The Optimatics Letter

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Optimizing Operational Set Points Using GA

Genetic algorithm optimization is emerging as perhaps the most useful and versatile optimization technique for pipe network problems. By linking the GA optimization model to an existing hydraulic simulation model, the GA can take full advantage of powerful simulation modeling capabilities.

All practical design considerations can be included in the optimization analysis, such as multiple loading patterns, extended period simulation, pump and valve operations, and water quality criteria. This article describes how the Optimatics Genetic Algorithm (OGA) derived operational set points while optimizing several alternative operating regimes for a complex distribution system.

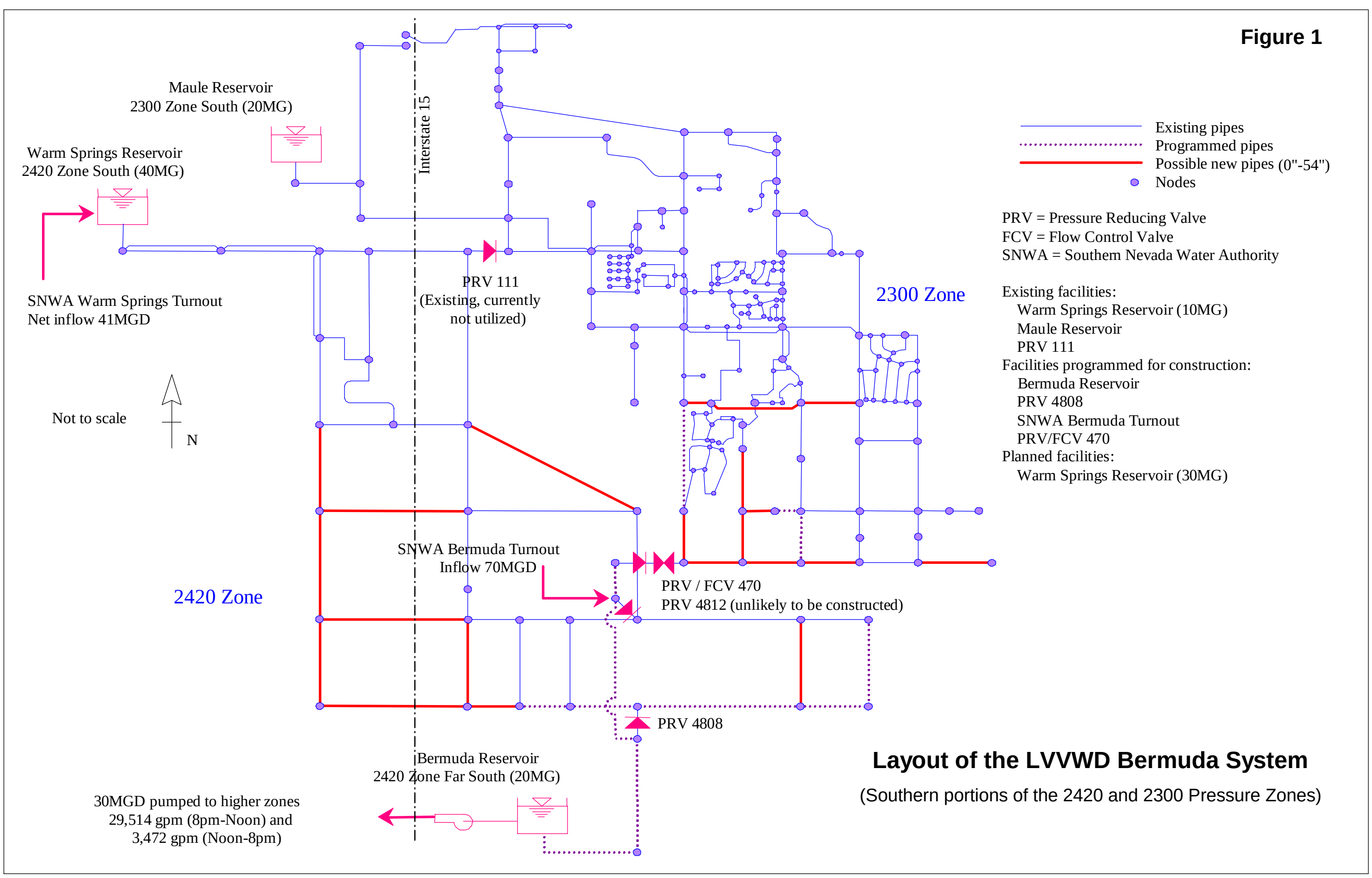
Las Vegas Valley Water District

Las Vegas Valley Water District serves nearly 900,000 people in its 126-mi^2 service area. The area's rapid growth keeps pressure on the District to plan system improvements and coordinate developer plans with great care.

The District recently updated its expansion plans for build-out in the southern portion of the 2300 and 2420 Pressure Zones, south of McCarran Airport and west of Henderson, Nevada. This "Bermuda System" area was modeled in separate KYPIPE zone models, including 300+ pipes, 3 ground storage reservoirs, and 3 major flow and pressure regulating facilities. Figure 1 presents a system layout.

Optimatics GA Optimization Study

The District requested Frey/Optimatics to review its Bermuda System expansion plans using GA optimization. The aim of the OGA study was to identify alternative low-cost combinations of new facilities, given the constraints imposed on the system. The OGA would also optimize the interface between the 2300 and 2420 Zones by analyzing pressure and flow regulating valve settings and operating schedules.



Layout of the LVVWD Bermuda System

(Southern portions of the 2420 and 2300 Pressure Zones)

As a first step, the two KYPIPE models were converted into a single EPANET model to better simulate the interactions between pressure zones. The OGA model was then formulated to determine optimal pipe sizes and locations for planned pipes, and optimal settings for pressure regulating valves (PRV) and flow control valves (FCV).

The District provided unit costs for pipe as a function of diameter, existing road pavement (dirt or paved road), and traffic volume (none, light, moderate and heavy for subdivision, city or main roads). New pipes crossing major highways incurred additional costs.

Critical System Constraints

Minimum levels of system performance were specified by the District, such as minimum pressure criteria for the year 2025 maximum day, peak hour, and maximum day plus fire flow conditions. Critical system constraints were evaluated using a 24-hour extended period simulation (EPS) of the maximum day. The OGA assigned penalties to any solution that failed to "exercise" Maule Reservoir at least 5 feet, or failed to balance all reservoirs at the end of the 24-hour simulation.

Alternative Operating Regimes

The District was particularly concerned the OGA optimized solutions would satisfy the 5-foot drawdown criteria for the troublesome Maule Reservoir. A mass balance analysis of flows to and from the 2300 Zone revealed the water level would draw down only 2.5 feet when injecting a constant rate of flow into the zone. It was necessary, therefore, to either adjust the flow setting of PRV/FCV 470 or the open/closed status of PRV 111 in order to force Maule Reservoir to exercise adequately.

Four alternative operating regimes were investigated, each differing in the utilization of existing PRV 111 and the operating rules for PRV 111 and PRV/FCV 470:

B1. Flow setting of PRV/FCV 470 is adjusted based on Maule Reservoir water level. Existing PRV 111 is not utilized.

B2. Flow setting of PRV/FCV 470 is adjusted based on Maule Reservoir water level. PRV 111 is utilized and operative at all times (no adjustment of status).

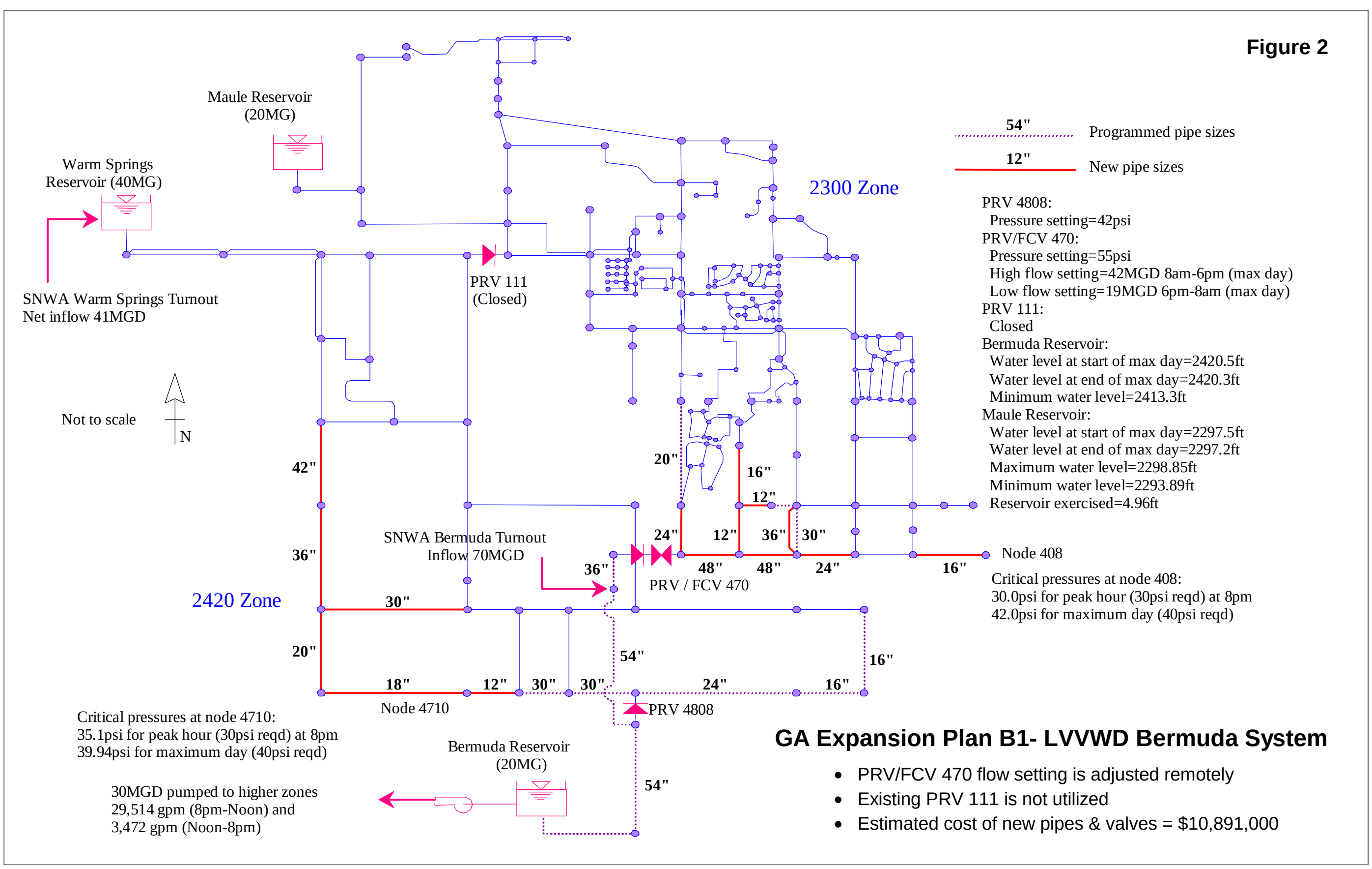
B3. Both the flow setting of PRV/FCV 470 and the open/closed status of PRV 111 are adjusted based on Maule Reservoir water level.

B4. Flow setting of PRV/FCV 470 is constant. Open/closed status of PRV 111 adjusted based on Maule Reservoir water level.

OGA Decision Variables

The OGA was used to optimize the Bermuda System expansion problem for the four different operating regimes outlined above. Approximately 85 decision variables were considered in each OGA run, including:

- Pipe sizes for all new pipes (0"-54")
- Pressure setting, flow setting and hourly operating schedule for



PRV/FCV 470

- Pressure setting and hourly operating schedule for PRV 111
- Pressure setting for PRV 4808
- Orifice diameter of an orifice plate to limit the rate of flow from PRV 111.

The OGA solutions were limited to two valve adjustments per day, since the District wanted to minimize the operators load: one opening and one closing of a PRV, and one low-flow and one high-flow setting for an FCV.

The orifice plate was to be installed in the valve vault downstream of PRV 111. The plate would limit the valve's flow rate to less than its existing capacity and at the same time would help exercise the Maule Reservoir water level. A more extensive upgrade of PRV 111 was deemed infeasible due to its location.

Optimized Expansion Plan Results

Optimized solutions were presented to the District for the four operating regimes listed above. The total cost of new pipe (including highway crossings) and new PRV and FCV/PRV facilities for the corresponding solutions were estimated as follows:

GA Solution B1.	$10,891,000
GA Solution B2.	$ 7,817,000
GA Solution B3.	$ 7,395,000
GA Solution B4.	$ 7,940,000

As can be seen, there is quite a range of facilities improvement costs among the four solutions. Solution B1's significantly higher cost results from PRV 111 not being utilized, so much larger pipe sizes are required to convey water south to feed Zone 2300 via PRV/FCV 470. (See Figure 2.)

Solutions B2, B3 and B4 utilize PRV 111 up to its existing capacity, but differ in how PRV 111 and PRV/FCV 470 are operated. Each option has different equipment and operational needs, and costs and benefits associated with it. Solution B4 was the District's preferred solution since it minimized operational requirements and limited flow via PRV/FCV 470 to acceptable levels. (See Figure 3.)

Following the OGA study, the District's Resource Department's **Planning Manager Laura Jacobsen** gave her impression of the optimization process:

> *"By far the most interesting aspect of the study was the range of solutions the GA technique generated. This allowed the District to review potential combinations of facilities which were not considered as part of the District's master planning process."*

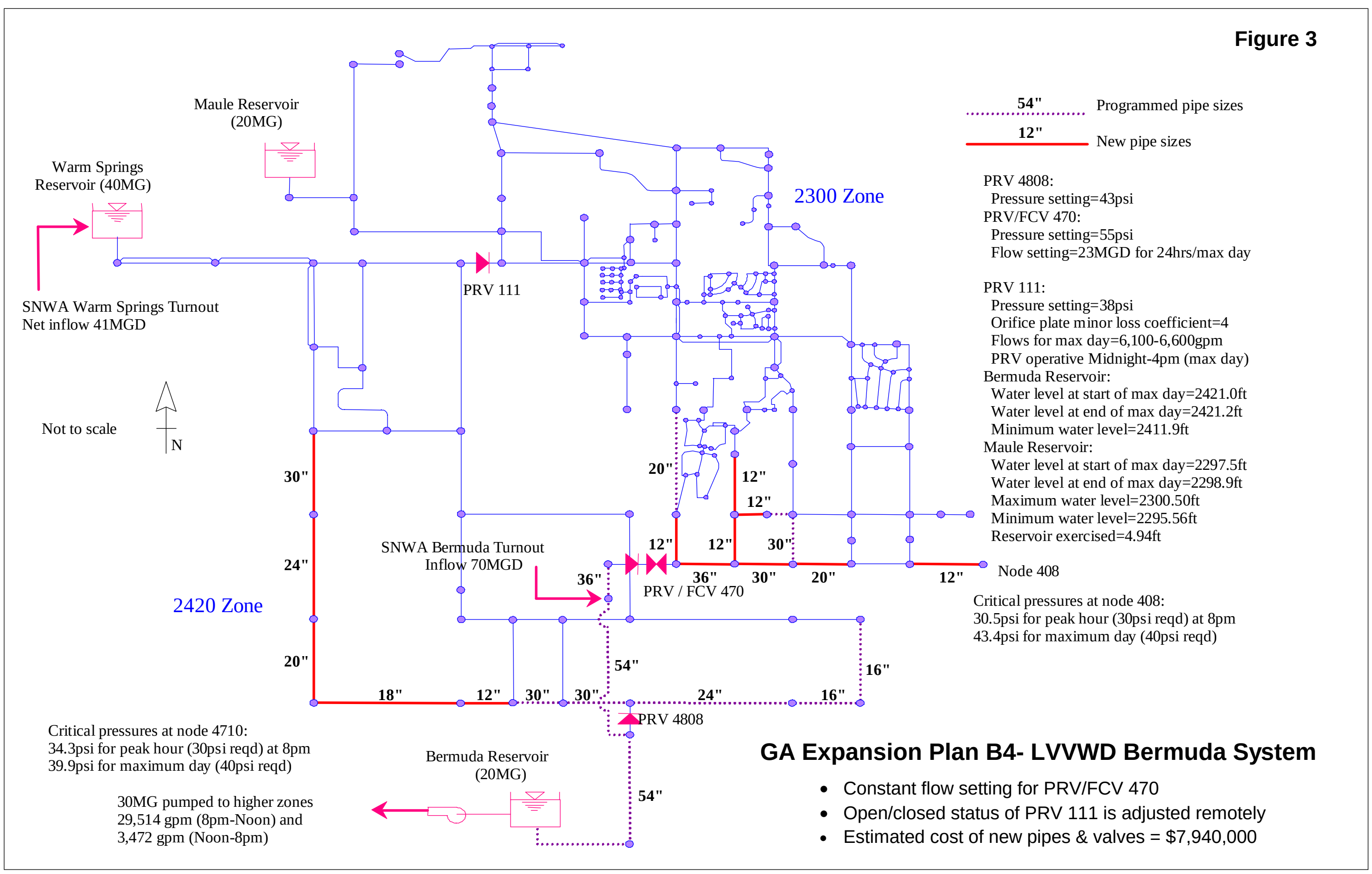


Figure 3

GA Expansion Plan B4- LVVWD Bermuda System

- Constant flow setting for PRV/FCV 470
- Open/closed status of PRV 111 is adjusted remotely
- Estimated cost of new pipes & valves = $7,940,000

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Advances in optimization for water utilities and consultants

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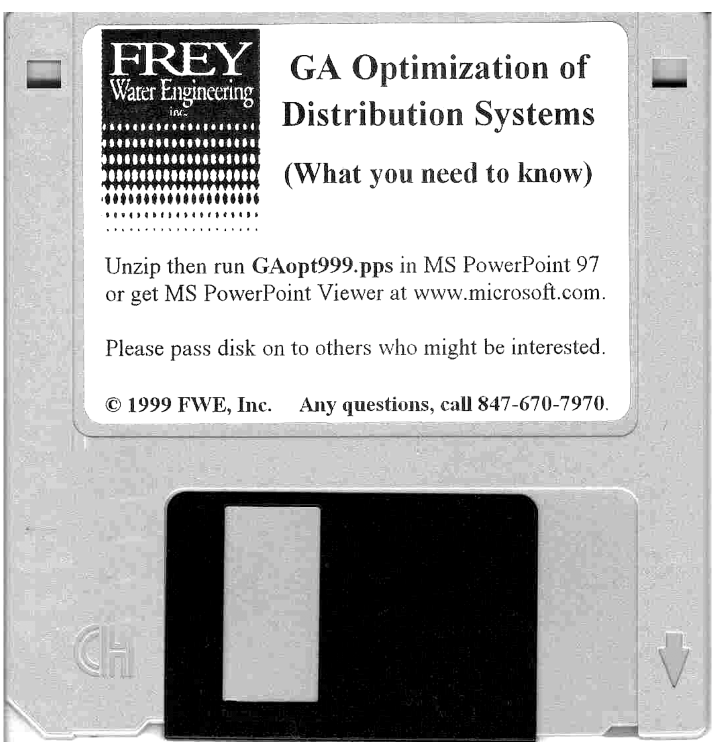

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