Demand Projections Update Report

City of Hillsboro, Oregon

April 30, 2018

Prepared by HDR Engineering, Inc.

Executive Summary

Background

The City of Hillsboro Water Department (City) has prepared a 2018 update to its water demand projections. The objectives of this update are to:

- Reflect changes in water usage characteristics associated with recent development;
- Capture the range of potential growth related to economic development; and,
- Identify the factors that most impact demand and analyze the sensitivity of demand to those variables.

In the past the City has used traditional demand forecasting approaches using land use based techniques, where water usage factors (e.g., in gallons per acre per day) are applied to projected future growth in land area to be served by the City. This update takes a different approach by using statistical analysis of historical water usage to define relationships between customer demand and influencing variables such as temperature, precipitation, and rates (i.e., price). These relationships are then used to project future demands per account based on potential changes to the influencing variables. This approach is taken where feasible and is then complemented by traditional methods for projecting components of demands for which the historical relationships are not as relevant (e.g., future industrial use, which depends more upon type of development rather than other influencing variables).

This 2018 water demand projection update incorporates future demands associated with redevelopment of Downtown, the development of South Hillsboro (SoHi) over the coming 20 years, the anticipated development of North Hillsboro (NoHi) and, further in the future, additional Future Growth Areas (FGA) on the outskirts of the City.

The demand projections update will be used in a subsequent water rate and system development charges study, including an update of the City's water funds financial model. The demand projections will also be used to support the City's Water Master Plan (WMP) Update, including an assessment of the system's infrastructure needs, development of the City's Water Department Capital Improvement Plan, and associated hydraulic and operations modeling.

Demand Forecast Results

Three scenarios are considered in this demand forecast:

- Low, which includes the impacts of rate increases.
- High, which includes the impacts of climate change (i.e., increasing temperatures and decreasing precipitation during some seasons).
- Baseline, which excludes the impacts of rate increases and climate change.

Figure ES-1 presents the baseline Average Day Demand (ADD) forecast. The figure depicts demands of the City's existing service area by customer class, while demands of future service areas are also shown according to their location (i.e., SoHi, NoHi, and FGA).

This chart depicts system-wide ADD increasing from approximately 20 mgd in 2018, to 49 mgd in 2070. Industrial demand comprises the largest share of the City's current overall demand, with the NoHi and FGA demand components, which include both industrial and residential demand, representing the largest segments of demand growth in the future.

Figure ES-1. Total System-wide Demand Forecast (Average Day Demand)

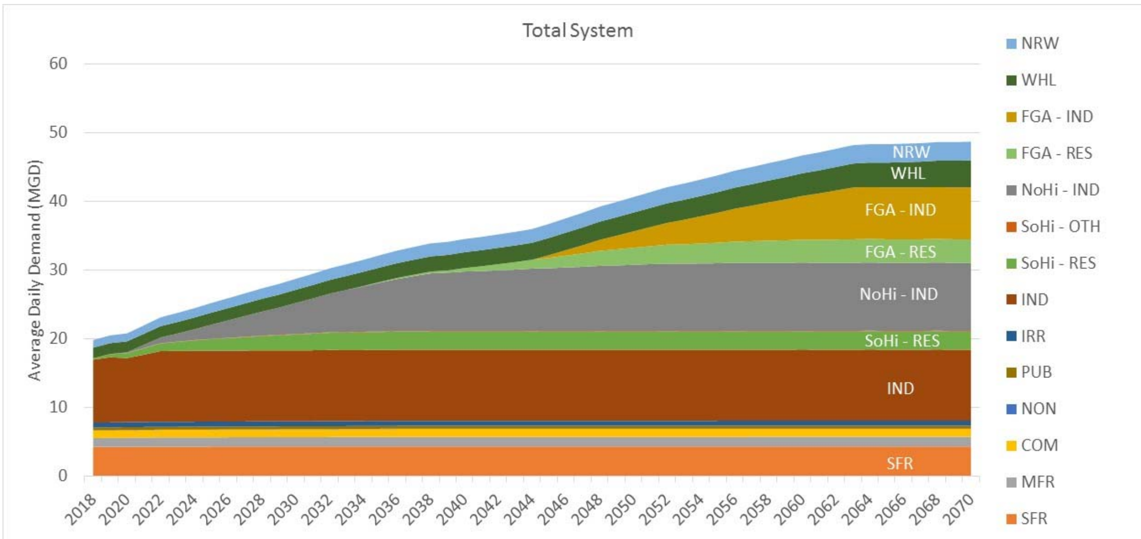
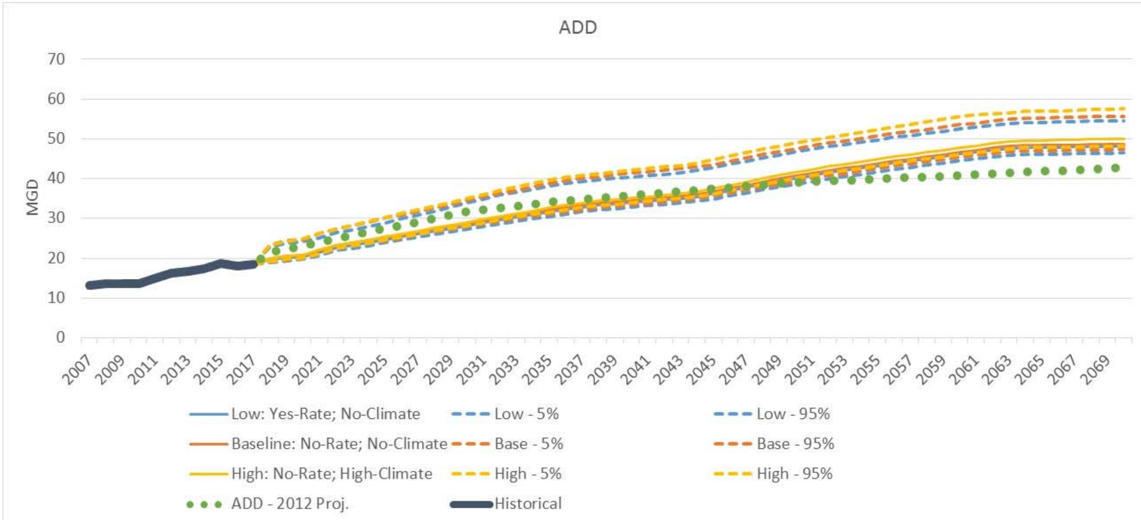


Figure ES-2 presents the system-wide ADD for all three scenarios: Low (considering the impacts for future rate increases), Baseline, and High (considering the impacts of climate change.

The forecasted demands are quite similar amongst the three scenarios. In 2070, the difference between the most likely outcomes for the Low and High scenarios (as represented by the solid lines) is only 2.0 mgd. The primary reason for the similar projections is the large portion of demand represented by industrial demand growth, which is not modeled to be impacted by either rate increases or climate change effects.

Uncertainty in the demand forecast is represented by the dashed lines in Figure ES-2, which indicate the 5th and 95th percentiles associated with each scenario. These capture the ranges in variables that influence projected demand, including weather fluctuations and uncertainty in the amount and timing of growth. Taken in consideration together, these results can be interpreted such that for a particular scenario, there is a 90 percent confidence that projected demand will fall between the dashed lines.

Figure ES-2. ADD (By Scenario and with Uncertainty Ranges)



Also included in Figure ES-2 are historical ADD values for 2007-2017, and the prior demand forecast developed in 2012. The 2018 projection is slightly lower than the 2012 projection for the first 20 years of the forecast period, after which the 2012 projection flattens out while the 2018 projection indicates a continued increase in demands through 2070. The difference in projections in the latter years is attributable primarily to the inclusion of the FGA in the 2018 forecast.

Table ES-1 provides a summary of ADD, Peak Season Average Day Demand (PSD, or the average day demand during the period of May - October), and Peak Day Demand (PDD, or the day of highest projected demand) for key years.

Table ES-1. Demand Forecast Summary (in mgd)

Year	Average Day Demand (ADD)	Peak Season Average Day Demand (PSD)	Peak Day Demand (PDD)
2018	19.8	22.9	35.6
2030	28.7	32.6	49.1
2050	40.6	46.3	68.7
2070	48.7	56.0	82.1

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Acronyms and Abbreviations

ADD	Average Day Demand
ASR	Aquifer Storage and Recovery
CCF	100 cubic feet
COM	Commercial
FGA	Future Growth Area
IND	Industrial
IRR	Irrigation
MFR	Multi-family Residential
MG	Million gallons
Mgd	Million gallons per day
NoHi	North Hillsboro
NON	Nonprofit
NRW	Non-revenue Water
OCCRI	Oregon Climate Change Research Institute
OLS	Ordinary Least Squares
PDD	Peak Day Demand
PRC	Population Research Center (PSU)
PSD	Peak Season Average Day Demand
PSU	Portland State University
PUB	Public
SFR	Single-family Residential
SoHi	South Hillsboro
SoHi-OTH	South Hillsboro Non-Residential
WHL	Wholesale
WMP	Water Master Plan

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1 Introduction

1.1 Purpose

This document summarizes an update to the water demand projections for the City of Hillsboro Water Department (City). The objectives of this update are threefold:

- Reflect changes in water usage characteristics associated with recent development.
- Capture the range of potential growth related to economic development.
- Identify the factors that most impact demand and analyze the sensitivity of demand to those variables.

The demand projections update will be used in a subsequent water rate and system development charges study, including an update of the City's water funds financial model. The demand projections will also be used to support the City's Water Master Plan (WMP) Update, including an assessment of the system's infrastructure needs, development of the City's Water Department Capital Improvement Plan, and associated hydraulic and operations modeling.

1.2 Prior Demand Forecast Efforts

This update is the latest in a series of water demand forecasts prepared by and for the City. Prior forecasts include:

- Demand projections related technical memorandum from *Water System Master Plan Volume 1 and 2*, Black and Veatch, 2013.
- *Demand Projections Update Memo*. City of Hillsboro, 2012.
- *Demand Scenarios and Updated Projections* technical memorandum, HDR, 2015.

These prior forecasts were developed primarily using traditional, land use based techniques, where water usage factors (e.g., in gallons per acre per day) are applied to projected future growth in land area to be served by the City. This update takes a different approach by using statistical analysis of historical water usage to define relationships between customer demand and influencing variables such as temperature, precipitation, and rates (i.e., price). These relationships are then used to project future demands per account based on potential changes to the influencing variables. This approach is taken where feasible and is then complemented by traditional methods for projecting components of demands for which the historical relationships are not as relevant (e.g., future industrial use, which depends more upon type of development rather than other influencing variables.)

1.3 Report Organization

Section 2 of this summary report provides an overview of the methodology used to prepare the forecast, Section 3 presents detailed results of the statistical analysis (i.e., regression modeling), and Section 4 presents a summary of the resulting demand forecast and key findings. Detailed output is contained within a spreadsheet-based model prepared for the City by HDR Engineering, Inc. (HDR).

2 Methodology

This section documents the methodology used to prepare the water demand forecast update. An overview of the various approaches employed is provided first, followed by more detailed descriptions of each.

2.1 Overview

The demand forecast was constructed using a risk-based format that integrates the uncertainty associated with multiple variables to generate a broad perspective on future demand. Within this over-arching framework, two general approaches were used to forecast the different components of demand, to best align the forecasting methodology with available data and the characteristics of each component. These approaches are defined as:

- **Forecasting Approach 1: Regression Modeling.** This approach uses statistical analysis to explore the historical relationships between demand and influencing variables in order to develop models that can predict future demand based on changes to those influencing variables. This approach was used to forecast demand for the following customer classes in the areas currently served by the City: Single-Family Residential (SFR), Multi-Family Residential (MFR), Commercial (COM), Public (PUB), Non-Profit (NON), and Irrigation (IRR). In addition, this approach was used to project SFR and MFR demand in the South Hillsboro (SoHi) growth area.
- **Forecasting Approach 2: Traditional Methods.** This approach involves multiple traditional demand forecasting methods. The predominant method is land use based forecasting (i.e., applying water use factors to areas of land). This is used in the forecast of future demands from current industrial customers (IND), and additional industrial growth projected to occur mainly in the North Hillsboro (NoHi) growth area and other Future Growth Areas (FGA). In addition to this method, other traditional techniques are used in specific instances where regression modeling or other methods are not suitable given the nature of the data or characteristics of use. These are discussed in more detail in the sub-sections that follow.

The demand forecast has been prepared for the entire City service area. Figure 1 shows the various geographic areas within the City's In Town system, including the existing service area, SoHi, NoHi (which includes ongoing development in North Hillsboro and Jackson East), and FGA. The latter are included because this is a long-range forecast, extending to 2070. The water service provider has not been determined for all portions of the FGA, but the City is including them in planning efforts to ensure adequate service can be provided if needed and to inform regional planning efforts. Also included, though not shown on Figure 1, are the demands associated with the City's Upper System (i.e., Cherry Grove).

Table 1 provides an overview of the various demand projection approaches and how they were applied to the existing and future components of the City's service area.

Figure 1. In Town Areas Included in Demand Forecast

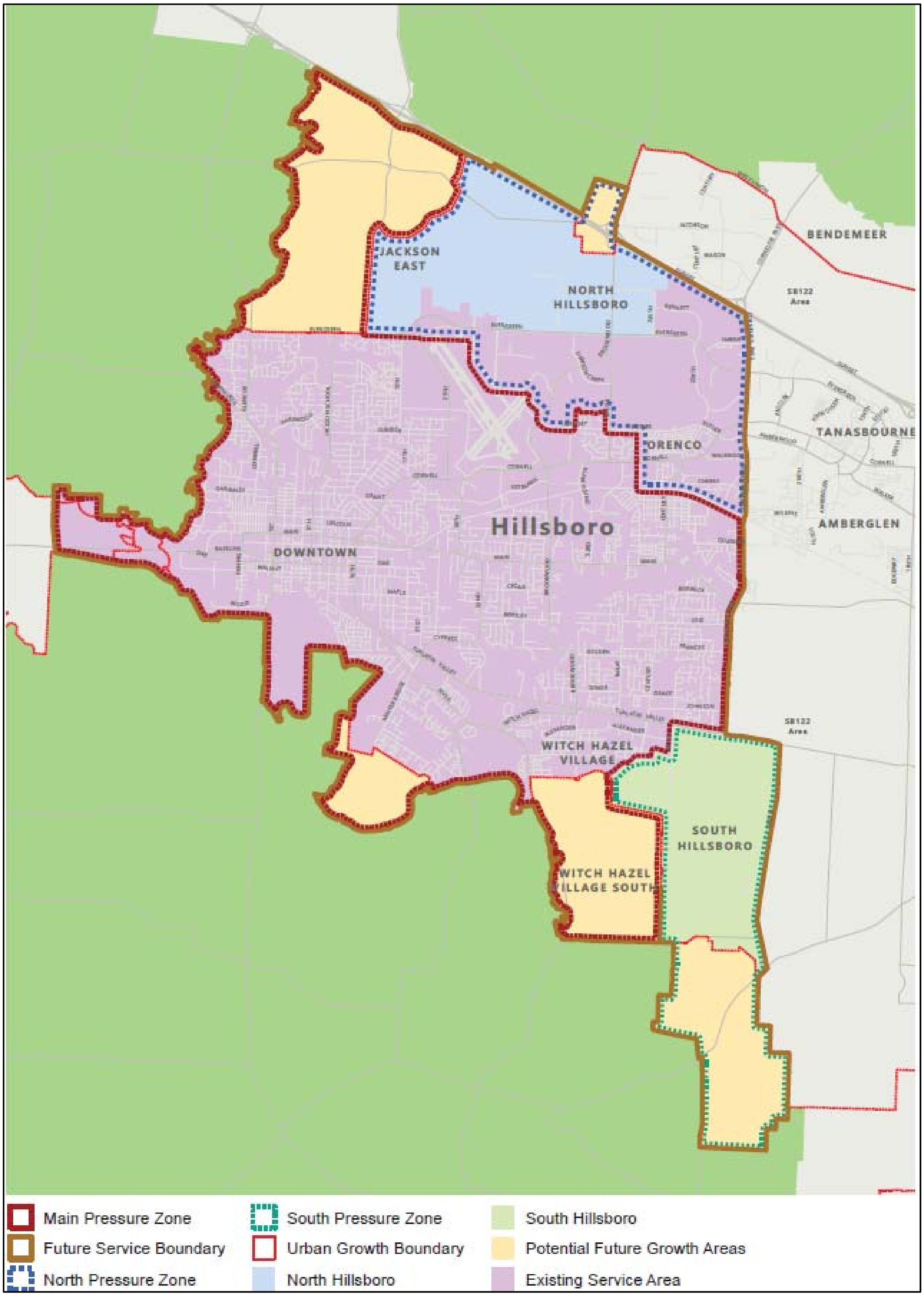

Table 1. Demand Projection Approach Overview

Method Summary			Description in Report Section	Retail Customer Classes						
				SFR	MFR	COM	NON	PUB	IND	IRR
Existing Service Area Component										
In Town	Existing Demand	Statistical regression modeling used to explore relationship between demand and influencing variables in order to develop models which can predict future demand based on changes to those variables. This approach was used to forecast SFR, MFR, COM, PUB, NON, and IRR. Time series model for industrial demand projection based on historical trends and industry forecasts. National and global market forces are the primary drivers of industrial production, not environmental, demographic, or water rates. IRR demands forecasted with a regression model which accounts for temperature and precipitation only, and not water rates.	SFR: 2.2.1, 3.2 MFR: 2.2.1, 3.3 COM: 2.2.1, 3.4 NON: 2.2.1, 3.6 PUB: 2.2.1, 3.5 IRR: 2.2.4 IND: 2.3; 4.1, 4.2	R	R	R	R	R	T	R*
	Future In-Fill	Potential for additional SFR units on 274 vacant tax lots. Includes 11.3 acres of vacant lands for an estimated additional 9 MFR accounts to be added over a 5-year period and completed by the end of 2022.	2.2.6, 3.2.2, 3.3.2	R	R	R	--	--	--	--
	Future Downtown Redevelopment	336 acres expected to be redeveloped over the next 20 years to same level of density as Orenco Station Community Area. Existing accounts in the downtown area were subtracted from the overall projection, and new accounts were added to SFR, MFR and COM customer classes.	2.2.6	R**	R**	R	--	--	--	--
Cherry Grove	Existing Demand	Based on both In Town and Cherry Grove accounts for MFR, COM, NON, PUB, IND, and IRR. A separate regression was conducted for SFR since SFR is the predominant customer class in Cherry Grove.	SFR: 3.2.3 All other classes: 2.2.2	R	R	R	R	R	T	R*
Future Service Area Component										
North Hillsboro (NoHi)	Industrial	1,360 acres (including Jackson East) available for development into four industrial land use categories: High Tech, Data Centers, Industrial, and Business Park	2.3; Appendix A	--	--	--	--	--	T	--
South Hillsboro (SoHi)	Residential	In order to capture water use characteristics in denser and more recent developments: ▪ SFR based on 3 clusters of In Town parcels (251 accounts) developed since 2012 ▪ MFR based on 6 accounts developed In Town since 2012	2.2.6; Appendix A	R**	R**	--	--	--	--	--
	Non-Residential	Based on billing records for similar existing accounts for new parks, schools, home owners association irrigation, and retail/office space	2.3; Appendix A	--	--	R	R	R		R*
Future Growth Areas (FGA)	In Town Residential	Includes 62 acres in SW Corner of Hwy 26 and Brookwood, 940 acres in Witch Hazel Village South, 361 acres in Southwest Hillsboro, 958 acres in South of South Hillsboro, and a portion of 1,769 acres in West of Jackson East. Assumed to develop similarly to South Hillsboro.	2.3; Table 7	R**	R**	--	--	--	--	--
	In Town Industrial	Includes 74 acres in NW Corner of Hwy 26 and Brookwood and a portion of 1,769 acres in West of Jackson East. Assumed to develop similarly to North Hillsboro.	2.3; Table 7	--	--	--	--	--	T	--
Additional Demand Components										
Wholesale (WHL)	LA Water Co-Op	Average daily demand predicted based on historic demand and population growth rate projections for Cherry Grove Service Area	2.4.1; Appendix B	O						
	City of Gaston	Four demand scenarios developed based on historic demand, a range of potential growth outcomes, and water loss reductions. The two most likely scenarios to occur are (1) low population growth with no change to water loss, and (2) high population growth with reduced water loss.	2.4.1; Appendix B	O						
	City of Cornelius	Four demand scenarios developed based on historic demands, estimated population growth, water loss reductions, and planned ASR well installations in 2019 and 2027. The two most likely scenarios to occur are: (1) low population growth with no change in water loss, and (2) high population growth with reduced water loss.	2.4.1; Appendix B	O						
Non-Revenue Water (NRW)	In Town and Cherry Grove	Non-revenue water is calculated by subtracting billed water consumption from total water production. Produced water is calculated by summing the metered monthly usage through Hillsboro's 14 meters, which deliver water from the City's two supply sources.	2.4.2; Table 8	O						

Notes:
R = Statistical Regression Modeling accounting for multiple variables (temperature, precipitation and water rates)
R* = Statistical Regression Modeling accounting for weather indicators of temperature and precipitation only (no rates)
R** = Statistical Regression Modeling based on a subset of accounts representing recent growth trends
T = Traditional Forecasting Method based on historical trends and water use factors per land area
-- = Not Analyzed
O = Other – based on separate forecasting efforts or existing relationships with other demand components

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Three scenarios were considered in the demand forecast, to consider the impacts of future rate adjustments and climate change, as summarized in Table 2.

Table 2. Demand Forecast Scenarios

Scenario	Impacts from Future Rate Adjustments Considered?	Impacts from Climate Change Considered?
Low	Yes	No
Baseline	No	No
High	No	Yes

For each scenario uncertainty in the forecast is also determined and expressed in the form of 5th and 95th percentiles, to capture the range of variability in key inputs of the model.

2.2 Forecasting Approach 1: Regression Modeling

2.2.1 Overview

Statistical regression models find mathematical relationships between a response (dependent) variable and one or more independent variables which are thought to influence the values in the response variable. The City's primary objective in this analysis is to understand the relationship of average monthly water consumption per account for different customer classes to that of water rates (i.e., price), weather indicators and growth and development. If the relationship can be quantified such that for every unit of change in the rates or weather indicators a specified impact on demand occurs, the City could then estimate what the average consumption per account would be. In this manner, forecasts of average monthly consumption over a desired time horizon would be possible based on forecasted rates, weather patterns and/or population statistics.

A detailed regression modeling approach was applied to the following customer classes: SFR, MFR, COM, PUB, and NON. The forecast of IRR demands utilized a simplified (i.e., non-statistically based) regression modeling approach based on relating demand to temperature and precipitation, due to the seasonal nature of the available data which limited the analysis. This is described in Section 2.2.4.

2.2.2 Data Sources

City of Hillsboro Billing Data

Detailed customer billing data for the classes of customers for which this approach was employed was available for the time period of 2014 to 2016. In addition, average monthly consumption per account was available for the years 2006 to 2010 for all customer classes. A gap in account level data exists between 2010 and 2014, due to a shift in the City's billing system.

Before the 2014 to 2016 billing data could be incorporated into the regression modelling process, the data had to be aggregated to produce an average monthly consumption per account for a given customer class. Billing cycles for customers varied from monthly, bi-monthly, and other intervals. For accounts with bi-monthly billing, their billing was distributed evenly over a two month period of usage. Accounts with uneven or infrequent billing cycles were removed from the analysis. Such accounts represented less than one percent of the total number of accounts, which was determined to not have a significant impact on the analysis.

Within the customer classes evaluated, certain sub-accounts were of interest and analyzed separately. These are:

- SFR accounts in the Cherry Grove area. The predominant customer class in this area is SFR, so that was the only class for which regression modeling was conducted specifically for Cherry Grove. For the other customer class accounts present in this area, which represent a minimal amount of demand, regression models were constructed based on all accounts in the In Town and Cherry Grove Systems.
- SFR and MFR accounts in the In Town System associated with recently developed parcels. The purpose of analyzing these subsets was to capture differences in water use characteristics associated with more recent, typically denser, development, which was then applied to projected future accounts in newly developing areas (i.e., South Hillsboro). For SFR, three clusters of parcels developed since 2012 were selected to represent recent development in this customer class, totaling 251 accounts. For MFR, six accounts were identified by City staff as having been developed within the past five years, and were chosen to represent recent development in this customer class. All these accounts were located in the In Town System. These assumptions were vetted with City Planning staff.

Table 3 shows the breakdown of the customer account types based on the 2014-2016 years of billing data.

Table 3. Number of Accounts with at Least One Bill during 2014 to 2016

Account Type	Number of Accounts
SFR (In Town)	26,027
SFR (Recent Development)	251
SFR (Cherry Grove)	480
MFR	305
MFR (Recent Development)	6
COM	1,046
PUB	115
NON	76
IRR	385

Average monthly water consumption usage (in units of 100 cubic feet, CCF) for the customer classes was available from a similar study conducted by HDR in 2010. At that time, account level billing data was previously aggregated at the monthly level by customer class for years 2006 to 2010. The data from this study supplemented the average monthly consumption trends observed over the recent 2014 to 2016 billing period where possible, so as to provide for a longer data set of average monthly usage per account.

Variables Tested in Regression Analysis

The regression analysis tested several variables to determine if they had a statistically significant influence on demands. Variables that passed the test were carried forward in analysis, and the others were dropped. The variables were of several types: environmental, demographic and economic. Table 4 presents the list of data sources used in defining the independent variables evaluated in the regression analysis.

Table 4. List of Data Sources Used for Regression Modeling

Data Type	Data Frequency	Source
Environmental		
Temperature, Precipitation, Evapotranspiration	Daily	Pacific Northwest Region Hydromet / AgriMet - https://www.usbr.gov/pn/agrimet/webarcread.html
Demographic: Population & Housing		
Population, Household Population, Number of Housing Units and Households, Average persons per Household, Vacancy Rate	Annual	Population Research Center, Portland State University
Economic: Employment		
County Employment Rate	Monthly	Bureau of Labor Statistics - https://www.bls.gov/eag/eag.or.htm
Economic: Water Rates		
Rates by customer class, meter size and block sizes (i.e., tiers)	Annual	City of Hillsboro Utilities Commission - Water Rates

2.2.3 Development of Regression Models

Regression analysis provides a means to relate a variable which one wants to estimate as a function of other variables whose values can be obtained either historically or by means of forecasted values. The variable of interest is termed the response or dependent variable and in this evaluation, is demand in terms of the average monthly usage per account at a given month in time. The variables from which relationships are to be quantified are termed independent variables. The independent variables used in this study are the average daily temperatures and precipitation in each month, and volume rate charged for every CCF of water consumption in a given month.

The regression method used is the Cochrane-Orcutt Regression method which is a special type of ordinary least squares (OLS) regression. OLS regression assumes that the error components from the model are independent from one observation to the next. If the error terms are not independent, i.e., serially correlated (autocorrelated), estimates of error variance (mean square error or regression mean square error) and variance of regression coefficients are underestimated and the confidence intervals are inaccurate.

One remedy for serial correlated data is the Cochrane-Orcutt Regression procedure. The basic steps to conduct this procedure are as follows:

1. *Ordinary least squares*. Regression coefficients and residuals are estimated using OLS.
2. *Estimation of serial correlation* (ρ). The serial correlation is estimated from the current residuals $\left(e_t = Y_t - \hat{Y}_t\right)$ using the formula:

$$\hat{\rho} = \frac{\sum_{t=2}^{n} e_t e_{t-1}}{\sum_{t=2}^{n} e_{t-1}^2}$$

3. *Obtain transformed data*. Create new data set using the following:

$$Y_t' = Y_t - \hat{\rho} Y_{t-1}$$

$$X_t' = X_t - \hat{\rho} X_{t-1}$$

4. *Fit model to transformed data*. OLS is then used to fit regression to transformed data.

$$Y_t' = b_0' + b_1' X_{1t}$$

5. *Create the regression model for the untransformed data.* The regression equation of the untransformed data is created using:

$$b_0 = \frac{b_0'}{1 - \hat{\rho}}$$

$$b_1 = b_1'$$

6. *Iterate until convergence is reached*. Steps 2-4 are repeated until ρ stabilizes (usually 4-5 iterations).

7. *Calculate Durbin-Watson test on transformed residuals*. The Durbin-Watson test indicates if the effects of serial correlation have been reduced. If the test is not rejected at a given probability level (10 percent in this analysis), then impacts from serial correlation has been reduced from the series. The Durbin-Watson test results for all models developed in this analysis indicate that serial correlation had been reduced after coefficient estimates had been revised according to the Cochrane-Orcutt method.

Other diagnostics used to assess the models tested per customer class were the overall goodness of fit as captured in the adjusted R^2 statistics. The closer the value is to 1, the more accurate are the model's coefficients in estimating the value of the dependent variable (demand) as a function of the independent variables (e.g., temperature). An R^2 of 1 denotes an error-free model which is unlikely as all models have a level of error in their estimates. Models with R^2 values greater than 0.7 are considered good fit models in this study and can be used for forecasting purposes.

Another consideration in the selection of the final models is whether the independent variables are not functions of each other. OLS and other types of regression models require that each independent variable cannot be expressed as a function of any other independent variable in the model. Variables were checked using correlation coefficient statistics to ensure variables were independent of each other. Independent variables could remain in the model provided that their correlation coefficient with any other variable in the models was less than 0.7.

The variables explained in Table 4 were all tested for statistical significance in the models. This is determined based on examination of the p-values, which indicate the probability of whether the relationship being tested is random or not. If not random, the p-value would be less than 10 percent. The smaller the p-value, the more likely that the relationship between the dependent variable and independent variable is due to a real relationship which is quantified by the coefficient associated with the independent variable. In this study, only variables with p-values 10 percent or less remained in the models as those with p-values higher than 10 percent are not statistically significant and do not provide information to help with forecasting of average monthly water consumption per account. Variables which were tested and had p-values greater than 10 percent, and hence were not included in the models, are monthly total population, household population, count of housing units, counts of households, average persons per household, County employment rates, and vacancy rates. The statistically significant variables vary by customer class and are discussed in more detail in Section 3.

2.2.4 Regression Modeling of Irrigation

The demands associated with the IRR customer class were treated in a simpler fashion than the OLS method, since their seasonality does not support the same approach taken with the other customer classes. A regression was made that developed a relationship between temperature and precipitation and the level of irrigation demand. This was incorporated into the model to define monthly irrigation demands.

2.2.5 Projections of Weather and Rate Variables

Projections of independent variables that were found to influence water demands (temperature, precipitation, and water rates) are then applied to the regression models to determine future water usage on a per account basis as a dependent variable. In order to predict future water usage, information on future temperature, precipitation and rates needed to be gathered or developed. The regression models are applied differently in the three scenarios: baseline, low and high. Data used for the projections of independent variables were:

- Baseline Scenario. In the Baseline scenario, the effects of water rate changes and climate change are not considered. As such, rates are held constant, and the natural variability in temperature and precipitation over the period of record of 1970–1999 is assumed. This is to remain consistent with the assumptions used by the Oregon Climate Change Research Institute (OCCRI) in projecting future effects of climate change, which are described below. As such, monthly data from the Pacific Northwest Hydromet system were used to define the baseline weather parameters.

- Low Scenario. In the Low scenario, the effects of increasing water rates are considered. Table 5 summarizes potential rate increases (expressed as percentage increases over prior year), as provided by the City, that were assumed to reflect the potential for rates to rise in order to support revenue requirements of the utility.

  Table 5. Potential Rate Increases

Year	Potential Annual Rate Increase
2019-2025	11%
2026	7%
2027 and beyond	3%

  To acknowledge that there is a limit to the amount customers will decrease water usage as a function of increasing rates (i.e., utilities typically observe a minimum usage threshold below which demand does not fall, mainly to support indoor water usage for domestic purposes), a rate "floor" was integrated into the models. This "floor" was defined on a monthly basis by customer class, based on a review of historical water usage characteristics for the years considered in the regression model analysis (2006–2010; 2014–2016). For non-peak season months, the observed minimum usage per account was taken to be the "floor." For peak season months, usage was allowed to go 5 percent below the observed minimum, based on the general reduction in summer-time demands that other utilities have observed as a function of rate increases. Additional detail regarding these assumptions is provided in Appendix A.

- High Scenario. In the High Scenario, the effects of climate change are considered by shifting temperature and precipitation, as set forth in a range of scenarios developed by OCCRI. Figure 2 presents the "Low" and "High" emission scenarios defined in OCCRI's Third Oregon Climate Assessment Report (2017). For this analysis, the "High" emission scenario is considered in the High demand forecast scenario. Seasonal effects on temperature and precipitation are factored into the monthly-based regression models, and the uncertainty associated with the range of values in the High emissions scenario are included in the demand forecast uncertainty analysis.

Figure 2. Projected Climate Change Impacts on Weather Variables

Table 2.2 Projected future changes in Oregon's mean annual and seasonal temperature (°F) from the historical baseline (1970–1999) for mid- and late-21st century under a low (RCP 4.5) and a high (RCP 8.5) future emissions pathway. Given are the average changes (bolded) from 35 global climate models and the 5th to 95th percentile range across the 35 models. (Data source: Rupp *et al.*, 2016)

	2050s		2080s	
	Low	High	Low	High
Annual	**3.6°F** (1.8, 5.4)	**5.0°F** (2.9, 6.9)	**4.6°F** (2.1, 6.7)	**8.2°F** (4.8, 10.7)
Winter (DJF)	**3.3°F** (1.6, 5.1)	**4.5°F** (2.4, 6.5)	**4.2°F** (1.8, 6.5)	**7.4°F** (4.2, 9.8)
Spring (MAM)	**3.1°F** (1.4, 5.0)	**4.1°F** (2.0, 5.9)	**3.8°F** (1.7, 6.0)	**6.7°F** (3.8, 9.2)
Summer (JJA)	**4.5°F** (2.2, 6.8)	**6.3°F** (3.6, 8.9)	**5.5°F** (2.7, 8.3)	**10.2°F** (6.5, 13.9)
Fall (SON)	**3.7°F** (1.5, 5.4)	**5.2°F** (2.6, 7.0)	**4.7°F** (2.0, 6.9)	**8.6°F** (4.6, 11.4)

Table 2.3 Projected future relative changes in Oregon's total annual and seasonal precipitation (%) from the historical baseline (1970–1999) for mid- and late-21st century under a low (RCP 4.5) and a high (RCP 8.5) future emissions pathway. Given are the average changes (bolded) from 35 global climate models and the 5th to 95th percentile range across the 35 models. (Data source: Rupp *et al.*, 2016)

	2050s		2080s	
	Low	High	Low	High
Annual	**1.9%** (−4.9, 9.0)	**2.7%** (−6.0, 11.4)	**3.4%** (−5.6, 15.3)	**6.3%** (−5.2, 19.9)
Winter (DJF)	**4.9%** (−6.4, 16.5)	**7.9%** (−4.7, 24.3)	**7.3%** (−6.3, 19.9)	**14.5%** (−2.8, 37.1)
Spring (MAM)	**1.9%** (−8.9, 12.1)	**2.7%** (−7.2, 17.4)	**3.4%** (−7.7, 14.9)	**3.6%** (−9.4, 15.6)
Summer (JJA)	**−6.3%** (−28.5, 16.1)	**−8.7%** (−33.1, 22.5)	**−4.6%** (−24.2, 22.3)	**−7.7%** (−38.7, 33.5)
Fall (SON)	**0.5%** (−17.0, 14.4)	**−0.8%** (−17.1, 14.9)	**1.5%** (−15.0, 18.1)	**1.9%** (−17.2, 24.2)

Source: OCCRI Third Oregon Climate Assessment Report (2017). Note: Only the "High" emission scenario is used in the High Scenario for demand projections.

2.2.6 Projections of Account Growth

The monthly water usage factors derived from the regression models are then multiplied by increases in projected account growth to arrive at overall demand for a customer class. The following assumptions were made regarding account growth. Customer class accounts included in the regression modeling but not specifically listed below were assumed to remain at current levels and experience no growth.

- In-Fill Growth in In Town System. Based on discussions with City Planning staff, the majority of the City's existing service area (with the notable exceptions of South Hillsboro, described below, and North Hillsboro, described in Section 2.3) is built-out. As such, only minor account growth in the SFR and MFR categories is assumed. A review of vacant tax lots within the In Town System indicates the potential for 274 additional SFR units within the existing service area, not including South Hillsboro and redevelopment potential that would exist with rezoning. Similarly, there are approximately 11.3 acres of vacant land zoned for MFR. Using a ratio of existing of 0.75 MFR accounts per acre, determined from review of MFR account and GIS land area data, this translates to an additional nine MFR accounts. This in-fill growth is assumed to occur over a five-year period and to be completed by end of 2022.

- Downtown Redevelopment Potential. The demand forecast assumes that a portion of the Downtown area will redevelop to be similar to the Orenco Station area. This is incorporated by assuming that 336 acres in the Downtown area (i.e., the size of the Orenco Station Community Plan area, which is equivalent to approximately 25 percent of the Downtown area) will redevelop to the same level of density as Orenco Station over the next 20 years. Table 6 summarizes the number of existing accounts that were subtracted from the demand and the number of new accounts that were added to reflect this redevelopment.

Table 6. Downtown Redevelopment Summary

	SRF	MFR	COM
Existing Accounts Subtracted	120	7	23
New Accounts Added	361	23	51

- South Hillsboro Residential Development. SFR and MFR account growth in SoHi is based on the most recent projections developed by City Planning staff, as documented in Appendix A. In summary, over the period of 2018-2037, it is assumed that 4,525 new SFR accounts come online in this area. During that same time frame, it is assumed that 449 MFR accounts come online, based on converting the available MFR acreage (596) to number of accounts based on the MFR account-to-acreage factor of 0.75, described above. The growth of these accounts over time is assumed to be according to the absorption schedule depicted in Appendix A. Non-residential demands in SoHi are addressed in Section 2.3.

2.3 Forecasting Approach 2: Traditional Forecasting

Traditional demand forecasting techniques were used to support projections for the components of the demand forecast for which regression modeling was not appropriate. The results for these components were then compiled with the results from Approach 1, according to the overview presented in Table 1. These traditional forecasting techniques are described below, organized according to customer class and geographic location.

2.3.1 Existing Industrial Demand (IND)

Regression modelling to project industrial demands was not performed because the driving variables in the regression analysis (temperature, precipitation, price), are not the driving factors for industrial production. Market forces, national and globally, are likely the most responsible factor in determining industrial output. Thus, time-series modeling based in historical trends and industry forecasts for the existing industrial customer base were used to determine the ongoing future base of industrial demand associated with current accounts. In the results tables and charts in Section 4, this component of demand is denoted as IND.

2.3.2 North Hillsboro Industrial Demand (NoHi-IND)

Industrial demand growth is projected to be substantial in NoHi. There are approximately 1,360 acres available in this area, including in the area referred to as Jackson East, to support development in the four industrial categories listed in Table 7. Key assumptions used to generate acreage-based demand forecasts for these categories, based on data obtained from City Planning and Economic Development staff and independent research conducted by HDR, are also included in the table. Details supporting these assumptions, including development timelines for specific portions of NoHi may be found in Appendix A. In the results tables and charts in Section 4, this component of demand is denoted as NoHi-IND.

Table 7. North Hillsboro Industrial Demand Forecast Assumptions

Industrial Land Use Category	Site Coverage (acres) (1)	Range of Water Use Factors	Data Source (2)
High Tech	244	2,600-57,000 gpd/acre	OR IFA 2015, City Input
Data Centers	107	0.01-0.41 gpd/SF (3)	OR IFA 2015, Existing City Data, Industry Research
Industrial	94	1,600-2,450 gpd/acre	OR IFA 2015
Business Park	87	1,600-2,450 gpd/acre	OR IFA 2015

(1) Acreage associated with NoHi area excluding Jackson East, for which planning-level information has been prepared by City Economic Development staff. Similar industrial development patterns have been assumed for Jackson East.
(2) Data Sources:
- OR IFA 2015: Oregon Infrastructure Finance Authority "State of Oregon Industrial Development Competitiveness Matrix" (Revision 5/4/2015).
- City Input: Recent development application information, as summarized by City Economic Development staff.
- Existing City Data: Review of current Data Center customers' water usage.
- Industry Research: Review of data center water usage specifications available online

(3) Depicted as gpd/square foot to reflect usage based on building size, as opposed to acreage of site development.

2.3.3 South Hillsboro Non-Residential Demand (SoHi-OTH)

Although SoHi will be predominantly residential in nature, there will be usage associated with new parks, schools, homeowner association irrigation, and retail/office space. Projected demands for uses of this nature are based upon the billing records of similar existing City accounts. Details regarding these assumptions are provided in Appendix A. In the results tables and charts in Section 4, this component of demand is denoted as SoHi-OTHER, or SoHi-OTH.

2.3.4 Future Growth Areas Demand (FGA)

Additional industrial and residential development is anticipated in the far future along the periphery of the existing In Town service area. Demands are included in this forecast with the Future Growth Areas, assuming that they will develop similarly to the industrial and residential development of NoHi and SoHi, respectively. Table 8 summarizes the key use and timing assumptions for the Future Growth Areas.

Table 8. Future Growth Area Uses and Timelines

Description	Primary Use	Acres	Initial Development Year (from 2016)	Estimated Development Timing (Years)
Southwest Corner of Hwy 26 and Brookwood	Residential	62	15-20	5-10
Witch Hazel Village South	Residential	940	10-20	15-20
Northwest Corner of Hwy 26 and Brookwood	Industrial	74	20-25	5-10
Southwest Hillsboro	Residential	361	20-25	10-15
South of South Hillsboro	Residential	958	20-25	15-20
West of Jackson East	Industrial/ Residential	1,769 (~1,000 ind.; ~769 res.)	25-30	15-20

2.4 Additional Demand Components

Different approaches than the above were used to project wholesale and non-revenue water demands into the future, as described below.

2.4.1 Wholesale Demands (WHL)

City staff prepared demand projections for the City's three wholesale customers: LA Water Co-Op, City of Gaston, and City of Cornelius. The City's share of demands from Joint Water Commission wholesale customers, North Plains and Westside Lutheran, are not included. The wholesale demand forecasts were based on historic demand information, current population, projected annual population growth, potential changes to water loss, and peaking factors. Projections for the City of Cornelius also included development of aquifer storage and recovery (ASR) wells and relied upon the 2017 Cornelius Water Master Plan. Appendix B contains the detailed demand projections and methodology. Summaries are provided below.

- LA Water Co-Op. Demand projections were created using historic demand information and population growth rate projections from the Portland State University (PSU) Population Research Center (PRC) for the City's Cherry Grove area. The average day demand (ADD) projections used historic average gallons per capita daily (gpcd) and an annual population growth rate. Peaking factors obtained from historic demand were applied to calculate peak season average day demand (PSD) and peak day demand (PDD). Results indicate LA Water Co-Op's ADD is projected to increase from 0.28 million gallons per day (mgd) in 2016 to 0.32 mgd in 2067.

- City of Gaston. Four demand projections were developed for Gaston, based upon historic demand and reflecting a range of potential population growth outcomes and water loss reductions. ADD was projected using two growth scenarios. In the first scenario, a low annual population growth scenario from the PSU PRC was used. In the second scenario a short-term annual population boom was modeled using information provided by City of Gaston staff. Water loss was divided into two scenarios as well. In the first scenario, historic water loss was projected to remain constant while in the second scenario water loss was aggressively curtailed. The two population and water loss scenarios result in four total scenarios with unique ADD projections. Historic demand was used to establish peaking factors for the PSD and PDD calculations.

  The two scenarios considered most likely to occur were the low population growth with no change in water loss, and the high population growth with water loss reduced. The latter scenario resulted in the highest demand which showed ADD may increase from 0.12 mgd in 2016 to 0.17 mgd in 2067.

- City of Cornelius. Four demand projections were also developed for Cornelius, following a rationale similar to that used for Gaston. Projections are based on historic demand and increase annually based on population and water loss scenarios. Two population scenarios were created for low and high population growth and also two water loss scenarios for different loss management approaches. The population scenarios were informed by the 2017 Cornelius Master Plan, which estimated the annual population growth rate and discussed the possibility of a short-term population boom. Water loss scenarios either maintain the current loss rates or provide for aggressive loss reduction based on information provided by City of Cornelius staff. ASR well information, including injection and recovery rates, and development timing was provided in the Cornelius Water Master Plan. All of the four scenarios use gallons per capita per day values that reflect the installation of ASR wells in 2019 and 2027. Historic demand and ASR well information was used to establish peaking factors for the PSD and PDD calculations.

  Two scenarios were considered most likely to occur including low population growth with no change in water loss, and high population growth with water loss reduced. The highest demand from these two scenarios for City of Cornelius was the scenario with low growth with no change to loss which showed ADD may increase from 1.02 mgd in 2016 to 3.26 mgd in 2067.

2.4.2 Non-Revenue Water (NRW)

Non-revenue water represents the difference between total water production and billed water consumption. Production was calculated by summing the metered monthly usage through Hillsboro's 14 master meters that measure water into the distribution system from the two supply sources. Total consumption represents the sum total of all billed usage for that year.

Table 9 presents a summary of the City's non-revenue water over the period of 2014–2016. The average amount of non-revenue water, expressed as a percentage of consumption, during this time period was 5.87 percent.[1] This value was applied to the total projected demand associated with all customer classes, as described in the preceding sections, to arrive at the amount of non-revenue water in future years. Doing this allows the City to plan for providing supply for non-billed usage.

Table 9. Summary of Non-Revenue Water, 2014-2016

Year	Total Production (MG)	Total Consumption (MG)	Non-Revenue Water (MG)	Non-Revenue Water (% of Production)	Non-Revenue Water (% of Consumption)
2014	6,352	6,017	335	5.27%	5.56%
2015	6,825	6,399	426	6.25%	6.66%
2016	6,583	6,246	337	5.12%	5.40%
Average	---	---	---	5.55%	5.87%

MG = million gallons

2.5 Peaking

Various peak demand metrics, relative to ADD, are of interest to the City. These are defined below:

- Peak Season Average Day Demand. This is defined as the average day demand over the course of the six-month peak season, defined as May 1–October 31. Because this demand forecast is built on monthly projections, the PSD is defined as the average daily demand over the sum of the six months considered to be peak season.
- Peak Day Demand. This is defined as the highest day of demand expected in a given year. Table 10 provides a summary of current City peaking factors, which are then used on a customer class basis in the demand forecast. This reflects the lower peaking characteristics of the City's industrial customers and its influence on the system-wide peaking factor. The demand projections assume that these peaking factors do not change in the future.

[1] These non-revenue water values are not the City's official record of water loss calculated through water audit accounting and presented in Water Management and Conservation Plans. Official water loss values present additional information on authorized non-revenue usage, unaccounted for water losses, and more.

Table 10. Peaking Factors

Class	Peaking Factor	Basis
Total City System	1.79	2013–2015 Average
Wholesale Customers (WHL)	1.83	Analysis of wholesale demands
Industrial Customers (IND)	1.26–1.5	Analysis of daily customer usage, and assumptions based on typical industrial usage patterns
Other Customer Classes (SFR, MFR, COM, NON, PUB, IRR)	2.49	Calculated, based on the other Peaking Factors

2.6 Aggregated Risk-Based Demand Forecast and Uncertainty Analysis

All of the water demand components described above were aggregated into a model designed to project water demands on an annual basis through 2070.

It is important to note that there are multiple variables within the model that entail uncertainties. These uncertainties directly influence the level of confidence that can be attributed to a singular demand forecast. Where these uncertainties are high, best practices in due diligence call for the application of risk analysis to comprehensively assess the impact of these uncertainties on the forecast. Risk analysis is a sound approach to evaluating these uncertainties. It entails the quantitative specification of uncertainties with probability distributions using Monte Carlo simulation methods (i.e., multiple iterations considering various combinations of input values) to determine a probabilistic range of outcomes. These results can then be interpreted with respect to the risk in making decisions based on one forecast versus another.

Details regarding the levels of uncertainty are integrated into the spreadsheet-based demand forecast model for the following variables. Unless otherwise noted, “normal” (i.e., bell shaped) distributions are applied to the ranges of value.

- Regression model coefficients. Ranges of values are based on standard errors, as defined through the statistical analysis used to build the regression models.
- Account growth. Ranges based on low and high ends defined as five percent lower or higher, respectively, than baseline growth assumptions.
- Monthly variability in seasonal climate (temperature and precipitation) data. Based on the variability in historical data for the baseline period of 1970–1999 reported by Hydromet.
- Seasonal variability in climate change impacts (temperature and precipitation) shown in Figure 2. Based on the range of values reported by OCCRI for the “high” emission scenario.
- Industrial water use factors. Ranges of values based on the information presented in Table 7. The probability distribution for the High-Tech water use factor is skewed to

the low end of the range, reflecting the low probability of future industries using extremely high amounts of water.

- Industrial growth timing. Both the initial start year and duration of development for future industrial growth in NoHi and the FGA have uncertainty, based on ranges projected by City Planning and Economic Development staff. The probability distributions for these variables are skewed toward the high end of the range, reflecting greater probabilities of later start dates and longer development durations. This was done by defining the median value (i.e., 50th percentile) of the range (for both start dates and development duration) as being 90 percent of the upper end of the range. For example, if the predicted development duration for a particular area is 10-20 years, this probability distribution means that 50 percent of the time, the values will be less than 90 percent of the upper range (or 18 years), and 50 percent of the time the values will be higher than 18 years.

3 Regression Model Results

The following section summarizes the regression models developed through the statistical analysis described in Section 2.1. A discussion of how to interpret the regression model equations is first provided, followed by details of the regression models, organized by customer class.

3.1 Regression Models as Equations

The regression models can essentially be thought of as equations that determine demand based on month-specific inputs that have been determined to be statistically significant for a given customer class (i.e., seasonality, temperature, precipitation, and rate, as appropriate per customer class). In its simplest terms, this can be expressed in the following way:

$$\begin{aligned} Demand = \; & (Intercept + Seasonality\ Factor) \\ & + (Temperature\ Coefficient)\ (Temperature) \\ & + (Precipitation\ Coefficient)\ (Precipitation) \\ & + (Rate\ Coefficient)\ (Rate) \end{aligned}$$

where:

Demand, the dependent variable, is average water usage per account per month (CCF).

Intercept is the value at which the fitted relationship crosses the y-axis, if one considers the independent variables as being plotted along the x-axis and the dependent variable as being plotted along the y-axis.

Seasonality Factor is an adjustment made to the intercept to increase regression fit on a seasonal basis. The seasonality factor is unit-less and is based on season (spring, summer, or fall), and is expressed as an increase or decrease relative to winter season demand.

Temperature, Precipitation, and Rate Coefficients are unit-less factors that describe the relationship between the independent variables of their respective names to the dependent variable (demand). A coefficient is multiplied by its respective independent variable.

Temperature, Precipitation, and Rate are the independent variables that are multiplied by their respective coefficients to calculate demand. They are expressed in units of degrees Fahrenheit, inches, and dollars per CCF, respectively.

Figure 3 provides an example of how independent variables (inputs) are used in the above equation for one customer class (SFR) in a given year. Explanatory notes are:

- The coefficients for the SFR regression model equation are shown at the top of the figure.
- Data inputs (seasonality factor, temperature, precipitation, and rate) are shown by month. These are the independent variables.
- Outputs are shown (in logarithmic form) for each demand component. The seasonal output is calculated by adding the seasonality factor to the intercept, while the remaining outputs are calculated by multiplying the inputs by their associated coefficients. This is the dependent variable.
- Outputs of each component are then summed by month in logarithmic CCF form. The outputs are then converted to exponential form, or simply CCF.
- Note that the interpretation of regression coefficients changes if the independent variable or dependent variable has been log transformed. Within this study the rate variable (independent) and output variable (dependent) are log transformed in all models, while the precipitation (independent) and temperature variable (independent) are not log transformed for most models. For this reason, regression coefficients for precipitation and temperature are typically interpreted using unit change in the independent variable (e.g., increase by 1 inch), while rate is interpreted using percent change in the independent variable (e.g., increase by 10 percent).

This framework applies to all of the regression models described in the following subsections.

Figure 3. Example Calculation of Monthly Water Usage per Account Using Regression Model

Customer Class: Single Family Residential (SFR)
Year: 2020

Model Coefficients			
Intercept	Temp	Precip	Rate
1.42	0.02	-0.18	-0.34

		Data Inputs				Output by Component (LN CCF Form)				Output Total	
Month	Season	Seasonality Factor	Mean Temp (degrees)	Mean Precip (inches)	Rate ($/CCF)	Season	Temp	Precip	Rate	(LN CCF Form)	(CCF Form)
1	W	0.00	39.93	0.19	1.54	1.42	0.71	-0.035	-0.52	1.58	4.85
2	W	0.00	43.08	0.17	1.54	1.42	0.77	-0.031	-0.52	1.64	5.15
3	S	0.05	47.00	0.13	1.54	1.47	0.84	-0.023	-0.52	1.76	5.84
4	S	0.05	50.69	0.08	1.54	1.47	0.91	-0.015	-0.52	1.84	6.29
5	S	0.05	56.41	0.06	1.54	1.47	1.01	-0.011	-0.52	1.94	6.99
6	M	0.06	61.67	0.05	1.54	1.48	1.10	-0.010	-0.52	2.05	7.78
7	M	0.06	66.66	0.03	1.54	1.48	1.19	-0.005	-0.52	2.15	8.55
8	M	0.06	66.57	0.03	1.54	1.48	1.19	-0.006	-0.52	2.14	8.53
9	A	0.04	61.79	0.06	1.54	1.46	1.11	-0.011	-0.52	2.04	7.67
10	A	0.04	52.90	0.09	1.54	1.46	0.95	-0.017	-0.52	1.87	6.50
11	A	0.04	45.20	0.20	1.54	1.46	0.81	-0.037	-0.52	1.71	5.55
12	W	0.00	39.88	0.21	1.54	1.42	0.71	-0.039	-0.52	1.57	4.83
										Total Annual Usage Per Account (CCF):	**78.53**
										Average Monthly Usage Per Account (CCF):	**6.54**

Other items of note when interpreting the regression models and their results are:

- Only those independent variables that were determined to be statistically significant are included in the equations. This is reflected in the figure for each model, which provides the parameters only for those coefficients that are statistically significant. The three variables that were statistically significant are temperature, precipitation, and rate; however, not all three of these were statistically significant for each model, as is explained in detail in Section 3.2.
- The figure for each model contains both "regression coefficients" and "standardized coefficients". The regression coefficients (b(i)) are the ones used mathematically in the model to predict demand based on inputs for the independent variables. The standardized coefficients (b'(i)) refer to how many standard deviations a dependent variable will change, per standard deviation increase in the predictor variable. This is provided solely to indicate which independent variables have a greater effect on the dependent variable (i.e., a higher standardized coefficient means a greater effect).

3.2 Single Family Regression Models

Three models were developed for the single family residential (SFR) class: In Town SFR, Recent Development SFR, and Cherry Grove SFR. Each are described separately below.

3.2.1 In Town Single Family Residential

The In Town SFR model has a satisfactory fit with the monthly time series with an R^2 of 0.70. Temperature influences water consumption such that for every 10° change in average daily temperature in a given month of interest, water consumption on average goes up by 22 percent, holding all other variables constant. On the other hand, water consumption goes down by 16 percent for every additional inch of rain[2], again, holding all other variables constant. The indicators for the season to which a month belong show a directional positive (though slight) impact of the seasons relative to the winter months. Price changes do influence water consumption usage for this class since every 10 percent increase in volume rate charges for a given month reduces average water consumption by 3.4 percent. Figure 4 summarizes the In Town SFR regression results.

Figure 4. Regression Results for In Town Single Family Residential (SFR) Accounts

Dependent Variable: Natural Logarithm of Average Usage per Month (CCF/account)
Adjusted R^2: 0.70

Independent Variable	Regression Coefficient b(i)	Standardized Coefficient b'(i)	T-Value to test H0:β(i)=0	P-Value	Reject H0 at 10%?
Intercept	1.42	0	10.35	<.01	Yes
Average daily temperature	0.02	0.72	8.94	<.01	Yes
Average daily precipitation	-0.18	-0.11	-1.64	0.11	No
LN(SFR Volume Rate)	-0.34	-0.19	-3.26	<.01	Yes
Spring Indicator	0.05	0.10	1.32	0.19	No
Summer Indicator	0.06	0.13	1.25	0.22	No
Fall Indicator	0.04	0.090	1.23	0.22	No

Interpretation of Regression Coefficients

Independent Variable	Units	Change in Variable by month	Change in Average Monthly Usage
Average daily temperature	Fahrenheit	10 ° ↑	22% ↑
Average daily precipitation	Inches	1" ↑	16% ↓
LN(SFR Volume Rate)	$ per CCF	10% ↑	3.4% ↓
Spring Indicator	Month is Apr, May, Jun	Month is either Apr, May or Jun	5% ↑ (relative to Winter)
Summer Indicator	Month is Jul, Aug, Sept	Month is either Jul, Aug, or Sept	6% ↑ (relative to Winter)
Fall Indicator	Month is Oct, Nov, Dec	Month is either Oct, Nov, or Dec	7% ↑(relative to Winter)

[2] For this model, precipitation is included in the model, although the p-value is greater than 0.10 (which is the threshold above which variables are typically considered not statistically significant). In this case, the exceedance of this threshold was minor and if it is removed the overall model fit declined substantially.

3.2.2 Recent Development Single Family Residential

The Recent Development SFR model has a satisfactory fit with the monthly time series with an R^2 of 0.87. Temperature and precipitation influence water consumption such that for every 10 percent change in average daily temperature in a given month of interest, water consumption on average goes up by 12 percent, holding all other variables constant while it goes down by 2 percent for every additional 10 percent increase in rain, again, holding all other variables constant. The sensitivity to temperature for this group suggests that heavy irrigation may be required to establish lawns for these new SFR units. The indicators for the season to which a month belong show a reduced impact of the spring and summer seasons relative to the winter months by reducing average monthly consumption by 5 and 79 percent, respectively, while holding all other variables constant. The effect of the fall season relative to winter is negligible. The fixed drop in consumption whenever a month of interest occurs in the warmer seasons mitigates the strong impact of increasing temperature changes on average monthly consumption per account. While the seasonal indicators could be removed from the model, removing them impacted the quality of the model's fit. Given the short time series available for this class of customers, the impact of volume rate changes over time was not statistically significant. Figure 5 summarizes the SFR Recent Development regression results.

Figure 5. Regression Results for Recent Development Single Family Residential (SFR) Accounts

Dependent Variable: Natural Logarithm of Average Usage per Month (CCF/account)
Adjusted R^2: 0.87

Independent Variable	Regression Coefficient b(i)	Standardized Coefficient b'(i)	T-Value to test H0:β(i)=0	P-Value	Reject H0 at 10%
Intercept	-3.10	0	-3.70	<.01	Yes
Average daily temperature	1.15	0.66	5.18	<.01	Yes
Average daily precipitation	-0.16	-0.57	-4.41	<.01	Yes
Spring Indicator	-0.05	-0.06	-0.50	0.62	No
Summer Indicator	-0.24	-0.29	-1.68	0.10	Yes
Fall Indicator	0.003	0.003	-0.04	0.97	No

Interpretation of Regression Coefficients

Independent Variable	Units	Change in Variable by month	Change in Average Monthly Usage
LN (Average daily temperature)	Fahrenheit	10% ↑	12% ↑
LN(Average daily precipitation)	Inches	10% ↑	2% ↓
Spring Indicator	Month is Apr, May, Jun	Month is either Apr, May or Jun	5% ↓ (relative to Winter)
Summer Indicator	Month is Jul, Aug, Sep	Month is either Jul, Aug, or Sep	79% ↓ (relative to Winter)
Fall Indicator	Month is Oct, Nov, Dec	Month is either Oct, Nov, or Dec	0.3% ↑ (relative to Winter)

3.2.3 Cherry Grove Single Family Residential

The Cherry Grove SFR model has a satisfactory fit with the monthly time series with an R^2 of 0.71. Temperature influences water consumption such that for every 10° change in average daily temperature in a given month of interest, water consumption on average goes up by 35 percent, holding all other variables constant. The indicators for the season were not included as temperature alone could explain most of the variation in this model. Given the short time series available for this class of customers, the impact of volume rate changes over time was not statistically significant. Figure 6 summarizes the Cherry Grove SFR regression results.

Figure 6. Regression Results for Cherry Grove Single Family Residential (SFR) Accounts

Dependent Variable: Natural Logarithm of Average Usage per Month (CCF/account)
Adjusted R^2: 0.71

Independent Variable	Regression Coefficient b(i)	Standardized Coefficient b'(i)	T-Value to test H0:β(i)=0	P-Value	Reject H0 at 10%?
Intercept	0.51	0	2.61	0.01	Yes
Average daily temperature	0.03	0.85	8.80	<.01	Yes

Interpretation of Regression Coefficients

Independent Variable	Units	Change in Variable by month	Change in Average Monthly Usage
Average daily temperature	Fahrenheit	10 ° ↑	35% ↑

3.3 Multi-Family Regression Models

Two models were developed for the multi-family residential (SFR) class: In Town MFR, and Recent Development SFR. Both are described separately below.

3.3.1 In Town Multi-Family Residential

The In Town MFR model has a modest fit with the monthly time series with an R^2 of only 0.45. Temperature influences water consumption such that for every 10° change in average daily temperature in a given month of interest, water consumption on average goes up by 11 percent, holding all other variables constant. The indicators for the season to which a month belong show a directional positive (though slight) impact of the seasons relative to the winter months. Price changes do influence water consumption usage for this class since every 10 percent increase in volume rate charges for a given month reduces average water consumption by 7.7 percent. Since the model's fit is low, caution should be exercised when forecasting MFR accounts' average monthly consumption. Figure 7 summarizes the MFR regression results.

Figure 7. Regression Results for Multi-Family Residential (MFR) Accounts

Dependent Variable: Natural Logarithm of Average Usage per Month (CCF/account)
Adjusted R^2: 0.45

Independent Variable	Regression Coefficient b(i)	Standardized Coefficient b'(i)	T-Value to test H0:β(i)=0	P-Value	Reject H0 at 10%?
Intercept	5.08	0	32.65	<.01	Yes
Average daily temperature	0.01	0.54	5.76	<.01	Yes
LN(MFR Volume Rate)	-0.77	-0.26	-3.18	<.01	Yes
Spring Indicator	0.01	0.04	0.39	0.70	No
Summer Indicator	0.05	0.15	1.12	0.26	No
Fall Indicator	0.03	0.11	1.08	0.28	No

Interpretation of Regression Coefficients

Independent Variable	Units	Change in Variable by month	Change in Average Monthly Usage
Average daily temperature	Fahrenheit	10 ° ↑	11% ↑
LN(MFR Volume Rate)	$ per CCF	10% ↑	7.7% ↓
Spring Indicator	Month is Apr, May, Jun	Month is either Apr, May or Jun	1% ↑ (relative to Winter)
Summer Indicator	Month is Jul, Aug, Sep	Month is either Jul, Aug, or Sep	5% ↑ (relative to Winter)
Fall Indicator	Month is Oct, Nov, Dec	Month is either Oct, Nov, or Dec	3% ↑ (relative to Winter)

3.3.2 Recent Development Multi-Family Residential

The Recent Development MFR model has a low fit with the monthly time series with an R^2 of 0.54. Temperature influences water consumption such that for every 10° change in average daily temperature in a given month of interest, water consumption on average goes up by 22 percent, holding all other variables constant. The indicators for the season to which a month belongs were not incorporated in this model as their inclusion caused the selected diagnostic statistics to fail. Given the short time series available for this class of customers, the impact of volume rate changes over time was not statistically significant. Figure 8 summarizes the MFR Recent Development regression results.

Figure 8. Regression Results for Recent Development Multi- Family Residential (MFR) Accounts

Dependent Variable: Natural Logarithm of Average Usage per Month (CCF/account)
Adjusted R^2: 0.54

Independent Variable	Regression Coefficient b(i)	Standardized Coefficient b'(i)	T-Value to test H0:β(i)=0	P-Value	Reject H0 at 10%?
Intercept	4.5	0	31.5	<.01	Yes
Average daily temperature	0.02	0.75	6.0	<.01	Yes

Interpretation of Regression Coefficients

Independent Variable	Units	Change in Variable by month	Change in Average Monthly Usage
Average daily temperature	Fahrenheit	10 ° ↑	22% ↑

3.4 Commercial Regression Model

The COM model has a satisfactory fit with the monthly time series with an R^2 of 0.71. Temperature and precipitation influence water consumption such that for every 10° change in average daily temperature in a given month of interest, water consumption on average goes up by 22 percent. The indicators for the season to which a month belong show a directional positive impact of the seasons relative to the winter months. Price changes do influence water consumption usage for this class since every 10 percent increase in volume rate charges for a given month reduces average water consumption by 4.4 percent. Figure 9 summarizes the COM regression results.

Figure 9. Regression Results for Commercial (COM) Accounts

Dependent Variable: Natural Logarithm of Average Usage per Month (CCF/account)
Adjusted R^2: 0.71

Independent Variable	Regression Coefficient b(i)	Standardized Coefficient b'(i)	T-Value to test H0:β(i)=0	P-Value	Reject H0 at 10%
Intercept	2.99	0	20.14	<.01	Yes
Average daily temperature	0.02	0.75	10.14	<.01	Yes
LN(COM Volume Rate)	-0.44	-0.20	-3.50	<.01	Yes
Spring Indicator	0.07	0.13	1.73	0.09	Yes
Summer Indicator	0.08	0.14	1.46	0.15	No
Fall Indicator	0.03	0.05	0.79	0.43	No

Interpretation of Regression Coefficients

Independent Variable	Units	Change in Variable by month	Change in Average Monthly Usage
Average daily temperature	Fahrenheit	10 ° ↑	22% ↑
LN(COM Volume Rate)	$ per CCF	10% ↑	4.4% ↓
Spring Indicator	Month is Apr, May, Jun	Month is either Apr, May or Jun	7% ↑ (relative to Winter)
Summer Indicator	Month is Jul, Aug, Sep	Month is either Jul, Aug, or Sep	8% ↑ (relative to Winter)
Fall Indicator	Month is Oct, Nov, Dec	Month is either Oct, Nov, or Dec	3% ↑ (relative to Winter)

3.5 Public Regression Model

The PUB model has a satisfactory fit with the monthly time series with an R^2 of 0.82. Temperature and precipitation influence water consumption such that for every 10° change in average daily temperature in a given month of interest, water consumption on average goes up by 50 percent, holding all other variables constant while it goes down by 31 percent for every additional inch of rain, again, holding all other variables constant. The indicators for the season to which a month belong show a positive impact of the spring, summer and fall seasons relative to the winter months by increasing average monthly consumption by 12, 22 and 9 percent, respectively. Price changes do influence water consumption usage for this class since every 10 percent increase in volume rate charges for a given month reduces average water consumption by 4.1 percent. Figure 10 summarizes the PUB regression results.

Figure 10. Regression Results for Public (PUB) Accounts

Dependent Variable: Natural Logarithm of Average Usage per Month (CCF/account)
Adjusted R^2: 0.82

Independent Variable	Regression Coefficient b(i)	Standardized Coefficient b'(i)	T-Value to test H0:β(i)=0	P-Value	Reject H0 at 10%
Intercept	3.35	0	17.95	<.01	Yes
Average daily temperature	0.04	0.73	10.46	<.01	Yes
Average daily precipitation	-0.37	-0.10	-1.78	0.08	Yes
LN(PUB Volume Rate)	-0.41	-0.15	-3.29	<.01	Yes
Spring Indicator	0.11	0.11	1.67	0.10	Yes
Summer Indicator	0.20	0.20	2.36	0.02	Yes
Fall Indicator	0.09	0.08	1.46	0.15	No

Interpretation of Regression Coefficients

Independent Variable	Units	Change in Variable by month	Change in Average Monthly Usage
Average daily temperature	Fahrenheit	10 ° ↑	50% ↑
Average daily precipitation	Inches	1" ↑	31% ↓
LN(PUB Volume Rate)	$ per CCF	10% ↑	4.1% ↓
Spring Indicator	Month is Apr, May, Jun	Month is either Apr, May or Jun	12% ↑ (relative to Winter)
Summer Indicator	Month is Jul, Aug, Sep	Month is either Jul, Aug, or Sep	22% ↑ (relative to Winter)
Fall Indicator	Month is Oct, Nov, Dec	Month is either Oct, Nov, or Dec	9% ↑ (relative to Winter)

3.6 Non-Profit Regression Model

The NON model has a satisfactory fit with the monthly time series with an R^2 of 0.77. Temperature and precipitation influence water consumption such that for every 10° change in average daily temperature in a given month of interest, water consumption on average goes up by 50 percent, holding all other variables constant while it goes down by 33 percent for every additional inch of rain, again, holding all other variables constant. The indicators for the season to which a month belong show a positive impact of the spring, summer and fall seasons relative to the winter months by increasing average monthly consumption by 12, 20, and 21 percent, respectively. Price changes do influence water consumption usage for this class since every 10 percent increase in volume rate charges for a given month reduces average water consumption by 7 percent. Figure 11 summarizes the NON regression results.

Figure 11. Regression Results for Non-Profit (NON) Accounts

Dependent Variable: Natural Logarithm of Average Usage per Month (CCF/account)
Adjusted R^2: 0.77

Independent Variable	Regression Coefficient b(i)	Standardized Coefficient b'(i)	T-Value to test H0:β(i)= 0	P-Value	Reject H0 at 10%
Intercept	1.31	0	5.20	<.01	Yes
Average daily temperature	0.04	0.76	11.73	<.01	Yes
Average daily precipitation	-0.40	-0.12	-2.07	0.04	Yes
LN(NON Volume Rate)	-0.70	-0.16	-3.12	<.01	Yes
Spring Indicator	0.11	0.11	1.72	0.09	Yes
Summer Indicator	0.18	0.19	2.20	0.03	Yes
Fall Indicator	0.19	0.20	3.11	<.01	Yes

Interpretation of Regression Coefficients

Independent Variable	Units	Change in Variable by month	Change in Average Monthly Usage
Average daily temperature	Fahrenheit	10 ° ↑	50% ↑
Average daily precipitation	Inches	1" ↑	33% ↓
LN(NON Volume Rate)	$ per CCF	10% ↑	7.0% ↓
Spring Indicator	Month is Apr, May, Jun	Month is either Apr, May or Jun	12% ↑ (relative to Winter)
Summer Indicator	Month is Jul, Aug, Sep	Month is either Jul, Aug, or Sep	20% ↑ (relative to Winter)
Fall Indicator	Month is Oct, Nov, Dec	Month is either Oct, Nov, or Dec	21% ↑ (relative to Winter)

3.7 Summary of Regression Model Results

A summary of the regression model results is provided below.

- All customer classes for which regression modeling was performed (single family residential, multi-family residential, commercial, public, nonprofit) exhibited a relationship between temperature and demand, with increases in temperature causing an increase in demand.
- The single family residential, public, and non-profit customer classes also exhibited a relationship between precipitation and demand, with increases in precipitation causing a reduction in demand.
- All customer classes exhibit a response to rates, to varying degrees, with increasing rates causing reductions in demand.
- The review of recently developed single family residential parcels indicated a much stronger relationship with temperature, potentially reflecting greater water usage necessary to establish landscaping and lawns.

4 Demand Forecast Results

Output from the aggregated risk-based forecast model is summarized below. Baseline scenario results are presented first, organized by customer class along with details regarding Average Day Demand (ADD), Peak Season Average Day Demand (PSD), and Peak Day Demand (PDD). This information is followed by results for the “low” and “high” scenarios, along with the findings from the uncertainty analysis. More detailed results are contained with the spreadsheet-based demand forecast model.

4.1 Baseline

Figure 12 presents the baseline ADD forecast. The figure depicts demands of the City’s existing service area by customer class (SFR, MFR, COM, NON, PUB, IRR), while demands of future service areas are shown according to their location and customer class (i.e., SoHi-RES, SoHi-OTH, NoHi-IND, FGA-IND, and FGA-RES). Demands from wholesale customers (WHL) and non-revenue water (NRW) are also shown.

This chart depicts system-wide ADD increasing from 19.8 mgd in 2018, to 48.7 mgd in 2070. Industrial demand comprises the largest share of the City’s current overall demand, with the NoHi and FGA demand components, which include both industrial and residential demand, representing the largest segments of demand growth in the future.

Figure 12. Total System-wide Demand Forecast (Average Day Demand)

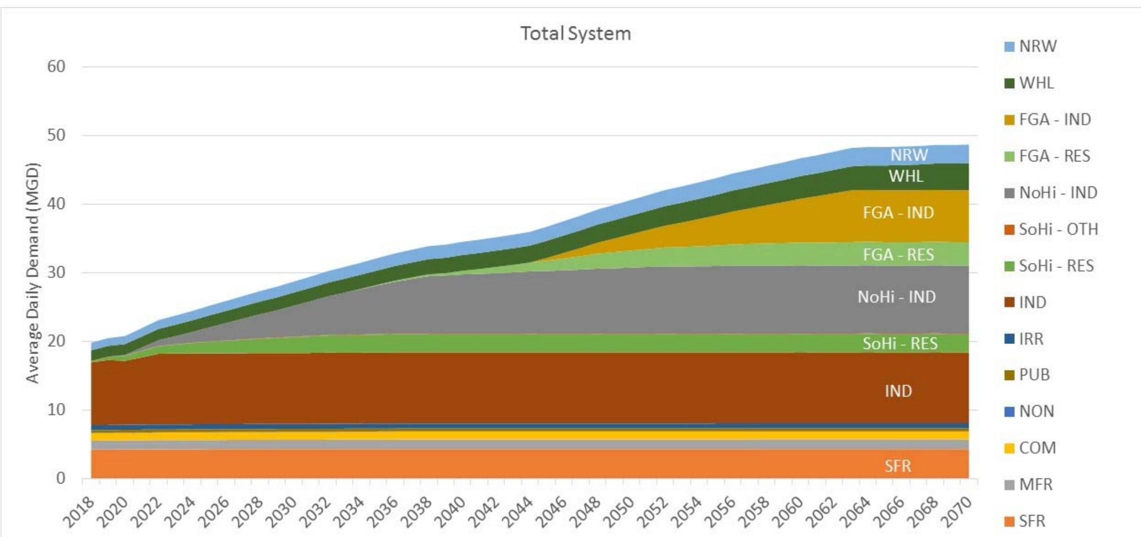


Table 11 provides additional detail by presenting yearly forecasts of the baseline demand for 2018-2070, in terms of annual demand, ADD, PSD, and PDD. On an annual basis, total demand is projected to increase from 7,233 MG in 2018, to 17,768 MG in 2070. On a PSD basis, demand is projected to increase from 22.9 mgd in 2018, to 56.0 mgd in 2070. PDD is projected to increase from 35.6 mgd in 2018, to 82.1 mgd in 2070.

Table 12 presents the forecast for specific years organized by demand component: customer classes, potential future service areas, wholesale customers and non-revenue water.

Table 13 presents the forecast according to the three pressure zones in the In Town service area. As such, demands associated with wholesale customers and the Cherry Grove (Upper System) service area are not included in Table 13. The South pressure zone relates to a proposed future pressure zone comprised of a portion of SoHi and the FGA to the south of SoHi. The boundaries associated with this new pressure zone are preliminary and will be refined during the course of developing the Water Master Plan (WMP). Thus, the demand allocation amongst pressure zones depicted in Table 13 is approximate and is expected to be refined during the WMP analysis.

Table 11. Total System-Wide Demand Forecast

Year	Annual (MG)	ADD (mgd)	PSD (mgd)	PDD (mgd)
2018	7,232	19.8	22.9	35.6
2019	7,480	20.5	23.4	36.1
2020	7,585	20.8	23.7	36.8
2021	8,011	21.9	25.1	38.6
2022	8,441	23.1	26.4	40.4
2023	8,676	23.8	27.1	41.6
2024	8,928	24.5	27.9	42.8
2025	9,199	25.2	28.8	44.1
2026	9,455	25.9	29.6	45.2
2027	9,718	26.6	30.2	45.7
2028	9,979	27.3	30.9	46.8
2029	10,211	28.0	31.7	47.9
2030	10,486	28.7	32.6	49.1
2031	10,751	29.5	33.4	50.2
2032	11,035	30.2	34.2	51.4
2033	11,261	30.9	35.0	52.4
2034	11,492	31.5	35.7	53.4
2035	11,742	32.2	36.5	54.5
2036	11,980	32.8	37.2	55.5
2037	12,177	33.4	37.8	56.3
2038	12,366	33.9	38.4	57.2
2039	12,444	34.1	38.6	57.5
2040	12,598	34.5	39.1	58.3
2041	12,711	34.8	39.5	58.8
2042	12,844	35.2	39.9	59.5
2043	12,977	35.6	40.3	60.2
2044	13,128	36.0	40.7	60.9
2045	13,402	36.7	41.7	62.2

Year	Annual (MG)	ADD (mgd)	PSD (mgd)	PDD (mgd)
2046	13,698	37.5	42.7	63.5
2047	13,994	38.3	43.6	64.9
2048	14,315	39.2	44.6	66.3
2049	14,564	39.9	45.5	67.5
2050	14,826	40.6	46.3	68.7
2051	15,087	41.3	47.2	69.9
2052	15,350	42.1	48.0	71.1
2053	15,541	42.6	48.7	72.0
2054	15,759	43.2	49.4	73.0
2055	15,978	43.8	50.1	74.0
2056	16,225	44.5	50.8	75.0
2057	16,416	45.0	51.6	75.9
2058	16,624	45.5	52.2	76.9
2059	16,814	46.1	52.9	77.7
2060	17,035	46.7	53.5	78.7
2061	17,195	47.1	54.1	79.4
2062	17,387	47.6	54.8	80.3
2063	17,579	48.2	55.4	81.1
2064	17,636	48.3	55.5	81.3
2065	17,630	48.3	55.6	81.4
2066	17,656	48.4	55.6	81.5
2067	17,683	48.4	55.7	81.6
2068	17,743	48.6	55.8	81.9
2069	17,739	48.6	55.9	81.9
2070	17,768	48.7	56.0	82.1

Table 12. Demand Forecast by Component (ADD, in mgd)

Year	SFR	MFR	COM	NON	PUB	IRR	IND	SoHi-RES	SoHi-OTH	NoHi-IND	FGA-RES	FGA-IND	WHL	NRW	Grand Total
2018	4.3	1.3	1.1	0.04	0.4	0.7	9.1	0.2	0.0	0.0	0.0	0.0	1.5	1.1	19.8
2025	4.3	1.4	1.1	0.04	0.4	0.7	10.3	1.7	0.0	2.0	0.0	0.0	1.8	1.4	25.2
2030	4.3	1.4	1.1	0.04	0.4	0.7	10.3	2.3	0.1	4.5	0.0	0.0	1.9	1.6	28.7
2040	4.3	1.4	1.1	0.04	0.4	0.7	10.4	2.6	0.1	8.6	0.5	0.0	2.3	1.9	34.5
2050	4.3	1.4	1.1	0.04	0.4	0.7	10.3	2.6	0.1	9.6	2.5	2.4	2.7	2.3	40.6
2060	4.3	1.4	1.1	0.04	0.4	0.7	10.4	2.6	0.1	9.9	3.3	6.4	3.3	2.6	46.7
2070	4.3	1.4	1.1	0.04	0.4	0.7	10.3	2.6	0.1	9.9	3.4	7.5	4.0	2.7	48.7

Table 13. Demand Forecast by Pressure Zone (mgd)

Year	ADD			PSD			PDD		
	North	Main	South	North	Main	South	North	Main	South
2018	8.80	7.85	0.35	9.78	9.44	0.43	11.93	17.76	0.76
2025	11.99	8.11	1.89	13.38	9.76	2.27	16.35	18.36	4.37
2030	14.45	8.26	2.54	16.16	9.96	3.05	19.84	18.72	5.89
2040	18.71	8.93	2.96	20.87	10.80	3.56	25.87	20.30	6.88
2050	20.20	12.56	3.47	22.56	15.23	4.16	27.90	26.79	8.06
2060	20.54	17.17	3.87	22.89	20.81	4.64	28.36	34.23	9.00
2070	20.51	18.62	3.89	22.91	22.62	4.65	28.33	36.65	9.04

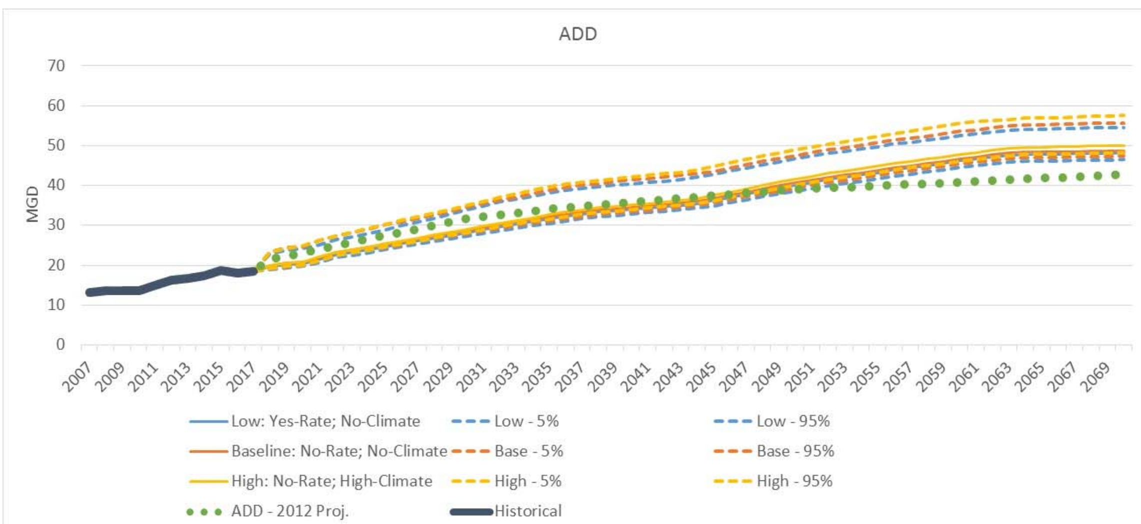
4.2 Scenarios and Uncertainty

Figure 13 presents the system-wide ADD for all three scenarios: Low (considering the impacts for future rate increases), Baseline (as described in detail in Section 4.1), and High (considering the impacts of climate change).

The forecasted demands are quite similar amongst the three scenarios. In 2070, the difference between the most likely outcomes for the Low and High scenarios (as represented by the solid lines) is only 1.9 mgd. The difference between the High and Baseline scenarios (1.3 mgd) is approximately twice the difference between the Baseline and Low scenarios (0.6 mgd). The primary reasons for the similar projections are:

- In the Low scenario, the imposition of the minimum usage "floor" on rate impacts limits the extent to which demands can decrease as a function of rate increases. Furthermore, because industrial demands represent the largest component of demand and demand growth, and rate increase impacts are not modeled as a part of the forecast for this customer class, the system-wide impact is fairly minor.
- In the High scenario, although demands in most customer classes increase seasonally as a function of increasing temperature and decreasing precipitation, such effects are not modeled for the industrial class; thus, limiting the influence of climate change on overall system-wide demands.

Figure 13. Average Day Demand (By Scenario and with Uncertainty Ranges)



The dashed lines in Figure 13 represent the 5th and 95th percentiles for each scenario. The 5th percentile means there is a 5 percent probability that demand will be lower than that value. The 95th percentile means there is a 95 percent probability that demand will be lower than that value. Taken in consideration together, these results can be interpreted such that for a particular scenario, there is a 90 percent confidence that projected demand will fall between the dashed lines. For example, for the Baseline scenario, there is a 90 percent probability that the ADD in 2070 will be between 47.3 and 55.6 mgd. The most likely projection (i.e., the solid line) for each scenario is closer to the

5th percentile than it is to the 95th percentile. This primarily is a function of the skewed probability distributions associated with industrial development timing (which is skewed to later start dates and longer development durations). See Section 2.6 for more detail.

Also included in Figure 13 are historical ADD values for 2007-2017, and the prior demand forecast developed in 2012. The 2018 projection is slightly lower than the 2012 projection for the first 20 years of the forecast period, after which the 2012 projection flattens out while the 2018 projection indicates a continued increase in demands through 2070. The difference in projections in the latter years is attributable primarily to the inclusion of the FGA in the 2018 forecast.

Figures 14 and 15 present data similar in format to that of Figure 13, but for PSD and PDD, respectively. The trends in similarity amongst scenarios and the 5th/95th percentiles seen in the ADD forecast are reflected in the PSD and PDD forecasts. The historical PDD values are under-represented because they are Hillsboro's daily demand on treatment plants, and do not include supply provided from finished water storage.

The Baseline PSD forecast projects PSD to increase from 22.9 mgd in 2018, to 32.6 mgd in 2030, and to 56.0 mgd by 2070. The Baseline PDD forecast projects PDD to increase from 35.6 mgd in 2018, to 49.1 mgd in 2030, and to 82.1 mgd by 2070.

Figure 14. Peak Season Demand (By Scenario and with Uncertainty Ranges)

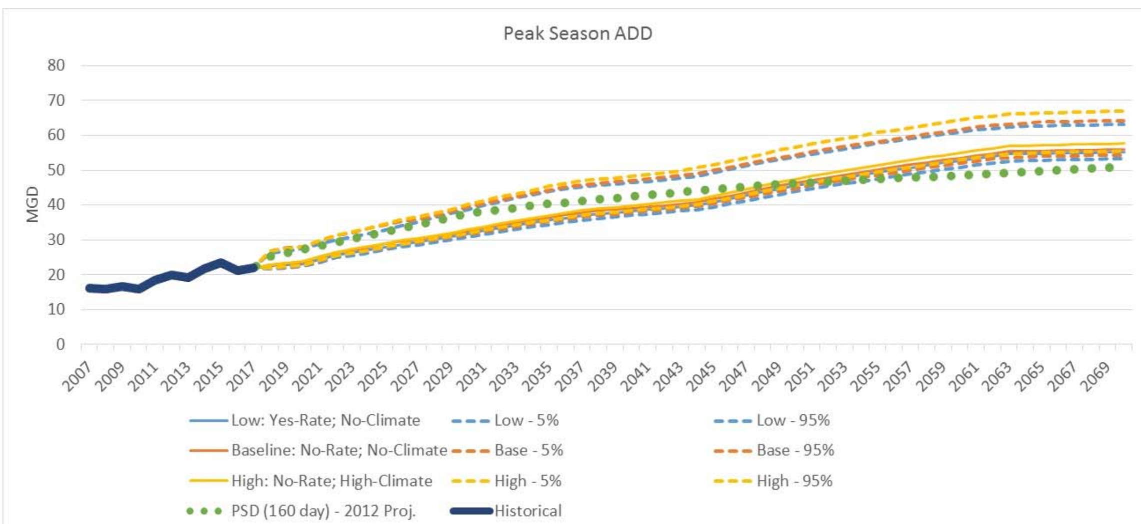
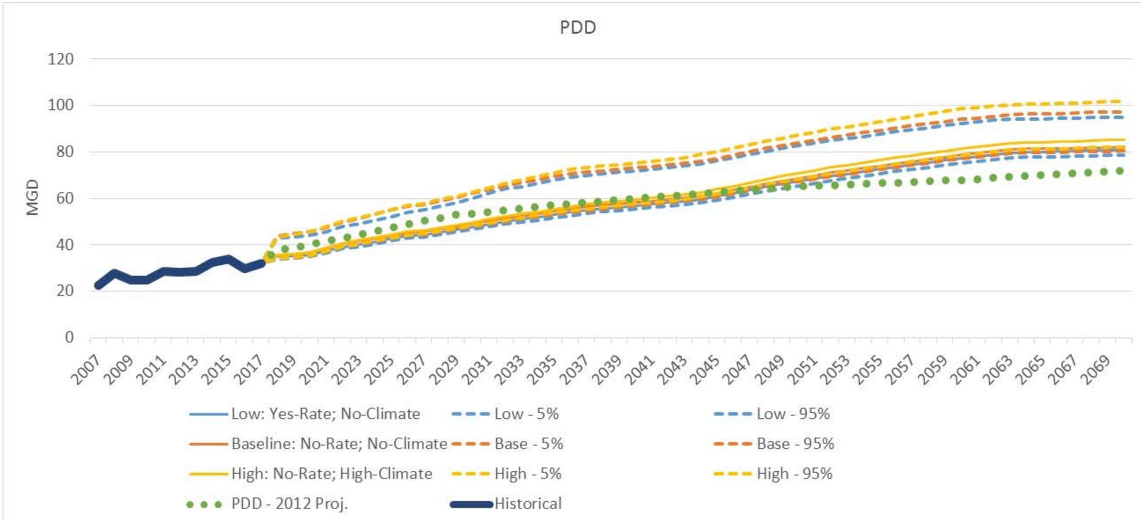


Figure 15. Peak Day Demand (By Scenario and with Uncertainty Ranges)



4.3 Key Findings and Next Steps

A summary of key findings from this analysis is provided below:

- Regression Modeling
    - All customer classes for which regression modeling was performed (single family residential, multi-family residential, commercial, public, non-profit) exhibited a relationship between temperature and demand, with increases in temperature causing an increase in demand.
    - The single family residential, public, and non-profit customer classes also exhibited a relationship between precipitation and demand, with increases in precipitation causing a reduction in demand.
    - All customer classes exhibit a response to rates, to varying degrees, with increasing rates causing reductions in demand.
    - The review of recently developed single family residential parcels indicated a much stronger relationship with temperature, potentially reflecting greater water usage necessary to establish landscaping and lawns.
- Risk-Based Demand Forecast (Baseline Scenario)
    - On an ADD basis, total system-wide demands are projected to increase from 19.8 mgd in 2018, to 48.7 mgd in 2070.
    - On a PDD basis, total system-wide demands are projected to increase from 35.6 mgd in 2018, to 82.1 mgd in 2070.
    - The demands associated with the existing customer base are projected to remain fairly static into the future.
    - Industrial growth in North Hillsboro and the Future Growth Areas represent the largest components of future demand growth.

  - Rate increases and climate change impacts are projected to have minimal influence in the overall system-wide demand, primarily due to the magnitude of industrial demands served by the City, which are modeled to not respond to such factors.

- Risk-Based Demand Forecast (Low and High Scenarios)

  The forecasted demands in the Low and High scenarios are quite similar to those of the Baseline scenario. This is primarily due to the following:

  - In the Low scenario, which incorporates the effects of future rate increases on demand, the imposition of a minimum usage "floor" on rate impacts limits the extent to which demands can decrease as a function of increased rates. Furthermore, because industrial demands represent the largest component of demand and demand growth, and rate increase impacts are not modeled as a part of the forecast for this customer class (because industrial use is not driven by rates), the system-wide impact is fairly minor.
  - In the High scenario, which incorporates the effects of climate change on demand, although demands in most customer classes increase seasonally as a function of increasing temperature and decreasing precipitation, such effects are not modeled for the industrial class (as seasonal peaking for this customer class is much lower than other classes); thus, limiting the influence of climate change on overall system-wide demands.

- Risk-Based Demand Forecast (Uncertainty Ranges)

  The demand forecast incorporates an uncertainty analysis, to acknowledge the variability in many of the factors that influence water demands and their timing. In addition to the "most likely" projection, the forecast presents the 5th and 95th percentiles for each scenario. The 5th percentile means there is a 5 percent probability that demand will be lower than that value. The 95th percentile means there is a 95 percent probability that demand will be lower than that value. The most likely projection for each scenario is much closer to the 5th percentile than it is to the 95th percentile. This primarily is a function of the skewed probability distributions associated with industrial development timing (which is skewed to later start dates and longer development durations).

The recommended next steps in use of this updated demand forecast are:

- Determine the appropriate projection(s) to use for Water Master Plan (WMP) purposes. Typically, the higher end of forecast ranges are used in this case, so as to be conservative for supply and storage capacity planning purposes. The WMP team will evaluate the various scenarios and levels of uncertainty identified in this forecast in the context of capacity planning and will recommend the appropriate levels of demand to incorporate in the WMP analysis. In so doing, the WMP team will also calculate peak hour demands (PHD) by applying an analysis of diurnal water usage patterns to the PDD developed in this forecast, to support pumping and pressure analyses.
- Determine the appropriate projection(s) to use in the next update of the City's water funds financial model. Typically, the lower to intermediate levels of a demand forecast are used for this purpose to protect against over-estimating future rate

revenue. The rate study team will consider the range of scenarios developed in this forecast in determining the most appropriate one to incorporate in the rate study.

- If possible, retrieve and incorporate data gaps in the City's billing records for years 2010 through 2013 in future regression modelling efforts.
- Consider inclusion of North Plains in future demand projections.

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Appendix A. Detailed Model Assumptions

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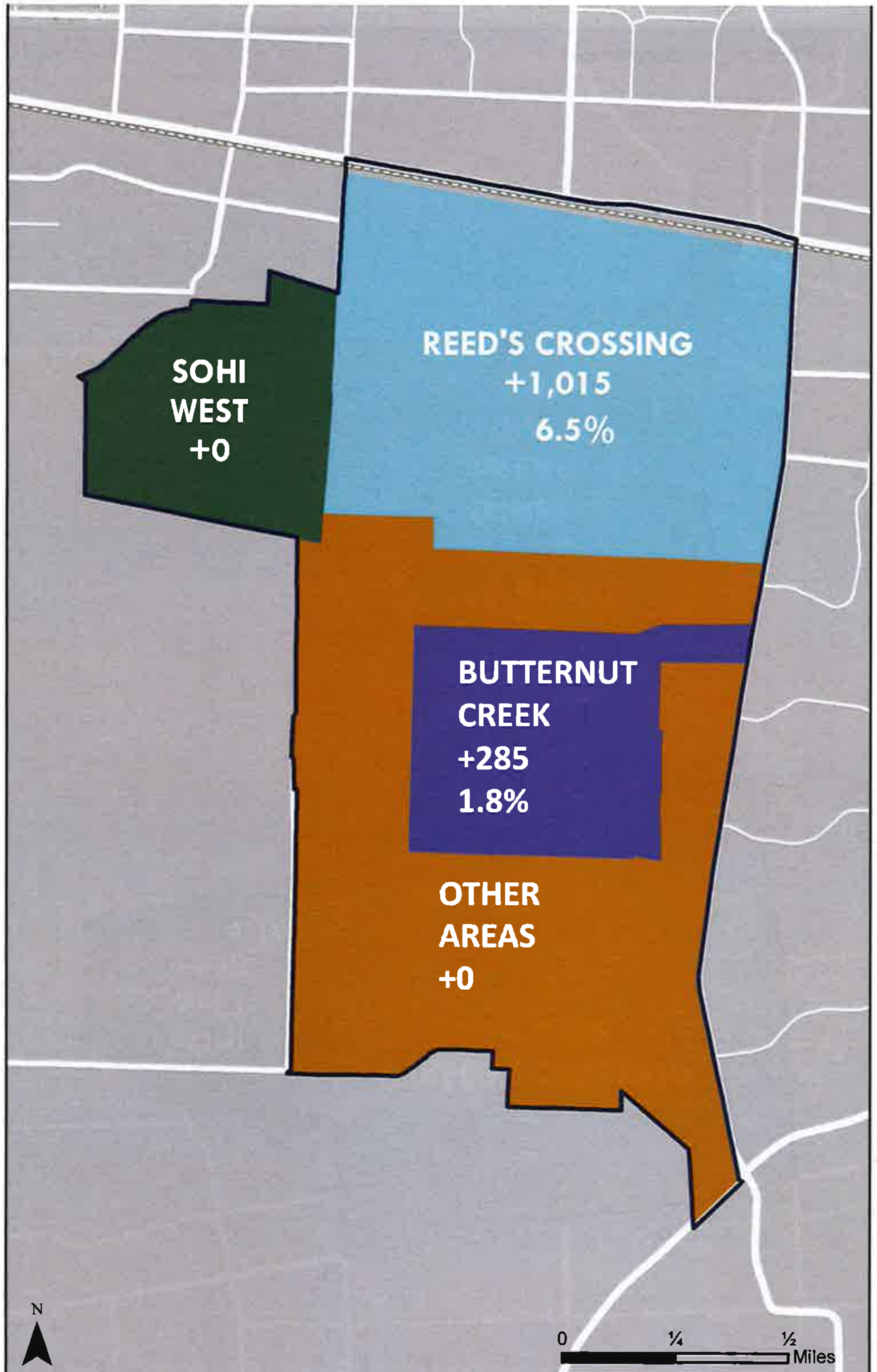
South Hillsboro

Planning Assumptions

(Residential Demands)

Fiscal Year Ending 6/30:		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Absorption Schedule															
Land Use	**Unit**														
Area 1 - Newland, Hanauer, and Pahlisch															
Single Family Detached	Dwelling Unit	226	340	340	187	146	145	145	144	71	71	71	71	70	69
Condo/Townhomes	Dwelling Unit	131	261	259	248	140	139	139	138	67	67	67	66	66	21
Apartments	Dwelling Unit	124	123	123	108	108	107	107	107	64	64	63	63	63	64
Retail/Service	1,000 GFA	27.0	26.0	26.0	23.7	23.7	23.7	23.7	23.7	12.1	12.1	12.1	12.1	12.1	13.0
Office	1,000 GFA	0.0	0.0	0.0	10.0	10.0	10.0	10.0	10.0	12.0	12.0	12.0	12.0	12.0	20.0
Library	1,000 GFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elementary School	Student	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Middle School	Student	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parks	Acre	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area 2 - All Other Properties															
Single Family Detached	Dwelling Unit	0	0	0	0	0	175	175	175	175	175	175	175	175	175
Condo/Townhomes	Dwelling Unit	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apartments	Dwelling Unit	0	0	0	0	0	20	20	20	20	20	20	20	20	19
Retail/Service	1,000 GFA	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Office	1,000 GFA	0.0	0.0	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Library	1,000 GFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elementary School	Student	0	0	0	0	1368	0	0	0	0	1368	0	0	0	0
Middle School	Student	0	0	0	0	0	0	0	0	0	982	0	0	0	0
Parks	Acre	0	4	4	4	4	4	4	4	4	4	4	4	4	4
South Hillsboro Total															
Single Family Detached	Dwelling Unit	226	340	340	187	146	320	320	319	246	246	246	246	245	244
Condo/Townhomes	Dwelling Unit	131	261	259	248	140	139	139	138	67	67	67	66	66	21
Apartments	Dwelling Unit	124	123	123	108	108	127	127	127	84	84	83	83	83	83
Retail/Service	1,000 GFA	27.0	26.0	26.0	23.7	23.7	24.7	24.7	24.7	13.1	13.1	13.1	13.1	13.1	14.0
Office	1,000 GFA	0.0	0.0	0.0	10.0	10.0	12.0	12.0	12.0	14.0	14.0	14.0	14.0	14.0	22.0
Library	1,000 GFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elementary School	Student	0	0	0	0	1368	0	0	0	0	1368	0	0	0	0
Middle School	Student	0	0	0	0	0	0	0	0	0	982	0	0	0	0
Parks	Acre	0	4	4	4	4	4	4	4	4	4	4	4	4	4

Fiscal Year Ending 6/30:		2032	2033	2034	2035	2036	2037	Totals	Notes	
Absorption Schedule										
Land Use	**Unit**									
Area 1 - Newland, Hanauer, and Pahlisch										
Single Family Detached	Dwelling Unit	69	0	0	0	0	0	2,165		
Condo/Townhomes	Dwelling Unit	21	0	0	0	0	0	1,830		2085
Apartments	Dwelling Unit	64	0	0	0	0	0	1,352		1830
Retail/Service	1,000 GFA	13.0	0.0	0.0	0.0	0.0	0.0	284.0		255
Office	1,000 GFA	20.0	0.0	0.0	0.0	0.0	0.0	150.0		17
Library	1,000 GFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Elementary School	Student	0	0	0	0	0	0	0		
Middle School	Student	0	0	0	0	0	0	0		
Parks	Acre	0	0	0	0	0	0	0		
Area 2 - All Other Properties										
Single Family Detached	Dwelling Unit	176	176	176	176	81	0	2,360		
Condo/Townhomes	Dwelling Unit	0	0	0	0	0	0	0		
Apartments	Dwelling Unit	19	19	19	19	19	19	293		
Retail/Service	1,000 GFA	1.0	1.0	0.0	0.0	0.0	0.0	11.0		
Office	1,000 GFA	2.0	2.0	2.0	2.0	2.0	2.0	30.0		
Library	1,000 GFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Elementary School	Student	0	0	0	0	0	0	2,736		
Middle School	Student	0	0	0	0	0	0	982		
Parks	Acre	4	4	4	4	4	0	67		
South Hillsboro Total										
Single Family Detached	Dwelling Unit	245	176	176	176	81	0	4,525		
Condo/Townhomes	Dwelling Unit	21	0	0	0	0	0	1,830		
Apartments	Dwelling Unit	83	19	19	19	19	19	1,645		
Retail/Service	1,000 GFA	14.0	1.0	0.0	0.0	0.0	0.0	295.0		
Office	1,000 GFA	22.0	2.0	2.0	2.0	2.0	2.0	180.0		
Library	1,000 GFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Elementary School	Student	0	0	0	0	0	0	2,736		
Middle School	Student	0	0	0	0	0	0	982		
Parks	Acre	4	4	4	4	4	0	67		



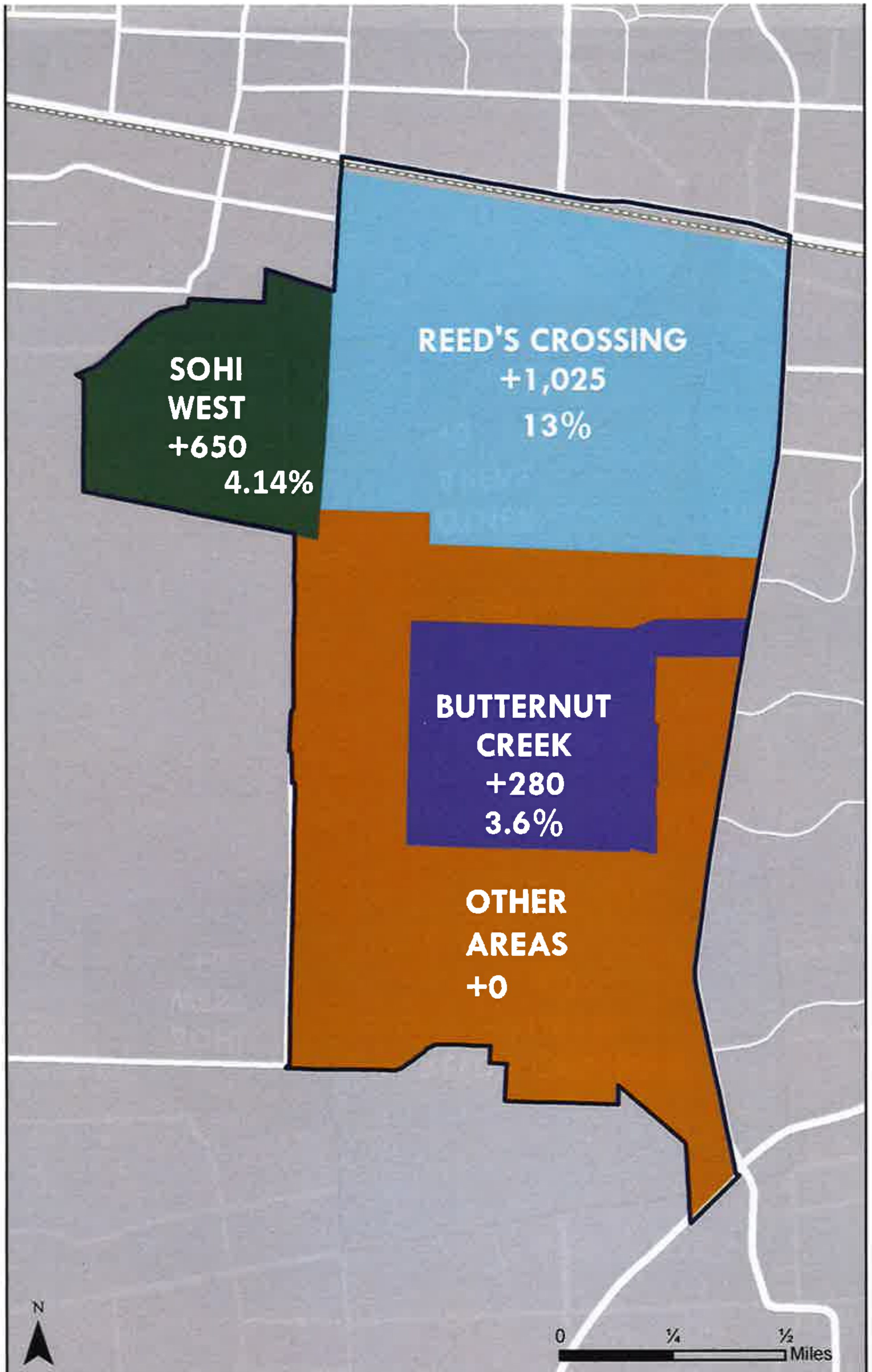
Estimated Population Added per Year by Development Area

2018

Previous Estimated Total Population	0
Reed's Crossing	1,015
Butternut Creek	285
SoHi West	0
Other Areas	0
SOUTH HILLSBORO TOTAL	1,300

Hillsboro Planning

Estimates are based on development projections. Actual numbers may differ from those presented here.



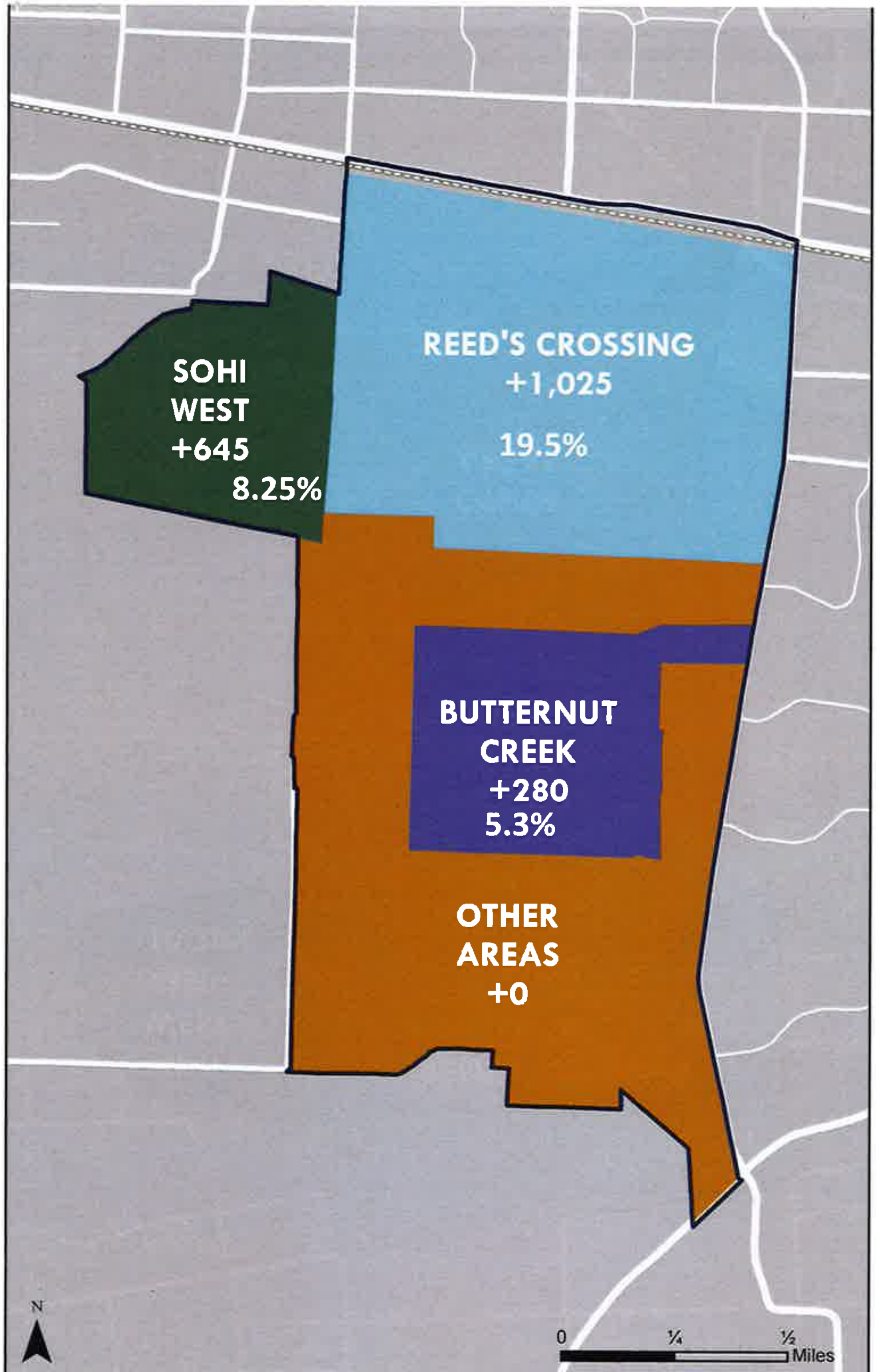
Estimated Population Added per Year by Development Area

2019

Previous Estimated Total Population	1,300
Reed's Crossing	2,040
Butternut Creek	565
SoHi West	650
Other Areas	0
SOUTH HILLSBORO TOTAL	3,255

Hillsboro Planning

Estimates are based on development projections.
Actual numbers may differ from those presented here.



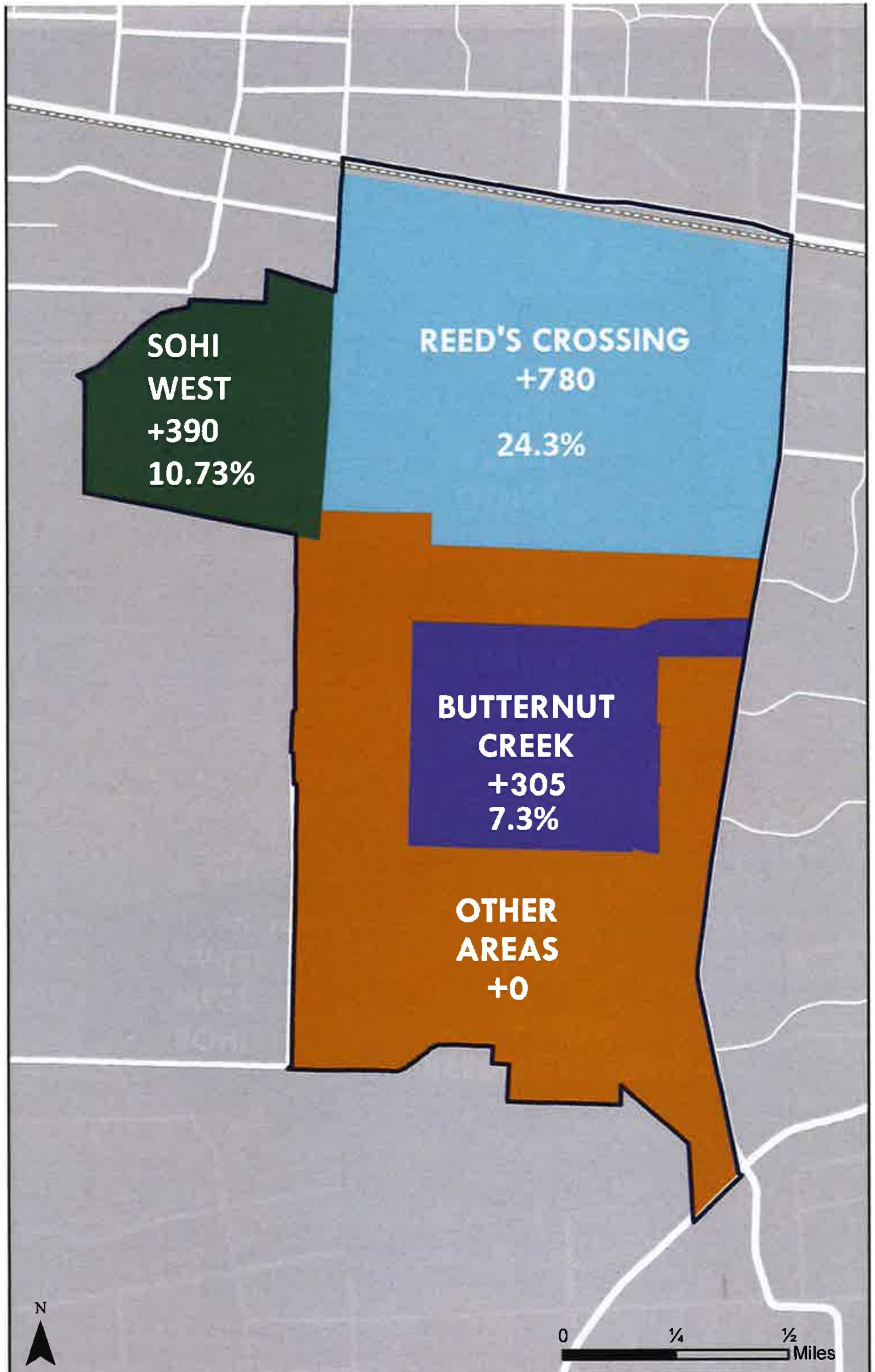
Estimated Population Added per Year by Development Area

2020

Previous Estimated Total Population	3,255
Reed's Crossing	3,065
Butternut Creek	845
SoHi West	1,295
Other Areas	0
SOUTH HILLSBORO TOTAL	5,205

Hillsboro Planning

Estimates are based on development projections. Actual numbers may differ from those presented here.



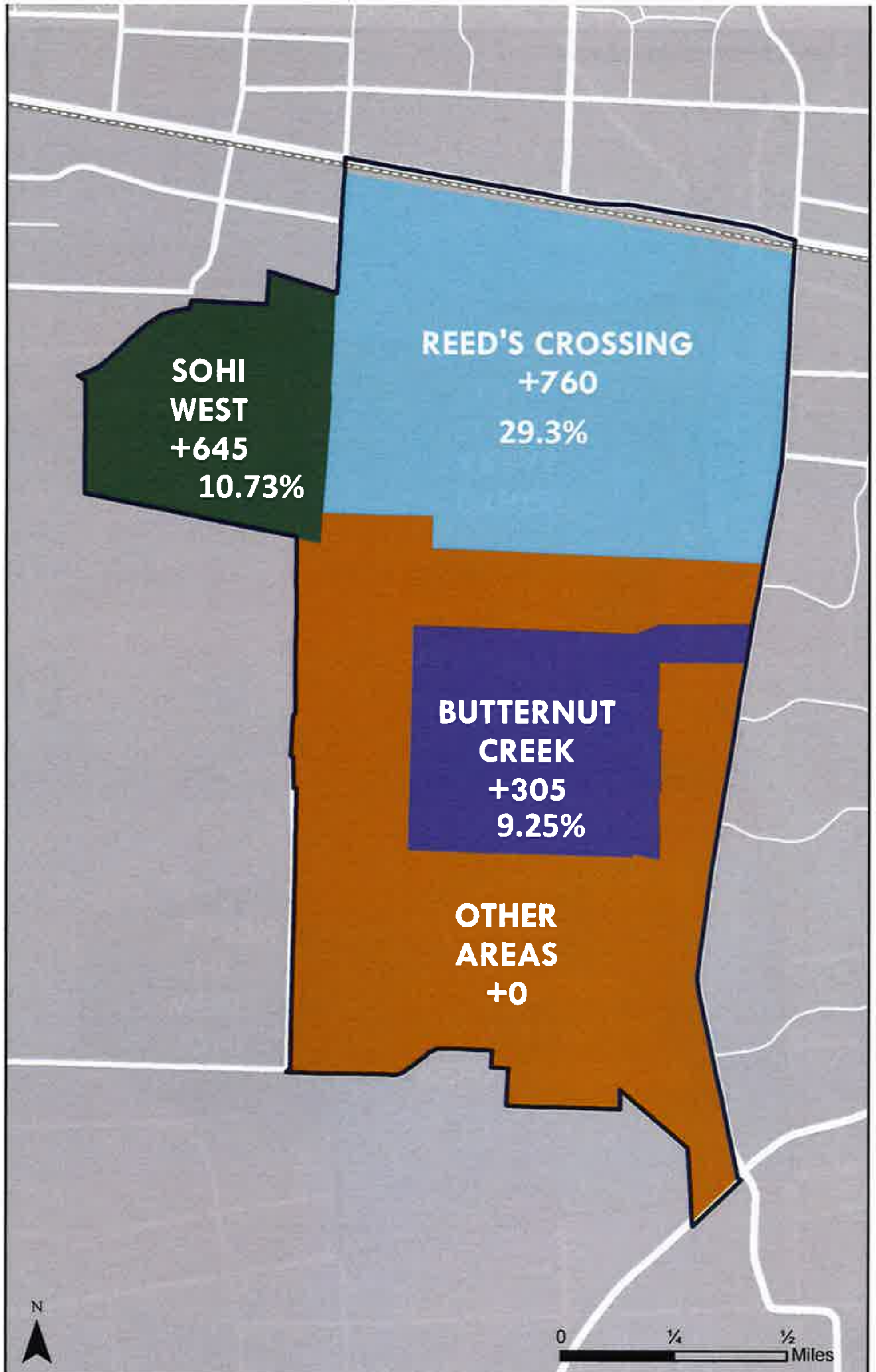
Estimated Population Added per Year by Development Area

2021

Previous Estimated Total Population	5,205
Reed's Crossing	3,845
Butternut Creek	1,150
SoHi West	1,685
Other Areas	0
SOUTH HILLSBORO TOTAL	**6,680**

Hillsboro Planning

Estimates are based on development projections. Actual numbers may differ from those presented here.



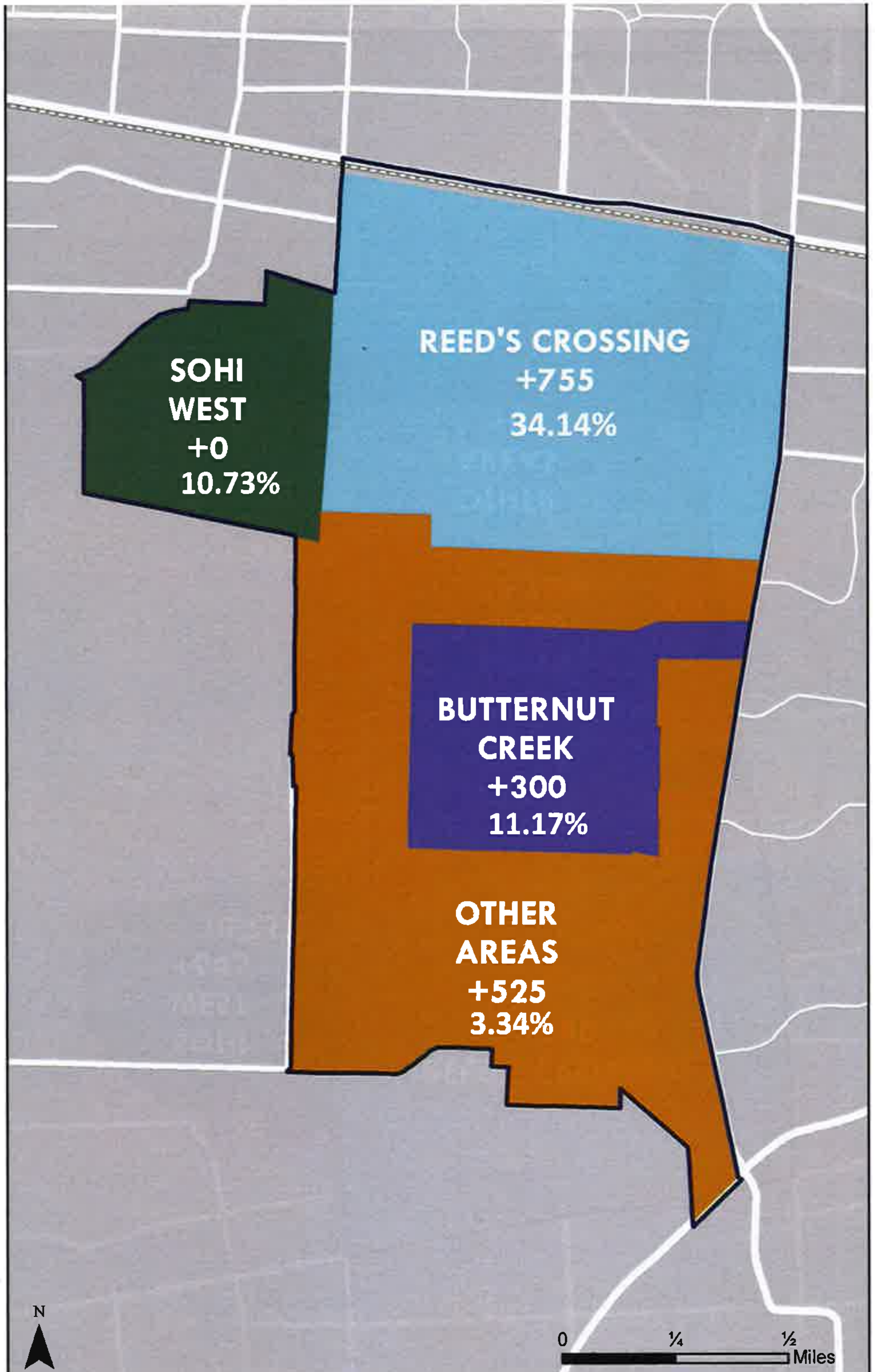
Estimated Population Added per Year by Development Area

2022

Previous Estimated Total Population	6,680
Reed's Crossing	4,605
Butternut Creek	1,455
SoHi West	1,685
Other Areas	0
SOUTH HILLSBORO TOTAL	7,745

Hillsboro Planning

Estimates are based on development projections. Actual numbers may differ from those presented here.



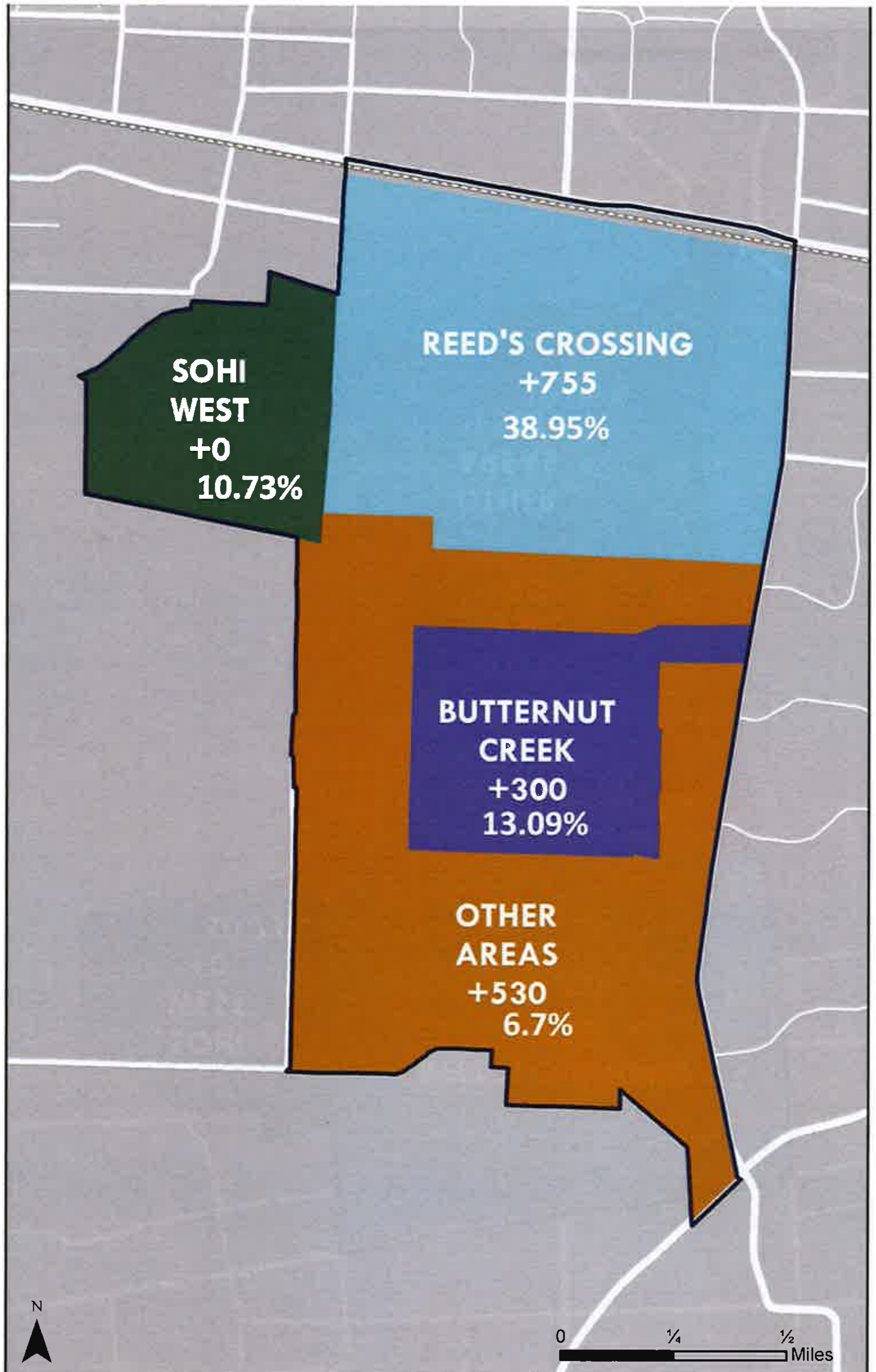
Estimated Population Added per Year by Development Area

2023

Previous Estimated Total Population	7,745
Reed's Crossing	5,360
Butternut Creek	1,755
SoHi West	1,685
Other Areas	525
SOUTH HILLSBORO TOTAL	9,325

Hillsboro Planning

Estimates are based on development projections. Actual numbers may differ from those presented here.



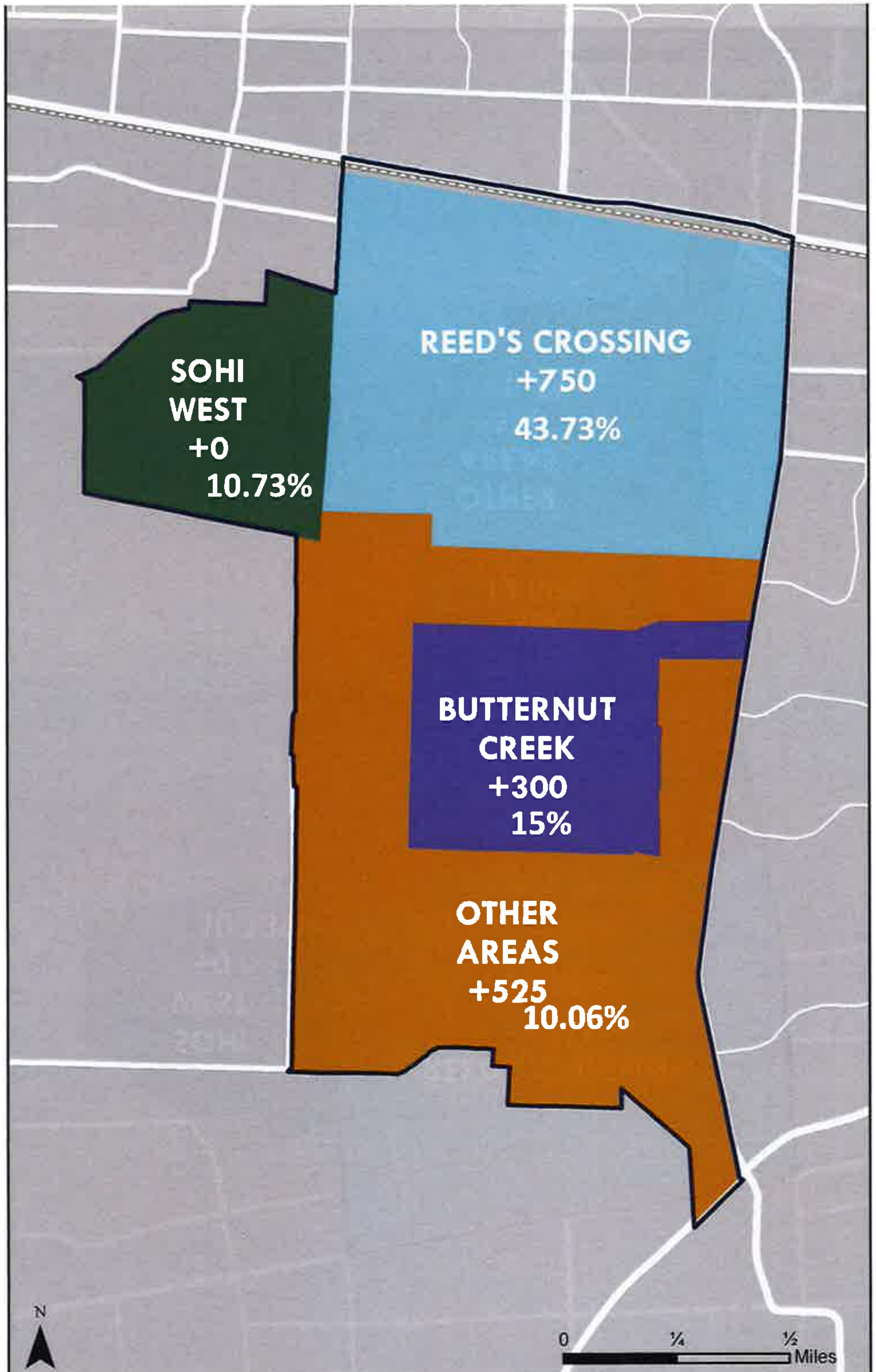
Estimated Population Added per Year by Development Area

2024

Previous Estimated Total Population	9,325
Reed's Crossing	6,115
Butternut Creek	2,055
SoHi West	1,685
Other Areas	1,055
SOUTH HILLSBORO TOTAL	10,910

Hillsboro Planning

Estimates are based on development projections. Actual numbers may differ from those presented here.



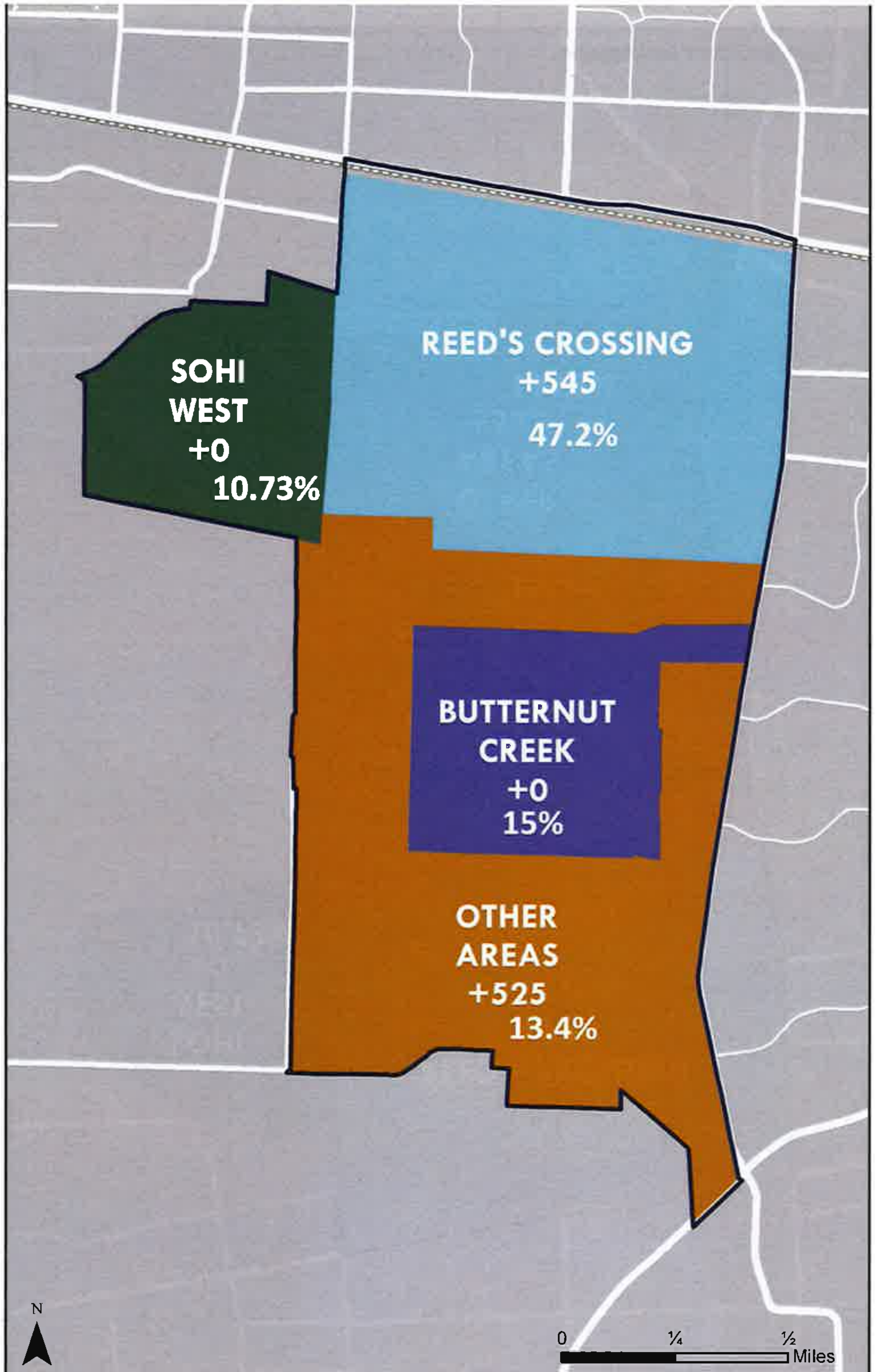
Estimated Population Added per Year by Development Area

2025

Previous Estimated Total Population	10,910
Reed's Crossing	6,865
Butternut Creek	2,355
SoHi West	1,685
Other Areas	1,580
SOUTH HILLSBORO TOTAL	12,485

Hillsboro Planning

Estimates are based on development projections. Actual numbers may differ from those presented here.



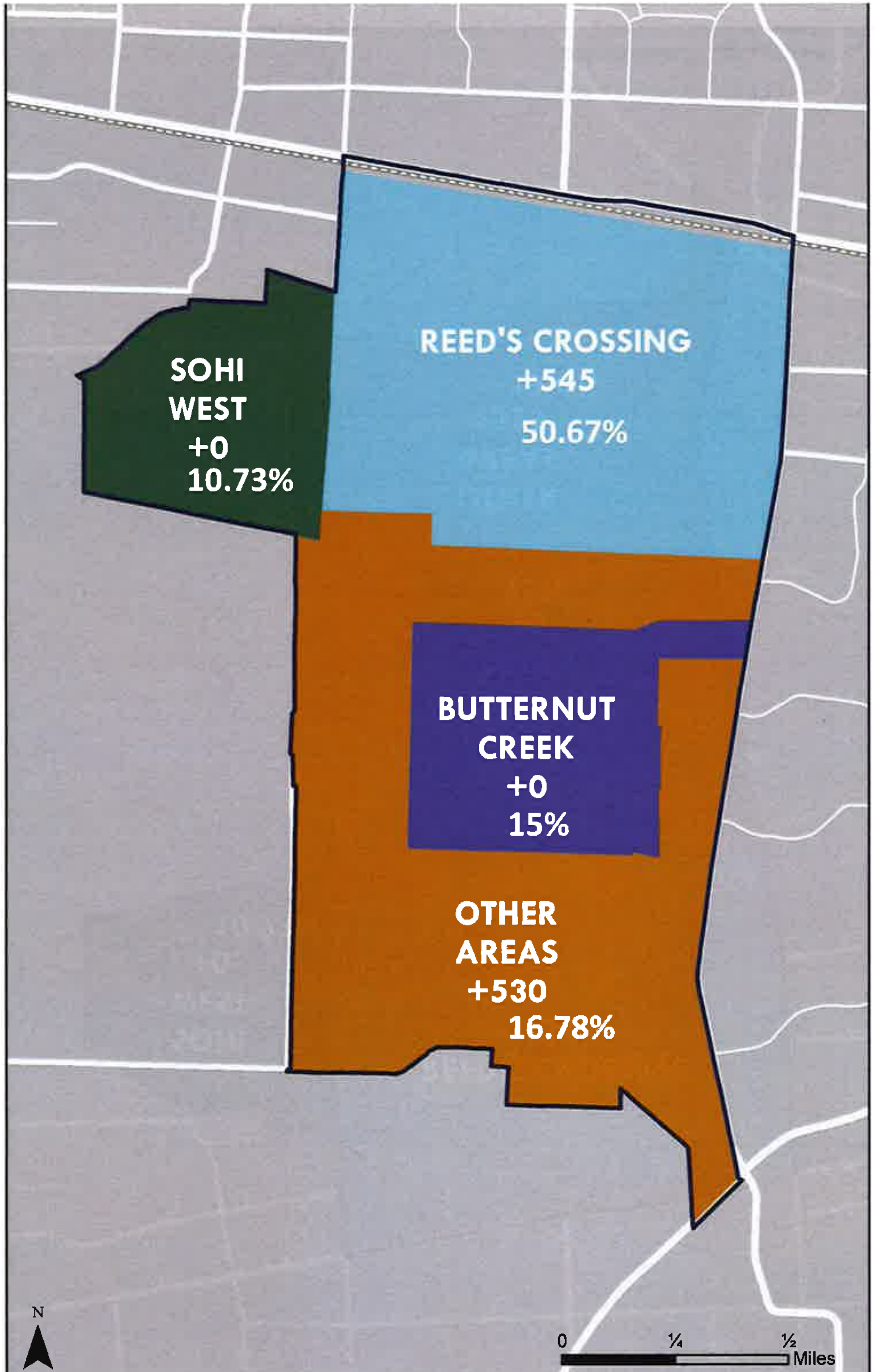
Estimated Population Added per Year by Development Area

2026

Previous Estimated Total Population	12,485
Reed's Crossing	7,410
Butternut Creek	2,355
SoHi West	1,685
Other Areas	2,105
SOUTH HILLSBORO TOTAL	13,555

Hillsboro Planning

Estimates are based on development projections. Actual numbers may differ from those presented here.



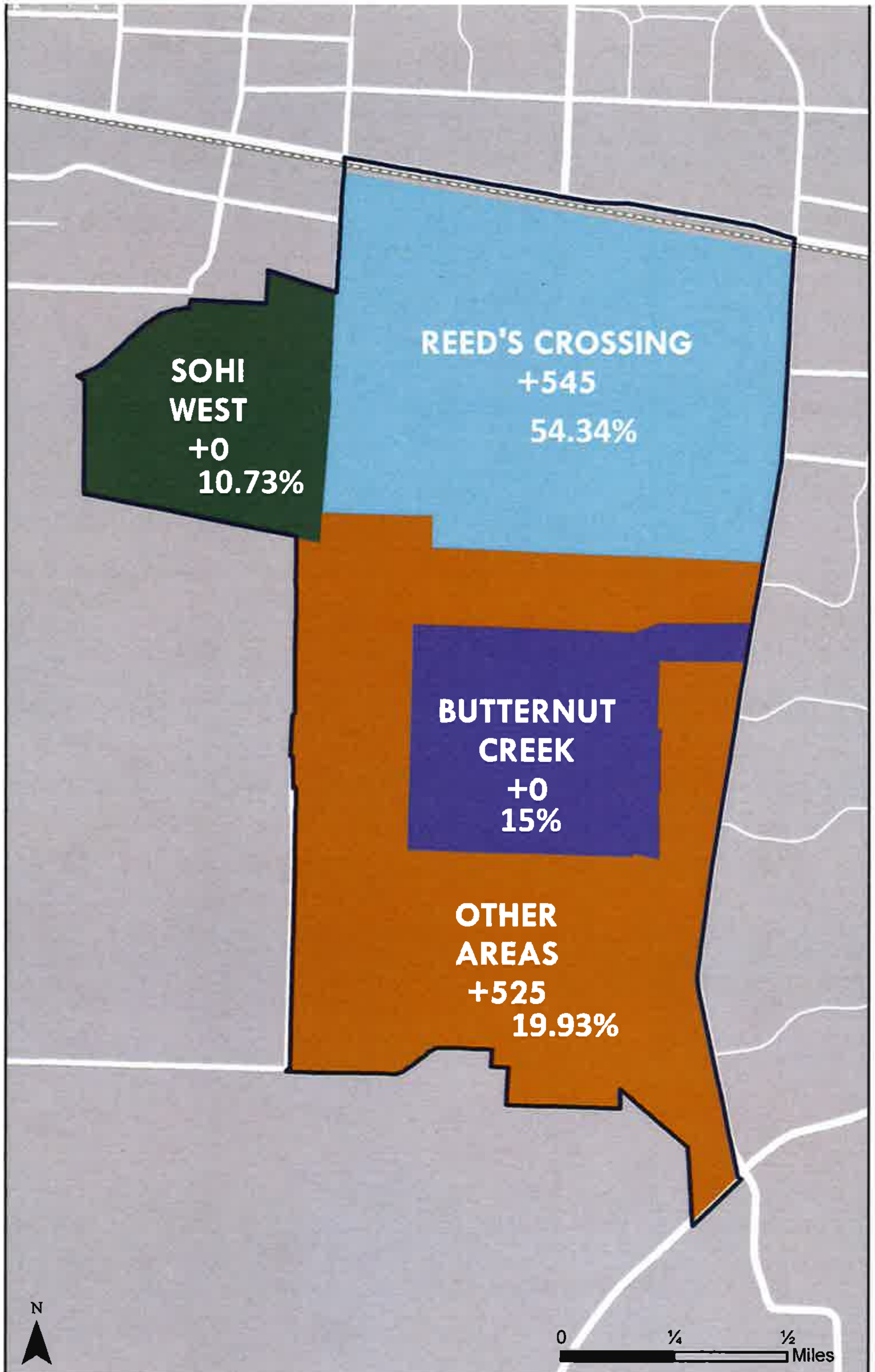
Estimated Population Added per Year by Development Area

2027

Previous Estimated Total Population	13,555
Reed's Crossing	545
Butternut Creek	0
SoHi West	0
Other Areas	530
SOUTH HILLSBORO TOTAL	14,630

Hillsboro Planning

Estimates are based on development projections. Actual numbers may differ from those presented here.



Estimated Population Added per Year by Development Area

2028

Previous Estimated Total Population	14,630
Reed's Crossing	545
Butternut Creek	0
SoHi West	0
Other Areas	525
SOUTH HILLSBORO TOTAL	15,700

Hillsboro Planning

Estimates are based on development projections. Actual numbers may differ from those presented here.

South Hillsboro

Planning Assumptions

(Non-Residential Demands)

SoHi Additional Non-Residential Demands

Updated 2018-01-26

Objective: Add COM and IRR demands to SFR and MFR demands in the projections. Even though small in comparison, this makes the SoHi projections comprehensive.
Approach:
1) COM. Based on 11 acres zoned for Retail/Service/Office. Use water use factor of 2,025 gal/acre/day (same as "Business Park (medium)" in NoHi IND forecast. Assume constant demand throughout year.
2) PUB. Schools. Assume 4 schools total (3 elementary and 1 middle school). Monthly usage based on billing data (2014-2016) for all existing schools (20 total).
3) IRR. Based on total of two categories, for which estimates are based directly on similar existing account usage, as analyzed in City billing data. Details are:
   a) Parks. Base usage on Rood Bridge Park (59 acres, so very similar). City billing data 2014-2016.
   b) HOAs. Assume 12 HOAs have irrigation accounts. Base off of average of 4 existing HOAs. City billing data 2014-2016.
4) Have these total demands grow over time, based on the growth assumptions on the next tab.

No. of Schools	4
No. of HOAs	12

Summary of Additional Non-Residential SoHi Demands (CCF)

	COM		PUB		IRR			
			Schools		Parks	HOA		
Month	gpad	TOTAL (CCF)	Per School	Total (CCF)	Total (CCF)	Per HOA	Total (CCF)	Total (CCF)
Jan	22275	923	116	462	38	249.9333	2999.2	3037
Feb	22275	834	91	363	38	200.2333	2402.8	2440
Mar	22275	893	125	500	79	289.1833	3470.2	3549
Apr	22275	923	108	432	79	255.35	3064.2	3143
May	22275	923	159	635	444	539.4167	6473	6917
Jun	22275	893	285	1141	444	792.5167	9510.2	9954
Jul	22275	923	891	3566	2055	2810.367	33724.4	35779
Aug	22275	893	978	3912	2055	2983.567	35802.8	37858
Sep	22275	923	1101	4405	926	2665.367	31984.4	32910
Oct	22275	923	501	2005	926	1465.533	17586.4	18512
Nov	22275	893	229	915	103	509.15	6109.8	6213
Dec	22275	923	106	424	103	263.2167	3158.6	3261
Annual Total		**10869**		**18760**	**7288**		**156286**	**163574**

South Hillsboro Growth in Non-Residential Demands:

Original Data from City Planning:

		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	Totals
COM																						
Retail/Service	1,000 GFA	27	26	26	23.7	23.7	24.7	24.7	24.7	13.1	13.1	13.1	13.1	13.1	14	14	1	0	0	0	0	295
Office	1,000 GFA	0	0	0	10	10	12	12	12	14	14	14	14	14	22	22	2	2	2	2	2	180
Subtotal Retail/Service + Office	1,000 GFA developed each year	**27**	**26**	**26**	**33.7**	**33.7**	**36.7**	**36.7**	**36.7**	**27.1**	**27.1**	**27.1**	**27.1**	**27.1**	**36**	**36**	**3**	**2**	**2**	**2**	**2**	**475**
PUB																						
Schools	# of schools coming online each year					1					2					1						4
IRR																						
Parks	# of acres online each year	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	67
MFR HOAs	track with parks growth																					0

For Use in HDR Forecast:

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Percentage of total demand (from other tab) coming online in each year:																				
COM	5.7%	5.5%	5.5%	7.1%	7.1%	7.7%	7.7%	7.7%	5.7%	5.7%	5.7%	5.7%	5.7%	7.6%	7.6%	0.6%	0.4%	0.4%	0.4%	0.4%
PUB	0%	0%	0%	0%	25%	0%	0%	0%	0%	50%	0%	0%	0%	0%	25%	0%	0%	0%	0%	0%
IRR	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%

North Hillsboro

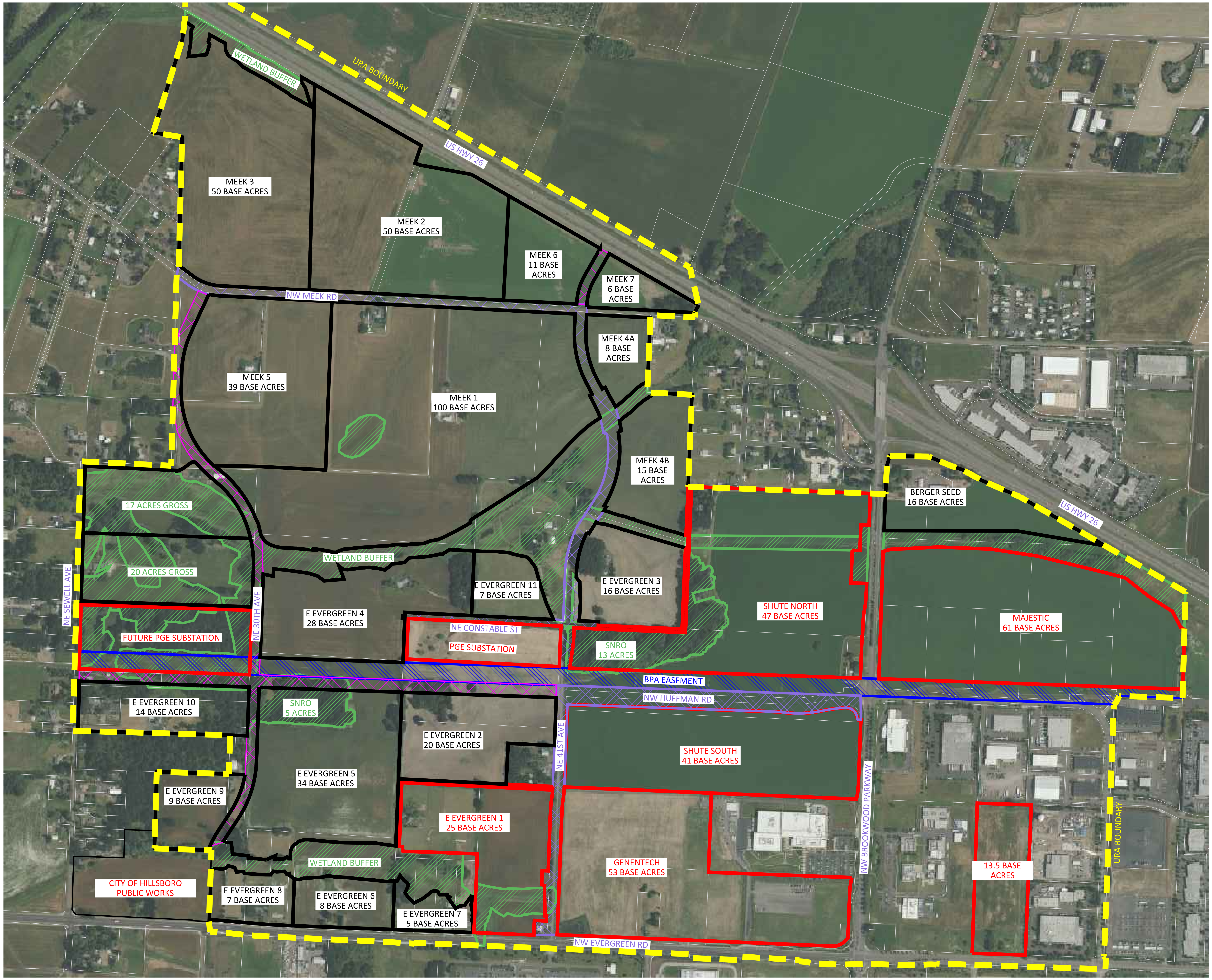
Planning Assumptions

ESTIMATED SQUARE FOOTAGE (REAL PROPERTY)			Industrial		Data Center		High Tech			Bus. Park (flex, office, retail)				ESTIMATED DEVELOPMENT TIMING			
Site[1]	Base Acres	Number of Property Owners	Actual[1] or Assumed Building Coverage (40%)	Total Site Coverage (Building, Parking & Circulation)	Actual[1] or Assumed Building Coverage (35%)	Total Site Coverage (Building, Parking & Circulation)	Actual[1] or Assumed Building Coverage (35%)	Actual[1] or Assumed Parking/Circulation Coverage (50%)	Total Site Coverage (Building, Parking & Circulation)	Actual[1] or Assumed Building Coverage (35%)	Total Site Coverage (Building, Parking & Circulation)	EZ	SIP	Initial Development Year (from 2016)	Additional Dev. Year	Additional Dev. Year	Est. Timing (Years)
Majestic	61	1	590,000	1,234,419	200,000	305,800				22,000	214,500	Y		1 - 5			5
Berger Seed (use TBD)	16	1															
Shute N	47	3			675,000	1,493,928						Y		1 - 5	5 - 10	11 - 20	1 - 20
Shute S	41	2			450,000	1,164,384						Y		1 - 5	5 - 10	11 - 20	1 - 10
Genentech	53	1					808,000	1,154,340	1,962,340			Y		1 - 5			1 - 20
TOK's Existing Development Site	13.5	1	290,000	554,627								Y					1 -20
Meek 1	100	6					1,524,600	2,178,000	3,702,600				Y	10 - 15			10 - 25
Meek 2	50	2					762,300	1,089,000	1,851,300				Y	5 - 10			5 - 15
Meek 3	50	1					762,300	1,089,000	1,851,300				Y	15 - 20			15 - 25
Meek 4A	8	1	139,392	296,208								?		5 to 10			5 - 10
Meek 4B	15	1								228,690	555,390	?		5 to 10			5 - 10
Meek 5	39	2								594,594	1,444,014	?		10 - 15			10 - 25
Meek 6	11	1	191,664	407,286								?		10 - 15			10 - 15
Meek 7	6	1	104,544	222,156								?		10 - 15			10 - 15
E.Evergr 1	25	2			300,000	735,600						?		1 - 5			1 - 15
E.Evergr 2	23	3	400,752	851,598								Y		5 - 10			5 - 10
E.Evergr 3	16	1			243,936	522,720						Y		5 - 10			5 - 15
E.Evergr 4	28	2								426,888	1,036,728	Y		5 -10			5 - 20
E.Evergr 5	34	6					518,364	740,520	1,258,884			Y		5 - 10			5 - 10
E.Evergr 6	8	1								121,968	296,208			10 - 15			10 - 15
E.Evergr 7	5	4	87,120	185,130										5 - 10			5 - 10
E.Evergr 8	7	5								106,722	259,182			5 - 10			5 - 10
E.Evergr 9	9	2	156,816	333,234								Y		5 - 10			5 - 10
E.Evergr 10	14	5			213,444	457,380						Y		10 - 15			10 - 15
E.Evergr 11 (use TBD)	7	1															
TOTALS:	*686.5*		*1,960,288*	*4,084,658*	*2,082,380*	*4,679,812*	*4,375,564*	*6,250,860*	*10,626,424*	*1,500,862*	*3,806,022*						

NOTES:

[1] Sites with data shown in red text are under contract, currently developing, or developed; if known, building and parking coverage are "actual". Sites shown in black text are available for future development.

ESTIMATE SQUARE FOOTAGE SUMMARY			
Use	Total Building Area (SF)	Total Site Area	% Project Area
Industrial	1,960,288	5,945,940	20%
Data Center	2,082,380	8,886,240	30%
High Tech	4,375,564	12,501,720	42%
Business Park	1,500,862	6,882,480	23%
TOTAL	9,919,094		



Legend

- URA Boundary
- Potential Development Sites
- Existing/Proposed Development Sites
- Natural Resources
- Right-of-Way (ROW)
- Potential Right-of-Way (ROW)
- BPA Easement
- Existing/previous property line

Base Acres =
Gross Acres - (ROW + Natural Resources)

N

0 300' 600'

NoHi Industrial URA
Potential Development Sites

SCALE: 1" = 300'

SCALE	PLAN	HORIZ.	VERT.	PROFILE	DRAWN:	CHECKED:
		1"=1,000'			JD	

#	DATE	REVISION	BY	APP'D

Hillsboro OREGON
150 E MAIN ST | 4TH FLOOR | HILLSBORO, OR 97123-4089
PHONE: 503.681.6146 | FAX: 503.681.6245

NORTH HILLSBORO RENEWAL AREA

POTENTIAL DEVELOPMENT SITES

PLOT DATE: 10/13/2016

FILE NAME: NOHI POTENTIAL DEVELOPMENT SITES.DWG

PROJECT NO.

SHEET NO.
--

Rate “Floor” Assumptions

For “Low” Scenario

Rate "Floor" Assumptions for use in Low Scenario

Summary of Historical Minimal Usage per Account (add data in CCF)

Based on complete data set (2006-2010, 2014-2016). May-Oct include a 5% adjustment down from observed historical low, to acknowledge potential reduction in peak season.

Use these in concert with regression models. Assume that monthly usage per accout cannot dip below these levels, even if regression models would indicate that rate increases would do so. These represent a bottom "floor" on demands.

Orange highlight represents numbers that changed since 1/21/2018. These values are final. Run with them.

	SFR	MFR	COM	IND	PUB	NON
Jan	5.67	153.36	33.44	2871.83	80.23	9.54
Feb	5.57	145.80	32.67	2559.68	82.07	10.00
Mar	5.88	147.32	32.13	2710.97	83.39	11.50
Apr	6.37	150.65	35.91	3201.81	110.90	12.85
May	6.53	167.60	42.09	3150.03	136.86	14.45
Jun	7.96	170.20	53.24	3236.85	156.15	22.57
Jul	9.69	206.57	68.23	3464.85	271.71	41.36
Aug	9.09	228.56	72.84	3209.03	274.65	43.63
Sep	6.69	185.90	51.61	3069.81	172.75	23.81
Oct	5.47	156.53	39.26	2802.35	107.23	13.45
Nov	5.89	153.22	34.61	2777.17	75.54	10.75
Dec	5.33	170.55	34.04	3006.30	84.48	10.69

Notes:

No data included for December 2010, and November and December 2016.

No data included for October and November 2010, for IND only.

IRR not included as there is no rate increase component to that customer class projection.

Appendix B. Wholesale Customer Demand Forecast Details

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MEMORANDUM

DATE: **November 7, 2017**

TO: **File**

FROM: **Kristel Fesler, Water Resources Program Coordinator**
Neha Subramanyam, Water Resources Specialist
Alexis Cooley, Water Resources Project Specialist

SUBJECT: **Demand Projections for Hillsboro Water Wholesale Customers**

Overview & Introduction

The City of Hillsboro Water Department (Hillsboro Water) wholesales water to the LA Water Co-Op (LA Water), the City of Cornelius (Cornelius), and the City of Gaston (Gaston). Demand projections for these customers were performed by City of Hillsboro in parallel with demand projections performed by HDR, Inc. The purpose of this work is to create an annual demand projection for the next fifty years, for 2017 until 2067.

The last comprehensive demand projections were performed as part of the Hillsboro Water 2013 Master Plan, which developed Average daily demand (ADD), peak season demand (PSD), and peak day demand (PDD) projections. The 2017 demand projections differ from the 2013 projections in a few ways:

- Multiple scenarios were created for Cornelius and Gaston which modify water consumption based on potential populations booms expected from major housing development, reductions in water loss, and Cornelius planned installation of two aquifer storage and recovery (ASR) wells.
- The 2017 projections uses new population growth rates from the Portland State University (PSU) Population Research Center (PRC) and Metro. The 2017 population growth rates for Gaston and LA Water are lower compared to the rates used in 2013, and the 2017 growth rate for Cornelius are similar to those used in 2013.
- Peak season is revised to be May 1 to October 30. The 2013 Master Plan used June 1 to September 30.

Key Indicators

Several indicators are used to project future water demand. Average daily demand (ADD), peak season demand (PSD), and peak day demand (PDD) are selected to represent projections used in this study. Generating these indicators relies on estimating their values in the past, and using the relationship between indicators to make future projections. Several other factors are used to generate indicators including annual population, gallons per capita day (gpcd) and peaking factor. The following calculations are used to determine baseline scenarios. Baseline scenarios do not include potential population booms, or reduced water loss. Cornelius's baseline projection includes the installation of two ASR wells.

- Gpcd is the total annual system demand divided by population and calendar days.
- Peaking factors are the average ratio of PSD/ADD or PDD/ADD in past years.
- ADD represents the average daily system demand. Projections are calculated on an annual basis as a product of projected population and past gpcd. Past ADD is determined as the annual system demand divided by annual number of days.
- PSD is the average daily system demand during peak season. Projections are calculated on an annual basis as the product of ADD and the PSD/ADD peaking factor. Past PSD is the total May to October demand divided by peak season days.
- PDD is the highest daily system demand that occurs in a calendar year. Projections are calculated on an annual basis as a product of ADD and the PDD/ADD peaking factor. The past PDD calculation is based on the best available data for the city, and differs between Cornelius where daily resolution data is available, and LA Water and Gaston where monthly data resolution is available.
    - The preferred method of calculating PDD requires daily meter data. Past PDD based upon daily data is available in the City of Cornelius Master Plan for 2001-2015.
    - An alternative method of calculating PDD uses monthly meter data. In LA Water and Gaston, past PDD are based upon the month with highest demand, divided by month days. The use of monthly data instead of daily data results in an underestimation of PDD. The true maximum PDD is not captured.

LA Water Co-Op

Monthly water sales from Hillsboro Water to LA Water are available from 2005-2016, providing twelve years of historical data. The demand projections for LA Water are the simplest of the three wholesale customers as only one scenario was developed. This scenario assumes a constant population growth rate and gpcd. Water statistics include:

- Average historic gpcd 126.3
- Peaking factor ADD/PSD is 1.2
- Peaking factor ADD/PDD is 1.7
- Projected population growth rate 0.39%
- Average historic water loss is not available for LA Water

Population

LA Water reported the 2015 service population of 2,100 people and 745 residences to Oregon Health Authority. PSU PRC calculated that the Hillsboro Cherry Grove service area had 2.75 people per household in 2016. Multiplying PSU PRC's estimated people per household (2.75) by the number of households served by LA Water (745) yields a service population of 2,049 people. This calculation confirms LA Water's self-reported service population. The higher of the two values, or 2,100 people, is used for the purpose of projecting demands. The population growth rate of 0.39% calculated by PSU PRC for the Hillsboro Cherry Grove system was used for predicting LA Water's future population. This rate is lower than the 1% growth rate which was used in the 2013 Master Plan.

Projection Results

The projected demands of LA Water are the lowest of the wholesale customers. As shown in the attached Figure 1, projections indicate there may be flat growth by 2027, with values creeping up only slightly by 2067. Low population in LA Water keeps demand growth low even with steady population increase. As expected, PDD has the greatest demand throughout the projection period and by 2067 is

0.2 mgd greater than ADD. Table 1 shows demand indicators for 2016, 2027 and 2067 and change from 2016 values.

Table 1- LA Water actuals and projections for 2016, 2027, and 2067. Change from 2016 demand actuals are depicted with blue (decrease), green (increase), and black (no change).

	ADD (mgd)	PSD (mgd)	PDD (mgd)
	2016		
Actual	0.28	0.34	0.44
	2027		
Projection	0.28	0.33	0.46
Δ 2016-2027	0.00	0.00	0.02
	2067		
Projection	0.32	0.38	0.54
Δ 2016-2067	0.04	0.04	0.10

City of Gaston

Water sales to Gaston on a monthly basis are available for 2005-2016, providing 12 years of historic data. Gaston projections include four water demand scenarios based on different conditions in population growth and water loss. The scenarios assume that customer behavior will remain the same and that the majority of Gaston's water savings will be found through a reduction in water loss percentage. Water statistics include:

- Average historic gpcd 176.4
- Peaking factor ADD/PSD is 1.1
- Peaking factor ADD/PDD is 1.3
- Historic water loss was 42%
- Projected population growth rate 0.38%

Population

Historic populations for Gaston are available from PSU PRC. This scenario uses a future population growth rate that is consistent with levels seen from 2000 to 2016, a 0.38% growth rate. This value is the same as PSU PRC's population growth forecast for Cherry Grove service area. This rate is lower than the 1.2% growth rate which was used in the 2013 Master Plan. However, a robust housing development may cause the 0.38% rate to spike, resulting in the need for a high population growth scenario.

Four demand projection scenarios were created:

1) **Low population growth, no change to water loss rates.** This scenario projects the status quo into the future.
2) **Low population growth, water loss rates are reduced.** Gaston provided eleven months of water loss information in 2016-2017. Water loss rates average 42%, with average loss of 1.5 mg per month. Gaston has indicated a desire to aggressively work towards reducing this water loss rate to 10%. This scenario includes a reduction of water loss over the next five years, reaching 10% by 2021. It is possible that water loss reduction by Gaston may not reduce demand from the perspective of Hillsboro Water. If Gaston's loss is produced by customer meter underestimation rather than pipe leakage, Gaston's demand could remain the same, even while Gaston works to update meters and reduce internal water loss.

3) **High population growth, no change to water loss rates.** This scenario is based on information from Gaston's Public Works Director, Brent Whitaker, who reported that a developer desires to build 300 homes in Gaston. To account for this possibility, a special population growth rate is used. Using housing statistics including the 2016 population of Gaston (640 people), number of people per household (2.75 people/household) and vacancy rate (5.4%), this development is estimated to increase Gaston's population to 1,420 people by 2027, a population growth rate of 7%. After 2027, growth rate returns to 0.38% rate. Housing statistics use the Cherry Grove service area and assume Gaston statistics are the same as Cherry Grove.
4) **High population growth, water loss rates are reduced.**

Projection Results

As shown in Figures 2 through 5 (attached) the results for Gaston Scenarios 2 and 3 represent the minimum and maximum demand that may occur in Gaston. Low population growth with reduced water loss is the lowest demand scenario whereas high population growth with no water loss reduction is the highest. In Figure 2, ADD projections from Scenario 3 are 233% higher than Scenario 2. This shows the important role that development pathways and water reduction play in future demand. Scenario 3 with highest demand is expected to be even higher than shown in Figure 4, since the PDD calculation used in Gaston underestimates peak demand. Scenario 1 and 4 are considered the most likely development pathways. Table 2 shows 2016, 2027, and 2067 demand indicators for Gaston, as well as the reduction or increase from 2016 demand values. It is notable that Table 2 shows Scenario 2 in 2027 and 2067 has lower ADD, PSD and PDD than 2016 actual demand values. These decreases are due to low population growth and aggressive water loss reduction. Gaston population expansion under the low growth scenario does not exceed 3 new residents per year. Water loss is decreased at a much faster rate, reducing about 75 gpcd for all Gaston residents. For this reason, 2016 demand is higher than Scenario 2 demand projections in Gaston.

Table 2- Gaston actuals and projections for 2016, 2027, and 2067. Change from 2016 demand actuals are depicted with blue (decrease), green (increase), and black (no change).

	ADD (mgd)	PSD (mgd)	PDD (mgd)
		2016	
Actual	0.12	0.13	0.15
		2027	
Min Projection (Scenario 2)	0.07	0.08	0.09
Δ 2016-2027	-0.05	-0.05	-0.05
Max projection (Scenario 3)	0.25	0.27	0.33
Δ 2016-2027	0.14	0.14	0.19
		2067	
Min Projection (Scenario 2)	0.08	0.09	0.11
Δ 2016-2067	-0.03	-0.04	-0.04
Max Projection (Scenario 3)	0.29	0.32	0.39
Δ 2016-2067	0.18	0.19	0.24

City of Cornelius

Cornelius demand projections are informed by the Cornelius Master Plan and demand projections for 2017-2035 that were completed by Cornelius in January 2017. The plan describes water purchases for 2001-2015 and this is supplemented with 2016 Hillsboro data, providing this study with sixteen years of historic data. Here four demand scenarios are created based on different conditions in population growth and water loss. The population growth and gpcd rates used in the demand projections presented in the Cornelius Master Plan were used to create a baseline projection. Since there is high confidence that Cornelius will be installing two ASR wells in the near and long-term, the baseline projection must be modified to capture storage and release from the ASR wells. Water statistics include:

- Average historic gpcd is 92
- Peaking factor ADD/PSD is 1.1
- Peaking factor ADD/PDD is 1.9
- Water loss is 20%
- Projected population growth rate is 2.1%

Population

The population growth rate of 2.1% from the Cornelius Master Plan were used for the low growth demand scenarios. This rate is higher than the 1.2% growth rate which was used in the 2013 Hillsboro Master Plan. A high growth population boom is also considered, estimating 4,000 new inhabitants by 2021.

ASR Capacity

Cornelius's first ASR implementation is planned for 2019, with a second ASR well 10 years after, by 2027. The winter injection rate is expected to be 50 million gallons (mg) over 180 days, or 0.288 million gallons per day (mgd). The summer recovery rate is expected to be 50 mg over 70 days, or 0.72 mgd. There is some uncertainty in summer recovery rates, and the Cornelius Master Plan lists 70 days, 83 days, and 90 days. A 70 day recovery period was used for demand forecasting since the shortest recovery period will result in the highest impact on PDD.

Four demand projection scenarios were created:

1) **Low population growth, no change to water loss rates, and new ASR wells.** Scenarios 1-4 incorporate adjustments based on planned ASR storage. The ASR wells are accounted for by reducing PSD and PDD by the projected ASR summer release capacity in 2019 and 2027. They will be able to reduce PSD by 0.55 mgd and PDD by 1.44 mgd, once both ASR wells are functional.
2) **Low population growth, water loss rates are reduced, and new ASR wells.** Water loss reduction is estimated as a reduction from 20% loss to 10% loss between 2017 and 2021.
3) **High population growth, no change to water loss rates, and new ASR wells.** A near-term boom in population is projected due to potential influx in development until 2021. This adds 4,000 people by year 2021, a growth rate of 6%. The low growth rate of 2.1% is used after 2021.
4) **High population growth, water loss rates are reduced, and new ASR wells.**

Projection Results

Similar to Gaston projections, results for Scenarios 2 and 3 shown in Figures 5 through 7 (attached) represent the minimum and maximum demand that may occur in Cornelius. Low population growth with reduced water loss is the lowest demand scenario whereas high population growth with no water loss reduction is the highest. ADD Scenario 3 projections are 29% higher than Scenario 2, as depicted in Figure 5. Scenarios 1 and 4 are considered the most likely development pathways. In Figure 6 and Figure 7, PSD and PDD demand projections show significant demand reduction resulting from the ASR installations. The PDD trend shown in Figure 7 is accurate and not underestimated, since daily data is available for this Cornelius. Table 3 shows the 2016, 2027 and 2067 demand indicators for Cornelius, as well as the change from 2016 demand values. Table 3 shows that PSD and PDD 2016 actual demand values are reduced in the 2027 projections for Scenario 2 and 3. These reductions are because both ASR installations are complete by 2027, which considerably reduces PSD and PDD. However, by 2067 the ASR demand savings are exceeded in Scenario 2 and 3, and demand growth is expected.

Table 3- Cornelius actuals and projections for 2016, 2027, and 2067.Change from 2016 demand actuals are depicted with blue (decrease), green (increase), and black (no change).

	ADD (mgd)	PSD (mgd)	PDD (mgd)
		2016	
Actual	1.02	1.17	1.17
		2027	
Min Projection (Scenario 2)	1.15	0.73	0.75
Δ 2016-2027	0.03	-0.44	-1.39
Max Projection (Scenario 3)	1.49	1.11	1.41
Δ 2016-2027	0.37	-0.06	-0.73
		2067	
Min Projection (Scenario 2)	2.66	2.40	3.62
Δ 2016-2067	1.54	1.23	1.48
Max Projection (Scenario 3)	3.45	3.29	5.16
Δ 2016-2067	2.33	2.12	3.02

Summary

Of City of Hillsboro wholesale customers, Cornelius has the largest water demand in the present and future. By 2027, a year after the Willamette Water Supply System is expected to complete, Cornelius ADD is projected to be between 1.15 to 1.49 mgd. By 2067 these values are expected to significantly increase, and ADD is projected to increase 2.66 to 3.45 mgd by 2067. The demand scenario with the greatest water conservation includes water loss reduction from 20% to 10% and low population growth. Even with high population growth, water loss reduction is able to reduce daily demand by almost half a million gallons a day on average over 2017-2067. The area could even see an overall reduction of 0.04 in peak daily demand by 2067 from 2016 levels, given the installation of ASR wells, low population growth and water loss reduction.

Gaston incurs the highest water loss of customers, at over 42% loss. For this reason, future Gaston usage will probably depend on whether loss reduction is achieved. Gaston ADD is projected to be between 0.07 to 0.25 mgd by 2027. By 2067 the ADD projection is between 0.08 to 0.29 mgd. Given high population growth, an average of 0.18 million gallons a day of additional water will be required in Gaston from 2017-2067 if loss is not reduced.

The LA Water Co-Op represents the customer with the least demand and projected increase. By 2027 LA Water ADD is expected to be 0.28 mgd, representing a mostly flat change from current rates of use. A modest increase of 0.04 mgd is expected by 2067, when ADD is projected to be 0.32 mgd. Low population and population growth contribute to low water demand growth over the next 50 years. Peak daily demand shows the greatest increase by 2067, with PDD up 0.1 mgd.

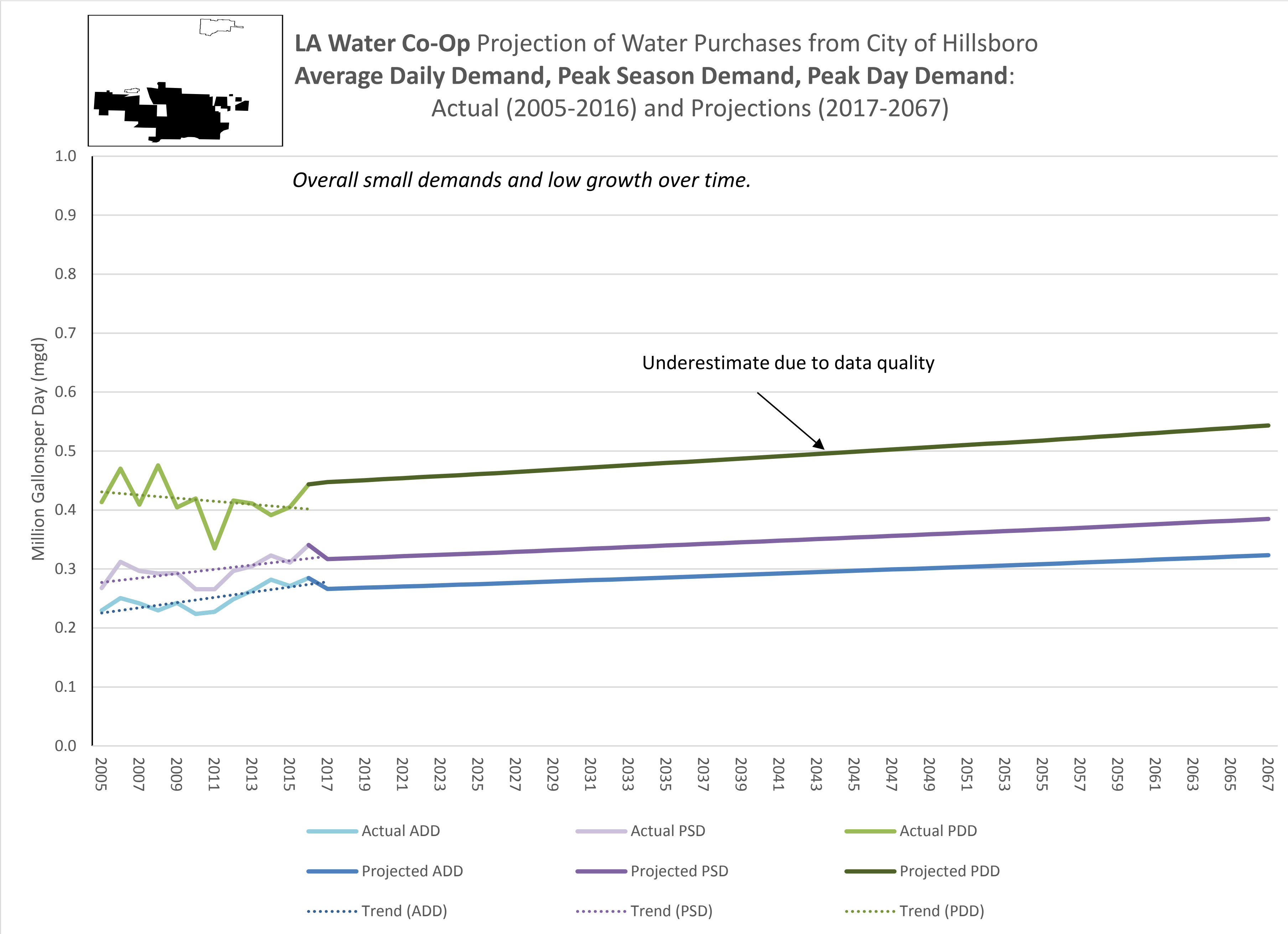

Figure 1- LA Water ADD, PSD, PDD projections

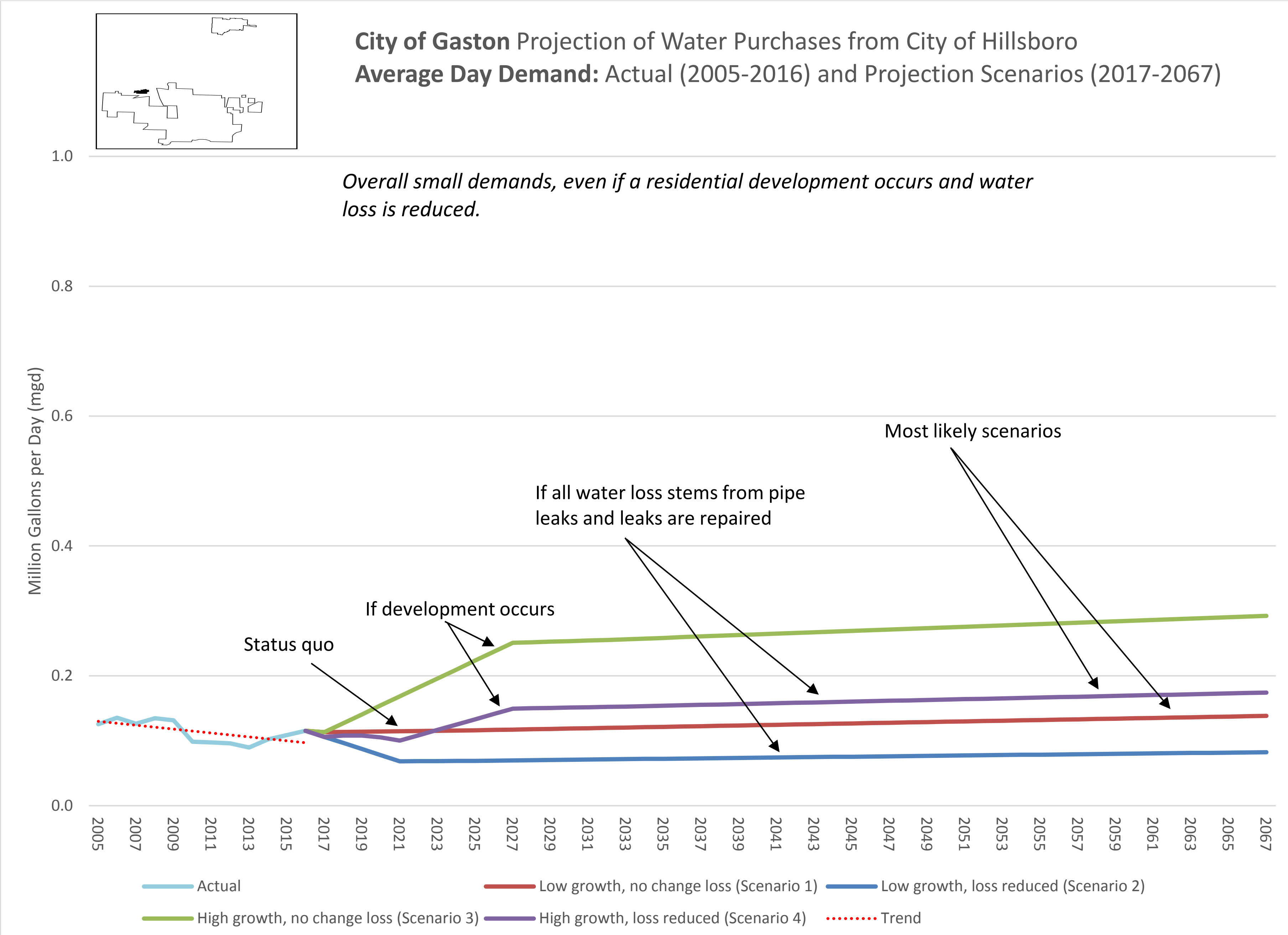

Figure 2- Gaston ADD projections

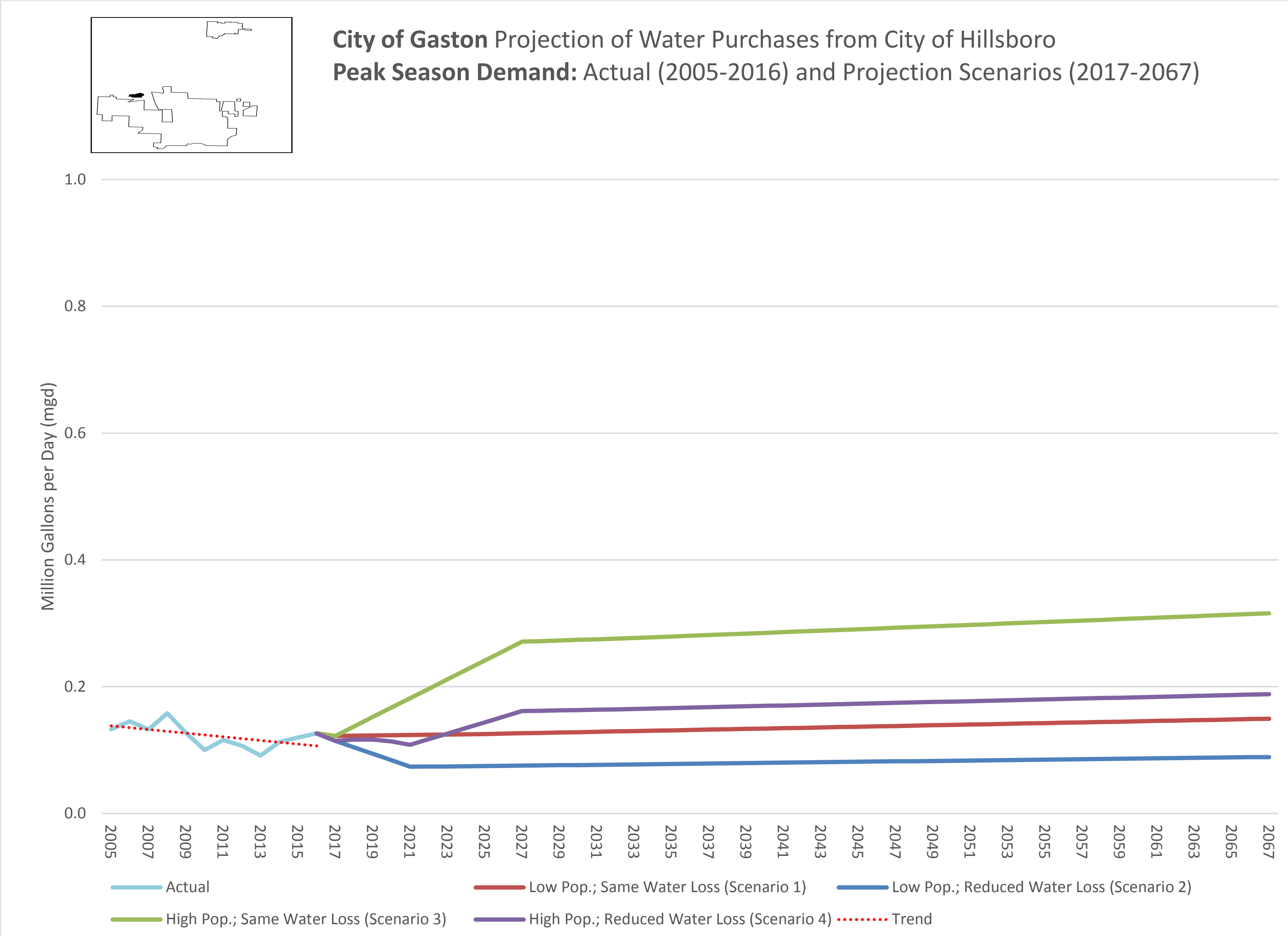

Figure 3- Gaston PSD projections

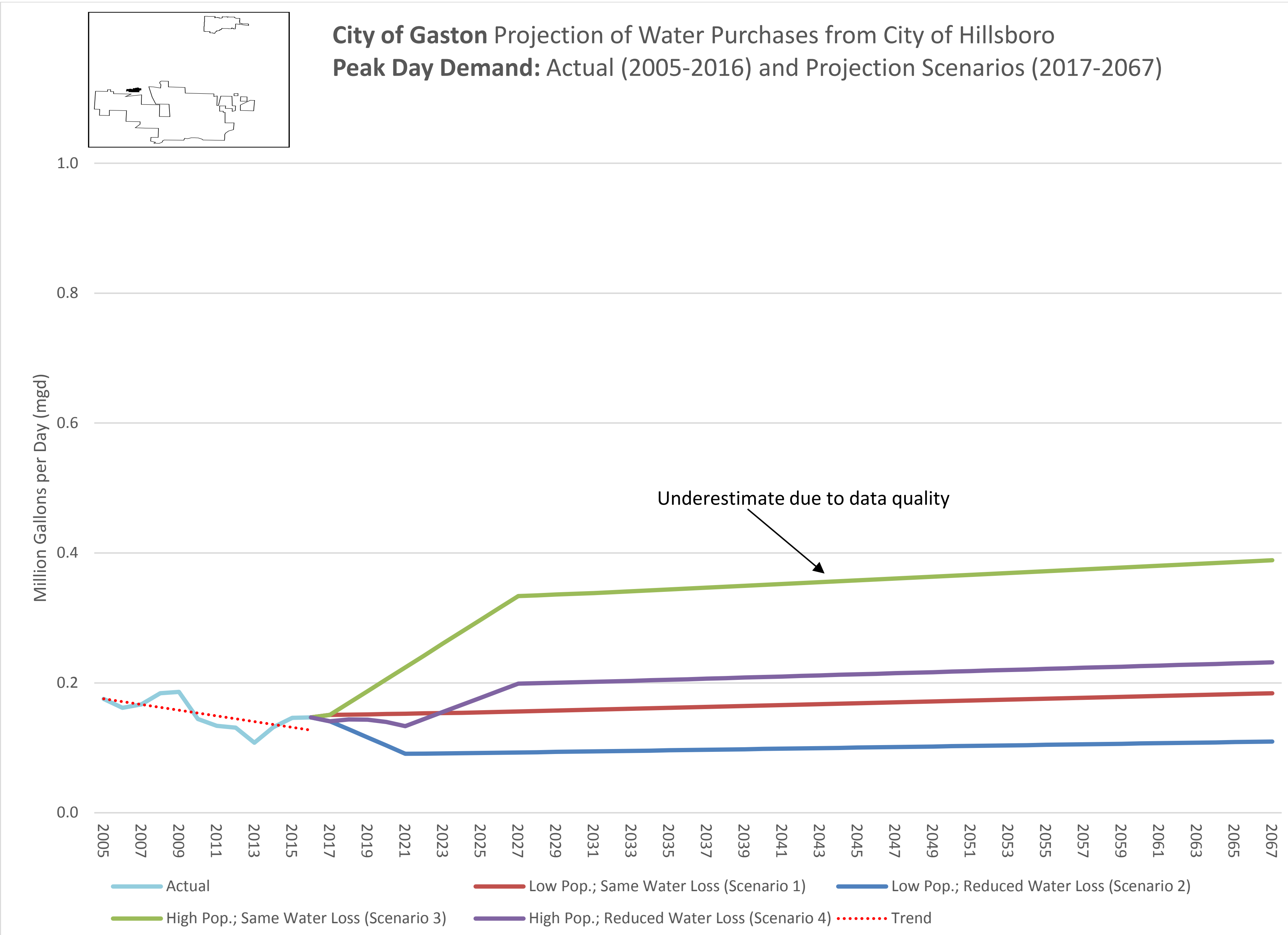

Figure 4- Gaston PDD projections

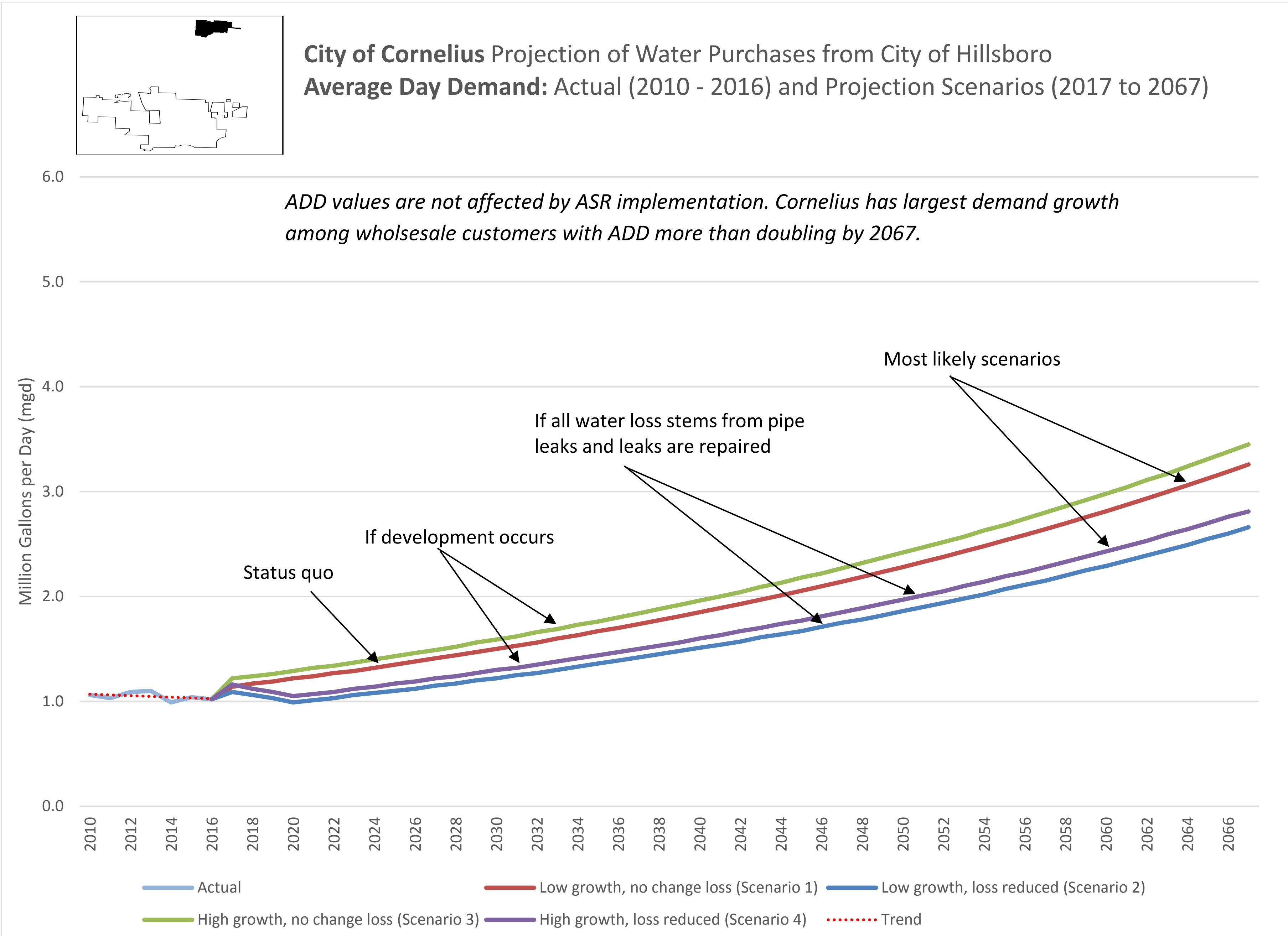

Figure 5- Cornelius ADD projections

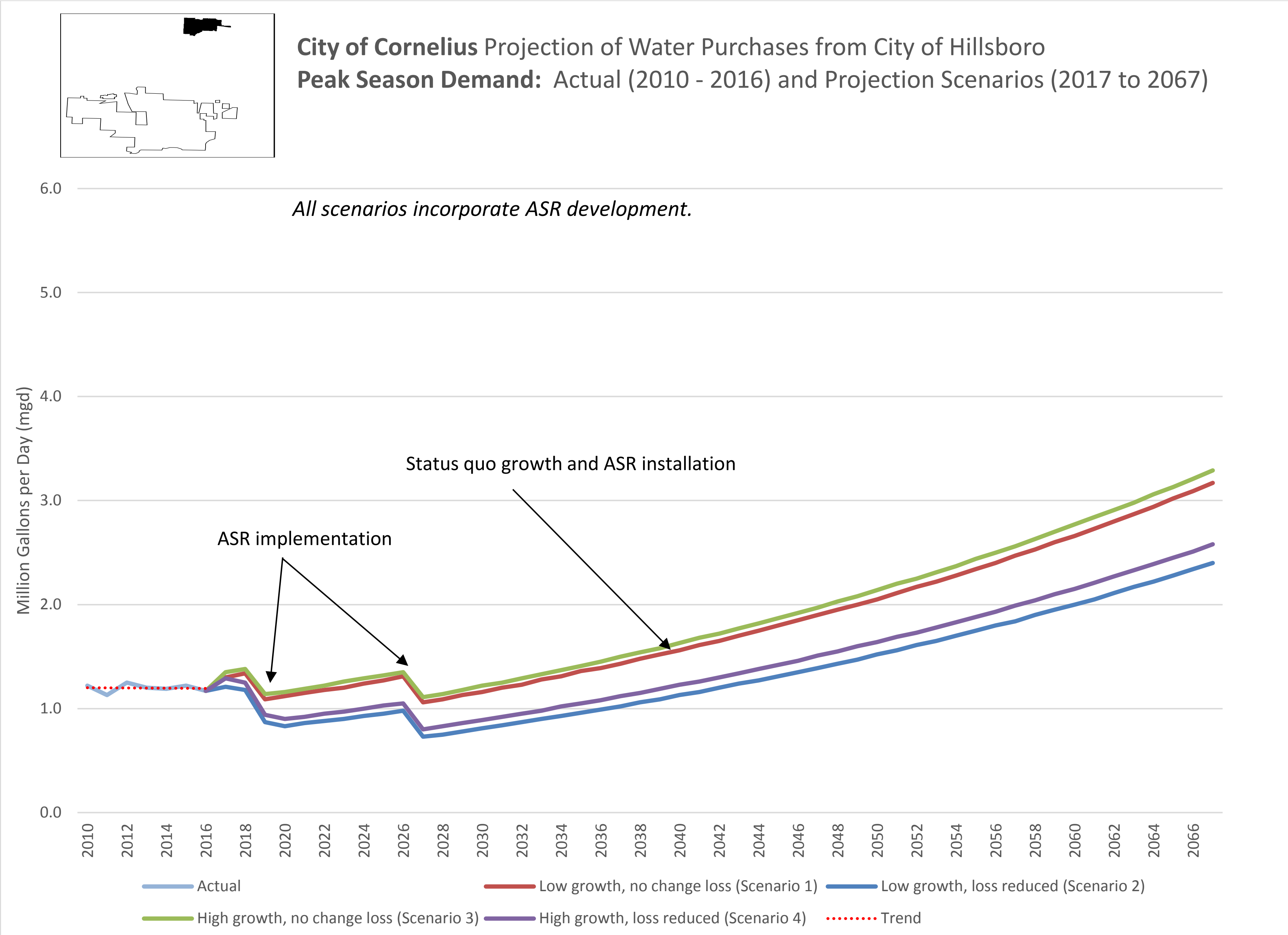

Figure 6- Cornelius PSD projections

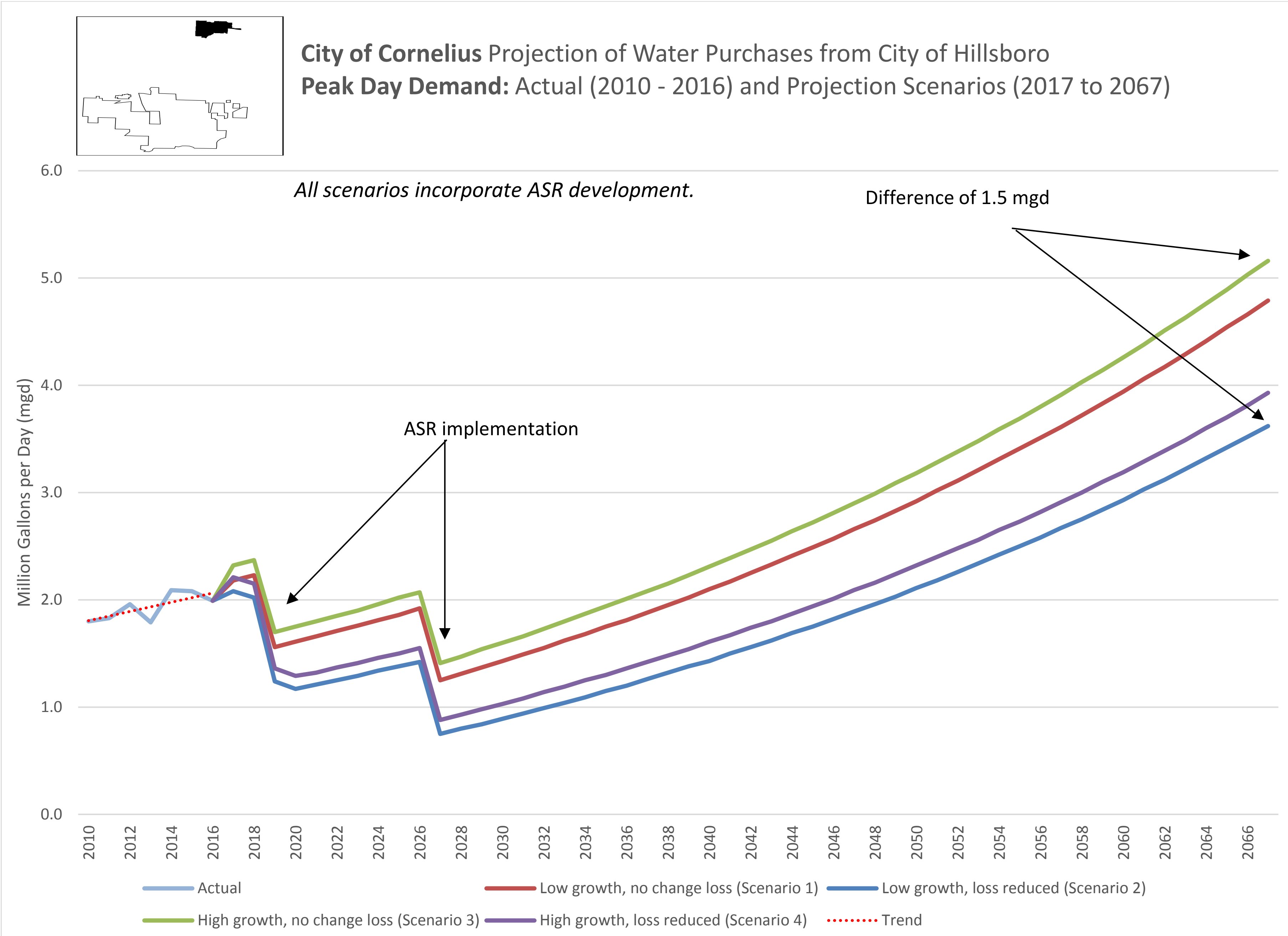

Figure 7- Cornelius PDD projections

Appendix C. Tabular Summaries of Low and High Demand Forecast Scenarios

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Table C-1. Low Scenario Demand Projections

Year	Annual (MG)	ADD (mgd)	PSD (mgd)	PDD (mgd)
2018	7,148	19.6	22.6	35.1
2019	7,349	20.1	22.9	35.2
2020	7,427	20.3	23.1	35.8
2021	7,834	21.5	24.4	37.5
2022	8,247	22.6	25.7	39.2
2023	8,470	23.2	26.4	40.3
2024	8,714	23.9	27.1	41.4
2025	8,978	24.6	27.9	42.7
2026	9,240	25.3	28.8	43.9
2027	9,512	26.1	29.4	44.3
2028	9,773	26.8	30.1	45.5
2029	10,004	27.4	30.9	46.5
2030	10,279	28.2	31.8	47.7
2031	10,544	28.9	32.6	48.9
2032	10,828	29.7	33.4	50.1
2033	11,054	30.3	34.2	51.0
2034	11,285	30.9	34.9	52.1
2035	11,535	31.6	35.7	53.1
2036	11,772	32.3	36.3	54.1
2037	11,969	32.8	37.0	55.0
2038	12,159	33.3	37.6	55.8
2039	12,237	33.5	37.8	56.2
2040	12,390	33.9	38.3	56.9
2041	12,503	34.3	38.7	57.5
2042	12,636	34.6	39.1	58.2
2043	12,769	35.0	39.5	58.8

Year	Annual (MG)	ADD (mgd)	PSD (mgd)	PDD (mgd)
2044	12,919	35.4	39.9	59.6
2045	13,193	36.1	40.9	60.8
2046	13,489	37.0	41.9	62.2
2047	13,784	37.8	42.8	63.6
2048	14,105	38.6	43.8	65.0
2049	14,355	39.3	44.7	66.2
2050	14,616	40.0	45.5	67.4
2051	14,877	40.8	46.4	68.6
2052	15,140	41.5	47.2	69.7
2053	15,331	42.0	47.9	70.6
2054	15,549	42.6	48.6	71.6
2055	15,767	43.2	49.3	72.6
2056	16,015	43.9	50.0	73.7
2057	16,206	44.4	50.8	74.6
2058	16,414	45.0	51.4	75.5
2059	16,604	45.5	52.1	76.4
2060	16,824	46.1	52.7	77.3
2061	16,985	46.5	53.3	78.1
2062	17,176	47.1	53.9	78.9
2063	17,368	47.6	54.6	79.8
2064	17,425	47.7	54.7	80.0
2065	17,419	47.7	54.7	80.0
2066	17,446	47.8	54.8	80.2
2067	17,473	47.9	54.9	80.3
2068	17,532	48.0	55.0	80.6
2069	17,529	48.0	55.1	80.6
2070	17,557	48.1	55.2	80.7

Table C-2. High Scenario Demand Projections

Year	Annual (MG)	ADD (mgd)	PSD (mgd)	PDD (mgd)
2018	7,232	19.8	22.9	35.6
2019	7,488	20.5	23.4	36.1
2020	7,601	20.8	23.8	36.9
2021	8,035	22.0	25.2	38.8
2022	8,473	23.2	26.5	40.7
2023	8,716	23.9	27.3	41.9
2024	8,977	24.6	28.1	43.1
2025	9,258	25.4	29.0	44.5
2026	9,522	26.1	29.9	45.7
2027	9,795	26.8	30.4	46.1
2028	10,065	27.6	31.2	47.4
2029	10,307	28.2	32.0	48.5
2030	10,592	29.0	32.9	49.8
2031	10,868	29.8	33.8	51.0
2032	11,163	30.6	34.7	52.3
2033	11,399	31.2	35.5	53.3
2034	11,642	31.9	36.2	54.3
2035	11,902	32.6	37.0	55.5
2036	12,151	33.3	37.8	56.6
2037	12,359	33.9	38.5	57.5
2038	12,559	34.4	39.1	58.4
2039	12,649	34.7	39.4	58.8
2040	12,813	35.1	39.8	59.6
2041	12,938	35.4	40.3	60.3
2042	13,082	35.8	40.7	61.0
2043	13,227	36.2	41.2	61.8
2044	13,389	36.7	41.7	62.6

Year	Annual (MG)	ADD (mgd)	PSD (mgd)	PDD (mgd)
2045	13,675	37.5	42.7	63.9
2046	13,983	38.3	43.7	65.4
2047	14,291	39.2	44.7	66.8
2048	14,624	40.1	45.7	68.3
2049	14,886	40.8	46.6	69.6
2050	15,160	41.5	47.5	70.9
2051	15,430	42.3	48.4	72.1
2052	15,700	43.0	49.2	73.3
2053	15,899	43.6	49.9	74.3
2054	16,126	44.2	50.7	75.3
2055	16,352	44.8	51.4	76.4
2056	16,608	45.5	52.2	77.5
2057	16,808	46.0	52.9	78.4
2058	17,024	46.6	53.6	79.5
2059	17,222	47.2	54.3	80.3
2060	17,451	47.8	54.9	81.3
2061	17,619	48.3	55.6	82.1
2062	17,819	48.8	56.3	83.0
2063	18,019	49.4	56.9	83.9
2064	18,084	49.5	57.0	84.2
2065	18,087	49.6	57.1	84.3
2066	18,122	49.6	57.2	84.5
2067	18,157	49.7	57.4	84.7
2068	18,225	49.9	57.5	85.0
2069	18,230	49.9	57.6	85.1
2070	18,267	50.0	57.7	85.3