The Optimatics Letter

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BSU Optimized Plan Alternatives

Optimizing a water system master plan using genetic algorithm (GA) optimization is one of the most powerful GA applications. A number of large municipal water utilities and private water companies have optimized system-wide plans to achieve significant capital and/or operating cost savings. These include Detroit Water and Sewerage Department, City of Albuquerque, City of Toronto & Region of York, Truckee Meadows Water Authority (serving Reno-Sparks, NV), and the Cities of Grand Prairie and Waco, TX.

Whereas the above systems each serve 100,000 people or more, Bonita Springs Utilities (BSU) represents a smaller water system that has also achieved excellent results utilizing GA optimization. As described in this article, BSU developed not just one but a series of alternative plans for its year 2020 distribution system. BSU is convinced the optimization process achieved significant cost savings compared to its original plans, and also identified valuable solution options that BSU would not have otherwise considered.

Bonita Springs Utilities System

Bonita Springs Utilities, Inc. was formed in 1971 to supply water to customers in and around the town of Bonita Springs in southwest Florida. BSU currently serves some 16,000 homes and businesses across a 50 mi^2 service area that stretches from the Gulf of Mexico to east of I-75. BSU pumps water from the lower Tamiami aquifer via two well fields to the 10.5-mgd East Terry Street water treatment plant.

BSU anticipates significant growth in population and demand over the next 20 years. From year 2000 to 2020, the population is projected to increase from about 44,000 to 75,000 with maximum day demand increasing from 7 mgd to 15 mgd.

To meet this increased demand, BSU has plans to add a reverse osmosis (RO) water treatment plant at the East Terry Street WTP site to be supplied with brackish water from the deeper Floridan aquifer. In addition, BSU is considering initiating an aquifer storage and recovery (ASR) operation to pump water during the rainy season into the aquifer at 650 ft depth for recovery in the dry season. The new ASR system would be located at the San Carlos Estates storage tank and have a capacity of up to 3 mgd.

Master Plan Study Objective

For the past several years, BSU has given serious attention to upgrading its water treatment and distribution system, and its plans for future growth. BSU recently upgraded its treatment processes and expanded its East Terry Street plant to 10.5 mgd. BSU also made a decision to update its system hydraulic model and to apply GA optimization to ensure that its year 2020 improvement plan would meet its specific needs at the lowest possible cost.

The BSU water master plan study was carried out by CH2M HILL and Optimatics/Frey staff in 2002. CH2M HILL modelers updated BSU's existing steady-state hydraulic simulation model using WaterCAD. Updated demand projections were prepared for years 2005 and 2020.

(Continued on page 2)

Bonita Springs Utilities had budgeted for 2 miles of new 36" water main along Terry Street—the optimization showed this main was not needed to meet year 2020 demands.

Updated Website Now Shows OGA Animations

A picture is worth a thousand words, so they say. Describing how Optimatics GA optimization can sort through hundreds of thousands of trial solutions to identify the most cost-effective near-optimal solutions is very difficult with words alone. A moving picture certainly helps—as you will see by visiting our website at www.frey-water.com, (or at www.optimatics.com to get a down-under flavor).

Our updated website presents a short animation of the Bonita Springs Utilities optimization search. The animation starts with an EPANET model screen-shot of the existing BSU system with the GA decisions highlighted—302 new pipes and 8 new tanks. The animation proceeds with pipes being re-sized or disappearing as the OGA search evaluates different combinations of pipe and tank sizes. Solution costs flash up, including penalties for violations of pressure and velocity criteria. We've been told the total visual experience is quite uplifting. Give it a try.

BSU, CH2M HILL and Optimatics/Frey staff next agreed that the optimization objective would be to minimize capital improvement costs to meet year 2020 peak hour demands and a number of critical fire-flow demand conditions. Specific design and performance criteria were defined. System data were collected and improvement costs developed. (Distinct pipe break demand cases could have been included to ensure redundancy, or the solutions simply refined later as desired.)

Optimatics GA Optimization Process

CH2M HILL exported the WaterCAD model to EPANET format so that it could be linked directly to the Optimatics GA model. Year 2020 demands were included. Dummy pipes and tanks were inserted to represent all of the possible new pipe and storage choices.

In total, 8 potential new storage site choices were identified, along with the choice to increase storage at any one of 3 existing sites and an option to decommission one elevated storage tank. Possible new pipes (302) were input at select locations to connect in the new tanks, to serve new areas and to provide extra capacity wherever needed. Figure 1 (on the back page) shows the allowable new pipe and tank choices input as decisions into the OGA model setup.

Dozens of OGA model runs were completed with the results discussed with BSU staff after each round of (1) preliminary runs, (2) interim runs, (3) final runs and (4) the without-ASR option runs. At each stage, several solutions were presented to compare different system configurations based in particular on different combinations of promising new storage sites. More than 30 million individual trial solutions were evaluated during the study to develop the lowest cost solution that fully meets BSU's specific needs.

Optimization Scenarios & Feedback

Preliminary GA runs were carried out to get the OGA model running properly using the 2020 peak hour demand case only. The preliminary optimized solutions were then simulated for maximum day plus fire flow conditions for numerous node locations to determine the worst case scenarios for the system. Eight critical fire-flow node locations were identified from 15 likely locations.

After reviewing the preliminary solutions, BSU identified its preferences among the potential new storage sites based on how difficult it would be to acquire land. BSU also expressed its preference for solutions with multiple new storages.

Interim GA runs were carried out for the case of a new ASR facility supplying 3 mgd, with the rest supplied from the East Terry Street

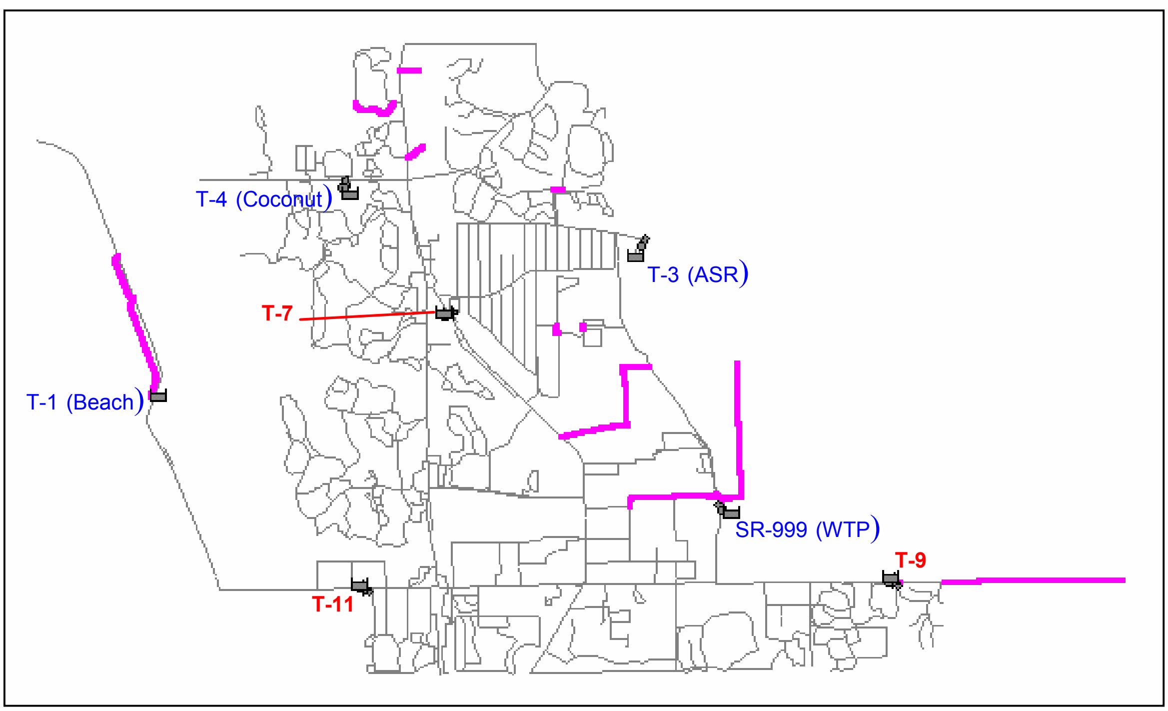

Figure 2. BSU's Optimized Year 2020 Solution 10e—*consisting of 31 new pipes, 3 new tanks with pump stations, and added storage at one existing tank site. Solution meets peak hour & 15 tested max day plus fire flow demands.*

WTP. Each interim GA run involved running the OGA to evaluate about 200,000 trial solutions for the 2020 peak hour demand condition plus 8 fire-flow demand cases. Each run thus produced system designs which complied with the design criteria for all 9 demand cases

Reviewing the interim solutions revealed that new storage sites T-5, T-7, T-9 and T-11 were consistently chosen by the OGA. In particular, using new storage site T-11 in the south was always significantly less costly than a solution that did not use site T-11. BSU pointed out, however, that site T-11 is in a well developed section of Bonita Springs where land could be at a premium.

Revised final solutions were next developed for the with-ASR case and optimized for different assumed mixes of new storage sites. Table 1 shows the estimated cost of new pipe for three assumed storage mixes ranges from $2.43 to $3.41 million. Differences in storage costs between sites were ignored since in all cases a total of 6.0 mg is assigned at new storage sites and 1.5 mg added at an existing site.

Comparison to without-ASR Case

A "what-if" scenario was next conducted to develop optimized solution alternatives for the case where the proposed new ASR facility is not built, and all supply is provided by the East Terry Street WTP. Again, three different assumed storage mixes were optimized. Table 1 shows that the estimated new pipe cost is higher than the with-ASR case, ranging from $4.48 to $5.64 million. For the without-ASR case, the solutions utilizing new tank site T-11 turned out to be more costly.

BSU's Opinion of the Solutions

Optimizing six alternative scenarios (Table 1) enabled BSU to make a fair comparison between the most promising solutions. For a variety of reasons, BSU has decided to proceed with its plans to construct an ASR facility to provide 3 mgd.

BSU selected solution 10e for its preferred 2020 plan. Though slightly more expensive than 10f, solution 10e includes several pipes that will be funded in part by developers. Further, if it turns out that the cost to acquire land and construct new storage at site T-11 adds more than $900,000 to the total plan cost, BSU can proceed with solution 10a instead.

Patrick Jennings, Director of Engineering is thrilled with the results of the optimization. Letting the GA apportion required new storage among 8 new and 3 existing sites resulted in selections he had not expected. The choice of Bonita Beach Road tank (T-11), for example, was a complete surprise to BSU. Likewise the large number of pipe alignments considered resulted in some unexpected selections, and much less pipe overall in the final solution. Mr. Jennings has stated that in addition to cost savings, BSU benefited with improvements to areas they did not realize needed upgrading.

Table 1: Comparison of Six Optimized Solutions for with-ASR and without-ASR Scenarios

	ASR Supplying 3 mgd			ASR Supply Not Operating		
	Solution 10a	**Solution 10e**	**Solution 10f**	**Solution 11g**	**Solution 11e**	**Solution 11f**
New storage sites in solution:	T-5, T-7, T-9	T-7, T-9, T-11	T-5, T-9, T-11	T-5, T-7, T-9	T-7, T-9, T-11	T-5, T-9, T-11
Capital cost items:						
New pipes	$3.408 m	$2.518 m	$2.426 m	$4.481 m	$5.641 m	$5.027 m
Storage at new sites	$3.000 m	$3.000 m	$3.000 m	$3.000 m	$3.000 m	$3.000 m
Additional storage at WTP, Coconut, and/or ASR site	$0.750 m	$0.750 m	$0.750 m	$0.750 m	$0.750 m	$0.750 m
New pump stations	$0.560 m	$0.561 m	$0.561 m	$0.560 m	$0.559 m	$0.559 m
Existing PS expansion	-	-	-	-	-	-
Total Cost	*$7.718 m*	***$6.829 m***	*$6.737 m*	*$8.791 m*	*$9.950 m*	*$9.336 m*

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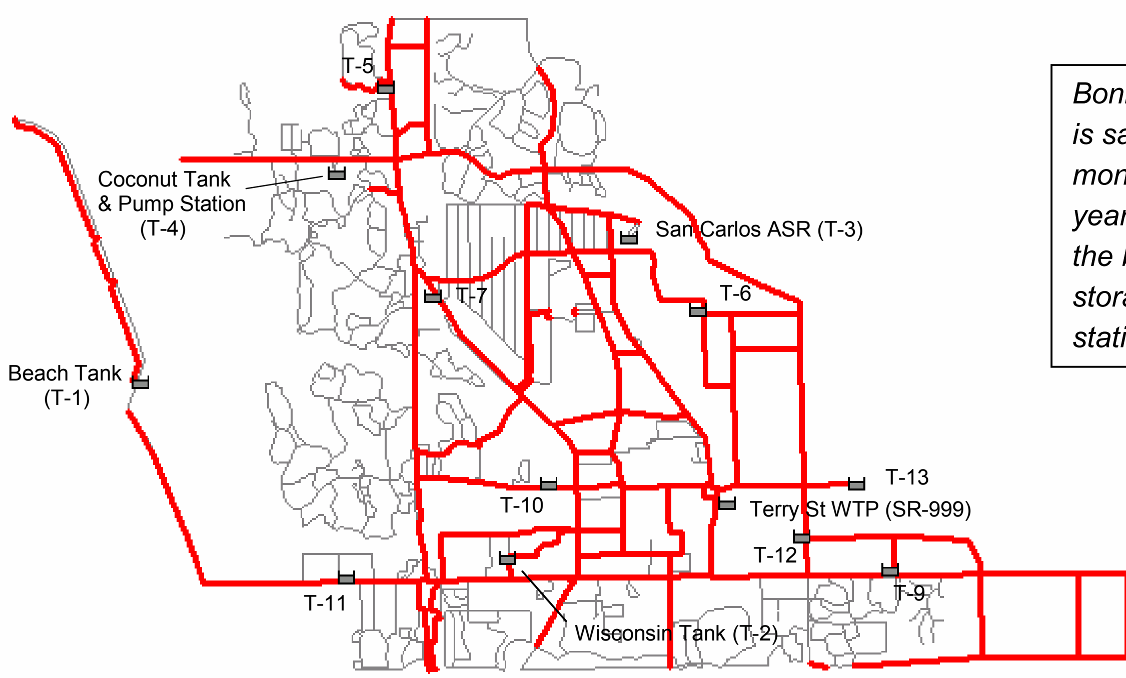
The Optimatics Letter *Advances in Optimization for Water Distribution System Design & Operations*



Bonita Springs Utilities is saving its customers money by optimizing its year 2020 plan to find the best mix of supply, storage, pipe and pump station improvements.

Figure 1. Allowable GA Choices—*302 possible new pipes, 8 new storage tanks and 3 storage expansions.*