Long-term forecast for municipal and industrial water demand and raw water consumption

Pronóstico a largo plazo de la demanda de agua municipal e industrial y consumo de agua cruda

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Febrero del 2001

Contrato No. 32314

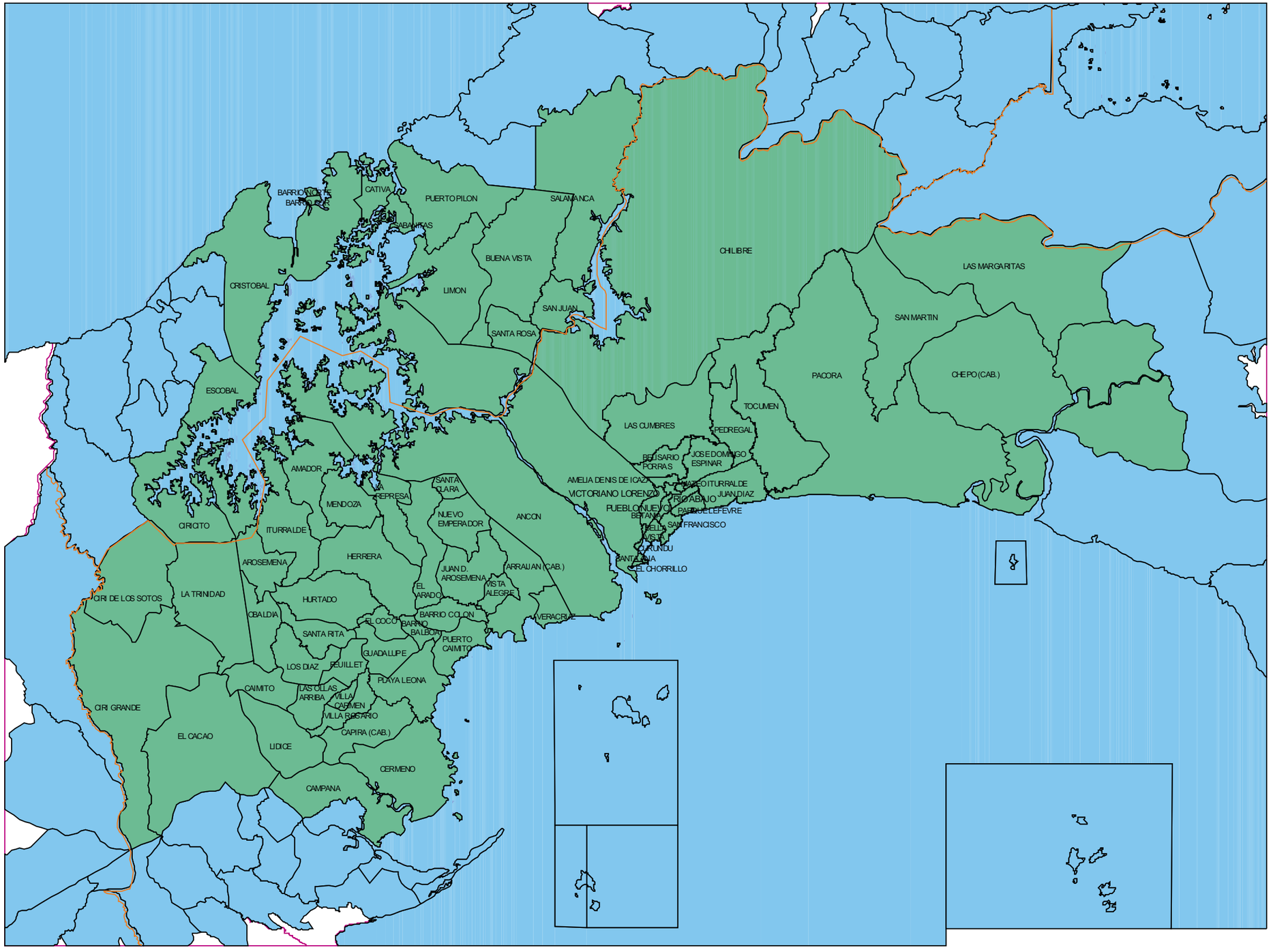
Resumen Ejecutivo

E.1 Basis for the Study

The abundant fresh water resources of the central part of the Republic of Panama are critically important as sources of supply for municipal and industrial (M&I) water systems serving more than 1.5 million people in the region and for the operation of the Panama Canal itself. Historically, the available supply of water in the region has been more than adequate to meet both of these needs. However, recent experience has demonstrated that the ability of the existing Panama Canal watershed to support Canal operations and meet municipal and industrial water requirements is not unlimited. During 1983 and 1997, extended dry periods resulted in low lake levels in the Canal system and restrictions on the passage of traffic through the Canal. As growth and development in the urban areas around the Canal and/or expansion of the Canal itself proceed, the potential for such shortfalls will increase unless projects are undertaken to increase the reliable supply of fresh water to the area.

The Panama Canal Authority (ACP) is keenly aware of this issue. Current studies of options for increasing the capacity of the Panama Canal include careful consideration of requirements for increasing water supply reliability in the region. Options being examined include projects to develop new sources of water for the Canal system and improvements to the water use efficiency of the Canal. Reliable forecasts of future M&I water needs are required as input to the evaluations of these alternatives for meeting the overall requirements for water throughout the region over the long term.

To establish reliable forecasts of future municipal and industrial water requirements in the area, a detailed analysis of demographic, development and water use trends has been performed for the urban and developing areas surrounding the Panama Canal as shown in Exhibit E.1. The resulting report presents a long-term (60 year) forecast of municipal and industrial water requirements for the study area along with conceptual alternatives for meeting these needs. The methodology used is also documented to provide a basis for future adjustments of the forecasts as new information becomes available.



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LONG TERM FORECAST FOR M/I WATER DEMAND

Water Demand Forecast Study Area

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E.2 Summary of Results

The analysis performed for this study confirms that significant increases in municipal and industrial (M&I) water requirements will occur in the study area over the next 60 years. As indicated in Table E.1, the probable water requirement forecast indicates a 39% increase over existing requirements by the year 2020 and a 105% increase over existing requirements by the year 2060. Projected increases in population for the study area over the same periods are 36% and 71%, indicating that factors other than population growth alone will contribute to future increases in M&I water requirements. Exhibits E.2 and E.3 show the relative significance of forecast increases in water requirements by geographic area and by component of overall water requirements.

Table E.1
Probable Projections of Population and Water Requirements

Year	Projected Population		Total Water Requirement	
	Population	% Increase from year 2000	mgd	% Increase from year 2000
2000	1,548,260	-	244.2	-
2010	1,867,746	21%	294.9	21%
2020	2,108,456	36%	339.4	39%
2030	2,310,036	49%	381.7	56%
2040	2,462,974	59%	422.3	73%
2050	2,571,481	66%	459.4	88%
2060	2,643,151	71%	499.5	105%

The largest increase in M&I water requirements within the study area (greater than 150 million gallons per day) is projected for the Panama Metropolitan service area that extends east from the Canal to the International Airport in Tocumen and north along the Transistmica Highway to Alajuela Lake. Significant increases in M&I water requirements are also projected for the Colon area (greater than 52 million gallons per day) and the rapidly developing Arraijan/Chorrera area located west of the Canal (almost 32 million gallons per day). Study area increases in M&I water requirements outside of these primarily urban areas total only about 19.9 million gallons per day (mgd).

The most likely options for development of additional water supply capacity to meet these needs include increasing the available yield of Gatun Lake through development of supplemental water supply reservoirs west of the existing Canal watershed or development of smaller, new water supply projects on rivers draining to the Pacific Ocean from basins outside of the existing Canal watershed. Conceptual evaluations of

these options indicate that both types of projects can provide additional water supply capacity. However, projects outside of the Canal watershed alone will not be sufficient to meet the significant increases in water requirements forecast. Even if projects outside of the Canal watershed are developed, withdrawals from the Gatun Lake/Alajuela Lake system will need to be increased 63% to 325 mgd to meet year 2060 water requirements. Should projects outside of the Canal watershed not be developed, withdrawals from the Gatun Lake/Alajuela Lake system would need to increase 138% to approximately 474 mgd by 2060.

The balance of this executive summary provides an overview of the forecast methodology used and the results of analyses performed to develop forecasting data and parameters.

E.3 Forecast Methodology

The water requirement forecast methodology adopted for this study relies upon a spatial analysis of future water requirements based on consideration of a wide range of factors. Exhibit E.4 provides a conceptual view of the general structure of the methodology used. Key features of the methodology include:

- a spatial basis that allows consideration of variability in demographic, economic and water use patterns within the study area using geographic information system technology (GIS);
- a direct relation to forecasts of development, population growth, and economic activity within region;
- separate consideration of the effects of demographic factors and water system operational factors on future water requirements; and
- a combination of historic basis and flexibility to allow for consideration of future changes in conditions in the study area.

Exhibit E.2
Projected Water Requirements by Water System Service Area

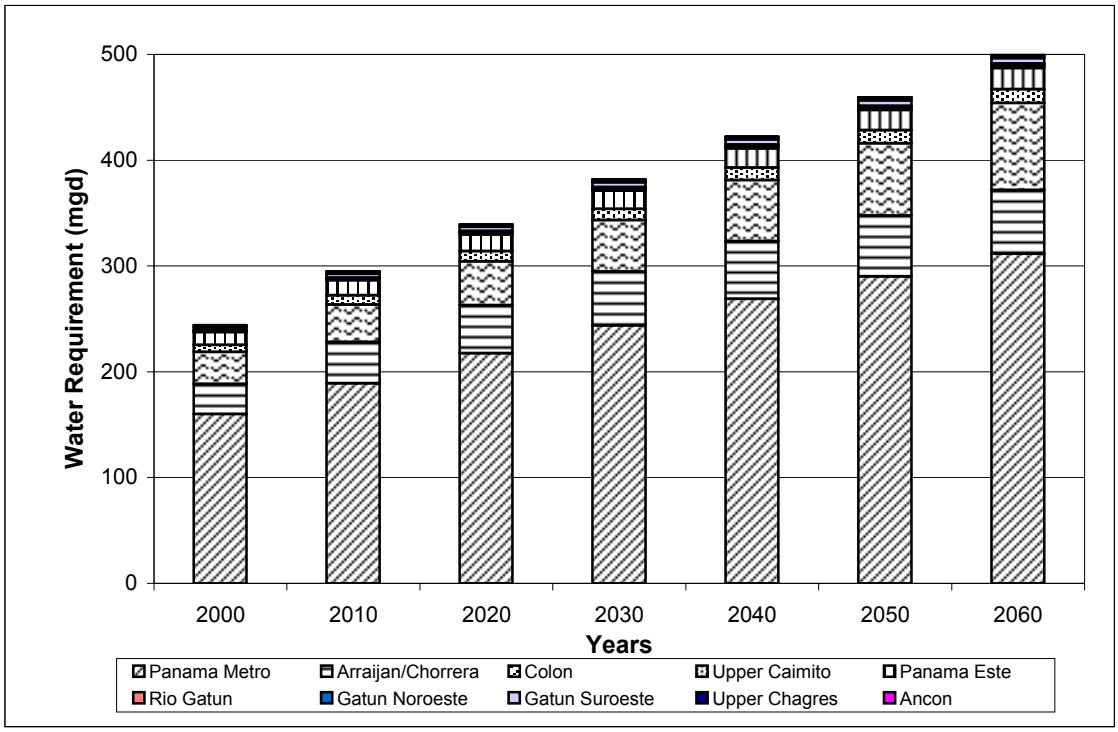
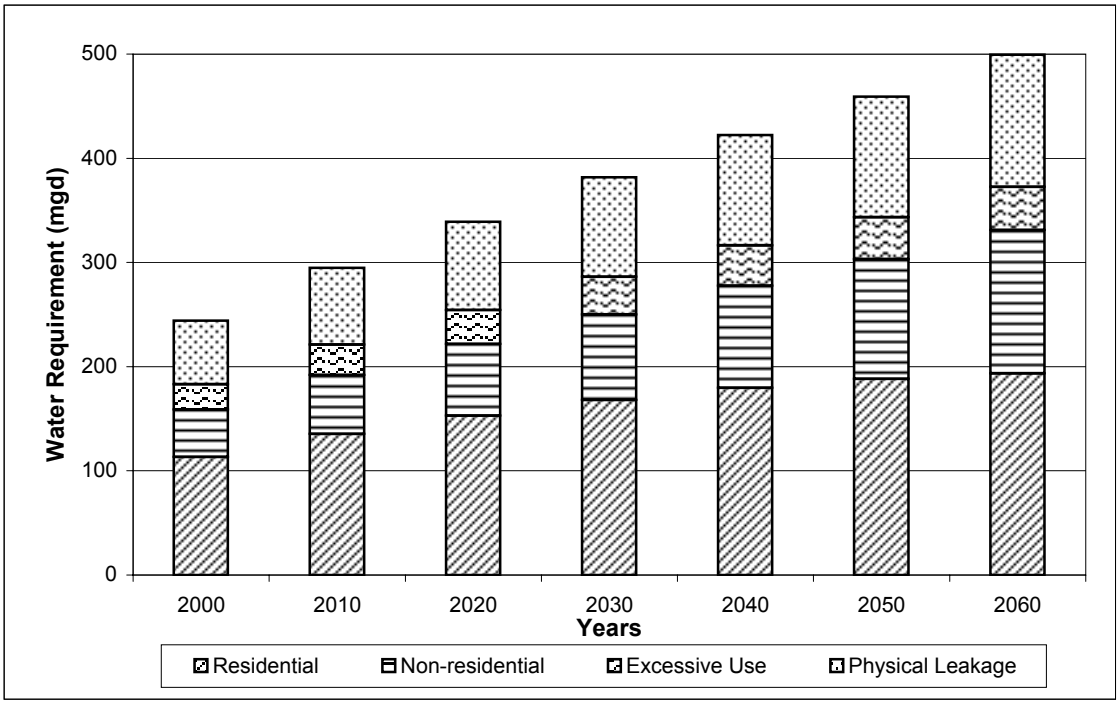


Exhibit E.3
Projected Water Requirements by Component



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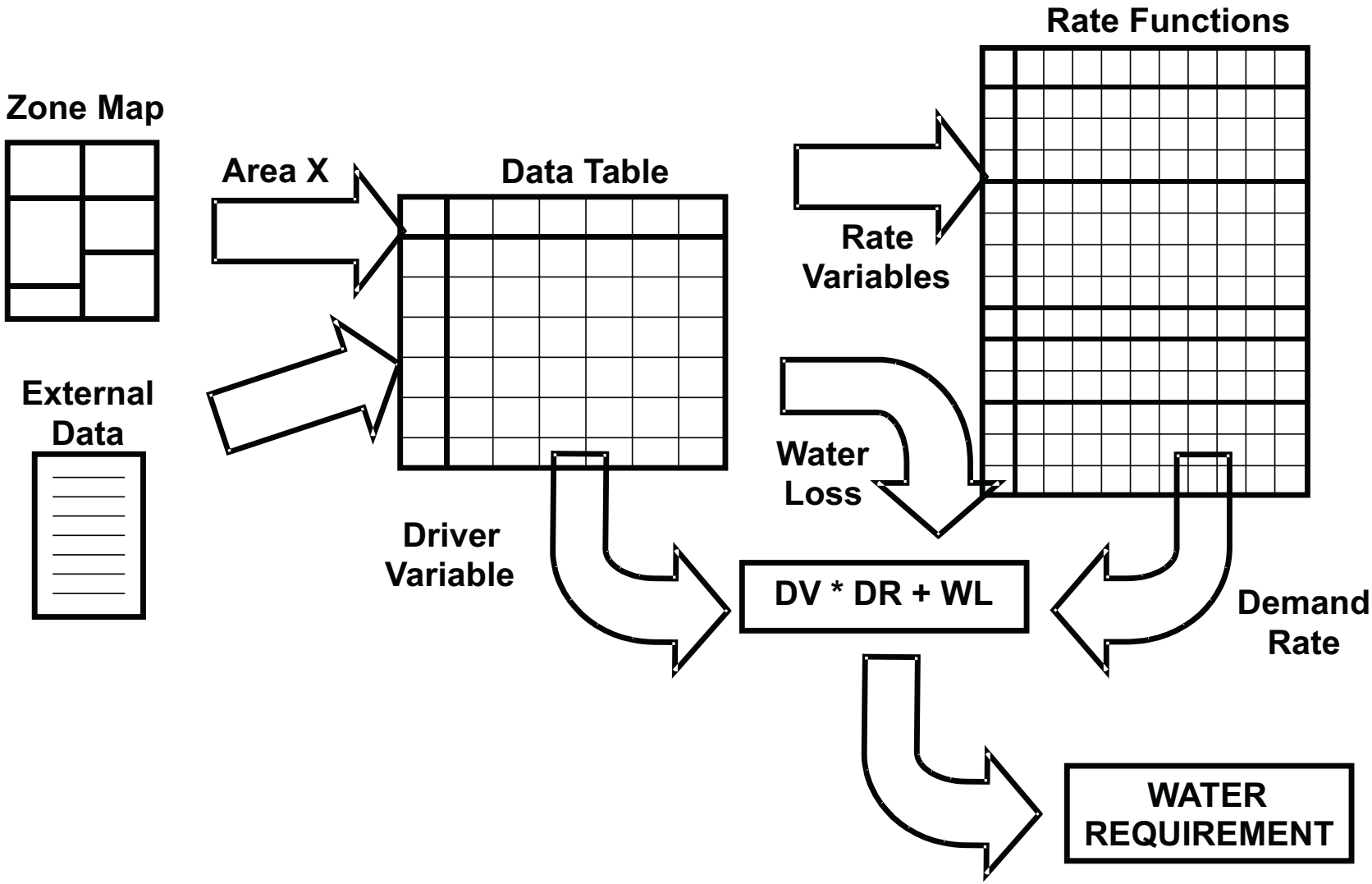

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Water Requirement Forecast Methodology

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The process used to implement this methodology consists of a series of activities beginning with definition of the study area for the forecast and ending with the production of water requirement forecasts by water supply service areas. Major activities included:

1. Definition of the forecast study area. The study area for the forecast was defined to include areas where M&I water requirements are currently, or might potentially, be met from resources within the Panama Canal watershed.

2. Characterization of study area population and economic development trends. The study area was divided into zones identified as having generally consistent demographic and economic characteristics. Detailed forecasts of future population growth and economic activity were prepared for each zone.

3. Development of base water demand patterns. Historic records of water consumption for both residential and non-residential uses were analyzed and compared with data from other Latin American and U.S. cities to establish base water demand patterns for various user categories and geographic zones.

4. Distribution of base demands by service area. Future water system service areas were defined based on the extent of existing water distribution facilities and consideration of natural barriers to system expansion. Geographic Information System (GIS) tools were used to re-allocate the base residential and non-residential water demands developed by zone to the water system service areas.

5. Consideration of water system operation factors. Historic data provided the basis for assumptions regarding the effects of current and likely future water system operations on overall water requirements. Key factors considered included levels of excessive use by unmetered customers and levels of physical leakage within the distribution system networks.

6. Forecast of water requirements by water system service area. Overall forecasts of water requirements by water system service area were generated by applying the operations factors to the base demand data and compiling total projected water requirements.

To facilitate updates and revisions of the forecast with future information, this methodology has been used as the basis for development of a forecasting model consisting of Microsoft Excel spreadsheet files linked to GIS zone and water service area maps. Detailed information regarding use of the forecasting model is included in Appendix G to the project report.

E.4 Population Growth and Development Trends

The population of the forecast study area has increased more than 250% over the past 40 years. High rates of growth within the region are expected to continue given the demographics of the area and external factors likely to promote new development. Key factors include the potential for redevelopment of former Canal Zone areas and anticipated expansion of Canal operations.

Presently, the majority of the population and economic activity within the study area is centered around the Metropolitan Areas of Panama City and Colon. More than 80% of the region's population is located within urban areas of Panama City, Arraijan and Colon. Approximately 70% of the region's employees work in the Panama City Metropolitan Area. About 64% of the economic value added in the region occurs in the Panama City Metropolitan Area; another 13% of the economic value added takes place in Colon.

Detailed analyses of demographic trends for the study area indicate that significant increases in population are expected to continue over the next 60 years, although growth rates are expected to gradually decrease. As shown in Table E.2, the population of the study area is projected to reach more than 2.64 million persons by 2060, representing an increase of 71% over the current level. Within the region the highest overall rate of growth (149% over 60 years) is projected for Arraijan/Chorrera areas west of the Panama Canal. However, the largest overall increase in population will occur in the Panama City Metropolitan Area, where an increase of more than 400,000 persons is expected during the planning period. Overall, population increases in the urban centers along the Pacific Coast (Chorrera, Arraijan, Panama City Metropolitan Area) will account for nearly 80% of the total study area increase. Exhibit E.5 shows relative growth within population zones used for forecast.

Table E.2
Projected Population Growth by Zones

Zone Name	Forecast Period							2000-2060 % Increase
	2000	2010	2020	2030	2040	2050	2060	
Zone 1	14,555	16,964	18,555	20,047	21,391	22,297	22,886	57%
Zone 2	23,293	29,475	32,949	35,873	38,153	39,710	40,791	75%
Zone 3	80,742	103,789	115,724	125,642	133,081	138,071	141,889	76%
Zone 4	145,924	234,699	280,465	317,032	339,329	353,434	363,818	149%
Zone 5	152,345	180,657	197,767	212,657	225,051	233,226	239,383	57%
Zone 6	136,627	150,217	161,057	171,590	181,644	188,371	193,222	41%
Zone 7	338,516	385,591	438,295	486,057	528,306	560,852	576,174	70%
Zone 8	656,258	766,354	863,644	941,138	996,019	1,035,520	1,064,988	62%
Total	1,548,260	1,867,746	2,108,456	2,310,036	2,462,974	2,571,481	2,643,151	71%

The economy of the study area is also projected to continue to grow. General economic trends for the region are positive, with annual growth in gross domestic product (GDP) estimated at 4.4% through 2020 and 2.3% over the 60 year period to 2060. Public consumption, export activity and investment in the region are also forecast to increase at 60-year average annual rates of 1.5%, 1.6% and 3.2% respectively. These conditions are predicted to accompany strong economic growth in a number of sectors. Projections developed for this study estimate a 435% increase in the metric tons of cargo handled in the study area by the year 2060. Value added through fabrication and construction is projected to increase 264% over the period, while tourist activity is expected to increase 170% and retail/office activity is projected to nearly double.

Future conditions described above represent "probable" conditions based on evaluations of currently available data and trends. However, actual conditions will depend on a large number of factors. Separate evaluations of "pessimistic" or low and "optimistic" or high trends for population growth and economic activity indicate a wide range of possible conditions.

Exhibit E.6 shows potential population growth based on rates varying from a low value of 33% over the period to a high value of 125%. Wide ranges for annual GDP growth (0.7% - 2.0%) and investment growth (1.0% - 2.0%) are also possible. As a result,

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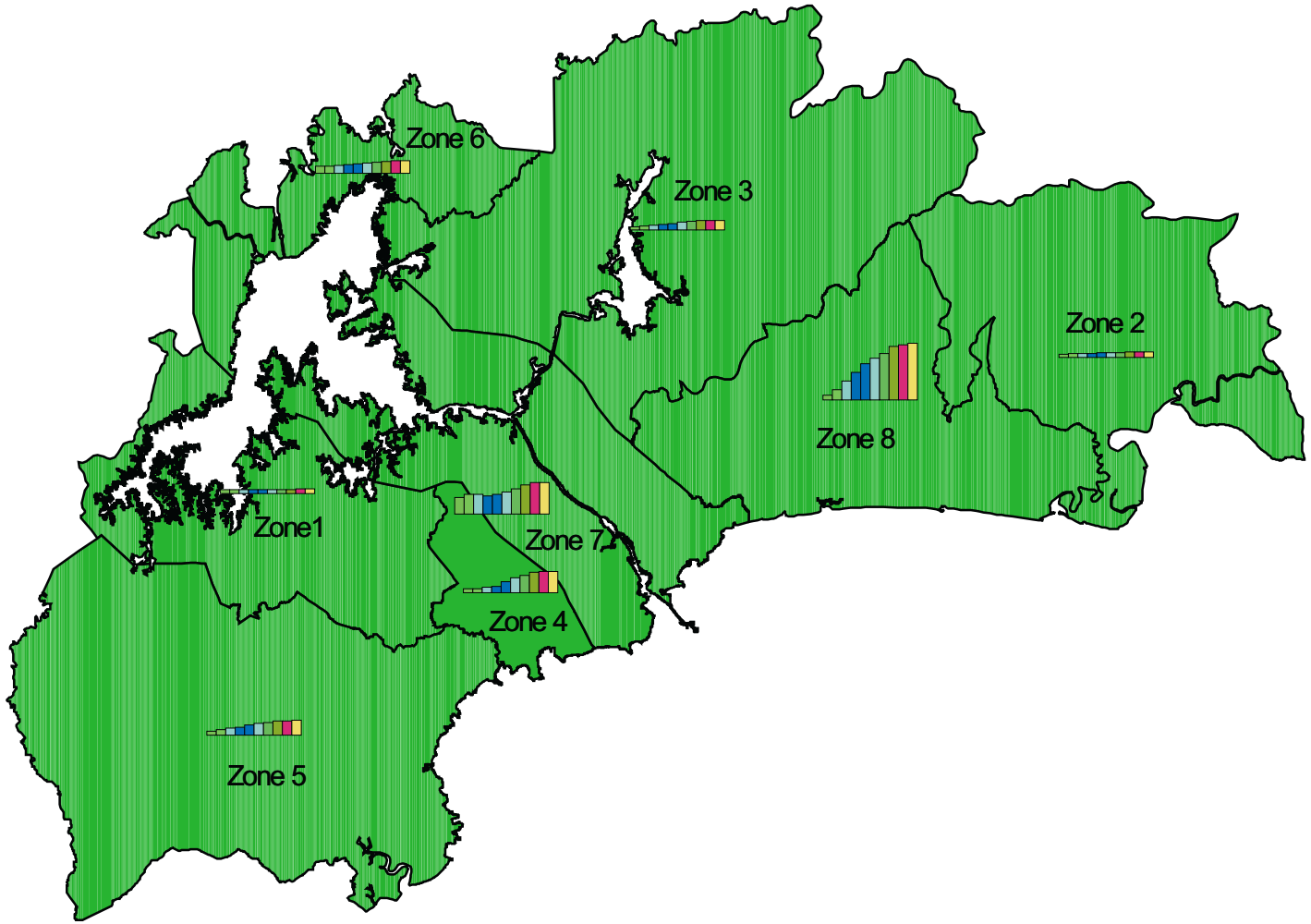

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Population Trends by Zone

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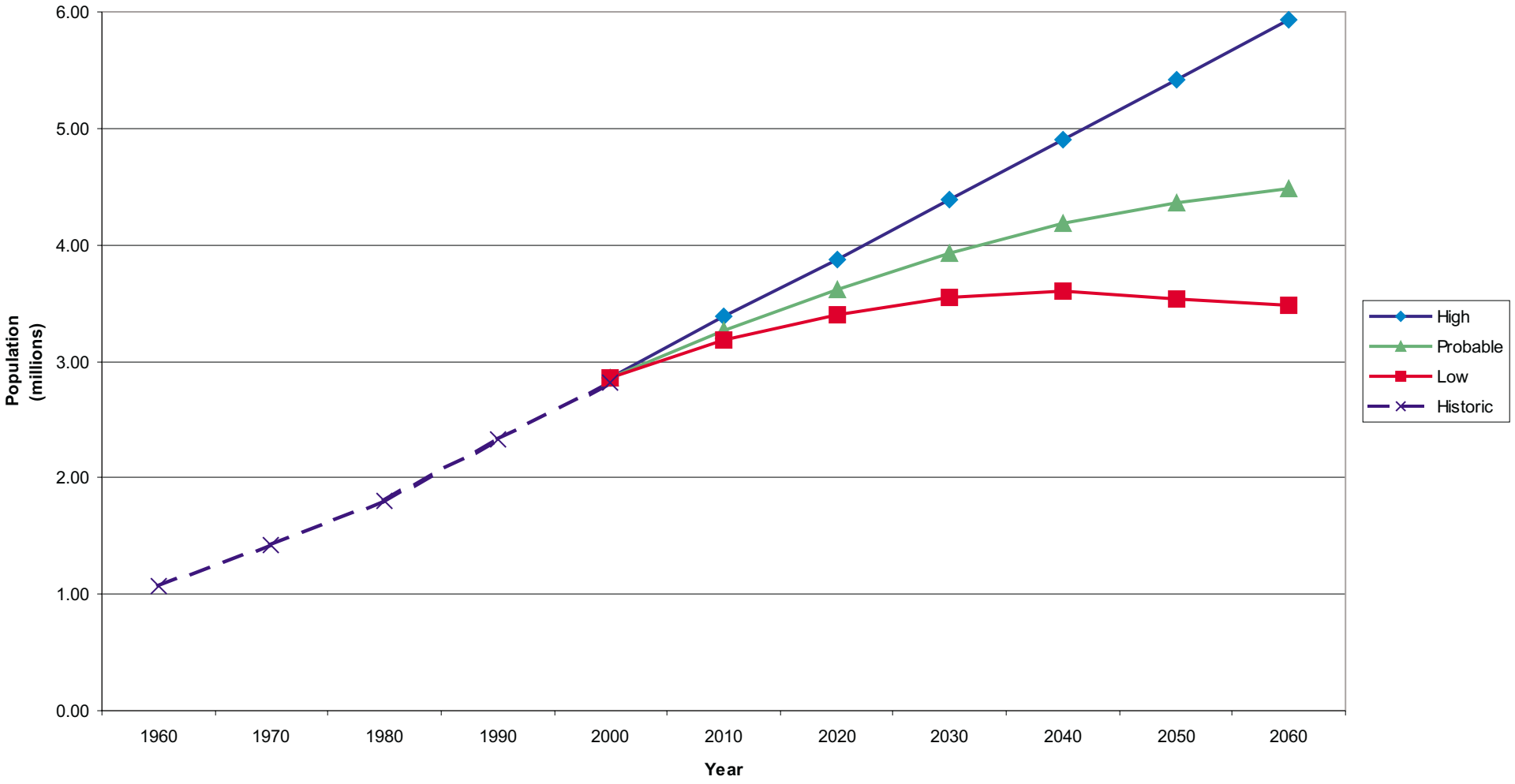

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LONG TERM FORECAST FOR M/I WATER DEMAND

Historic and Projected Population - Republic of Panama United Nations 1996 Analysis

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E.5 Water Use Trends

Municipal and industrial water requirements in the study area are made up of a number of component requirements as shown in Exhibit E.7. At the same time, these requirements are met by several water supply entities operating a range of systems throughout the region. These systems include large centralized systems, small centralized system, local and individual wells, and industrial/commercial systems.

E.5.1 Current water supply conditions

Presently available data indicate that about 80% of the study area population receives its supply of water from centralized water systems. Surface water serves as the primary source of M&I water for the area, accounting for more than 98% of the estimated existing supply. In 1999, total withdrawals from surface water sources for large systems supplying M&I requirements in the study area were approximately 225 mgd. Of this total 92%, or about 206 mgd was taken from sources within the traditional Panama Canal watershed. Approximately 134 mgd was withdrawn at IDAAN facilities (Chilibre, Sabanitas). The balance of the M&I withdrawals from the Canal watershed occurred at the PCA's Miraflores and Mount Hope water treatment plants.

Data reported by IDAAN for 1998 indicated gross per capita water withdrawal rates for M&I systems in four major service areas in the region ranging from 83 gallons per capita per day (gpcd) in Arraijan to 151 gpcd in the Panama Metropolitan area to 243 gpcd in Colon. Such rates are very high when compared to values for other cities and countries in Latin America, and at the high end of the range of values observed for urban areas in the United States.

Detailed data supplied by IDAAN for previous studies indicate that the existing customer base for centralized water supply systems in the study area is primarily residential in character. Data from 1993, summarized in Table E.3, indicate that about 88% of IDAAN's customer connections were for residential users at that time.

Detailed consumption data by user class varies in availability and accuracy due to relatively low levels of metering. IDAAN data reproduced in Table E.4 indicate that about 50% of the customer connections in the study area were metered in 1998. While this value is low by modern standards, it represents a significant increase from conditions in 1993 when the metered percentage was only 38%.

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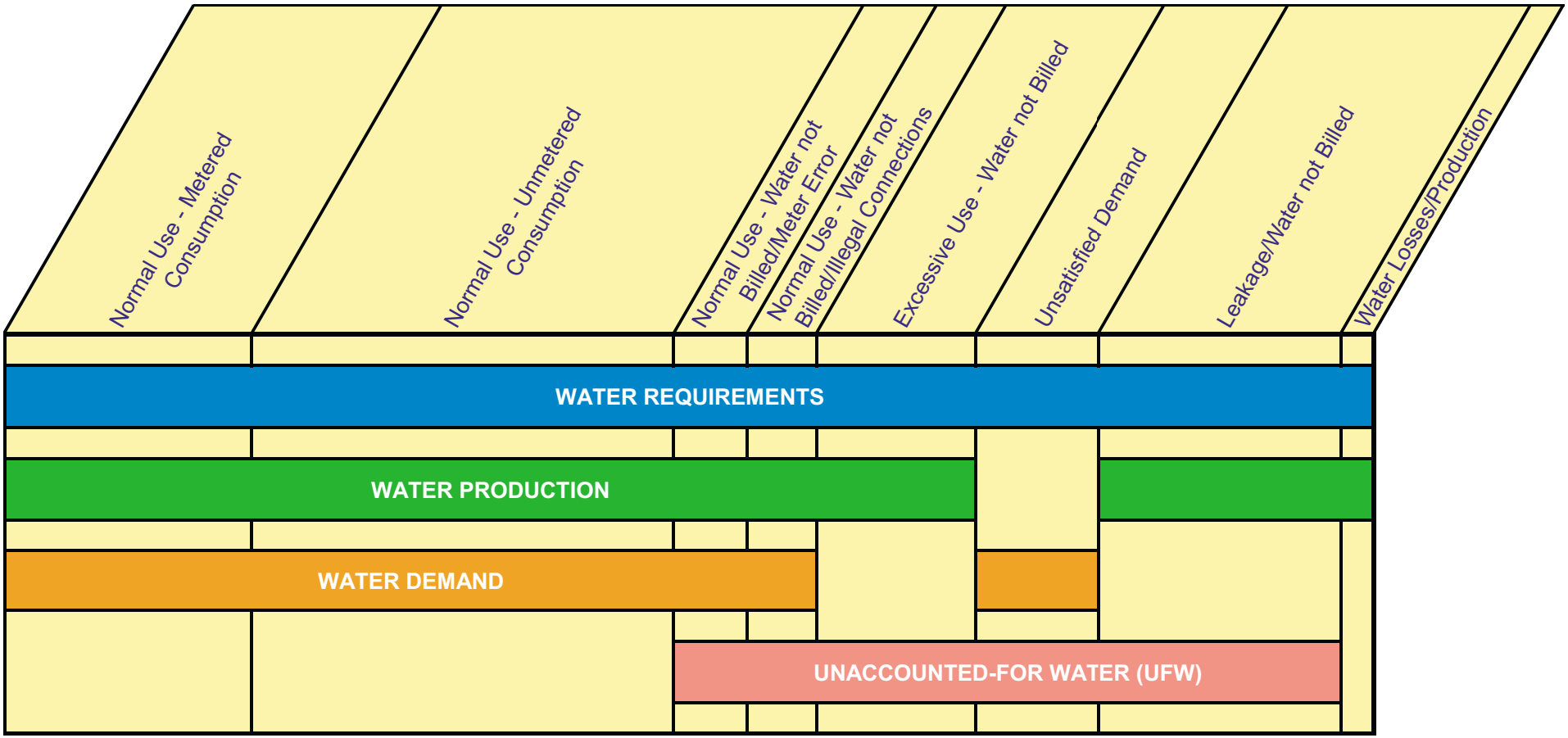

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LONG TERM FORECAST FOR M/I WATER DEMAND

Elements of Water Requirements

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Table E.3
Distribution of IDAAN Customers by User Category - 1993

User Class	Panama Metro	Colon	Arraijan	Chorrera	Urban Centers
Residential	126,619	9,268	5,232	11,315	152,434
Commercial	6,059	816	85	517	7477
Industrial	13,026	29	2	22	13,079
Gov/Auto/Mun	908	286	12	66	1,272
Total 1993	146,612	10,399	5,331	11,920	174,262

Source: Study of Operational, Financial, and Administrative Improvements. Final Report Prepared for IDAAN, Harza Engineering Company International, L.P., 1993.

Table E.4
Status of IDAAN Metered Connections and Consumption - 1998

User Class	Panama Metro	Colon	Arraijan	Panama Oeste	Panama Este/Darien
Total Connections	167745	19225	24935	22977	5871
Metered Connections	86343	5341	14560	14992	889
Metered % of Connections	51.5%	27.8%	58.4%	65.2%	15.1%
Reported Total Consumption (MG/year)	35187.6	6400.2	2812.3	2874	610.9
Metered Consumption (MG/year)	15946.6	873.5	1596.0	1729	123.3
Metered % of Reported Consumption (MG/year)	45.3%	13.6%	56.8%	60.2%	20.2%

Source: Compendio de los Sistemas de Acueductos y Alcantarillados, Serie No. 12 de 1998. Volumen 4. IDAAN Oficina de Planificacion. Febrero 2000.

The approximately 50% of IDAAN's study area connections identified as metered account for only about 42.3 % of IDAAN's reported total consumption based on data published by IDAAN. If estimates of total consumption are assumed to be reasonable, these data suggest that metered customers generally use less water than unmetered customers. Therefore, levels of metering are important to forecasts of future water use trends.

E.5.2 Unit Rates for Forecasting Water Demands

The forecasting model used for this analysis requires unit rates for residential water use and selected categories of non-residential use as key input. Residential and non-residential unit rates have been defined based on IDAAN metering data and published data for other areas in Latin America and the United States.

Analyses of historic metering data and related demographic factors show that residential water use rates in the study area can be related to factors such as population density, housing density, housing category, number of persons per household, median household income, and percentage of households with water service. Exhibit E.8 shows a comparison between actual and predicted residential unit rates based on regression analyses using the parameters described above. Selected base demand rates for residential users in the study area are summarized in Table E.5. Given that these rates are comparable with rates for many urban areas in the United States and generally high when compared to rates for similar areas in Latin America, base demand rates are assumed to remain constant over the planning period of this study.

Non-residential unit rates developed for ten water use groups selected to represent conditions in the study area are summarized in Table E.6. The non-residential rates are based on historic IDAAN water use data, a regional census of business establishments, and general measures of economic activity. As with the residential values, these rates have been assumed to remain constant over the planning period.

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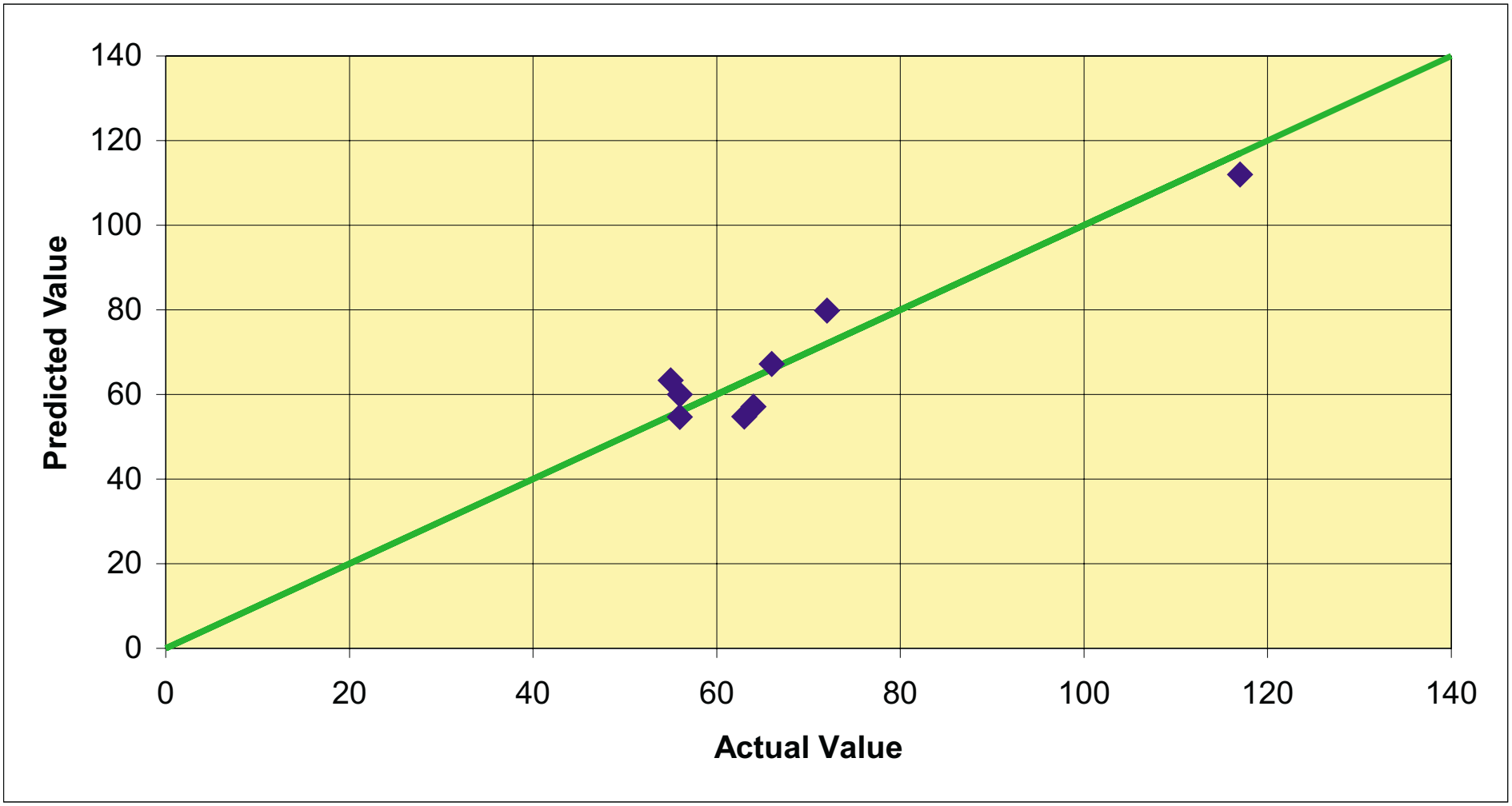

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LONG TERM FORECAST FOR M/I WATER DEMAND

Regression Analysis Results - Percapita Water Use as a Function of Demographic Charicteristics

HARZA CELA	February 2001	Exhibit E.8

Table E.5
Selected Base Demand Rates for Residential Water Use

Zone No.	Zone Name	Base Residential Water Use (gpcd)
1	Zone 1	63.7
2	Zone 2	76.3
3	Zone 3	73.0
4	Zone 4	64.0
5	Zone 5	62.3
6	Zone 6	68.7
7	Zone 7	117.0
8	Zone 8	56.0

Table E.6
Selected Base Demand Rates for Non-Residential Water Use

Water Use Group	Unit of Measure	Base Demand Rate (gal per day/Unit of Measure)
Agriculture	gpd/hectare	100
Wet Industry	gpd/employees	287
Other Mfg	gpd/employees	172
Ports	gpd/metric tons	0.07
Utilities	gpd/employees	56
Fab Const	gpd/1000 1982 Balboas	8997
Retail Office	gpd/employees	10
Schools	gpd/students	9.2
Hospitals	gpd/beds	135
Tourism	gpd/guests/year	0.66

E.6 Water System Operation Factors

Overall water requirements within the study area depend upon factors related to water system operation as well as general demographic conditions. System operation factors that may impact total water requirements include:

- extent of centralized service
- level of service/system performance
- level of customer metering
- level of leakage/losses in distribution systems
- level of production losses
- conservation practices
- price elasticity

Historic data for water systems in the project study area indicate that the most important of these factors for this analysis are parameters related to levels of unaccounted-for-water. These factors include the level of customer metering and the level of leakage/losses in the distribution system. Because the goal of this study is to forecast total, potential water requirements for the study area rather than actual use, the other parameters are not directly considered in this analysis.

Levels of unaccounted-for-water (UFW) in the forecast study area have historically been very high. Data published by IDAAN for 1998 indicate that between 35% and 50% of the water produced at its treatment facilities cannot be accounted-for through customer metering and estimates. Previous studies for IDAAN have suggested that this unaccounted-for-water consists of a combination of administrative losses, related to the degree and effectiveness of customer metering, and physical losses associated with leakage in distribution networks.

Past data compiled by IDAAN and its consultants suggest that unmetered customers, whose water bills are based on estimates rather than actual use, tend to use significantly more water than metered customers. A detailed pilot study performed for IDAAN in 1985 estimated that this excessive use by unmetered customers was equal to about 44% of normal usage by metered customers. Using this value of 44% and current levels of unmetered connections in the study area, excessive water use is estimated to account for as much as 24.5 mgd, or about 10% of total current supply.

The balance of IDAAN's current unaccounted-for-water (approximately 60 mgd) is assumed to be associated with physical leakage in water distribution networks. Using

this approach, current levels of distribution system leakage are estimated to range from about 23% in the Panama Metropolitan and Arraijan systems to 34% in Colon and 38% in Panama Oeste. Table E.7 shows estimated levels of unaccounted-for water along with the estimated relative distribution between excessive use and physical leakage.

The impact of these factors on long-term water requirements in the study area is highly dependent upon the success of IDAAN's efforts to reduce levels of unaccounted-for-water. Based on IDAAN's limited success in these areas in recent years, current levels of metering, excessive use rates and physical leakage levels are assumed to remain steady over time for the purpose of this forecast.

Table E.7
Reported Levels of Unaccounted-for Water and Distribution between Excessive Use and Leakage

IDAAN Water System	% of Supply		
	Average UFW	Estimated Excessive Use	Physical Leakage
Colon	45%	11%	34%
Panama Metro	33%	10%	23%
Arraijan	36%	13%	23%
Panama Oeste	47%	9%	38%

E.7 Water Requirement Forecasts

The overall forecast of future water requirements for the study area reflects consideration of the various data and analyses described above. A forecasting model consisting of Microsoft Excel spreadsheets linked to GIS-based study area maps provides a structured framework for the generation and updating of water requirement estimates. Intermediate outputs from the model provide a basis for the overall forecasts.

- Future conditions within the study area are defined in terms of projections of future population and economic activity by zone. Table E.8 provides a summary of projections of future population and economic activity within the study area.

Table E.8

Table E.8
Summary of Population and Economic Activities Projections by Zone

Zone Name	Economic Activity - Units						
	2000	2010	2020	2030	2040	2050	2060
Population - People							
Zone 1	14,555	16,964	18,555	20,047	21,391	22,297	22,886
Zone 2	23,293	29,475	32,949	35,873	38,153	39,710	40,791
Zone 3	80,742	103,789	115,724	125,642	133,081	138,071	141,889
Zone 4	145,924	234,699	280,465	317,032	339,329	353,434	363,818
Zone 5	152,345	180,657	197,767	212,657	225,051	233,226	239,383
Zone 6	136,627	150,217	161,057	171,590	181,644	188,371	193,222
Zone 7	338,516	385,591	438,295	486,057	528,306	560,852	576,174
Zone 8	656,258	766,354	863,644	941,138	996,019	1,035,520	1,064,988
Total	1,548,260	1,867,746	2,108,456	2,310,036	2,462,974	2,571,481	2,643,151
Agriculture - Hectares							
Zone 1	2,199	2,141	2,086	2,035	1,987	1,942	1,900
Zone 2	11,404	11,173	10,961	10,766	10,589	10,429	10,286
Zone 3	4,003	3,912	3,828	3,750	3,678	3,612	3,552
Zone 4	2,150	2,141	2,135	2,133	2,134	2,139	2,147
Zone 5	9,339	9,080	8,836	8,606	8,390	8,188	7,999
Zone 6	525	519	513	508	504	501	499
Zone 7	302	291	281	271	262	253	245
Zone 8	3,381	3,317	3,258	3,204	3,155	3,111	3,072
Total	33,302	32,574	31,898	31,273	30,699	30,175	29,700
Wet Industry - Employees							
Zone 1	3	4	4	5	5	6	6
Zone 2	439	537	629	707	778	804	849
Zone 3	1,630	1,991	2,334	2,624	2,887	2,984	3,150
Zone 4	1,707	2,085	2,445	2,748	3,025	3,126	3,300
Zone 5	1,730	2,114	2,478	2,786	3,066	3,168	3,345
Zone 6	991	1,210	1,419	1,595	1,755	1,814	1,915
Zone 7	34,134	41,695	48,875	54,949	60,470	62,492	65,975
Zone 8	14,321	17,493	20,505	23,053	25,370	26,218	27,679
Total	54,955	67,128	78,689	88,468	97,356	100,611	106,219
Other Manufacturing - Employees							
Zone 1	3	4	4	5	5	6	6
Zone 2	5	6	7	8	8	9	9
Zone 3	699	854	1,001	1,125	1,238	1,280	1,351
Zone 4	25	30	36	40	44	46	48
Zone 5	174	212	249	280	308	318	336
Zone 6	409	500	586	659	725	749	791
Zone 7	7,745	9,460	11,089	12,467	13,720	14,179	14,969
Zone 8	11,893	14,527	17,029	19,146	21,069	21,774	22,987
Total	20,952	25,593	30,001	33,729	37,118	38,359	40,497
Ports/Warehouse - Metric Tons							
Zone 1	0	0	0	0	0	0	0
Zone 2	0	0	0	0	0	0	0
Zone 3	0	0	0	0	0	0	0
Zone 4	0	0	0	0	0	0	0
Zone 5	1,369,764	1,811,513	2,395,726	3,168,347	4,190,139	5,541,459	7,328,580
Zone 6	12,327,876	16,303,616	21,561,533	28,515,127	37,711,255	49,873,135	65,957,222
Zone 7	10,958,112	14,492,103	19,165,807	25,346,780	33,521,116	44,331,676	58,628,641
Zone 8	2,739,528	3,623,026	4,791,452	6,336,695	8,380,279	11,082,919	14,657,160
Total	27,395,281	36,230,259	47,914,517	63,366,949	83,802,790	110,829,190	146,571,603
Utilities - Employees							
Zone 1	113	138	162	182	200	207	218
Zone 2	181	221	259	291	320	331	349
Zone 3	1,437	1,755	2,058	2,313	2,546	2,631	2,777
Zone 4	1,134	1,385	1,623	1,825	2,008	2,075	2,191
Zone 5	1,183	1,446	1,695	1,905	2,097	2,167	2,287
Zone 6	1,061	1,297	1,520	1,709	1,880	1,943	2,052
Zone 7	2,637	3,221	3,776	4,245	4,672	4,828	5,097
Zone 8	5,098	6,228	7,300	8,207	9,032	9,334	9,854
Total	12,845	15,690	18,392	20,678	22,755	23,516	24,827

Table E.8 (Continued)
Summary of Population and Economic Activities Projections by Zone

Zone Name	Economic Activity - Units						
	2000	2010	2020	2030	2040	2050	2060
Fabrication/Construction - 1000 1982 Balboas							
Zone 1	3	4	6	7	9	10	12
Zone 2	5	7	9	12	14	16	19
Zone 3	18	25	32	40	49	57	66
Zone 4	33	45	59	74	90	103	121
Zone 5	36	48	63	79	96	111	130
Zone 6	33	44	58	72	88	101	118
Zone 7	164	223	291	363	444	511	599
Zone 8	173	235	307	383	469	538	631
Total	466	632	824	1,030	1,260	1,447	1,697
Retail Office - Employees							
Zone 1	511	624	732	822	905	935	987
Zone 2	2,736	3,342	3,918	4,405	4,847	5,009	5,289
Zone 3	3,580	4,374	5,127	5,764	6,343	6,555	6,920
Zone 4	5,248	6,410	7,514	8,448	9,297	9,608	10,144
Zone 5	16,452	20,096	23,557	26,484	29,145	30,120	31,798
Zone 6	45,011	54,981	64,449	72,459	79,739	82,405	86,998
Zone 7	386,600	472,234	553,561	622,353	684,882	707,782	747,231
Zone 8	52,060	63,591	74,543	83,806	92,227	95,310	100,622
Total	512,197	625,652	733,400	824,541	907,385	937,725	989,989
Schools - Students							
Zone 1	4,043	4,641	5,052	5,434	5,789	6,053	6,257
Zone 2	6,471	8,080	8,992	9,750	10,359	10,836	11,211
Zone 3	22,428	28,442	31,570	34,132	36,095	37,550	38,860
Zone 4	40,535	64,579	76,882	86,560	92,479	96,708	100,296
Zone 5	42,318	49,605	54,096	57,935	61,219	63,698	65,862
Zone 6	41,401	44,936	47,978	50,913	53,805	55,987	57,845
Zone 7	112,839	116,670	125,229	133,927	143,553	151,063	155,960
Zone 8	218,753	252,205	271,603	287,059	299,797	308,971	319,443
Total	488,787	569,158	621,401	665,710	703,095	730,866	755,734
Hospitals - Beds							
Zone 1	22	25	27	29	31	33	34
Zone 2	37	47	52	56	60	62	65
Zone 3	137	174	193	209	221	230	238
Zone 4	263	418	498	561	599	627	650
Zone 5	335	393	428	459	485	504	522
Zone 6	369	400	427	454	479	499	515
Zone 7	1,320	1,365	1,465	1,567	1,680	1,767	1,825
Zone 8	2,428	2,799	3,015	3,186	3,328	3,430	3,546
Total	4,911	5,622	6,106	6,521	6,883	7,152	7,394
Tourism - Guests							
Zone 1	1,899	2,278	2,592	2,914	3,245	3,546	3,917
Zone 2	3,038	4,221	5,226	6,304	7,452	8,672	10,528
Zone 3	45,636	60,844	71,003	80,706	89,729	98,140	109,483
Zone 4	95,169	158,482	197,212	232,084	259,175	283,293	313,971
Zone 5	139,097	167,481	187,609	206,388	224,014	239,422	257,722
Zone 6	106,923	131,223	158,419	190,082	227,139	267,241	331,983
Zone 7	515,133	598,886	722,787	869,154	1,047,519	1,239,449	1,525,692
Zone 8	256,797	316,891	365,269	413,209	461,899	509,516	583,331
Total	1,163,691	1,440,306	1,710,116	2,000,841	2,320,171	2,649,281	3,136,628

- "Base" water demands are computed using population and economic activity forecasts and unit water use rates for each population/economic zone. For the probable forecast, unit water use rates are assumed to remain constant over time. Tables E.9 and E.10 summarize projections of base water demands within each study area population/economic zone.

- Base water demands developed for study area population/economic zones are allocated to predicted water system service areas based on GIS analysis of current and predicted conditions. Tables E.11 and E.12 show projected base water demands within the predicted water system service areas. Exhibit E.9 shows the boundaries of the projected water system service areas.

- Factors related to water system operations (level of metering, excessive use factors, physical leakage allowances) are applied to generate overall water requirement estimates for water system service areas. Table E.13 provides a summary of projected total water requirements in the study area through the year 2060.

Given the inherent uncertainty involved in long-term forecasting of water requirements, the possible effects of variations in key factors affecting water needs in the area have also been considered. Optimistic (high) and pessimistic (low) projections intended to bracket the likely range of future conditions in the study area are shown in Table E.14.

An analysis of the sensitivity of water requirement forecasts to possible variations in future conditions has also been performed to identify key parameters that should be monitored over time. The analysis shows that the water requirement forecasts are sensitive to a number of parameters. However, the most critical inputs include per capita consumption rates and assumptions regarding excessive water use by unmetered customers and physical leakage in distribution systems. Overall results are less sensitive to population and economic forecasts. As such, future efforts related to monitoring and updating of these forecasts should include an emphasis on tracking of actual rates of water usage and the actual effects of water loss management efforts.

Table E.9
Projected Base Water Demands – Residential Water Use by Zone

Zone No.	Zone Name	mgd						
		2000	2010	2020	2030	2040	2050	2060
1	Zone 1	0.9	1.1	1.2	1.3	1.4	1.4	1.5
2	Zone 2	1.8	2.2	2.5	2.7	2.9	3.0	3.1
3	Zone 3	5.9	7.6	8.4	9.2	9.7	10.1	10.4
4	Zone 4	9.3	15.0	17.9	20.3	21.7	22.6	23.3
5	Zone 5	9.5	11.3	12.3	13.2	14.0	14.5	14.9
6	Zone 6	9.4	10.3	11.1	11.8	12.5	12.9	13.3
7	Zone 7	39.6	45.1	51.3	56.9	61.8	65.6	67.4
8	Zone 8	36.7	42.9	48.4	52.7	55.8	58.0	59.6
Total Study Area		113.2	135.5	153.1	168.1	179.8	188.2	193.4

Table E.10
Projected Base Water Demands – Non-residential Water Use by Zone

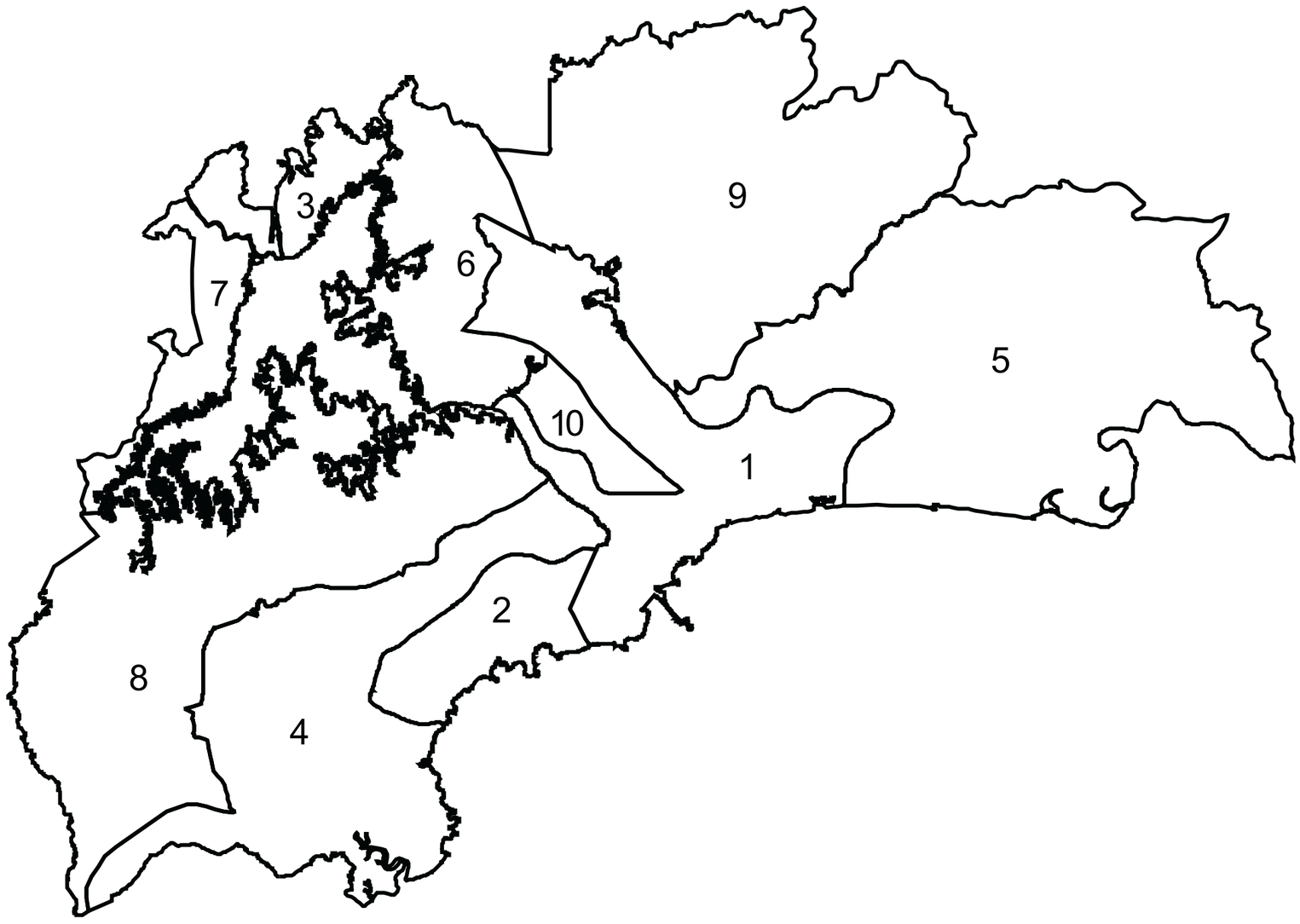
Zone No.	Zone Name	mgd						
		2000	2010	2020	2030	2040	2050	2060
1	Zone 1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
2	Zone 2	1.4	1.4	1.4	1.4	1.5	1.5	1.5
3	Zone 3	1.3	1.5	1.7	1.8	2.0	2.1	2.2
4	Zone 4	1.3	1.7	2.0	2.2	2.5	2.6	2.8
5	Zone 5	2.9	3.4	3.9	4.5	5.3	6.1	7.3
6	Zone 6	7.8	10.2	13.2	17.2	22.3	28.9	37.6
7	Zone 7	20.3	25.4	31.0	37.0	44.0	51.0	60.5
8	Zone 8	10.3	12.7	15.1	17.5	20.1	22.3	25.5
Total Study Area		45.5	56.4	68.5	82.0	97.9	114.8	137.7

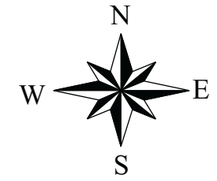
Table E.11
Projected Base Water Demands – Residential Water Use by Water System Service Area

Service Area No.	Service Area Name	mgd						
		2000	2010	2020	2030	2040	2050	2060
1	Panama Metro	76.7	89.0	100.6	110.6	118.7	124.7	128.2
2	Arraijan/Chorrera	15.6	22.0	25.5	28.3	30.1	31.4	32.2
3	Colon	9.3	10.2	10.9	11.6	12.3	12.8	13.1
4	Upper Caimito	2.9	3.8	4.3	4.7	5.0	5.2	5.4
5	Panama Este	5.6	6.7	7.6	8.2	8.7	9.1	9.3
6	Rio Gatun	0.6	0.7	0.8	0.9	0.9	1.0	1.0
7	Gatun Noroeste	0.3	0.4	0.4	0.4	0.5	0.5	0.5
8	Gatun Suroeste	1.2	1.5	1.7	1.8	2.0	2.0	2.1
9	Upper Chagres	0.8	1.0	1.1	1.2	1.3	1.4	1.4
10	Ancon	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total Study Area		113.2	135.5	153.1	168.1	179.8	188.2	193.4

Table E.12
Projected Base Water Demands – Non-residential Water Use by Water System Service Area

Service Area No.	Service Area Name	mgd						
		2000	2010	2020	2030	2040	2050	2060
1	Panama Metro	30.4	37.6	45.5	53.8	63.1	72.2	84.5
2	Arraijan/Chorrera	3.4	4.1	4.8	5.6	6.4	7.2	8.2
3	Colon	7.7	10.0	13.1	16.9	22.0	28.5	37.1
4	Upper Caimito	0.8	0.9	1.0	1.2	1.4	1.6	1.8
5	Panama Este	2.4	2.7	3.0	3.3	3.6	3.8	4.1
6	Rio Gatun	0.1	0.1	0.2	0.2	0.2	0.2	0.2
7	Gatun Noreste	0.2	0.2	0.2	0.3	0.4	0.5	0.6
8	Gatun Suroeste	0.3	0.4	0.4	0.4	0.5	0.5	0.6
9	Upper Chagres	0.2	0.2	0.2	0.2	0.3	0.3	0.3
10	Ancon	0.1	0.1	0.1	0.1	0.2	0.2	0.2
Total Study Area		45.5	56.4	68.5	82.0	97.9	114.8	137.7





LEGEND:

Water Service Area Boundary

WATER SERVICE AREA:

1	Panama Metro
2	Arraijan/Chorrera
3	Colon
4	Upper Caimito
5	Panama Este
6	Rio Gatun
7	Gatun Noroeste
8	Gatun Suroeste
9	Upper Chagres
10	Ancon

Scale 0 10 20 Kilometers

AUTORIDAD DEL CANAL DE PANAMA
Oficina de Proyectos de Capacidad del Canal

CONTRACT NO. CC-3-536

LONG TERM FORECAST FOR M/I WATER DEMAND

Water System Service Area

HARZA CELA | February 2001 | Exhibit E-9

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Table E.13
Projected Water Requirements – Probable Scenario

Table E.14
Optimistic and Pessimistic Water Requirement Forecasts

Year	mgd		
	Probable	Optimistic	Pessimistic
2000	244.2	244.2	244.2
2010	294.9	301.4	289.4
2020	339.4	355.0	326.3
2030	381.7	409.9	359.5
2040	422.3	468.5	384.9
2050	459.4	528.0	405.3
2060	499.5	595.5	433.5

E.8 Conceptual Water Supply Alternatives

Forecasts of future water requirements developed for this study confirm that future needs will be significantly greater than existing and/or planned water supply and production capacity in the study area. The greatest increases in water requirements are projected to occur in and around existing urban centers, further increasing demands on the limited existing systems. Development of significant additional sources of supply and construction of new production and distribution facilities will be required to meet demands within the next 20 years.

Conceptual supply alternatives considered as means of meeting future water requirements in the area were established based on three possible strategies:

- Alternative 1 assumes a continued high level of dependence upon the Canal watershed as a primary source of water for M&I needs;
- Alternative 2 assumes an emphasis on development of potential M&I water supply sources outside of the traditional Canal watershed; and
- Alternative 3 considers a hybrid strategy where dependence upon the Canal watershed is offset by moderate development of new sources.

The basis for each of the three alternatives is shown in Tables E.15 and E.16. All three options appear feasible at the conceptual level. However, regardless of the approach taken to development of new capacity, the need for increased M&I withdrawals from the

Canal watershed will be significant (63% - 138% increase over existing, depending on the role of other projects). Actual needs for increased withdrawals from the Canal watershed will depend upon the feasibility and cost-effectiveness of alternatives for developing supply from sources outside of Canal watershed. The most likely opportunities for development of new source and production capacity include: the Rio Caimito, Rio Pacora, and Bayano Reservoir watersheds. Decisions related to development of these projects will have significant impacts on future water transmission and distribution needs in Panama as well, as they will affect the direction from which water will be supplied to the networks.

E.9 Summary

Over the next 60 years, water resource planners and water supply system managers will have to work together to develop the projects and facilities needed to meet significant increases in water requirements within the study area. Regardless of the overall water resource management strategy adopted, significant increases in the withdrawal of water from the traditional Canal watershed will be needed. Major capital expenditures for new treatment, conveyance and distribution facilities will also be needed.

Table E.15
Summary of Conceptual Supply Plans – Proposed Allocation of Supply by Source
2060

	Canal Watershed	Pacific Watersheds (East)	Pacific Watersheds (West)	Groundwater	Other Sources	Total
	(All units are millions of gallons per day - mgd)					
Alternative 1						
Existing Capacity	200.1	9.0	9.5	4.3	0.0	222.9
Planned Expansions	67.0	0.0	0.0	0.0	0.0	67.0
Additional Expansions	207.0	0.0	0.0	2.8	0.0	209.8
Total Supply Alternative 1	**474.1**	**9.0**	**9.5**	**7.1**	**0.0**	**499.7**
Alternative 2						
Existing Capacity	200.1	9.0	9.5	4.3	0.0	222.9
Planned Expansions	67.0	0.0	0.0	0.0	0.0	67.0
Additional Expansions	58.0	119.6	32.0	0.9	0.0	210.5
Total Supply Alternative 2	**325.1**	**128.6**	**41.5**	**5.2**	**0.0**	**500.4**
Alternative 3						
Existing Capacity	200.1	9.0	9.5	4.3	0.0	222.9
Planned Expansions	67.0	0.0	0.0	0.0	0.0	67.0
Additional Expansions	158.0	54.6	0.0	-0.3	0.0	212.3
Total Supply Alternative 3	**425.1**	**63.6**	**9.5**	**4.0**	**0.0**	**502.2**

Table E.16
Summary of Conceptual Supply Plans – Required Additional Capacity by Source
2060

	Canal Watershed	Pacific Watersheds (East)	Pacific Watersheds (West)	Groundwater	Other Sources	Total
	(All units are millions of gallons per day - mgd)					
Alternative 1						
Planned Expansions	67.0	0.0	0.0	0.0	0.0	67.0
Additional Expansions	207.0	0.0	0.0	2.8	0.0	209.8
Total Supply Alternative 1	**274.0**	**0.0**	**0.0**	**2.8**	**0.0**	**276.8**
Alternative 2						
Planned Expansions	67.0	0.0	0.0	0.0	0.0	67.0
Additional Expansions	58.0	119.6	32.0	0.9	0.0	210.5
Total Supply Alternative 2	**125.0**	**119.6**	**32.0**	**0.9**	**0.0**	**277.5**
Alternative 3						
Planned Expansions	67.0	0.0	0.0	0.0	0.0	67.0
Additional Expansions	158.0	54.6	0.0	-0.3	0.0	212.3
Total Supply Alternative 3	**225.0**	**54.6**	**0.0**	**-0.3**	**0.0**	**279.3**