CANAL DE PANAMÁ

Panama Canal Watershed

Municipal and Industrial Water Demand and Raw Water Consumption Forecast 2020-2050

September 2018

Stantec

In association with CELA "Justo Arosemena"

Final Demand Forecast Update Report

Panama Canal Watershed Municipal and Industrial Water Demand and Raw Water Consumption Forecast, 2020 - 2050

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Executive Summary

ES-1 Introduction

The Panama Canal Watershed (Watershed) is the land area that drains to the Panama Canal (Canal), as shown in **Figure ES.1**. It provides all the water needed for navigation in the Canal, as well as a majority of the water for municipal and industrial (M&I) needs in the Panama City metropolitan area and other communities near the Canal (such as Colon). The Watershed is critical for Canal operations and providing the water needed for residential, commercial and industrial uses in Panama's most populated and urbanized areas.

The Canal and all associated land and facilities, including the Watershed, are managed by Autoridad del Canal de Panama (ACP). This agency is responsible for all planning related to the Canal, including long-range planning for water supply needed for Canal operations.

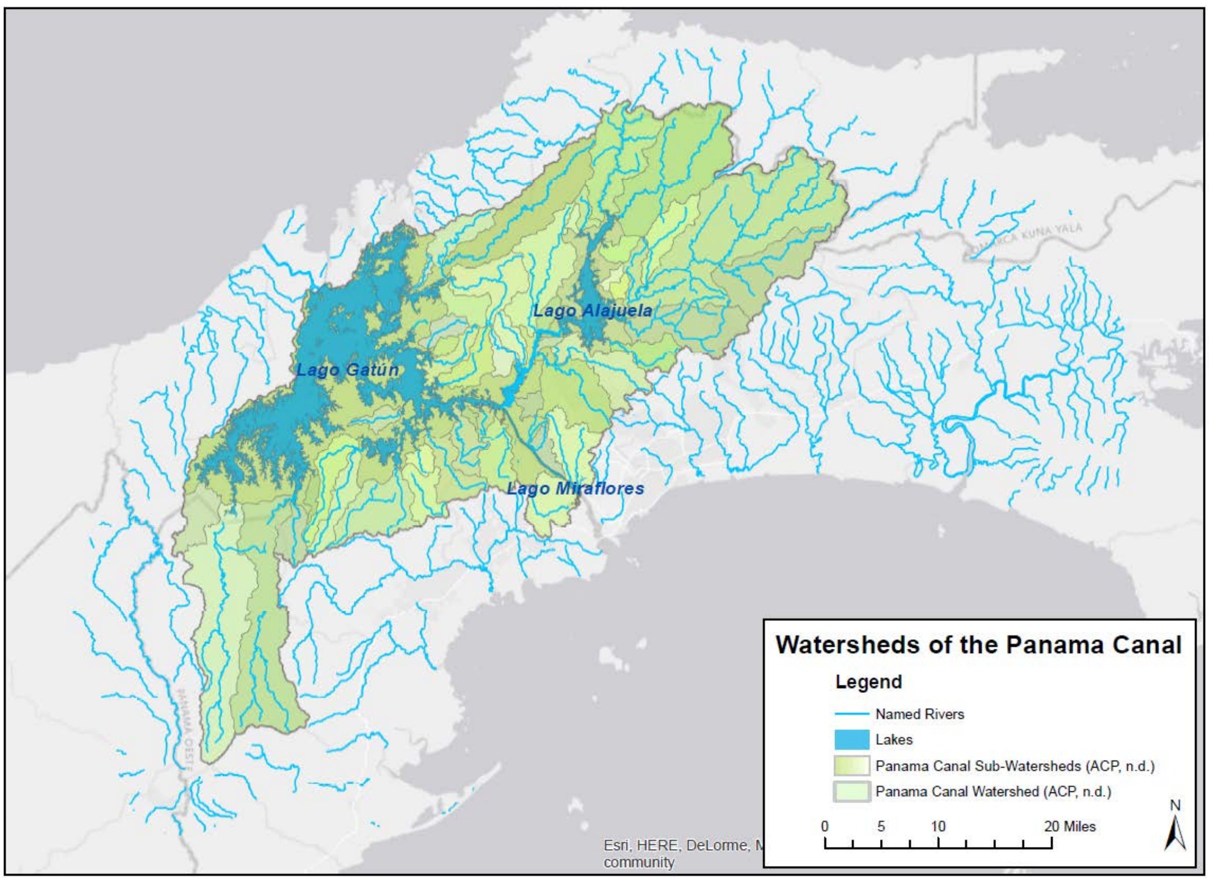

Figure ES.1 – Watershed boundary and fresh surface water bodies in the Watershed and near the Panama Canal

Because of the growing navigation and M&I uses of water from the Watershed, ACP is concerned about the ability of the available resource to supply both needs in the future. In 1999, ACP commissioned a long-term M&I water demand forecast for the areas receiving water from the Watershed (2000 Study; Harza 2000). This forecast was based on a demand forecast model created for the region (2000 Demand Model), and consisted of estimates of water demand between 2000 and 2060 for "optimistic" (high growth), "probable", and "pessimistic" (low growth) scenarios. In recent years ACP has observed that actual water use has exceeded the forecasts from the 2000 Demand Model, raising additional concerns that available supplies from the Watershed may not be sufficient to meet all navigation and M&I demands in the future. As a result, ACP commissioned the current study to:

- Investigate the reasons for the difference between actual and forecasted water demands;
- Update the demand forecast model;
- Prepare revised forecasts of future M&I demands from the Panama Canal Watershed from 2020 to 2050;
- Compare results to other Latin American cities; and
- Summarize conceptual alternatives for developing additional M&I water sources.

This project was completed by Stantec under contract to ACP. Stantec subcontracted with Centro de Estudios Latinoamericanos (CELA) for conducting population forecasts, economic forecasts, relationships between economic parameters and non-residential water use, and research into demographic, economic and other information for Latin American cities similar to Panama City. Preliminary project documentation in the form of technical memoranda was reviewed by ACP staff, and four workshops were conducted to discuss study methods and interim results.

ES-2 Data Sources

Data required for the Study was collected from local governmental agencies. Water related data was obtained from ACP and Instituto de Acueductos y Alcantarillados Nacionales (IDAAN), the municipal water utility supplying all the area within the Canal region. Demographic and economic data was obtained primarily from Instituto Nacional de Estadistica y Censo (INEC).

Stantec was responsible for collecting and reviewing the data required for this Study. Stantec was not responsible for the quality of the data obtained from ACP or other agencies. Stantec was not tasked with validating the accuracy of the data and was not in a position to determine its veracity. Stantec relied on the data collected from public agencies for preparation of the water demand and raw water consumption forecast.

Primary sources of M&I water use data used to support this study are summarized **Table ES.1**.

Table ES.1 – Summary of M&I water use data sources

Data Type	Data Set	Period of Record	Source
Raw Water Extraction Data	Monthly extractions from Lake Gatun and Lake Alajuela	Lake Gatun from 01/1914 – 10/2017 Lake Alajuela from 01/1978 – 12/2012	ACP
Water Production Data	Monthly volume of water produced at WTPs*	Monthly, January 2000 – December 2017	ACP and IDAAN
Water Consumption Data	Monthly for corregimientos and types as described in Section 2.3	Monthly, January 2000 – December 2017	IDAAN
Population Data	Annual by corregimiento from 2000 to 2017	Annual, 2000 to 2017	INEC
Economic Data	Monthly INEC economic indicators	Monthly, 2000 to 2017	INEC

*water treatment plants

ES-3 Previous Forecast Evaluation

Forecasted water demands from the 2000 Study were compared to observed data for the period 2000-2017 to identify differences between actual and forecasted demands and inform the development of the updated Demand Model.

The 2000 Demand Model forecasted water demands from 2000 to 2060 in three categories: residential, non-residential, and unaccounted-for-water (UFW). Residential demands were forecasted by multiplying a fixed per capita water consumption rate by a projected future population and increasing the unmetered population’s consumption by an excessive use percentage. Non-residential demands were forecasted by multiplying an economic activity parameter (e.g. number of tourists, tonnage of cargo) by a water consumption rate. UFW was forecasted by applying a water loss percentage to the residential and non-residential consumption. The 2000 Study forecasted demands for three future population projections: optimistic, probable, and pessimistic.

2000 Study forecasts were compared to IDAAN observed consumption data for the period 2000 to 2017. The 2000 Study forecasted demands in Population Zones developed by CELA for the 2000 Study, while IDAAN observed consumption was provided by IDAAN region. The IDAAN regions and Population Zones are shown in **Figure ES.2**.

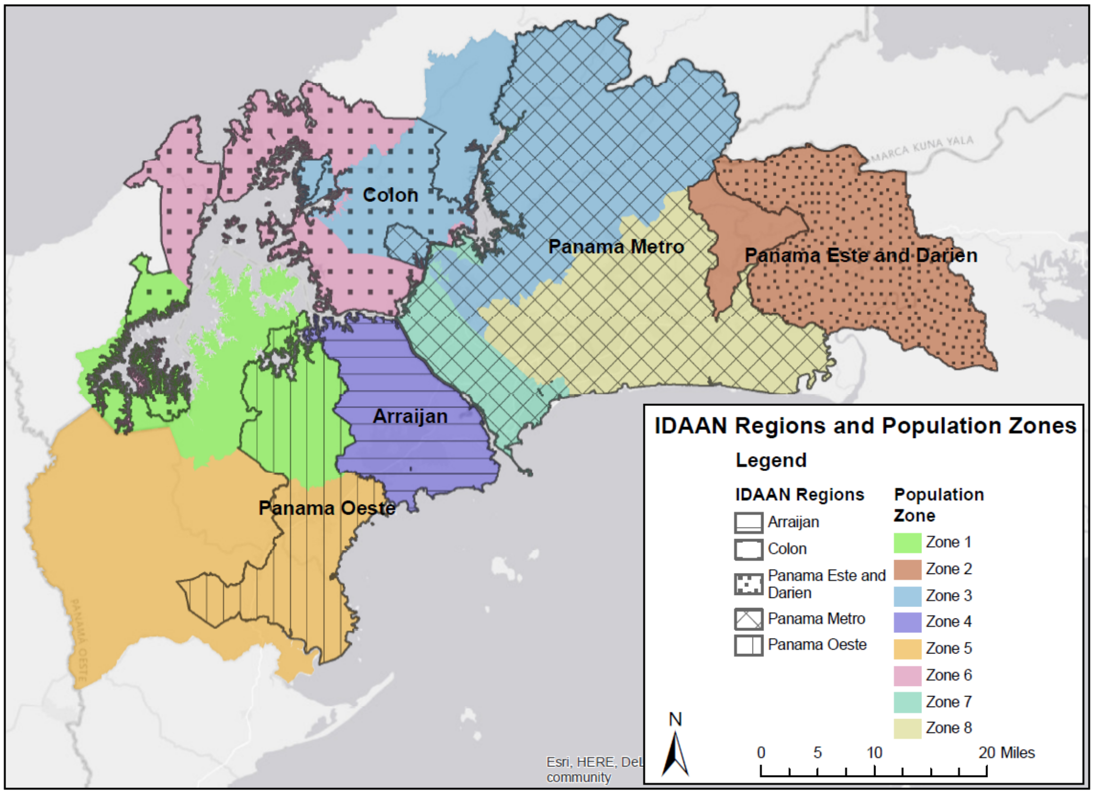

Figure ES.2 – IDAAN regions and Population Zones used in the Study

The comparison of actual to forecasted total water requirement (i.e., total water necessary to be produced at WTPs to supply all customer demands and all system losses) is shown in **Figure ES.3** for the period 2000-2017. Actual total water requirement includes all extractions from Gatun and Alhajuela lakes. Forecasted data only includes water use in areas for which IDAAN has actual recorded or estimated water use (Population Zones 3, 4, 6, 7 and 8). This highlights how observed total water requirement grew more rapidly than the 2000 Study forecast, exceeding the forecast after 2010. When the components of the 2000 Study forecast were compared to the IDAAN observed data, observed residential and non-residential consumption were found to be lower than what was forecasted, as shown in **Figure ES.4**. Note that in the 2000 Study non-residential demand forecast was not varied by scenario. However, observed UFW was higher than what was forecasted, as shown in **Figure ES.5**. This difference in UFW is significant enough to cause the observed total water requirement to be greater than what was forecasted by the 2000 Study.

This informed the update of the Demand Model in two ways. First, the Demand Model should improve the forecasting of UFW. Second, the Demand Model should better capture both the variability in the IDAAN observed consumption data and the uncertainty in the future conditions such as population and the number of customers metered. Therefore, the updated Demand Model was developed to incorporate concepts of planning under uncertainty, which has been successfully applied in water resources planning problems throughout the world.

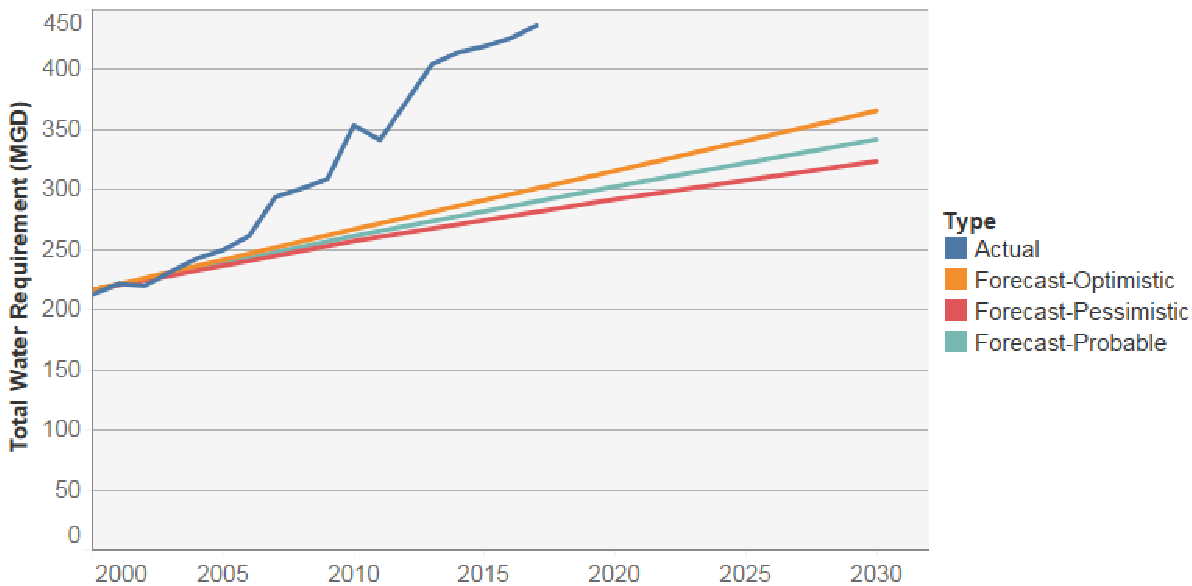

Figure ES.3 – Comparison of 2000 Study forecasted total water requirement and IDAAN observed consumption data for Population Zones 3, 4, 6, 7 and 8

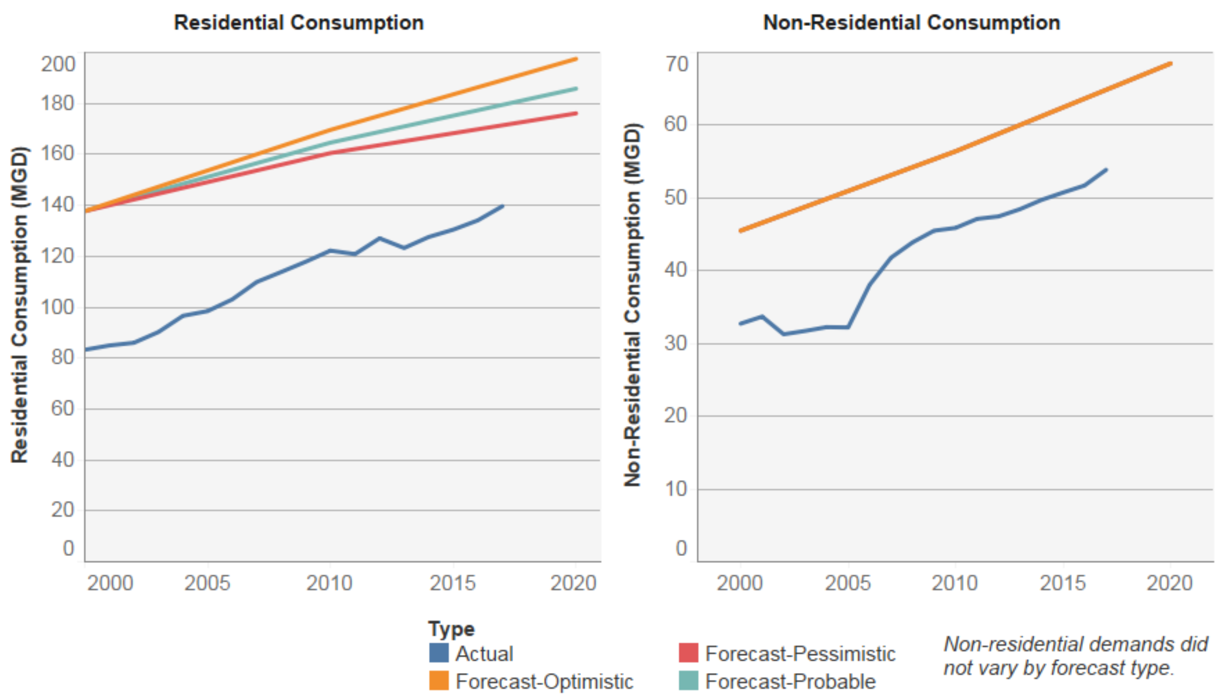

Figure ES.4 – Comparison of 2000 Study forecasted residential and non-residential consumption and IDAAN observed consumption data for Population Zones 3, 4, 6, 7 and 8

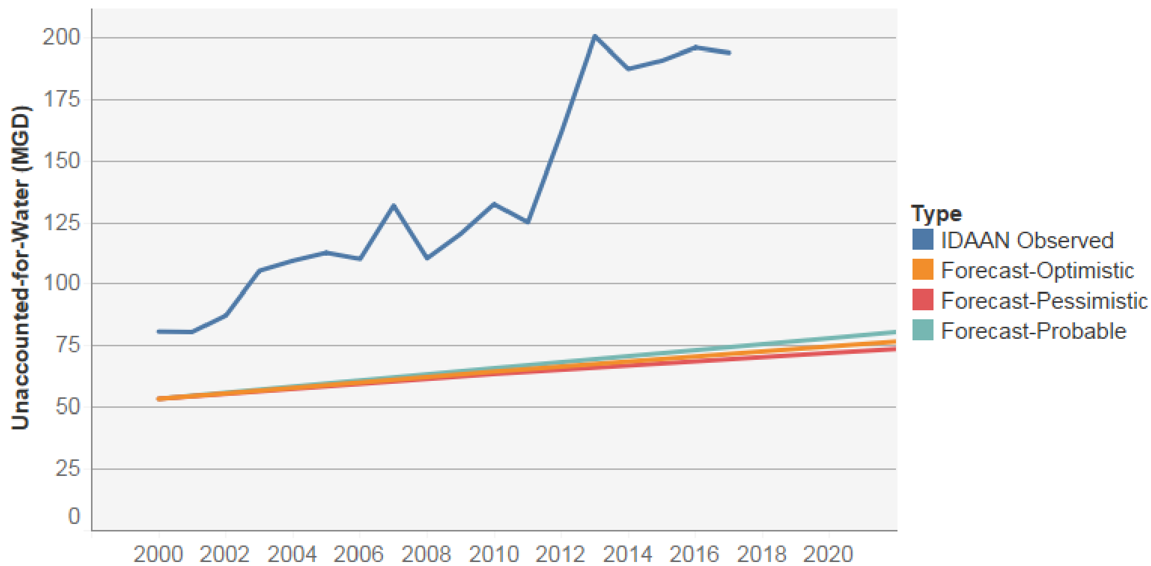

Figure ES.5 – Comparison of 2000 Study forecasted UFW and IDAAN observed data for Population Zones 3, 4, 6, 7 and 8

ES-4 Demand Forecast Model Development

Figure ES.6 shows conceptually the potential destinations for water extracted from the Watershed. The objective of the Demand Model needed by ACP is to estimate future extractions from the Watershed for M&I purposes. WTPs must extract the volume of water from the Watershed required to meet M&I demands of customers connected to the water distribution system plus losses in the WTP and distribution system. The Demand Model forecasts these M&I demands and losses for the Population Zones shown in **Figure ES.2** in 5-year increments from 2020 to 2050.

The Demand Model forecasts the future water requirement using parameters grouped into three water-use categories: residential use, non-residential use, and infrastructure losses. Residential and non-residential consumption is categorized as “beneficial use consumption,” which is water that is actively used by any person, business, or industry. This includes water use that is metered and unmetered or unaccounted for, as long as it was delivered to a customer and put to beneficial use. The Demand Model assumes that people who currently receive water from IDAAN will continue to do so in the future. There is also a segment of the population who does not receive a reliable supply of water from the IDAAN system who will be included in the Demand Model. Water that is not put to beneficial use either due to leakage or losses from the distribution system is considered lost.

Beneficial accounted for consumption is divided into residential and non-residential components in the Demand Model. Residential water use includes water used for all domestic purposes in homes, apartments, etc.; and non-residential water use includes water used for commercial, industrial, and government purposes.

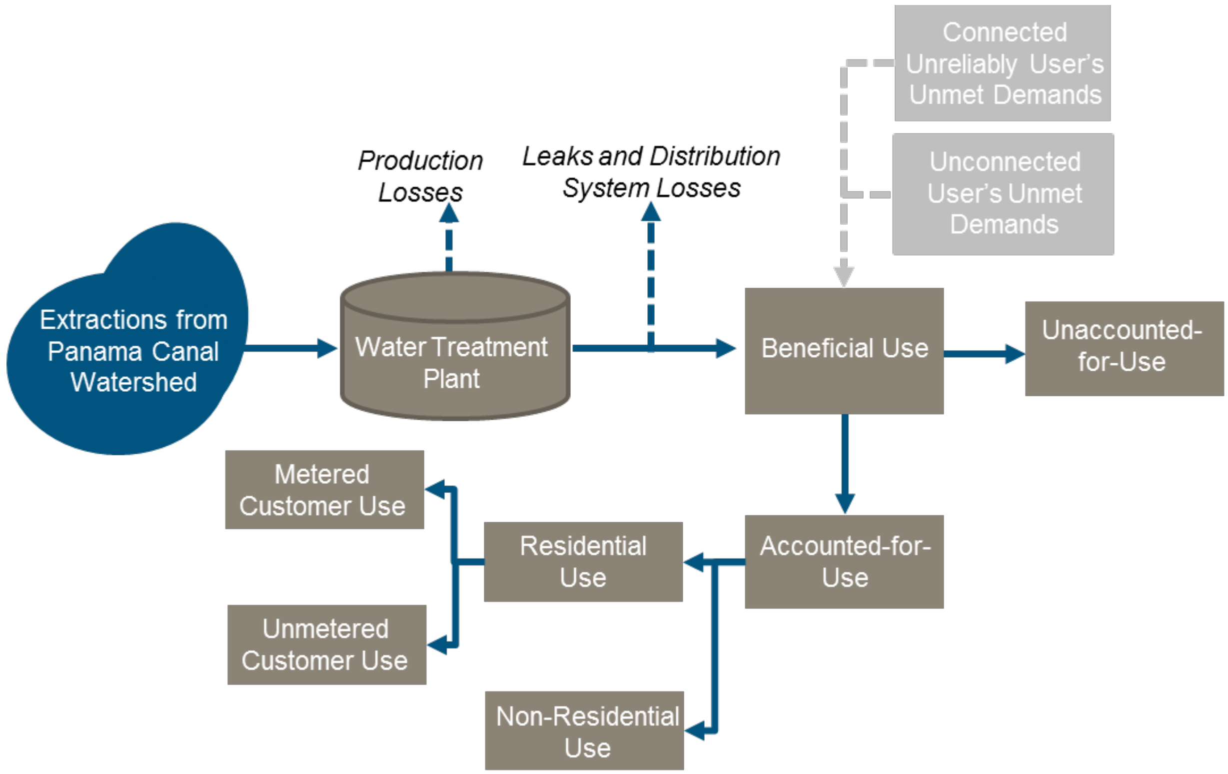

Figure ES.6 – Schematic of water use components included in Demand Model

Residential consumption is forecasted by multiplying population of a water user type (e.g. metered, unmetered) by an associated per capita use rate. Per capita use rates and water user type population estimates were developed for metered and unmetered customers and four corregimiento development types: urban, suburban, rural, and vacation. By developing different per capita use rates and dividing the population into these different development types, the Demand Model better captures the variability seen in the IDAAN observed consumption data from 2000 to 2017. Unmetered per capita use rates are based on the IDAAN observed consumption data and are significantly higher than metered per capita use rates.

The Demand Model forecasts non-residential consumption using two economic parameters developed and tracked by INEC: the Monthly Principal Economic Indicators (PIEM, in Spanish) and the Monthly Economic Indicators (IMAE, in Spanish). Regression equations to estimate future non-residential water use were developed for each Population Zone using IDAAN observed consumption data as the dependent variable and the PIEM and IMAE economic indicators as the independent variables.

The Demand Model forecasts physical system losses by assuming a percentage of the water extracted from all sources is lost in the WTP production process and in the water distribution system. Based on a limited amount of local data supplemented with research into other water utilities, the WTP production loss rate was assumed to be 10 percent of water production and distribution system infrastructure losses were assumed to be 20 percent of water production.

To account for the variability in the IDAAN observed consumption data and the uncertainty in future conditions, a planning scenario methodology was applied in which certain parameters in the Demand Model were set according to plausible future conditions that could occur. In total, the following six parameters in the Demand Model can be changed:

- **Future Population** – Does future population growth occur at a faster or slower rate than recently observed history
- **Economic Activity** – Does the economic growth occur at a faster or slower rate than recently observed history
- **Water System Connection** – How much of the population not reliably connected to the IDAAN system currently gains access to a reliable supply of water in the future
- **Metering and Accounting** – How much of the population is metered by IDAAN
- **Asset Management** – Are improvements made to WTP and distribution system infrastructure and operations to reduce losses
- **Service Area Expansion** – Does IDAAN expand the geographic area served by the Watershed beyond the eight Population Zones

The future population parameter was set according to three population growth projections: optimistic, probable, and pessimistic. The economic activity parameter was set according to three economic growth projections: high, probable, and low. The population growth projections and economic growth projections were combined accordingly as listed in **Table ES.2**.

Table ES.2 – Population and economic growth projection scenario combinations

Scenario	Population Scenario	Economic Scenario
Optimistic/High	Optimistic	High
Probable/High	Probable	High
Optimistic/Probable	Optimistic	Probable
Probable/Probable	Probable	Probable
Pessimistic/Probable	Pessimistic	Probable
Probable/Low	Probable	Low
Pessimistic/Low	Pessimistic	Low

The remaining parameters were set according to four water system scenarios that represent plausible future conditions of the IDAAN water system. The four water system scenarios are shown in **Table ES.3** and are:

- **Current** – Future water system connection and IDAAN management is consistent with the recent history.
- **Minimum Water Requirement** – Future water system connection remains the same, the service area is not expanded, asset management is significantly improved, and full

metering of customers is completed. This scenario gives the low reasonable bookend of future water requirement.

- **Maximum Water Requirement** – Additional population is connected reliably to the IDAAN system, the Study Area is expanded to include Population Zone 9, no improvements are made to accounting, metering, or billing and there is no change in asset management. This scenario gives the high reasonable bookend of future water requirement.
- **Probable** – Additional population is connected reliably to the IDAAN system, the service area is not expanded, IDAAN moderately improves its accounting, metering, and billing program, and IDAAN has minor additional asset management investment. This scenario represents the most likely future water requirement based on input from ACP staff in the second project workshop.

Table ES.3 – Water system scenarios simulated in Demand Model

	Water System Scenario			
Scenarios	Current	Minimum Water Requirement	Maximum Water Requirement	Probable
Water System Connection Scenario	Current	Current	Improved (50% of current unconnected residents are connected)	Improved (50% of current unconnected residents are connected)
Metering and Accounting Scenario	Current	Full (95% of customers are metered)	Current	Moderate (50% of current unmetered customers are metered)
Asset Management Scenario	Current	High (50% reduction in losses)	Current	Minor (25% reduction in losses)
Service Area Expansion Scenario	Current	Current	Population Zone 9 (could be proxy for some other new service area)	Current

The water system scenarios listed in **Table ES.3** were simulated in the Demand Model across each combination of population growth and economic growth projection listed in **Table ES.2.** Total future water requirement was forecasted for 28 different future conditions.

Forecasted water requirement from the four water system scenarios is based on assumptions around service area expansion, population connection, metering, and asset management. The water demand system will gradually change through time as changes are implemented, however in the Demand Model these gradual changes are simulated as instantaneous in time. For example, it is unlikely that the changes in metering and infrastructure assumed in the Minimum Water Requirement scenario will be in place by 2020. However, it is possible that those changes will be fully implemented by 2050. Therefore, when developing the High, Medium, Low, and No Action demand forecasts, results from the Current water system scenario were gradually combined through the future with results from the demand forecast scenario's water system scenario. This captures the gradual transition of the IDAAN system from current conditions to the future assumed conditions.

ES-5 Future Demand Forecast Results and Analysis

Figure ES.7 shows the forecasted future water requirement in million gallons per day (MGD) of the four water system scenarios (listed in **Table ES.3**) under the seven population and economic growth projections (listed in **Table ES.2).** The charts in this figure assume all the conditions in each scenario take effect immediately in 2020. Adjustments to account for the transition from existing demands are described below.

Under the Current scenario, future water requirement is expected to grow from 510 MGD to between 775 MGD and 860 MGD in 2050, depending on future population and economic growth. The Maximum Requirement conditions increase future water requirement by approximately 100 MGD compared to the Current scenario. Probable and Minimum Requirement conditions could significantly reduce future water requirement by 250 MGD and 400 MGD, respectively, in 2050. Comparing results across the four water system scenarios shows that there is significant variability in future water requirement depending on how IDAAN manages the water system.

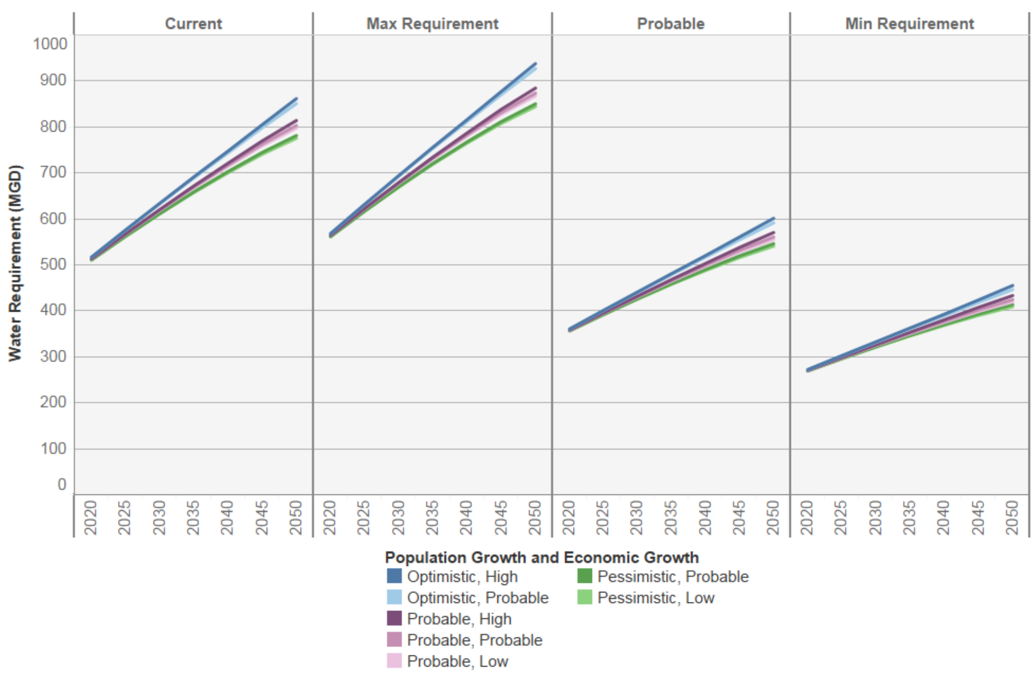

Figure ES.7 – Forecasted total water requirement of the four water system scenarios under the seven population and economic growth forecasts

Figure ES.8 shows the residential consumption component of the total water requirement across the four water system scenarios and the probable population growth projection, highlighting the source of the significant variability in future water requirement. Note that Partially Met Demands represent residential consumption by people who are connected to the IDAAN system but do not receive a reliable supply of water. Conditions of the Maximum Requirement and Current scenarios produce a high volume of unmetered consumption as unmetered water users have a significantly higher per capita consumption rate than metered water users. The Probable and Minimum Requirement scenarios assume that a significant portion of presently unmetered water users become metered water users, which reduces both unmetered consumption and total residential consumption. Because losses in the Demand Model are forecasted as a percent of residential and non-residential consumption, any reductions in these types of consumption will also reduce losses.

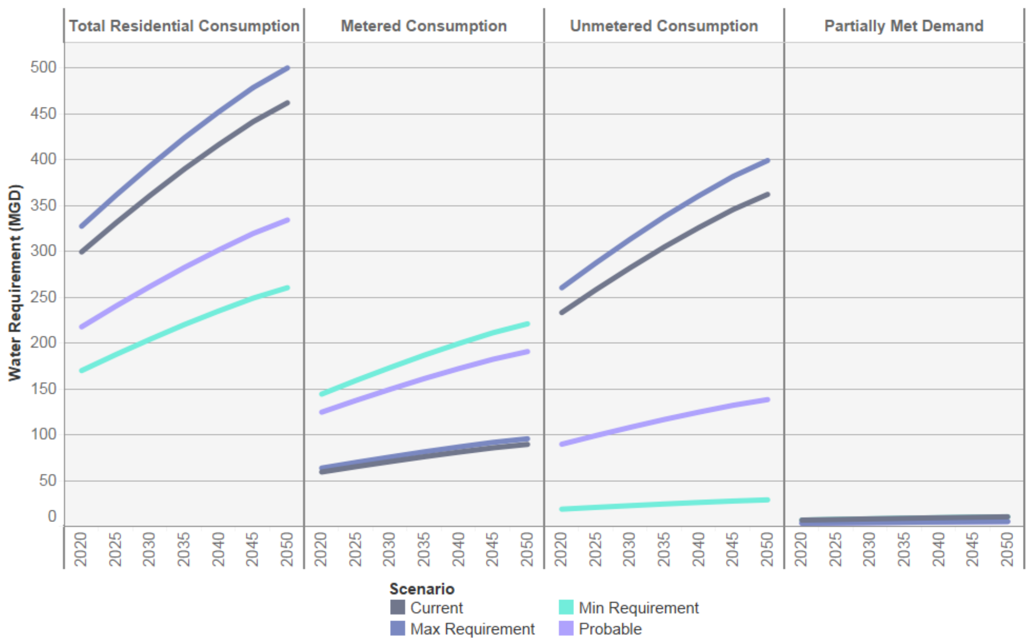

Figure ES.8 – Comparison between water system scenarios of forecasted residential consumption and its components under probable population projection

Results from these 28 future conditions were analyzed and used to develop four demand forecast scenarios for use by ACP in future planning. These are defined as:

- **High scenario** – Maximum Water Requirement water system scenario under the optimistic population growth projection and the high economic growth projection
- **Medium scenario** – Probable water system scenario under the probable population growth projection and the probable economic growth projection
- **Low scenario** – Minimum Water Requirement water system scenario under the pessimistic population growth projection and the low economic growth projection
- **No Action scenario** – Current water system scenario under the probable population and economic growth projections

Figure ES.9 displays and **Table ES.4** lists the future water requirement for the High, Medium, Low, and No Action future demand forecast scenarios. In each of these scenarios the estimated demand assumes a gradual transition of the IDAAN system from current conditions to the assumed future conditions. Future water requirement across the four future demand forecast scenarios will be relatively similar to 2025 as the water system is assumed to be similar to current conditions. After 2025, water requirement will continue to steadily increase under the High scenario as population grows and no changes are made to metering or asset management, ultimately reaching 925 MGD at 2050. Under the Medium scenario, water requirement will slowly increase, reaching a maximum of 590 MGD from 2035 to 2040 before slowly decreasing to 560 MGD at 2050. Under the Low scenario, water requirement will reach a maximum of 562 MGD at 2025 before steadily decreasing to a value of 408 MGD at 2050.

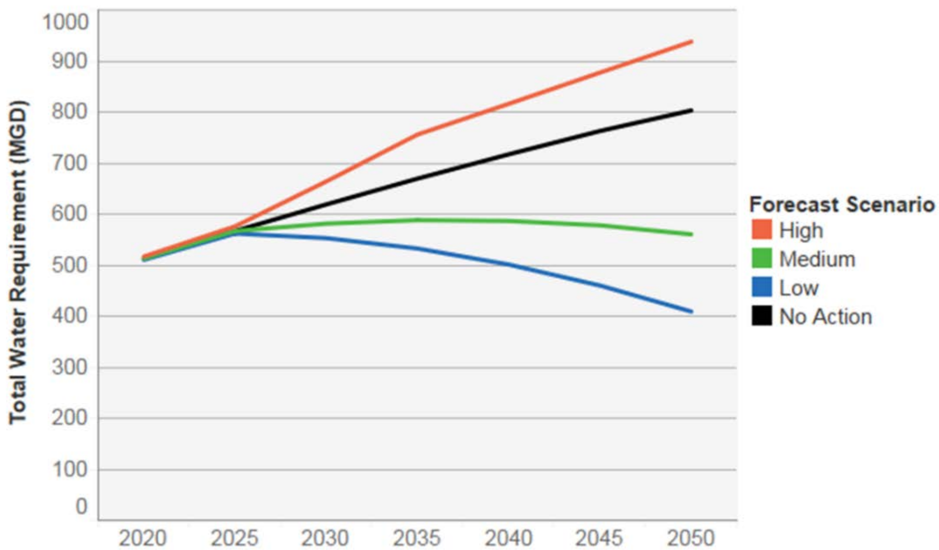

Figure ES.9 – Forecasted total water requirement for High, Medium, Low, and No Action demand forecast scenarios

Table ES.4 – Summary of forecasted total water requirement demand forecast scenarios

Year	Total Water Requirement (MGD) High Scenario	Medium Scenario	Low Scenario	No Action Scenario
2017	437	437	437	437
2020	517	513	510	513
2025	576	567	562	567
2030	664	581	553	619
2035	756	588	532	670
2040	817	586	501	717
2045	878	578	459	763
2050	939	560	408	803
2017 to 2050 Average Annual Growth Rate	2.34%	0.75%	-0.21%	1.86%

Figure ES.10 shows the components of the forecasted total water requirement for the four demand forecast scenarios. Residential consumption, non-residential consumption, and losses under the High scenario are all higher than the Medium and Low scenario and increase through 2050. Non-residential consumption increases to 2050 across all four scenarios even with decreases in the Medium and Low scenario residential consumption and losses. This is because non-residential consumption is tied to economic growth with the demand model assuming that any economic growth will lead to growth in non-residential consumption.

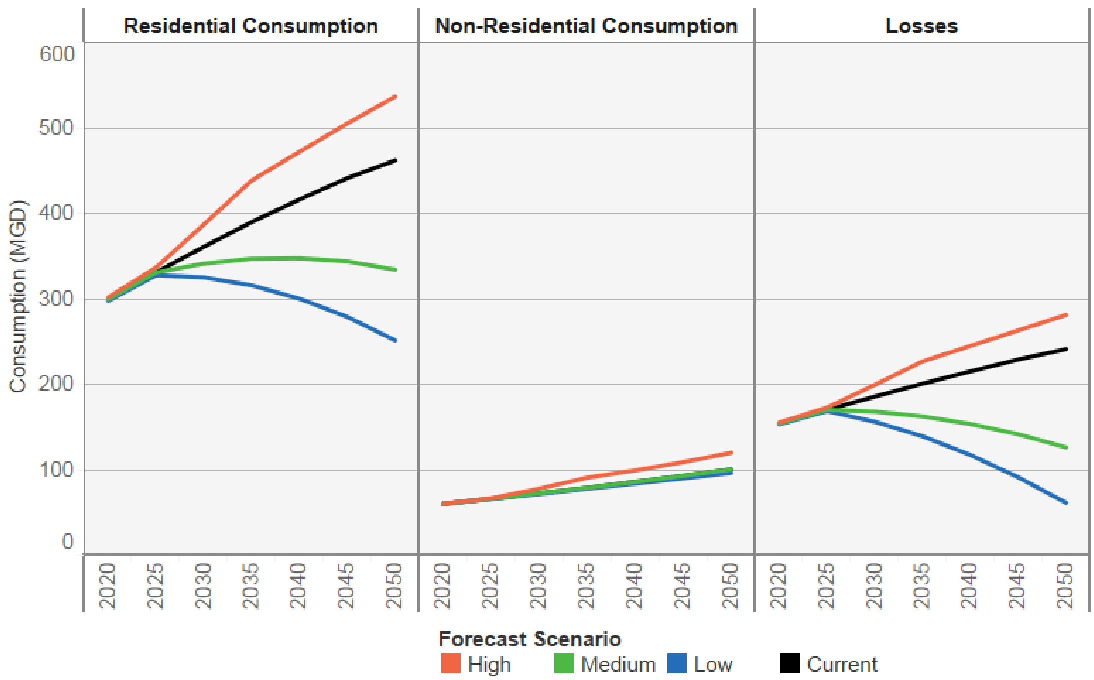

Figure ES.10 – Components of forecasted total future water requirement under the four demand forecast scenarios

Figure ES.12 shows the 2050 total water requirement by Population Zone for the four demand forecast scenarios and **Figure ES.13** shows the average annual growth in total water requirement between 2020 and 2050. Note that because Population Zone 9 does not have a total requirement in 2020, its growth rate is not included. Population Zones correspond to the key shown in **Figure ES.11**. At 2050, Population Zone 8 has the highest total water requirement across all three demand forecast scenarios. Population Zone 8 also has the highest variability in total water requirement across the three demand forecast scenarios, with a difference of 247 MGD between the High and Low scenario. Population Zones 3, 4, and 8 all have the highest percentage variability among the three scenarios ranging from 150 percent to 160 percent. These Population Zones with high variability are geographically where changes in metering and asset management will have the most significant impact and where future efforts could be focused.

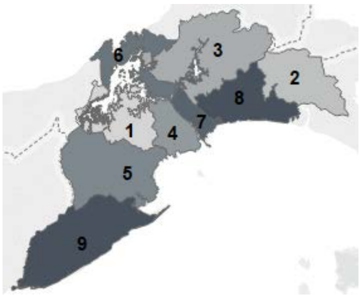

Figure ES.11 – Study Area Population Zones key

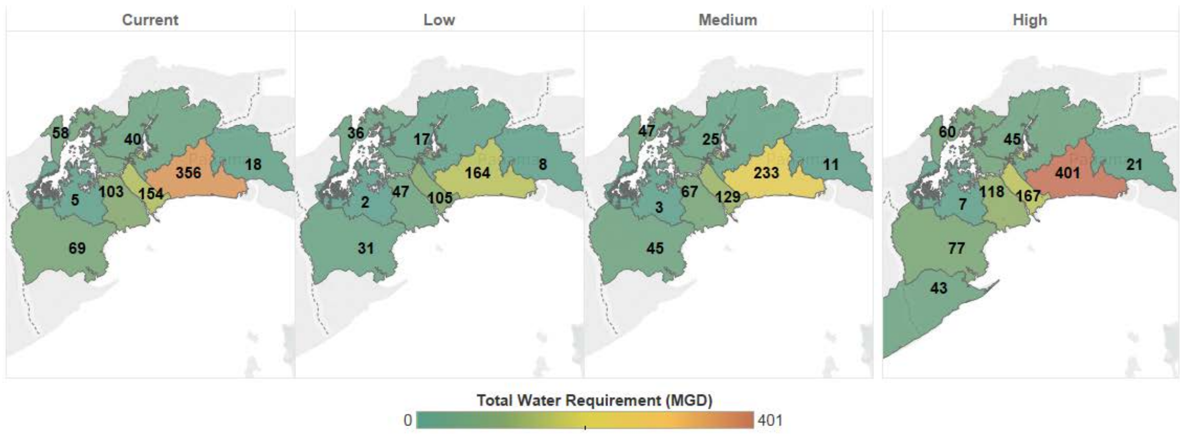

Figure ES.12 – 2050 total water requirement by Population Zone for the four demand forecast scenarios

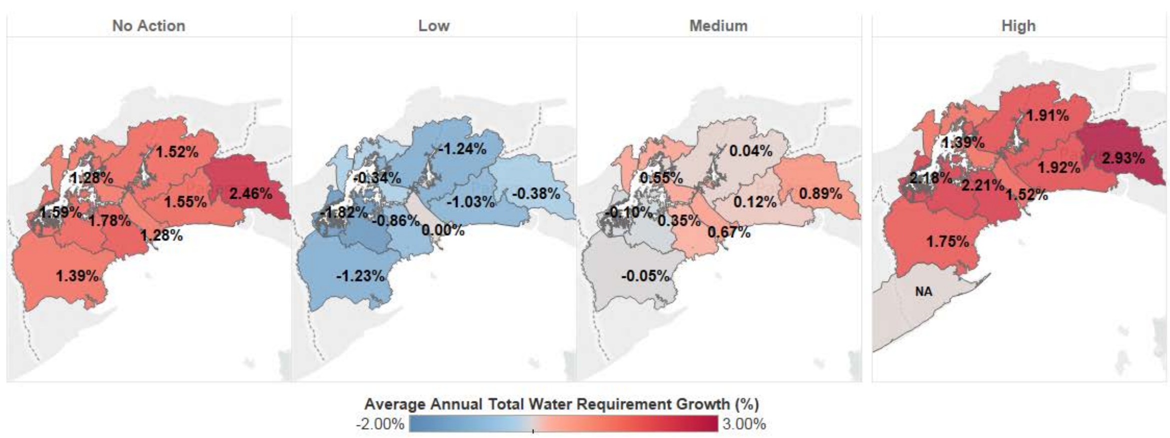

Figure ES.13 – Average annual growth rate in total water requirement by Population Zone for the four demand forecast scenarios

ES-6 Comparison of Results to Other Studies and Locations

Results from the Study (referred to as the 2018 Study in this section for clarity) and the population and economic growth projects used in modeled scenarios were compared to similar information from the 2000 Study.

Population growth projections from the 2018 Study are all higher than the 2000 Study, with differences in population between the two studies in 2050 varying from 1 million to 1.75 million. Additionally, the 2000 Study's Pessimistic growth projection showed population decreasing by 2050 while all population growth projections from the 2018 Study show population increasing.

Figure ES.14 shows how the forecasted total water requirement compares between the two studies under the three similar forecast scenarios (Optimistic/High, Probable/Medium, and Pessimistic/Low). The 2018 Study's High scenario forecasts future water requirement to be significantly higher than the 2000 Study's Optimistic scenario. The Medium scenario's future water requirement is approximately 100 MGD higher than the 2000 Study's Probable scenario. The Low scenario's future water requirement is nearly the same as the 2000 Study's Low scenario.

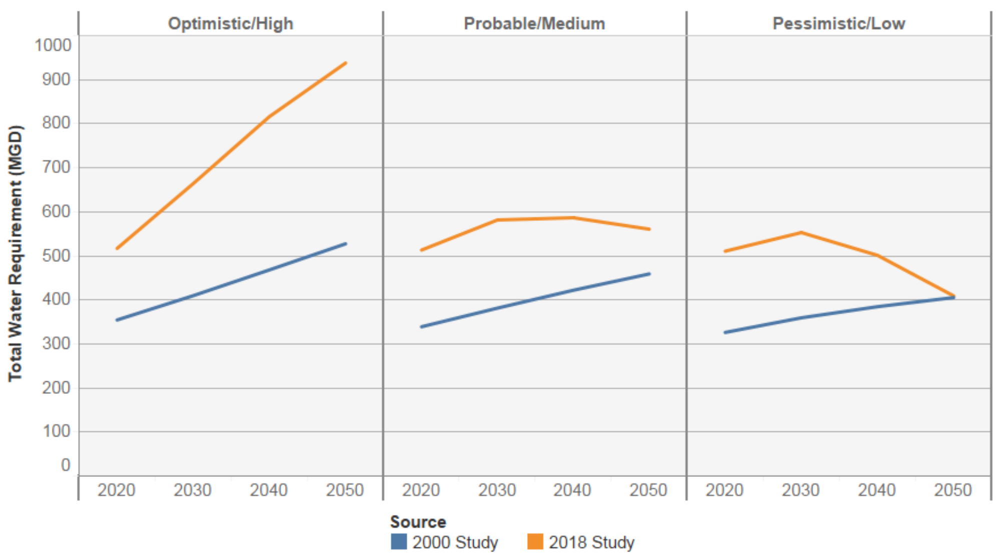

Figure ES.14 – Comparison of future total water requirement between the 2018 Study's High/Medium/Low scenarios and the 2000 Study's Optimistic/Probable/Pessimistic scenarios

Figure ES.15 depicts the total per capita water consumption in other Latin American countries in 2015 based on available data from the Inter-American Development Bank (IDB) and World Bank (IDB 2017, World Bank 2018). This data source estimates water consumption for Panama at 96 gallons per capita per day (GPCD), which is at the upper end of the range for Latin American countries.

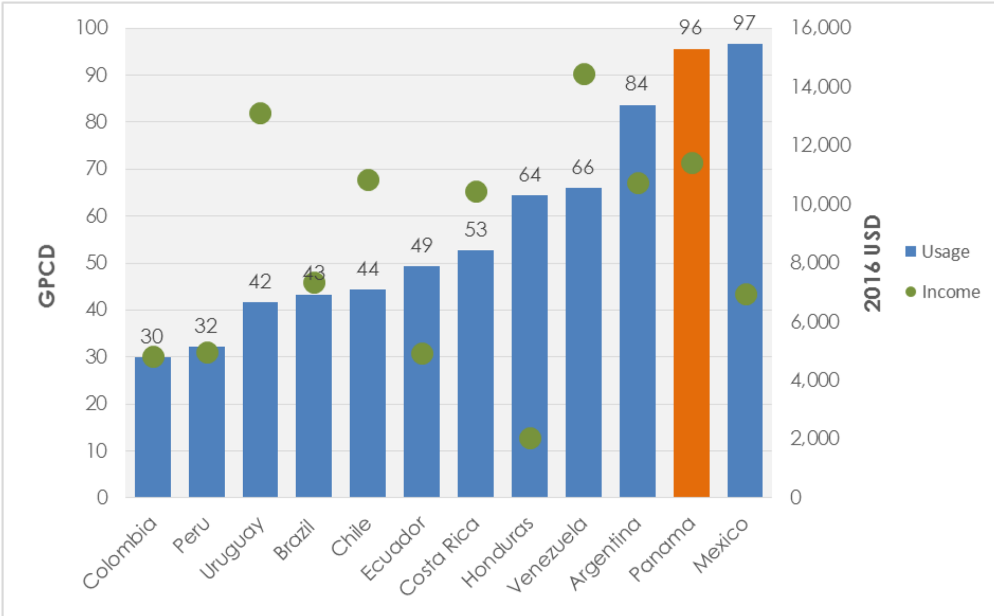

Figure ES.15 – Total per capita water consumption and net national income per capita for various Latin American countries

Figure ES.16 shows the median price of water per cubic meter in Latin American countries for which consistent data was available. The median price of water sold by water utilities in Panama is significantly less than that of most Latin American water utilities. This comparison suggests that Panamanians use more water and pay less for it than most other Latin Americans.

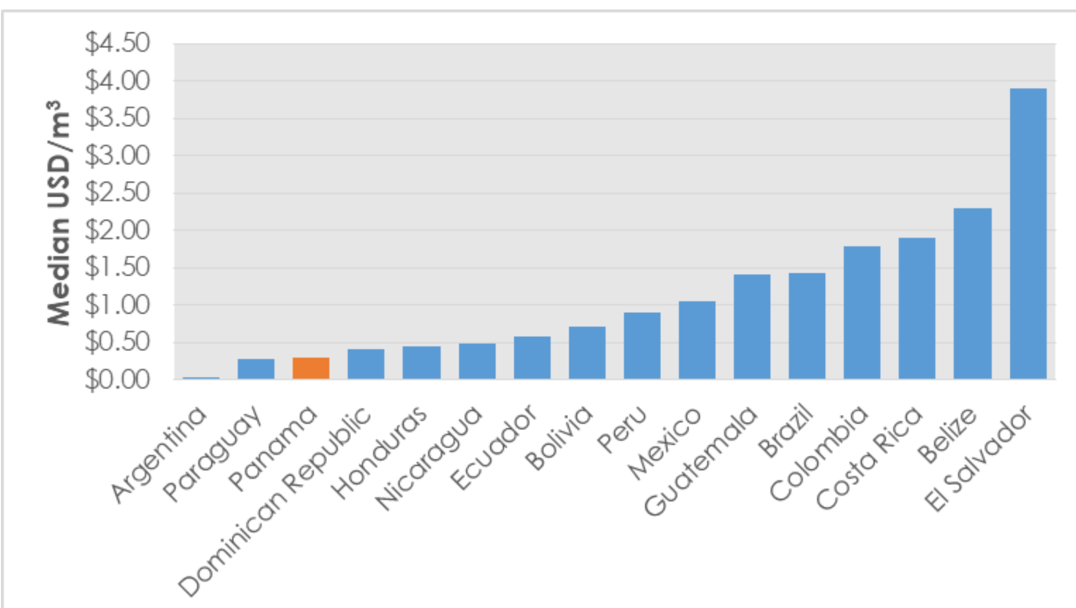

Figure ES.16 – Median price of water per cubic meter for various Latin American countries

A more detailed comparison was performed for water use patterns in Panama City, Cartagena, Colombia and Guayaquil, Ecuador. The other two Latin American cities were selected based on their similarity to Panama City in terms of size, location and economic activity. Key comparisons are summarized in **Table ES.5**. The following conclusions for water use conditions in the Panama City study area were drawn.

- Panama City per capita use is significantly higher than the other two cities.
- Both Cartagena and Guayaquil have high percentages of the population served with a reliable water supply and very high percentages of metering, but a low per capita use rate. This may show the value of a metering program in reducing per capita use.
- More efficient use in Cartagena and Guayaquil compared to Panama City indicates a greater emphasis on and investment in applying best practices in water management, which may be partially attributed to privatization of their municipal water utilities. In general, the price of water in Panama City is lower than in Guayaquil, but may be higher or lower than in Cartagena, depending on the residential use category.
- Appropriate water pricing policies and investment of the additional revenue in the Panama City water supply system could be expected to reduce per capita use rates based on comparison with Cartagena and Guayaquil.
- All three cities rely almost entirely on surface water resources. Like Panama City, neither Cartagena nor Guayaquil have invested heavily in alternatives to their historical surface water sources such as groundwater, wastewater reuse, or desalination.

Table ES.5 – Comparison of Three Latin American cities

Statistic	Cartagena	Guayaquil	Panama City
Population (2016)	1,288,490 (1)	2,788,363 (2)	880,691 (9) – Panama City proper / 1,489,952(6a) IDAAN Panama Metro área (2015)
City area (km²)	572	345	275
Population density (people/km²)	1,699	5,660	3,203
Production of drinking water (2015)	79 MGD (3)	260 MGD (2)	303 MGD (6a) Panama Metro water service area only
Per capita water consumption	40 GPCD (8)	45 GPCD	104 GPCD (10)
Percentage of population served with reliable water supply	99.9% (3)	75% (2) – 97%	84% (6b)
Percentage of UFW	31% (3)	54% (2)	40% - 55%
Percentage of metered customers	99% (3)	99% (2)	57%
Average price of water (average of all customer categories) (11)	\$0.11/m³ (3) (2015)	\$0.55/m³ (2015)	\$0.21/m³ (2018)
Movement of containers, 2017 (TEUS)	2,561,000 (7)	1,871,591 (7)	2,986,617 (Balboa) (7) 3,891,209 (Colón) (7)
Port Ranking in Latin America (2018)	5th	7th	2nd
Emphasis on water conservation	Moderate	Fair	Poor

1. Departamento Administrativo Nacional de Estadística, Republica de Colombia.
2. Proyección al año 2016 de Interagua, *Ajuste y revisión del plan maestro agua potable, alcantarilla sanitaria y alcantarilla pluvial* Tomo1, Guayaquil: Interagua.
3. Aguas de Cartagena, 2016, *Reporte de sostenibilidad*, Cartagena: Aguas de Cartagena.
5. Instituto Nacional de Estadística y Censo (IDEN), (2016), Panamá.

6a. IDAAN, 2016, *Boletín Estadístico*, Nº29, Cuadro B.1, Panamá.

6b. IDAAN, 2016, *Boletín Estadístico*, Nº29, Cuadro A-3, Panamá.

8. Angulo et al, 2017, “Cartagena’s Water Distribution System”, *Procedia Engineering,* 186(2017),28-35.
9. Population for Panana Metro área. Source: INEC.
10. Based on Panama Metro consumption data for 2015 from IDAAN *Boletín Estadístico*, Nº29
11. Calculated total revenue divided by total volume of water sold.

ES-7 Future Water Supply Options

Current WTP capacity to supply water to the Study Area is about 424 MGD for WTPs drawing from the Watershed (409 MGD) and from other sources (15 MGD). This capacity is exceeded by nearly all 28 of the total water requirement forecasts well prior to 2050. A range of options inside and outside the Watershed were evaluated for increasing water supply to meet future water needs in the area served by the Watershed. These are summarized in **Table ES.6**.

Table ES.6 – Summary of water supply alternatives

Alternative	Approximate Yield	Approximate Cost
Current Capacity	424 MGD	-
IDAAN Planned WTP Expansions	185 MGD	$3.7 million/MGD capital cost; conveyance upgrades and O&M not included
Water Efficiency Measures		
Leak and Loss Reduction	56 MGD	$2.6 million/MGD capital cost
Metering (115,000 meters)	48 MGD	$1.2 million/MGD capital cost
Conservation	41-94 MGD in 2050	$1.1 million/MGD for one-time measures; $1.2 million/yr/MGD for ongoing measures
New Freshwater Sources		
Rio Chagres	<73 MGD	$558 million (1) for dam and appurtenances plus $3.7 million/MGD for treatment cost ($11.4 million/MGD)
Rio Pacora	55 MGD	$511 million (1) for dam and appurtenances plus $3.7 million/MGD for treatment cost ($13.0 million/MGD)
Rio Mamoni	50 MGD	No estimate
Bayano Reservoir	Not determined	No estimate
Rio Caimito	60 MGD	$487 million (1) for dam, WTP and appurtenances ($12.3 million/MGD)
Rio Indio	870 MGD	$359 million (2) for dam, inter-basin transfer and appurtenances plus $3.7 million/MGD for treatment ($4.1 million/MGD)

Alternative	Approximate Yield	Approximate Cost
Rio Cocle del Norte	1,499 MGD	$877 million [1] for dam, inter-basin transfer and appurtenances plus $3.7 million/MGD for treatment ($4.3 million/MGD)
Rio Grande	Not determined	No estimate
Groundwater	0	Limited resource
Wastewater Reclamation	0	Impractical compared to other options based on cost and the abundance of freshwater sources
Desalination	0	Impractical compared to other options based on cost and the abundance of freshwater sources

1. Cost in 2018 dollars, escalated 3%/year from U.S. Army Corp of Engineers (USACE) (1999) cost estimates.
2. Cost in 2018 dollars, escalated by 3% per year from MHW (2003) cost estimate

There are many different combinations of structural and non-structural water supply options that would provide sufficient water supply to meet estimated 2050 water demands based on even the most optimistic population, economic and water system projections. Solutions could be developed that do not rely on additional withdrawals from the Watershed. To be conservative, prudent planning for future water supply in the Panama City region should include projects in all of the identified categories.

It is noted that the M&I water supply needs discussed in this report do not consider future needs for navigation. Many of the same projects considered for M&I supply could also be needed to meet increased future navigation demands at the Canal. The use of water from the Watershed for both navigation and M&I water suggests that sources outside the Watershed should be considered carefully for M&I use before additional water within the Watershed is developed for M&I use.

ES-8 Conclusions and Summary

The 2000 Study forecasted future M&I water requirements from the Watershed that also supplies the water used to operate the Panama Canal. This Study updated the 2000 Study by utilizing more recent observed consumption data and more sophisticated methods to generate four new forecasts of future water requirement for the Watershed – a High Forecast, Medium Forecast, Low Forecast and No Action Forecast. The forecasts of future water requirement for these four scenarios are summarized in **Table ES.7**.

Table ES.7 – Summary of forecasted total water requirement demand forecast scenario

Year	Total Water Requirement (MGD) High Scenario	Medium Scenario	Low Scenario	No Action Scenario
2017	437	437	437	437
2020	517	513	510	513
2025	576	567	562	567
2030	664	581	553	619
2035	756	588	532	670
2040	817	586	501	717
2045	878	578	459	763
2050	939	560	408	803
2017 to 2050 Average Annual Growth Rate	2.34%	0.75%	-0.21%	1.86%

The new demand forecasts are up to 78 percent higher than the forecasts from the 2000 Demand Model. New M&I supply of 379 MGD is needed by 2050 for the No Action Forecast. This represents an 89 percent increase over 2017 demand, which is equivalent to 6.9 daily lockages in the Panama Canal. Under the High Forecast 514 MGD of new supply would be needed in 2050, representing a 121 percent increase (9.3 daily lockages) over 2017 demand.

There is substantial variability in forecasted total water requirement between the four demand forecast scenarios. The most significant contributor to this variability is the uncertainty around the percentage of the water customer base that is metered versus unmetered, because unmetered customers were assumed to use water at a much higher rate than metered customers. Therefore, close monitoring of how IDAAN meters and accounts for their water users will help indicate which of the four forecast scenarios is the best representation of actual conditions.

In addition, data from IDAAN indicates that demand is tied to the amount of available supply. Increasing supply through construction of new water treatments plants or development of other water sources makes it possible to connect more customers to the IDAAN system, and provide water more reliably to existing customers whose use is limited by lack of continuous water service. Expansion of the IDAAN customer base should be tracked by ACP in the future; if many new customers are added to the IDAAN system with reliable water service, it could influence total water requirement toward the High forecast.

The Demand Model developed for the Study has several limitations. It is based on historical water use data that has a high degree of uncertainty and variability, causing uncertainty in the results. Due to the limited amount of available data, the non-residential consumption forecast was performed using a simplified approach. Indicators of commercial and industrial activity such as gross domestic product (GDP) or specific major projects should be monitored. The Demand Model also took a conservative approach to forecasting consumption for unmetered customers and assumed a high unmetered per capita use rate. If better data on unmetered per capita use becomes available, it will improve the forecast.

Additional water sources and water resources projects will be needed to meet future M&I demands in the Study Area. Per capita water use including UFW in Panama in general and in the Study Area in particular is higher than in other similar Latin American cities. Therefore, water efficiency measures such as loss reduction, metering and water conservation could be effective in reducing future M&I water demand. In addition to new and expanded WTPs planned by IDAAN in the Watershed, there are a number of potentially feasible surface water development options outside the Watershed that could meet M&I demand in the Panama City region without competing for water needed for future Panama Canal operations. Alternate sources such as wastewater reclamation and seawater desalination do not appear to be competitive with new surface water sources within the 2050 planning horizon.

Abbreviations

2000 Study	2000 Harza Study
2018 Study	Panama Canal Watershed Municipal and Industrial Demand and Raw Water Consumption Forecast, 2020 to 2050 (same as Study)
ACP	Autoridad del Canal de Panama
CELA	Centro de Estudios Latinoamericanos
Demand Model	Panama Canal Watershed raw water requirement forecast model
IB-Net	International Benchmarking Network
IDAAN	Instituto de Acueductos y Alcantarillados Nacionales
GDP	gross domestic product
GIS	geographic information system
GPCD	gallons per capita per day
GPD	gallons per day
IDAAN	Instituto de Acueductos y Alcantarillados Nacionales
IDB	Inter-American Development Bank
IMAE	Monthly Economic Indicators
INEC	Instituto Nacional de Estadistica y Censo
M&I	municipal and industrial
MGD	million gallons per day
PIEM	Monthly Principal Economic Indicators
Study	Panama Canal Watershed Municipal and Industrial Demand and Raw Water Consumption Forecast, 2020 to 2050 (same as 2018 Study)
TM	Technical Memorandum
UFW	unaccounted-for-water
USACE	United States Army Corps of Engineers

Watershed	Panama Canal Watershed
WSA	Water Service Area
WTP	water treatment plant
WHO	World Health Organization

Glossary

Centralized Water Distribution System	Infrastructure facility where potable water is treated at a central location then distributed in pipelines to premises
Cointegration	Refers to statistical techniques that sort out whether relationships between trended data sources are spurious (or due to chance) or meaningful by testing whether such trends follow a common integration or trend.
Connected Unreliably Water User (Residential)	Customer that is connected to a centralized water distribution system but does not have a reliable improved supply of water when needed
Customer	Holder of a water service account with IDAAN
Demand Forecast Scenario	Forecast of water requirement and its' components from 2020 to 2050 considering current conditions.
Economic Growth Projection	Set of conditions used to project future economic activity.
Improved Water Supply	Treated potable water that can be safely consumed by customers
Metered Water User (Residential)	Customer that is connected to a centralized water distribution system, receives a reliable improved supply of water, is accounted for by IDAAN, and has their water use measured
Ordinary Least Squares	Regression technique that minimizes square error terms in the estimation of a fitted line that seeks to explain the relationship between the independent and dependent variables in the model
Population Growth Projection	Set of conditions used to project future population.
Population per Customer	Number of individual people per IDAAN customer account
R^2	Measure of fit (explanatory power) between the dependent variable and the model used. Ranges from 0 to 100 percent.
Reliable Supply	Improved water is available when needed by the customer

Serial Correlation	Statistical phenomenon where data sources are consecutively related, namely whether a past data point is more likely than not to be followed by another one which is higher or lower
t-test	Statistical test that measures the relationship between the excess difference over the expected value of a data sample over its adjusted standard deviation. As the t-test is higher, the relationship is more indicative of a phenomenon not due to chance
Total Water Requirement	Sum of residential consumption, non-residential consumption, and infrastructure losses.
UFW (Residential)	Customer that is connected to a centralized water distribution system, receives a reliable improved supply of water, but is not accounted for by IDAAN.
Unrealized and Unmet Demand	Residential demands that would occur rapidly if a population were to have access to a reliable supply of improved water
Unmetered Water User (Residential)	Customer that is connected to a centralized water distribution system, receives a reliable improved supply of water, is accounted for by IDAAN, but does not have their water use measure
Water System Scenario	Forecast of water requirement and its' components from 2020 to 2050 under an assumed set of water system conditions (e.g. metering, asset management).
When Needed	Improved water supply is available on premises at least 50 percent of the time

1.0 INTRODUCTION

1.1 BACKGROUND

The country of Panama is growing because of a strong economy, stable government and tropical climate. A large portion of that growth is occurring in the Panama City region, and is related to economic activity associated with the Panama Canal (Canal). With the recent addition of the third set of locks, the capacity of the Canal has increased and is carrying more traffic every year.

The Panama Canal Watershed (Watershed) is the land area that drains to the Canal. It provides all the water needed for navigation in the Canal, as well as a majority of the water for municipal and industrial (M&I) needs in the Panama City metropolitan area and other communities near the Canal (such as Colon). The Watershed is critical both for Canal operations and for providing the water needed for residential, commercial and industrial uses in Panama's most populated and urbanized areas.

The Canal and all associated land and facilities, including the Watershed, are managed by Autoridad del Canal de Panama (ACP). This agency is responsible for all planning related to the Canal, including long-range planning for water supply needed for Canal operations. The municipal water utility supplying all the area within the Canal region is Instituto de Acueductos y Alcantarillados Nacionales (IDAAN). IDAAN is responsible for collecting, treating and distributing water for municipal customers, and planning for their future needs.

Because of the competing navigation and M&I uses of water from the Watershed, ACP is concerned about the ability of the available resource to supply both needs in the future. In 1999, ACP commissioned a long-term M&I water demand forecast for the areas receiving water from the Watershed (Harza 2000). This forecast was based on a demand forecast model created for the region (2000 Demand Model), and consisted of estimates of water demand between 2000 and 2070 for "optimistic" (high growth), "probable", and "pessimistic" (low growth) scenarios. In recent years ACP has observed that actual water use has exceeded the forecasts from the 2000 Demand Model, raising additional concerns that available supplies from the Watershed may not be sufficient to meet all navigation and M&I demands in the future. As a result, ACP commissioned the current study to investigate the reasons for the difference between actual and forecasted water demands, and to update the model and prepare revised forecasts of future M&I demands from the Panama Canal Watershed.

1.2 SCOPE OF WORK

The Scope of Work for this study was defined in the Terms of References for the project contract and consisted of the following tasks.

Task 1 – Data Collection. Collect all water use, population and economic data necessary to characterize observed water use, investigate reasons for differences between the results of the 2000 Demand Model and actual water use, and prepare an updated demand model.

Task 2 – Forecast Comparison. Compare actual vs forecasted water demand in the area served by the Panama Canal Watershed for the period 2000-2017, and determine reasons for differences between actual and forecasted water demand.

Task 3 – Demand Forecast Update. Prepare an updated water demand forecast model for the area served by the Panama Canal Watershed, and develop optimistic, probable and pessimistic demand estimates from 2020 to 2050.

Task 4 – Comparative Analysis. Compare water use conditions in Panama and the project study area to other Latin American cities and countries, and prepare a more detailed comparison of water use conditions between Panama City and two Latin American cities. Prepare a high-level evaluation of alternatives for meeting future M&I water demands to 2050.

Task 5 – Report and Technical Transfer. Prepare a project summary report, and conduct a workshop training ACP staff in use of the updated demand forecast model.

1.3 STUDY AREA AND DEFINITIONS

The Study Area consists of the geographic area that is either presently served or could potentially be served in the future by supply sources from within the Watershed. The Watershed boundary and bodies of water are shown in **Figure 1.1**.

Corregimientos were the smallest geographic division used to assemble the water use, population, and other data in the Study Area. When selecting corregimientos to include in the Study Area, all corregimientos included in the 2000 Study and corregimientos that were created after 2000 but within the 2000 Study Area were included.

Corregimientos were added to the Study Area based on consultation with IDAAN regarding long-term plans for expansion of the distribution system. The Study Area is described in detail in Section 4.3. At the time of this Study, IDAAN plans on adding or expanding water treatment plant (WTP) and distribution capacity to serve corregimientos within the 2000 Study Area. IDAAN was also considering the new La Arenosa WTP that would provide water to corregimientos outside the 2000 Study Area, but decided to suspend the project in December 2017. IDAAN currently plans to serve these areas from new facilities capturing water from local streams. Because this Study is a long-term forecast, the corregimientos that would have been served by the La Arenosa WTP will be included in an expanded Study Area because this project or one similar to it could occur in the long-term future. However, these new corregimientos will only be included in the future water requirement forecast under certain scenarios defined in Section 4.7.5.

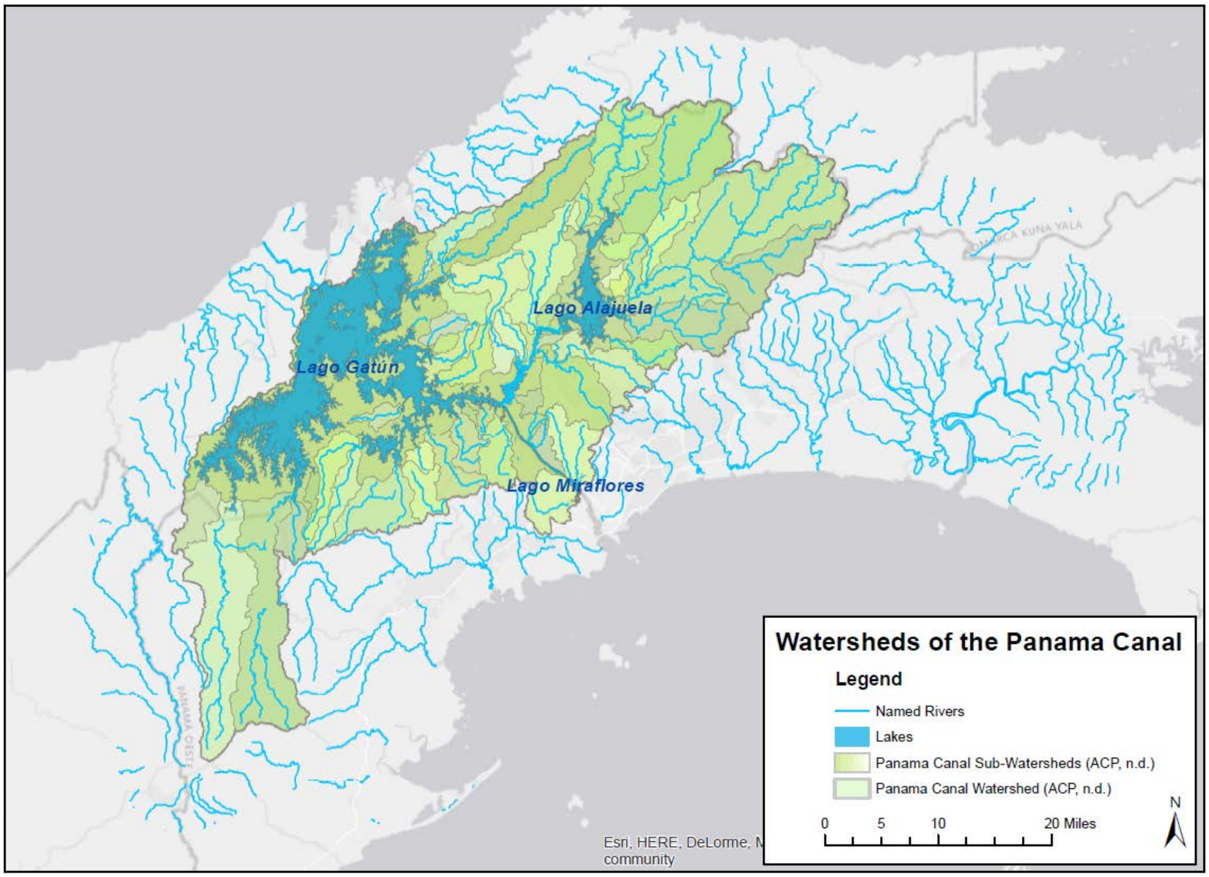

Figure 1.1 – Watershed boundary and fresh surface water bodies in the Watershed and near the Panama Canal

This study uses a number of terms for types of water use, types of water data, and types of water customers. These terms are described in detail in subsequent sections of this report. **Figure 1.2** provides a high level graphical comparison of many of these terms.

1.4 AUTHORIZATION

The Panama Canal Watershed M&I demand model update was prepared by Stantec in accordance with a contract with ACP dated 1 December 2017. Stantec subcontracted with Centro de Estudios Latinoamericanos (CELA) for conducting population forecasts, economic forecasts, relationships between economic parameters and non-residential water use, and research into demographic, economic and other information for Latin American cities similar to Panama City.

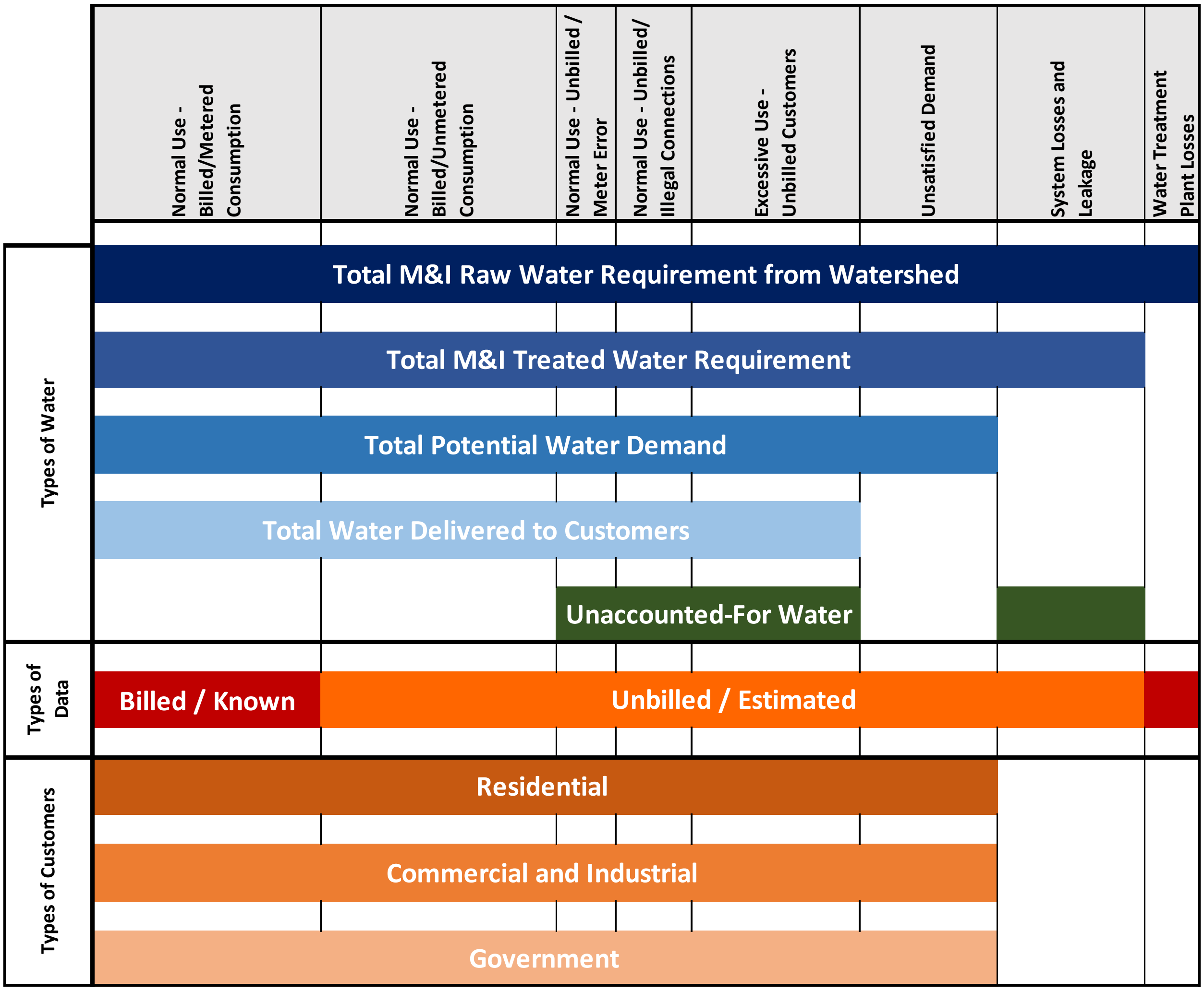

Figure 1.2 – Components of water requirements, water data, and water customers

1.5 COORDINATION

Results of the M&I demand forecast model update study were coordinated with ACP staff. Draft technical memoranda were reviewed by ACP and final technical memoranda were prepared by Stantec based on the review comments.

Workshops with ACP were conducted at four milestones:

- Preparation of draft data collection TM
- Preparation of draft forecast comparison TM
- Preparation of draft model description and model forecast assumptions TMs
- Preparation of draft project report

Feedback provided by ACP at the workshops was incorporated into preparation of final TMs.

1.6 ACKNOWLEDGEMENTS

This study was conducted by the following Stantec and CELA staff:

Project Manager – Manuel Gonzalez

Technical Lead – Chip Paulson

Project Engineer – Neil Stewart

Support Staff – Samantha Mauzy, Wendy Gutierrez

Geographic Information System (GIS) Expert – Eric Zimmerman

CELA Demographer – Dr. Marco Gandasegui

CELA Economist – Dr. Eloy Fisher

CELA Project Manager – Dr. Azael Carrera

This project would not have been possible without the support of ACP management and technical staff who provided data, direction and reviews of draft materials. In particular the project team would like to thank Francisco Pelaez, Abelardo Bal and Karen Anguizola for their valuable assistance.

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2.0 DATA SOURCES

The section summarizes the results of the data collection, review and organization effort for the Study. It summarizes the content that was included in the *Data Collection Technical Memorandum* (Stantec 2018a), which is contained in **Appendix A**.

Stantec was responsible for collecting and reviewing the data required for this Study. Staff of ACP provided data collected and maintained by their own agency, and made contacts for Stantec with outside agencies to gain their support in providing the required data to the study team.

Stantec was not responsible for the quality of the data obtained from ACP or other agencies. Stantec was not tasked with validating the accuracy of the data and was not in a position to determine its veracity. Stantec relied on the data described in this section for preparation of the water demand and raw water consumption forecast.

2.1 RAW WATER EXTRACTION DATA

The Study evaluated the M&I consumption of water derived from sources within the Watershed. While there are numerous raw water extraction sources in the Watershed, a large majority of raw water is extracted from two fresh-water bodies: Lake Gatun and Lake Alajuela. The finest temporal scale adopted for the data used in this study is a monthly time step.

Observed data recording the volume of water extracted or withdrawn from the raw water sources in the Watershed was collected from ACP and IDAAN for the period from 2000 to 2017. The entirety of the consumption data is included in **Appendix A** of the *Data Collection Technical Memorandum* (Stantec 2018a).

ACP provided several sources of raw water extraction data. These are:

- Monthly municipal withdrawals from Lake Gatun from January 1914 to December 2017
- Monthly municipal withdrawals from Lake Alajuela from January 1978 to December 2017
- Monthly withdrawals for ACP uses from January 2000 to December 2017
- Annual additional withdrawals from Lake Gatun or Lake Alajuela not through a major treatment plant from 2006 to 2017
- GIS data (locations and other information) on: corregimientos, drinking water intakes, water intakes, water tanks, pump stations, stand pipe valves, raw water mains, rivers, lakes, Panama Canal watershed and sub-watersheds

Figure 2.1 shows the data collected for observed extraction from Lake Gatun and Lake Alajuela for municipal purposes. The top panel shows monthly extraction and the bottom panel shows the annual extraction sum. Observed extraction data from Lake Gatun and Lake Alajuela was available from 1915 through 2017. 2000 to 2017 annual M&I extractions from the two lakes are listed in **Table 2.1**.

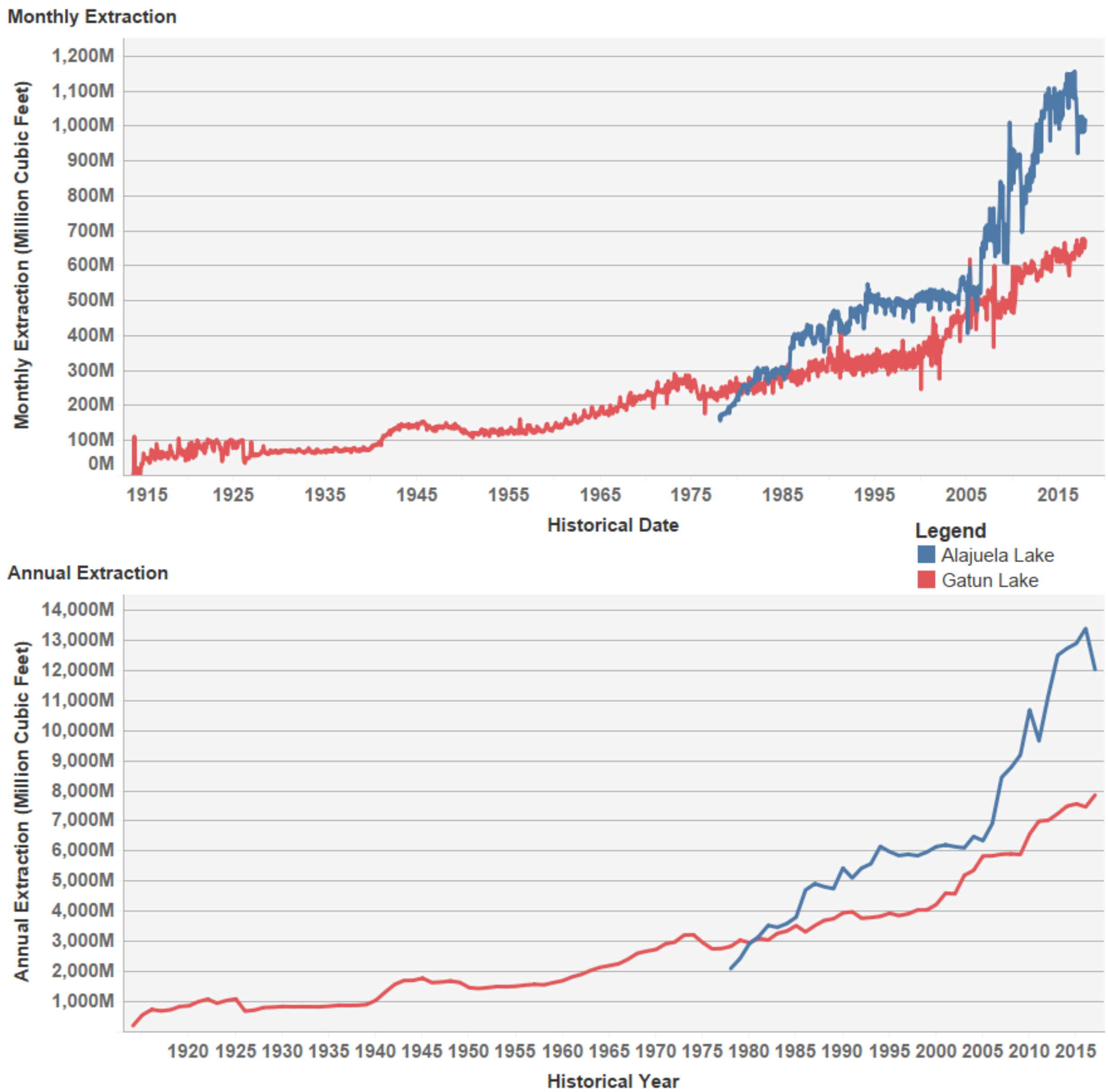


Figure 2.1 – Observed monthly and annual extraction from Gatun and Alajuela lakes

Table 2.1 – Annual M&I extractions from Alajuela and Gatun lakes

Year	Alajuela Lake Extractions (million gallons)	Gatun Lake Extractions (million gallons)	Total Extraction (million cubic feet)	Total Extraction (million gallons)	Total Extractions (MGD*)
2000	45,995	31,618	10,375	77,613	212.6
2001	46,426	34,450	10,812	80,876	221.6
2002	45,992	34,263	10,729	80,255	219.9
2003	45,690	38,888	11,307	84,578	231.7
2004	48,505	40,090	11,843	88,595	242.7
2005	47,487	43,680	12,187	91,167	249.8
2006	51,734	43,707	12,759	95,441	261.5
2007	63,218	44,124	14,349	107,342	294.1
2008	65,633	44,200	14,683	109,833	300.9
2009	68,751	44,054	15,080	112,805	309.1
2010	79,977	49,146	17,261	129,123	353.8
2011	72,286	52,339	16,660	124,625	341.4
2012	83,552	52,536	18,192	136,088	372.8
2013	93,539	54,191	19,749	147,730	404.7
2014	95,221	56,060	20,223	151,281	414.5
2015	96,469	56,598	20,462	153,067	419.4
2016	100,163	55,878	20,860	156,041	427.5
2017	100,701	58,804	21,321	159,505	437.0

*million gallons per day

2.2 WATER PRODUCTION DATA

Extraction of raw water from the Watershed that is not used for navigation at the Canal primarily occurs to provide potable water for M&I purposes. Potable water is produced at WTPs in the region, and hence this report uses the term “water production” to refer to water treated at WTPs for M&I use. There has been significant growth in municipal production since 2000, the year of the Harza 2000 water demand forecast. However, the demands met historically are in many cases significantly lower than the amount of water extracted from surface water sources as summarized in Section 3. Therefore, the observed volume of water produced by WTPs drawing water from the Watershed was required as part of the water demand forecast model update. When combined with consumption data this allowed for an assessment of unaccounted-for-water (UFW) and system losses because direct estimates of those factors were not available from water agencies.

Water production facilities are owned/operated either by ACP or IDAAN, therefore data was obtained from both. Observed WTP plant production volumes were obtained from 2000 to 2017 on a monthly time step for the major WTPs supplied with raw water from the Watershed. The entirety of the consumption data is included in **Appendix A** of the *Data Collection Technical Memorandum* (Stantec 2018a).

ACP provided several sources of potable water production data. These are:

- Monthly M&I treatment plant production within the Watershed, including IDAAN-operated plants from January 1985 to December 2017:
- GIS data for corregimientos, lakes, and rivers as well and ACP-operated water meters, water tanks, pump stations, stand pipe valves, water mains, lakes, rivers.

IDAAN provided water production data related to their WTPs. These are:

- Monthly production for Sabanitas WTP, Gatun WTP, Escobal WTP, and Chilibre WTP as well as water purchased from ACP from January 2000 to December 2017.

Comparing the ACP production data to the IDAAN production data, ACP data on IDAAN facilities is consistent with IDAAN data. The ACP dataset was used for production of ACP facilities and the IDAAN data set was used for production of IDAAN facilities.

Table 2.2 lists the potable WTPs for the Study Area, their capacity and the source of the production data.

Table 2.2 – WTP WSAs in the Watershed

WTP Name	Capacity (MGD)	Operation Start	Data Source
Cabra	2.0	2001	IDAAN
Chepo	0.9	Pre-2000	IDAAN
Chilibre	220.0	Pre-2000	IDAAN
Chorrera	9.5	Pre-2000	IDAAN
Escobal	0.1	Pre-2000	IDAAN
Laguna Alta	20	2002	ACP
Mananitas	0.7	Pre-2000	IDAAN
Mendoza	40.0	2009	ACP
Miraflores	48.0	Pre-2000	ACP
Monte Esperanza	34.0	Pre-2000	ACP
Pacora	0.4	2004	IDAAN
Rio Gatun	2.0	Pre-2000	IDAAN
Sabanitas	6.0	Pre-2000	IDAAN
Tocumen	1.5	Pre-2000	IDAAN

*Water Service Area

Figure 2.2 shows and **Table 2.3** and **Table 2.4** lists the observed annual production of the facilities listed in **Table 2.2** that are within the Watershed. The top panel shows annual production data by treatment plant for ACP-sourced data while the middle and bottom panels show the IDAAN-sourced data.

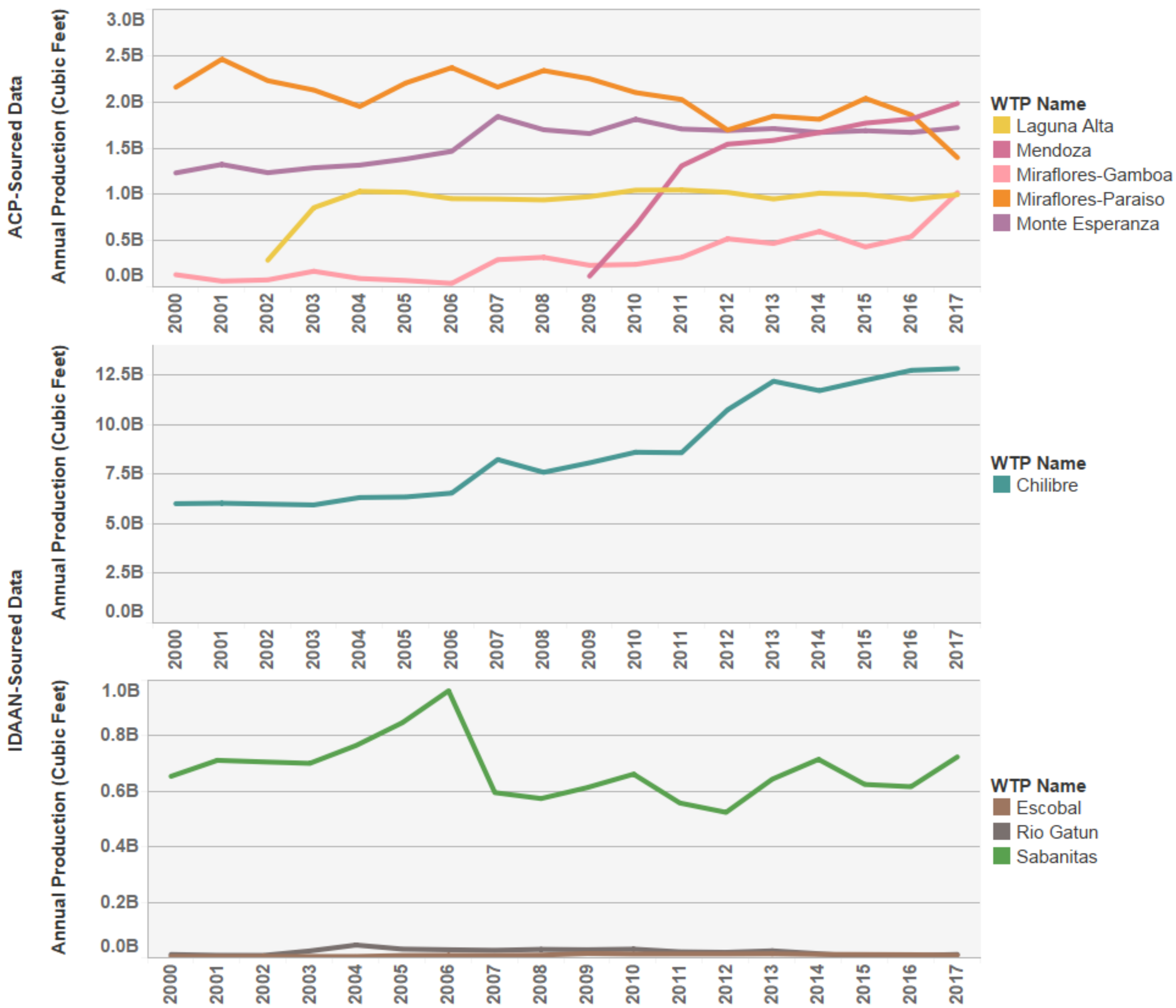


Figure 2.2 – Observed production for WTPs within the Watershed

Table 2.3 – Annual production of WTPs that extract from Watershed in million gallons

	Annual Production (million gallons)								
Year	Laguna Alta	Mendoza	Miraflores-Gamboa	Miraflores-Paraiso	Monte Esperanza	Chilibre	Escobal	Rio Gatun	Sabanitas
2000	0	0	979	16150	9214	45005	37	88	4893
2001	0	0	463	18412	9898	45188	36	66	5324
2002	2155	0	560	16674	9231	44853	36	64	5281
2003	6401	0	1258	15917	9627	44536	36	184	5242
2004	7719	0	673	14587	9845	47328	34	343	5723
2005	7647	0	511	16488	10338	47546	61	234	6338
2006	7131	0	277	17726	10959	48992	65	216	7198
2007	7100	0	2195	16156	13774	61660	63	201	4453
2008	7027	0	2386	17493	12704	56848	72	226	4293
2009	7290	868	1739	16832	12399	60443	116	216	4590
2010	7819	4960	1812	15713	13551	64427	104	233	4951
2011	7837	9785	2379	15156	12766	64244	104	160	4173
2012	7643	11538	3883	12685	12638	80434	104	146	3921
2013	7105	11841	3507	13806	12800	91226	108	187	4816
2014	7572	12474	4476	13551	12485	87667	92	109	5350
2015	7461	13242	3227	15242	12630	91583	87	28	4673
2016	7082	13578	4058	13906	12489	95345	83	59	4613
2017	7450	14833	7614	10457	12868	96004	68	90	5414

Table 2.4 – Annual production of WTPs that extract from Watershed in million cubic feet

	Annual Production (million cubic feet)								
Year	Laguna Alta	Mendoza	Miraflores-Gamboa	Miraflores-Paraiso	Monte Esperanza	Chilibre	Escobal	Rio Gatun	Sabanitas
2000	0	0	130.9	2,158.9	1,231.7	6,016.3	4.9	11.8	654.1
2001	0	0	61.9	2,461.3	1,323.2	6,040.8	4.8	8.8	711.7
2002	288.1	0	74.9	2,229.0	1,234.0	5,996.0	4.8	8.6	706.0
2003	855.7	0	168.2	2,127.8	1,286.9	5,953.6	4.8	24.6	700.8
2004	1,031.9	0	90.0	1,950.0	1,316.1	6,326.9	4.5	45.9	765.1
2005	1,022.3	0	68.3	2,204.1	1,382.0	6,356.0	8.2	31.3	847.3
2006	953.3	0	37.0	2,369.6	1,465.0	6,549.3	8.7	28.9	962.2
2007	949.1	0	293.4	2,159.8	1,841.3	8,242.8	8.4	26.9	595.3
2008	939.4	0	319.0	2,338.5	1,698.3	7,599.5	9.6	30.2	573.9
2009	974.5	116.0	232.5	2,250.1	1,657.5	8,080.1	15.5	28.9	613.6
2010	1,045.3	663.1	242.2	2,100.5	1,811.5	8,612.7	13.9	31.1	661.9
2011	1,047.7	1,308.1	318.0	2,026.1	1,706.6	8,588.2	13.9	21.4	557.9
2012	1,021.7	1,542.4	519.1	1,695.7	1,689.5	10,752.5	13.9	19.5	524.2
2013	949.8	1,582.9	468.8	1,845.6	1,711.1	12,195.2	14.4	25.0	643.8
2014	1,012.2	1,667.5	598.4	1,811.5	1,669.0	11,719.4	12.3	14.6	715.2
2015	997.4	1,770.2	431.4	2,037.6	1,688.4	12,242.9	11.6	3.7	624.7
2016	946.7	1,815.1	542.5	1,859.0	1,669.5	12,745.8	11.1	7.9	616.7
2017	995.9	1,982.9	1,017.8	1,397.9	1,720.2	12,833.9	9.1	12.0	723.7

2.3 WATER CONSUMPTION DATA

Water consumption in the M&I sector refers to actual water use at the customer level, whether residential, commercial, industrial or governmental. Data on consumption for agricultural water users or water needed for environmental purposes was not needed for the M&I water demand forecast study and was not acquired.

Demand data was collected at the corregimiento level to have adequate spatial resolution of water consumption analyses. Monthly demand data was collected to define water use characteristics by customer type. The entirety of the consumption data is included in **Appendix A** of the *Data Collection Technical Memorandum* (Stantec 2018a).

ACP provided several sources of potable water consumption data:

- Monthly for ACP-uses from January 2000 to December 2017
- GIS data on corregimientos

IDAAN provided several sources of potable water consumption data. These are:

- Monthly residential, commercial, governmental, industrial, and municipal consumption summarized by corregimiento and then by WSA for different metering types from January 2000 to December 2017.
- Daily customer-level billing data for January 2000 to December 2017.

Figure 2.3 shows the IDAAN regional boundaries and their corresponding corregimientos. Tan colored corregimientos are outside any current IDAAN region and do not have observed consumption information available. Corregimientos that are not served by IDAAN and do not have observed consumption data, but are within the Watershed, are listed in **Table 2.5**. **Table 2.6** lists the corregimientos with consumption data provided by IDAAN and which region they are included. This table notes which corregimientos were created after the 2000 Harza Study and outside the Study Area, which excludes their demands. A map showing the location of all the corregimientos in the Study Area is provided in Section 4.3.

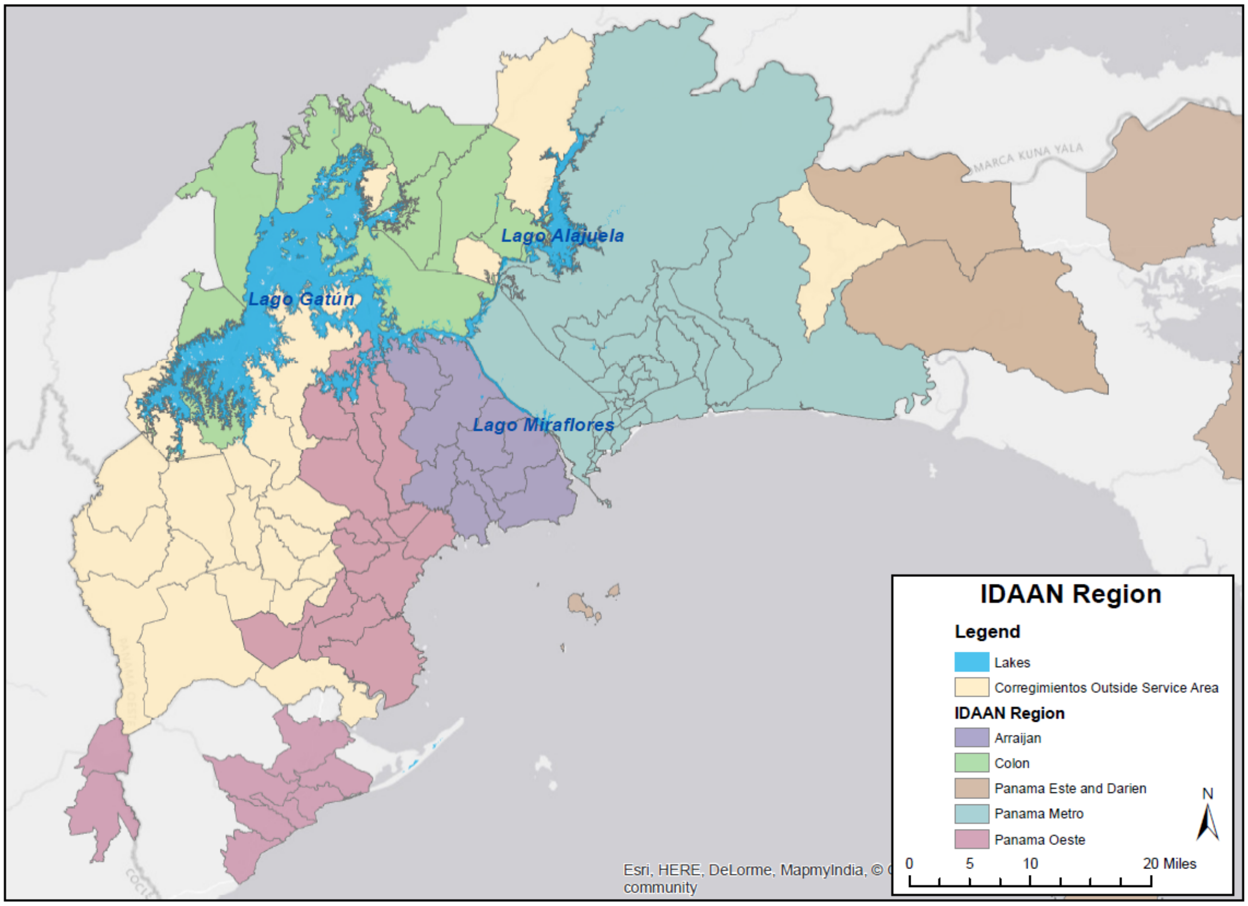


Figure 2.3 – IDAAN regions and current corregimiento boundaries

Table 2.5 – Corregimientos without IDAAN consumption data

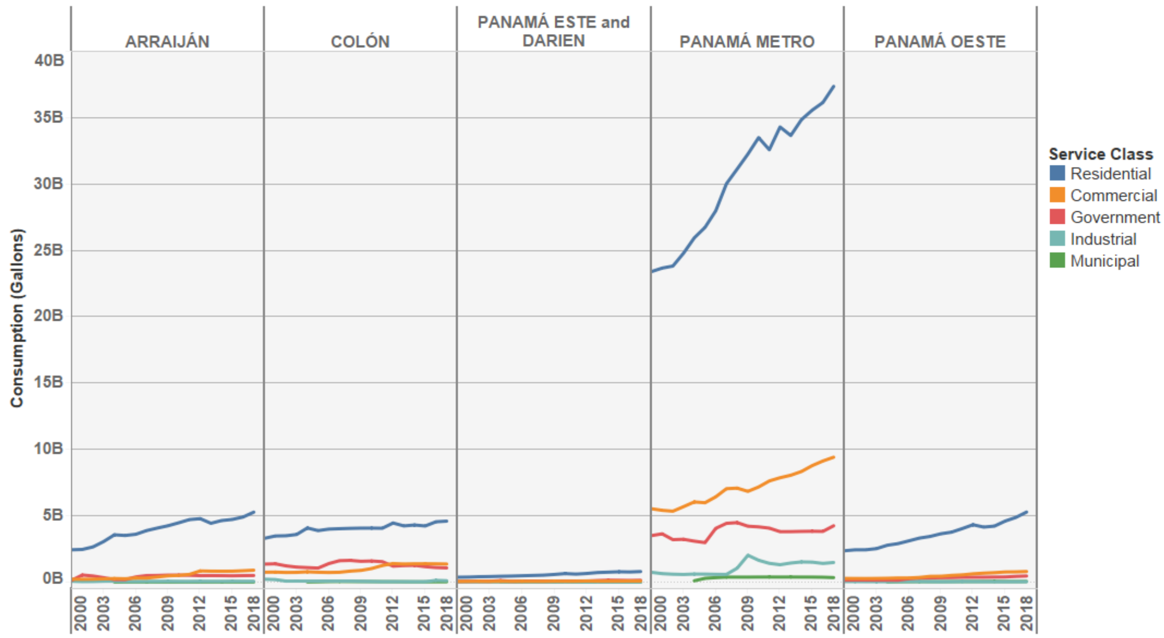
Corregimiento	Corregimiento
Amador	La Chorerra
Arosemena	La Trinidad
Caimito	Las Ollas Arriba
Calidonia	Los Diaz
Campana	Nueva Providencia
Cirí de los Sotos	Obaldía
Cirí Grande	Salamanca
Ciricito	San Martín
El Cacao	Santa Rita
Feuillet	Santa Rosa
Hurtado	Villa Carmen
Iturralde	

Table 2.6 – List of corregimientos in IDAAN regions with consumption data

Arraiján	Colón	Panamá Este and Darien	Panamá Metro	Panamá Oeste
Arraiján (cab.)	Barrio Norte	Cañita[2]	24 de Diciembre[1]	Barrio Balboa[3]
Burunga[1]	Barrio Sur	Chepigana[2]	Alcalde Díaz[1]	Barrio Colón[3]
Cerro Silvestre[1]	Buena Vista	Chepo	Amelia Denis de Icaza	Bejuco[2]
Juan Demostenes Arosemena	Cativá	El Real de Santa María[2]	Ancón	Cabuya[2]
Nuevo Emperador	Cristobal	Garachiné[2]	Arnulfo Arias[1]	Capira (cab.)
Santa Clara	Escobal	Jaqué[2]	Belisario Frias[1]	Cermeño
Veracruz	Limón	La Palma (cab.)[2]	Belisario Porras	Chame (cab.)[2]
Vista Alegre	Puerto Pilón	Las Margaritas	Bella Vista	El Arado
	Sabanitas	Metetí[1]	Betania	El Coco
	San Juan	Río Iglesias[2]	Chilibre	El Valle[2]
		Saboga[2]	Curundú	Guadalupe
		San Miguel (cab.)[2]	El Chorrillo	Herrera
		Santa Fé[1]	Ernesto Cordoba Campos[1]	La Represa
		Taboga[2]	Jose Domingo Espinar	Las Lajas[2]
		Tortí[1]	Juan Diaz	Lídice
		Tucutí[2]	La Exposición o Calidonia[2]	Mendoza
		Yaviza[2]	Las Cumbres	Nueva Gorgona[2]
			Las Mañanitas[1]	Playa Leona
			Mateo Iturralde	Puerto Caimito
			Omar Torrijos[1]	San Carlos (cab.)[2]
			Pacora	San José[2]
			Parque Lefevre	Villa Rosario
			Pedregal (pma)	
			Pueblo Nuevo	
			Rio Abajo	
			Rufina Alfaro[1]	
			San Felipe	
			San Francisco	
			Santa Ana	
			Tocumen	
			Victoriano Lorenzo	

1. Corregimiento was created after 2000
2. Corregimiento outside Study area and will be excluded
3. Corregimientos were combined in 2000 Demand Model under the name La Chorerra

Figure 2.4 shows the annual water use by customer service class for the five WSA identified by IDAAN. Each of these service areas has monthly consumption data for the five water service classes from January 2000 through December 2017.



Source: IDAAN

Figure 2.4 – Annual water service class consumption for each IDAAN region

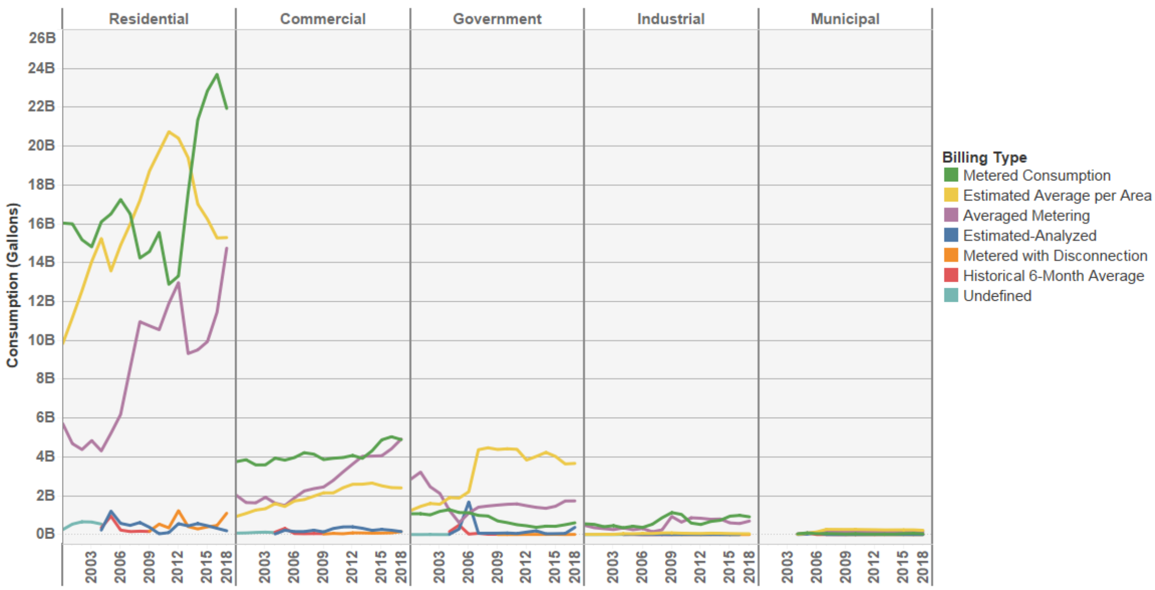
Water consumption data from IDAAN comes from different sources. Some of it comes directly from meter readings attached to customer accounts, and some comes from estimates of water consumption for unmetered customers. The data sources are categorized as “billing types” in the IDAAN customer water consumption data base. **Source:** IDAAN

Figure 2.5 shows water consumption data for each customer class aggregated by the seven billing types used by IDAAN to categorize the source of their data (e.g., metered and unmetered). The definitions of each billing type are provided below. Two of the billing types (Promedio Historico 6 Meses and Undefined) were not defined by IDAAN, however their consumption relative to the others is insignificant so they will be included in the unmetered customer category. In using this data *consumo medido* is metered consumption, the rest will be included in unmetered consumption.

- *Consumo Medido* (Metered Consumption): Monthly consumption measured by a meter. These data span January 2000 to December 2017 for each of the service classes.
- *Estimado Promedio Area* (Estimated Average per Area): Monthly consumption assigned depending on the economic activity of the area as the customer does not have a meter. These data span January 2000 to December 2017 for each of the service classes.
- *Medidor Promediado* (Averaged Metering):   Customer has a meter, but it was not used to measure consumption (damaged meter, no access to meter, etc.) so consumption is

estimated using the average of the last six months. These data span January 2000 to December 2017 for each of the service classes.

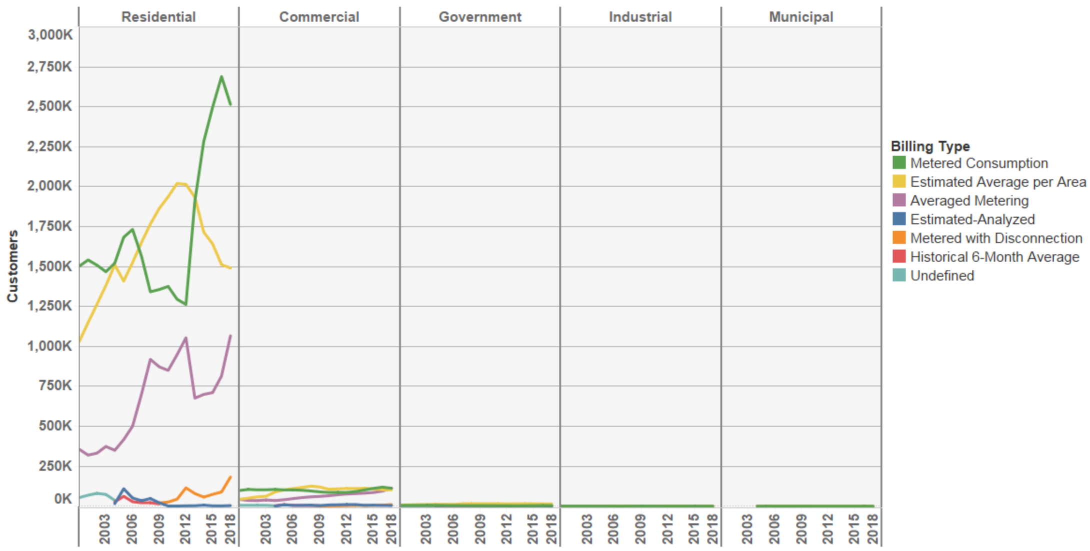
- *Estimado Analizado* (Analyzed Estimate): Customer has a meter, but it was not used to measure consumption (damaged meter, no access to meter, etc.) and there is not six months of data to take an averaged metering. Therefore, IDAAN analyzes the situation case by case and assigns a consumption estimate. These data span November 2004 to December 2017 for each of the service classes.
- *Medido Con Reliquidacion* (Metered with Disconnection): Customers with meters but they were disconnected during the month for various reasons. These data span July 2009 to July 2017 for each of the service classes.
- *Promedio Historico 6 Meses* (Historical 6-Month Average): Unknown how consumption for this billing type is determined. These data span July 2004 to July 2009 for each of the service classes.
- *Undefined*: No billing type defined, unknown how consumption for this billing type is determined. These data span January 2000 to May 2004 for each of the service classes.



Source: IDAAN

Figure 2.5 – Annual service class consumption separated by billing type

Figure 2.6 shows the number of customers for each service class and billing type. There are significantly more residential customers than any other type, however all service classes have metered consumption customers.



Source: IDAAN

Figure 2.6 – Number of customers by service class and billing type

2.4 POPULATION DATA

Historical population data within the study area was required for the Study. Population is a key water demand driver; it was used in the 2000 Harza Study, and was the parameter used to forecast future residential water use in the current study.

The 2000 Harza Study collected, summarized, and predicted population data by Population Zone through 2060. Population Zones were created in the 2000 Harza Study by CELA to group similar economic regions together. **Figure 2.7** shows the Population Zones from the 2000 Harza Study. **Table 2.7** lists the corregimientos contained in each Population Zone. Corregimientos in Population Zones are consistent with the 2000 Harza Study and new corregimientos created since the 2000 Harza Study were assigned a Population Zone based on geography.

In this Study population data was collected annually for the period 2000 to 2017 at the corregimiento level and is included in **Appendix A** of the *Data Collection Technical Memorandum* (Stantec 2018a). CELA, under subcontract to Stantec, provided population data and reported data from the Instituto Nacional de Estadistica y Censo (INEC) estimates and official Census (CENSO) data as follows:

- 2000 and 2010 Census population for each corregimiento broken down by age groups and gender
- 2000 to 2017 INEC population estimations by corregimiento broken down by age groups and gender

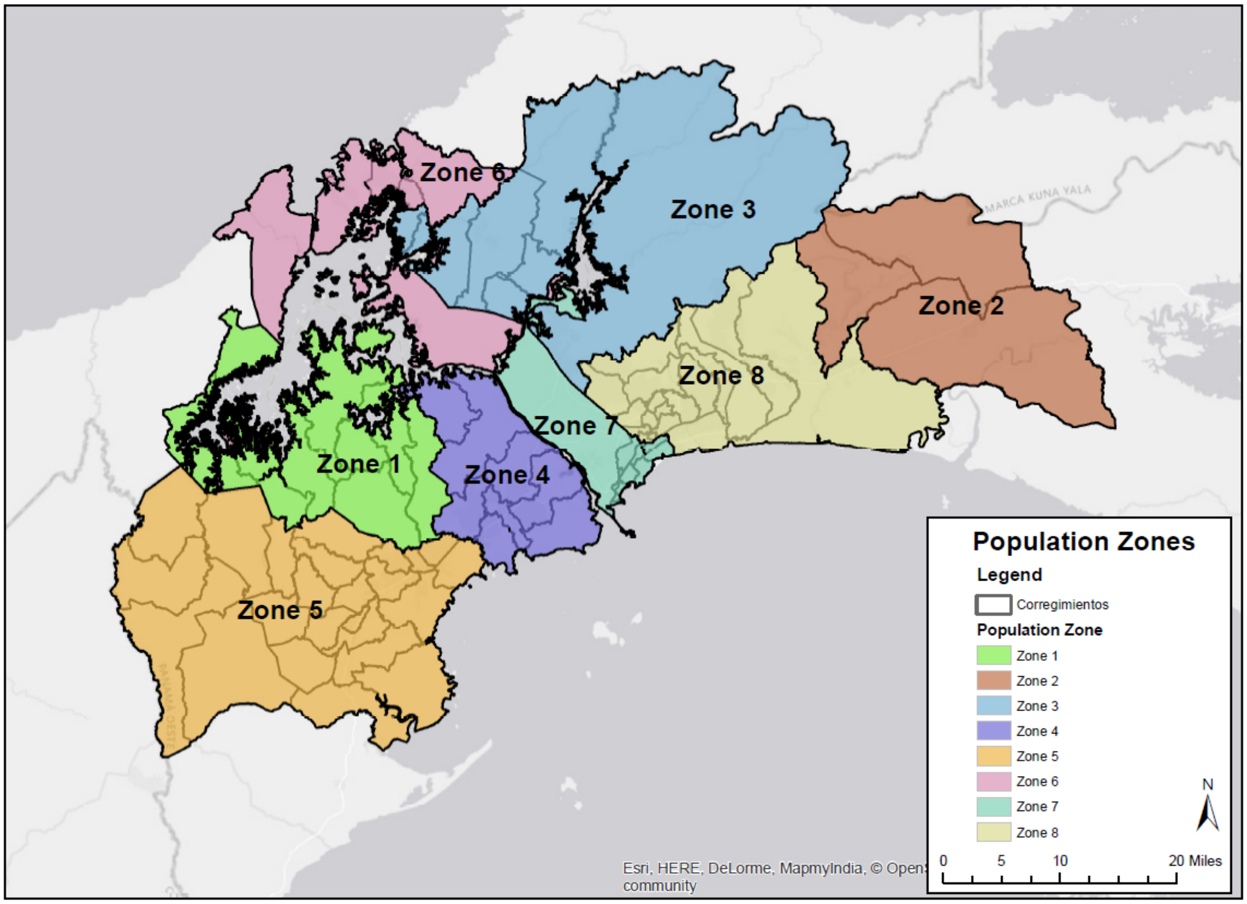


Figure 2.7 – Map of Population Zones based on 2000 Harza Study

Table 2.7 – Corregimientos in each Population Zone

Zone 1	Zone 5	Zone 7
Escobal	Caimito	Ancón
Amador	Barrio Balboa[2]	Bella Vista
Arosemena	Barrio Colón[2]	Betania
Ciricito	Campana	Calidonia
El Arado	Capira (cab.)	Curundú
Herrera	Cermeño	El Chorrillo
Iturralde	Cirí de los Sotos	Parque Lefevre
La Represa	Cirí Grande	Pueblo Nuevo
Mendoza	El Cacao	Rio Abajo
Zone 2	El Coco	San Felipe
Chepo	Feuillet	San Francisco
Las Margaritas	Guadalupe	Santa Ana
San Martín	Hurtado	**Zone 8**
Zone 3	La Trinidad	24 de Diciembre[1]
Buena Vista	Las Ollas Arriba	Alcalde Díaz[1]
Chilibre	Lídice	Amelia Denis de Icaza
Limón	Los Diaz	Arnulfo Arias[1]
Nueva Providencia	Obaldía	Belisario Frias[1]
Salamanca	Playa Leona	Belisario Porras
San Juan	Puerto Caimito	Ernesto Cordoba Campos[1]
Santa Rosa	Santa Rita	Jose Domingo Espinar
Zone 4	Santa Rosa[1]	Juan Diaz
Arraiján (cab.)	Villa Carmen	Las Cumbres
Burunga[1]	Villa Rosario	Las Mañanitas[1]
Cerro Silvestre[1]	**Zone 6**	Mateo Iturralde
Juan Demostenes Arosemena	Barrio Norte	Omar Torrijos[1]
Nuevo Emperador	Barrio Sur	Pacora
Santa Clara	Cativá	Pedregal (pma)
Veracruz	Cristobal	Rufina Alfaro[1]
Vista Alegre	Puerto Pilón	Tocumen
	Sabanitas	Victoriano Lorenzo

1. Corregimiento was created after 2000 and was assigned to a zone based on geography
2. Corregimientos were combined in 2000 Demand Model under the name La Chorerra

Figure 2.8 summarizes and **Table 2.8** lists the population data by Population Zone. There is census data for each corregimiento for 2000 and 2010 and population estimates by INEC for 2000 to 2017 (a census is only completed every decade). The jump in population between 2009 and 2010 occurs because data for 2001-2009 was estimated by INEC whereas the 2010 population is based on actual census data. INEC does not go back and adjust population estimated for previous years based on new census data.

Immigration is an important factor affecting population in the study area. Immigration can include internal immigration from rural to urban areas within Panama, or external immigration of residents from other countries. The population data obtained from INEC includes that agency's best estimate of population including immigrants. It is recognized that immigrants, particularly illegal immigrants, may not be represented accurately in the INEC population estimates. However, this is the best available information for this study

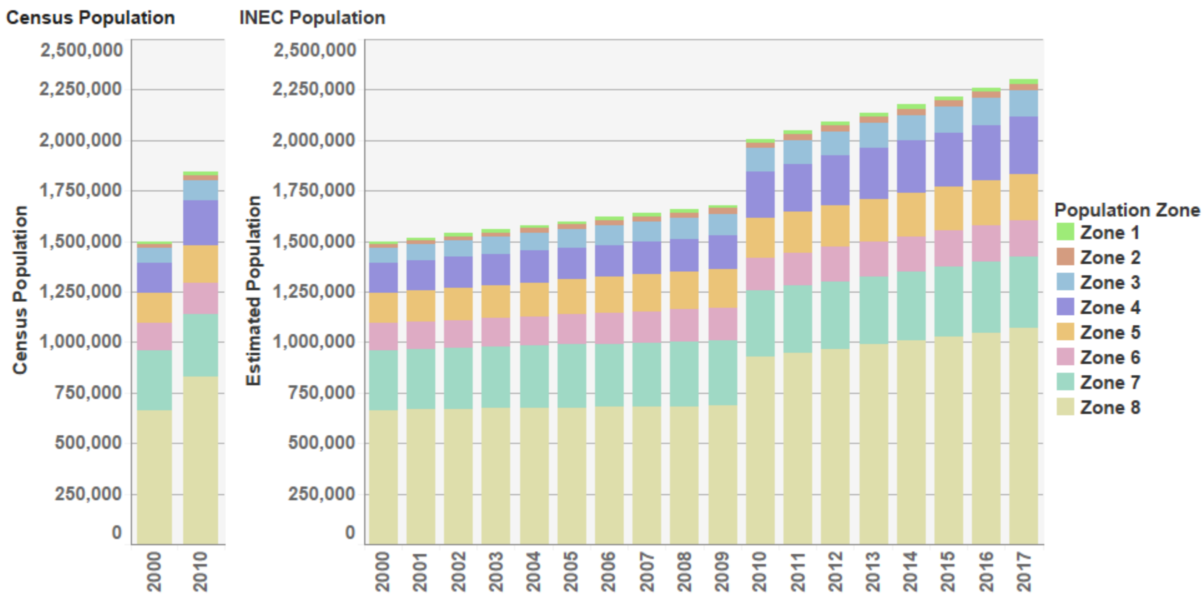


Figure 2.8 – Summary of Population by Zone based on 2000 Harza Study

Table 2.8 – Summary of INEC population estimates

INEC Estimated Population in Persons								
Year	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
2000	13,048	17,234	75,040	149,918	149,301	134,911	293,167	664,966
2001	13,547	18,232	78,932	151,418	154,024	137,740	296,719	667,189
2002	14,049	19,231	82,825	152,916	158,746	140,567	300,270	669,410
2003	14,548	20,229	86,716	154,416	163,470	143,397	303,821	671,634
2004	15,049	21,228	90,607	155,914	168,192	146,224	307,373	673,856
2005	15,549	22,226	94,502	157,416	172,919	149,054	310,929	676,081
2006	16,045	23,224	98,393	158,913	177,637	151,881	314,478	678,301
2007	16,546	24,223	102,285	160,412	182,362	154,709	318,030	680,523
2008	17,045	25,221	106,175	161,911	187,083	157,538	321,581	682,747
2009	17,547	26,220	110,069	163,410	191,808	160,366	325,132	684,968
2010	18,046	27,218	113,960	230,311	196,528	163,194	328,684	927,107
2011	18,515	28,090	116,892	238,713	200,692	166,069	331,719	946,172
2012	18,989	28,927	119,971	246,801	204,888	168,825	335,122	967,119
2013	19,434	29,746	122,948	254,764	208,921	171,618	338,698	987,694
2014	19,893	30,546	125,785	262,517	212,905	174,431	342,405	1,007,545
2015	20,335	31,349	128,565	270,191	216,873	177,229	346,269	1,027,367
2016	20,731	31,994	131,214	276,999	220,707	180,134	350,411	1,047,574
2017	21,098	32,605	133,872	283,443	224,442	183,016	354,810	1,067,780

2.5 ECONOMIC DATA

Non-residential water use for the eight zones of the Study Area is based on indicators found in the Monthly Principal Economic Indicators (PIEM, in Spanish) and the Monthly Economic Indicators (IMAE, in Spanish), provided by INEC.

The PIEM indicators describe 27 broad industrial, commercial and governmental activities in Panama and present the data in units of production (or dollars where applicable). The IMAE is a short-term economic indicator built from a sub-set of activities included in the quarterly and yearly gross domestic product (GDP) estimates. The PIEM and IMAE indicators were sourced from INEC from January 2008 to December 2017. These data are included in tabular form in **Appendix C** of the *Water Demand Forecast Model Description Technical Memorandum* (Stantec 2018a).

3.0 PREVIOUS FORECAST EVALUATION

This section summarizes the results of the comparison of the demand forecast developed as part of the 2000 Study to observed conditions between 2000 and 2017. The full evaluation of the previous water demand forecast relative to actual water use is detailed in the *Forecast Comparison Technical Memorandum* (Stantec 2018b), included in **Appendix B**.

3.1 METHODS

3.1.1 2000 Study Demand Model

The 2000 Demand Model forecasted future water requirements in the Study Area from 2000 to 2060 in 10-year increments under three future growth scenarios: Probable, Optimistic (high growth), and Pessimistic (low growth). Future water requirements consisted of water use in three categories: residential water use, non-residential water use, and UFW. The 2000 Demand Model used WSAs as the basic geographic unit of the forecast process, which were overlaid on top of the Population Zones, as shown in **Figure 3.1**.

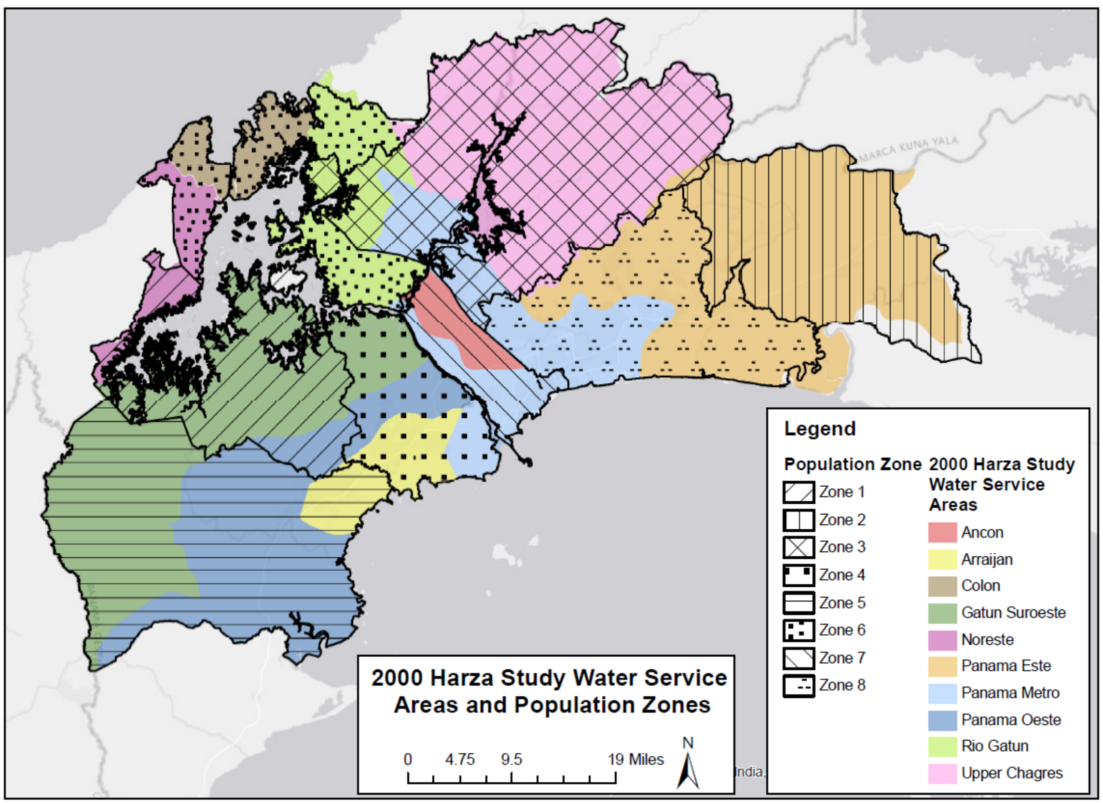


Figure 3.1 – 2000 Demand Model WSAs

The 2000 Demand Model forecast for residential demand was comprised of a residential base demand and an unmetered excessive use demand. The unmetered excessive use was the water use by unmetered customers over and above the water use by metered customers. Based on experience unmetered customers in Panama were known to use more water per capita than metered customers.

Residential base demand was calculated for an assumed population by multiplying a residential demand rate in gallons per capita per day (GPCD) by the population to get a residential base demand value in gallons per day (GPD). The residential per capita use rate was estimated based on observed water use from 1996-1999. **Table 3.1** lists the residential demand rate for each Population Zone used in the 2000 Demand Model (as shown in **Figure 2.7**).

Table 3.1 – Per capita residential water use by Population Zone

Population Zone	Residential Demand Rate (GPCD)
Zone 1	63.7
Zone 2	76.3
Zone 3	73.0
Zone 4	64.0
Zone 5	62.3
Zone 6	68.7
Zone 7	117.0
Zone 8	56.0

To estimate the excessive use of unmetered residential customers, the 2000 Demand Model did the following:

1. Multiply WSA residential base demand by the percentage of residential customers in that WSA that are unmetered
2. Increase the unmetered customer base demand by an excess use factor
3. Add this excess use by unmetered customers to the residential base demand

Table 3.2 lists the estimated percentage of metered residential customers by WSA, which stayed constant for all future years and growth scenarios. The excess use factor was 44 percent for all future years and growth scenarios. Section 9.2.1.2 from the 2000 Harza Study summarizes how this excess use factor was determined. The combination of the base residential demand and the excess use by unmetered customers comprised the forecasted residential demand.

Table 3.2 – Assumed percentage of customers metered in 2000 Demand Model

WSA Name	Percent of Residential Connections Metered
Panama Metro	51.9%
Arraijan/Chorrera	58.6%
Colon	28.4%
Upper Caimito	65.0%
Panama Este	51.9%
Rio Gatun	28.4%
Gatun Noroeste	28.4%
Gatun Suroeste	28.4%
Upper Chagres	51.9%
Ancon	51.9%

The 2000 Demand Model forecasted non-residential demand based on the water use in different types of commercial and industrial economic activities that occur within the Study Area. To determine consumption for each economic activity, the estimated value for the driver of each economic type was multiplied by the assumed water demand rate for that economic category. The demand by economic activity was then summed across all economic activities to determine the non-residential demand for each Population Zone. **Table 3.3** lists the demand rate for each economic activity. Section 7 and Section 9.2.2 in the 2000 Harza Study provide more detail on how these values were determined. The same non-residential forecast was used for the three future scenarios.

Table 3.3 – Water demand rate for economic activity

Activity	Demand Rate	
Agriculture	100	GPD/Hectare
Wet Industry	246.74	GPD/Employees
Other Manufacturing	124.88	GPD/Employees
Ports	0.53	GPD/Metric Tons
Utilities	51.86	GPD/Employees
Fabricated Construction	5775.97	GPD/1000 1982 Balboas
Retail/Office	7.41	GPD/Employees
Schools	6.19	GPD/Students
Hospitals	140.7	GPD/Beds
Tourism	0.53	GPD/Guests

To quantify UFW, the total water demand (residential demand and non-residential demand) was divided by the inverse of what was called the centralized system leakage factor (i.e., the percentage of UFW). The total demand was subtracted from this value to calculate the UFW volume. This was added to the total demand to calculate the total water requirement, as this value is the amount of water the WTPs would need to produce and therefore is the amount of water needed to be extracted from the Watershed. **Table 3.4** lists the centralized system leakage factor for each WSA. These factors did not vary by future year for forecast type. Section 9.2.3 of the 2000 Harza Study details how these factors were determined.

Table 3.4 – Leakage factor used to estimate UFW in 2000 Demand Model

WSA Name	Centralized System Leakage Factor
Panama Metro	23%
Arraijan/Chorrera	23%
Colon	34%
Upper Caimito	38%
Panama Este	23%
Rio Gatun	34%
Gatun Noroeste	34%
Gatun Suroeste	34%
Upper Chagres	23%
Ancon	23%

3.1.2 Observed Data for Comparison

Water consumption data was provided by IDAAN as described in Section 2.3. The observed record of this data is from January 2000 to December 2017 on a monthly timescale. Observed consumption was provided at the corregimiento level for all corregimientos within the Study Area served by IDAAN.

All corregimientos have, at a minimum, residential consumption data. The IDAAN residential consumption data was classified into metered or estimated consumption, and if estimated, how it was estimated. For this comparison, residential consumption data classified by IDAAN as “consumo medido” was referred to as “metered consumption”, and all other classifications were referred to as “unmetered consumption” as defined in Section 2.3.

Non-residential consumption data was also provided by corregimiento. IDAAN has four types of non-residential consumption water use categories: commercial, industrial, government, and municipal. For this comparison, government and municipal consumption were combined into what is referred to as government. The different non-residential consumption billing classifications were combined into a single consumption value for the three use categories: commercial, industrial, and government. Not all corregimientos have all types of non-residential water uses.

The data for actual population to compare with the 2000 Study population projections came directly from INEC and was provided by CELA as described in Section 2.4.

Water production data for WTPs was provided by both ACP and IDAAN for their respective facilities. For this comparison, IDAAN production data for WTPs they operate and IDAAN's accounting of ACP WTP-generated water IDAAN purchased was used. IDAAN provided WTP production and water accounting data in three regions: Panama Metro, Colon, and Arraijan on a monthly time step from January 2000 through December 2017. IDAAN production data includes monthly production from the IDAAN-operated WTPs (Sabanitas, Gatun, Escobal, and Chilibre) in addition to the monthly volume of water purchased from ACP. **Figure 3.2** shows how the IDAAN regions with production data relate to the Population Zones. There are areas within the Population Zones that are not currently served by IDAAN; however, they are shown on the maps because they could at some future time receive water from IDAAN.

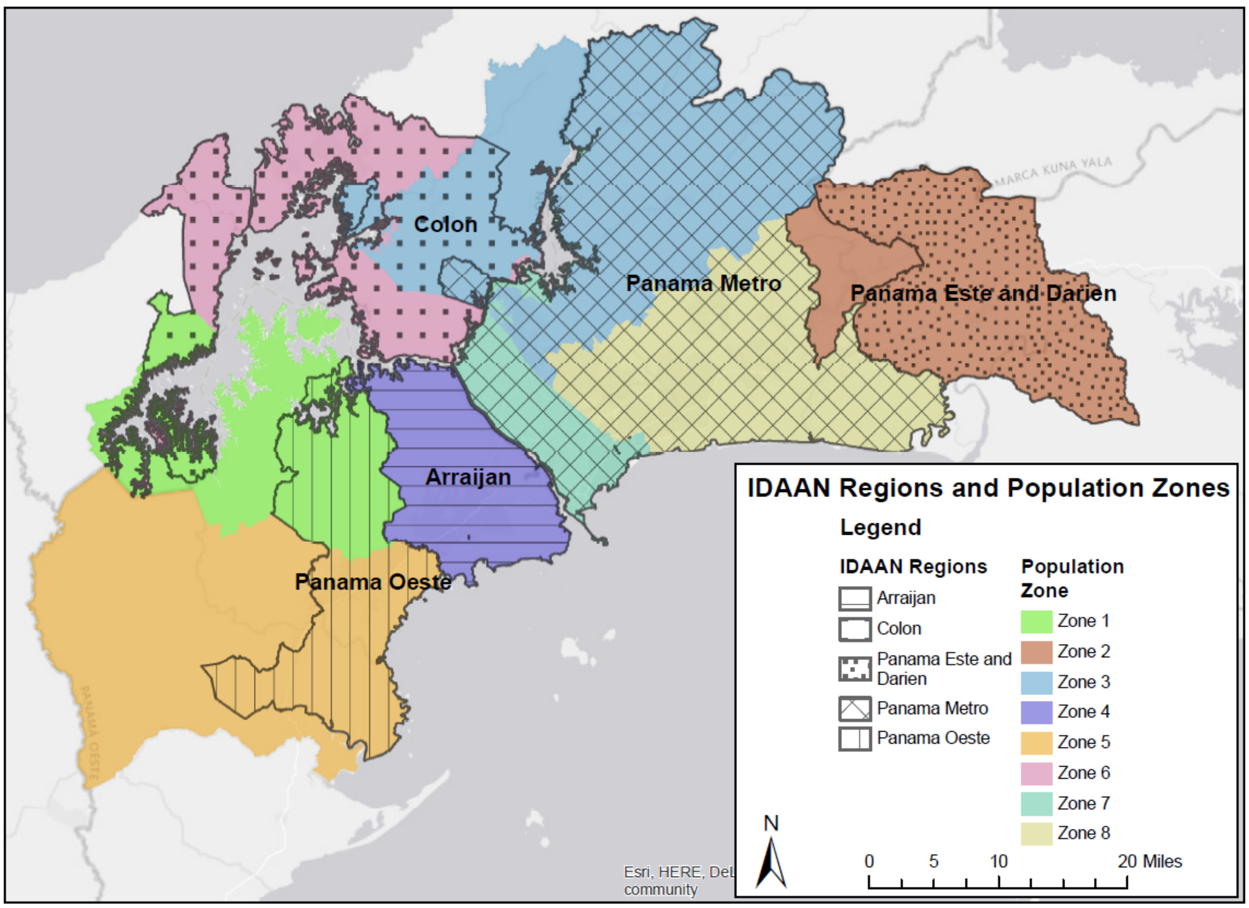


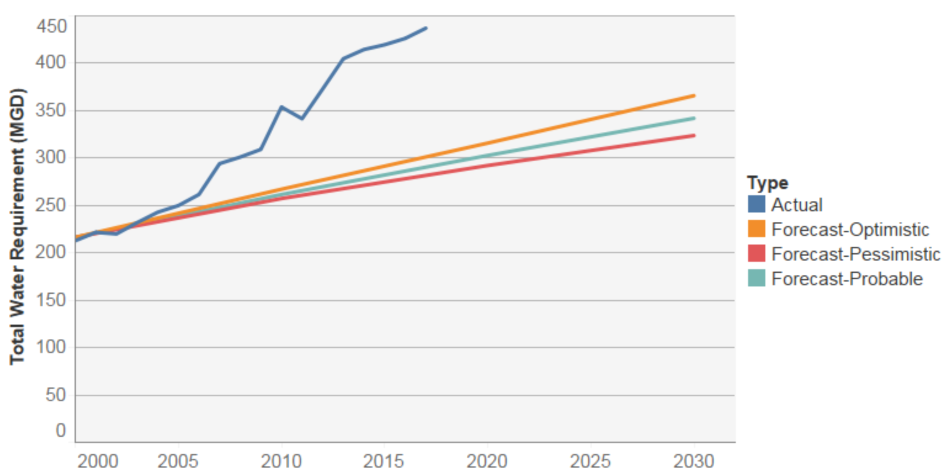
Figure 3.2 – IDAAN regions and Population Zones

3.2 RESULTS OF PREVIOUS FORECAST EVALUATION

3.2.1 Comparison of Total Water Requirement

As this Study is interested in the updating the 2000 Demand Model to improve forecasts of future water demand from the Watershed, the observed IDAAN production data was compared to the forecasted total water requirement. **From 2000-2017**

Figure 3.3 shows this comparison for the three regions with production data from IDAAN and the total across these regions. This figure also includes the 1995 to 1999 data used to create the 2000 Demand Model. From 1995 to 1999, total water production was relatively constant. Since 2000 in the Arraijan and Colon regions, observed water production has been consistent with the forecasted total water requirement. Since 2000 in the Panama Metro region, observed water production has been higher than forecasted total water requirement, with total water production after 2010 significantly higher than the forecasted total water requirement.



From 2000-2017

Figure 3.3 – Comparison of 2000 Harza Study forecasted total water requirement and observed water production

The next step in the comparison was to remove UFW and only compare accounted-for customer use. Forecasted UFW was calculated using the method described in Section 2.4. Actual UFW is the difference between WTP production and accounted-for customer use. **Figure 3.4** compares forecasted and observed total water demands with the top panel showing the sum across all zones and the bottom panel showing the comparison by Population Zone. With UFW removed from the comparison, observed demands are lower than all three forecasts when summed across Population Zone. The same relationship is true for nearly all individual zones, with only Zone 8 (Panama City area) having observed total demand that falls within the forecasted area. Zone 7 has the most significant difference between forecasted and observed demands.

The observed makeup of these total demands was compared to the forecasted values and their underlying parameters to identify why observed customer uses are lower than forecasted. Then, forecasted and observed UFW was compared.

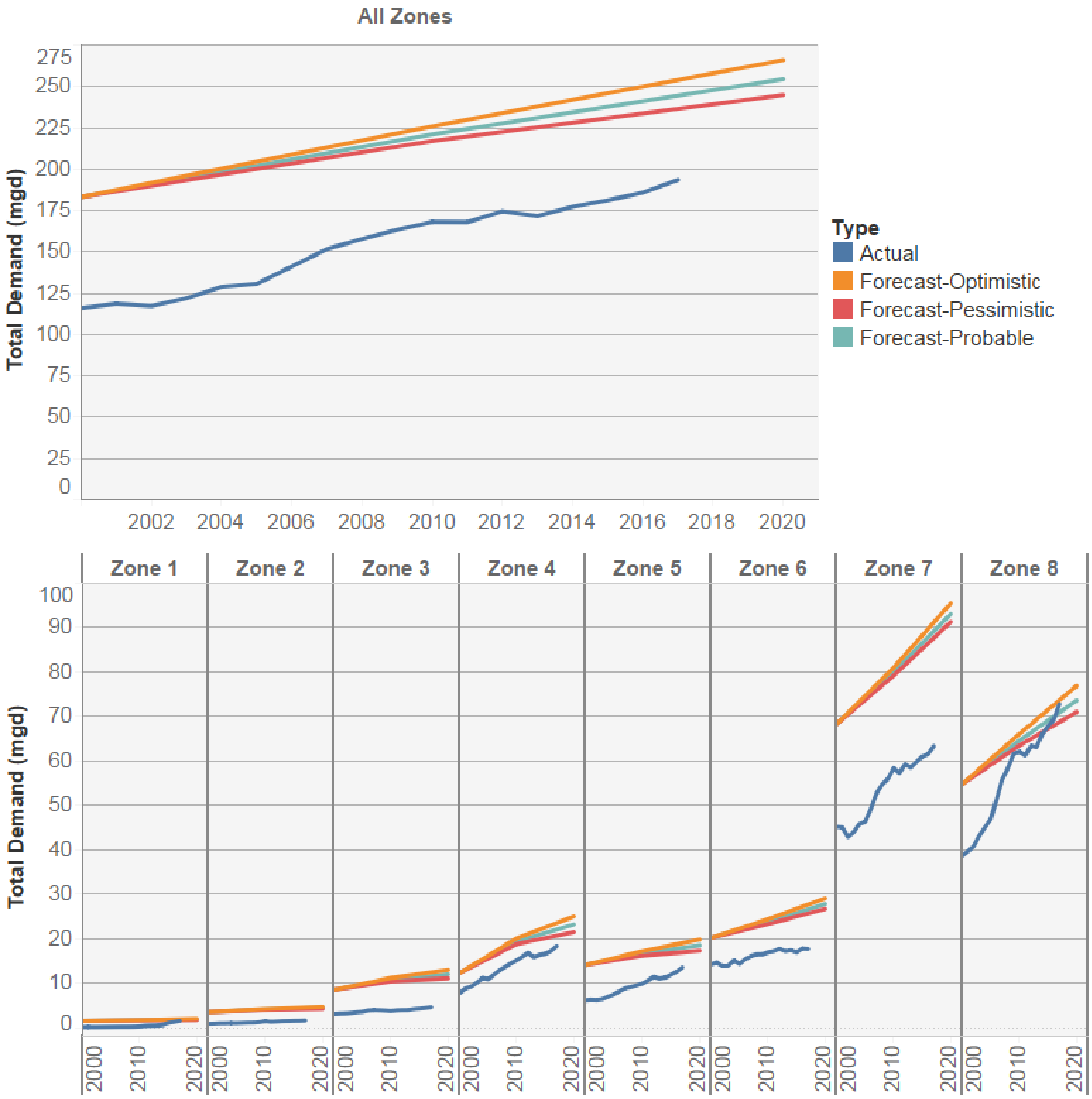


Figure 3.4 – Comparison of forecasted and actual total customer water use, excluding UFW

3.2.2 Comparison of Residential Water Use

Figure 3.5 compares the forecasted and observed residential customer water use. With the exception of Zone 8 (eastern Panama City area), observed residential demand is lower than all three forecasts. Observed residential demand is significantly lower than forecasted in Zone 7 (central Panama City). The different methods used by the 2000 Demand Model and IDAAN to estimate unmetered demands cause the differences at 2000, when the Demand Model was calibrated to, to be large.

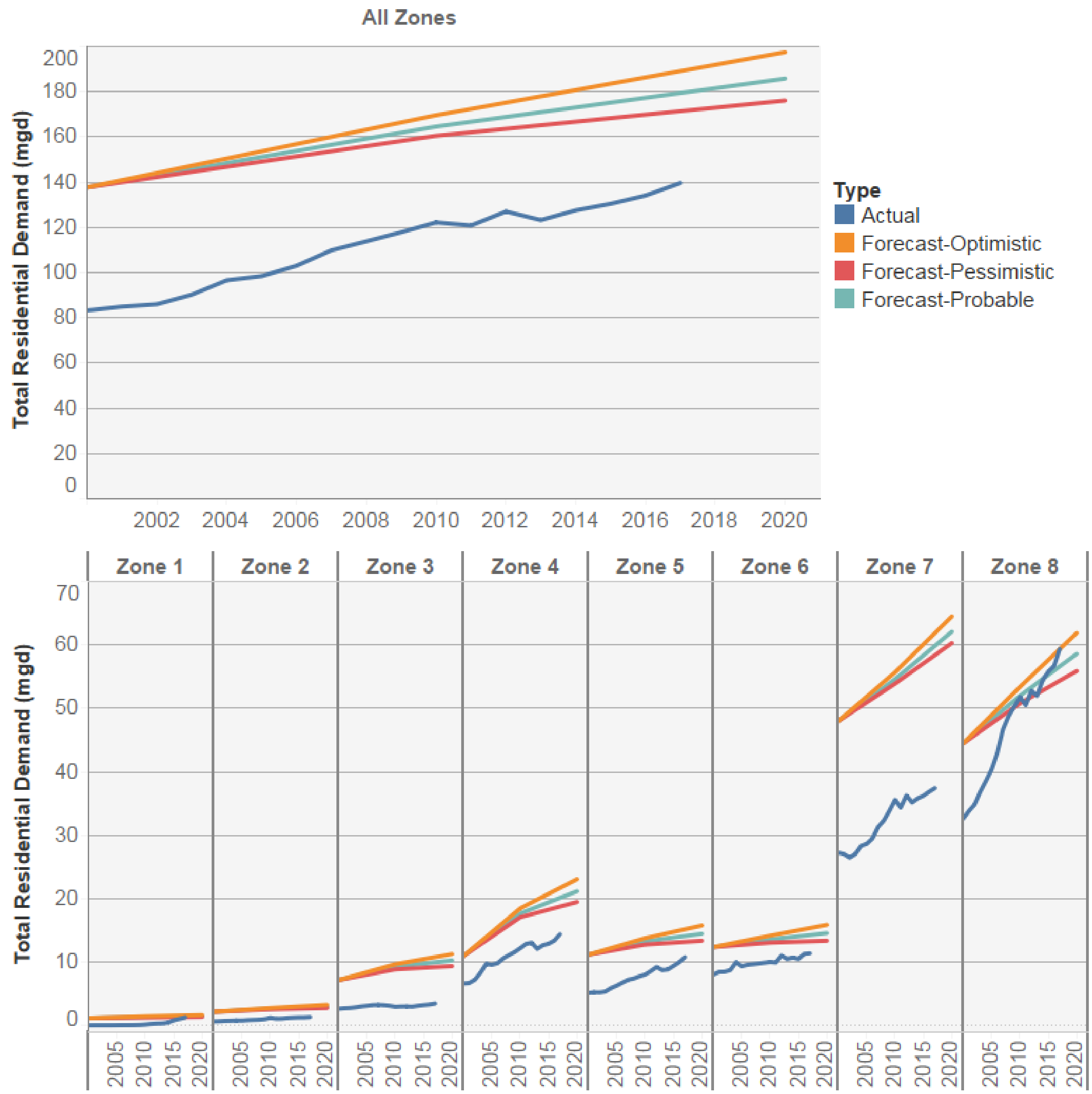
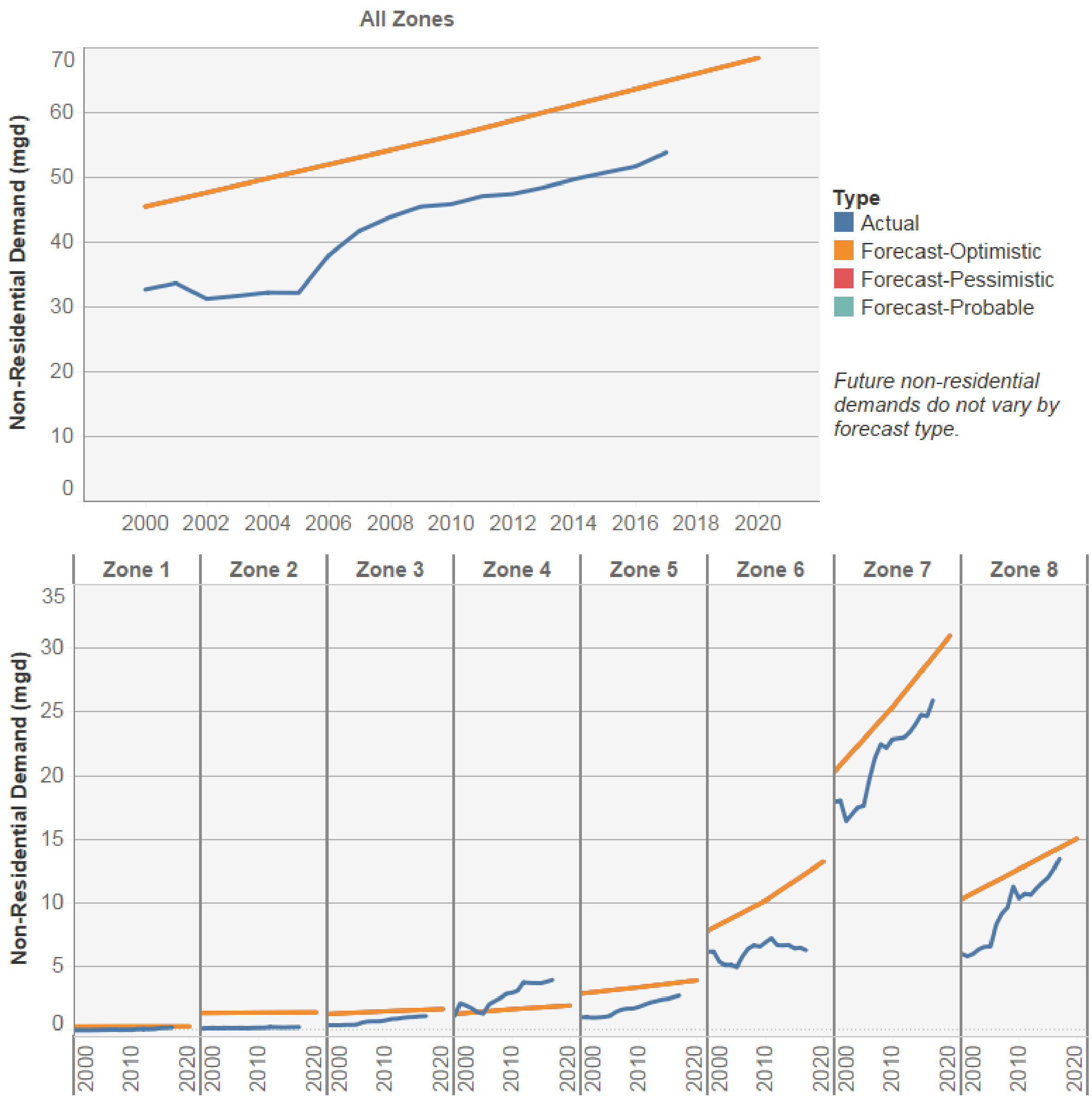


Figure 3.5 – Comparison of forecasted and actual total residential demands

3.2.3 Comparison of Non-Residential Water Use

Figure 3.6 compares the non-residential consumption forecasted by the 2000 Demand Model and actual observed non-residential consumption. For non-residential consumption there was no variation in the different growth scenarios. Forecasted non-residential demand was higher than actual observed demands for all zones with the exception of Zone 4. From 2010 to 2017, the forecasted non-residential demands were approximately 20 percent higher than actual.



Note: Probable, Optimistic, and Pessimistic water demand scenarios have the same estimate of future non-residential demand.

Figure 3.6 – Comparison of forecasted and actual non-residential demands

3.2.4 Comparison of UFW

Figure 3.7 compares the forecasted and observed UFW for the three regions for which IDAAN provided total production data as well as the total UFW across these three regions. Observed UFW was determined by subtracting the total accounted-for-water consumed from the total water production at the WTPs. Across all regions, observed UFW is higher than forecasted in the 2000 Demand Model, with recent actual UFW being 170 percent higher than what was forecasted. It is noted that observed UFW is on the order of 40 percent of total water production or higher.

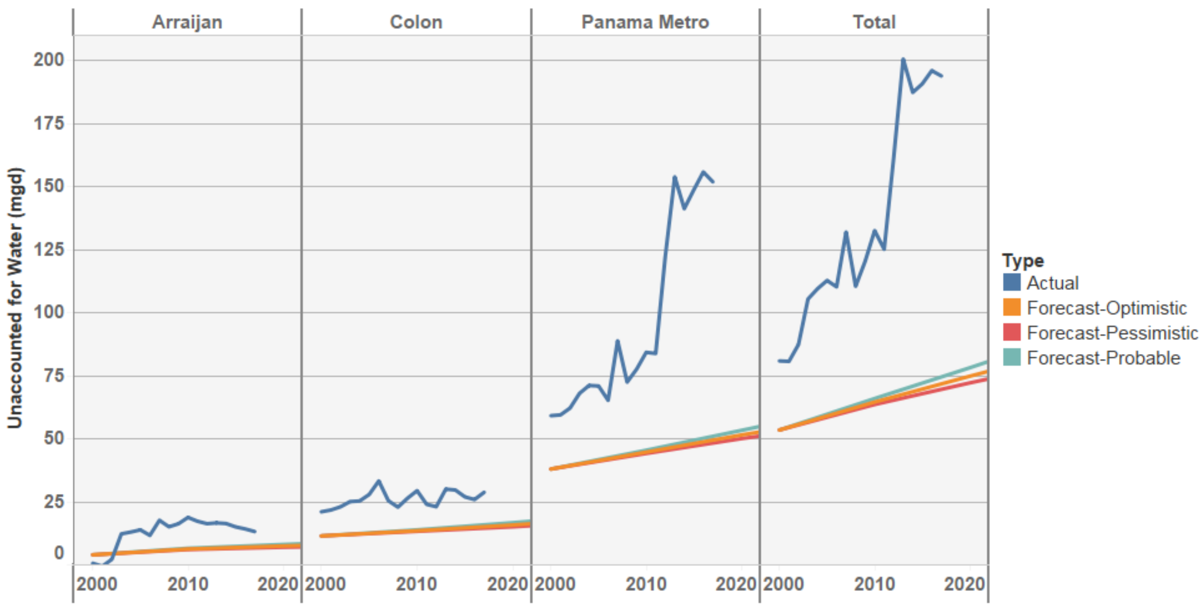
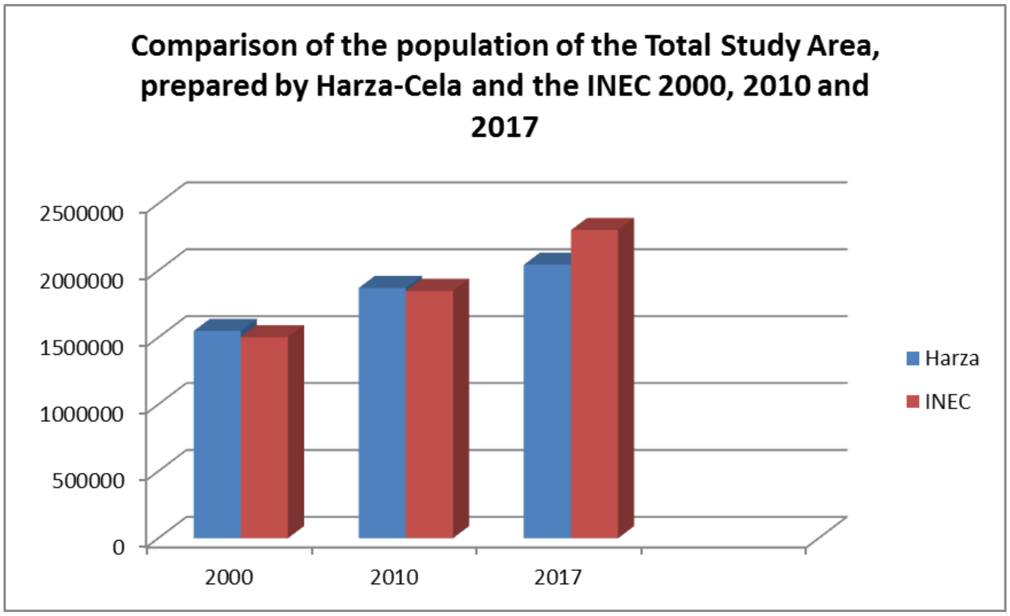


Figure 3.7 – Forecasted and actual observed UFW

3.2.5 Comparison of Population

From 2000-2017

Figure 3.8 compares the actual and forecasted total population in the Study Area. The 2000 Demand Study predicted a total of 1,548,260 inhabitants for the Study Area in 2000, while the census of that year established that there were 1,501,160 inhabitants. In 2010, the 2000 Demand Study predicted that there would be 1,869,753 inhabitants, a little more than what INEC determined (1,847,508). The projection for 2017 from the 2000 Demand Study was 2,043,178 people in the Study Area, and according to the official estimates the actual population was 2,302,607 in 2017. Viewed in global terms the 2000 projections were fairly accurate, tracking well with actual population through 2010 but falling short of actual population in 2017 by 12.7 percent.

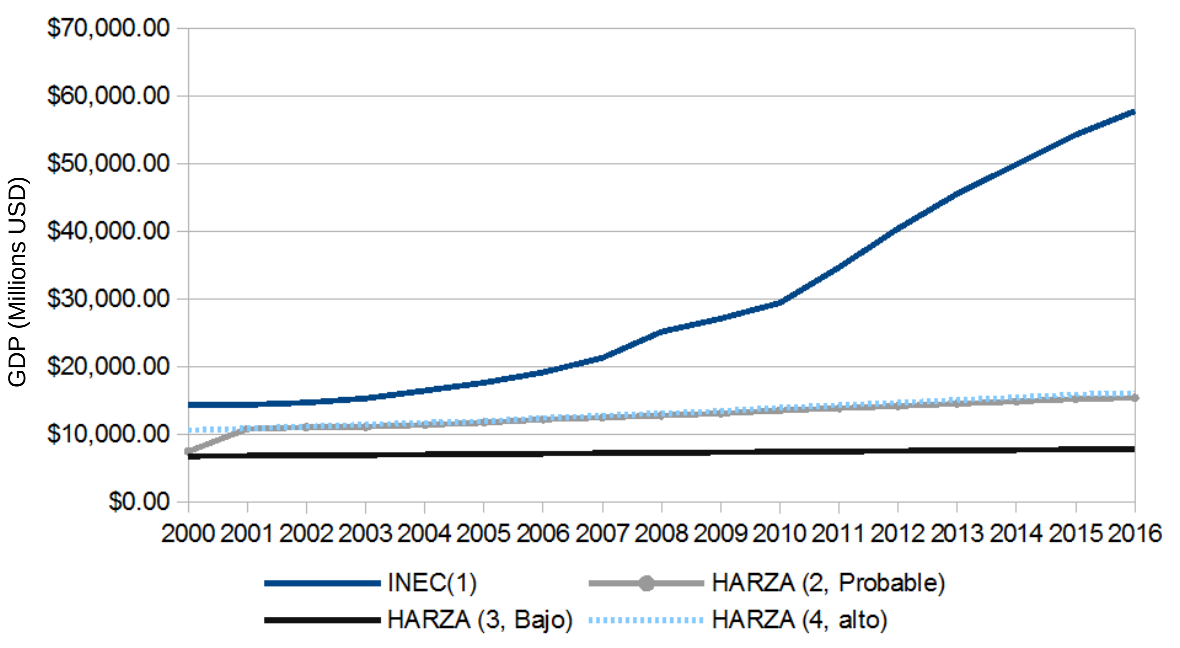


From 2000-2017

Figure 3.8 – Comparison of actual and forecasted population in Study Area

3.2.6 Comparison of Economic Activity

A primary indicator of economic activity that drives non-residential water use and overall regional growth is GDP. **Figure 3.9** presents a comparison between the GDP levels for the Republic of Panama as measured by INEC and the 2000 Demand Study projections. As the graph shows, the 2000 Demand Study projections were linear projections of economic growth prior to 2000, compared to the non-linear rates in economic growth which actually occurred. While for the first few years actual GDP remained close to the projected values, the increase in world commerce pre-2008 and the rapid growth of Panama during and after the Canal expansion quickly overcame such assumptions. The higher GDP would lead to higher commercial/industrial activity, expanded population, and a higher standard of living for many residents – all of which would generate an increase in overall water use in the Study Area.



Note: GDP measured by the INEC and economic projections proposed by Harza-CELA. In Millions of Dollars. The economic series was linked to pre-2008 using official rates of growth. Source: INEC and Harza (2000).

From 2000-2016

Figure 3.9 – Actual and forecasted Panama GDP

3.2.7 Summary

This forecast comparison lead to the following conclusions.

- *Higher Population* – Actual population in the Study Area tracked well with the 2000 Demand Model forecast between 2000 and 2010, but by 2017 actual population was 12.7 percent higher than the forecasted population in the Probable scenario. The greater-than-expected population was a key factor in the greater-than-expected total water requirement.
- *Lower Residential Demands* – Actual residential demands were consistently lower than what was forecast in the 2000 Demand Model. This is because the residential per capita use value assumed in the 2000 Demand Model was higher than actual per capital use values for residential customers. Also, the excessive use by unmetered customers assumed in the 2000 Demand Model was higher than the actual excessive use calculated from the observed IDAAN data.
- *Lower Non-Residential Demands* – Actual non-residential demands were consistently lower than what was forecast in the 2000 Demand Model. The actual non-residential consumption could not be compared to the forecasted non-residential consumption because it is unknown how IDAAN classifies individual customers into the non-residential demand categories (i.e., commercial, industrial, government).
- *Higher UFW* – Actual UFW was consistently and significantly two times higher than what was forecast in the 2000 Demand Model. For the three regions with production data provided by IDAAN, actual UFW was double what was forecasted.

- *More Robust Economy* – Economic activity in Panama from 2000 to 2017 as measured by GDP was much higher than anticipated in the 2000 Demand Model. This could have contributed to higher water production compared to the forecast.

3.3 IMPLICATIONS FOR DEMAND MODEL UPDATE

Based on the results of comparing the various components and drivers of actual use and forecasted water demand, four key strategies for updating the demand model were identified and applied. These are shown in **Figure 3.10 a**nd summarized below.

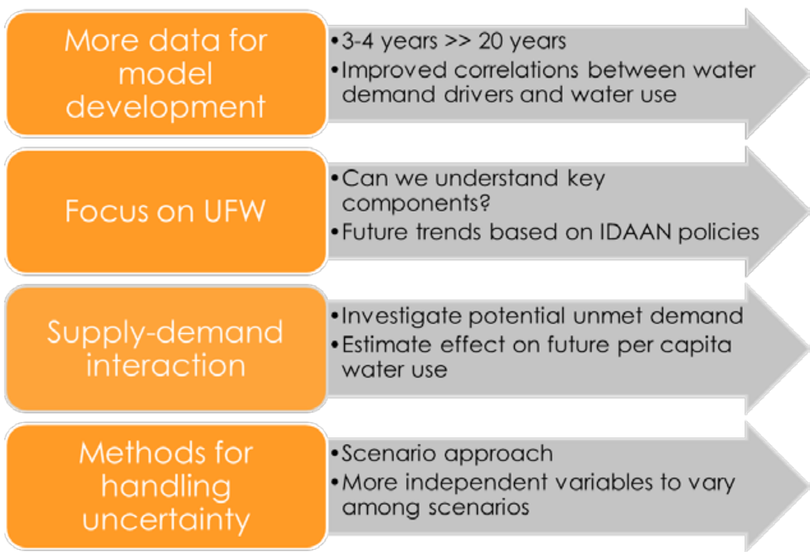


Figure 3.10 – Key strategies for Demand Model update

- The 2000 Demand Model was developed with only a few years of observed data (1995 or 1996 through 1999) for many of the important model parameters. An additional 17 years of observed data would improve the ability to develop a demand model that responds appropriately to the key inputs.
- The difference in UFW is ultimately the major driver behind the 2000 Demand Model forecast for total water requirement being lower than actual water use as measured by WTP production. Improved understanding of the magnitude and makeup of each of these components would improve the skill of the demand forecast model.
- Review of observed data in the Study suggest that there is an interaction between supply and demand due to a large number of unconnected or under-served residential water customers, and that increasing supply would result in an increase in demand even if other factors remain the same.

A key take-away from the analysis of observed data for water use and water use drivers from 2000 to 2017 is that there is considerable uncertainty around all the key parameters in the demand forecast model. Observed data shows wide variability from month to month and year to year, making it difficult to predict likely values for these variables in the future. This situation is often addressed by adopting a scenario approach to planning, in which key parameters are varied over an appropriate range to develop a broad spectrum of possible future conditions.

This approach was adopted to a limited extent in the 2000 Study, in which three future scenarios were investigated (Probable, Optimistic, Pessimistic) that varied the future population parameter. The variability in parameters exhibited over the 2000 to 2017 period suggests a more robust scenario planning approach could be warranted for the demand model update. The 2000 Demand Model was set up with several parameters that could be varied, but only two parameters were varied by year for each Population Zone (population and economic activity). The updated model could incorporate uncertainty in a more robust way by allowing for variability in several parameters affecting water use. This is depicted in **Figure 3.11**. Means of incorporating additional uncertainty in the updated Demand Model were considered and discussed with ACP.

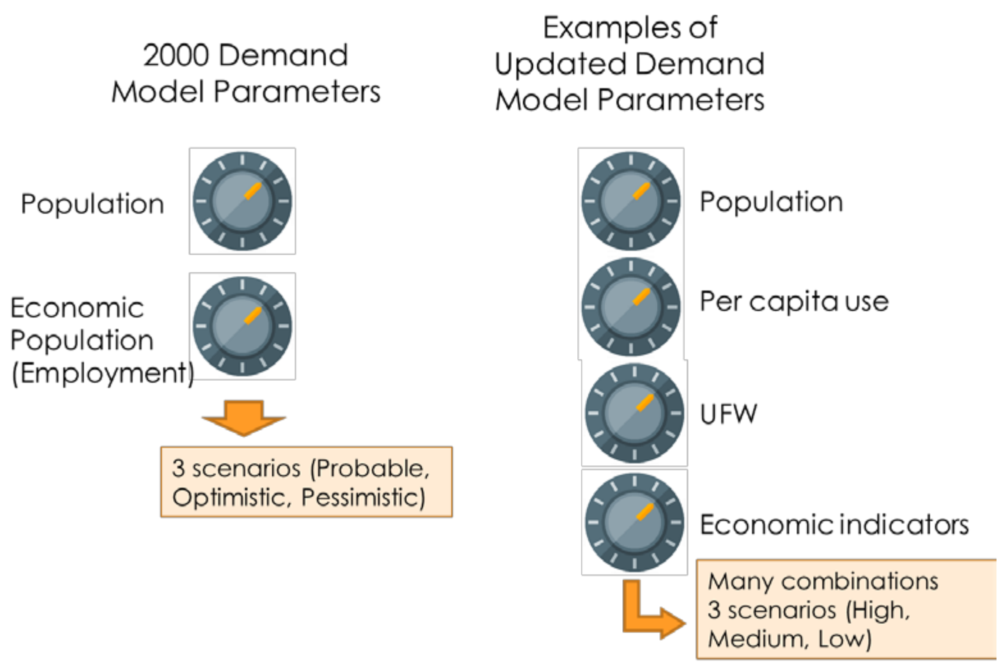


Figure 3.11 – Possible expanded scenario planning process for Demand Model

4.0 DEMAND FORECAST MODEL DEVELOPMENT

This section summarizes the components of the Demand Model used to forecast total water requirement from the Watershed. The Demand Model consists of two major components: the parameters used to calculate total water requirement, and the projections and scenarios that are inputs for specific forecasts. The *Water Demand Forecast Model Description Technical Memorandum* (Stantec 2018c) describes in detail the Demand Model parameters and is included in **Appendix C**. The *Water Demand Forecast Assumptions Technical Memorandum* (Stantec 2018d) describes in detail the projections and scenarios and is included in **Appendix D**.

4.1 METHODOLOGY OVERVIEW

4.1.1 Demand Model Overview

Figure 4.1 is a schematic of the water use components included in the Demand Model. The objective of the Demand Model needed by ACP is to estimate future extractions from the Watershed for M&I purposes. WTPs must extract the volume of water from the Watershed required to meet M&I demands of customers connected to the water distribution system plus losses in the WTPs and distribution system.

The Demand Model forecasts the future water requirement using parameters grouped into three water-use categories: residential use, non-residential use, and infrastructure losses. Residential and non-residential consumption is categorized as “beneficial use consumption,” which is water that is actively used by any person, business, or industry. This includes water use that is metered and unmetered or unaccounted for, as long as it was delivered to a customer and put to beneficial use. The Demand Model assumes that people who currently receive water from IDAAN will continue to in the future. There is also a segment of the population who does not receive a reliable supply of water from the IDAAN system who will be included in the Demand Model as well. Water that is not put to beneficial use either due to leakage or losses from the distribution system is considered lost. Infrastructure parameters that estimate the volume of this lost water are described in Section 4.4.3.

Beneficial accounted for consumption is comprised of residential and non-residential components in the Demand Model. Residential water use includes water used for all domestic purposes in homes, apartments, etc.; and non-residential water use includes water used for commercial, industrial, and government purposes. The residential consumption parameters are summarized in Section 4.4.1 and non-residential consumption parameters are summarized in Section 4.4.2.

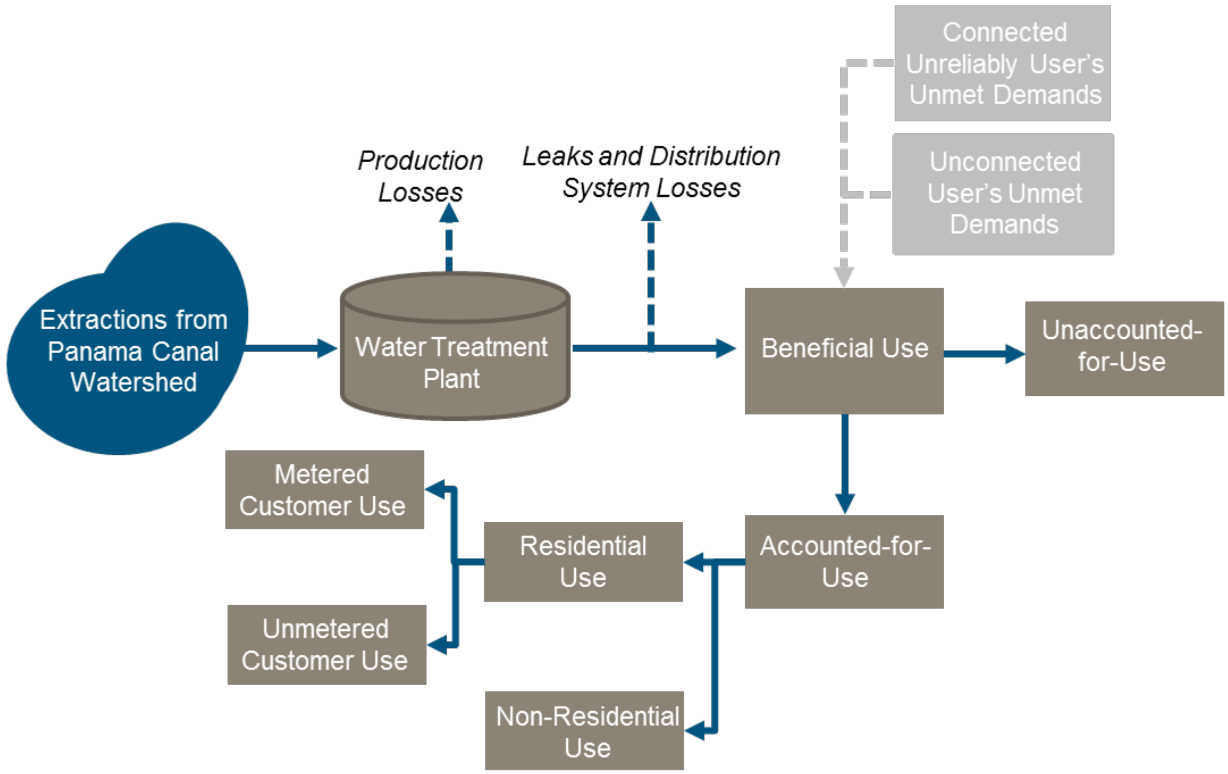


Figure 4.1 – Schematic of water use components in Demand Model

4.1.2 Planning Under Uncertainty

The observed variability in the data available for water consumption in the Study Area, and in some cases the questionable quality of that data, indicates there is a high degree of uncertainty associated with the information used to create the Demand Model. In addition, future conditions related to drivers of water use in the Study Area such as population growth and economic vitality are uncertain. This is evidenced by the substantial differences between actual water use between 2000 and 2017 and the forecasted water use from the 2000 Harza Study demand model as described in the *Forecast Comparison TM*. These factors indicate that significant potential future uncertainty needs to be captured in the Demand Model for it to be an effective planning tool. Therefore, the development of the Demand Model incorporated techniques for planning under uncertainty.

One technique that was used was developing water demand forecast parameters using the variability in the observed data as a representation of potential future uncertainty. For these parameters, ranges of values were developed that capture the observed variability in the observed record and possible future variability based on assumptions for future condition scenarios. This technique is beneficial when uncertainty around these parameters cannot be controlled or well estimated, such as for per capita water use or the number of unmetered customers.

Another technique that was used was to develop scenarios that set values for parameters that have minimal observed variability but significant future uncertainty. Scenarios are narrative descriptions of qualitative future conditions that have associated quantitative impacts on parameters. For example, the narrative scenario of increased foreign investment in Panama would be translated to the Demand Model with more rapid population and economic growth compared to a baseline future. Another narrative scenario could be increased emphasis on metering and accounting for customers by IDAAN which would be translated into the Demand Model with a reduced number of unmetered and unaccounted for customers.

4.2 TEMPORAL SCOPE

The Demand Model was developed using data from 2000 to 2017 and forecasts total water requirement and its components at 2020, 2025, 2030, 2035, 2040, 2045, and 2050.

4.3 GEOGRAPHIC SCOPE

The Study Area for the Demand Model consists of the geographic area that is either presently served or could potentially be served in the future by supply sources from within the Watershed.

Corregimientos were the smallest geographic division used to aggregate the water use, population, and other data in the Study Area. When selecting corregimientos to include in the Study Area, all corregimientos included in the 2000 Study and corregimientos that were created after 2000 but within the 2000 Study Area were included.

Corregimientos were added to the Study Area based on consultation with IDAAN regarding long-term plans for expansion of the distribution system. At the time of this Study, IDAAN planned on adding or expanding WTP and distribution capacity to serve corregimientos within the 2000 Study Area. IDAAN was also considering the new La Arenosa WTP that would provide water to corregimientos outside the 2000 Study Area, but decided to suspend the project in December 2017. IDAAN currently plans to serve these areas from new facilities capturing water from local streams outside the Watershed. Because this Study is a long-term forecast, the corregimientos that would have been served by the La Arenosa WTP were included in an expanded Study Area because this project or one similar to it could occur in the long-term future. However, these new corregimientos would only be included in the future water requirement forecast under certain scenarios defined in Section 4.7.

The Population Zones from the 2000 Study were used again for this Study, and were modified to include new corregimientos created after 2000. Corregimientos in the expanded study area were all grouped into a single new Population Zone. In total there are nine Population Zones:

- Zone 1 is the northwest interior of the Watershed
- Zone 2 is the far eastern interior of the Watershed
- Zone 3 is the northeastern interior of the Watershed
- Zone 4 is the Arraijan district which includes the western suburban areas of Panama City
- Zone 5 is the Chorrera and Capira districts

- Zone 6 is the Colon district
- Zone 7 is the urban areas of Panama City
- Zone 8 is the suburban areas east of Panama City
- Zone 9 is the expanded Study Area southwest of the Watershed and Panama City

Table 4.2 lists the corregimientos included in each Population Zone and **Figure 4.2** shows the geographic extent of the Population Zones with the included corregimientos.

Residential consumption parameters were developed for four corregimiento development types: urban, suburban, rural, and vacation. Corregimientos within the Study Area were classified into one of the four development type categories qualitatively by CELA using the following definitions:

- Urban corregimientos have a large percentage of land developed with high-density multi-family residences, commercial offices, hotels and concentrated industry.
- Suburban corregimientos have a large percentage of land developed with low-density single or multi-family residences, low-rise offices, and strip malls or low-density commercial development.
- Rural corregimientos have a low percentage of land developed with most non-agricultural water use being for permanent residents.
- Vacation corregimientos have a low percentage of available land developed with most non-agricultural water use being for hotels, resorts, or second vacation homes.

Some Population Zones contain corregimientos of different development types. Therefore, the percentage of the population belonging to each development type within a Population Zone was determined using the 2020 probable population forecasts for the corregimientos in that Population Zone. **Table 4.1** shows the percentage of each Population Zone's population classified into each development type.

Table 4.1 – Percent of total population by development type across Population Zones

Population Zone	Rural	Suburban	Urban	Vacation
Zone 1	100%			
Zone 2	13%	87%		
Zone 3	14%	86%		
Zone 4	3%	97%		
Zone 5	16%	84%		
Zone 6		11%	89%	
Zone 7		11%	89%	
Zone 8		100%		
Zone 9	49%	9%		42%

Table 4.2 – List of corregimientos in Study Area and Population Zone

Zone 1	Zone 5	Zone 7	Zone 9
Amador	Barrio Balboa[2]	Ancón	Anton (Cabecera)
Arosemena	Barrio Colón[2]	Bella Vista	Bejuco
Ciricito	Caimito	Betania	Buenos Aires
El Arado	Campana	La Exposición o Calidonia	Caballero
Escobal	Capira (cab.)	Curundú	Cabuya (Anton)
Herrera	Cermeño	El Chorrillo	Cabuya (Chame)
Iturralde	Cirí de los Sotos	Parque Lefevre	Chame (Cabecera)
La Represa	Cirí Grande	Pueblo Nuevo	Chica
Mendoza	El Cacao	Rio Abajo	El Chiru
Zone 2	El Coco	San Felipe	El Espino
Chepo	Feuillet	San Francisco	El Higo
Las Margaritas	Guadalupe	Santa Ana	El Libano
San Martín	Hurtado	**Zone 8**	El Retiro
Zone	La Trinidad	24 de Diciembre[1]	El Valle
Buena Vista	Las Ollas Arriba	Alcalde Díaz[1]	Guayabito
Chilibre	Lídice	Amelia Denis de Icaza	Juan Diaz (Anton)
Limón	Los Diaz	Arnulfo Arias[1]	La Ermita
Nueva Providencia	Obaldía	Belisario Frias[1]	La Laguna
Salamanca	Playa Leona	Belisario Porras	Las Lajas
San Juan	Puerto Caimito	Ernesto Cordoba Campos[1]	Las Uvas
Santa Rosa (Colon)	Santa Rita (La Chorrera)	Jose Domingo Espinar	Los Llanitos
Zone 4	Santa Rosa (Capira)[1]	Juan Diaz (Panama)	Nueva Gorgona
Arraiján (cab.)	Villa Carmen	Las Cumbres	Punta Chame
Burunga[1]	Villa Rosario	Las Mañanitas[1]	Rio Hato
Cerro Silvestre[1]	**Zone 6**	Mateo Iturralde	Sajalices
Juan Demostenes Arosemena	Barrio Norte	Omar Torrijos[1]	San Carlos (Cabecera)
Nuevo Emperador	Barrio Sur	Pacora	San Jose
Santa Clara	Cativá	Pedregal (pma)	San Juan de Dios
Veracruz	Cristobal	Rufina Alfaro[1]	Santa Rita (Anton)
Vista Alegre	Puerto Pilón	Tocumen	Sora
	Sabanitas	Victoriano Lorenzo	

1. Corregimiento was created after 2000 and assigned to a zone based on geography
2. Corregimientos were combined in 2000 Demand Model under the name La Chorerra.

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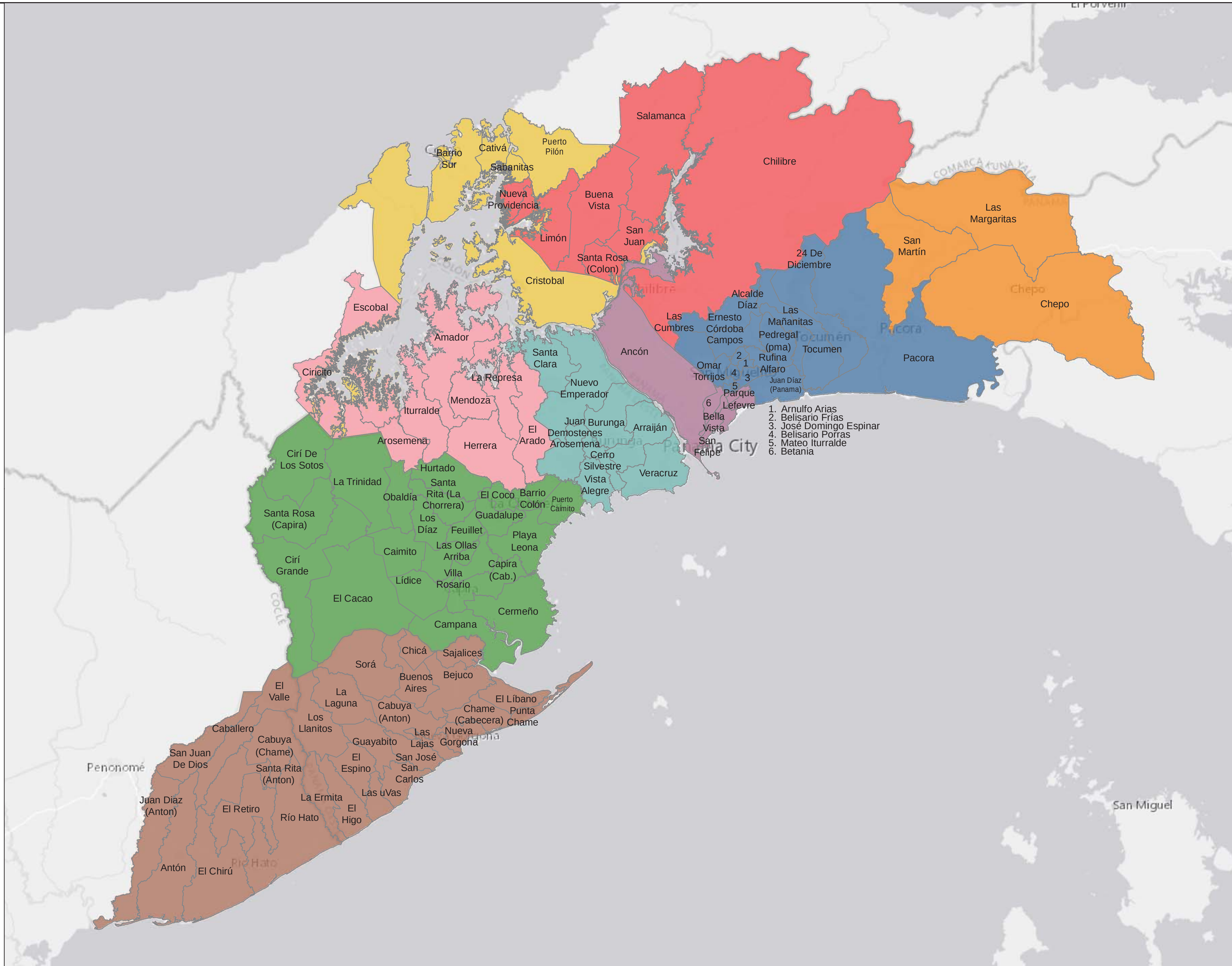


Stantec

Legend

Corregimientos

Population Zone

- Zone 1
- Zone 2
- Zone 3
- Zone 4
- Zone 5
- Zone 6
- Zone 7
- Zone 8
- Zone 9

N

0 6 12 Kilometers

1:608,680 (At original document size of 11x17)

Notes

1. Coordinate System: WGS 1984 UTM Zone 17N

Project Location

Panama

Client/Project

Autoridad del Canal de Panama
Panama Canal Watershed Municipal and Industrial Water Demand and Raw Water Consumption Forecast, 2020 - 2050

Title

Figure 4.2 - Corregimientos and Population Zones in Study Area

4.4 DEMAND FORECAST PARAMETERS

This section describes the development of the water demand forecast parameters incorporated into the analytical processes used in the Demand Model to estimate future M&I water demand from Watershed sources.

4.4.1 Residential Demand Forecast Parameters

The Demand Model forecasts residential consumption by first dividing the population of the Study Area into five water user types, then multiplying a per capita water use parameter by a population parameter for each water user type. **Figure 4.3** defines the five types of water users in the Study Area. The terms used to describe these users in this study and their definitions are:

- *Metered* users are connected to the IDAAN water distribution system and their water use is accounted for by IDAAN based on measurement of the actual volume of water they consume using a water meter.
- *Unmetered* users are connected to the IDAAN water distribution system and their water use is accounted for by IDAAN by setting a fixed estimate of consumption that is not tied to the volume of water they actually use.
- *Unaccounted-For* users receive water from IDAAN facilities, but the connections are unknown or not accounted for by IDAAN and therefore no record of their water use.
- *Connected Unreliably* users receive water from IDAAN facilities but the supply of water is not reliable in that it is frequently interrupted or not always available
- *Unconnected* users do not receive water from IDAAN facilities and do not have access to water on their premises (e.g., they rely on wells or trucked water or other similar sources).

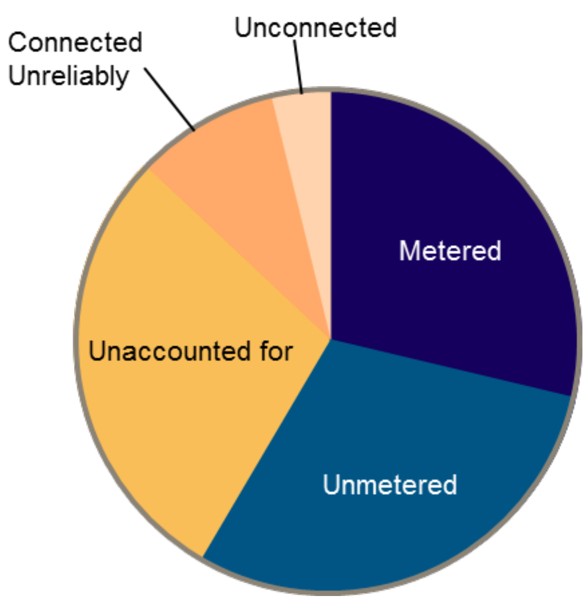


Figure 4.3 – Conceptual depiction of residential water user types in Study Area

Figure 4.4 shows the residential consumption parameters in the Demand Model for the five water user types. These parameters were developed using available observed consumption data provided by IDAAN whenever possible, and population percentage estimates from the World Health Organization (WHO) when data from IDAAN was not available (i.e., for the percentage of water users connected unreliably and the percentage of the population that is not connected to a centralized water system). Because of the variability in the observed consumption data, ranges were adopted for some parameters to capture this uncertainty when forecasting future water consumption.

Unconnected Water Users	*% of Population Unconnected* *Unconnected Unmet Per Capita Demand*
Connected Unreliably Water Users	*% of Population Connected Unreliably* *Unreliably Connected Unmet Per Capita Demand*
Unaccounted For Water Users	*% of Population Unaccounted For* *Unaccounted for Per Capita Use*
Unmetered Water Users	*% of Population Unmetered* *Unmetered Per Capita Use*
Metered Water Users	*% of Population Metered* *Metered Per Capita Use*

Figure 4.4 – Overview of residential consumption parameters for Demand Model

Table 4.3 summarizes the parameters used in the Demand Model to estimate residential water use. To incorporate the variability of the per capita use parameter, the Demand Model assumes that 25 percent of the population consumes water at the low per capita rate, 50 percent of the population consumes water at the medium per capita rate, and 25 percent of the population consumes water at the high per capita use rate. This assumed is for both the metered and unmetered per capita use rates. More detail on development of these parameters can be found in **Appendix D**.

Table 4.3 – Residential water use Demand Model parameters

<table>
<tr><th rowspan="2">Residential Water Use Category</th><th rowspan="2">Population Parameter (Percentage of Total Population)</th><th colspan="4">Per Capita Use Parameter (GPCD)</th></tr>
<tr><th>Type</th><th>Low</th><th>Medium</th><th>High</th></tr>
<tr><td rowspan="4">Metered</td><td rowspan="4">Urban: 51%
Suburban: 30%
Rural: 24%
Vacation: 5%</td><td>Urban</td><td>69</td><td>83</td><td>93</td></tr>
<tr><td>Suburban</td><td>55</td><td>63</td><td>75</td></tr>
<tr><td>Rural</td><td>34</td><td>42</td><td>45</td></tr>
<tr><td>Vacation</td><td>43</td><td>46</td><td>49</td></tr>
<tr><td rowspan="2">Unmetered</td><td rowspan="2">Urban: 39% (range 37% to 41%)
Suburban: 42% (range 37% to 52%)
Rural: 31% (range 25% to 49%)
Vacation: 81% (range 36% to 86%)</td><td>Type</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td>All</td><td>111</td><td>160</td><td>232</td></tr>
<tr><td>Unaccounted For</td><td>Urban: 0%
Suburban: 18%
Rural: 19%
Vacation: 5%</td><td colspan="4">Same as Unmetered</td></tr>
<tr><td>Connected Unreliably</td><td>Urban: 8%
Suburban: 8%
Rural: 11%
Vacation: 8%</td><td colspan="4">Same as Metered</td></tr>
<tr><td>Unconnected</td><td>Urban: 2%
Suburban: 2%
Rural: 15%
Vacation: 2%</td><td colspan="4">Same as Metered</td></tr>
</table>

4.4.2 Non-Residential Demand Forecast Parameters

The Demand Model forecasts non-residential consumption using the PIEM and the IMAE generated by the INEC.

As described in the *Water Demand Model Description TM*, regression equations in the form shown in Equation 1 were developed for each Population Zone to compute non-residential consumption based on the PIEM and IMAE economic indicators.

$$Zone_n = \beta_0 + \beta_1(PIEM_n) + \beta_2(IMAE) + \epsilon \qquad \text{(Equation 1)}$$

In this equation, n is the Zone (1-8), β_0 is a constant (which measures the mean effect of the dependent variable), β_1 is the regression coefficient of the selected PIEM indicator (n) with respect to the dependent variable, and β_2 is the regression coefficient of the IMAE, or the influence of economic activity in non-residential water use. ε is the error term. The model reads as follows: For one marginal increase in a PIEM indicator, Zone *n* water use increases or decreases by β_1 gallons. Also, per one marginal increase in an IMAE indicator, Zone *n* water use increases or decreases by β_2 gallons.

Table 4.4 shows the PIEM variables found to be correlated with non-residential water use at a statistically significant level in each Population Zone, and the single PIEM variable that gives the best explanatory correlation with non-residential water use when combined with IMAE as the other explanatory variable in Equation 1. **Figure 4.5** shows on a map the single PIEM variable with the best explanatory correlation by Population Zone.

As described in Section 4.3, a new Population Zone (Population Zone 9) was included in the Study Area, which is shown in **Figure 4.2**. Because this Population Zone is outside the current IDAAN service area, observed non-residential consumption data is not available for Population Zone 9. Non-residential consumption for Population Zone 9 was forecasted as 25 percent of its residential consumption. This 25 percent factor was based on the 2010 to 2017 average observed non-residential demand as a percentage of metered and unmetered residential demand for Population Zone 5 (shown in **Figure 4.7**), which is geographically and demographically the most similar to Population Zone 9.

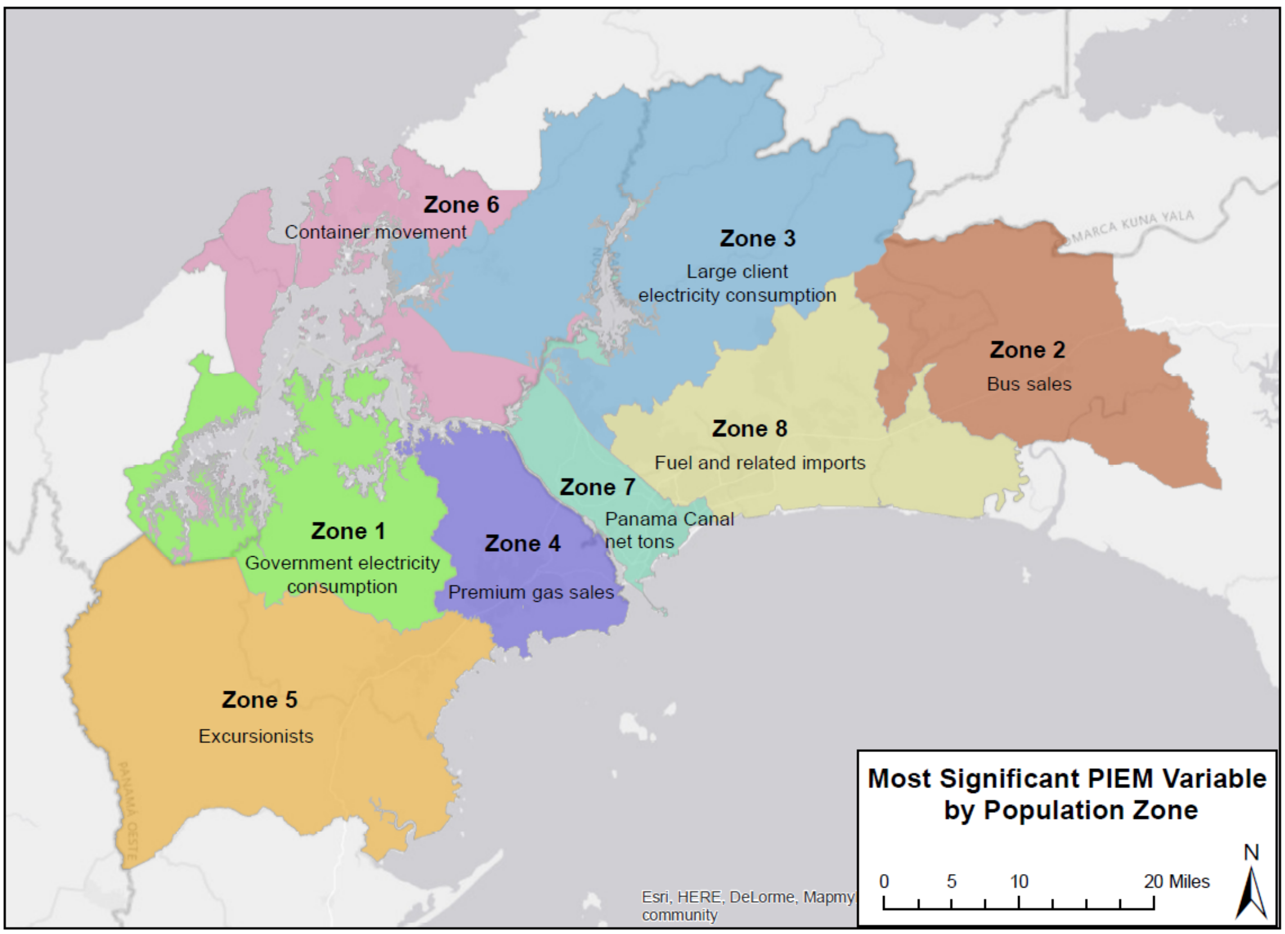


Figure 4.5 – Most significant PIEM variable by Population Zone

In addition to the non-residential forecasting method described above, ACP currently has contracts with individual entities that allow them to extract a certain volume of water from the Watershed. These additional water uses are shown in **Figure 4.6** and are typically between 24 MGD and 25 MGD, with most of that use dominated by industrial uses. Within the industrial category, 23 MGD of annual industrial use is by the entity Empresas Melo, S.A. which uses the supply for power generation. Therefore, 90 percent of these additional non-residential consumptions is due to this single user. Because ACP fully controls the volume of water extracted from the Watershed by these users, these additional extractions are not included in the Demand Model. However, ACP still needs to consider these withdrawals when evaluating the capacity of available water resources to support M&I uses and Canal operations.

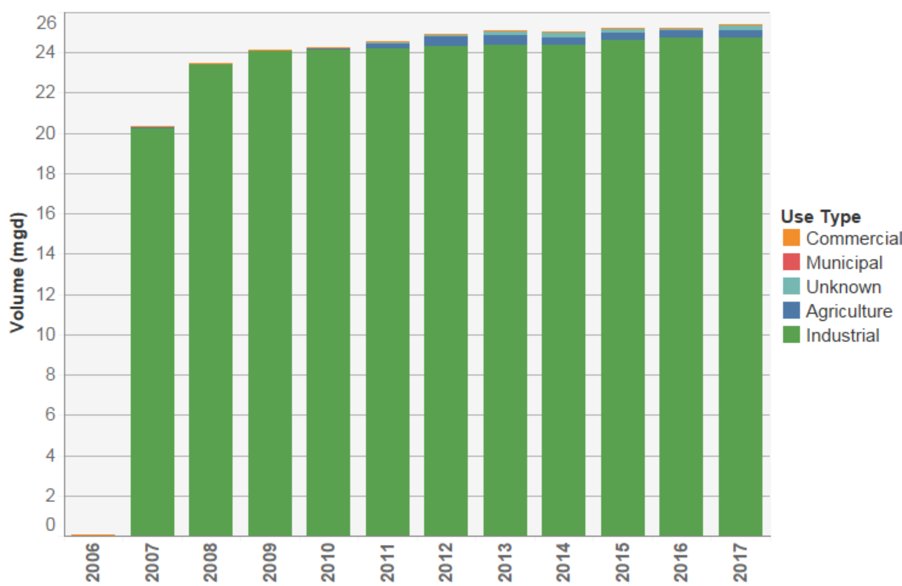


Figure 4.6 – Additional water use by individual entities with ACP contracts

Table 4.4 – Statistically significant regression variables for estimating non-residential water use by Population Zone

Population Zone	Statistically Significant Explanatory PIEM Variables	Most Significant PIEM Variable
Zone 1	Government electricity consumption	Government electricity consumption
Zone 2	Bus sales, Other capital imports	Bus sales
Zone 3	Meat production, Residential electricity consumption, Commercial electricity consumption, Large client electricity consumption, Imports of non-durable consumptions goods, Crew and in-transit, Expenditures of visitors, Toll Revenue – Panama Canal, Bulk cargo, Container cargo, Container movement	Large client electricity consumption
Zone 4	Meat production, Premium gas sales	Premium gas sales
Zone 5	Poultry production, Residential electricity consumption, Commercial electricity consumption, Government electricity consumption, Large client electricity consumption, Generator electricity consumption, Premium gas sales, Non-durable consumption good imports, Semi-durable consumption goods imports, Excursionists, Crew and in-transit, Toll revenue, Panama Canal net tons, Container cargo, Container movement	Excursionists
Zone 6	Meat production, Pork production, Large client electricity consumption, Non-durable consumption goods imports, Container cargo, Container movement	Container movement
Zone 7	Meat production, Poultry production, Government electrical consumption, Generator electrical consumption, Electrical losses, Premium gas sales, Minivan sales, Excursionists, Panama Canal net tons	Panama Canal net tons
Zone 8	Meat production, Milk powder, Soda production, Residential electricity consumption, Government electricity consumption, Generator electricity consumption, Fuel and related imports	Fuel and related imports

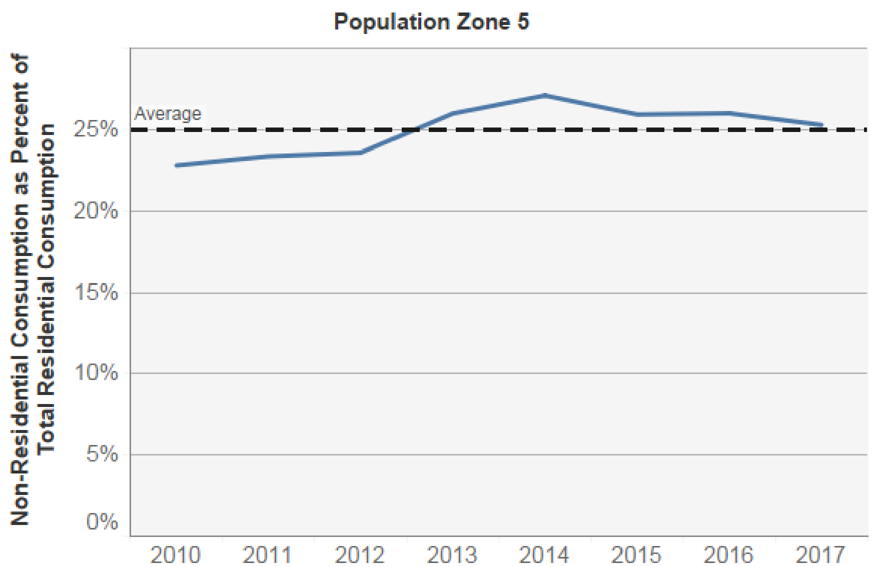


Figure 4.7 – IDAAN observed non-residential consumption as percent of total residential consumption for Population Zone 5

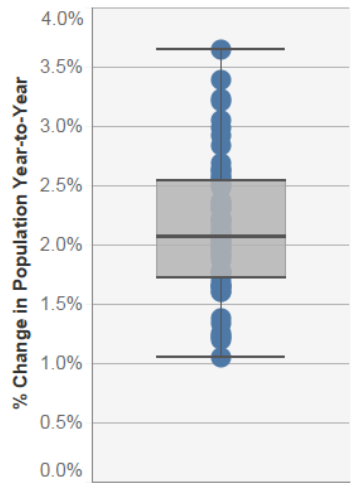
During the model verification process the non-residential demand consumption parameters described above inadequately captured growth in non-residential demands tied to population. Therefore an additional parameter was added that scales outputs from the regression equations based on population growth to improve the forecasted growth of non-residential demands.

The regression equations were developed and calibrated to 2017 observed non-residential demands. Therefore the additional parameter scales regression equation outputs based on the number of years between the year being forecasted and 2017. The scaling factor was developed using the year-to-year change in observed population as this data set is the most reliable data set available for the Study and should correlate well with increase in general commercial water use. **Note:** Each point represents a year and Population Zone

Figure 4.8 shows the year-to-year change in 2011 to 2017 observed population for the study area by population zone (each point represents a year and Population Zone), with the median percentage change shown as 2.07%.

Using this result, Equation 1 was modified to scale the regression equation outputs by 2 percent multiplied by the number of years between 2017 and the year being forecast, as shown in Equation 2. In Equation 2, *t* is the current year being forecast (e.g. 2025) and will always be greater than 2017.

$$Zone_n = (\beta_0 + \beta_1(PIEM_n) + \beta_2(IMAE) + \epsilon) * \left(1 + 2\% * (t - 2017)\right) \qquad \text{(Equation 2)}$$



Note: Each point represents a year and Population Zone

Figure 4.8 – Year to year change in 2011 to 2017 INEC population

4.4.3 Infrastructure Parameters

The Demand Model accounts for losses in the water production process (at raw water intakes and WTPs) and in the water distribution process (in pipelines and pump stations). Losses and leakage are a portion of the large fraction of UFW – from 40 to 65 percent for years between 2000 and 2017 – that makes up the IDAAN M&I water budget. The Demand Model estimates losses in water production and water distribution facilities as a function of total water produced at the WTPs. Water loss parameters were estimated from a combination of observed data in the Study Area and typical industry values, as described in Section 4.5.2 in the *Water Demand Forecast Assumption Technical Memorandum* (Stantec 2018d) in **Appendix D**.

Table 4.5 summarizes the Demand Model variables used for estimating water losses associated with production and distribution of water derived from the Watershed for M&I uses.

It is noted that throughout this report the term "losses" refers only to physical losses in the water treatment and distribution infrastructure. Water use that is not tracked and other "administrative" losses are captured in the UFW estimates.

Table 4.5 – Infrastructure loss Demand Model parameters

Type of Loss	Loss as Percentage of Total Water Produced at All WTPs
Water production facilities	10%
Water distribution facilities	20%

4.5 POPULATION GROWTH PROJECTIONS

Three population growth projections were developed for this Study that capture different assumptions around population growth between 2020 and 2050 due to economic factors, inter-Panamanian migration, and international migration. These three projections are defined below, using the same titles as used in the 2000 Demand Model. **Table 4.6** lists the factors used to estimate population for the Probable and Pessimistic projections based on population for the Optimistic projection for this Study. These projections are described in more detail in Section 5.0 of the *Water Demand Forecast Assumption Technical Memorandum* (Stantec 2018d) in **Appendix D**.

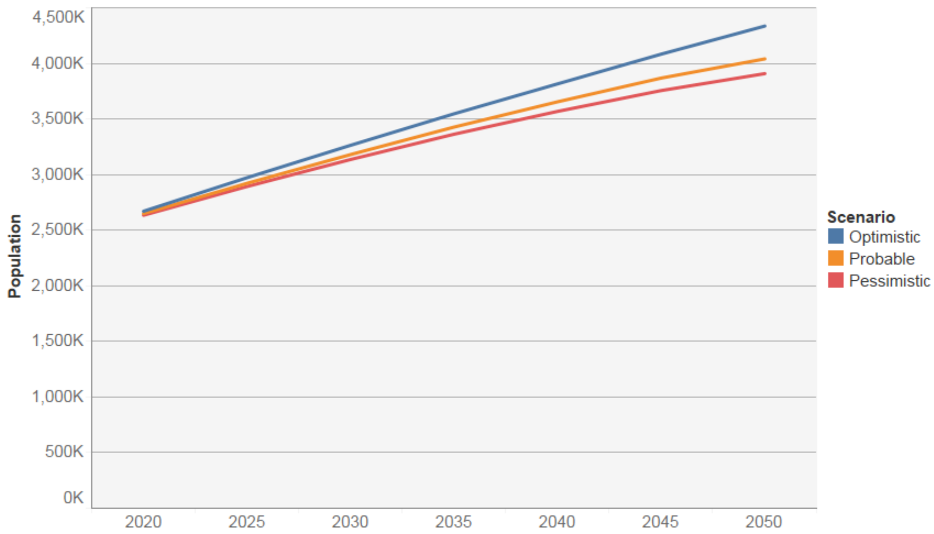
- **Optimistic**: This projection assumes large-scale foreign investment, construction of the railway to Chiriquí, possible new canal expansion, expansion of ports platform both in the Atlantic and Pacific, and foreign companies foray into production and assembly of different products. This growth will require the recruitment of foreign labor, so the scenario assumes the volume of population immigrant, differential by sex, will be higher than the most recent five-year period (2010 to 2015).
- **Probable:** This projection assumes less planned investments than the Optimistic scenario, and economic growth continues at normal levels without major fluctuation. It assumes Panama remains attractive for foreign immigrants, but with more restrictions than in the Optimistic scenario, lowering migration. It is assumed that immigration will be lower compared to the Optimistic scenario due to less employment opportunity; relative to the five-year period of 2010-15 the Probable scenario assumed 15 percent less immigration in 2010-2015 increasing to 55 percent less in 2045-50.
- **Pessimistic:** This projection assumes Panama ceases to be an attractive country for foreign immigrants, so more migration occurs to other countries. A difference in percentage of immigrants compared to recent observed conditions is estimated in relation to the Optimistic scenario. It is assumed immigration is 25 percent lower than observed in the five-year period of 2010-15, increasing to 70 percent lower in 2045-50.

Table 4.6 – Percentage estimate of international net migrator balance for Probable and Pessimistic population projections in relation to Optimistic population projections

Five Year Period	Optimistic Scenario	Probable Scenario	Pessimistic Scenario
2010-15	1.00	0.85	0.75
2015-20	1.00	0.80	0.65
2020-25	1.00	0.68	0.53
2025-30	1.00	0.63	0.48
2030-35	1.00	0.59	0.44
2035-40	1.00	0.54	0.39
2040-45	1.00	0.50	0.35
2045-50	1.00	0.45	0.30

Note: Includes Population Zone 9

Figure 4.9 shows the projected population of the Study Area (including Population Zone 9) from 2020 to 2050 in 5-year increments under the three population scenarios. At 2050, the population of the Study Area is projected to be 4.3 million people under the Optimistic scenario, 4.04 million people under the Probable scenario, and 3.9 million under the Pessimistic scenario. The average annual growth rates between 2020 and 2050 are 1.63 percent for the Optimistic scenario, 1.41 percent for the Probable scenario, and 1.32 percent for the Pessimistic scenario.



Note: Includes Population Zone 9

Figure 4.9 – Projected Study Area population for three scenarios

Figure 4.10 shows and **Table 4.7** lists how the projected population is distributed among the nine Population Zones included in the Study Area. Population Zone 8 will continue to have the largest population and will have the most significant growth. By 2050, Population Zone 4 will surpass Population Zone 7 as having the second largest population.

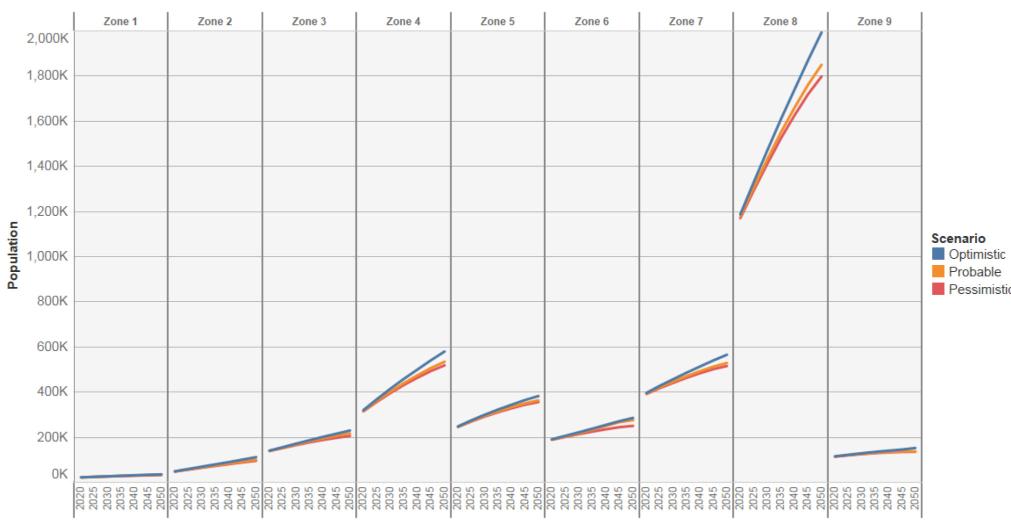
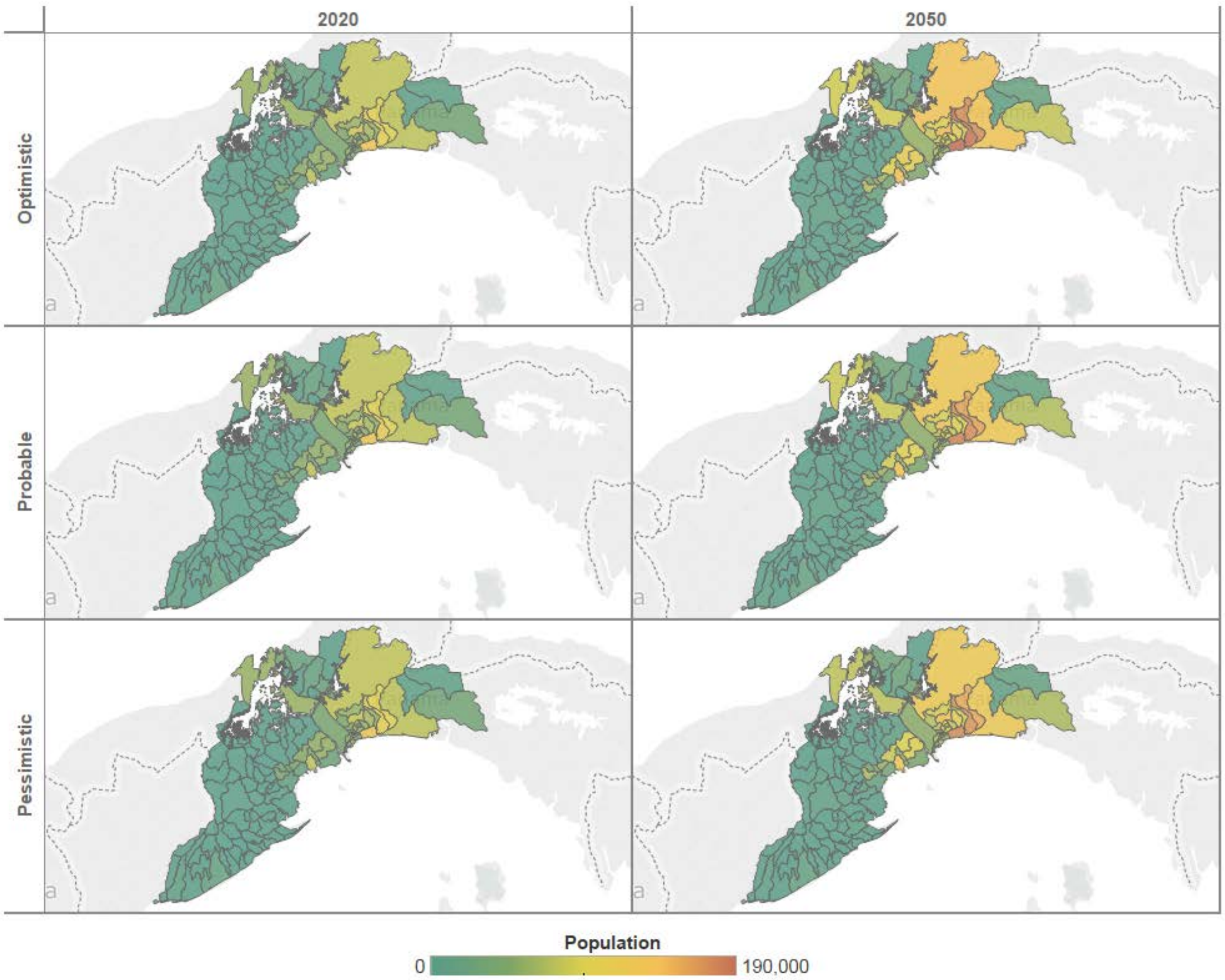


Figure 4.10 – Projected population by Population Zone

Figure 4.11 shows geographically the distribution of the population projections for the entire Study Area, with each panel showing a different population scenario at 2020 (left column) or 2050 (right column). Colors correspond to the population at the corregimiento level, with green shades indicating the lowest population and red shades indicating the highest population. Comparing growth between 2020 and 2050 shows that a majority of population growth will occur in the suburbs east and west of Panama City. Rural areas outside Panama City will have minimum growth occur.



Note: Shades of yellow/red indicate higher population at the corregimiento level for 2020 (left column) and 2050 (right column) under the three population scenarios (as rows).

Figure 4.11 – Projected population shown geographically by corregimiento

Figure 4.12 shows the same information but highlighting the Panama City area. Much of the future growth will occur in suburban areas outside the urbanized core both to the east and west of Panama City. Corregimientos comprising the urbanized area will experience less growth because they are already close to being built out.

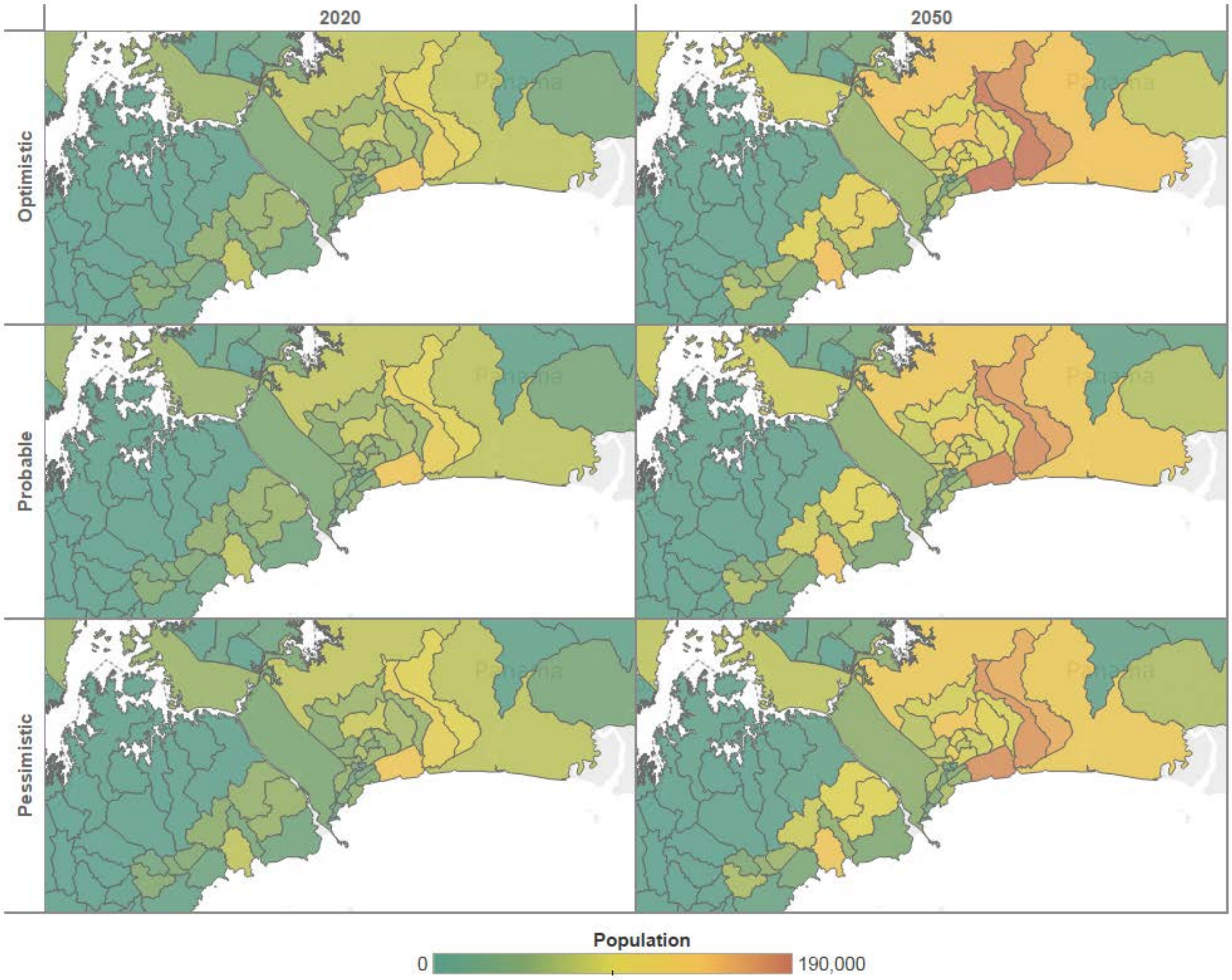


Figure 4.12 – Projected population shown geographically by corregimiento for Panama City metro region

These future projections of population were used as inputs to the Demand Model to forecast the future residential water requirement of the Watershed.

Table 4.7 – Projected population by growth projection

	Projected Population (persons)									
	Year	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Optimistic	**2020**	22,245	49,252	140,692	320,025	247,932	190,800	396,479	1,187,635	115,096
	2025	24,645	59,484	156,111	368,672	275,001	206,322	428,058	1,331,122	122,310
	2030	27,015	69,674	171,685	415,136	299,944	222,012	457,243	1,471,453	129,022
	2035	29,320	79,938	187,051	458,944	322,866	238,150	486,113	1,609,203	135,073
	2040	31,519	90,122	201,786	500,062	344,087	254,841	513,521	1,739,374	140,490
	2045	33,644	100,864	215,698	541,237	364,730	271,324	540,546	1,869,388	145,537
	2050	35,582	111,669	229,695	579,665	382,472	285,636	565,357	1,993,001	152,277
Probable	**2020**	22,138	48,450	139,746	316,836	246,554	189,619	393,586	1,177,782	115,096
	2025	24,344	57,557	153,665	361,027	271,744	203,222	421,554	1,307,587	120,754
	2030	26,518	66,420	167,753	402,344	294,498	217,589	446,593	1,431,908	126,315
	2035	28,627	75,167	181,835	440,168	314,920	233,727	470,767	1,550,917	130,964
	2040	30,628	83,569	195,128	474,498	333,300	250,490	492,802	1,659,458	134,668
	2045	32,499	92,026	207,189	506,897	350,240	267,054	512,928	1,761,250	137,592
	2050	33,919	99,995	216,968	534,459	363,296	275,572	528,919	1,849,768	137,144
Pessimistic	**2020**	22,043	47,787	139,048	314,575	245,518	188,795	391,494	1,170,834	114,071
	2025	24,152	56,362	152,286	356,754	269,790	201,464	417,695	1,294,223	120,005
	2030	26,188	64,726	165,205	395,984	291,576	213,587	441,060	1,411,996	125,177
	2035	28,061	72,938	177,362	431,653	310,977	224,963	463,519	1,524,181	129,399
	2040	29,761	80,765	188,186	463,792	328,313	235,353	483,764	1,625,698	132,643
	2045	31,295	88,552	197,394	493,634	344,023	244,589	501,807	1,719,103	135,039
	2050	32,520	95,752	205,647	518,313	355,745	250,455	515,432	1,798,130	135,603

4.6 ECONOMIC GROWTH PROJECTIONS

Three economic growth projections were created for this Study. Additional information about these economic growth projections is included in Section 6.0 of the *Water Demand Forecast Assumption Technical Memorandum* (Stantec 2018d) in **Appendix D**.

1. *High*: Estimated growth rate of six (6) percent per year – this is the high end of economic growth prospects going forward, and is in line with accelerated rates of fiscal expansion and foreign investment.
2. *Probable*: Estimated growth rate of four (4) percent per year – this is the most probable scenario, and is in line with the gradual slowdown of demographic growth and stable to increasing productivity levels given foreign investment.
3. *Low*: Estimated growth rate of two (2) percent per year – this is the low end of economic growth prospects, buttressed only in the demand generating capacity of slowing rates of population growth and low investment.

Future non-residential consumption projections were developed for Population Zones 1 to 8 using Equation 2, the parameters listed in **Table 4.8**, and economic projection inputs from INEC adjusted using the scenario percentages described above. These future projections are shown in **Table 4.9**. The PIEM indicators forecasted in **Table 4.9** were identified using a statistical correlation process described in Section 4.4.2. With the exception of Population Zone 6, non-residential consumption is forecasted to increase in the future, with the greatest increase occurring in Population Zones 4, 7, and 8. These non-residential forecasts as well as the non-residential forecast for Population Zone 9 were incorporated into the final Demand Model.

Table 4.8 – Non-residential projection parameters by Population Zone

Population Zone	β_0	β_1 (PIEM)	β_2 (IMAE)
Zone 1	-8,499,780	74.44	22,158
Zone 2	2,739,440	5,439.05	11,768
Zone 3	3,663,670	56.81	90,446
Zone 4	16,595,100	-1,506.00	402,702
Zone 5	13,699,100	375,699.00	186,884
Zone 6	216,105,000	64.87	-185,229
Zone 7	612,076,000	2,831.25	436,263
Zone 8	211,137,000	-161.64	641,151
Zone 9[1]	NA	NA	NA

1. Population Zone 9 non-residential use will be forecasted differently, as observed consumption used to develop regressions is not available.

Table 4.9 – Forecasted economic parameters

			INEC Indicator Value							
	Year	IMAE Indicator	Zone 1 ElecGob	Zone 2 Buses	Zone 3 ElecGranCl	Zone 4 HighOct	Zone 5 Excur.	Zone 6 MovCon	Zone 7 TNCP	Zone 8 ImpCombLub
High	2020	387	1234994	1245	438914	202586	298	6975100	420748	1968373
	2025	518	1257385	1268	467964	214824	321	7105098	427523	1994095
	2030	693	1280181	1292	498937	227801	346	7237519	434407	2020154
	2035	927	1303391	1316	531959	241562	372	7372407	441403	2046553
	2040	1241	1327022	1340	567167	256155	401	7509810	448510	2073296
	2045	1660	1351081	1365	604705	271629	432	7649773	455733	2100390
	2050	2222	1375576	1391	644728	288038	466	7792345	463071	2127837
Probable	2020	365	1234994	1245	438914	202586	298	6975100	420748	1968373
	2025	445	1257385	1268	467964	214824	321	7105098	427523	1994095
	2030	541	1280181	1292	498937	227801	346	7237519	434407	2020154
	2035	658	1303391	1316	531959	241562	372	7372407	441403	2046553
	2040	801	1327022	1340	567167	256155	401	7509810	448510	2073296
	2045	974	1351081	1365	604705	271629	432	7649773	455733	2100390
	2050	1185	1375576	1391	644728	288038	466	7792345	463071	2127837
Low	2020	345	1234994	1245	438914	202586	298	6975100	420748	1968373
	2025	381	1257385	1268	467964	214824	321	7105098	427523	1994095
	2030	420	1280181	1292	498937	227801	346	7237519	434407	2020154
	2035	464	1303391	1316	531959	241562	372	7372407	441403	2046553
	2040	512	1327022	1340	567167	256155	401	7509810	448510	2073296
	2045	565	1351081	1365	604705	271629	432	7649773	455733	2100390
	2050	624	1375576	1391	644728	288038	466	7792345	463071	2127837

4.7 FUTURE WATER SYSTEM SCENARIOS

As described previously, the Demand Model was prepared to accommodate uncertainty around future conditions in the water systems receiving water from the Watershed. This uncertainty was handled by developing water system scenarios around the key components driving uncertainty in water infrastructure and water utility policies. These are:

- Water system connections (i.e., how many residents who currently have no water service or unreliable water service from IDAAN are eventually supplied with reliable service)
- Improved metering and accounting
- Improved asset management (i.e., to reduce leaks and losses)
- Expansion of service area (i.e., to include customers not currently served by IDAAN with water from the Watershed)

This section describes those scenarios. It is noted that water conservation that could reduce per capita use rates was not considered in the development of future water system scenarios. Rather, conservation was included as a water supply alternative and is described in Section 7.3.3.

4.7.1 Water System Connection Scenarios

The population within the Study Area that is either unconnected or connected unreliably to the IDAAN water distribution system represents a significant future uncertainty when forecasting future water requirement. This population has unmet demands that would be rapidly realized if and when they gained access to the IDAAN service area. When that occurs, extractions from the Watershed would rapidly increase over a relatively short period of time as this population begins using water in a pattern similar to the population that is reliably connected now. This behavior has occurred in the observed consumption pattern, as described in **Appendix B** of the *Forecast Comparison Technical Memorandum* (Stantec 2018b).

To capture this future uncertainty, two scenarios were developed around this sector of population that vary the "percent unconnected' and "percent connected unreliably" parameters. The two scenarios are:

- **Current conditions** – This scenario is the status quo, and assumes the percentage of the population that is unconnected or connected unreliably remains the same as the WHO estimates described in *Water Demand Forecast Model Description Technical Memorandum* (Stantec 2018c) in **Appendix C**.
- **Improved connections** – This scenario assumes that 50 percent of the unconnected and connected unreliably population is reliably connected to an IDAAN wsa, which was deemed as a reasonable future condition.

Parameters for these two waters system connection scenarios are listed in **Table 4.10**.

Table 4.10 – Water system connection scenario assumptions

Development Type	Percent of Population	Current Scenario	Improved Connections Scenario
Urban, Suburban, Vacation	Unconnected	2%	1%
	Connected Unreliably	8%	4%
	Connected Reliably	90%	95%
Rural	Unconnected	15%	7.5%
	Connected Unreliably	11%	5.5%
	Connected Reliably	74%	87%

4.7.2 Improved Metering and Accounting Processes

IDAAN recognizes that customer metering when preparing customer bills has an important effect on customer water use. As described previously, per capita water use by unmetered customers is significantly higher than per capita use by metered customers. Future water demand scenarios require an assumption for the percentage of customers that are metered.

IDAAN could implement new programs to improve its metering program and increase the number of customers in different categories that are metered. This would require a significant investment of resources by IDAAN, and the effectiveness of those programs is unknown. To capture the uncertainty in this important factor affecting future water demand, three scenarios for IDAAN metering are used: Current, Moderate Improvement, and Full Metering/Billing. These are described as follows.

- **Current**: assume the median of the observed percentage of metered customers for each development type applies in the future.
- **Moderate Improvement**: assume there are no longer any unaccounted-for customers and the percentage of unmetered customers is reduced by half from the observed median.
- **Full Metering/Billing**: assume 5 percent of customers are unmetered and 95 percent are metered across all development types.

The percentage of unmetered customers for each scenario is presented in **Table 4.11** for each land use type. Note that the percentage values for the Current scenario are in percentage of reliably connected population, not overall population. Percentage values for the Current scenario were based on observed IDAAN data as described in Section 4.5 of the *Demand Model Development TM*. Percentage values for the Moderate Improvement and Full

Metering/Billing Scenario were deemed as reasonable representations of future conditions.

Table 4.11 – IDAAN metering and accounting scenario assumptions

Development Type	Percent of Connected Population	Current Scenario			Moderate Improvement Scenario	Full Metering/Billing Scenario
		High	Medium	Low		
Urban	Unaccounted-For:	0%	0%	0%	0%	0%
	Unmetered:	46%	43%	41%	21%	5%
	Metered:	54%	57%	59%	79%	95%
Suburban	Unaccounted-For:	20%	20%	20%	0%	0%
	Unmetered:	58%	47%	41%	23%	5%
	Metered:	22%	33%	39%	77%	95%
Rural	Unaccounted-For:	26%	26%	26%	0%	0%
	Unmetered:	66%	42%	34%	21%	5%
	Metered:	8%	32%	41%	79%	95%
Vacation	Unaccounted-For:	5%	5%	5%	0%	0%
	Unmetered:	95%	90%	40%	45%	5%
	Metered:	0%	5%	55%	55%	95%

4.7.3 Improved Asset Management

The Demand Model includes assumptions for physical water losses at WTPs and in the distribution system. These are expressed as a percentage of the WTP production. Current condition values in the model are based on limited actual data at the ACP WTPs for paired lake extraction and WTP production in 1997-2006, a brief ACP review of their WTP efficiency in 2018, and industry standard data for WTP and distribution system losses. There is considerable uncertainty around these values. The losses in IDAAN facilities are assumed to be higher than typical industry values because of challenges in funding adequate asset management. If additional financial resources were allocated to improving and maintaining WTPs and distribution system infrastructure, losses could be reduced significantly.

To develop scenarios incorporating the influence of IDAAN asset management on future total water requirements, two future condition assumptions were developed.

- **Current** –10 percent losses in WTPs and 20 percent losses in the distribution system (expressed as a percentage of WTP production)
- **Moderately Improved Asset Management** – assumes asset maintenance is moderately improved such that loss rates are 25 percent less than current conditions. This gives a 7.5 percent loss at WTPs and a 15 percent loss in the distribution system (expressed as a percentage of WTP production)
- **Improved Asset Management** – assume asset maintenance is improved such that loss rates are more consistent with but still higher than those in the United States and other

developing countries; assume 5 percent WTP losses and 10 percent distribution system losses.

Note that these percentages only reflect physical losses in the infrastructure system. As described previously, the percentage of total UFW is much higher.

4.7.4 Expansion of Service Area

As described previously, there is a potential that the IDAAN service area that relies on supplies from the Watershed could be expanded. The recent example is the La Arenosa WTP that would have served the area southwest of Panama City if it had not been suspended. Other expansions to the IDAAN service area relying on Watershed sources could occur in the future, but are unknown at present.

To account for this possibility, two possible service area assumptions were incorporated into future scenarios.

- **Current IDAAN service area** – assume no change to current geographic extent of IDAAN service area around the Watershed
- **Expanded IDAAN service area** – assume Population Zone 9 is incorporated into the IDAAN service area and is supplied with water from the Watershed

4.7.5 Summary of Water System Scenarios Used

Based on input from ACP staff at the Forecast Assumptions workshop, four water system scenarios were selected for simulation across seven population and economic scenario combinations in the Demand Model. The four water system scenarios are shown in **Table 4.12** and listed below.

- **Current** – Future water system connection and IDAAN management is consistent with the recent history.
- **Minimum Water Requirement** – Future water system connection remains the same, the service area is not expanded, asset management is significantly improved, and full metering of customers is completed. This scenario gives the low reasonable bookend of future water requirement.
- **Maximum Water Requirement** – Additional population is connected reliably to the IDAAN system, the Study Area is expanded to include Population Zone 9, no improvements are made to accounting, metering, or billing and there is no change in asset management. This scenario gives the high reasonable bookend of future water requirement.
- **Probable** – Additional population is connected reliably to the IDAAN system, the service area is not expanded, IDAAN moderately improves its accounting, metering, and billing program, and IDAAN has minor additional asset management investment. This scenario represents the most likely future water requirement.

Table 4.12 – Water system scenarios simulated in Demand Model

Water System Scenario				
Scenarios	Current	Minimum Water Requirement	Maximum Water Requirement	Probable
Water System Connection Scenario	Current	Current	Improved (50% of current unconnected residents are connected)	Improved (50% of current unconnected residents are connected)
Metering and Accounting Scenario	Current	Full (95% of customers are metered)	Current	Moderate (50% of current unmetered customers are metered)
Asset Management Scenario	Current	High (50% reduction in losses)	Current	Minor (25% reduction in losses)
Service Area Expansion Scenario	Current	Current	Population Zone 9 (could be proxy for some other new service area)	Current

Each water system scenario was simulated across seven combinations of population projections and economic projections, which are shown in **Table 4.13**.

Table 4.13 – Definition of water demand forecast population and economic projections

Scenario	Population Projection	Economic Projection
Optimistic/High	Optimistic	High
Probable/High	Probable	High
Optimistic/Probable	Optimistic	Probable
Probable/Probable	Probable	Probable
Pessimistic/Probable	Pessimistic	Probable
Probable/Low	Probable	Low
Pessimistic/Low	Pessimistic	Low

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5.0 FUTURE DEMAND FORECAST RESULTS AND ANALYSIS

This section presents the results of applying the Demand Model described in Section 4.4 with the population growth projections described in Section 4.5 and economic growth projections described in Section 4.6 under the future water system scenarios described in Section 4.7. An overview of the Demand Model results is presented first, followed by analysis of each future scenario, and ending with a comparison between the different water system scenarios. These water system scenarios were ultimately used as the basis for the three final Demand Forecast Scenarios, which are described in Section 6.1.

5.1 RESULTS OVERVIEW

The Demand Model was used to develop forecasts of future total water requirement for seven combinations of population and economic growth projections and four future water system scenarios, for a total of 28 future total water requirement forecasts. Each future water requirement forecast includes seven future points in time between 2020 and 2050, and is aggregated from forecasts for the eight or nine Population Zones (depending on the water system scenario). Full tabular listings of these results are included in **Appendix E**. **Figure 5.1** shows the results of the 28 future water requirement forecasts from 2020 to 2050 in 5-year increments. These future water requirement forecasts will be described in more detail in succeeding sections. In each case the conditions incorporated into the scenario (e.g., asset management or customer metering) were assumed to occur immediately. The method to account for the transition from actual existing water use to the forecasted water use in each scenario is discussed later in this report.

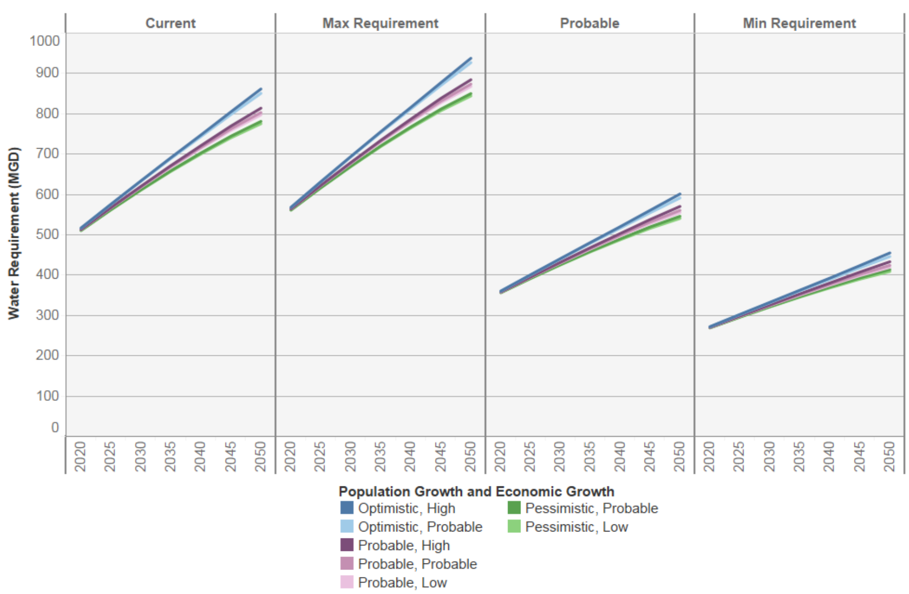


Figure 5.1 – Forecasted total water requirement of the four water system scenarios under the seven population and economic growth forecasts

5.2 CURRENT WATER SYSTEM SCENARIO ANALYSIS

This section presents Demand Model results for the seven population and economic growth projections under the Current water system scenario. The assumptions of the Current water system scenario are:

- No change in the percentage of population connected reliably to the IDAAN system
- Metering and accounting of customers is similar to the 2011 to 2017 observed period
- 30 percent losses due to distribution system leakages and WTP inefficiencies
- No expansion of IDAAN service area

Figure 5.2 and **Figure 5.3** shows the forecasted total water requirement and the forecasted residential consumption, non-residential consumption, and losses that comprise it under the Current scenario from 2020 to 2050 in two formats. Future water requirement at 2050 under this scenario varies between 774 MGD and 863 MGD, depending on the economic and population growth projection assumed. A majority of this future water requirement would be comprised of residential consumption with a corresponding increase in infrastructure losses.

Figure 5.2 – Forecasted total water requirement, residential consumption, non-residential consumption, and losses for Current scenario

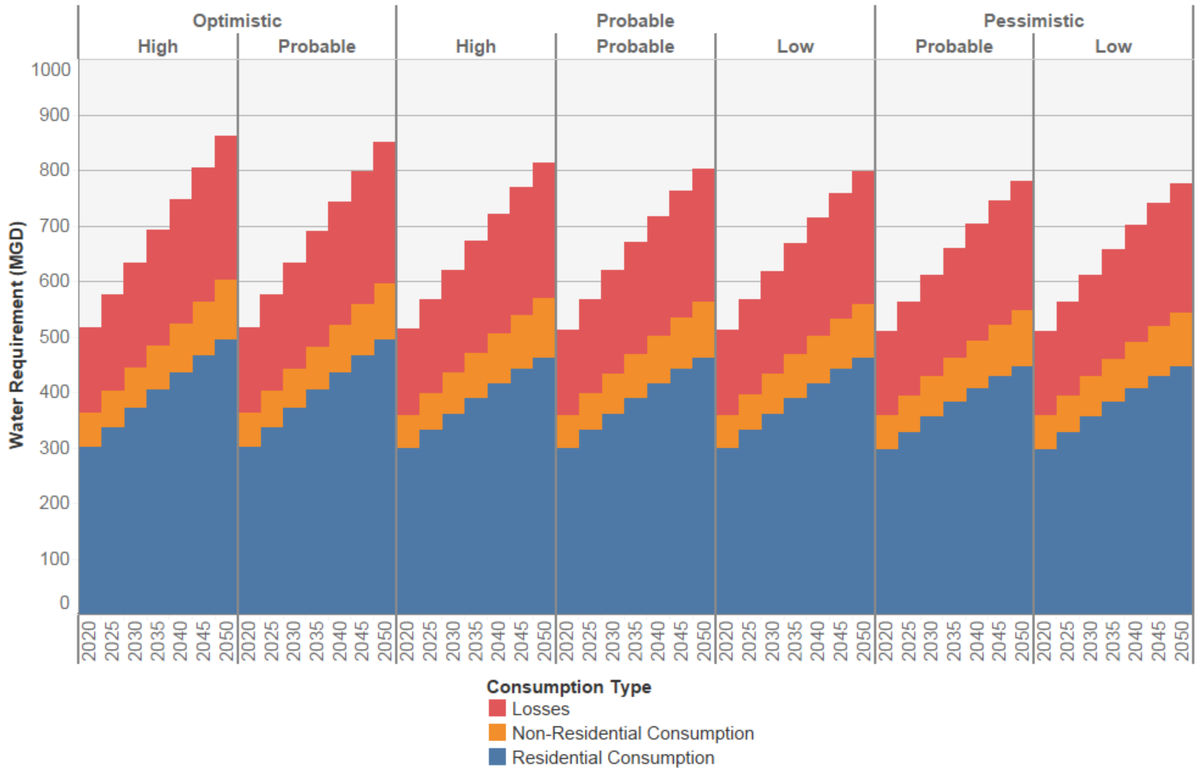


Figure 5.3 – Forecasted residential consumption, non-residential consumption, and losses for Current scenario as stacked bar chart

Figure 5.4 shows the geographical distribution of the forecasted total water requirement across the eight Population Zones corresponding to the key shown in **Figure 5.5**. To better highlight the geography, future water requirement is shown for 2020, 2035, and 2050 under the lowest, probable, and highest economic and population growth projections. A majority of the future water requirement and the highest percentage and magnitude of growth in future total water requirement is contained in Population Zone 8. For example, under the Probable population and economic growth projection, future total water requirement in Population Zone 8 is forecasted to grow from 225 MGD to 356 MGD, an increase of 131 MGD (58 percent). Moderate increases in future total water requirement are forecasted for Population Zones 3, 4, 5, 6, and 7.

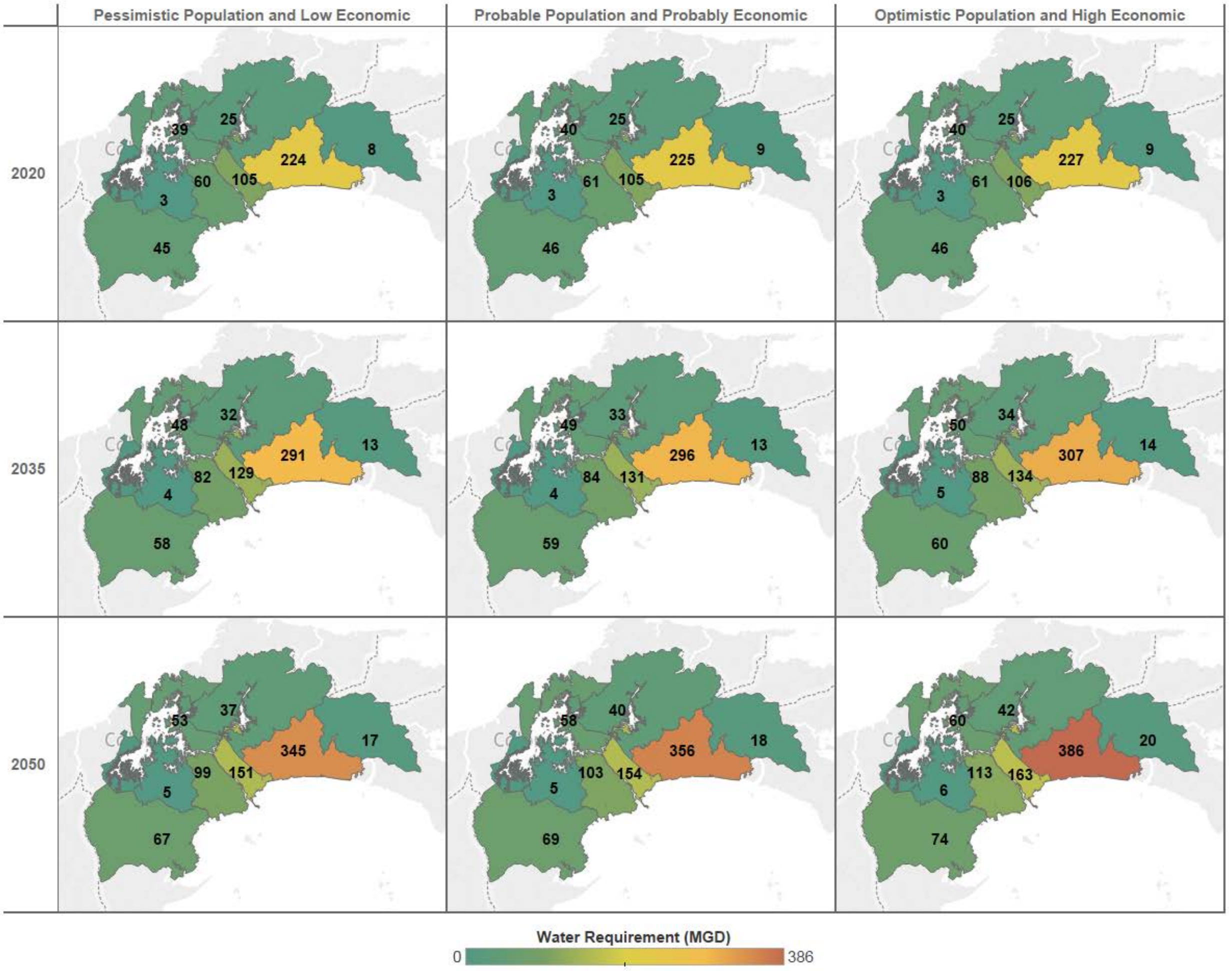


Figure 5.4 – Population Zone map of forecasted total water requirement at select future years and population/economic growth projection combinations for Current scenario

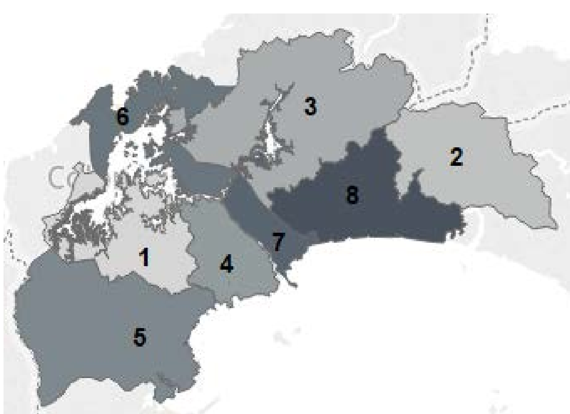


Figure 5.5 – Study Area Population Zones key

A majority of future total water requirement will be for residential consumption and the nature of its composition is important to understanding the impacts of population growth. The portion of the population that is metered by IDAAN compared to the portion of the population that is unmetered has a significant impact on future residential consumption, as the unmetered population is assumed to consume significantly more water per capita than the metered population.

Figure 5.6 shows how the projected population is divided among the different water user types as defined in Section 4.4.1. Under the Current scenario, a majority of the future population will continue to be unmetered and unaccounted-for customers, who have a high per capita water use rate. By 2050, an estimated 2.2 million people would be within these two water user types under the Probable population forecast. This translates to a significant portion, approximately 75 percent, of residential water consumption being unmetered, as shown in **Figure 5.7**.

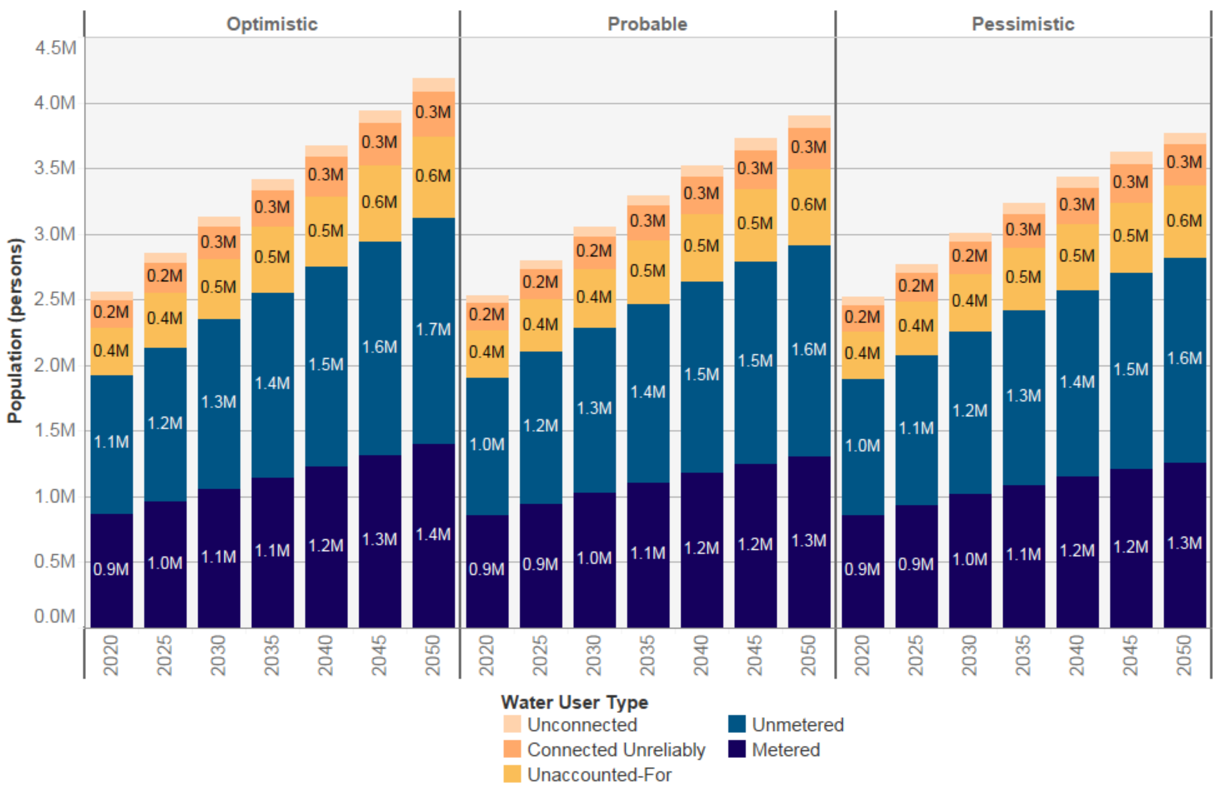


Figure 5.6 – Distribution of forecasted population to different water user types under Current scenario

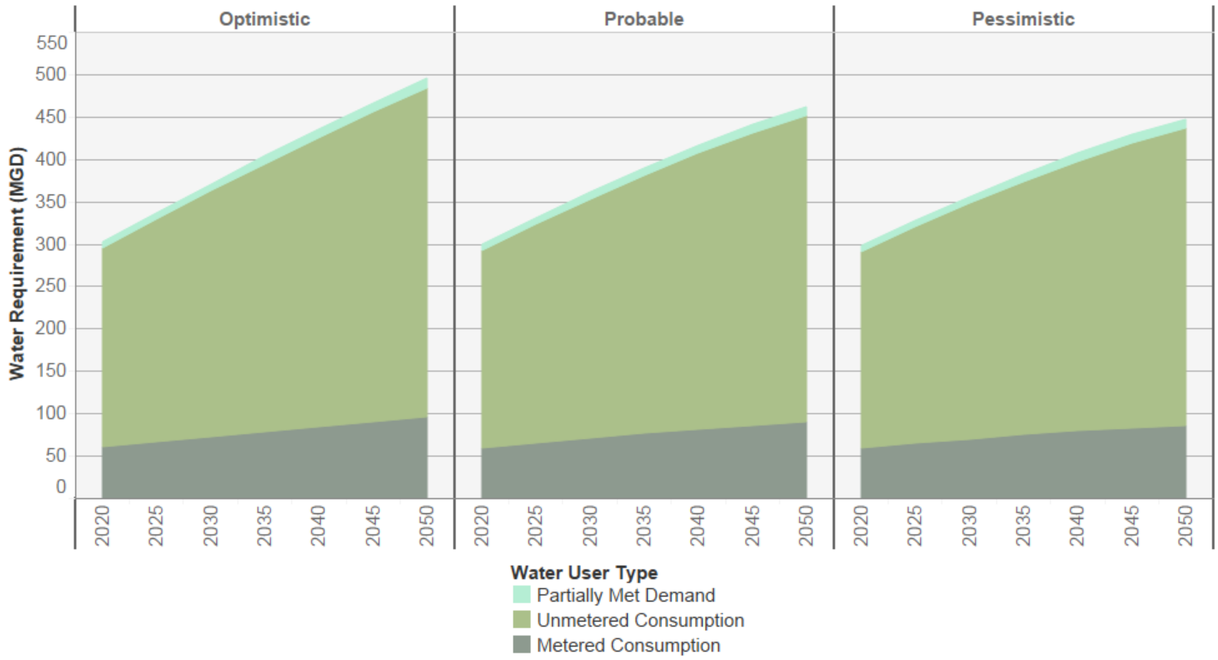


Figure 5.7 – Components of forecasted residential consumption for Current scenario under three population growth projections

Table 5.1 tabulates the forecasted future water requirement and **Table 5.2** compares this forecast to 2017 observed data for the IDAAN service area. Under the Current water system scenario, future total water requirement is forecasted to grow by 80 percent to 100 percent between 2020 and 2050 compared to 2017. The primary driver of this growth in water requirement is the increase in unmetered or unaccounted-for users, which have high per capita consumption compared to metered customers. Also because of this increase in residential consumption, the water losses in infrastructure required to treat and deliver this water would increase proportionally.

Table 5.1 – Forecasted total water requirement for all Population Zones for Current Scenario

Forecasted Total Water Requirement in MGD (All Population Zones)							
Year	Optimistic Pop. Proj.		Probable Pop. Proj.			Pessimistic Pop. Proj.	
	High	Probable	High	Probable	Low	Probable	Low
2017	437	437	437	437	437	437	437
2020	517	517	513	513	513	511	510
2025	576	575	568	567	566	562	562
2030	634	633	620	619	618	612	611
2035	692	689	672	669	667	659	657
2040	748	743	722	717	714	703	700
2045	806	798	770	763	758	745	740
2050	863	851	815	803	796	781	774
2017 to 2050 Average Annual Growth Rate	2.08%	2.04%	1.91%	1.86%	1.83%	1.78%	1.75%

Table 5.2 – Comparison of forecasted total water requirement to 2017 observed IDAAN service area data for Current Scenario

Forecasted Total Water Requirement in MGD (Zones 3, 4, 6, 7 and 8)							
Year	Optimistic Pop. Proj.		Probable Pop. Proj.			Pessimistic Pop. Proj.	
	High	Probable	High	Probable	Low	Probable	Low
2017[1]	376	376	376	376	376	376	376
2020	459	459	456	456	455	453	453
2025	511	510	503	503	502	499	498
2030	562	561	550	548	547	542	541
2035	613	610	595	593	591	584	582
2040	663	659	639	635	632	622	620
2045	713	707	682	676	671	659	655
2050	764	753	722	711	705	691	685
Percent Change from 2017 (Zones 3, 4, 6, 7 and 8)							
2020	22%	22%	21%	21%	21%	20%	20%
2025	36%	36%	34%	34%	34%	33%	32%
2030	49%	49%	46%	46%	46%	44%	44%
2035	63%	62%	58%	58%	57%	55%	55%
2040	76%	75%	70%	69%	68%	65%	65%
2045	90%	88%	81%	80%	79%	75%	74%
2050	103%	100%	91%	89%	88%	84%	82%
2017 to 2050 Average Annual Growth Rate	2.17%	2.13%	2.00%	1.95%	1.92%	1.86%	1.83%

1. Value based on IDAAN data

5.3 PROBABLE WATER SYSTEM SCENARIO ANALYSIS

This section presents Demand Model results for the seven population and economic growth projections under the Probable water system scenario. The assumptions of the Probable water system scenario are:

- 50 percent of the current unconnected or connected unreliably population are connected reliably to the IDAAN system
- 50 percent of current unmetered customers are metered
- 25 percent reduction in losses due to distribution system leakages and WTP inefficiencies
- No expansion of IDAAN service area

Figure 5.8 and **Figure 5.9** show the forecasted total water requirement and the forecasted residential consumption, non-residential consumption, and losses that comprise it under the Probable scenario from 2020 to 2050 in two formats. Future water requirement at 2050 under this scenario varies between 539 MGD and 602 MGD, depending on the economic and population growth projection assumed. A majority of this future water requirement would be comprised of residential consumption with a corresponding increase in infrastructure losses.

Figure 5.8 – Forecasted total water requirement, residential consumption, non-residential consumption, and losses for Probable scenario

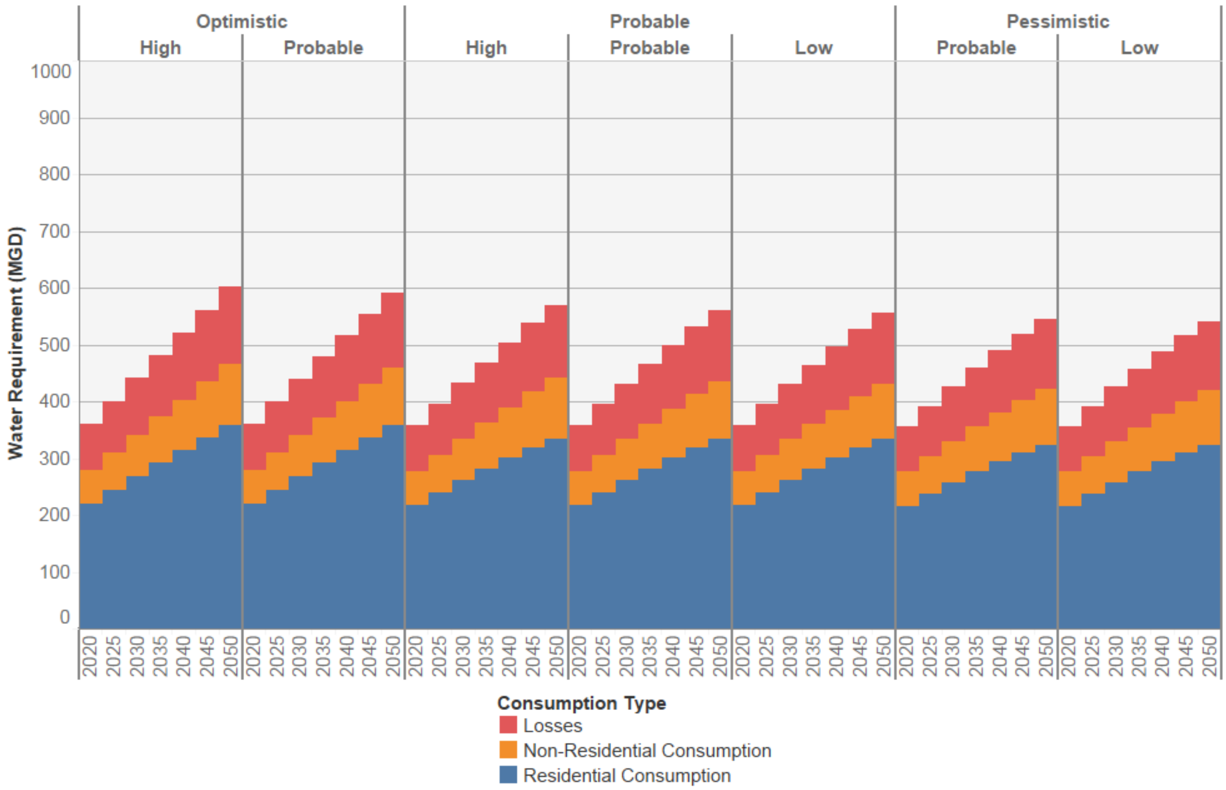


Figure 5.9 – Forecasted residential consumption, non-residential consumption, and losses for Probable scenario as stacked bar chart

Figure 5.10 shows the geographical distribution of the forecasted total water requirement across the eight Population Zones corresponding to the key shown in **Figure 5.5**. To better highlight the geography, future water requirement is shown for 2020, 2035, and 2050 under the lowest, probable, and highest economic and population growth projections. A majority of the future water requirement and the highest percentage and magnitude of growth in future total water requirement is contained in Population Zone 8. For example, under the Probable population and economic growth projection, future total water requirement in Population Zone 8 is forecasted to grow from 147 MGD to 223 MGD, an increase of 76 MGD (52 percent). Moderate increases in future total water requirement are forecasted for Population Zones 3, 4, 5, 6, and 7.

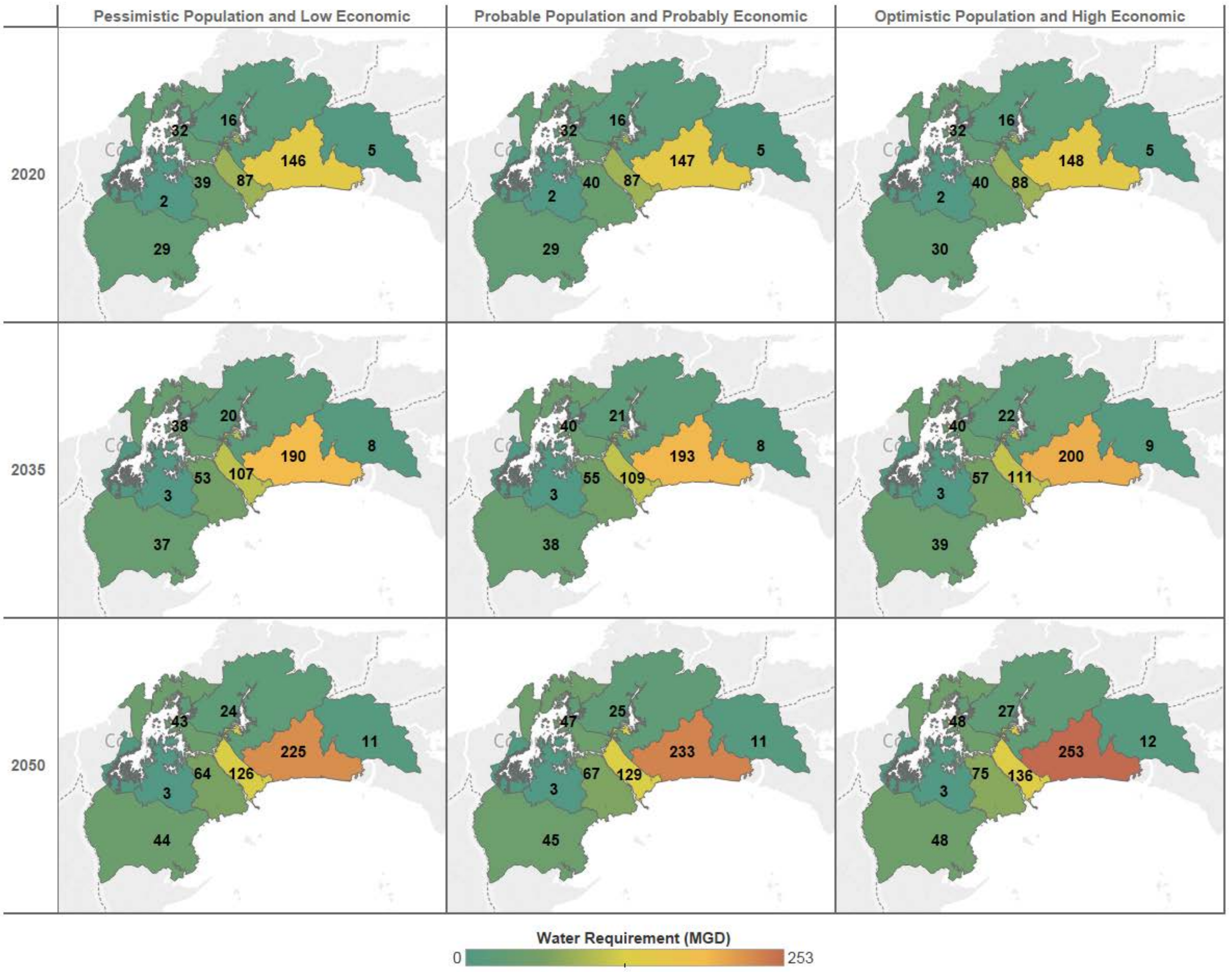


Figure 5.10 – Population Zone map of forecasted total water requirement at select future years and population/economic growth projection combinations for Probable scenario

A majority of future total water requirement will be for residential consumption and the nature of its composition is important to understanding the impacts of population growth. The portion of the population that is metered by IDAAN compared to the portion of the population that is unmetered has a significant impact on future residential consumption, as the unmetered population is assumed to consume significantly more water per capita than the metered population.

Figure 5.11 shows how the projected population is divided among the different water user types as defined in Section 4.4.1. Under the Probable scenario, a majority of the future population will be metered customers. By 2050, an estimated 2.9 million people, approximately 74 percent of the total reliably connected population, would be metered under the Probable population forecast. 800,000 people would still be unmetered, and will have higher per capita water consumption. **Figure 5.12** shows that metered consumption is the majority of forecasted residential consumption with unmetered consumption contributing a sizeable portion to consumption.

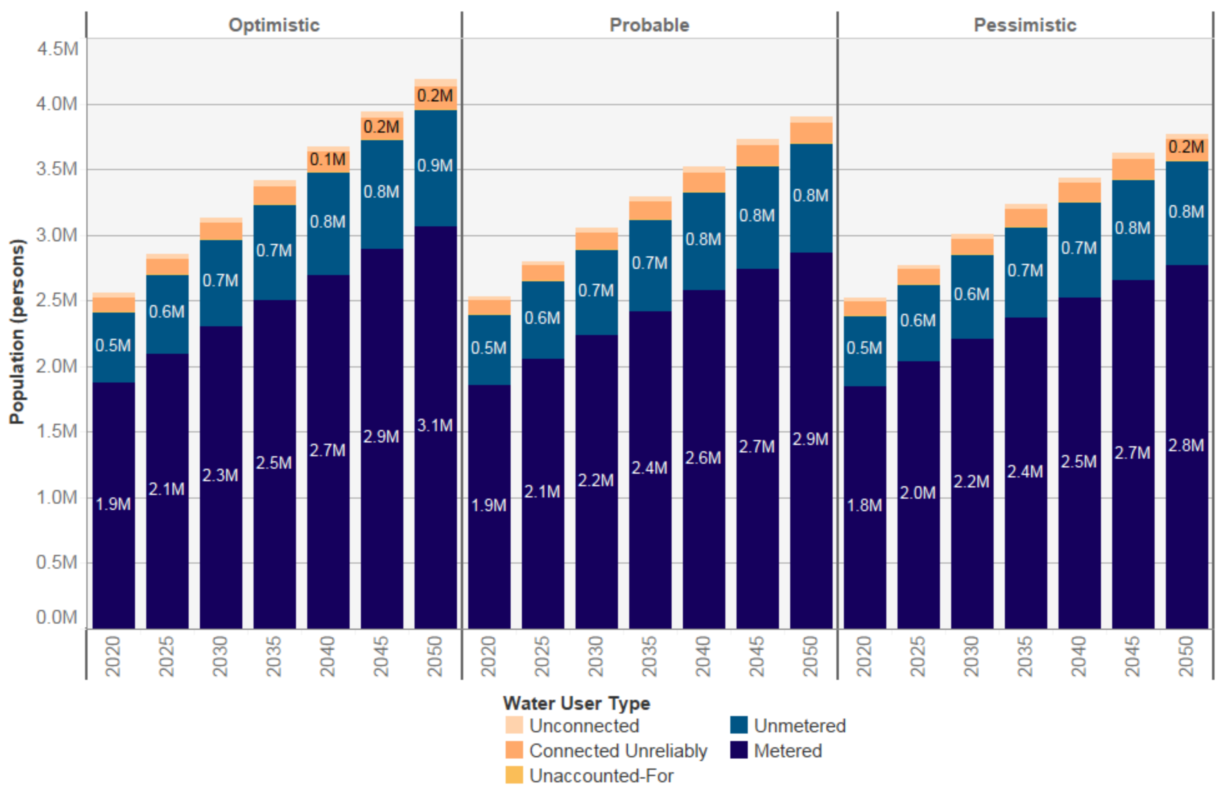


Figure 5.11 – Distribution of forecasted population to different water user types under the Probable scenarios

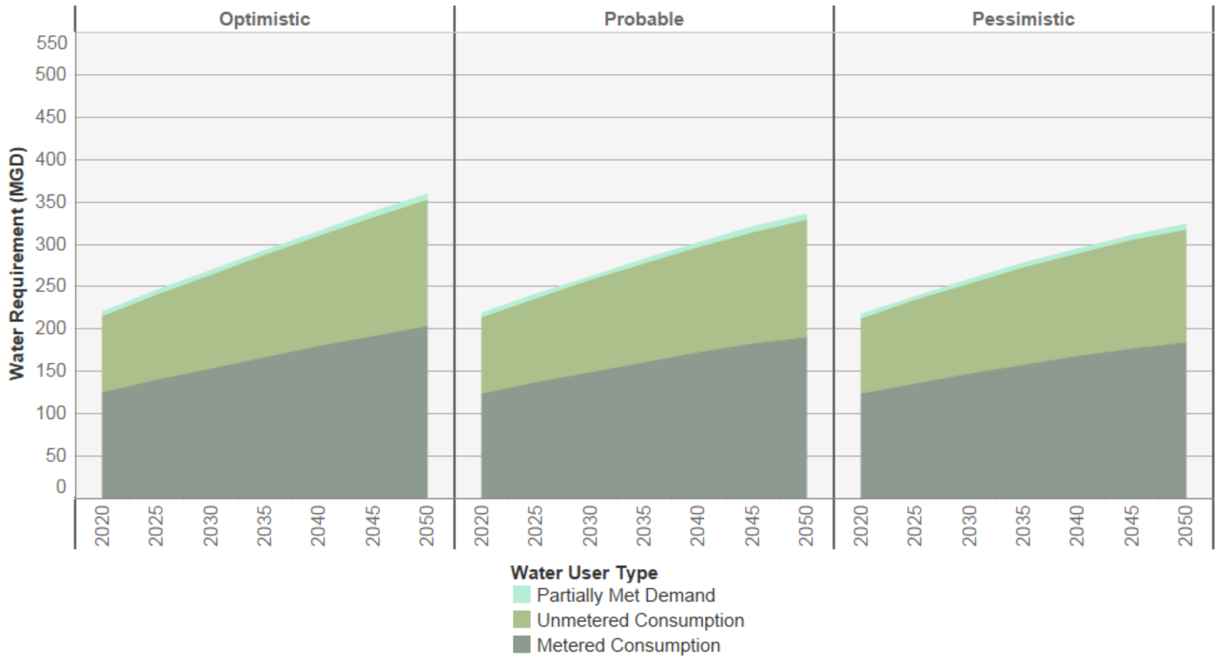


Figure 5.12 – Components of forecasted residential consumption for Probable scenario under three Population growth projections

Table 5.3 tabulates the forecasted future water requirement and **Table 5.4** compares this forecast to 2017 observed data for the IDAAN service area. Under the Probable water system scenario, future total water requirement is forecasted to grow by 28 percent to 43 percent by 2050 compared to 2017. The primary driver of this growth in water requirement is the increase in population and the continued presence of a large number of unmetered users, which have high per capita consumption compared to metered customers.

Table 5.3 – Forecasted total water requirement for all Population Zones for Probable Scenario

Forecasted Total Water Requirement in MGD (All Population Zones)							
Year	Optimistic Pop. Proj.		Probable Pop. Proj.			Pessimistic Pop. Proj.	
	High	Probable	High	Probable	Low	Probable	Low
2017	437	437	437	437	437	437	437
2020	360	360	358	358	358	356	356
2025	401	401	396	395	395	392	392
2030	441	440	432	431	430	426	425
2035	481	479	468	466	464	459	457
2040	521	517	504	499	496	490	487
2045	562	555	539	532	527	520	515
2050	602	591	572	560	554	546	539
2017 to 2050 Average Annual Growth Rate	0.98%	0.92%	0.82%	0.75%	0.72%	0.68%	0.64%

Table 5.4 – Comparison of forecasted total water requirement to 2017 observed IDAAN service area data for Probable Scenario

Forecasted Total Water Requirement in MGD (Zones 3, 4, 6, 7 and 8)							
Year	Optimistic Pop. Proj.		Probable Pop. Proj.			Pessimistic Pop. Proj.	
	High	Probable	High	Probable	Low	Probable	Low
2017[1]	376	376	376	376	376	376	376
2020	323	323	321	321	321	320	320
2025	359	359	355	354	354	351	351
2030	395	394	387	386	385	382	381
2035	431	428	419	417	415	411	409
2040	466	462	451	447	444	438	436
2045	502	496	482	476	472	464	460
2050	538	529	511	501	495	488	482
Percent Change from 2017 (Zones 3, 4, 6, 7 and 8)							
2020	-14%	-14%	-15%	-15%	-15%	-15%	-15%
2025	-5%	-5%	-6%	-6%	-6%	-7%	-7%
2030	5%	5%	3%	3%	2%	2%	1%
2035	14%	14%	11%	11%	11%	9%	9%
2040	24%	23%	20%	19%	18%	16%	16%
2045	33%	32%	28%	27%	26%	23%	23%
2050	43%	41%	36%	33%	32%	30%	28%
2017[1] to 2050 Average Annual Growth Rate	1.09%	1.04%	0.93%	0.87%	0.84%	0.79%	0.76%

1. Value based on IDAAN data

5.4 MAXIMUM WATER SYSTEM SCENARIO ANALYSIS

This section presents Demand Model results for the seven population and economic growth projections under the Maximum Requirement water system scenario. The assumptions of the Maximum Requirement water system scenario are:

- 50 percent of the current unconnected or connected unreliably population are connected reliably to the IDAAN system
- Metering and accounting of customers is similar to the 2011 to 2017 observed period
- 30 percent physical losses due to distribution system leakages and WTP inefficiencies
- Corregimientos in Population Zone 9 are added IDAAN service area supplied by the Watershed

Figure 5.13 and **Figure 5.14** shows the forecasted total water requirement and the forecasted residential consumption, non-residential consumption, and losses that comprise it under the Maximum Requirement scenario from 2020 to 2050 in two formats. Future water requirement at 2050 under this scenario varies between 843 MGD and 939 MGD, depending on the economic and population growth projection assumed. A majority of this future water requirement would be comprised of residential consumption with a corresponding increase in infrastructure losses.

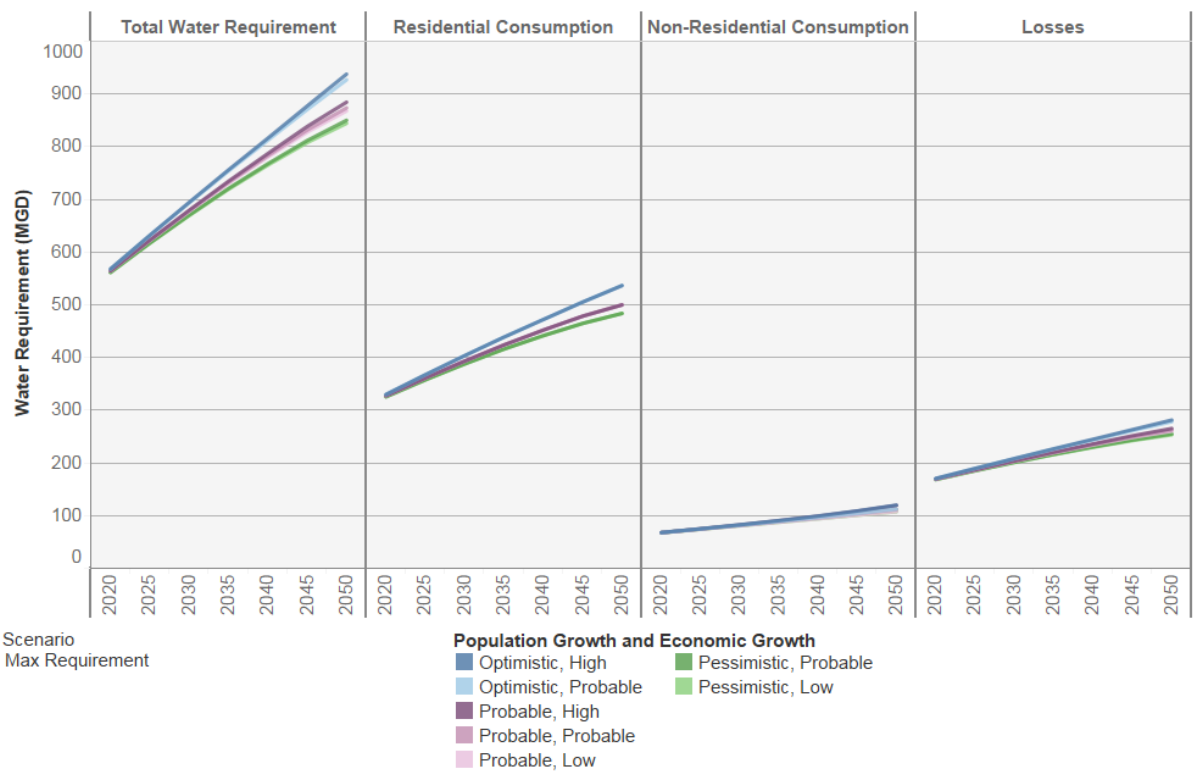


Figure 5.13 – Forecasted total water requirement, residential consumption, non-residential consumption, and losses for Maximum Requirement scenario

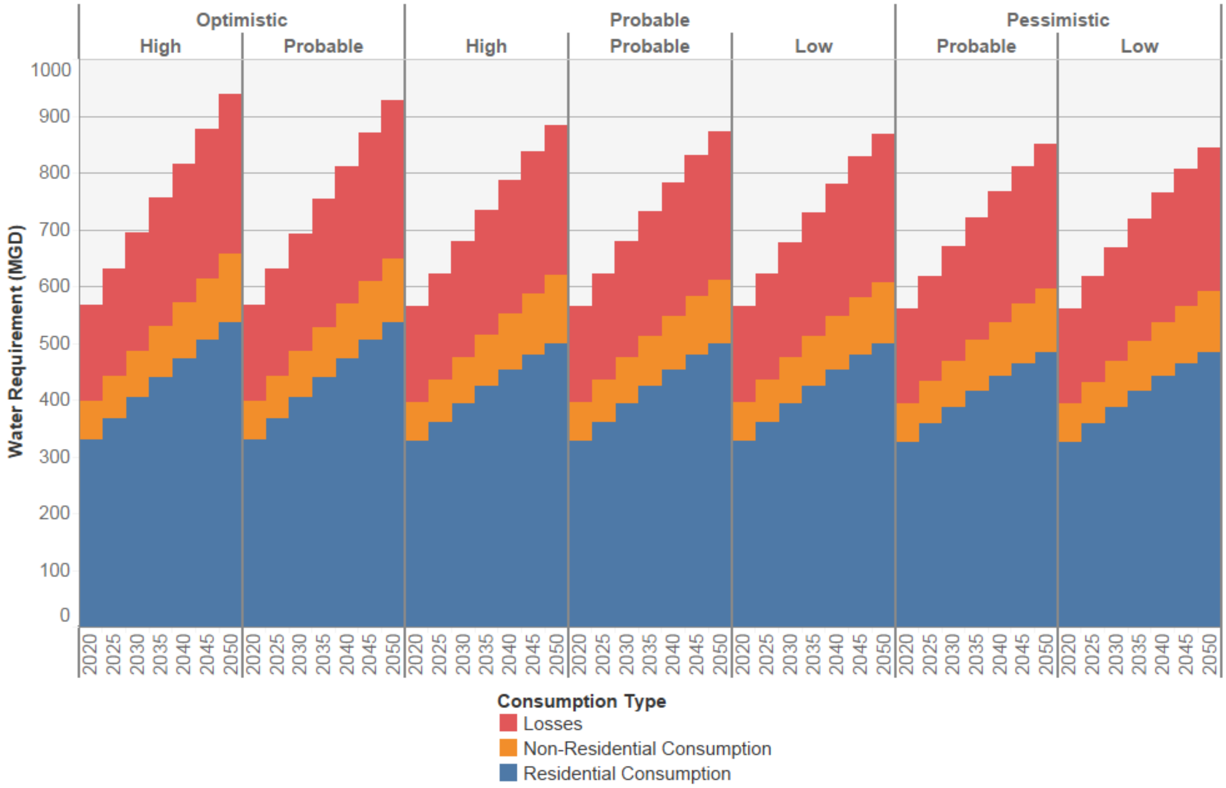


Figure 5.14 – Forecasted residential consumption, non-residential consumption, and losses for Maximum Requirement scenario as stacked bar chart

Figure 5.15 shows the geographical distribution of the forecasted total water requirement across the nine Population Zones corresponding to the key shown in **Figure 5.5**. To better highlight the geography, future water requirement is shown for 2020, 2035, and 2050 under the lowest, probable, and highest economic and population growth projections. A majority of the future water requirement and the highest percentage and magnitude of growth in future total water requirement is contained in Population Zone 8. For example, under the Probable population and economic growth projection, future total water requirement in Population Zone 8 is forecasted to grow from 234 MGD to 370 MGD, an increase of 136 MGD (58 percent). Moderate increases in future total water requirement are forecasted for Population Zones 3, 4, 5, 6, and 7.

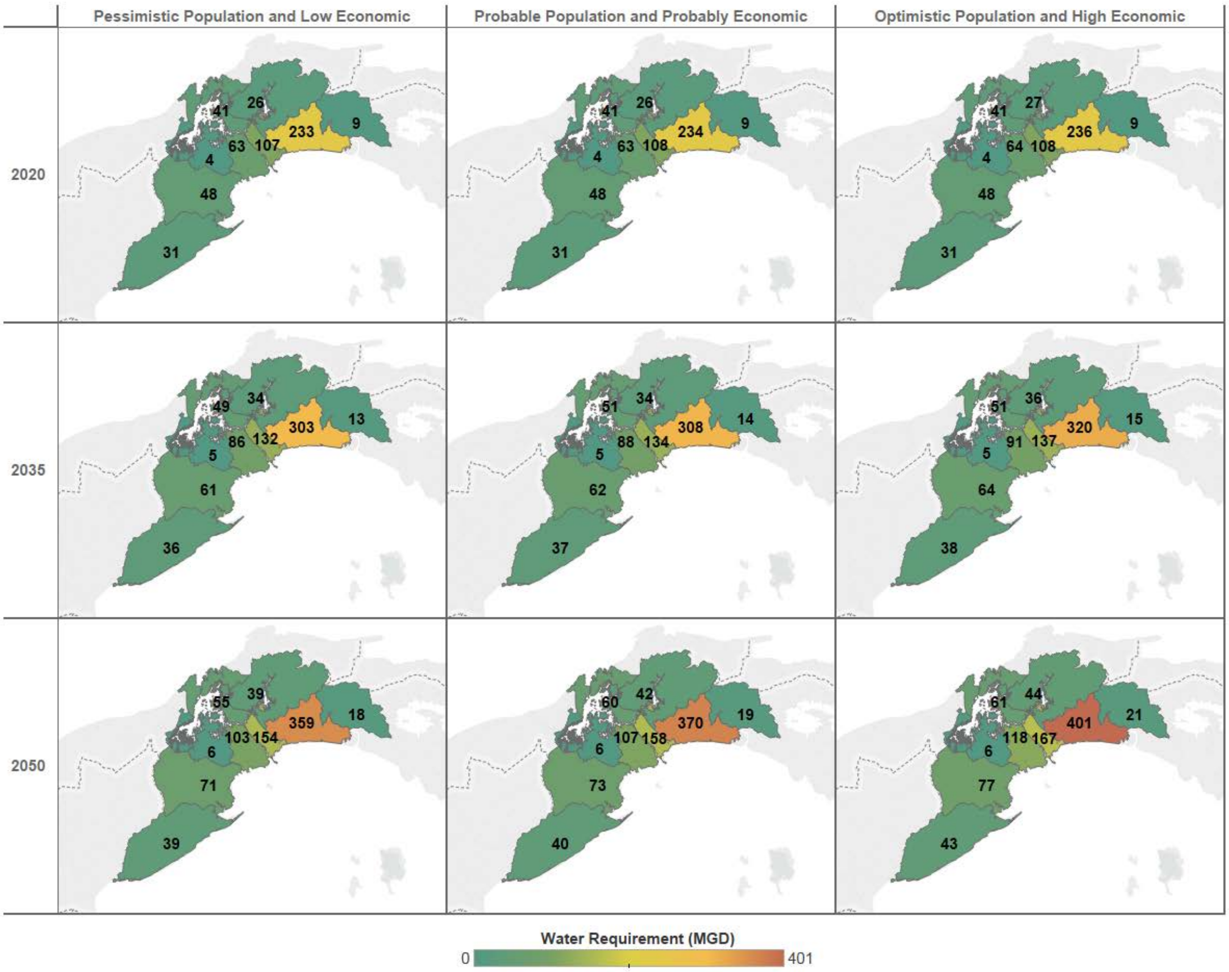


Figure 5.15 – Population Zone map of forecasted total water requirement at select future years and population/economic growth projection combinations for Maximum Requirement scenario

A majority of future total water requirement will be for residential consumption and the nature of its composition is important to understanding the impacts of population growth. The portion of the population that is metered by IDAAN compared to the portion of the population that is unmetered has a significant impact on future residential consumption, as the unmetered population is assumed to consume significantly more water per capita than the metered population. The addition of Population Zone 9 does not significantly increase either the metered or unmetered.

Figure 5.16 shows how the projected population is divided among the different water user types as defined in Section 4.4.1. Under the Maximum Requirement scenario, a majority of the future population will continue to be unmetered and unaccounted-for customers, who have a high per capita water use rate. By 2050, an estimated 2.2 million people would be within these two water user types under the Probable population forecast. This translates to a significant portion, approximately 75 percent, of residential water consumption being unmetered, as shown in **Figure 5.17**.

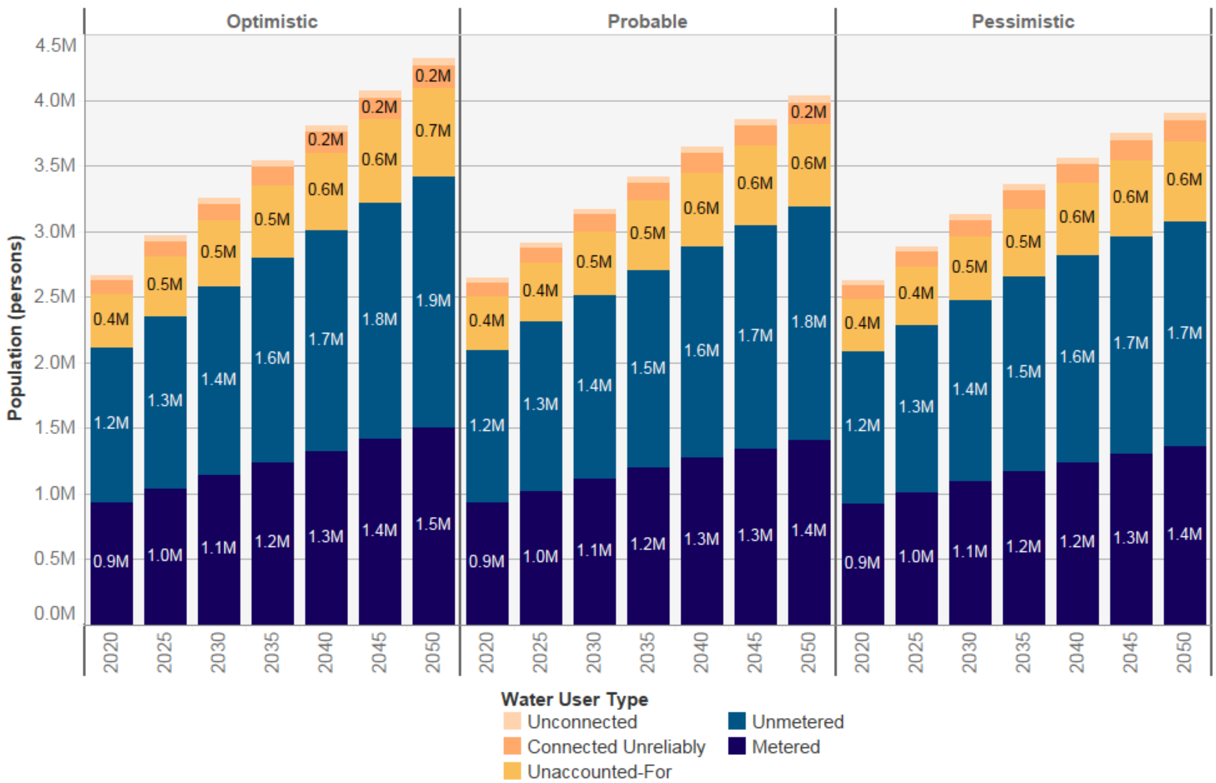


Figure 5.16 – Distribution of forecasted population to different water user types under Maximum Requirement scenario

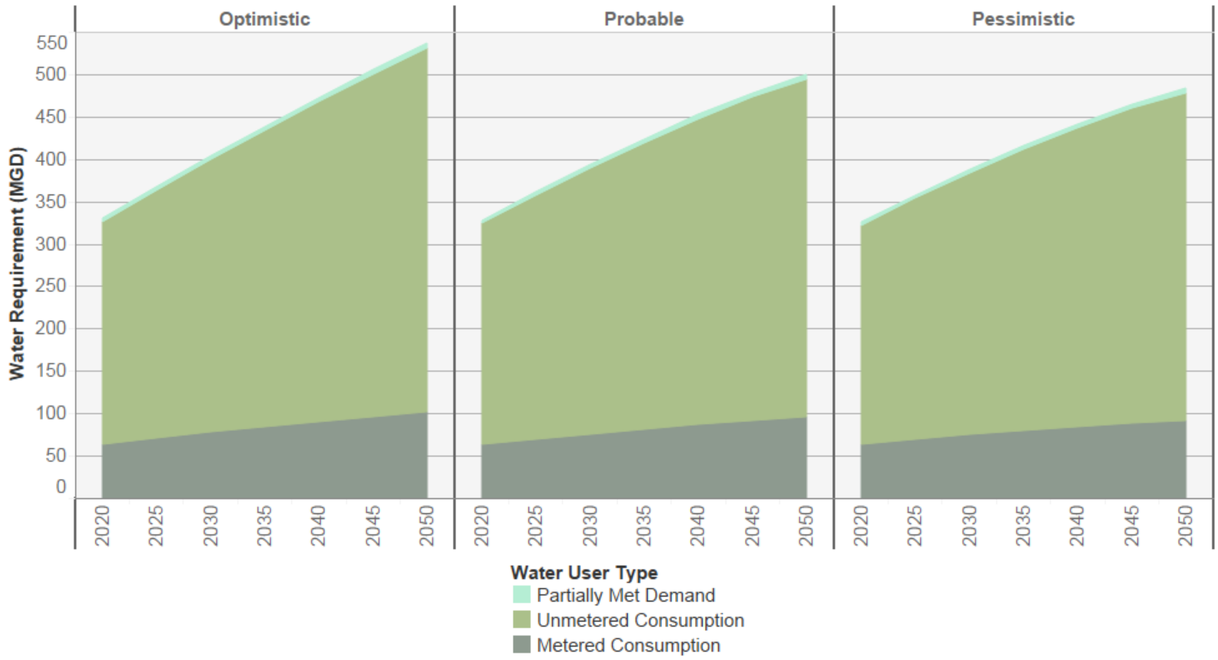


Figure 5.17 – Components of forecasted residential consumption for Maximum Requirement scenario under three Population growth projections

Table 5.5 tabulates the forecasted future water requirement and **Table 5.6** compares this forecast to 2017 observed data for the IDAAN service area. Under the Probable water system scenario, future total water requirement is forecasted to grow by 89 percent to 110 percent by 2050 compared to 2017. The primary driver of this growth in water requirement is the increase in unmetered or unaccounted-for users, which have high per capita consumption compared to metered customers. Also because of this increase in residential consumption, the water losses in infrastructure required to treat and deliver this water would increase proportionally. The expansion of the service area to include Population Zone 9 has a marginal increase in total water requirement.

Table 5.5 – Forecasted total water requirement for all Population Zones for Maximum Requirement Scenario

Forecasted Total Water Requirement in MGD (All Population Zones)							
Year	Optimistic Pop. Proj.		Probable Pop. Proj.			Pessimistic Pop. Proj.	
	High	Probable	High	Probable	Low	Probable	Low
2017	437	437	437	437	437	437	437
2020	568	568	564	564	564	561	561
2025	632	631	623	622	622	617	616
2030	694	693	679	678	677	670	669
2035	756	754	735	732	730	721	719
2040	817	812	787	783	780	768	764
2045	878	870	839	832	827	812	807
2050	939	927	886	874	866	850	843
2017 to 2050 Average Annual Growth Rate	2.34%	2.31%	2.16%	2.12%	2.09%	2.04%	2.01%

Table 5.6 – Comparison of forecasted total water requirement to 2017 observed IDAAN service area data for Maximum Requirement Scenario

Forecasted Total Water Requirement in MGD (Zones 3, 4, 6, 7 and 8)							
Year	Optimistic Pop. Proj.		Probable Pop. Proj.			Pessimistic Pop. Proj.	
	High	Probable	High	Probable	Low	Probable	Low
2017[1]	376	376	376	376	376	376	376
2020	475	475	472	472	472	470	470
2025	529	529	522	521	521	517	516
2030	582	581	570	568	567	562	561
2035	635	633	617	614	613	605	603
2040	686	682	662	658	655	645	642
2045	739	732	707	700	696	683	678
2050	791	781	747	737	730	716	709
Percent Change from 2017 (Zones 3, 4, 6, 7 and 8)							
2020	26%	26%	26%	26%	26%	25%	25%
2025	41%	41%	39%	39%	39%	38%	37%
2030	55%	55%	51%	51%	51%	49%	49%
2035	69%	68%	64%	63%	63%	61%	60%
2040	82%	81%	76%	75%	74%	72%	71%
2045	96%	95%	88%	86%	85%	82%	81%
2050	110%	108%	98%	96%	94%	90%	89%
2017[1] to 2050 Average Annual Growth Rate	2.28%	2.24%	2.10%	2.06%	2.03%	1.97%	1.94%

1. Value based on IDAAN data

5.5 MINIMUM WATER SYSTEM SCENARIO ANALYSIS

This section presents Demand Model results for the seven population and economic growth projections under the Minimum Requirement water system scenario. The assumptions of the Minimum Requirement water system scenario are:

- No change in the percentage of population connected reliably to the IDAAN system
- 95 percent of the reliably connected population is metered
- 50 percent in losses due to distribution system leakages and WTP inefficiencies
- No expansion of IDAAN service area

Figure 5.18 and **Figure 5.19** shows the forecasted total water requirement and the forecasted residential consumption, non-residential consumption, and losses that comprise it under the Minimum Requirement scenario from 2020 to 2050 in two formats. Future water requirement at 2050 under this scenario varies between 408 MGD and 456 MGD, depending on the economic and population growth projection assumed. A majority of this future water requirement would be comprised of residential consumption.

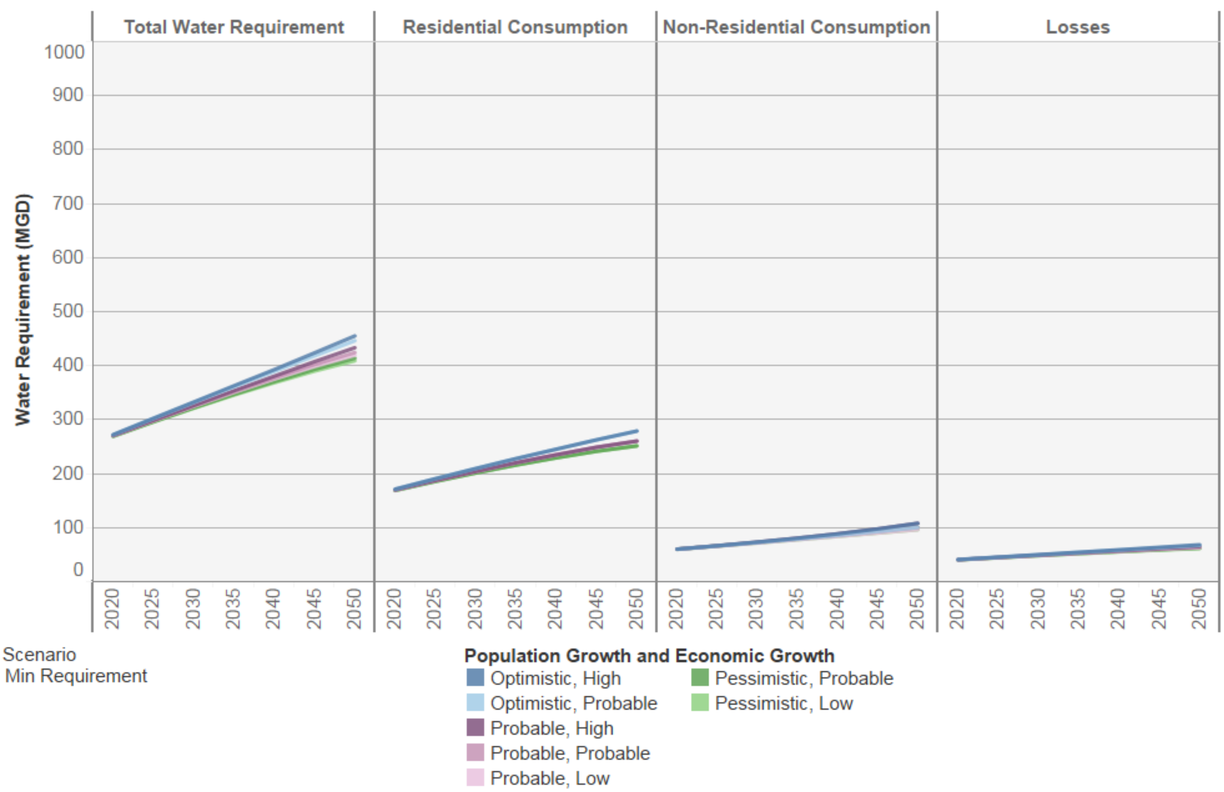


Figure 5.18 – Forecasted total water requirement, residential consumption, non-residential consumption, and losses for Minimum Requirement scenario

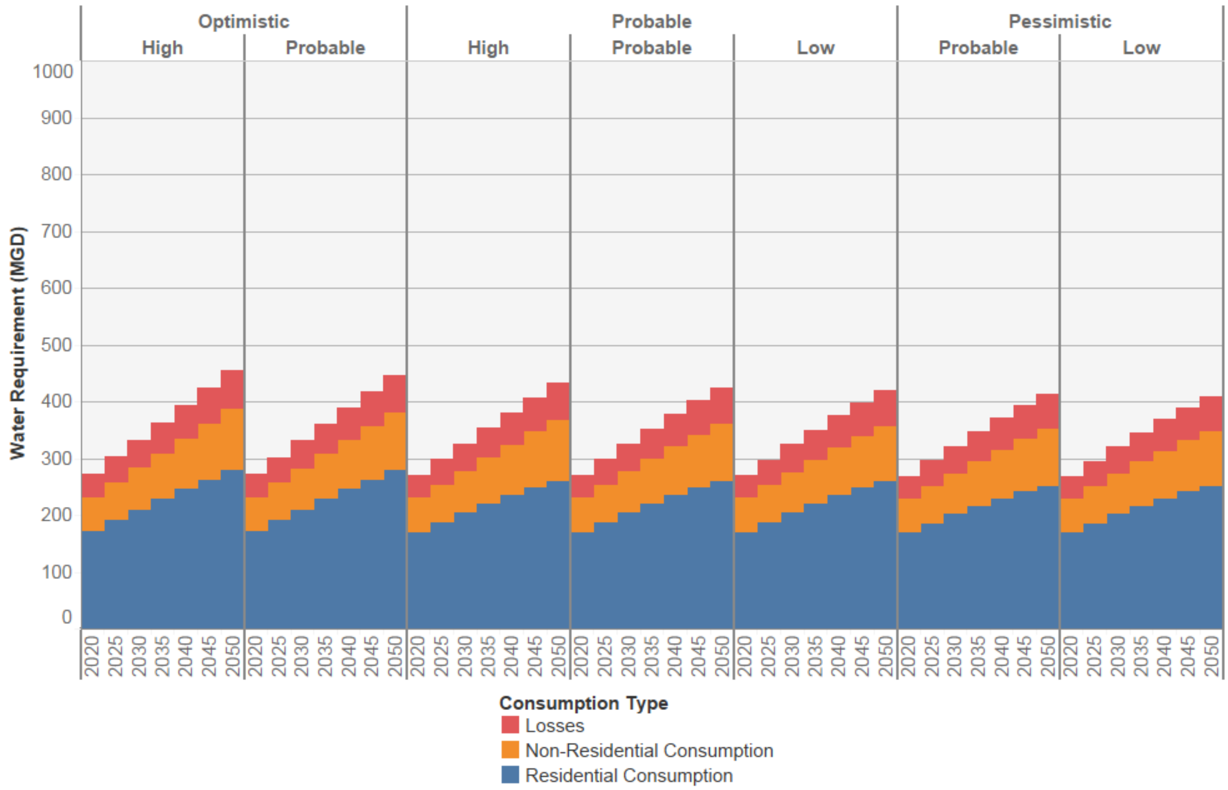


Figure 5.19 – Forecasted residential consumption, non-residential consumption, and losses for Minimum Requirement scenario as stacked bar chart

Figure 5.20 shows the geographical distribution of the forecasted total water requirement across the eight Population Zones corresponding to the key shown in **Figure 5.5**. To better highlight the geography, future water requirement is shown for 2020, 2035, and 2050 under the lowest, probable, and highest economic and population growth projections. A majority of the future water requirement and the highest percentage and magnitude of growth in future total water requirement is contained in Population Zone 8. For example, under the Probable population and economic growth projection, future total water requirement in Population Zone 8 is forecasted to grow from 107 MGD to 170 MGD, an increase of 63 MGD (59 percent). Moderate increases in future total water requirement are forecasted for Population Zones 3, 4, 5, 6, and 7.

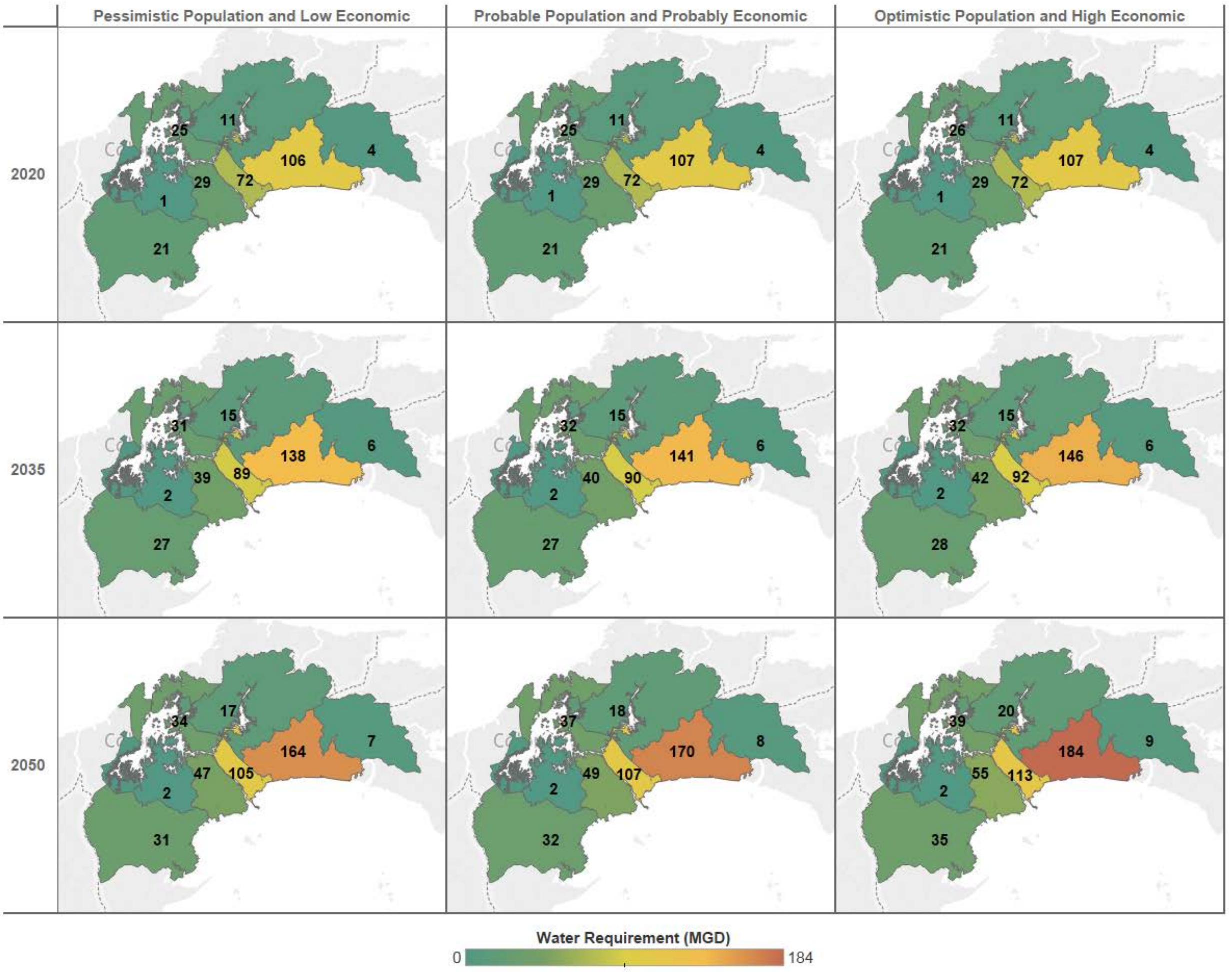


Figure 5.20 – Population Zone map of forecasted total water requirement at select future years and population/economic growth projection combinations for Minimum Requirement scenario

A majority of future total water requirement will be for residential consumption and the nature of its composition is important to understanding the impacts of population growth. The portion of the population that is metered by IDAAN compared to the portion of the population that is unmetered has a significant impact on future residential consumption, as the unmetered population is assumed to consume significantly more water per capita than the metered population.

Figure 5.21 shows how the projected population is divided among the different water user types as defined in Section 4.4.1. Under the Minimum Requirement scenario, nearly the entire future population will be metered customers. By 2050, an estimated 3.3 million people would be within these two water user types under the Probable population forecast. There majority of the remaining population is either unreliably connected to the IDAAN system or unmetered. **Figure 5.22** shows that metered consumption will comprise nearly all of the forecasted residential consumption.

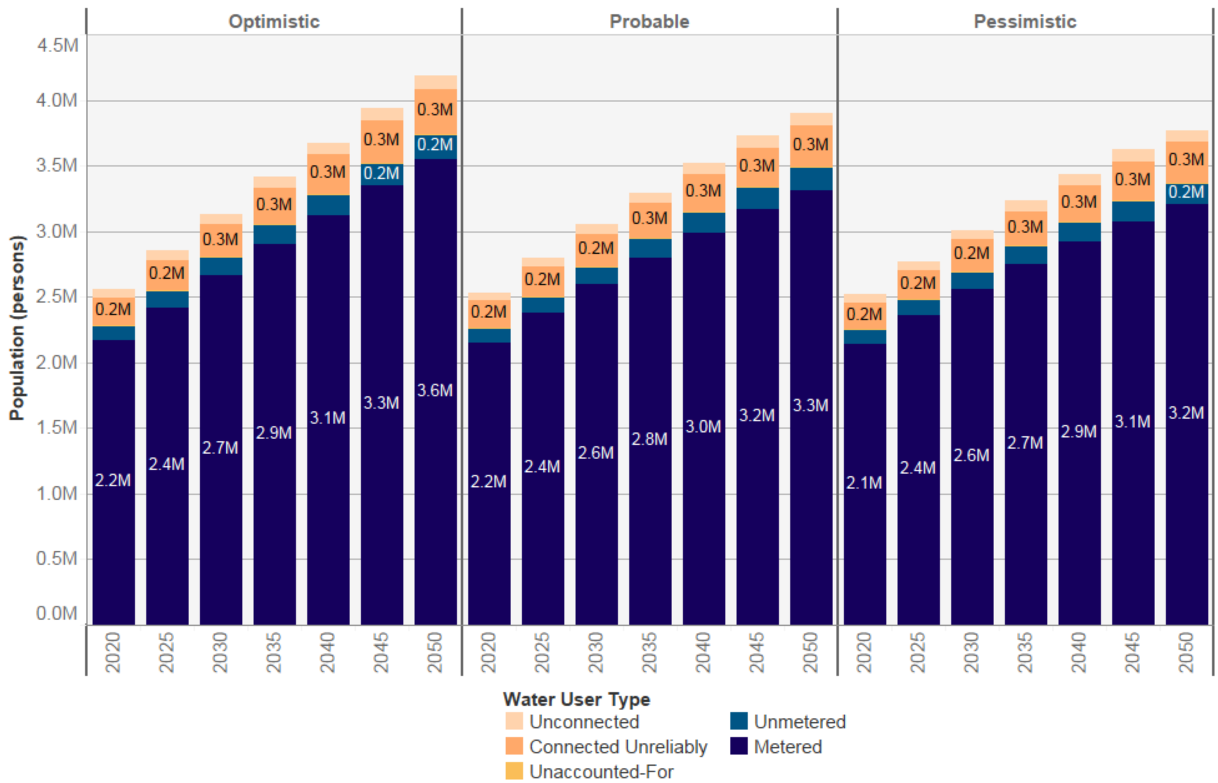


Figure 5.21 – Distribution of forecasted population to different water user types under Minimum Requirement scenario

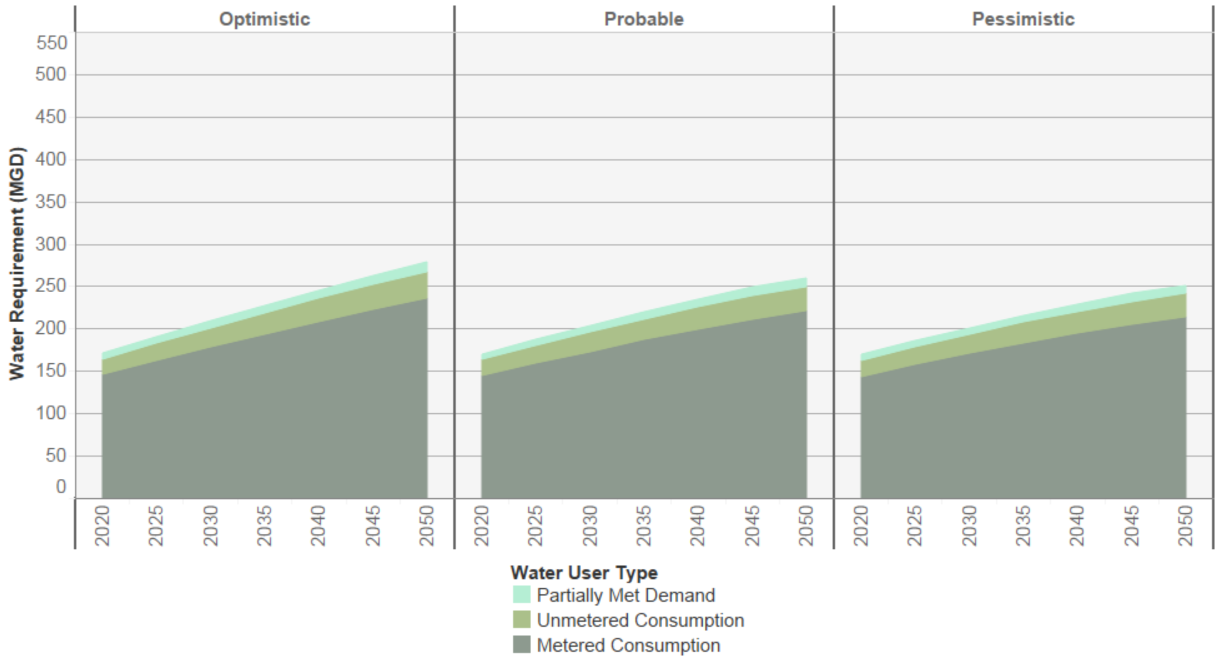


Figure 5.22 – Components of forecasted residential consumption for Minimum Requirement scenario under three Population growth projections

Table 5.7 tabulates the forecasted future water requirement and **Table 5.8** compares this forecast to 2017 observed data for the IDAAN service area. Under the Minimum Requirement water system scenario, future total water requirement is forecasted to either grow by 9 percent or decrease by 2 percent compared to 2017. Under this scenario, most future years have a forecasted total water requirement less than 2017 due the increased number of metered customers. A more detailed discussion of this is in Section 6.1. The primary driver of this result is the shift of nearly the entire unmetered and unaccounted-for population into the metered water user type group. The reduction in forecasted residential consumption due to the lower per capita use by metered customers offsets the increase in forecasted residential consumption due to population growth through 2050.

Table 5.7 – Forecasted total water requirement for all Population Zones for Minimum Requirement Scenario

Forecasted Total Water Requirement in MGD (All Population Zones)							
Year	Optimistic Pop. Proj.		Probable Pop. Proj.			Pessimistic Pop. Proj.	
	High	Probable	High	Probable	Low	Probable	Low
2017	437	437	437	437	437	437	437
2020	272	272	270	270	270	269	269
2025	302	302	299	298	298	296	295
2030	333	331	326	325	324	322	321
2035	363	361	354	352	350	347	345
2040	393	389	381	377	374	370	368
2045	424	418	408	402	398	393	389
2050	456	446	434	424	418	414	408
2017 to 2050 Average Annual Growth Rate	0.13%	0.06%	-0.02%	-0.09%	-0.13%	-0.16%	-0.21%

Table 5.8 – Comparison of forecasted total water requirement to 2017 observed IDAAN service area data for Minimum Requirement Scenario

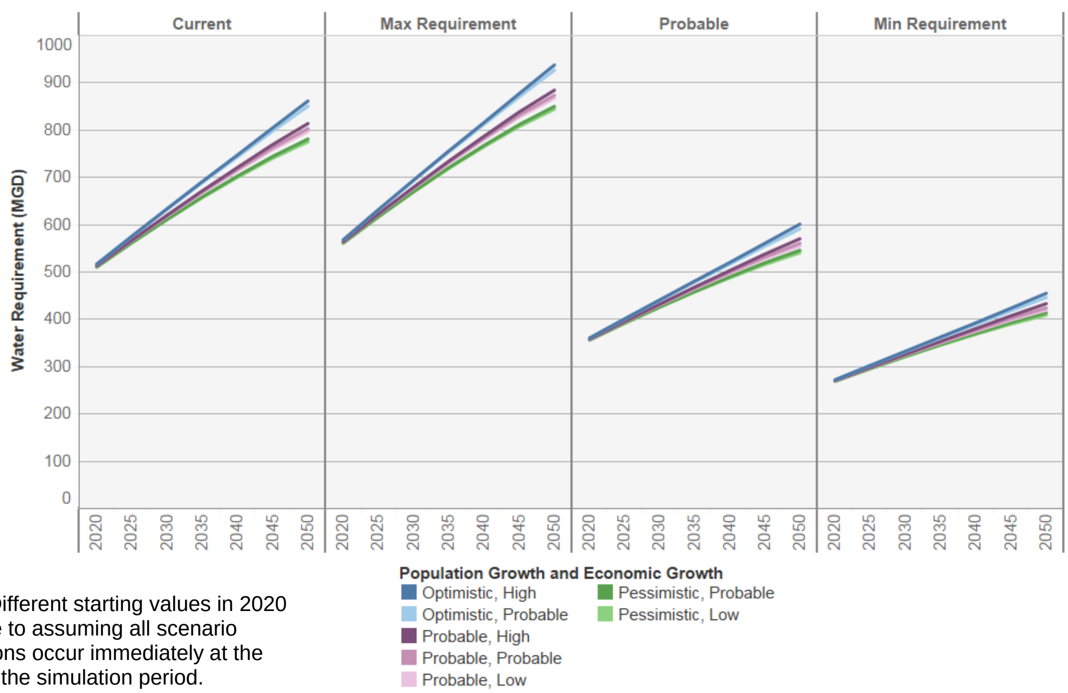
Forecasted Total Water Requirement in MGD (Zones 3, 4, 6, 7 and 8)							
Year	Optimistic Pop. Proj.		Probable Pop. Proj.			Pessimistic Pop. Proj.	
	High	Probable	High	Probable	Low	Probable	Low
2017[1]	376	376	376	376	376	376	376
2020	246	246	244	244	244	243	243
2025	273	273	270	269	269	267	267
2030	300	299	294	293	292	290	289
2035	327	325	319	317	316	313	311
2040	354	351	343	340	337	334	331
2045	382	376	368	362	358	354	350
2050	411	402	391	382	376	372	367
Percent Change from 2017 (Zones 3, 4, 6, 7 and 8)							
2020	-35%	-35%	-35%	-35%	-35%	-35%	-35%
2025	-27%	-27%	-28%	-28%	-28%	-29%	-29%
2030	-20%	-20%	-22%	-22%	-22%	-23%	-23%
2035	-13%	-14%	-15%	-16%	-16%	-17%	-17%
2040	-6%	-7%	-9%	-10%	-10%	-11%	-12%
2045	1%	0%	-2%	-4%	-5%	-6%	-7%
2050	9%	7%	4%	2%	1%	-1%	-2%
2017[1] to 2050 Average Annual Growth Rate	0.27%	0.20%	0.12%	0.05%	0.00%	-0.03%	-0.07%

1. Value based on IDAAN data

5.6 COMPARISON OF DEMAND FORECAST RESULTS FOR FOUR WATER SYSTEM SCENARIOS

To develop the High, Medium, and Low demand forecast scenarios, results from the four water system scenarios and seven economic and population growth projections were compared. **Figure 5.23** reproduces the total water requirement forecast for each of these from 2020 to 2050, with **Figure 5.24** showing the percent change in the total water requirement forecast from the Current water system scenario under the probable economic and population growth forecast.

Overall, the Maximum Requirement scenario has the highest future water requirement forecast with the Minimum Requirement scenario having the lowest, since that's the way they were defined. The Current scenario future water requirement forecast is 5 percent to 15 percent below the Maximum Requirement. The Probable scenario water requirement forecast is 25 percent to 35 percent below the Current scenario with the Minimum Requirement scenario 43 percent to 50 percent below the Current scenario. Because the difference between total water requirement forecasted by the Current and Maximum Requirement scenario is small, there is minimal room for water requirement to grow in the future. However, since the difference between total water requirement forecasted by the Current and the Probable/Minimum Requirement forecast is large, there is significant potential to reduce the future water requirement. Possible methods of achieving that reduction are described in Section 7.3.



Note: Different starting values in 2020 are due to assuming all scenario conditions occur immediately at the start of the simulation period.

Figure 5.23 – Forecasted total water requirement of the four water system scenarios under the seven population and economic growth forecasts

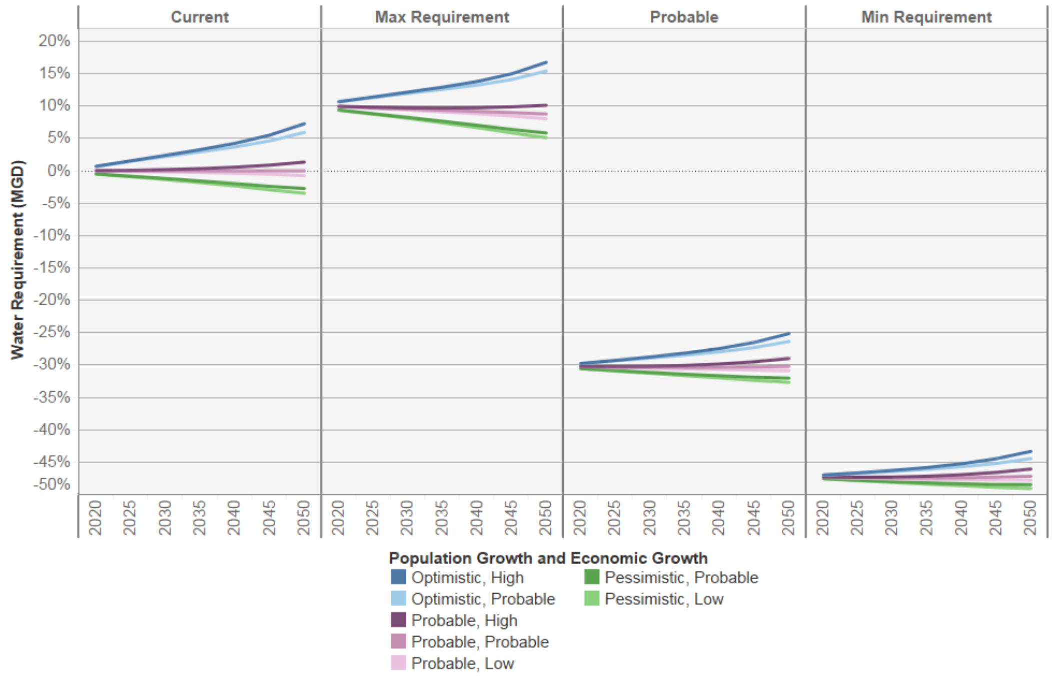


Figure 5.24 – Difference in forecasted total water requirement from Current water system scenario and probable population and economic growth projections

Figure 5.25 shows the composition of the total water requirement in the residential consumption, non-residential consumption, and infrastructure loss components for each water system scenario under the probable economic and population growth projection. A majority of the differences between the Current/Maximum Requirement scenarios and the Probable/Minimum Requirement scenarios are in the residential consumption. Because infrastructure losses are forecasted as a percent of residential and non-residential consumption, these decreases in residential consumption have a compounding decrease in infrastructure losses.

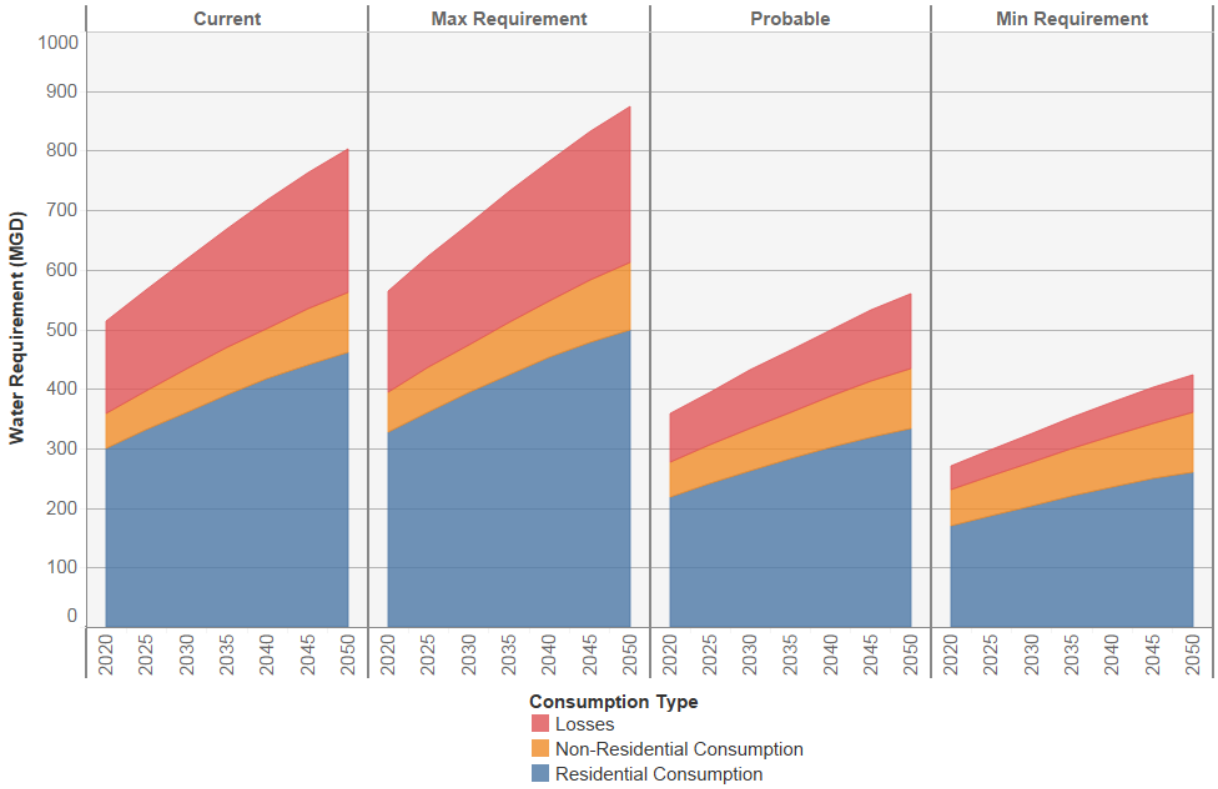


Figure 5.25 – Components of forecasted total water requirement by water system scenario under the probable population and economic growth projections

As detailed in Section 4.4.1, residential consumption is forecasted based on how much of the population falls into different water user type categories. **Figure 5.26** compares the distribution of population to each water user type for the four water system scenarios under the probable population growth projection.

Total population is the same for the Current, Probable, and Minimum Requirement scenarios and slightly higher for the Maximum Requirement scenario as it includes Population Zone 9. However, the metered population is, by 2050, 1.6 million higher for the Probable and 2 million higher for the Minimum Requirement scenarios compared to the Current scenarios. A majority of this metered population increase is from the metering of previously unmetered and UFW users. The future metered population under the Maximum Requirement and Current scenario continues to be lower than the unmetered and unaccounted-for population, with the difference between the two becoming larger further in time.

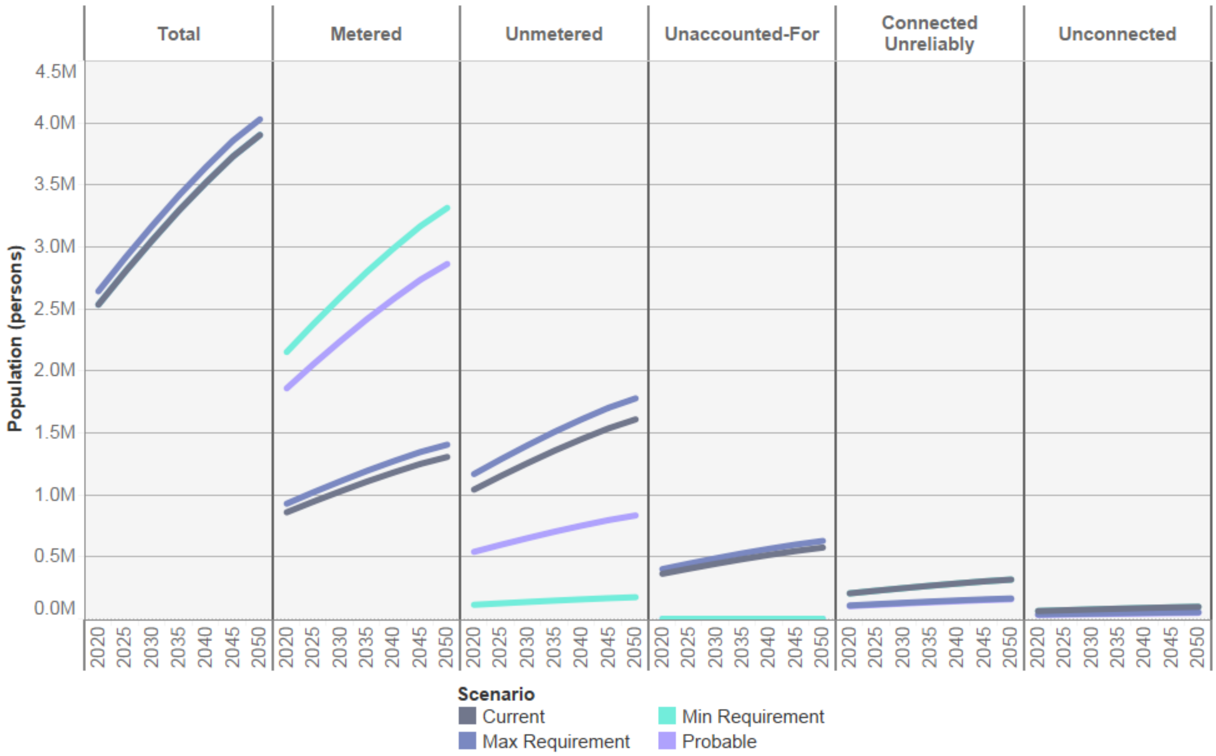


Figure 5.26 – Comparison between water system scenarios of population in different water user types under probable population projection

Figure 5.27 shows the components of the residential consumption forecast across the four water system scenarios by volume and **Figure 5.28** shows the volumetric difference from the Current scenario. These figures highlight the impacts of the shift in population to the metered water user type. Under the Probable scenario at 2050, metered consumption is 100 MGD higher and unmetered consumption 225 MGD lower, resulting in a net decrease of 125 MGD. The Minimum Requirement reduces overall residential consumption by 200 MGD compared to the Current scenario. Because the per capita use rate of unmetered customers is significantly higher than the per capita use rate of metered customers, even moderate reductions in the unmetered population lead to significant reductions in residential consumption.

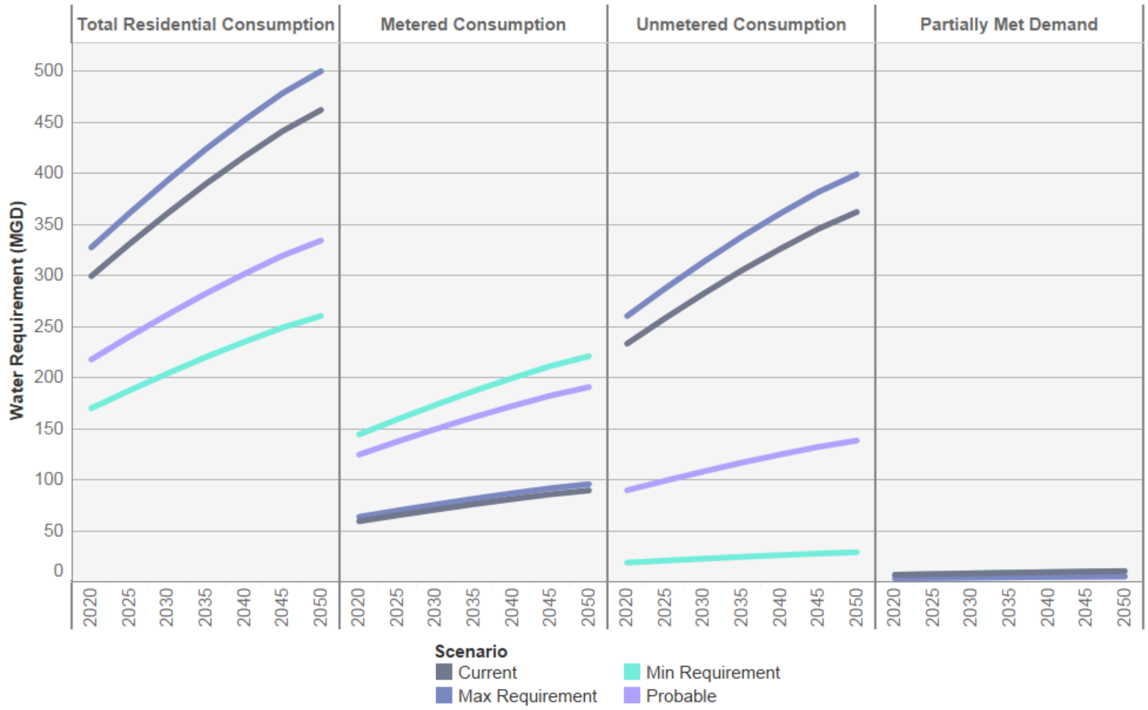


Figure 5.27 – Comparison between water system scenarios of forecasted residential consumption and its components under probable population projection

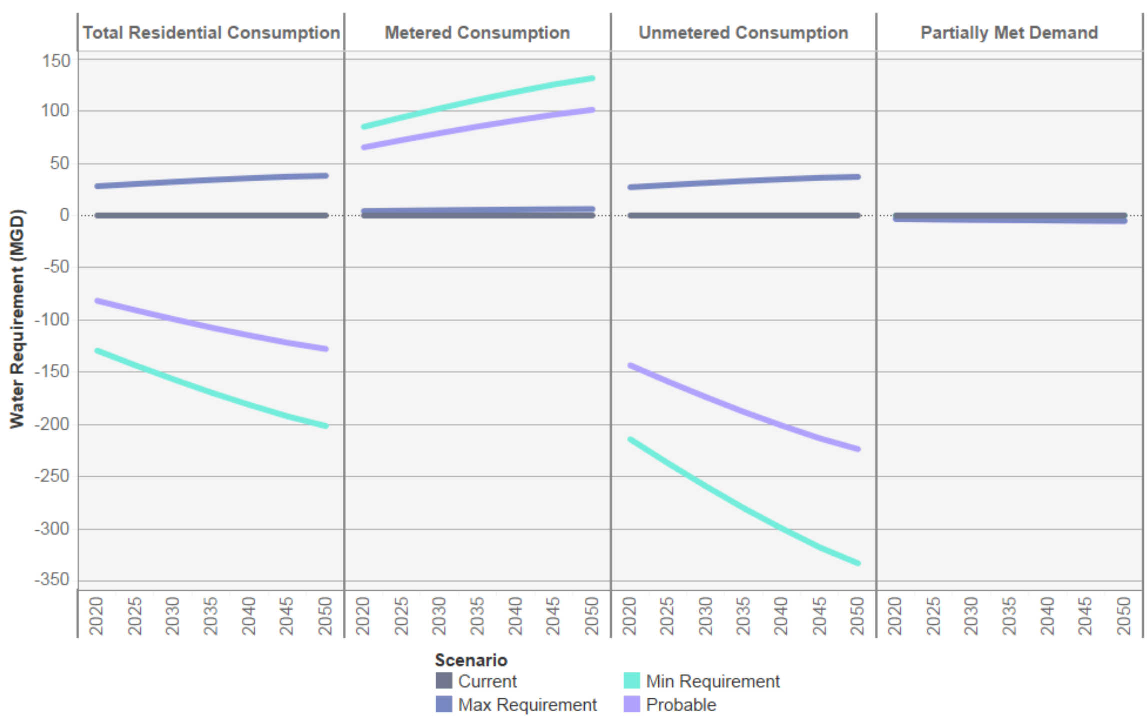


Figure 5.28 – Difference from Current water system scenario of forecasted residential consumption and its components under probable population projection

Future water requirement was also forecasted for the seven feasible combinations of population and economic growth projections for each of the water system scenarios. **Figure 5.29** shows the difference in the residential forecast between the probable and optimistic/pessimistic population growth projections under the four water system scenarios. This figure highlights the impact of the different population growth projections across the four water system scenarios on residential consumption. For the Current scenario at 2050, the difference between the optimistic and pessimistic population growth projections is roughly 50 MGD. A 50 MGD variation due to population growth is approximately 10 percent of the overall Current scenario 2050 residential water consumption forecast of 462 MGD (from **Figure 5.27**). This indicates a moderate sensitivity of future residential water consumption to population growth. This 50 MGD variation is approximately 6 percent of the overall water requirement forecast at 2050 for the Current scenario of 800 MGD. Other scenarios show similar impacts of population growth projections on both residential consumption and total water requirement.

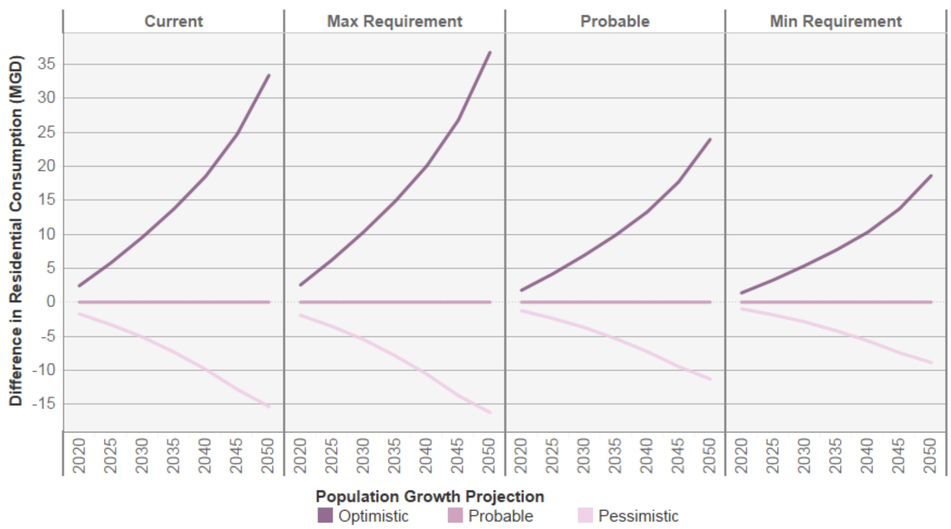


Figure 5.29 – Residential consumption by population projection shown as difference from probable population growth forecast by water system scenario

Figure 5.30 shows the future non-residential consumption forecast under the four water system scenarios and **Figure 5.31** shows the difference in this forecast between the probable and high/low economic growth projections. These figures highlight the impact of the different economic growth projections across the four water system scenarios on non-residential consumption. For the Current scenario at 2050, the difference between the High and Low economic growth projections is roughly 12 MGD. A 12 MGD variation due to economic growth is approximately 12 percent of the overall Current scenario 2050 non-residential water consumption forecast of 100 MGD. This indicates a moderate sensitivity of future nonresidential water consumption to economic conditions. This 12 MGD variation is approximately 1.5 percent of the overall water requirement forecast at 2050 for the Current scenario of 800 MGD. Other scenarios show similar impacts of economic growth projections on both non-residential consumption and total water requirement.

Figure 5.30 – Forecasted non-residential consumption by economic growth projection under each water system scenario

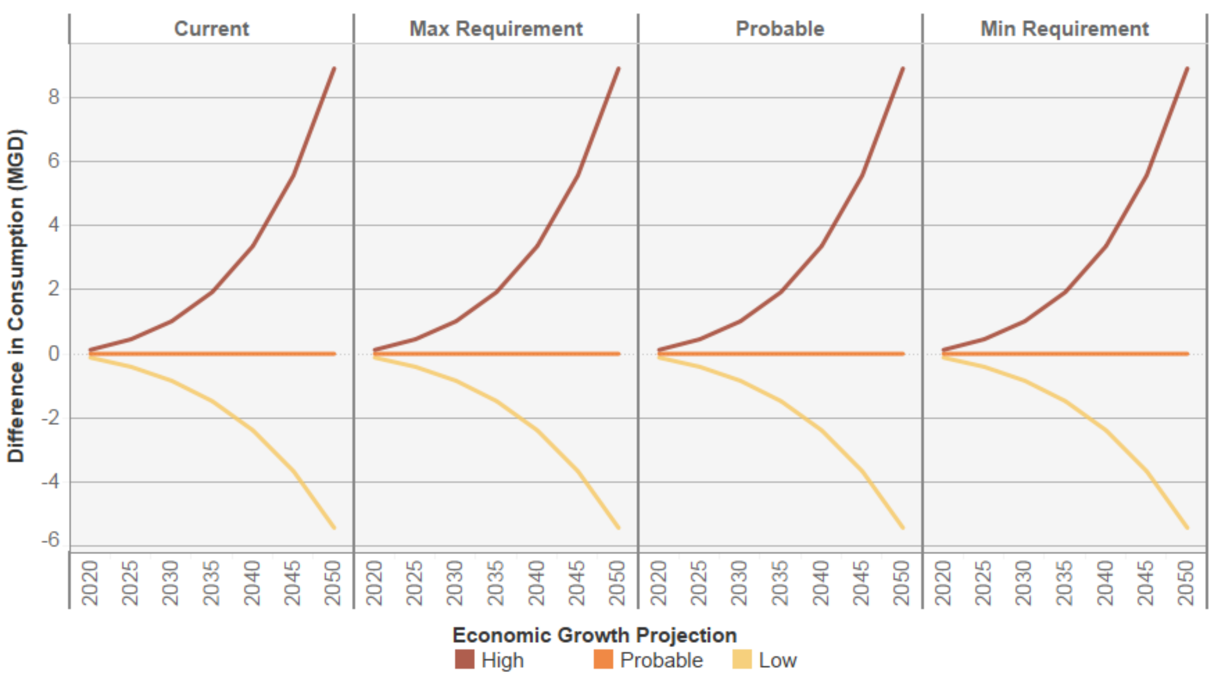


Figure 5.31 – Non-residential consumption by economic projection shown as difference from probable economic growth forecast by water system scenario

5.7 SUMMARY

There is significant variability in the future water requirement forecasted between the four water system scenarios. A majority of this variability is due to the distribution of population in the metered and unmetered water user types. Impacts of increased population growth and/or increased economic growth are less significant than impacts due to changes in metering of customers. Both the Probable and Minimum Requirement scenarios increase the metering of currently unmetered and unaccounted-for customers, which significantly reduces the residential consumption component of the total water requirement forecast. The Maximum Requirement scenario when compared to the Current scenario slightly increases future water requirement, mainly due to the expansion of the IDAAN service area. Therefore, if future conditions are consistent with current conditions, the water requirement will be close to the maximum possible based on demographics, population, and water use characteristics. However, increasing the metering of customers can significantly reduce the future water requirement.

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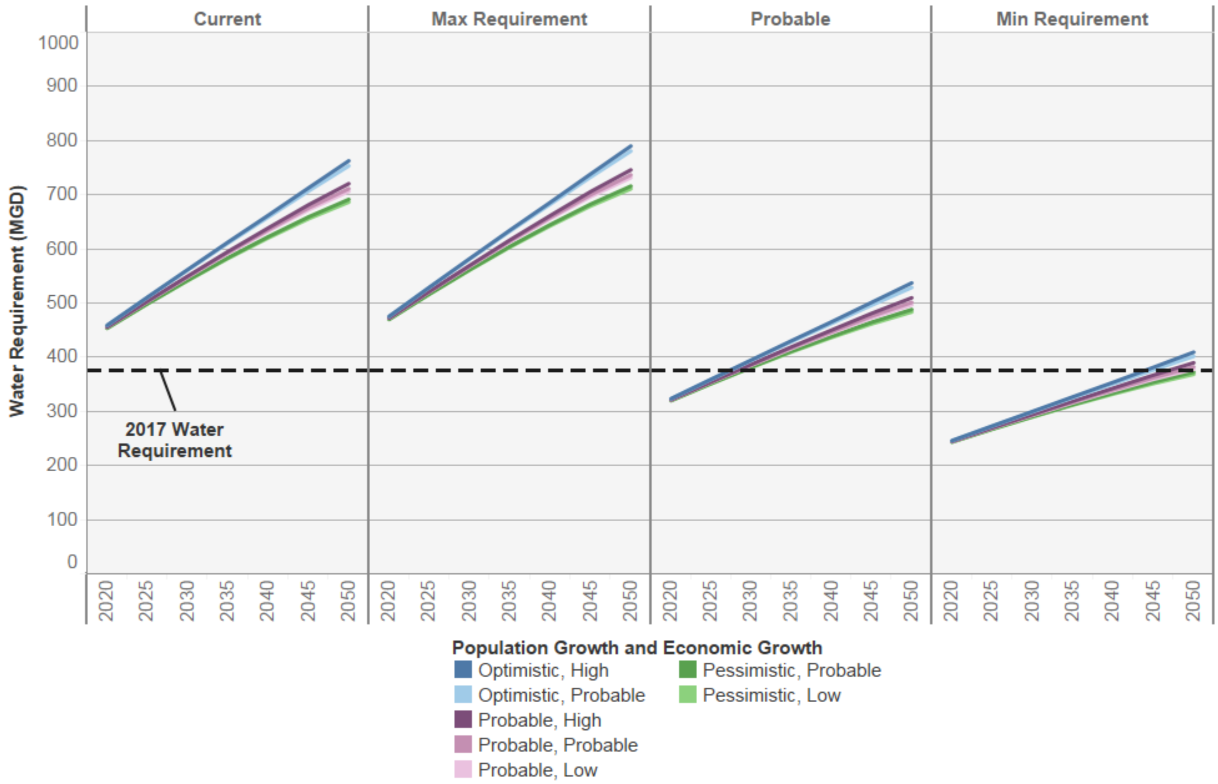
6.0 FUTURE DEMAND FORECAST CONCLUSIONS

6.1 HIGH, MEDIUM, LOW, AND NO ACTION DEMAND FORECAST SCENARIOS

This Study evaluated future water requirement forecast under four water system scenarios and seven combinations of population and economic growth projections. Results from these water system scenarios and growth combinations were the basis for assembling four future demand forecast scenarios selected by ACP for planning: High, Medium, Low, and No Action.

Forecasted water requirement from the four water system scenarios is based on assumptions around service area expansion, population connection, metering, and asset management. The water demand system will gradually change through time as changes are implemented, however in the Demand Model these gradual changes are simulated as instantaneous in time and take effect in the first year of simulation. This causes a disconnect between a scenario's future water requirement and what is reasonable to occur in the near-term.

Figure 6.1 shows this disconnect by comparing the forecasted future water requirement to the actual 2017 total water requirement. Note the 2017 water requirement is based on available data from IDAAN and covers a subset of the Study Area; future water requirement in this figure is displayed only for Population Zones 3, 4, 6, 7, and 8. For example, the 2020 forecasted future water requirement of these Population Zones under the Minimum Requirement scenario is 245 MGD, which is 130 MGD less than the 2017 observed water requirement of 375 MGD. It is unlikely that the changes in metering and infrastructure required for future requirement to be 245 MGD will be in place by 2020. However, it is possible that those changes will be fully implemented by 2050. To rephrase generally, while the starting point of the Minimum Requirement scenario is improbable, the end point is possible. This concept applies to the other water system scenarios as well.



2017 Water Requirement for IDAAN service area

Figure 6.1 – Comparison between forecasted future water requirement within IDAAN service area (Population Zones 3, 4, 6, 7 and 8) and 2017 observed water requirement

To account for this disconnect, the future demand forecast scenarios proportionally combined future water requirement forecasted by the Current scenario and either the Maximum Requirement, Probable, or Minimum Requirement scenario. This combining process captured the gradual transition of the water system from the assumptions under the Current scenario to the assumptions under one of the other scenarios. How these scenarios were combined is described as follows:

- The *High Scenario* assumed Current conditions at 2020 and 2025, Max Requirement conditions from 2035 to 2050, and 50 percent Current conditions and 50 percent Max Requirement conditions at 2030 according to the percentage values listed in **Table 6.1**.
- The *Medium Scenario* assumed Current conditions at 2020 and 2025 and Probable conditions at 2050. From 2030 to 2045 the two scenarios were combined according to the percentage values listed in **Table 6.1**.
- The *Low Scenario* assumed Current conditions at 2020 and 2025 and Min Requirement conditions at 2050. From 2030 to 2045 the two scenarios were combined according to the percentage values listed in **Table 6.1**.
- The *No Action* scenario assumed Current conditions from 2020 to 2050 according to the percentage values listed in **Table 6.1**.

The primary assumption underlying these combinations is that there will be minimal changes to how IDAAN operates and manages their system until 2030. If IDAAN institues major changes to how the system is operated or managed significanltly earlier or later than 2030, then this assumption will no longer be valid.

Table 6.1 – Percentage values used to combine the Current scenario with Probable or Minimum Requirement scenario

	Percent of Water System Scenario						
	High Forecast		**Medium Forecast**		**Low Forecast**		**No Action**
Year	Current	Max Req.	Current	Probable	Current	Min Req.	Current
2020	100%	0%	100%	0%	100%	0%	100%
2025	100%	0%	100%	0%	100%	0%	100%
2030	50%	50%	80%	20%	80%	20%	100%
2035	0%	100%	60%	40%	60%	40%	100%
2040	0%	100%	40%	60%	40%	60%	100%
2045	0%	100%	20%	80%	20%	80%	100%
2050	0%	100%	0%	100%	0%	100%	100%

The final step in preparing the future demand forecasts was selecting the population and economic growth projection. The High scenario used the Optimistic population growth scenario and the High economic growth scenario. The Medium and No Action scenarios used the Probable population growth scenario and the Probable economic growth scenario. The Low scenario used the Pessimistic population growth scenario and the Low economic growth scenario.

Figure 6.2 displays and **Table 6.2** lists the estimated future water requirement for the High, Medium, Low, and No Action future demand forecast scenarios based on the logic described above. Detailed future water requirement tables are included in **Appendix E**. Future water requirement across the four future demand forecast scenarios will be relatively similar until 2025 as the water system conditions are assumed to be similar to current conditions. After 2025, water requirement will continue to steadily increase under the High and No Action scenarios as population grows and no changes are made to metering or asset management, ultimately reaching 939 MGD and 803 MGD at 2050, respectively. Under the Medium scenario, water requirement will slowly increase, topping out at 590 MGD from 2035 to 2040 before slowly decreasing to 560 MGD at 2050 as unmetered customers are converted to metered customers and system losses are reduced. Under the Low scenario, water requirement will reach a maximum of 562 MGD at 2025 before steadily decreasing to a value of 408 MGD at 2050.

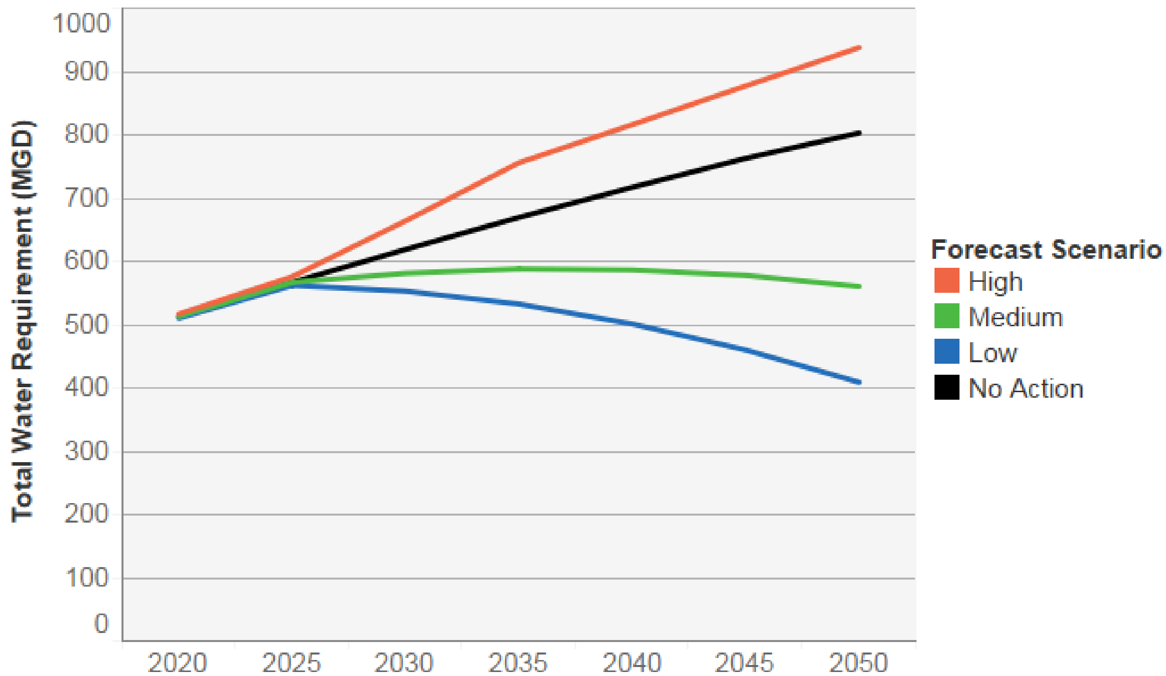


Figure 6.2 – Forecasted total water requirement for High, Medium, Low, and No Action demand forecast scenarios

Table 6.2 – Summary of forecasted total water requirement for High, Medium, and Low demand forecast scenarios

	Total Water Requirement (MGD)			
Year	High Scenario	Medium Scenario	Low Scenario	No Action Scenario
2017	437	437	437	437
2020	517	513	510	513
2025	576	567	562	567
2030	664	581	553	619
2035	756	588	532	670
2040	817	586	501	717
2045	878	578	459	763
2050	939	560	408	803
2017 to 2050 Average Annual Growth Rate	2.34%	0.75%	-0.21%	1.86%

Figure 6.3 shows the components of the forecasted total water requirement for the four demand forecast scenarios. Similar to total water requirement, residential consumption, non-residential consumption, and losses under the High and No Action scenarios are all higher than the Medium and Low scenario and increase through 2050. Non-residential consumption increases to 2050 across all four scenarios even with decreases in the Medium and Low scenario's residential consumption and losses. This is because non-residential consumption is tied to economic growth with the demand model assuming that any economic growth will lead to growth in non-residential consumption.

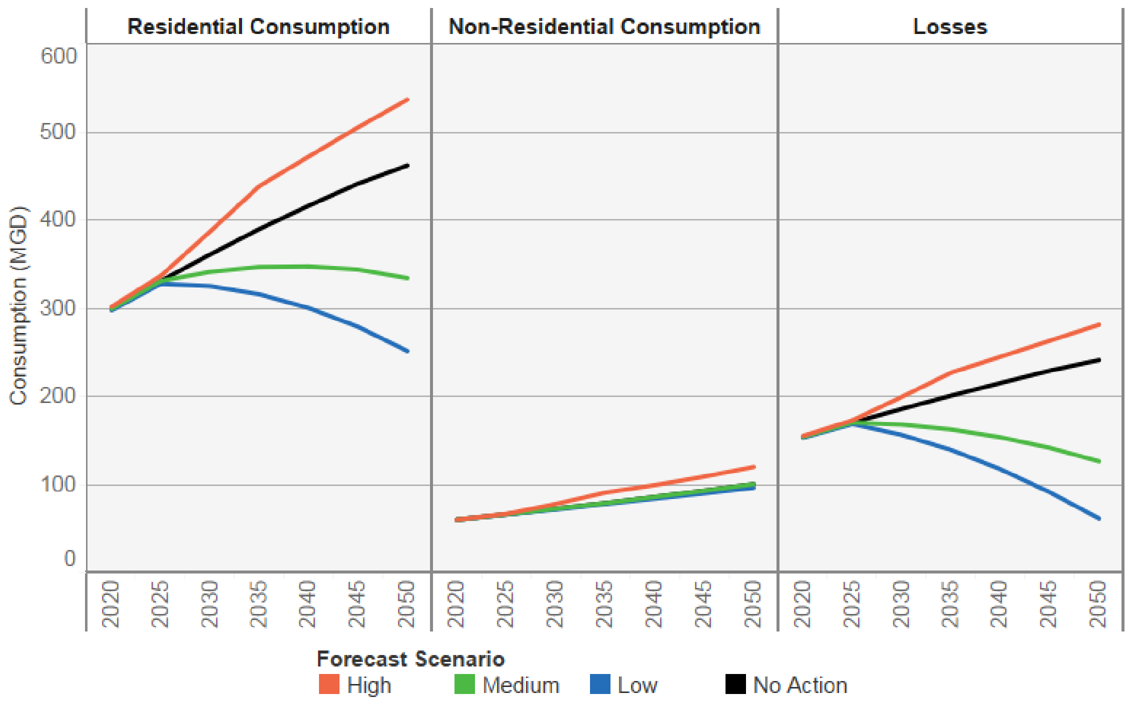


Figure 6.3 – Components of forecasted total future water requirement under the three demand forecast scenarios

Figure 6.4 shows the 2050 total water requirement by Population Zone for the four demand forecast scenarios and **Figure 6.5** shows the average annual growth in total water requirement between 2020 and 2050. Note that because Population Zone 9 does not have a total requirement in 2020, its growth rate is not included. Population Zones correspond to the key shown in **Figure 6.6**. At 2050, Population Zone 8 has the highest total water requirement across all four demand forecast scenarios. Population Zone 8 also has the highest variability in total water requirement across the four demand forecast scenarios, with a difference of 247 MGD between the High and Low scenario. Population Zones 3, 4, and 8 all have the highest percentage variability between the four scenarios between 150 percent and 160 percent. These Population Zones with high variability are geographically where changes in metering and asset management will have the most significant impact and future efforts could be focused there.

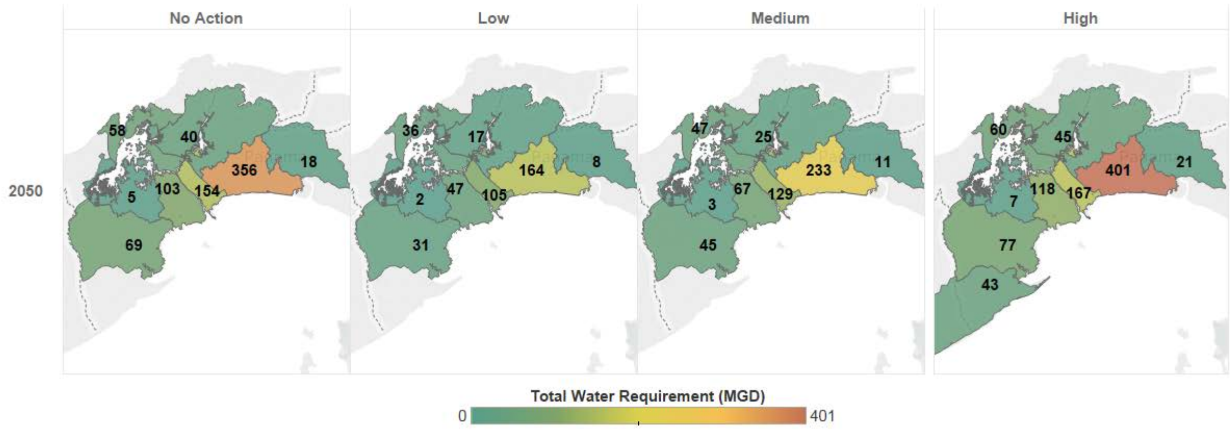


Figure 6.4 – 2050 total water requirement by Population Zone for the three demand forecast scenarios

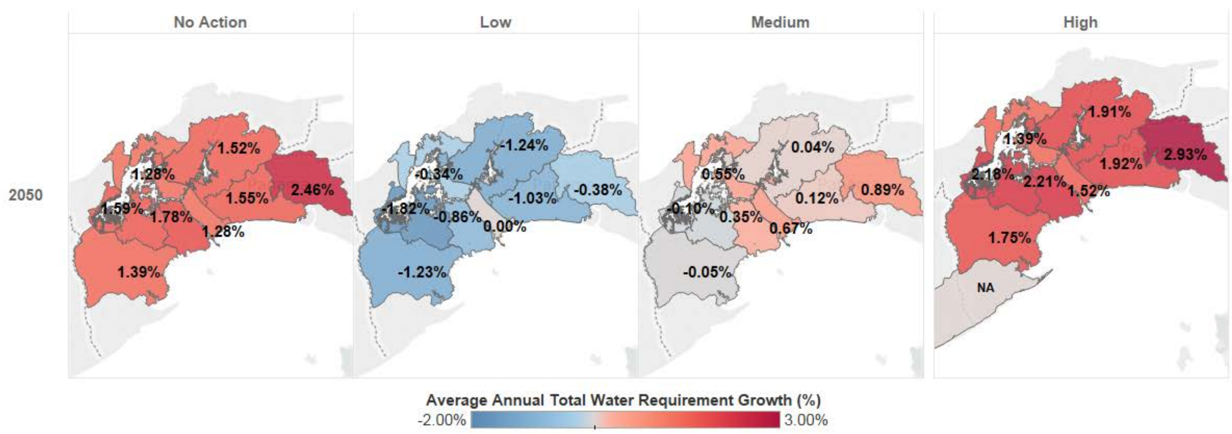


Figure 6.5 – Average annual growth rate in total water requirement by Population Zone for the four demand forecast scenarios

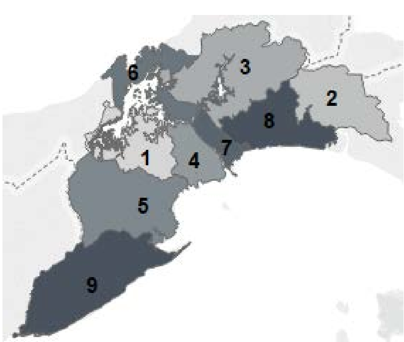


Figure 6.6 – Study Area Population Zones key

Figure 6.7 shows how forecasted total water requirement grows through time from 2020 to 2045 by Population Zone under the No Action demand forecast scenario. **Figure 6.8** shows the same but under the High demand forecast scenario, **Figure 6.9** shows the Medium demand forecast scenario, and **Figure 6.10** shows the Low demand forecast scenario. Population Zones correspond to the key shown in **Figure 6.6**. Under the High scenario, total water requirement increases in all Population Zones through all future years. Under the Medium scenario, total water requirement increases in all Population Zones until 2035, after which it decreases. Under the Low scenario, total water requirement peaks in 2025 across all Population Zones. In both the Medium and Low scenario, change in total water requirement at the Population Zone level is within 10 percent from 2025 to 2045, indicating that even as population continues to grow the overall water requirement remains steady.

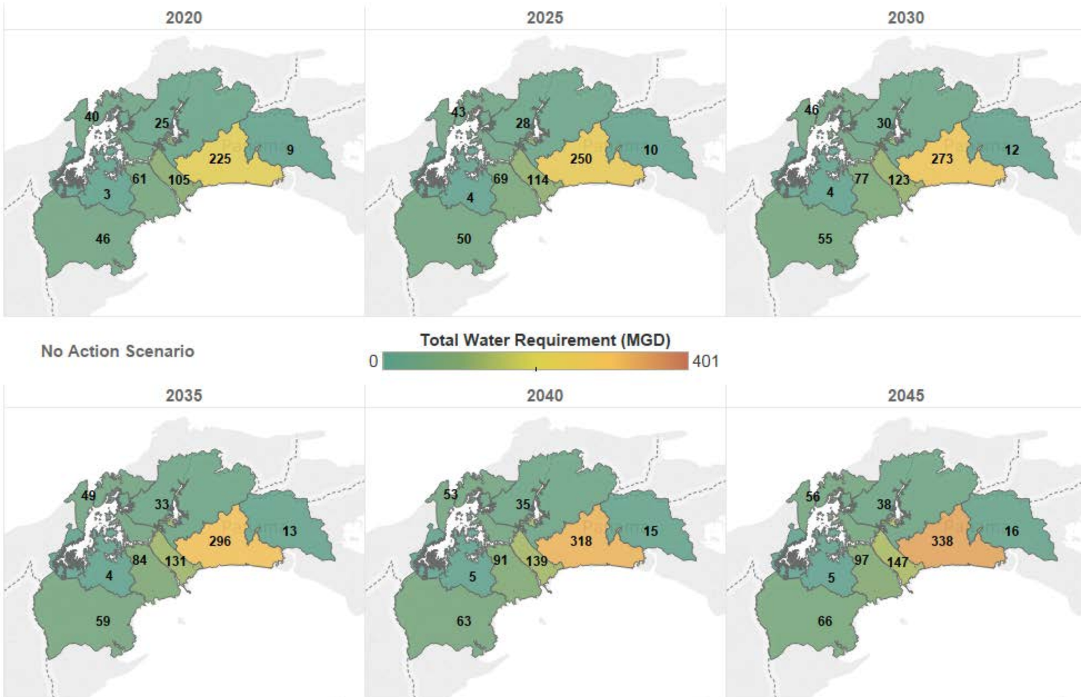


Figure 6.7 – 2020 to 2045 total water requirement by Population Zone under the No Action demand forecast scenario

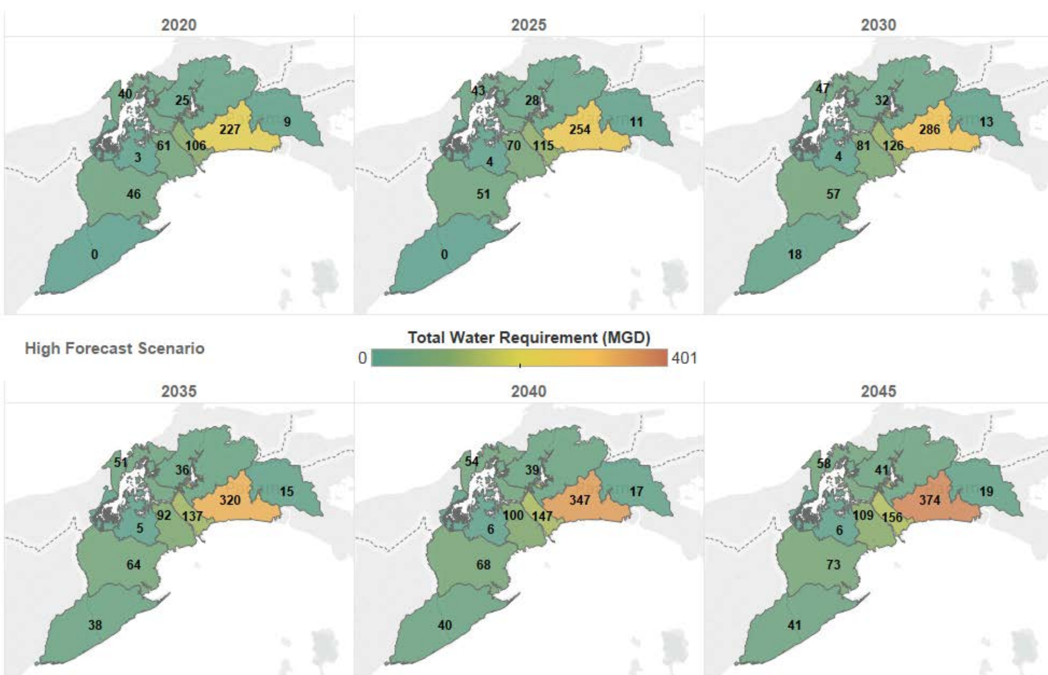


Figure 6.8 – 2020 to 2045 total water requirement by Population Zone under the High demand forecast scenario

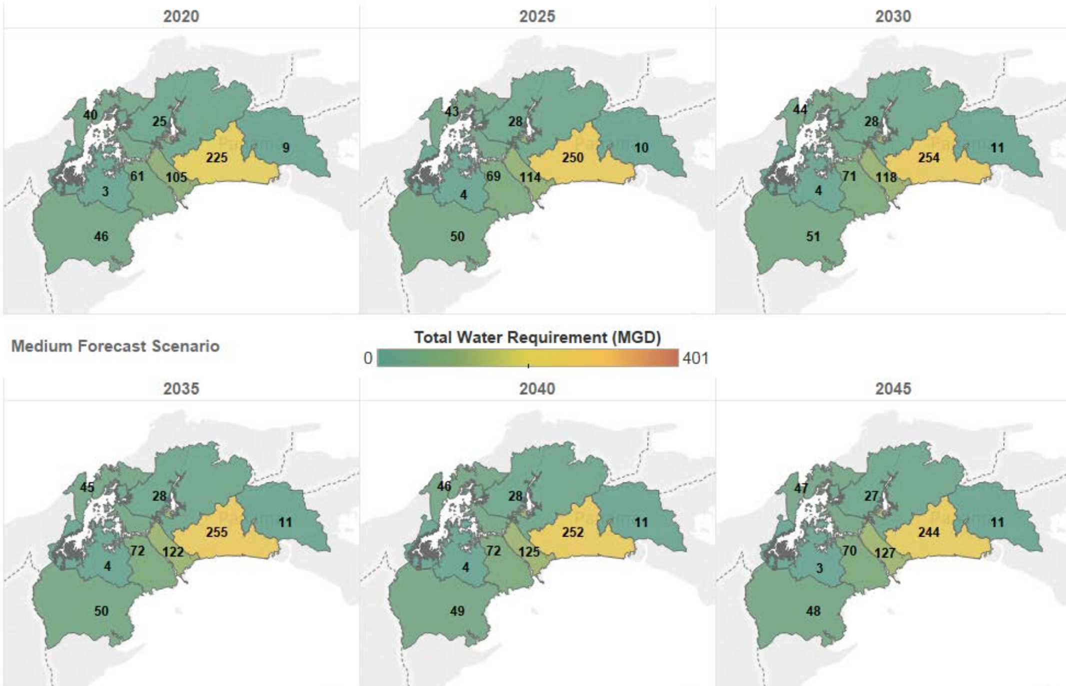


Figure 6.9 – 2020 to 2045 total water requirement by Population Zone under the Medium demand forecast scenario

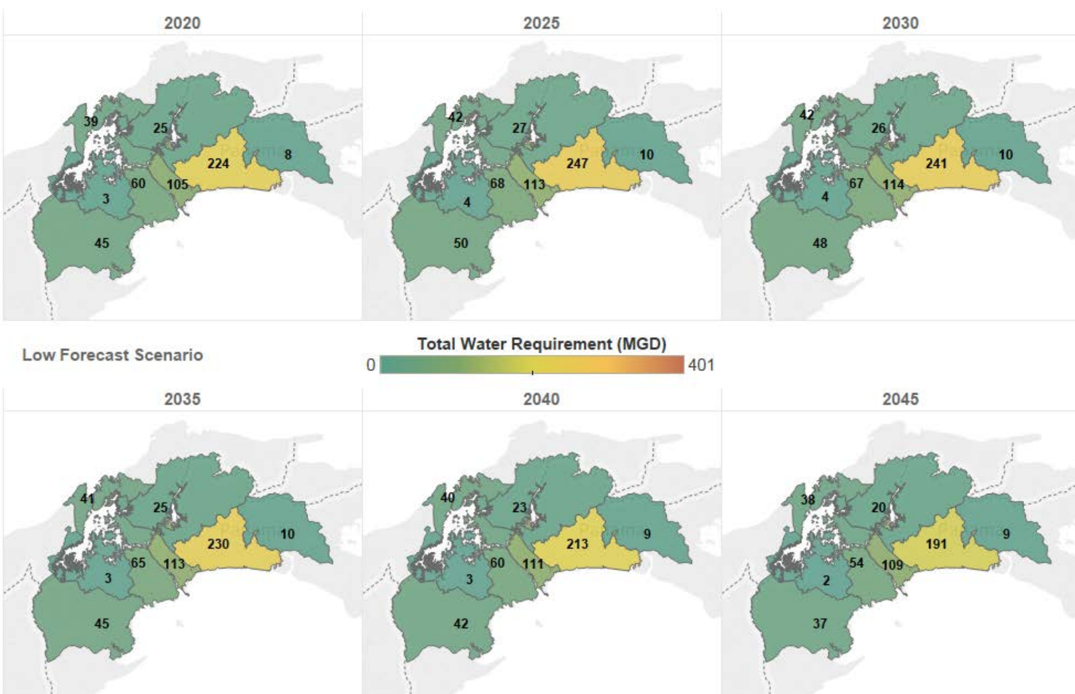


Figure 6.10 – 2020 to 2045 total water requirement by Population Zone under the Low demand forecast scenario

6.2 COMPARSION TO 2000 DEMAND MODEL

Results from the Study (referred to as the 2018 Study in this section to avoid confusion) were compared to results of the 2000 Study as part of the analysis. **Figure 6.11** shows how population projections from the two studies compare for the three common population growth projections. Population growth projections from the new Study are all higher than the 2000 Study, with differences in population at 2050 ranging from 1 million to 1.75 million. Additionally, the 2000 Study's Pessimistic growth projection showed population decreasing by 2050 while all population growth projections from the 2018 Study show population increasing.

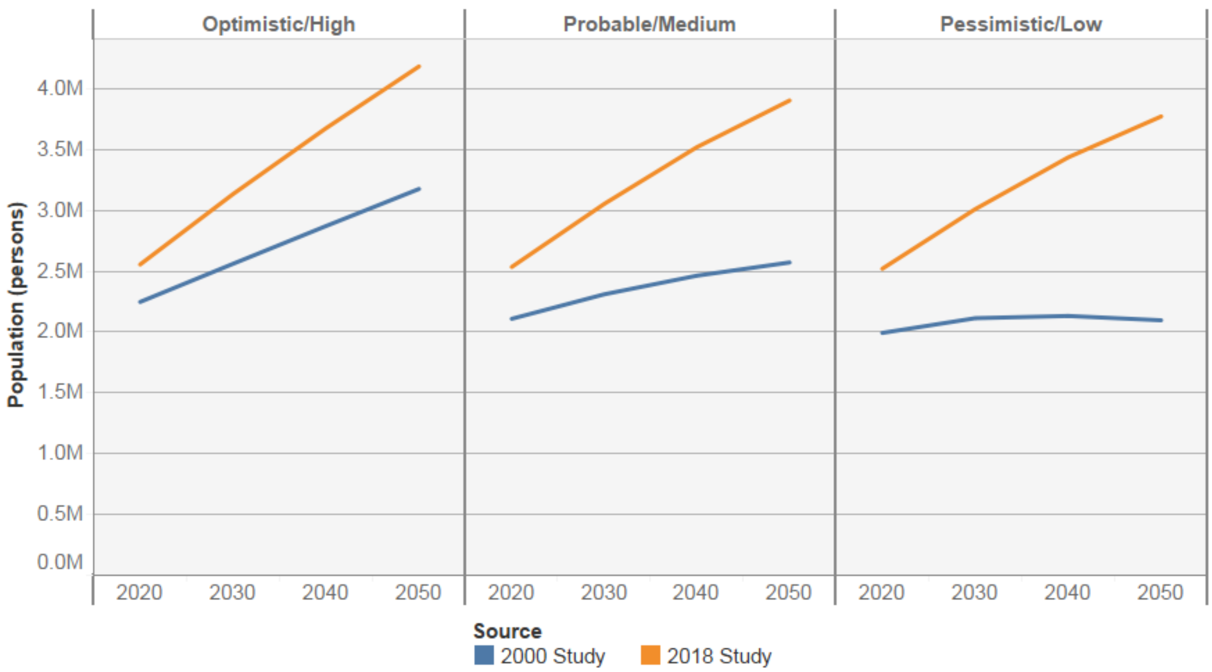


Figure 6.11 – Comparison in projected population between 2018 and 2000 Study

Figure 6.12 shows how the forecasted total water requirement compares between the two studies under the three comparable forecast scenarios (Optimistic/High, Probable/Medium, and Pessimistic/Low). The 2018 Study's High scenario forecasts future water requirement to be significantly higher than the 2000 Study's Optimistic scenario. The Medium scenario's future water requirement is approximately 100 MGD higher than the 2000 Study's Probable scenario. The Low scenario's future water requirement is nearly the same as the 2000 Study's Low scenario. Another difference between the 2018 Study's Medium and Low scenario and the 2000 Study's Probable and Pessimistic scenario is that the 2018 Study forecasts future water requirement to start decreasing by 2050. The 2018 Study Medium and Low forecasts show a decreasing trend in total water requirement by 2050 as the increasing number of metered customers lowers per capita residential consumption and ultimately total water requirement.

Figure 6.12 – Comparison of future total water requirement between 2018 Study's High/Medium/Low scenario and 2000 Study's Optimistic/Probable/Pessimistic scenario

Figure 6.13 shows how the components of the forecasted total water requirement (residential consumption, non-residential consumption, and losses) compare between comparable scenarios in the two studies. Across all forecast scenarios, forecasted residential consumption from the 2018 Study is higher than the 2000 Study. Forecasted non-residential consumption between both studies are similar in both volume and growth. Forecasted losses under the 2018 Study's Medium and Low scenario are lower than losses from the 2000 Study by 2050. This is due to the increase in metered customers and corresponding decrease in residential water use forecasted by the 2018 Study under the Medium and Low scenarios. Since losses are calculated as a percentage of total water production, losses calculated in the 2018 Study are less than those from the 2000 Study even though the loss rates are similar.

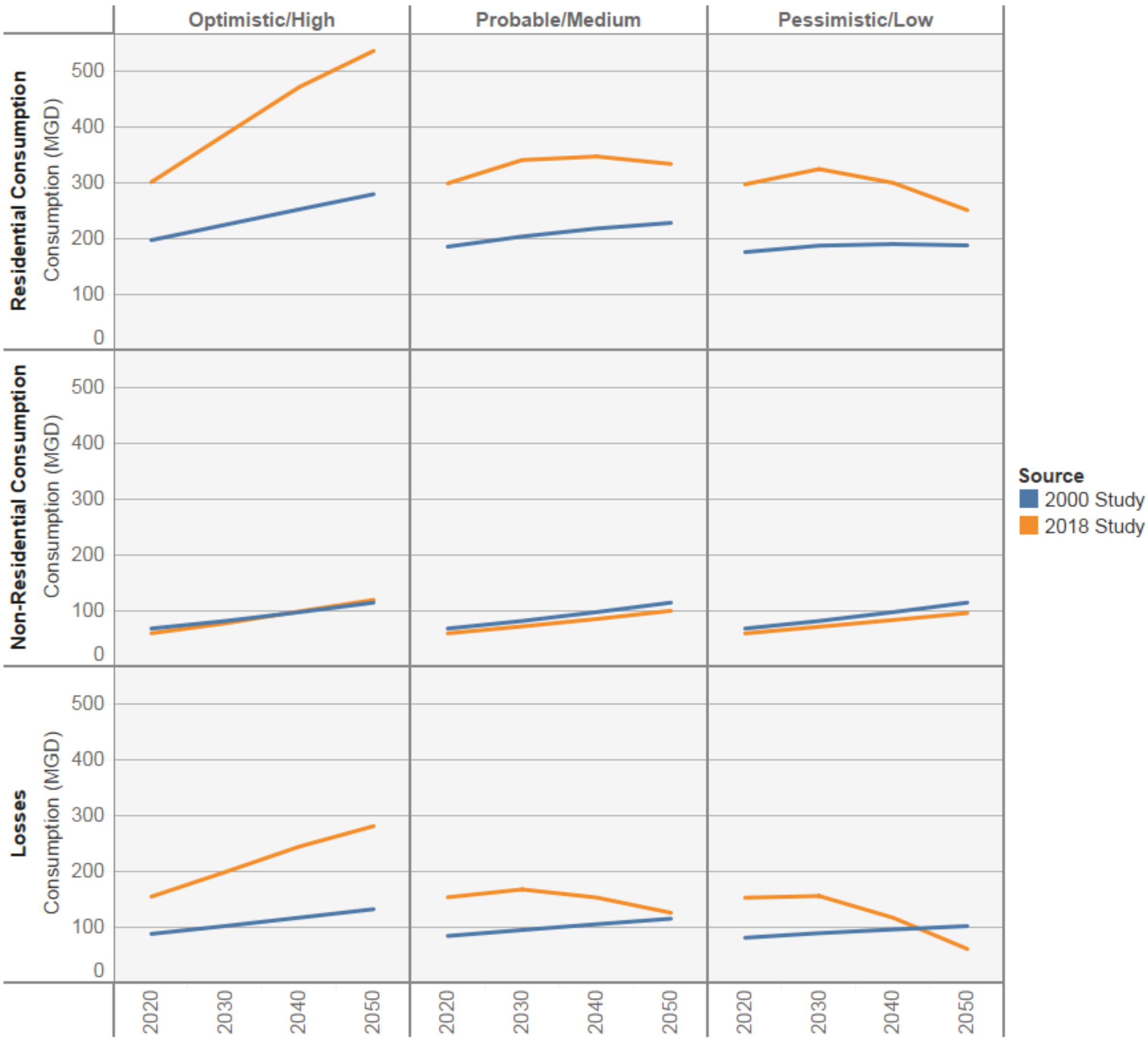


Figure 6.13 – Comparison of future total water requirement components between the Study's High/Medium/Low scenario and the 2000 Study's Optimistic/Probable/Pessimistic scenario

The variation in the scenarios for forecasted total water requirement is significantly greater for the 2018 Study compared to the 2000 Study. The difference between the High and Low forecast scenario from the 2018 Study is 529 MGD, compared to a 122 MGD variation between the 2000 Study's Optimistic and Pessimistic scenarios. This difference highlights how the Demand Model developed for the 2018 Study captures wider uncertainty in both observed data and future conditions compared to the 2000 Demand Model. At the time of the 2000 Study, planning under uncertainty for water resources applications was an emerging concept which has now become standard practice at the time of the 2018 Study.

Comparing the demand forecast scenarios between the studies further highlights how implementing concepts of planning under uncertainty for the Study impacted forecasted total water requirement. The High scenario from the 2018 Study forecasted 2050 total water requirement 400 MGD higher compared to the 2000 Study's optimistic scenario while the Low scenario from the 2018 Study and the Pessimistic scenario from the 2000 Study forecasted almost the same total water requirement at 2050. The difference in water system assumptions between the 2018 Study's High and Low scenarios, especially in metering and asset management, are the primary reason their respective forecasted future water requirement is significantly different. In summary, forecasted water requirement from the 2018 Study has a higher range than the 2000 Study due to an increased emphasis on capturing uncertainty. However, there are still similarities between the two studies, specifically in non-residential consumption and the Low/Pessimistic forecast scenarios.

6.3 COMPARISON TO OTHER ENTITIES

Research was conducted into water consumption patterns in other Latin American cities and countries and United States cities, and those patterns were compared to water consumption in the areas served with water from the Panama Canal Watershed. The comparative water consumption analysis included two aspects: (1) a high-level review of a wide variety of Latin American countries and cities in Latin America and the United States, and (2) a more detailed review of two Latin American cities that are similar to Panama City (Cartagena, Colombia and Guayaquil, Ecuador). The purpose of the comparative water consumption analysis was to:

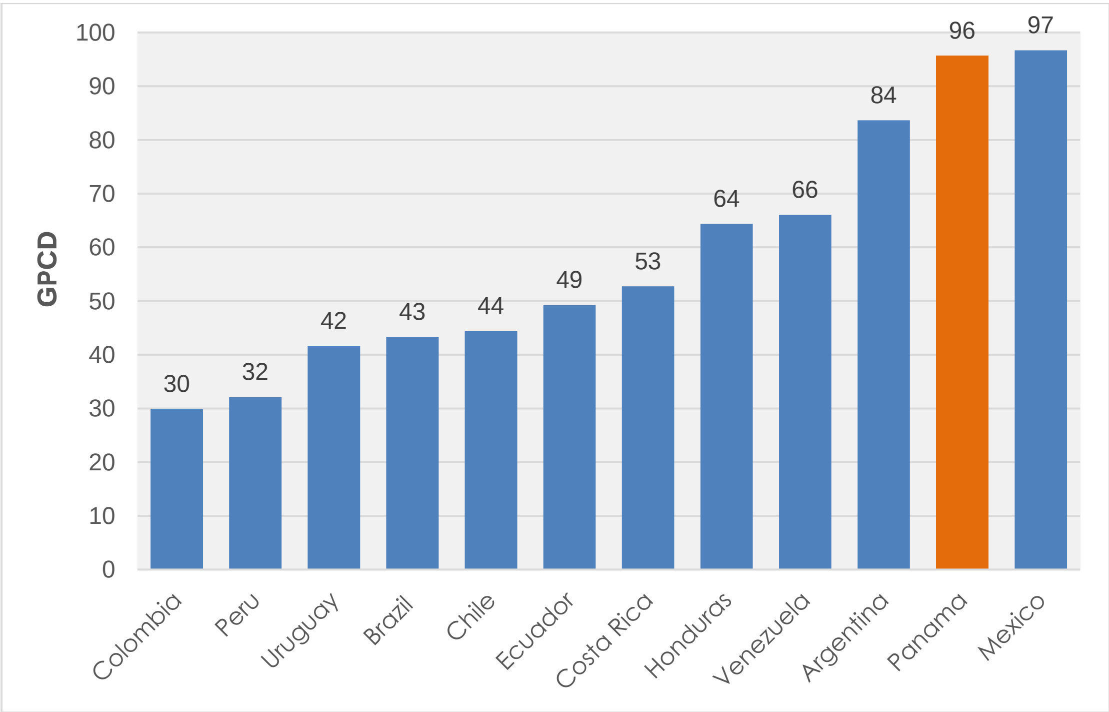
- Validate water consumption history and forecasts for the Panama Canal Watershed
- Explain why Panama City per capita use is higher than other Latin American cities
- Benchmark cost and pricing data and pricing strategies for water supply, production and distribution

This section summarizes the results of the comparative water use analysis. The full evaluation is presented in *Comparative Water Use and Cost Technical Memorandum* (Stantec 2018e) in **Appendix F**.

6.3.1 Comparison of Study Area Water Use to Other Latin American Cities and Countries and U.S. Cities

Figure 6.14 depicts the total per capita water consumption in other Latin American countries in 2015 based on available data from the Inter-American Development Bank (IDB) and World Bank (IDB 2015, World Bank 2018). The median and first and third quartiles of the data from this source are shown in **Table 6.3**. This data source estimates water consumption for Panama at 96 GPCD, which is at the upper end of the range for Latin American countries.

Other recent water consumption data for a variety of Latin American cities and countries was compiled from a variety of internet sources. This data is shown in **Table 6.4**. The median and first and third quartiles of the data from these sources are shown in **Table 6.5**. The difference between the statistics derived from these two datasets is indicative of the difficulty in comparing water consumption data from different sources and times. The data from the variety of sources shows a lower per capita consumption rate than the IDB source. The Panama Canal Watershed region water consumption estimate of about 85 GPCD in 2017, as estimated from data presented in the *Forecast Comparison Technical Memorandum* (Stantec 2018b) in **Appendix B**, is near the top of the range of data in **Table 6.4.**



Source: IDB 2015, World Bank 2018

Figure 6.14 – Total per capita water consumption for selected Latin American countries

Table 6.3 – Selected statistics for IDB water consumption data for Latin American countries

Statistic	Water Consumption[1] (gal/person/day)
First Quartile	43
Median	51
Third Quartile	70

1. 2015

Table 6.4 – Miscellaneous total water consumption data for Latin American cities/countries

Country or City	Total Water Consumption (gal/person/day)	Total Water Consumption (gal/person/day)	Year
Bolivia Altiplano	100	26	2013
Bolivia El Valle	120	32	2013
Bolivia Oriente	150	40	2013
Colombia	98	26	2013
Bogota, Colombia	130	34	2017
Mexico	280	74	2012
Mexico	366	97	2017
Mexico (urban)	173	46	2011
Mexico City	315	83	2017
Venezuela	250	66	2016
Costa Rica	200	53	2014
Costa Rica	160	42	2017
Peru	163	43	2017
Peru (urban)	142	37	2017
Brazil	108	28	2015
El Salvador (urban)	118	31	2017
Guatemala (urban)	125	33	2017
Ecuador	237	63	2015
Argentina	336	89	2017
Buenos Aires	345	91	2017
Chile	170	45	2009
Tegucigalpa, Honduras	172	45	2017
Panama	370	98	2017

1. From 2009-2017

Source: Various websites and news reports

Table 6.5 – Selected statistics for miscellaneous total water consumption data for Latin American cities/countries

Statistic	Total Water Consumption[1] (gal/person/day)
First Quartile	34
Median	45
Third Quartile	70

1. From 2009-2017

A number of factors can explain differences in water consumption between cities or counties. One of these factors is relative prosperity. More affluent communities have better developed water systems, fewer unconnected residents, and residents with access to more water-using appliances like dishwashers and clothes washers; they tend to use more per capita than less affluent communities. To explore whether some of the difference in per capita use in Latin American countries can be explained by prosperity, the net national income per capita was plotted with per capita water use for each country. This is shown in **Figure 6.15**. The data shows a slight positive correlation between per capita water use and national prosperity, but it is not consistent. Panama's level of affluence is relatively high compared to the other Latin American countries shown in the figure; this corresponds to a high per capita water use also.

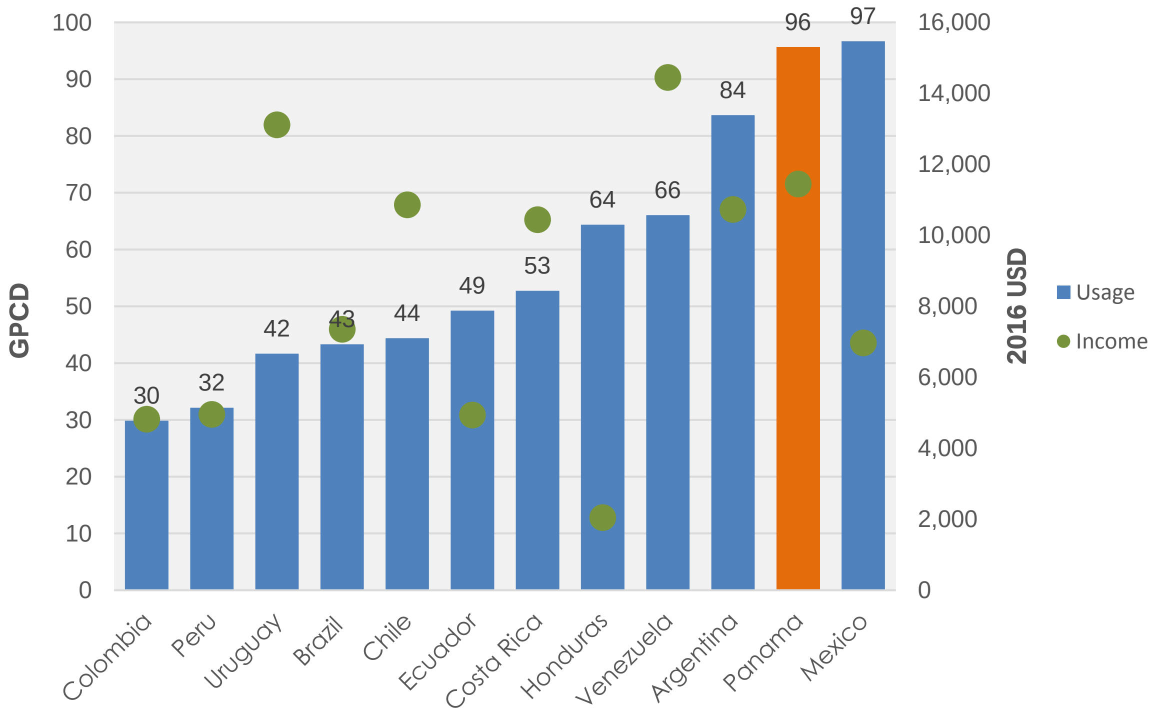


Figure 6.15 – Residential water usage and net national income per capita for various Latin American countries

Data from **Figure 6.15** and **Table 6.4** show that Panama is at the upper end of the range of per capita water consumption for Latin American cities and counties. Total water production in the Panama Canal Watershed Study Area in particular was 163 GPCD in 2017 including losses and UFW and 80 GPCD for actual documented use based on data provided by IDAAN. By comparison total consumption for Latin American countries in 2015 averaged about 51 GPCD.

To compare Study Area water-use to water consumption in more fully developed countries, data was collected for residential water demand in a range of cities in the United States. **Figure 6.16** – compares residential per capita water consumption in the Study Area and in the United States. In these figures residential per capita consumption for the Study Area was taken from Table 4.1 in the *Forecast Comparison Technical Memorandum* (Stantec 2018b) in **Appendix B**, and is the average of observed residential per capita water consumption by Population Zone over the period 2000-2017. Residential per capita water consumption in the Study Area Population Zones is generally lower than in most US cities, with the exception of Population Zone 7 (Panama City) which is more typical of most US cities. Zone 7 has the most modern development and affluent residents, so it is understandable that residential per capita water consumption in that area more closely resembles US cities.

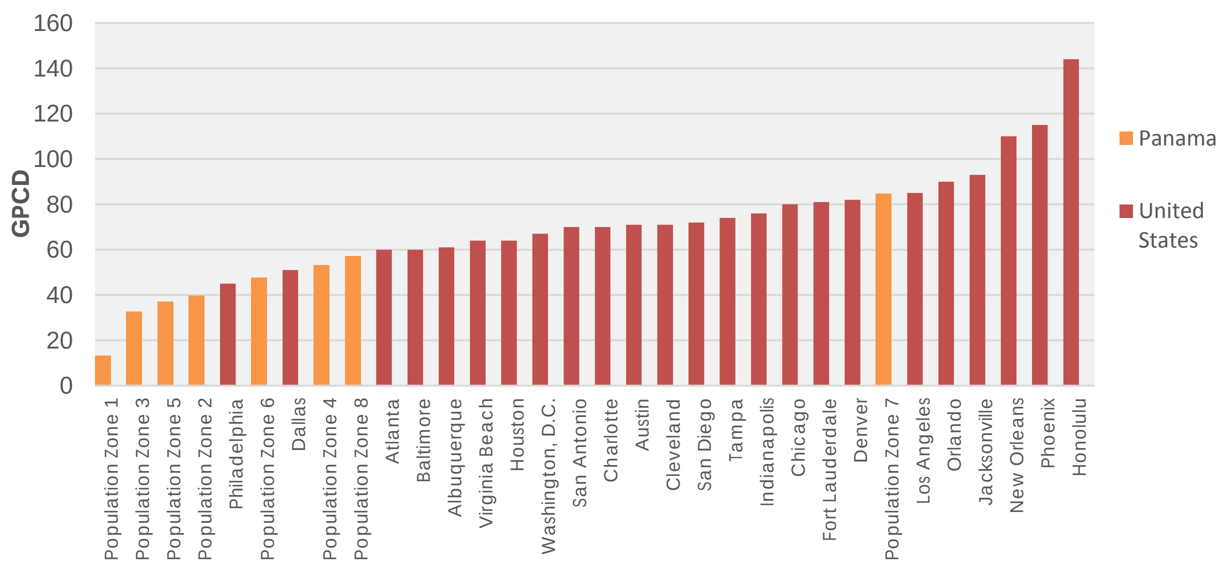


Figure 6.16 – Residential per capita consumption in Study Area and US cities

The water use comparisons in this section suggest that water use in the Study Area, and in Panama in general, is high relative to other Latin American countries. The 2000 Demand Study came to the same conclusion. This suggests there are opportunities for improvement in water efficiency. Previous analyses of this project have indicated that high a percentage of unmetered customers and UFW are partially responsible for the high-water consumption data in the Study Area. Implementation of metering loss reduction and conservation programs by IDAAN could produce savings and help drive down per capita use to be more consistent with the rest of Latin America. These sorts of programs are included in the lower water demand forecast scenarios described previously in this report.

On the other hand, the fact that Panama water use is significantly lower than most developed US cities suggests that for future scenarios in which urban living and affluence in response to continued economic development, per capita water use in the Study Area could also be driven higher.

6.3.2 Latin American Water Pricing Data Comparison

This section summarizes water pricing data from other Latin American cities and countries. The purpose of the analysis is to compare water pricing strategies in the Study Area to other Latin American regions to evaluate whether water is undervalued in Panama and whether additional revenue could be available to the water utility in the Study Area by adopting more realistic pricing schedules.

Most regions in Latin America employ a tiered rate system for water charges, in which charges increase with increasing water usage. Systems vary in their complexity. For example, Paraguay organizes customers into only three categories—subsidized residential, non-subsidized residential, and non-residential. Bolivia, on the other hand, organizes residential customers into four sub-categories based on the home's characteristics, and has four other categories for industrial, commercial, municipal, and social water customers.

Figure 6.17 shows the median price of water per cubic meter in Latin American countries for which data was available. Prices are as reported by the International Benchmarking Network (IB-Net) website, the World Bank (2018), or as reported by the individual country's water utility, assuming average household size and average water consumption.

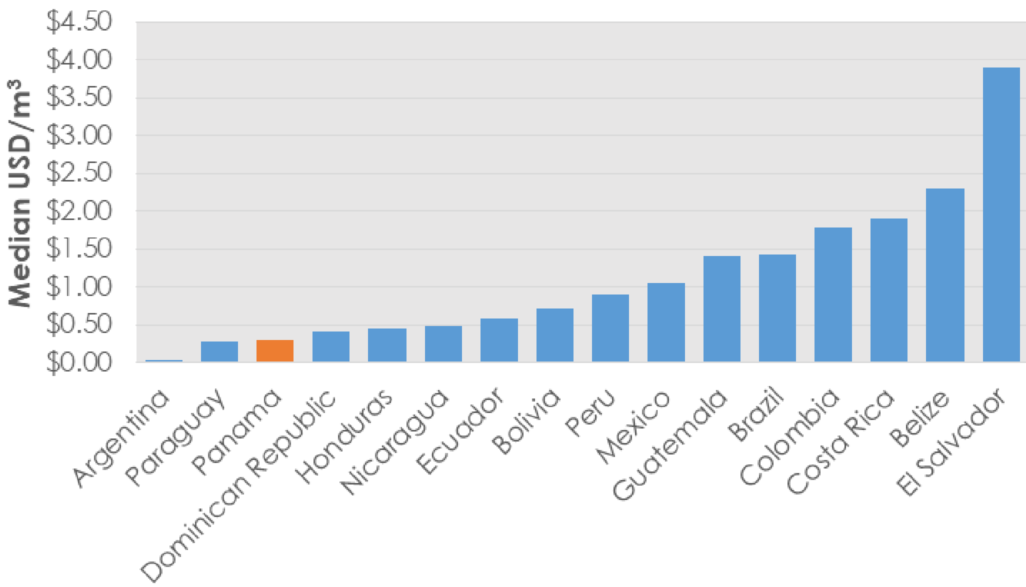


Figure 6.17 – Median price of water per cubic meter for various Latin American countries
Sources: IB-Net (2018), and World Bank (2018).

As shown in **Figure 6.17**, the median price of water sold by water utilities in Panama is about $0.30/m^3, which is significantly less than that of most Latin American water utilities. Since IDAAN is the largest M&I utility in Panama, the price of water shown in the figure should be reflective of pricing in the Study Area as well. As shown previously in **Figure 6.15**, net per capita income for Panama is greater than that of most Latin American countries. It is expected the water utility customers in the Study Area have an ability to pay a higher cost for water than they are currently paying. Higher but reasonable rates would generate more revenue for the water utility and provide the means for financing better asset management programs and infrastructure improvements.

The comparison of water use and water pricing information across Latin American countries suggests that Panamanians use more water and pay less for it than most other Latin Americans.

6.3.3 Detailed Comparison to Two Latin American Cities

Introduction. In this section development and water use conditions in Panama City are compared to two similar Latin American cities – Cartagena, Colombia and Guayaquil, Ecuador. The purpose of this comparison is to better understand conditions in the Study Area relative to other Latin American cities, and identify water development and management strategies used in those cities that may be transferrable to Panama City to reduce the stress on the Panama Canal Watershed. Cartagena and Guayaquil were selected by CELA based on their understanding of a wide variety of cities in Latin America.

Overview of Cites. Panama City is a very important port because of its geographical position that allowed, at the beginning of the 20th century, the construction of the Panama Canal that unites the two largest oceans on earth. It is also the capital of the Republic of Panama. The port cities of Cartagena (Colombia) and Guayaquil (Ecuador) have similarities to Panama City. This section analyzes these similarities in terms of history, population, production and consumption of drinking water, as well as the port movement. **Figure 6.18** is a map showing the location of the three cities.

Figure 6.18 – Locations of Panama City, Cartagena, and Guayaquil

History. The cities of Panama City, Cartagena and Guayaquil have colonial roots; all were founded during the conquest of the Americas by Spain. Panama City was founded in 1519 to facilitate the Spanish expansion through the western basin (America) of the Pacific. Cartagena was founded in 1533 and served as a gateway for the colonization of the interior of what is now Colombia. Guayaquil was born as a shipyard in 1547 for the Spanish ships that traveled along the South American coast.

Because they have similar histories, these cities have similar observed development patterns and water systems. Current water systems are outgrowths of nearly 500 years of development and redevelopment, including multiple conversions of antiquated systems to new technologies (e.g., different pipe materials, pressurized distribution systems, customer metering, etc.).

Population. Guayaquil is the largest of the three cities, with more than 2.5 million inhabitants; Panama City proper has about 880,700 people, with about 1,526,00 people living in the metropolitan area; and Cartagena has just over 1 million inhabitants. The three cities experienced rapid demographic growth in the second half of the 20th century. Currently, they are going through the so-called 'demographic transition' common to developing countries, which implies a more moderate increase in future population as birth rates decline. Unemployment and informal employment predominate in the three cities.

Water System Overview. Panama City modernized its potable water system when the Panama Canal was built in the early 1900s. Throughout the second half of the 20^{th} century, with the growth of the city, the administration of the water system became difficult. Currently, the system is subject to high water losses, a large percentage of UFW, and a high percentage of unbilled or unpaying customers.

In the cases of Cartagena and Guayaquil, their aqueduct and sewer systems were modernized after the Second World War. Currently, they have the same administration problems as Panama City in terms of high system losses (31 percent and 25 percent, respectively) and UFW. In these two cities, the water system was granted to private companies. The potable water utility in Cartagena was converted to a public-private partnership (AGUACAR) in 1995, and the water utility in Guayaquil converted to a public-private partnership (Interagua and Emapag) in 1996. In the case of Panama City, the administration of water is managed by IDAAN, a public entity. The fact that Cartagena and Guayaquil have privatized water systems while Panama City has a public water utility is a significant difference that could substantially affect current water supply conditions.

Water sources for the three cities are similar.

- Panama City is served almost entirely by surface water, primarily from the Rio Chagres and the Panama Canal Watershed.
- Cartagena is served by surface water from the Rio Grande de la Magdelena watershed.
- Guayaquil is served by surface water from the Rio Daule watershed.

None of these cities have pursued alternate sources such as wastewater reclamation or desalination.

Table 6.7 includes data on the use of water in the three cities and the percentage of the population that has reliable water service.

Water Use Data. Per capita water consumption for Cartagena is about 40 GPCD, and per capita water consumption for Guayaquil is about 45 GPCD. By comparison, per capita water consumption in Panama City is much higher at about 125 GPCD. The cities have relatively similar commercial and industrial activity related to ports, with the exception of the Panama Canal. The Canal alone would not be responsible for the difference in per capita water use; other factors like inefficient water use, losses, and a society used to abundant water supply likely play a part in the high use rate.

Other water related statistics were gathered for the two selected cities.

- The percentage of customers reliably served with municipal water is 99 percent in Cartagena and 75-97 percent in Guayaquil, compared to 84 percent in Panama City. The greater coverage indicates a more intentional focus on and investment in connecting customers, which may be related to privatization of the water utilities in Cartagena and Guayaquil.
- The percentage of UFW is about 31 percent in Cartagena, 54 percent in Guayaquil, and 40-55 percent in Panama City. All these values are high and reflect the difficulty of minimizing losses and illegal connection and tracking all water users in Latin American cities.
- The percentage of metered customers is about 99 percent in Cartagena and Guayaquil but only about 57 percent in Panama City. This indicates a greater investment in metering existing and new customers in Cartagena and Guayaquil, which may be related to privatization of the water utilities. The percentage of metered customers in Guayaquil was only 24 percent prior to entering into the private concession agreement. Apparently, the concessionaire has been successful in metering its known customers, thereby reducing per capita water usage and increasing revenue through the more reliable and accurate customer billing process tied to metered water use records.

Price of Water. The average price of water was estimated from the rate tables for each water utility and the total amount of water sold. Average prices are sometimes difficult to compare because of the difference in rate structures. Water utilities in Cartagena, Guayaquil, and Panama City all employ differential rate structures for residential, commercial, industrial, and government customers. All residential customers in Guayaquil and Panama City are charged for the volume of water they consume, with per unit prices increasing as consumption increases. This type of rate structure is commonly used in the United States as a water conservation measure, because it creates a price incentive for the customer to minimize water use.

On the other hand, in Cartagena, residential customers are charged flat rates based on the size of their house, their socioeconomic status, and their consumption range. After AGUACAR assumed responsibility for the water utility, customers were grouped into six residential categories based on the size and features of their house that are a surrogate for economic status. Levels 1-3 are below average income, Level 4 is average income, and Levels 5-6 are above average income. Rates for Level 4 were set at the actual cost of providing water. Rates for lower levels were set lower and the actual cost of service and rates for higher levels were set higher than the actual cost of service, such that higher income customers subsidize lower income customers. Only customers in the first three categories, with smaller and less developed houses, are charged higher prices for excessive consumption. Any consumption in excess of 16m^3 is subject to a flat rate, regardless of residential category. A comparison of example charges for different volumes of consumption in each city are outlined in **Table 6.6**. The ranges for Cartagena represent the charges for users in residential category 1 (lowest price) to users in residential category 6 (highest price). The pricing structure in Cartagena is designed to make water more affordable for low-income customers rather than to provide an incentive for all customers to use less water. In the conversion to AGUACAR management of the water utility, typical monthly water costs for some customers when up and for others it went down.

Table 6.6 – Comparison of water prices in Cartagena, Guayaquil, and Panama City

Consumption per Month	Total Price (USD)		
	Cartagena	Guayaquil	Panama City
15m^3	$2.64-$20.45	$4.83	$3.12
30m^3	$2.94-$20.45	$14.31	$6.32
45m^3	$2.94-$20.45	$30.38	$16.05
61m^3	$2.94-$20.45	$53.07	$24.32

As seen in **Table 6.6**, Cartagena's rate structure does not create a price incentive for customers to conserve water. Guayaquil and Panama City both have rate structures that incentivize customers to use less water, but the price comparison suggests that water is undervalued in Panama City compared to Guayaquil. This is consistent with the previous finding that water tends to be undervalued in Panama relative to other Latin American countries.

Summary. **Table 6.7** summarizes the comparison of relevant data for Panama City, Cartagena and Guayaquil. Note that some of the water system data (e.g., percentage of households served) is self-reported by the water utility and was not independently verified.

Table 6.7 – Comparison of three Latin American cities

Statistic	Cartagena	Guayaquil	Panama City
Population (2016)	1,288,490 (1)	2,788,363 (2)	880,691 (9) – Panama City proper / 1,489,952(6a) IDAAN Panama Metro área (2015)
City area (km^2)	572	345	275
Population density (people/km^2)	1,699	5,660	3,203
Production of drinking water (2015)	79 MGD (3)	260 MGD (2)	303 MGD (6a) Panama Metro WSA only
Per capita water consumption	40 GPCD (8)	45 GPCD	104 GPCD (10)
Percentage of population served with reliable water supply	99.9% (3)	75% (2) – 97%	84% (6b)
Percentage of UFW	31% (3)	54% (2)	40% - 55%
Percentage of metered customers	99% (3)	99% (2)	57%
Average price of water (average of all customer categories) (11)	$0.11/m^3$ (3) (2015)	$0.55/m^3$ (2015)	$0.21/m^3$ (2018)
Movement of containers, 2017 (TEUS)	2,561,000 (7)	1,871,591 (7)	2,986,617 (Balboa) (7) 3,891,209 (Colón) (7)
Port Ranking in Latin America (2018)	5th	7th	2nd
Emphasis on water conservation	Moderate	Fair	Poor

1. Departamento Administrativo Nacional de Estadística, Republica de Colombia.
2. Proyección al año 2016 de Interagua, *Ajuste y revisión del plan maestro agua potable, alcantarilla sanitaria y alcantarilla pluvial* Tomo1, Guayaquil: Interagua.
3. Aguas de Cartagena, 2016, *Reporte de sostenibilidad*, Cartagena: Aguas de Cartagena.
5. Instituto Nacional de Estadística y Censo (IDEN), (2016), Panamá.
6a. IDAAN, 2016, *Boletín Estadístico*, Nº29, Cuadro B.1, Panamá.
6b. IDAAN, 2016, *Boletín Estadístico*, Nº29, Cuadro A-3, Panamá.
7. CEPAL, 2018, "Ranking de movimiento portuario de contenedores 2017", *Nota informativa*, Santiago de Chile: CEPAL, 18 de mayo.
8. Angulo et al, 2017, "Cartagena's Water Distribution System", *Procedia Engineering,* 186(2017),28-35.
9. Population for Panana Metro área. Source: INEC.
10. Based on Panama Metro consumption data for 2015 from IDAAN *Boletín Estadístico*, Nº29
11. Calculated total revenue divided by total volume of wáter sold.

Based on this review of information for Panama City, Cartagena and Guayaquil, the following conclusions for water use conditions in the Panama City study area can be drawn.

- Panama City per capita use is significantly higher than the other two cities.
- Both Cartagena and Guayaquil have high percentages of the population served with a reliable water supply and very high percentages of metering, but a low per capita use rate. This may show the value of a metering program in reducing per capita use.
- More efficient use in Cartagena and Guayaquil compared to Panama City indicates a greater focus on, and investment, in applying best practices in water management, which

may be partially attributed to privatization of their municipal water utilities. In general, the price of water in Panama City is lower than in Guayaquil, but may be higher or lower than in Cartagena, depending on the residential use category.

- Appropriate water pricing policies and investment of the additional revenue in the Panama City water supply system could be expected to reduce per capita use rates based on comparison with Cartagena and Guayaquil.
- All three cities rely almost entirely on surface water resources. Like Panama City, neither Cartagena nor Guayaquil have invested heavily in alternatives to their observed surface water sources such as groundwater, wastewater reuse, or desalination.
- Water loss rates in all three cities are relatively high, indicating the challenge of managing water loss in large urban areas with aging infrastructure.

The following applications to the Study Area may be drawn from the foregoing comparison with other Latin American cities and countries.

- Water conservation should be an increased emphasis of IDAAN, particularly through education and outreach activities. Water conservation programs would be effective in reducing per capita water use and stretching existing supplies.
- Water pricing should be reviewed by IDAAN as a water conservation incentive, in conjunction with an improved bill collection program to increase utility revenue from current potable water production.
- Customer metering should be an increased emphasis of IDAAN. Metering is expected to reduce per capita water use for currently unmetered customers, stretching existing supplies.
- Improved asset management to reduce physical leaks and losses should be an increased emphasis of IDAAN. Improved asset management would reduce the amount of water needed from Lake Gatun and Lake Alajuela to meet future demands.
- A change of governance structure in the IDAAN water utility should be considered if system improvements and efficiencies cannot be achieved under the current structure. Full privatization or a public-private partnership have been effective in other Latin American cities and should be considered as an option.
- ACP should collaborate with IDAAN to the extent possible to achieve these changes, because they would take pressure off the Watershed to provide additional supply to meet future M&I demands. This could occur through political influence, administrative support, or cost sharing.

7.0 FUTURE WATER SUPPLY OPTIONS

7.1 INTRODUCTION

This section presents a high-level review of possible alternatives to increasing water supply to meet future demand by simply withdrawing more water from the Panama Canal Watershed. For this study these alternatives were presented only at a conceptual level to assist ACP in determining which options may be worth further consideration by themselves, IDAAN, and other organizations responsible for water resources planning in Panama. Additional information on future water supply options is provided in *Comparative Water Use and Cost Technical Memorandum* in **Appendix F**.

Preliminary results from the Demand Forecast Model discussed in Section 6 demonstrate a wide range of estimated 2050 total water requirements for the scenarios investigated. As discussed below, the current M&I water treatment capacity for the Panama Canal Watershed study area is about 400 MGD (see **Table 7.2**). Total water requirement estimates for 2050 under the various scenarios vary from 409 MGD to 938 MGD depending on assumptions for water system conditions and population and economic growth. In many scenarios total water requirement exceeds 400 MGD by 2030. Results of applying the updated Demand Model to the range of future water scenarios demonstrate the need to develop substantial new supplies for the Study Area over the next 10 to 30 years.

The following water supply options are discussed in this section.

- Expansion of existing system
- Water efficiency measures
- New freshwater sources
- Wastewater reclamation
- Desalination

7.2 EXPANSION OF EXISTING SYSTEM

This water supply alternative represents a continuation of the past water development strategy for Central Panama. It consists of increasing withdrawals from the current raw water sources in the Panama Canal Watershed (primarily Lake Gatun and Lake Alajuela) and expanding treatment capacity at existing WTPs or constructing new plants drawing from the same sources. A critical factor in this alternative is that any additional water developed from the Watershed for M&I purposes is water that cannot be used for Canal operations.

IDAAN's current plans to expand existing water treatment capacity are an example of this strategy. **Table 7.1** lists IDAAN's planned WTP expansions and new construction with a total new treatment capacity of 185 MGD.

Table 7.1 – IDAAN planned WTP expansions and new construction in Study Area

WTP Name	Planned Capacity	Planned Operation Start Year	Source of Supply[1]
Gamboa	60 MGD initial 80 MGD ultimate	Late 2019	Watershed
Howard	40 MGD initial 60 MGD ultimate	Late 2019	Watershed
Sabanitas Phase 2	45 MGD (30 MGD expansion)	Early 2019	Watershed
Chilibre Expansion	265 MGD (15 MGD expansion)	Early 2019	Watershed
Total New Supply	185 MGD		

1. Watershed = Panama Canal Watershed

Total current treatment capacity for WTPs drawing water from the Watershed is approximately 424 MGD, as listed in **Table 7.2**. With addition of the proposed water treatment capacity from IDAAN the total treatment capacity for M&I use from the Watershed will be 609 MGD. Forecasts of total water requirement for the Study Area in 2050 range from 409 MGD to 938 MGD. Sixteen of the 28 future demand scenarios have total water requirements exceeding 609 MGD in 2050, indicating that under most future scenarios additional water supply would be needed even with the planned additional water treatment capacity.

Table 7.2 – Total current treatment capacity for WTPs in Study Area

WTP Name	Current Capacity (MGD)	Source of Supply[1]
Cabra	2.0	Non-Watershed
Chepo	0.9	Non-Watershed
Chilibre	250.0	Watershed
Chorrera	9.5	Non-Watershed
Escobal	0.1	Watershed
Laguna Alta	20	Watershed
Mananitas	0.7	Non-Watershed
Mendoza	40.0	Watershed
Miraflores	48.0	Watershed
Monte Esperanza	34.0	Watershed
Pacora	0.4	Non-Watershed
Rio Gatun	2.0	Watershed
Sabanitas	15.0	Watershed
Tocumen	1.5	Non-Watershed
Total Capacity from Watershed	409.1	Watershed
Total Capacity from Outside Watershed	15.0	Non-Watershed
Total M&I Capacity	424	Total

1. Watershed = Panama Canal Watershed

IDAAN budgets for key WTP additions and expansions are summarized in **Table 7.3**. The average cost of new WTP capacity is $3.7 million per MGD. Additional conveyance capacity would also be needed to deliver treated water to M&I customers. This could add substantially to the total project cost.

Table 7.3 – IDAAN new WTP budgets

WTP	Capacity (MGD)	Design and Construction Budget	$/MGD
Howard	60	$211,807,517	$3,530,125
Gamboa	60	$238,927,642	$3,982,127
Sabanitas Expansion	30	$108,849,328	$3,628,311
Average (rounded)			**$3,700,000**

Source: IDAAN 2018

Building new WTPs and expanding existing plants on the same water sources currently utilized is an efficient and well understood solution to addressing future water shortages. However, it does not deal with the existing water use inefficiencies in the Study Area, and puts additional stress on the Panama Canal Watershed and Canal operations. Other alternatives that limit the amount of additional water that must be taken from the Watershed reservoirs to meet future M&I demands could be more valuable socioeconomically to ACP and to Panama.

Figure 7.1 shows how the capacity of the IDAAN system with these new WTPs compares to the total water requirement forecasted by the four scenarios described in Section 6.1. Under the High and No Action scenarios, the planned IDAAN system capacity with these new WTPs is insufficient to meet projected total water requirement after the years 2026 and 2029, respectively.

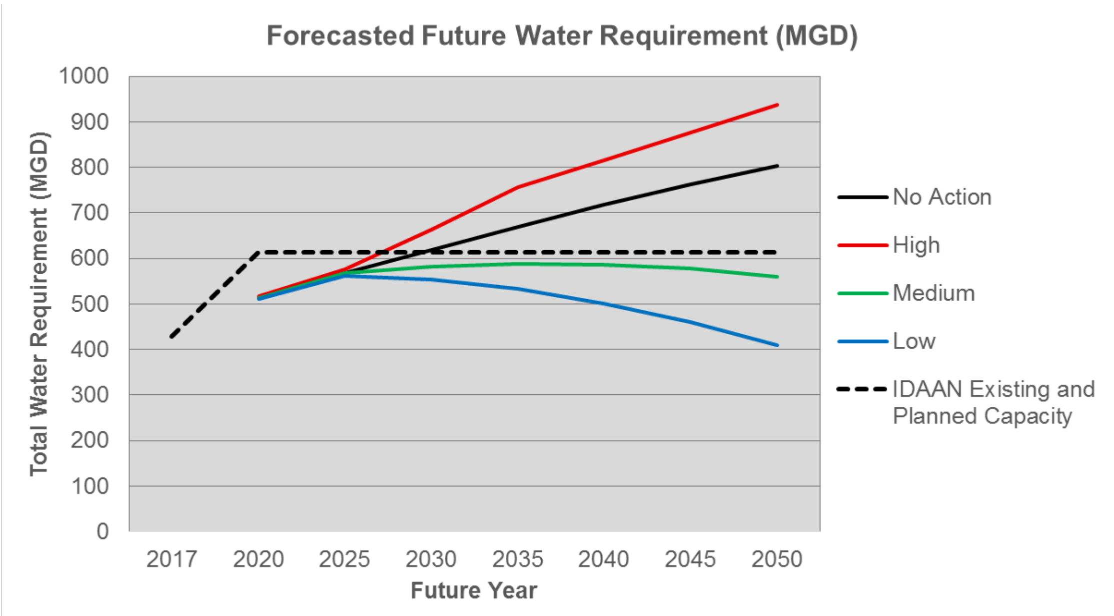


Figure 7.1 – Comparison between planned IDAAN system capacity and forecasted total water requirement

7.3 WATER EFFICIENCY MEASURES

This water supply alternative consists of a collection of possible measures that IDAAN and/or other organizations as well as water customers could take to improve the efficiency of using existing supplies. The primary measures that could be implemented include:

1. Reduction of losses in treatment and delivery infrastructure
2. Improved metering and tracking of use by existing customers to reduce UFW
3. Conservation measures to reduce the per capita use rate by residential and commercial customers

The first two water efficiency measures – loss reduction and metering – address deficiencies in the current system. Both measures would have to be implemented by IDAAN, although funding could come from outside sources. Water conservation is a measure that would occur at the customer level.

7.3.1 Leaks and Losses

Data for existing losses and leaks in the study area is limited. In the water demand forecast model it was assumed that losses in WTPs and intake structures are about 10 percent of water produced, and distribution system losses are about 20 percent of water produced. Reducing these loss factors by half would increase usable supply by 15 percent of the water produced. For current conditions in which the total water production from Study Area WTPs is 385 MGD, this would generate 56 MGD of additional usable supply.

Reducing leaks and losses to save 56 MGD would require a substantial investment on the part of IDAAN. In the past IDAAN has not had the financial capability to make this level of investment. Most Latin American water utilities face a similar problem – original construction deficiencies and deferred maintenance over many years create a situation in which significant reductions in distribution system losses can only be achieved with very large commitments of funding and labor. In most cases it is considered easier (and perhaps more politically supportable) to construct new water supply facilities than to improve the efficiency of existing facilities.

For example, Companhia de Saneamento Básico do Estado de São Paulo (SABESP), the water utility in São Paulo, Brazil, began investing in water loss reduction in 2009 to address the 27 percent estimated total losses in their distribution system at the time caused by leaks and illegal connections. The goal of the program is to reduce total losses to 19 percent by 2020, which represents a savings of 642 MGD. SABESP forecasts the program will require investment of $1.7 billion USD between 2009 and 2020, representing a cost of $2.6 million per MGD saved. (SABESP 2017) This unit cost is less than the average WTP cost of $3.7 million per MGD for the planned IDAAN WTP improvements at the existing Watershed sources of supply.

In the Study Area, if losses were reduced by 15 percent the savings would be 56 MGD. At a cost of $2.6 million per MGD (based on the data from Sao Paulo) the total cost of the loss reduction program would be $146 million. This compares to a cost of about $560 million to provide 185 MGD of new capacity by constructing the planned IDAAN water treatment projects.

7.3.2 Metering

Installation of water meters and conversion of unmetered customers to metered customers is assumed to reduce the per capita use rate of those customers. The Demand Model uses a per capita use rate of 83 GPCD for urban metered residential customers, 63 GPCD for suburban metered residential customers, and 160 GPCD for unmetered residential customers. (See

Table 4.3 for a description of these parameters.) Metering would save 77 GPCD for the average urban unmetered residential customer and 97 GPCD for the average suburban unmetered residential customer.

Table 7.4 shows the number of meters required to supply meters to all currently unmetered residential customers in the Study Area. Realistically IDAAN would not be able to meter all residential customers, but a modest metering program capturing half of the current unmetered customer base would require deployment of about 115,000 meters. If for example 115,000 new meters are installed with half dedicated to urban residential customers and half to suburban residential customers, 48 MGD would be saved. (This assumes 3.7 persons per urban customer account and 5.6 persons per suburban customer account; these values were estimated from observed data as summarized in Table 4.4 of the *Water Demand Forecast Model Description TM*).

Table 7.4 – Number of meters for all unmetered customers in Study Area

Development Type	Number of Accounts	Median % Unmetered	Number of Meters Required
Urban	85,000	43%	36,550
Suburban	325,000	58%	188,500
Rural	10,000	67%	6,700
Total			**231,750**

"Number of Accounts" from Figure 4.10 in *Water Demand Forecast Model Description TM*

"Median % Unmetered" from Table 4.8 in *Water Demand Forecast Model Description TM*

There are many different types of water metering programs currently used in the water utility industry. These include:

- Basic metering, which includes standard manually read meters
- Automated Meter Reading (AMR), which includes meters that send information to a remote digital meter reader
- Advanced Meter Infrastructure (AMI), which includes two-way meters that send information to a remote digital meter reader and also allow the reader to send information to the meter or to the customer

Prices for different types of meters vary, and the cost of a metering program is strongly inversely proportional to the number of meters to be deployed (i.e., the larger the program, the lower the unit cost per meter installed). Assuming IDAAN would not implement an AMI program, the cost of installing a typical residential water meter is about $500. The cost for IDAAN to install meters for 50 percent of its current unmetered customers - 115,000 new residential water meters - would be about $57,500,000. Assuming average savings of 48 MGD for meters installed in half urban and half suburban areas, a metering program would cost $1.2 million per MGD saved. This does not include maintenance costs for the metering system, which would vary greatly based on the type of metering system implemented. Compared to an average of $3.7 million per MGD spent on IDAAN WTP expansion at existing sources of supply in the Watershed, meter installation may be a cost-effective option for increasing potable water supply, depending on maintenance and labor costs. (Note that the $3.7 million per MGD estimate for WTP expansion is capital cost only; operation of WTPs also involved significant O&M costs.) It is an important part of any future water development strategy because it maximizes the efficient use of water than can be treated and conveyed within current infrastructure capacities.

7.3.3 Water Conservation

Water conservation measures are often considered in two categories: passive and active. Passive conservation measures occur without active ongoing engagement or effort by the water utility or other organization. Examples are national laws that prohibit sale of water-wasting brands of appliances (e.g., washing machines and dishwashers), and trends in land development leading to more dense development with smaller areas of outdoor landscaping that need supplemental watering. These measures will reduce per capita use without any further intervention from the water utility. Other water conservation measures such as public outreach and education, water audits of large commercial users, and increasing block water rate structures that incentivize efficient water use are active conservation measures that require investment and commitment of staff time from the water utility. Ultimately the objective of all these conservation measures is to change customer behavior in ways that result in less waste and more efficient water use.

Most passive measures primarily affect indoor use, while active measures can address either indoor or outdoor use. In the US both passive and active measures have been responsible for significant M&I water savings of over 20 percent in many large cities over the past two decades. The largest savings have occurred in outdoor water use, with reduced landscaping area and sprinkler system design changes resulting in substantial reductions in the amount of water used for landscape watering. Because of the humid Panama climate and limited use of water for outdoor landscaping, these savings would not be achievable in the Study Area.

The primary conservation measure employed by IDAAN is public education on the benefits of efficient water use. This has been a fairly limited effort in the past, but could be expanded in the future. There are no estimates of the effectiveness of past IDAAN public education activities in terms of improved water use efficiency.

Studies of passive water conservation in urban US water utilities suggest that savings of about 15 percent can be achieved just through implementation of plumbing code and retail regulations mandating sale of water-saving appliances. In Panama a savings of 5 percent may be a more reasonable estimate. If active conservation measures by IDAAN and other agencies could gain another 5 percent in savings, the total water savings through conservation would be 10 percent. In the Study Area, at the current water consumption rate of 185 MGD (excluding losses and UFW) this would represent 19 MGD that would be made available for future development. In 2050 a savings of 10 percent would represent 41 – 94 MGD, depending on the future scenario.

Costs for different types of water conservation measures vary widely. Data for the unit cost of water saved by various water conservation measures was obtained from research performed by Maddaus Water Management, a US firm specializing in water conservation planning (Maddaus

Water Management 2014). Unit annual costs were obtained for a variety of conservation measures that apply to indoor use, since outdoor water use is a small component of total water use in the Study Area. These are shown in **Table 7.5**. Because the mix of particular conservation measures IDAAN may adopt in the future is unknown, the annual average cost to implement a range of indoor water conservation programs was adopted as the average unit cost of all the indoor measures IDAAN could reasonably consider implementing. In addition, some conservation measures are implemented on a one-time basis and others are recurring programs that must continue to be implemented annually. The conservation measures in each of these categories are also shown in **Table 7.5**. The average cost of implementing one-time conservation measures for IDAAN was assumed to be $1.1 million per MGD of water saved. The average annual cost of implementing the ongoing conservation measures for IDAAN was assumed to be $1.2 million/year per MGD of water saved, or $38 million per MGD over 30 years.

Table 7.6 shows calculations of the one-time and annual recurring costs required to achieve these levels of savings for the low and high demand forecasts. The investment to achieve this level of savings would be about $34-$79 million in one-time costs plus annual costs that would increase to $13-$29 million/year in 2050.

Table 7.5 – Unit costs of potential conservation measures

Measure	Unit Cost ($/acre-ft/yr)	One-Time Cost	Annual Recurring Cost
Water Budget Based Billing	$200	X	
SF Residential Water Audits	$900		X
MF Water Audits	$500		X
SF Leak Repair Assistance	$3,400	X	
HE Urinal Rebate	$900	X	
Government Building Fixtures	$300	X	
Prohibit Water Waste	$2,900		X
Top CII Users	$500	X	
School Education	$700		X
Ramped Education	$700		X
Average ($/AFY)		$1,060	$1,140
Average Assumed for IDAAN ($/AFY)		$1,000	$1,100
Average Assumed for IDAAN ($/MGD)		$1,120,000	$1,230,000

Table 7.6 – Estimate of IDAAN costs for conservation measures

Parameter	One-Time Cost Conservation Measures	Annual Cost Conservation Measures
Percentage of Savings Achieved	75%	25%
Unit Cost ($/MGD)	$1,120,000	$1,230,000
Target Savings for Low Demand Forecast (41 MGD)	30.8 MGD	10.2 MGD
One-Time Cost	$34 million	-
Annual Cost	-	$13 million/year
Target Savings for High Demand Forecast (94 MGD)	70.5 MGD	23.5 MGD
One-Time Cost	$79 million	-
Annual Cost	-	$29 million/year

7.4 NEW FRESHWATER SOURCES

In addition to the new and expanded WTPs described previously, other options for developing new freshwater sources have been identified in the past. These are briefly described in this section, based on their geographic location. Additional information for these options can be found in the *Comparative Water Use and Cost Technical Memorandum* in **Appendix F**, the 2000 Demand Study report, and the sources cited in the following sections.

7.4.1 Panama Canal Watershed Projects

There is significant potential for development of new surface water supply sources in the Panama Canal Watershed in addition to the proposed WTP projects. Specific potential water supply projects in the Watershed were identified in past studies, including a Reconnaissance Study by the U.S. Army Corps Engineers (2000) and subsequent studies by ACP. These reservoirs were evaluated as options for increasing the supply of water available to operate the Panama Canal, but could potentially be used to increase M&I water supply instead.

- Rio Chagres – A new reservoir would be constructed on the Chagres River upstream of existing Lake Alajuela with up to 519 MCM of usable storage. Average annual flow at the dam site is 50 CMS (1,577 MCM/yr). Net yield when operated to provide a constant M&I supply in conjunction with Lake Alajuela and without adversely affecting Canal operations is not known but could be substantially less than 73 MGD (estimated annual yield when operated for Canal navigation). Capital cost for the Rio Chagres Project estimated by the U.S. Army Corp of Engineers (USACE) (1999) was $319 million ($4.4 million/MGD).

- Rio Ciri Grande – A new dam and lake would be constructed on the Rio Ciri Grande in the western part of the Panama Canal watershed above Gatun Lake. Average flow at the dam site is 9.3 CMS (293 MCM/yr). Usable storage volume is up to 136 MCM.
- Lower Trinidad - The Rio Trinidad watershed is located on the western side of the Panama Canal watershed. The proposed dam site would be located within Gatun Lake across the Trinidad arm near the city of Escobal. Average flow at the dam site is 32 CMS (1009 MCM/yr). Usable storage volume is up to 798 MCM.
- Caño Quebrado - The Rio Caño Quebrado watershed comprises a portion of the western side of the Panama Canal watershed. The proposed dam site would be located within Gatun Lake across the Rio Caño Quebrado arm near the city of La Laguna. Average flow at the dam site is 10.2 CMS (322 MCM/yr). Usable storage volume is up to 104 MCM.
- Raise Gatun Lake – Raise the maximum operating lake level by 1.5 feet. This would create 11.1 MCM of additional usable storage in the dry season. This project is currently being implemented by ACP.
- Raise Lake Ajahuela – Raise the maximum operating level by 2 to 4 feet. This would create 31-63 MCM of additional usable storage.

All Panama Canal Watershed storage alternatives would capture water currently available for use for the Canal and for M&I purposes at the existing WTPs drawing from Gatun Lake and Lake Alajuela. Additional operational studies would be needed to determine their net benefit for M&I water supply improvement without reducing water available to the Canal or to existing WTPs.

7.4.2 Pacific Watershed (East) Projects

Opportunities for development of new water supply and treatment facilities in the Pacific basin east of the Canal watershed exist in both the Rio Pacora and Rio Mamoni watersheds.

- Rio Pacora - The Rio Pacora watershed is located about 35 km east of Panama City and 20 km inland from the Pacific Ocean. The project would consist of a 36.5 MCM reservoir, water treatment facilities, and a pipeline to convey water from the treatment plant to the Tocumen International Airport where it would be connected to the existing Panama Metropolitan water distribution system. The project could produce a firm yield of about 55 MGD. The USACE (1999) capital cost estimate for the project was $292 million ($5.3 million/MGD).
- Rio Mamoni - This source was included as an option in the previous Water Demand Study report (Harza 2000), and was considered by ACP in a high-level evaluation of potential water supply options (ACP 2015). Given the relative similarity of the Rio Mamoni watershed to the Rio Pacora watershed, it is likely the Rio Mamoni watershed could produce a firm yield of about 50 MGD based on the estimated mean annual flow.
- Bayano Reservoir - This is an existing reservoir located about 40 km east of Panama City and about 30 km from the closest connection to the Panama City water system. The reservoir is currently used solely for generation of hydroelectric power. With a capacity of 2,700 MCM (2,200,000 AF), Bayano Reservoir is the second largest lake (after Lake Gatun) and second largest source of hydroelectric power in Panama. It may be technically feasible to use this existing reservoir as a water supply source, either at its current size or at an enlarged size. ACP conducted a study of Bayano Reservoir as a source of navigation water supply (ACP 2015) and roughly estimated the usable flow at this site for navigation

purposes, but there is not an estimate of the potential firm annual water supply yield available from this basin. Any analysis would have to account for the effects on power generation of operating the reservoir for water supply in addition to hydroelectric power. Use of this source for drinking water would require a new WTP and over 50 km of conveyance to the demand centers near Panama City. ACP is currently continuing to study this project.

For any of these three projects, major improvements to the existing Panama metropolitan area water distribution system would be needed to accommodate new large supplies at the eastern end of the service area.

7.4.3 Pacific Watershed (West) Projects

- Rio Caimito - The Rio Caimito enters the Pacific Ocean about 20 km west of Panama City. The Corps of Engineers Reconnaissance Study identified a dam site about 17 km west of Chorrera with a drainage area of 136 km^2. The Rio Caimito Project would consist of a new reservoir with 48 MCM to 128 MCM of usable storage; water treatment facilities; and a pipeline to convey treated water to the existing Chorrera water distribution system. The project would produce a firm yield of about 60 MGD. The USACE (1999) estimated the capital cost for the dam, WTP and conveyance facilities to be $278 million ($4.9 million/MGD).
- Rio Grande - The Rio Grande watershed is located in the Colce watershed west of Panama City and drains to the Pacific Ocean over 100 km west of the city. The potential for navigation or M&I water supply development in this basin was identified by ACP (ACP 2015). A firm yield estimate of M&I supply has not been determined. A cost estimate for this project was not available, but it would involve significant transmission system costs given the large distance (about 80 km) from the nearest connection to the IDAAN distribution system.

7.4.4 Atlantic Watershed (West) Projects

Providing water directly to the Panama City region from the watersheds draining to the Atlantic Ocean is not practical. However, new supplies from Atlantic watersheds could meet demands in Colon and the surrounding communities, or could be diverted into the Panama Canal Watershed and supply existing or new WTPs drawing from Lake Gatun.

- Rio Indio - The Rio Indio Water Supply Project was identified by the Corps of Engineers and subsequently studied by ACP as a way to augment the supply of water to the Panama Canal (MWH 2003). The Rio Indio watershed is located southwest of Lake Gatun. The project would consist of a new dam and 1,700 MCM (1.4 million acre-feet) reservoir on the Rio Indio channel and an 8,350 m long tunnel to transfer water from the new reservoir to Lake Gatun. The annual firm yield of the project would be about 1,200 MCM/year (about 870 MGD). The estimated capital cost for the project was about $230 million ($0.26 million/MGD) for the dam, conveyance facility, and appurtenances in 2001 dollars. The project would have the benefit of supplying water either for M&I use or for Canal operations. It is noted that ACP is currently studying this option in more detail; updated facility plans and costs are not available.

- Rio Cocle - Three alternative storage projects in the Rio Colce watershed were identified by the USACE (1999). All would involve construction of a new dam and inter-basin transfer facilities from the new reservoir into Indio Lake, and from there into the Panama Canal Watershed. The option with the lowest capital cost and best benefit-cost ratio was the Rio Cocle del Norte option. The Rio Cocle del Norte watershed is located to the west of the Panama Canal watershed. The proposed Rio Cocle del Norte dam site would be approximately 15 km inland from the Atlantic Ocean, and approximately 7 km downstream of the confluence of Rio Cocle del Norte and Rio Toabre. The average flow at the dam site is 109 CMS (3,438 MCM/yr). Usable storage would vary from 1.05-2.09 MCM depending on the operating plan. If the usable flow is 60 percent of the average flow, the annual yield would be 1,499 MGD. The project capital cost was estimated to be $501 million in 1999.

7.4.5 Summary of New Freshwater Sources

There are many technically viable options for developing new freshwater sources for M&I uses both inside and outside the Panama Canal Watershed. Developing new sources in the Watershed for M&I supply would adversely affect the local supply available for Canal operations, and could require development and importation of supplemental supplies from surrounding watersheds. Feasible options for developing M&I water supplies from other basins east and west of Panama City would involve new dams, WTPs, and long conveyance facilities to connect to the current distribution system. These options have the advantage of not directly reducing the flow available for Canal operations from the Panama Canal Watershed, but have the disadvantage of requiring more new conveyance infrastructure because they cannot rely only on existing infrastructure associated with water supply systems in the Watershed and they require new dedicated transmission facilities from the source to a connection to the existing water distribution system in population centers. Implementation of any new reservoir project would face significant social challenges related to environmental effects, displacement of people, and/or impacts on agricultural lands.

7.4.6 Groundwater

Groundwater is currently a very limited source of supply in the Study Area due to the limited capacity of wells drilled into the volcanic rock comprising the regional geology, and to the abundance of good quality surface water. IDAAN data indicate that wells account for less than 2 percent of M&I use in the Study Area. The Corps of Engineers Reconnaissance Study estimated that 11,000 wells would need to pump for 16 hours per day to produce 55 MGD. Therefore, it is assumed that groundwater wells will continue to be used in rural areas without access to reliable surface water systems but will not constitute a major source of new M&I supply.

7.5 WASTEWATER RECLAMATION

Wastewater reclamation consists of treating M&I wastewater for reuse as a source of M&I water supply. While in a broad sense treated wastewater may be reused for other purposes, (e.g., agricultural water supply), in the M&I context of this project wastewater reclamation could be a source of nonpotable water for landscape irrigation and certain industrial uses, or indirect or direct potable reuse for drinking water.

7.5.1 Nonpotable Uses

In many cities with limited raw water supplies wastewater is treated and reclaimed for nonpotable use for irrigating large urban landscape areas (e.g., parks, golf courses, cemeteries) or certain industrial applications that do not require high quality water (e.g., industrial cooling). In both cases use of reclaimed wastewater requires a separate distribution system because the reclaimed wastewater cannot be conveyed in the treated water distribution system supplying water for potable use. In many cases it also requires additional treatment beyond the quality primary wastewater treatment facilities normally produce.

In Panama, the wet climate means little supplemental water is required for outdoor irrigation, making development of a separate treatment and distribution system for this purpose impractical. The only instance in which wastewater reclamation may be a practical alternative for M&I supply is if a large industry located close to an existing wastewater treatment plant could use the treated wastewater for cooling or another industrial process. Limited applications such as this would not substantially reduce the need for development of new surface water supplies to meet growing demands in the Panama Canal Watershed region. It is also possible that treated wastewater could be pumped to the Miraflores Locks as a supplemental source of lockage water, reducing the draw on Lake Gatun for navigation and freeing up that water for M&I use. That option is expected to be very expensive compared to options that rely on local freshwater and delivery by gravity.

7.5.2 Potable Uses

Potable reuse of wastewater can take two forms: indirect potable reuse in which treated wastewater is blended with other raw water supplies prior to water treatment for M&I use, or direct potable reuse in which treated wastewater is treated to drinking water standards and introduced to the potable water distribution system along with other treated raw water supplies. Direct potable reuse is currently applied on only a limited basis in developed countries; currently there are only three permitted direct potable reuse operations in the United States. However, this technology is improving and costs are declining. A major obstacle to many applications is public opposition to “toilet to tap” systems in which treated wastewater is used as drinking water. Due to cost, public concerns, and the availability of abundant freshwater supplies, direct potable reuse is not considered a practical water supply option for the Study Area within the planning horizon of this study.

Indirect potable reuse could be accomplished in several different ways, the most straightforward being discharge of treated wastewater into surface lakes or streams or groundwater aquifers where it would be blended with native supplies and then the blended water would be treated for potable use. In practical terms this requires wastewater discharges to be upstream of points of raw water diversions to avoid high pumping costs. **Figure 7.2** is a map showing locations of the existing wastewater treatment plants and existing WTPs. The only wastewater treatment plants are located on the coast. Pumping wastewater back up into drainages upstream of WTP intakes or finding other ways to blend it with other raw water sources would not be practical compared to other supply options available.

New technologies may be developed in the future to reduce the cost of treated wastewater to potable quality. In addition, public acceptance of this water source may improve over time as it becomes a more common solution to critical supply problems in water-short regions. However, it does not appear to be a practical solution relative to other options within the 2050 planning horizon for this study.

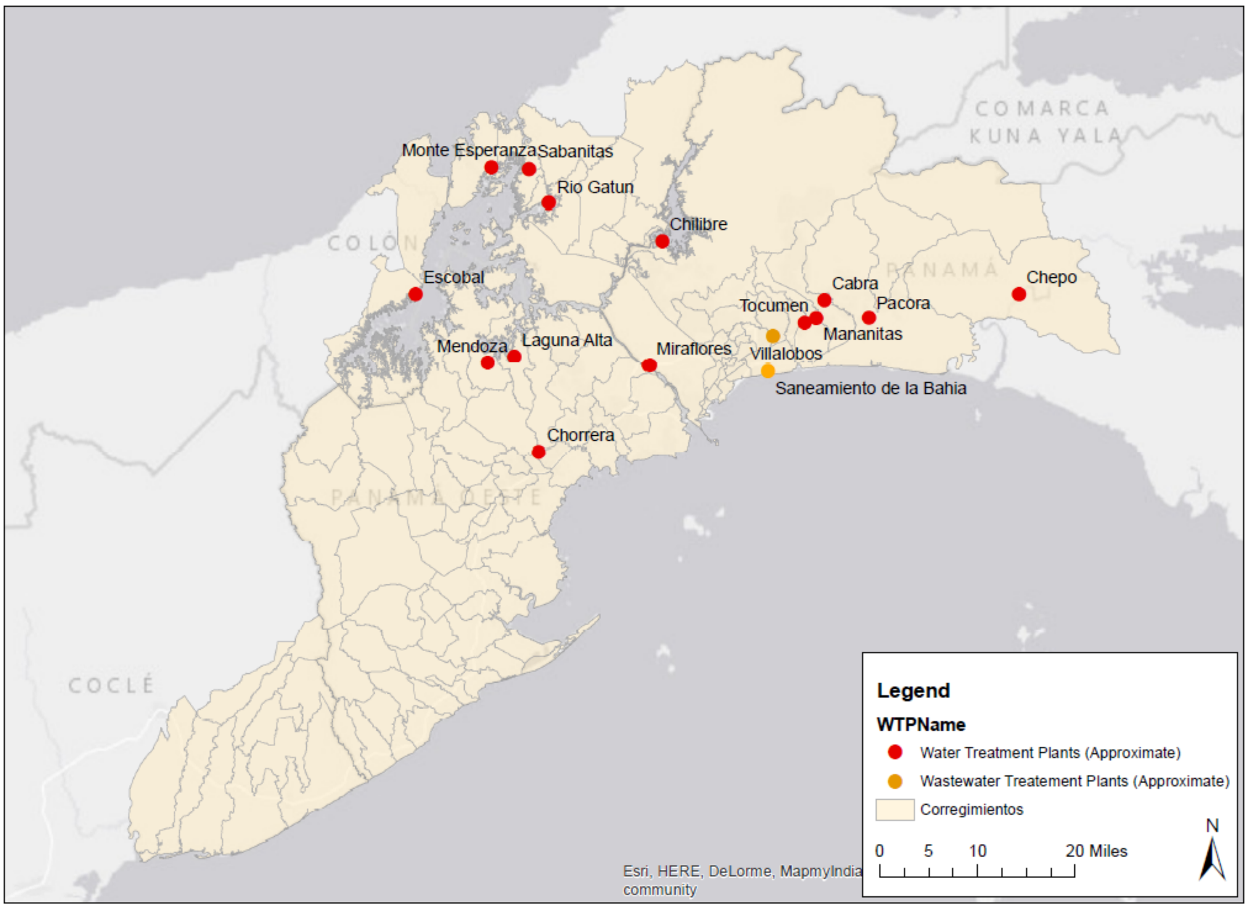


Figure 7.2 – Existing water and wastewater treatment plants in Study Area

7.6 DESALINATION

Desalination of seawater is being increasingly considered as a potential source of M&I supply in water-limited areas. Improvements in membrane technology are increasing the efficiency of treatment techniques and reducing their overall cost. Examples of current desalination systems worldwide include the following.

- Saudi Arabia – With no rivers or lakes, minimal precipitation, and severely depleted groundwater, Saudi Arabia produces more desalinated water than any other country in the world out of necessity. A total of 27 large-scale desalination plants increased capacity from 870 MGD in 2011 to 1320 MGD in 2018, breaking the world record for desalination. Construction is planned for 9 more desalination plants with total additional capacity of 60 MGD.
- United Arab Emirates – UAE has one of the highest residential per capita use rates in the world, with residents using an average 160 GPCD. Like Saudi Arabia, minimal freshwater sources exist. Seventy desalination plants provide a total of 1080 MGD, accounting for 40 percent of total water use.
- United States – The US has over 300 municipal desalination plants and more than 2000 industrial desalination plants, providing more than 760 MGD. Desalination is concentrated in coastal states like Florida, California, and Texas, where drought is frequent and local freshwater sources are stressed. The infrastructure and energy required to pump freshwater from hundreds of miles away means that desalination is a more cost-effective option in some locations.
- Australia – Six desalination plants in Australia have a total of 450 MGD capacity. While Perth and Adelaide receive 29 percent and 22 percent, respectively, of their potable water from continuously operating desalination plants, three other plants remain on standby and only produce desalinated water as an alternative when drought depletes reservoir levels.
- Israel – Five large-scale desalination plants provide 420 MGD of potable water, meeting 70 percent of residential water demand.

Seawater desalination remains a very expensive relative to other options, and is currently only used in extremely water-short areas where other sources of supply are not available. The typical cost of treatment by desalination is about $3,000 to $4,500 per million gallons, not including construction costs. In comparison, conventional freshwater sources typically cost about $2,000 per million gallons to treat. Construction costs for desalination plants range from $6 million/MGD to $14 million/MGD, with cost inversely proportional to treatment capacity.

Given the abundance of surface water sources in the region, desalination of seawater is not considered to be a likely or cost-effective option relative to other options for developing significant M&I supplies within the 2050 planning horizon of this study.

7.7 SUMMARY

Table 7.7 summarizes alternatives for increasing water supply to meet future water needs in the area served by the Panama Canal Watershed. Current WTP capacity for WTPs serving the Study is about 424 MGD. 2050 demands under the various scenarios vary from 409 MGD to 938 MGD, indicating a need for up to 538 MGD additional supply within this timeframe.

Figure 7.3 shows the distribution of total water requirement estimated for the twenty-eight 2050 demand scenarios developed for this study. Several potential water supply portfolios could be conceived from the available options. It is noted that project yields and base costs for new reservoir projects are taken from past studies, some as old as 2000; new more detailed studies of reservoir siting, sizing, operations, transmission pipelines, etc. would be needed to complete a fair and comprehensive evaluation of storage alternatives under current conditions.

- If IDAAN implements all currently planned WTP projects, total available supply would be 609 MGD. This would meet the requirements for 50percent of the 2050 demand scenarios developed for this project, but increased withdrawals from the Watershed reservoirs would reduce the amount of water available for Canal operations.
- If only the water efficiency projects (loss reduction, metering, conservation) were implemented in a “non-structural” alternative (including no implementation of currently planned IDAAN WTP construction and expansions), total available supply in 2050 would be about 542 MGD to 595 MGD. This would meet the requirements for 29-46 percent of the 2050 demand scenarios developed for this project.
- If about 50 MGD could be developed in the Rio Chagres basin and Bayano Reservoir combined, an extra 215 MGD in new freshwater resources in Pacific basins outside of the Panama Canal Watershed could be added to the supply sources (50 MGD from Rio Chagres/Bayano, 55 MGD from Rio Pacora, 50 MGD from Rio Mamoni, and 60 MGD from Rio Caimito). This would increase the total supply to 824 MGD when combined with the IDAAN treatment plant projects currently under design and construction, which would meet total water requirements for 68 percent of the 2050 demand scenarios developed for this project.
- The Rio Indio storage and diversion project, if implemented at the maximum size, could meet all future water needs by itself.
- Implementing only non-structural options and options that do not rely on new supply from the Panama Canal Watershed for which yields are available from **Table 7.7** would produce a total supply of about 919 MGD without the Rio Indio project, which would provide sufficient supply for 93 percent of the 2050 demand scenarios. Including only 19MGD from any of the other non-Watershed storage projects for which yields have not been estimated – e.g., Bayano Reservoir expansion, Rio Grande project - would provide sufficient supply for all potential demand scenarios in 2050 without additional water development in the natural Panama Canal Watershed.

Table 7.7 – Summary of water supply alternatives

Alternative	Approximate Yield	Approximate Cost
Current Capacity	424 MGD	-
IDAAN Planned WTP Expansions	185 MGD	$3.7 million/MGD capital cost; conveyance upgrades and O&M not included
Water Efficiency Measures		
Leak and Loss Reduction	56 MGD	$2.6 million/MGD capital cost
Metering (115,000 meters)	48 MGD	$1.2 million/MGD capital cost
Conservation	41-94 MGD in 2050	$1.1 million/MGD for one-time measures; $1.2 million/yr/MGD for ongoing measures
New Freshwater Sources		
Rio Chagres	<73 MGD	$558 million (1) for dam and appurtenances plus $3.7 million/MGD for treatment cost ($11.4 million/MGD)
Rio Pacora	55 MGD	$511 million (1) for dam and appurtenances plus $3.7 million/MGD for treatment cost ($13.0 million/MGD)
Rio Mamoni	50 MGD	No estimate
Bayano Reservoir	Not determined	No estimate
Rio Caimito	60 MGD	$487 million (1) for dam, WTP and appurtenances ($12.3 million/MGD)
Rio Indio	870 MGD	$359 million (2) for dam, inter-basin transfer and appurtenances plus $3.7 million/MGD for treatment ($4.1 million/MGD)
Rio Cocle del Norte	1,499 MGD	$877 million (1) for dam, inter-basin transfer and appurtenances plus $3.7 million/MGD for treatment ($4.3 million/MGD)
Rio Grande	Not determined	No estimate
Groundwater	0	Limited resource
Wastewater Reclamation	0	Impractical compared to other options based on cost and the abundance of freshwater sources
Desalination	0	Impractical compared to other options based on cost and the abundance of freshwater sources

1. Cost in 2018 dollars, escalated by 3%/year from USACE (1999) cost estimates.
2. Cost in 2018 dollars, escalated by 3%/year from MWH (2003) cost estimate.

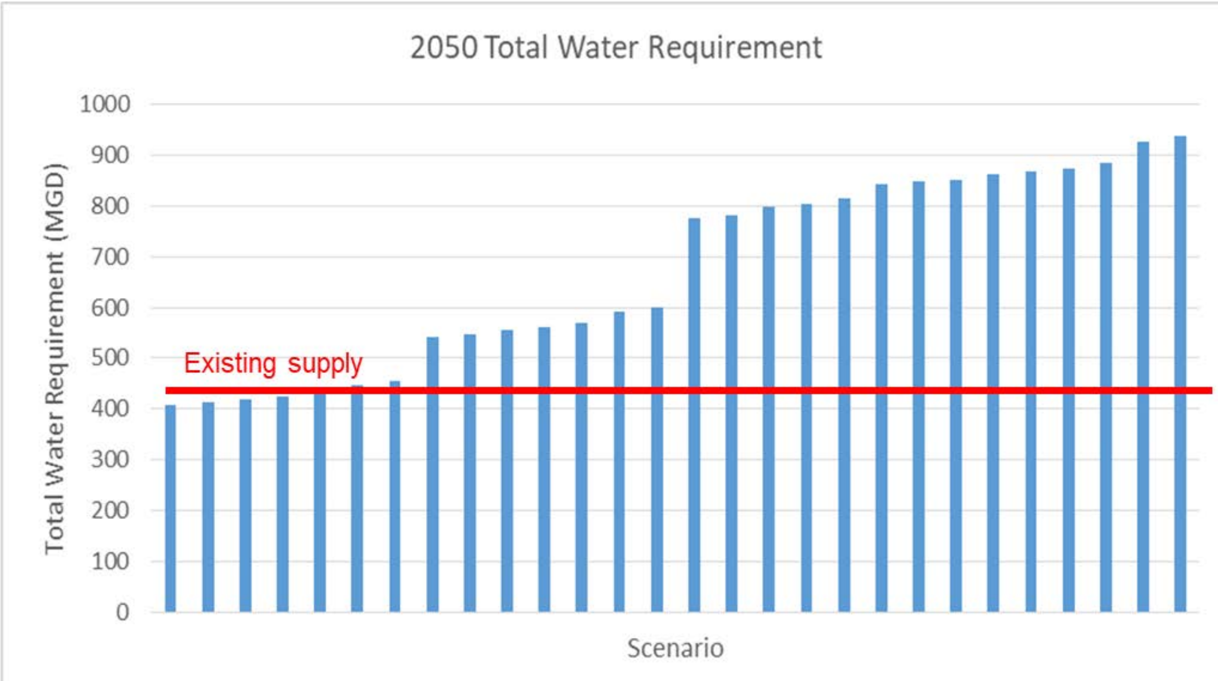


Figure 7.3 – 2050 Total Water Requirement for All Demand Forecast Scenarios

In summary, there are many potential combinations of structural and non-structural water supply options that would provide sufficient water supply to meet estimated 2050 water demands based on even the most optimistic (i.e., highest) population, economic and water system projections. Solutions could be developed that do not rely on additional withdrawals from the Panama Canal Watershed. Many of these are non-structural measures that are less expensive on a per-MGD basis than the WTP projects currently being implemented by IDAAN. However, these non-structural measures are not capable of meeting the future supply gap by themselves. In addition, they are not within ACP control and must be implemented by IDAAN or other governmental agencies. To be conservative, prudent planning for future water supply in the Panama City region should include projects in all of the identified categories.

It is noted that the M&I water supply needs discussed in this report do not consider future needs for navigation. Many of the same projects considered for M&I supply could also be needed to meet increased future navigation demands at the Canal. The use of water from the Panama Canal Watershed for both navigation and M&I water suggests that sources outside the Watershed should be considered carefully for M&I use before additional water within the Watershed is developed for M&I use..

8.0 SUMMARY

The 2000 Study forecasted future M&I water requirements from the Watershed to estimate when water used to operate the Panama Canal and water used to meet M&I demands could be in conflict. Since 2000, there have been significant factors affecting water use in Panama causing the observed water requirement to outpace what was forecasted by the 2000 Study. This Study updated the 2000 Study by utilizing more recent observed consumption data and more sophisticated methods to generate four new forecasts of future water requirement for the Watershed – a High Forecast, Medium Forecast, Low Forecast, and No Action Forecast. The demand forecasts for these four scenarios are summarized in **Table 8.1**.

Table 8.1 – Summary of forecasted total water requirement for High, Medium, Low, and No Action demand forecast scenario

	Total Water Requirement (MGD)			
Year	High Scenario	Medium Scenario	Low Scenario	No Action Scenario
2017	437	437	437	437
2020	517	513	510	513
2025	576	567	562	567
2030	664	581	553	619
2035	756	588	532	670
2040	817	586	501	717
2045	878	578	459	763
2050	939	560	408	803
2017 to 2050 Average Annual Growth Rate	2.34%	0.75%	-0.21%	1.86%

The new demand forecasts are up to 78 percent higher than the forecasts from the 2000 Demand Model. New M&I supply of 379 MGD is needed by 2050 for the No Action Forecast. This represents an 89 percent increase over 2017 demand, which is equivalent to 6.9 daily lockages in the Panama Canal. Under the High Forecast 514 MGD of new supply would be needed in 2050, representing a 121 percent increase (9.3 daily lockages) over 2017 demand.

There is substantial variability in forecasted total water requirement between the four demand forecast scenarios. This is because the Demand Model was developed to capture the significant uncertainty both in the observed data used to develop the model parameters and in the future conditions affecting water demand. The most significant contributor to this variability is the uncertainty around the percentage of the water customer base that is metered versus unmetered and IDAAN's ability to manage UFWr. Therefore, close monitoring of how IDAAN meters and accounts for their water users will help indicate which of the four forecast scenarios is the best representation of actual conditions.

The Medium and Low demand forecast scenarios estimate that total water requirement will peak between 2020 and 2050. Many major municipal water providers in the US observed a peak in total water requirement occur between the 1990s and the 2000s and have since observed a gradually consistent reduction since due to improved water efficiency, water conservation, greater development density with less irrigated landscaping, and other factors. Therefore, it is reasonable that by 2050, the Panama City metropolitan area could also observe this trend. When that peak could occur and the total water requirement associated with it is difficult to reliably forecast. The assumptions of the Medium scenario show a peak total requirement of 580 to 590 MGD occurring between 2030 and 2040. The assumptions of the Low scenario show a peak total requirement of 555 MGD to 565 MGD occurring between 2025 and 2030.

The Demand Model developed for the Study has several limitations. It is based on historical water use data that has a high degree of uncertainty and variability, causing uncertainty in the results. Due to the limited amount of available data, the non-residential consumption forecast was performed using a simplified approach. While observed non-residential consumption is less than residential consumption, increases in commercial and industrial activity due to economic growth and the impacts of the Panama Canal Expansion may increase it. Therefore indicators of commercial and industrial activity such as GDP or specific major projects should be monitored. The Demand Model also took a conservative approach to forecasting consumption for unmetered customers and assumed a higher unmetered per capita use rate. If better data on unmetered per capita use becomes available it will improve the forecast.

The most significant factor impacting forecasted total water requirement is how much of the population served by IDAAN is unmetered. If the future unmetered population is consistent with current conditions, then total water requirement will continue to grow along a trajectory similar to the High demand forecast scenario. However if IDAAN implements a robust water meter installation program and increases the percentage of metered customers, total water requirement will grow at a slower pace and potentially decrease by 2050 similar to the Medium or Low demand forecast scenario. Improving metering is both the most cost effective and easiest-to-implement future water supply option. Therefore, if ACP is concerned about water supply availability in the future, incentivizing IDAAN to improve metering of their customers would be an effective first step at controlling the total water requirement from the Watershed.

In addition, data from IDAAN indicates that demand is tied to the amount of available supply. Increasing supply through construction of new water treatments plants or development of other water sources makes it possible to connect more customers to the IDAAN system, and provide water more reliably to existing customers whose use is limited by lack of continuous water service. Expansion of the IDAAN customer base should be tracked by ACP in the future; if many new customers are added to the IDAAN system with reliable water service, it could influence total water requirement toward the High forecast.

There are many feasible and cost-effective alternatives available to ACP, IDAAN and other governmental agencies to address the future M&I supply gap in the area served with water from the Watershed. Many of these do not rely on additional withdrawals from the Watershed, including:

- Water conservation (unit cost of $1.1 million/MGD for one-time measures $1.2 million/MGD/yr for ongoing measures)
- Metering and system extension (unit cost of $1.2 million/MGD)
- Physical loss reduction (unit cost of $2.6 million/MGD)
- Reservoirs, conveyance and water treatment in other watersheds (unit cost of $4 million - $13 million/MGD)

It is noted that the first three alternatives, while addressing current inefficient water management conditions and having a unit cost less than the cost of water treatment projects currently being implemented by IDAAN ($3.7 million), are not capable of meeting the full future supply gap and cannot be implemented independently by ACP.

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