CHAPTER 8 – WATER SYSTEM FACILITIES

8.1 Introduction

Based upon the hydraulic modeling described in Chapter 6 of this volume and the condition assessment of facilities provided in Chapter 7 of this volume, improvements to the water source, pumping and transmission, storage, treatment and distribution facilities are required to provide potable water in sufficient quantity and quality to meet the demands of GWA customers. This Chapter will summarize improvements needed to the water distribution lines, booster stations, reservoirs, wells, transmission lines and water treatment facilities.

8.2 Water Loss

As noted in Chapter 3 of this volume, Water Budget, there is a significant amount of unaccounted for water that is being pumped out of the ground or diverted from surface waters that are not reaching GWA's consumers. Water loss in the GWA system is estimated to be 50% of production. Based on population, the usage is approximately 251 gpcd. Water loss of 15% or less is considered the water industry standard and water usage, including outdoor use, should conservatively not exceed 150 gpcd. As identified in Chapter 4 of this volume, Water Loss Control, a great deal of water loss can be attributed to leaks in the water system. Though there has been some evidence of unauthorized water use, most of the water loss is assumed to be due to leakage. Correcting this leakage should provide sufficient water for GWA for 20 years without the development of new water sources.

The first priority of improvements should seek to decrease the high level of water loss in the system, as there is an adequate quantity of water being produced from existing well sources and the Santa Rita Spring. A system-wide leak detection program will aid in determining areas in the water system that has significant leaks that requires replacement of water lines. The replacement of deteriorated or substandard sections of waterlines will improve the quantity of water and available pressure in the distribution system.

Based upon the GWA - Water Leak Detection Study on All Three Public Water System (Appendix 2A of this volume), dated September 12, 2005, an initial leak detection study was performed to identify locations of water loss in the water system. The locations and estimated quantity of water loss is summarized in Chapter 4, Water Loss Control. One approach to repairing the leaks or replacing sections of water lines with leaks is to target the locations with the highest estimated water loss. For example, eliminating the leaks in the locations with the 10 highest quantity of water loss (e.g., 28,000 gpd or greater) would eliminate about 2/3 (380,000 out of 570,000 gallons) of the total water loss estimated. A summary of the water loss reduction that could be achieved is provided in Table 8-1, with the highest estimated water loss listed first.

The prioritization of repair should also consider other factors such as ease of access, cost of repair, age and condition of line, cost effectiveness of replacement vs. repair of line and/or valve, upgrades required to support existing or future development, impact to public and proximity to other repair or replacement work required.

Table 8-1 – Priority List for Waterline Repair or Replacement

Priority	Location	Type of Leak	Potential Reduction in Water Loss (GPD)
1	Agat Village – North Santa Cruz St & Tomas Rivera St.	Hydrant Lateral	72,000
2	Yona Village – Jota Road across House #386	Main Line	56,000
3	Piti Village	Service Line	38,000
4	Merizo Village – Route 4, In front of House #1145	Service Line	36,000
5	Cabras Area	Miscellaneous	35,858
6	Yona Village – Water Booster Pump Station 25	Pressure Line	28,880
7 (tie)	Piti Main Village	Defective Valve	28,000
7 (tie)	Santa Rita Village – Chalan Kindo, vicinity of House #180B	Waterline Valve	28,000
7 (tie)	Route 4 – Before the bridge after Arriola Beach	Main Line (12-inch	28,000
7 (tie)	Yigo Village – Chalan Tun Luis Takano	Main Line	28,000

Note: Refer to Chapter 4 for more information regarding the location of these leaks.

Based upon an August 11, 2006 GWA inter-office memorandum from the Leak Detection Program Coordinator to the Assistant General Manager, Compliance and Safety, GWA has started to address some of the leaks detected in the Water Leak Detection Study. GWA is in the process of installing two six-inch-diameter master meters in the Cabras (Commercial Port) area to account for the approximate water loss of 36,000 gpd due to leaks, under registering or inoperative meters and illegal connections. In addition to the leaks discovered during the Water Leak Detection Study, GWA also repaired six service line leaks in the Harmon Cliff Line area that had an estimated leakage of 36,000 gpd and discovered one illegal connection on Hamburger Road in Harmon that had an estimated 7,200 gpd of unauthorized water use.

8.3 Fire Protection

Some of the water supply and pressure problems reported are also related to waterlines of insufficient size and inadequate layout that create insufficient water service volume and pressure. This section will first provide design criteria that will be used as a basis for developing water distribution system improvement and secondly identify system deficiencies that should be corrected

Due to the absence of water system standards for GWA, the Water System Standards (WSS) for the State of Hawaii will be used as a guide to determine what water distribution system improvements should be made and realistically implemented for GWA's system. In some cases, GWA has identified specific planning criteria that are different from the Hawaii WSS that they prefer to use. One such example is the maximum pumping pressure of 90 psi that is lower than the 125 psi allowed in the Hawaii WSS. The second priority of improvements should provide water mains that are adequately sized to provide fire protection for the designated land use area. Urban areas with a higher congestion of development will require higher fire flow with larger mains, while rural areas with lower densities can generally be supported by eight-inch mains.

8.3.1 Planning Criteria

Criteria for improving the water distribution system includes providing adequate waterline sizes to maintain minimum fire flows and pressures, limit maximum velocities and high head losses and provide minimum residual pressures for domestic use. The criteria also addresses

spacing of fire hydrants based upon land use. The criteria identified hereafter provides guidance for planning of future water system facilities, however, GWA should develop their own comprehensive set of water system standards that are comparable to that developed for Hawaii.

8.3.1.1 Fire Flow Requirements

Fire flow requirements are summarized in Table 8-2.

Table 8-2 – Fire Flow Requirements

Land Use	Flow (GPM)/Duration (HRS)/Fire Hydrant Spacing (FT)
Rural	1000/2/500
Single Family	1000/2/350
Low-Rise Apartments	1500/2/350
Schools, Neighborhood Businesses, Small Shopping Centers and High-Rise Apartments	2000/2/250
Light Industry, Downtown Business, Large Shopping Centers and Hospitals	2000/2/250
Heavy Industry, Hotels	2500/2/250

Notes:

1. On dead end streets, the last fire hydrant (F.H.) shall be located at one half the spacing distance for F.H.'s from the last house/unit (frontage property line or to the driveway/access for the property).
2. Spacing of the F.H. shall be measured along the roadway.

8.3.1.2 Pipeline Sizing

Pipelines should be sized to meet the following requirements:

- Maximum daily flow of 150% of the average daily flow plus fire flow with a residual pressure of 20 psi at critical fire hydrants adjacent to the fire flow.
- Peak hour flow of 300% of the average daily flow with a minimum residual of 40 psi.
- The carrying capacity of the water mains shall be based upon the Hazen-Williams "C" coefficients listed in Table 8-3.

Table 8-3 – Water Main "C" Coefficient

Pipe Diameter (Inches)	Hazen-Williams "C" Coefficient
4-inch, 6-inch	100
8-inch, 12-inch	110
16-inch, 20-inch	120
24-inch and larger	130

- The maximum velocity in water mains (without fire flows) is six feet per second (fps).

- The maximum velocity in distribution mains with fire flow at maximum day domestic flow is 10 fps. The maximum velocity in transmission mains without water services or fire flow is 20 fps.
- The maximum static or pumping pressure, whichever is greater, shall not exceed 90 psi.

8.3.1.3 Reservoir Capacity

Reservoirs should be sized to meet the following requirements:

- Capacity shall satisfy maximum day consumption. Reservoirs shall be full at beginning of the 24-hour period with no input from groundwater or surface water sources.
- Meet maximum day flow plus fire flow for the duration of the fire (i.e., two hours). Reservoir shall be assumed to be 3/4 full at the start of the fire, with credit for incoming flow from supply pumps feeding the reservoir, with the largest pump in the pump station or well out of service.
- The minimum reservoir size shall be 100,000 gallon. Reservoir size shall be as approved by GWA.
- When two or more reservoirs are available to serve the same distribution system, the combined capacity of the reservoirs shall be taken into account in assessing the level of fire protection capacity for facilities.

8.3.1.4 Total Pump Capacity

The total pump capacity shall be based on the criterion that yields the maximum pumpage based upon the following:

- Meet maximum day demand with an operating time of 16 hours simultaneously with maximum fire flow required independent of the storage provided by reservoirs. A standby unit may be used to determine the total flow required.
- Meet maximum day demand during the duration of fire plus fire demand without 3/4 of the reservoir storage.
- Meet maximum day demand with an operating time of 16 hours with the largest pumping unit considered to be out of service.

8.3.2 Fire Flow Protection

Fire flow requirements for various land uses are provided in Table 8-2, with the minimum fire flow of 1,000 gpm for a duration of two hours. In consideration of the flow velocities from fire plus domestic flows, water mains should be adequately sized so that the maximum velocities with fire flow alone should be kept below 10 fps. A summary of flow velocities for standard pipe diameters and varying levels of fire flow is provided in Table 8-4.

Table 8-4 – Fire Flow Velocities

Pipe Velocities (FPS)				
Fire Flow (GPM)	6-Inch	8-Inch	12-Inch	16-Inch
1000	11.35	6.38	2.84	1.60
1500	17.02	9.57	4.26	2.39
2000	22.70	12.77	5.68	3.19
2500	28.37	15.96	7.09	3.99

Note: Reference Table 8-2 for corresponding land use and other fire flow criteria.

In order to prevent excessive velocities during fire flows, the minimum pipe size provided for distribution system mains should be eight inches. As identified in Table 8-4, an eight-inch main can accommodate rural, single family and low-rise apartment areas that have fire flow requirements in the range of 1,000 to 1,500 GPM. A 12-inch main would generally be adequate to accommodate fire flow requirements for more developed urban areas of the island that include schools, businesses, shopping centers, high-rise apartments, hotels and industrial areas. All water distribution lines that are smaller than eight inches and have fire hydrants connected to them should be upgraded to eight inches or larger depending upon the fire flow service level required as identified in Table 8-2. In particular, any areas with older water lines that have been shown to have leaks and inadequate service pressures and flows should be replaced.

Based upon the hydraulic model of the water system, as discussed in Chapter 6, Water System Hydraulic Modeling of this volume, improvements to the water distribution system were identified for the Southern, Central and Northern Systems for the 2005 CPM and 2025 CIM. In order to meet the fire flow requirements identified earlier in this chapter, increases in pipes sizes or installation of new segments to provide loops in the water distribution system and increases in reservoir and booster pump station capacity are required. Tables 8-5, 8-6 and 8-7 summarize the 2005 CPM improvements recommended for the water distribution systems in the Southern, Central and Northern Systems, respectively.

Recommended booster pump stations to improve water service pressures in the distribution system for the 2005 CPM are summarized in Table 8-8.

Recommended reservoirs to improve water storage for fire protection or adequate service pressures for the 2005 CPM are summarized in Table 8-9.

Table 8-5 – 2005 CPM Southern Distribution System Improvements

No.	Area	Description	Length	Comment
S1	Malojloj Elevated	Increase 6-inch waterline to 8 inches along Fangualoan St. from Malojloj Well St. to S-15 and on to connection to 12-inch waterline along Route 4.	4200	Improve available fire flow in this area
S2	Malojloj Elevated	Increase 6-inch waterline to 8 inches along Kalamasa and Barcinas	1900	Improve available fire flow in this area and further south
S3	Malojloj Elevated	Connect the 6-inch and 8-inch pipes with a new 8-inch pipe at the intersection of Malojloj Well and Route 4	50	Need to verify the location of these two pipes.
S4	Malojloj Elevated	Increase the 6-inch waterline parallel to Route 4 from Fangualoan to Ates to 8-inch.	550	Improve available fire flow in this area.
S5	Malojloj	Install 8-inch waterline from the end of the waterline on Quinene to Baza to Route 4 to complete loop. Install 8-inch waterline along Santiago, from Route 4 to Quinene.	700, 1400	Improve available fire flow in this area.
S6	Malojloj	Connect the 8-inch and 12-inch pipes with a new 8-inch pipe at the intersection of Acfalle and Route 4	50	Need to verify the location of these two pipes.
S7	Inarajan	Install 8-inch waterline to complete loop of 6-inch waterline at the ends of Chagamin St. and Y Peca Lane	500	Need to verify if connection between dead-end leg lines is feasible, or if the waterline along Chagamin St. should be extended to Ad'Man Dr. and connected back to the 12-inch main on Route 4.
S8	Inarajan	Increase 6-inch waterline to 8 inches along Route 4 at interconnection of parallel 8-inch and 12-inch lines about 1900 feet south of As Quede St.	200	Improve available fire flow in this area and further to the south and west
S9	Merizo	Increase the 6-inch and 8-inch waterline along Chalan Joseph A Cruz from Route 4 south of Mata Ave to Merizo Reservoir to 8-inch and 12-inch.	1600, 3600	Improve available fire flow in this area.
S10	Umatac	Increase the 6-inch waterline along Road A from Jesus A. Quidachay to Road B to 8-inch.	550	Improve available fire flow in this area.
S11	Umatac	Increase 6-inch waterline to 12 inches along Route 4 from Bile St. to the transition from the 6-inch to 12-inch waterline about 1000 feet south of Jesus A. Quidachay St.	4500	Improve available fire flow in this area
S12	Umatac	Increase 6-inch and 4-inch waterlines to 8 inches along Route 4 and Route 2, from Jesus A. Quidachay St to Lasafua Reservoir and to Agat/Umatac Reservoir.	13,000	Need to verify if there are any segments of 12-inch line along this length of line. Improve available fire flow in this area

Table 8-6 – 2005 CPM Central Distribution System Improvements

No.	Area	Description	Length	Comment
C1	Talofofo	Install booster pump station near Windward Hills #2 Reservoir and increase 8-inch waterline to 12 inches along Route 4A southeastward to San Miguel St.	6000	Improve fire flow and pressures in Talofofo. There is a need to site a dedicated elevated storage tank in Talofofo to replace the previous one abandoned
C2	Talofofo	Increase 8-inch waterline to 12 inches along Route 4A from San Miguel St. southward to Manual P Mantanona Lane	3800	Evaluate if an elevated storage tank w/ overflow @ 500' can be placed in this area with a ground elevation of about 382 feet.
C3	Talofofo	Increase 6-inch waterline to 8 inches along Ernest P. Santos from Johnny S. Taitague. northward to Ralph Santos	2900	Improve substandard fire flow and pressure in this area
C4	Santa Rita	Increase 8-inch waterline to 12 inches along Route 17 from Chalan J. Kindo intersection and eastward along Route 17 to Sinifa Reservoir	3000	Reduce max-day velocities that exceed six fps and improve fire flows
C5	Agat	Install 8-inch waterline from the dead-end 6-inch line along S16 to the 10-inch line on Kalachucha.	400	Improve substandard fire flow and pressure in this area
C6	Agat	Increase 6-inch waterline to 12 inches along Umang from S-11 eastward to S-41.	1200	Improve substandard fire flow and pressure in this area

Table 8-7 – 2005 CPM Northern Distribution System Improvements

No.	Area	Description	Length	Comment
N1	Santa Rosa*	Extend 6-inch waterline on north end of Tun Thomas Dongo to 12-inch line with an 8-inch waterline.	300	Improve available fire flow in this area
N2	Santa Rosa*	Increase 6-inch waterline to 8 inches to the east of Santa Rosa Reservoir (not including branched 6 inch lines).	3000	Improve available fire flow in this area. Verify the ground elevation at this area.
N3	Santa Rosa	Increase 6-inch waterline on Tun Luis Tugong and Rosa to 8 inches.	2300	Improve available fire flow in this area
N4	Santa Rosa	Increase 8-inch waterline on Anao and S-1 to 12 inches (or larger).	2600	Improve available fire flow and pressure in this area
N5	Yigo Elevated*	Increase 8-inch waterline to 12 inches along Chalan Arendo to Chalan Emsley.	4900	Improve available fire flow and pressure in this area
N6	Yigo Elevated*	Connect dead end pipes along Chalan Emsley with a new 8-inch pipe	1600	Improve available fire flow and pressure in this area
N7	Yigo Elevated*	Connect dead end pipes at the west end of the Yigo Elevated zone with a new 8-inch pipe	900	Improve available fire flow and pressure in this area

Table 8-7 – 2005 CPM Northern Distribution System Improvements (continued)

No.	Area	Description	Length	Comment
N8	Yigo Elevated*	Increase 6-inch waterline at the south end of the Yigo Elevated zone to a new 8-inch pipe.	300	Improve available fire flow and pressure in this area
N9	Mataguac Zone*	Increase 6-inch waterline to 8 inches along Chalan Maanao from Route 1 (Marine Drive) thru Mataguac BPS to Evangelista Road.	2300	Improve available fire flow, pressure and velocity in this area.
N10	Mataguac Zone*	Increase 6-inch waterline to 8 inches along Envangelista from Route 1 (near Well Y-17).	600	Improve available fire flow, pressure and velocity in this area.
N11	Mataguac Zone	Install 8-inch waterline along Chalan Sarana from Chalan Kaskahu to Chalan Okso. Install PRV where Mataguac and Yigo Zones meet.	800	Improve available fire flow and pressure in this area.
N12	Yigo Zone *	Increase 6-inch waterline on Ton Jose to 8 inches. Install 8-inch waterline along Chalan Paharu, from Well Y-23 to Ton Jose.	1600 and 2800	Improve fire flow in this area.
N13	Yigo Zone *	Increase 6-inch waterline to 8 inches along Chalan Langet, from Route 1 to Ree. Install 8-inch waterline on Ree from Chalan Langet to 12-inch line on Aga. (Near lower portion of Route 1, southwest of Well Y-10)	600 and 650	Improve available fire flow in this area.
N14	Yigo Zone	Install 8-inch waterline along Aababang from Aapacha to Road K (adjacent to Route 1, north of Wells Y-5 & Y-6)	300	Improve available fire flow in this area.
N15	Yigo Zone	Increase 6-inch waterline to 8 inches along Milalak from Marine Drive westward (not including branch lines).	1800	Improve available fire flow in this area.
N16	Yigo Zone	Increase section of 8-inch waterline to 12 inches along Highway 15 between 12-inch lines at Road B. Wendy and Gayinero Dr.	3600	Reduce max-day velocities that exceed six fps and improve fire flows
N17	Yigo Zone	Increase 6-inch waterline along Chaguian Machananao to 12 inches from Route 9 southward (including only main waterline).	5300	Improve available fire flow in this area.
N18	Yigo Zone	Install 6-inch waterline on Entrada to complete looping of 6-inch waterlines along Azud, Amarillo and Apaca Streets. Connect end of 6-inch waterline along Chalan Santa Bernadita to 12-inch line along Route 9.	500 and 400	Improve available fire flow in this area.
N19	Yigo Zone	Install 8-inch connection between ends of Quezon and Magsaysay. Near Well F-09.	500	Improve available fire flow in this area.
N20	Astumbo	Install 8-inch waterline on Chiote between Kamute and Chalan A'Abang.	200	Improve available fire flow in this area.

Table 8-7 – 2005 CPM Northern Distribution System Improvements (continued)

No.	Area	Description	Length	Comment
N21	Astumbo	Increase 6-inch waterline along Chalan Ibang to 12-inch line. Increase 6-inch waterline on S-13 to 8 inches. Increase 6-inch waterline on Chalan Pakpak from S-13 to Chalan Bongbong to 8 inches. Increase 6-inch waterline on Chalan Puegue Matchena from Chanlan Balako to Chanlan Pakpak to 8-inch line.	2400 400 850 2300	Improve available fire flow and pressure in this area.
N22	Kaiser	Install an 8-inch waterline along Lada from Adora to connect to the 14-inch line along Ukudo (north of Well D-18)	800	Improve available fire flow and pressure in this area.
N23	Kaiser	Connect 8-inch waterline to 24-inch line along Route 1/Marine Drive, northeast of the intersection with Route 16. (Below Well H-1)	200	Improve available fire flow and pressure in this area.
N24	Kaiser	Install 8-inch connection from Fatima to 6-inch waterline along Santa Monica.	800	Improve available fire flow and pressure in this area.
N25	Kaiser	Install 14-inch connection along Ukudo from south of Lada to 12-inch line on Santa Monica.	800	Improve available fire flow and pressure in this area.
N26	Kaiser	Connect 8-inch waterline at the end of D.G. Benavente to the 10-inch to the west with a new 8-inch to complete loop.	100	Improve available fire flow and pressure in this area.
N27	Tumon *	Extend 6-inch waterline along Hospital to Pale San Vitores to complete loop.	300	Improve available fire flow in this area.
N28	Tumon	Install 8-inch waterline from end of Father San Vitores Street to end of Father Duenas Drive to complete loop along these streets and Gov. Skinner St., Gov. Bradley St. and Father Ramon St.	1500	Improve available fire flow and pressure in this area.
N29	Hyundai *	Increase 6-inch waterline along Bello Road to 8 inches from Chalan Villagomez to Duenas (north of Hyundai Reservoir).	1200	Improve available fire flow and pressure in this area.
N30	Hyundai *	Install 12-inch connection along Corenso to connect North Sabana Barrigada to South Sabana Barrigada (west of Hyundai Reservoir).	1500	Improve available fire flow and pressure in this area. Verify the existing pipe size and connection location.
N31	Mangilao/Chaot	Install an 8-inch waterline from end of Inilado to the 6-inch on Jesus Mariano to complete loop. Install an 8-inch waterline from end of Jesus Mariano to the 6-inch on Alstom to complete loop (southwest of Mangilao Reservoir).	2700, 950	Improve available fire flow and pressure in this area.

Table 8-7 – 2005 CPM Northern Distribution System Improvements (continued)

No.	Area	Description	Length	Comment
N32	Mangilao/Chaot	Install an 8-inch waterline from end of Lalo to the 6-inch on Costat to complete loop. Install an 8-inch waterline from end of Bilmar to the 12-inch on Route 10 to complete loop (north of Mangilao Reservoir).	450, 1600	Improve available fire flow and pressure in this area.
N33	Mangilao/Chaot	Extend the 8-inch waterline from end of Guzman to the 6-inch on Route 8 to complete loop. Install an 8-inch waterline from end of Lizama to the 6-inch on the east to complete loop (north of Mangilao Reservoir).	400, 550	Improve available fire flow and pressure in this area.
N34	Mangilao/Chaot	Increase 6-inch waterline along Campus to 8 inches (southwest of Mangilao Reservoir).	1200	Improve available fire flow and pressure in this area.
N35	Mangilao/Chaot	Install 8-inch waterline south along Dimas St. to Carlos Lane. Install 8-inch line south along Juan Muna St. to 8-inch along Corten Torres St. Install 8-inch line from First St. off of Iglesias St. to East Rojas St. to complete loop. Install 8-inch line from Rita P. Muna to Dong (Southwest of Mangilao Reservoir).	750, 300 and 100	Improve available fire flow and pressure in this area.
N36	Piti/Agana *	Increase 4-inch waterline along Luna to 8 inches, from Gutierrez to Route 7.	1500	Improve available fire flow and pressure in this area.
N37	Piti/Agana *	Install 12-inch connection along Chalan Obispo from Route 7A south to Pale Kieran Hickey Dr. and connect up 8-inch along Haiguas Dr.	800, 1100	Improve available fire flow and pressure in this area.
N38	Piti/Agana *	Connect the 6-inch waterline from end of San Ramon to Route 7A with a new 8-inch.	50	Improve available fire flow and pressure in this area.
N39	Pulantat	Extend 8-inch line on Arterio A. Cruz to 16-inch line on Route 4 (south of Pago Bay booster).	300	Improve available fire flow in this area.
N40	Pulantat	Install 8-inch main along Pulantat Road from connection with 12-inch main at Chalan Teleforo intersection to 6-inch line at S-37 intersections to complete loop.	2600	Improve available fire flow in this area.
N41	Pulantat	Increase 6-inch waterline at the intersection between Pulantat and Tomas Quichocho to 12 inches.	100	Improve available fire flow and pressure in this area.
N42	Pulantat	Increase 6-inch waterline along As Aguero, As Taisipic and Munoz to eight inches.	3200	Improve available fire flow in this area.
N43	Pulantat	Connect the two parallel waterlines (12-inch & 16-inch) at the intersection of Route 4 and Sis. Mary Eucharita Dr. with a new 8-inch.	50	Improve available fire flow in this area.

Table 8-8 – 2005 CPM Recommended Booster Pump Stations

No.	System	Area	Description	Pump Requirements	Comment
B1	South	Agat	Provide BPS along Route 2 to boost pressure from Agat/Umatac Reservoir to Agat Elevated Tank	250 gpm at 125-foot TDH	Capacity of Lasafua Reservoir is inadequate to supply its service area.
B2	Central	Talofofo	Provide BPS along Route 4A to boost pressure from Windward Hills #2 Reservoir to Talofofo.	400 gpm at 100-foot TDH	New 12-inch transmission line required as well.
B3	North	Dededo	Provide BPS along Marine Drive to transfer water and boost pressure from Kaiser Zone to Barrigada Zone.	400 gpm at 100-foot TDH	Verify pipe connection at the intersection of Marine Drive and Manha.

Table 8-9 – 2005 CPM Recommended Reservoirs

No.	System	Area	Description	Tank Requirements	Comment
R1	South	Agat	Provide 0.1 MG elevated tank to replace existing Lasafua Reservoir.	Overflow elevation should be set at 500 feet.	Capacity of Lasafua Reservoir is inadequate to supply its service area.
R2	Central	Talofofo	Provide 0.1 MG elevated tank.	Overflow elevation should be set at 510 feet.	Tank elevation needs to be set high enough to service homes in the 300 to 382-foot elevation.
R3	Northern	Mataguac	Provide 0.1 MG elevated tank downstream from the Mataguac BPS.	Overflow elevation should be set at 728 feet.	BPS currently discharges directly into the distribution system.
R4	Northern	Barrigada	Provide additional 2.0 MG storage near to Barrigada #3.	Overflow elevation to be set at 481 feet to match Barrigada #3.	Evaluate cost effectiveness of using only a partially full Barrigada #2 (due to overflow elevation at 497.8 feet) compared to constructing a new tank.

8.4 PRV Station Improvements

Due to the varied elevation of reservoirs across the island, water pressures in the distribution system will vary depending upon the elevation of the pipeline in relation to the water level in the reservoir. A description of the pressure zones established for GWA's system based upon the overflow elevation of reservoirs is described in Chapter 1, Water System Description of this volume. In some cases, a reservoir is not available for a pressure zone, but is created from a booster pump station servicing an isolated area of the water distribution system. A review of GWA files and hydraulic modeling of the system indicates that a PRV or closed valve is needed to isolate one pressure zone from another. Figures 8-1 and 8-2, identifies the location of known PRVs or closed valves in the distribution system and the pressure zones that the PRVs separate.

Although a closed valve can effectively isolate one pressure zone from another, it does not allow flow from one pressure zone to another. Thus, the installation of a PRV can be more effective in allowing the transport of water from a higher pressure zone to a lower pressure zone, particularly when water is needed for periods of high demand, such as for fire fighting. A PRV will require the proper downstream settings depending upon the appropriate differential in pressure between the higher and lower pressure zones and will also require more maintenance to keep it in proper working order. In some instances a Pressure Sustaining Valve (PSV) is needed on the upstream end of the PRV station in order to maintain adequate pressure and flow in the higher pressure zone. A PRV is required at the boundaries between the pressure zones identified on Figures 8-1 and 8-2, for each water main that bridges across the pressure zones. A summary of recommended PRV stations is provided in Table 8-10.

Figure 8-1 – Pressure Zone Map of Northern Guam

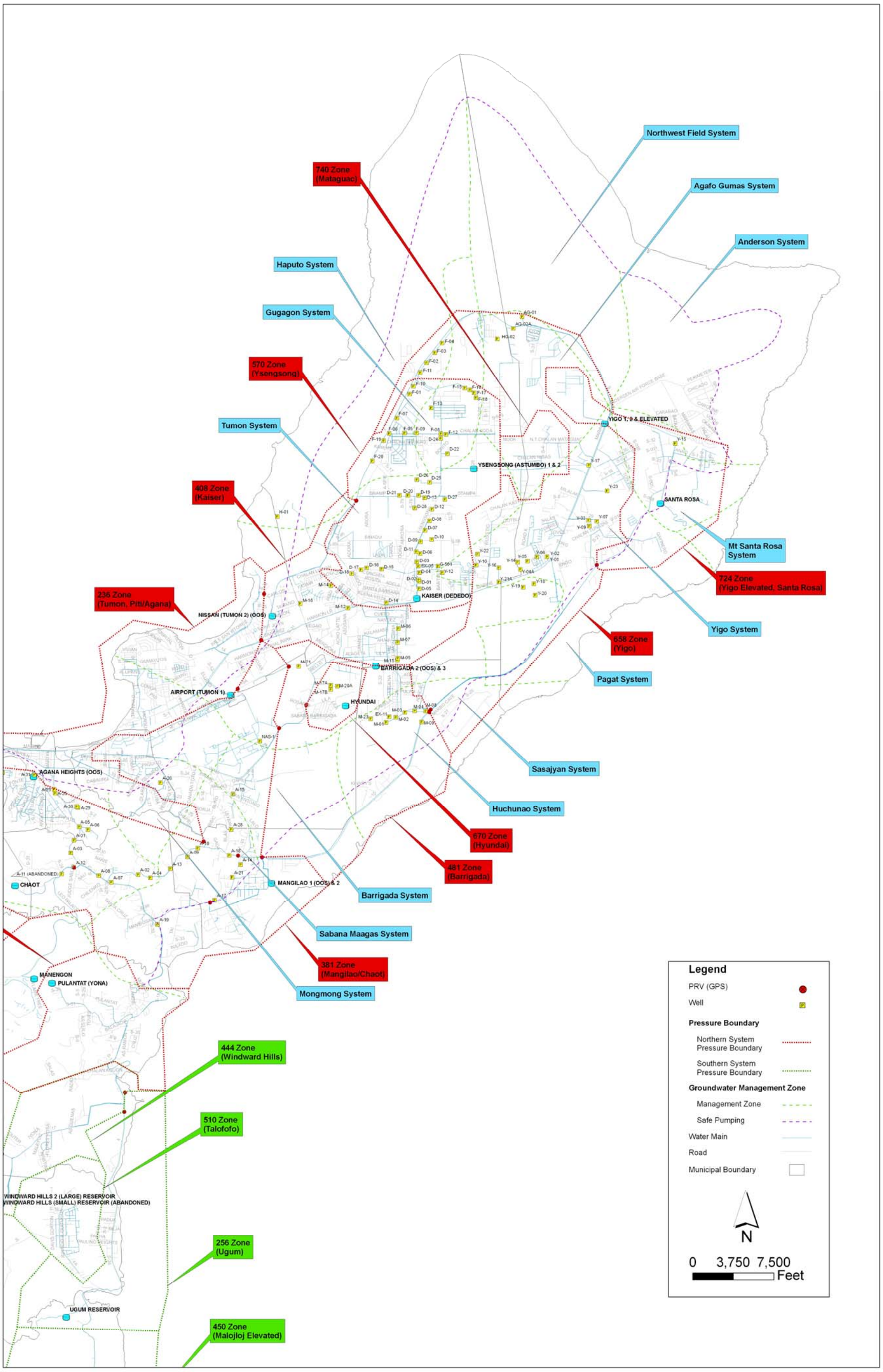


Figure 8-2 – Pressure Zone Map of Southern Guam

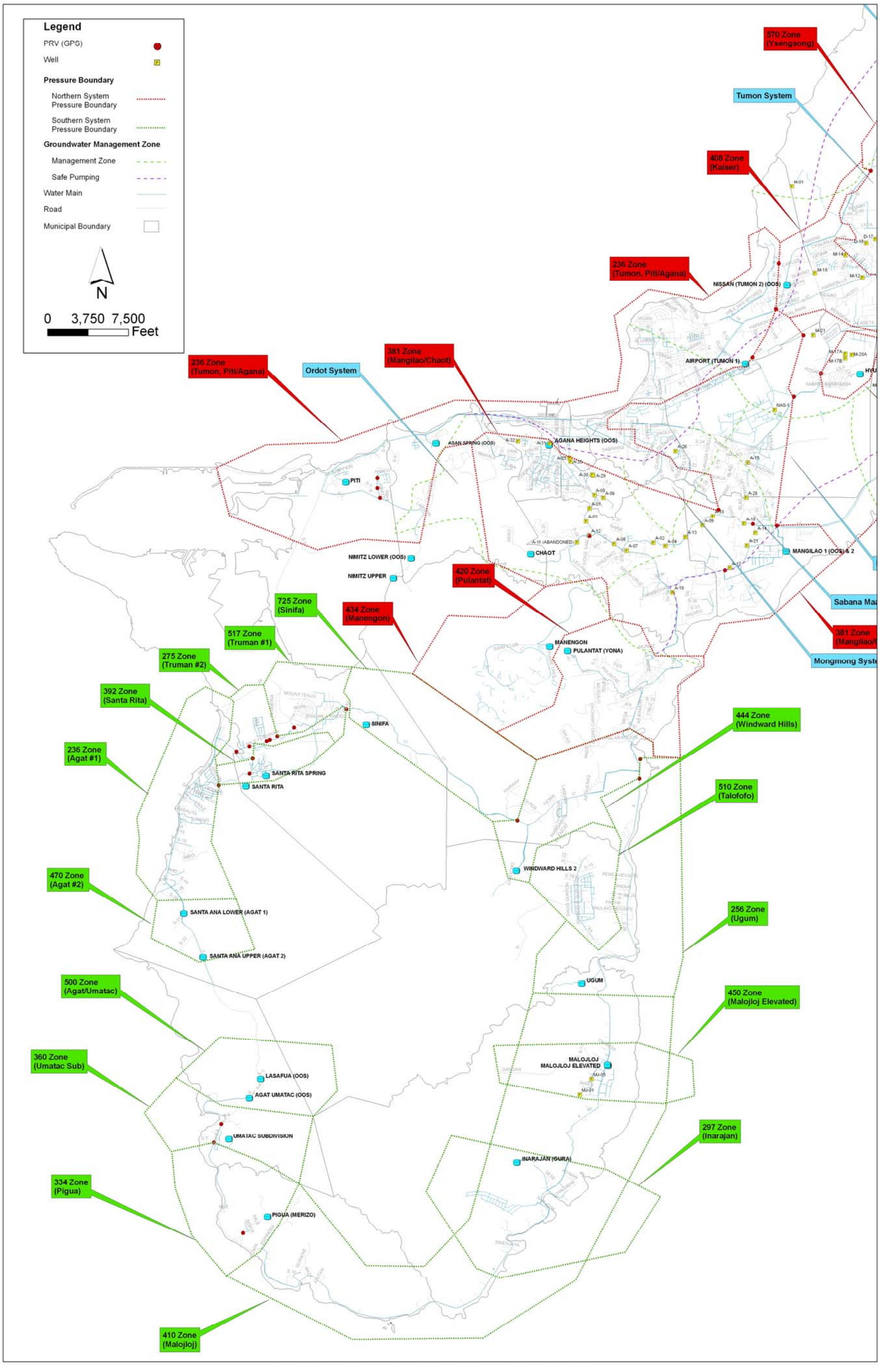


Table 8-10 – PRV Station Improvements

No.	High Pressure Zone	Low Pressure Zone	Street	Waterline Diameter	Comment
1	Mataguac 740	Yigo 658	Install PRV along Chalan Sabana, west of the intersection with Chalan Kaskahu	6	Modeled as a proposed PRV
2	Yigo 658	Ysengsong 570	Install PRV or closed valve along Route 1/MarineDrive, East of intersection with Bartolu (south of Well Y-12)	12	Modeled as a proposed PRV
3	Yigo 658	Ysengsong 570	Install PRV or closed valve along Route 3 south of Well F-11	12	Modeled as a proposed PRV
4	Yigo 658	Ysengsong 570	Install PRV or closed valve along Nanka south of Well F-11	8	Modeled as a proposed PRV
5	Yigo 658	Ysengsong 570	Install one PRV and one closed valve along Route 3 at intersection with Ysengsong	20, 12	Modeled as a proposed PRV and a check valve
6	Ysengsong 570	Kaiser 408	Install PRV along Lada, east of the intersection with Ukudo	8	Modeled as a proposed PRV
7	Ysengsong 570	Kaiser 408	Install PRV along Santa Monica, north of the intersection with Chalan Henry Kaiser	12	Modeled as a proposed PRV
8	Ysengsong 570	Kaiser 408	Install one PRV and one closed valve along Route 26/Y-Sengsong, north of the intersection with Route 1/ Marine Drive. (Near Well D-14)	12	Modeled as a proposed PRV and a closed valve
9	Ysengsong 570	Kaiser 408	Install PRV or closed valve along Cueto, near intersection with Chando. (East of Well M-12)	12	Modeled as a proposed PRV
10	Barrigada 481	Kaiser 408	Install PRV or closed valve near Well D-06 and D-11)	12	Modeled as a proposed PRV
11	Barrigada 481	Mangilao/ Chaot 381	Install PRV along Route 16, southwest of intersection with Sabana Barrigada and northeast of Well NAS-1.	16	Modeled as a proposed PRV
12	Kaiser 408	Piti/Tumon 236	Install PRV or closed valve along Pale San Vitores near intersection with Route 1/Marine Drive (west of Nissan Tank).	12	Modeled as a proposed PRV. Verify the Altitude Control Valve on Nissan Tank function properly
13	Kaiser 408	Piti/Tumon 236	Install PRV along Route 1/Marine Drive near intersection with Adrian Sanchez Street	24	Modeled as a proposed PRV. Verify the locations of existing PRVs

Table 8-10 – PRV Station Improvements (continued)

No.	High Pressure Zone	Low Pressure Zone	Street	Waterline Diameter	Comment
14	Kaiser 408	Piti/Tumon 236	Install PRV along Adrian Sanchez St. near intersection with Route 1/Marine Drive.	14	Modeled as a proposed PRV. Verify the locations of existing PRVs
15	Mangilao/ Chaot 381	Piti/Tumon 236	Install PRV or closed valve along Route 8, west of the intersection with Biang and east of S-2.	8	Modeled as a proposed PRV
16	Mangilao/ Chaot 381	Piti/Tumon 236	Install PRV or closed valve along Chalan R.S. Sanchez, north of the intersection with Manibusan.	8	Modeled as a proposed PRV
17	Mangilao/ Chaot 381	Piti/Tumon 236	Install PRV or closed valve along Route 33, north of the intersection with Canada Toto Loop. (Southeast of Well A-26)	8	Modeled as a proposed PRV
18	Mangilao/ Chaot 381	Piti/Tumon 236	Install PRV or closed valve along Canada Toto Loop, north of the intersection with Chapel.	8	Modeled as a proposed PRV
19	Mangilao/ Chaot 381	Piti/Tumon 236	Install PRV or closed valve along Route 6, north of the intersection with Candelaria Road. (West of Well, A-32)	6	Modeled as a proposed PRV
20	Mangilao/ Chaot 381	Piti/Tumon 236	Install PRV along Route 7, just west of intersection with Frank Javiar (North of Well A-31)	10	Modeled as a proposed PRV
21	Mangilao/ Chaot 381	Piti/Tumon 236	Install PRV along Frank Javiar just southeast of Agana Heights Reservoir	10	Modeled as a proposed PRV
22	Mangilao/ Chaot 381	Piti/Tumon 236	Install PRV along Route 4 just south of Well A-23	12	Modeled as an assumed check valve
23	-	-	Not Used	-	-
24	Malojloj 410	Inarajan 297	Install PRV north of intersection of Route 4 and Tinaga	8	Modeled as a proposed flow control valve
25	Malojloj 410	Inarajan 297	Install PRV at intersection of Route 4 and Tun Enemico & Regina	8	Modeled as a proposed PRV
26	Malojloj 410	Pigua 334	Install PRV at intersection of Route 4 and Espinosa Ave. along Route 4, west of the waterline on Espinosa Ave.	8	Modeled as an assumed check valve, verify the number of waterline on Espinosa Ave.

8.5 Wells

The current operation of GWA's wells, though functional, poses operational challenges and some security risks. The uncertainty of designating the Northern System as GWUDI of surface water necessitates consideration of alternatives to the current system design and operation.

Some or all of the existing wells could qualify for filtration avoidance, but additional monitoring is required to determine if they qualify. For example, Figures 2-1 and 2-2 in Chapter 2 of this volume show the wells that have had coliform hits during the past five years, but the quantities have not been sufficiently quantified to determine if filtration avoidance could be met. If any well does not meet the filtration avoidance criteria, filtration would need to be added, or the well would need to be abandoned. Adding filtration to each well is impractical. Beginning a process of adding filters to individual, problematic wells could occur. However, there is no guarantee that more wells could fail to meet the filtration avoidance criteria in the future.

GWA has completed the design of a water transmission line that extends from the Agana Heights Reservoir to the Chaot Reservoir. Wells A-1, A-3, A-5, A-6, A-12, A-23, A-25, A-31 and A-32 will be connected to this transmission line. Wells A-31, A-23, A-6, A-25 and A-5, are five of the six wells that have the most frequent coliform hits. On-site chlorination at the well will be relocated to each reservoir. If filtration is required, it can also be located at the respective reservoirs. A hydraulic analysis was performed on this proposed transmission line in July 2006. The technical memorandum generated from this analysis and submitted to GWA is included in Appendix 2C.

Given the uncertainty of the GWUDI designation, the ability of each well to meet the filtration avoidance criteria and the security risks associated with the existing system design, transmission lines to potential common treatment points is a practical approach. Table 8-11 identifies transmission lines in order of priority. The locations of the proposed transmission lines in the northern Guam region are shown on Figures 8-3 and 8-4. Some of the wells are isolated or sufficiently distant from the proposed transmission lines and they should be evaluated as to cost and feasibility of connecting those wells to the transmission lines. It is possible that a focused effort on reducing local and system water losses could reduce or eliminate the need for connecting isolated wells.

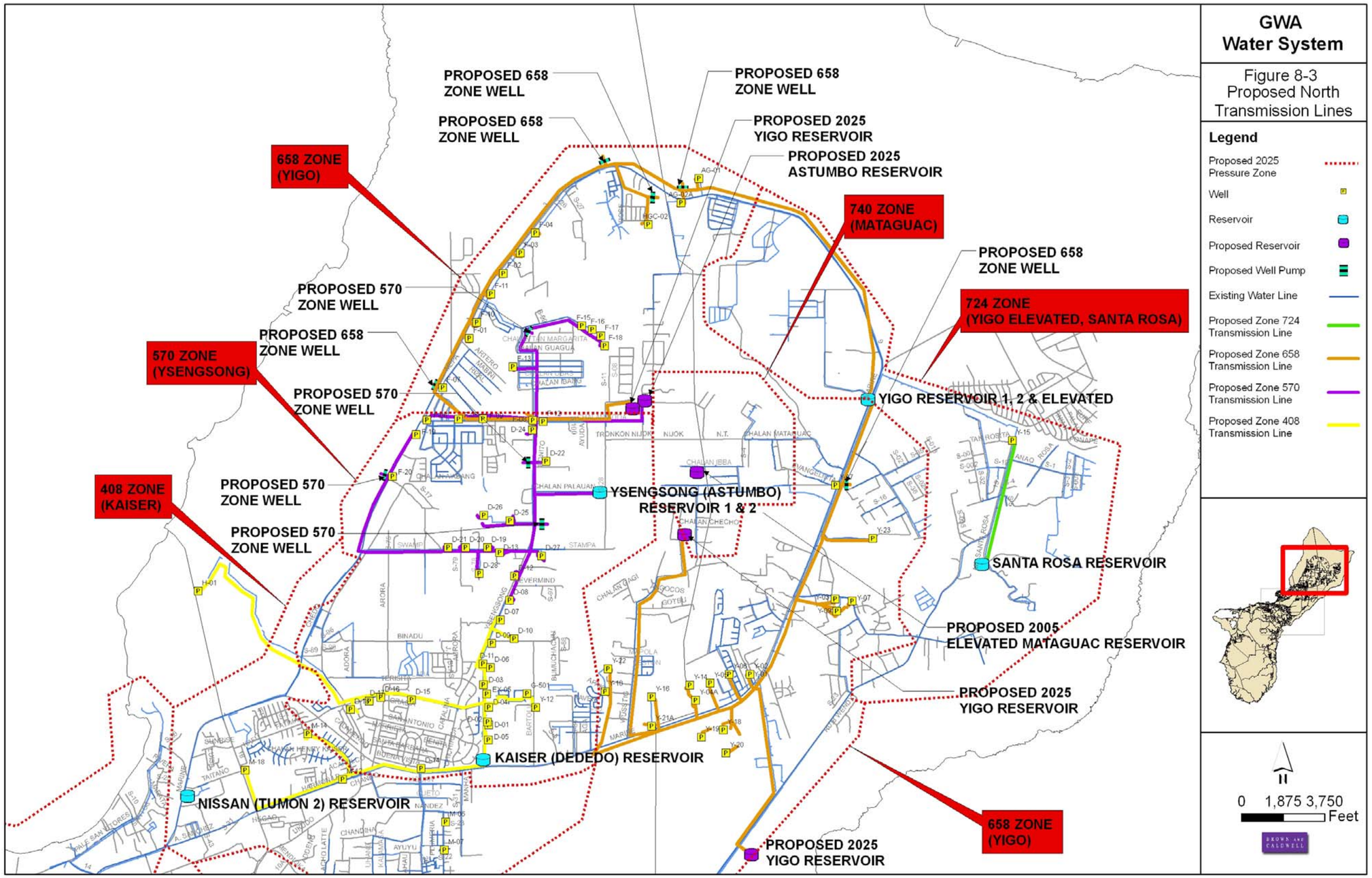
In July 2005, GWA presented an alternative concept of well development and centralized treatment and transmission of water through the proposed use of six Ranney-type collector wells to replace the individual vertical well system. Brown and Caldwell was contracted to conduct an initial feasibility study for the collector well concept that is independent of the WRMP. A copy of the draft Phase 1 and Phase 2 feasibility studies conducted for the collector wells is provided in Appendix 2D for reference. Due to the preliminary nature of the collector well concept and additional studies that are required to determine its viability, the impact upon the proposed CIP projects for improvement to the water system is not known at this time. Thus, it is premature at this time to prioritize or eliminate any of the recommended CIP projects. Revisions to the proposed CIP projects and their timetable for construction can be revised at a later time once the collector well concept is further developed.

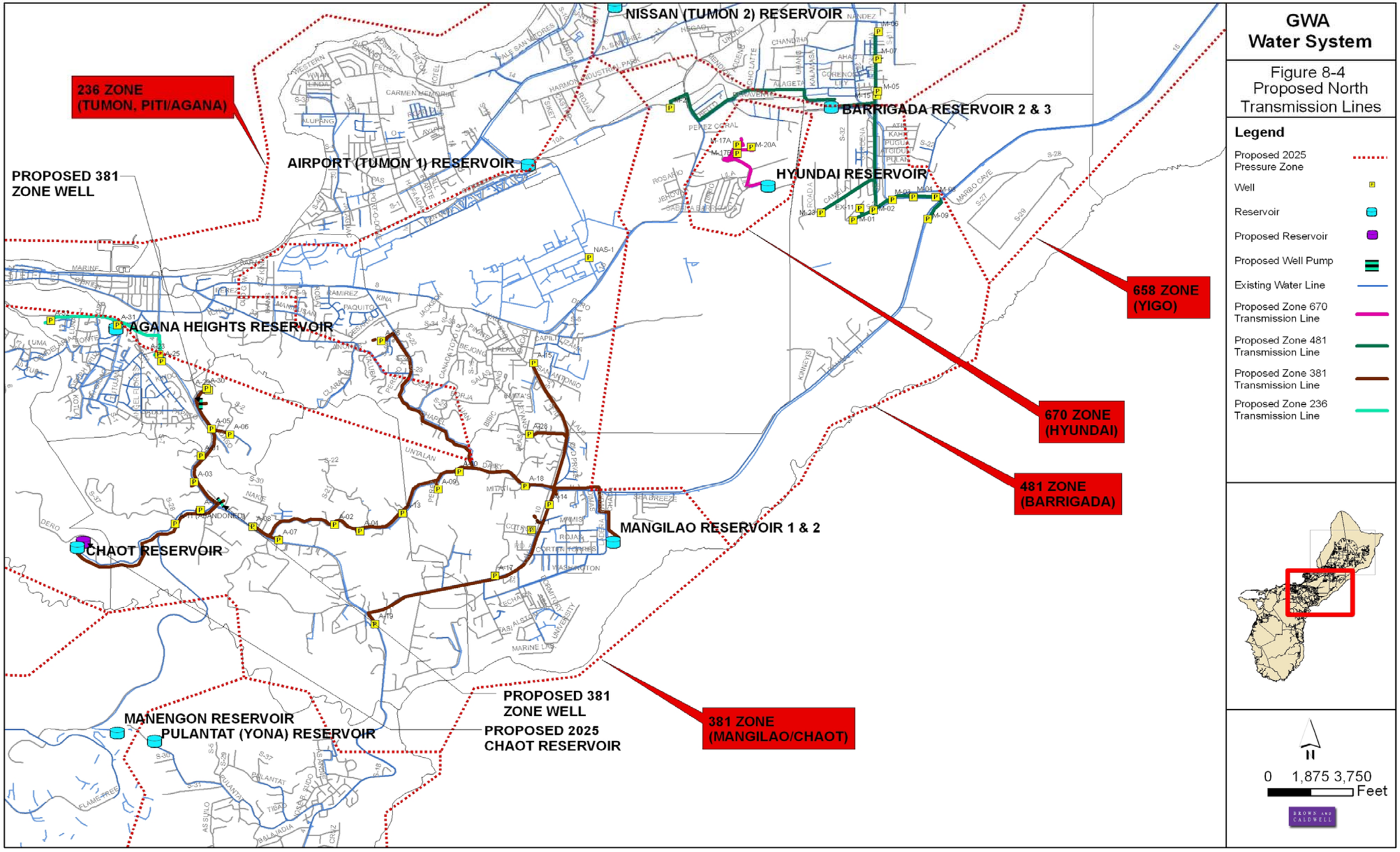
Table 8-11 – Recommended Raw Water Transmission Lines

No.	Description	Wells	Length & Diameter	Comments
1	Zone 236 Transmission Line: serving the Agana Heights Reservoir along Route 4 and Route 7. (Figure 8-4)	A-23, A-25, A-31 and A-32.	3,400' - 8" 4,000' – 12"	This transmission line is part of the Sinajana Transmission Line project that has been designed and is being prepared for bid.
2	Zone 381 Transmission Line: serving the Chaot Reservoir along Route 4 and Dero Dr. (Figure 8-4)	A-01, A-03, A-05, A-06, A-12, A-29 and A-30.	350' - 12" 1,900' - 16" 14,200' - 24"	This transmission line is part of the Sinajana Transmission Line project that has been designed and is being prepared for bid. Although not included at this time, Wells A-29 and A-30 should be connected to this transmission line in the future. The two wells are assumed to be connected for the "lengths" identified to the left. Also, the designed pipe diameters need to be revised to those recommended herein, since future demands and CIP improvements will require more conveyance capacity.
3	Zone 408 Transmission Line: serving the Kaiser Reservoir along Santa Monica Ave., Route 1 and Route 28. (Figure 8-3)	D-01 thru D-07, D-09 thru D-11, D-14 thru D-18, EX-05, GHURA-501, H-01, M-12, M-14, M-18 and Y-12	44,700' - 12" 2,400' - 16" 100' - 24"	Wells D-7, D-4 and D-17, have a history of fecal coliform hits, though only D-4 showed their presence from 2003 through 2005. This is the second highest concentration of wells with fecal coliform hits, following the A-series. Also, Wells H-01, M-14 and M-18 are a considerable distance from the Kaiser Reservoir and should be evaluated in the future for their feasibility as part of this transmission main.
4	Zone 570 Transmission Line: serving the Ysengsong Reservoirs along Route 3, Swamp Rd., Route 28 and Chalan Isang. (Figure 8-3)	D-08, D-12, D-13, D-19 thru D-22, D-24 thru D-28, F-05, F-06, F-09, F-12, F-13, F-15 thru F-20	35,300' - 12" 5,100' - 16" 11,100' - 24"	D-13, D-19, D-21, D-22 and F-13 have a history of fecal coliform hits.
5	Zone 658 Transmission Line: serving the Yigo Reservoirs along Route 3, Route 9 and Route 1. (Figure 8-3)	AG-01, AG-02A, F-01 thru F-04, F-07, F-08, F-10, F-11, HGC-2, Y-01 thru Y-07, Y-09, Y-10, Y-14 and Y-16 thru Y-23	51,900' - 12" 45,800' - 16" 10,700' - 24"	F-02 and F-10 have a history of fecal coliform hits. The Yigo Pressure Zone is the largest zone that will require the highest amount of pipeline capital improvement expenditure.
6	Zone 381 Transmission Line: serving the Mangilao Reservoirs along Route 15, Route 10 and Chapel Rd. (Figure 8-4)	A-02, A-04, A-07, A-08, A-09, A-10, A-13, A-14, A-15, A-17, A-18, A-19, A-21, A-26 and A-28	23,750' - 12" 22,600' - 16" 5,200' - 24"	Although Wells A-15, A-19 and A-26 are included in this transmission line, they are located a considerable distance from the Mangilao Reservoirs. They should be evaluated in the future for their feasibility as part of this transmission line.

Table 8-11 – Recommended Raw Water Transmission Lines (continued)

No.	Description	Wells	Length & Diameter	Comments
7	Zone 481Transmission Line: serving the Barrigada Reservoirs along Route 26, S-3, and Lemon China Rd.(Figure 8-4)	EX-11, M-01 thru M-09, M-15, M-21 and M-23	26,800' - 12" 2,000' - 16"	M-21 is located a considerable distance from the Barrigada Reservoirs. It should be evaluated in the future for its feasibility as part of this transmission line.
8	Zone 670 Transmission Line: serving the Hyundai Reservoir along Juan C. Fejeran Rd.(Figure 8-4)	M-17A, M-20A and M-17B	5,600' - 12"	--
9	Zone 724 Transmission Line: serving the Santa Rosa Reservoir along Route 15. (Figure 8-3)	Y-15	6,000' - 12"	--
		Total Accumulated Length	~323,000 feet	


PROPOSED 658 ZONE WELL
PROPOSED 658 ZONE WELL
PROPOSED 658 ZONE WELL
PROPOSED 2025 YIGO RESERVOIR
PROPOSED 2025 ASTUMBO RESERVOIR
658 ZONE (YIGO)
740 ZONE (MATAGUAC)
PROPOSED 658 ZONE WELL
PROPOSED 570 ZONE WELL
724 ZONE (YIGO ELEVATED, SANTA ROSA)
PROPOSED 658 ZONE WELL
570 ZONE (YSENGSONG)
YIGO RESERVOIR 1, 2 & ELEVATED
PROPOSED 570 ZONE WELL
408 ZONE (KAISER)
PROPOSED 570 ZONE WELL
YSENGSONG (ASTUMBO) RESERVOIR 1 & 2
PROPOSED 570 ZONE WELL
SANTA ROSA RESERVOIR
PROPOSED 2005 ELEVATED MATAGUAC RESERVOIR
PROPOSED 2025 YIGO RESERVOIR
KAISER (DEDEDO) RESERVOIR
NISSAN (TUMON 2) RESERVOIR
658 ZONE (YIGO)
PROPOSED 2025 YIGO RESERVOIR
GWA Water System
Figure 8-3 Proposed North Transmission Lines
Legend
Proposed 2025 Pressure Zone
Well
Reservoir
Proposed Reservoir
Proposed Well Pump
Existing Water Line
Proposed Zone 724 Transmission Line
Proposed Zone 658 Transmission Line
Proposed Zone 570 Transmission Line
Proposed Zone 408 Transmission Line
0 1,875 3,750
Feet
BROWN AND CALDWELL


NISSAN (TUMON 2) RESERVOIR
236 ZONE
(TUMON, PITI/AGANA)
PROPOSED 381
ZONE WELL
AIRPORT (TUMON 1) RESERVOIR
BARRIGADA RESERVOIR 2 & 3
HYUNDAI RESERVOIR
658 ZONE
(YIGO)
AGANA HEIGHTS RESERVOIR
670 ZONE
(HYUNDAI)
481 ZONE
(BARRIGADA)
MANGILAO RESERVOIR 1 & 2
CHAOT RESERVOIR
PROPOSED 381
ZONE WELL
MANENGON RESERVOIR
PULANTAT (YONA) RESERVOIR
PROPOSED 2025
CHAOT RESERVOIR
381 ZONE
(MANGILAO/CHAOT)
GWA
Water System
Figure 8-4
Proposed North
Transmission Lines
Legend
Proposed 2025
Pressure Zone
Well
Reservoir
Proposed Reservoir
Proposed Well Pump
Existing Water Line
Proposed Zone 670
Transmission Line
Proposed Zone 481
Transmission Line
Proposed Zone 381
Transmission Line
Proposed Zone 236
Transmission Line
0 1,875 3,750
Feet
BROWN AND
CALDWELL

8.6 Water Treatment Facilities

The Ugum WTP is the primary source of drinking water for the Southern Public Water System. Two low producing wells (MJ-01 and MJ-05) provide back-up supplies, but are insufficient to serve the entire Southern System. Though performance reliability of the Ugum WTP has improved over the past two years there are risks associated with existing equipment, structures and capacity limiting factors.

As discussed in Chapter 2 of this volume, one of the four filters was damaged by an earthquake and cannot be used. The other filters have significant media loss and require upgrading. GWA has begun a procurement process to replace the filters with membrane filtration. This would bring the Ugum WTP to a full capacity of 4.0 mgd and would only be limited by the availability of raw water from the Ugum River. Hydraulic modeling shows that full production of 4.0 mgd from the Ugum WTP could be used to supplement approximately 1.3 to 2.1 mgd of the water supplied from the Northern System to the Central System as well as some of the system supplied by the U.S. Navy. The modeling results are presented in Table 8-12.

The use of Navy-supplied water could be eliminated entirely if the Ugum WTP production can be increased to 7.2 mgd. This would require a larger number of capital projects, including an upgrade of the Ugum WTP and construction of a larger raw water storage reservoir than would be needed for drought considerations. The modeling results are presented in Table 8-13.

The Ugum WTP can adequately supply the Southern System's current demand. However, the existing shallow pool diversion cannot adequate supply 4.0 mgd year-round and is particularly susceptible to drought conditions. The existing intake also silts up and cannot result in excessive turbidity in the raw water to the treatment facility.

The existing finished 2.0 million gallon water reservoir has significant typhoon damage and there is no option currently for taking it off-line for rehabilitation. A second reservoir is needed to perform adequate maintenance on the existing reservoir.

The capital improvement project for the Ugum WTP is provided in Table 8-14. It includes improvements for reliability and redundancy for 4.0 mgd of production. The capital improvement program does not include land acquisition and raw water storage construction "drought-proofing" the 4.0 mgd capacity because of its high cost (estimated $10 million for land acquisition and $83 million for dam construction).

Table 8-12 – Modeling Results from Ugum WTP for 4.0 mgd Supply

Modeling Criteria	Modeling Results
– Ugum WTP production of 4.0 mgd – Two closed flow control valves at the Route 4 and 17 Junction installed so no water from the North System can be delivered to Brigade BPS. – Closed valve opened at the Route 4 and 17 Junction, so water from Ugum WTP can be delivered to Brigade BPS. – No Changes to Brigade BPS. – No Changes to Windward Hill BPS. – No Changes to Sinifa Area. – Navy Water Supply Meters Number 222 and 69 Turned-on. – No changes to Santa Rita Spring BPS. – Pump operating control point (On @ 20 feet and Off @ 31 feet) for the Santa Ana Upper BPS to a relative low Agat #2 Reservoir level.	– During high demand period, Navy water supply will continue to support the customers west of the Sinifa Reservoir and Ugum WTP will supply all the water needs east of the Sinifa Reservoir (Talafofo, Windward Hill, Baza Garden etc.). – During low demand period, Ugum WTP will supply water to the area west of the Sinifa Reservoir through the Windward Hill BPS and thus Navy water supply can be minimized. – The 24-hour simulation results showed that there is adequate overall pressure and water supply for the South System. – Maximum Day Demand for the South System: 5,162 gpm. – Water Supply for the South System: o Ugum – 2,800 gpm o Santa Rita Spring - 165 gpm o Navy Meter 69 – 1,637 gpm o Navy Meter 222 - 180 gpm o Total: 4,782 gpm – The Southern System water supply and demand is close to being balanced (- 380 gpm).

Table 8-13 – Modeling Results from Ugum WTP for 7.2 mgd Supply

Modeling Criteria	Modeling Results
– Ugum WTP production of 7.2 MGD. – Pipeline diameter from Ugum WTP to Brigade BPS increased from 12-inch to 16-inch. – Two closed flow control valves installed at the Route 4 and 17 Junction, so no water from the North System can be delivered to Brigade BPS. – Closed valve opened at the Route 4 and 17 Junction, so water from Ugum WTP can be delivered to Brigade BPS. – Pump capacity of the Brigade BPS increased to 3200 gpm. – Design Pumping Head of the Brigade BPS Pumps increased to 450 feet. – Pump capacity of the Windward Hill BPS increased to 2200 gpm. – Design Pumping Head of the Windward Hill BPS Pumps increased to 400 feet. – A new pressure zone created for customers around existing Sinifa Reservoir. – A new Sinifa BPS installed to supply water to the existing Sinifa Reservoir. – A new 1.0 MG Sinifa reservoir added at elevation 525 feet. – The pump operating control point (On @ 5 feet and Off @10 feet) for the new Sinifa BPS set to a relative low existing Sinifa Reservoir level. – Navy Water Supply Meter numbers 222 and 69 turned off. – The Santa Rita Spring BPS supply limited to approximately 165 gpm. – The pump operating control point (On @20 feet and Off @ 31 feet) for the Santa Ana Upper BPS set to a relative low Agat #2 Reservoir level.	– There are adequate overall pressure and water supply for the South System. – Maximum Day Demand for the South System: 5,162 gpm. – Water Supply for the South System: o Ugum – 5,000 gpm, o Santa Rita Spring - 165 gpm. o Total: 5,165 gpm. – The Southern System water supply and demand is balanced.

Table 8-14 – Ugum WTP Improvements

No.	Description	Requirement	Comment
1	Replace dual media filters with membrane filters.	Plant capacity of 3.0 to 7.0 million gallons per day depending on raw water turbidity.	One of the existing filters cannot be used due to structural earthquake damage. A project for installation of membrane filters in two of the dual media structures is currently underway and expected to be completed by December 2006.
2	Construct a new finished water reservoir.	2.0 million gallon reservoir.	The existing reservoir has structural and corrosion damage but cannot be taken off-line as the sole source reservoir. A second reservoir would provide an opportunity to rehabilitate the existing reservoir.
3	Provide chemical feed equipment redundancy.	Redundant chemical feed facilities - coagulants and flocculants.	There is no redundancy in chemical feed, which affects the reliability of the system.
4	Modify the raw water intake to minimize siltation.	Reposition the intake to minimize siltation and highly turbid raw water.	The current intake is susceptible to silting up and overloading the treatment plant with high turbidity raw water.
5	Construct a raw water reservoir (not included in capital improvement program because of high cost)	An on-line or off-line portion of the Ugum River would be dammed to provide approximately 150 million gallons of storage to ensure drought protection.	The current diversion does not provide any storage.

8.7 Future Water System Facilities Improvements

Increases in population throughout the island will increase water demand and create deficiencies in the water source, pumping and transmission, storage and distribution system. Water system improvements required to support the growing population over the next 20 years was identified through modeling of the projected future conditions. Tables 8-15 and 8-16 summarize the 2025 CIM improvements recommended for the water distribution systems in the southern and northern systems, respectively. Recommended booster pump stations to improve water service pressures in the distribution system for the 2025 CIM are summarized in Table 8-17. Recommended reservoirs to improve water storage for fire protection or adequate service pressures for the 2025 CIM are summarized in Table 8-18. Recommended supply wells in the northern system to meet the increased demand for the 2025 CIM are summarized in Table 8-19.

Table 8-15 – 2025 CIM Southern Distribution System Improvements

No.	Area	Description	Length (Feet)	Comment
1	Malojloj	Increase Malojloj Reservoir 12-inch inlet/outlet pipe to 24-inch and continue down Route 4 to Malojloj Well St.	3250	Improve available fire flow in this area
2	Malojloj	Increase 12-inch waterline along Route 4 from Malojloj Well St. to Tinaga St. to 16-inch	7450	Improve available fire flow in this area and further south
3	Malojloj	Increase 8-inch waterline along Route 4 from Tinaga St. to Tun Enemico & Regina St. to 12-inch	17,000	Improve available fire flow in this area and further south

Table 8-16 – 2025 CIM Northern Distribution System Improvements

No.	Area	Description	Length (Feet)	Comment
1	Mangilao/ Chaot	Increase Chaot Reservoir 12-inch inlet/outlet pipe to 24-inch down Dero Rd. to Route 4, then north up Route 4 to Chalan Canton Tutujan and west to Senator Gibson Ct.	13,500	Reduce velocity and improve pressure in this area.
2	Kaiser	Install 24-inch distribution transmission main from Kaiser Reservoir and west along Route 1 to Chalan Liguan.	7480	Increase conveyance capacity and Improve pressure in this area
3	Kaiser	Install 16-inch transmission line from Kaiser Reservoir to Barrigada Reservoirs via Route 1 and Route 26 as part of a booster line to fill proposed Yigo CIP Reservoir.	8900	Supply for proposed Yigo Reservoir on Route 15.
4	Barrigada	Install 12-inch transmission line from Barrigada Reservoirs to Route 26 as part of a booster line to fill proposed Yigo CIP Reservoir.	1100	Supply for proposed Yigo Reservoir on Route 15.
5	Barrigada	Install 16-inch transmission line from Chalan Villagomez, southward on Route 26 and northeast on Route 15 as part of a booster line to fill proposed Yigo CIP Reservoir.	20,600	Supply for proposed Yigo Reservoir on Route 15.
6	Yigo Zone	Increase existing 12-inch distribution main to 16-inch on Route 15, northward from Route 26 to the proposed Yigo CIP Reservoir.	12,600	Increase conveyance capacity and improve pressure in the Adacao Rd. area
7	Yigo Zone	Install 24-inch outlet pipe for proposed Yigo CIP Reservoir and connect to distribution main on Route 15	700	Increase supply and conveyance capacity and improve pressure in Adacao Rd. area
8	Yigo Zone	Increase existing 8-inch distribution main to 12-inch on Adacao Rd. and Route 26	4800	Increase conveyance capacity and improve pressure in the Adacao Rd. area

Table 8-16 – 2025 CIM Northern Distribution System Improvements (continued)

No.	Area	Description	Length (feet)	Comment
9	Yigo Zone	Increase existing 2-inch distribution main to 8 inches, joining Wusstig Rd. and Chalan Islas Marianas	3400	Improve loop capacity to increase pressure and lower velocity in this area
10	Yigo Zone	Install parallel 16-inch distribution main on Wusstig Rd., from Route 1 to proposed Yigo CIP Reservoir.	10,600	Increase supply and improve pressure in this area
11	Yigo Zone	Install 12-inch distribution main that connects existing parallel mains on Route 1 at Chalan La Chanch	100	Improve loop capacity and conveyance in this area
12	Yigo Zone	Install 16-inch parallel main from Yigo Reservoirs, along Route 1 and west through Route 9 to Chalan Santa Bernadita	12,500	Part of the proposed pressure zone boundary adjustment that transfers some of the existing area served by the 658 pressure zone into the higher 724 pressure zone.
13	Yigo Zone	Install 16-inch outlet pipe from proposed Yigo CIP Reservoir to proposed 2005 CIP main on road S-11.	1600	Part of the proposed pressure zone boundary adjustment that transfers some of the existing area served by the 570 pressure zone into the higher 658 pressure zone.
14	Astumbo	Increase inlet/outlet pipe for existing Astumbo Reservoirs to 24-inch.	6100	Increase conveyance capacity, reduce velocity and improve pressures in this area.
15	Astumbo	Install 24-inch outlet pipe for proposed Astumbo CIP Reservoir, westward from Chalan Koda to Chalan Ibang	6400	Increase supply in this area.
16	Astumbo	Increase existing 12-inch distribution main on Ysengsong Rd. to 24 inches, northward from Chalan Lahe to Chalan Koda	7200	Increase conveyance capacity and improve pressure in this area.
17	Astumbo	Increase existing 12-inch distribution main on Ysengsong Rd. to 24 inches, from Chalan Ibang to Chalan Hachon	2050	Increase conveyance capacity and improve pressure in this area.
18	Astumbo	Increase existing 12-inch distribution main on Ysengsong Rd. to 16 inches, from Chalan Hachon to Route 3.	2900	Increase conveyance capacity and improve pressure in this area.
19	Astumbo	Increase existing distribution mains to 10 inches for area bordered by Ysengsong Rd. to the north, Kamute and Chalan A'Abang to the south, Chalan Hachon to the east and Chalan Fago and Nika to the west	31,000	Increase conveyance capacity and improve pressure in this area.

Table 8-17 – 2025 CIM Recommended Booster Pump Stations

No.	System	Area	Description	Pump Requirements	Comment
1	North	Kaiser	Provide BPS at Kaiser Reservoir to boost water to proposed Yigo CIP Reservoir on Route 15	1800 gpm at 330-foot TDH	Yigo transmission mains are inadequate to fill proposed CIP reservoir and Kaiser Reservoir has sufficient capacity.
2	North	Barrigada	Provide BPS at Barrigada Reservoirs to boost water to proposed Yigo CIP Reservoir on Route 15	1800 gpm at 300-foot TDH	Yigo transmission mains are inadequate to fill proposed CIP reservoir and Barrigada Reservoirs have sufficient capacity.

Table 8-18 – 2025 CIM Recommended Reservoirs*

No.	System	Area	Description	Tank Requirements	Comment
1	Northern	Yigo	Provide 0.2 MG elevated tank near Flores Cadena and Chalan Koda.	Overflow elevation should be set at 658 feet.	Existing Yigo Reservoirs are too far from this area to provide sufficient pressure or supply.
2	Northern	Yigo	Provide 0.3 MG elevated tank up Wusstig Rd. near Chalan Sabana Pale.	Overflow elevation should be set at 658 feet.	Existing Yigo Reservoirs are too far from this area to provide sufficient pressure or supply.
3	Northern	Yigo	Provide 0.2 MG elevated tank along Route 15 northeast of Route 26.	Overflow elevation should be set at 658 feet.	Existing Yigo Reservoirs are too far from this area to provide sufficient pressure or supply.
4	Northern	Astumbo	Provide additional 2.0 MG storage near Flores Cadena and Chalan Koda.	Overflow elevation to be set at 570 feet.	Existing Astumbo Reservoirs do not have sufficient capacity, especially after incorporating the 2005 recommended pressure zone boundary changes to serve former Kaiser area.
5	Northern	Chaot	Provide additional 2.0 MG storage at existing Chaot Reservoir site.	Overflow elevation to be set at 381 feet.	Existing Chaot Reservoir lacks sufficient capacity and existing Mangilao Reservoirs are too far to provide adequate supply and pressure in this area.

* See Figures 8-3 & 8-4 for locations

Table 8-19 – 2025 CIM Recommended Raw Water Supply Wells*

No.	System	Area	Description	Comment
1	North	Yigo	Provide new groundwater wells totaling 1900 gpm. Install 290 gpm on the west portion along Route 3. Install 1200 gpm on the north portion along Route 9. Install 410 gpm on the east portion along Route 1.	New supply is necessary to prevent the storage reservoirs from draining during max day demand.
2	North	Astumbo	Provide new groundwater wells totaling 1800 gpm. Install 600 gpm on the north portion along Chalan Lumasu. Install 1200 gpm near the existing Astumbo Reservoirs along Ysengsong Rd.	New supply is necessary to prevent the storage reservoirs from draining during max day demand
3	North	Chaot	Provide new groundwater wells totaling 1050 gpm along Route 4.	New supply is necessary to prevent the storage reservoirs from draining during max day demand

*See Figures 8-3 & 8-4 for locations

8.8 Hydraulic Profiles

Hydraulic profiles illustrating the aforementioned 2005 CIP recommendations are provided on Figure 8-5 for the northern system and Figure 8-6 for the south and central water systems. Hydraulic profiles illustrating the 2025 CIM recommendations are provided on Figure 8-7 for the northern system and Figure 8-8 for the south and central water systems. The sizes of water mains connecting the BPS to reservoirs are also indicated on the hydraulic profiles, as well as selected water sources and service areas.

Figure 8-5 – 2005 CIP Hydraulic Profile for North Network

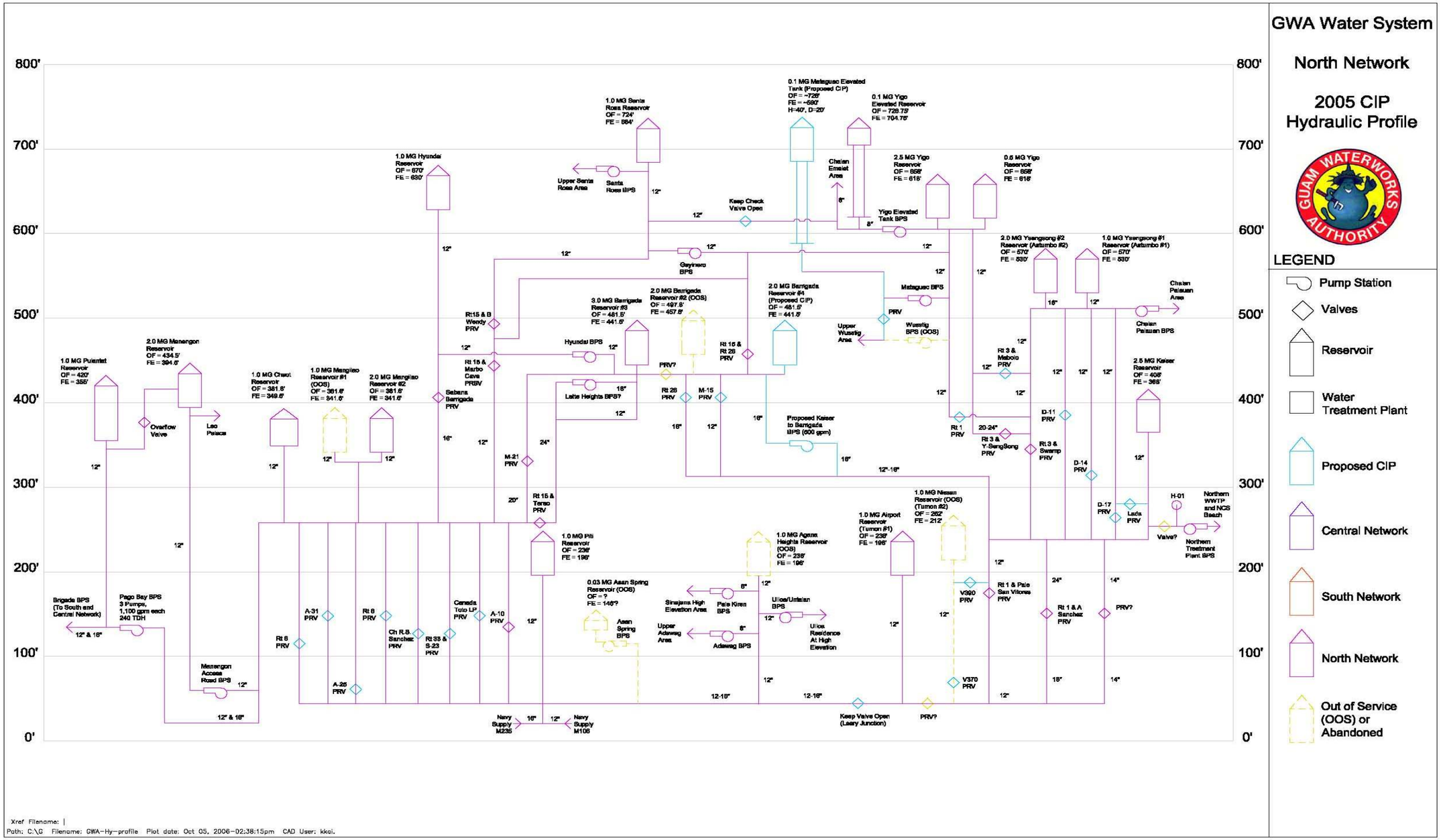
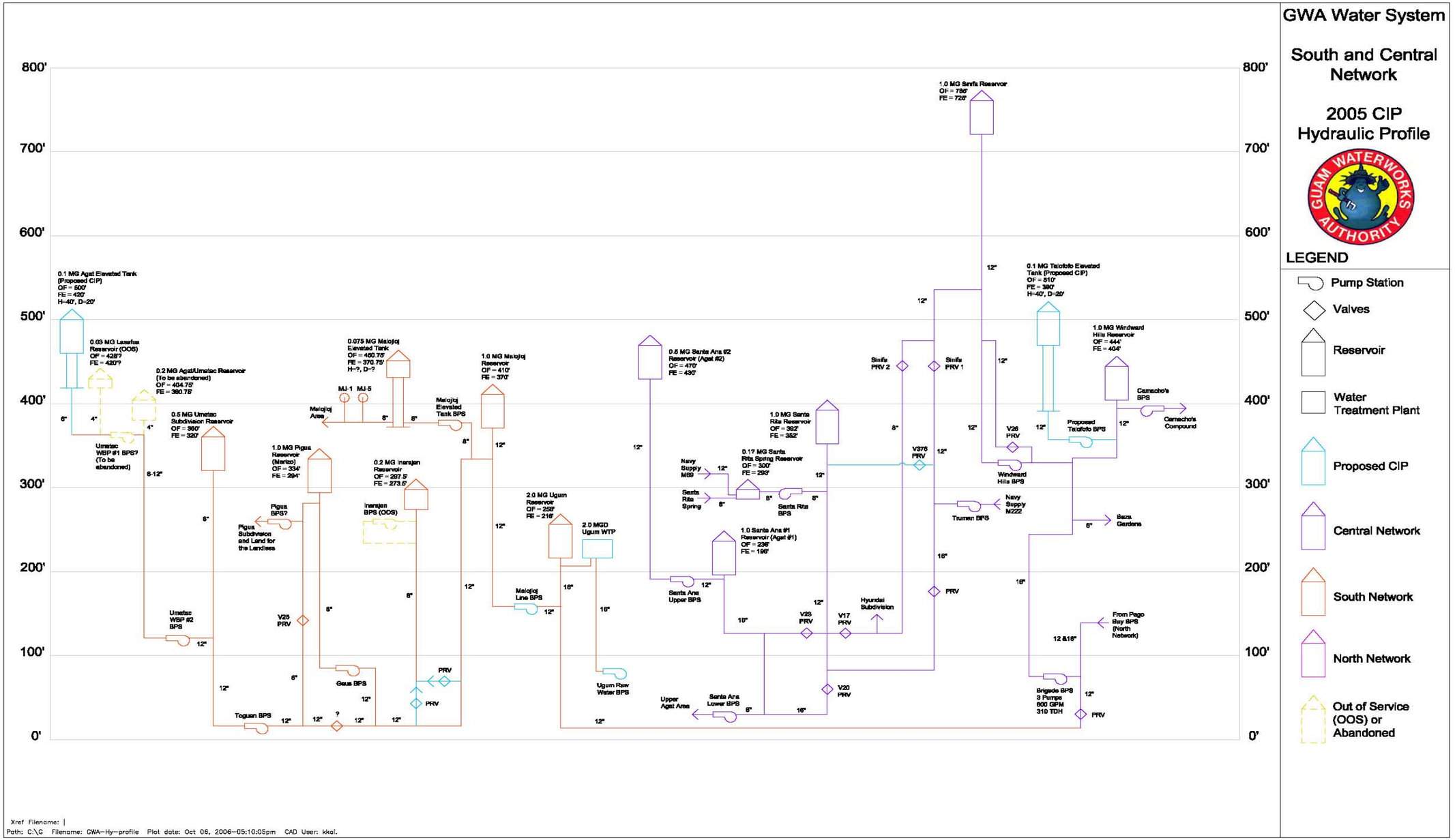


Figure 8-6 – 2005 CIP Hydraulic Profile for South & Central Network



Xref Filename: |
Path: C:\G Filename: GWA-Hy-profile Plot date: Oct 06, 2006-05:10:05pm CAD User: kkai.

Figure 8-7 – 2025 CIM Hydraulic Profile for North Network

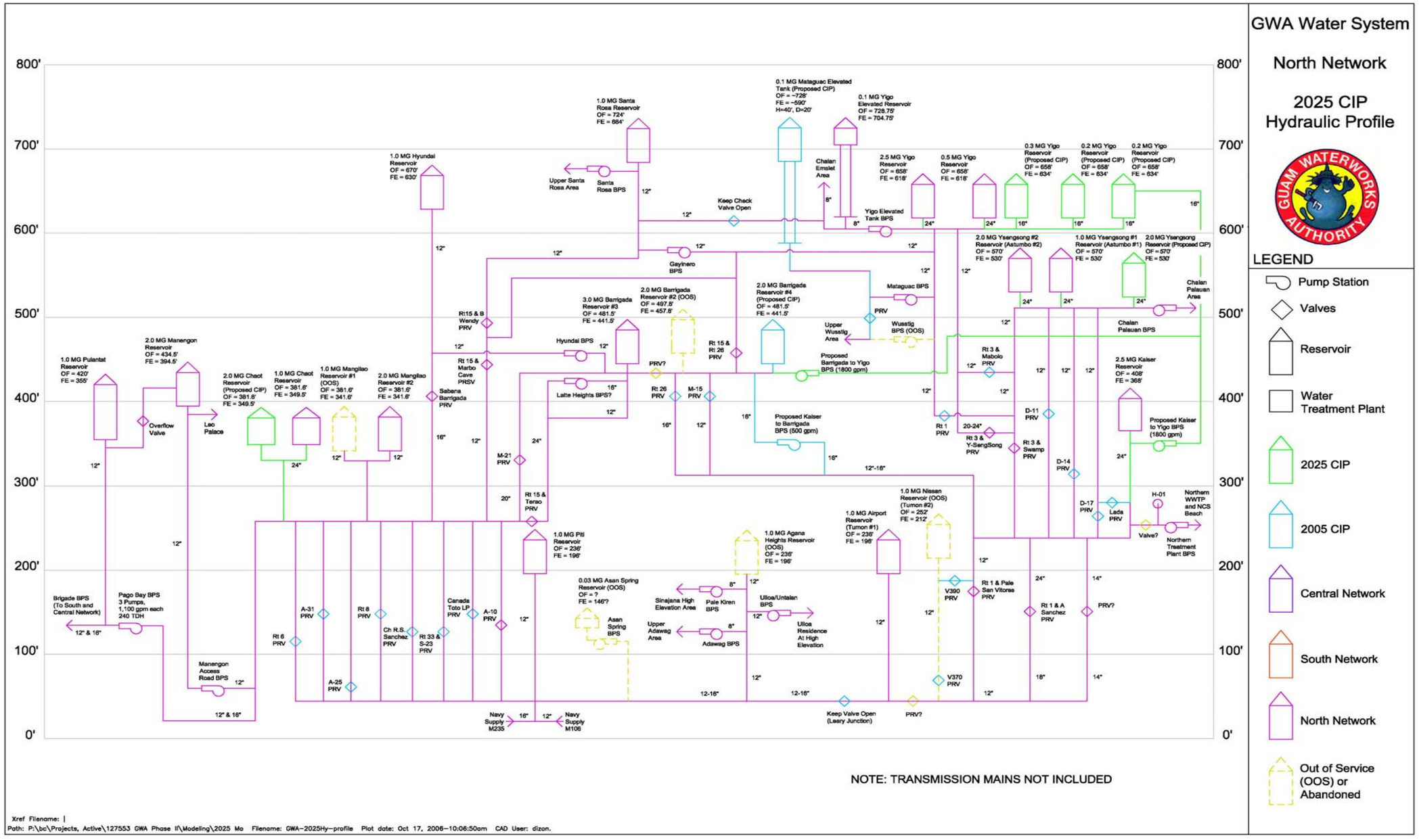
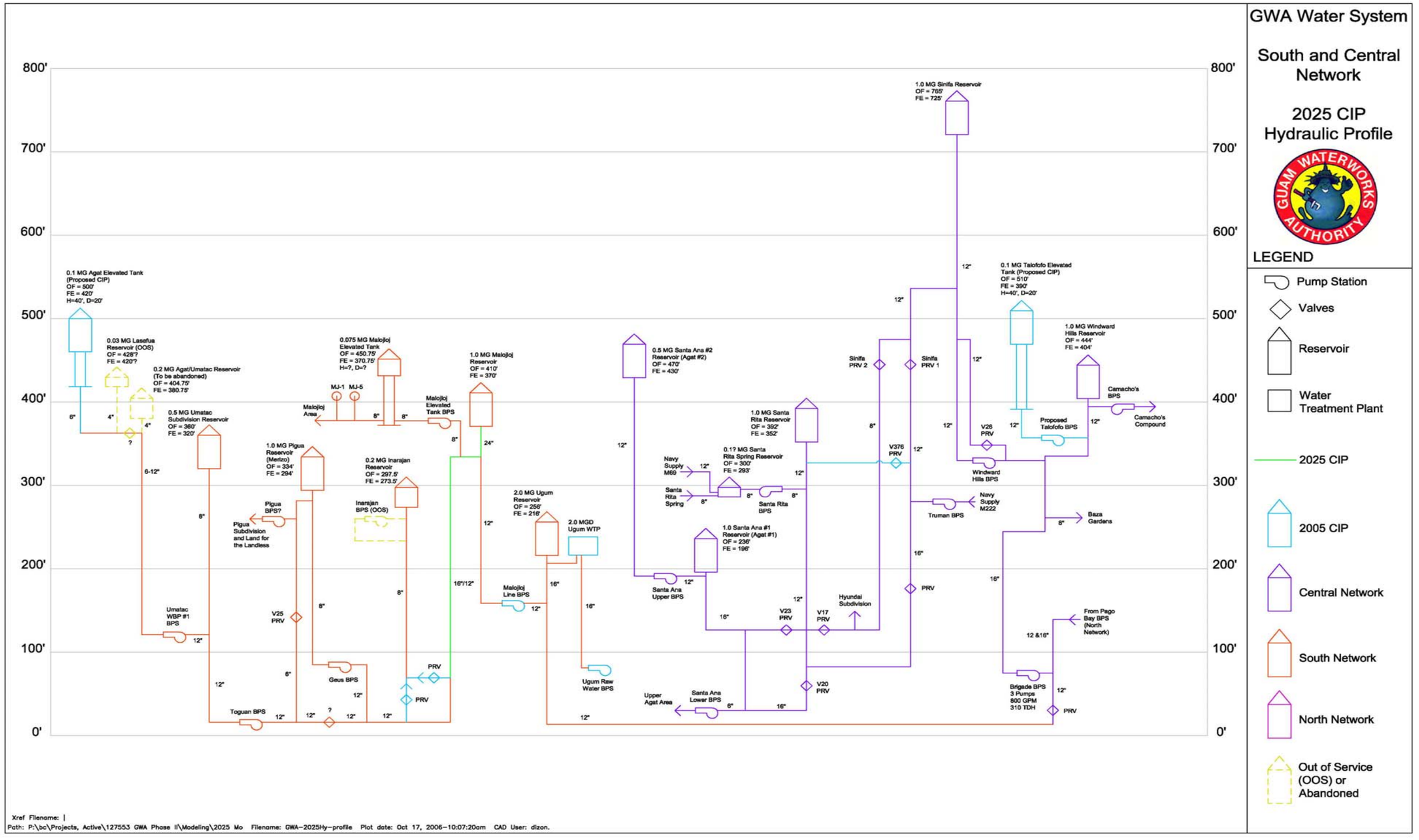


Figure 8-8 – 2025 CIM Hydraulic Profile for South & Central Network



8.9 Conclusions

- There is approximately 119,000 feet of pipe system-wide that does not meet fire flow and pressure standards
- All three public water systems have insufficient reservoir capacity to meet fire flow and pressure standards
- The current operational pressure zones are inadequate and need realignment

8.10 2005 CPM Recommendations

- Upgrade approximately 55,000 feet of pipe in the Northern System to meet fire flow and pressure standards
- Upgrade approximately 17,000 feet of pipe in the Central System to meet fire flow and pressure standards
- Upgrade approximately 38,000 feet of pipe in the Southern System to meet fire flow and pressure standards
- Add two new reservoirs in the Northern System to meet fire flow and pressure standards
- Add a new reservoir and a new booster station in the Central System to meet fire flow and pressure standards
- Add a new booster station and a replacement reservoir in the Southern System to meet fire flow and pressure standards

8.11 2025 CIM Recommendations

- Install PRV/PSV stations to define or realign pressure zone boundaries
- The 2025 CIM includes approximately 323,000 feet of raw water transmission lines.
- All existing groundwater well pumps will need to be re-evaluated for lift capacity when transmission line projects get underway in the Northern System. A determination will be made at that time whether or not new pumps need to be installed for the existing wells.
- Upgrade approximately 28,000 feet of pipe in the Southern System to meet fire flow and pressure standards
- Install/upgrade approximately 154,000 feet of pipe in the Northern System to meet fire flow and pressure standards as a result of disconnecting all wells from the distribution system and serving customers exclusively from reservoirs
- Add two new booster stations in the Northern System to help with maintaining reservoir levels
- Add five new storage reservoirs in the Northern System to help meet fire flow, pressure and supply requirements
- Add approximately 4800 gpm of groundwater supply in the Northern System to meet increased demand

8.12 CIP Impacts

The recommendations provided in the previous sections have the following impacts on the CIP:

- Northern Distribution System Improvements (2005)
- Central Distribution System Improvements (2005)
- Southern Distribution System Improvements (2005)
- Reservoir Improvements (2005)
- Booster Pumping Station Improvements (2005)
- Pressure Zone Realignment/Development (2025)
- Northern Transmission Main Improvements (2025)
- Northern Distribution System Improvements (2025)
- Southern Distribution System Improvements (2025)
- Booster Pumping Station Improvements (2025)
- Reservoir Improvements (2025)
- Water Source Improvements (2025)

As stated in Chapter 6, not all water system deficiencies are eliminated by implementing the CIP recommendations herein. In regards to the Hawaii WSS being used as a guide throughout the hydraulic analyses, certain criteria were unable to be met without extensive upgrades and extremely high capital expenditures. For instance, the first criteria under storage reservoir sizing in Section 8.3.1.3 states that capacity shall satisfy maximum day consumption, where the reservoirs shall be full at the beginning of the 24-hour period with no input from groundwater or surface water sources. This requirement of eliminating all contribution from groundwater wells or surface water sources imposes a very stringent condition on the GWA system. Essentially, the storage reservoirs would be required to supply the entire maximum day demand of about 70 MG, which is almost double the storage volume that the GWA system would have with the 2025 CIM recommendations fully implemented. Similarly, in Section 8.3.1.4, the requirement is that pumps must meet maximum day demand with an operating time of 16 hours simultaneously with maximum fire flow required, independent of the storage provided by reservoirs. This criterion does not seem to be applicable to the groundwater wells if they are disconnected from the distribution system and pumped directly into reservoirs through transmission lines, as is modeled in the 2025 CIM. However, if the criterion did apply to the groundwater wells, they would also be required to supply the entire maximum day demand, which would exceed the sustainable yield of the Northern Lens. Applying this criterion to booster pump stations would require each station to have a capacity equal to the maximum day demand plus fire flow for the zone it supplies water to. These criteria would require more improvements than what would be considered financially feasible for GWA. Therefore, it is important for GWA to develop its own water system standards that will allow for enough infrastructure redundancy to provide a safe and reliable system for its customers while still being economically feasible to implement.