Water Conservation Planning in the St. Johns River Water Management District

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Water conservation estimates are essential to planning for and permitting future water use. As more strain is placed on Florida's water supplies, water conservation efforts aim to alleviate the environmental, economic, and political impacts of increasing demands. The District's effort to quantify water conservation potential is a fundamental component in planning.

A water conservation analysis tool was developed in order to accomplish the detailed task of quantitatively measuring the potential for water conservation in the District in the 2010 Water Supply Plan. This three-phase effort relied initially on the use of national benchmark studies from the Awwa Research Foundation (now Water Research Foundation) and the Environmental Protection Agency and research conducted in Florida, as well as county appraiser parcel information including Department of Revenue (DOR) codes.

With collaboration from participating utilities, the study progressed to a more localized creation of District-specific benchmarks of water use, using utility-provided account level data. Jones, Edmunds and Associates carried out both initial phases in response to a District request for proposals. The third phase culminated in the creation of a linear programming tool by District staff members and the eventual abandonment of the use of benchmarks in favor of the use of water consumption frequency distributions.

The driving force behind the use of distributions was the customer consumption input needed for the new linear programming tool. The new tool uses the number of accounts and opportunities for conservation at each 1,000 gallons of consumption in order to calculate conservation potential.

Development of a Linear Programming Tool for Water Conservation Planning & Permitting

District staff started the third phase of work in February 2011 using account level consumption data from Gainesville Regional Utilities (GRU); the cities of Leesburg, Palm Bay, and Palm Coast; and St. Johns County Utilities. Some key objectives were to: 1) obtain additional account level utility data, 2) refine assumptions, 3) address the recommendations from the second phase, 4) develop alternative ways to estimate existing water use, and 5) create a water conservation optimization tool that uses linear programming.

Single Family Water Use Methodology

Time-series consumption data is used to separate indoor use (the minimum month of consumption) from outdoor use (the higher-use months) within each residential bin of use. Depending on the volume of outdoor use, accounts are classified as either in-ground irrigators using automatic timers or hose irrigators.

If the difference between indoor and outdoor use was greater than 10,000 gallons (10 KGal), the account was considered to be an in-ground irrigator. This method was verified during the second phase of work using separate irrigation meters and smart meters. This further separation is needed in order to target appropriate strategies for in-ground irrigators and hose irrigators.

Once indoor and outdoor water use were established for each account, consumption frequencies could be compiled reflecting indoor and outdoor use within each utility. The frequency analysis for each utility showed that each customer class, when disaggregated into single-family, multi-family, and limited classes of commercial industrial and institutional use, was distributed consistently for all sampled utilities.

Merging account level data with prop-

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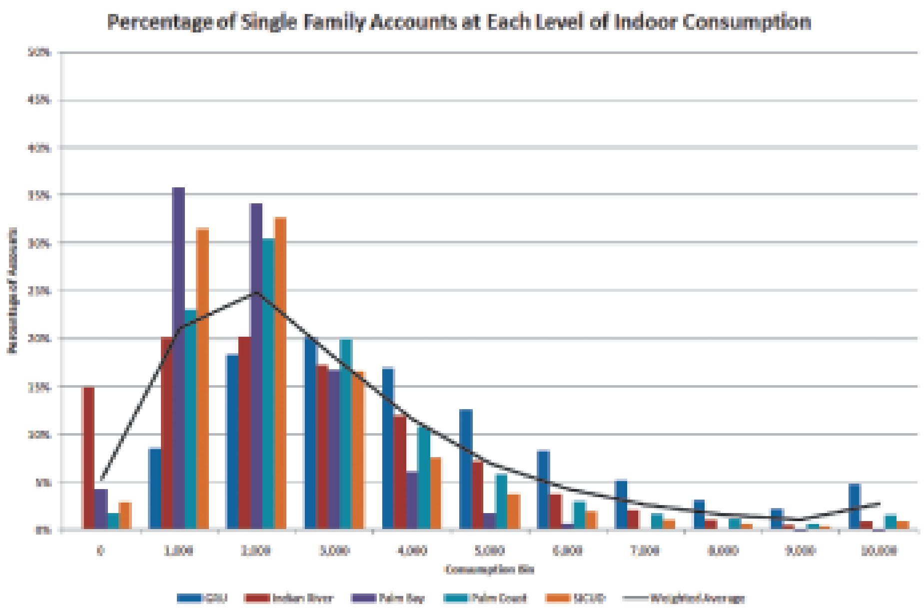

Figure 1 – Percentage of single family accounts at each level of indoor consumption: This figure shows the distributions of each utility's indoor use, along with their weighted average.

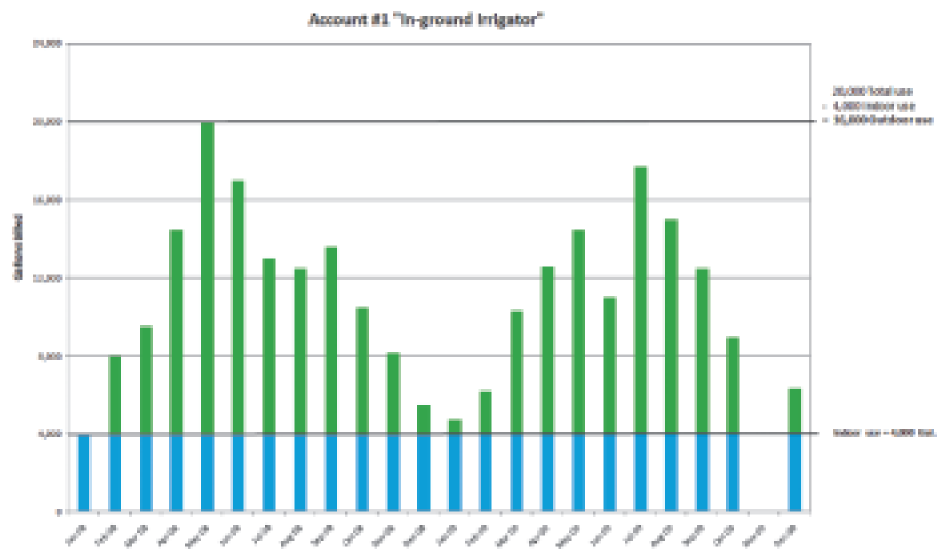

Figure 2 – In-ground irrigator water use: This graph displays the method of separating indoor and outdoor use. The maximum month minus the minimum month of consumption in this case is 16 KGal. This account is classified as using an in-ground irrigation system because the maximum month minus the minimum month of nonzero consumption is greater than 10 Kgal.

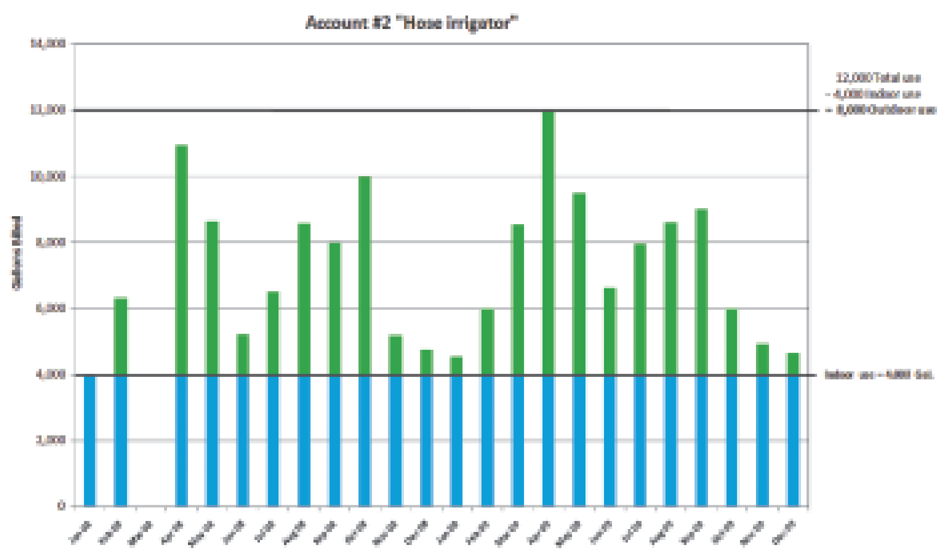

Figure 3 – Hose irrigator water use: This graph represents a water use customer in which the maximum month of consumption minus the minimum month of nonzero consumption is less than 10 KGal.

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erty appraiser data allowed District staff to standardize the descriptor for the property, which would normally vary from utility to utility. From these distributions, the percent of customers at each 1,000 gallons of consumption could be calculated for each of the five utilities.

The distributions in Figure 1, expressed as the percent of customers at each 1,000 gallons of indoor consumption per month, showed promise as a tool for estimating use in utilities, which had not provided data. The five utilities' distributions were weighted and averaged and subsequently were tested on a utility excluded from the average.

The results of this method of estimating use were compared to the results derived by the District using the weighted average benchmarks of water use per square foot in the second-phase report. The distribution using the same parcels used in the water-use-per-square-foot method showed that the benchmark distribution was skewed to the left and therefore had undercounted the average and total amount of use. The decision was made to further investigate the possibility of using customer water-use frequency distributions instead of the weighted-average-per-square-foot benchmarks.

The trade-off in abandoning this benchmark method was a loss in spatial information necessary to associate water use with the parcel being considered for an implementation. Even so, the benchmark method can not accurately predict the highly variable consumption on parcels within each user group, but any shortfall caused by the use of consumption frequency tables and graphs is true only for utilities whose use is being estimated.

For those utilities that provide account level consumption data, the use of customer consumption data is invaluable in developing a tool that can optimize the selection of fixtures in order to maximize savings while minimizing costs. The results are no longer mutually exclusive selections of strategies but collectively exhaustive selections based on the lowest cost, while maximizing savings.

Consider the in-ground irrigator and hose irrigator data in Figures 2 and 3. Both examples use 4,000 indoor gallons per month, according to the methodology used. In the consumption frequency graph for Utility X (Figure 4), both customers are represented in the 4,000-gallon level of use, which makes up a little over 10 percent of the single-family residential customers in this utility. When outdoor use is considered (Figure 5), the two examples fall under different levels of consumption: The in-ground irrigator falls under the 16 KGal level of use, while the hose irrigator falls under the eight KGal of use.

The amount of water use separated into levels of consumption is very important when we consider conservation practices because it forces us to think about water savings that are created by implementation as dependent on the amount of usage in each customer class at each level of KGal consumption. The amount of savings for each fixture depends on the amount of water the customer uses while the price for each fixture is fixed at each level of consumption.

Accounts are further split into groups based on the year in which they were built. These groupings, called build-out categories, are defined as ranges during which various plumbing standards were adopted.

The first build-out, containing homes built in 1984 and earlier, has no plumbing standard. The fixtures in these accounts use the most water. The second build-out, from 1985 to 1993, is when the National Plumbing Code was in effect. This code set a standard for new fixture efficiencies. As technology progressed, a new policy was adopted.

The accounts built in 1994 to the present, the third build-out, fall under the Federal Energy Act. Any future growth, or the fourth build-out, is expected to be subject to the same standards currently in place under the Federal Energy Act.

<u>**Multi-family Water-Use Methodology**</u>

In order to estimate water conservation potential for multi-family accounts, the consumption was linked to a single unit (apartment, condominium, etc). There were a number of challenges involved with making the account level consumption match up with the parcel information.

The account level utility data for multi-family can come in two forms: individually metered or master metered. Most of the individually (sub) metered accounts were ready for analysis. A small portion of these accounts required additional processing.

The multi-family property appraiser data was screened based on the ownership and square footage in order to determine the number of units on each parcel. Some multi-family units were individually owned, while in other cases the entire building or complex had one owner. Where units are individually owned but the water is master-metered, the total volume was divided by the number of owners (units) in order to get the average consumption per unit for that ac-

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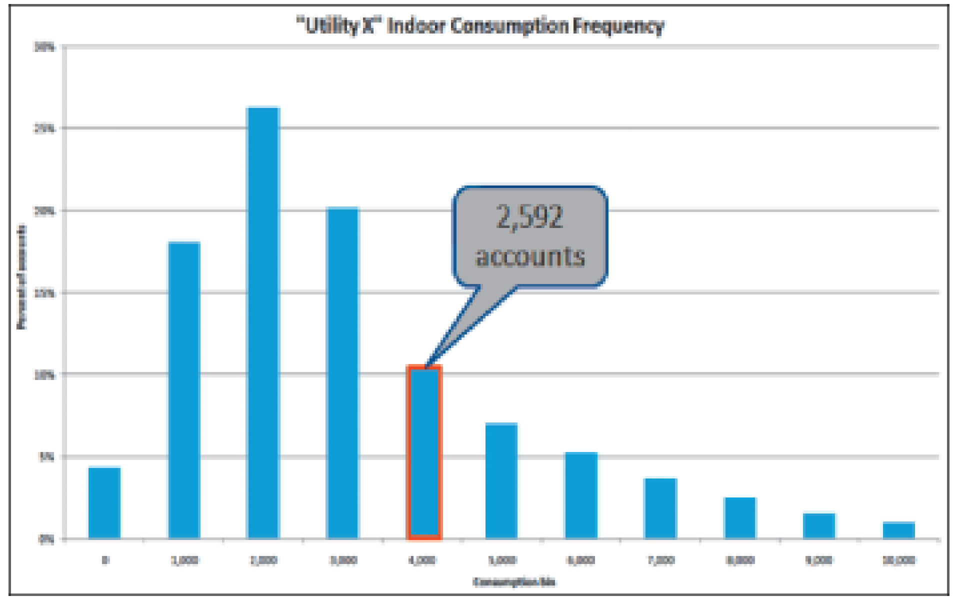

Figure 4 – Indoor consumption frequency: This graph represents the indoor consumption frequency for sample Utility "X". Both example accounts fall in the 4,000-gallon consumption bin.

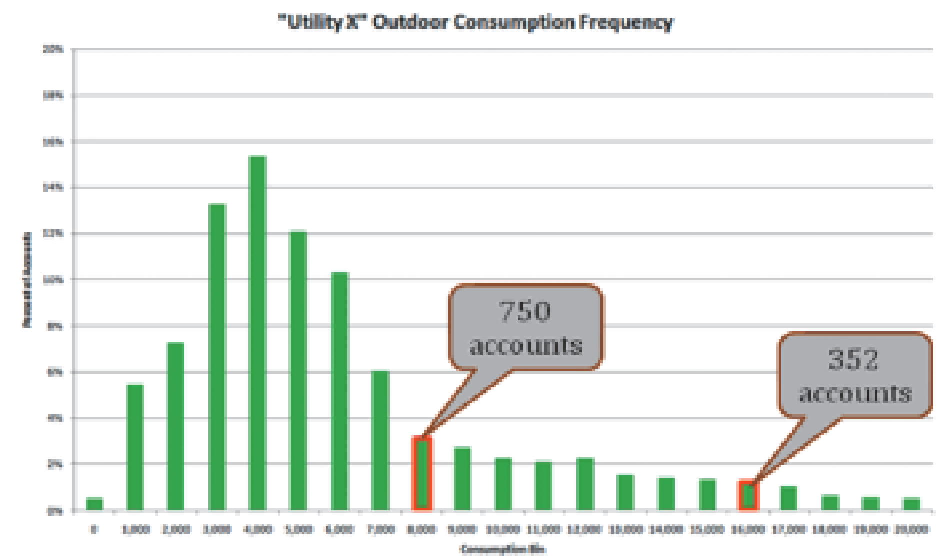

Figure 5 – Outdoor consumption frequency: In this graph, the hose irrigator is one of 750 accounts using 8,000 gallons outdoors, while the in-ground irrigator is one of 352 accounts using 16,000 gallons outdoors.

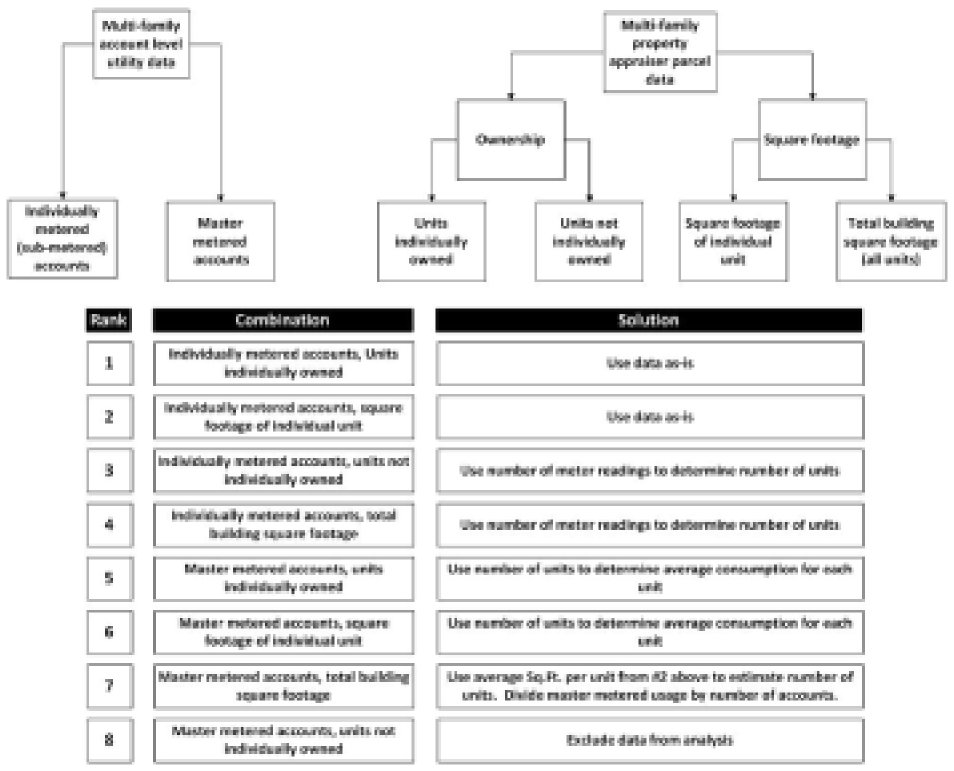

Figure 6 – Multi-family account workflow: This diagram shows how multi-family account and parcel data are processed to generate water use per unit.

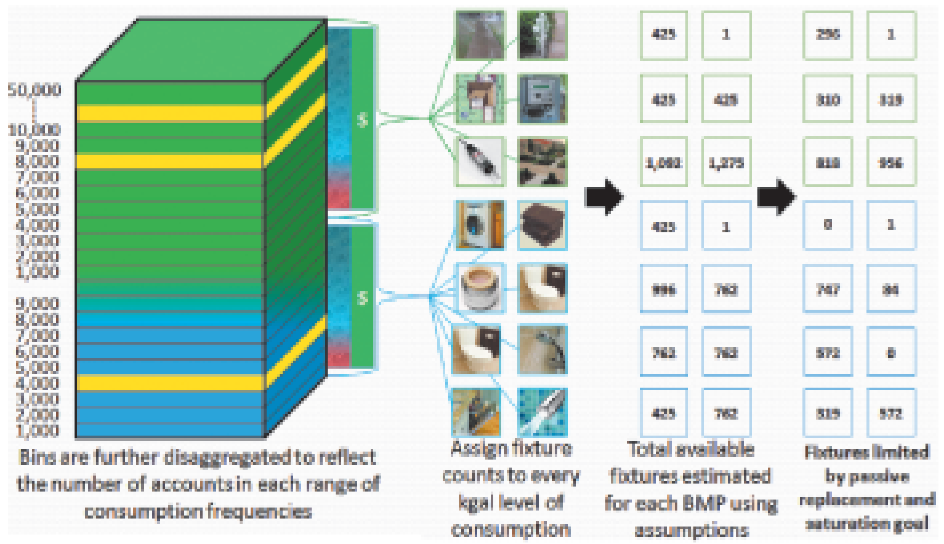

Figure 7 – Water conservation potential and fixture counts applied to consumption levels: Water-use bins developed in the second work phase are disaggregated by levels of consumption (1 KGal to 10 KGal for indoor; 1 KGal to 30 KGal for outdoor). An initial estimate of fixtures is derived and then reduced by saturation rate for the fixture and saturation goal of the utility.

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count. Where multi-family units did not have individual owners and the consumption data was sub-metered, it was assumed that each consumption record is one unit.

In some cases it was impossible to determine the number of multi-family units based on the square footage, owner information, or master metered consumption. These parcels and accounts were excluded from the analysis and represented a small percentage of total parcels.

Once the number of units at each consumption level within each build-out had been determined, the number of fixtures was calculated. The methodology to calculate multi-family fixtures was established in the first phase of work.

Initially the number of bathrooms per square foot of building area was derived using multi-family parcel data from Gainesville Regional Utilities (GRU) and Vero Beach's service area boundaries. This data provided estimates of bathrooms in multi-family parcels. There were discrepancies between the number of units on a parcel and the number of listed bathrooms, causing the number of bathrooms to be underestimated. The first and second work phases assumed each unit contains two bathrooms and one kitchen sink.

Figure 6 shows how each combination of multi-family account and parcel data are screened and processed.

The average monthly consumption, excluding zero-use months, was considered multi-family total indoor use. As in the first two phases, outdoor consumption was assumed zero. Consumption was capped at 10 KGal, which reflects the same maximum monthly indoor use for single-family accounts. Any multi-family accounts exceeding this cap were adjusted down to 10 KGal in this way; no accounts were excluded from the analysis based on consumption. The number of accounts and fixtures at each KGal level of consumption within each build-out were totaled for use in the linear programming tool.

Single- & Multi-Family Indoor Water Conservation Savings Methodology

Estimating conservation potential requires that accounts be disaggregated into levels of consumption. Residential accounts are separated by year-built ranges (BO1-BO4), representing three periods of plumbing standards and future construction. The customers are further disaggregated into 1 KGal levels of consumption within each build-out.

Fixture counts or replacement opportunities are calculated for the customers/accounts at each level of consumption. The total number of fixtures, or replacement opportunities, are reduced by the estimate of passive replacement per year for the best management practice (BMP), and further reduced by the saturation goal of the utility. Some important assumptions in this methodology include:

- End-use proportions for each customer class (residential indoor, hotels, hospitals, restaurants, etc)
- Indoor/outdoor split (max month-min month)
- Outdoor use (average of all months' consumption above minimum month)
- Fixture counts or replacement opportunities (based on engineering assumptions)
- Passive replacement (unique to each fixture, customer class, build-out)
- Fixture efficiency (gallons per day, gallons per month, etc.) before and after replacement
- BMP costs

The most important of these assumptions is the end-use proportions. These proportions affix a volume of consumption to each end-use, which scales up or down depending on the total monthly consumption. In other words, the shower use in the home at 1-KGal level of use in one month is 195 gallons, while the shower use in a 10-KGal use home is 1,950 gallons per month.

Estimates of fixture counts, or replacement opportunities, are based on engineering assumptions that allow a geographic information system (GIS) program to calculate the number of fixtures on each parcel. The assumption was made that the maximum number of each type of fixture that would be replaced in a residence would be two. The logic behind this assumption is that in a home with multiple bathrooms, only two are typically used because of convenience to the residents.

Once fixture counts are established for each account, the accounts are grouped by year built, then sub-grouped by indoor and outdoor consumption levels. The total number of each fixture type is preserved at this level. The total number of fixtures available to be replaced depends on the replacement fixture's passive replacement assumption. Passive replacement refers to the rate at which a utility's customers are replacing their old fixtures with more efficient replacement fixtures currently on the market.

Each fixture replacement also has an assumed saturation rate, which is the percent of total original fixtures that the utility is aiming to replace through program replacement. This rate varies depending on a utility's specifications, based on its water conservation program experience.

The saturation rate further reduces the number of replacement opportunities, or program replacements. For example, a utility establishes a saturation goal of 75 percent for toilet replacements. An ultra-low-flow toilet BMP has a passive replacement assumption of 4 percent per year. If a 20-year planning horizon were used, the saturation goal would be met in year 18. This would mean zero program replacement opportunities for this particular BMP, given the stated criteria. Adjusting the implementation period or passive replacement assumption could allow for some program replacement opportunities.

For BMPs with opportunities for program replacement, a percent savings is calculated based on assumptions made for the existing fixture's efficiency. The percent savings is calculated as:

$$\frac{\text{Existing Efficiency} - \text{BMP Efficiency}}{\text{Existing Efficiency}}$$

This percent savings then is applied to

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Code	Problem	Frequency of Occurrence	As a Percent of Homes Evaluated	As a Percent of Total Problems	Cumulative Percent of Total
10	Turf and landscape area irrigated in the same zone	2,419	70.8	11.7	11.7
20	Mixed sprinkler/emitter sizes & unmatched application rates in the same zone	2,246	65.7	10.9	22.6
40	Stream of water blocked by vegetation	2,029	59.4	9.8	32.5
52	Operating time too frequent	1,827	53.5	8.9	41.3
50	Operating time too long	1,773	51.9	8.6	49.9
32	Sprinkler heads not properly adjusted, causing overflow on paved areas	1,333	39	6.5	56.4
21	Mixed sprinkler/emitter brands or types in the same zone	1,252	36.7	6.1	62.4
53	No rain shut-off device	1,076	31.5	5.2	67.7
30	Leaks and broken valves, pipe, laterals lines (Poly-tubing), emitters, sprinklers	971	28.4	4.7	72.4
55	No irrigation water management plan	782	22.9	3.8	76.2
23	Poor overlap due to improper sprinkler/emitter alignment or spacing	729	21.3	3.5	79.7

Table 1 – Residential irrigation audits: This table, derived from *"Frequency of Residential Irrigation Maintenance Problems" (Dukes and Olmstead, 2011)*, gives the percentage of accounts with each problem code type.

		$/Kgal	
Maximize Savings	627,569	$1.23	
Minimize Cost	$3,500,000		
Constraints			
Number of Fixtures	25,549	<=	73,432
Cost	$3,500,000	<=	$3,500,000
Savings (gpd)	627,569	>=	150,000

Table 2 – Linear programming target cell and constraints cells: This table shows the output from the linear programming equation. Here the savings were maximized given the thresholds for available fixtures, cost, and savings.

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the proportion of water currently being used by the fixture type. For example, the assumption for toilet water use is 26.7 percent of all indoor water. In a 1,000-gallon indoor use per month account, that would be equal to 267 gallons. Replacing a five-gallon toilet with a 1.2-gallon toilet would be a savings of 76 percent, equaling a savings of about 201 gallons per month. In other words, the five-gallon-per-flush toilet used 267 gallons per month, but after it is replaced with a 1.2-gallon-per-flush toilet, only 66 gallons would be used per month.

Single-Family Outdoor Water Conservation Savings Methodology

The outdoor replacement opportunities were approached in a very different way from the fixture count approach used for indoor. The replacement opportunities in outdoor use can not rely on fixture counts for the number and type of heads because of the high variability in the installation of in-ground irrigation systems in Florida. This issue is being addressed through extensive training of the green industry in Florida, but the results of this approach are not evident in the irrigation systems currently installed.

In order to estimate the number of replacement opportunities available in the outdoor portion of the analysis, the District relied on a study by Dukes and Olmstead, "*Frequency of Residential Irrigation Maintenance Problems*," which surveyed approximately 3,400 in-ground irrigation systems in Northeast Florida. The study used "trouble codes" to describe the problems typically found in a large sample size of systems to be addressed in order to realize savings. Those trouble codes described the level of maintenance required to deliver an amount of savings as well as the cost to provide these levels of savings.

The District's approach uses the percentage of in-ground irrigators with each trouble code from the Dukes and Olmstead study. The District placed the trouble codes into three groups: operation, repair, and design-based audits. The selected implementations reflect the number of service calls and the cost needed to perform the services associated with level or levels of audit. The three audits increase in complexity and cost to resolve. Where the higher levels of service are needed, the costs are assumed to include any lower levels of audit.

Both the single- and multi-family indoor water conservation savings methodology and the single-family outdoor water conservation savings methodology processes are described in Figure 7. The commercial categories follow a similar approach.

Commercial, Industrial, Institutional (CII) Indoor Water Conservation Savings Methodology

The CII customer classes are assumed to use water only indoors. The BMPs can vary by customer class but mainly focus on domestic uses, which include faucets, toilets, urinals, showers, and kitchen uses. Additional CII uses include kitchen pre-rinse spray valves and water recycling laundry machines.

The assumption for the proportion of consumption by each end use of water comes from the East Bay Municipal Utility District (EBMUD) study, "*The WaterSmart Guidebook: A Water Use Efficiency Plan and Review Guide for New Businesses*" (EBMUD,

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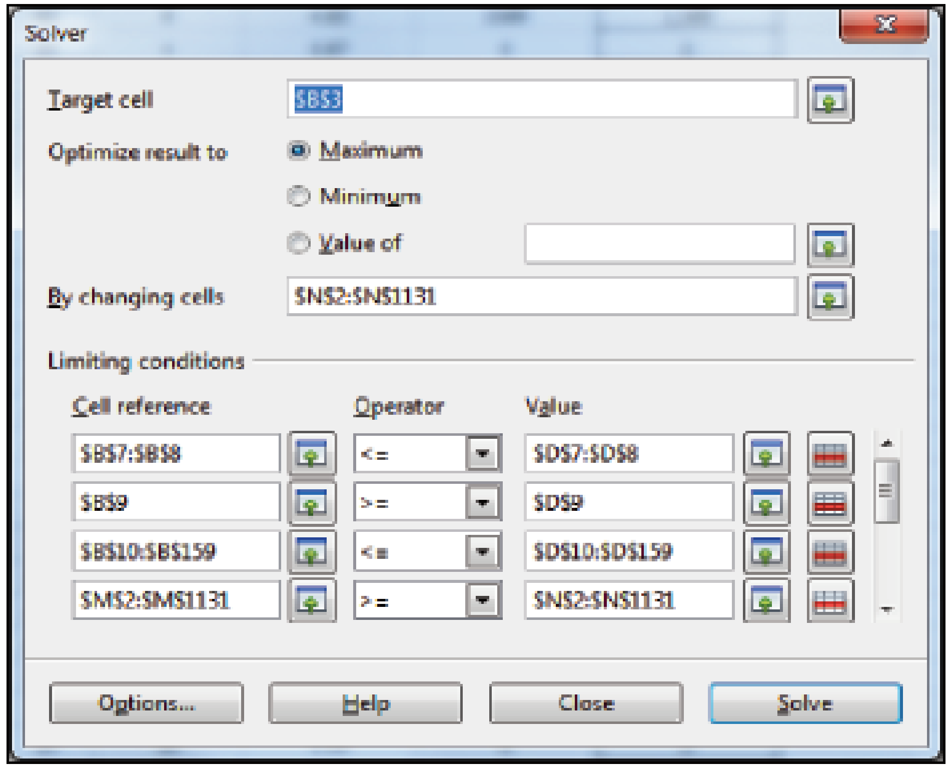

Figure 8 – Linear programming solver input: The target cell, changing cells, and constraints are defined in the solver set-up window.

Table 3 – Linear programming output: This table shows how the BMPs are configured in the linear programming tool.

Fixture ID	Consumption	Fixture Type	Number of Fixtures	Cost	Savings (GPD)	Available Fixtures	Selected Fixtures
X1	1,000	HE Shower heads	1	40	4	1606	1,606
X2		Low Flow Bathroom Faucet Aerators	1	15	2	0	0
X3		Low Flow Kitchen Faucet Aerators	1	15	1	0	0
X1131	50,000	Water-wise Florida Landscape- Outdoor	1	5,000	1,400	0	0

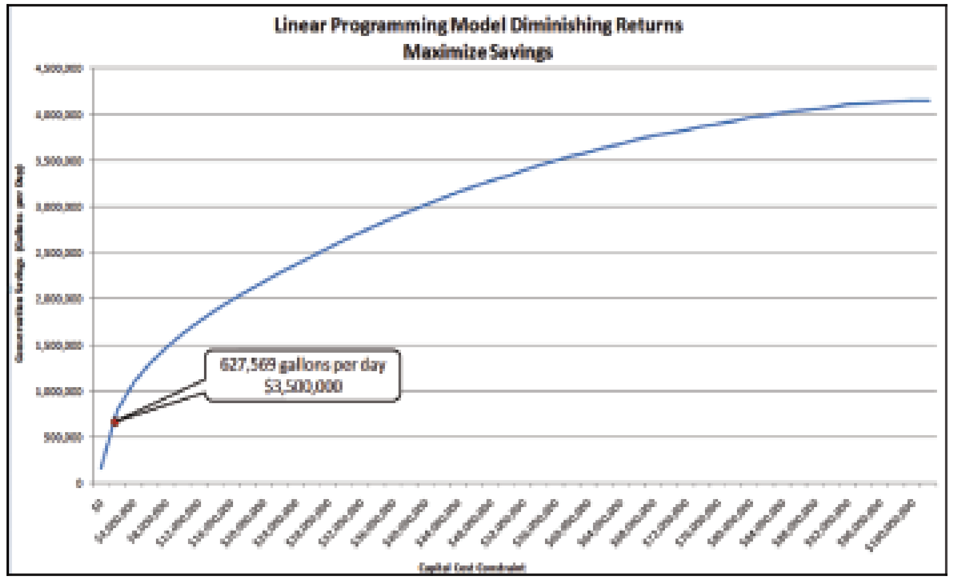

Figure 9 – Linear programming diminishing returns graph: It is possible to illustrate a point of diminishing returns for savings at various levels of available budget. In this case the budget was increased by $2 million until the point of diminishing returns was reached at approximately $76 million.

Figure 10 – Linking linear programming output back to parcels: The results of the linear programming tool can be related back to the candidate accounts or parcels in GIS.

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2008), which contains sections for each major CII water-using category. Each section describes the percentage of total water applied to each end use. These percentages were used in the first and second work phases. The EBMUD study also provides several options for reducing consumption within each end use.

Water Conservation Potential Analysis: A New Approach

A linear programming model is used to identify the most cost-effective BMP implementations. The following simplified equation outlines how each BMP is evaluated and limited by each constraint.

The equation can be stated as:

Maximize:

$X_1 + \ldots X_{1,131}$

Subject to:

Total fixtures <= 73,432

Total savings >= 150,000 gallons/day

Total cost <= $3.5 Million

The actual program represented in Table 2 is the "answer," or output, of the equation in the cell labeled Maximize Savings. Under the "Constraints" column, the labels for the maximum number of fixtures that can be selected must be less than or equal to 73,432; the maximum budget is $3.5 million; and the stated goal for savings is 150,000 gpd (right side). The number of actual fixtures selected was 25,549 at a cost of $3.5 million and a savings of 627,569 gpd.

The yellow highlighted number is the unit cost (cost per KGal), determined by annualizing $3.5 million cost over 20 years, using a discount rate of 5 percent and then dividing the annualized cost by the savings delivered each year. In terms of water supply costs, $1.23 per KGal is very competitive.

Proper configuration of the solver (Figure 8) is needed to run the tool successfully. The target cell, or maximized savings, is specified. The changing cells represent the variables, or number of fixtures, that the linear programming process will select given the constraints. The constraints, also called "limiting conditions," are selected in the spreadsheet.

The first constraint represents the total number of replacement opportunities and the total cost. Since they have the same operator, they can be grouped into one range of cell references. The second constraint is the total savings from all BMPs selected.

The third constraint limits replacements to the number of available opportunities for each fixture type and each level of consump-

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tion. The fourth constraint is what prevents some outdoor BMPs from being "double counted." Without this constraint, the BMPs selected that are competing directly for the same end use of water could exceed the number of replacement opportunities.

The results in this particular run (Table 3) selected all 1,606 high-efficiency showerhead fixtures. Notice the designation X_1 at consumption level 1KGal, which represents the high-efficiency showerheads with the accompanying cost, saving, and available fixtures shown. The designation X_{1131} at the 30 KGal level is Water-wise Florida Landscape – Outdoor. Because of passive replacement, none of the aerators were available for selection, nor were the landscape options at the levels of consumption shown.

Linear Programming Tool Results

One of the advantages of setting up the linear programming tool is the ability to change the inputs to run any scenario. Figure 9 shows the cost constraint being increased by $2 million of available budget for each run. This has been done for the residential indoor and outdoor for Utility X below:

The unit cost for a BMP implementation is calculated as the annualized capital cost (over 20 years at a 5 percent discount rate) divided by the annualized water savings in thousands of gallons. This calculation results in a cost per 1,000 gallons, which can be compared directly to the production cost of alternative and traditional water supplies. A maximum unit cost can be set, which will eliminate any conservation opportunities exceeding the threshold.

It is important to note that in accounts with lower consumption levels, the unit cost for any BMP will be greater than a high-use account. This is the governing concept behind the linear programming tool developed in this phase of the work.

The most important part of the process is to ensure that the fixtures selected by the linear programming tool can be linked back to the candidate parcels at each level of consumption. A utility might choose to develop a conservation plan based on the expected costs and savings from this analysis. An operations budget and timeline also must be developed for a conservation plan. This work was accomplished using GIS, so a link exists between the linear programming tool and the parcels through the consumption level and build-out category.

Figure 10 shows candidate parcels at the 10 KGal level of use for the 261 fixture replacements selected by the tool at that level of consumption. There may be hundreds, or even thousands, of candidate parcels utility-wide on which to implement the 261 conservation opportunities.

An account's eligibility must be field verified prior to confirming that a particular 10-KGal level user is in fact a suitable candidate. This type of field verification must occur whether or not this analysis has been done; however, the decision-making power of the optimization tool ensures that when these replacements are made, they represent the most savings for the least cost for the utility.

Using the Linear Programming Tool

The District's linear programming tool was designed to be used by a variety of users, including:

- Utilities
- Water Management District staff
- Planners
- Business leaders
- Professional associations
- Developers
- Water conservation researchers
- Water conservation companies
- Environmental groups

The linear programming tool is adaptable to whatever input data is available. The ideal data inputs for the tool are account-level monthly consumption that has been linked to property appraiser parcel data. Depending on the user of the tool, only certain data or capabilities for processing the data may be available.

When the actual account level data can be joined to parcels, the accounts can be disaggregated by build-out and consumption level. Fixture counts are totaled for each consumption level and build-out; then they automatically are rolled into the linear programming tool. A utility director or consultant would be able to join the account data to parcels and fully customize the tool to the utility. This scenario represents the best output the tool can deliver.

Where consumption data are not available but served account locations are known, the weighted average consumption frequencies are applied to the served parcels. Fixture counts are developed from the attributes in the served parcels, and the totals are rolled into the linear programming tool.

If consumption and account location data are not available but parcel data can be obtained, the weighted average consumption frequency for each customer class from other utilities can be applied to the parcels within a service area. Then fixture counts at each randomly assigned level of consumption are generated by the tool.

Assumptions must be made regarding served and unserved parcels and characteristics of use. A student who may not have the information available to the utility or may lack the capability to link the account data in order to run the tool would need to use this methodology.

The tool can be scaled up or down to any number of accounts. For example, it can analyze a single account to determine the most cost-effective conservation for a homeowner, or it could be run on an entire apartment complex or several properties to help managers decide the most cost-effective fixtures to replace.

The output summary contains a bill calculator for residential and commercial accounts that can be customized to a utility's rate structure. The tool calculates the customer's bill before and after fixture replacement. The payback period in months is calculated by dividing the cost of conservation by the monthly savings in the bill.

Next Steps

The next steps in the development of the tool are to include additional BMPs, evaluate energy savings assumptions, and incorporate suggestions or improvements from additional collaborating utilities. The District also plans to continue to work with additional utilities to develop water conservation plans, on a voluntary basis. The plans would include this analysis, as well as a budget and timeline for implementation.

Funding for these large-scale projects is extremely important, especially in an era of shrinking budgets. Currently the analysis places the burden of funding on the utility in order to compare the water conservation strategies with alternative and traditional water supply source development. Funding the plan implementation might actually involve a combination of creative funding opportunities.

Water conserving rates can serve to shorten the payback period for customers to make the needed investments in equipment themselves. Rebates are designed to encourage customers to make needed investments. Energy or water savings companies are willing to make the investment and guarantee the water savings. Capitalizing water conservation costs can be justified by deferring investment in water supply and treatment expansions.

The District is continuing to investigate these and additional alternative financing mechanisms and incentives for water conservation.