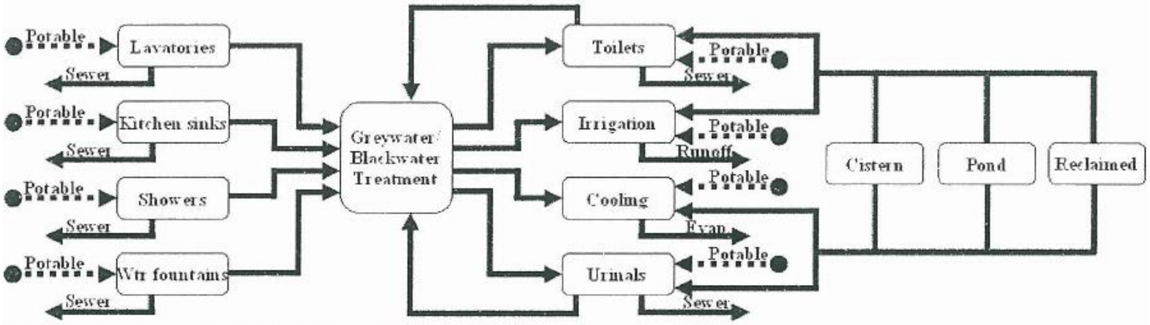
LEARNING GATE SCHOOL MODEL



Overhead picture of the Learning Gate Community School

Learning Gate collects rainwater in the new classrooms (shown in white) and uses it to flush toilets. What if the whole school used rainwater for toilet flushing? The **Learning Gate School** STELLA model will let you play with different water saving techniques for the school (or any building), such as:

- Rainwater capture
- Eco-Machine – a wastewater treatment system that uses natural plants
- Storing and using water in a pond
- Reclaimed water – water from the wastewater treatment plant that has been treated for reuse



Schematic of possible water flows in a school or building.

Questions About the Model:

1. **Keep the Design Areas in the green irrigation tables the same. Which landscape factors increase Water Demand the most: Low, Average, or High?**

   High

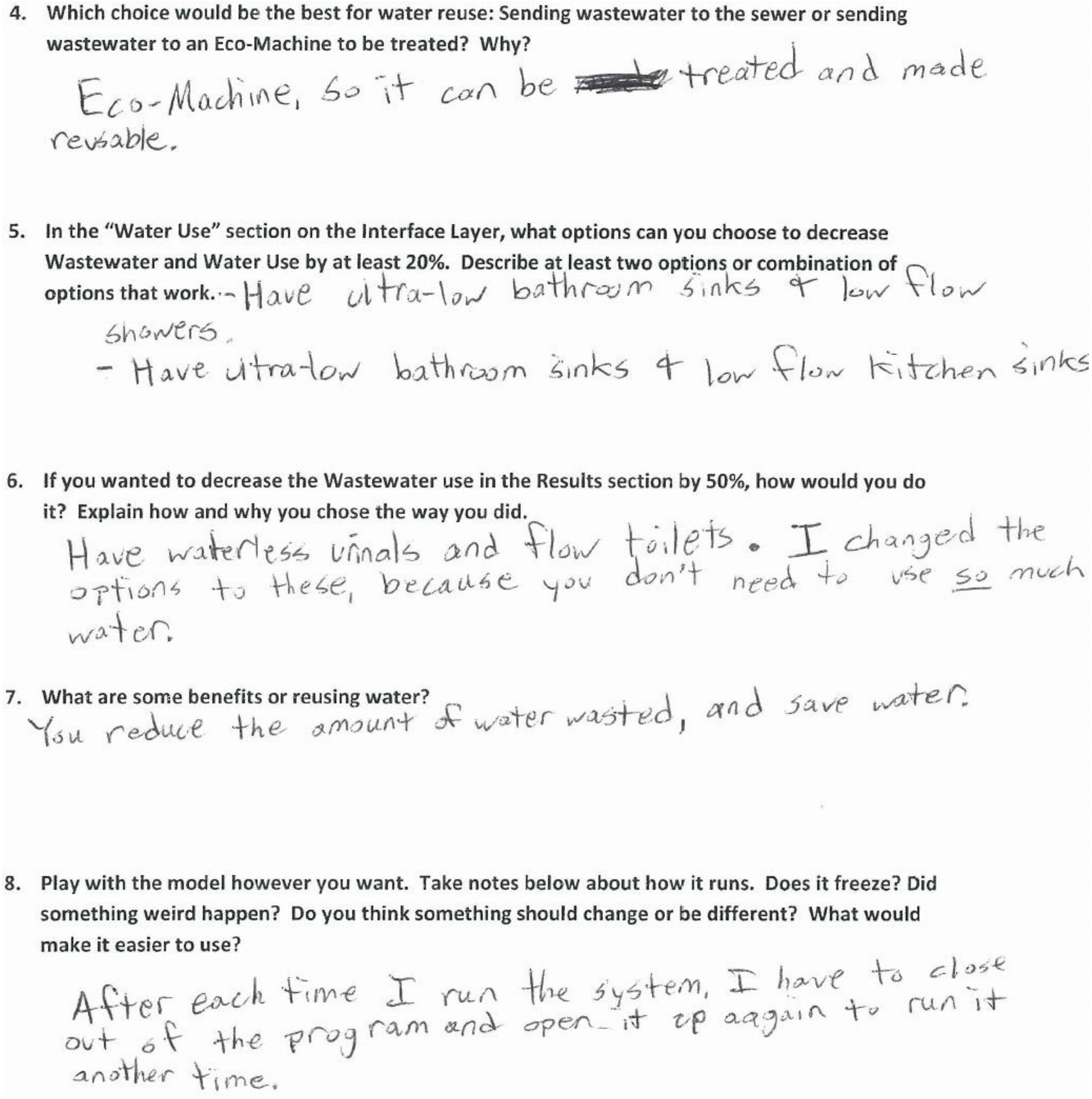
2. **Which irrigation system uses more water: Drip irrigation or Sprinklers?**

   Sprinklers

3. **Which Toilet Fixture uses the least amount of water?**

   Flow

Appendix G (Continued)



4. **Which choice would be the best for water reuse: Sending wastewater to the sewer or sending wastewater to an Eco-Machine to be treated? Why?**

Eco-Machine, so it can be treated and made reusable.

5. **In the "Water Use" section on the Interface Layer, what options can you choose to decrease Wastewater and Water Use by at least 20%. Describe at least two options or combination of options that work.**

- Have ultra-low bathroom sinks & low flow showers.
- Have ultra-low bathroom sinks & low flow kitchen sinks

6. **If you wanted to decrease the Wastewater use in the Results section by 50%, how would you do it? Explain how and why you chose the way you did.**

Have waterless urinals and flow toilets. I changed the options to these, because you don't need to use so much water.

7. **What are some benefits or reusing water?**

You reduce the amount of water wasted, and save water.

8. **Play with the model however you want. Take notes below about how it runs. Does it freeze? Did something weird happen? Do you think something should change or be different? What would make it easier to use?**

After each time I run the system, I have to close out of the program and open it up aagain to run it another time.