October 2008

Black and Veatch

Phase 2

Yield and Demand Study

Final Technical Memorandum

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Final Technical Memorandum

Veolia Water Indianapolis, LLC

October 2008

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TITLE DIVISION

VEOLIA WATER INDIANAPOLIS
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Section 1

1. DEMAND EVALUATION INTRODUCTION

1.1 PROJECT SCOPE AND OBJECTIVES

The scope of this study is to review and update the Phase 1 Demand Study prepared by Black and Veatch (B&V) in 2003. The Phase 2 Demand Study includes an evaluation of historic and current demands and a projection of future water demands. The scope also includes the preparation of tabular data indicating the projected spatial allocation of demand for use by Veolia Water Indianapolis (VWI) in updating their distribution system hydraulic model. Water demand projections are presented for the 2010 and 2020 planning years.

1.2 INFORMATION REVIEWED AND EVALUATED

Veolia Water Indianapolis provided water production and metered consumption data for years 2001 through 2007, and an updated pressure zone map of the Indianapolis Water system. Metered consumption data for 2002 and 2006 was provided in the form of comma-separated value files, which were converted to a database for further use. Data were provided for the period from December through November of the following year rather than calendar years. For example, consumption data for 2002 represents the period from December 1991 through November 2002. Metered consumption data for 2007 was provided in shapefile format. Water production information, including average day demand (ADD), maximum day demand (MDD), and maximum hour demand (MHD) for individual pressure zones and the overall system were provided in spreadsheet format.

VWI also provided two recent reports concerning water demand in the Indianapolis area. One report is the October 2004 "Water Conservation Plan" and the second is the September 2006 "Short and Long Term Plan".

Transportation Analysis Zone (TAZ) population and employment data for 1996 and 2030 was obtained from the Indianapolis Metropolitan Planning Organization. Supplemental population data was also obtained from the Indiana STATS website.

1.3 APPROACH

Updated average day, maximum day, and maximum hour demand projections were developed for individual pressure zones and the system as a whole for the designated planning years of 2010 and 2020. Historical data for the 5-year period from 2002 through 2006 indicating the estimated number of customers and corresponding metered water consumption was the primary basis for the projections. Available population data was also used to assess the growth rate for each pressure zone between 2010 and 2020.

Projections were developed for the following 17 pressure zones:

- Avon
- Ben Davis
- Castleton
- Central
- Cumberland
- Flackville
- Harbour
- Lafayette
- Meridian Hills
- Morgan
- Nora
- Northeast
- Northwest
- Plainfield
- Southeast
- Southport
- Southwest

The location of these pressure zones as part of Indianapolis Department of Water's (DOW's) overall service area is illustrated on Figure 1-1. The area bounded by the pressure zones represents a total area of 762 square miles and encompasses all or parts of eight counties and over 30 municipalities.

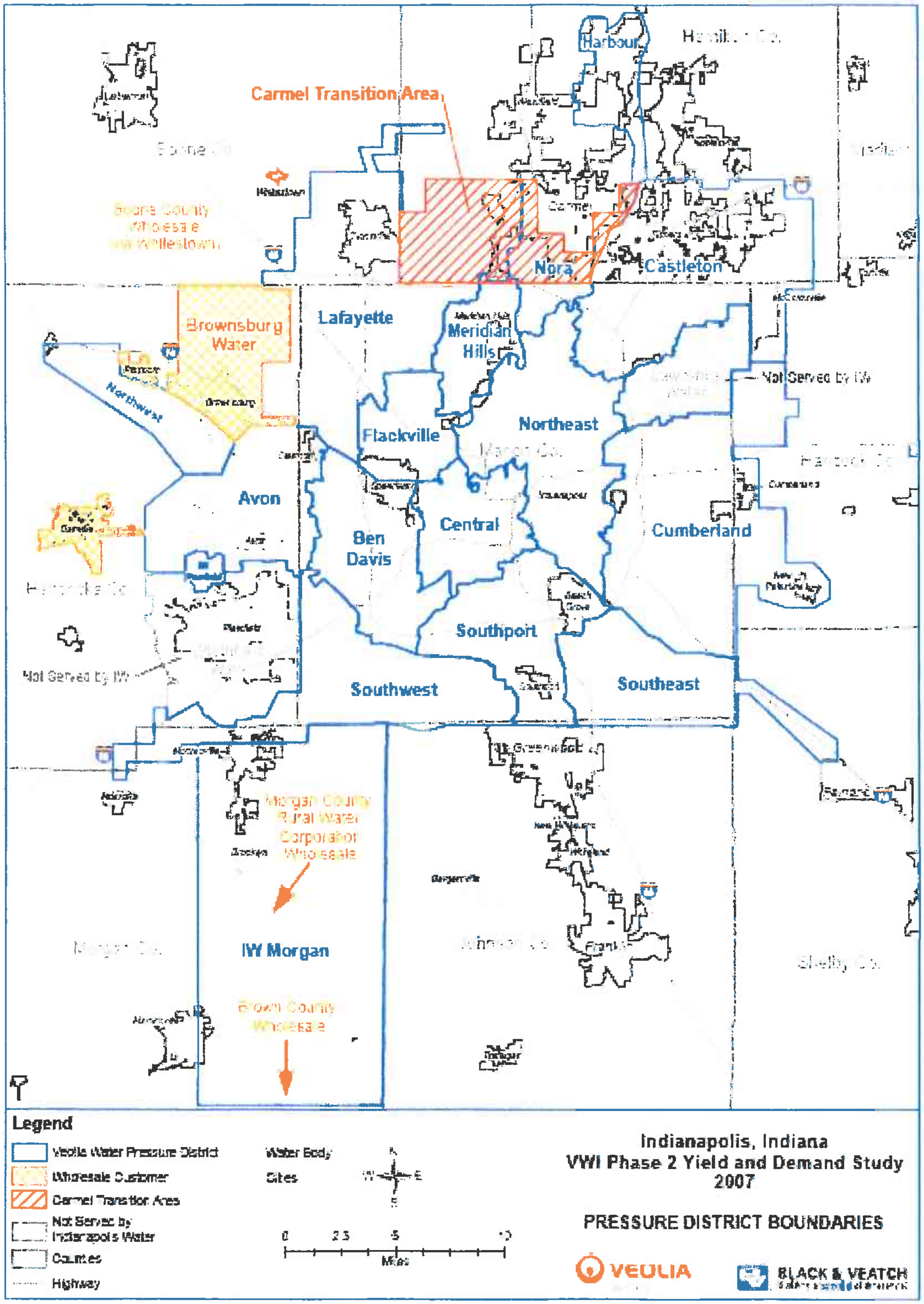

Figure 1-1 Pressure District Boundaries

One of the municipalities identified on Figure 1-1, the Town of Carmel, includes a group of existing DOW customers that are being disconnected from the existing system and will be served by other means after about 2010. The area in which these customers are located is identified as the "Carmel Transition Area" in Figure 1-1 and encompasses portions of the Lafayette, Meridian Hills, and Nora Pressure Zones. A separate set of projections were developed for the Carmel area to facilitate the development of demand projections for 2020 that represent the remainder of the system.

Since historic system delivery information was also provided for Boone County, (i.e., Whitestown (formerly Boone County Utility) and Brown County (Brown County Water Utility)), these wholesale customers were also treated as individual pressure zones for the purpose of developing estimates of their projected water demand.

Projections were developed on a disaggregated customer basis by grouping IW's customer base into three categories; residential, non-residential, and other. Trend analyses were performed to assess the historical growth rate for customers in each category and pressure zone. These trends were used to project the number of customers in 2010. For the residential customer category only, the calculated annual population growth rates from available data for 1996 and projections through 2030 were applied to determine the projected number of residential customers in each pressure zone by 2020. The projected number of non-residential and other customers in 2020 was determined by maintaining the historical relationship between these customers and the number of residential customers.

Consumption factors representing the historic metered water consumption divided by the corresponding number of meters (customers) were calculated for each customer category and pressure zone. These consumption factors, in gallons per customer per day (GPCD), were applied to the projected number of customers in 2010 and 2020 in order to calculate the projected metered water consumption.

Three different demand projection scenarios, "Low", "Medium", and "High", were developed using the minimum, average, and maximum customer consumption factors from the historical data for each customer category and pressure zone.

Unaccounted-for Water (UAW), which is also referred to by VWI as non-revenue water (NRW) represents the difference between net system delivery and metered consumption and is expressed either as a total volume or as a percentage of ADD. Historical system delivery information was used to calculate the annual volume of UAW for each pressure zone by computing the difference between system delivery and water sales. UAW as a percentage of each pressure zone's annual system delivery was also computed. An average UAW percentage was determined and applied to the projected total metered consumption for each pressure zone. The UAW percentage was adjusted to be consistent with the system-wide UAW percentages of 15 percent for 2010, and 13.5 percent by 2020 as prescribed by VWI.

The resulting ADD projections reflect water demand associated with growth within the existing service area but does not include service to a couple of future, large developments – Lebanon and Duke. Therefore, projected demand that is associated with these developments has been added to the baseline projections for the pressure zones that are anticipated to serve them.

Information regarding current and historic system deliveries to the majority of existing wholesale customers was not provided. Therefore, it could not be subtracted from the consumption associated with other customers in order to develop separate projections for the wholesale customers only. The development of separate projections for wholesale customers is also precluded by the fact that wholesale customer meters are read monthly. As a result, the magnitude of historic daily system deliveries is unknown, and their actual MDD cannot be distinguished from the MDD attributed to the remainder of the customers within a pressure zone. Therefore, projected consumption associated with existing wholesale customers was considered to be incorporated in the overall projections for each pressure zone and the system as a whole. These customers include the following:

- Town of Danville,
- Town of Brownsburg, and
- Morgan County Rural Water Corporation (MCRWC).

The MDDs and MHDs were also projected for individual pressure zones and the overall system. The first step in this process was to calculate the historic ratio of MDD to ADD and MHD to MDD for each pressure zone and the overall system.

The historic ratios were analyzed over a five year period to determine their variability and mean values.

An accepted industry practice is to incorporate a safe factor in the determination of MDD:ADD ratios for projection purposes. The upper 95th percent confidence interval represents the statistical likelihood that projected MDD would be exceeded only once in 20 years instead of once every 2 years as would be the case if the average MDD:ADD ratios were used. The upper 95th confidence intervals for MDD:ADD and the average values for MHD:MDD were calculated for each pressure zone and the overall system and multiplied by the projected ADD (excluding additional developer demand) and MDD, respectively, to obtain projected MDD and MHD.

In a manner similar to that described above for ADD, additional MDD and MHD associated with large developments were estimated and added to the baseline projections for MDD and MHD. As noted above, MDD and MHD associated with existing wholesale customers is reflected in historic peak demand days.

System-wide projections for ADD represent the sum of the projections for individual pressure zones. However, historical data provided by VWI appropriately reflect the MDD and MHD for individual pressure zones, as well as system-wide quantities. Since the MDD and MHD values for individual pressure zones may occur at different times, their sum is generally about 5 to 10 percent higher than the overall system demand. Both estimates are useful for system planning purposes. The system-wide projections indicate adequate supply and production capacity assuming sufficient delivery capacity to the pressure zones. The individual pressure zone estimates indicate capacity to effectively distribute and deliver water to meet customer demands.

1.4 ACRONYMS AND ABBREVIATIONS

ac	Acre
ADD	Average Day Demand
AWWA	American Water Works Association
B&V	Black & Veatch
bgs	Below Ground Surface
CD	Compact Disk
cfs	Cubic Feet per Second
CSO	Combined Sewer Overflow

DOW	Department of Water
DPW	Indianapolis Department of Public Works
est.	Estimated
FC	Fall Creek
ft	Feet/Foot
FEMA	Federal Emergency Management Administration
GMS	Groundwater Modeling System
GPCD	Gallons per Customer per Day
gpm	Gallons per Minute
GWF	Geist Wellfield
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
IPL	Indianapolis Power and Light
IW	Indianapolis Water
MCRWC	Morgan County Rural Water Corporation
MDD	Maximum Day Demand
mgd	Million Gallons per Day
MHD	Maximum Hour Demand
min	Minimum
MSL	Mean Sea Level
NCDC	National Climate Data Center
NOAA	National Oceanic and Atmospheric Administration
NRW	Non-Revenue Water
RS	Riverside
SWF	South Wellfield
SWWF	Significant Water Withdrawal Facilities
TAZ	Transportation Analysis Zone
UAW	Unaccounted for Water
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VWI	Veolia Water Indianapolis
WR	White River
WRN	White River North
yr	Year

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Section 2

2. POPULATION AND HISTORICAL DATA

The purpose of this section is to summarize the population and historical customer, water consumption, and system delivery data that are the primary bases for the water demand projections. The information is generally summarized by pressure zone. In addition, information is also presented for the City of Carmel, which will be renewed from the existing system and served by Carmel Utilities after 2010. This information is needed to facilitate the development of separate projections for the Carmel area, which will be excluded from those for the remainder of the system in 2020.

2.1 POPULATION PROJECTIONS

The 2003 demand evaluation prepared by Black & Veatch reported that Indianapolis Water (IW) provided service to a total of 920,300 people in the Indianapolis metropolitan area, including Marion County and portions of surrounding counties.

Information regarding the estimated population served was not provided and was not estimated as part of the current study. Population data used in this study are 1996 population estimates and projected populations for 2030 based on Transportation Analysis Zones (TAZ). Both were obtained in a format in which population was distributed geographically by TAZ. There were a total of 1,285 TAZ zones that were provided for the Indianapolis metropolitan area.

Figure 2-1 shows the distribution of population density in 1996 by TAZ. As shown in this figure the most densely populated areas include areas of the Northeast and Central pressure zones, while Lafayette and Nora pressure zones have the lowest density per acre. In general, the periphery of the service area is less densely populated than the central region.

TAZ-level data is the primary means for guiding longer-term (2020) water demand projections within individual pressure zones. The projected population growth rates by pressure zone were also used to guide customer projections between the baseline year (2006) and 2010.

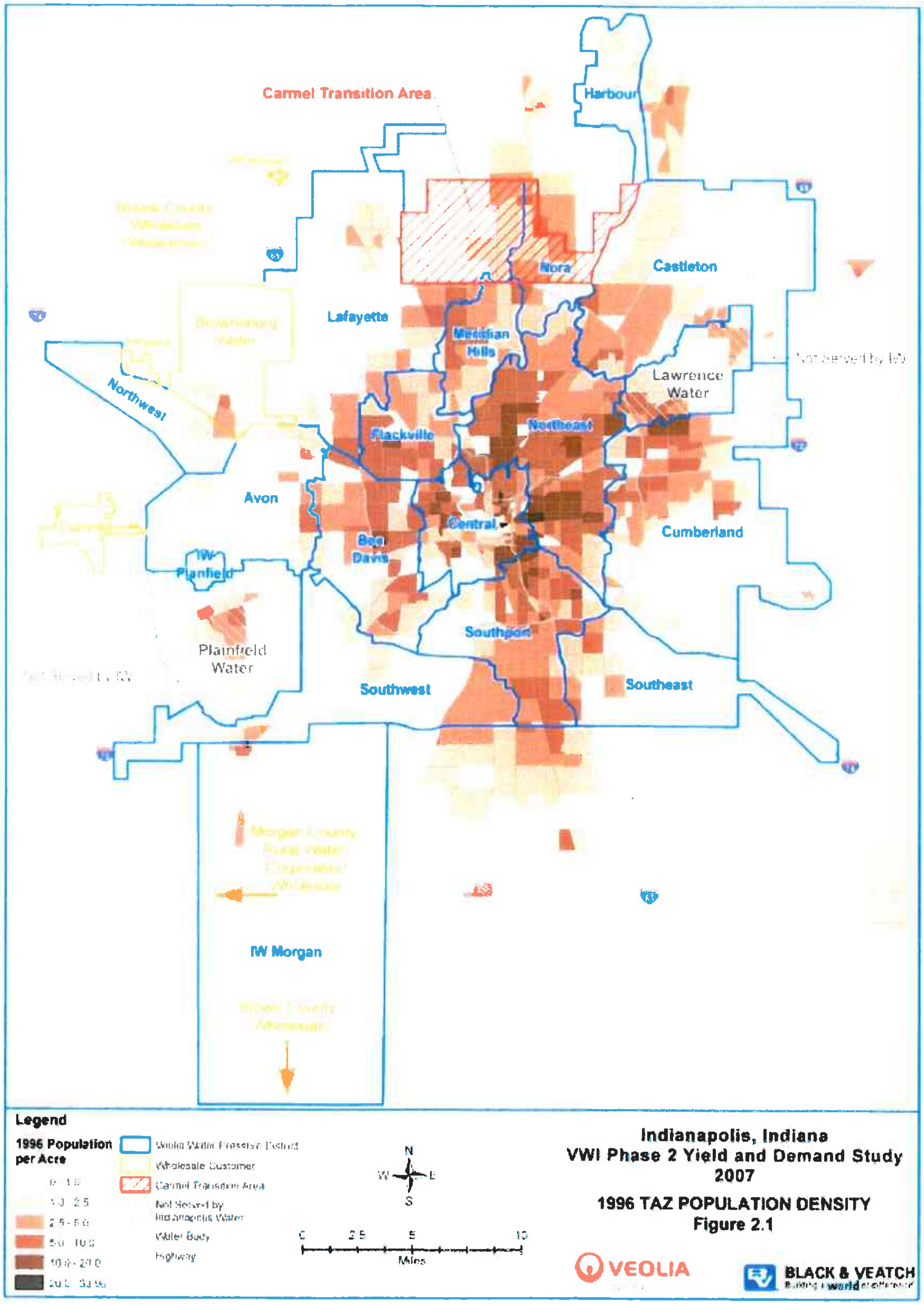

Figure 2-1 1996 Population Density by TAZ

Figure 2-2 illustrates the population growth rate by TAZ. The figure shows that a large percentage of the overall system is projected to show flat to negative population growth. Several TAZ within the Lafayette and Castleton pressure zones are projected to significant growth, while the Northeast and Central pressure zones are projected to experience population declines in several areas.

Historic population for 1996 was summarized by pressure zone by joining TAZ-level population at the TAZ level to the pressure zone boundaries. The pressure zone boundaries intersected approximately 900 TAZ zones. In cases where boundaries crossed TAZ, TAZ population was divided and assigned in proportion to the relative area of the TAZ in each pressure zone. The results are summarized in Table 2-1.

According to Table 2-1, the total population in 1996 in the areas encompassing IW's current service area was about 890,600. The total population for 2003 was estimated by interpolation from the 1996 data and projections for 2030. If the areas currently served represented the service area in 2003, the total population of about 946,200 would imply an average population served of over 97 percent.

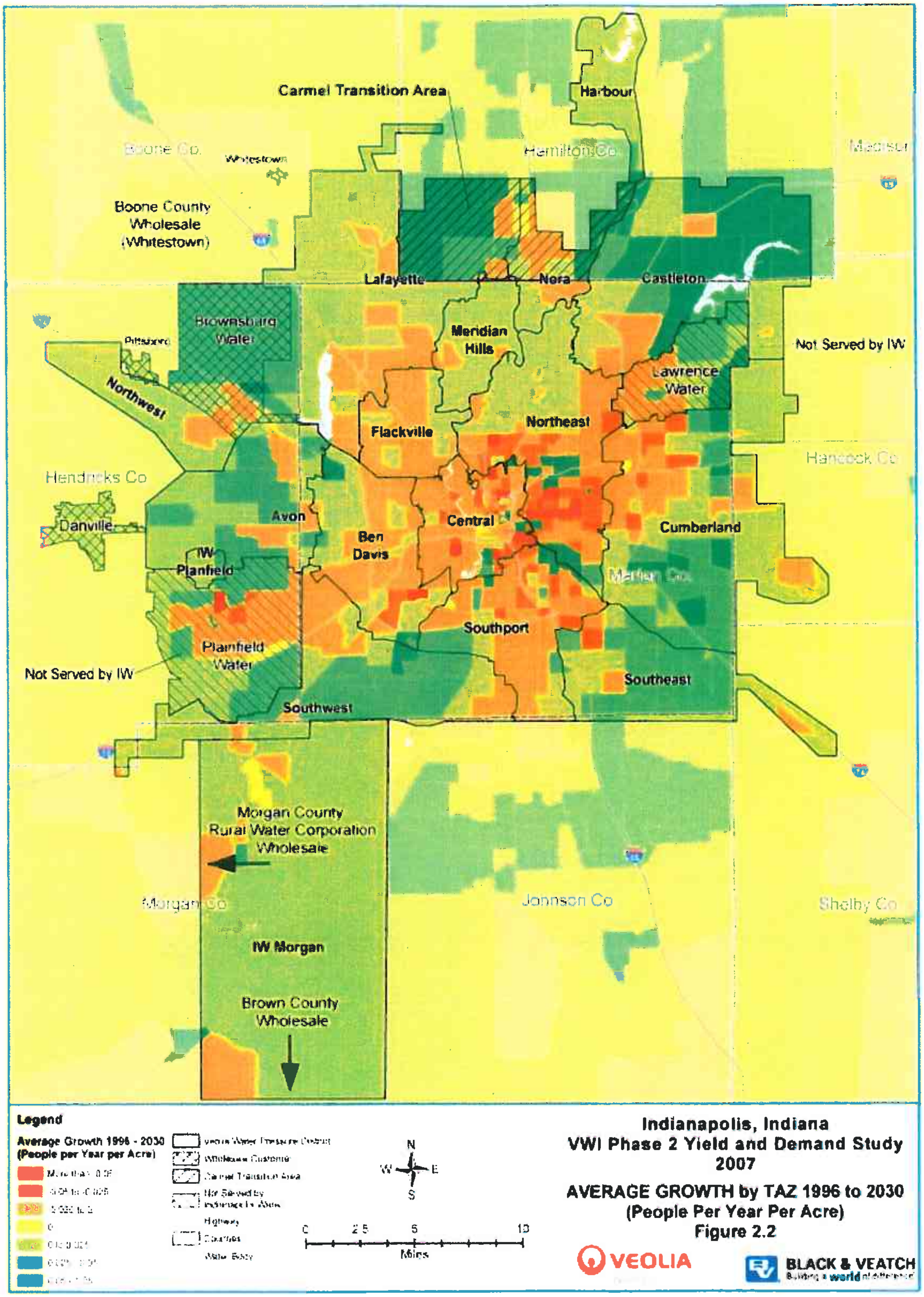

Figure 2-2 Average Population Growth by TAZ – 1996-2030

Table 2-1 Population and Growth Rate				
	Population			2010-2020 Annual Growth Rate
Pressure Zone	**1996**	**2003**	**2030**	
Avon	22,887	26,246	39,203	1.51%
Ben Davis	70,006	70,427	72,051	0.08%
Castleton	57,631	75,325	143,574	2.43%
Central	77,245	76,684	74,518	-0.11%
Cumberland	85,972	91,906	114,792	0.83%
Flackville	54,822	54,674	54,103	-0.04%
Harbour	6,106	7,396	12,371	1.94%
Lafayette	58,251	68,567	108,359	1.73%
Lafayette (Without Carmel)	*47,040*	*49,667*	*59,799*	*0.70%*
Meridian Hills	37,963	38,521	40,675	0.20%
Meridian Hills (Without Carmel)	*37,697*	*38,242*	*40,346*	*0.20%*
Morgan	26,424	29,218	39,997	1.18%
Nora	21,148	22,797	29,155	0.92%
Nora (Without Carmel)	*6,336*	*6,436*	*6,823*	*0.22%*
Northeast	221,291	223,132	230,233	0.12%
Northwest	5,756	6,523	9,479	1.41%
Plainfield	894	1,149	2,131	2.34%
Southeast	22,074	25,677	39,574	1.63%
Southport	91,870	92,921	96,973	0.16%
Southwest	30,299	35,037	53,310	1.58%
TOTAL	**890,639**	**946,198**	**1,160,498**	**0.77%**
Carmel	26,289	35,540	71,221	2.62 %
Boone County [1]	41,021	49,965	62,752	1.47%
Brown County [2]	14,608	15,339	14,732	0.53%

Notes:
1. Carmel is not a pressure zone but a part of the system that will be disconnected and served by other means after 2010.
2. Indicated growth rate for Boone County reflects average for Boone County and Lafayette
3. Indicated growth rate for Brown County reflects average for Brown County and Morgan

Although population data was not used to directly project water demand for this study, Table 2-1 indicates that the information for deriving the residential customer growth rates between 2010 and 2020 are generally consistent with population estimates referenced in prior studies. In addition, the availability of population estimates by TAZ is beneficial for facilitating allocation of demand to the hydraulic model. TAZ-level projections provide a basis for incorporating relative differences in the magnitude and location of predicted future changes in population to be reflected in the hydraulic model demand allocation.

According to Table 2-1, the overall annual population growth rate is projected to be approximately 0.8 percent. Annual growth rates for individual pressure zones ranged from -0.1 percent in Central to 2.4 percent in Castleton. The population growth rates in adjacent areas of Boone and Brown Counties were estimated by averaging the county-wide rates and those of the pressure zones from which they are served (Lafayette for Boone County and Morgan for Brown County).

The Carmel area is not a pressure zone, but a part of the system that will be disconnected and served by other means after 2010. The Carmel transition area falls within three pressure districts: Lafayette, Meridian Hills and Nora. The 2010 demand projections for these three pressure zones include the Carmel area, while the 2020 demand projections are based on customers and population projections that exclude the Carmel area.

An overall population projection for the Carmel area is also shown in Table 2-1. As shown, the projected growth rate for the Carmel area is 2.6 percent per year, which is the highest for any zone in the system. The average growth rate from 2010 to 2020 for Lafayette with Carmel is 1.73 percent per year, while the annual growth rate without Carmel is 0.7 percent. For Meridian Hills, the growth rate from 2010 to 2020 with and without Carmel remains the same. For Nora, the annual growth rate with Carmel is 0.92 percent, and without Carmel it is 0.22 percent.

2.2 CUSTOMERS AND METERED WATER CONSUMPTION

Information regarding metered water sales was provided by VWI in the form of comma-separated value files and shapefiles for 2002 through 2007. Data from 2002 through 2006 was converted into a database and used for assessing the historic number of customers and corresponding metered water consumption for each pressure zone.

The following database fields were used to analyze customer and consumption data and organize each record by year, customer category, and pressure zone:

- Year
- Latitude/Longitude for the meter location (centroid of customer parcel)
- Customer ID
- Street Address
- Zip Code

- Quarterly Water Sales
- Water Service Class Type

For any given year, each record that had a unique address, customer ID, and service class was counted as a separate customer provided that the summation of quarterly water sales was greater than zero. This assumption allows for the possibility of a single property to be counted as two or more customers, such as would be the case with separate domestic and irrigation meters.

Not all of the records in each year were provided with latitude/longitude coordinates for the meter location. Therefore, a geocoding process was undertaken in order to associate a street address and zip code with the correct location. All records that were matched to a location based on latitude/longitude or geocoding were associated with a pressure zone or grouped into a category of records that fell outside the pressure zone boundaries.

The customers were also categorized into one of three customer categories -- Residential, Non-residential, and Other -- based on water service class types. Disaggregation by service class provides a means to relate the residential portion of the customer base to population, and compare trends in customer growth rates and water usage characteristics between different pressure zones and over time.

Table 2-2 shows how each of DOW's service class types are categorized for demand projection purposes. The residential category includes residential, apartment and multi-family customers. The non-residential category includes industrial, hospitals and commercial service classes. The other category includes private and public fire protection and public meters.

A tabular summary of the top 100 customers is provided in Appendix A. Most of the large customers are likely to be non-residential, including industrial customers such as Eli Lilly Store, Covanta Indianapolis, Inc., National Starch and Quaker Oats, or wholesale customers such as Town of Brownsburg, Town of Danville and Whitestown Utility.

A tabular summary of the number of customers and corresponding metered water consumption by customer category and pressure zone is provided for 2002 through 2006 in Appendix B and Appendix C.

Table 2-2
Breakdown of Customer Type

Customer Category	Service Class Types
Residential	• Apartment • Condominium • Multi-Family Dwelling • Residential • Residential-Unmeter
Non-Residential	• City-County • Colleges • Commercial • Commercial-Unmeter • Hospitals • Industrial • Irrigation • Schools • State
Other	• Other Utilities • Private Fire Protection • Public Fire Protection • Public Metered • Other • No Cust Class Type

2.3 SYSTEM DELIVERY

Historic annual, maximum day, and maximum hour system delivery information was provided by VWI in the form of monthly consumption report spreadsheets. These sheets contained the monthly system deliveries and year-to-date total, maximum day, and maximum hour deliveries for each pressure zone and the overall system. Data from the December reports for 2002 through 2006 were reviewed and used to develop current demand projections for VWI, which are presented in millions of gallons per day (mgd).

Table 2-3 provides a summary of the calculated average day demand (ADD) for each of the pressure zones (including wholesale deliveries to Boone County and Brown County) and the overall system. With some noted exceptions the data are considered to represent the net, i.e., flow in minus flow out, system deliveries to each pressure zone. The consumption reports for 2005 and 2006 indicate that water delivered from Ben Davis was not included in the supply to Southwest. This indicates that Southwest's actual ADD is higher than the values shown in Table 2-3. Similarly, flow from Nora to Meridian Hills through the Nora Bleeder was not considered in calculating the ADD for both Nora and Meridian Hills, which indicates that Nora's actual ADD is likely lower and Meridian Hills is likely higher than the values shown in Table 2-3. The net system delivery for Harbour includes production within Harbour plus supply from Westfield minus the amount of water sent back to Westfield.

Total ADD for the system ranged from 136.7 mgd in 2003 to 153.4 mgd in 2007 and averaged 142.7 mgd over the 6-year period. Table 2-3 indicates that system delivery to the Northeast and Central pressure zones are the largest, whereas Morgan, Plainfield, and Boone and Brown Counties ADDs are generally less than about 0.5 mgd.

Annual system delivery for Nora is included in the ADD for Meridian Hills for 2002. Similarly, 2006 ADD for McCordsville and Terry Airport are included in the total ADD for Castleton and Lafayette, respectively. Annual system delivery for Zionsville is also included in the total ADD for Lafayette for all years.

Table 2-3
Average Day Demand (mgd)

Pressure Zone	2002	2003	2004	2005	2006	2007
Avon	4.2	4.1	4.7	5.3	5.2	5.8
Ben Davis	9.3	9.4	9.0	9.9	9.4	10.4
Boone County[1]	0.1	0.2	0.3	0.3	0.6	0.3
Brown County[1]	0.4	0.3	0.2	0.3	0.3	0.4
Castleton	13.5	12.2	12.7	14.0	13.4	16.6
Central	25.2	26.7	24.0	22.8	23.0	24.9
Cumberland	13.8	13.2	13.9	14.4	13.0	13.9
Flackville	6.7	6.3	6.5	6.5	6.4	6.6
Harbour	0.6	1.2	1.4	1.6	1.3	1.6
Lafayette	13.6	12.8	14.3	15.2	13.3	16.4
Meridian Hills	7.1	4.7	4.3	4.5	4.3	4.5
Morgan	0.3	0.3	0.3	0.3	0.3	0.3
Nora	N/A	1.8	2.4	2.4	2.2	2.3
Northeast	26.5	26.6	28.7	29.4	28.0	29.2
Northwest	0.9	0.9	1.2	1.5	1.5	1.4
Plainfield	0.0	0.3	0.5	0.2	0.3	0.5
Southeast	3.2	3.0	3.7	4.3	4.4	4.8
Southport	10.3	9.9	10.3	10.4	9.8	10.7
Southwest	2.7	2.7	3.4	3.0	3.5	2.9
TOTAL	**138.4**	**136.7**	**141.6**	**146.3**	**140.0**	**153.4**

[1] – Boone and Brown County are wholesale customers and not pressure zones
N/A – Not Available

Table 2-4 summarizes historic maximum day demand (MDD) system deliveries for each pressure zone and the overall system. Reported system-wide MDD ranged from 195 mgd in 2004 to over 228 mgd in 2007 and averaged about 212.7 mgd over the six year period. Harbour system delivery is not included in the reported system-wide MDD. Accordingly, the MDD values for the system reflect the summation of the system-wide MDD and Harbour's individual MDD. While Central and Northeast experience the largest MDDs, both Castleton and Lafayette are close and reflect large increases relative to their annual system deliveries. With the exception of a MDD of 4.13 mgd for Boone County in 2006, all of the smallest pressure zones in terms of ADD also had MDDs of about 1.0 mgd. The MDD is not available for Harbour and Plainfield for 2002.

Table 2-4
Maximum Day Demand (mgd)

Presure Zone	2002	2003	2004	2005	2006	2007
Avon	8.5	7.6	8.8	10.7	10.0	10.8
Ben Davis	14.6	16.4	14.2	18.5	17.3	16.5
Boone County[1]	0.8	0.7	0.7	1.0	4.1	0.7
Brown County[1]	1.0	0.6	0.5	0.5	0.6	0.7
Castleton	31.3	28.3	23.9	29.6	27.0	31.9
Central	36.0	34.8	30.3	31.9	35.4	33.5
Cumberland	22.1	19.9	22.5	22.5	18.8	21.1
Flackville	9.9	8.3	8.5	8.7	8.2	8.9
Harbour	N/A	2.3	2.6	2.7	2.1	2.9
Lafayette	28.5	25.3	25.0	29.8	25.4	32.3
Meridian Hills	13.6	7.6	6.7	8.1	7.3	8.6
Morgan	1.0	0.6	0.5	0.5	0.6	0.7
Nora	0.0	4.7	3.9	5.0	4.5	6.3
Northeast	35.2	32.6	35.3	36.6	34.9	36.7
Northwest	1.8	1.8	2.0	2.8	2.2	3.4
Plainfield	0.0	1.9	1.1	0.7	1.0	1.2
Southeast	7.5	6.0	6.6	8.6	8.0	8.0
Southport	15.8	14.4	13.0	15.0	13.8	15.3
Southwest	7.8	9.7	8.0	6.6	7.1	0.0
SYSTEM[2]	**221.6**	**205.3**	**197.1**	**227.8**	**204.7**	**231.1**

1 – Boone and Brown County are wholesale customers and not pressure zones
2 – Not sum of values for individual pressure zones. Values reflect the summation of system-wide MDD and Harbour MDD; Harbour demand is not included in the reported system-wide MDD.

VWI's monthly consumption reports included the volume of water delivered to individual pressure zones during the maximum hour demand. Accordingly, these volumes were multiplied by 24 to convert them to the equivalent Maximum Hour Demand (MHD) and are summarized in Table 2-5. The MHD is not available for Harbour, and reported system-wide MDH numbers do not include Harbour.

Table 2-5
Maximum Hour Demand (mgd)

Pressure Zone	2002	2003	2004	2005	2006	2007
Avon	15.1	15.8	15.2	17.3	14.5	18.5
Ben Davis	20.4	20.8	18.0	23.2	22.1	20.8
Boone County[1]	1.5	1.9	2.8	0.0	0.0	1.3
Brown County[1]	1.3	1.0	1.3	0.8	1.8	2.6
Castleton	46.8	43.3	40.0	44.7	0.0	124.4
Central	66.1	96.2	131.6	44.7	165.1	124.4
Cumberland	31.1	28.7	27.8	36.8	34.8	30.7
Flackville	13.0	15.8	10.9	15.8	14.3	12.2
Harbour	N/A	N/A	N/A	N/A	N/A	N/A
Lafayette	45.2	43.1	41.7	40.6	36.7	44.8
Meridian Hills	22.5	25.2	50.2	0.0	0.0	0.0
Morgan	1.8	1.9	2.7	1.7	1.4	1.7
Nora	0.0	12.0	6.3	9.7	6.6	9.6
Northeast	74.1	68.7	44.7	69.1	46.8	0.0
Northwest	2.7	2.9	3.8	3.5	0.0	4.2
Plainfield	0.0	2.4	12.5	1.2	2.2	2.4
Southeast	19.0	12.5	11.4	16.7	15.3	22.8
Southport	39.2	23.9	35.4	20.0	35.4	34.3
Southwest	27.3	25.1	32.5	12.6	20.3	0.0
SYSTEM	**300.3**	**271.4**	**252.9**	**306.1**	**247.0**	**312.7**

[1] – Boone and Brown County are wholesale customers and not pressure zones

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Section 3

3. CUSTOMER AND DEMAND PROJECTIONS

This section describes the development of Average Day Demand (ADD), Maximum Day Demand (MDD), and Maximum Hour Demand (MHD) projections for Veolia Water Indianapolis (VWI). As indicated in Section 1.3, the approach is based on the use of historic customer and metered consumption data to establish a baseline and evaluate trends. Projected water demands are developed starting from the 2006 customer base and using trended customer and predicted population growth rates and historic relationships between residential and other customer categories to project the future number of customers.

Historic water consumption factors, unaccounted for water (UAW) percentages, and MDD:ADD and MDH:MDD ratios are used along with information regarding potential development demands to calculate the water demand associated with the projected customer base. Projections are developed for individual pressure zones and the overall system. 2020 projections for Lafayette, Meridian Hills and Nora are based on population and customer projections that do not include Carmel, as well as historic water consumption factors that exclude Carmel.

Key elements of this approach are discussed in the following sections.

3.1 CUSTOMER GROWTH

Table 3-1 summarizes the recent historic and projected annual customer growth rates for the individual pressure zones and the overall system by customer category. Based on values interpolated from the Transportation Analysis Aone (TAZ) population data, future system-wide residential growth rates are projected to decline to an average of 4,616 customers per year between 2006 and 2010, and 2,603 customers per year between 2010 and 2020 (including the impact of Carmel transition customers).

Projected growth rates were determined for individual pressure zones based on historic customer growth and population projections. Residential growth rates through 2010 reflect either the average growth rate over the past two years or a longer-term trend based on data from 2002, which either resulted in growth rates that were more similar to the projected population growth rates. Residential customer projections for 2020 were based on the projected population growth rates.

Table 3-1
Historic and Projected Annual Customer Growth Rates (Customers per Year)

	Non-Residential			Residential			Other		
	2002-2006	**to 2010**	**to 2020**	**2002-2006**	**to 2010**	**to 2020**	**2002-2006**	**to 2010**	**to 2020**
Avon	11	11	8	412	373	221	-1	-1	1
Ben Davis	7	7	3	267	124	17	1	1	0
Boone County	0	0	0	0	0	0	0	0	0
Brown County	0	0	0	0	0	0	0	0	0
Castleton	44	53	60	776	752	980	-3	-3	4
Central	5	3	-4	315	-6	-28	4	3	-2
Cumberland	34	30	57	1,381	1,376	322	-1	-1	2
Flackville	-4	-4	6	223	83	-6	-1	0	0
Harbour	-5	-4	5	124	117	112	0	0	0
Lafayette	24	25	56	747	696	562	-2	-3	4
Lafayette (Without Carmel)	17	16	35	649	661	173	-1	-1	2
Meridian Hills	2	2	6	198	189	22	0	0	0
Meridian Hills (Without Carmel)	3	3	6	197	188	21	0	0	0
Morgan	0	0	1	283	44	23	0	0	0
Nora	8	9	-1	64	-23	34	0	0	0
Nora (Without Carmel)	3	3	7	61	39	3	0	0	0
Northeast	-14	-15	3	529	-305	90	0	0	0
Northwest	1	1	1	17	17	3	0	0	0
Plainfield	0	0	0	26	23	19	0	-1	1
Southeast	16	17	11	933	528	304	0	0	1
Southport	10	7	10	466	241	46	0	-1	0
Southwest	9	10	8	817	385	302	-1	-1	2
TOTAL	**148**	**152**	**216***	**7,579**	**4,616**	**2,603***	**-5**	**-6**	**13***

* - 2020 numbers reflect total without Carmel.

Customer growth rates through 2010 for non-residential and other customer categories are based on linear regressions of data since 2002. For 2020, the number of non-residential and other customers was projected based on the average historical ratio to residential customers.

Projections were not developed for IW's Boone County or Brown County wholesale customers. In addition, customer data for 2003 appeared anomalous and were not included in the analyses discussed above to determine projected growth rates.

3.2 METERED CONSUMPTION

Metered consumption for each customer category and pressure zone was projected by multiplying the projected number of customers by appropriate consumption factors. Historic consumption factors were determined from data for 2002 through 2006. Table 3-2 provides a summary of the average consumption factors.

Table 3-2
Average Consumption Factors (GPCD)

Pressure Zone	Non-Residential	Residential	Other
Avon	2,743	192	308
Ben Davis	2,397	202	3,600
Boone County	296,104	0	0
Brown County	315,409	0	0
Castleton	1,502	254	1,541
Central	5,271	183	8,944
Cumberland	2,054	215	735
Flackville	1,528	263	2,330
Harbour	970	221	522
Lafayette	2,322	266	1,388
Lafayette (Without Carmel)	2,243	255	1,652
Meridian Hills	2,919	348	894
Meridian Hills (Without Carmel)	2,933	348	894
Morgan	85,402	153	0
Nora	2,461	226	550
Nora (Without Carmel)	2,839	290	952
Northeast	1,311	179	617
Northwest	240,513	186	0
Plainfield	187	242	170
Southeast	2,049	194	888
Southport	1,461	212	1,514
Southwest	3,672	192	1,028
System[1]	**2,518**	**214**	**2,793**

[1] – System averages including Carmel

According to Table 3-2, residential customer usage is the most consistent across pressure zones, ranging from 153 gallons per customer per day (GPCD) in Morgan to 348 GPCD in Meridian Hills and averaging 214 GPCD for the overall system. With the exception of Plainfield, Morgan and Northwest, non-residential consumption was also fairly uniform, averaging 2,518 GPCD for the overall system. Pittsboro is a wholesale customer served by the Northwest pressure district. Pittosboro is classified by VWI as industrial customer and therefore falls under the non-residential category. The inclusion of this wholesale customer in the non-residential category could be the reason for the significantly higher average GPCD value for the Northwest pressure district. For most pressure zones, other consumption ranged from less than 1,000 GPCD to about 2,000 GPCD.

Since both Boone County and Brown County represent a single wholesale customer (both historically and projected for the future), their computed average consumption factors were not used to project their future metered consumption. Instead, future average annual metered consumption for these customers was obtained based on a linear trend of their historic system delivery.

In addition to average water consumption factors, minimum and maximum water consumption factors were also calculated for each customer category and pressure zone and used to develop alternative demand projection scenarios for 2010 and 2020. The purpose of the alternative projections is to bracket the range of potential future demands that may occur in any given year due to weather variability. Use of the historic minimum and maximum values or individual categories and pressure zones should enable this objective to be met.

A summary of the historic and projected metered consumption for VWI pressure zones and wholesale water to Boone and Brown Counties is provided in Appendix C. The Appendix C tables also include the historic data and projections for unaccounted-for water, additional wholesale consumption, and maximum day and maximum hour demands. These additional components of water demand are discussed in the following sections.

3.3 UNACCOUNTED-FOR WATER

Unaccounted-for water (UAW), which is also referred to by VWI as non-revenue water (NRW) is the difference between the total volume of finished water pumped into the system and the total volume of water metered to consumers. The UAW can be calculated for any portion of the system in which both the net system delivery and metered customer consumption are measured.

Historical UAW was obtained by subtracting total metered water consumption from the annual ADD. The UAW estimates are available for the pressure zones from 2002 through 2006. Average historical UAW as a percentage of ADD for individual pressure zones are shown on Figure 3-1.

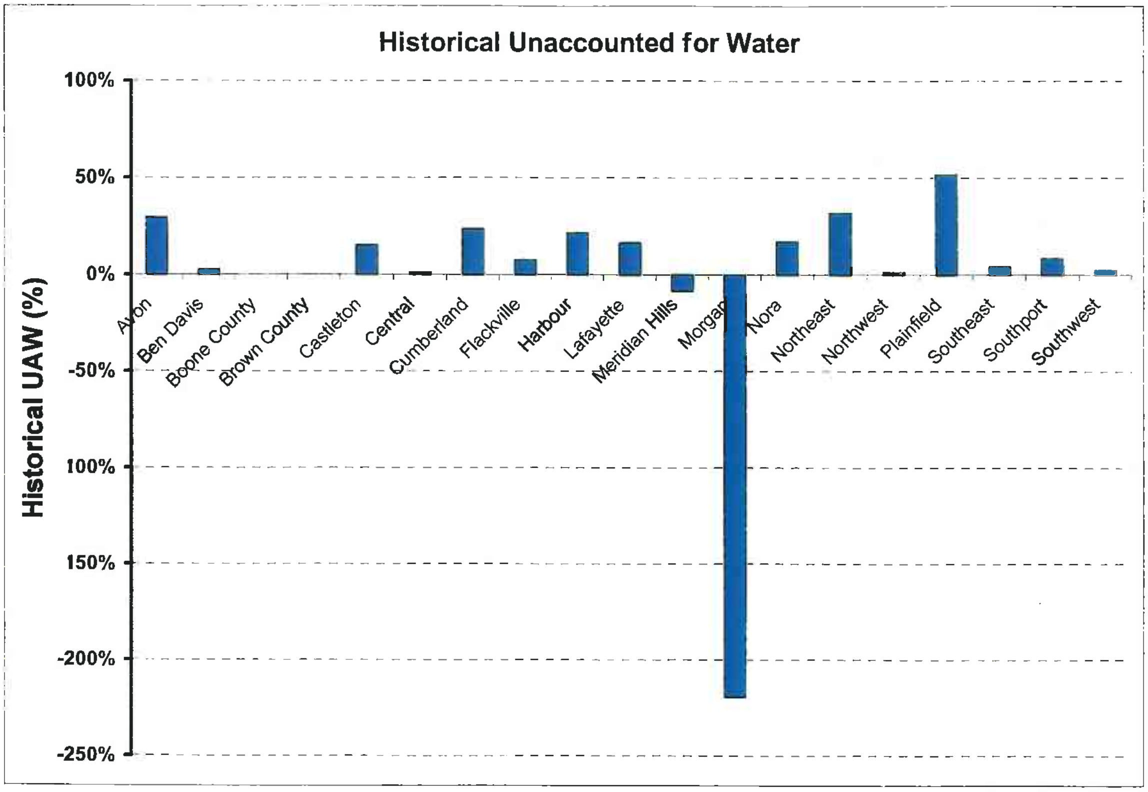

Figure 3-1 Historical Unaccounted for Water

The UAW for the overall system ranged from about 14 million gallons per day (mgd) to over 22 mgd, which corresponds to percentages ranging from about 10 percent to almost 16 percent of the total annual average day demand. The UAW for the overall system averaged 14.2% from 2002 through 2006. The UAW for individual pressure zones was less than 20% for most zones. However, average UAW exceeded 20% in Avon, Cumberland, Harbour, Northeast and Plainfield.

Some skewing of the UAW numbers in Figure 3-1 is the outcome of the lack of instantaneous flow metering through some of the bleeder valves, which allow flow between the pressure zones. While the majority of the system's bleeders are metered real time, particularly in those areas where most of the consumption occurs, a small number of the meters are not. These areas are typically those that have been removed or redistricted from larger service territories to help address pressure issues.

Pressure zones that are supplied by unmetered bleeders have unreported system delivery, which leads to lowered calculated UAW. However, the pressure zone supplying water to an unmetered bleeder has higher than actual net system delivery, leading to higher UAW.

Calculated UAW for Meridian Hills, Southwest and Morgan were negative, which means that either the recorded metered consumption is higher than the actual consumption or that the reported delivery is lower than the actual delivery to these pressure zones. Meridian Hills' apparent negative UAW might partially be attributed to the fact that the system delivery reports did not include flow from the Nora District into Meridian Hills. The unmetered Nora bleeder may also result in an artificially high UAW for the Nora District, which was calculated to be 27 percent in 2006. Morgan's high negative UAW of 220% may be attributed to under-reported system delivery.

Southwest's negative UAW could be attributed to an under estimation of delivery from Ben Davis through the Hoffman Road and/or Perimeter Road bleeders. In contrast to Southwest's negative UAW, UAW in the Ben Davis District range from 10 to 20 percent. On a combined basis, UAW for Southwest and Ben Davis Districts would be about two percent, and this level of UAW was used in the projections for both pressure zones reflected in Figure 3-1.

Flow through the Bloyd and Dearborn bleeders from White River Station into the Northeast District is not metered; however, the combined flow through the meters is calculated as the difference between the flow into the pipeline(s) feeding the station and other bleeders being supplied from the station that are metered.

In addition to sources of supply, flow from the following booster stations and tanks is unmetered:

- New Palestine
- New Clermont Tank and Booster
- St. Vincent Booster Station and Tank

While these unmetered facilities could skew the reported maximum hour and maximum day system delivery, the impact on ADD and resulting UAW is likely to be minimal. Flow to the Town of Zionsville is unmetered. However, since Zionsville is considered a part of the Lafayette District, the lack of metering at this location has no impact on Lafayette's UAW.

VWI conducted a water loss audit for the water system for 2007. The Water Audit Software, approved by the American Water Works Association (AWWA) Water Loss Control Committee, was the application used to perform the audit. The results of this audit showed that unaccounted for water for the system was 18 percent. As a result of this finding, VWI established target UAW percentages for the system of 15% for 2010 and 13.5% for 2020.

For the purpose of this study, UAW was distributed among the different pressure zones in the same proportion as their average historical UAW such that the overall system UAW is 15% for 2010 and 13.5% for 2020. The resulting UAW for each pressure zone is summarized in the projection tables in Appendix C.

3.4 WHOLESALE CUSTOMERS AND DEVELOPMENTS

Previous demand evaluation studies for the water system included supply to wholesale customers and additional demands associated with planned developments. The primary intent for considering wholesale customers was to establish projections that reflected their maximum water purchase agreement amounts. Demand for planned developments was also added to the baseline projections in order to reflect the delivery of water to customers located outside of the study area or in areas where projected demand for specific developments was anticipated to exceed the amount that would be calculated from population projections alone.

The potential for wholesale customers and large developments to impact water demand projections was also considered for the current study. Ideally, all of the historic water sales or customer usage associated with wholesale customers would be subtracted from historic ADD, MDD, and MHD. Following the subtraction, the corresponding projections for these same customers and any new customers/developments would be added to the projections for the rest of the customer base.

As described in the sections below, information provided by VWI enabled this approach to be taken for Boone and Brown Counties and certain new developments only. Metered water consumption or wholesale quantities were not provided on an annual basis or under maximum day demand conditions for other customers and could not be separated from the overall demands for the pressure zones from which they are served. For this reason and because it is difficult to know whether a particular maximum purchase amount is exceeded on any given day, it was not possible to prepare separate projections for other wholesale customers. Instead, future wholesale consumption is considered to be reflected in the projections for the overall system and individual pressure zones. This is a reasonable assumption as long as future annual consumption and the relative amount of water used by wholesale customers during peak period demands follow historic trends. Modifications to the projections should be considered should VWI become aware of significant changes that would affect the average consumption factors and ratios used to derive the water demand projections.

3.4.1 Boone and Brown Counties

VWI provides wholesale water to parts of Boone County through purchases by the Town of Whitestown. VWI previously provided service to former Boone County Utility customers. Boone County Utility was acquired by the Town of Whitestown but its customers continue to be supplied by IW via the Lafayette Pressure Zone. VWI also provides wholesale water service to Brown County Water Utility via the Morgan Pressure Zone.

The table for Boone County in Appendix C indicates that historical annual water sales increased from 0.06 mgd in 2002 to 0.56 mgd in 2006. Based on the historical trend, 2010 and 2020 annual sales to Boone County are projected to be 0.94 mgd and 1.09 mgd, respectively.

Boone County's historic MDD:ADD ratios were calculated for 2002 through 2006. Values for 2002 and 2006 were not considered representative. Excluding MDD:ADD ratios of 13.6 and 7.4 for 2002 and 2006, respectively, the upper 95th percent confidence interval for Boone County is 3.36. Use of this ratio results in projected MDD of 3.17 mgd and 3.66 mgd in 2010 and 2020. Although these amounts exceed Boone County's existing maximum purchased water amount of 2 mgd, the above MDD values were used in the projections for Boone County. Based on a historical average MHD:MDD of 2.94, Boone County's MHD is projected to increase from 2.76 mgd in 2004 to 9.3 mgd and 10.8 mgd in 2010 and 2020, respectively.

Wholesale water to Brown County Water Utility in Brown County is provided by a connection to IW's Morgan Pressure Zone. The table for Brown County in Appendix C indicates that historical annual water sales decreased from 0.45 mgd in 2002 to 0.28 mgd in 2006. Based on the historical trend, 2010 and 2020 annual sales to Brown County are projected to be 0.32 mgd and 0.33 mgd, respectively. Brown County's historic MDD:ADD ratios were calculated for 2002 through 2006, and the upper 95th percent confidence interval for Boone County was determined to be 2.61. Use of this ratio results in projected MDD of 0.82 mgd and 0.87 mgd in 2010 and 2020. These amounts are less than Brown County's existing maximum daily purchased water amount of 1.5 mgd. Similarly, based on a historical average MHD:MDD of 2.00, Brown County's MHD is projected to be 1.64 mgd and 1.73 mgd in 2010 and 2020, respectively. Brown County is permitted to take water at rates as high as 2.16 mgd.

3.4.2 Lebanon and Duke Developments

Information referenced in previous studies and/or provided by VWI indicates that demand associated with the Duke Development and Lebanon should be added to the base projections for the Lafayette Pressure Zone. Information provided for Lebanon includes a 1.0 mgd maximum day demand. This amount has been added to the baseline MDD projections for Lafayette. Additional ADD and MHD demands associated with service to Lebanon were estimated using Lafayette's MDD:ADD and MHD:MDD ratios of 2.15 and 1.55, respectively.

A similar approach was used to estimate the additional demand associated with the Duke Development, for which VWI estimated a build-out (Year 2020) MDD of 1.0 mgd. Projections for 2010 were developed assuming 25 percent build-out. Corresponding ADD and MHD projections were developed using the same MDD:ADD and MHD:MDD ratios noted above for Lebanon. The estimated additional water demands for these customers are summarized in Table 3-3, and incorporated in the overall demand projection tables in Appendix C.

Table 3-3
Estimated Additional Water Demands for Wholesale Customers and Developments

Pressure Zone	2010 ADD (mgd)	2010 MDD/MHD (mgd)	2020 ADD (mgd)	2020 MDD/MHD (mgd)
Lafayette	Lebanon – 0.46 mgd Duke – 0.12 mgd	Lebanon – 1.0/1.55 mgd Duke – 0.25/0.39 mgd	Lebanon – 0.46 mgd Duke – 0.46 mgd	Lebanon – 1.0/1.55 mgd Duke – 1.0/1.55 mgd

3.4.3 Other Wholesale Customers

VWI's other wholesale customers are summarized in Table 3-4.

Table 3-4
Other Wholesale Customers

Wholesale Customer	Served By
Danville	Avon
Brownsburg	Avon
MCRWC	Southwest

Wholesale water to the Town of Danville and Town of Brownsburg is provided via connections to the Avon Pressure Zone. No information on metered flow to Danville or Brownsburg for Avon's maximum demand days is available. Wholesale water to the MCRWC is provided via a connection to the Southwest Pressure Zone. Future projections for Southwest are considered to adequately encompass any increased annual supply to Morgan County Rural Water Corporation (MCRWC).

In addition to the customers summarized in Table 3-4, other wholesale customers that are served within IW's existing pressure zones include: Zionsville (Lafayette), Pittsboro (Northwest), and Tri-county (Southwest). Pittsboro and Tri-county are considered retail customers (with no maximum purchase amounts).

3.5 AVERAGE DAY DEMAND

Average day demand represents the historical net system delivery for individual pressure zones and the overall system. Figure 3-2 displays the ADD water for the historical years 1975 through 2007 and for the future planning years. Historically, the highest ADD for the VWI system, 153.4 mgd, occurred in 2007. The lowest ADD over the past 6 years, 136.7 mgd, occurred in 2003.

For the future planning years, ADD was calculated by adding the projected total water consumption to the projected UAW and adding any additional demand associated with large developments. System-wide ADD is projected to increase to 154.8 MGD by 2010 and 162.5 MGD by 2020 for the "medium" scenario.

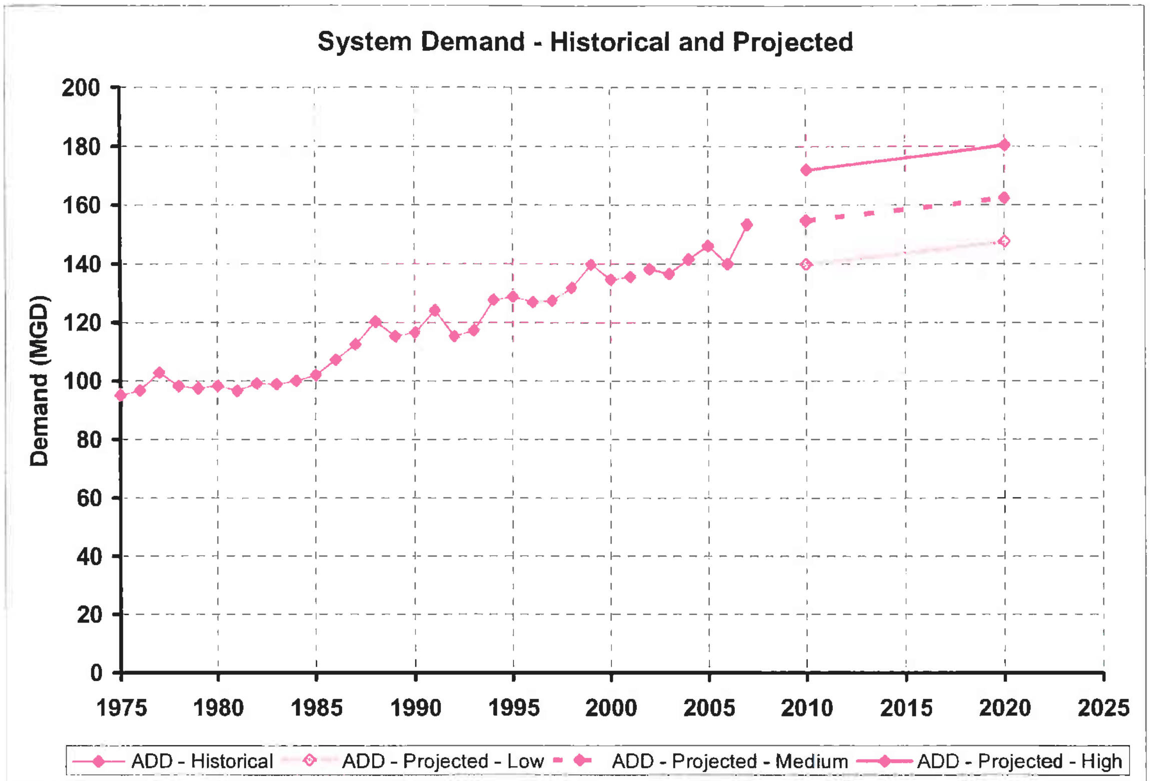

Figure 3-2 System Average Day Demand

Table 3-5 Projected Average Day Demand (mgd)						
	2010			2020		
Pressure Zone	Low	Medium	High	Low	Medium	High
Avon	4.8	5.7	6.5	5.4	6.4	7.3
Ben Davis	7.7	8.4	9.0	7.8	8.4	9.1
Boone County	0.9	0.9	0.9	1.1	1.1	1.1
Brown County	0.3	0.3	0.3	0.3	0.3	0.3
Castleton	13.8	15.0	16.3	17.3	18.9	20.5
Central	22.7	24.4	27.5	22.3	23.9	26.9
Cumberland	15.8	16.7	17.8	17.7	18.8	20.0
Flackville	6.1	6.6	7.2	6.1	6.6	7.2
Harbour	1.3	1.6	1.8	1.6	1.9	2.2
Lafayette[1]	13.8	16.1	17.3	13.3	14.4	15.3
Meridian Hills	4.5	4.8	5.2	4.8	5.0	5.4
Morgan	0.2	0.3	0.4	0.5	0.6	0.7
Nora[1]	2.1	2.4	2.6	1.8	1.9	2.0
Northeast	26.1	29.1	35.0	25.5	28.4	34.3
Northwest	1.3	1.9	2.2	2.3	3.2	3.8
Plainfield	0.3	0.4	0.4	0.4	0.5	0.5
Southeast	4.3	4.6	4.9	5.0	5.5	5.8
Southport	9.7	10.5	11.2	9.9	10.7	11.4
Southwest	4.2	5.1	5.7	5.0	6.0	6.7
TOTAL	**140.1**	**154.8**	**172.2**	**147.9**	**162.5**	**180.5**

[1] – Reduction in demand from 2010 to 2020 in the Lafayette and Nora pressure zones reflects removal of the Carmel transition area.

3.6 MAXIMUM DAY DEMAND

Maximum Day Demand represents the highest net system delivery to individual pressure zones and the entire system on any day in a year. Figure 3-3 displays the historical MDD since 1975 and projected MDD for the future planning years. The historical highest MDD for the VWI system, 231.1 mgd, occurred in 2007. The lowest MDD over the past six years, 197.1 MGD, was observed in 2004.

The MDD was projected by multiplying ADD by a ratio or multiplication factor representing the historic relationship between MDD and ADD. A statistical safety factor was applied to reflect the probability that an exceedance of the ratio will not occur. A safety factor equal to the upper 95th percent confidence interval was used, which reflects the statistical probability that the ratio of MDD to ADD would be exceeded no more than once in 20 years. The resulting ratios for the majority of the pressure zones and the overall system are summarized in Table 3-6, and the calculated ratios of MHD to MDD are also shown.

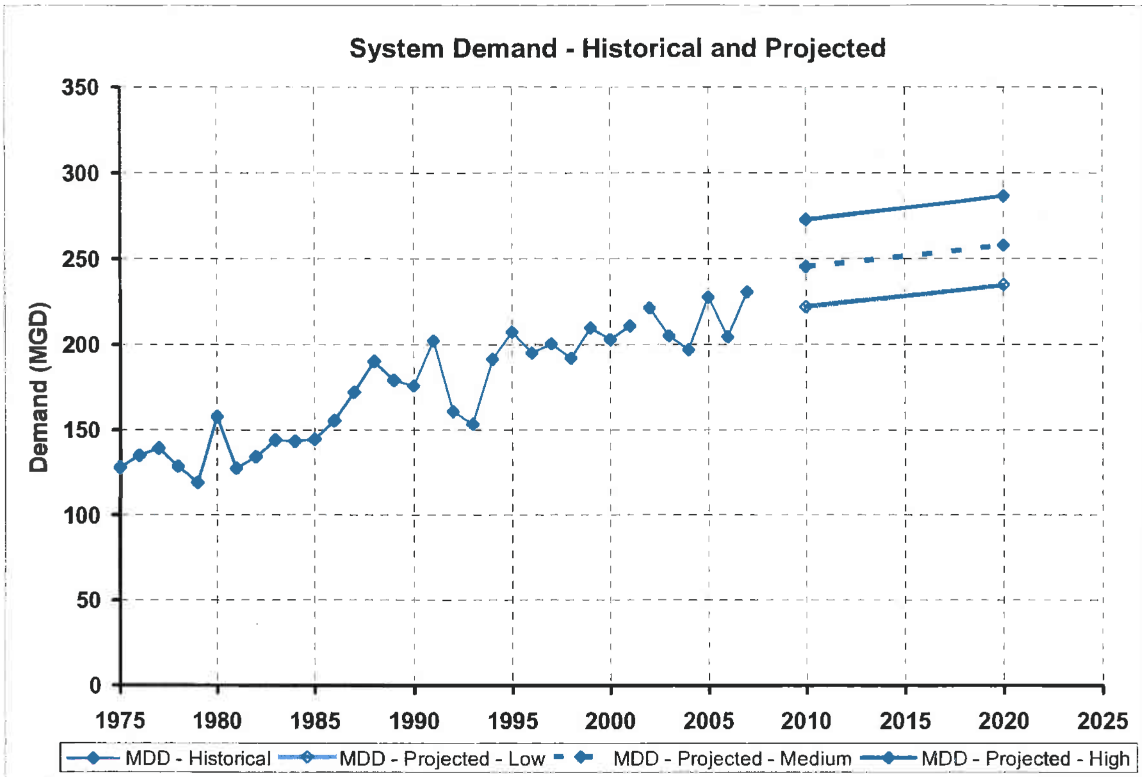

Figure 3-3 System Maximum Day Demand

Table 3-6 MDD/ADD and MHD/MDD Ratios		
Pressure Zone	**MDD/ADD**	**MHD/MDD**
Avon	2.08	1.73
Ben Davis	1.96	1.30
Boone County	3.36	2.94
Brown County	2.61	2.00
Castleton	2.44	1.55
Central	1.57	3.00
Cumberland	1.67	1.51
Flackville	1.48	1.61
Harbour	2.08	N/A
Lafayette	2.15	1.55
Meridian Hills	1.94	3.30
Morgan	3.16	3.16
Nora	2.74	1.90
Northeast	1.33	1.74
Northwest	2.17	1.58
Plainfield	3.61	1.71
Southeast	2.38	2.03
Southport	1.58	2.15
Southwest	3.67	2.99
System (2002 – 2006)	**1.64**	**1.30**

The upper 95th percent confidence interval ratio was calculated by adding the product of the inverse of the standard normal cumulative distribution for a probability of 95 percent, and the standard deviation of historical data to the average MDD:ADD value from Year 2002 through 2006 historical data.

If the historical MDD:ADD ratios were the same, then the standard deviation would be zero and the upper 95th percent confidence interval would equal the average historical ratio. The greater the variability in the historic values, the greater the standard deviation and resulting safety factor that is applied to project future MDD. Use of a recurrence interval of 20 years is a conservative value consistent with industry standards.

The MDD:ADD ratios for the upper 95th percent confidence interval were applied to the projected ADD in order to calculate the projected MDD for each pressure zone, and the resulting MDDs are presented in Appendix C and summarized in Table 3-7. Table 3-7 indicates that the future MDD for the overall system is projected to increase to 245.7 mgd by 2010, and 258.1 mgd by 2020 for the "medium" demand scenario.

Table 3-7
Projected Maximum Day Demand (mgd)

Pressure Zone	2010			2020		
	Low	Medium	High	Low	Medium	High
Avon	10.0	11.9	13.5	11.2	13.4	15.3
Ben Davis	15.1	16.4	17.6	15.2	16.5	17.8
Boone County	3.2	3.2	3.2	3.7	3.7	3.7
Brown County	0.8	0.8	0.8	0.9	0.9	0.9
Castleton	33.8	36.7	39.8	42.3	46.1	50.0
Central	35.6	38.2	43.1	34.9	37.5	42.2
Cumberland	26.3	27.9	29.6	29.6	31.3	33.3
Flackville	9.0	9.7	10.7	9.0	9.8	10.7
Harbour	2.8	3.3	3.7	3.4	4.0	4.6
Lafayette[1]	29.6	34.7	37.3	28.5	30.9	32.9
Meridian Hills[1]	8.8	9.2	10.0	9.2	9.7	10.5
Morgan	0.7	0.9	1.2	1.5	1.9	2.4
Nora[1]	5.7	6.7	7.2	4.9	5.2	5.5
Northeast	34.7	38.5	46.4	33.8	37.7	45.4
Northwest	2.9	4.1	4.9	4.9	7.0	8.3
Plainfield	1.3	1.4	1.6	1.5	1.7	1.9
Southeast	10.1	11.0	11.6	12.0	13.0	13.7
Southport	15.3	16.6	17.6	15.5	16.9	18.0
Southwest	15.5	18.8	21.1	18.2	22.1	24.7
SYSTEM[2]	**222.3**	**245.7**	**273.3**	**234.9**	**258.1**	**286.6**

1 – Reduction in demand from 2010 to 2020 reflects disconnection of the Carmel transition area.

3.7 MAXIMUM HOUR DEMAND

Maximum Hour Demand represents the highest net system delivery recorded for any hour during a year. Figure 3-4 displays the historical and projected MHD for the IW system. The historical maximum MHD for the VWI system, 313 mgd, occurred in 2007. The lowest ADD in recent years, 247 MGD, occurred in 2006.

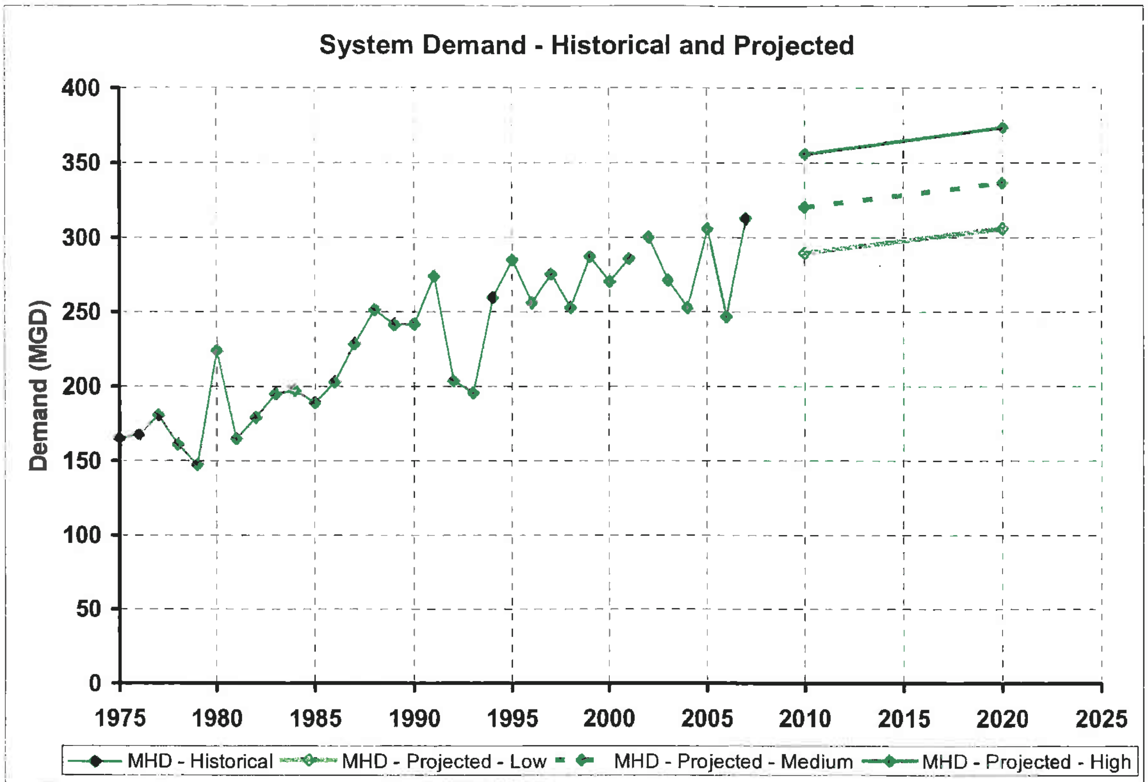

Figure 3-4 System Maximum Hour Demand

MHD is typically projected by multiplying MDD by a ratio or multiplication factor representing the historic relationship between MHD and MDD or ADD. Projections for IW were developed based on the 5-year average ratio of MHD to MDD. The resulting MHD projections are shown in Table 3-8. Table 3-8 indicates that the future MHD for the system is projected to increase to 320.3 mgd by 2010 and 336.6 mgd by 2020 for the "medium" scenario.

Table 3-8
Projected Maximum Hour Demand (mgd)

Pressure Zone	Year 2010			Year 2020		
	Low	Medium	High	Low	Medium	High
Avon	17.2	20.6	23.4	19.4	23.2	26.4
Ben Davis	19.6	21.2	22.8	19.7	21.4	23.0
Boone County	9.3	9.3	9.3	10.8	10.8	10.8
Brown County	1.6	1.6	1.6	1.7	1.7	1.7
Castleton	52.6	57.1	61.9	65.8	71.6	77.8
Central	106.8	114.7	129.3	104.8	112.6	126.7
Cumberland	39.9	42.2	44.8	44.7	47.3	50.4
Flackville	14.5	15.7	17.2	14.6	15.8	17.3
Harbour	N/A	N/A	N/A	N/A	N/A	N/A
Lafayette[1]	45.9	53.9	57.9	44.3	48.0	51.0
Meridian Hills[1]	29.0	30.5	33.1	30.5	32.1	34.6
Morgan	2.3	2.9	3.7	4.6	5.9	7.5
Nora[1]	10.7	12.7	13.6	9.4	9.9	10.4
Northeast	60.4	67.1	80.8	58.8	65.6	79.1
Northwest	4.5	6.5	7.7	7.7	11.1	13.1
Plainfield	2.1	2.4	2.7	2.6	2.9	3.2
Southeast	20.6	22.3	23.6	24.3	26.4	27.9
Southport	32.9	35.8	38.0	33.5	36.4	38.7
Southwest	46.4	56.3	62.8	54.3	66.0	73.9
SYSTEM[2]	**289.8**	**320.3**	**356.2**	**306.4**	**336.6**	**373.7**

1 – Reduction in demand from 2010 to 2020 reflects disconnection of the Carmel transition area.

2 – Does not include Harbour.

October 2008

Black and Veatch

Phase 2

Yield and Demand Study

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Section 4

4. DEMAND ALLOCATION

The purpose of this section is to summarize data that is included in Appendix D that is intended for use in allocating demand to VWI's hydraulic model. These data will enable demands to be assigned to model nodes for the base year (2006) and two projection years (2010 and 2020). The information described below also includes a general overview of a process that can be used to allocate demand using the data provided in Appendix D.

As described in Section 4.1, the data provided in Appendix D consists of a combination of a spreadsheet, shapefiles, and a geodatabase that will enable the special distribution of demand to be assigned to the hydraulic model for each of the aforementioned average day demand (ADD) scenarios. Base year demands are intended to be assigned using a geodatabase of actual customer locations, which are supplemented by a spreadsheet containing the estimated amount of water consumption and unaccounted-for water (UAW) associated with each of the pressure zones. A shapefile containing the estimated demand change in each of the Transportation Analysis Zones (TAZ) is provided for use in allocating demand in each of the projection years.

The allocation process described in Section 4.2 reflects the use of actual customer locations to determine the distribution of demand for approximately 80 percent of the base year ADD. The projected change in population within each of the TAZs was used to adjust the base year demand allocation for the future projection years. Although other factors will influence the relative amounts of growth throughout the service area, population is the only one for which projections were available for use on this study.

4.1 DATA DESCRIPTION

Appendix D contains an Excel spreadsheet summarizing the 2006 unmatched (where address information for the billing meter was not complete and/or exact spatial locations could not be determined) consumption for each pressure zone, as well as the UAW for each district for 2006, 2010 and 2020. It also includes a geodatabase with the location of the 2006 billing meters and their corresponding 2006 consumption values.

The appendix also includes a shapefile for the TAZ layer, which can be used to assign the projected consumption to model nodes. The TAZ layer shapefile attribute data includes the difference in the projected demand for 2010 and the recorded consumption for 2006 for each TAZ. The attribute data also contain the difference in the projected demand for 2010 and 2020. This shapefile can be used to distribute the increase in demand to the nodes lying within a particular TAZ.

4.2 BASE YEAR ALLOCATION PROCESS

For the base year 2006, billing meter geodatabase can be used to automatically assign the demand to the model nodes by using the hydraulic modeling software's demand allocation tool. Unmatched customer consumption should be distributed to different pressure zones in the same proportion as the geocoded consumption, with each node within a zone receiving an equal share. UAW water for each pressure zone should also be distributed equally to the junctions within a particular zone. This process will allocate demand to those nodes created during the model construction process including any nodes that are intended to be assigned demands for specific customers such as wholesale customers, large water users, or locations identified for future development.

In general, the information provided in Appendix D does not identify separate demands that are required to be associated with specific nodes. Exceptions include Boone County (Whitestown), Brown County, and planned developments for Duke and Lebanon. The demands for these customers are not included in the geodatabase or shapefile and must be added to the model at the appropriate locations. If VWI identifies additional customers for which assignment of demands to specific nodes is desired, then the corresponding consumption would need to be subtracted from the system demands prior to completing the allocation steps described above. The consumption could then be assigned to the specific nodes.

A base year maximum day demand (MDD) demand scenario can be developed by multiplying the ADD demand scenario by the system wide MDD:ADD ratio for 2006. Maximum hour demand (MHD) demand scenario for base year can be developed by multiplying the MDD demand scenario by the system wide 2006 MHD:MDD ratio. The ratio between 2007 (or 2008) MDD or MHD and 2006 ADD could also be used to develop more recent base year peak demand conditions using the ADD demand allocation for 2006. Use of these global demand factors will result in demands that match the system-wide peak demand conditions.

Pressure-zone specific peaking factors can also be applied to separately evaluate maximum day and maximum hour conditions for individual pressure zones.

4.3 PROJECTION-YEAR ALLOCATION PROCESS

The allocation process for the projection years 2010 and 2020 is similar to the base year allocation process. However, one key difference is the use of the TAZ shapefile to assign an increase (or decrease) in demand to the model junctions rather than loading a completely new set of demands for these years. The increase in consumption from 2006 to 2010 and 2010 to 2020 for a particular TAZ should be equally distributed to the model junctions lying within that TAZ, and repeated for the TAZ within the service area. The process of assigning UAW and applying peaking factors for MDD and MHD would be the same as for the base year scenario described in Section 4.2.

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Section 5

5. DEMAND EVALUATION SUMMARY

5.1 OVERVIEW

The projected water demands indicate growth in most Indianapolis water system pressure zones for 2010 and 2020. The average day demand (ADD) increased at an average rate of 1.75 mgd per year between 1975 and the Year 2000. Since the Year 2000, the average rate of increase in ADD has been 2.16 mgd per year. These data indicate that recent growth and expansion of the IW system has kept pace with the historical trend.

Based on a projected system-wide demand of 154.8 mgd by 2010, the trend for the 10-year period will be an increase of 2.15 mgd per year. In contrast, slower growth, coupled with the loss of the Carmel area, is projected to result in an average ADD increase of about 0.8 mgd per year between 2010 and 2020. The projected ADD increase from 2010 to 2020 would be about 1.3 mgd per year without the loss of Carmel.

The largest share of growth is expected to occur within the Cumberland, Southwest, and Castleton pressure zones. Lafayette and Central are also projected to experience increases by 2010; however, the loss of Carmel from the Lafayette pressure zone and a projected decline in population for Central will reduce ADD for these zones by 2020. Ben Davis is another pressure zone in which demand is projected to decrease between 2010 and 2020. In addition to continued growth within Cumberland, Castleton, and Southwest, the Northwest pressure zone is also projected to experience a relatively large increase in ADD between 2010 and 2020.

The peaking characteristics of the system reflect a combination of climate-related influences, changes in the customer mix, demographic characteristics, water rate structures, and lifestyle changes impacting the nature and amount of water use – primarily for outdoor irrigation. The ratio of maximum day demand (MDD) to ADD is a common benchmark for a water system's peaking characteristics. Therefore, the trend of historic MDD:ADD ratios for the water system since 1975 was reviewed to evaluate the impact on future projections.

The average MDD:ADD ratio since Year 1975 is 1.46, and the long-term trend is an increase of 0.05 every 10 years. However, the trend over the past 20 years is a decline of only 0.02 every 10 years, which indicates that the peaking characteristic has stabilized. In the absence of a definitive trend and to capture the current composition of the system, data over the past five years was used for the purpose of projecting future MDD for the water system. A safety factor was applied to the resulting average value of 1.48, resulting in a MDD:ADD ratio of 1.58 that was used in the development of the 2010 and 2020 MDD projections.

5.2 COMPARISON WITH PRIOR PROJECTIONS

As discussed in Section 3, system-wide ADD for the “medium” scenario is projected to increase to 154.8 mgd by 2010 and 162.5 mgd by 2020. These demands are about 5.0 mgd higher that the projections from the 2003 Phase 1 projections of 149 mgd in 2010 and 157.5 mgd by 2020. Although current projections for the “medium” demand scenario are higher, previous projections are within the range bracketed by current “low” scenario projections of 140.1 mgd in 2010 and 147.9 mgd by 2020.

“Medium” scenario projections for MDD are for an increase to 245.7 mgd in 2010 and 258.1 mgd by 2020. The 2003 Phase 1 report did not include MDD projections; however, VWI developed its own MDD projections of 257 mgd and 276 mgd for 2010 and 2020, respectively, and included them in its September 2006 Short- and Long-Term Plan. While developed from 2020 ADD projection of 157.5 mgd and a similar MDD:ADD ratio of 1.53, they also include additional demand associated with existing and future wholesale customers and planned developments.

According to the Short- and Long-Term Plan, the anticipated conversion of the Carmel system was a consideration in establishing the MDD of 257 mgd for 2010. As indicated previously, the currently projected 2010 MDD, 245.7 mgd, includes Carmel, thereby precluding an equal comparison with the above figure. A primary reason the current projections are lower is that they do not include additional demand associated with wholesale customers, but instead consider that demand to be reflected in the historical water consumption and peaking factors. Nevertheless, the current “high” scenario projections of 273 mgd and 286 mgd in 2010 and 2020, respectively, establish upper brackets for the earlier projections.

Since sales to wholesale customers cannot be determined on a daily basis, the magnitude of their contribution to the system-wide peak demands is unknown. These customers may be taking more than their maximum purchase agreement amounts on any given day, and the resulting impact on demand is not currently quantified. As the actual consumption and total maximum purchase amounts associated with these customers increase, eliminating the uncertainty in their water usage by installing meters to monitor daily or continuous sales will have increasing value with respect to demand projections and overall water supply planning.

The above comparisons with prior demand projections are useful for setting new benchmarks that will be used to guide recommendations and projects needed to maintain adequate and reliable water supply service to VWI customers. However, there are significant differences in the approaches used to develop the current and historical demand projections, and these differences should be considered in any comparisons that are made.

5.3 DEMAND MANAGEMENT

The current demand projections and alternative demand scenarios developed for the water system rely on recent water consumption trends exhibited by VWI's customers. The water consumption factors were observed to vary spatially from pressure zone to pressure zone, temporally as impacted by weather, and across customer categories. As previously indicated in Section 3.2, consumption factors representing the average values from Year 2002 through 2006 were used to develop the "medium" scenario water demand projections. No adjustments were made to account for the likelihood that higher consumption would occur during hot, dry years or to address the use of demand management as a means to promote efficient water use and/or require water use reductions under drought conditions.

Accordingly the purpose of this section is to briefly describe industry water demand management approaches and corresponding water savings potential, and compare them with current and proposed measures for the water system. Although not a focus of this report, VWI's assumptions regarding the level of UAW that can be achieved and programs that will need to be implemented to maintain these levels should be recognized as another key factor affecting the ability to provide a reliable source of supply for VWI's customers. In any case, decisions regarding the implementation of leakage reduction and/or pipeline renewal programs can be made independent of demand management strategies.

Water demand management strategies are generally considered either long-term or short-term in nature. Long-term water demand management strategies include measures designed to promote efficient water use practices that, once in place, are considered relatively permanent. Short-term water demand management strategies typically involve some sort of water use restrictions that are put in place to reduce water use on a temporary basis. Water use restrictions are usually put in place in response to water emergencies associated with events occurring within the water system such as a treatment facility failure, fire, water main breaks, and interruptions or shortages in source of supply capacity as could be the case in the event of a drought.

5.3.1 Conservation

Elements of long-term conservation programs can be implemented by various groups, including the end users (residential, industrial and agricultural) and water suppliers (utilities). Table 5-1 lists some of the common practices for water conservation by each of these entities.

Table 5-1
Examples of Water Conservation Practices

Residential End User	Industrial End User	Agricultural End User	Water Suppliers (Utilities)
Low-flush toilets	Water reuse and recycling	Irrigation practices to distribute water more effectively	Metering
Toilet displacement devices	Cooling water recirculation	Monitoring soil and water conditions	Leak detection programs
Low-flow showerheads and faucets	Reuse of deionized water	Water reuse and recycling	Water main rehabilitation programs
Faucet aerators	Efficient landscape irrigation practices		Water reuse
Pressure reducing valves on service connection			Retrofit programs
Gray water use			Modifications to existing rate structure
Efficient landscape irrigation (xeriscape)			Public education

In order to develop a cost-effective water conservation program, the United States Environmental Protection Agency (USEPA) and American Water Works Association (AWWA) recommend that the following activities be analyzed:

- Review detailed demand forecasts
- Review existing water system profile and descriptions of planned facilities
- Evaluate the effectiveness of existing conservation measures
- Define conservation potential
- Identify conservation measures
- Determine feasible measures
- Perform benefit-cost evaluations
- Select and package conservation measures
- Combine overall estimated savings
- Optimize demand forecasts

As shown in Table 5-1, long-term savings from water conservation efforts can be achieved with respect to both indoor and outdoor water usage. Potential savings of upwards of 20 to 30 percent may be possible depending on a number of factors that vary from system to system and for different areas within individual water systems. Savings of this magnitude may take many years to attain, and require selection of the right combination of technology, policies, and economic incentives. The percentage savings possible also depends on a water system's existing level of water use efficiency, as more water-efficient systems may only attain the lower end of the range of potential savings and/or require more time to do so.

The cost-effectiveness of achieving any feasible level of water savings will depend on the above factors, as well as a particular water system's existing and projected source of supply adequacy, system growth, and available alternatives for supplementing or offsetting the need for additional water supplies. Consequently, feasible elements of a long-term conservation program may or may not be included in a strategy to maintain adequate supply capacity. However, given the uncertain magnitude and duration of drought conditions, proactive long-term conservation efforts have the advantage of being able to preserve available water supply and perhaps avoid the need for drastic water use reduction measures and their associated costs.

5.3.2 Water Restrictions

Per the AWWA Manual of Water Supply Practices, *Water Conservation Programs - A Planning Manual*, "water restrictions can be a useful emergency tool for drought management or service disruptions." Water restrictions are typically implemented through policies or local ordinances that may include one or more of the following elements:

- Odd/even watering days
- Time-of-day restrictions
- Car or truck washing
- Sidewalk and street cleaning
- Outdoor watering ban

In addition to the water restriction program elements, other factors that influence the ultimate savings potential include whether the measures are mandatory or voluntary, whether they are accompanied by time-of-day restrictions, and whether tiered water rate structures are implemented.

These savings can be expressed in terms of their reduction of maximum hour, maximum day, summer average day, and annual average day demands. Measures that mandate the elimination of certain water uses should generally result in a reduction in demands over all durations. However, the benefits of odd/even watering restrictions are less clear. Theoretically, it should reduce the maximum day demand. However, odd/even watering may result in an unexpected increase in the use of water since people are alerted to the fact that they can only water on certain days. This could lead to the unintended consequence of "concentrating" demand to a level higher than would have occurred without the restrictions. Odd/even restrictions are even less likely to achieve a substantial reduction in summer average day demand, particularly if the restrictions are not accompanied by time-of-day limitations or tiered water rates, which influence the convenience, watering efficiency, and cost of lawn watering.

The severe dry conditions that persisted through parts of eastern U.S. during 2007 and early 2008 necessitated the implementation of various water use reduction measures. Preliminary information for a few systems in the Southeast United States indicates that water use was reduced by about of 20 to 30 percent. Although the data have not been comprehensively evaluated, the savings appear to reflect the effect of outdoor watering restrictions on summer average day demand conditions. This range appears consistent with at least one literature article indicating that a 25 percent reduction in outdoor water use and a 15 percent reduction in indoor water use could be attained as a result of restrictions, and maintained for a period of up to two years without having a substantial negative impact. Over the past five years, peak summer day demands in the Indianapolis water system have ranged from 200 to 230 mgd. Considering an estimated summer irrigation demand of 60 mgd, VWI's potential savings associated with water restrictions is at the upper end of the range noted above.

Like long-term conservation savings, the reduction in water demand associated with water restrictions is water system specific. The relative proportion of outdoor irrigation to total consumption for the average water customer is a major factor affecting the water savings potential associated with water restrictions.

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Section 6

6. YIELD EVALUATION INTRODUCTION

6.1 PROJECT SCOPE AND OBJECTIVES

The Indianapolis water system provides potable water to nearly a million people. Since the City is not located near a large river or large body of water, Indianapolis relies on a complex system of surface and groundwater sources, multiple water treatment facilities, and a large network of distribution pipelines for potable water supply. Yield studies of this complex water system have been performed since the 1920s to inform the water utility, customers, and the community about the ability of the system to meet water demands in times of drought.

In 2007, Veolia Water Indianapolis (VWI) directed Black & Veatch (B&V) to perform an updated yield evaluation of the water system. This evaluation uses the valuable experiences of VWI personnel during high water demands and system details known at this time or anticipated in the future to develop a more refined daily yield analysis. This study provides an estimate of yield that can be compared to both average day and maximum day demands. The information presented in this report will assist VWI and the City in developing sustainable water resources for the Indianapolis area and in addressing the financial, social, and environmental issues associated with sustainable development.

This technical memorandum includes a summary of the following major scope items:

- Data collection and review
- Evaluation of water production in recent years
- Selection of drought conditions for system evaluation
- Development of surface water and groundwater models to evaluate the safe water supply yield of the system
- Results of the yield evaluation
- Comparison of yield to future water demands Draft Demand Evaluation Technical Memorandum, Black & Veatch, 2008
- Recommendations for future water supply

The scope of this technical memorandum and the Demand Evaluation Technical Memorandum does not include an evaluation of the adequacy of the pipes and treatment facilities to distribute water to VWI's customers. Rather, the intent of the memoranda is to provide "book-end" information for how much water can be obtained at the sources of supply and how much water will be consumed throughout the City in the future. VWI has a hydraulic model of the distribution system and will be performing analyses of how to move water from the sources of supply to the customers using the results of these yield and demand evaluations.

6.2 INFORMATION COLLECTED AND REVIEWED

Because of the complexity of the Indianapolis water supply system, a large amount of information was collected and reviewed. Major pieces of information include recent production and consumption records, system capacity, reservoir data, streamflow data, climate data, operational constraints, minimum downstream flow requirements, data for other water users in the area and upstream of Indianapolis, hydrogeologic information, recent groundwater reports, pressure district information, and population data. A complete list of the information reviewed and the sources of the information is given in Section 15.0.

6.3 ACRONYMS AND ABBREVIATIONS

ac	Acre
ADD	Average Day Demand
AWWA	American Water Works Association
B&V	Black & Veatch
bgs	Below Ground Surface
CD	Compact Disk
cfs	Cubic Feet per Second
CSO	Combined Sewer Overflow
DOW	Department of Water
DPW	Indianapolis Department of Public Works
est.	Estimated
FC	Fall Creek
ft	Feet/Foot
FEMA	Federal Emergency Management Administration
GMS	Groundwater Modeling System
GPCD	Gallons per Customer per Day
gpm	Gallons per Minute
GWF	Geist Wellfield

IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
IPL	Indianapolis Power and Light
IW	Indianapolis Water
MCRWC	Morgan County Rural Water Corporation
MDD	Maximum Day Demand
mgd	Million Gallons per Day
MHD	Maximum Hour Demand
min	Minimum
MSL	Mean Sea Level
NCDC	National Climate Data Center
NOAA	National Oceanic and Atmospheric Administration
NRW	Non-Revenue Water
RS	Riverside
SWF	South Wellfield
SWWF	Significant Water Withdrawal Facilities
TAZ	Transportation Analysis Zone
UAW	Unaccounted for Water
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VWI	Veolia Water Indianapolis
WR	White River
WRN	White River North
yr	Year

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Section 7

7. SOURCES OF SUPPLY AND RECENT WATER PRODUCTION

The sources of supply for Indianapolis have been described in detail in previous reports, including "Short and Long Term Plan" (VWI, 2006), "Water Conservation Plan" (VWI, 2004), and "Water Supply Yield and Demand Evaluation" (Black & Veatch, 2003). Each source of supply, shown on Figure 7-1, is summarized briefly in this section, including information on recent production from these sources and a historical look at the City's water supply.

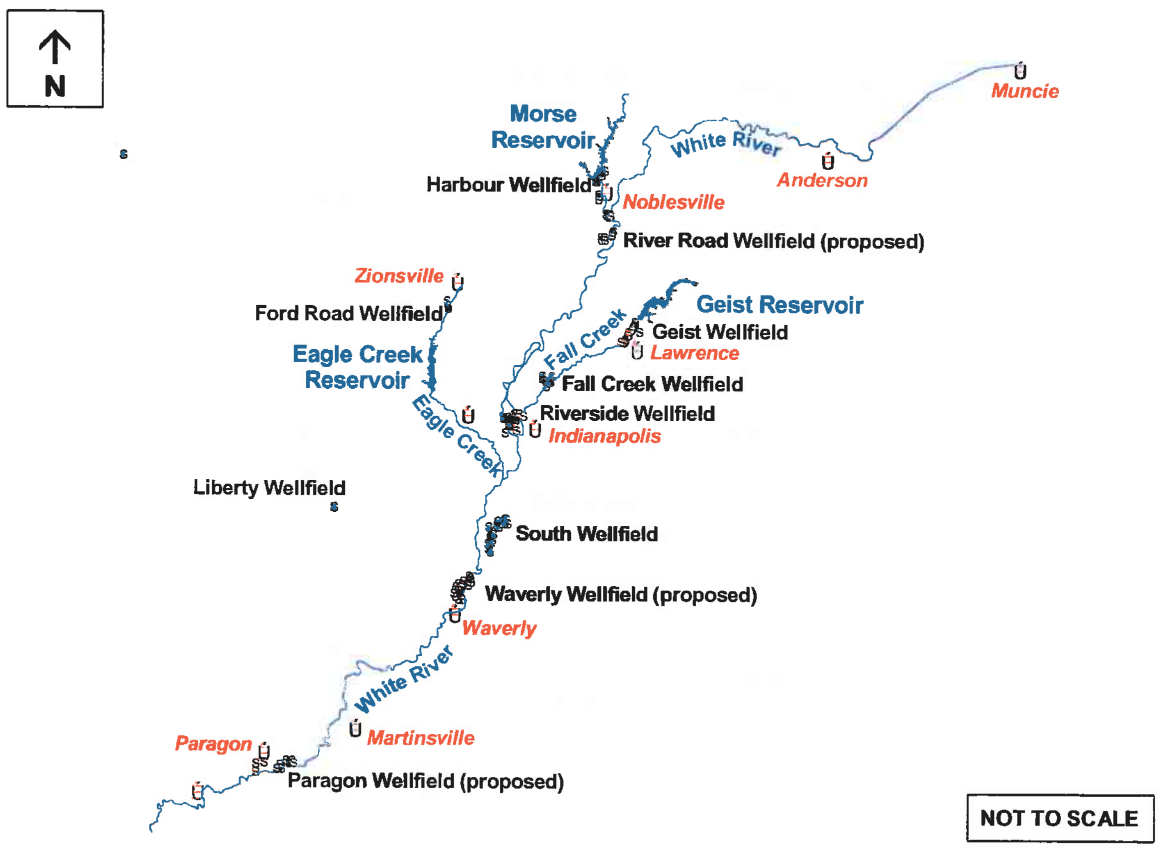

Figure 7-1 City of Indianapolis Water Supply Sources (2008)

7.1 BRIEF HISTORY OF THE PUBLIC WATER SUPPLY IN INDIANAPOLIS

The Indianapolis Central Canal was constructed in the mid-1800s as a means of transportation, recreation, and to provide power to companies such as sawmills and woolen mills. In 1870 the Water Works Company of Indianapolis began using the canal water to generate power to pump two large diameter groundwater wells for a public water supply. Initially, it was difficult to get people to give up their private wells for the new public supply. In 1873, there were only about 800 customers out of a population of about 50,000, and by 1880, only 1400 customers out of a population of about 75,000. The Water Works was then sold to the Indianapolis Water Company (IWC) in 1881; In 1896, IWC developed a total of twenty-six deep bedrock wells in the Riverside area capable of producing up to 14 million gallons per day (mgd). In 1904, the Water Company began treating surface water from the canal using slow sand filters with a capacity of 36 mgd. Of the total capacity of nearly 50 mgd, IWC was supplying an average of 16 mgd to 14,296 customers, including contracts with ice-making companies and power companies (Bakken, 2003).

The first water supply yield and demand study completed in 1923 concluded that the natural flows in the White River and Fall Creek were not sufficient to meet the City's growing water needs (Giffin, 1981). In the 1920s and 1930s, IWC negotiated several rate increases allowing the construction of additional infrastructure including Geist Reservoir. IWC later decided that another reservoir needed to be constructed to supplement natural White River streamflows during dry conditions. Additional rate increases were negotiated in the early 1950s for the construction of Morse Reservoir. The reported yield of the White River system was tripled from 25 mgd to 75 mgd with Morse Reservoir, although it is unknown what drought conditions for which this estimate was made. The rate increases for these costly supply expansions were most likely justified in large part due to the dry climate conditions of the 1930s, 1940s, and 1950s.

Additional drought conditions in the late-1960s spurred the idea for another reservoir of nearly 21 billion gallons called Highland Reservoir on Mud Creek to the west of Geist Reservoir. This proposal met political opposition. The reservoir proposal was rejected in the early 1970s, and water company officials warned that, someday, the decision would be regretted because of future water shortage and reduction in land availability. The publisher of The Indianapolis Star at the time said "The termination of the Highland (Reservoir) proposal spells trouble down the road. I just can't believe that there's enough well water to supply the future needs of this metropolitan area" (Giffin, 1981). Following the rejection of the Highland Reservoir, there were proposals to enlarge the storage volume of Geist Reservoir or construct a new reservoir upstream of Geist, but neither of these ideas moved forward.

Eagle Creek Reservoir was completed by the City of Indianapolis in 1967 for the primary purpose of flood control. Water rights have been granted to Indianapolis Water by the City since 1976 for an average of 12.4 mgd for water supply.

Water supply yield studies have been updated approximately every decade since the 1970s to gain a better understanding of this complex system in an attempt to optimize the use of available water resources to meet growing demands. Since the 1970s, some additional surface water facility capacity has been added, such as the White River North facility and upgrades to the White River and Fall Creek facilities, and new wells have been installed at South Wellfield, Geist, Ford Road, and White River North to tap groundwater supplies. Today, over 80 percent of the City's water needs are being met from water supplies developed prior to the 1970s, with most of this being met by surface water from the Morse-White River and Geist-Fall Creek systems.

Figures 7-2 and 7-3 show the estimated historical customers served and average day consumption (Bakken, 2003; VWI, 2006; Black & Veatch, 2003).

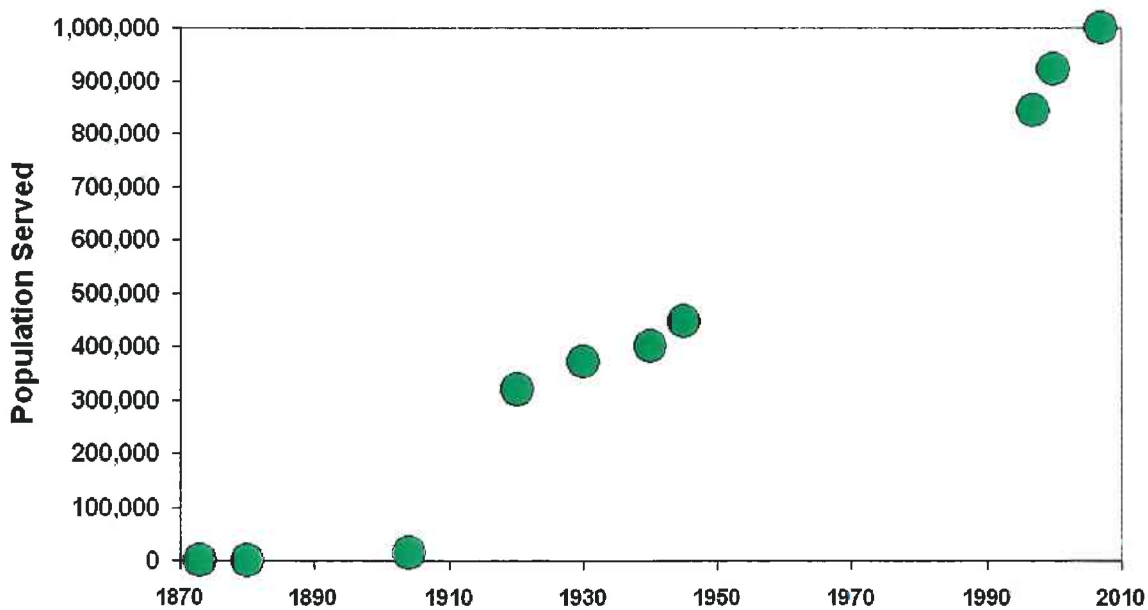

Figure 7-2 Historical Customers

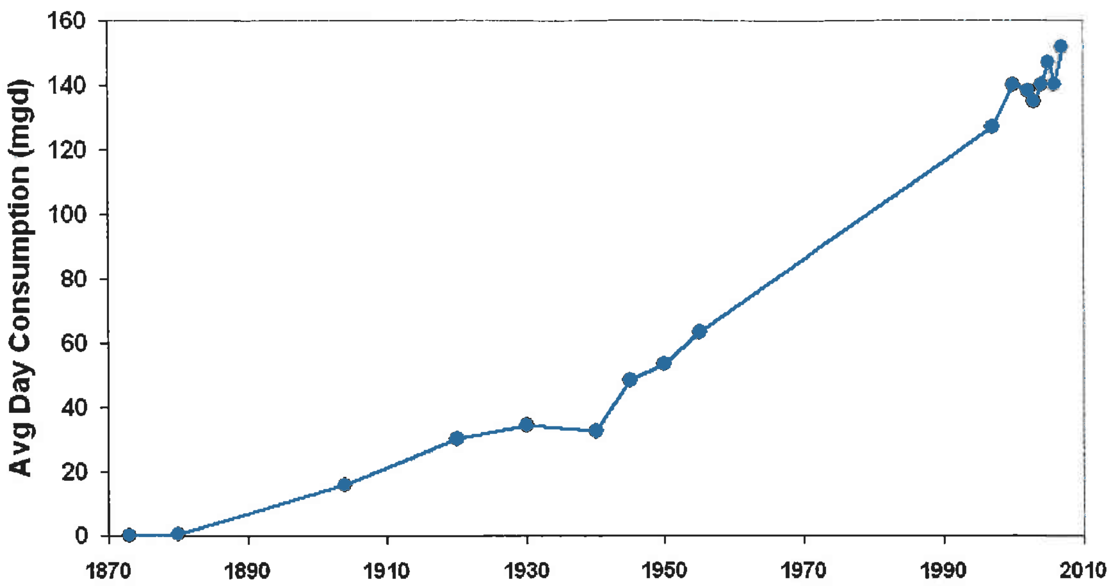

Figure 7-3 Historical Average Day Consumption

(see Figure 4-1 in Water Conservation Plan (VWI, 2004) for more detail from 1940 to present)
(see Demand Report for more detailed annual numbers from 1975-2007)

7.2 RECENT PRODUCTION

Figure 7-4 shows how water consumption has increased in recent decades.

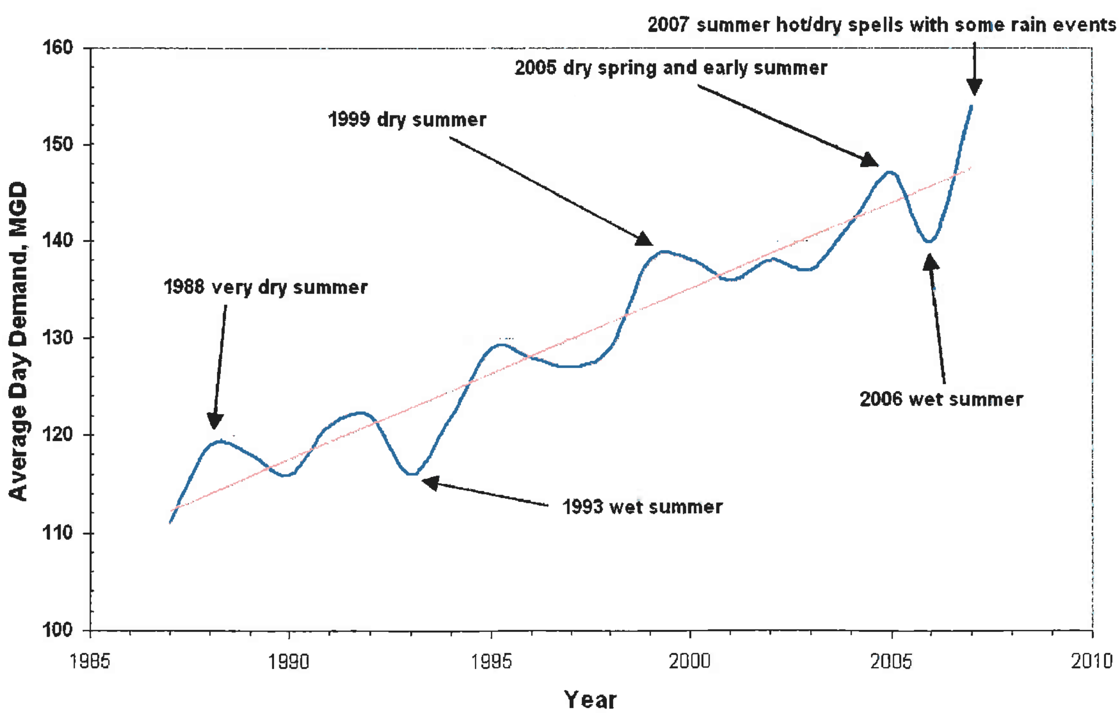

Figure 7-4 Average Day Consumption in Recent Decades

The graph shows how water production fluctuates depending on the weather conditions from year to year. VWI had an average 2007 daily production of about 153 mgd. Average daily production from 2002 through 2006 ranged from approximately 136.7 to 146.5 mgd. Maximum daily production in 2007 occurred on 6/13/2007 when a total of approximately 229 mgd of raw water was produced. This exceeded the maximum day production of about 225 mgd that occurred on 6/26/2005. The total rated treatment capacity of the existing system is approximately 213.8 mgd. When production exceeds this level, the existing water system capacity* begins to be compromised (see Figure 7-5).

Recent summertime water production records showed that water customers used the most amount of water early in the summer. Through the rest of the summer, water production spiked to between 200 and 225 mgd for about a week or so on about three or four more occasions. Between these spikes, production dropped to between 160 to 180 mgd for approximately a week. These drops in production corresponded to periods following rainfall events, as shown on Figure 7-6, accompanied by slightly cooler temperatures. The difference between peak water production and low water production during the summer months agrees with the City's estimate of about 60 mgd for outdoor irrigation (Department of Waterworks press release 4/17/2008).

* "Capacity" refers to the size of pumps, treatment facilities, and pipes. It should not be confused with the term "yield", which refers to the amount of raw water available at the sources of supply. For purposes of this report, capacity is related to man-made facility limitations; yield is related to the availability of raw water in streams and aquifers for a selected drought condition

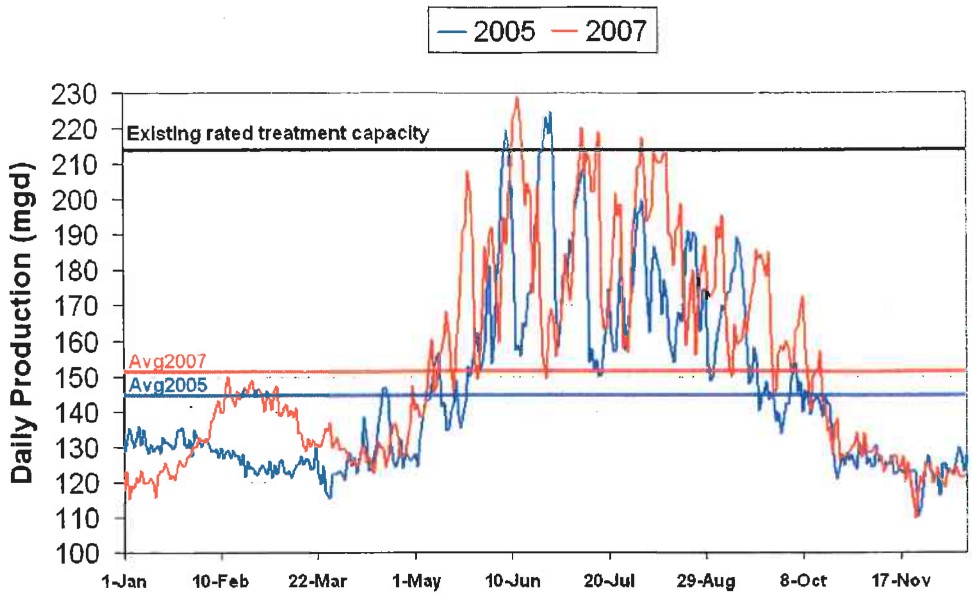

Figure 7-5 Total Raw Water Production 2005 and 2007

(from VWI spreadsheets Pc05dec.xls, Pc07dec.xls, and HWCProduction2007Dec.xls; does not include water purchased from others such as Westfield or Plainfield)

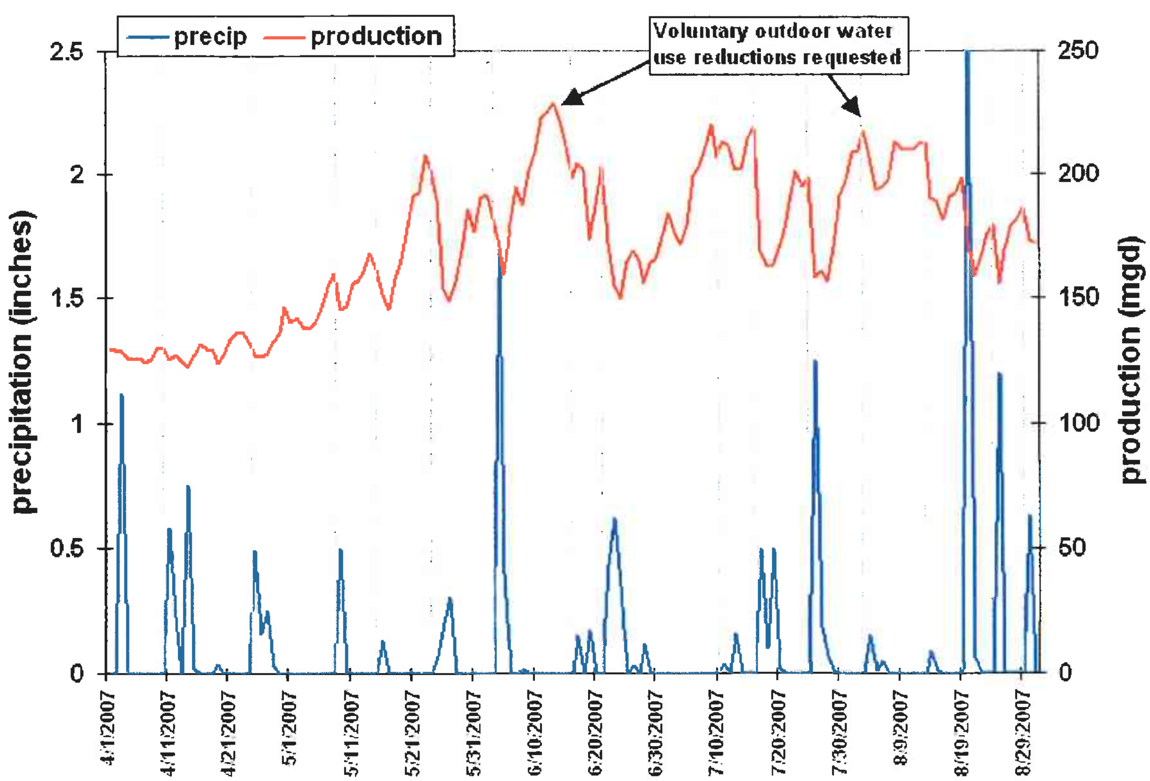

Figure 7-6 2007 Summertime Production versus Precipitation

(Vertical gray lines show beginning of rain event, which correspond with decreases in outdoor water usage on every occasion)

In 2007, surface water accounted for between 70 and 90 percent of the water treated by VWI, with groundwater accounting for the remaining 10 to 30 percent, as shown on Figure 7-7. Figure 7-8 shows the approximate total amount of groundwater and surface water produced in 2007.

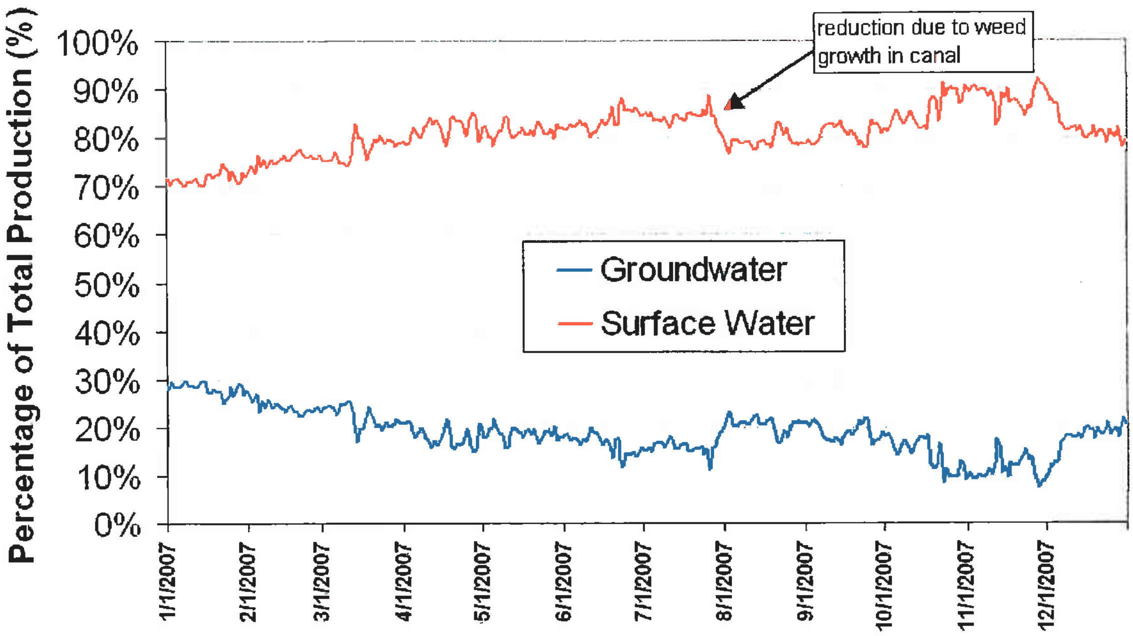

Figure 7-7 2007 Groundwater versus Surface Water Production Percentages

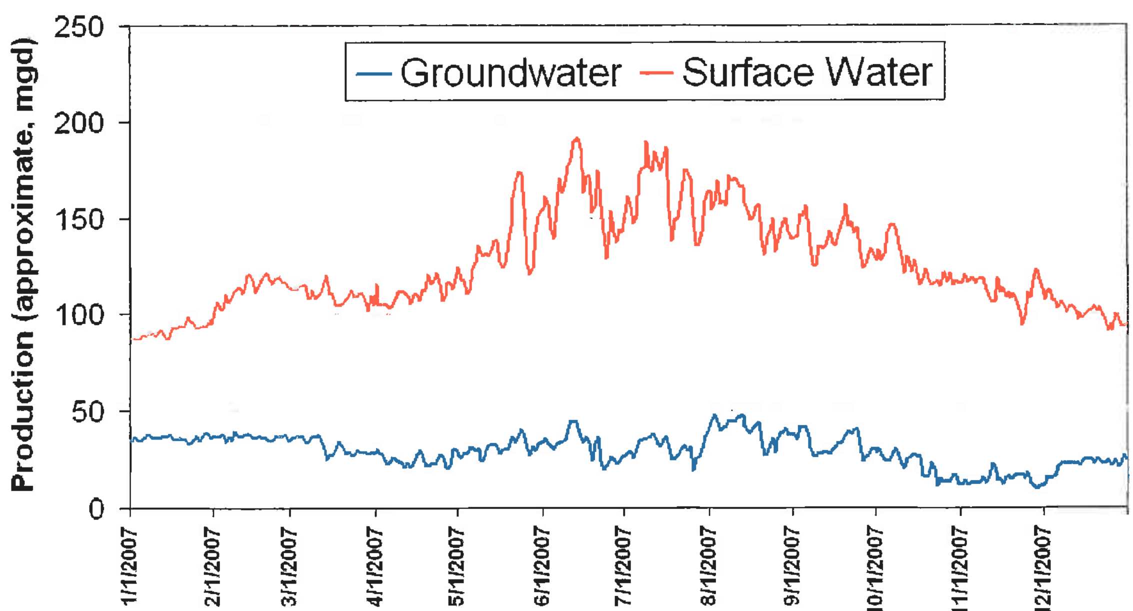

Figure 7-8 2007 Groundwater versus Surface Water Production

These graphs show that the groundwater production was relatively consistent throughout 2007, with some decrease in the spring and occasionally in the summer in response to declining groundwater levels and periods of reduced demands. VWI relies primarily on increased surface water production in the summer in response to higher demands. In late July, surface water production decreased slightly because of weed growth in the canal. From September through December, production from both surface water and groundwater decreased with lower demands.*

7.3 SURFACE WATER SOURCES

The primary sources of surface water include the White River and its tributaries, Fall Creek and Eagle Creek. For a city the size of Indianapolis, the natural flows in these streams would not be sufficient to meet water demands; therefore, are used to store water during periods of higher streamflows and release water during periods of lower streamflows.

7.3.1 White River-Morse Reservoir

The White River system, as shown on Figure 7-9, is the primary source of water for Indianapolis. As the City grew, natural streamflow in the White River and groundwater in the aquifer at Riverside were no longer sufficient to meet water demands. Because of this, Morse Reservoir was constructed in 1955 on Cicero Creek, a tributary of the White River. When natural flows in the White River decrease, VWI personnel call for water releases from Morse Reservoir to supplement streamflows to both the White River and White River North surface water treatment plants. Major considerations for this surface water supply include (1) deciding when to make releases from the reservoir and how much to release; (2) maintaining minimum flows over the Broad Ripple Dam; (3) accounting for water supply canal issues such as weed growth, sedimentation, and seepage losses, (4) deciding how much streamflow to divert to each treatment plant; and (5) deciding the percentage of surface water and groundwater to pump and treat at each plant.

Based on a bathymetric survey performed by the United States Geological Survey (USGS) in 1996, sedimentation did not appear to be a significant issue

* If groundwater production could be significantly reduced in the wintertime (relying primarily on surface water when higher streamflows are available in the winter), more groundwater yield may be available in the summer months during peak demands. However, VWI must produce groundwater in the wintertime in order to (1) reduce main breaks in the distribution system, (2) enhance alum coagulation at the plants and (3) as a side benefit prevent ice from forming in the basins at the plants.

for Morse Reservoir, although it is prudent to continue to monitor for any changes in reservoir storage.

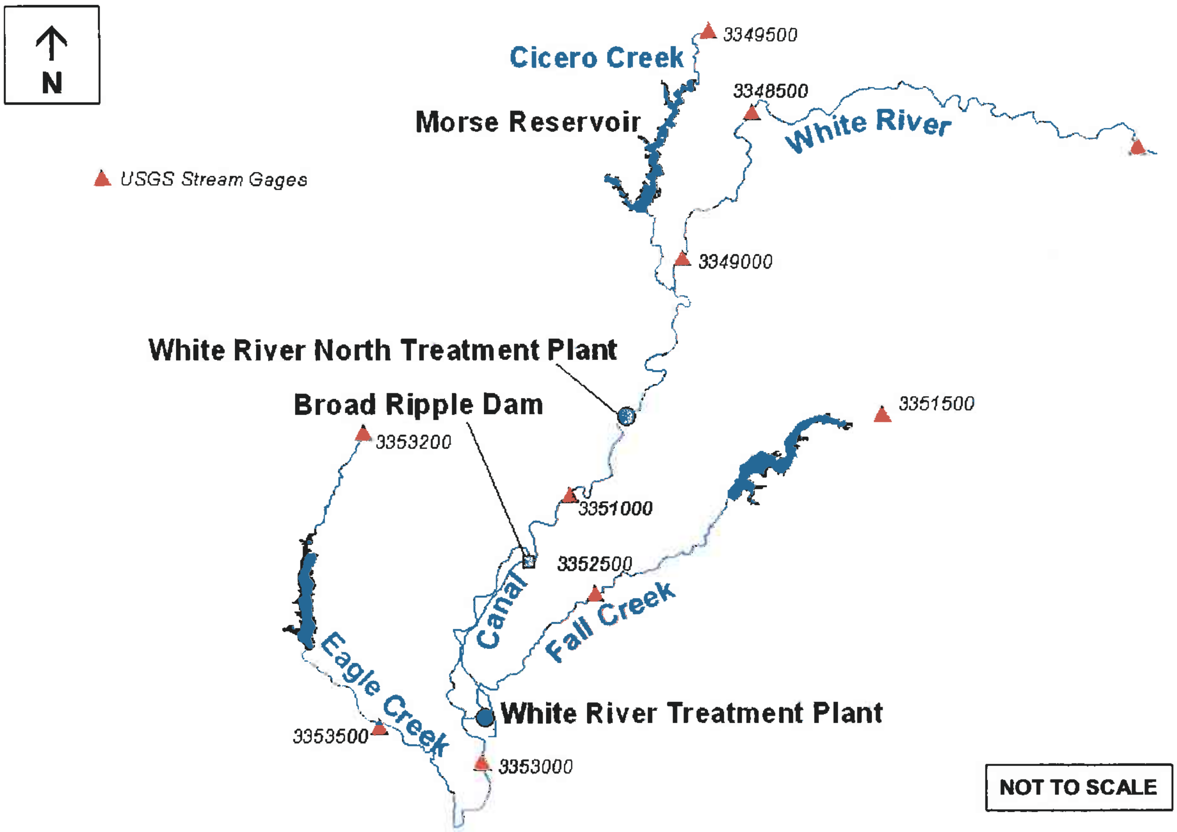

Figure 7-9 White River Surface Water System

7.3.2 Fall Creek-Geist Reservoir

Fall Creek is the second largest source of surface water for Indianapolis. Figure 7-10 shows the Fall Creek system. In order to maintain enough streamflow in Fall Creek for a reliable source of water, Geist Reservoir was constructed in 1943. Releases are made from the reservoir, and streamflow is diverted at Keystone Dam to the Fall Creek Water Treatment Plant. Major considerations for this surface water supply include (1) deciding when to make releases from the reservoir and how much to release; (2) maintaining minimum flows over Keystone Dam; and (3) deciding the percentage of surface water and groundwater to pump and treat at the treatment plant.

Based on a bathymetric survey performed by the USGS in 1996, sedimentation did not appear to be a significant issue for Geist Reservoir, although it is prudent to continue to monitor for any changes in reservoir storage.

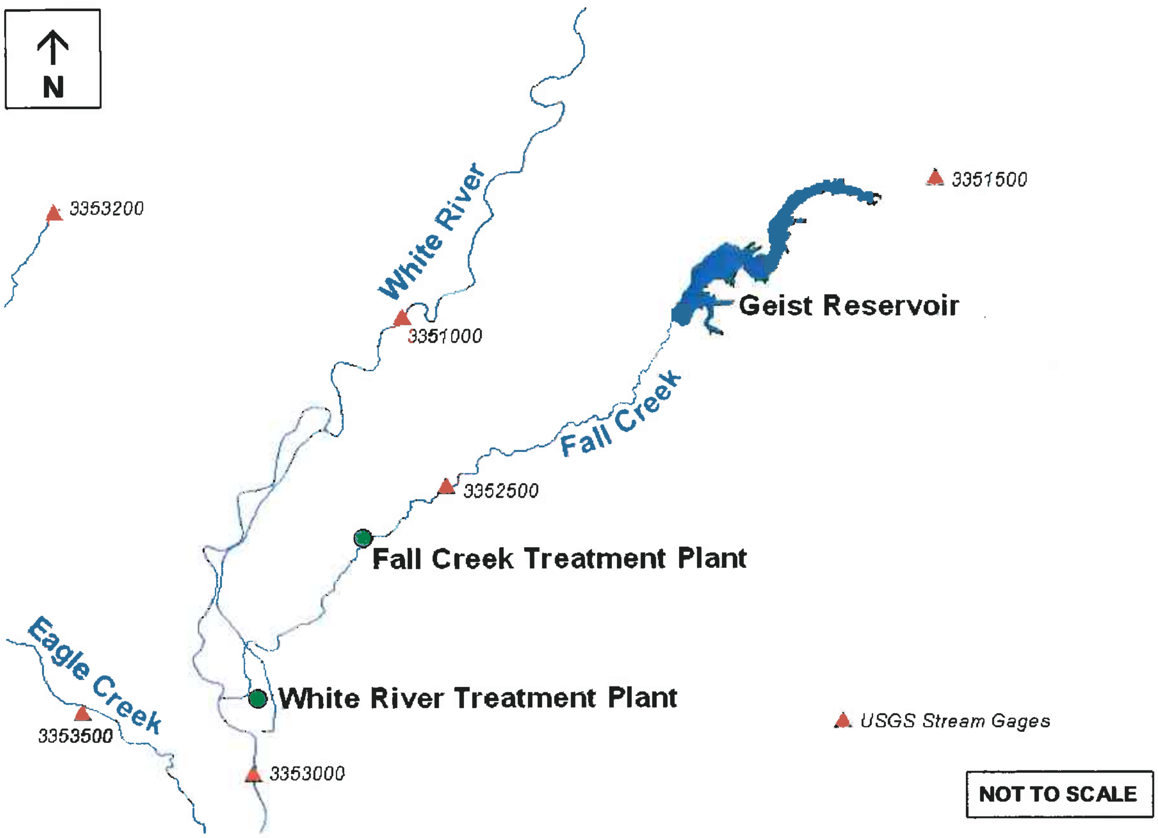

Figure 7-10 Fall Creek Surface Water System

7.3.3 Eagle Creek Reservoir

Eagle Creek Reservoir, completed in 1969, provides another source of surface water for Indianapolis. Unlike Morse and Geist Reservoirs, water is pumped directly from Eagle Creek Reservoir, treated at the Moses Treatment Plant, and distributed to customers. The City of Indianapolis Department of Public Works (DPW) controls the operation of Eagle Creek Reservoir. VWI has an agreement for an average annual usage of up to 12.4 mgd and a maximum monthly usage of up to 19.8 mgd. The Town of Speedway also has an allocation of water from the reservoir, and there is a minimum release required for downstream flows in Eagle Creek. DPW reserves the right to limit water allocations from the reservoir as the reservoir level drops, so VWI would have less flexibility with the water usage from this reservoir during drought than from Morse and Geist Reservoirs. The Indiana Department of Natural Resources (IDNR) conducted a bathymetric study in the mid-1990s on Eagle Creek Reservoir. There was no indication that sedimentation was a significant problem at that time, although it is prudent to continue to monitor changes in the bottom of the reservoir to determine if the storage is significantly changing over time.

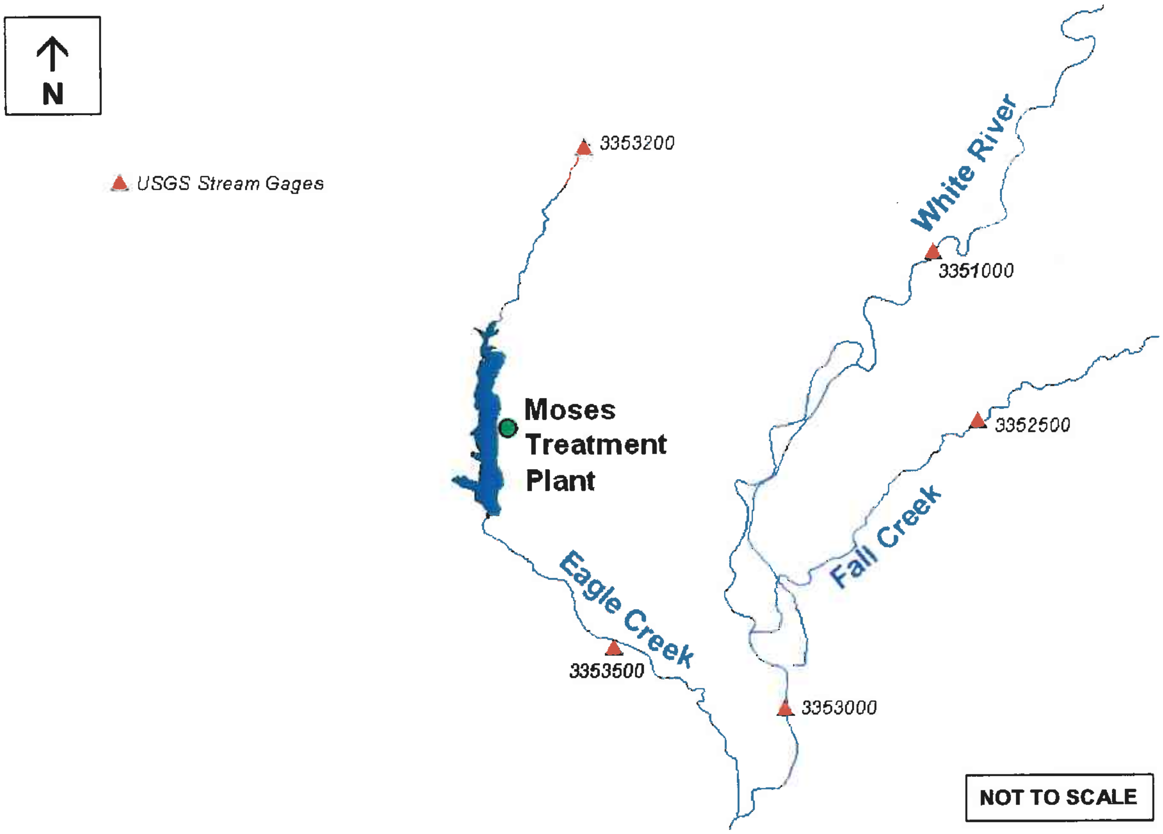

Figure 7-11 Eagle Creek Reservoir

7.4 GROUNDWATER SOURCES

Groundwater accounted for approximately 10 to 30 percent of the total production in 2007. Some of the water supply wells are nearly 100 years old, with some wells producing groundwater from the deeper carbonate bedrock aquifer and some wells pumping from the unconsolidated alluvial or outwash aquifers. It is believed that most of the groundwater pumped from the bedrock aquifers is induced downward from the overlying sand and gravel aquifers, although aquifer testing is required to verify this. All of the wellfields produce groundwater from complex aquifers with layers of coarse sand and gravel and layers of finer glacial till. This has made the day-to-day operation of the wellfields and the evaluation of the aquifers quite challenging, especially during drier climate conditions such as the summer of 2007 when the aquifers received less recharge. In the figures showing the wellfields, wells are color-coded based on the past few years of production data, the number of hours the wells were operated, and the estimated pumping rate of the wells.

7.4.1 Riverside/White River Wellfield

The Riverside (RS) / White River (WR) Wellfield is located near the confluence of White River and Fall Creek as shown on Figure 7-12. By 1896, up to 26 deep bedrock wells had been installed in the Riverside area with a production capacity of up to 14 mgd. Later, in the 1940s, several shallow wells were constructed in the sand and gravel aquifer to serve as an emergency water supply (Bakken, 2003). Today, the wellfield consists of 13 of the original 26 deep bedrock wells constructed in the 1890s. Some of these wells are completed to depths exceeding 400 feet below ground surface (bgs). The total rated pumping capacity for these bedrock wells is 8800 gallons per minute (gpm). There are nine shallower alluvial/outwash wells completed to a depth of up to approximately 100 feet in the Riverside/White River Wellfield. The total rated pumping capacity of these wells is about 8450 gpm. There is a clay layer about 10 to 20 feet thick that divides the lower sand and gravel from the upper sand and gravel in the vicinity of the wells (Brown, et. al., 1995). Because of mutual interference of drawdown between wells and the limited ability of the aquifer to replenish itself during dry conditions, all of the wells cannot sustain their maximum pumping capacities for extended periods of time without adversely pumping the groundwater levels below the tops of the well screens.

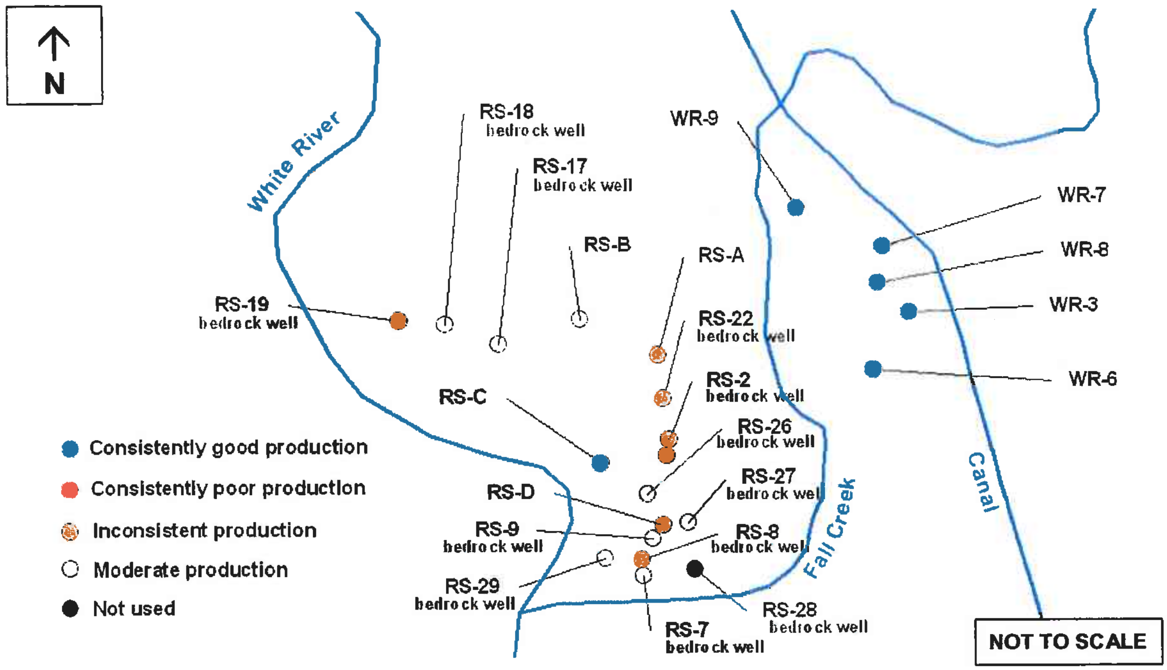

Figure 7-12 Riverside/White River Wellfield

7.4.2 Fall Creek Wellfield

The Fall Creek (FC) Wellfield is located near the Fall Creek Water Treatment Plant, as shown in Figure 7-13. The wellfield consists of five carbonate bedrock wells drilled to depths approaching 400 feet bgs with a rated total pumping capacity of 3800 gpm, and five shallower wells in the overlying sand and gravel aquifer to depths of up to 100 feet with a total pumping capacity of 4700 gpm. Till and clay units overlie much of the sand and gravel aquifer from which the wells produce groundwater, which inhibits recharge, but is also believed to protect the quality of the groundwater from surface contamination. Because of mutual interference of drawdown between wells and the limited ability of the aquifer to replenish itself during dry conditions, all of the wells cannot sustain their maximum pumping capacities for extended periods of time without adversely pumping the groundwater levels below the tops of the well screens.

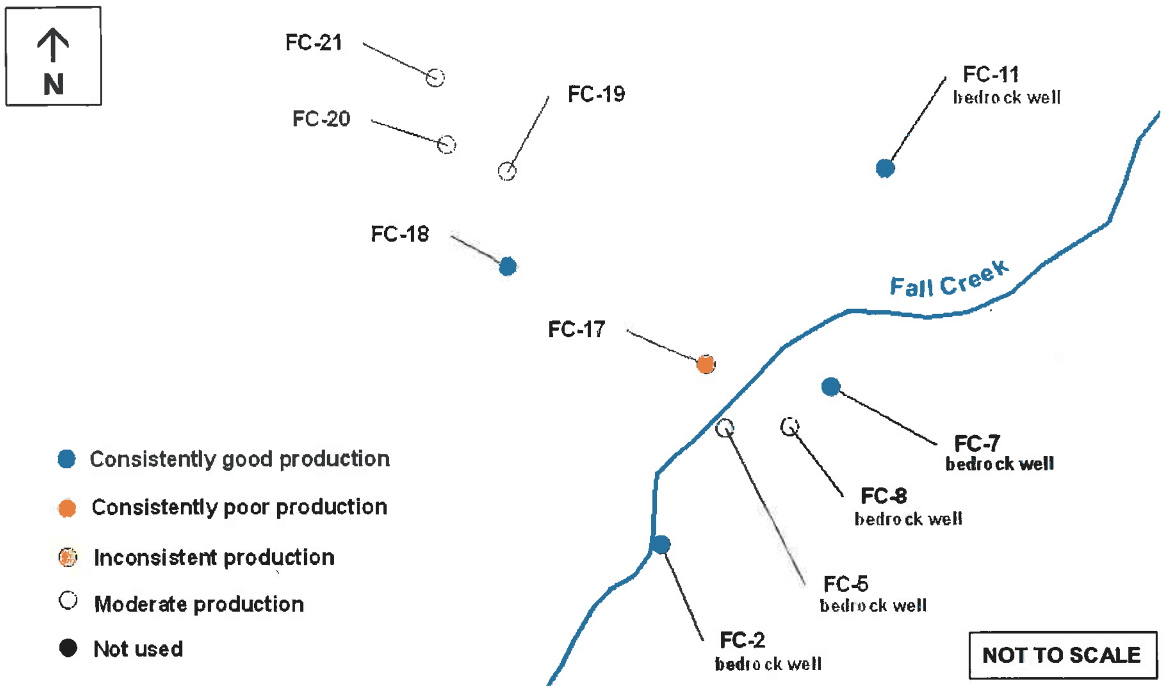

Figure 7-13 Fall Creek Wellfield

7.4.3 Geist Wellfield

Geist Wellfield (GWF) is located along Fall Creek just downstream of the Geist Reservoir dam, as shown on Figure 7-14. The wellfield consists of eight wells drilled to depths of up to 100 feet bgs with a total rated pumping capacity of 8840 gpm. The City of Lawrence has five wells located in close proximity to the Geist Wellfield. Brown et. al. (1995) shows a cross section near the wellfield that indicates a thick layer of till overlying most of the sand and gravel deposits from which the wells produce groundwater. This till layer most likely inhibits recharge from Fall Creek and from precipitation, but also may protect the quality of the groundwater from surface contamination. Because of mutual interference of drawdown between wells and the limited ability of the aquifer to replenish itself during dry conditions, all of the wells cannot sustain their maximum pumping capacities for extended periods of time without adversely pumping the groundwater levels below the tops of the well screens.

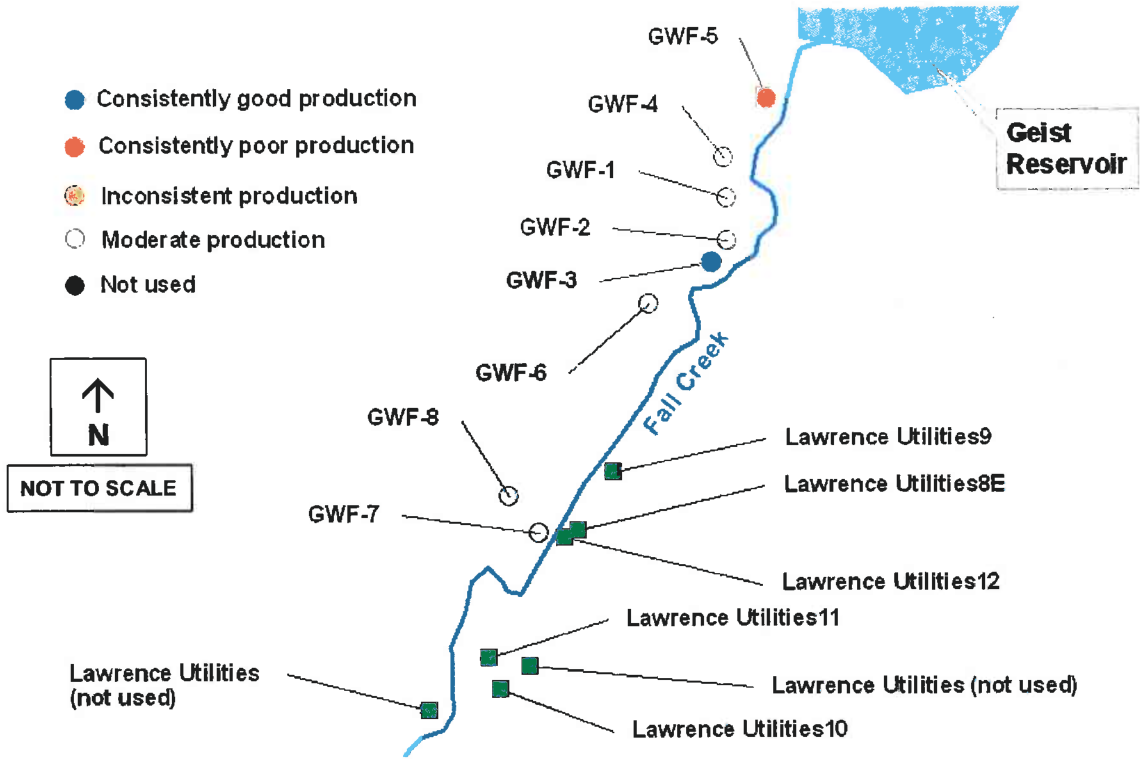

Figure 7-14 Geist Wellfield

7.4.4 White River North Wellfield

The White River North (WRN) Wellfield is located in Hamilton County along the White River between 146th and 166th Streets as indicated on Figure 7-15. The wellfield consists of three wells with depths of about 120 feet with one well drilled to a depth of 206 feet. Four new wells are under development at 146th Street. The total pumping capacity of these seven wells is estimated to be 8,450 gpm. Westfield has six wells near this area, Carmel has 14 wells in the area, and Noblesville has one well with significant usage reported to IDNR in recent years. Till and clay layers divide and cap the sand and gravel aquifer in various places, inhibiting recharge. The depth of the sand and gravel aquifer is apparently quite variable in the area, with WRN-5 being screened to a depth of over 200 feet, but the nearby well WRN-4 screened to a depth of just over 100 feet. The variability in aquifer depth and the clay layers make this a very complex aquifer.

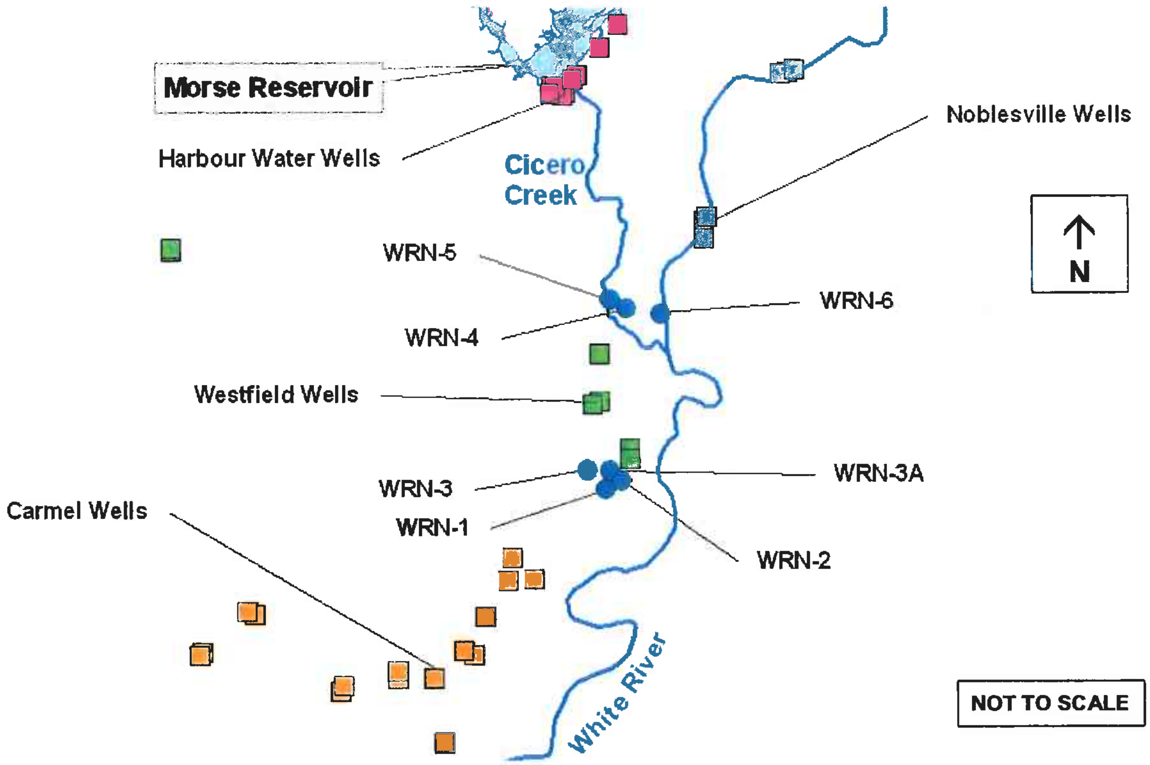

Figure 7-15 White River North Wellfield

7.4.5 South/Harding Wellfield

The South and Harding Wellfields (SWF) are located south of Indianapolis to the east of the White River as indicated on Figure 7-16. There are 19 wells drilled to depths of up to 110 feet into an outwash sand and gravel aquifer. The total rated pumping capacity of all the wells is 26,400 gpm. Complex till and clay layers divide the sand and gravel aquifer into various zones, inhibiting recharge. The wells also are located a significant distance to the east of White River because the sand and gravel is not very thick immediately adjacent to the river (Brown et. al., 1995). Because of mutual interference of drawdown between wells and the limited ability of the aquifer to replenish itself during dry conditions, all of the wells cannot sustain their maximum pumping capacities for extended periods of time without adversely pumping the groundwater levels below the tops of the well screens. As requested by VWI, this evaluation incorporates the results of recent modeling performed by others into the system yield model, and no further groundwater evaluation of wellfield yield was performed here.

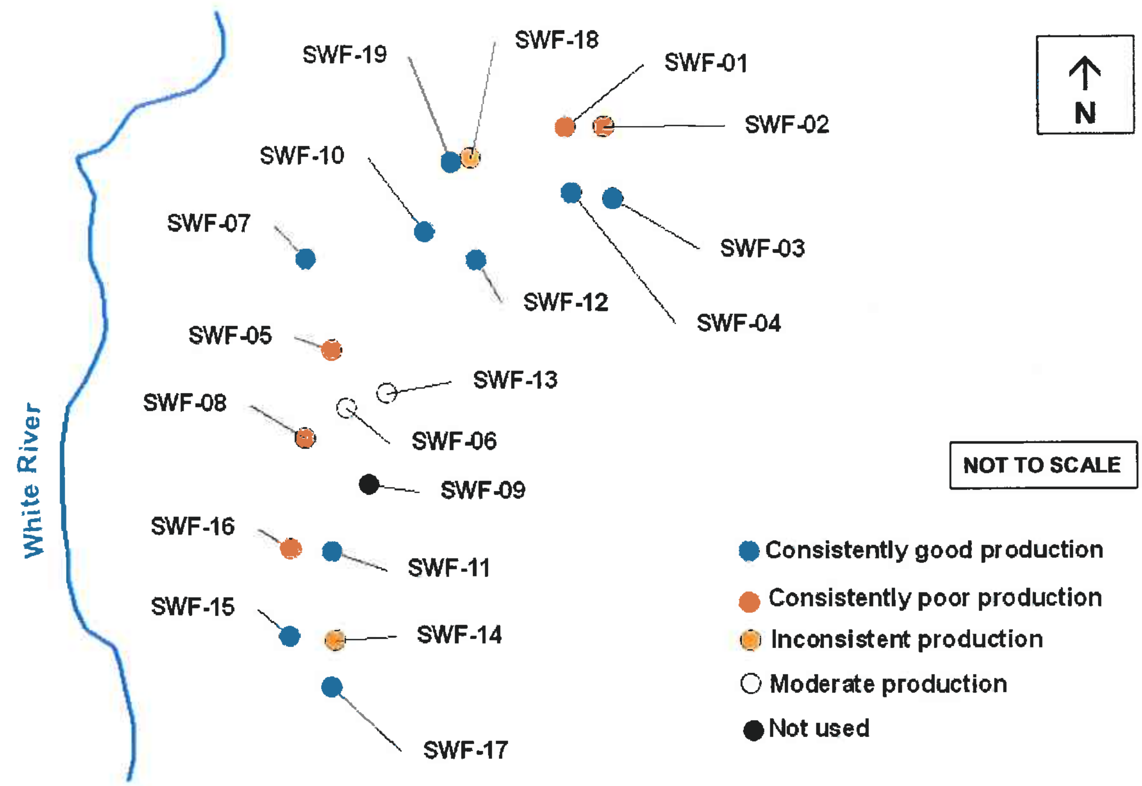

Figure 7-16 South/Harding Wellfield

7.4.6 Ford Road Wellfield

VWI has four wells located near Ford Road to the north of Eagle Creek Reservoir. The total pumping capacity of these wells is 1800 gpm, and the wells are drilled to depths of up to approximately 90 feet. Recent records indicate that each well produces only about 200 to 300 gpm on average over the summer months.

7.4.7 Harbour, Liberty, and Darlington Wellfields

The Harbour Wellfield, located just downstream of Morse Reservoir, has a total of nine wells. In recent years, the wells have been pumped at only a fraction of their original capacities. The Liberty and Darlington wells are no longer in service. For purposes of this evaluation, these three wellfields are not considered to yield any significant water for the City in the future.

7.4.8 Proposed Wellfields

A wellfield is proposed south of Indianapolis along the White River near the Morgan County-Johnson County line as shown on Figure 7-17. Prior to testing and modeling this site, the hope was that the wellfield could provide up to 60 mgd of water supply yield for the City utilizing a combination of horizontal collector wells and vertical wells. However, testing and modeling performed in 2007 by others shows that the yield at this site may be significantly less than this because of limited connection between the aquifer and the White River. Additional testing has been proposed to try to maximize the yield from this site (WHPA, 2007). As requested by VWI, this evaluation incorporates the results of this recent work into the system yield model, and no further groundwater evaluation of wellfield yield is performed here.

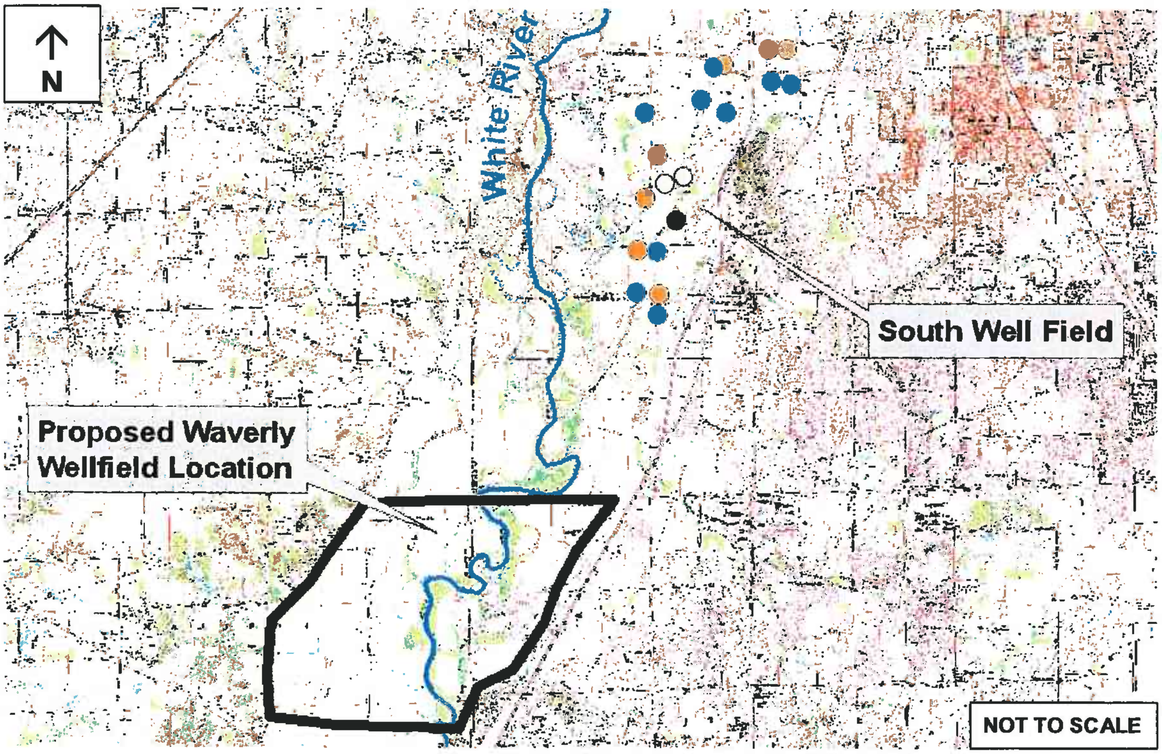

Figure 7-17 Proposed Waverly Wellfield

Another wellfield near Paragon, Indiana, further downstream along the White River (see Figure 7-1) has been proposed. Similar to the Waverly Wellfield, hydrogeologic testing at the site will reveal whether or not horizontal collector wells are feasible. The Paragon Wellfield is not considered here because it has not been considered by VWI for an additional source of supply until beyond the 2020 planning horizon for this evaluation and because of the uncertainties with the aquifer characteristics at this time.

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Section 8

8. DROUGHT CONDITIONS FOR WATER SYSTEM DESIGN

Hot and dry conditions experienced in Indianapolis in the summers of 2005 and 2007 resulted in periods of high demands stressing the water system. These events have provided valuable insight to potential system deficiencies and to questions about what might happen during more severe and extended drought conditions. Occasional summer rains in 2005 and 2007 resulted in periods of lower demands and respite for the water system. During a severe drought, summertime rainfall events will be less frequent, or will not occur at all for several months, so the demand for water could be expected to stay high for much of the summer. Multi-year droughts are much more severe than single-year droughts because the surface water reservoirs and groundwater aquifers will not be refilled in the winter, magnifying the potential for a water shortage in the following year. The water resources will not necessarily be available in the streams and aquifers to meet these high demands during an extended drought.

There are many definitions of "drought" related to meteorology, agriculture, hydrology, and water supply. The United States Army Corps of Engineers (USACE) responded to the 1988-1989 drought with a study and report to Congress entitled "National Study of Water Management During Drought" (1995). In that report, they defined drought as "*periods of time when natural or managed water systems do not provide enough water to meet established human and environmental uses because of natural shortfalls in precipitation or streamflow*". This definition is appropriate for this water supply evaluation. Major droughts that have been recorded in the Midwest over the past 100 years include 1914-1915, 1930s, 1940-1941, mid-1950s, mid-1960s, and 1988-1989. Since the mid-1960s, no Midwestern drought has ranked in the top three on record. "The need for drought assessment is particularly great if a water supply system has experienced even mild or moderate drought concerns since the mid-1960s" (Winstanley et.al., 2006). Precipitation and streamflow records confirm that the most significant dry periods in the Indianapolis area occurred before the 1970s (Black & Veatch, 1985; 2003). Looking at historical White River flows past Noblesville, the median flow from the 1930s through the 1960s was only about 300 cubic feet per second (cfs), compared to approximately 470 cfs from 1970 to today, 530 cfs from 1990 to today, and 583 cfs from 2000 to today as shown by Figure 8-1.

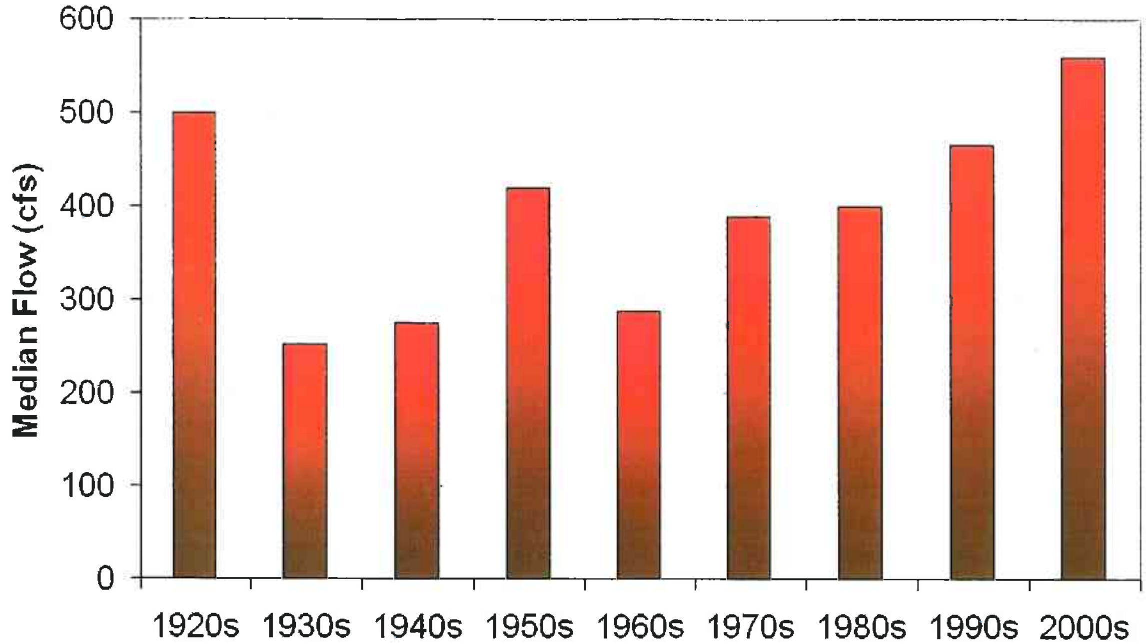

Figure 8-1 White River Median Flow Past Noblesville, IN

(this location was chosen because it is not influenced by the major reservoirs in Indianapolis)

Although the drought of the 1930s occurred for nearly the entire decade and severely affected agriculture, the drought of 1940-1941 was the most intense multi-year drought that has ever been recorded in Indianapolis for water supply; probability analyses of precipitation, streamflow, and reservoir yield have shown that the drought of 1940-1941 has a chance of approximately 1 to 4 percent of recurring in any given year. More recently, the 1988-1989 drought was moderately severe in comparison to the 1940-1941 drought, and a drought of this magnitude has been estimated to have approximately a 10 percent chance of recurring in any given year in the Indianapolis area.* To put the severity of the 1940-1941 drought into perspective, Figures 8-2 and 8-3 show the total flow volume and flow rates in the White River entering the City for various 15-month periods, showing the dryness of the winter between 1940 and 1941. If the streamflow in the White River past Noblesville is any indication of the climate in Indianapolis, the summer of 2007 ranks as the 40th driest summer out of 90 years

* 1988 had one of the driest and hottest summers in Indiana since the 1940s. In November of 1988, the minimum pool elevations of Morse and Geist Reservoirs reached 803.91 ft and 778.36 ft, respectively, or about 6 to 7 feet below the tops of their dams. 1989 was wetter, offering some relief for the area. "The drought of 1988, although severe, was of much less duration and intensity than some droughts experienced in the past. As Indiana's need for water increases, droughts of even less intensity than that of 1988 probably will result in similar water shortages and agricultural losses." (USGS, 1992). In 1988, the average day production for the Indianapolis water system was approximately 119 mgd, compared to over 150 mgd in 2007

of record, as shown on Figure 8-4. The summers of 1940, 1988, and 1941 rank as the 3rd, 4th, and 7th driest on record. No summer since 1990 ranks in the Top 20 driest (1999 was 21st). In fact, seven of the wettest summers have occurred since 1990. Figure 8-5 shows the driest years considering both summer and winter flows past Noblesville.

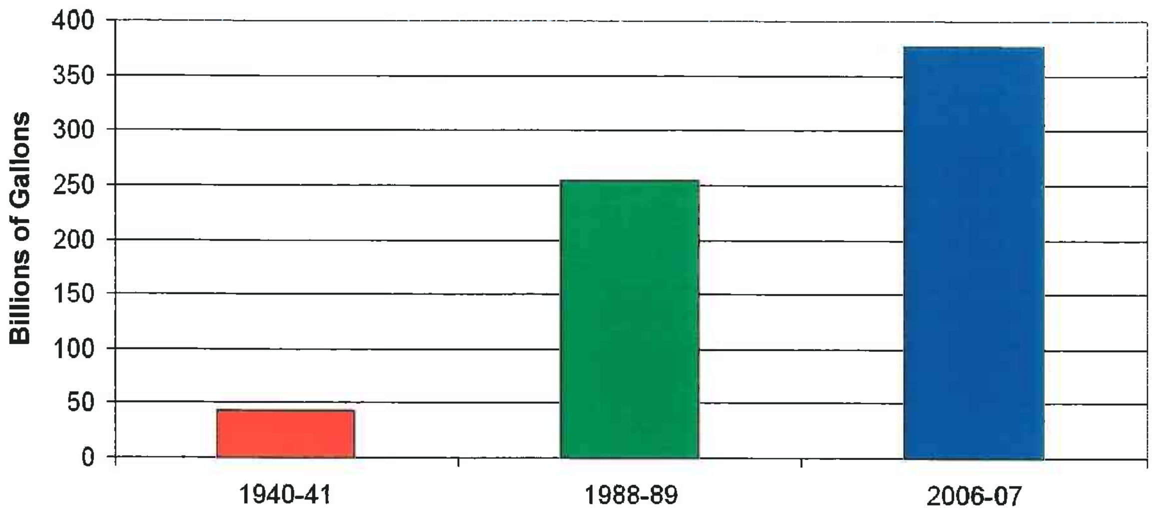

Figure 8-2 Total Volume of Flow in the White River past Noblesville

(over a 15-month period from July of first year through September of second year; this location was chosen because it is not influenced by the major reservoirs in Indianapolis)

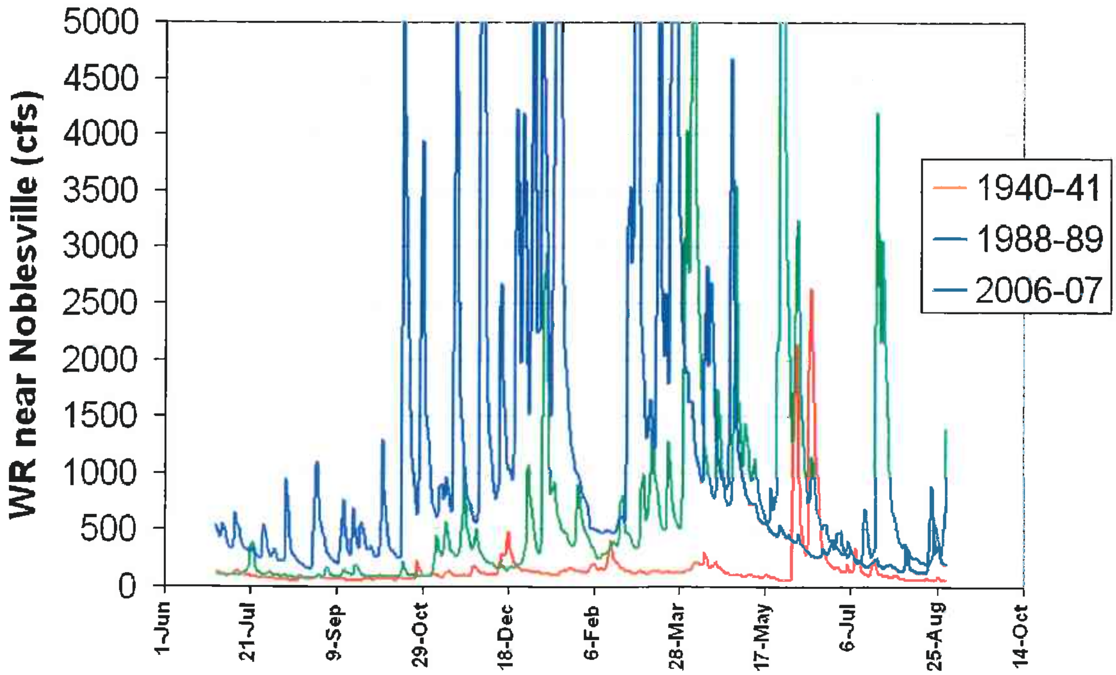

Figure 8-3 River Flowrate Comparison

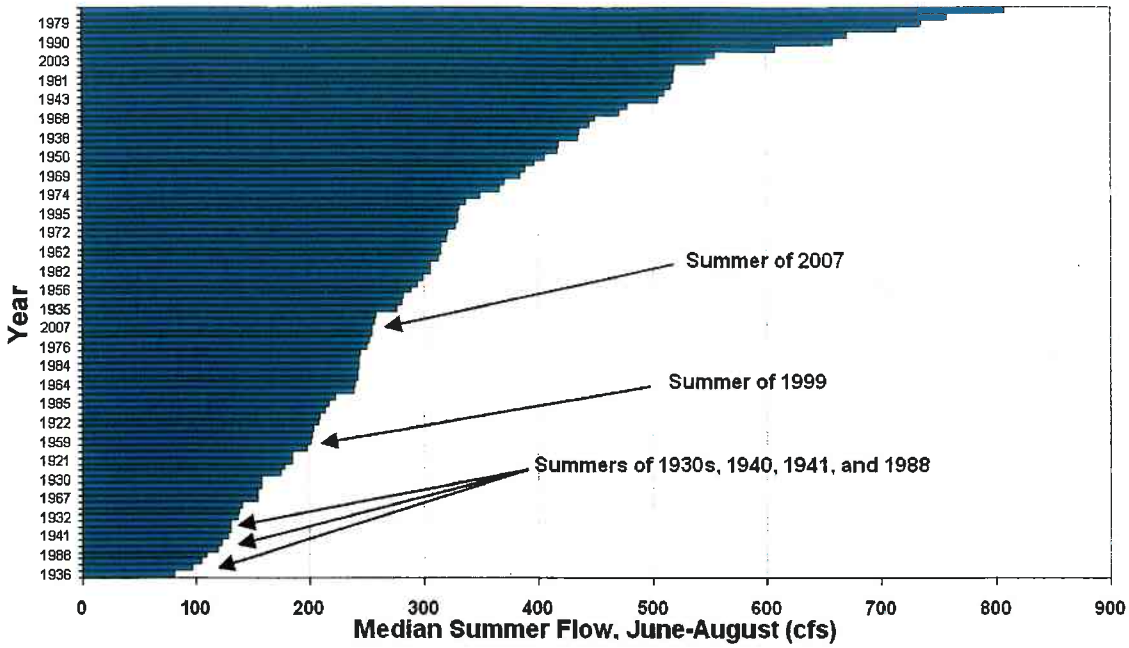

Figure 8-4 Driest Summers as Indicated by Streamflow in the White River past Noblesville from June-August

(this location was chosen because it is not influenced by the major reservoirs)

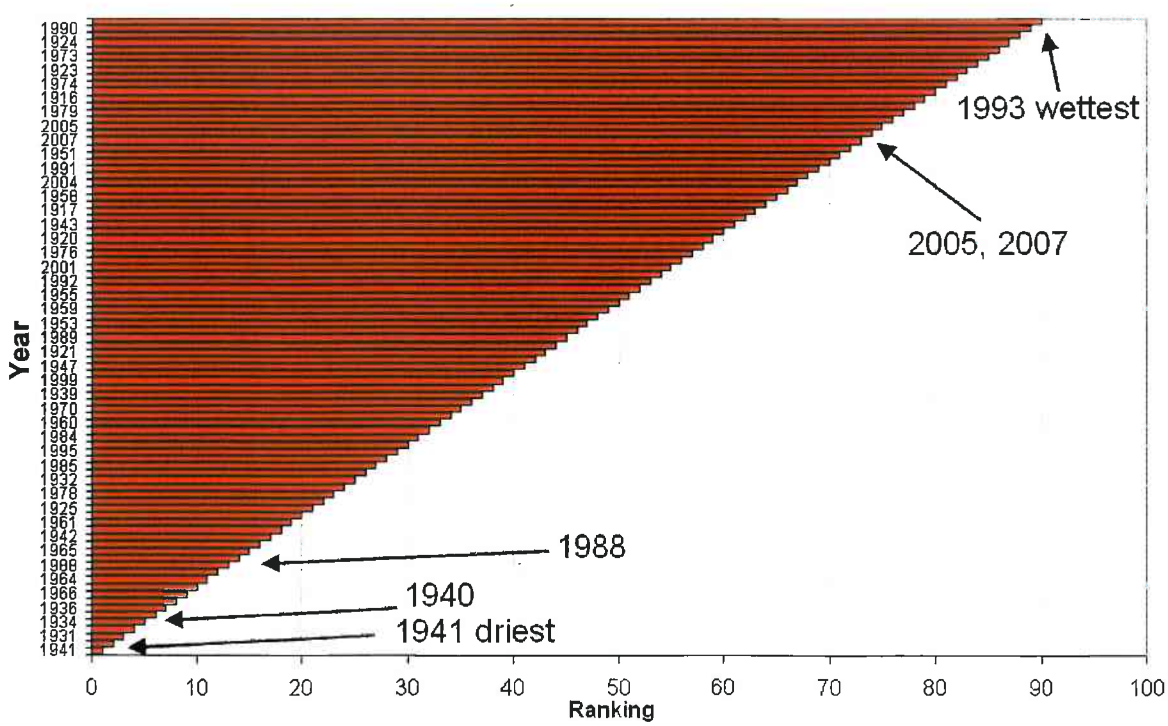

Figure 8-5 Driest Years Considering both Summer and Winter Streamflow in the White River past Noblesville from Jan-Mar & Jun-Aug

(this location was chosen because it is not influenced by the major reservoirs)

In the past, the Department of Waterworks has questioned what level of "drought tolerance" is acceptable for the Indianapolis area. "*Determining an appropriate drought recurrence interval for water supply planning is extremely difficult due to the highly unpredictable nature of droughts…Serious consideration needs to be given to the potential magnitude of the urban water shortage in order to consider which decision-makers should be involved in deciding what constitutes acceptable risk for shortages*" (Georgeson, 1985). The 1995 USACE report to Congress states "*water supply planning is a strategic endeavor that attempts to balance water supply and use, mindful of economic and environmental costs*". Ideally, the choice of the design drought should be such that the cost of the water supply expansion plus the cost of losses resulting from a drought in excess of the design drought should be minimized. Difficulty lies with the large uncertainty in trying to assign a dollar figure to the economic, environmental, and social impacts associated with water shortages such as public complaints, water conflicts, reduced fire protection, adverse health effects, temporary/emergency water supplies, power outages, industrial costs, detraction of new businesses or development, etc.. Therefore, common practice for a water utility is to choose a significant historical drought for system design.

The Ten States Standards "Recommended Standards for Water Works" (2003) for northeastern states including Indiana recommends the following:

"The quantity of (surface) water at the source shall …

- *be adequate to meet the maximum projected water demand of the service area as shown by calculations based on a one in fifty year drought or the extreme drought of record, and should include consideration of multiple year droughts. Requirements for flows downstream of the intake shall comply with requirements of the appropriate reviewing authority*
- *provide a reasonable surplus for anticipated growth,*
- *be adequate to compensate for all losses such as silting, evaporation, seepage, etc.,*
- *be adequate to provide ample water for other legal users of the source.*

The total developed groundwater source capacity, unless otherwise specified by the reviewing authority, shall equal or exceed the design maximum day demand with the largest producing well out of service."

Other Midwestern states have regulations stating that the drought of record, or the drought with a two-percent chance of recurrence (one in fifty year drought), should be used for water supply planning, and other cities both larger and smaller than Indianapolis are currently planning and designing their systems based on the drought-of-record for their areas. This has been accepted practice in the waterworks industry to ensure that facilities such as water treatment plants and pipelines be adequately sized to meet peak demands during normal climate conditions, and to ensure that there are enough wells, surface water intakes, and/or storage facilities to capture and store enough raw water during a severe drought to meet the needs of a community. A large investment in pumping, treatment, and piping improvements at one of the existing sources may provide additional yield during normal climate conditions, but only a fraction of the added capacity may be realized during a drought because of the limited supply of water at that location.

Figure 8-6 provides a chart that helps to illustrate how consumption has outpaced both facility capacity and water supply yield in the past half century in the Indianapolis area. This figure shows that consumption has outpaced both facility capacity and yield at the sources of supply during a severe drought. When this happens, "Qy" illustrates the amount of supply that must be obtained at another, new source of supply. Then, the resulting treatment, pumping, and piping facilities associated with this new source of supply should be adequate to account for the existing facilities capacity deficit of "Qc" (Qc is the similar to the capacity deficit approached in the summer of 2007). For this reason the Ten States Standards recommends designing a water utility for the drought-of-record. One of the primary goals of this study is to determine "Qy". "Qy" and "Qc" might be reduced through demand management, which would reduce the cost of system improvements. This study does not address demand management.

This evaluation focuses on the 1940-1941 drought conditions for the safe yield of VWI's system, as have previous studies, with some major revisions to the system constraints and assumptions. The 1988-1989 drought and the 2007 dry summer conditions are also evaluated here to provide VWI and the City with an understanding of system adequacy for less severe climate conditions. Obviously, designing the water system for less severe climate conditions costs less but provides a system with less reliability.

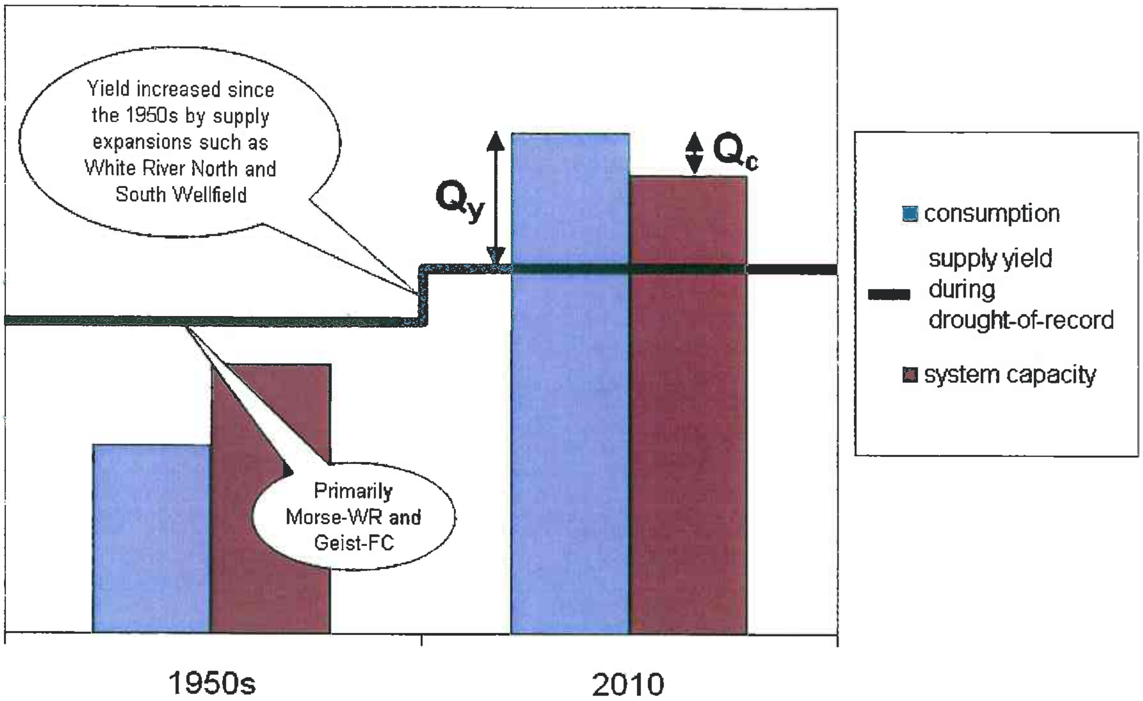

Figure 8-6 System Capacity vs. Yield vs. Consumption

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Section 9

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9. GROUNDWATER YIELD EVALUATION

9.1 SOFTWARE APPLICATION

Groundwater Modeling System (GMS) Version 5.1 was used to develop the planning-level groundwater models for this evaluation. GMS is a software application developed at Brigham Young University used as a pre- and post-processor for the United States Geological Survey (USGS) groundwater flow model, MODFLOW-2000 (Harbaugh, et.al., 2000). MODFLOW is the most widely used groundwater flow code in use today, capable of simulating the primary aquifer flow processes such as pumping from wells, interaction between the aquifer and streams, and recharge. GMS offers a variety of tools that expedite the development of groundwater models and the analysis of the results.

9.2 GROUNDWATER CONSTRAINTS AND ASSUMPTIONS

System constraints must be incorporated into the groundwater models in order to evaluate system yield. These constraints are not related to treatment capacity or pipe capacity; they are related to raw water issues such as minimum allowable flows in streams, minimum reservoir levels, minimum groundwater levels, etc.. Where data are lacking, assumptions must be made to estimate yield. Black & Veatch (B&V) worked closely with Veolia Water Indianapolis (VWI) to develop these major assumptions and gather information for system constraints. For the groundwater system, the following constraints and assumptions were used:

- *Existing Well Production in Recent Years.* VWI does not currently have a means of measuring and recording flowrates from individual wells. In order to report water usage to Indiana Department of Natural Resources (IDNR), VWI estimates the total volume of water pumped from individual wells by multiplying the total number of hours each well was operated by the rated capacity of the pump inside the well. This method may overestimate the actual volume of water pumped because the pumping rate is something less than the rated pump capacity depending on total dynamic head and well efficiency at any given time. In an attempt to check this assumption, the total groundwater production by the Geist, South/Harding, White River, and Fall Creek plants was compared to the reported water usage provided by IDNR for the summer of 2005. Table 9-1 shows this comparison. Note the average daily production rates may be skewed by the storage at the treatment plants and may not reflect the exact amount of water pumped from wells.

Table 9-1
Comparison of Production versus IDNR Water Usage Reports

Wellfield, Month	Average Daily Production (mgd)	Estimated Usage Reported to IDNR (mgd) (hours x pump capacity)	Difference (%)
Geist Wellfield, June 2005	2.19	1.9	-13%
Geist Wellfield, July 2005	2.65	4.16	+57%
Geist Wellfield, August 2005	2.52	2.53	-0.3%
South Wellfield, June 2005	16.81	15.77	-6%
South Wellfield, July 2005	14.39	18.78	+30%
South Wellfield, August 2005	13.45	7.65	-43%
Riverside/White River, June 2005	8.7	10.74	+23%
Riverside/White River, July 2005	6.1	8.52	+40%
Riverside/White River, August 2005	11.2	16.5	+47%
Fall Creek, June 2005	6.9	7.16	+4%
Fall Creek, July 2005	6.9	7.28	+6%
Fall Creek, August 2005	7.0	6.41	-8%

Groundwater usage reported to IDNR was both significantly higher and lower than the groundwater production at the plants, so use of this data to determine the actual flowrate from each well was not possible. However, Table 9-2 shows the IDNR reported usage for each wellfield from 2003 to 2005.

Table 9-2
Current Average Well Production Estimation
(estimated from well run times)

Wellfield	Average Reported to IDNR 2003-2005 (mgd)	Average Reported to IDNR for June, July and August for 2003-2005 (mgd)
RS/WR, 24 total wells	19.21	20.45
Fall Creek, 7 total wells	9.37	8.64
Ford Road, 4 total wells	1.66	1.76
Geist, 5 total wells	3.84	4.05
SWF, 19 total wells	21.93	21.68
Total, 59 wells	56.01	56.58
Average, per well	0.94 mgd	0.96 mgd
Total Drought Yield per well assuming some overestimate using well hours x pump capacity, and assuming yield is significantly reduced during extended drought conditions	0.5 – 0.6 mgd	0.5 – 0.6 mgd

During drought conditions the average yield per well was estimated to be about 0.5 million gallons per day (mgd) due to reduced aquifer recharge and increased well interference. This provides a practical estimate of how much additional yield could be expected by expanding the existing wellfields, and gives an initial estimate of drought well yields that can be compared to the groundwater model results given later in this report. This estimate of individual well yield is typical of other municipal wells such as those owned by Lawrence, Carmel, and Westfield that report summertime usage between 0.1 to 3.2 mgd per well, with an average of around 1 mgd per well for 2003 through 2005. Whether or not the cities meter the flow from individual wells or if flows are estimated from well run times similar to VWI is unknown. During drought, the yields from these other municipal wells is expected to be lower than the reported values.

- *Existing Well Condition.* VWI is considering inspection of their wells, including geophysical and/or television surveys to determine the condition of the wells. This evaluation does not attempt to determine the condition of existing wells or which wells are in need of maintenance or replacement. The groundwater models focus on the potential yield of the aquifers at each of the wellfields.

- *Aquifer Layering and Thickness.* Available boring logs were obtained from IDNR and VWI, along with published mapping, and were used to determine the layers of till, sand, gravel, and bedrock near each of the wellfields (Casey, 1992; IDNR, 2002; Herring, 1976). Ground surface elevations were obtained from the USGS National Map Seamless Server and from survey information collected by VWI. Three-dimensional representations of the ground and aquifer layer interfaces were developed using commercially available surface mapping and GIS software for use in the planning-level groundwater models of the wellfields.
- *Aquifer Hydraulic Characteristics.* Because of how glacial activity deposited and mixed the unconsolidated soils and eroded bedrock, the aquifer materials and thicknesses beneath the Indianapolis area are complex and highly variable across short distances. As for most aquifer settings, due to the cost of drilling, there is not enough historical data to determine the aquifer variability at all points, so simplifying assumptions were made to evaluate the aquifer system using groundwater models. For the planning-level groundwater models developed for this study, the aquifers were generally conceptualized as zones of (1) glacial till in upland areas away from the streams or capping the sands and gravels near the streams, (2) alluvial sands and gravels near the streams, (3) glacial outwash sands and gravels adjacent to the alluvium, and (4) deeper bedrock composed of carbonate limestone/dolomite of Silurian and Devonian age or New Albany Shale. The glacial till is composed of a high percentage of fine-grained material such as clay or silt, with a lower hydraulic conductivity than the coarser sands and gravels. The hydraulic conductivity of bedrock in the area is reported to be highly variable across short distances depending on the degree of jointing/fracturing that exists. The hydraulic conductivity of the New Albany Shale that is present beneath southern Indianapolis is believed to be quite low, although limited information is available for this shale. Table 9-3 gives the published information for the aquifer characteristics in the area. The ranges of published values reflect tests performed by others in various locations around the Indianapolis area. These values were used as a guide in developing the models.

- *Aquifer Storage.* Transient groundwater models are required to estimate the time-varying groundwater conditions such as periods of limited recharge, varying well production rates, etc. Unlike a steady-state model where groundwater inflows and outflows are in equilibrium, a transient model involves a change in groundwater storage. Typically, storage decreases during drought conditions where the recharge inflow from precipitation and streamflow can be very low, while at the same time, the outflow to wells is often higher than normal. Like other hydraulic parameters, storage properties for the various aquifers in the Indianapolis area is relatively uncertain and can be highly variable depending on the aquifer materials, intermixing, and whether the aquifer is confined or unconfined. The storage term is higher for unconfined aquifers because the voids between the soil material is dewatered as the aquifer releases water from storage. The storage term for a confined aquifer is called storativity and is often on the order of 10^{-3} to 10^{-5}. The storage term for an unconfined aquifer is called the specific yield and typically ranges from about 10^{-2} to 0.3 (Freeze and Cherry, 1979). These values were used as a guide in selecting storage terms for the models. Pumping from the City's wellfields may, at times, cause portions of the aquifer to switch from confined/semi-confined to unconfined conditions in areas where clay layers separate the aquifers. If and when this happens, the manner in which the aquifer releases water to the wells can become rather complex.

Table 9-3
Published Hydraulic Conductivities in the Indianapolis Area

Source	Aquifer Zone	Transmissivity (gpd/ft)	Assumed thickness (ft)	Horizontal or Vertical K	K (ft/day)
IDNR, 2002	alluvium	14,690 – 150,560	10 - 150	horizontal	25 – 252
Bugliosi, 1990	alluvium	74,800 – 209,500	80	horizontal	125 – 350
Cable et.al., 1971	alluvium	-	-	horizontal	200 – 334
Meyer, 1978	alluvium	-	-	horizontal	354
USGS/IDNR, 1983	alluvium	-	-	horizontal	200 – 400
Bloyd, 1974	alluvium	-	-	horizontal	267
Bobay, 1988	alluvium	-	-	horizontal	100 – 240
Herring, 1976	alluvium	-	-	horizontal	500 – 700
Black & Veatch, 2003	alluvium	-	-	horizontal	500
Meyer et.al., 1975	outwash	-	-	vertical	24
USGS/IDNR, 1983	outwash	-	-	horizontal	50
IDNR, 2002	till	1370 – 29,700	0 – 80	horizontal	-
Freeze and Cherry, 1979	till	-	-	horizontal	0.3 (textbook value)
Herring, 1976	till	-	-	vertical	0.003
Meyer et.al., 1975	silt and clay (till)	-	-	vertical	0.0001 – 0.07
Bugliosi, 1990	till	-	-	vertical	7e-6 – 0.07
Bobay, 1988	deep sand and gravel	-	-	horizontal	40 – 100
IDNR, 2002	outwash	1940 – 54,870	20 - 40	horizontal	89
IDNR, 2002	shale	110 – 1130	50	horizontal	0.3 – 3
Freeze & Cherry, 1979	shale	-	-	horizontal	3e-5 (textbook value)
Casey, 1992	upper carbonate	70 – 28,000	-	Horizontal	0.01 – 500 (highly variable)
Bugliosi, 1992	carbonate	-	-	horizontal	5 – 100
Cable et.al., 1971 Fenelon and Bobay, 1994	upper 100' of carbonate	-	-	horizontal	13.4 (avg, but highly variable)
Black & Veatch, 2003	carbonate	-	-	horizontal	3 – 100 (avg of 15)
Black & Veatch, 2006	deep carbonate	-	-	horizontal	0.0003 – 0.03 (packer tests)
Freeze & Cherry, 1979	limestone /dolomite	-	-	horizontal	0.03 (textbook value)

- *Vertical Connection Between Aquifers.* No information was discovered concerning the connection of the carbonate bedrock aquifer with the overlying unconsolidated aquifers in the Indianapolis area. Aquifer testing would be required to determine this connection. Aquifer testing has also been recommended by others to determine the feasibility of shallow collector wells and the degree of connection between the deep sand and gravel aquifer with shallower sand and gravel aquifer at the proposed Waverly Wellfield site (WHPA, 2007). Similar information for the hydraulic connection between shallow and deep unconsolidated units within all of the existing wellfields where clay layers divide the upper and lower alluvial/outwash aquifers is lacking. For purposes of this report, the majority of the joints and fractures in the bedrock were assumed to be near the top of the carbonate bedrock and that the bedrock wells induce flow downward through these joints from the overlying sand and gravel aquifers into the bedrock wells. For the complex sand and gravel aquifers, the interbedded clay layers were assumed to be present within all wellfields, restricting vertical flow.
- *Connection of Aquifers with Streams.* Prior to settlement in Indianapolis, groundwater typically discharged to the major streams. Today, where the natural system has been altered with the construction of dams and wells, the flow may be reversed from the streams into the aquifer. A well completed in a shallow sand and gravel aquifer near a stream may induce some infiltration of surface water through the streambed toward the well. Very little information is available to determine the connection between aquifers and major streams in the Indianapolis area. Recent operational issues during the summer of 2007 and recent testing and modeling at the South Wellfield and Waverly Wellfield indicate that clay layers tend to inhibit streamflow from moving toward the wells. Estimates of the streambed permeabilities and aquifer-stream interaction were obtained from available references (Smith, 1983; Walton, 1964; Herring, 1976; Meyer, 1979).
- *Recharge.* Recharge from precipitation is a highly uncertain parameter. Published information was used to estimate the amount of recharge in the upland till areas and in the low-lying areas adjacent to the streams (Bechert and Heckard, 1966; Cable et. al., 1971; Meyer et. al., 1975;

Gillies, 1976; Herring, 1976; Smith, 1983; Bloyd, 1974; Fenelon and Bobay, 1994).

- *Tops of Existing Well Screens.* The elevations of the tops of the well screens give an indication of the maximum allowable drawdown of groundwater levels in the wellfields. These critical elevations were used as a guide in estimating the yield for the wells. VWI provided information on the depth to the tops of the well screens and elevations of the wells so that the tops of the screens could be converted to elevations for modeling purposes. Table 9-4 provides a list of existing wells, their surface elevations from which depths are measured, the estimated top-of-screen elevations, coordinates for the wells and with the aquifer from which the well produces groundwater.

  For the bedrock wells, since there are no screens, it is assumed that the pump intakes are generally set near the bedrock surface based on the deeper critical pumping depths provided by VWI. Typically, the groundwater levels around the bedrock wells cannot be drawn down to the bedrock surface without drawing the level below the top of nearby alluvial wells. Therefore, the groundwater levels near the alluvial wells tend to control the yield at these wellfields.

Table 9-4
Existing VWI Wells

Well	X UTM Zone 16 NAD27	Y UTM Zone 16 NAD27	Aquifer	Reference Elevation (ft)	Estimated Top of Screen (ft)
SWF-01	569200	4391235	Sand/Gravel	654.53	573.53
SWF-02	569500	4391235	Sand/Gravel	662.59	582.59
SWF-03	569575	4390675	Sand/Gravel	679.43	599.43
SWF-04	569250	4390725	Sand/Gravel	678.93	608.93
SWF-05	567400	4389520	Sand/Gravel	658.61	576.61
SWF-06	567515	4389065	Sand/Gravel	666.62	591.62
SWF-07	567200	4390220	Sand/Gravel	668.12	617.12
SWF-08	567190	4388835	Sand/Gravel	657.32	587.32
SWF-09	567690	4388475	Sand/Gravel	666.17	590.17
SWF-10	568110	4390425	Sand/Gravel	670.56	599.56
SWF-11	567400	4387960	Sand/Gravel	654.53	586.03
SWF-12	568512	4390201	Sand/Gravel	667.32	597.32
SWF-13	567819	4389176	Sand/Gravel	669.03	585.03
SWF-14	567420	4387270	Sand/Gravel	653.53	583.53
SWF-15	567060	4387300	Sand/Gravel	653.56	583.56
SWF-16	567080	4387980	Sand/Gravel	655.09	590.09
SWF-17	567390	4386920	Sand/Gravel	661.59	602.09
SWF-18	568470	4390990	Sand/Gravel	668.9	598.9
SWF-19	568320	4390950	Sand/Gravel	668.18	594.18
GWF-1	586375	4417175	Sand/Gravel	758.56	684.56
GWF-2	586375	4417025	Sand/Gravel	758	681
GWF-3	586325	4416950	Sand/Gravel	757.25	685.25
GWF-4	586365	4417310	Sand/Gravel	759.84	684.84
GWF-5	586520	4417520	Sand/Gravel	759.83	689.83
GWF-6	586103	4416811	Sand/Gravel	755.06	NA
GWF-7	585712	4416016	Sand/Gravel	758.54	NA
GWF-8	585610	4416143	Sand/Gravel	754.86	NA
RS-17	569306	4404520	Bedrock	698.96	NA
RS-18	569096	4404602	Bedrock	699.51	NA
RS-19	568911	4404618	Bedrock	698.53	NA
RS-2	569986	4404145	Bedrock	695.89	NA
RS-22	569963	4404307	Bedrock	695.93	NA
RS-26	569900	4403925	Bedrock	694	NA
RS-27	570061	4403812	Bedrock	694.03	NA
RS-28	570083	4403625	Bedrock	693.4	NA
RS-29	569726	4403670	Bedrock	699	NA
RS-3	569978	4404078	Bedrock	696	NA
RS-7	569880	4403602	Bedrock	696.12	NA
RS-8	569873	4403665	Bedrock	695.34	NA
RS-9	569916	4403747	Bedrock	691.73	NA
RS-A	569943	4404476	Sand/Gravel	696.37	617.37

Table 9-4 Continued Existing VWI Wells					
Well	X UTM Zone 16 NAD27	Y UTM Zone 16 NAD27	Aquifer	Reference Elevation (ft)	Estimated Top of Screen (ft)
RS-B	569630	4404620	Sand/Gravel	702.35	637.35
RS-C	569710	4404050	Sand/Gravel	697.17	634.67
RS-D	569960	4403800	Sand/Gravel	694.74	640.74
WR-3	570949	4404643	Sand/Gravel	707.18	670.58
WR-6	570806	4404420	Sand/Gravel	707.96	664.96
WR-7	570845	4404908	Sand/Gravel	701.64	644.64
WR-8	570823	4404764	Sand/Gravel	700.04	643.04
WR-9	570506	4405061	Sand/Gravel	698	638
FC-2	574678	4408848	Bedrock	726.98	NA
FC-5	574897	4409238	Bedrock	722.71	NA
FC-7	575257	4409380	Bedrock	721	NA
FC-8	575117	4409244	Bedrock	724.87	NA
FC-11	575445	4410110	Bedrock	732.25	NA
FC-17	574833	4409453	Sand/Gravel	736.47	674.97
FC-18	574166	4409789	Sand/Gravel	742.32	656.32
FC-19	574167	4410107	Sand/Gravel	743.66	683.66
FC-20	573964	4410196	Sand/Gravel	743.95	678.95
FC-21	573930	4410418	Sand/Gravel	742.25	677.25
FRW-1	561669.4	4419126	Sand/Gravel	809.01	780.01
FRW-2	561660.6	4419102	Sand/Gravel	808.14	762.14
FRW-3	561686.5	4419361	Sand/Gravel	809.01	736.01
FRW-4	561567.5	4419989	Sand/Gravel	NA	NA
WRN-4	582487	4431819	Sand/Gravel	752.13	676.13
WRN-5	582153	4431968	Sand/Gravel	752.46	565.46
WRN-6	583107	4431713	Sand/Gravel	759.51	678.51
WRN-1	582071	4428386	Sand/Gravel	756.92	NA
WRN-2	582371	4428555	Sand/Gravel	757.25	NA
WRN-3A	582157	4428749	Sand/Gravel	748.75	NA

- *Other Groundwater Users.* Groundwater production from other users near each wellfield was determined using IDNR's database for Significant Water Withdrawal Facilities (SWWFs). A SWWF is defined by IDNR as "the water withdrawal facilities of a person that, in the aggregate from all sources and by all methods, has the capability of withdrawing more than 100,000 gallons of ground water, surface water, or ground and surface water combined in one (1) day." This is equivalent to a well capable of producing about 69 gallons per minute (gpm) or more. IDNR currently maintains records for approximately 6,000 ground-water wells of this capacity in Indiana. Groundwater production not reported to IDNR was not included in these models. Significant groundwater users in the vicinity of VWI's wellfields include the Cities of Lawrence, Carmel, Westfield, and Speedway in addition to several large industrial users. Table 9-5 lists the significant groundwater users included in the groundwater models.

Table 9-5
Other Significant Groundwater Users

Groundwater User	IDNR Source ID	IDNR 2003-2005 Average Reported Usage (gpm)
Allison Transmission	11	55
Allison Transmission	12	48
Allison Transmission	5A	48
Allison Transmission	7A	32
American United Life Insurance Company	1E	595
American United Life Insurance Company	2N	80
American United Life Insurance Company	3W	106
American United Life Insurance Company	4S	285
American United Life Insurance Company	5W	159
Cargill DCI Inc	2	19
Carmel	3	199
Carmel	4	164
Carmel	5	313
Carmel	6	733
Carmel	7	242
Carmel	9	823
Carmel	13	850
Carmel	14	851
Carmel	15	500
Carmel	16	147
Carmel	17	1349
Carmel	18	729
Carmel	21	1183
Carmel	19	631
CB Richard Ellis	2	420
CB Richard Ellis	3	65
CB Richard Ellis	4	20
Central Parking System	1	51
Central Parking System	2	55

Table 9-5 Continued
Other Significant Groundwater Users

Groundwater User	IDNR Source ID	IDNR 2003-2005 Average Reported Usage (gpm)
Coca-Cola Bottling Company	Null	31
Coca-Cola Bottling Company	Null	101
Coca-Cola Bottling Company	Null	101
Diamond Chain Company	1	93
Eli Lilly & Co	8	2886
Eli Lilly & Co	9	997
Eli Lilly & Co	10	1025
Eli Lilly & Co	11	398
Firestone	4	126
Firestone	3A	280
Firestone	EW-1	82
Firestone	EW-2 and Adjacent Well (Null)	924
Firestone	EW-3	289
Firestone	EW-4	939
General Motors	2	48
General Motors	4	37
Home City Ice	1	34
Indianapolis Marion County	2	120
Indianapolis Marion County	3	150
Indianapolis Marion County	1A	27
Indianapolis Marion County	1B	61
Indy Motor Speedway Golf Course	1	211
Lawrence Utilities	9	446
Lawrence Utilities	10	647
Lawrence Utilities	11	291
Lawrence Utilities	12	814
Lawrence Utilities	8E	248
Magnode Corporation	2	97
National Starch & Chemical	11	247
National Starch & Chemical	14	151
National Starch & Chemical	16	92
National Starch & Chemical	RSP-15	206
Indiana American Noblesville		1315
Peerless Pump Co	1	181
Town of Speedway	2	165

Table 9-5 Continued
Other Significant Groundwater Users

Groundwater User	IDNR Source ID	IDNR 2003-2005 Average Reported Usage (gpm)
Town of Speedway	3	76
Town of Speedway	4	59
Town of Speedway	6	103
Town of Speedway	8	36
Town of Speedway	9	48
Town of Speedway	11	80
Town of Speedway	12	57
Town of Speedway	13	67
Town of Speedway	10R	42
Town of Speedway	14R	75
Town of Speedway	7R	44
Westfield	5	857
Westfield	6	334
Westfield	7	330
Westfield	8	1732
Westfield	9	725
Westfield	Null	634

- *South Wellfield Yield.* Groundwater modeling performed recently indicates the drought yield of the South/Harding wellfield is around 7 to 10 mgd, which would be equivalent to about 250 to 400 gpm per well (WHPA, 2007). The reported yield is only about 20 to 25 percent of the total rated pumping capacity of the wellfield. These estimates were used for this yield evaluation. Further groundwater evaluation was not performed here.
- *Waverly Wellfield Yield.* Recent aquifer testing data and groundwater modeling by others at the Waverly site indicated that, because of clay layers encountered during drilling, this wellfield may be able to yield up to 24 mgd during drought conditions utilizing a combination of vertical wells and collector wells on the available property (WHPA, 2007). The collector wells need to be screened in the shallow sand and gravel to induce river recharge since there is a dividing clay layer separating the upper and lower portions of the sand and gravel aquifer. The testing report indicates that more testing is required to determine if shallow collector wells are feasible in this area. Until further testing is conducted at this site for the shallow collector wells, the drought yield of the Waverly site was assumed to be 24 mgd.

The intent of this study is to develop planning-level groundwater models using available information to form the basis for yield evaluation, with the understanding that the models can be refined in the future with additional calibration as data become available through aquifer testing or monitoring data.

9.3 WELLFIELDS MODELED

The Riverside, White River, White River North, Fall Creek, and Geist Wellfields were modeled for this yield evaluation. The South Wellfield and Waverly Wellfields were recently modeled by others, and the results of those models are incorporated into the system yield model discussed in Section 9.7. The Ford Road Wellfield has a total of four wells, and the yield of this wellfield is estimated in Section 9.7 based on recent production data and knowledge about the aquifer in that area. Harbour Water, Liberty, and Darlington Wellfields are used infrequently or no longer used, so yield models were not prepared for those wellfields.

Figure 9-1shows the extents of the planning-level groundwater models developed for this study. Red dots indicate VWI wells and gray layers represent the ground surface elevations. See Section 7.2 for detailed maps of individual well locations for each wellfield. The development of these models is described below.

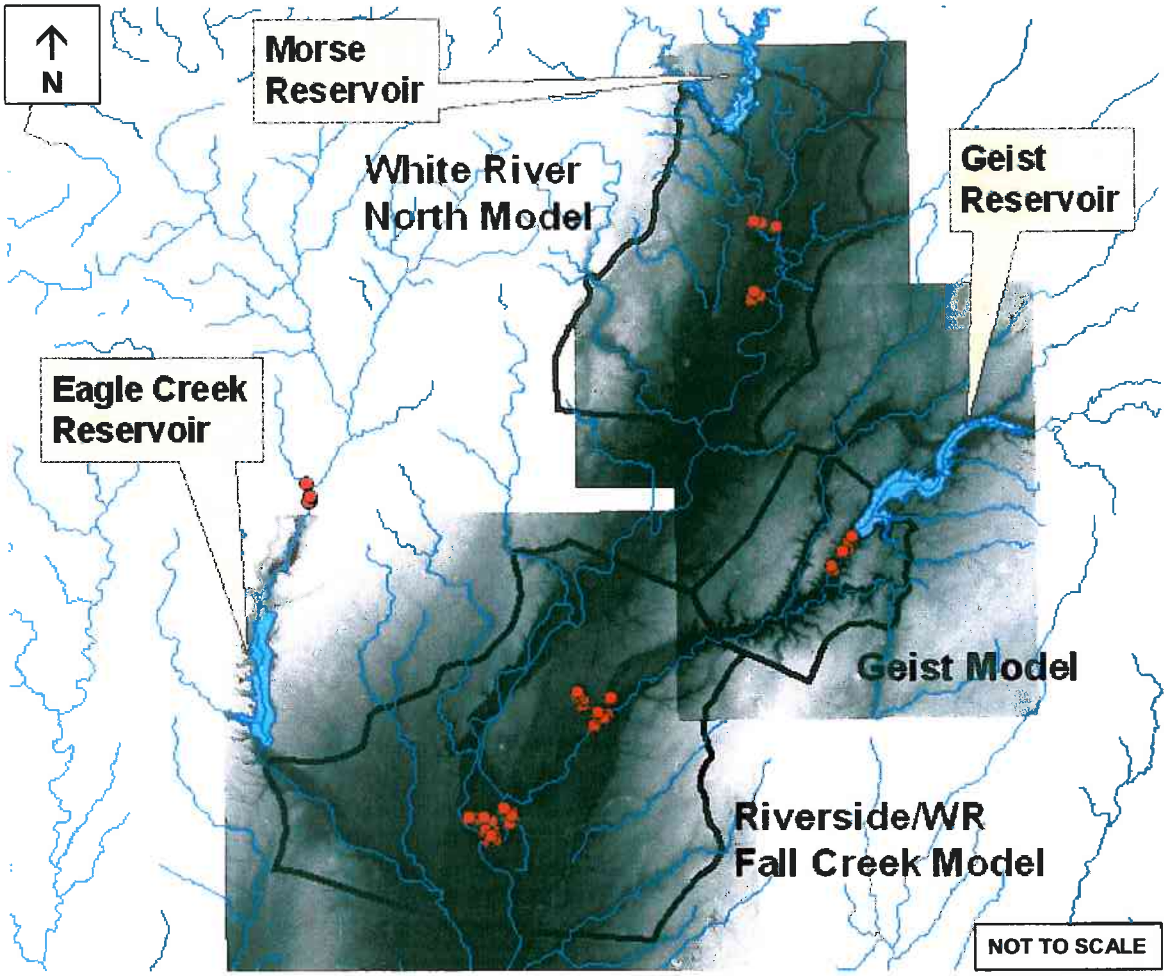

Figure 9-1 Planning-Level Groundwater Models for This Study

9.4 RIVERSIDE, WHITE RIVER, AND FALL CREEK WELLFIELDS GROUNDWATER MODEL DEVELOPMENT

Because the wellfields are in close proximity to one another and include both shallow sand and gravel wells and deep bedrock wells, the Riverside, White River, and Fall Creek Wellfields were combined together for evaluation.

9.4.1 Model Grid and Boundary Conditions

The extents for the groundwater model of the Riverside, White River, and Fall Creek Wellfields are shown on Figure 9-2.

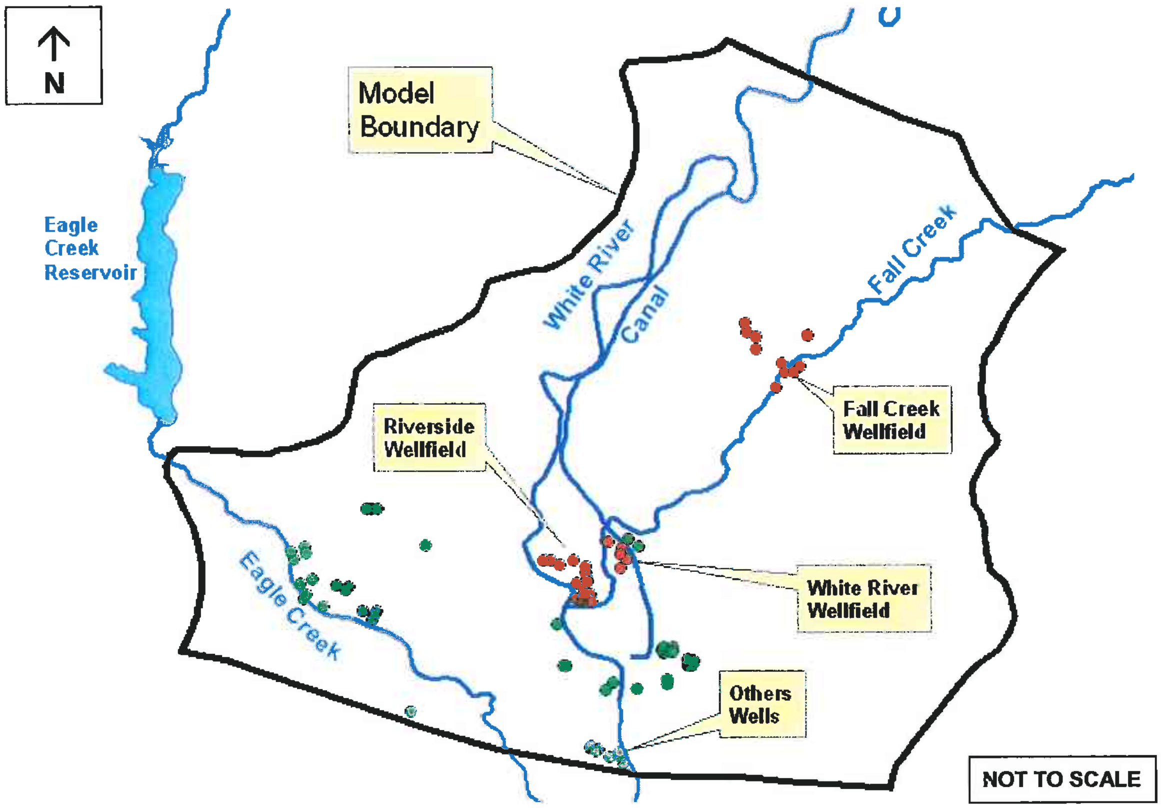

Figure 9-2 Riverside, White River, and Fall Creek Model Extents

The boundaries of the model were set far away from the study area to minimize the effect of the assumptions made for the boundary conditions on the yield of the City's wells. The boundaries were selected based on available groundwater contour mapping (IDNR, 2002; Herring, 1976), with the east and west bounds of the model representing a groundwater elevation of 750 feet. The model was discretized into grid cells with horizontal dimensions of 250 feet by 250 feet which provided enough detail to estimate well yield. The grid cells were oriented to align the grid with the primary groundwater flow direction. Vertically, the model was divided into a total of four layers, as follows:

- Layer 1 – Upper unconsolidated aquifer
- Layer 2 – Lower unconsolidated aquifer from which most shallow wells produce groundwater
- Layer 3 – Upper portion of the bedrock, with carbonate in the northern portion of the model and shale in the southern portion of the model
- Layer 4 – Slightly deeper portion of the bedrock aquifer

The bottom of layer 4 is considered to be a "no-flow" boundary, because recent packer testing revealed that the carbonate bedrock becomes much less permeable with depth, and most fractures and joints are located in the top 100 feet of the bedrock (Black & Veatch, 2007; Cable et. al., 1971). The total number of active grid cells representing the aquifer system for this model is approximately 172,200.

9.4.2 Aquifer Characteristics

Published information was used to assign hydraulic conductivity values to the till, outwash, alluvium, and bedrock. Boring logs and mapping of the surficial and bedrock geology were used to delineate zones of these aquifer materials (IDNR, 2002). Limited information was discovered for the storage properties for the various aquifers in the Indianapolis area, so textbook values were used (Walton, 2007; Freeze and Cherry, 1979). Table 9-6 shows the range of hydraulic conductivity and storage terms used for the model.

Table 9-6
Hydraulic Characteristics for Riverside, White River, Fall Creek Wellfield Model

Layer	Hydraulic Conductivity (ft/day)	Specific Yield	Specific Storage
Till, Upper Aquifer with Higher % of Fines or Clay Layers	10-25	0.05-0.15	0.00005
Outwash	200-300	0.25	0.005
Alluvium	250-350	0.3	0.005
Bedrock	5-40	NA	0.00005
Shale	1	NA	0.00005

9.4.3 Wells

Significant groundwater use as reported to IDNR for 2003-2005 was used to identify other wells in addition to the VWI wells to include in the groundwater model. The average usage and the monthly variation in pumping rates reported to IDNR for each well was used as a guide for setting the pumping rates in the groundwater model for both long-term steady state conditions and for shorter-term transient conditions during drought. Table 9-7 lists the wells represented in the Riverside/White River/Fall Creek groundwater model. As previously indicated, Figure 7-12 shows the locations of these wells within the model boundary.

9.4.4 Recharge

Groundwater recharge can be quite variable and uncertain depending on occurrence and distribution of precipitation, topography, and the type of soil through which water must percolate to reach the groundwater table. The presence of glacial till or interbedded layers of fine-grained material within the aquifer inhibits recharge, as do man-made features such as buildings, paved areas, and storm sewers. As described in Section 7.4.2, published information from past studies was used to estimate recharge for both normal conditions and for drought conditions.

Table 9-7
IDNR Significant Use Wells Represented in the Riverside/White River/Fall Creek Groundwater Model

HomeCityIce1	IndyMarionCo2	Speedway12	FC-21	RS-2
PeerlessPump1	IndyMarionCo1B	Speedway14R	FC-20	RS-3
Cargill2	CentralParkingSystem1	Speedway11	FC-19	RS-26
IndustAnodizing3	CentralParkingSystem2	Speedway13	FC-18	RS-29
IndustAnodizing2	DiamondChain1	Speedway9	FC-11	RS-27
GeneralMotors2	EliLilly9	Speedway10R	FC-17	RS-D
GeneralMotors4	EliLilly8	Speedway8	FC-5	RS-9
AmerUnitedLife5W	EliLilly11	Speedway3	FC-8	RS-8
AmerUnitedLife3W	EliLilly10	Speedway4	FC-7	RS-7
AmerUnitedLife4S	NatStarch&ChemRSP15	Speedway7R	FC-2	RS-28
AmerUnitedLife2N	NatStarch&Chem16	Speedway6	RS-19	WR-9
AmerUnitedLife1E	NatStarch&Chem14	Speedway2	RS-18	WR-7
CBRichardEllis3	NatStarch&Chem11	Allison Transmission11	RS-17	WR-8
CBRichardEllis2	Coca-Cola1	Allison Transmission12	RS-B	WR-3
CBRichardEllis4	Coca-Cola2	Allison Transmission7A	RS-A	WR-6
IndyMarionCo1A	Coca-Cola3	Allison Transmission5A	RS-22	
IndyMarionCo3	MotorSpeedway1	MagnodeCorporation	RS-C	

The average annual precipitation in the Indianapolis area is 40.95 inches (NOAA, 2006). It has been estimated that nearly 70 percent of the precipitation that falls in the area is lost to evaporation or transpiration, with the remaining 30 percent either running off through streams or as subsurface flow (Cable et. al., 1971). Areas covered by glacial till are estimated to have approximately 2 to 5 inches per year of recharge and about 6 to 12 inches per year in areas adjacent to major streams such as White River, Fall Creek, and Eagle Creek. These values were used in the groundwater model for normal, steady state conditions. During drought, some amount of precipitation is expected to occur in the cooler months, but very little if any is expected during warmer months. For the drought conditions model, recharge was only applied during the winter months in the low-lying areas near the major stream at a rate of 5 inches per year for those months, and no recharge occurred during the warmer months.

9.4.5 Streams

Groundwater discharges to streams where the groundwater levels are higher than the stream stage. Streams can provide a significant source of recharge to the aquifer where the stage in the stream is higher than the groundwater levels. The degree of hydraulic connection between the streams and the aquifers depends on the hydraulic conductivity and thickness of the streambed sediment and any intervening layers of clay or silt that inhibit flow from the stream to the aquifer. The yield of a wellfield is higher in areas with good hydraulic connection with streams. In Indianapolis, most significant groundwater wells are screened in a deeper portion of the aquifer that is separated from the streams by layers of clay.

Historical streamflows and stream stages were obtained from the USGS (USGS, 2007) for all major streamgages in the area, and rating curves were developed. The effective Floodplain Insurance Study of Marion County was obtained and reviewed to determine stream profiles (FEMA, 2005). Within the boundary of the Riverside/White River/Fall Creek groundwater model, flows in the White River are typically 4 to 8 feet deep during average flow conditions, with flows deeper and wider behind dams. Fall Creek has a flow depth of about 3 to 4 feet, and Eagle Creek is 2 to 3 feet deep during average conditions. During drought, low streamflows cause a reduction in the amount of induced recharge to the wellfields. Published information described in Section 9.2 was used to estimate the streambed conductance for the White River, Fall Creek, and Eagle Creek. Values of approximately 1 to 1.5 feet per day were used for the streambed hydraulic conductivity. Average stream widths were determined using USGS mapping and aerial photos, and a sediment thickness of 1 foot was assumed. The water supply canal was also simulated in the model. The hydraulic conductivity of the canal bottom was adjusted in the groundwater model until a reasonable match of 27.6 mgd was achieved with the reported canal seepage loss of 21 cfs (Meyer, 1979). This seepage from the canal is a source of recharge for the aquifer system. Some of this water may find its way to nearby wells such as the White River wells adjacent to the southern end of the canal. Smaller streams such as Pleasant Run, Pogues Run, Crooked Creek, and Little Eagle Creek were not considered to add any significant flow to the groundwater system during drought, but were included as "drains" in the model (using MODFLOW's Drain Package) which conservatively allows for a loss of groundwater if the groundwater levels rise above the streambeds.

9.5 WHITE RIVER NORTH WELLFIELD GROUNDWATER MODEL DEVELOPMENT

The White River North Wellfield is a relatively new wellfield with several wells located in Hamilton County near 146th and 166th Streets near the confluence of White River and Cicero Creek. This section describes the groundwater model developed for this wellfield.

9.5.1 Model Grid and Boundary Conditions

The extents for the groundwater model of the White River North Wellfield are shown on Figure 9-3.

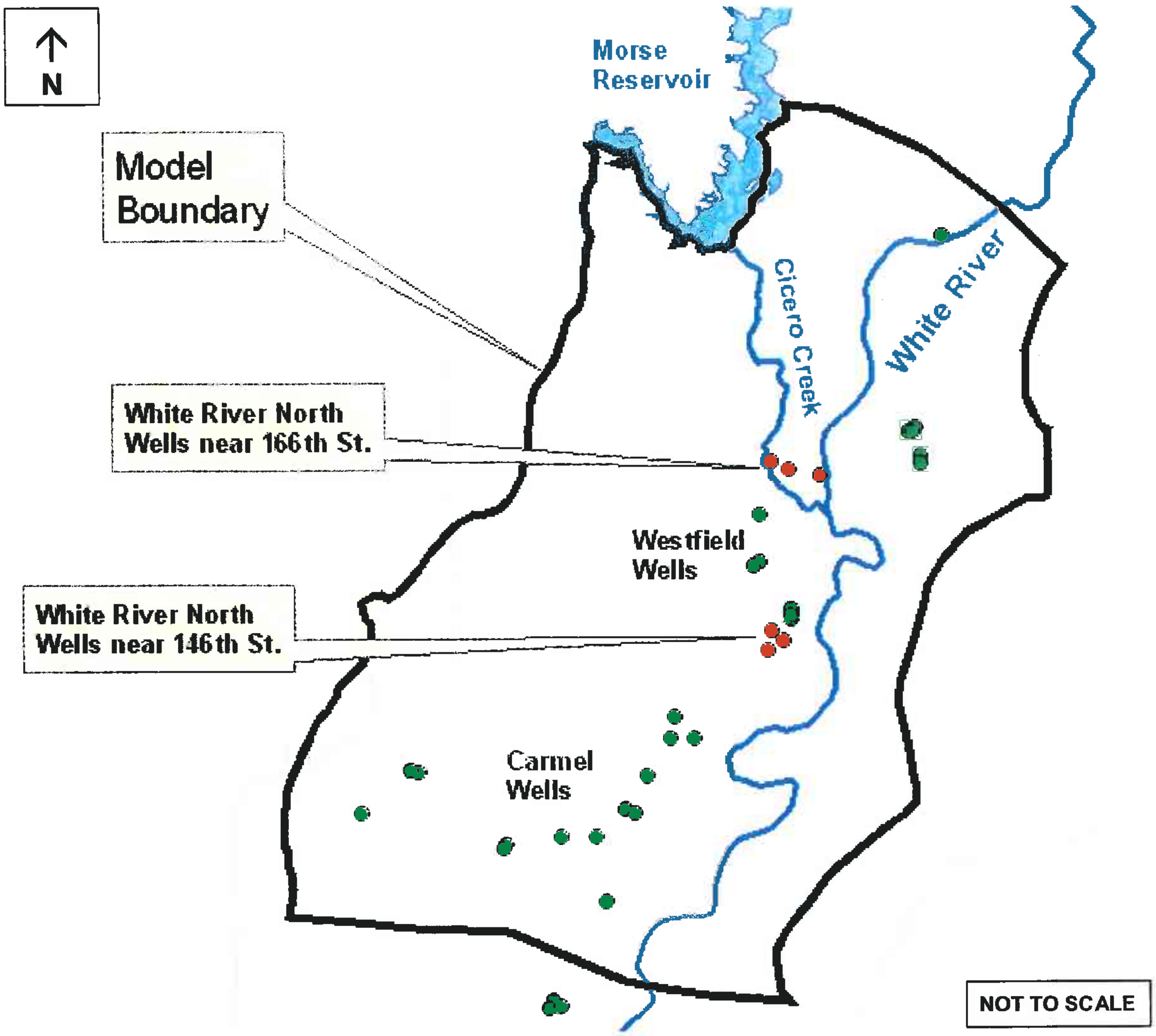

Figure 9-3 White River North Model Extents

The boundaries of the model were set far away from the study area to minimize the effect of the assumptions made for the boundary conditions on the yield of the City's wells. The boundaries were selected based on available groundwater contour mapping (IDNR, 2002; Herring, 1976), with the west boundary of the model representing a groundwater elevation of 825 feet and the east boundary representing 775 feet. The boundary along Morse Reservoir was simulated as a constant head at elevation 810 feet for the steady state simulation and an elevation of 794 feet for the transient simulation during drought. The model was discretized into grid cells with horizontal dimensions of 250 feet by 250 feet which provides enough detail to estimate well yield. The grid cells were oriented slightly to align the grid with the primary groundwater flow direction. Vertically, the model was divided into two layers, as follows:

- Layer 1 – Upper unconsolidated aquifer
- Layer 2 – Lower unconsolidated aquifer from which most wells produce groundwater in the area

The bottom of layer 2 is considered to be a "no-flow" boundary with the assumption that no significant flow is contributed to the unconsolidated aquifer from the deeper bedrock aquifer. The total number of active grid cells representing the aquifer system for this model is 44,242.

9.5.2 Aquifer Characteristics

Published information was used to assign hydraulic conductivity values to the till, outwash, and alluvium. Boring logs and mapping of the surficial geology were used to delineate zones of these aquifer materials (IDNR, 2002). Limited information was discovered for the storage properties for the various aquifers in the Indianapolis area, so textbook values were used (Walton, 2007; Freeze and Cherry, 1979). Table 9-8 shows the range of hydraulic conductivity and storage terms used for the model.

Table 9-8
Hydraulic Characteristics for White River North Wellfield Model

Layer	Hydraulic Conductivity (ft/day)	Specific Yield	Specific Storage
Till, Upper Aquifer with Higher % of Fines or Clay Layers	10-25	0.05-0.15	0.00005
Outwash	220	0.25	0.005
Alluvium	350	0.3	0.005

9.5.3 Wells

Significant groundwater use as reported to IDNR for 2003-2005 was used to identify other wells in addition to the VWI wells to include in the groundwater model as described in Section 7.4.2. The average usage and the monthly variation in pumping rates reported to IDNR for each well was used as a guide for setting the pumping rates in the groundwater model for both long-term steady state conditions and for shorter-term transient conditions during drought. Table 9-9 lists the wells represented in the White River North groundwater model. Figure 7-15 shows the locations of these wells within the model boundary.

Table 9-9
IDNR Significant Use Wells Represented in the White River North Groundwater Model

Noblesville	Westfield 9	Carmel 6
Firestone EW-2 and Null	Carmel 17	Carmel 4
Firestone 4	Carmel 18	Carmel 3
Firestone 3A	Carmel 19	WRN-5
Firestone EW-1	Carmel 21	WRN-4
Firestone EW-4	Carmel 14	WRN-6
Firestone EW-3	Carmel 13	WRN-3A
Westfield 7	Carmel 7	WRN-1
Westfield 5	Carmel 9	WRN-2
Westfield 6	Carmel 16	WRN-3
Westfield 8	Carmel 15	
Westfield Null	Carmel 5	

9.5.4 Recharge

The discussion of groundwater recharge for the Riverside, White River, Fall Creek model in Section 9.4.4 applies to this groundwater model also.

9.5.5 Streams

Groundwater discharges to streams where the groundwater levels are higher than the stream stage. Streams can provide a significant source of recharge to the aquifer where the stage in the stream is higher than the groundwater levels. The degree of hydraulic connection between the streams and the aquifers depends on the hydraulic conductivity and thickness of the streambed sediment and any intervening layers of clay or silt that inhibit flow from the stream to the aquifer. The yield of a wellfield is higher in areas with good hydraulic connection with streams. In Indianapolis, most significant groundwater wells are screened in a deeper portion of the aquifer that is separated from the streams by layers of clay.

Historical streamflows and stream stages were obtained from the USGS (USGS, 2007) for all major streamgages in the area, and rating curves were developed. The effective Floodplain Insurance Study of Marion County was obtained and reviewed to determine stream profiles (FEMA, 2005). Within the boundary of the White River North groundwater model, flows in the White River are typically 4 feet deep during average flow conditions, and flows in Cicero Creek are approximately 2 feet deep depending on releases or spills from Morse Reservoir. During drought, streamflow depth becomes less which reduces the amount of recharge from the streams to the aquifer. Published information described in

Section 9.2 was used to estimate the streambed conductance for the White River, and Cicero Creek was estimated using published information for Fall Creek and Eagle Creek since it is a smaller stream. Values of approximately 1.5 feet per day were used for the streambed hydraulic conductivity for the White River, and a lower value of about 0.1 feet per day was used for Cicero Creek. Average stream widths were determined using USGS mapping and aerial photos, and a sediment thickness of 1 foot was assumed. Smaller streams such as Stony Creek and Cool Creek were not considered to add any significant flow to the groundwater system during drought, but were included as "drains" in the model which conservatively allows for a loss of groundwater if the groundwater levels rise above the streambeds.

9.6 GEIST WELLFIELD GROUNDWATER MODEL DEVELOPMENT

The Geist Wellfield has eight wells located just downstream of Geist Reservoir along Fall Creek. This section describes the groundwater model developed for this wellfield.

9.6.1 Model Grid and Boundary Conditions

The extents for the groundwater model of the Geist Wellfield are shown on Figure 9-4.

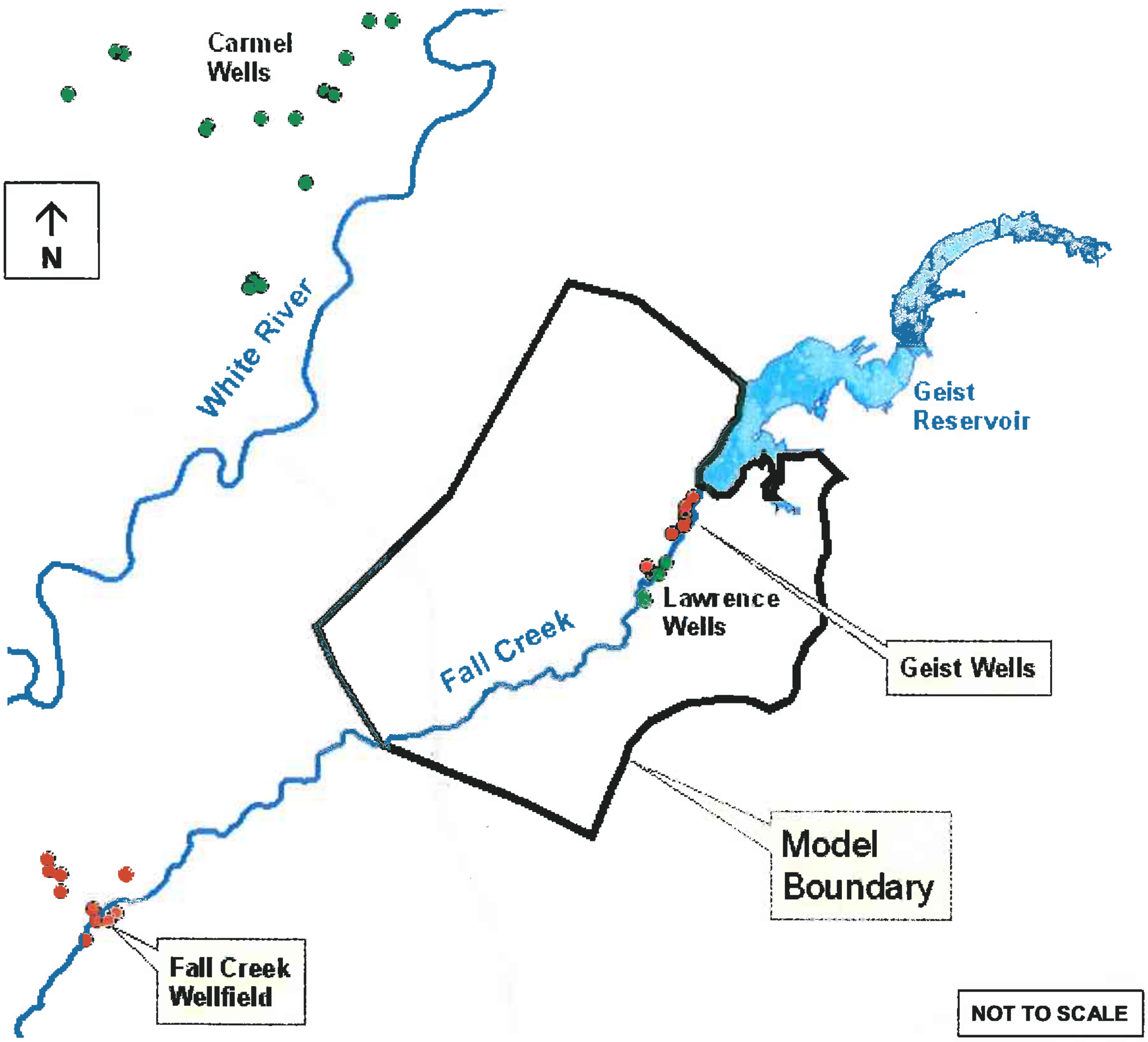

Figure 9-4 Geist Model Extents

The boundaries of the model were set far away from the study area to minimize the effect of the assumptions made for the boundary conditions on the yield of the City's wells. The boundaries were selected based on available groundwater contour mapping (IDNR, 2002; Herring, 1976), with the north boundary of the model representing a groundwater elevation of 750 to 790 feet and the south boundary representing 800 feet. The boundary along Geist Reservoir was simulated as a constant head at elevation 790 feet for the steady state simulation and an elevation of 778 feet for the transient simulation during drought. The model was discretized into grid cells with horizontal dimensions of 250 feet by 250 feet which provides enough detail to estimate well yield. The grid cells were oriented to align the grid with the primary groundwater flow direction. Vertically, the model was divided into two layers, as follows:

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- Layer 1 – Upper unconsolidated aquifer
- Layer 2 – Lower unconsolidated aquifer from which most wells produce groundwater in the area

The bottom of layer 2 is considered to be a “no-flow” boundary with the assumption that no significant flow is contributed to the unconsolidated aquifer from the deeper bedrock aquifer. The total number of active grid cells representing the aquifer system for this model is 21,246.

9.6.2 Aquifer Characteristics

Published information was used to assign hydraulic conductivity values to the till, outwash, and alluvium. Boring logs and mapping of the surficial geology were used to delineate zones of these aquifer materials (IDNR, 2002). Limited information was discovered for the storage properties for the various aquifers in the Indianapolis area, so textbook values were used (Walton, 2007; Freeze and Cherry, 1979). Table 9-10 shows the range of hydraulic conductivity and storage terms used for the model.

Table 9-10
Hydraulic Characteristics for White River North Wellfield Model

Layer	Hydraulic Conductivity (ft/day)	Specific Yield	Specific Storage
Till, Upper Aquifer with Higher % of Fines or Clay Layers	10-25	0.05-0.15	0.00005
Outwash	50-200	0.25	0.005
Alluvium	250	0.3	0.005

9.6.3 Wells

Significant groundwater use as reported to IDNR for 2003-2005 was used to identify other wells. The average usage and the monthly variation in pumping rates reported to IDNR for each well was used as a guide for setting the pumping rates in the groundwater model for both long-term steady state conditions and for shorter-term transient conditions during drought. Table 9-11 lists the wells represented in the Geist groundwater model. Figure 7-14 shows the locations of these wells within the model boundary.

Table 9-11 IDNR Significant Use Wells Represented in the Geist Groundwater Model
GWF-1
GWF-2
GWF-3
GWF-4
GWF-5
GWF-6
GWF-7
GWF-8
Lawrence Utilities8E
Lawrence Utilities9
Lawrence Utilities10
Lawrence Utilities11
Lawrence Utilities12

9.6.4 Recharge

The discussion of groundwater recharge for the Riverside, White River, Fall Creek model in Section 9.4.4 applies to this groundwater model also.

9.6.5 Streams

Groundwater discharges to streams where the groundwater levels are higher than the stream stage. Streams can provide a significant source of recharge to the aquifer where the stage in the stream is higher than the groundwater levels. The degree of hydraulic connection between the streams and the aquifers depends on the hydraulic conductivity and thickness of the streambed sediment and any intervening layers of clay or silt that inhibit flow from the stream to the aquifer. The yield of a wellfield is higher in areas with good hydraulic connection with streams. In Indianapolis, most significant groundwater wells are screened in a deeper portion of the aquifer that is separated from the streams by layers of clay.

Historical streamflows and stream stages were obtained from the USGS (USGS, 2007) for all major streamgages in the area, and rating curves were developed. The effective Floodplain Insurance Study of Marion County was obtained and reviewed to determine stream profiles (FEMA, 2005). Within the boundary of the Geist groundwater model, flows in Fall Creek are typically 3 to 4 feet deep during average flow conditions. During drought, streamflow depth becomes less which reduces the amount of recharge from the streams to the aquifer. Published information described in Section 9.2 was used to estimate the streambed conductance for Fall Creek. A value of 1.3 feet per day was used for the streambed hydraulic conductivity for Fall Creek. Average stream width was determined with USGS mapping and aerial photos, and a sediment thickness of 1 foot was assumed. Smaller streams such as Mud Creek and Indian Creek were not considered to add any significant flow to the groundwater system during drought, but were included as “drains” in the model.

9.7 WELLFIELD YIELD RESULTS

9.7.1 Riverside/White River/Fall Creek Wellfield Model Results

The Riverside/White River/Fall Creek groundwater model parameters for hydraulic conductivity, recharge, and streambed conductance were varied within a reasonable range of published values until the steady-state and the transient groundwater simulations produced reasonable results when compared to IDNR data. Table 9-12 gives the groundwater inflows to and groundwater outflows from the steady-state groundwater model.

Table 9-12
Riverside/White River/Fall Creek Steady-State Groundwater Model

Flow Component	Inflow	Outflow
Constant Head Boundary	+16% (10.7 mgd)	-3% (2.3 mgd)
Stream Recharge	+48% (33.0 mgd)	-
Recharge	+36% (24.9 mgd)	-
Baseflow to Streams	-	-45% (31.0 mgd)
Wells	-	-52% (35.3 mgd)

The steady-state model is dominated by inflows from streams and recharge and by outflows to wells and streams. Flows along the model boundaries were monitored to make sure that reasonable flow was occurring through the glacial till. The canal bottom conductance was adjusted by assigning a canal hydraulic conductivity of 0.35 feet per day. Figure 9-5 shows the groundwater contours for Layer 2 from the steady-state model. Significant drawdown occurs around the major pumping centers as shown by the closed contour lines around the wells.

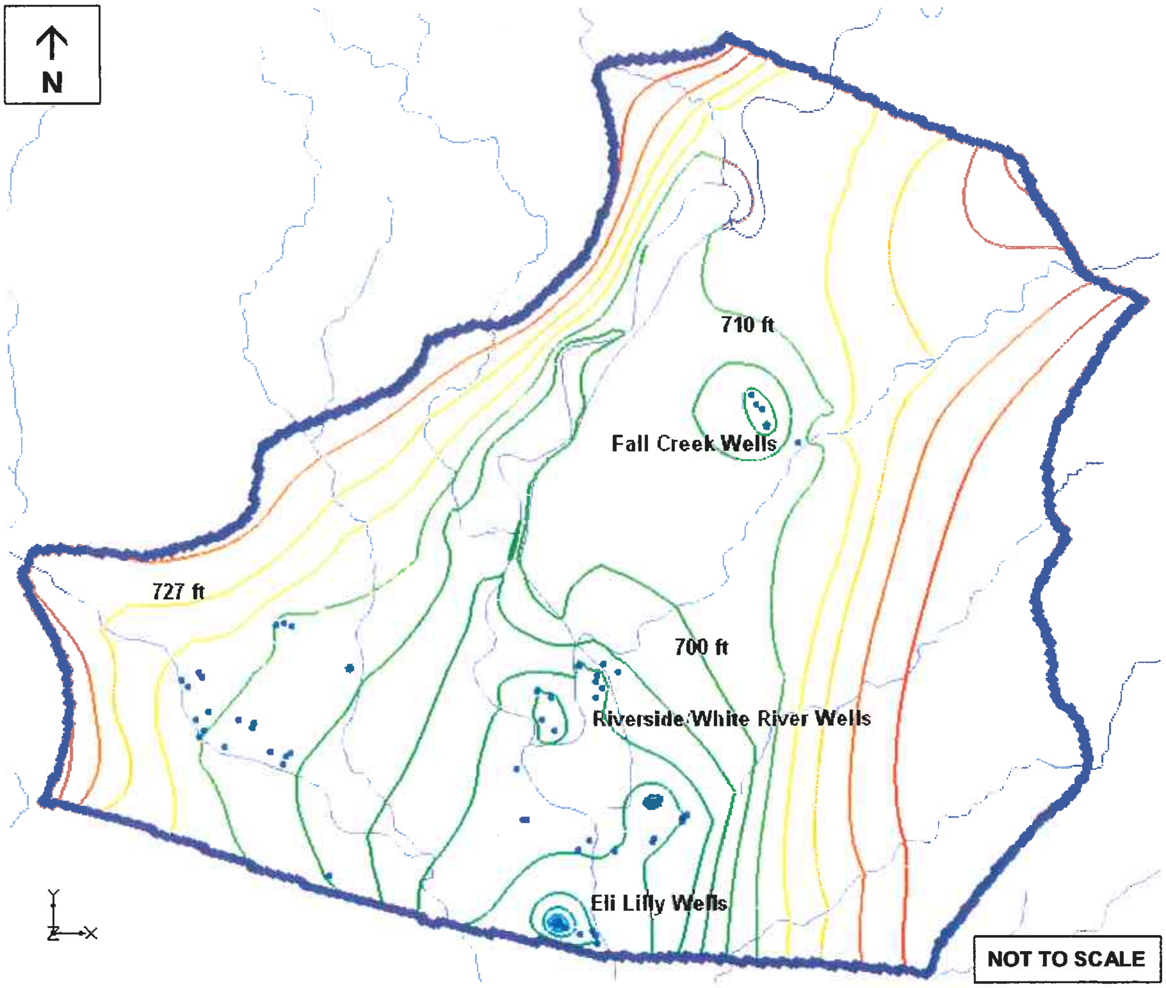

Figure 9-5 Riverside/White River/Fall Creek Wellfield – Steady-State Model, Groundwater Contours for Layer 2

(bedrock wells in Layer 4 of model not shown here)

Transient simulations were performed for this area for a period of two years to represent a typical duration for a severe drought in the Indianapolis area. The resulting groundwater levels were monitored around the wellfields to make sure that excessive drawdown did not occur. Figure 9-6 gives the groundwater flow budget for the transient model of the Riverside/White River/Fall Creek model over the duration of the two-year drought conditions simulation.

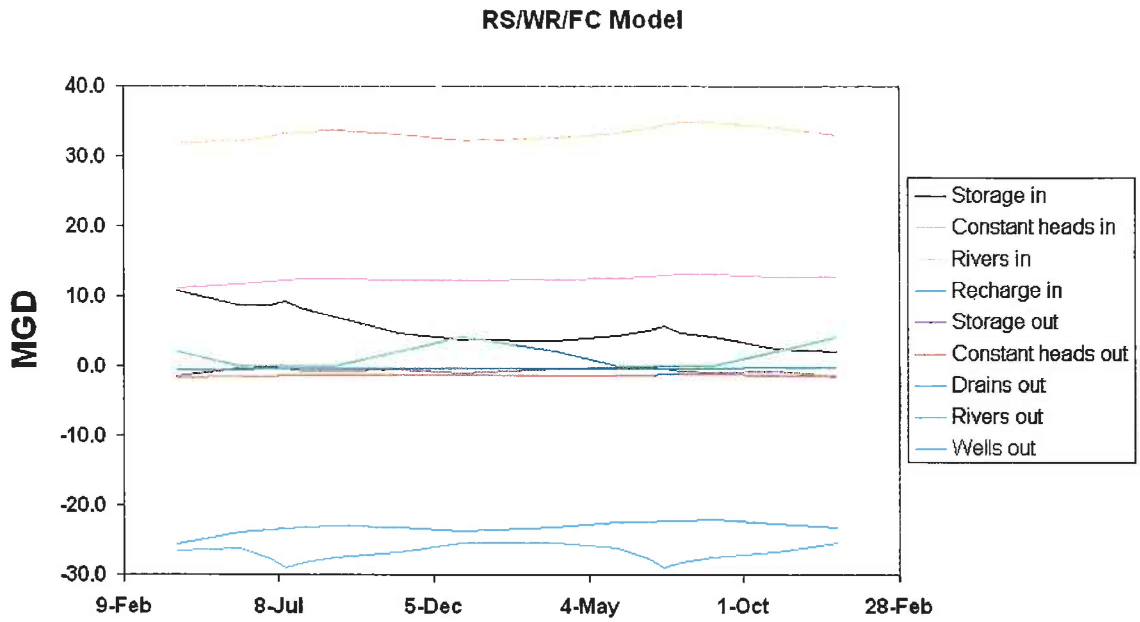

Figure 9-6 Riverside/White River/Fall Creek Model Drought Conditions Groundwater Budget

Recharge was significantly reduced for this simulation, so the flow to wells during a drought must come from the groundwater that is stored in the aquifer and increased flow from other sources such as the streams and regional groundwater flow. Stream recharge, baseflow discharge to streams, discharge to wells, and storage are the primary components of the groundwater flow budget for the drought-conditions model. Because of the lack of data for streambed conductance, several simulations were performed to determine the effect on the groundwater budget if streambed conductance values used in the model were reduced by 25 percent. Less stream recharge results and the wells were still able to yield the same amount of groundwater without causing excessive drawdown. However, if testing were performed and streambed conductance values were determined to be much less than the values used for these planning-level models, the wells would need to rely to a greater extent on the groundwater in storage, and the drought yields would most likely be lower than reported here.

Figure 9-7 shows a plan view of the groundwater contours in the midst of the two-year drought simulation, and Figure 9-8 shows cross section A-A' which is drawn through the location of well RS-C in the Riverside Wellfield.

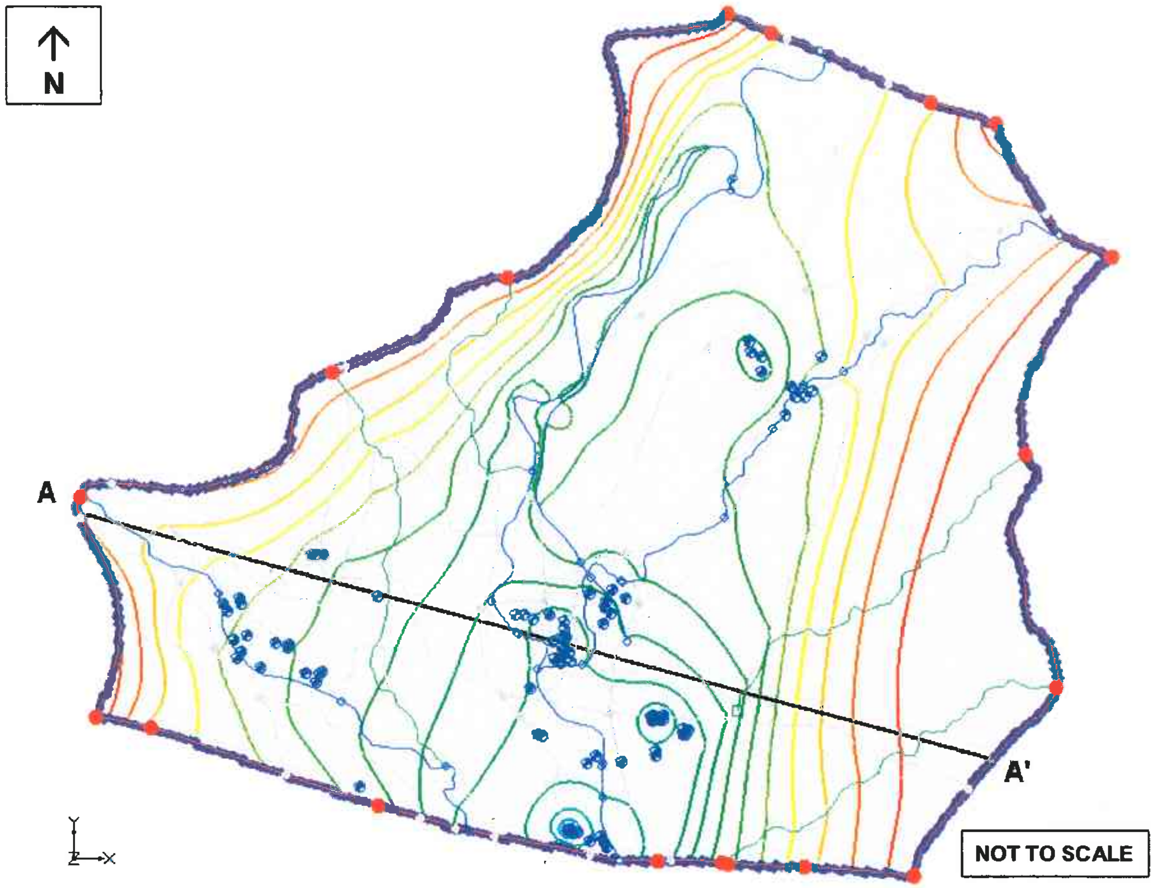

Figure 9-7 Riverside/White River/Fall Creek Model – Groundwater Contours in the Middle of the Two-Year Drought Simulation

(see Figure 9-8 for Cross Section A-A')

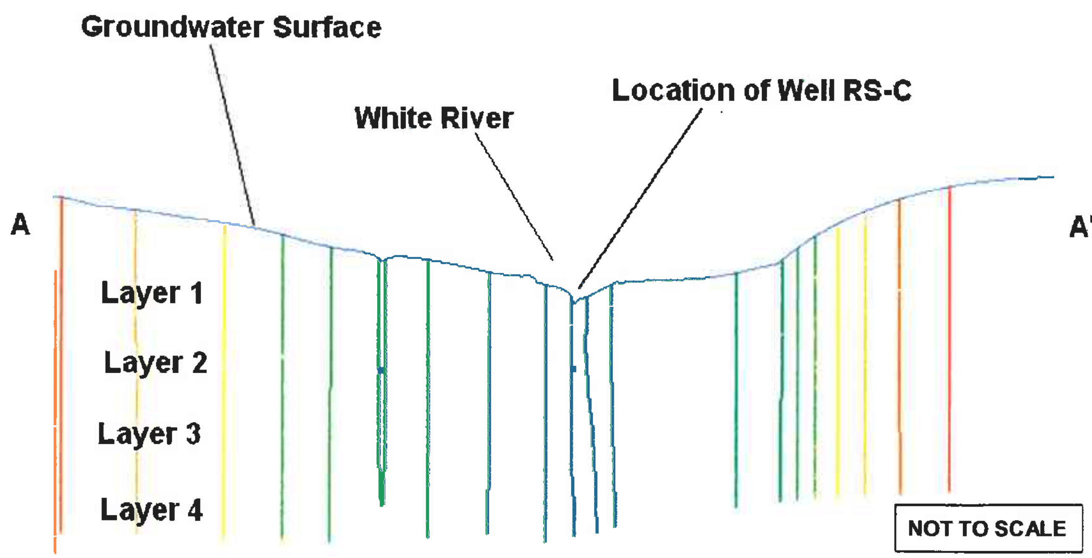

Figure 9-8 Riverside/White River/Fall Creek Model – Cross Section A-A' from Figure 9-7

Table 9-13 summarizes the estimated yield of the Riverside, White River, and Fall Creek wellfields during drought conditions.

Table 9-13
Planning-Level Wellfield Yield

Wellfield	Average Drought Yield (mgd)	Max Drought Yield (mgd)
Riverside	7.3	8.1
White River	4.2	4.5
Fall Creek	5.9	6.8

The actual groundwater production for 2007 for the White River and Fall Creek Treatment Plants is shown in Figures 9-9 and 9-10. The groundwater production ranged from 3 to 7 mgd through the dry summer of 2007 for both the White River plant and the Fall Creek plant, compared to the groundwater model which a yield for the Riverside/White River wells of approximately 11 to 13 mgd and the Fall Creek wells at approximately 6 to 7 mgd during drought conditions. The actual production in 2007 for the Riverside/White River wells was significantly lower than the model predicted and the actual production of the Fall Creek wells is relatively close to what the model predicted. The discrepancy of the Riverside/White River wellfield could be due to a number of issues, such as decisions as to how the wellfield was operated in 2007 in response to demands, condition of the old wells in the wellfield, or the connectivity with streams and recharge in the Riverside area was less than in the Fall Creek Wellfield. The actual production of 3 to 7 mgd for the Riverside/White River wells in 2007 is only about 12 to 28 percent of the total rated pumping capacity of the wellfield and approximately 95 to 220 gpm per well. Based on production from other municipal wells around Indianapolis, the Riverside/White River wells should be able to sustain greater pumping rates than this. If not, the wells may be in need of maintenance, or aquifer testing may be needed to determine the reason for such low yields. For purposes of this study, the model shows the yield of the aquifer in this area is 11 to 13 mgd or 350 to 410 gpm per well. These values are more agreeable with what might be expected in the Indianapolis area during drought.

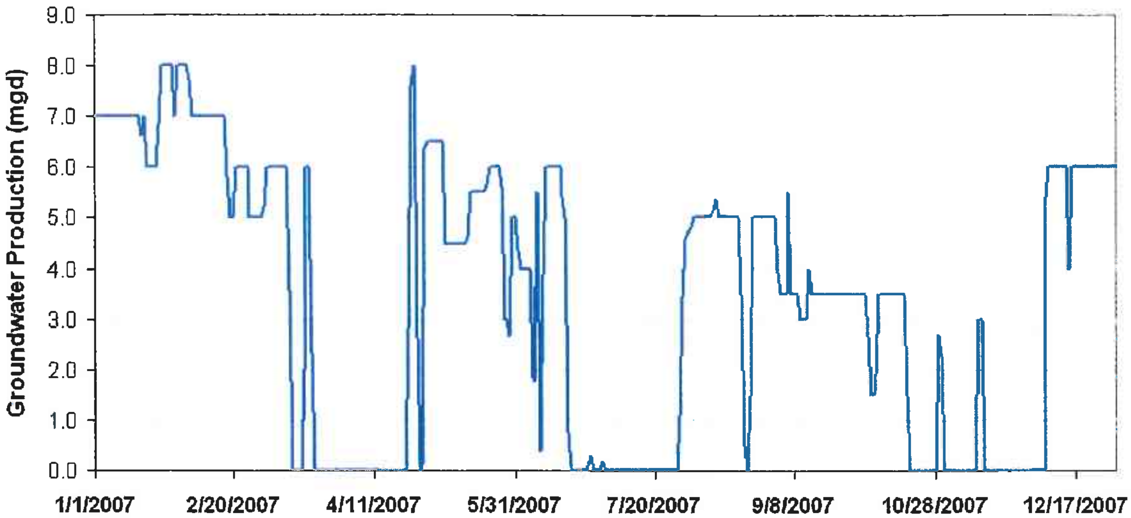

Figure 9-9 2007 Groundwater Production at White River Plant

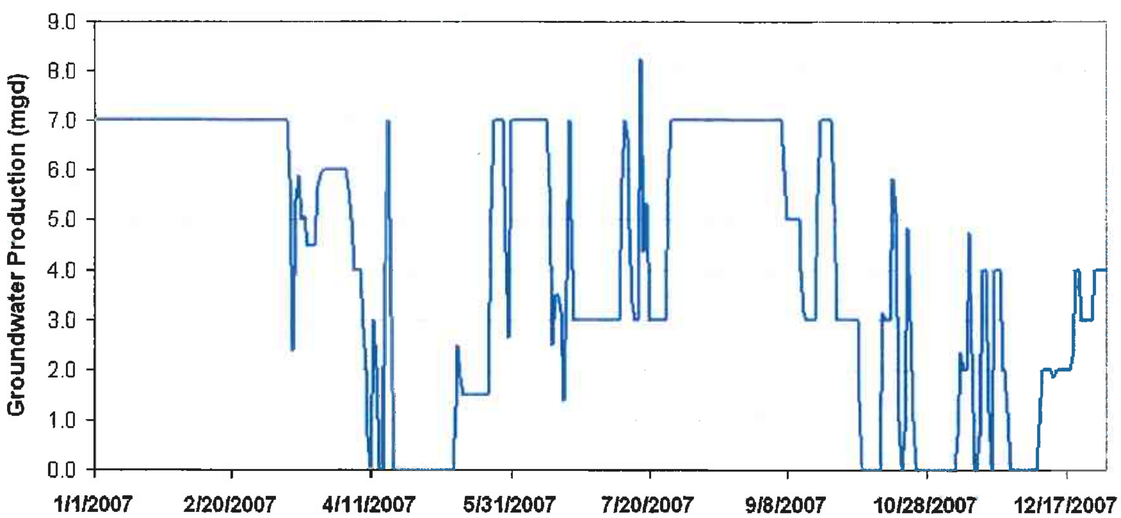

Figure 9-10 2007 Groundwater Production at Fall Creek Plant

Using the planning-level groundwater model several model runs were attempted by adding new wells near the existing White River alluvial wells. This can be seen in Figure 9-11. The area near the White River alluvial wells was chosen because sources indicate that the clay layer appears to be present near the Riverside wells but not near the White River wells, which may allow more recharge from the streams and from precipitation (Brown et.al, 1995). Also, the reported pumping rates from the White River alluvial wells are significantly higher than those from the Riverside alluvial wells. A total of four new White River alluvial wells were added along Fall Creek to maximize recharge, with a separation of about 1000 feet between wells. The model shows that the four new wells could add nearly 4 mgd with the drawdown approaching the maximum allowable drawdown. Testing at these locations would be required to confirm the hydraulic connection with Fall Creek and to determine if there are any intervening clay layers that may inhibit recharge.

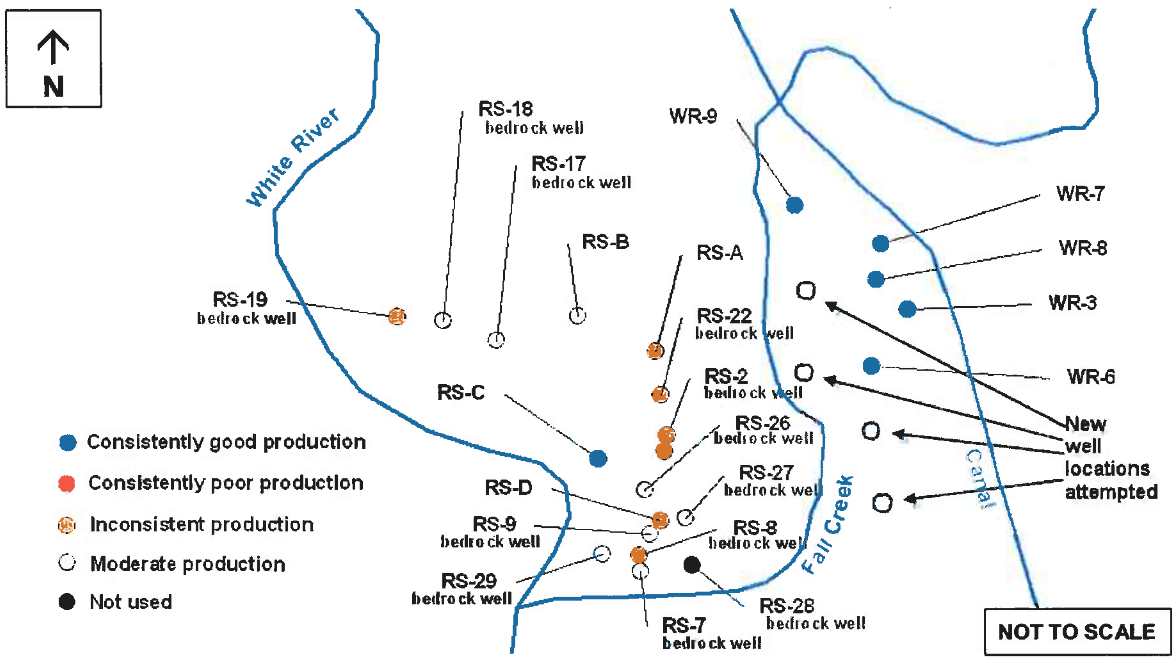

Figure 9-11 Attempted New Well Locations in White River Wellfield

For the Fall Creek wellfield, a total of four new alluvial wells were added to the planning-level groundwater model, as shown on Figure 9-12, to determine if additional yield is available from the aquifer. Simulations were performed by increasing the pumping rates from these four new wells until groundwater levels approached the maximum allowable drawdown. With each well producing approximately 1 mgd the groundwater levels began to exceed the allowable drawdown. However, the model indicated that there may be three or four favorable locations for new alluvial wells capable of producing an estimated 2 to 3 mgd of additional yield provided that adequate spacing is maintained between wells to minimize interference. Well should be located as close to Fall Creek as possible to try to maximize recharge, although, historically, the quality of the water in the shallow aquifer and in Fall Creek have been a concern. Aquifer testing is required to confirm the aquifer materials and hydraulic connection with Fall Creek.

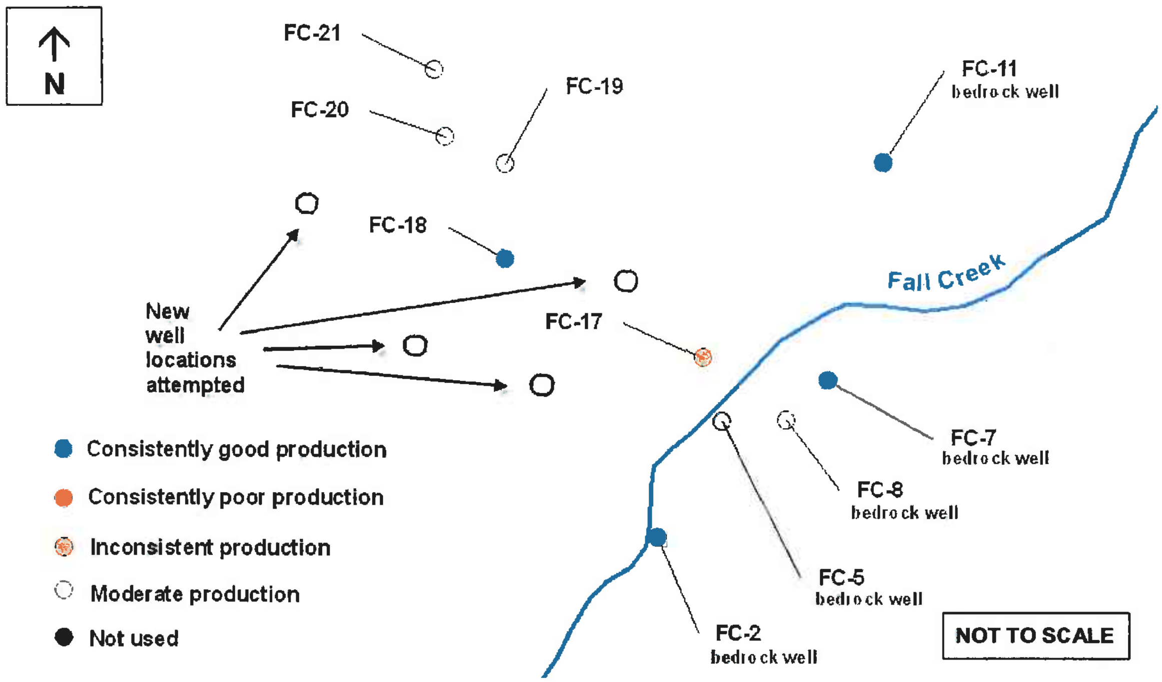

Figure 9-12 Attempted New Well Locations in Fall Creek Wellfield

9.7.2 White River North Wellfield Model Results

The White River North groundwater model parameters for hydraulic conductivity, recharge, and streambed conductance were varied within a reasonable range of published values until the steady-state and the transient groundwater simulations produced reasonable results when compared to the IDNR data. Table 9-14 gives the groundwater inflows to and groundwater outflows from the steady-state groundwater model.

Table 9-14
White River North Steady-State Groundwater Model

Flow Component	Inflow	Outflow
Constant Head Boundary	+42% (13.0 mgd)	-8% (2.5 mgd)
Stream Recharge	+17% (5.2 mgd)	-
Recharge	+41% (13.0 mgd)	-
Baseflow to Streams	-	-24% (7.6 mgd)
Wells	-	-68% (21.1 mgd)

The steady-state model is dominated by inflows from recharge and regional groundwater flow and by outflows to wells. According to the model results, stream recharge is not as significant in this area as in the Riverside/White River wellfield area, because most of the wells in this area are further from major streams. With a significant percentage of the groundwater budget being contributed through the constant head boundaries of the model, regional groundwater flow was monitored to make sure that reasonable flow was occurring through the glacial till. The groundwater model gives flows ranging from 0.32 to 0.78 mgd per mile of till. This is reasonably close to reported values of about 11.7 mgd of flux across an estimated 17.5 miles of constant head boundaries reported by the USGS for a study performed in 1976 near Carmel, Indiana (equivalent to about 0.67 mgd/mile along the boundaries). The USGS study showed that the groundwater budget for the 1970s conditions was dominated by inflows from recharge and regional groundwater flow and by outflows to streams (USGS, 1976). Since that study, well pumping has increased significantly, so this study shows that a larger percentage of outflow from the groundwater system currently goes to wells instead of to the streams in the area. Figure 9-13 shows the groundwater contours for Layer 2 from the steady-state model.

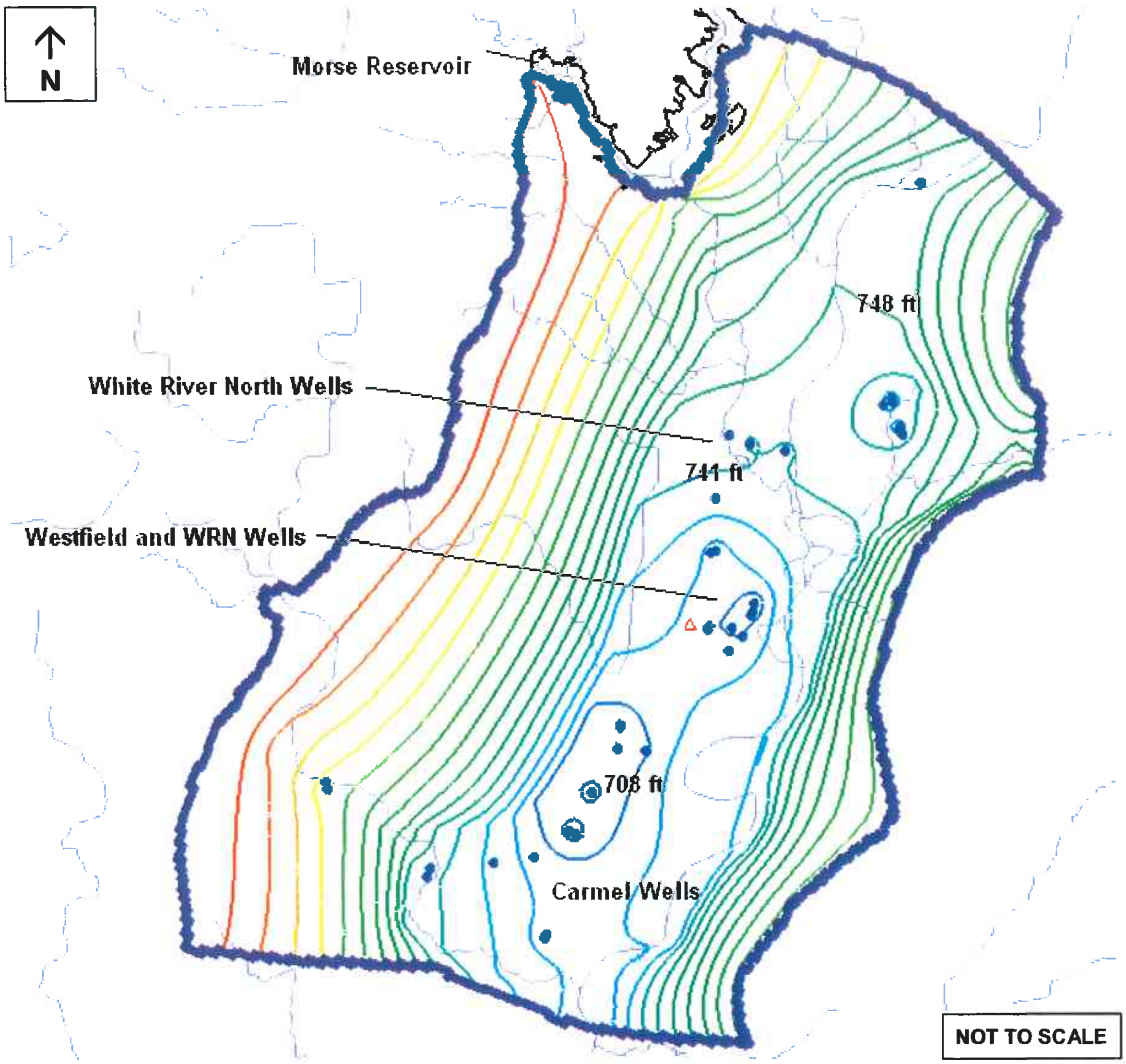

Figure 9-13 White River North Wellfield – Steady-State Model, Groundwater Contours for Layer 2

Transient simulations were performed for a period of two years to represent a typical duration for a severe drought in the Indianapolis area. The resulting groundwater levels were monitored around the wellfields to make sure that excessive drawdown did not occur. Figure 9-14 gives the groundwater flow budget for the transient model of the White River North Wellfield model over the duration of the two-year drought conditions simulation.

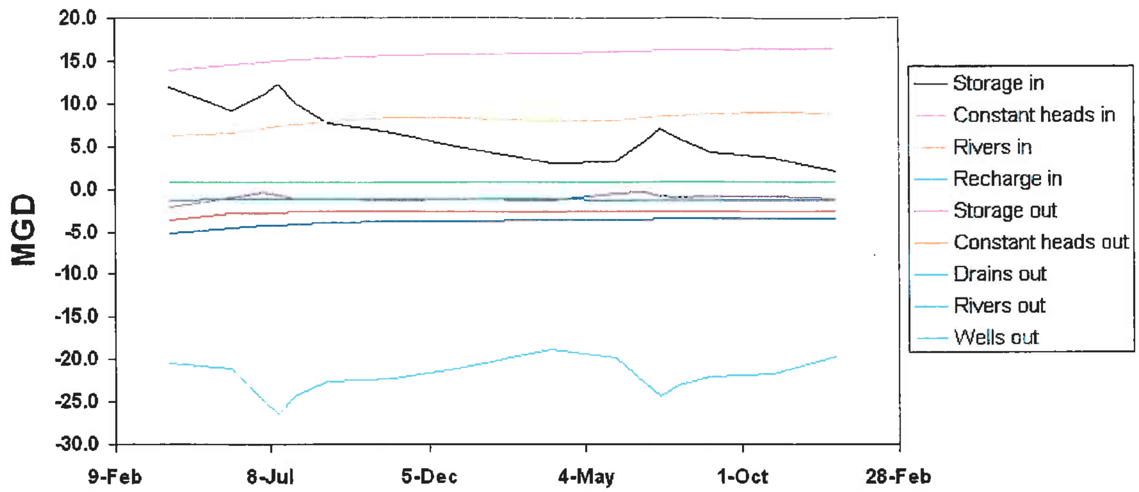

Figure 9-14 White River North Wellfield Model Drought Conditions Groundw ater Budget

Recharge was significantly reduced for this simulation, so the flow to wells during a drought must come from the groundwater that is stored in the aquifer and increased flow from other sources. Regional groundwater inflow, storage, stream recharge, and discharge to wells are the primary components of the groundwater flow budget for the drought-conditions model. Figure 9-15 shows a plan view of the groundwater contours in the midst of the two-year drought simulation, and Figure 9-16 shows cross section A-A' drawn through the location of well WRN-2 in the White River North Wellfield. The cross section shows how the sand and gravel aquifer is deeper near the White River North wells, but surrounding boring logs show significantly less sand and gravel, highlighting the variability in the aquifer layering in the area. This is also true to the south near the City of Carmel wellfield where the City's wells are located in a thicker portion of sand and gravel to the west of the White River, with a "thinning-out" of the sand and gravel adjacent to and to the east of White River. The cross section and plan view also show a significant cone-of-depression in the vicinity of the White River North, Westfield, and Carmel wells.

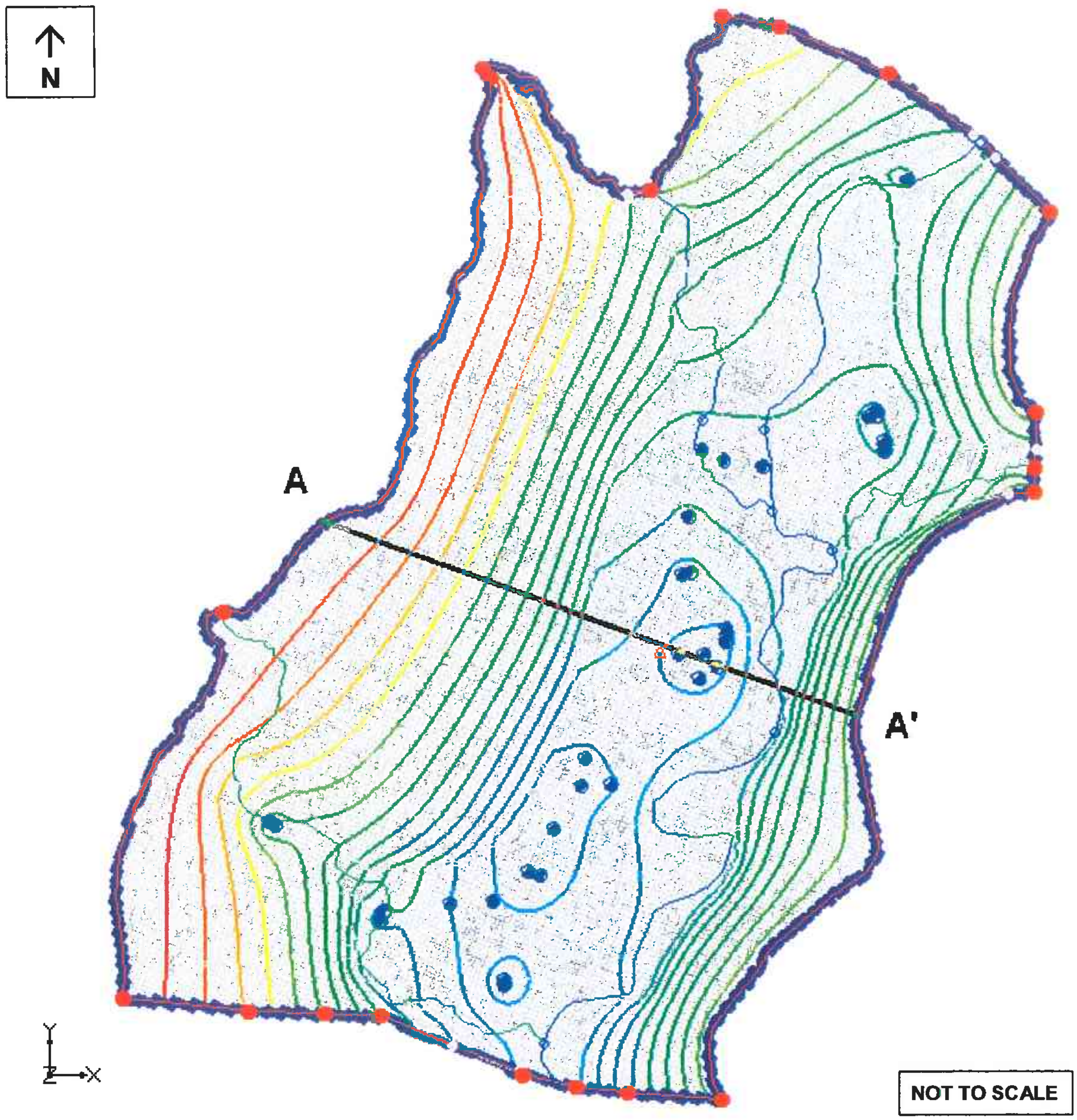

Figure 9-15 White River North Wellfield Model – Groundwater Contours in the Middle of the Two-Year Drought Simulation

(see Figure 9-16 for Cros Section A-A')

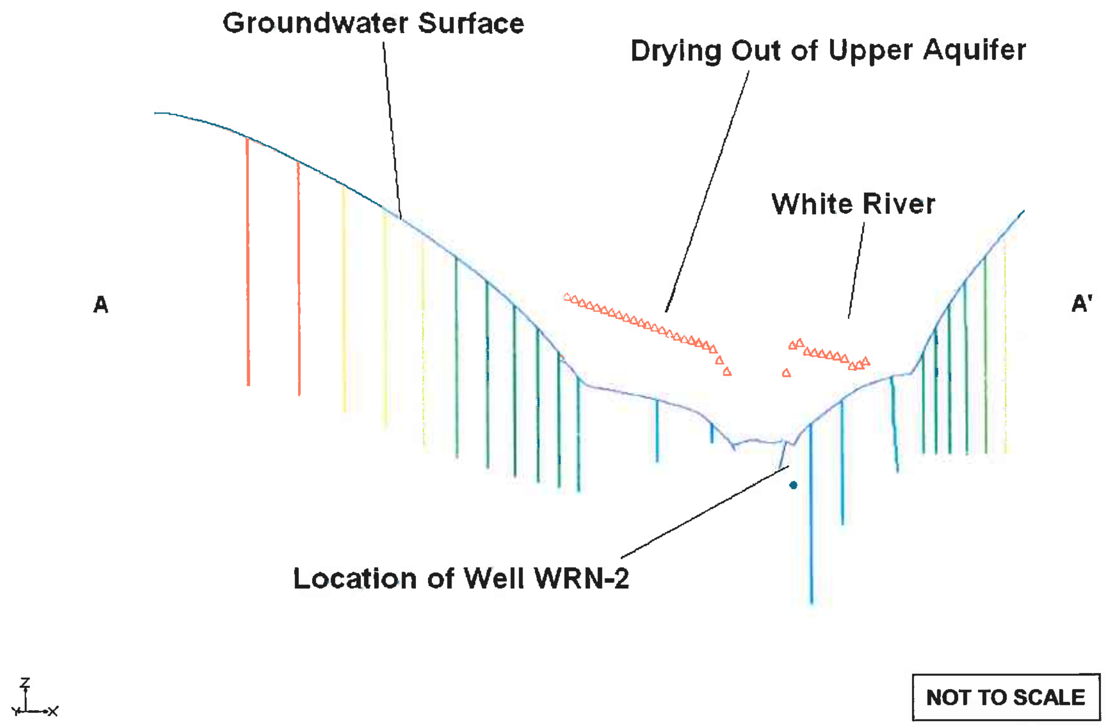

Figure 9-16 White River North Wellfield Model – Cross Section A-A' from Figure 9-15

Table 9-15 summarizes the estimated yield of the White River North Wellfield during drought conditions.

Table 9-15 Planning-Level Wellfield Yield		
Wellfield	**Average Drought Yield (mgd)**	**Max Drought Yield (mgd)**
White River North	7.6	8.7

Seven wells in the White River North wellfield should be able to produce 750 gpm per well on average and up to a maximum of 860 gpm per well during drought conditions. This is a higher yield per well than the Riverside/White River Wellfield because of fewer wells in the area competing for groundwater and deep pockets of sand and gravel encountered by the White River North wells. For comparison, pump testing results in 2007 in the area showed that pumps with capacities of up to 1600 gpm should be installed in wells WRN-1, WRN-2, and WRN-3A; however, because of the clay layers of varying thicknesses serving to inhibit recharge within the aquifer, these maximum rates could only be sustained for a period of 180 days. For a period of 365 days, rates of about 1100 to 1500 gpm per well could be sustained (NAWS, 2007). During a severe drought lasting for two years, these sustainable yields will be further reduced, making the model yield of 750 to 860 gpm per well during drought quite reasonable. If more wells are added in the area in the future, the yield per well will become less due to interference.

The actual groundwater production for 2007 for the White River North Plant is shown in Figure 9-17. The groundwater production ranged between 2 and 3 mgd through the summer of 2007. This averages about 460 to 700 gpm per well, similar to the yield reported by the model. Figure 9-17 shows that the White River North Wellfield was not continuously pumped at 2 to 3 mgd during the summer of 2007, but was interrupted by periods of essentially no production. This may have been due to problems with too much drawdown, or because of periods of reduced demand. Based on the fluctuation of total production in 2007, the fluctuation in production from the White River North Wellfield is believed to be because of demand and not aquifer limitations.

Several model runs were attempted by adding new wells near the confluence of White River and Cicero Creek as shown on Figure 9-18. The addition of new wells dried the aquifer and the model did not converge on a solution. To get the model to converge with the addition of new wells, the pumping rates of the existing wells would need to be reduced. Results such as this indicate that the information presented above provide a planning-level estimate of the yield of the aquifer in the White River North area during drought.

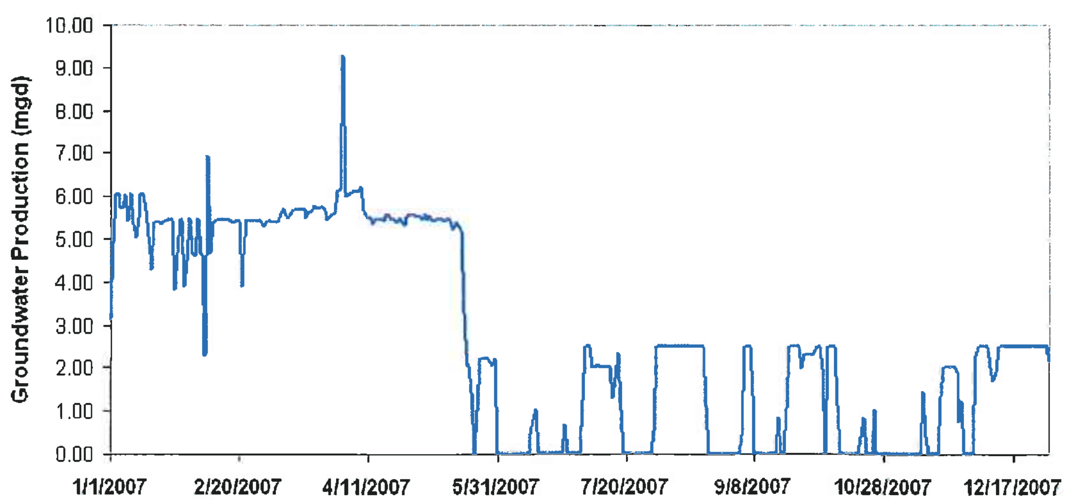

Figure 9-17 2007 Groundwater Production at White River North Plant

(Source: spreadsheet "Inflow Distribution-2007.xls" provided by VWI)

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Because of the significant variability in the depth of the sand and gravel aquifer, hydrogeologic testing may reveal additional deep pockets of sand and gravel with the capability of adding yield during dry conditions. In a review of the aquifer near the Carmel in 1976, the USGS notes the importance of locating wells as close to the White River as possible to maximize recharge and maintaining adequate separation between wells in order to obtain pumping rates between 350 to 800 gpm per well (USGS, 1976). Since 1976, a significant number of wells have been installed in the area, so finding locations for new wells with adequate separation is more difficult today. As shown on Figure 9-18, most of the Westfield and Carmel wells are located a significant distance to the west of White River because the sand and gravel aquifer is not very thick immediately adjacent to the river. Unfortunately, this area to the west of the White River has complex layers of silt and clay which inhibit recharge from precipitation (USGS, 1976; NAWS, 2007). Because of the complexity of the clay layers and the variability in the depth of the aquifer, new well sites must be determined through aquifer testing, and the model should be updated with the new data to refine estimates of yield in the area.

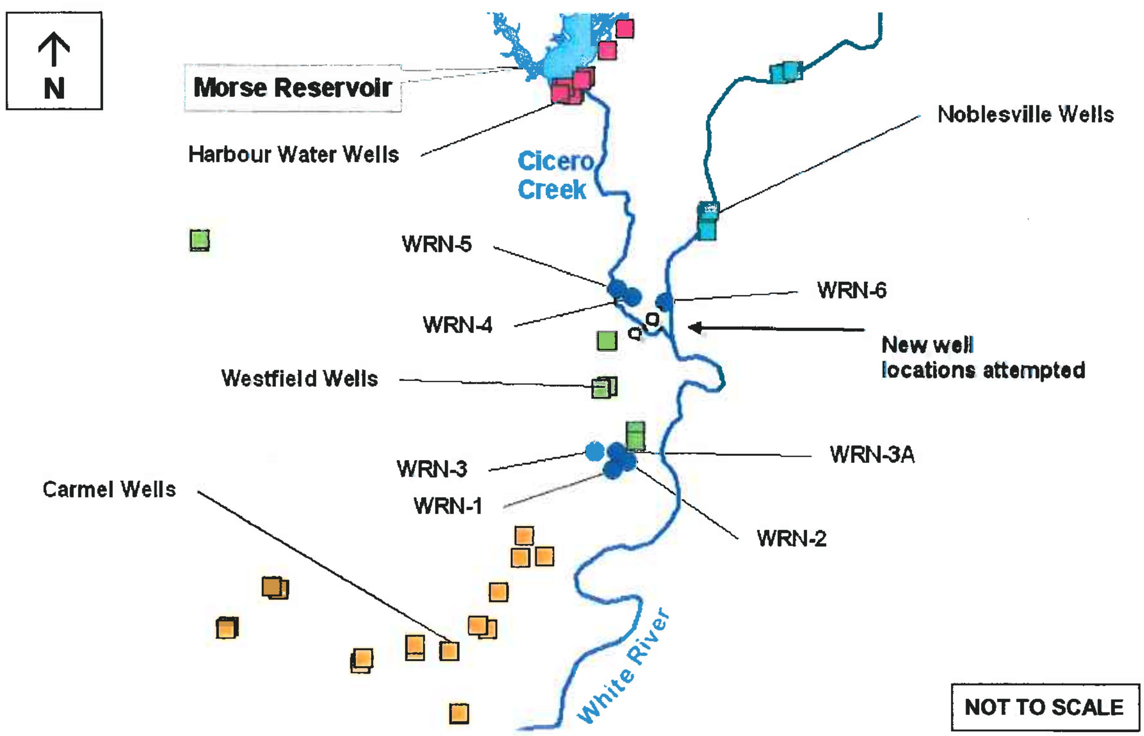

Figure 9-18 Attempted New Well Locations in White River North Wellfield

9.7.3 Geist Wellfield Model Results

The Geist Wellfield groundwater model parameters for hydraulic conductivity, recharge, and streambed conductance were varied within a reasonable range of published values until the steady-state and the transient groundwater simulations produced reasonable groundwater surfaces when compared to the IDNR data. Table 9-16 gives the groundwater inflows to and groundwater outflows from the steady-state groundwater model.

Table 9-16
Geist Steady-State Groundwater Model

Flow Component	Inflow	Outflow
Constant Head Boundary	+25% (2.76 mgd)	-9% (1.0 mgd)
Stream Recharge	+35% (3.89 mgd)	-
Recharge	+40% (4.32 mgd)	-
Baseflow to Streams	-	-35% (2.97 mgd)
Wells	-	-56% (6.18 mgd)

The steady-state model is dominated by inflows from recharge and Fall Creek and by outflows to wells and to Fall Creek. Regional groundwater flow was monitored to make sure that reasonable flow was occurring through the glacial till. The groundwater model gives flows of up to 0.24 mgd per mile of till. This is within range of reported values of about 0.67 mgd/mile along the boundaries reported by the USGS in a 1976 study. Groundwater discharges to the downstream end of Fall Creek in the model at a rate of about 1.24 cubic feet per second (cfs) per mile of stream, compared to baseflows of 2 to 4 cfs per mile estimated for the White River (Smith, 1983). Since Fall Creek has a reportedly smaller streambed conductance than the White River, this value is considered reasonable. The resulting groundwater contours for Layer 2 from the steady-state model are shown in Figure 9-19.

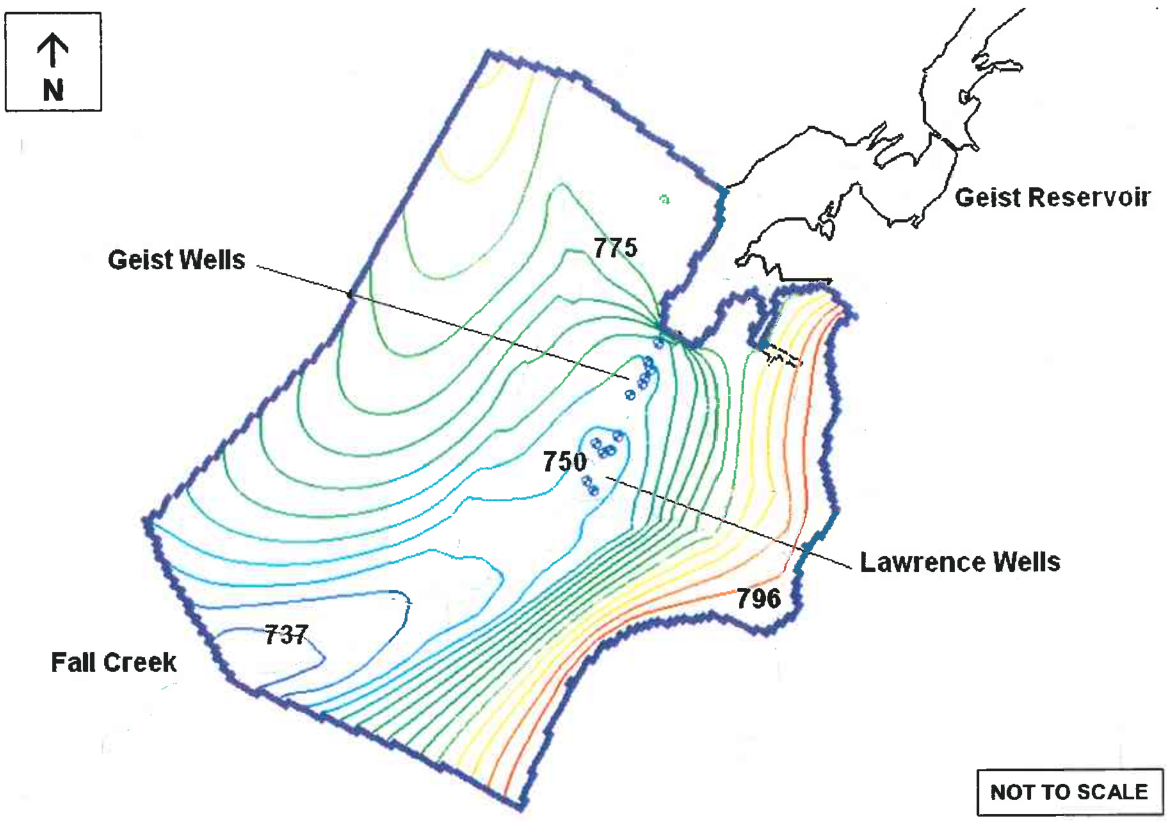

Figure 9-19 Geist Wellfield – Steady-State Model, Groundwater Contours for Layer 2

Transient simulations were performed for a period of two years to represent a typical duration for a severe drought in the Indianapolis area. The resulting groundwater levels were monitored around the wellfield to make sure that excessive drawdown did not occur. Figure 9-20 gives the groundwater flow budget for the transient model of the Geist Wellfield model over the duration of the two-year drought conditions simulation.

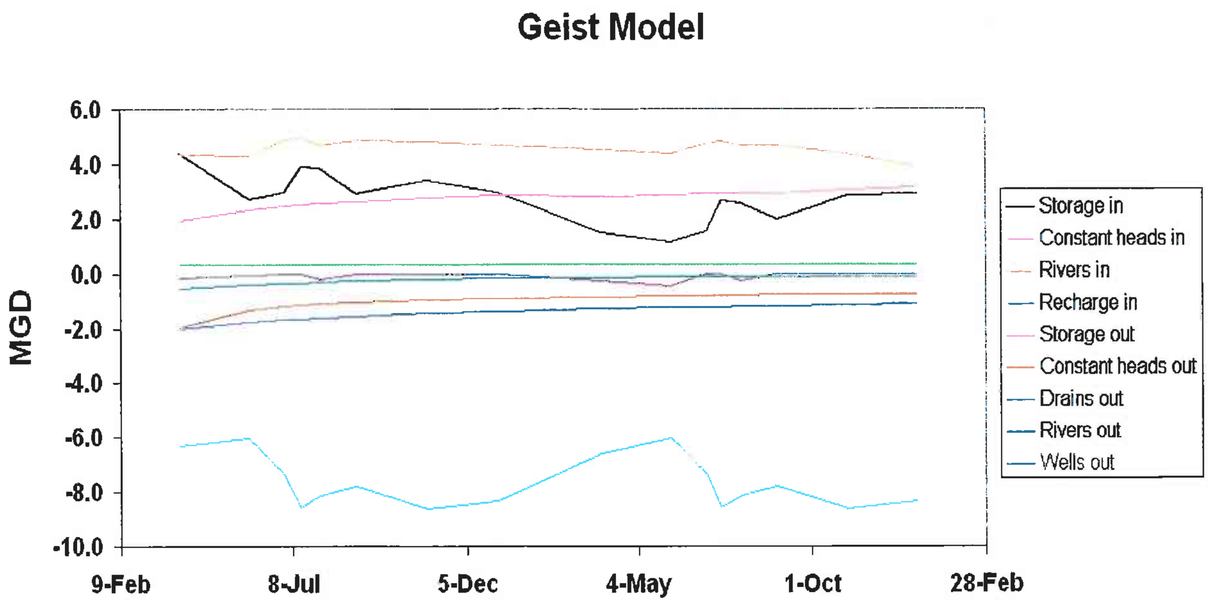

Figure 9-20 Geist Wellfield Model Drought Conditions Groundw ater Budget

Recharge was significantly reduced for this simulation, so the flow to wells during a drought must come from the groundwater that is stored in the aquifer and increased flow from other sources. Regional groundwater inflow, storage, stream recharge, and discharge to wells are the primary components of the groundwater flow budget for the drought-conditions model. Figure 9-21 shows a plan view of the groundwater contours in the midst of the two-year drought simulation, and Figure 9-22 shows cross section A-A' drawn through the location of well GWF-7 in the Geist Wellfield. The cross section shows the thickness of the sand and gravel aquifer (Layer 2) near Fall Creek and the relatively steep valley of Fall Creek in relation to other stream valleys in the area. Layer 1 represents a relatively thick layer of glacial till located on either side of Fall Creek.

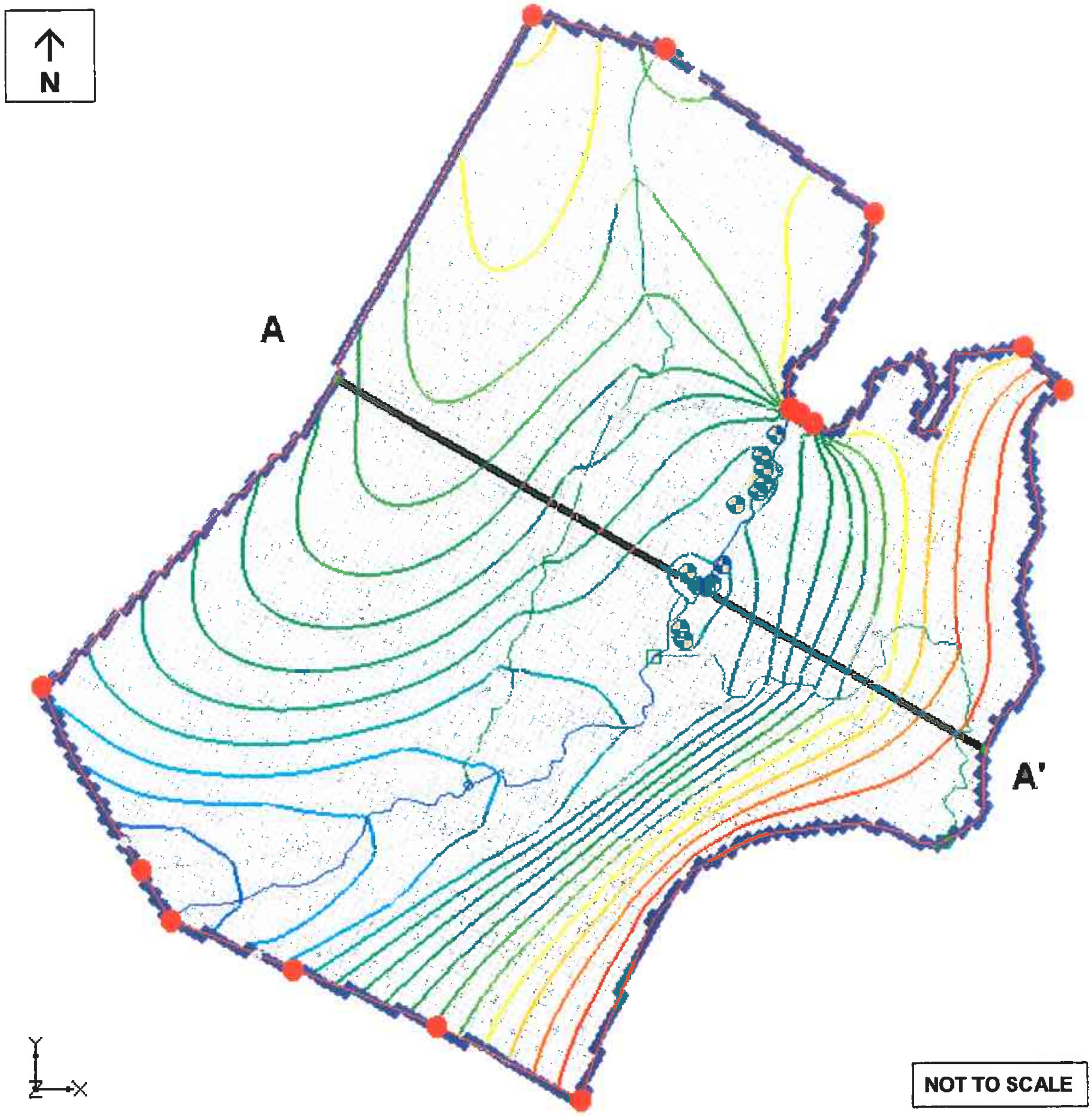

Figure 9-21 Geist Wellfield Model – Groundwater Contours in the Middle of the Two-Year Drought Simulation

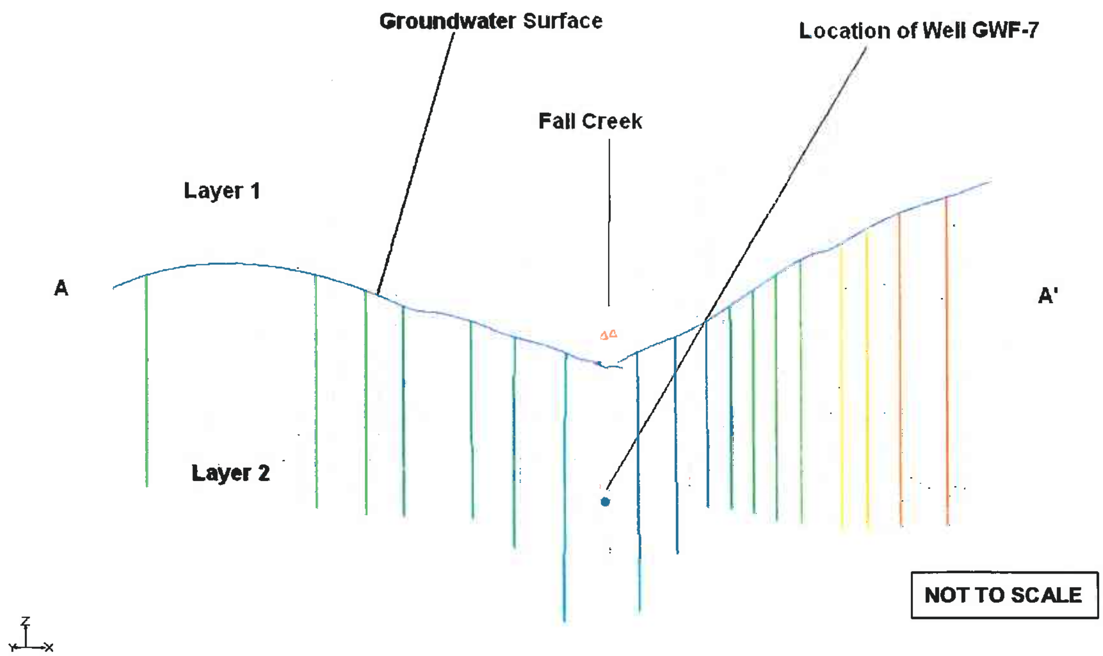

Figure 9-22 Geist Wellfield Model – Cross Section A-A' from Figure 9-21

Table 9-17 summarizes the estimated yield of the Geist Wellfield during drought conditions.

Table 9-17
Planning-Level Wellfield Yield

Wellfield	Average Drought Yield (mgd)	Max Drought Yield (mgd)
Geist	4.4	7.1

Eight wells in the Geist Wellfield should be able to produce 380 gpm per well on average and up to a maximum of 620 gpm per well during drought conditions. The groundwater production for 2007 for the Geist Wellfield is illustrated in Figure 9-23. The groundwater production ranged from about 3 to 7 mgd through the dry summer of 2007. Similarly, the model predicted an average production of 3.5 mgd and the maximum day production of 7.3 mgd. If more wells are added in the area in the future, the yield per well will become less due to interference. The model shows that the average Lawrence well yield during drought is about 400 to 430 gpm per well. Lawrence's average well usag,e as reported to IDNR from 2003 to 2005, is about 800 gpm to over 1000 gpm at times, so another source of water may be needed during drought.

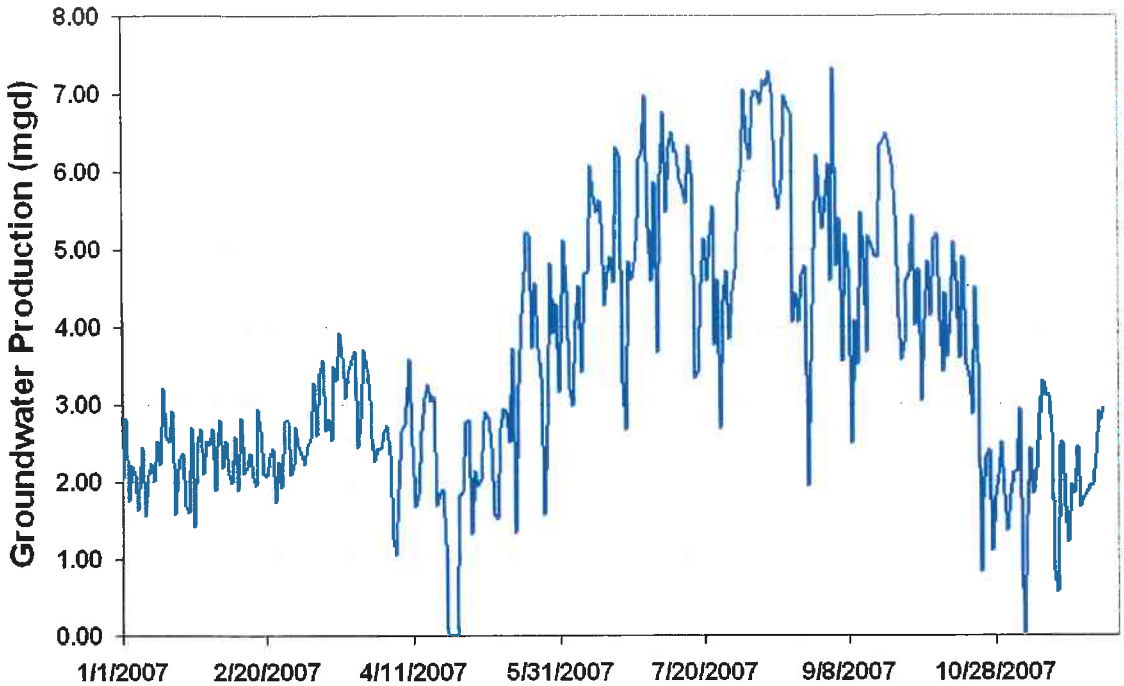

Figure 9-23 2007 Groundwater Production at Geist

(Source: spreadsheet "Pc07Nov.xls" provided by VWI)

Because no testing has been performed to determine the actual aquifer-stream interaction in this area, several simulations were performed to determine the effect on well yield if the streambed conductance of Fall Creek were reduced. A reduction in conductance of 50 percent caused a reduction in well yield of approximately 25 percent. Similar for other VWI wellfields, the model results are sensitive to the stream conductance, and any future aquifer testing of aquifer-stream interaction near the City's wellfields should be used to update the models.

Several model runs were attempted by adding new wells along Fall Creek between the existing Geist wells and the Lawrence wells, in the area indicated on Figure 9-24. The addition of new wells caused drying of the aquifer and the model did not converge on a solution. To get the model to converge with the addition of new wells, the pumping rates of the existing wells would need to be reduced. Results such as this indicate that the information presented above provide a planning-level estimate of the yield of the aquifer in the Geist/Lawrence wellfield area during drought.

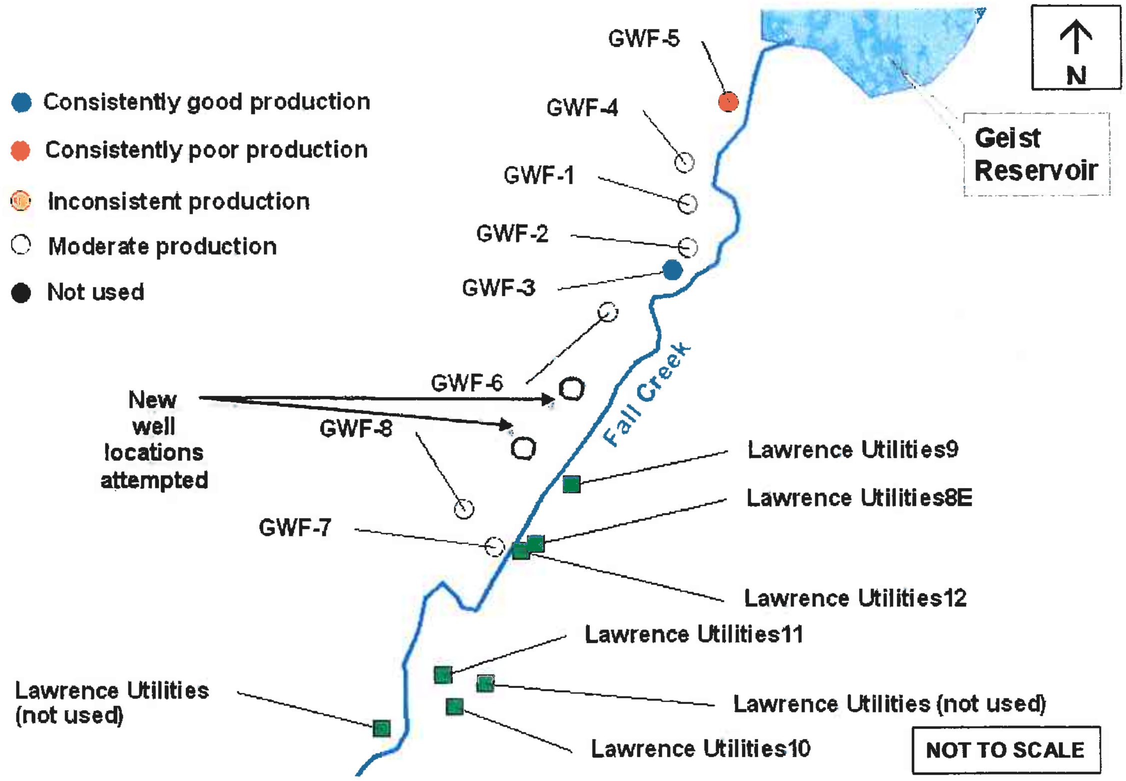

Figure 9-24 Attempted New Well Locations in Geist Wellfield

9.7.4 Other Wellfield Yields

Ford Road Wellfield consists of four wells in the alluvium along Eagle Creek to the north of Eagle Creek Reservoir. Wells are at depths between 60 and 90 feet below ground surface. The top of one of the well screens is only 30 feet below ground surface resulting in less available drawdown than at other wellfields. Based on IDNR records from 2003 to 2005, reported groundwater usage from these four wells is between 1.7 and 2.0 mgd, or about 300 gpm to 350 gpm per well. During the dry conditions of 2007, the production at Ford Road was between 0.7 and 1.2 mgd, or about 120 to 210 gpm per well. During a severe drought, the yield is not expected to be more than in 2007. For purposes of this report a yield of up to 1 mgd was assumed during a drought from these four wells.

Recent aquifer testing and modeling at the Waverly and South Wellfields shows that the Waverly Wellfield might be able to produce up to 24 mgd during drought. This may be possible if further testing shows that shallow horizontal collector wells are feasible (WHPA, 2007), and that the South Wellfield will be able to produce up to 8 mgd during a 50-year drought (WHPA, 2007). These yields were used, and no further evaluation was performed for this study.

October 2008

Black and Veatch

Phase 2

Yield and Demand Study

Final Technical Memorandum

Section 10

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10. TOTAL SYSTEM YIELD EVALUATION

10.1 SYSTEM MODEL DEVELOPMENT

A yield model was developed for the entire Veolia Water Indianapolis (VWI) water supply system, building upon the model developed for the Phase 1 yield and demand study (Black & Veatch, 2003). This Phase 2 model offers a number of refinements including a daily time step and VWI's assistance in reassessing of the system constraints and assumptions based on operations in recent dry years. The major components of the water supply system yield model are:

- Daily streamflow accounting at critical locations along the White River, Fall Creek, and Eagle Creek
- Minimum streamflows for power plants and environmental purposes
- Morse, Geist, and Eagle Creek Reservoir daily stages, areas, and volumes, considering sedimentation, precipitation, evaporation, inflows, releases, and minimum allowable levels
- Upstream depletions from other communities and consumptive use of water
- Wastewater return flows at Belmont and Southport Treatment Plants
- Streamflow depletion near wellfields
- Wellfield yields from planning-level groundwater models incorporated

Figure 10-1 shows an illustration of some of the major system considerations included in the yield model.

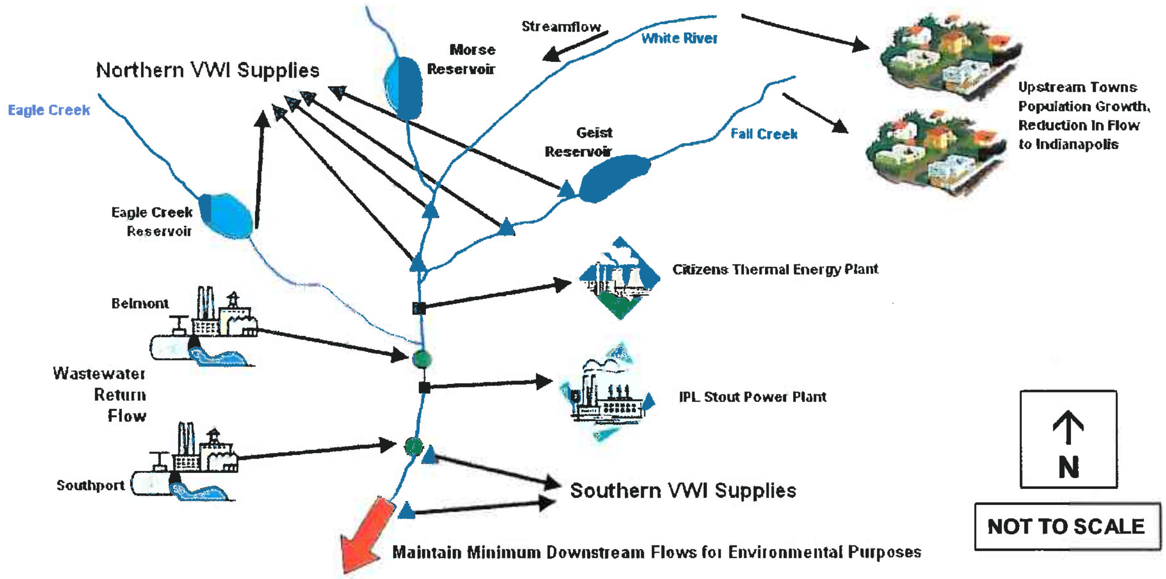

Figure 10-1 Illustration of Several Major Considerations for System Yield

The system yield model was set up to provide warnings and charts that "flag" the user of system constraints and assumptions such as drawing the reservoirs below their minimum allowable elevations, lowering streamflows below the minimum allowable thresholds, or exceeding treatment capacities. The user is allowed to vary the production at each of the surface water and groundwater sources of supply until all of the system constraints are met resulting in estimates of yield at each source and total system yield. As will be the case during a drought, increasing the yield at upstream sources in the model (e.g., the White River North facilities) results in lower yield at downstream sources (e.g., the White River facilities).

10.1.1 Streamflows

A significant amount of historical streamflow data was collected from the United States Geological Survey (USGS) for the stream gages shown in Table 10-1. Incremental daily streamflows at critical locations in the Indianapolis area were derived from the historical data by using area-weighted adjustment of the data from the nearest USGS stream gage. Consideration was given to the period of record for each gage, the year each reservoir was built, the locations of major water supply diversions, and the locations of major wastewater outfalls in order to make a good assessment of natural streamflows and to avoid "double-counting" water in the model. The streamgage locations are shown on Figure 10-2.

Table 10-1
USGS Streamgages

USGS Streamgage	Period of Record
White River near Centerton	10/1/1930 – current
White River at Waverly	7/29/1986 – 9/30/1988
White River at Stout Power Plant	10/1/1992 – current
White River at Indianapolis	5/6/1904 – current
White River near Nora	10/1/1929 – current
White River at Noblesville	10/1/1946 – current
White River near Noblesville	10/1/1915 – 9/30/1974
White River at Anderson	10/1/1925 – current
Fall Creek at Millersville	10/1/1929 – current
Fall Creek near Fortville	7/1/1941 – current
Eagle Creek at Indianapolis	4/1/1939 – current
Eagle Creek at Zionsville	10/1/1957 – current
Cicero Creek near Arcadia	10/1/1954 – 9/30/1976

Note: Other gage data was obtained and reviewed to determine drought flows for smaller streams such as Mud Creek, Indian Creek, Stony Creek, Crooked Creek, Little Eagle Creek, and Cool Creek

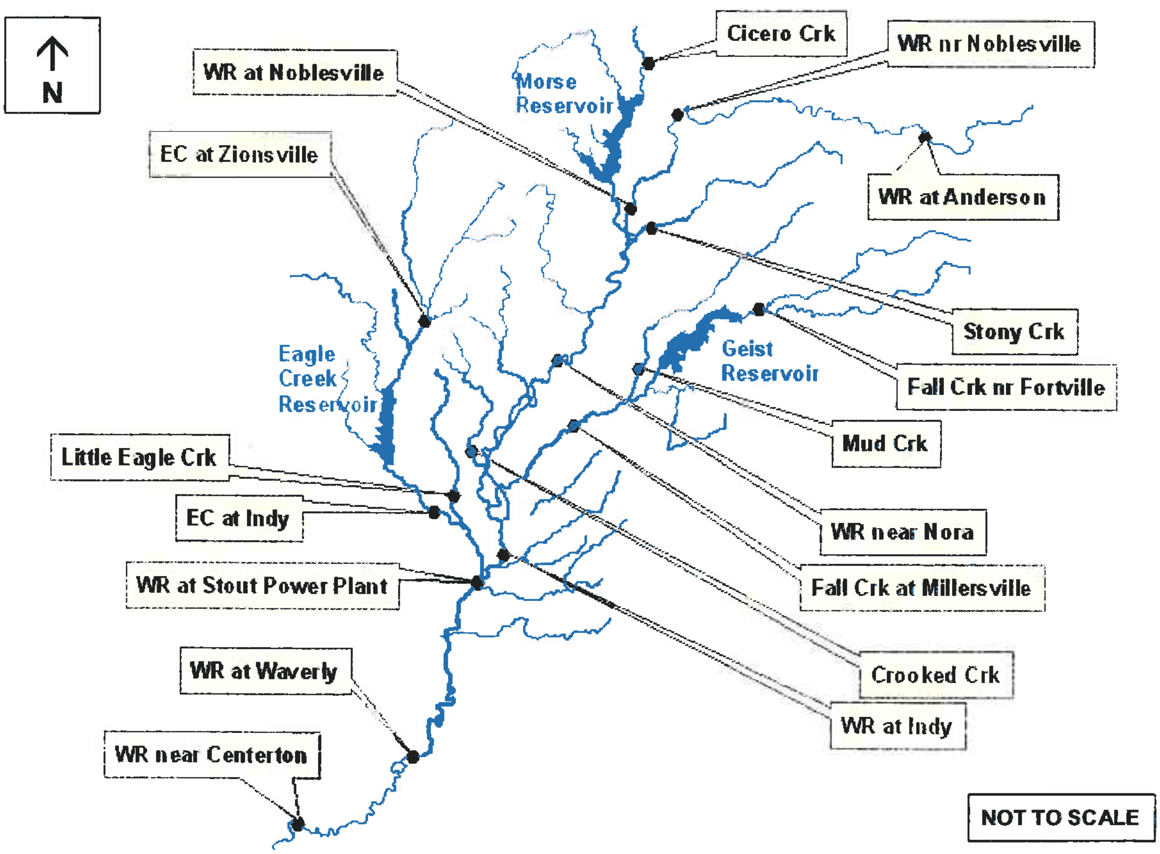

Figure 10-2 USGS Streamgages Used to Derive System Streamflows

For the droughts selected for yield analysis, streamflows were accounted within the system yield model on a daily basis at the following locations:

- Morse Reservoir inflow
- Morse Reservoir dam
- Confluence of White River and Cicero Creek
- White River past White River North Facilities
- White River at Broad Ripple Dam
- Canal
- White River past Riverside Wellfield
- Confluence of White River and Fall Creek
- Geist Reservoir inflow
- Geist Reservoir dam
- Fall Creek past Geist Wellfield
- Fall Creek past Fall Creek Wellfield/Fall Creek Treatment Plant
- Fall Creek past Keystone Dam
- Fall Creek past White River Wellfield
- Eagle Creek Reservoir inflow
- Eagle Creek Reservoir dam
- White River past Citizens Thermal Energy Plant
- Confluence of White River and Eagle Creek
- White River past Belmont Wastewater Outfall
- White River past IPL Stout Power Plant
- White River past Southport Wastewater Outfall
- White River past South Wellfield
- White River past Waverly Wellfield

10.1.2 Precipitation and Evaporation

Historical precipitation and evaporation data were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Climate Data Center (NCDC). Precipitation data from Whitestown, Indianapolis International Airport, and Anderson's sewage plant were obtained, and evaporation data was obtained for Geist Reservoir. Net daily evaporation (evaporation minus precipitation) was calculated and input into the system yield model for each of the reservoirs.

10.1.3 Reservoirs

Bathymetric data was collected for Morse and Geist Reservoirs by the USGS in 1996. Indiana Department of Natural Resources (IDNR) surveyed Eagle Creek Reservoir in the mid-1990s. The three-dimensional representations of the reservoirs created during the 2003 yield and demand study provided an estimate of the sedimentation rates and were used to develop the potential future stage-area-volume curves for the 2010 and 2020 planning horizons of this evaluation. The estimated sedimentation rates of the reservoirs are 64 acre-feet per year for Morse, 42 acre-feet per year for Geist, and 27 acre-feet per year for Eagle Creek Reservoir, which were used to reduce the storage in the reservoirs and develop the rating curves shown on Figures 10-3 through 10-5.

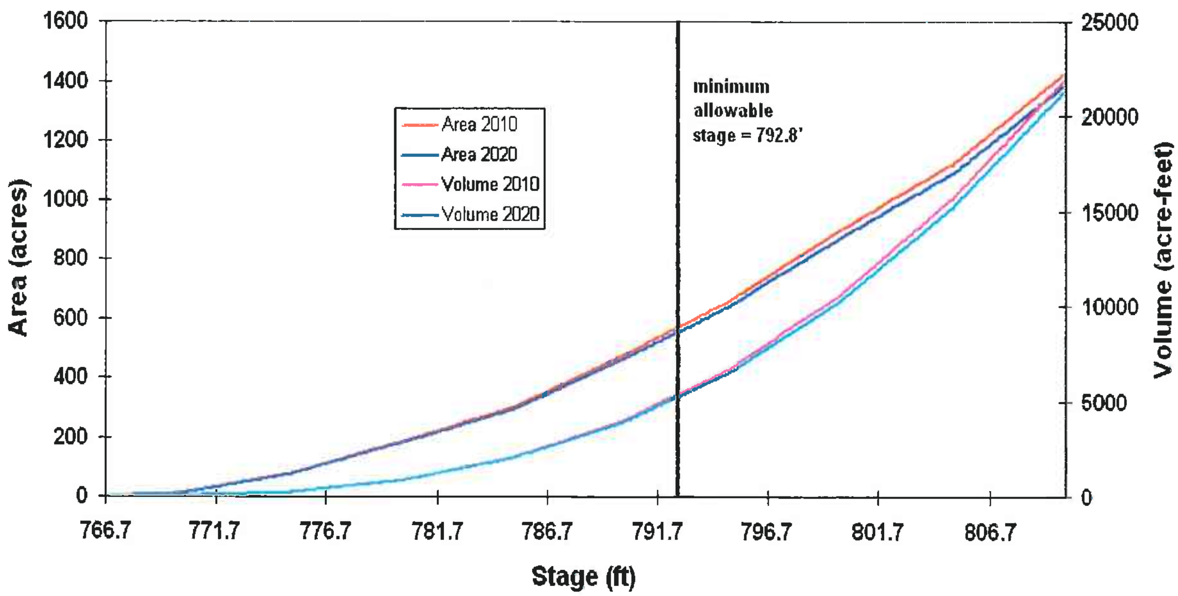

Figure 10-3 Morse Reservoir Future Conditions

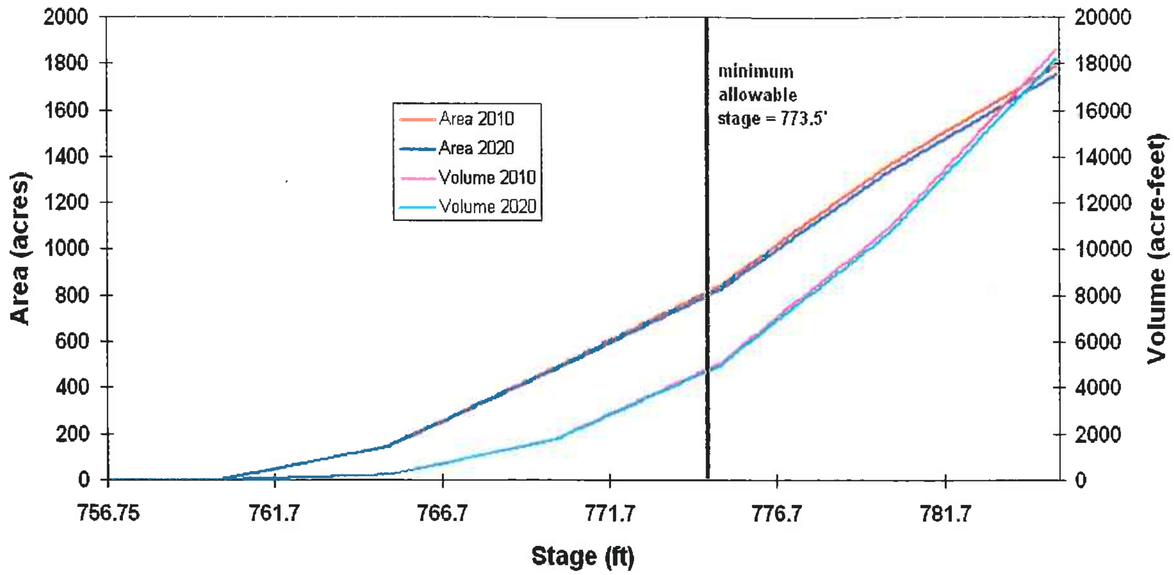

Figure 10-4 Geist Reservoir Future Conditions

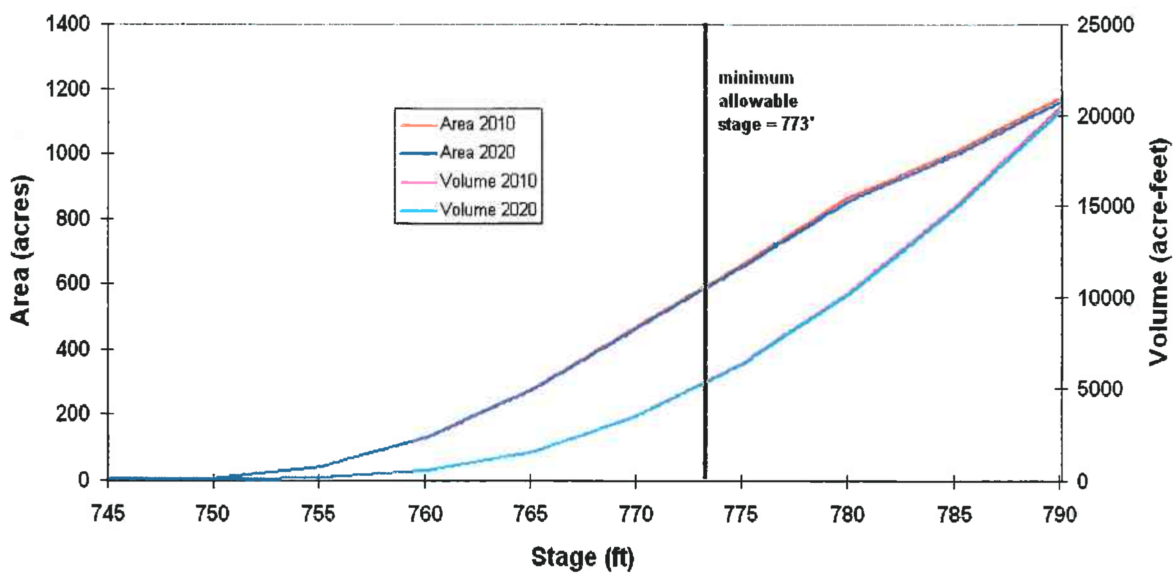

Figure 10-5 Eagle Creek Reservoir Future Conditions

The minimum allowable stages of 792.8 ft, 773.5 feet, and 773 feet for Morse, Geist, and Eagle Creek reservoirs, respectively, are also indicated on the charts. The selection of these minimum reservoir elevations is discussed in Section 10.2. The dam elevations are 810 feet for Morse, 785 feet for Geist, and 790 feet for

Eagle Creek Reservoir. The system yield model accounts for spills out of the reservoirs when the reservoir levels exceed their dam elevations.

10.1.4 Upstream Depletions and Consumptive Use

Historical streamflow data accounts for conditions in the watershed at the time the flows were measured, such as upstream water use, wastewater return flows, groundwater interaction, reservoir releases, reservoir storage, etc. These flows must be adjusted to account for population growth and increased water use that have and will occur in the watershed through the planning horizon of 2010 and 2020. In order to adjust the streamflows, the White River, Fall Creek, and Eagle Creek watersheds were subdivided at critical locations for VWI's water supplies. Within each subdivision historical population trends and census data were used to project future populations. Due to the severity of the drought of 1940-1941, upstream depletions and consumptive use were calculated in detail for the 2010 and 2020 planning horizons by projecting the increase in water use from 1940 to 2010 and from 1940 to 2020. The depletions and consumptive use since the droughts of 1988-1989 and 2007 were estimated based on linear interpolation of the detailed 1940 calculations. Table 10-2 gives a listing of all communities within each subdivision used to calculate the increased water use through years 2010 and 2020. Because limited census data for rural areas was reviewed, the rural population in 2010 and 2020 was estimated to have grown slightly since 1940.

Table 10-2
Communities Used to Calculate Upstream Depletions

Communities Upstream of White River North		
Alexandria	*Farmland*	*River Forest*
Anderson	*Frankton*	*Selma*
Blountsville	*Gaston*	*Summitville*
Chesterfield	*Lapel*	*Winchester*
Country Club Heights	*Muncie*	*Woodlawn Heights*
Daleville	*Noblesville (minusHarbour)*	*Yorktown*
Edgewood	*Orestes*	
Elwood	*Parker City*	
Communities Upstream of Morse Reservoir		
Arcadia	*Cicero*	
Atlanta	*Tipton*	
Communities Upstream of Geist Reservoir		
Fortville	*Middletown*	*Springport*
Ingalls	*Mount Summit*	*Sulphur Springs*
Markleville	*Pendleton*	
Communities Upstream of Eagle Creek Reservoir		
Sheridan		
Communities Between White River North and Riverside/White River Wellfield		
Carmel	*Westfield*	
Communities Between Geist Reservoir and Fall Creek Wellfield		
Lawrence		
Communities Between Eagle Creek Reservoir and South Wellfield		
Speedway		

Previous yield studies estimate that the average water usage in 1940 was approximately 125 gallons per capita per day (gpcd). Future water usage in 2010 and 2020 was assumed to be as much as 200 gpcd in upstream areas based on various data sources. Based on a comparison between IDNR water usage records and Indiana Department of Environmental Management (IDEM) wastewater return flow records, approximately 70 percent of the water used in the upstream areas for municipal and agricultural purposes was estimated to return to the streams or aquifers, and 30 percent is lost to evaporation or other losses. 95 percent of water diverted for energy production in the watershed is returned to the streams based on conversations with local power companies. The model also accounts for new inflows to the streams since 1940, such as the water from Muncie's Prairie Creek Reservoir and groundwater pumped from off-stream aquifers and returned to the White River as wastewater. Obviously, additional evaluation could be performed by working with IDNR, IDEM, and upstream communities to identify data gaps and refine these estimates of depletions and consumptive use. However, the estimates shown in Table 10-3 are considered more than adequate for this evaluation of VWI's system, and were used to project drought streamflows available to VWI in Planning Years 2010 and 2020.

Table 10-3
Upstream Depletions and Consumptive Use

Watershed Subdivision	1940 to 2010 (mgd)	1940 to 2020 (mgd)
Upstream of White River North	-4.2	-4.6
Upstream of Morse Reservoir	-0.7	-0.8
Upstream of Geist Reservoir	-1.7	-1.8
Upstream of Eagle Creek Reservoir	-0.3	-0.3
Between WRN and RS/WR Wellfields (Carmel and Westfield)	-5.5	-6.6
Between Geist Reservoir and Fall Creek Wellfield (depletions from Lawrence wells accounted with groundwater model, not here; this only accounts for depletions caused by uses other than municipal use)	-0.1	-0.1
Between Eagle Creek Reservoir and South Wellfield (Speedway and, mainly, power plants)	-7.1	-7.1

Recent water usage reported to IDNR for 2003 and 2004 in the White River watershed is given on Figure 10-6.

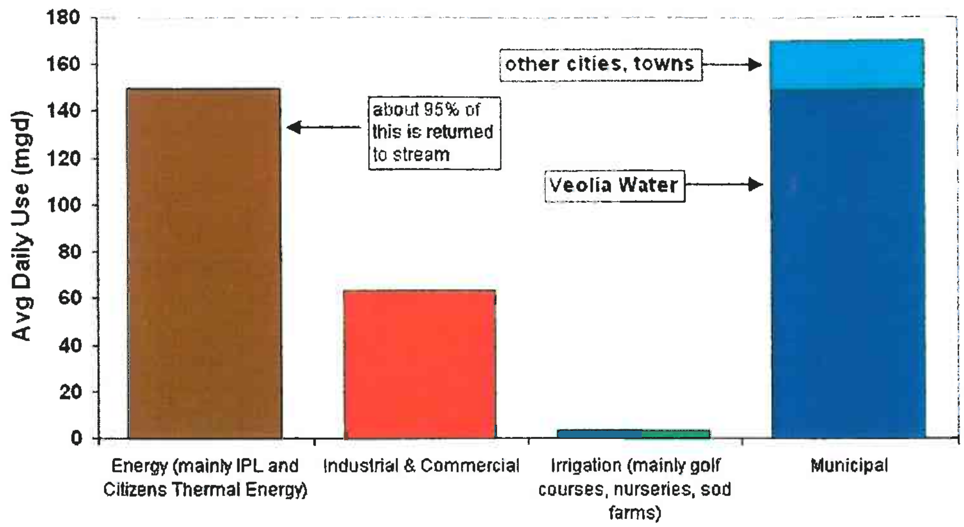

Figure 10-6 Reported Water Use in the White River Watershed Within and Upstream of Indianapolis

10.1.5 Production Variability

To effectively evaluate system yield, developing an understanding of how today's production varies from day-to-day is important to determine how water might be removed from various sources during a future drought event. Water production in recent years gives an indication of how demands in Indianapolis fluctuate. The 2007 production data in Figure 10-7 show that the maximum demand in the summer caused production to be up to between 150 and 160 percent of the annual average day production. Groundwater was pumped at relatively high rates for short periods of time in the summer, allowing the groundwater levels to recover. As mentioned in Section 7.2, VWI must utilize groundwater in the wintertime in order to (1) reduce main breaks in the distribution system, (2) enhance alum coagulation at the plants, and (3) prevent ice from forming in the basins at the plants. Surface water production, compared to the average annual values, did not fluctuate as much as groundwater production in 2007. Overall, total water production in 2007 varied from approximately 75 to 155 percent of average day production.

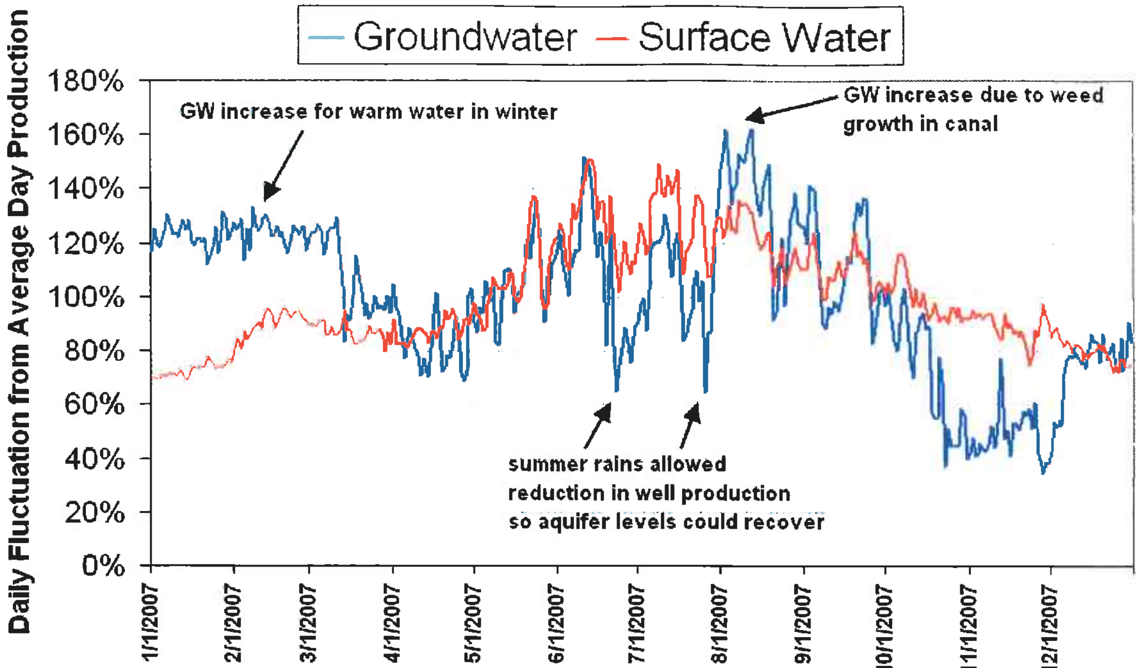

Figure 10-7 Fluctuation in Water Production in 2007

As described in Section 8.0, demands may remain high during a drought in the absence of occasional rain events. Summertime production is expected to stay at or above 150% of average day production for most of the summer during drought. Unless significant water usage restrictions or conservation practices are enforced, the average day demand during drought is expected to be higher than during a normal year. This will exhaust water supplies more rapidly. In the first year of a multi-year drought, if the production increases to 150 percent of average day for most of the summer combined with overall higher annual average day production, the production curve could significantly flatten out in the second year providing less peaking ability.

The production data for 2005 and 2007 shows a wintertime water production of roughly 120 to 130 million gallons per day (mgd). These wintertime demands cannot be managed as much as summertime demands through the use of restrictions. As a result, the system yield model targets a minimum of 120 to 130 mgd through the cooler months (November, December, January, February, March).

10.1.6 Groundwater-Surface Water Interaction

Groundwater and surface water are interconnected to some degree depending on the streambed sediment properties and clay layering in the aquifers. An iterative approach was used between the surface water model and the groundwater models to evaluate system yield. Initial surface water model runs were made to determine the magnitude of streamflows at critical locations along the major streams during drought conditions. Rating curves were developed from USGS data to determine the range of water surface elevations to be expected, and these elevations were used as input to the groundwater model. The planning-level groundwater models were then used to estimate the magnitude of the streamflow depletions near the major wellfields. These stream depletions were incorporated into the system yield model, along with the yield of each wellfield, to determine overall system yield.

10.2 SURFACE WATER CONSTRAINTS AND ASSUMPTIONS

Similar to the groundwater constraints and assumptions given in Section 9.2, surface water constraints and assumptions must be incorporated into the system yield model. These constraints are not related to treatment capacity or pipe capacity, but instead are related to the raw water. Where data are lacking, assumptions must be made to estimate yield. Black & Veatch worked closely with VWI to develop these major assumptions and gather information for system constraints. For the surface water system, the following constraints and assumptions were used:

- *Minimum streamflows downstream of Indianapolis* – IDNR recommends a minimum flow of approximately 246 cubic feet per second (cfs) (159 mgd) for the White River near Centerton, Indiana. This is based on the 7Q10 flow (defined as the 7-day low flow that has a 10 percent chance of occurring in any given year). IDNR's preference is that the summation of all flows bypassing the VWI surface water intakes and other users, discharged by wastewater facilities, and accumulating in the White River meet or exceed 159 mgd at Centerton to maintain enough streamflow for the environmental purposes. Because the 1940-1941 drought was more severe than a 10 percent event, the natural streamflows in the White River were lower than 246 cfs at that time (minimum flow that occurred was only about 94 cfs). The Centerton streamgage data shows that the streamflow has dropped below 246 cfs on several other occasions in the past. IDNR's stance during a drought more severe that a 10-percent event is unclear. Also unclear is whether or not the White River near Centerton will be the only stream location near Indianapolis with a minimum streamflow requirement or if there will be other locations along White River, Fall Creek, or Eagle Creek that could limit the available yield for Indianapolis in the future. IDNR is currently working with a task force on policies for Indiana during times of water shortage, and they expect to have recommendations for these policies completed in 2009. In addition to minimum streamflow requirements, IDNR may have recommendations for water usage priorities (domestic consumption, public supply consumption, energy, agricultural, etc.) and may have guidelines requiring a community to show that, during a drought, they are using water for essential needs. If IDNR decides to enforce 7Q10 streamflows at multiple locations, the water supply yield for Indianapolis may be reduced. This evaluation aims to maintain a minimum streamflow of approximately 159 mgd in the White River past Centerton, Indiana, with some latitude to drop below this value slightly during the critical period of the 1940-1941 drought simulation.

- *Power plants on the White River* – Since the 1800s, power companies have had contracts with water companies in Indianapolis for the use of streamflow from the White River for generating steam for heating buildings and for cooling water. In 1910, the Indianapolis Light and Heat Company (now known as Indianapolis Power and Light (IPL)) signed a fifty year agreement with the Indianapolis Water Company for use of up to 72 mgd from the canal for steam generation. The agreement may have been updated in 1946 with another contract granting the power company usage of up to approximately 72 mgd of cooling water (Bakken, 2003). Today, Citizens Thermal Energy has a plant on the White River near Washington Street just downstream of the White River Treatment Plant. Water is diverted for plant operations from the White River at a rate approaching 50 mgd according to IDNR water usage records (see Figure 10-8). Most of this water is returned back to the White River. For purposes of this evaluation, 48 mgd must be maintained past the Citizens Thermal Plant.

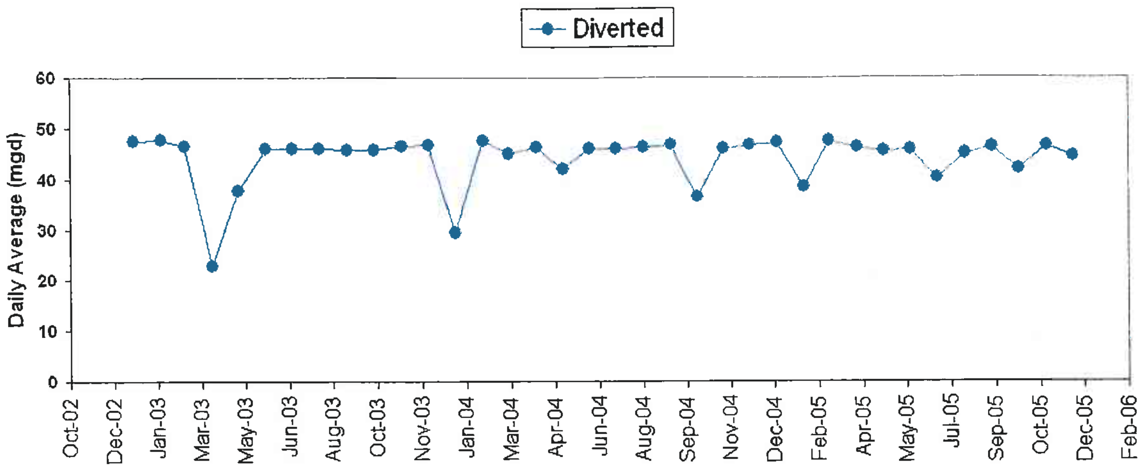

Figure 10-8 Citizens Thermal Plant, Reported White River Diversions

The Stout Power Plant near the Hanna Avenue and Harding Street intersection operated by IPL requires flow in the White River for their plant operations. IDNR records show that more than 140 mgd is diverted for some months to the Stout power plant as shown by Figure 10-9; however, IPL personnel said they would like for VWI to plan on maintaining 100 mgd past the Stout Power Plant.

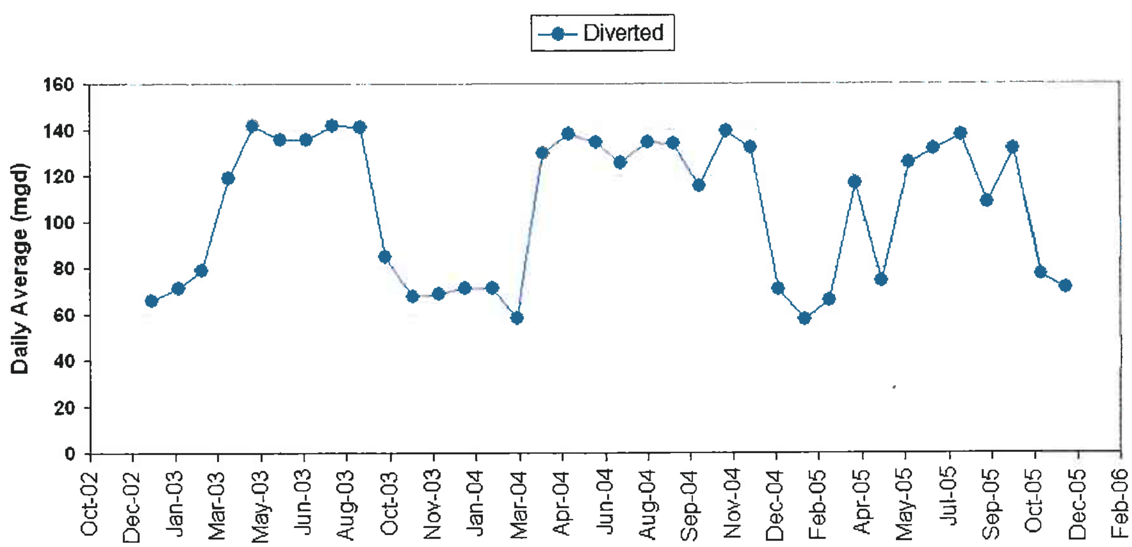

Figure 10-9 IPL Stout Power Plant, Reported White River Diversions

Figures 10-10 and 10-11 show the flow in the White River before Morse and Geist Reservoirs were built. White River flows have historically dropped below the plants' requirements on a number of occasions. The plants would not have enough water during drought if it were not for the reservoirs and the wastewater return flows. Today, a large percentage of the required 100 mgd past the Stout Power Plant is met by wastewater return flows from the Belmont wastewater plant. During the course of a severe drought, water availability may limit the wastewater flow to the Belmont plant, and cause lower flows past the Stout Power Plant (Note this evaluation acknowledges that return flows at the wastewater plants may be lower during dry conditions. Wastewater discharges from the dry month of September 1999 were used to estimate return flows). The Citizens Thermal plant does not have a wastewater plant located upstream from it and is also located upstream of the White River-Eagle Creek confluence. Therefore, during a severe drought, VWI will need to make significant releases from Morse and/or Geist Reservoirs to maintain about 48 mgd past the Citizens Thermal plant, and possibly some releases to supplement wastewater effluent past the Stout plant.

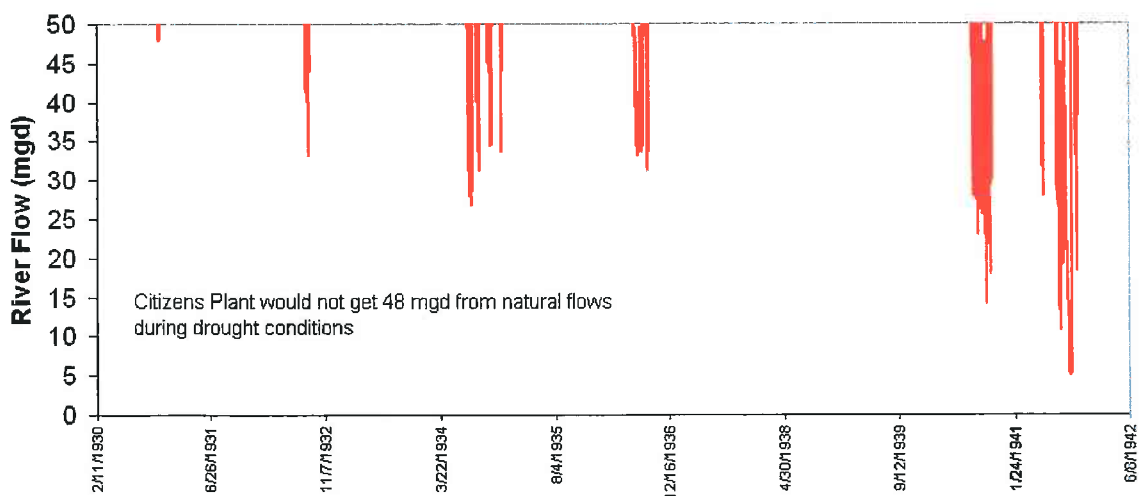

Figure 10-10 Natural White River Flows Past Citizens Thermal Plant

(estimated from USGS Streamgage 03353000 White River at Indianapolis prior to Morse and Geist Reservoirs)

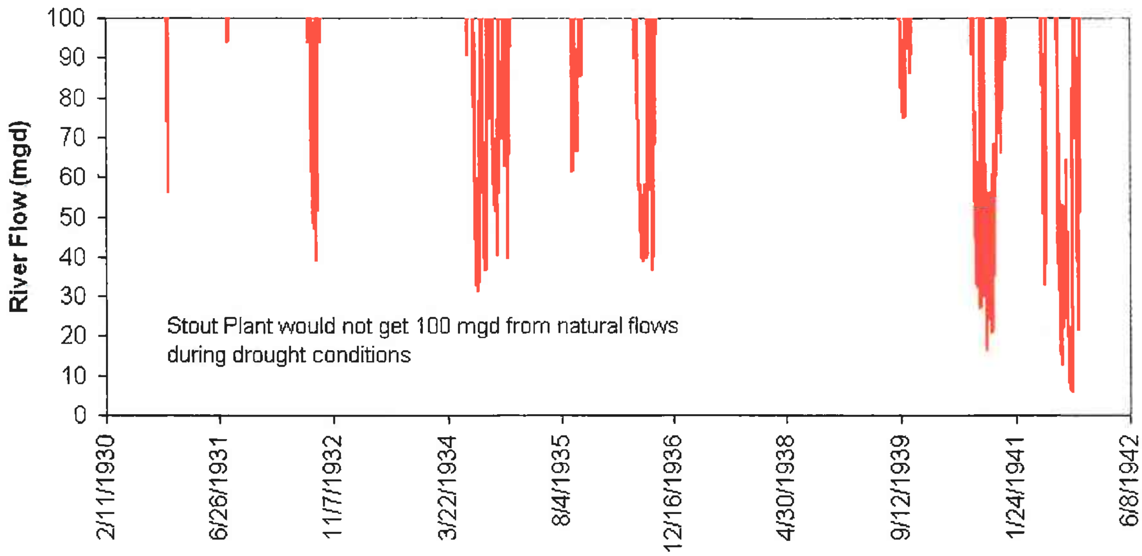

Figure 10-11 Natural White River Flows Past IPL's Stout Power Plant

(estimated from USGS Streamgage 03353000 White River at Indianapolis prior to Morse and Geist Reservoirs)

- *Account for some inefficiency with reservoir releases* – VWI operators must monitor streamflows, weather forecasts, and predict water demands in upcoming days to determine if it is necessary to make releases from Morse and Geist Reservoirs to supplement streamflows to the surface water plants. Usually, the call for releases will err on the side of caution and more water will be released than will actually be captured for water supply. The excess water will flow downstream past Broad Ripple Dam and Keystone Dam. Although this excess water will help to maintain flows past the power plants during drought, the water will not be available for VWI's water supply since there are no intakes in southern Indianapolis along the White River. The yield model accounts for an "overrelease" of 10 mgd from Morse Reservoir and an "overrelease" of 5 mgd from Geist Reservoir each time a release is made from either of these reservoirs.
- *Minimum flows over Dams* – In general, both Keystone Dam and Broad Ripple Dam must maintain an inch or two of flow over their crests. A minimum flow of 5 mgd is maintained over Keystone Dam. A minimum flow of greater than 5 mgd is maintained over Broad Ripple Dam. This flow will generally be maintained through a drought due to releases for the downstream power plants and the "overreleases" from Morse and Geist Reservoirs described above. If IDNR's water shortage

task force decides to impose minimum streamflows on White River or Fall Creek within the City limits, these assumptions for minimum streamflows downstream of Broad Ripple and Keystone dams will need to be revisited in the yield model.

- *Indianapolis Central Canal* – The water company in Indianapolis has always been concerned about minimizing seepage losses from the canal (Bakken, 2003). The USGS recently proposed a new study of the canal to be performed to determine today's seepage losses and loss in capacity due to sedimentation. The groundwater and surface water models for this evaluation account for at least 21 cfs lost as surface water (or gained as groundwater). Also, the surface water model limits the canal capacity to 96 mgd, with a maximum capacity of 75 mgd in the summer when weed/vegetation growth inhibits flow. Any new findings from future studies by the USGS for canal capacity and seepage losses should be used to update these yield models.
- *Minimum allowable reservoir levels and sedimentation* – An assumption from previous studies was that the reservoirs will be drawn down as low as possible during the most critical stage of a severe drought. VWI and Black & Veatch reviewed the remaining wetted footprints of the reservoirs at these levels in relation to the surrounding homes and decided to increase the minimum allowable reservoir levels such that a minimum of 25 percent storage volume is maintained in Morse and Geist Reservoirs. Since the City of Indianapolis Department of Public Works reserves the right to curtail water usage from Eagle Creek Reservoir when the reservoir drops below elevation 773 feet, that elevation is considered the minimum for Eagle Creek Reservoir for purposes of this study. Table Table 10-4 summarizes the critical reservoir conditions that are maintained for this evaluation. The table also gives the sedimentation rate as determined using 1995-1996 bathymetry data from the USGS and IDNR (Black & Veatch, 2003). These sedimentation rates were used to create stage-area-storage curves for each of the reservoirs for the 2010 and 2020 planning horizon for this evaluation.

Table 10-4
Critical Reservoir Assumptions

Reservoir	Min Depth (ft)	Min Stage (ft above MSL)	Min Area 2010 (acres)	Min Volume 2010 (ac-ft)	Sedimentation Rate (ac-ft/yr)
Morse	26	792.8	580	5533	64
Geist	17	773.5	741	4123	42
Eagle Creek	28	773	585	5273	27

Based on droughts experienced in other parts of the United States, the most telling sign of the severity of a future drought in the Indianapolis area will most likely be the reservoirs as they approach these critical levels as shown on Figures 10-12 through 10-14. There will be difficulties in allowing the reservoirs to drop to these levels without knowing when the drought will end.

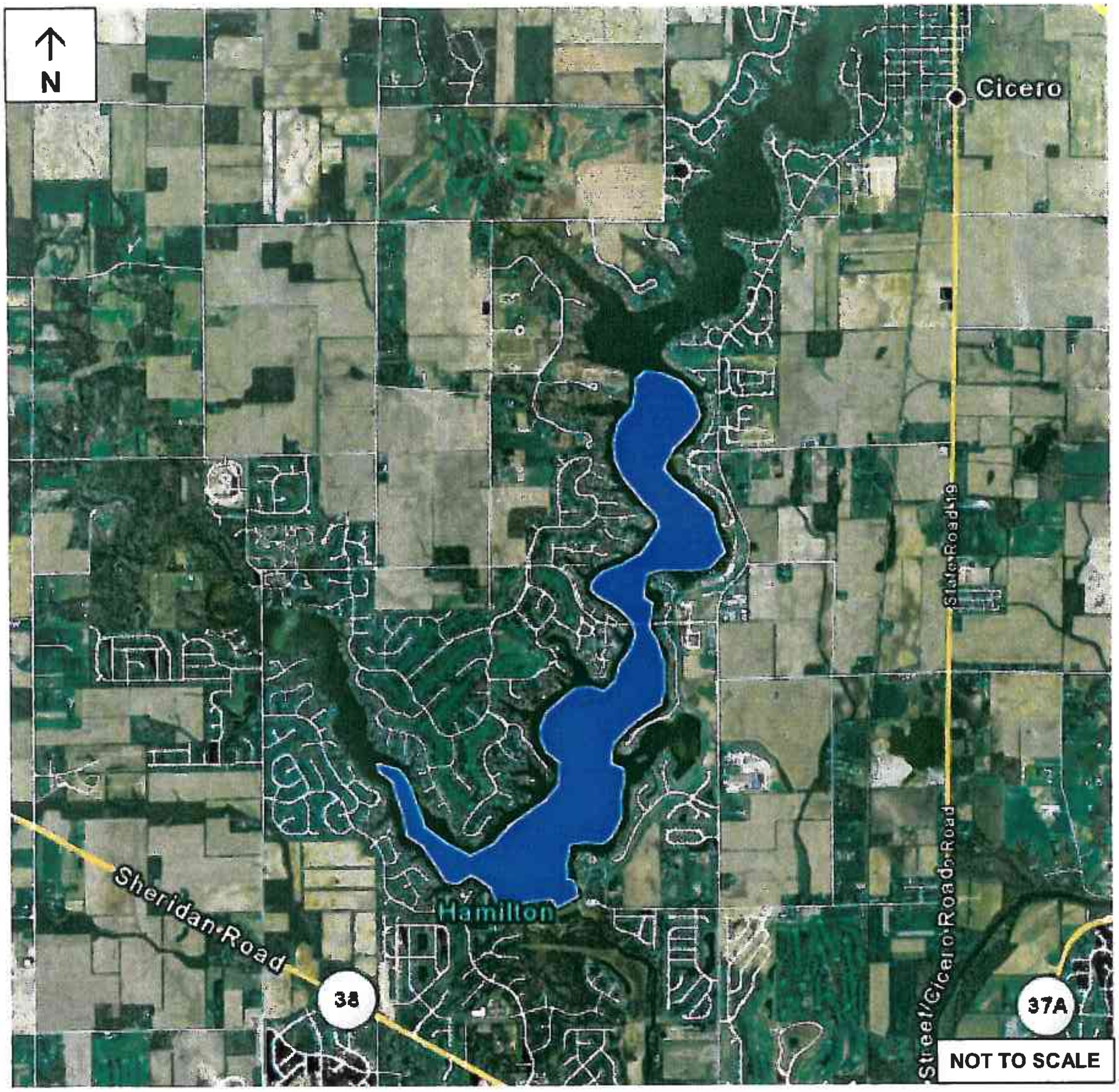

Figure 10-12 Morse Reservoir at Minimum Allowable Level

Aerial Photo Source: Google Earth

Figure 10-13 Geist Reservoir at Minimum Allowable Level

Aerial Photo Source: Google Earth

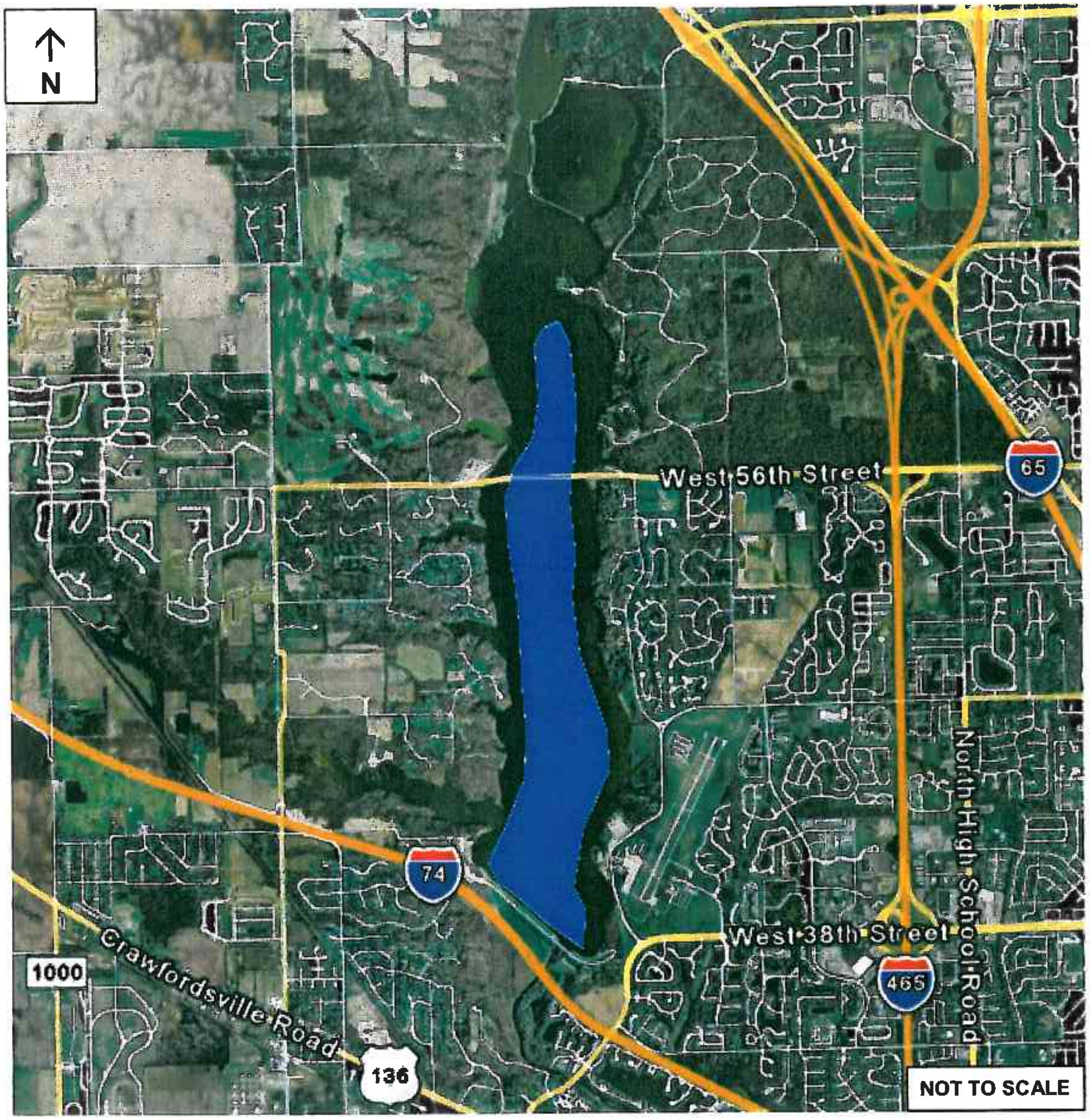

Figure 10-14 Eagle Creek Reservoir at Minimum Allowable Level

Aerial Photo Source: Google Earth

Table 10-15 shows the lowest recorded levels of Morse and Geist Reservoirs since 1985. As shown, the minimum reservoir levels assumed for this evaluation are much lower than has been recorded in the past 22 years.

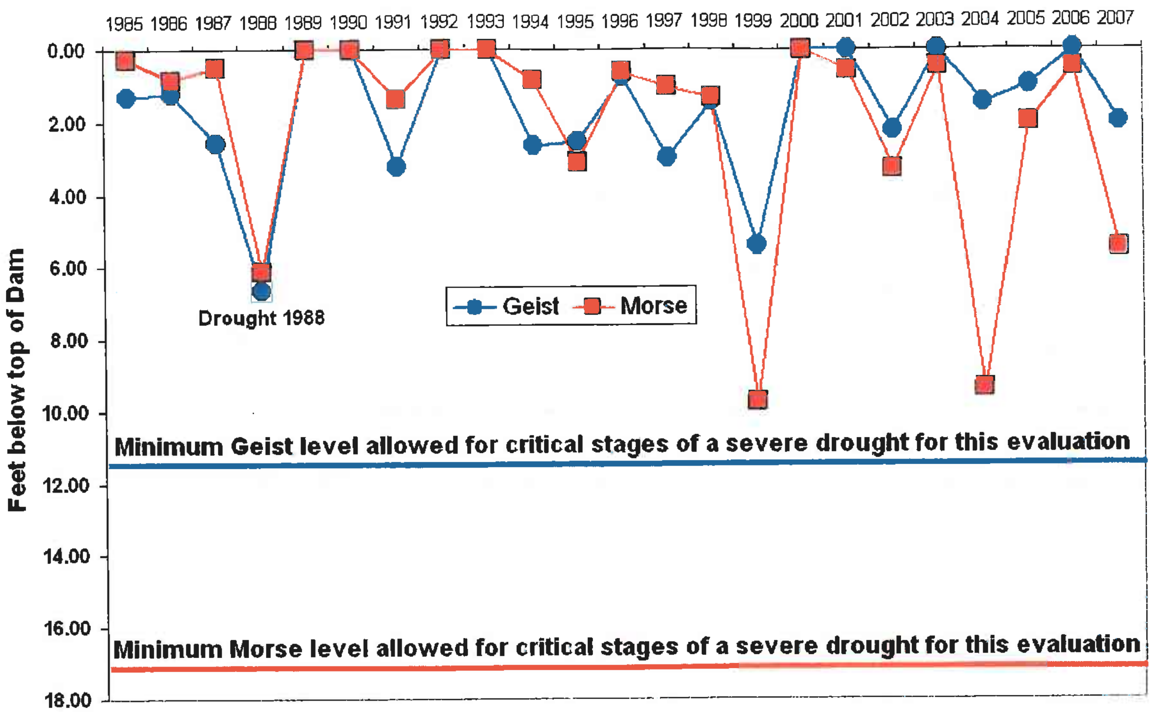

Figure 10-15 Annual Minimum Reservoir Levels

- *Unaccounted-For Water.* "Unaccounted-for water" (UAW) includes water that is produced at the sources of supply but is not billed to a customer and represents a significant amount of water for the VWI system. From 2002 through 2006, UAW averaged approximately 14.2 percent, (about 20 mgd during an average day of production). VWI conducted a study in 2007, resulting in an estimated UAW for the system of 18 percent. The amount of UAW that is actually used by customers and simply not billed, versus the amount of water that is lost from the system through leaks or other losses is unknown. After discussions with VWI a conservative assumption that this water be part of the demand was made. Therefore, the demand projections discussed in Section 10.3 reflect the quantity of water that is required to be produced and delivered to the system.
- *New Surface Water Intake on White River upstream of 16th Street.* VWI is currently constructing a new intake on the White River upstream of the Emerichsville Dam. This new intake will serve as an emergency intake structure to capture water during times when there is plenty of water in the White River but the canal capacity is limited by weed growth, sedimentation, or other reasons. During a severe drought

however, this new intake structure on the White River will not add any significant yield because of limited flow in the White River. If a means of storage is added with this intake in the future, this could potentially increase the yield of the system during drought by capturing streamflow when available in the winter and spring months and storing it for later use.

- *Future Combined Sewer Overflow (CSO) Improvements.* This evaluation does not attempt to forecast future sewer improvements to capture and control combined sewer overflows. A future deep tunnel system will capture runoff from small storm events and ultimately route these flows to the wastewater treatment plants downstream of the City, and this could reduce the streamflow past VWI's water intakes resulting in a reduction in yield from what is presented in this report. This yield model should be revisited as the CSO improvements are finalized to determine what, if any, effect these improvements will have on water supply.
- *Proposed Geist Surface Water Treatment Plant.* VWI's Short and Long Term Plan (2006) proposes the idea of a new surface water treatment plant to treat water directly from Geist Reservoir. This new plant may add some yield because pumping and treating water directly from a reservoir is more efficient because there would be less water loss to evaporation and seepage/bank storage in Fall Creek between the reservoir and Keystone Dam and there would be less guesswork regarding releases from Geist Reservoir. As described later in this report, there appears to be additional yield available from the Geist-Fall Creek surface water supply during mild drought conditions. However, during more severe drought conditions, any yield gained at a new Geist surface water plant would be offset by reduced yield available at Keystone dam, resulting in no gain in yield. New wells installed in the Fall Creek Wellfield may add some new yield as suggested in the Short and Long Term Plan (up to possibly 2 to 3 mgd of new yield during drought, see Section 8.6.1), but a new Geist surface water plant by itself would not add a large amount of yield during a severe drought.
- *Demand Management.* This evaluation focuses on "supply side" investments, where the availability of water is considered. If the cost of system improvements to capture, treat and deliver enough water during the drought-of-record is deemed too high, demand management

such as water use restrictions and conservation is necessary to limit the amount of water that is needed. The Board of Directors for the Department of Waterworks adopted a "Wise Water Use Policy" on April 27, 2006, recommending water conservation measures and voluntary outdoor water use reductions during times of water shortage. A draft water conservation ordinance is currently available for public comment describing advisory, warning, and emergency stages of drought and recommended voluntary and mandatory water use restrictions.

In 2007, there was plenty of water in the reservoirs and streams, but treatment and distribution capacity was the concern for several weeks in the summer. Residential customers were asked to water their lawns less frequently to reduce water demands. During a more severe drought more aggressive forms of demand management may be required to protect the limited water supplies in the streams, reservoirs, and aquifers. Recent data shows the average water usage per residential customer ranges from approximately 153 gallons per customer per day (GPCD) to 348 GPCD for the various pressure zones (Black & Veatch, 2008). At these rates, there is potential for reduction in water usage through a variety of measures such as conservation and outdoor water use reduction. VWI has considered demand management in their 2006 Short and Long Term Plan and in their 2004 Water Conservation Plan. Ultimately, VWI may choose to combine the findings of this evaluation with those to determine how much demand management will reduce the deficit between supply and demand during drought, which will provide a reduced target for developing future water supplies.

- *Climate Change.* The scope of this yield evaluation did not include an evaluation of the effect of climate change on the City's water supply. Current global climate change models show that climate change could result in more dramatic weather fluctuations including periods of both wetter conditions and drier conditions, and there is uncertainty with what may happen on a local scale such as in Indiana or the Midwestern United States.

  For long-range planning, and with advances in climate change prediction at the local scale, VWI may consider performing some scenario modeling with this system yield model to determine the range of effects climate change may have on the City's water supply. The results of the scenario modeling would give the City an idea of what could be expected for contingency planning.

10.3 PROJECTED WATER DEMANDS DURING DROUGHT CONDITIONS

The Demand Evaluation Technical Memorandum (Black & Veatch, 2008) reported projected 2010 and 2020 water demands for Indianapolis Water customers, as shown in Table 10-5.

Table 10-5
Projected Water Demands (Demand Memo, 2008)

Year	Avg. Day Demand "most likely" estimate[1] (mgd)	Max. Day Demand "most likely" estimate[2] (mgd)
2010	154.8	245.7
2020	162.5	258.1

[1] Based on 2002-2006 consumption during normal-to-wet years. During drought, the demand should be higher.
[2] Based on historical MDD:ADD ratios, plus a safety factor.

The demand evaluation used available consumption and production data from 2002 through 2006 in developing these projections. Since this five year period was wetter than normal, average day demands during a future drought may be expected to be higher than the "most likely" average day demands given in Table 5-5. Based on studies from other areas, there is about a six percent increase in the average demand during the period of a drought compared to a similar period of normal weather. Therefore, the "most likely" average day demands shown in Table 10-5 are multiplied by 1.06 to obtain average day demands during drought conditions. The "most likely" maximum day demands include a safety factor, and are considered reasonable for a future drought condition. Table 10-6 gives the projected water demands during drought conditions to compare to the water supply yield results given in the following section.

Table 10-6
Projected Demands for Drought Conditions

Year	Average Day Demand (mgd)	Maximum Day Demand (mgd)	Ratio* MDD:ADD
2007 (for comparison)	151 (approx)	230 (approx)	1.52
2010	164.1	245.7	1.50
2020	172.3	258.1	1.50

* See Demand Memo for more detailed information about historical MDD and ADD

10.4 RESULTS OF SYSTEM YIELD EVALUATION

Table 10-7 shows the drought scenarios evaluated for system yield, in order from least severe to most severe. The drought conditions were selected to give an estimate of the yield of the Indianapolis water supply system under a range of climate conditions (2007 is considered a typical-to-somewhat dry summer, 1988-89 is considered a moderate drought, and 1940-41 is considered a severe drought). Yield will be slightly less in Planning Year 2020 than in 2010 because of some reservoir sedimentation and additional future water depletions and consumptive use by other water users in the watershed. However, the model shows that 2010 and 2020 system yields are nearly the same. Therefore, the 2020 yield model results given in this section are compared to the projected demands in Planning Years 2010 and 2020.

Table 10-7 Droughts Scenarios Evaluated (from least severe to most severe)
2007 Climate Conditions for Planning Year 2010
2007 Climate Conditions for Planning Year 2020
1988-1989 Drought Conditions for Planning Year 2010
1988-1989 Drought Conditions for Planning Year 2020
1940-1941 Drought Conditions for Planning Year 2010
1940-1941 Drought Conditions for Planning Year 2020

10.4.1 Future System Yield for 2007 Climate Conditions

For climate conditions similar to 2007, the system yield model shows that the existing sources of supply plus Waverly Wellfield will have an average day yield of up to approximately 237 mgd, with a maximum day yield of about 336 mgd through Planning Year 2020. If Waverly Wellfield is not constructed, these values drop to approximately 213 mgd for average day system yield, and approximately 312 mgd for maximum day system yield under 2007 climate conditions. A conservative assumption that production will increase and remain high much of the summer was made.

Table 10-8 shows the breakdown of yield at each of the sources of supply for this dry summer scenario. Without considering the treatment or distribution capacities or the locations of the water demands, this table shows that, during climate conditions similar to 2007, there will be enough water in the streams, reservoirs, and aquifers to meet the projected average day demand of approximately 164.1 mgd and maximum day demand of 245.7 mgd for Planning Year 2010 during drought conditions, with or without Waverly Wellfield. For Planning Year 2020

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during drought, the average day yield is greater than the projected average day demand of 172.3 mgd, and the maximum day yield is greater than the projected maximum day demand of 258.1 mgd, with or without Waverly Wellfield. This assumes that the reservoirs and aquifers are full of water at the beginning of the year, as they were at the beginning of 2007. This confirms that facility capacity was the limiting factor in 2007, not raw water supply, as shown by Figure 10-16. The yield curves show the maximum yield assuming the reservoirs are drawn down to their minimum levels, which would most likely not be acceptable for climate conditions similar to 2007.

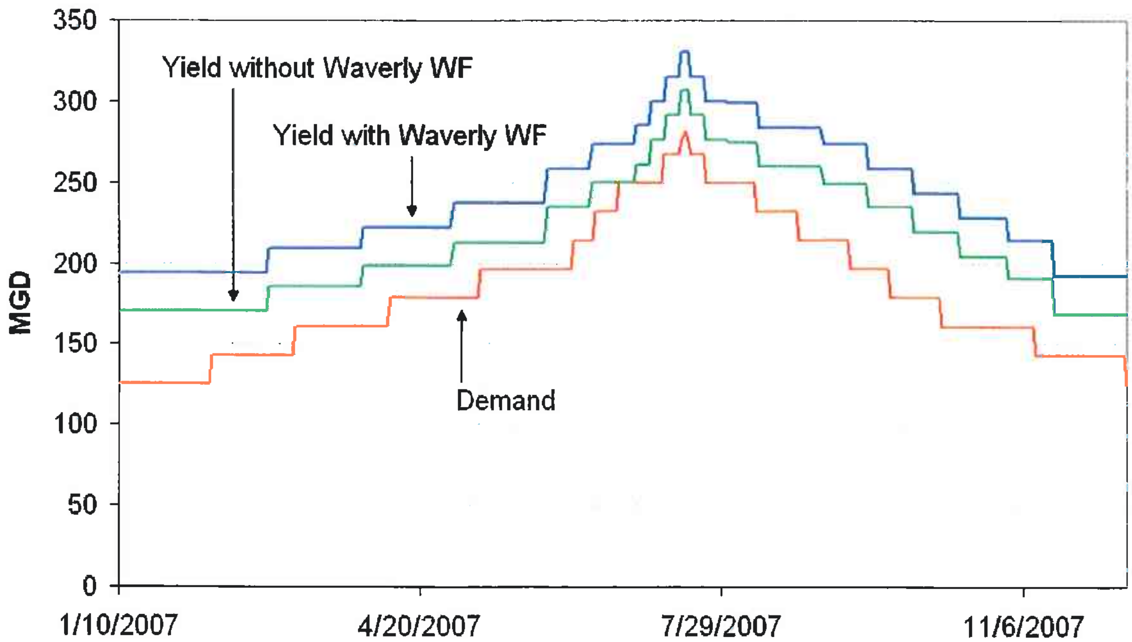

Figure 10-16 Yield vs. Demand for Planning Year 2020 for 2007 Climate Conditions

Table 10-8
System Yield for 2007 Dry Summer Conditions
(disregarding treatment and delivery capacity)

Source	Average Day Yield (mgd)	Maximum Day Yield (mgd)
White River North Surface Water	31.8	49.9
White River Surface Water	61.8	96.9
Fall Creek Surface Water	58.0	91.0
Eagle Creek Surface Water (limited by contract with City)	11.9	18.7
Riverside/White River Wellfield	11.5 (compared to actual average day of about 3.4 mgd in 2007*)	12.6 (compared to actual max day production of about 8 mgd in 2007)
White River North Wellfield	7.6 (from seven WRN wells) (compared to actual average day of about 2.75 mgd in 2007 from 3 wells)	8.7 (from seven WRN wells) (compared to actual max day of about 9.3 mgd in 2007 from 3 wells**)
Fall Creek Wellfield	5.9 (compared to actual average day of about 4.2 mgd in 2007)	6.8 (compared to actual max day of about 8.25 mgd in 2007)
Geist Wellfield	4.6 (compared to actual average day of about 3.5 mgd in 2007)	7.1 (compared to actual max day of about 7.3 mgd in 2007)
South/Harding Wellfield (based on actual production in the summer of 2007 since modeling not performed for SWF for this evaluation)	19.0 (during drought conditions more severe than 2007, SWF is reported to have drought yields of 10 mgd, 8 mgd, and 6 mgd for 20-year, 50-year, and 100-year droughts, respectively (WHPA, 2007))	19.0 (during drought conditions more severe than 2007, SWF is reported to have drought yields of 10 mgd, 8 mgd, and 6 mgd for 20-year, 50-year, and 100-year droughts, respectively (WHPA, 2007))
Waverly Wellfield (Sustainable drought yield estimated by others using a combination of vertical wells and shallow collector wells, pending additional testing for the feasibility of shallow collector wells (WHPA, 2007))	24.0 (if testing reveals shallow collector wells are not feasible, the sustainable drought yield may be less than this from the available land at the Waverly site using only vertical wells)	24.0 (if testing reveals shallow collector wells are not feasible, the sustainable drought yield may be less than this from the available land at the Waverly site using only vertical wells)
Ford Road Wellfield	1.0	1.0
TOTAL SYSTEM YIELD	237.1 (or 213.1 without Waverly)	335.7 (or 311.7 without Waverly)

* Unlike the other wellfields, the planning-level model of the Riverside/White River Wellfield shows a significantly higher yield for 2007 conditions than was actually produced in 2007. This may be due to several reasons such as many of the old wells may be in need of maintenance, which was not considered by the model, and/or the alluvial and bedrock aquifers experience much lower recharge than assumed by the model in this area due to clay layering, which would need to be confirmed by well diagnostics and aquifer testing.

** spreadsheet "Inflow Distribution-2007.xls" shows the 3 WRN wells were pumped at very high rates on 4/1/2007; however, during the summer the wells were pumped at peak rates similar to the results of the planning-level model

Table 10-9 and Table 10-10 show the yield compared to the projected demands and to the proposed rated treatment capacities at each plant in Planning Year 2010 and 2020, respectively.

Table 10-9
System Yield for 2007 Dry Summer Conditions Compared to Projected Demands and Proposed Treatment Capacity for Planning Year 2010

Plant (surface water plus groundwater at each plant)	Max Day Yield Possible Based on Water Resources (mgd)	Max Day Yield Required to Meet Max Day Demand of 245.7 mgd in 2010 if Waverly Not Online (mgd)	Max Day Yield Required to Meet Max Day Demand of 245.7 mgd in 2010 if Waverly is Online (mgd)	Proposed Rated Treatment Plant Capacity (mgd) (VWI Short and Long Term Plan, 2006)
White River North (assumes this plant is upgraded by 2010)	58.6	58.6	58.6	60
White River	109.5	95.2	75.9	96 (120 hydraulic)
Fall Creek	97.8	44.7	40	32 (40 hydraulic)
Moses (limited by contract with City)	18.7	18.7	18.7	16 (20 hydraulic)
Geist	7.1	7.1	7.1	8
South/Harding (est. by others)	19.0	19.0 (if Waverly not online)	43.0 (if Waverly is online)	54
Waverly (est. by others) (assume treated at SWF)	0.0 (if not online) 24.0 (if online)			
Ford Road	1.0	1.0	1.0	2.6
Harbour (no modeling performed)	Assumed zero	Assumed zero	Assumed zero	-
TOTAL	311.7 (335.7 if Waverly online)	245.7	245.7	268.6 rated (304.6 hydraulic)

Note: Any water typically purchased by VWI from other water utilities such as Westfield (up to 1.5 mgd) or Plainfield (up to 2.0 mgd) will most likely be limited by their systems' capacity limitations and their systems' increased water demands in a dry summer, so it is conservatively assumed that those sources of water will provide no meaningful yield during drought conditions.

Table 10-10
System Yield for 2007 Dry Summer Conditions Compared to Projected Demands and Proposed Treatment Capacity for Planning Year 2020

Plant (surface water plus groundwater at each plant)	Max Day Yield Possible Based on Water Resources (mgd)	Max Day Yield Required to Meet Max Day Demand of 258.1 mgd in 2020 if Waverly Not Online (mgd)	Max Day Yield Required to Meet Max Day Demand of 258.1 mgd in 2020 if Waverly is Online (mgd)	Proposed Rated Treatment Plant Capacity (mgd) (VWI Short and Long Term Plan, 2006)
White River North (assumes this plant is upgraded by 2010)	58.6	58.6	58.6	60
White River	109.5	109.5	89.7	96 (120 hydraulic)
Fall Creek	97.8	44.2	40.0	32 (40 hydraulic)
Moses (limited by contract with City)	18.7	18.7	18.7	16 (20 hydraulic)
Geist	7.1	7.1	7.1	8
South/Harding (est. by others)	19.0	19.0 (if Waverly not online)	43.0 (if Waverly is online)	54
Waverly (est. by others) (assume treated at SWF)	0.0 (if not online) 24.0 (if online)			
Ford Road	1.0	1.0	1.0	2.6
Harbour (no modeling performed)	Assumed zero	Assumed zero	Assumed zero	-
TOTAL	311.7 (335.7 if Waverly online)	258.1	258.1	268.6 rated (304.6 hydraulic)

Note: Any water typically purchased by VWI from other water utilities such as Westfield (up to 1.5 mgd) or Plainfield (up to 2.0 mgd) will most likely be limited by their systems' capacity limitations and their systems' increased water demands in a dry summer, so it is conservatively assumed that those sources of water will provide no meaningful yield during drought conditions.

The system yield model confirms that there is a surplus of available yield from the White River, White River North, and Fall Creek surface water facilities during climate conditions similar to 2007. The potential yield of the Geist-Fall Creek surface water supplies for 2007 climate conditions is significantly higher than the proposed treatment capacity (91 mgd yield versus 40 mgd proposed capacity). (However, to obtain 91 mgd of yield, Geist Reservoir would need to be drawn to a very low level, which would not be acceptable to the public during climate conditions similar to 2007.) Therefore, upgrading the Fall Creek treatment plant to 91 mgd does not appear to be justified. If Waverly wellfield is not on-line by 2010 or 2020 and climate conditions similar to 2007 were to occur, increasing the Fall Creek plant treatment capacity to 45 mgd and 68 mgd, respectively, is necessary and beneficial. Still, with an upgrade of the Fall Creek treatment plant capacity to 68 mgd, much of this capacity could not be utilized during a severe drought.

Again, this yield simulation is conservative, and assumes that demands will remain high much of the summer. Actual production in the summer of 2007 fluctuated significantly in response to occasional rainfall events. Periods of lower production following rainfall events conserved the storage in Morse and Geist Reservoirs during 2007. If the yield model allowed this significant fluctuation in production to replicate actual 2007 production, the system yield would be higher than reported in the tables above.

Testing and modeling by others in 2007 has shown that the South/Harding and Waverly wellfields have limited hydraulic connection with the White River, indicating that a large investment in treatment upgrades at South Wellfield from the South/Harding/Waverly wells may not be justified. If future testing shows Waverly wellfield can yield 24 mgd, the total yield of Waverly and South/Harding wells would be 43 mgd compared to a proposed treatment capacity of 54 mgd. To justify a 54 mgd plant, aquifer testing would need to show that the yield of these southern wellfields can be increased to 54 mgd using shallow horizontal collector wells or significantly expanding the wellfield properties to install as many wells as possible. Also, as discussed in the VWI Short and Long Term Plan (2006), there may be issues with expanding the South Wellfield plant to treat water pumped from shallow collector wells since the water would be considered groundwater under the influence of surface water.

In summary for 2007 climate conditions, the model shows that surface water yield will be available in White River and Fall Creek supplemented by releases from the reservoirs. Upgrades to these surface water facilities would be a more reliable and feasible method of providing additional yield during a dry year than adding more wells to the existing wellfields since there appears to be limited connection between the aquifer and stream.

There are uncertainties about the South/Harding and Waverly wellfield yields and treatment requirements, so upgrading the South Wellfield groundwater plant to the proposed capacity of 54 mgd may not be justified. The surface water yield at the White River plant will continue to be the primary water supply for VWI, and the 120 mgd capacity of the plant should continue to be utilized through combined operation of the canal, the new White River intake, and the Riverside/White River wells.

Since 2007 was not considered a drought year, residents along the reservoirs may have concerns if the water system is designed to lower the reservoirs to their minimum levels every hot/dry summer in which demand is high. To avoid frequently lowering the reservoirs, the possibility for a new source of supply or a significant expansion of one of the wellfields may need to be explored. Evaluation of severe drought conditions, described below, along with VWI's subsequent hydraulic modeling, will help decide the best course of action.

10.4.2 Future System Yield for 1988-1989 Drought Conditions

This refined yield evaluation using a daily time-step confirms that 1988 was one of the driest years on record for Indianapolis, although the drought was not as extended as other multi-year droughts. Table 10-11 shows the breakdown of yield at each of the sources of supply for this drought scenario. This table shows that during drought conditions similar to 1988 the average day system yield of 161.3 mgd will come very close to meeting the projected 2010 average day demand of 164.1 mgd during drought. However, the maximum day system yield of approximately 216.8 mgd will not meet the projected 2010 maximum day demand of approximately 245.7 mgd during drought. This is without considering the treatment or distribution capacities, the locations of the water demands, and assuming Waverly Wellfield can yield 24 mgd.

For Planning Year 2020, the system yield under 1988 drought conditions with Waverly Wellfield will fall short of meeting the projected average day demand of 172.3 mgd and the projected maximum day demand of 258.1 mgd during drought.

Table 10-12 and Table 10-13 show the yield compared to the projected demands and to the proposed rated treatment capacities at each plant in Planning Year 2010 and 2020, respectively.

The average day system yield could be increased, but at the expense of system peaking ability in the summertime. Conversely, the maximum day yield could meet or exceed the projected maximum day demand, but at the expense of obtaining enough water in the wintertime to meet the system's minimum water requirements. The yield evaluation attempted to balance the supplies to get the most average day yield to try to meet minimum wintertime water requirements while getting the most maximum day yield to try to meet summertime peak demands. The yield model shows that, during a severely dry year such as 1988, both of these objectives cannot be met from the existing sources of supply.

The White River North plant could be upgraded to treat nearly 33 mgd of surface water for 1988 drought conditions, which is slightly higher than the existing 30-mgd surface water hydraulic capacity of the plant. To avoid upgrading the White River North surface water treatment capacity beyond 30 mgd, this excess surface water could be allowed to pass by the White River North intake and be picked up downstream by the canal or the new White River intake. However, hydraulic modeling that will be performed by VWI may show some advantages to capturing the water at the White River North treatment plant as opposed to the White River treatment plant under 1988 drought conditions.

Table 10-11
System Yield for 1988 Drought Conditions
(disregarding treatment and delivery capacity)

Source	Average Day Yield (mgd)	Maximum Day Yield (mgd)
White River North Surface Water	21.4	32.4
White River Surface Water	28.3	42.8
Fall Creek Surface Water	35.0	52.9
Eagle Creek Surface Water (limited by contract with City)	12.2	18.5
Riverside/White River Wellfield	11.5 (compared to actual average day of about 3.4 mgd in 2007*)	12.6 (compared to actual max day production of about 8 mgd in 2007)
White River North Wellfield	7.6 (from seven WRN wells) (compared to actual average day of about 2.75 mgd in 2007 from 3 wells)	8.7 (from seven WRN wells) (compared to actual max day of about 9.3 mgd in 2007 from 3 wells**)
Fall Creek Wellfield	5.9 (compared to actual average day of about 4.2 mgd in 2007)	6.8 (compared to actual max day of about 8.25 mgd in 2007)
Geist Wellfield	4.4 (compared to actual average day of about 3.5 mgd in 2007)	7.1 (compared to actual max day of about 7.3 mgd in 2007)
South/Harding Wellfield	10.0 (SWF is reported to have drought yields of 10 mgd, 8 mgd, and 6 mgd for 20-year, 50-year, and 100-year droughts, respectively (WHPA, 2007))	10.0 (SWF is reported to have drought yields of 10 mgd, 8 mgd, and 6 mgd for 20-year, 50-year, and 100-year droughts, respectively (WHPA, 2007))
Waverly Wellfield (Sustainable drought yield estimated by others using a combination of vertical wells and shallow collector wells, pending additional testing for the feasibility of shallow collector wells (WHPA, 2007))	24.0 (if testing reveals shallow collector wells are not feasible, the sustainable drought yield may be less than this from the available land at the Waverly site using only vertical wells)	24.0 (if testing reveals shallow collector wells are not feasible, the sustainable drought yield may be less than this from the available land at the Waverly site using only vertical wells)
Ford Road Wellfield	1.0	1.0
TOTAL SYSTEM YIELD	161.3 (or 137.3 without Waverly)	216.8 (or 192.8 without Waverly)

* Unlike the other wellfields, the planning-level model of the Riverside/White River Wellfield shows a significantly higher yield for 2007 conditions than was actually produced in 2007. This may be due to several reasons such as (1) some of the old wells may be in need of maintenance, which was not considered by the model, (2) the alluvial and bedrock aquifers experience much lower recharge than assumed by the model in this area due to clay layering, which would need to be confirmed by aquifer testing, and/or (3) the Riverside wellfield average day production in 2007 was lower than it could have been because the cool months were relatively wet.

** spreadsheet "Inflow Distribution-2007.xls" shows the 3 WRN wells were pumped at very high rates on 4/1/2007; however, during the summer the wells were pumped at peak rates similar to the results of the planning-level model

Table 10-12
System Yield for 1988 Drought Conditions Compared to Projected Demands and Proposed Treatment Capacity for Planning Year 2010

<table>
<tr><th>Plant (surface water plus groundwater at each plant)</th><th>Max Day Yield Possible Based on Water Resources (mgd)</th><th>Max Day Yield Required to Meet Max Day Demand of 245.7 mgd in 2010 if Waverly Not Online (mgd)</th><th>Max Day Yield Required to Meet Max Day Demand of 245.7 mgd in 2010 if Waverly is Online (mgd)</th><th>Proposed Rated Treatment Plant Capacity (mgd) (VWI Short and Long Term Plan, 2006)</th></tr>
<tr><td>White River North (assumes this plant is upgraded by 2010)</td><td>41.1</td><td>41.1</td><td>41.1</td><td>60</td></tr>
<tr><td>White River</td><td>55.4</td><td>55.4</td><td>55.4</td><td>96 (120 hydraulic)</td></tr>
<tr><td>Fall Creek</td><td>59.7</td><td>59.7</td><td>59.7</td><td>32 (40 hydraulic)</td></tr>
<tr><td>Moses (limited by contract with City)</td><td>18.5</td><td>18.5</td><td>18.5</td><td>16 (20 hydraulic)</td></tr>
<tr><td>Geist</td><td>7.1</td><td>7.1</td><td>7.1</td><td>8</td></tr>
<tr><td>South/Harding (est. by others)</td><td>10.0</td><td rowspan="2">10.0 (if Waverly not online)</td><td rowspan="2">34.0 (if Waverly is online)</td><td rowspan="2">54</td></tr>
<tr><td>Waverly (est. by others) (assume treated at SWF)</td><td>0.0 (if not online)
24.0 (if online)</td></tr>
<tr><td>Ford Road</td><td>1.0</td><td>1.0</td><td>1.0</td><td>2.6</td></tr>
<tr><td>Harbour (no modeling performed)</td><td>Assumed zero</td><td>Assumed zero</td><td>Assumed zero</td><td>-</td></tr>
<tr><td>TOTAL</td><td>192.8 (216.8 if Waverly online)</td><td>192.8 (deficit of 52.9)</td><td>216.8 (deficit of 28.9)</td><td>268.6 rated (304.6 hydraulic)</td></tr>
<tr><td colspan="5">Note: Any water typically purchased by VWI from other water utilities such as Westfield (up to 1.5 mgd) or Plainfield (up to 2.0 mgd) will most likely be limited by their systems' capacity limitations and their systems' increased water demands in a dry summer, so it is conservatively assumed that those sources of water will provide no meaningful yield during drought conditions.</td></tr>
</table>

Table 10-13
System Yield for 1988 Drought Conditions Compared to Projected Demands and Proposed Treatment Capacity for Planning Year 2020

Plant (surface water plus groundwater at each plant)	Max Day Yield Possible Based on Water Resources (mgd)	Max Day Yield Required to Meet Max Day Demand of 258.1 mgd in 2020 if Waverly Not Online (mgd)	Max Day Yield Required to Meet Max Day Demand of 258.1 mgd in 2020 if Waverly is Online (mgd)	Proposed Rated Treatment Plant Capacity (mgd) (VWI Short and Long Term Plan, 2006)
White River North (assumes this plant is upgraded by 2010)	41.1	41.1	41.1	60
White River	55.4	55.4	55.4	96 (120 hydraulic)
Fall Creek	59.7	59.7	59.7	32 (40 hydraulic)
Moses (limited by contract with City)	18.5	18.5	18.5	16 (20 hydraulic)
Geist	7.1	7.1	7.1	8
South/Harding (est. by others)	10.0	10.0 (if Waverly not online)	34.0 (if Waverly is online)	54
Waverly (est. by others) (assume treated at SWF)	0.0 (if not online) 24.0 (if online)			
Ford Road	1.0	1.0	1.0	2.6
Harbour (no modeling performed)	Assumed zero	Assumed zero	Assumed zero	-
TOTAL	192.8 (219.8 if Waverly online)	192.8 (deficit of 65.3)	216.8 (deficit of 41.3)	268.6 rated (304.6 hydraulic)

Note: Any water typically purchased by VWI from other water utilities such as Westfield (up to 1.5 mgd) or Plainfield (up to 2.0 mgd) will most likely be limited by their systems' capacity limitations and their systems' increased water demands in a dry summer, so it is conservatively assumed that those sources of water will provide no meaningful yield during drought conditions.

The model shows that under 1988 drought conditions, the proposed Fall Creek treatment capacity upgrade to 40 mgd will not be sufficient to utilize up to nearly 60 mgd of available yield from the Fall Creek surface water. If the Fall Creek plant capacity is only upgraded to 40 mgd, Geist Reservoir will not be fully-utilized during this drought. Also under 1988 drought conditions, the proposed 54 mgd of groundwater treatment capacity at the South Wellfield plant will be much more than the available groundwater yield from South/Harding/Waverly wellfields. Therefore, it would be more beneficial to upgrade the Fall Creek treatment capacity to nearly 60 mgd, and reduce the future capacity of the South Wellfield groundwater plant, assuming Waverly wellfield can yield 24 mgd and using a yield of 8 mgd for South Wellfield as reported by others (WHPA, 2007). Also note that VWI may decide the South Wellfield plant capacity should be more than 34 mgd to allow more groundwater production during non-drought years.

Even if the Fall Creek treatment capacity is upgraded to nearly 60 mgd, and the Waverly Wellfield is developed to obtain 24 mgd of additional drought yield, the system yield will still fall short of meeting projected maximum day demands by approximately 29 mgd by year 2010 and approximately 41 mgd by year 2020 under 1988 drought conditions. This significant deficit reflects the impact to system yield caused by the constraints and assumptions used by this evaluation described in Sections 9.2 and 10.2. This deficit cannot be overcome by adding vertical wells within the existing wellfield properties.

Another significant issue to consider is that 1988 was essentially a severe one-year drought event, since the climate of 1989 was significantly wetter than 1988. It will be a difficult decition for VWI to allow the reservoirs to be drawn down to their minimum allowable levels in the first year of a severe drought, since history has shown that droughts may continue into subsequent years. By designing the water supply system to the two-year drought of record from 1940-1941, the Indianapolis water system would be much better prepared to meet future water demands through both one-year and two-year drought events. The modeling results for the 1940-1941 drought-of-record are described in the following section.

10.4.3 Future System Yield for 1940-1941 Drought Conditions

Table 10-14 shows the yield at each of the sources of supply for the 1940-1941 drought-of-record for Indianapolis. During drought conditions similar to 1940-1941, the average day system yield and maximum day system yield fall well short of meeting the projected average day and maximum day demands in 2010 and 2020. The system yield in the second year of the drought (1941) is dramatically reduced since the supplies are depleted during the first year of the drought. Again, the yield deficit does not consider the treatment capacities, distribution capacities or the locations of the water demands, and assumes Waverly Wellfield will yield 24 mgd. This gives an indication of the limited streamflows and precipitation that occurred in 1940 and 1941.

Table 10-14
System Yield for 1940-1941 Drought Conditions
(disregarding treatment and delivery capacity)

Source	**Average Day Yield (mgd) (for entire 2 year drought period)**	**Maximum Day Yield (mgd) (in Year 2 of drought after drought has depleted storage)**
White River North Surface Water	15.5	15.0
White River Surface Water	11.0	6.0
Fall Creek Surface Water	18.9	9.3
Eagle Creek Surface Water (limited by contract with City)	10.5	10.1
Riverside/White River Wellfield	11.5 (compared to actual average day of about 3.4 mgd in 2007*)	12.6 (compared to actual max day production of about 8 mgd in 2007)
White River North Wellfield	7.6 (from seven WRN wells) (compared to actual average day of about 2.75 mgd in 2007 from 3 wells)	8.7 (from seven WRN wells) (compared to actual max day of about 9.3 mgd in 2007 from 3 wells**)
Fall Creek Wellfield	5.9 (compared to actual average day of about 4.2 mgd in 2007)	6.8 (compared to actual max day of about 8.25 mgd in 2007)
Geist Wellfield	4.4 (compared to actual average day of about 3.5 mgd in 2007)	7.1 (compared to actual max day of about 7.3 mgd in 2007)
South/Harding Wellfield	8.0 (SWF is reported to have drought yields of 10 mgd, 8 mgd, and 6 mgd for 20-year, 50-year, and 100-year droughts, respectively (WHPA, 2007))	8.0 (SWF is reported to have drought yields of 10 mgd, 8 mgd, and 6 mgd for 20-year, 50-year, and 100-year droughts, respectively (WHPA, 2007))
Waverly Wellfield (Sustainable drought yield estimated by others using a combination of vertical wells and shallow collector wells, pending additional testing for the feasibility of shallow collector wells (WHPA, 2007))	24.0 (if testing reveals shallow collector wells are not feasible, the sustainable drought yield may be less than this from the available land at the Waverly site using only vertical wells)	24.0 (if testing reveals shallow collector wells are not feasible, the sustainable drought yield may be less than this from the available land at the Waverly site using only vertical wells)
Ford Road Wellfield	1.0	1.0
TOTAL SYSTEM YIELD	118.3*** (or 94.3 without Waverly)	108.6**** (or 84.6 without Waverly)

* Unlike the other wellfields, the planning-level model of the Riverside/White River Wellfield shows a significantly higher yield for 2007 conditions than was actually produced in 2007. This may be due to several reasons such as many of the old wells may be in need of maintenance, which was not considered by the model, and/or the alluvial and bedrock aquifers experience much lower recharge than assumed by the model in this area due to clay layering, which would need to be confirmed by well diagnostics and aquifer testing.

** spreadsheet "Inflow Distribution-2007.xls" shows the 3 WRN wells were pumped at very high rates on 4/1/2007; however, during the summer the wells were pumped at peak rates similar to the results of the planning-level model

*** in 1941, the average day yield is only about 82 mgd, after storage is depleted

**** in 1941; early in the first summer of the drought (1940) the system maximum day yield is higher, but the yield is significantly impacted in 1941 after storage is depleted

The system yield model simulated climate conditions from 1/1/1940 through 3/31/1942 in order to cover the entire drought-of-record. At the onset of a drought similar to 1940-1941, without knowing the drought-of-record is about to occur, the model assumes that VWI would operate the system as it always has, in order to produce somewhere between approximately 120 mgd and 150 mgd in the cooler months to meet demands and will continue to meet demands through the first summer of the drought. With these considerations, the model indicates that the system will reach a maximum yield of about 196 mgd in June of 1940, but will drop dramatically for the remainder of 1940 and through most of 1941. Streamflows and precipitation will become extremely low during this period and the storage in the reservoirs and aquifers will become depleted. In the months of July and August during the second year of this drought, when maximum day demands are projected to reach 246 mgd by 2010 and 258 mgd by 2020 (without demand management), the water resources at the existing sources of supply may only be able to yield a little more than 100 mgd. This indicates the severity of the drought-of-record and the impact to yield caused by the system constraints and assumptions given in Sections 9.2 and 10.2 of this report.

Table 10-15 and Table 10-16 show the yield compared to the projected demands and to the proposed rated treatment capacities at each plant in Planning Year 2010 and 2020, respectively.

<table>
<tr><th colspan="5">Table 10-15
System Yield for 1940-1941 Drought Conditions Compared to Projected Demands and Proposed Treatment Capacity for Planning Year 2010</th></tr>
<tr><th>Plant (surface water plus groundwater at each plant)</th><th>Max Day Yield Possible Based on Water Resources* (mgd)</th><th>Max Day Yield Required to Meet Max Day Demand of 245.7 mgd in 2010 if Waverly Not Online (mgd)</th><th>Max Day Yield Required to Meet Max Day Demand of 245.7 mgd in 2010 if Waverly is Online (mgd)</th><th>Proposed Rated Treatment Plant Capacity (mgd) (VWI Short and Long Term Plan, 2006)</th></tr>
<tr><td>White River North (assumes this plant is upgraded by 2010)</td><td>23.7</td><td>23.7</td><td>23.7</td><td>60</td></tr>
<tr><td>White River</td><td>18.6</td><td>18.6</td><td>18.6</td><td>96 (120 hydraulic)</td></tr>
<tr><td>Fall Creek</td><td>16.1</td><td>16.1</td><td>16.1</td><td>32 (40 hydraulic)</td></tr>
<tr><td>Moses (limited by contract with City)</td><td>10.1</td><td>10.1</td><td>10.1</td><td>16 (20 hydraulic)</td></tr>
<tr><td>Geist</td><td>7.1</td><td>7.1</td><td>7.1</td><td>8</td></tr>
<tr><td>South/Harding (est. by others)</td><td>8.0</td><td rowspan="2">8.0 (if Waverly not online)</td><td rowspan="2">32.0 (if Waverly is online)</td><td rowspan="2">54</td></tr>
<tr><td>Waverly (est. by others) (assume treated at SWF)</td><td>0.0 (if not online)

24.0 (if online)</td></tr>
<tr><td>Ford Road</td><td>1.0</td><td>1.0</td><td>1.0</td><td>2.6</td></tr>
<tr><td>Harbour (no modeling performed)</td><td>Assumed zero</td><td>Assumed zero</td><td>Assumed zero</td><td>-</td></tr>
<tr><td>TOTAL</td><td>108.6 (84.6 if Waverly not online)</td><td>84.6** (deficit of 161.1)</td><td>108.6** (deficit of 137.1)</td><td>268.6 rated (304.6 hydraulic)</td></tr>
<tr><td colspan="5">Note: Any water typically purchased by VWI from other water utilities such as Westfield (up to 1.5 mgd) or Plainfield (up to 2.0 mgd) will most likely be limited by their systems' capacity limitations and their systems' increased water demands in a dry summer, so it is conservatively assumed that those sources of water will provide no meaningful yield during drought conditions.
* In second year of drought-of-record after supplies are depleted in first year.
** Also, note that up to about 196 mgd of max day yield will occur early in the summer of 1940, and the yield will be significantly lower from July 1940 through the fall of 1941; there isn't enough storage in the existing reservoirs to handle this drought with all of the assumptions and constraints chosen for this analysis</td></tr>
</table>

<table>
<tr><th colspan="5">Table 10-16
System Yield for 1940-1941 Drought Conditions Compared to Projected Demands and Proposed Treatment Capacity for Planning Year 2020</th></tr>
<tr><th>Plant
(surface water plus groundwater at each plant)</th><th>Max Day Yield Possible Based on Water Resources*
(mgd)</th><th>Max Day Yield Required to Meet Max Day Demand of 258.1 mgd in 2020 if Waverly Not Online (mgd)</th><th>Max Day Yield Required to Meet Max Day Demand of 258.1 mgd in 2020 if Waverly is Online
(mgd)</th><th>Proposed Rated Treatment Plant Capacity
(mgd)
(VWI Short and Long Term Plan, 2006)</th></tr>
<tr><td>White River North (assumes this plant is upgraded by 2010)</td><td>23.7</td><td>23.7</td><td>23.7</td><td>60</td></tr>
<tr><td>White River</td><td>18.6</td><td>18.6</td><td>18.6</td><td>96 (120 hydraulic)</td></tr>
<tr><td>Fall Creek</td><td>16.1</td><td>16.1</td><td>16.1</td><td>32 (40 hydraulic)</td></tr>
<tr><td>Moses (limited by contract with City)</td><td>10.1</td><td>10.1</td><td>10.1</td><td>16 (20 hydraulic)</td></tr>
<tr><td>Geist</td><td>7.1</td><td>7.1</td><td>7.1</td><td>8</td></tr>
<tr><td>South/Harding
(est. by others)</td><td>8.0</td><td rowspan="2">8.0
(if Waverly not online)</td><td rowspan="2">32.0
(if Waverly is online)</td><td rowspan="2">54</td></tr>
<tr><td>Waverly
(est. by others)
(assume treated at SWF)</td><td>0.0 (if not online)

24.0 (if online)</td></tr>
<tr><td>Ford Road</td><td>1.0</td><td>1.0</td><td>1.0</td><td>2.6</td></tr>
<tr><td>Harbour
(no modeling performed)</td><td>Assumed zero</td><td>Assumed zero</td><td>Assumed zero</td><td>-</td></tr>
<tr><td>TOTAL</td><td>108.6
(84.6 if Waverly not online)</td><td>84.6**
(deficit of173.5)</td><td>108.6**
(deficit of 149.5)</td><td>268.6 rated
(304.6 hydraulic)</td></tr>
<tr><td colspan="5">Note: Any water typically purchased by VWI from other water utilities such as Westfield (up to 1.5 mgd) or Plainfield (up to 2.0 mgd) will most likely be limited by their systems' capacity limitations and their systems' increased water demands in a dry summer, so it is conservatively assumed that those sources of water will provide no meaningful yield during drought conditions.
* In second year of drought-of-record after supplies are depleted in first year.
** Also, note that up to about 196 mgd of max day yield will occur early in the summer of 1940, and the yield will be significantly lower from July 1940 through the fall of 1941; there isn't enough storage in the existing reservoirs to handle this drought with all of the assumptions and constraints chosen for this analysis</td></tr>
</table>

The yield evaluation attempted to balance the supplies to get the most average day yield to try to meet minimum wintertime water requirements while getting the most maximum day yield to try to meet summertime peak demands. The yield model shows that, during the drought-of-record, neither of these objectives could be met from the existing sources of supply.

Thus, the proposed treatment capacities of the White River North, White River, and Fall Creek treatment plants of 60 mgd, 120 mgd, and 40 mgd, respectively, are more than adequate to treat the maximum available yield at these sources of supply during the drought-of-record. Treatment capacity upgrades at these plants may be justified for less severe climate conditions, but the added capacity will not be fully-utilized during the drought-of-record. *(For example, recall that for the less severe 1988 drought conditions, the yield model shows that up to 60 mgd of treatment capacity may be justified for the Fall Creek plant. This shows the importance of choosing the drought conditions and level of risk for system design.)*

The model assumes that releases will be made from Morse Reservoir instead of Geist Reservoir to maintain downstream power plant flows. If releases were made from Geist Reservoir to provide flow to the power plants, it would reduce the yield available from Geist Reservoir, and increase the yield of Morse Reservoir, but the overall system yield will remain the same.

Similar to other climate conditions evaluated, the proposed 54 mgd of groundwater treatment capacity at the South Wellfield plant will be much more than the available groundwater yield from South/Harding/Waverly wellfields during 1940-1941 drought conditions. Based on this, the future capacity of the South Wellfield groundwater plant of 54 mgd may be too high. This may not be the case if groundwater yield is discovered during future testing.

Figures 10-17 and 10-18 show selected system diagnostics from the yield model during the drought-of-record. The graphs show that system yield reaches a maximum of about 196 mgd in June of 1940, then is dramatically reduced as the drought continues and intensifies. Morse and Geist Reservoirs reach their minimum allowable levels in both late December of 1940 and in November of 1941. Due to adequate incoming streamflows and the contractual limitation with the City for 12.4 mgd of average day water supply, Eagle Creek Reservoir does not reach its minimum allowable level in 1940, but does reach its minimum level in December of 1941. The flow over Broad Ripple Dam remains more than adequate for the entire drought because minimum flows need to be maintained for the downstream power plants.

The yield model shows that releases of about 30 mgd or more from Morse Reservoir are required for much of the summer and fall months in both 1940 and 1941 to maintain 48 mgd past the Citizens Thermal plant, which has a significant impact on the water supply yield. By maintaining 48 mgd past Citizens Thermal, and since recent testing of the South and Waverly Wellfields shows that the White River flow (supplemented by the wastewater return flows) will not be significantly depleted by the wells, the IPL Stout Power Plant minimum required flow of 100 mgd is maintained for the duration of the drought. The final graph on Figure 10-18 shows the net White River streamflow leaving the area. Although the 7Q10 flow of 159 mgd is not maintained at all times, IDNR may grant an exception to this rule since the 1940-1941 drought condition is more severe than a 10-year event. In fact, it is estimated that the actual streamflow in White River past Centerton reached as low as 61 mgd during 1940-41, showing that the presence of the water supply reservoirs and wastewater plants create much more flow than occurred naturally during this drought.

The final graph on Figure 10-18 also shows that, even during the worst drought-of-record, there are occasional periods where significant flow occurs in the White River past Waverly. This tendency was noted by VWI personnel in 2007 when, following occasional rainfall events during the summer, there was flow in the river that could not be captured. If there was a way to capture these occasional spikes in river flow in southern Indianapolis and store the water for later use, the yield of the system could be increased. As shown on Figure 10-19, the model shows the total volume of water in excess of the 7Q10 streamflow flowing past Waverly from 7/1/1940 to 9/30/1941 is about 22,300 million gallons. This is 150 percent of the total usable volumes of all three existing reservoirs combined. Most of this excess flow occurs in just a few episodes in the winter and spring of 1941, each lasting a week or two. With a 100-mgd surface water intake located near or south of Waverly, it is estimated that over 20 percent of this volume could be captured during the drought-of-record while still leaving the 7Q10 flow in the river. The model could be used to determine the size of a storage facility and surface water intake that might be technically, economically, and environmentally feasible. Of course, land availability, cost, implementation time, and percentage of wastewater effluent in the river are very significant issues that would need to be considered.

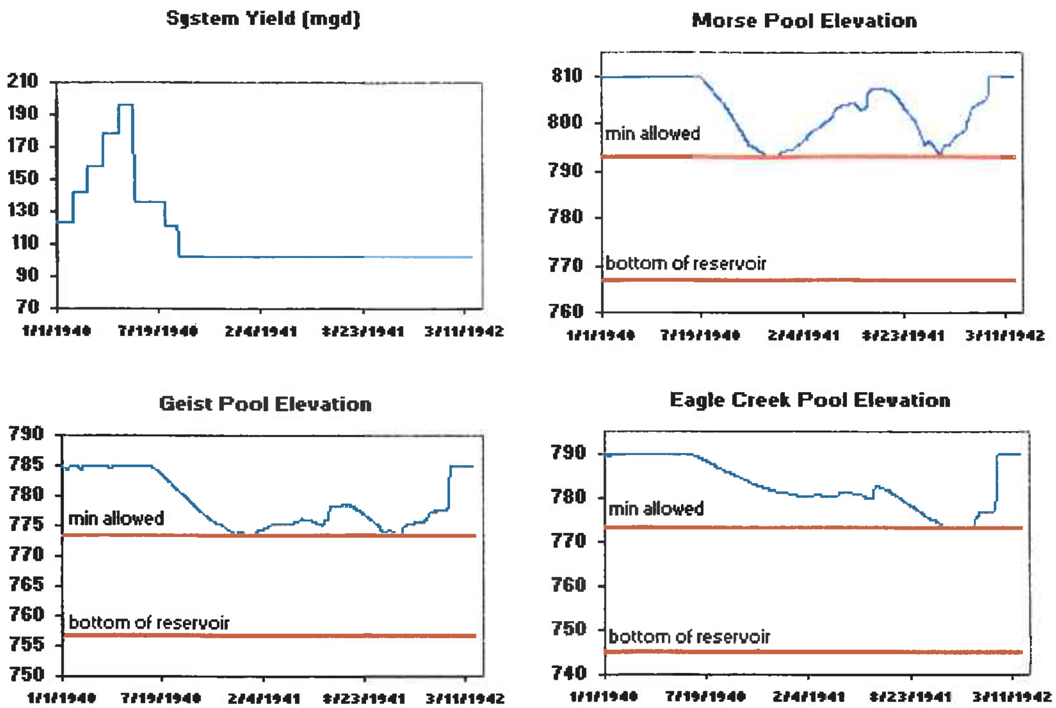

Figure 10-17 System Diagnostics from Yield Model for Drought-of-Record

(Part 1 of 2)

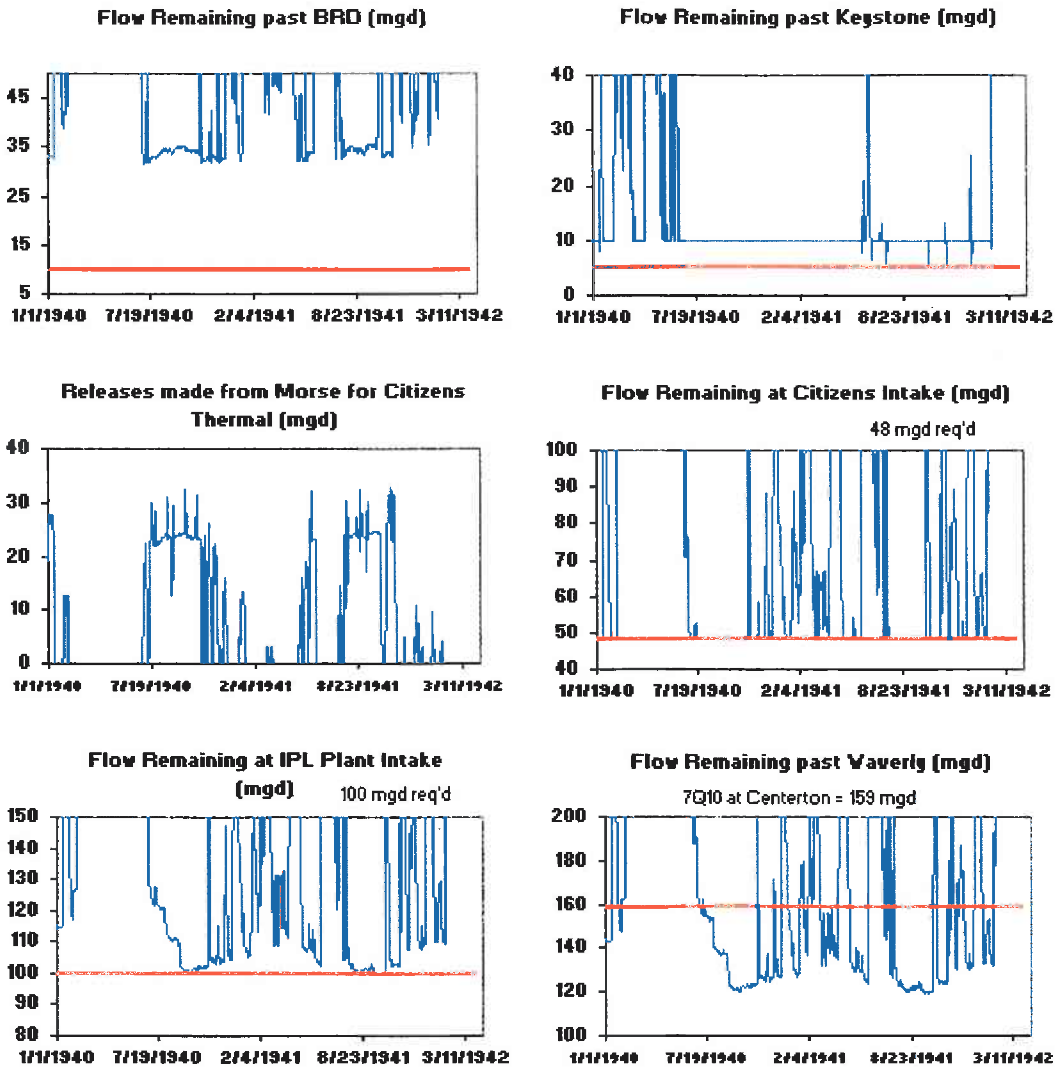

Figure 10-18 System Diagnostics from Yield Model for Drought-of-Record

(Part 2 of 2)

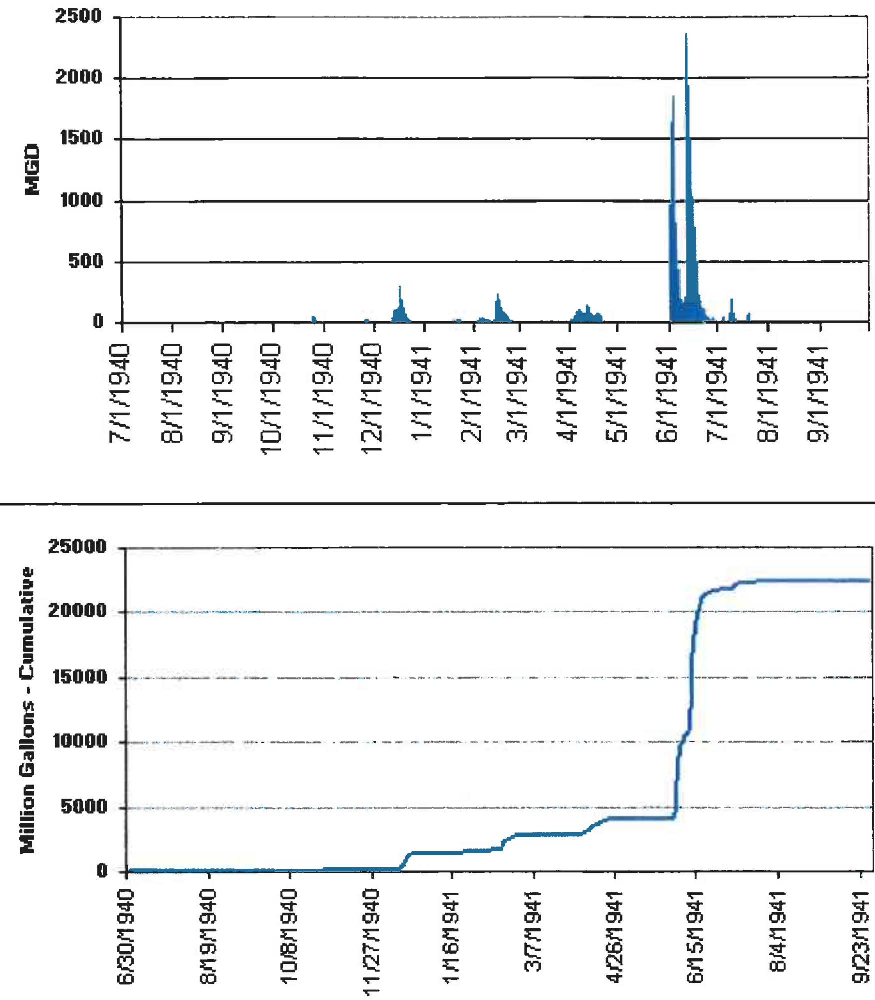

Figure 10-19 Potential White River Flow Past Waverly in Excess of 7Q10 During 1940-1941 Drought-of-Record Conditions

In summary for 1940-1941 drought conditions, the model shows that if the Waverly Wellfield is developed and the existing treatment plant capacities were increased as proposed, the system yield from the existing sources of supply will still be much lower than the projected maximum day demands in 2010 and 2020. Much of the treatment plant capacity cannot be utilized because of the lack of raw water. This significant deficit reflects both the severity of the 1940-1941 drought and the impact to system yield caused by the constraints and assumptions used by this evaluation, as described in Sections 9.2 and 10.2. This deficit cannot be overcome by adding vertical wells within the existing wellfield properties. However, to the south of the City, there will be occasions where flow accumulates in the White River in excess of the 7Q10 flow that might be captured to increase system yield.

Figure 10-20 gives an estimate of how yields may compare to demands over the duration of the two-year drought of record. Prior to knowing the drought-of-record is about to occur, VWI would most likely operate the system to meet demands. However, if it is not recognized early in the summer of the first year that the drought is severe, and consumption is not significantly reduced, the reservoirs will drop below their minimum allowable levels, and yield will be even less in the second year of the drought than shown on Figure 10-20. It will be very difficult to justify such a reduction in consumption so early in the first year of a drought. If the production is not reduced as shown on Figure 10-20, then the reservoirs will reach their lowest allowable levels later in the drought and will not be available for supply.

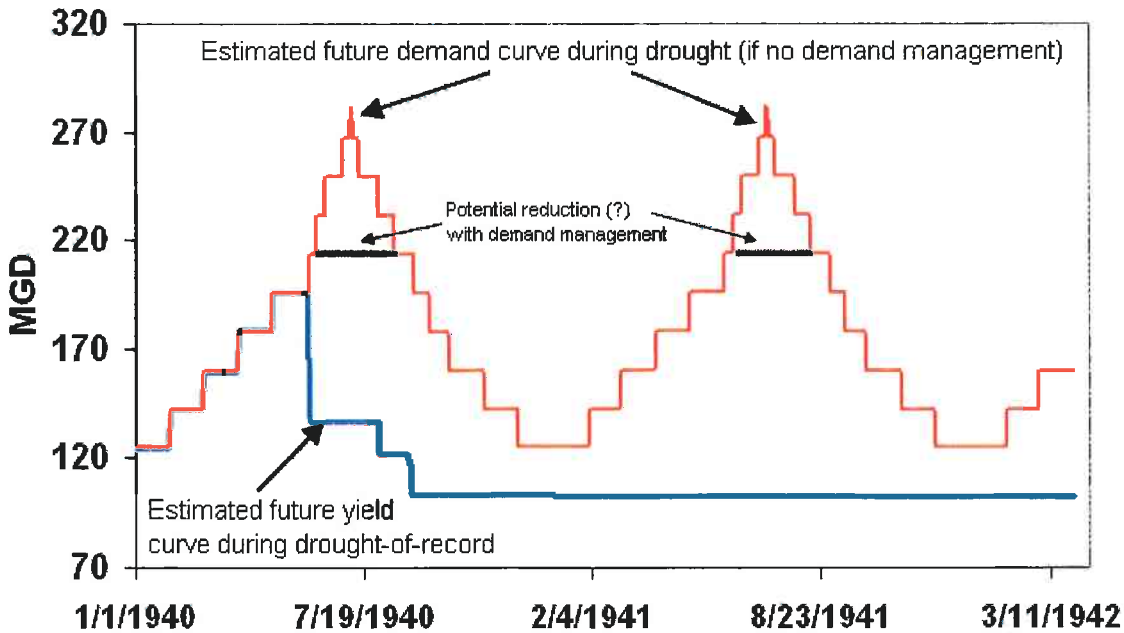

Figure 10-20 Scenario for Transient Yield Versus Demand During Drought-of-Record

(note the reduction in consumption by using demand management is only provided for illustration purposes and would need to be evaluated in more detail by VWI using the results of the 2004 Water Conservation Plan)

During drought, the existing water supply relies heavily on the available storage in the three reservoirs. This evaluation shows that this volume is not sufficient to provide enough water to meet demands for the drought-of-record. Figure 10-21 shows that even if the water system were operated continuously at the same rate to stretch the reservoir storage volume for the duration of the drought-of-record, the system would not provide enough water to meet minimum essential demands.

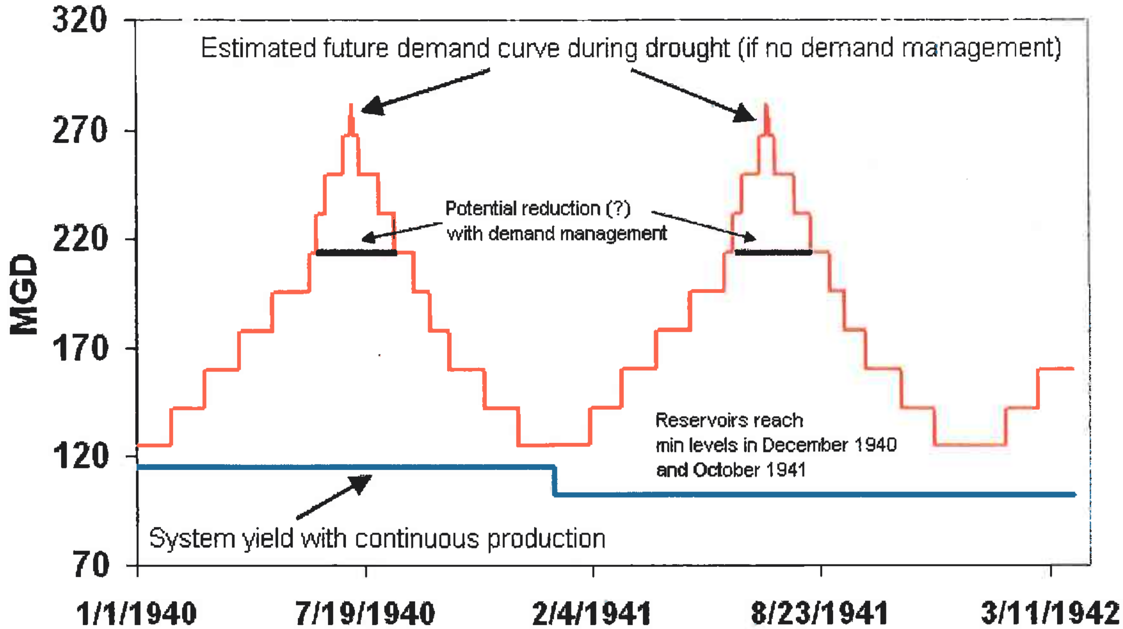

Figure 10-21 Scenario for Constant Yield Versus Demand during Drought-of-Record

(this shows there is not enough storage for the drought -of-record)

For comparison, Figure 10-22 gives the deficit between yield and demand for the less severe drought of 1988-1989. The figures show that the deficit for 1988 is not as great as it is for the 1940-1941 drought, and that for 1989, the yield is greater than the demand.

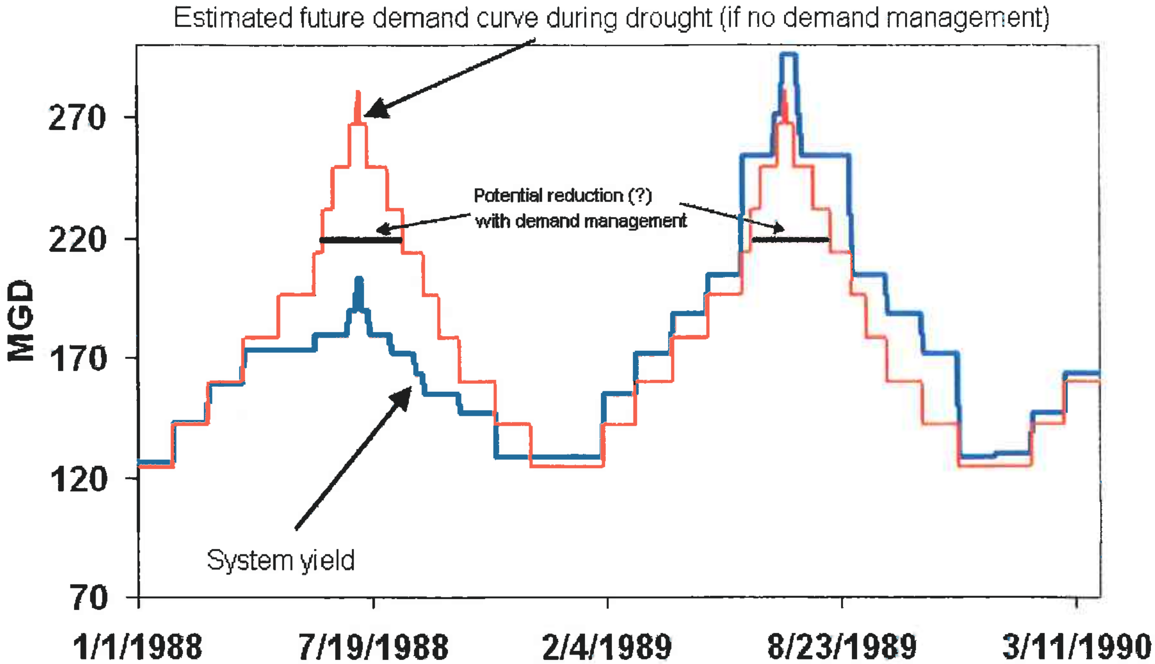

Figure 10-22 Scenario for Transient Yield Versus Demand During 1988-1989 Drought

(demands are met in second year of this drought, but not in first year)

Of course, there are a large number of variables that might influence the timing and magnitude of consumption and production during the course of a severe drought. These graphs give possible scenarios showing the large deficit between supply and demand during various droughts. The deficit may be reduced with such measures as demand management, allowing the reservoirs to be drawn down to extremely low levels and eliminating reservoir releases for downstream power plants or environmental flows.

10.5 SCENARIO MODELING FOR THE INDIANAPOLIS WATER SYSTEM

There is an opportunity for VWI to use the system yield model to evaluate a variety of "what-if" scenarios for the Indianapolis Water system. For example, VWI could investigate ways of using the yield model for operational decisions of ideal locations to produce water under a given set of conditions such as time of year, streamflows at critical locations, reservoir levels, and weather forecasts. Several "what-if" scenarios were simulated, as follows:

Scenario #1 – What if the reservoirs would not have been full on 1/1/2007?

The system yield model for 2007 climate conditions shows that if the reservoirs started on 1/1/2007 up to 10 feet below their dam spillway elevations, the yield would not be impacted. This is because the stream inflows to the reservoirs in January through June were enough to fill the reservoirs prior to the peak summer demand season.

Scenario #2 - *What if the reservoirs would have been 5 feet below the spillcrests on 6/1/2007?*

The model shows that yield would have exceeded demands in 2007 even if the reservoirs began the peak pumping season 5 feet below their dam spillway elevations. This is because the inflows to the reservoirs exceeded outflows.

Scenario #3 – *Looking at the 1988-1989 drought, the driest 8-month period occurred from mid-April 1988 through December 1988. What if the reservoirs began on 1/1/1988 up to 10 feet below the dam spillway elevations?*

The model shows yield would not have been lower than if the reservoirs began 1988 full, since inflows from January through April of 1988 were sufficient to offset outflows. However, for 1988-1989 conditions, whether the reservoirs were full or not on 1/1/1988, the maximum day yield of the system would not meet the projected maximum day demand for 2010 and 2020.

Scenario #4 – *For 1988-1989 drought conditions, what if the reservoirs began on 4/15/1988 about 5 feet below their dam spillway elevations?*

According to the model, the average day and maximum day system yield would decrease by about 5 to 10 percent, furthering the deficit between available water supply and the projected average day and maximum day demands in 2010 and 2020.

Many "what-if" scenarios can be simulated with the system yield model to investigate the possibility of a yield deficit under a variety of combinations of system conditions at various times of the year. Scenario modeling would provide information to assist VWI and the City in developing "drought triggers" that could be used to determine when to ask for voluntary or mandatory water use reductions. It may be possible to use the model to help establish "triggers" by considering factors such as (1) time of year, (2) reservoir levels, (3) streamflows, (4) climate forecast, (5) antecedent climate conditions, (6) anticipated water demands, etc. The results could be used to supplement VWI's knowledge of the system and the Department of Waterworks' water conservation ordinance.

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11. PROXIMITY OF WATER SUPPLY TO FUTURE DEMAND LOCATIONS

Veolia Water Indianapolis (VWI) will perform hydraulic modeling of the system, using the results of this system yield evaluation and distributing water to the pressure districts based on the results of the demand evaluation for Planning Years 2010 and 2020 (Black & Veatch, 2008). The hydraulic modeling will link the supplies to the projected demands and identify where pipe or other facility improvements are necessary. The hydraulic model, along with VWI's knowledge of the distribution system, will help identify the preferred locations for producing water during times of drought.

The system yield results in this technical memorandum represent the total amount of water than can be produced during various drought events. Although the total yield will remain the same, there is some flexibility for where the water can be produced. For example, the hydraulic model may determine that it would be best to produce as much surface water as possible from the White River North plant as opposed to the White River plant because White River North is closer to the growing water demands in the northern portion of the Indianapolis area. This would shift some yield from the White River plant to the White River North plant.

Significant growth is expected to occur in the Cumberland, Castleton, Southeast, Southwest, and Avon pressure zones (Black & Veatch, 2008). Southeast and Southwest would ideally be served by the southern wellfields, but since recent testing has shown the yield of these wellfields during drought could be limited, sending some additional water to these pressure zones from the White River plant in the future may be necessary. According to the yield model, this will be possible during a dry year such as 2007 or a mild drought, but will not be possible during a more severe drought. Growth in the Cumberland and Castleton zones will place additional demands on the Fall Creek/Geist supplies. Growth to the north, in areas such as Harbour and Meridian Hills will place more demands on the White River North supplies. VWI's hydraulic model will be used to distribute water to these growth areas, and will identify where deficiencies exist between demand and supply.

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12. COMPARISON OF YIELD RESULTS TO 2003 YIELD STUDY

The following significant changes to the system constraints and assumptions reduced the yield reported in the 2003 Yield and Demand evaluation:

- Recent aquifer testing and modeling at the southern wellfield sites, along with operational experiences in 2007, show that the hydraulic connection between the streams and the aquifers is much more limited than previously assumed prior to testing. This results in significant yield reduction for the wellfields during extended drought conditions because the wellfields will need to be cycled to avoid drawing the groundwater table too low.
- With the findings in 2007 that the southern wellfield sites have limited ability to induce streamflow into the aquifer and uncertainties about whether future testing will show that shallow horizontal collector wells are feasible at Waverly (or Paragon), the return flows from the Belmont and Southport treatment plants will essentially be lost downstream. This has a significant impact on the future groundwater yield of the system.
- The maximum groundwater drawdowns allowed at each wellfield using the planning-level groundwater models developed for this study consider the difficulty for the operators to adjust pumping from each well to optimize the depletion of groundwater storage in the midst of a severe drought. This has been the experience of other water utilities during drought conditions.
- Liberty, Darlington, Harbour, and Paragon wellfields are not considered to add any yield to the system for Planning Years 2010 and 2020 for this evaluation.
- The White River minimum flow requirement of 100 million gallong per day (mgd) at Waverly, 100 mgd at the Stout Power Plant and 50 mgd at the Citizens Thermal Plant have a significant impact on water supply yield because releases from the reservoirs must be made to meet these downstream flow requirements.
- The reservoirs were not allowed to be drawn down as low as previous studies due to concerns of the usable storage volume. When the reservoirs are drawn down below 25 percent of their total volumes,

public concern of low reservoir levels and uncertainties about how Indianapolis Department of Public Works (DPW) will regulate Eagle Creek Reservoir were also concerns in the new study.

- For this evaluation, it was decided to assume the seepage from the canal is over 13 mgd based on a 1979 USGS study of the canal compared to 2 mgd from a 1977 USGS study of streamflows along the canal. Vegetation growth also limits canal capacity in the summer. Canal seepage and capacity are uncertain at this time, and this assumption should be revisited if the USGS performs an updated study of the canal.
- The transition from a monthly to a daily time step requires more detailed evaluation of day-to-day operational issues and inefficiencies. For example, the system operators may call for releases from the reservoirs, causing more flow bypassing Broad Ripple dam and Keystone dam which cannot be recovered downstream due to the lack of a surface water intake in southern Indianapolis.

To illustrate the effect of these decisions, system yield modeling was performed with less conservative assumptions as follows:

- Allowed the reservoirs to be drawn very low, to the levels assumed for previous evaluations
- No releases from the reservoirs to meet minimum downstream flow requirements for the power plants or the environment
- Used a canal seepage of 2 mgd from a 1977 USGS streamgage study, as opposed to about 14 mgd from a 1979 USGS study

Figure 12-1 shows that with these less conservative assumptions, there is an increase in system yield from the previous, more conservative assumptions.

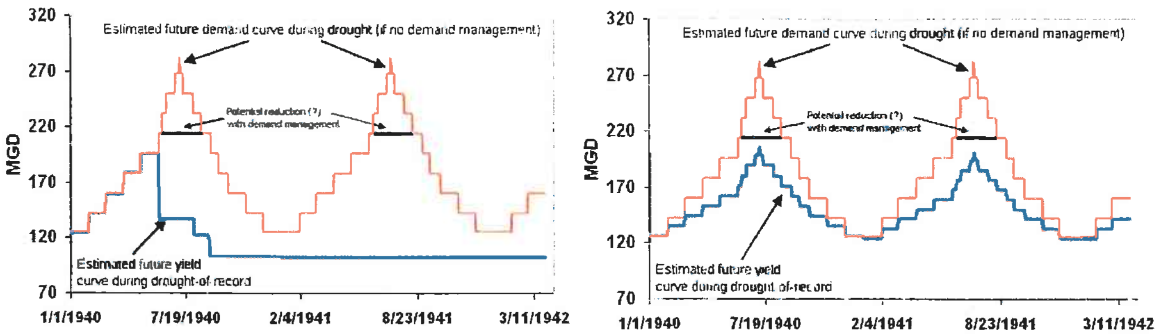

Figure 12-1 Effect of System Constraints and Assumptions on Yield

(graph to the left is Figure 5-20 of this report)

The graph to the right on Figure 12-1 shows the effect of shifting a significant amount of water during the drought-of-record from the power plants and the environment to the VWI water system. The minimum flow past the Citizens Thermal Plant reaches 16 mgd, as opposed to the 48 mgd that they currently need. Because of the Belmont Plant return flows to the White River, the minimum flow past the Stout Plant is 87 mgd, which is nearly equal to their required 100 mgd. The minimum flow in the White River past Waverly is 119 mgd, which is considered adequate for the drought-of-record. The magnitude of canal seepage needs to be verified. Or, to eliminate canal seepage as much as possible VWI could allow all of the flow to bypass Broad Ripple dam to be captured at the new White River intake during a severe drought. Achieving the yield shown on the graph to the right on Figure 12-1 would require running the reservoirs down to extremely low levels in the second year of this drought. The remaining deficit shown on the graph to the right can primarily be attributed to the testing in 2007 that revealed the southern wellfields will not be able to provide the yield previously anticipated, as well as the overreleases from Morse and Geist Reservoirs.

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13. YIELD EVALUATION SUMMARY AND RECOMMENDATIONS

Indianapolis has a complex and wide-ranging water system devised to serve its growing population. Due to the fact that the City is not located near any large body of water, they have diversified their water portfolio into a number of reservoirs and wellfields. An evaluation was done to identify the water supply yield in various drought conditions as well as an in-depth look at system constraints and assumptions largely influencing the magnitude of the yield. This water supply evaluation shows that the Indianapolis Water System requires additional yield to meet demands during drought conditions.

With the constraints and assumptions used in this evaluation, it is concluded that the existing water system in Indianapolis will not be able to yield enough water to meet demands during climate conditions similar to the 1940-1941 drought-of-record. This assumes the addition of several wells added to the existing wellfields, and the proposed Waverly wellfield and existing treatment plant upgrades. Some constraints and assumptions considered include upstream depletion, minimum downstream flow requirements, limited connection of the aquifers to streams and minimum reservoir levels. If the 1988 drought conditions recur and the existing reservoirs and wellfields are operated efficiently, the system may produce enough water to meet average day demands. Additionally, the system may not be able to meet the summertime peak demands without significant reductions in future consumption through water use restrictions or conservation. The system yield model confirms that 2007 was a much wetter year than historic drought years, and that there was sufficient raw water available at the existing sources of supply to meet demands. Table 13-1 and 13-2 summarize the deficit under various historical climate conditions.

Table 13-1
2010 Maximum Day Demand versus Maximum Day Yield during Various Climate Conditions
(assuming no demand management to reduce consumption, and assuming Waverly Wellfield will yield 24 mgd)

Climate Condition	Max Day Demand (mgd)	Max Day Yield (mgd)	Deficit (mgd)
2007 (typical-to-dry year)	245.7	>245.7	Surplus
1988-89 (moderate drought)	245.7	216.8	28.9
1940-41 (severe drought)	245.7	108.6 (in second year of drought)	137.1 (in second year of drought)

Table 13-2
2010 Average Day Demand versus Average Day Yield during Various Climate Conditions
(assuming no demand management to reduce consumption, and assuming Waverly Wellfield will yield 24 mgd)

Climate Condition	Max Day Demand (mgd)	Max Day Yield (mgd)	Deficit (mgd)
2007 (typical-to-dry year)	164.1	>164.1	Surplus
1988-89 (moderate drought)	164.1	161.3	2.8
1940-41 (severe drought)	164.1	82 (in second year)	82.1

It should be emphasized that the yield model should be used to size a future additional source of supply to make sure the entire system of surface water and groundwater supplies will be capable of meeting both average day and maximum day demands. The deficits shown in both Tables 13-1 and 13-2 should be considered when evaluating future sources of supply.

If the climate returns to the much drier conditions, as seen prior to the 1970s, it can be concluded that, with the addition of Waverly Wellfield, the water system will have an estimated probability of about 10 to 20 percent of not meeting demands in any given year. Traditionally, it is recommended to have a system with 2 percent annual probability of not meeting demands.

The model shows the average day yield of the existing system could be increased during a drought, but at the expense of the system's peaking ability in the summertime. Conversely, the maximum day yield could be increased, but at the expense of obtaining enough water to meet the system's wintertime water requirements. This evaluation attempted to balance the supplies to get the most yield to try to meet average day water requirements while also trying to meet summertime peak demands. The yield model shows that, during a severe drought, both of these objectives cannot be met from the existing sources of supply plus Waverly Wellfield.

If 2007 climate conditions were used to size the upgrades to existing facilities to capture, treat, and distribute water, these capacity upgrades would not be fully utilized during more severe drought conditions. For example, the new intake on the White River near 16th Street will add yield during climate conditions similar to 2007 but will not add any significant yield during the drought-of-record since the available White River flow (past the canal plus the new intake) will be much lower than the White River treatment plant capacity.

Of the existing sources of supply, the Morse-White River and Geist-Fall Creek surface water supplies will continue to be the most reliable during dry climate conditions. However, as the City's water demands grow, it may become unacceptable to frequently draw these reservoirs down to low levels every dry summer. For example, the yield evaluation shows that over 90 million gallons per day (mgd) of yield could be obtained from the Geist-Fall Creek surface water supply during a summer similar to 2007. But to produce this amount of water, it would require drawing Geist Reservoir down to its minimum allowable level, which is not acceptable considering that 2007 is not even a drought year. Therefore, upgrading the Fall Creek treatment plant to such a large capacity is not recommended. During the drought-of-record, the yield model shows the Geist-Fall Creek surface water supply plus the Fall Creek groundwater supply can yield slightly more than the proposed Fall Creek hydraulic treatment capacity of 40 mgd. For moderate drought conditions such as 1988-1989, there is justification for upgrading the capacity to approximately 60 mgd to fully utilize the storage in Geist Reservoir and maximize its yield.

The yield model indicates that the proposed treatment capacities of up to 60 mgd for the White River North plant and up to 120 mgd for the White River plant will be fully utilized during climate conditions similar to 2007. However, these capacities would only be approximately 54% utilized during drought conditions of 1988-1989, and 24% utilized during drought conditions of 1940-1941.

For Eagle Creek Reservoir, the current contract with the City for water allocations (12.4 mgd long-term average, and 19.84 mgd maximum month) is close to matching the available surface water yield during 1940-1941 drought conditions. Therefore, it does not appear beneficial to try to renegotiate this contract for more water or upgrade the Moses plant if the system is designed for the drought-of-record. However, if a less severe drought is selected for system design, more yield could be obtained from Eagle Creek Reservoir than currently contracted with the City. For example, for 1988 drought conditions, it may be possible to obtain a yield of about 17.7 mgd average day and about 26.7 mgd maximum day. It appears the current contract with the City will last for another 18 years or so.

Drawing the reservoirs down to their minimum allowable levels should be reserved for severe droughts. Veolia Water Indianapolis (VWI) would need to recognize the severity of a dry year similar to 1988 or 1940 by monitoring precipitation, streamflows, water usage, time of year, and drought predictions, and then make the decision to allow the reservoirs to be drawn down to their minimum levels. The risk of following through with this decision in the first dry year is the uncertainty of whether or not the drought will continue into a second year. If the reservoirs do not refill and the drought continues, the system yield may be severely impacted the second year.

In performing these yield analyses and looking at recorded streamflows, it shows that streamflows usually keep the reservoirs full until late spring or early summer at the beginning of a drought. Then, with an extended period of dry conditions historically lasting anywhere between 6 and 24 months, the reservoirs become depleted, hitting their low points in December. Some recovery occurs over the winter months followed by another depletion of supplies the following summer. In 1999-2000, Black & Veatch (B&V) performed scenario modeling for Morse Reservoir based on concerns that the reservoir did not refill over the winter months. The intent of that evaluation was to consider only Morse Reservoir and not the entire system or downstream flow requirements. However, it showed that Morse Reservoir could be somewhat below the dam spillway elevation from January to March and still have a very high probability of meeting its targeted yield through some droughts. Yet it would need to be filling in April and relatively full by May to maintain a high probability of meeting target yield through the drought. Thus, it can be concluded that the most critical time of year for the reservoirs to be relatively full of water is around April or May of each year. Along with monitoring precipitation and streamflow, VWI should continue to observe the springtime reservoir levels to determine the onset of a future drought using the reservoir design curves.

Under drought conditions, the groundwater models show that it may be possible to add 5 new wells to the existing wellfield properties. Because of the variability in aquifer depth and aquifer material, drilling and testing is required to confirm well yields and well placement. This testing may reveal additional groundwater yield than predicted through the models by identifying optimum locations for more wells. Optimum locations would be deep pockets of saturated sand and gravel, locations with better hydraulic connection with the streams, or potential locations for shallow collector wells. The planning-level groundwater models show that it may be possible to obtain an additional yield of up to 5 mgd if sufficient separation between wells is maintained. Wellfield yields might be increased by acquiring more land to expand the wellfield properties and spread the pumping out over a larger area. The feasibility of land acquisition around the existing wellfields would need to be determined. Expansion of the wellfield properties will need to consider other groundwater users and the possibility of future increases in their well production. The data collected during testing will be used to refine the planning-level groundwater models. However, considering the magnitude of the yield deficit for the drought-of-record, several new wells within the existing wellfields and expansion of the existing wellfield properties will not add enough yield for the system to meet future water demands.

There are several ways to try to reduce the deficit between supply and demand during a future drought, thus significantly reducing the cost of system improvements:

- Once the new intake on the White River is completed, VWI will have the option of capturing river flow using the canal or allowing the flow to bypass Broad Ripple Dam and capture it at the new intake. VWI may choose the latter option instead of diverting the flow down the canal in order to reduce reported canal seepage losses of up to about 14 mgd (Meyer, 1979).
- Investigation of unaccounted-for water of up to about 15 percent may reveal ways to reduce the amount of water that is physically lost from the system.
- Demand management, as recently proposed by the Department of Waterworks, can be used to reduce water consumption. Additional

evaluation may be required to quantify the amount of reduction that could be achieved through approaches such as outdoor water use restrictions, tiered water rates, and low-flow devices. Following these measures the remaining need for additional water sources can be determined.

- VWI may consider installing a network of monitoring wells in and around the existing wellfields and/or pressure transducers inside the existing production wells to try to optimize pumping during drought conditions. By providing operators with real-time data to justify pumping distribution, this may increase the yield of each of the wellfields during a summer such as 2007 or a mild drought. VWI's 2004 Water Conservation Plan notes the lack of historical groundwater monitoring at the wellfields and issues with the cost and time associated with being able to collect the groundwater level data in the future. Noting this cost and the probability that optimizing the wellfield pumping may not provide a large amount of additional yield during a severe drought, this might not be a viable means of increasing system yield.
- Many of the wells are very old. Well inspections may reveal which wells are in need of rehabilitation due to screen incrustation and/or biofouling. Also, aquifer testing at the existing wellfields would help in understanding the vertical connection between aquifers and streams.
- VWI, the downstream power plants, and Indiana Department of Natural Resources (IDNR) may work together in a sustainable solutions workshop to determine potential alternatives for supplying cooling water to the plants, such as using wastewater return flows. In addition, determine the State of Indiana's future policies for times of water shortage and what the targeted minimum stream flow would be, whether or not 7Q10 will be enforced for severe droughts.
- VWI and the City may continue to inform the public that the original intent of Morse and Geist Reservoirs was for water supply and that during times of drought the reservoirs must be drawn very low. With significant growth in water demands, the frequency of reservoir level fluctuation could increase in the future.

This evaluation raises the following questions that should be addressed to assist VWI and the City in planning for future water supply:

- *Which drought condition will VWI and the City design to?* Other cities, both larger and smaller than Indianapolis, also not located near a significant body of water are currently evaluating and designing their systems for the drought-of-record. Designing to the drought-of-record is more costly, but provides a system with more reliability. By designing for the 1940-1941 drought-of-record, the reliability of the system to yield enough water to meet future demands in 2010 and 2020 would be 95 to 98 percent each year. Designing to the 1988-1989 drought would give an annual reliability of 80 to 90 percent. Designing the system for the 2007 climate conditions would give significantly less reliability. By applying financial resources to an additional source of supply, along with associated treatment and conveyance capacity upgrades, VWI would prepare for not only summer conditions similar to 2007 when consumption exceeds facility capacity, but also to drought conditions when consumption will exceed both facility capacity and available water supplies.
- *Instead of releasing water from the reservoirs for the power plants during a severe drought, are there other creative ideas to supply cooling water to the plants that will not affect the City's water supply?*
- *What will IDNR's water shortage task force decide in 2009 for minimum environmental flows in and around Indianapolis for their updated Water Shortage Plan for Indiana?* Each United States Geological Survey (USGS) stream gage has an associated 7Q10, and if IDNR's task force decides to enforce these minimum streamflows at a number of locations in the Indianapolis area during a severe drought, VWI's water supply yield could be reduced. Figure 13-1 shows the minimum flows in the yield model for 1940-1941 drought conditions compared to the 7Q10 flows. When a drought of this magnitude recurs, the model shows that the reservoirs and wastewater return flows will provide streamflows that are higher than actual flows were during 1940-1941. It seems reasonable that IDNR would allow streamflows to go lower than 7Q10 within and downstream of Indianapolis if a similar drought were to occur again.

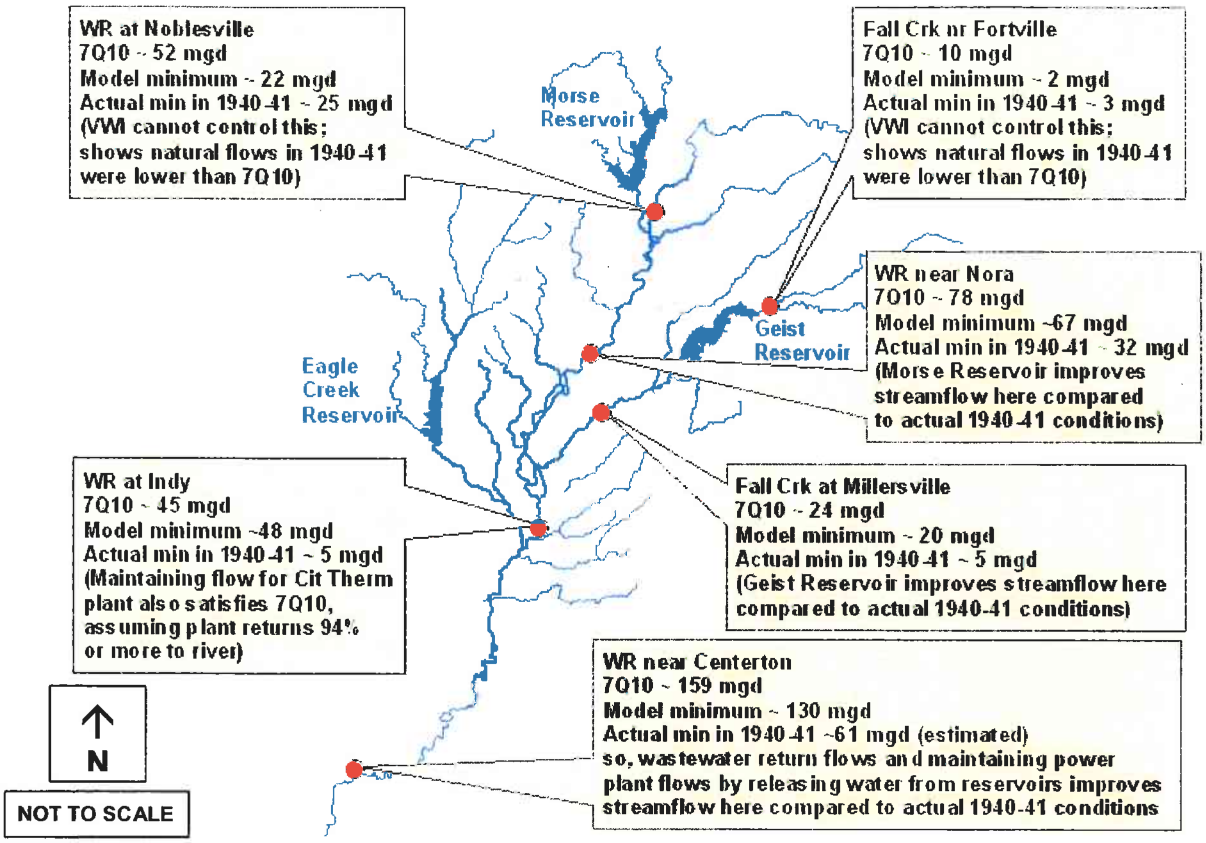

Figure 13-1 7Q10 Flows (10% Chance of Occurrence) Compared with Minimum Streamflows from Yield Model for 1940-1941 Drought Conditions (1-4% Chance of Occurrence)

Notes:
(1) 7Q10 values obtained from IDNR (Centerton) and VWI 2004 Water Conservation Plan
(2) model does not extend to Centerton, so minimum flow was estimated by comparing USGS gage data at Waverly and Centerton for 1988 drought conditions and adding 10 % to the remaining model flow past the proposed Waverly Wellfield location
(3) model shows slightly lower streamflows entering Indianapolis at WR at Noblesville and Fall Creek near Fortville than in 1940-41 because of added upstream depletions from increased water usage in the watershed since the 1940s

- *Should VWI allow the reservoirs to drop below about 20 to 30 feet of depth during critical periods of the design drought to increase yield?*
- Without testing similar to that proposed at the Waverly Wellfield site, there is uncertainty about the stream-aquifer connection at the existing wellfields and about the vertical connection of shallow and deep aquifers. *To try to optimize yield from the wellfields, should testing be performed to obtain more knowledge about the existing wellfields? Or, with the likelihood that optimizing the existing wellfield yields would not provide a large amount of additional yield, should testing instead be focused at Waverly and other sites along the White River south of*

Indianapolis to try to find locations for horizontal collector wells which could provide more significant yield?

- *As an alternative to southern wellfield expansions with uncertain connection with the White River, can a surface water intake be installed downstream of Indianapolis on the White River?* Ideally, a means of storing the surface water collected from a southern intake would provide the most yield.
- *Can the effluent from the Belmont and Southport plants be conveyed back upstream to one of the reservoirs or above one of the intakes to increase system yield? If so, what issues are involved with indirect wastewater reuse?*

Based on this evaluation, VWI may need to look outside of the White River watershed for new supplies if the following are true:

- It is decided that the water system will be designed such that water demands will be met during future climate conditions similar to the drought-of-record.
- All stakeholders are comfortable with the constraints and assumptions used for this evaluation (Sections 9.2 and 10.2).
- Aquifer testing and groundwater modeling show that new shallow collector wells along the White River south of the City are not feasible.
- A new surface water intake south of the City along the White River is not feasible.
- Recycling of treated flows from the Belmont and Southport plants is not an option.
- Stakeholders cannot determine a way to significantly reduce water demands during drought for both Indianapolis Water customers and other major water users in the area.

As shown on Figure 10-20 in Section 10.4.3, even if consumption is significantly reduced through water restrictions, the magnitude of the maximum day yield deficit could be on the order of approximately 100 mgd or more by 2020 if the drought-of-record were to occur again. Outside of the White River watershed, the most reliable sources of supply are the Wabash River approximately 57 miles to the west and the Ohio River approximately 75 miles to the southeast (Figure 13-2). A very cursory look at the capital costs to develop a new 100-mgd surface water supply at these sources, including an intake, pipeline, treatment plant, and pump stations would be on the order of $500 million for the Wabash River to $600 million for the Ohio River. These costs per mgd of supply are comparable to the costs other cities are considering for new sources of water. The costs would need to be considered in much more detail, and are only given here for initial estimates. Many other factors would also need to be evaluated. For example, it may be determined that groundwater supply is more favorable than surface water supply in the Wabash River valley. Other factors to consider to minimize costs would be the potential for facility phasing, research of funding alternatives, and regional wholesale, as well as an assessment of the sustainability of the project and effect on the environment and other water users. It may also be decided to obtain more than 100 mgd from the new source of supply.

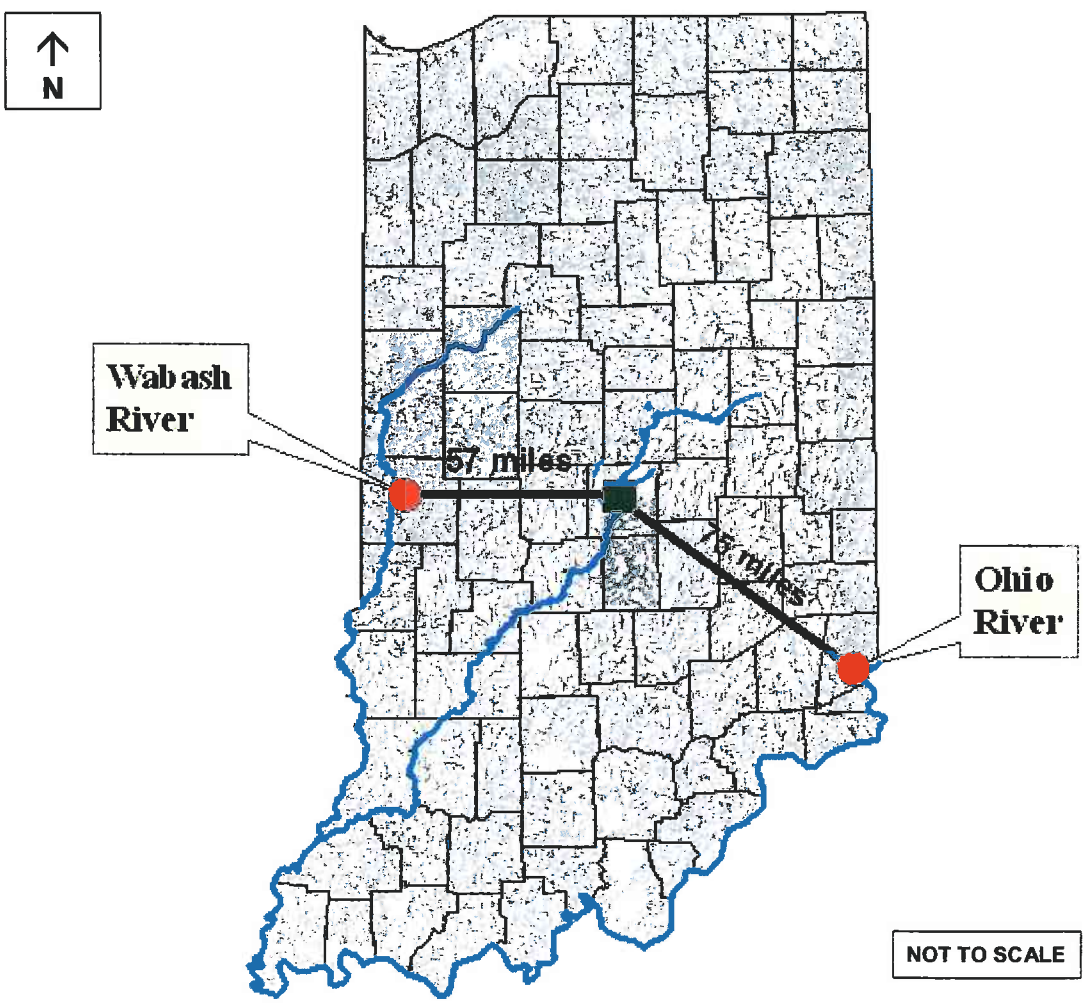

Figure 13-2 Reliable Water Sources Outside of White River Watershed

If it is determined that developing a new water source for the drought-of-record is not economically, environmentally, and/or socially acceptable, a contingency plan should be developed for the region to minimize the impacts of large water shortages during a severe drought. VWI and other stakeholders may consider the potential amount of water that could be saved through mandatory water restrictions, conservation, and other creative ideas. Then, the contingency plan should address the remaining difference between the "essential" demands and available yield during the drought-of-record, the possibility of other smaller water users looking to Indianapolis for emergency water supply, and the impacts of not having that water.

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14. YIELD EVALUATION NEXT STEPS

1. Department of Waterworks (DOW) and Veolia Water Indianapolis (VWI) to determine answers to the questions in Section 13.0.

2. DOW and VWI to perform hydraulic modeling using the results of the yield and demand evaluations.

3. DOW and VWI to decide how much to upgrade the White River North (WRN) treatment plant capacity.

    a. For 2007 climate conditions, available maximum day yield will allow up to 50 million gallons per day (mgd) of surface water capacity to be utilized.

    b. For 1988 drought conditions, the proposed 48 mgd of surface water treatment capacity is more than the 32.4 mgd of available maximum daily yield.

    c. For 1940-1941 drought conditions, the proposed 48 mgd of surface water treatment capacity will be significantly higher than approximately 15 mgd of available maximum day yield. DOW and VWI may still choose to have 48 mgd of surface water treatment capacity for non-drought years, but the capacity may go unused during drought conditions.

    d. The 12 mgd of proposed groundwater treatment capacity is adequate unless future aquifer testing shows favorable locations for additional wells.

4. DOW and VWI to decide how much to upgrade the Fall Creek (FC) treatment plant capacity.

    a. For 2007 climate conditions and if Geist Reservoir is drawn down to its minimum allowable level, up to 98 mgd of available maximum day yield could be obtained at the FC plant. However, assuming the WRN treatment plant capacity is upgraded to 60 mgd and the Waverly Wellfield will yield 24 mgd, a Fall Creek treatment capacity of 44 mgd (slightly higher than the proposed

40 mgd capacity) will help the system yield enough water to meet maximum day demands through Year 2020. This is based on 2007 climate conditions, and assuming the reservoirs are allowed to be drawn down quite low.

b. If Geist Reservoir is drawn to its minimum level under 1988 drought conditions, the FC plant capacity needs to be upgraded to 60 mgd to maximize the available yield from the reservoir.

c. Under 1940-1941 drought conditions, the available maximum day yield is 16 mgd. DOW and VWI may choose to upgrade the FC plant capacity to obtain more yield during non-drought years, but a significant amount of this added capacity would be unused during the drought of record.

5. Consider the White River (WR) Treatment Plant capacity.

a. For the climate conditions evaluated, 96 mgd of rated treatment capacity and 120 mgd hydraulic capacity will be sufficient to treat all of the available maximum day yield from the White River. This is based on yields from the canal and the new intake upstream of Emerichsville Dam. For the drought of record, as much as 80 percent of this treatment capacity is estimated to go unused, due to various system constraints of maintaining power plant flows and reservoir levels.

6. Consider the T.W. Moses Treatment Plant capacity.

For the drought of record, the available yield is not enough to upgrade the T.W. Moses treatment capacity or to renegotiate the contract with the City for Eagle Creek Reservoir water. For less severe drought conditions similar to 1988, there is some available yield that would go unused under the current contract with the City.

7. Upgrade the South Wellfield (SWF) Treatment Plant capacity to 54 mgd.

Assuming the SWF treatment plant will treat groundwater from both the South Wellfield and the Waverly Wellfield, the proposed capacity of 54 mgd will be in excess of available yield unless future aquifer testing shows locations for more wells.

8. Proceed with aquifer testing at the Waverly site and other potential locations for collector wells south of the City along the White River. Finalize the available yield for the south wellfields and determine the benefit of further development of these sources of supply.

9. DOW and VWI may wish to consider the feasibility and potential costs of alternative sources of supply outside of the White River watershed.

10. Develop a firm estimate of the amount of demand reduction that could be achieved through water restrictions and conservation, so the size of any new water source can be minimized.

11. Consider economic, environmental and social issues (i.e., Triple Bottom Line) associated with developing a new source of supply, not developing a new source of supply, as well as contingency planning.

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15. YIELD EVALUATION REFERENCES

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    - Morse Reservoir algorithm for operations
    - Reservoir and stream levels
    - Available well data
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    - WHPA, “Geist Well Field Capture Zone Delineation”, March 2000
    - WHPA, “Ford Road Well Field Capture Zone Delineation”

  - WHPA, "Phase II and III: Waverly Wellfield Design Analysis", July 2007
  - CH2M Hill, "Indianapolis Water Company South Well Field Wellhead Protection Area Delineation", March 2000
  - WHPA, "Optimization, Impact and Drought Analysis for Indianapolis South Well Field", September 2007
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- IDNR, 2007-2008, Personal correspondence to obtain data for significant water users in the White River Basin
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- VWI, 2007-2008, Personal correspondence for operational issues, constraints, and assumptions

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Appendix A

APPENDIX A – TOP 100 WATER CUSTOMERS

Customer Name	Address
Eli Lilly Store 2	1555 Kentucky Av Pit 1/2
Covanta Indpls Inc	2320 S Harding St
Indopco Inc/ National Starch	1515 Drover St
Quaker Oats	5858 Decatur Blvd
IWC-Morgan	9002 Paddock Rd
Town Of Brownsburg	3502 N State Road 267
Indopco Inc /National Starch	1050 W Raymond St
Vertellus Agriculture &	3500 W Minnesota St
Indopco Inc/National Starch	1515 Drover St
Ista/Aimco	601 Beachway Dr
Citizens Thermal Energy	1146 Division St
International Truck & Eng Corp	5500 Brookville Rd
Clarian Health Partners	1825 N Senate Ave
Iupui	960 W Michigan St
Dept Of Public Works	2700 S Belmont Ave
Town Of Danville	4002 E Us Highway 36
AF Properties Llc	12 S Bradley Ave
Citizens Gas	2970 Prospect St
Kroger Dairy Kro-052-000	400 S Shortridge Rd
Pepsi Cola	5411 W 78th St
Community Hospital	1500 N Ritter Ave
St Francis Hosp	101 N 17th Ave
Whitestown Utility	7201 E State Road 334
Barrett Gabe A	356 N Arlington Ave
Westview Med Hosp	3630 Guion Rd
Dynamic Bar Products Llc	8000 N County Road 225 E
Tri-County Conserve Distr	8033 W County Li Rd So
Conagra Dairy Foods #01625	4300 W 62nd St
Wm N Wishard Mem Hosp	960 Locke St
Nhp Oak Lp	4047 N Post Rd
Citizens Gas & Coke	3133 Southeastern Ave
Eli Lilly Store 1	401 E Mccarty St
Quemetco Corp	7870 W Morris St
United Hospital Svcs Llc	9948 Park Davis Dr
Dow Agrosciences	9330 Zionsville Rd # 306a
Town Of Pittsboro	2225 E Us Highway 136
Spanish Oaks Apartments	10501 E 38th St
Briarwood Apts	4580 N High School Rd
St Vincent Hospital	2001 W 86th St
Waterford Village	7155 Knobwood Dr
Piedmont-Nantucket Cove	2913 E Hanna Ave
Mike's Car Wash	9540 Corporation Dr

Customer Name	Address
Eli Lilly Store #1	355 E Merrill St
Automotive Components Holdings	6900 English Ave
Lake Nora Arms	9000 N College Ave
Village Green Mgmt Co	7202 Fall Creek Rd
St Francis Hosp Ctr	8111 S Emerson Ave # B
Indpls Zoological Society	1200 W Washington St
Cca Marion County Jail Ii	730 E Washington St
Va Hospital #138	1481 W 10th St
Community Hospital North	7150 Clearvista Dr
Mid-America Mgmt Corp	8330 Township Li Rd
Sensient Flavors	5510 W Raymond St
Long Acre Trailer Park	4701 Madison Ave
Raytheon Systems Co	1901 N Arlington Av
Progress Linen	333 N College Ave
Zidan Management Group	9600 E 21st St
Siemens Water Technologies	6125 Guion Rd
Mcknight Property Mgmt Llc	1 Indiana Sq
Health Institute Of Indiana	3660 Guion Rd
Indpls Airport Authority	2640 Hoffman Rd
Valleybrook Mobile Home	4620 S High School Rd
Dept Of Administration	400 W Market St
Indpls Int Airport	2500 S High School Rd
Araku Valley Llc	6800 E 56th St
St Vincent Hosp And Health Ctr	2001 W 86th St # A
Interstate Brands	2929 N Shadeland Ave
Highland Country Club	1050 W 52nd St
Pacers Sports & Entertnmt	125 S Pennsylvania St
Indpls Marion County Bldg Auth	220 E Maryland St
Oaktree Apartments	4047 N Post Rd
Tenth & Meridian Assoc	950 N Meridian St
Simon Prop Store 0564	57 W Washington St
Slc Operating Ltd Ptnship	8787 Keystone Xng
Kingsmill Dev Co Llc	4250 N High School Rd
Michiana Owner Llc	9231 Mariwood Pkwy
Westminster Landmark Llc	1099 N Meridian St
Macquarie Offc Monument Cntr I	1 E Ohio St
Candletree Llc	4514 Candletree Cir
Scarborough Sq Apts	4604 N High School Rd
Capitol Improvements	200 W Maryland St
Core Riverbend	8900 Allisonville Rd
In Dept Of Admin Controller	650 W Washington St
Forest Hills Apt	5442 W Vermont St
3 Fountains West Inc	5556 W 42nd St
Sunblest Apts	8300 E 116th St

Customer Name	Address
Williamsburg North	6316 Brookline Dr
Adam's Mark Hotel	2544 Executive Dr
Sun Comm Oper Ltr Prtnrs	9000 W 10th St
Hub Property Gallc	130 W Maryland St
Pan Am Sce I Llc	201 S Capitol Ave
Willow Glen Apt	4880 Willow Glen Dr
Claypool Development Corp	110 W Washington St #A
Mike's Car Wash Inc	3345 W 86th St
Rolls-Royce Corp	1800 S Moreland Av
Sarah Shank Pumphouse	2901 S Keystone Ave
Crosswinds Partner	6700 W Washington St
The Woods At Oak Crossing	3790 N Kessler Blv
Spinnaker Apartments	7501 W 38th St
Hyatt Regency	137 W Washington St

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APPENDIX B

SUMMARY OF CUSTOMERS AND CONSUMPTION BY CATEGORY AND PRESSURE ZONE (YEARS 2002-2006)

Year 2002								
	Number of Customers by Customer Category				Consumption by Customer Category (mgd)			
Pressure Zone	Non-Residential	Residential	Other	Total	Non-Residential	Residential	Other	Total
Avon	384	10,502	20	10,906	0.72	2.14	0.01	2.87
Ben Davis	1,546	18,586	49	20,181	4.04	4.00	0.19	8.23
Castleton	1,830	29,955	68	31,853	2.77	8.32	0.12	11.20
Central	3,363	24,993	129	28,485	19.20	4.71	1.49	25.40
Cumberland	1,906	26,142	55	28,104	4.15	6.05	0.04	10.24
Flackville	1,170	14,981	21	16,172	1.60	4.32	0.06	5.98
Harbour	74	4,307	5	4,386	0.06	1.10	0.00	1.16
Lafayette	1,846	24,300	67	23,069	4.28	7.15	0.10	11.53
Liberty	1	101	0	105	0.01	0.01	0.00	0.02
Meridian Hills	497	9,055	10	9,810	1.46	3.42	0.01	4.89
Morgan	7	553	0	546	0.79	0.08	0.00	0.87
Nora	412	3,401	19	3,931	1.03	0.84	0.01	1.88
Northeast	4,294	75,657	142	82,204	5.14	17.29	0.10	22.53
Northwest	3	60	0	64	0.90	0.01	0.00	0.91
Plainfield	8	532	19	583	0.00	0.12	0.00	0.13
Southeast	378	11,437	15	12,147	0.74	2.35	0.02	3.11
Southport	2,218	26,270	45	29,274	3.23	5.91	0.06	9.20
Southwest	354	12,945	32	13,689	0.90	2.72	0.04	3.67
TOTAL	**20,292**	**293,776**	**697**	**315,510**	**51.02**	**70.55**	**2.25**	**123.83**
Without Liberty	20,291	293,675	697	315,405	51.02	70.54	2.25	123.81

Year 2003								
Number of Customers by Customer Category					Consumption by Customer Category (mgd)			
Pressure Zone	Non-Residential	Residential	Other	Total	Non-Residential	Residential	Other	Total
Avon	394	11,788	22	12,204	0.85	2.07	0.00	2.92
Ben Davis	1,591	20,460	50	22,101	3.86	3.89	0.19	7.94
Castleton	1,969	33,275	61	35,305	2.85	7.67	0.11	10.62
Central	3,519	28,441	142	32,102	17.68	4.57	1.42	23.67
Cumberland	2,019	29,757	54	31,830	4.04	5.98	0.04	10.06
Flackville	1,218	16,866	20	18,105	1.88	4.15	0.03	6.07
Harbour	63	4,737	7	4,807	0.06	1.00	0.00	1.06
Lafayette	1,951	27,209	65	29,224	4.23	6.56	0.09	10.88
Liberty	0	123	0	123	0.00	0.01	0.00	0.01
Meridian Hills	535	9,852	10	10,396	1.43	3.33	0.01	4.76
Morgan	7	637	0	644	0.73	0.09	0.00	0.82
Nora	457	3,854	16	4,327	1.10	0.82	0.01	1.93
Northeast	4,517	86,080	147	90,744	5.63	13.75	0.10	19.48
Northwest	5	75	0	80	0.89	0.01	0.00	0.90
Plainfield	9	583	19	610	0.00	0.13	0.00	0.13
Southeast	405	13,299	21	13,725	0.86	2.36	0.01	3.23
Southport	2,331	29,216	45	31,592	3.17	5.67	0.06	8.90
Southwest	352	14,963	31	15,347	1.18	2.54	0.02	3.73
TOTAL	**21,342**	**331,213**	**711**	**353,266**	**50.44**	**64.61**	**2.10**	**117.14**
Without Liberty	21,342	331,090	711	353,143	50.44	64.60	2.10	117.13

Year 2004								
	Number of Customers by Customer Category				Consumption by Customer Category (mgd)			
Pressure Zone	**Non-Residential**	**Residential**	**Other**	**Total**	**Non-Residential**	**Residential**	**Other**	**Total**
Avon	381	11,403	19	11,804	1.28	2.23	0.01	3.52
Ben Davis	1,553	19,409	52	21,014	3.69	3.99	0.19	7.87
Castleton	1,922	31,298	54	33,274	3.10	8.27	0.09	11.46
Central	3,407	26,266	150	29,822	18.26	5.97	1.14	25.36
Cumberland	1,978	28,874	51	30,903	3.94	6.36	0.04	10.34
Flackville	1,157	15,707	19	16,882	1.91	4.05	0.05	6.02
Harbour	59	4,425	4	4,487	0.06	1.06	0.00	1.12
Lafayette	1,913	25,896	65	27,874	4.57	7.57	0.09	12.22
Liberty	2	124	0	126	0.00	0.01	0.00	0.01
Meridian Hills	509	9,468	11	9,988	1.51	3.18	0.01	4.70
Morgan	9	1,597	0	1,606	0.54	0.26	0.00	0.81
Nora	453	3,703	17	4,173	1.17	0.94	0.01	2.12
Northeast	4,245	78,383	144	82,772	5.84	13.49	0.08	19.41
Northwest	5	74	0	79	1.13	0.01	0.00	1.14
Plainfield	9	572	17	598	0.00	0.15	0.00	0.16
Southeast	422	14,111	18	14,550	0.86	2.85	0.02	3.72
Southport	2,221	27,653	40	29,914	3.43	5.90	0.07	9.39
Southwest	348	15,444	27	15,819	1.38	3.11	0.02	4.51
TOTAL	**20,593**	**314,405**	**688**	**335,686**	**52.65**	**69.41**	**1.81**	**123.87**
Without Liberty	20,591	314,281	688	335,560	52.65	69.39	1.81	123.86

Year 2005								
	Number of Customers by Customer Category				Consumption by Customer Category (mgd)			
Pressure Zone	Non-Residential	Residential	Other	Total	Non-Residential	Residential	Other	Total
Avon	410	11,682	18	12,110	1.47	2.35	0.01	3.83
Ben Davis	1,556	19,520	52	21,129	3.72	4.02	0.19	7.93
Castleton	2,072	31,931	55	34,058	3.06	8.50	0.08	11.63
Central	3,373	26,049	140	29,562	17.67	4.52	1.03	23.22
Cumberland	1,966	30,220	51	32,238	4.16	6.57	0.04	10.77
Flackville	1,153	15,686	23	16,862	1.80	4.20	0.05	6.05
Harbour	60	4,564	4	4,627	0.06	0.98	0.00	1.04
Lafayette	1,936	27,018	58	29,013	4.65	7.84	0.08	12.58
Liberty	1	119	0	120	0.00	0.02	0.00	0.02
Meridian Hills	505	9,628	10	10,143	1.59	3.33	0.01	4.93
Morgan	10	1,635	0	1,645	0.70	0.26	0.00	0.96
Nora	457	3,813	19	4,289	1.16	0.95	0.01	2.12
Northeast	4,233	78,034	143	82,410	5.74	13.29	0.09	19.12
Northwest	5	107	0	113	1.38	0.02	0.00	1.40
Plainfield	10	568	17	594	0.00	0.15	0.00	0.16
Southeast	447	14,854	16	15,317	0.95	3.05	0.01	4.01
Southport	2,209	27,934	42	30,185	3.45	5.95	0.08	9.49
Southwest	382	15,971	27	16,380	1.63	3.29	0.05	4.96
TOTAL	**20,786**	**319,333**	**674**	**340,793**	**53.19**	**69.28**	**1.74**	**124.22**
Without Liberty	20,785	319,214	674	340,673	53.19	69.26	1.74	124.20

Year 2006								
	Number of Customers by Customer Category				Consumption by Customer Category (mgd)			
Pressure Zone	Non-Residential	Residential	Other	Total	Non-Residential	Residential	Other	Total
Avon	428	12,150	18	12,596	1.18	2.23	0.00	3.42
Ben Davis	1,575	19,656	53	21,285	3.43	3.83	0.16	7.43
Castleton	2,007	33,060	56	35,122	2.93	7.68	0.06	10.67
Central	3,382	26,253	144	29,778	16.99	4.38	1.18	22.55
Cumberland	2,042	31,666	52	33,760	4.05	6.55	0.04	10.63
Flackville	1,153	15,872	19	17,045	1.75	4.00	0.04	5.79
Harbour	56	4,801	5	4,862	0.06	0.90	0.00	0.97
Lafayette	1,940	27,287	57	29,284	4.52	5.75	0.07	10.34
Liberty	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Meridian Hills	506	9,847	10	10,363	1.46	3.40	0.01	4.86
Morgan	9	1,686	0	1,694	0.74	0.26	0.00	1.00
Nora	442	3,658	21	4,120	1.00	0.61	0.01	1.63
Northeast	4,239	77,772	144	82,156	5.85	12.69	0.08	18.61
Northwest	5	128	0	133	1.53	0.02	0.00	1.55
Plainfield	9	637	17	662	0.00	0.15	0.00	0.15
Southeast	442	15,167	13	15,623	0.89	2.71	0.01	3.61
Southport	2,257	28,135	44	30,436	3.11	6.10	0.06	9.27
Southwest	389	16,214	27	16,630	1.65	2.80	0.02	4.47
TOTAL	**20,882**	**323,990**	**678**	**345,550**	**51.15**	**64.06**	**1.74**	**116.95**

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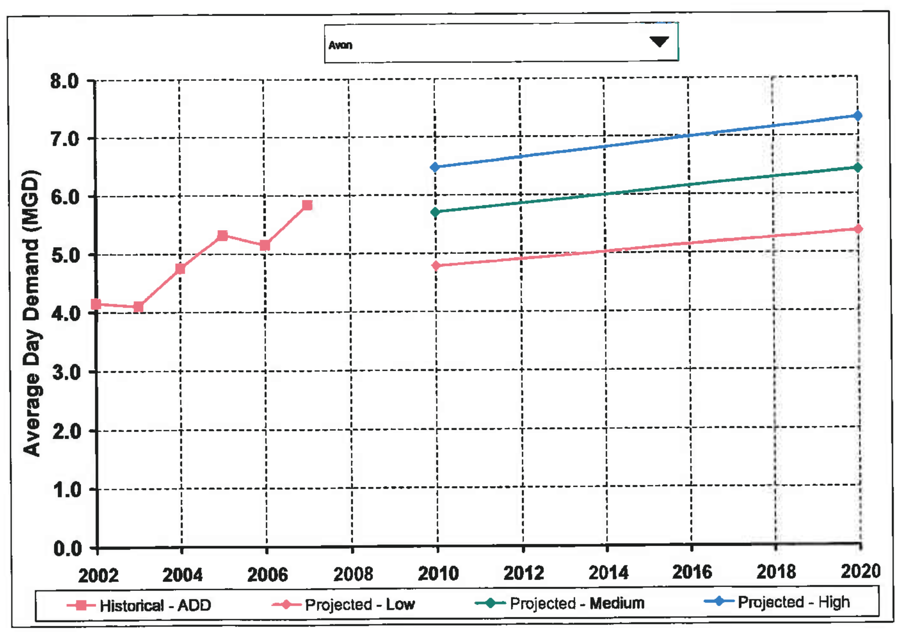
Appendix C

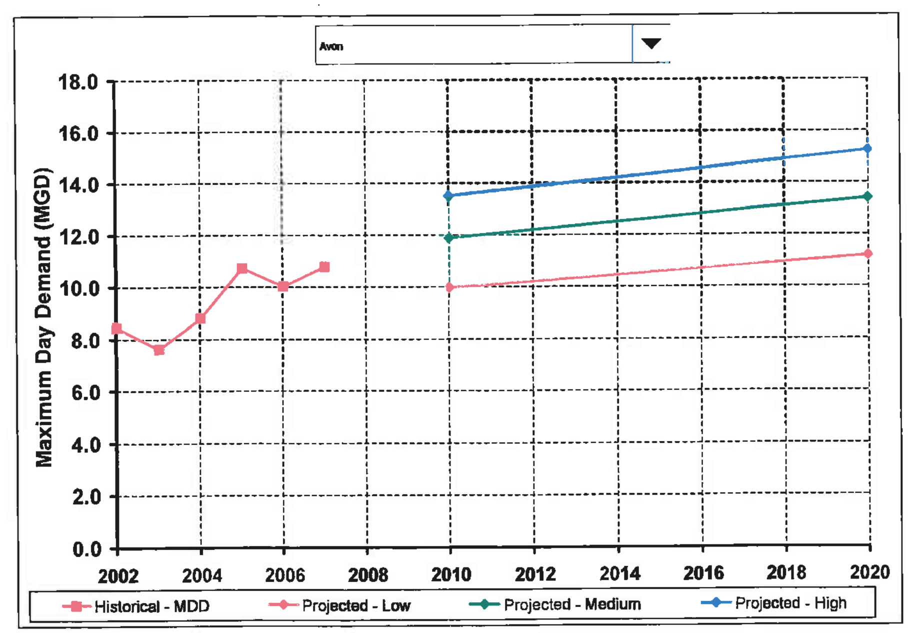
Demand Projection Summary

AVON

	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	0.72	2.14	0.01	2.87	1.28	30.9%	4.15	8.46	2.04	15.06	1.78
2003	0.85	2.07	0.00	2.92	1.19	28.9%	4.11	7.62	1.85	15.78	2.07
2004	1.28	2.23	0.01	3.52	1.23	25.9%	4.75	8.79	1.85	15.22	1.73
2005	1.47	2.35	0.01	3.83	1.49	28.1%	5.32	10.73	2.02	17.35	1.62
2006	1.18	2.23	0.00	3.42	1.74	33.7%	5.16	10.02	1.94	14.55	1.45
2007							5.84	10.78		18.55	
AVG						29.5%					

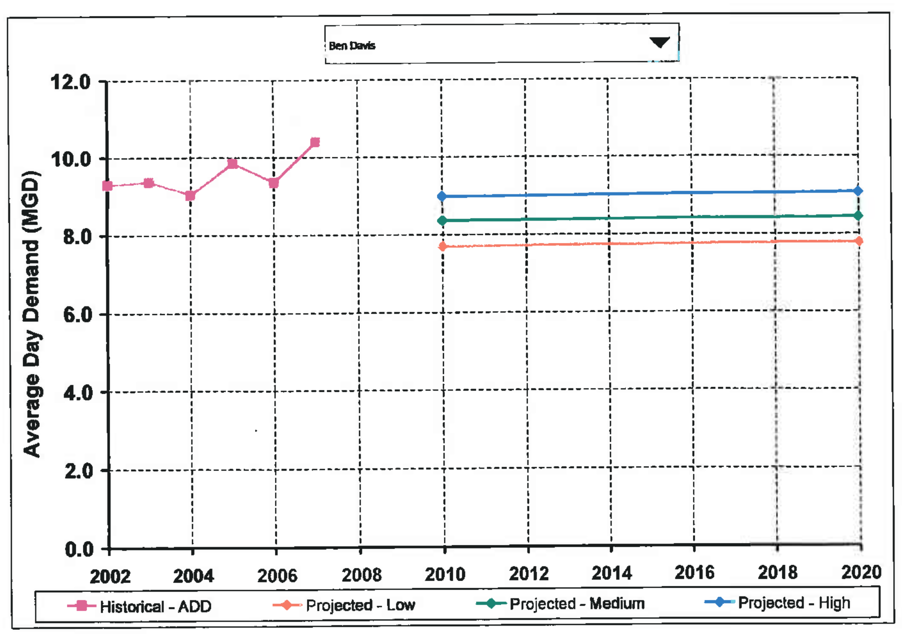
	Projected - Consumption (MGD)				Projected - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	0.89	2.39	0.00	3.28	1.50	31.3%	4.78	9.96	2.08	17.24	1.73
2020	1.03	2.78	0.01	3.82	1.56	29.0%	5.38	11.20	2.08	19.38	1.73
2010	1.30	2.62	0.00	3.92	1.78	31.3%	5.71	11.89	2.08	20.58	1.73
2020	1.51	3.05	0.01	4.56	1.87	29.1%	6.44	13.41	2.08	23.21	1.73
2010	1.69	2.79	0.01	4.49	2.00	30.8%	6.48	13.51	2.08	23.37	1.73
2020	1.97	3.24	0.01	5.22	2.10	28.7%	7.32	15.26	2.08	26.40	1.73

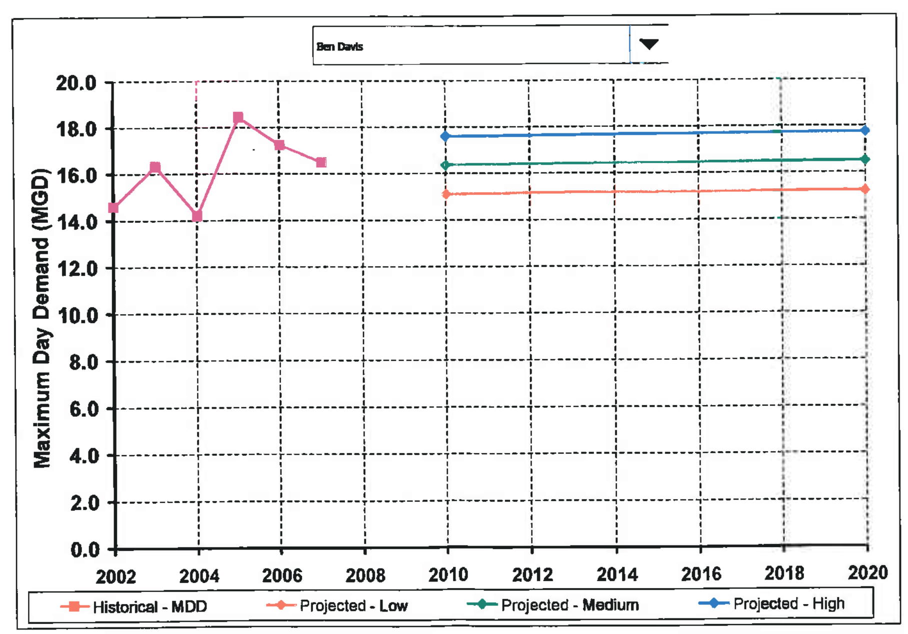


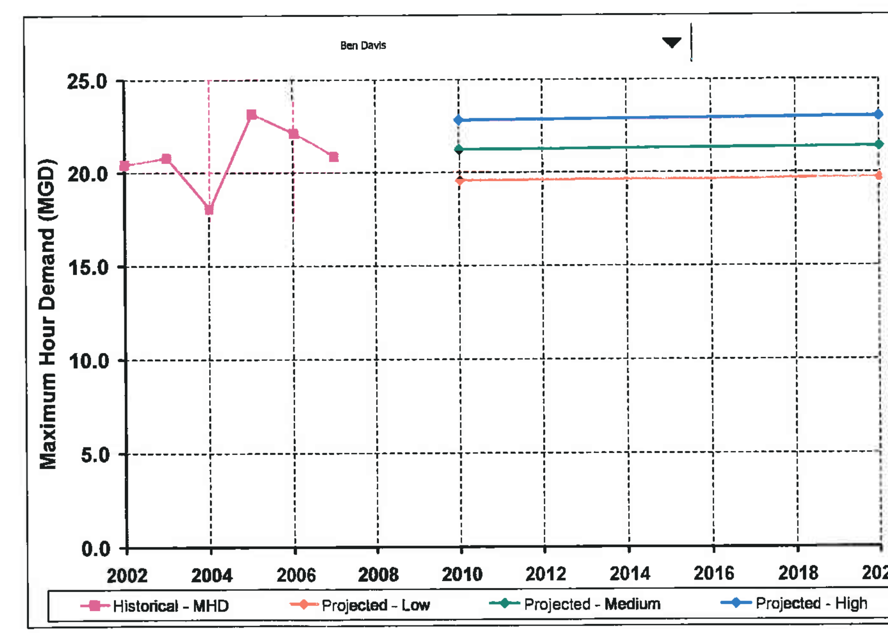


BEN DAVIS

	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	4.04	4.00	0.19	8.23	1.05	11.4%	9.29	14.58	1.57	20.43	1.40
2003	3.86	3.89	0.19	7.94	1.41	15.1%	9.36	16.35	1.75	20.80	1.27
2004	3.69	3.99	0.19	7.87	1.16	12.8%	9.03	14.22	1.58	18.05	1.27
2005	3.72	4.02	0.19	7.93	1.92	19.5%	9.85	18.46	1.87	23.18	1.26
2006	3.43	3.83	0.16	7.43	1.93	20.6%	9.36	17.26	1.84	22.09	1.28
2007							10.40	16.50		20.84	
AVG				7.79	1.605612	15.9%					
	Projected - Consumption (MGD)				Projected - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	3.48	3.83	0.18	7.50	0.21	2.8%	7.71	15.10	1.96	19.57	1.30
2020	3.54	3.87	0.17	7.58	0.19	2.5%	7.77	15.22	1.96	19.72	1.30
2010	3.84	4.08	0.21	8.12	0.23	2.7%	8.35	16.36	1.96	21.20	1.30
2020	3.91	4.11	0.19	8.21	0.21	2.5%	8.42	16.50	1.96	21.38	1.30
2010	4.19	4.34	0.22	8.74	0.24	2.7%	8.98	17.60	1.96	22.81	1.30
2020	4.26	4.37	0.20	8.84	0.22	2.4%	9.06	17.75	1.96	23.00	1.30

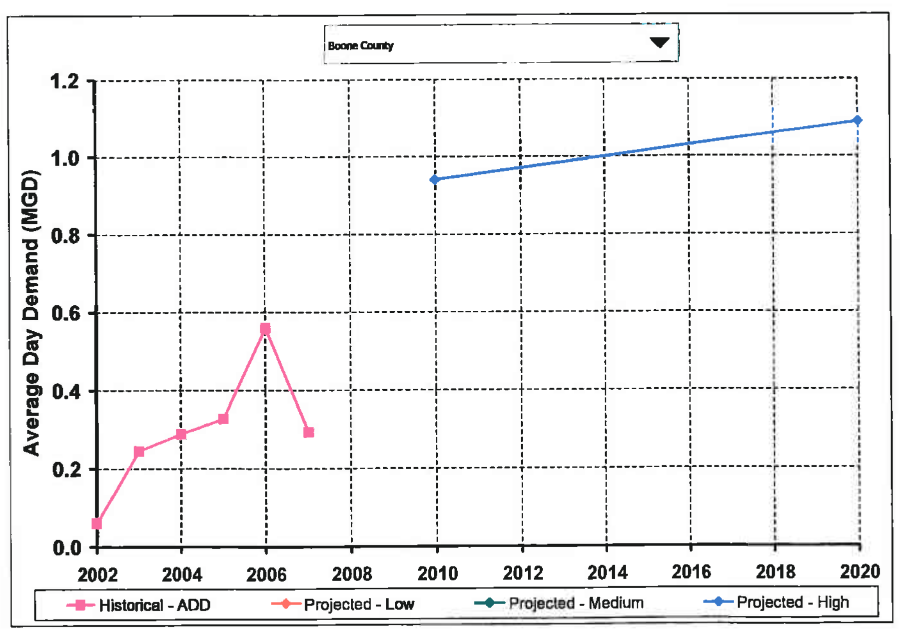


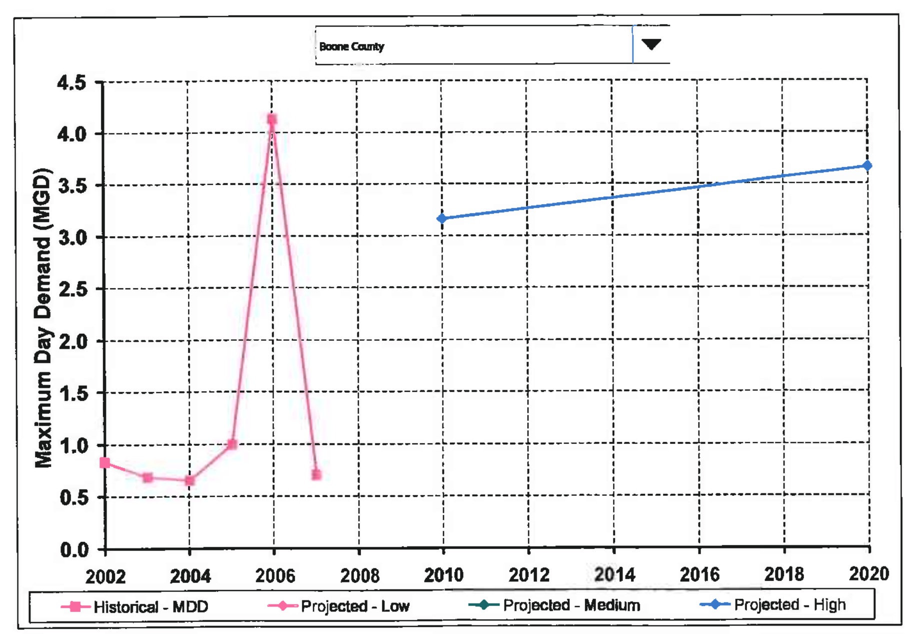


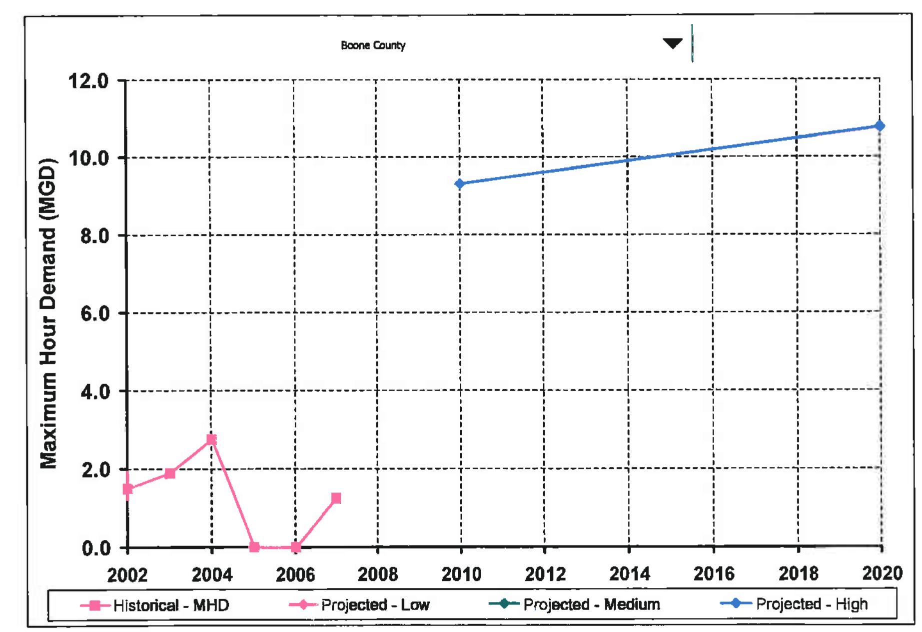


BOONE COUNTY

Year	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	0.06	0.00	0.00	0.06	0.00	0.0%	0.06	0.83	13.55	1.50	1.81
2003	0.25	0.00	0.00	0.25	0.00	0.0%	0.25	0.68	2.78	1.90	2.78
2004	0.29	0.00	0.00	0.29	0.00	0.0%	0.29	0.65	2.27	2.76	4.23
2005	0.33	0.00	0.00	0.33	0.00	0.0%	0.33	1.00	3.05	N/A	N/A
2006	0.56	0.00	0.00	0.56	0.00	0.0%	0.56	4.13	7.39	N/A	N/A
2007							0.29	0.71		1.25	
AVG						0.0%					
	Projected - Consumption (MGD)				**Projected - Demand (MGD)**						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	0.94	0.00	0.00	0.94	0.00	0.0%	0.94	3.17	3.36	9.31	2.94
2020	1.09	0.00	0.00	1.09	0.00	0.0%	1.09	3.66	3.36	10.77	2.94
2010	0.94	0.00	0.00	0.94	0.00	0.0%	0.94	3.17	3.36	9.31	2.94
2020	1.09	0.00	0.00	1.09	0.00	0.0%	1.09	3.66	3.36	10.77	2.94
2010	0.94	0.00	0.00	0.94	0.00	0.0%	0.94	3.17	3.36	9.31	2.94
2020	1.09	0.00	0.00	1.09	0.00	0.0%	1.09	3.66	3.36	10.77	2.94

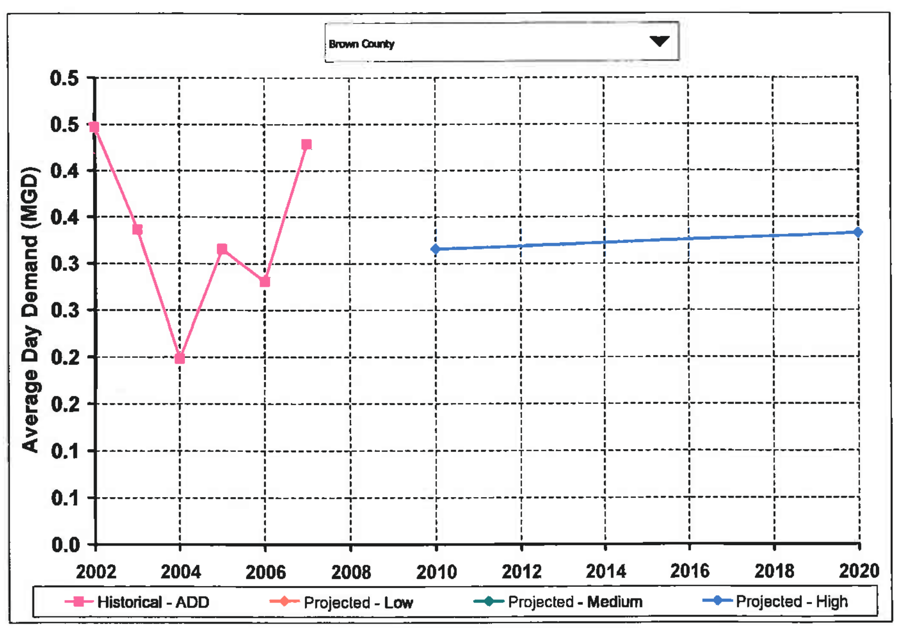


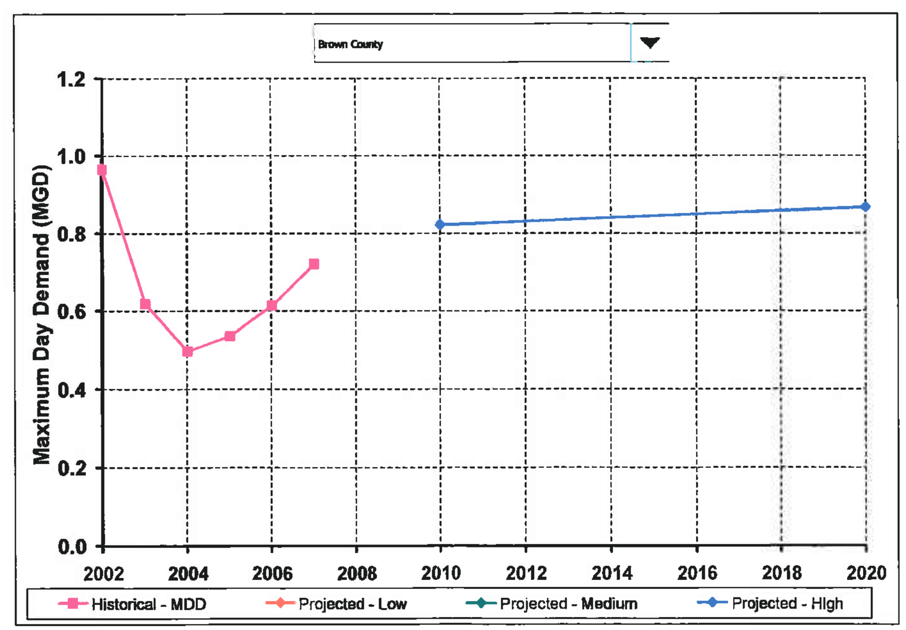




BROWN COUNTY

	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	0.45	0.00	0.00	0.45	0.00	0.0%	0.45	0.96	2.16	1.26	1.31
2003	0.34	0.00	0.00	0.34	0.00	0.0%	0.34	0.62	1.84	0.97	1.57
2004	0.20	0.00	0.00	0.20	0.00	0.0%	0.20	0.50	2.51	1.29	2.58
2005	0.32	0.00	0.00	0.32	0.00	0.0%	0.32	0.54	1.70	0.81	1.51
2006	0.28	0.00	0.00	0.28	0.00	0.0%	0.28	0.61	2.19	1.85	3.01
2007							0.43	0.72		2.55	
AVG						0.0%					
	Projected - Consumption (MGD)				Projected - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	0.32	0.00	0.00	0.32	0.00	0.0%	0.32	0.82	2.61	1.64	2.00
2020	0.33	0.00	0.00	0.33	0.00	0.0%	0.33	0.87	2.61	1.73	2.00
2010	0.32	0.00	0.00	0.32	0.00	0.0%	0.32	0.82	2.61	1.64	2.00
2020	0.33	0.00	0.00	0.33	0.00	0.0%	0.33	0.87	2.61	1.73	2.00
2010	0.32	0.00	0.00	0.32	0.00	0.0%	0.32	0.82	2.61	1.64	2.00
2020	0.33	0.00	0.00	0.33	0.00	0.0%	0.33	0.87	2.61	1.73	2.00

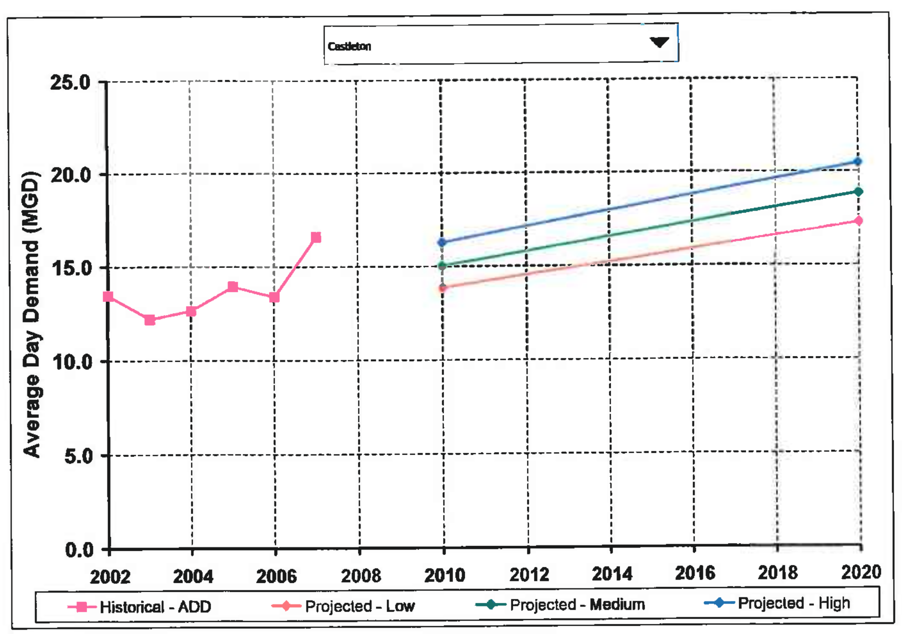


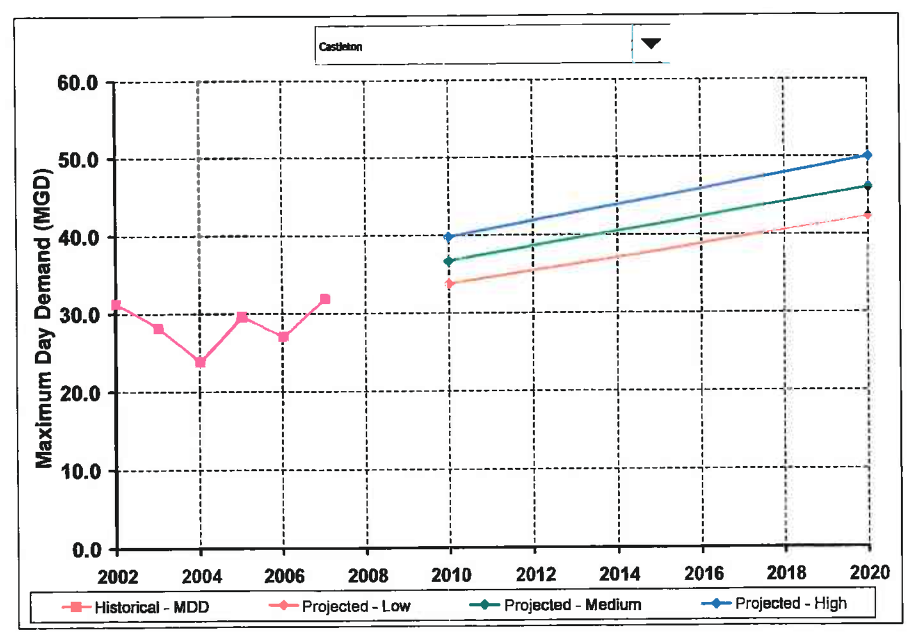


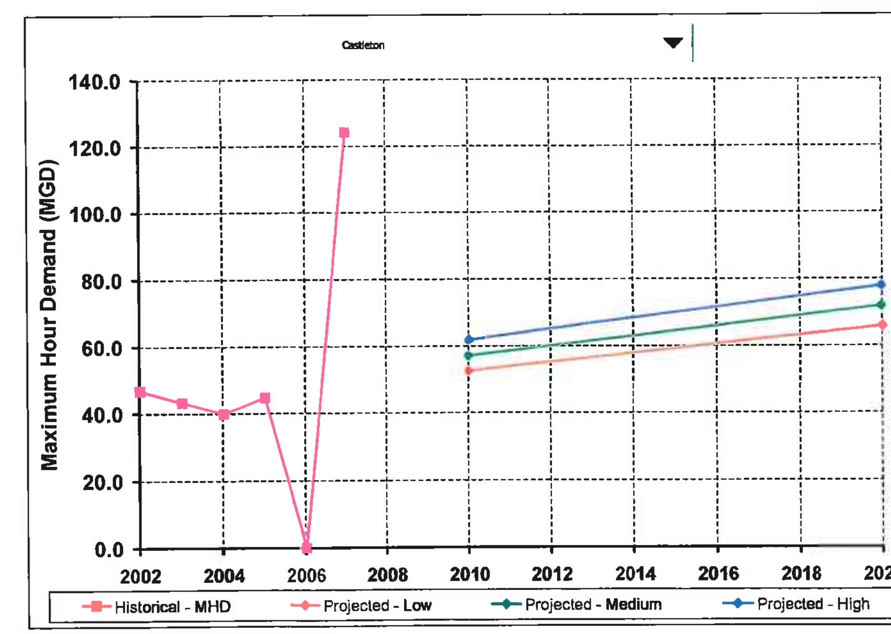
CASTLETON

	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	2.77	8.32	0.12	11.20	2.27	16.9%	13.48	31.32	2.32	46.81	1.49
2003	2.85	7.67	0.11	10.62	1.61	13.2%	12.23	28.28	2.31	43.30	1.53
2004	3.10	8.27	0.09	11.46	1.21	9.5%	12.67	23.86	1.88	40.04	1.68
2005	3.06	8.50	0.08	11.63	2.32	16.6%	13.95	29.56	2.12	44.74	1.51
2006	2.93	7.68	0.06	10.67	2.72	20.3%	13.39	27.05	2.02	N/A	N/A
2007							16.61	31.86		124.37	
AVG						15.3%					

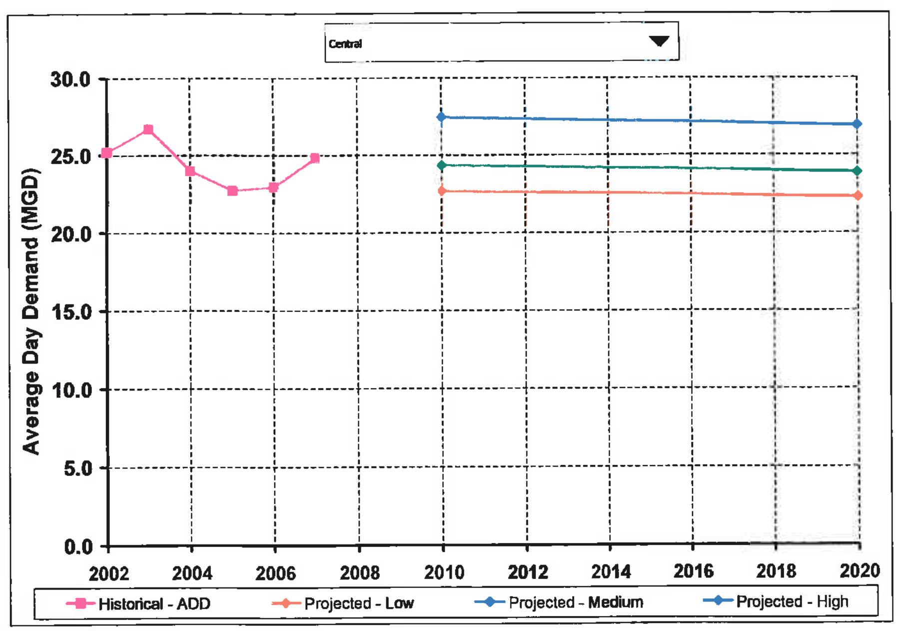
	Projected - Consumption (MGD)				Projected - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	3.21	8.31	0.04	11.56	2.28	16.5%	13.84	33.82	2.44	52.56	1.55
2020	4.07	10.57	0.09	14.73	2.59	15.0%	17.33	42.33	2.44	65.79	1.55
2010	3.33	9.17	0.07	12.57	2.47	16.4%	15.03	36.73	2.44	57.09	1.55
2020	4.23	11.66	0.13	16.02	2.84	15.0%	18.86	46.08	2.44	71.62	1.55
2010	3.58	10.02	0.08	13.68	2.63	16.1%	16.31	39.84	2.44	61.92	1.55
2020	4.55	12.74	0.15	17.44	3.03	14.8%	20.48	50.03	2.44	77.76	1.55

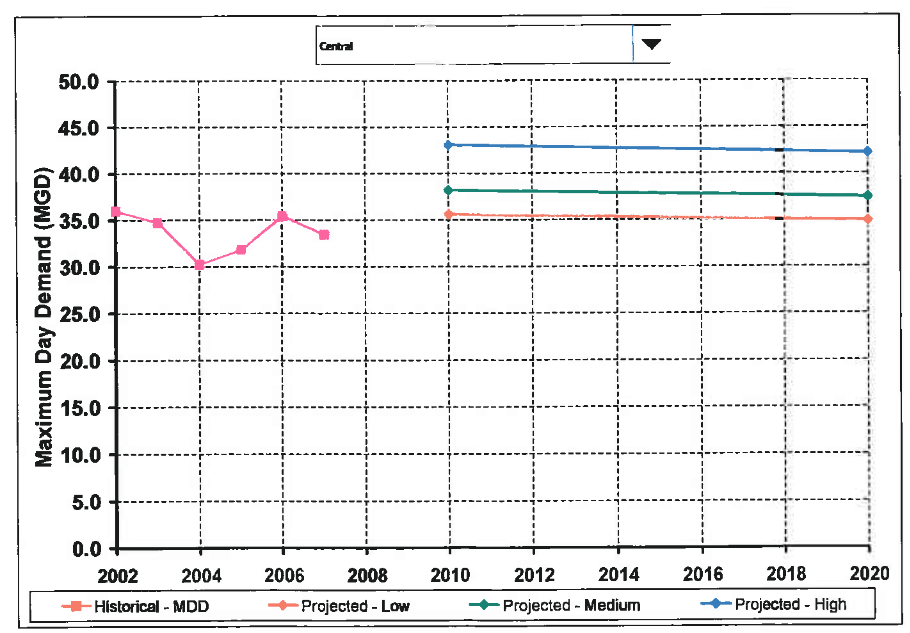


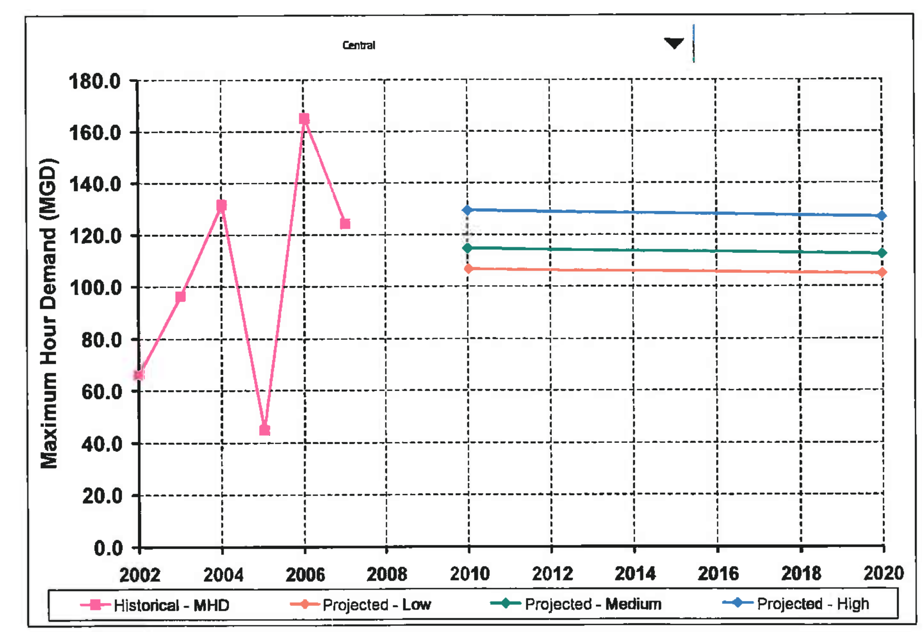




CENTRAL											
	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	19.20	4.71	1.49	25.40	-0.16	-0.6%	25.24	35.99	1.43	66.14	1.84
2003	17.68	4.57	1.42	23.67	3.05	11.4%	26.72	34.75	1.30	96.17	2.77
2004	18.26	5.97	1.14	25.36	-1.35	-5.6%	24.02	30.28	1.26	131.58	4.35
2005	17.67	4.52	1.03	23.22	-0.46	-2.0%	22.75	31.87	1.40	44.74	1.40
2006	16.99	4.38	1.18	22.55	0.45	2.0%	23.00	35.44	1.54	165.14	4.66
2007							24.87	33.46		124.37	
AVG						1.0%					
	Projected - Consumption (MGD)				Projected - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	17.05	4.22	1.16	22.43	0.25	1.1%	22.68	35.55	1.57	106.76	3.00
2020	16.85	4.17	1.02	22.04	0.22	1.0%	22.26	34.90	1.57	104.79	3.00
2010	17.89	4.81	1.41	24.11	0.27	1.1%	24.38	38.21	1.57	114.75	3.00
2020	17.68	4.76	1.24	23.68	0.24	1.0%	23.92	37.49	1.57	112.57	3.00
2010	19.38	5.96	1.83	27.17	0.30	1.1%	27.47	43.05	1.57	129.29	3.00
2020	19.15	5.90	1.61	26.66	0.26	1.0%	26.92	42.20	1.57	126.72	3.00

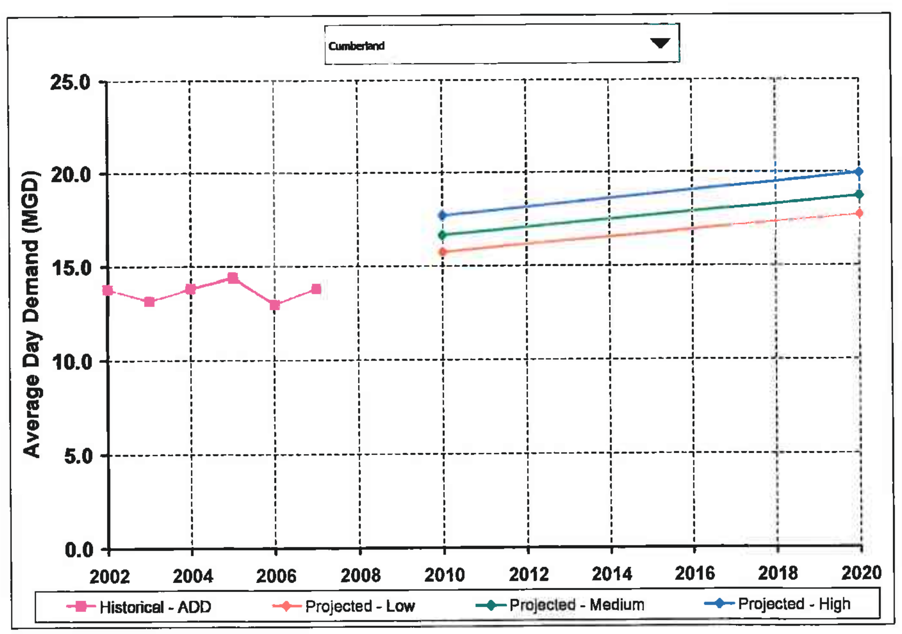


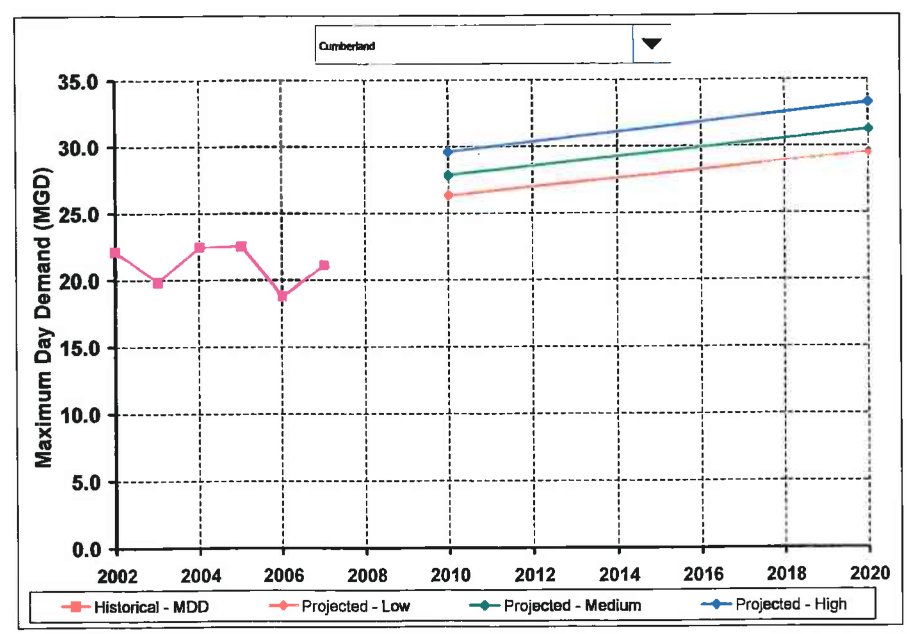


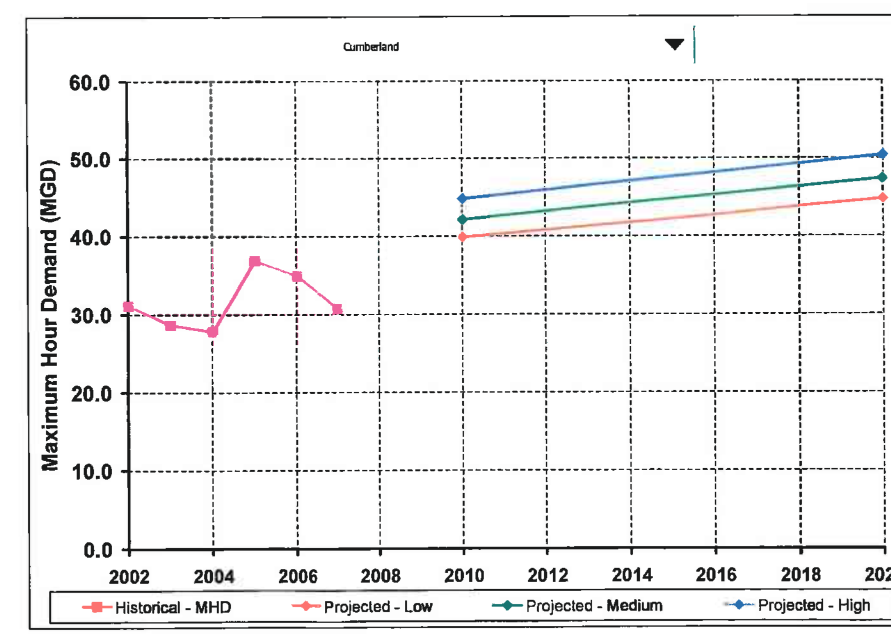


CUMBERLAND

	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	4.15	6.05	0.04	10.24	3.56	25.8%	13.81	22.13	1.60	31.14	1.41
2003	4.04	5.98	0.04	10.06	3.12	23.7%	13.19	19.88	1.51	28.66	1.44
2004	3.94	6.36	0.04	10.34	3.52	25.4%	13.86	22.51	1.62	27.79	1.23
2005	4.16	6.57	0.04	10.77	3.66	25.4%	14.43	22.55	1.56	36.82	1.63
2006	4.05	6.55	0.04	10.63	2.37	18.2%	13.01	18.80	1.45	34.81	1.85
2007							13.85	21.11		30.68	
AVG						23.7%					
	Projected - Consumption (MGD)				Projected - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	4.29	7.48	0.03	11.80	3.99	25.3%	15.79	26.35	1.67	39.88	1.51
2020	5.43	8.12	0.05	13.60	4.12	23.2%	17.72	29.56	1.67	44.75	1.51
2010	4.44	8.01	0.04	12.49	4.21	25.2%	16.70	27.85	1.67	42.16	1.51
2020	5.62	8.70	0.05	14.38	4.38	23.3%	18.75	31.28	1.67	47.35	1.51
2010	4.71	8.60	0.04	13.35	4.41	24.8%	17.76	29.62	1.67	44.84	1.51
2020	5.96	9.35	0.06	15.37	4.59	23.0%	19.96	33.29	1.67	50.40	1.51



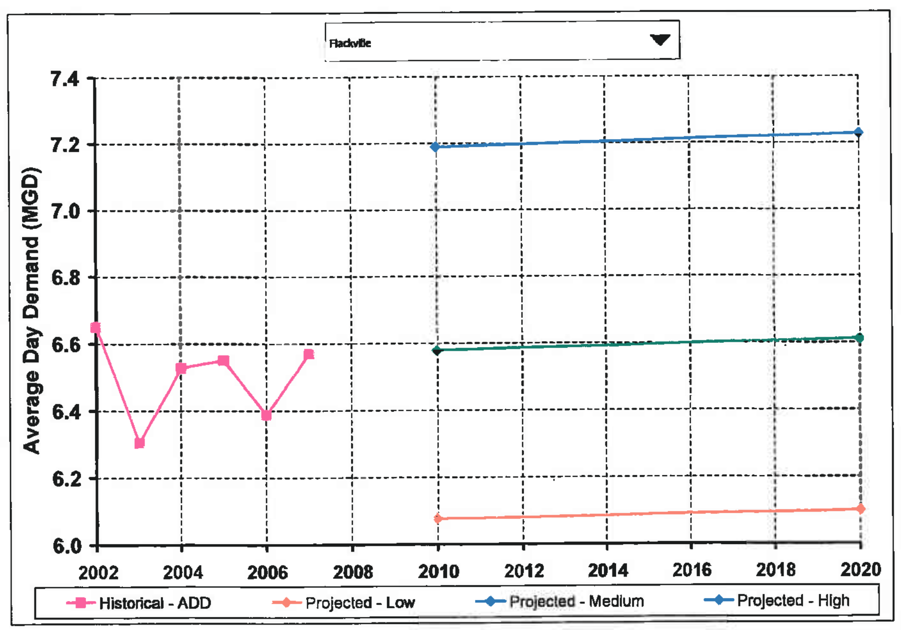


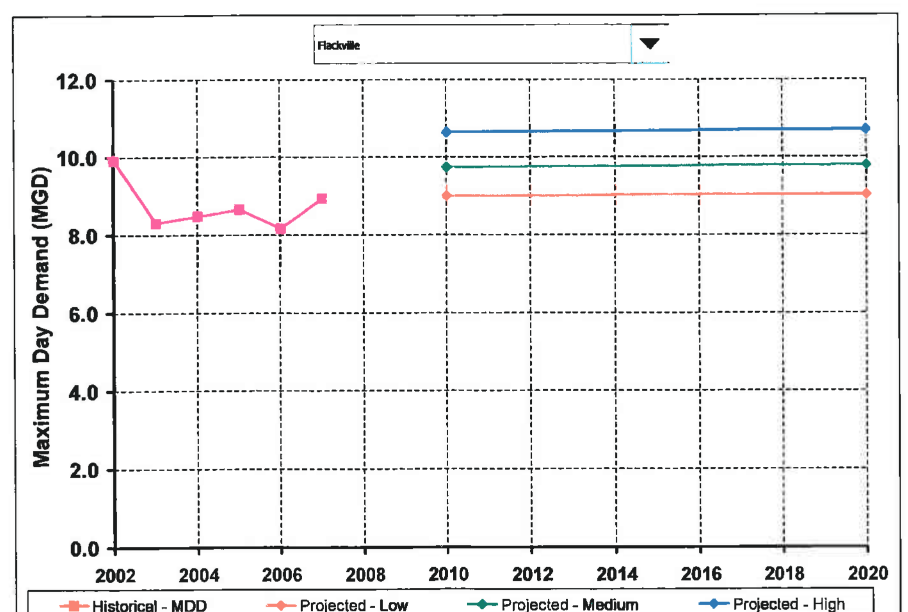


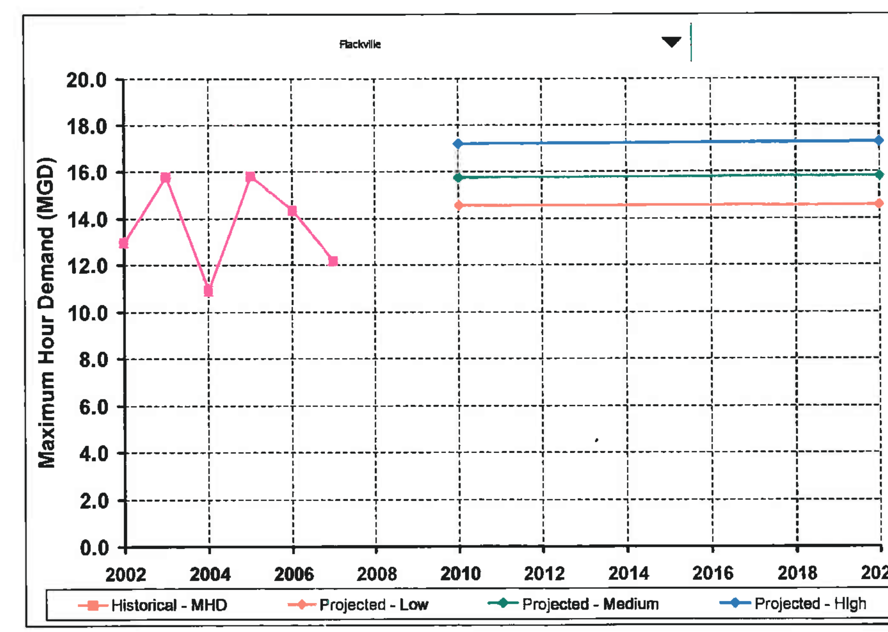
FLACKVILLE

	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	1.60	4.32	0.06	5.98	0.67	10.1%	6.65	9.92	1.49	12.99	1.31
2003	1.88	4.15	0.03	6.07	0.23	3.7%	6.30	8.31	1.32	15.80	1.90
2004	1.91	4.05	0.05	6.02	0.51	7.8%	6.53	8.48	1.30	10.91	1.29
2005	1.80	4.20	0.05	6.05	0.50	7.6%	6.55	8.67	1.32	15.81	1.82
2006	1.75	4.00	0.04	5.79	0.60	9.4%	6.39	8.18	1.28	14.34	1.75
2007							6.57	8.95		12.19	
AVG						7.7%					

	Projected - Consumption (MGD)				Projected - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	1.55	3.99	0.03	5.57	0.51	8.3%	6.08	9.01	1.48	14.54	1.61
2020	1.63	3.98	0.04	5.64	0.46	7.5%	6.10	9.04	1.48	14.59	1.61
2010	1.74	4.25	0.04	6.03	0.55	8.3%	6.58	9.75	1.48	15.74	1.61
2020	1.83	4.24	0.05	6.11	0.50	7.6%	6.61	9.80	1.48	15.82	1.61
2010	1.88	4.68	0.05	6.60	0.59	8.2%	7.19	10.65	1.48	17.20	1.61
2020	1.97	4.66	0.06	6.69	0.54	7.4%	7.23	10.71	1.48	17.29	1.61

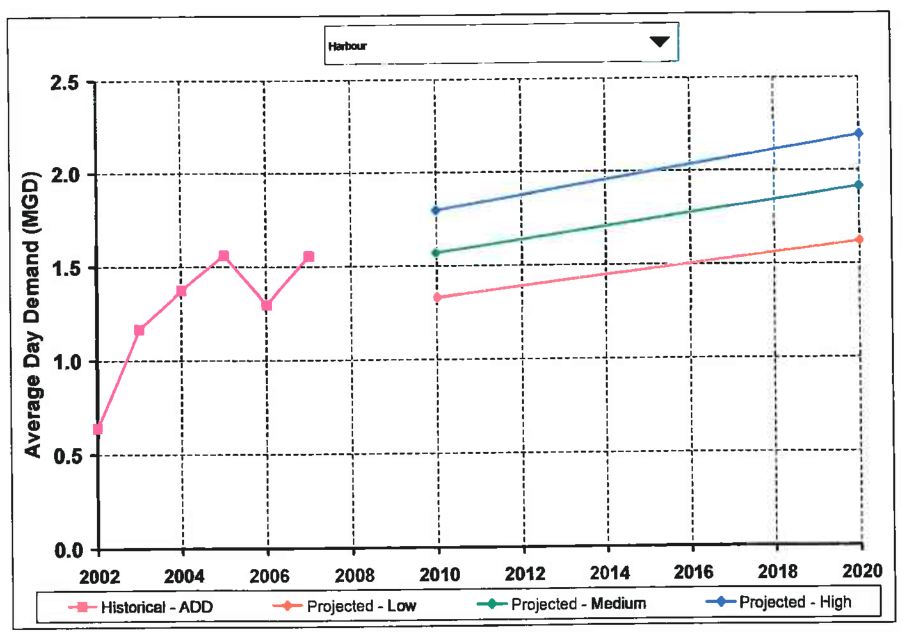


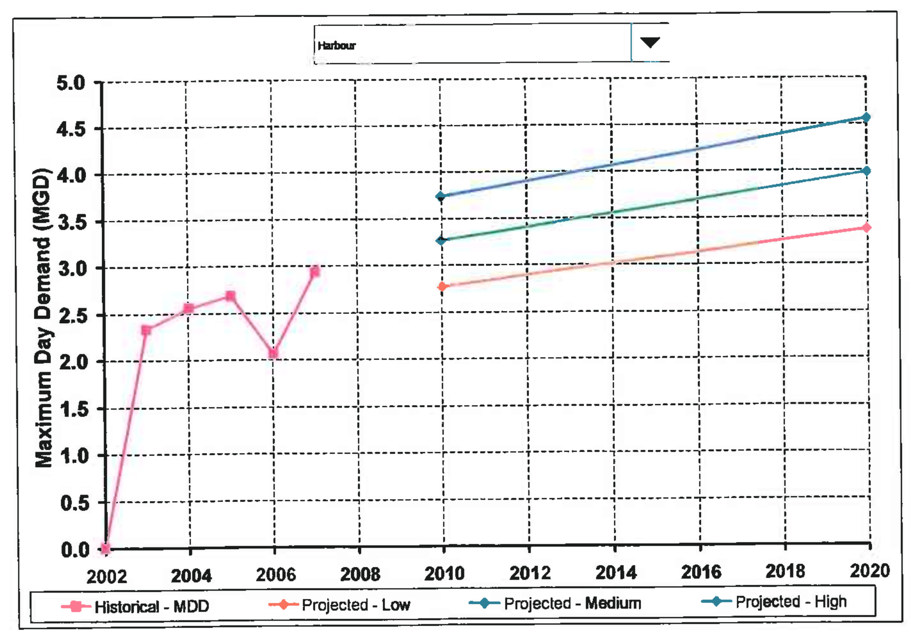


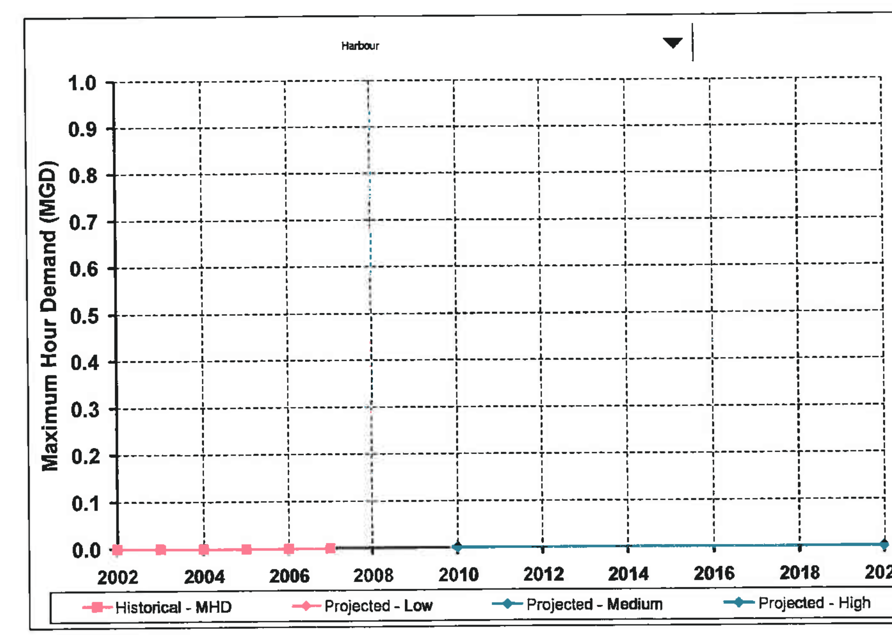


HARBOUR

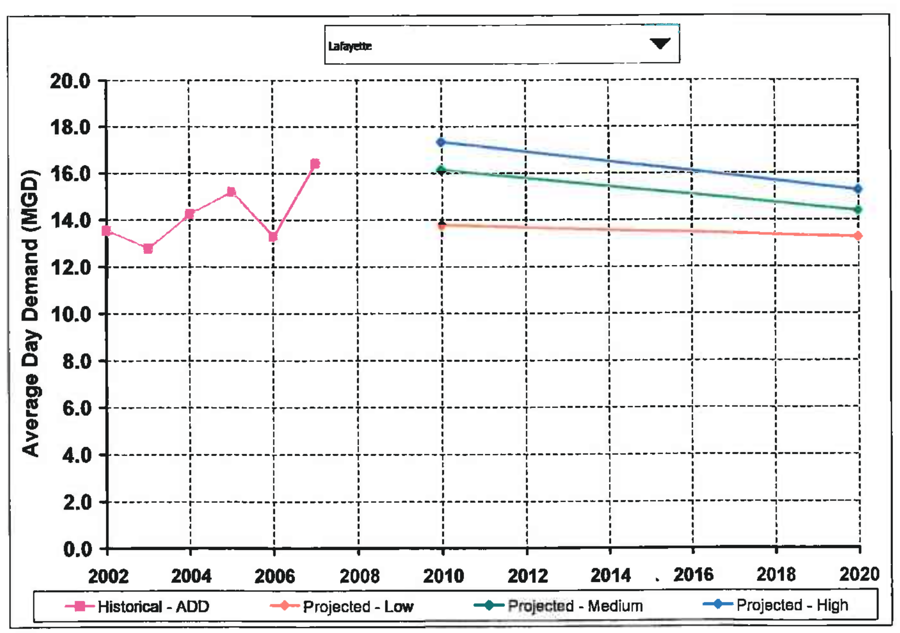
	Historical - Consumption (MGD)					Historical - Demand (MGD)						
	Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
Historical	2002	0.06	1.10	0.00	1.16	-0.52	-81.4%	0.64	N/A	N/A	N/A	N/A
Historical	2003	0.06	1.00	0.00	1.06	0.11	9.1%	1.17	2.33	2.00	N/A	N/A
Historical	2004	0.06	1.06	0.00	1.12	0.26	18.8%	1.38	2.56	1.86	N/A	N/A
Historical	2005	0.06	0.98	0.00	1.04	0.52	33.5%	1.56	2.69	1.72	N/A	N/A
Historical	2006	0.06	0.90	0.00	0.97	0.33	25.7%	1.30	2.07	1.59	N/A	N/A
	2007							1.56	2.94		N/A	
	AVG						21.8%					
	Projected - Consumption (MGD)					Projected - Demand (MGD)						
	Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
Low	2010	0.03	0.99	0.00	1.02	0.31	23.3%	1.33	2.77	2.08	N/A	N/A
Low	2020	0.07	1.20	0.00	1.28	0.35	21.3%	1.62	3.37	2.08	N/A	N/A
Medium	2010	0.04	1.17	0.00	1.21	0.36	23.2%	1.57	3.27	2.08	N/A	N/A
Medium	2020	0.09	1.42	0.00	1.50	0.41	21.4%	1.91	3.98	2.08	N/A	N/A
High	2010	0.04	1.34	0.00	1.39	0.41	22.8%	1.80	3.74	2.08	N/A	N/A
High	2020	0.09	1.63	0.00	1.73	0.46	21.1%	2.19	4.56	2.08	N/A	N/A

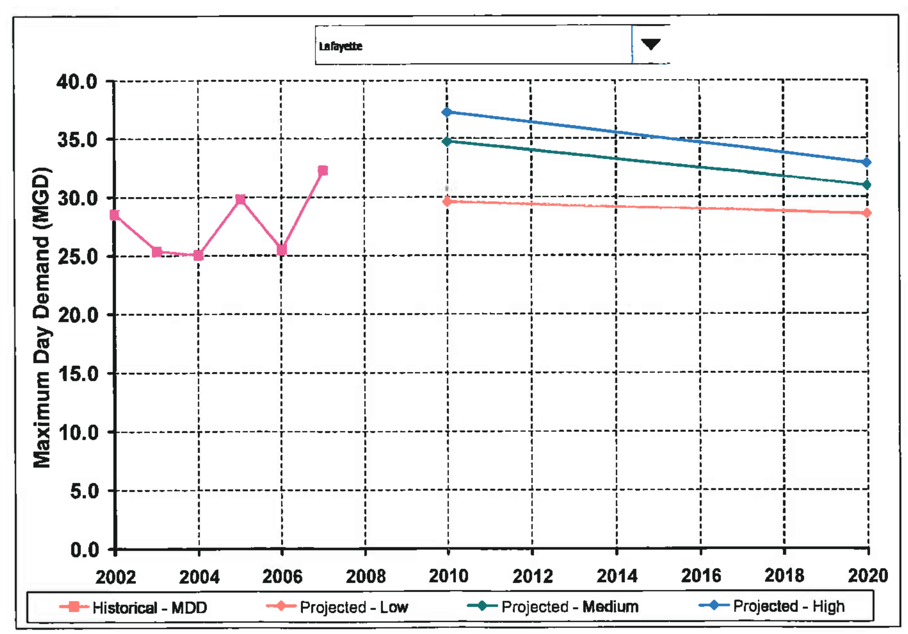


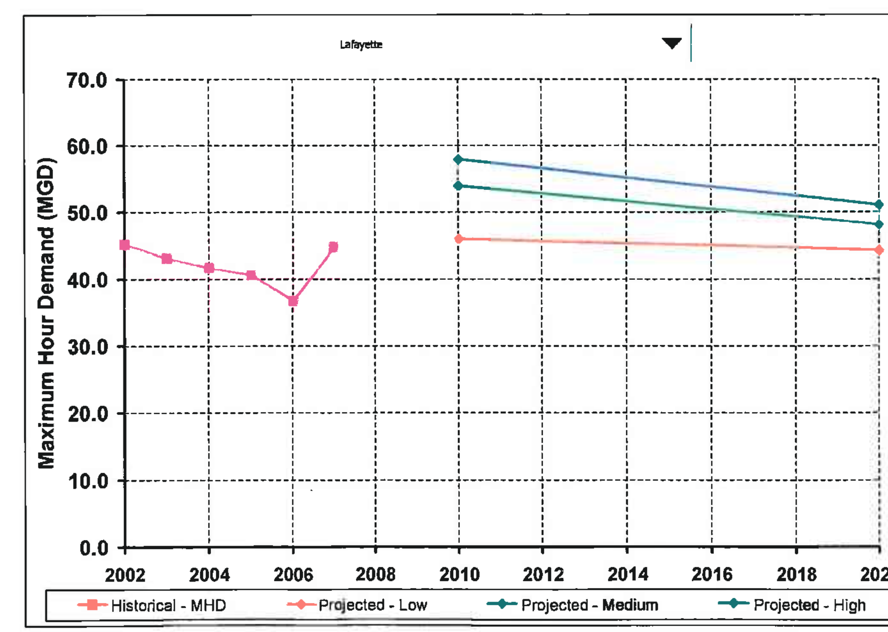




LAFAYETTE																	
	Historical - Consumption (MGD)				Historical - Demand (MGD)												
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	Dev ADD	Total ADD	MDD	MDD:ADD	Dev MDD	Total MDD	MHD	MHD:MDD	Dev MHD	Total MHD
2002	4.28	7.15	0.10	11.53	2.02	14.9%	13.55	0	13.55	28.50	2.10	0	28.50	45.15	1.58	0	45.15
2003	4.23	6.56	0.09	10.88	1.90	14.9%	12.78	0	12.78	25.34	1.98	0	25.34	43.14	1.70	0	43.14
2004	4.57	7.57	0.09	12.22	2.03	14.3%	14.25	0	14.25	24.99	1.75	0	24.99	41.69	1.67	0	41.69
2005	4.65	7.84	0.08	12.58	2.61	17.2%	15.19	0	15.19	29.76	1.96	0	29.76	40.58	1.36	0	40.58
2006	4.52	5.75	0.07	10.34	2.93	22.1%	13.27	0	13.27	25.44	1.92	0	25.44	36.71	1.44	0	36.71
2007							16.42		16.42	32.27			32.27	44.79			44.79
AVG						16.7%											
	Projected - Consumption (MGD)				Projected - Demand (MGD)												
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	Dev ADD	Total ADD	MDD	MDD:ADD	Dev MDD	Total MDD	MHD	MHD:MDD	Dev MHD	Total MHD
2010	4.4	6.3	0.1	10.8	2.4	17.9%	13.2	0.58	13.8	28.3	2.15	1.25	29.6	44.0	1.55	1.94	45.9
2020	4.3	5.9	0.1	10.3	2.0	16.3%	12.3	0.93	13.3	26.5	2.15	2.00	28.5	41.2	1.55	3.10	44.3
2010	4.7	8.0	0.1	12.8	2.8	17.8%	15.6	0.58	16.1	33.5	2.15	1.25	34.7	52.0	1.55	1.94	53.9
2020	4.6	6.6	0.1	11.3	2.2	16.4%	13.5	0.93	14.4	28.9	2.15	2.00	30.9	44.9	1.55	3.10	48.0
2010	4.9	8.8	0.1	13.8	2.9	17.5%	16.8	0.58	17.3	36.0	2.15	1.25	37.3	55.9	1.55	1.94	57.9
2020	4.7	7.2	0.1	12.0	2.3	16.1%	14.4	0.93	15.3	30.9	2.15	2.00	32.9	47.9	1.55	3.10	51.0

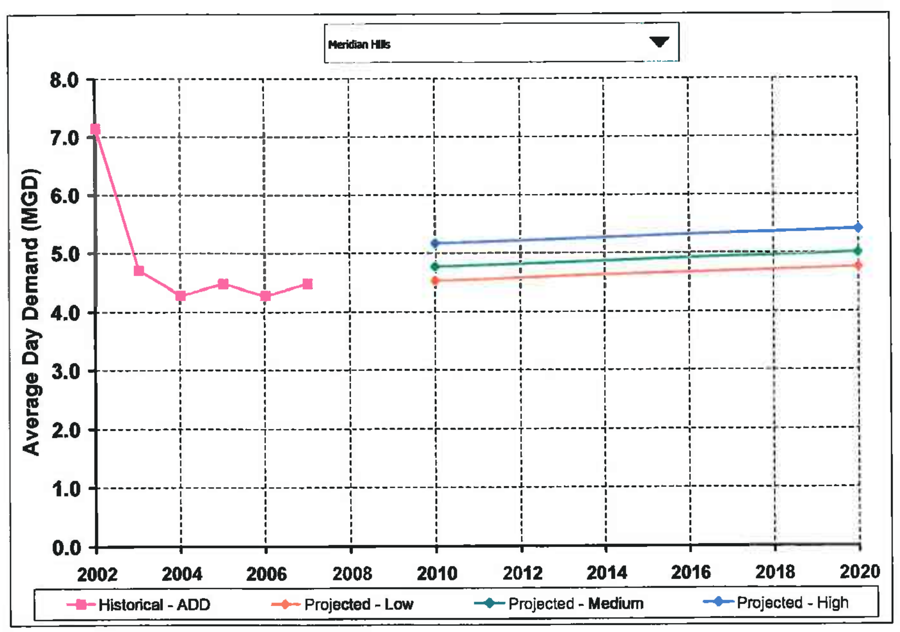


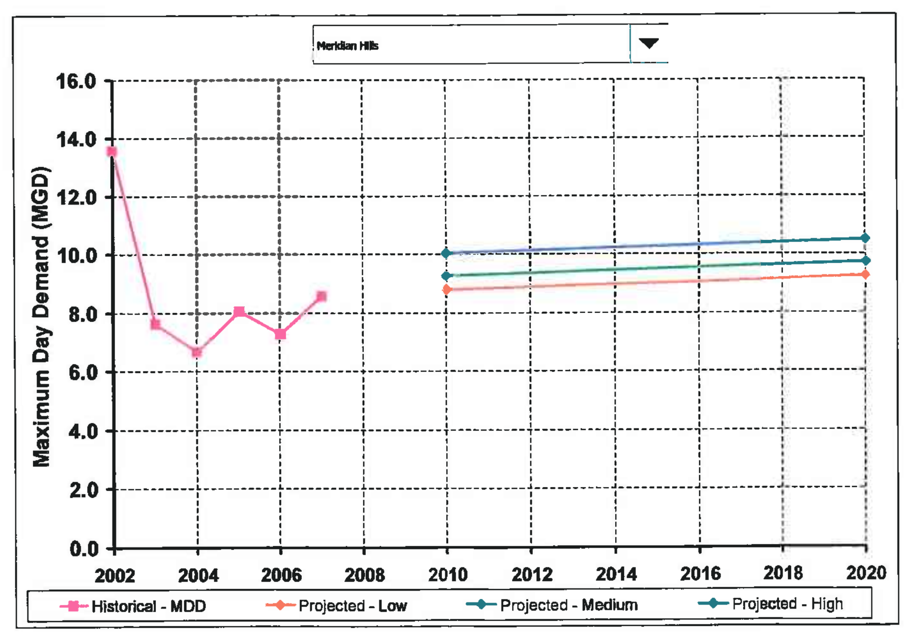


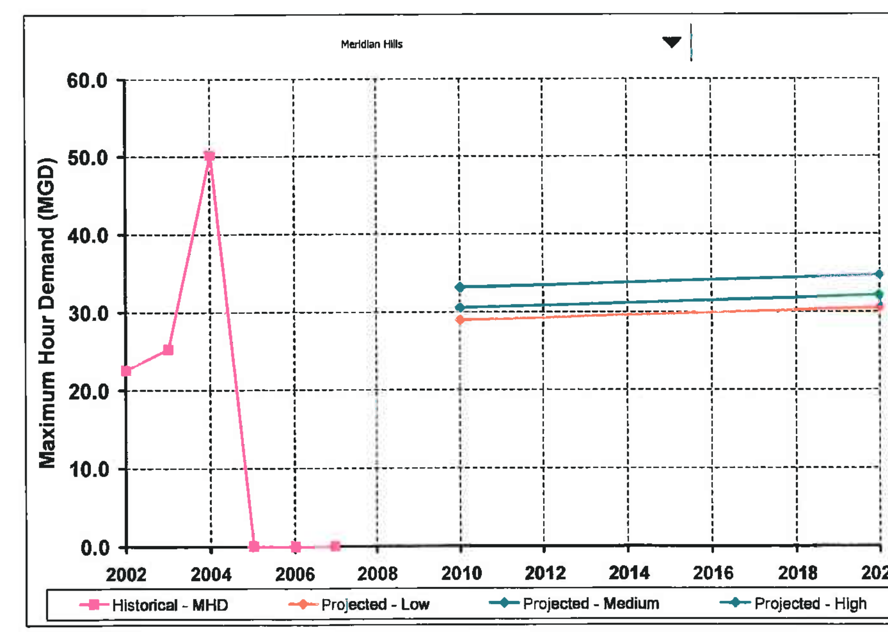


MERIDIAN HILLS

Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
	Historical - Consumption (MGD)				Historical - Demand (MGD)						
2002	1.46	3.42	0.01	4.89	n/a	n/a	7.15	13.58	1.90	22.50	1.66
2003	1.43	3.33	0.01	4.76	-0.05	-1.0%	4.71	7.63	1.62	25.18	3.30
2004	1.51	3.18	0.01	4.70	-0.41	-9.6%	4.29	6.66	1.55	50.21	7.54
2005	1.59	3.33	0.01	4.93	-0.44	-9.8%	4.48	8.07	1.80	N/A	N/A
2006	1.46	3.40	0.01	4.86	-0.58	-13.5%	4.29	7.28	1.70	N/A	N/A
2007							4.49	8.57		N/A	
AVG						-8.5%					
	Projected - Consumption (MGD)				Projected - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	1.38	3.56	0.01	4.95	-0.42	-9.3%	4.52	8.78	1.94	28.99	3.30
2020	1.53	3.62	0.01	5.15	-0.39	-8.3%	4.76	9.24	1.94	30.50	3.30
2010	1.51	3.69	0.01	5.21	-0.44	-9.3%	4.76	9.25	1.94	30.52	3.30
2020	1.66	3.75	0.01	5.42	-0.42	-8.3%	5.01	9.72	1.94	32.07	3.30
2010	1.62	4.00	0.01	5.64	-0.47	-9.1%	5.17	10.03	1.94	33.11	3.30
2020	1.78	4.06	0.01	5.85	-0.44	-8.1%	5.41	10.50	1.94	34.65	3.30

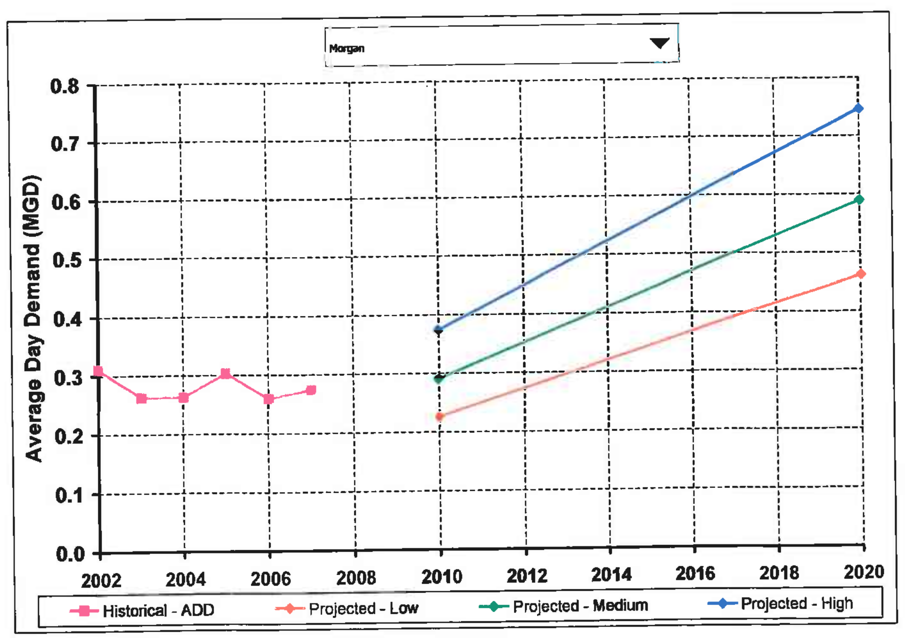


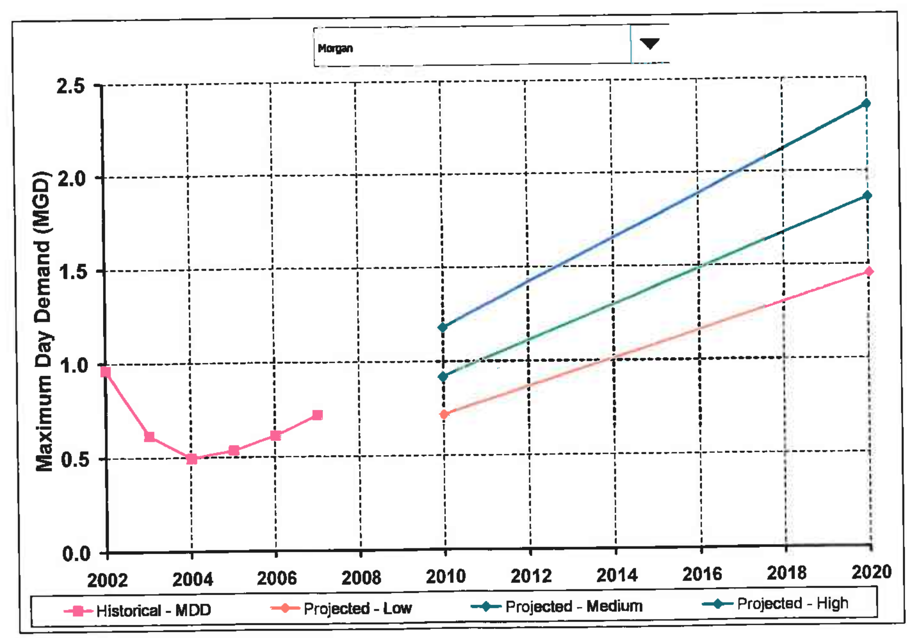


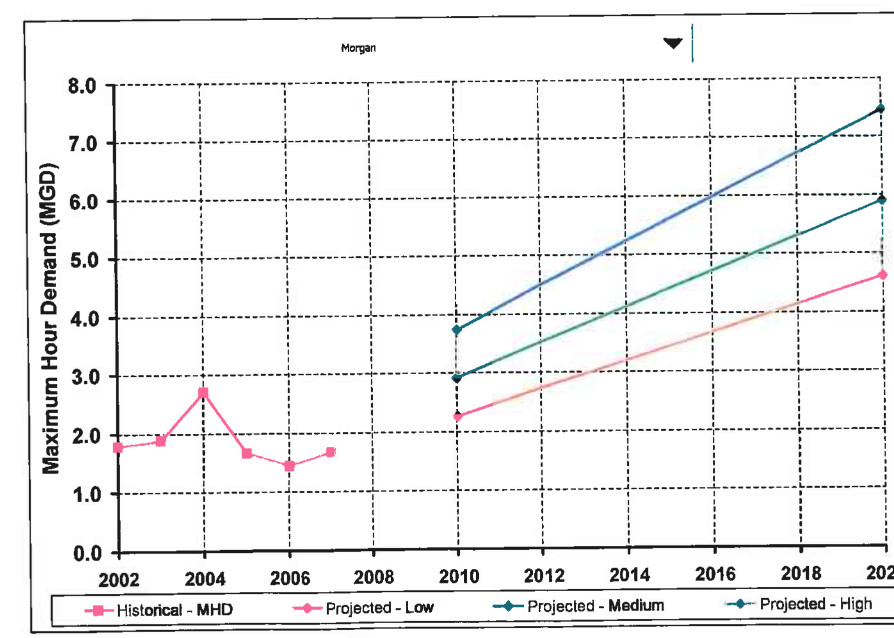


MORGAN

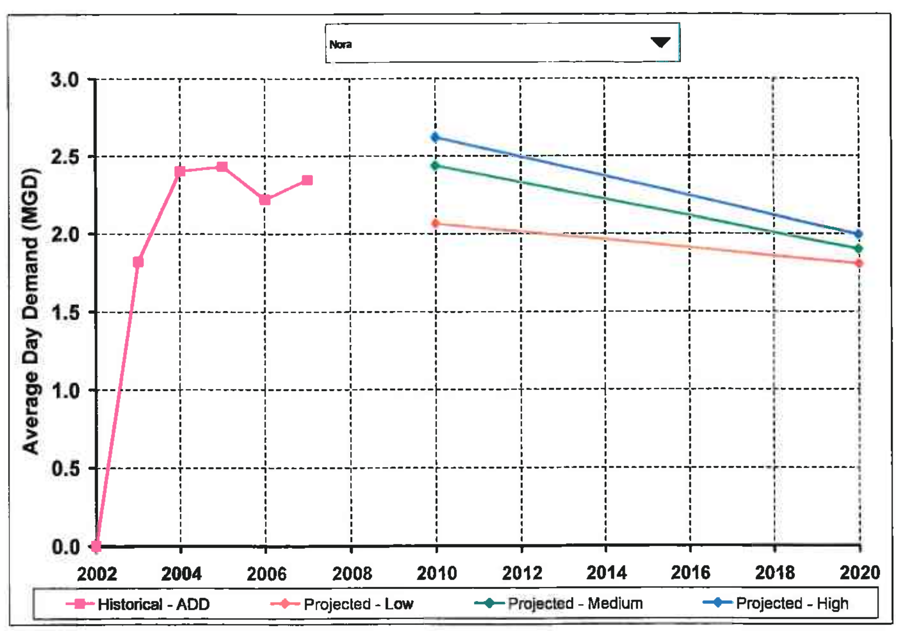
	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	0.79	0.08	0.00	0.87	-0.56	-181.9%	0.31	0.96	3.11	1.79	1.86
2003	0.73	0.09	0.00	0.82	-0.55	-210.0%	0.26	0.62	2.35	1.89	3.05
2004	0.54	0.26	0.00	0.81	-0.54	-206.4%	0.26	0.50	1.89	2.72	5.47
2005	0.70	0.26	0.00	0.96	-0.66	-215.8%	0.30	0.54	1.77	1.66	3.10
2006	0.74	0.26	0.00	1.00	-0.74	-283.9%	0.26	0.61	2.36	1.44	2.35
2007							0.28	0.72		1.67	
AVG						-219.6%					
	Projected - Consumption (MGD)				**Projected - Demand (MGD)**						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	0.64	0.26	0.00	0.90	-0.68	-298.0%	0.23	0.72	3.16	2.27	3.16
2020	1.10	0.29	0.00	1.40	-0.94	-202.7%	0.46	1.46	3.16	4.62	3.16
2010	0.86	0.29	0.00	1.15	-0.86	-294.3%	0.29	0.92	3.16	2.92	3.16
2020	1.48	0.32	0.00	1.81	-1.22	-206.2%	0.59	1.86	3.16	5.90	3.16
2010	1.08	0.31	0.00	1.39	-1.01	-270.4%	0.37	1.18	3.16	3.75	3.16
2020	1.86	0.35	0.00	2.20	-1.46	-195.0%	0.75	2.36	3.16	7.47	3.16

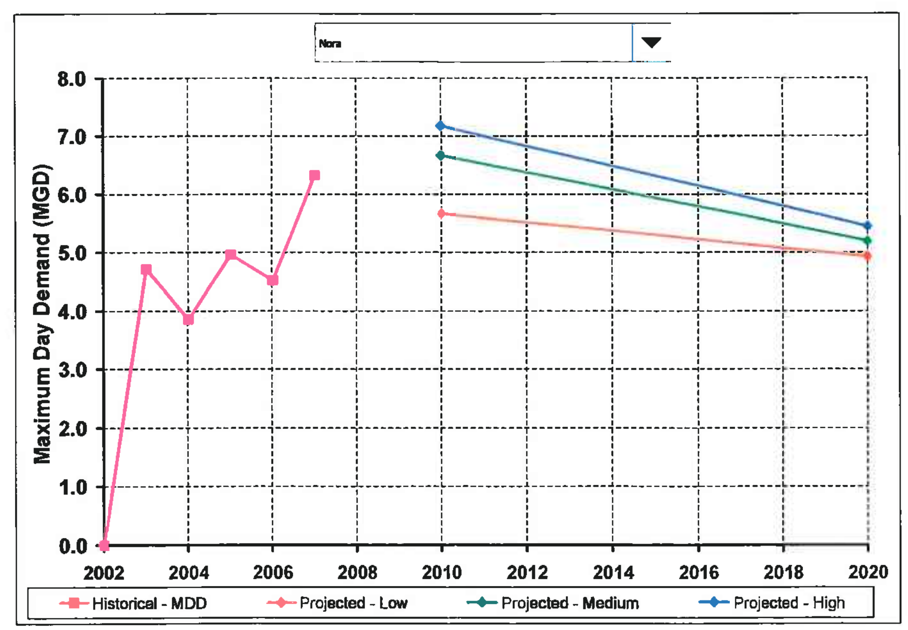


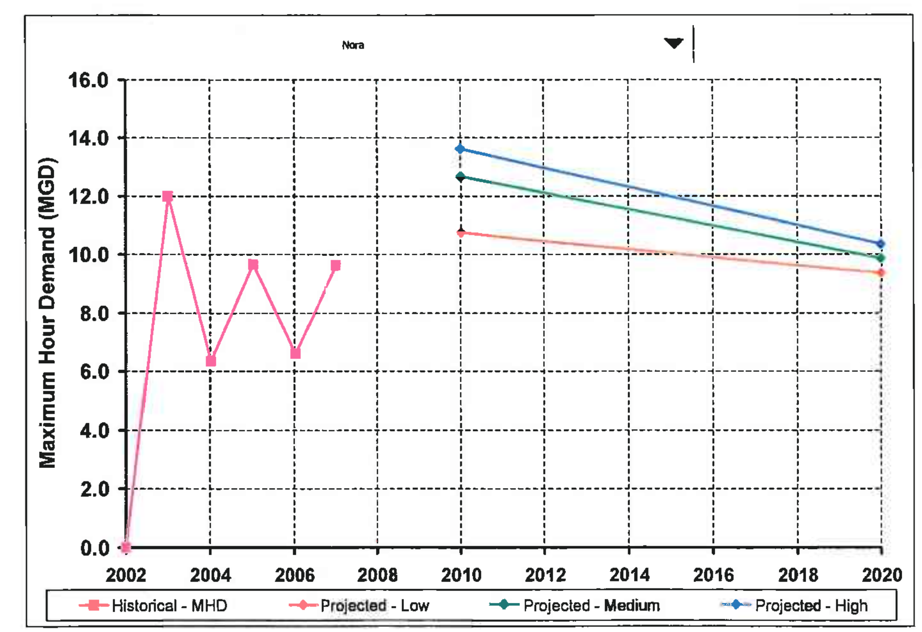




	NORA											
		Historical - Consumption (MGD)				Historical - Demand (MGD)						
	Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
Historical	2002	1.03	0.84	0.01	1.88	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Historical	2003	1.10	0.82	0.01	1.93	-0.11	-6.2%	1.82	4.71	2.60	11.98	2.54
Historical	2004	1.17	0.94	0.01	2.12	0.28	11.7%	2.40	3.86	1.61	6.34	1.64
Historical	2005	1.16	0.95	0.01	2.12	0.31	12.7%	2.43	4.97	2.04	9.65	1.94
Historical	2006	1.00	0.61	0.01	1.63	0.59	26.7%	2.22	4.53	2.04	6.60	1.46
	2007							2.35	6.33		9.62	
	AVG						17.0%					
		Projected - Consumption (MGD)				Projected - Demand (MGD)						
	Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
Low	2010	1.08	0.60	0.01	1.69	0.38	18.3%	2.07	5.67	2.74	10.75	1.90
Low	2020	1.11	0.38	0.01	1.50	0.30	16.7%	1.80	4.93	2.74	9.36	1.90
Medium	2010	1.17	0.81	0.01	1.99	0.44	18.2%	2.44	6.67	2.74	12.66	1.90
Medium	2020	1.16	0.41	0.01	1.58	0.32	16.8%	1.90	5.20	2.74	9.86	1.90
High	2010	1.23	0.91	0.02	2.15	0.47	17.9%	2.62	7.18	2.74	13.62	1.90
High	2020	1.20	0.45	0.02	1.67	0.33	16.5%	1.99	5.46	2.74	10.35	1.90

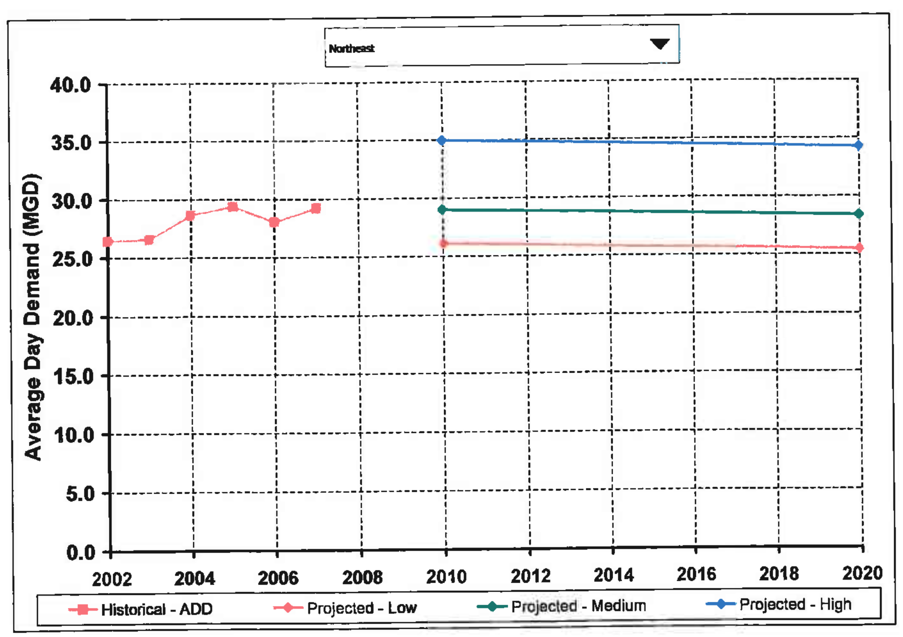


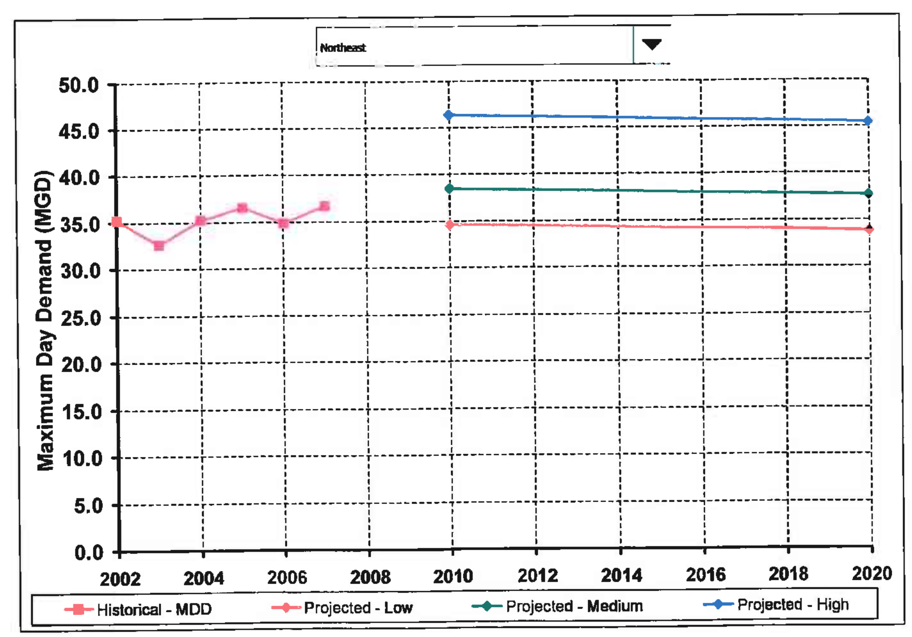


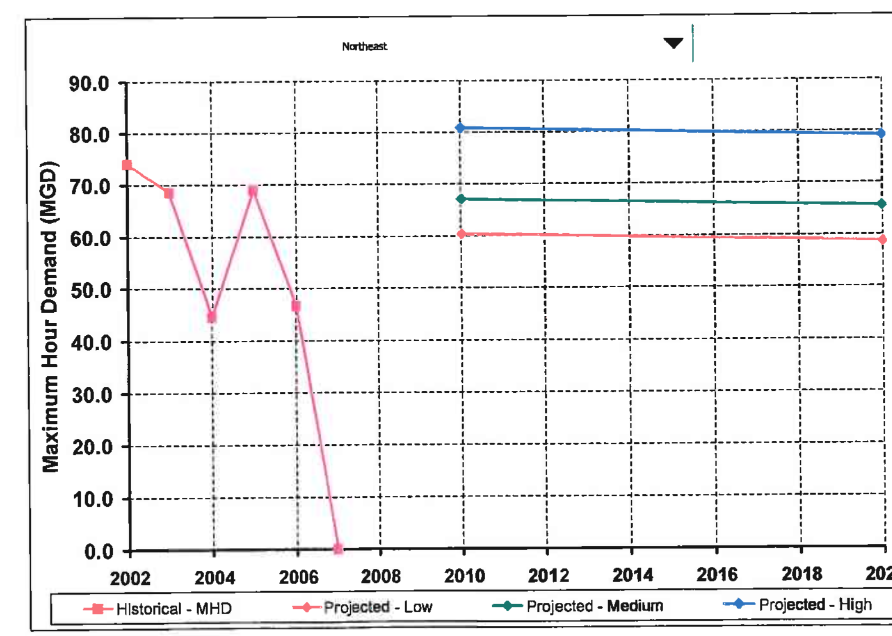


NORTHEAST

	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	5.14	17.29	0.10	22.53	3.93	14.9%	26.46	35.22	1.33	74.13	2.11
2003	5.63	13.75	0.10	19.48	7.13	26.8%	26.62	32.63	1.23	68.69	2.11
2004	5.84	13.49	0.08	19.41	9.28	32.3%	28.68	35.28	1.23	44.74	1.27
2005	5.74	13.29	0.09	19.12	10.25	34.9%	29.37	36.59	1.25	69.11	1.89
2006	5.85	12.69	0.08	18.61	9.42	33.6%	28.03	34.91	1.25	46.78	1.34
2007							29.20	36.71		N/A	
AVG						31.9%					
	Projected - Consumption (MGD)				**Projected - Demand (MGD)**						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	5.01	12.23	0.08	17.31	8.84	33.8%	26.15	34.68	1.33	60.39	1.74
2020	5.05	12.37	0.07	17.49	7.99	31.4%	25.48	33.79	1.33	58.85	1.74
2010	5.48	13.69	0.09	19.26	9.80	33.7%	29.06	38.54	1.33	67.11	1.74
2020	5.53	13.85	0.09	19.46	8.94	31.5%	28.40	37.66	1.33	65.58	1.74
2010	5.77	17.50	0.10	23.37	11.63	33.2%	35.00	46.42	1.33	80.83	1.74
2020	5.81	17.70	0.10	23.62	10.65	31.1%	34.26	45.44	1.33	79.14	1.74

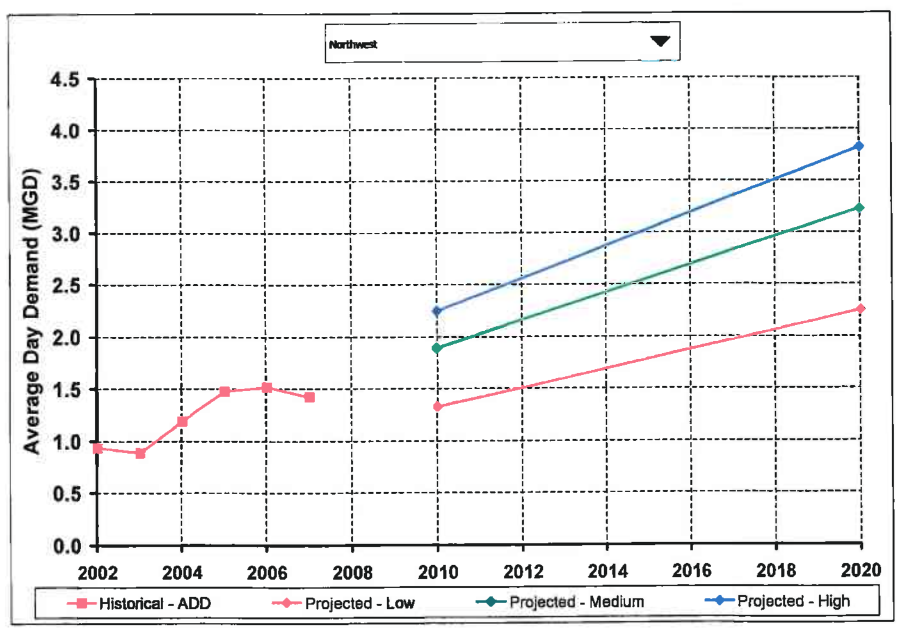


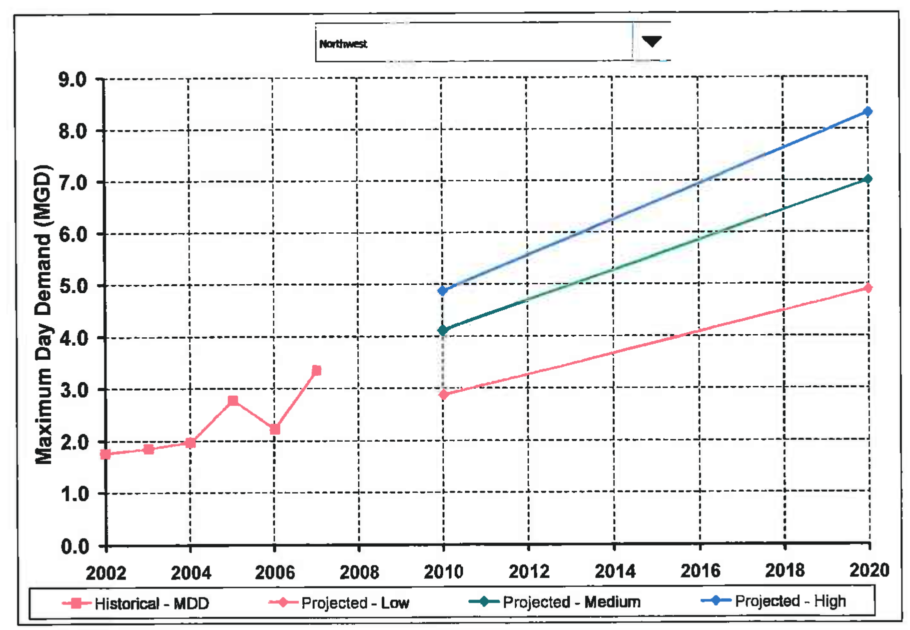


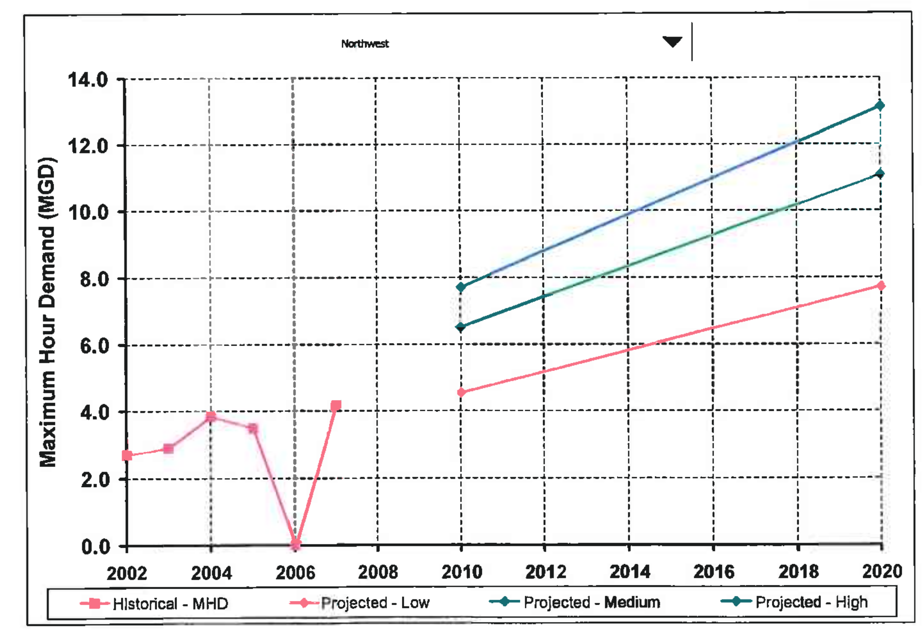


NORTHWEST

	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	0.90	0.01	0.00	0.91	0.03	3.5%	0.94	1.76	1.87	2.71	1.54
2003	0.89	0.01	0.00	0.90	-0.01	-1.5%	0.89	1.85	2.07	2.91	1.57
2004	1.13	0.01	0.00	1.14	0.05	4.5%	1.19	1.97	1.65	3.83	1.95
2005	1.38	0.02	0.00	1.40	0.07	4.9%	1.48	2.77	1.87	3.48	1.26
2006	1.53	0.02	0.00	1.55	-0.03	-2.1%	1.52	2.22	1.46	N/A	N/A
2007							1.42	3.35		4.18	
AVG						1.5%					
	Projected - Consumption (MGD)				**Projected - Demand (MGD)**						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	1.27	0.03	0.00	1.30	0.02	1.6%	1.32	2.88	2.17	4.55	1.58
2020	2.18	0.04	0.00	2.22	0.03	1.4%	2.25	4.90	2.17	7.73	1.58
2010	1.83	0.04	0.00	1.86	0.03	1.6%	1.89	4.11	2.17	6.49	1.58
2020	3.14	0.04	0.00	3.18	0.05	1.4%	3.23	7.01	2.17	11.07	1.58
2010	2.17	0.04	0.00	2.21	0.03	1.6%	2.24	4.87	2.17	7.70	1.58
2020	3.73	0.05	0.00	3.77	0.05	1.4%	3.83	8.32	2.17	13.14	1.58

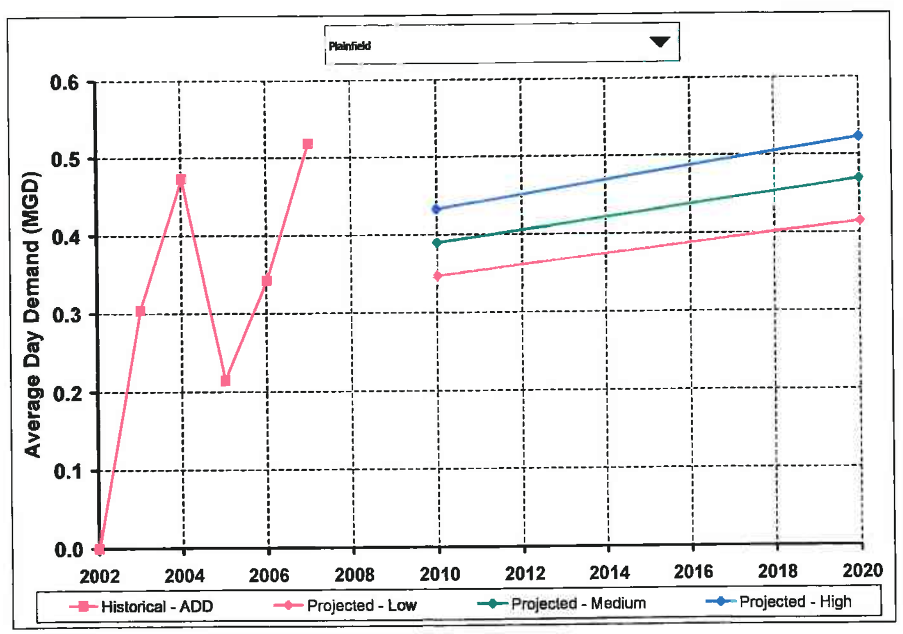


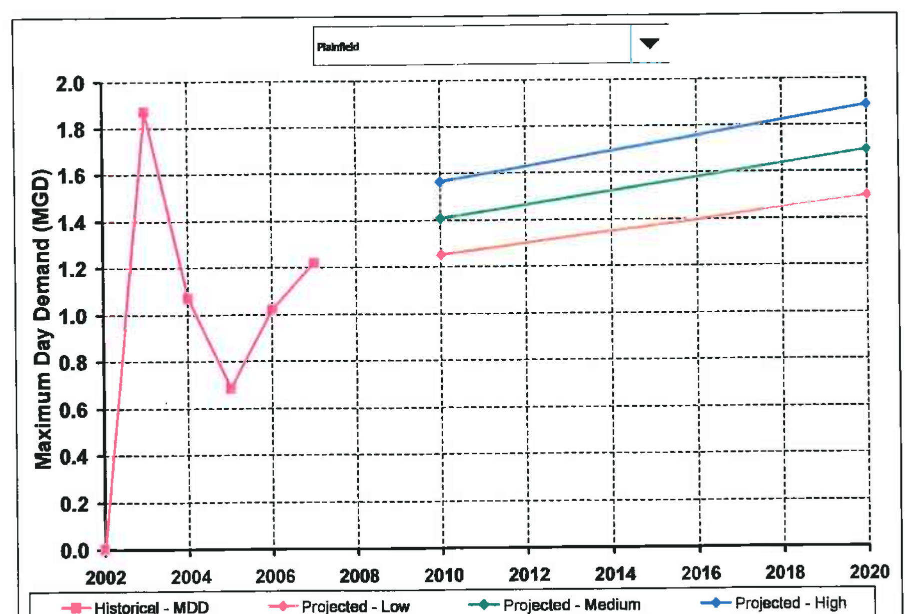


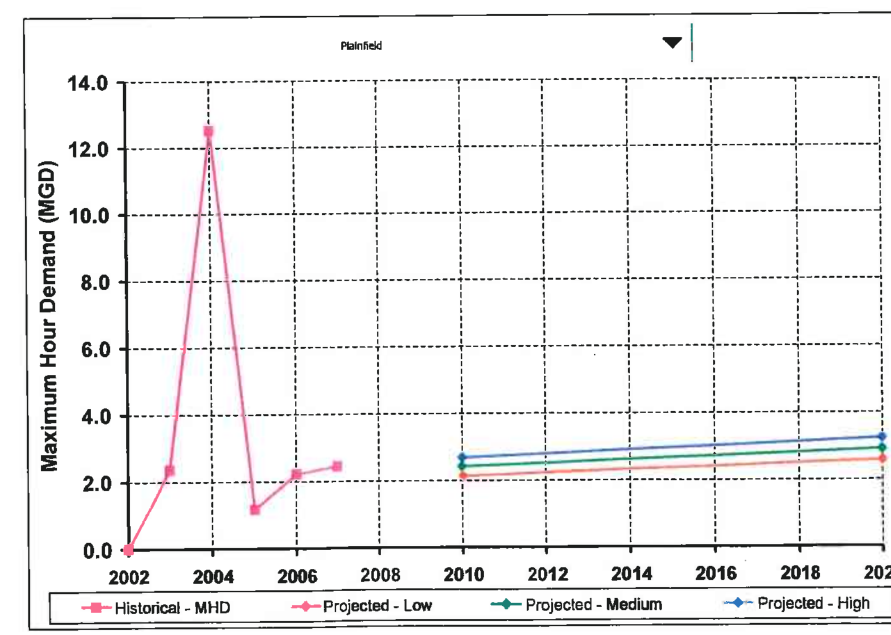


PLAINFIELD

		Historical - Consumption (MGD)				Historical - Demand (MGD)						
	Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
Historical	2002	0.00	0.12	0.00	0.13	-0.13	N/A	0.00	N/A	N/A	N/A	N/A
Historical	2003	0.00	0.13	0.00	0.13	0.18	57.5%	0.31	1.87	6.14	2.36	1.26
Historical	2004	0.00	0.15	0.00	0.16	0.32	67.3%	0.47	1.07	2.26	12.53	11.68
Historical	2005	0.00	0.15	0.00	0.16	0.06	26.0%	0.22	0.69	3.19	1.17	1.70
Historical	2006	0.00	0.15	0.00	0.15	0.19	56.1%	0.34	1.02	2.99	2.22	2.17
	2007							0.52	1.22		2.44	
	AVG						51.7%					
		Projected - Consumption (MGD)				**Projected - Demand (MGD)**						
	Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
Low	2010	0.00	0.16	0.00	0.16	0.19	53.9%	0.35	1.25	3.61	2.14	1.71
Low	2020	0.00	0.20	0.00	0.20	0.21	51.1%	0.42	1.50	3.61	2.56	1.71
Medium	2010	0.00	0.18	0.00	0.18	0.21	53.8%	0.39	1.41	3.61	2.41	1.71
Medium	2020	0.00	0.22	0.00	0.23	0.24	51.2%	0.47	1.69	3.61	2.90	1.71
High	2010	0.00	0.20	0.00	0.20	0.23	53.2%	0.43	1.56	3.61	2.67	1.71
High	2020	0.00	0.25	0.01	0.26	0.27	50.8%	0.52	1.89	3.61	3.23	1.71

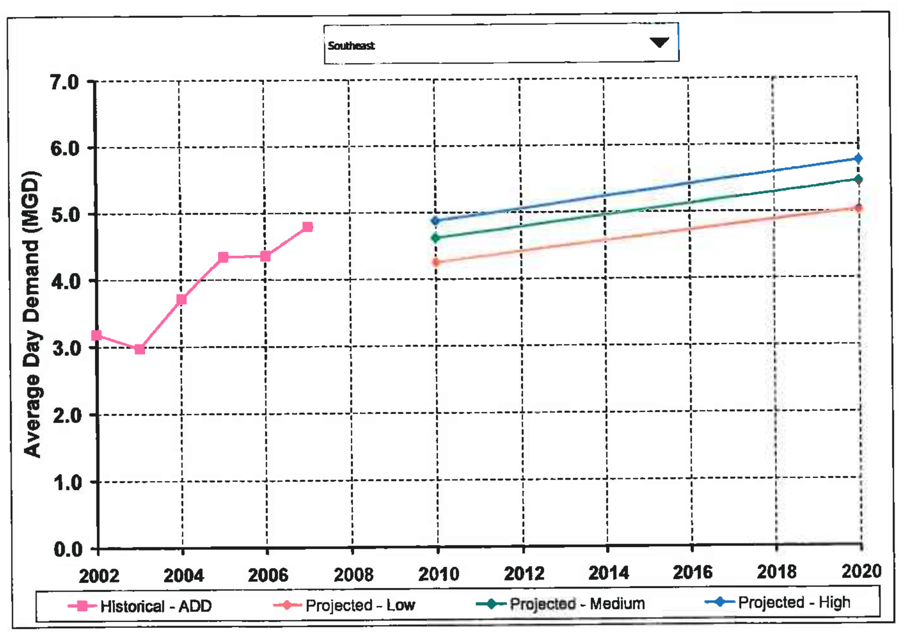


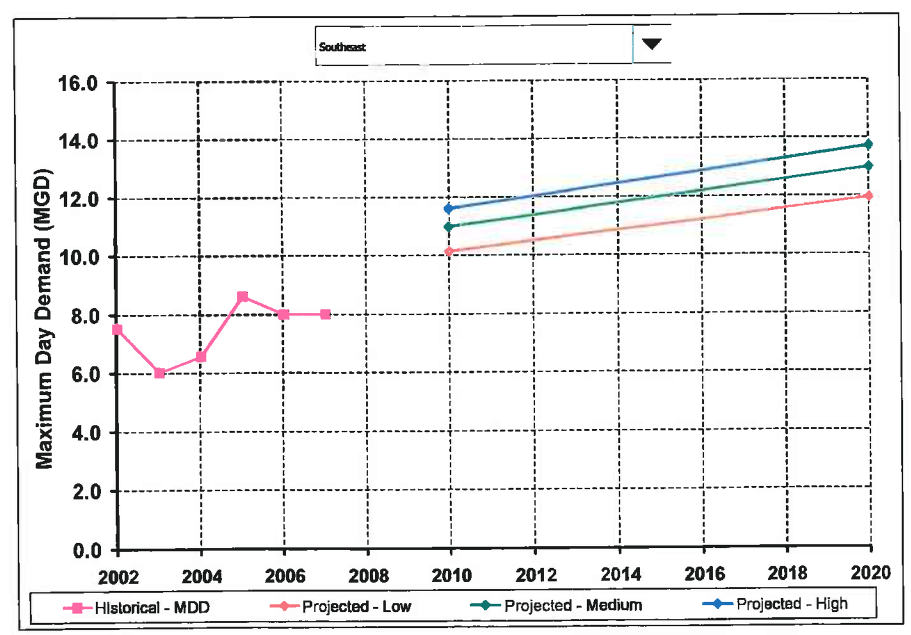


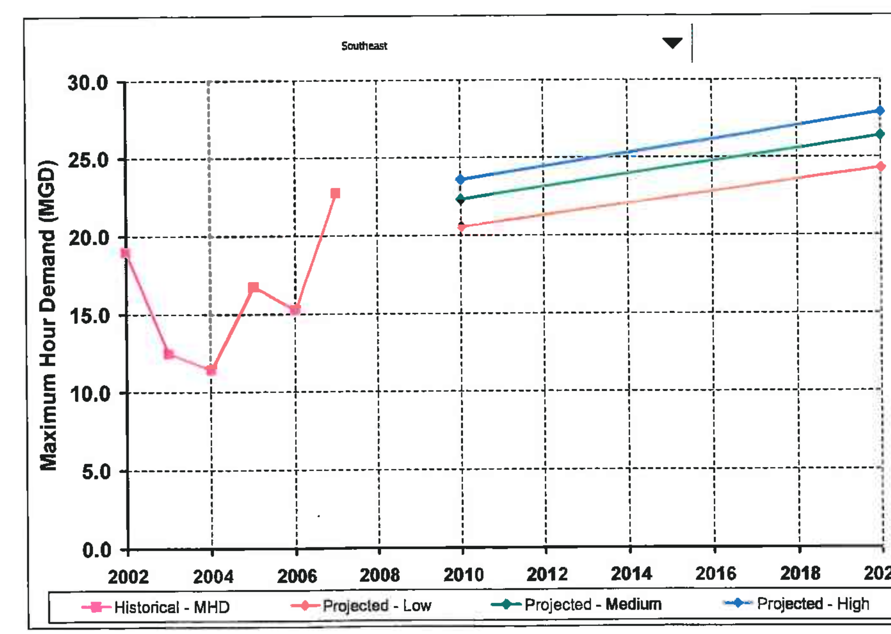


SOUTHEAST

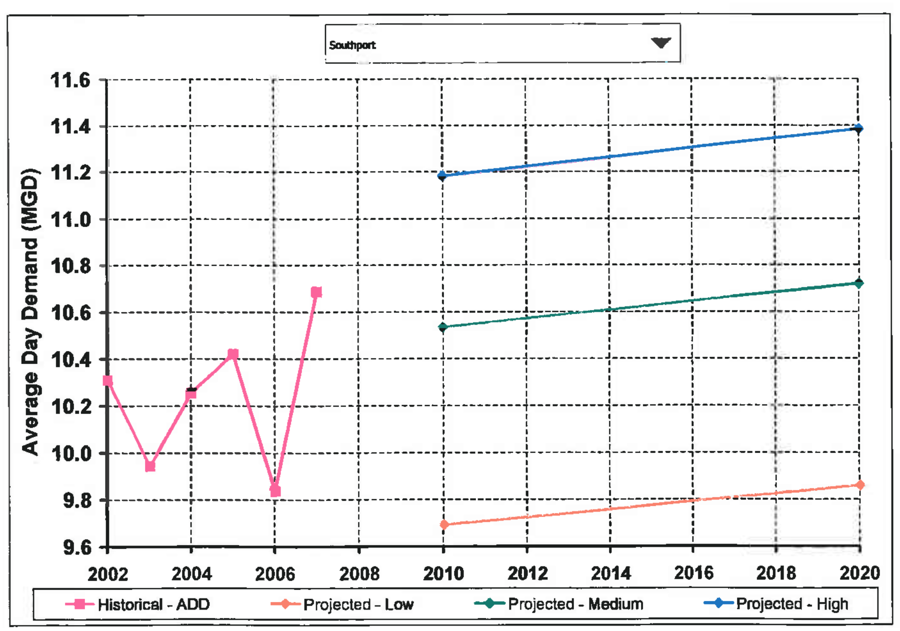
	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	0.74	2.35	0.02	3.11	0.08	2.4%	3.19	7.54	2.37	18.97	2.52
2003	0.86	2.36	0.01	3.23	-0.25	-8.5%	2.98	6.04	2.03	12.47	2.06
2004	0.86	2.85	0.02	3.72	0.00	0.1%	3.73	6.59	1.77	11.41	1.73
2005	0.95	3.05	0.01	4.01	0.34	7.9%	4.35	8.64	1.99	16.73	1.94
2006	0.89	2.71	0.01	3.61	0.75	17.2%	4.37	8.01	1.83	15.26	1.91
2007							4.80	8.01		22.75	
AVG						4.2%					
	Projected - Consumption (MGD)				**Projected - Demand (MGD)**						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	1.00	3.06	0.01	4.07	0.19	4.5%	4.26	10.14	2.38	20.59	2.03
2020	1.21	3.60	0.02	4.83	0.21	4.1%	5.03	11.97	2.38	24.32	2.03
2010	1.05	3.35	0.01	4.41	0.21	4.5%	4.62	10.99	2.38	22.31	2.03
2020	1.27	3.94	0.02	5.23	0.22	4.1%	5.45	12.98	2.38	26.36	2.03
2010	1.09	3.56	0.02	4.66	0.22	4.4%	4.88	11.61	2.38	23.57	2.03
2020	1.32	4.18	0.03	5.53	0.23	4.0%	5.77	13.72	2.38	27.87	2.03

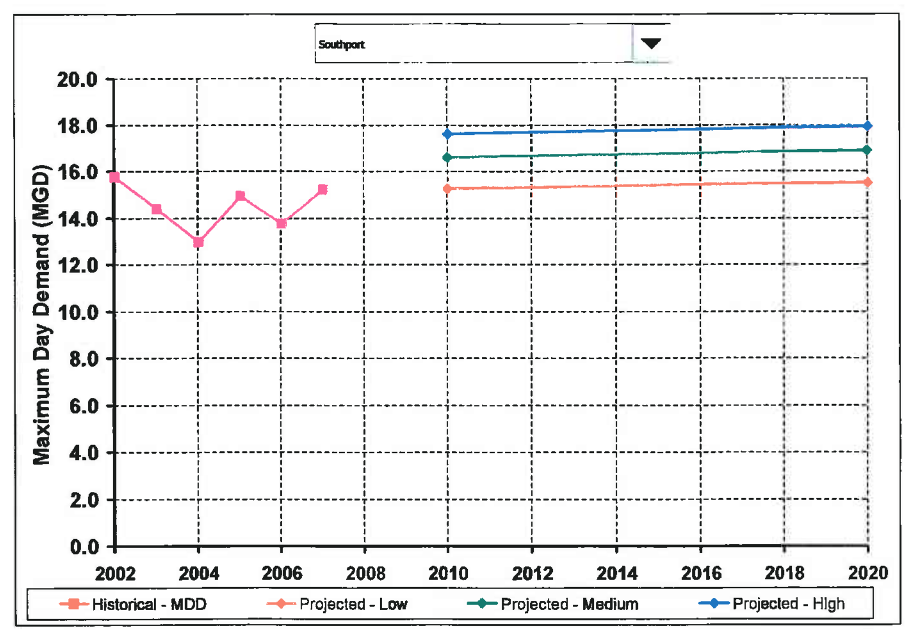






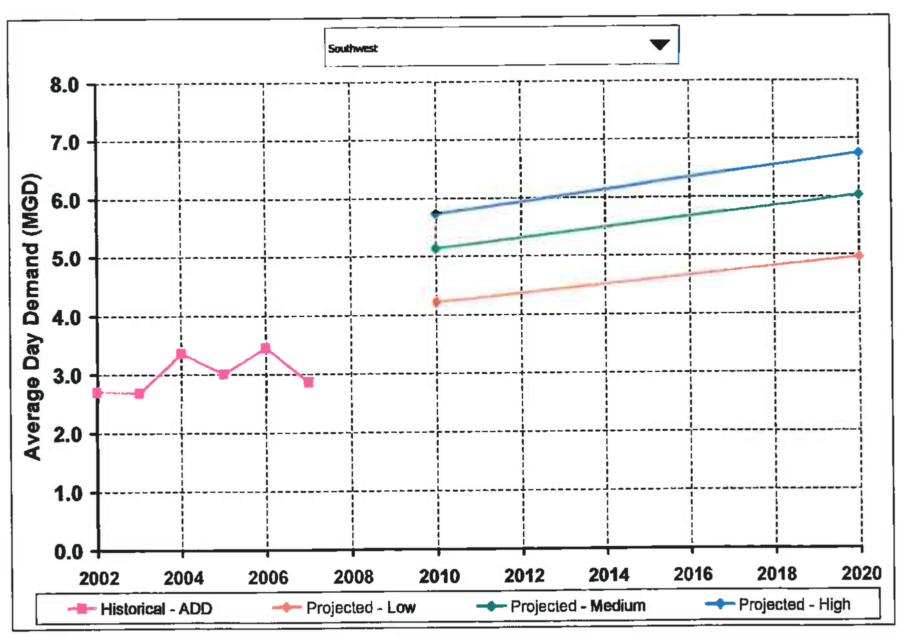
SOUTHPORT											
	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	3.23	5.91	0.06	9.20	1.11	10.8%	10.31	15.78	1.53	39.16	2.48
2003	3.17	5.67	0.06	8.90	1.04	10.4%	9.94	14.44	1.45	23.88	1.65
2004	3.43	5.90	0.07	9.39	0.86	8.4%	10.26	13.00	1.27	35.39	2.72
2005	3.45	5.95	0.08	9.49	0.93	9.0%	10.42	14.97	1.44	20.04	1.34
2006	3.11	6.10	0.06	9.27	0.56	5.7%	9.84	13.80	1.40	35.44	2.57
2007							10.69	15.25		34.33	
AVG						8.4%					
	Projected - Consumption (MGD)				Projected - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	3.11	5.65	0.05	8.82	0.88	9.1%	9.69	15.29	1.58	32.91	2.15
2020	3.25	5.74	0.06	9.05	0.81	8.2%	9.86	15.54	1.58	33.46	2.15
2010	3.34	6.18	0.06	9.58	0.95	9.0%	10.54	16.61	1.58	35.77	2.15
2020	3.49	6.28	0.07	9.84	0.88	8.2%	10.72	16.91	1.58	36.39	2.15
2010	3.57	6.54	0.08	10.19	0.99	8.9%	11.18	17.63	1.58	37.96	2.15
2020	3.73	6.65	0.09	10.47	0.92	8.1%	11.39	17.96	1.58	38.65	2.15

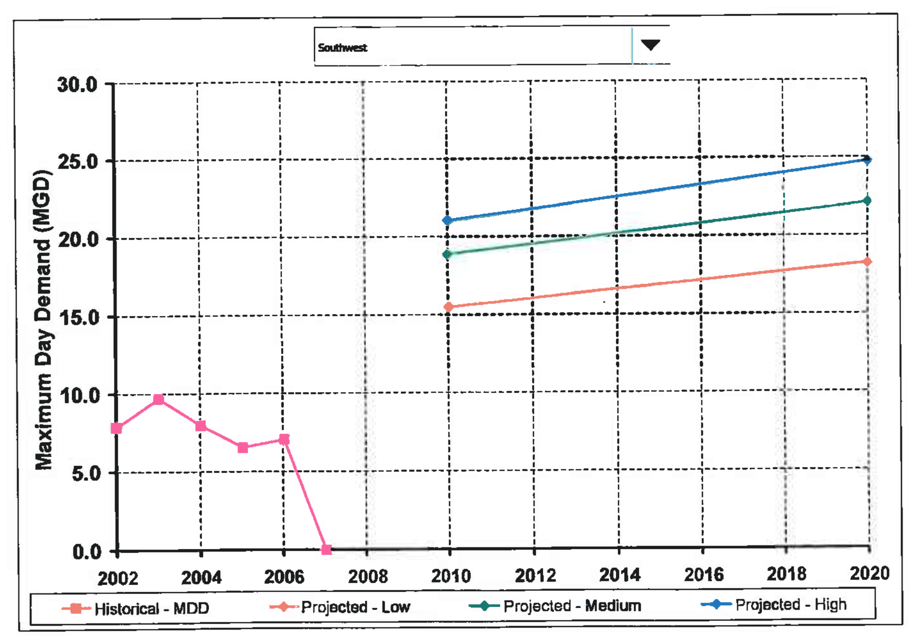


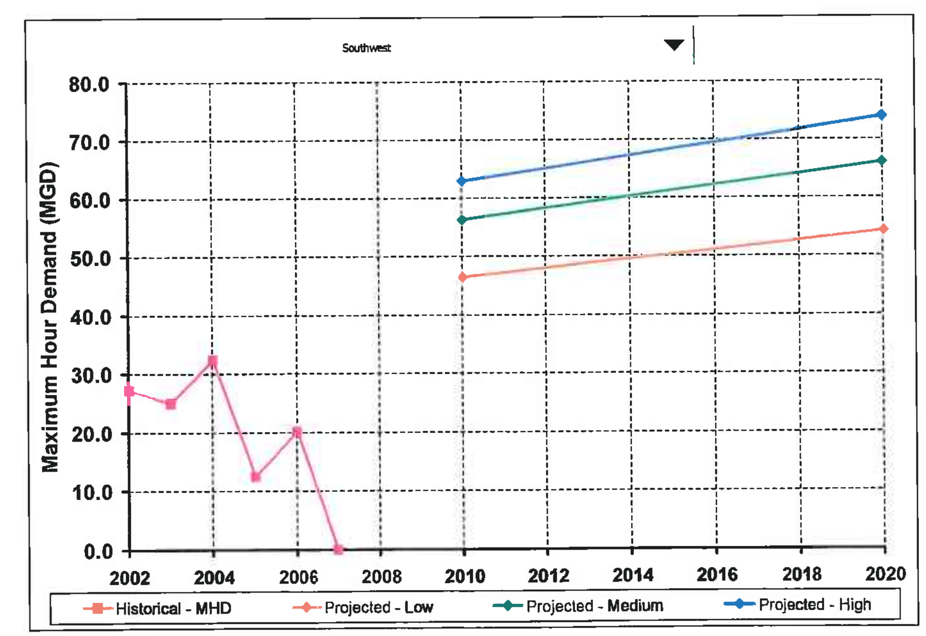


SOUTHWEST

	Historical - Consumption (MGD)				Historical - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2002	0.90	2.72	0.04	3.67	-0.95	-35.2%	2.71	7.84	2.89	27.27	3.48
2003	1.18	2.54	0.02	3.73	-1.04	-38.8%	2.69	9.70	3.60	25.07	2.59
2004	1.38	3.11	0.02	4.51	-1.14	-34.0%	3.36	7.97	2.37	32.48	4.08
2005	1.63	3.29	0.05	4.96	-1.95	-64.9%	3.01	6.55	2.18	12.56	1.92
2006	1.65	2.80	0.02	4.47	-1.01	-29.3%	3.45	7.06	2.04	20.26	2.87
2007							2.86	N/A		0.00	
AVG				4.41808	-1.2887	-41.8%					
	Projected - Consumption (MGD)				Projected - Demand (MGD)						
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	MDD	MDD:ADD	MHD	MHD:MDD
2010	1.09	3.01	0.01	4.12	0.12	2.8%	4.24	15.54	3.67	46.38	2.99
2020	1.29	3.53	0.02	4.84	0.12	2.5%	4.96	18.21	3.67	54.35	2.99
2010	1.57	3.41	0.02	5.00	0.14	2.7%	5.14	18.85	3.67	56.26	2.99
2020	1.85	3.99	0.04	5.88	0.15	2.5%	6.03	22.12	3.67	66.02	2.99
2010	1.82	3.73	0.04	5.58	0.15	2.7%	5.74	21.05	3.67	62.84	2.99
2020	2.15	4.36	0.07	6.58	0.16	2.4%	6.74	24.74	3.67	73.86	2.99







SYSTEM

	Historical - Consumption (MGD)				Historical - Demand (MGD)													
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	Dev ADD	Total ADD	MDD	MDD:ADD	Dev MDD	Total MDD	MHD	MHD:MDD	Dev MHD	Total MHD
2002	51.52	70.54	2.25	124.3	14.07	10.2%	138.4	0	138.4	221.6	1.60	N/A	221.6	300.3	1.36	N/A	300.3
2003	51.02	64.60	2.10	117.7	18.95	13.9%	136.7	0	136.7	205.3	1.50	N/A	205.3	271.4	1.32	N/A	271.4
2004	53.14	69.39	1.81	124.3	17.26	12.2%	141.6	0	141.6	197.1	1.39	N/A	197.1	252.9	1.28	N/A	252.9
2005	53.84	69.26	1.74	124.8	21.47	14.7%	146.3	0	146.3	227.8	1.56	N/A	227.8	306.1	1.34	N/A	306.1
2006	51.99	64.06	1.74	117.8	22.24	15.9%	140.0	0	140.0	204.7	1.46	N/A	204.7	247.0	1.21	N/A	247.0
2007							153.4		153.4	231.1	1.51	N/A	231.1	312.7	1.35	N/A	312.7
AVG						14.2%											

	Projected - Consumption (MGD)				Projected - Demand (MGD)												
Year	Non-Res	Res	Other	Total	UAW	%UAW	ADD	Dev ADD	Total ADD	MDD	MDD:ADD	Dev MDD	Total MDD	MHD	MHD:MDD	Dev MHD	Total MHD
2010	50.76	66.12	1.68	118.6	20.92	15.0%	139.5	0.6	140.1	221.0	1.58	1.3	222.3	287.8	1.30	1.94	289.8
2020	55.09	70.39	1.64	127.1	19.84	13.5%	147.0	0.9	147.9	232.9	1.58	2.0	234.9	303.3	1.30	3.10	306.4
2010	55.38	73.72	2.04	131.1	23.14	15.0%	154.3	0.6	154.8	244.5	1.58	1.3	245.7	318.4	1.30	1.94	320.3
2020	60.44	77.31	2.01	139.8	21.81	13.5%	161.6	0.9	162.5	256.1	1.58	2.0	258.1	333.5	1.30	3.10	336.6
2010	59.99	83.35	2.55	145.9	25.75	15.0%	171.6	0.6	172.2	272.0	1.58	1.3	273.3	354.2	1.30	1.94	356.2
2020	65.68	87.13	2.54	155.3	24.25	13.5%	179.6	0.9	180.5	284.6	1.58	2.0	286.6	370.6	1.30	3.10	373.7