3. Wastewater Flow Projections

This chapter summarizes the historic wastewater flow analysis and the use of the DFAM-WW, refined for wastewater flow estimates, to estimate existing and projected wastewater flows in the City's system. A review and analysis of historic wastewater flows and rainfall data provided by the City was performed and completed. DFAM-WW, as explained in Chapter 2, was refined for wastewater flow estimates. Additionally, this chapter also includes a strategy to address infiltration & inflow (I&I).

The components of wastewater flow evaluated include: Annual Average Flow (AAF), Maximum Day Flow (MDF), Maximum Month Flow (MMF), Peak Hour Flow (PHF), Average Dry Weather Flow (ADWF), Maximum Dry Weather Flow (MDWF) and Average Wet Weather Flow (AWWF). These flow components encompass different time frames (annual, monthly, daily, and hourly) but are all reduced to consistent terms expressed in million gallons per day (mgd). The flow components are defined as follows:

- Annual Average Flow (AAF) is the total flow over a one year period divided by 365 days. This flow factor is typically used to compare with other calculated flow factors to assess the level of peak flow and I&I in the system.
- Maximum Day Flow (MDF) is the maximum flow during one 24-hour period (midnight to midnight) during the year. This flow factor is typically used to size pump stations and unit WWTP processes that rely on short-term hydraulic detention times for proper performance such as chlorine contact tanks and equalization basins.
- Maximum Month Flow (MMF) is the average daily flow during the maximum calendar month. This flow factor is typically used to design unit WWTP processes and used as a critical flow in determining effluent limits for toxic substances on the basis of chronic toxicity for a surface water discharge.
- Peak Hour Flow (PHF) is defined as the peak sustained flow rate occurring during a one-hour period. This flow factor is typically used to design collection and interceptor sewers, pump stations, piping, flow meters, and certain physical WWTP processes such as grit chambers and sedimentation tanks, whose performance can be affected by sudden high hydraulic inputs.
- Average Dry Weather Flow (ADWF) is the average daily flow during periods without rainfall. This flow factor is used to assess the flow generated from households, employment, and industrial customers (without I&I). The households, employees, and industrial components are also called demographic or sanitary flows.
- Maximum Dry Weather Flow (MDWF) is the maximum daily flow during periods without rainfall. This flow factor is also referred to as the maximum demographic or sanitary flow.
- Average Wet Weather Flow (AWWF) is the average daily flow during rainfall periods. This flow factor is used to assess the level of I&I in the system.
- Infiltration & Inflow (I&I) is the contribution to wastewater flows from extraneous groundwater or stormwater entering the collection system. Infiltration is characterized by leaky pipes and manholes allowing groundwater to infiltrate the collection system. Inflow is

the direct connection of stormwater to the wastewater collection system through sources such as manhole cleanout lids, roof downspouts, and catchbasins.

The historic and projected AAF, MDF, MMF, PHF, ADWF, MDWF, and AWWF for the City are presented in this Chapter.

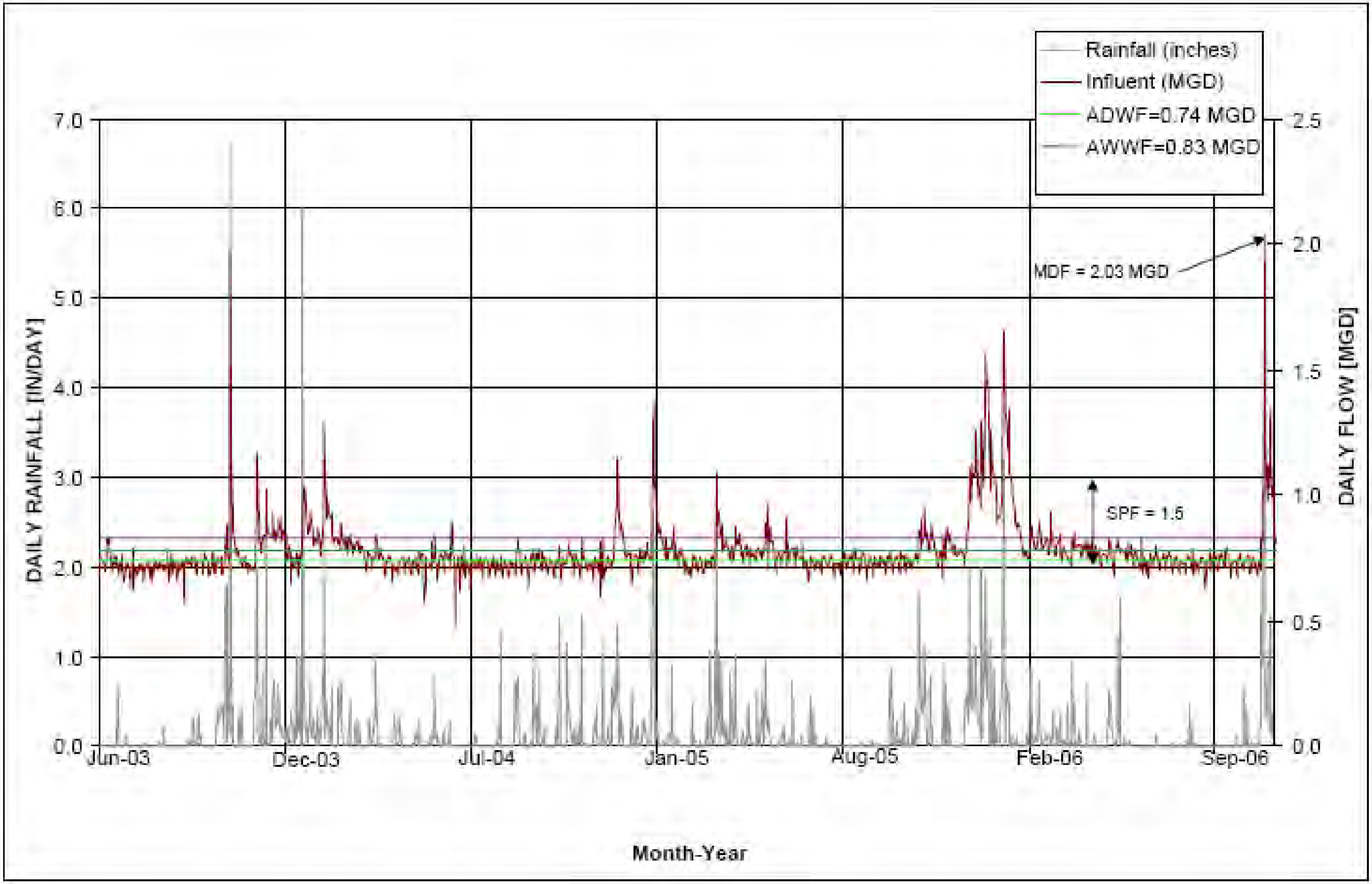
3.1. Historic Wastewater Flows

Recorded data provided by the City includes the daily rainfall and WWTP influent flow between June 2003 and November 2006 (1,267 days). The MDF recorded at the WWTP was 2.037 MGD. This data is illustrated in Figure 3-1.

The instantaneous flow data at the WWTP influent is displayed on a digital readout. The instantaneous flow is recorded on circular charts that have a one week duration (Sunday to Sunday). The maximum instantaneous flow that can be recorded on the circle charts is approximately 1,500 GPM or 2 MGD. However, City staff has observed a maximum instantaneous flow of 2,236 GPM (3.22 MGD) on the digital readout. The City estimates that this instantaneous flow continued for at least one hour during the December 2007 storm. Therefore, the observed 3.22 MGD is used as the historic PHF.

Digital maximum instantaneous or hourly flow data is not available. Therefore, hourly rainfall data was not acquired.

Figure 3-1. Daily Rainfall and WWTP Flow



The City does not have a true dry season since it receives rainfall throughout the year. Therefore, the historic data provided by the City was organized so that the daily WWTP flows could be correlated for days with zero rainfall (693 of the 1,267 days) and for days with measurable rainfall, instead of organizing by traditional wet weather (October to April) and dry weather (May to September) seasons. The following table is a summary of observations from the historic rainfall and WWTP influent data. Figures 3-2 and 3-3 also illustrate WWTP flows for days with either zero or measurable rainfall.

Table 3-1. Summary of Observations from Historic Rainfall and WWTP Influent Data

WWTP Influent Flow	Dry Weather Flow (On days with zero rainfall)	Wet Weather Flow (On days with measurable rainfall)
Average	0.743 MGD	0.827 MGD
Maximum	1.118 MGD (*SPF = 1.5)	2.037 MGD (also MDF)
Minimum	0.478 MGD	0.597 MGD

*The SPF was calculated by dividing the maximum DWF by the average DWF.

Figure 3-2. WWTP Flows for Days with Zero Rainfall

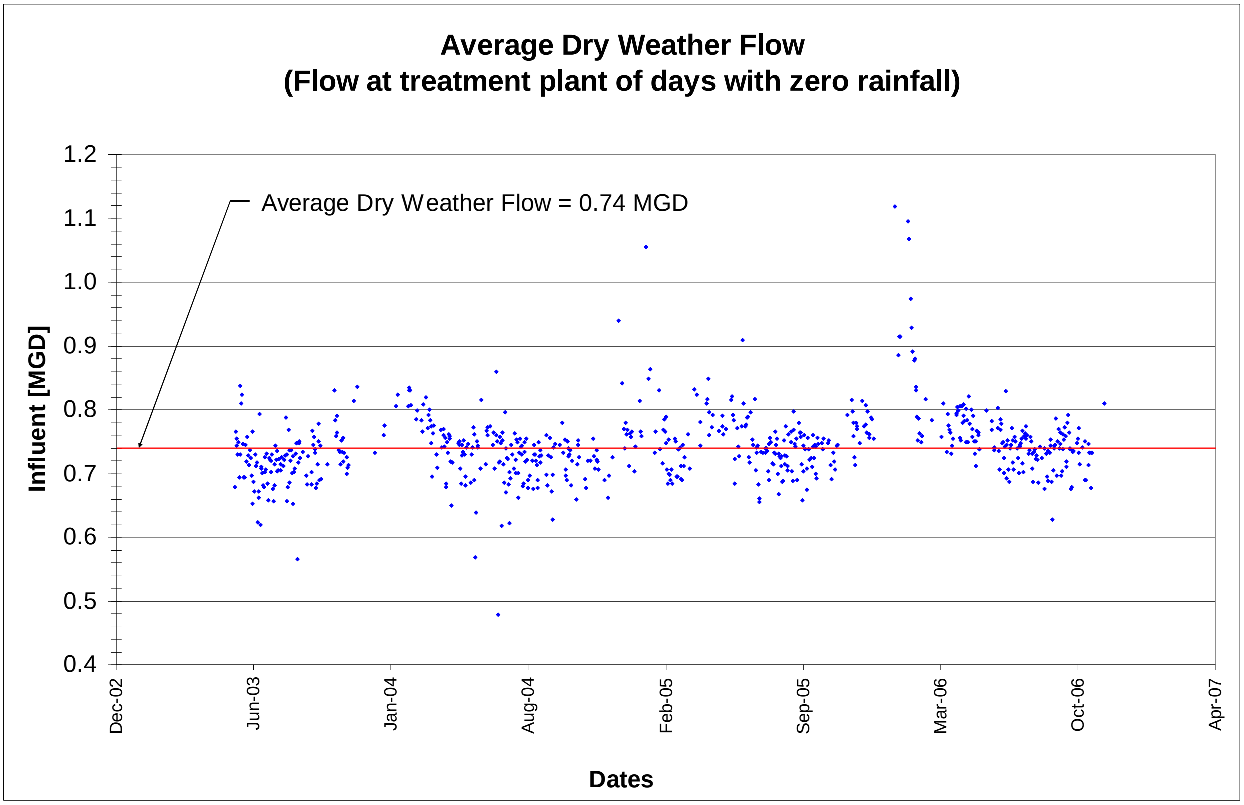
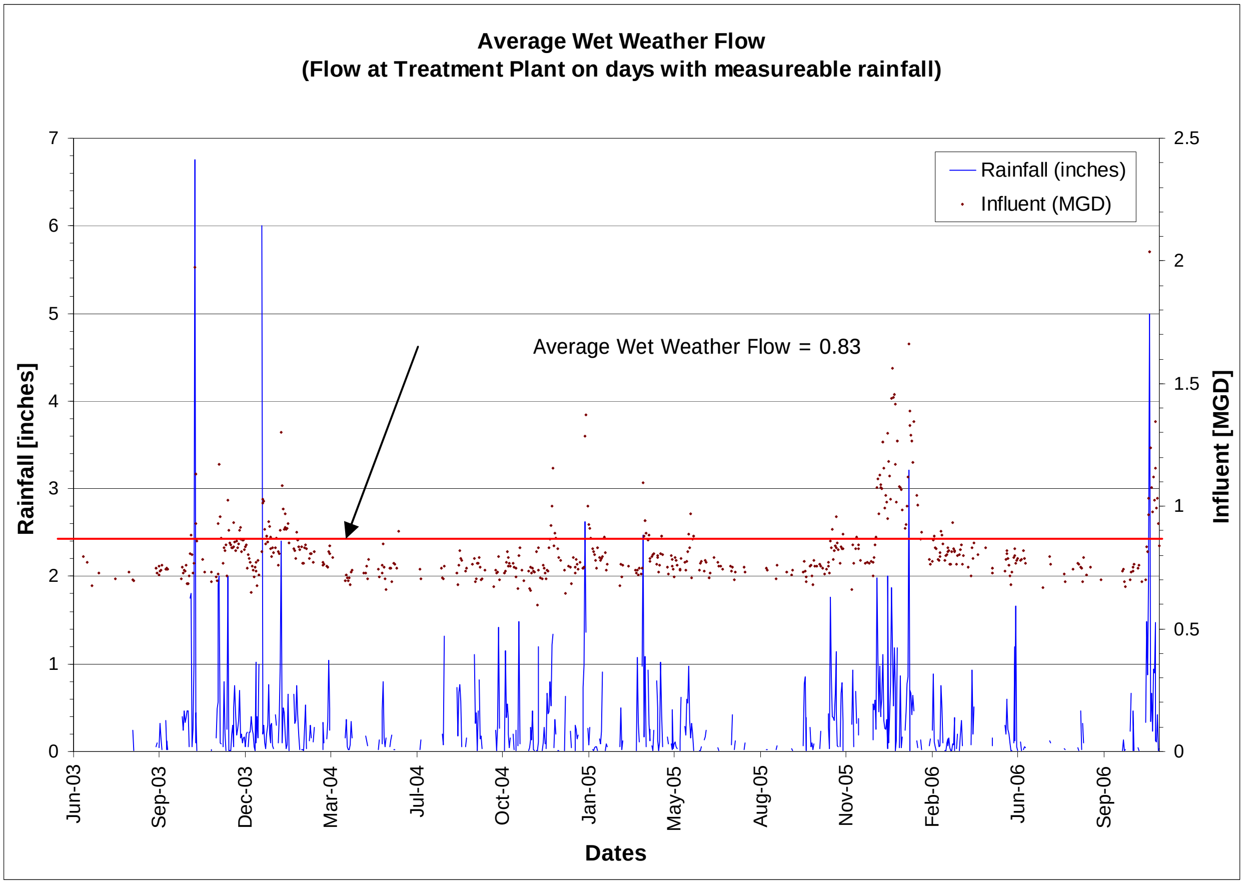


Figure 3-3. WWTP Flows for Days with Measurable Rainfall



Since there were days of zero rainfall during the winter season (flows equal ADWF), the assumption is made that infiltration from groundwater has little affect on the system.

3.1.1. Historic Lift Station and WWTP Flow Calculations

All lift stations are installed with constant speed pumps, with the exception of Lift Station 2A and Lift Station 3A which have pumps with variable frequency drives (VFDs). To calculate the flows for each lift station, the installed pump capacity for each lift station was multiplied by the corresponding daily run time data provided by the City. This effort should provide appropriate results for the lift stations with constant speed pumps. However, the lift stations with VFDs likely don't operate at full pump capacity throughout the daily run time documented, so calculated flows estimated using this technique are likely to be higher than actual conditions. This discrepancy applies primarily to Lift Station 2A. Since Lift Station 3A conveys all flows collected in the system and discharges directly to the WWTP, the flow data from Lift Station 3A can be correlated (or replaced) by the flows documented for the WWTP influent. The comparison of historic/observed wastewater flows with estimated current and future wastewater flows using the DFAM-WW is discussed in Section 3.2.4.

The graph representing the historic WWTP influent flow and corresponding rainfall is shown on Figure 3-3, which indicates the correlation between rainfall events and increased flows in the wastewater collection system.

3.1.2. Historic Flow Data for Selected Wastewater Customers

The City also collected historic billing data (for the years 2004 through 2006) for analysis of the following customers:

- Wollochet Harbor Sewer District
- Canterwood STEP Association and Rush Division 12 STEP Association
- Goodman Middle School and Harbor Heights Elementary School

This billing data was used to estimate historic wastewater flows from these customers. The calculation results of historic flows for these customers are presented in Table 3-2.

Table 3-2. Selected Wastewater Customer Historic Flow Estimates

Customer	Annual Average Flow (AAF)
Wollochet Harbor Sewer District	11,000 gallons per day
Canterwood STEP Association	40,000 gallons per day
Rush Division 12 STEP Association	5,000 gallons per day
Goodman Middle School	14,000 gallons per day
Harbor Heights Elementary School	8,000 gallons per day

Calculation of flows from these customers was required in order to estimate current and future flows using DFAM-WW, since DFAM-WW does not account for currently non-sewered parcels (parcels not billed individually by the City for sewer service) and for demographics located outside the City's UGA boundary. The Canterwood STEP Association and the Rush Division 12 STEP Association are currently non-sewered individual accounts, but are billed in aggregate by the City. The Wollochet Harbor Sewer District and the two schools are located outside the City's UGA boundary.

3.2. Collection System Infiltration and Inflow (I&I)

The historic wastewater flow analysis indicates the significance of inflow from rainfall as the primary source of I&I in the collection system. This section focuses on evaluating individual wastewater basins within the collection system to identify and prioritize areas where inflow may be most prevalent, to determine a strategy for I&I corrective activities. Basin-level I&I evaluations included previous I&I studies and observations, pump station flow and rainfall correlation, and estimated basin I&I flows. Two I&I reduction alternatives are presented, followed by the City's strategy to address I&I.

In order to estimate the rainfall's effects of wastewater flow, the historic data was sorted and ranked by maximum daily rainfall and maximum daily flow. The days with the most rainfall do not directly correlate to the highest witnessed WWTP flows. On selected days, 4.99 and 6.76 inches of rainfall produced approximately 2 MGD, while on another day 6 inches of rainfall produced only 0.814 MGD. This analysis indicates that daily rainfall does not directly affect daily WWTP flows (i.e., inflow from catchbasins or roof downspouts). The next step was to investigate the correlation of the number of days and amount of rainfall leading up to maximum rainfall events and wastewater flows. This was done through the following steps:

1. Grouping consecutive rainfall days
2 Counting back the number of days before a maximum daily rainfall where there was zero rainfall
3 Calculating the total amount of rainfall that had fallen within those consecutive measurable rainfall days.

As a result, several consecutive days of rainfall appears to correlate with increased WWTP flows, indicating a trend that is historically related to interflow. To verify this observation, the data was sorted by descending consecutive number of days since zero rain to observe the correlation of previous days of rainfall to observed wastewater flows. The results indicate that approximately five to six days of rain totaling 4 to 12 inches resulted in 1.3 to 2.0 MGD in WWTP flows. Approximately two days of consecutive rain totaling 2 to 4 inches resulted in approximately 1.0 to 1.1 MGD in WWTP flows.

Note that one day with 6 inches rainfall (January 6, 2004) with no prior rainfall had limited affect on the WWTP flows. However, according to the historic rainfall and influent data, two days of consecutive rain on January 6 – 7, 2004 (6.7 inches total), had produced a maximum of 1.026 MGD at the WWTP.

3.2.1. Equivalent I&I Factor

The Rational Method was used to calculate the equivalent drainage area that impacts the WWTP flows. This method provides an equivalent I&I factor correlating rainfall and measured treatment plant flows. The total preceding rainfall, daily rainfall, and WWTP influent values are estimates from the historic data provided by the City.

$$\text{Rational Method : } Q = ciA \rightarrow cA = \frac{Q}{i}$$

$$Q = \text{Inflow } \left(\frac{ac-in}{day}\right)$$

$$i = \text{Daily Rainfall (inches)}$$

$$cA = \text{Runoff Factor x Area = Equivalent I\&I Factor (acres)}$$

Inflow, *Q*, was calculated by subtracting the ADWF from the WWTP Influent values. An equivalent I&I factor of 8 acres is utilized with precipitation data to calculate the I&I portion of total wastewater flows.

3.2.2. I&I Reduction Alternatives

A general alternative to reduce I&I in the City's collection system is to consider repairing and replacing existing collection system components. The challenge of repairing and replacing existing collection system components is identifying the location and cost-effective measures to implement the projects. Most I&I reduction projects requiring repair or replacement of existing facilities is expensive. Even more challenging is implementing I&I reduction projects where repair or replacement of the facilities are located on wastewater customers' private property.

Pipe segments may be difficult to repair or replace on private property and high flows from Gig Harbor have been observed by the City during some rain events. Focusing on remedies of known defects within the public right-of-way will be the starting point for the City to monitor the cost-effectiveness of I&I reduction.

3.2.3. I&I Reduction Strategy

The various I&I analyses presented above indicate varying priority basins. The City plans to begin addressing some of the known defects and monitor the results. The following lists the City's strategy and priorities for addressing I&I in the collection system:

1. Focus first on addressing known defects identified by observation or increased pump station run times. Addressing defects in the public right-of-way will likely be easier to implement first before addressing defects on private property.
2. Record daily rainfall data and pump station flow run time to further evaluate wet weather flows. Conduct detailed I&I evaluation on priority basins when appropriate data justifies.

3.3. Current and Future Wastewater Flow-Generating Demographics

Wastewater flows in the City under current and future conditions were estimated using the Demographic Forecast Allocation Model – Wastewater (DFAM-WW). Description of the wastewater flow estimates is provided in this section.

The DFAM-WW used the demographic data and applied average wastewater unit flow rates to estimate the Average Dry Weather Flow (ADWF) and Sanitary Peak Flow (SPF) for each basin. The I&I factors were used as the basis and applied to calculate the MDF, MMF, and PHF for each wastewater basin.

3.3.1. Sewered and Non-Sewered Parcels

Sewered and non-sewered parcel estimates used in the DFAM-WW were reassigned to wastewater basins within the DFAM-WW. Existing sewered parcels are based on the City's billing database and the location of sewered parcels is presented in Appendix B. The demographic estimates prepared for the DFAM-WW were based on the Buildable Lands Inventory (BLI) and Buildable Lands Analysis (BLA) completed for the City. The BLI and BLA analyzed each parcel in the City's UGA to identify undeveloped, developed, and redevelopable parcels which were correlated to each of the demographic components (single family, multi-family, etc.).

DFAM-WW has been developed with the capability to distribute demographics for each wastewater basin into sewered and non-sewered categories. The DFAM-WW estimates sewered and unsewered demographics by multiplying demographics for each wastewater basin by an estimate of the percent sewered within the wastewater basin. Estimates of percent sewered are applied to the years 2008, 2025, and 2050, by wastewater basin, for single family and multi-family households, and employment. The 2008 percent of demographics sewered for each wastewater basin is estimated based on tax parcel information extracted from the BLA correlated to the City's wastewater utility billing database. Estimates of future percent sewered included in the DFAM-WW are rough estimates that can be further scrutinized by City staff in the future as growth develops. Estimates of the future percent sewered accounts for two components: (1) how quickly do currently unsewered, developed parcels connect to the public sewer system, and (2) the assumption is applied regarding whether new development is sewered at the time of development or a future time. The DFAM-WW currently applies the following assumptions:

- Year 2025 (20-year planning horizon): Fifty percent of unsewered, developed parcels from 2008 are sewered in 2025. Ninety percent of demographics associated with new development are sewered.
- Year 2050 (year of buildout identified by the City): One hundred percent of unsewered, developed parcels from 2008 are sewered in 2050. One hundred percent of demographics associated with new development are sewered.
- The DFAM-WW currently estimates the annual percentages by using a straight-line linear trend between data points requested by the City (2008, 2025 and 2050).

DFAM-WW has the capability to modify the estimated future percentage of sewered parcels within each wastewater basin to allow for further refinement and correlation of future wastewater flows with growth and development trends to be identified by the City.

The sewered and non-sewered demographic projections using DFAM-WW are presented in Table 3-3.

Table 3-3. Sewered and Non-Sewered Demographic Estimates using DFAM-WW

Year	Single Family House		Multifamily House		Employment		Prison Inmates[1]	School Enrollment[2
	Sewered	Non-Sewered	Sewered	Non-Sewered	Sewered	Non-Sewered		
2005	1,324	2,308	848	1,225	14,530	6,197	896	5,625
2025	5,787	1,071	2,575	610	32,213	8,138	996	9,007
2050	7,608	0	3,466	10	45,517	69	996	12,194

1. The Washington Corrections Center for Women (WCCW) is currently sewered.
2. Existing schools are sewered. Current methodology assumes equal distribution of school enrollment growth across existing schools, and that new schools would be connected to the sewer system upon construction. Need to identify where new schools will be built and when.

3.3.2. DFAM-WW Correlation with Historic Flows

Basin specific comparisons of historic/observed wastewater flows to current flow estimates from the DFAM-WW as an effort to determine a level of calibration is not feasible due to the fact that the majority of the City's wastewater collection system consists of lift stations pumping in series. The flows in most lift stations include cumulative flows from the upstream lift station(s). However, the appropriate comparison of historic/observed wastewater flows with DFAM-WW projected flows apply to the total flows at the WWTP.

3.3.3. DFAM-WW Results and Conclusion

Tables 3-4 and 3-5 present output from the forecasting model for the entire Gig Harbor UGA. Table 3-4 displays total values for the six demographic categories contained in the model. Table 3-5 presents three demographic categories for which data is broken down further into sewered and unsewered categories. For the sake of brevity, only selected years are shown at five-year intervals. The actual model generates results for each year through 2050. The model can generate similar tables for any individual wastewater basin.

Figure 3-4 displays the growth in demographic categories in a graphic format. This graph is contained within the model and can be generated either for the UGA as a whole or for individual wastewater basins.

It is anticipated the City will utilize the model for utility planning services and will update it as needed to ensure input data and forecasts remain current.

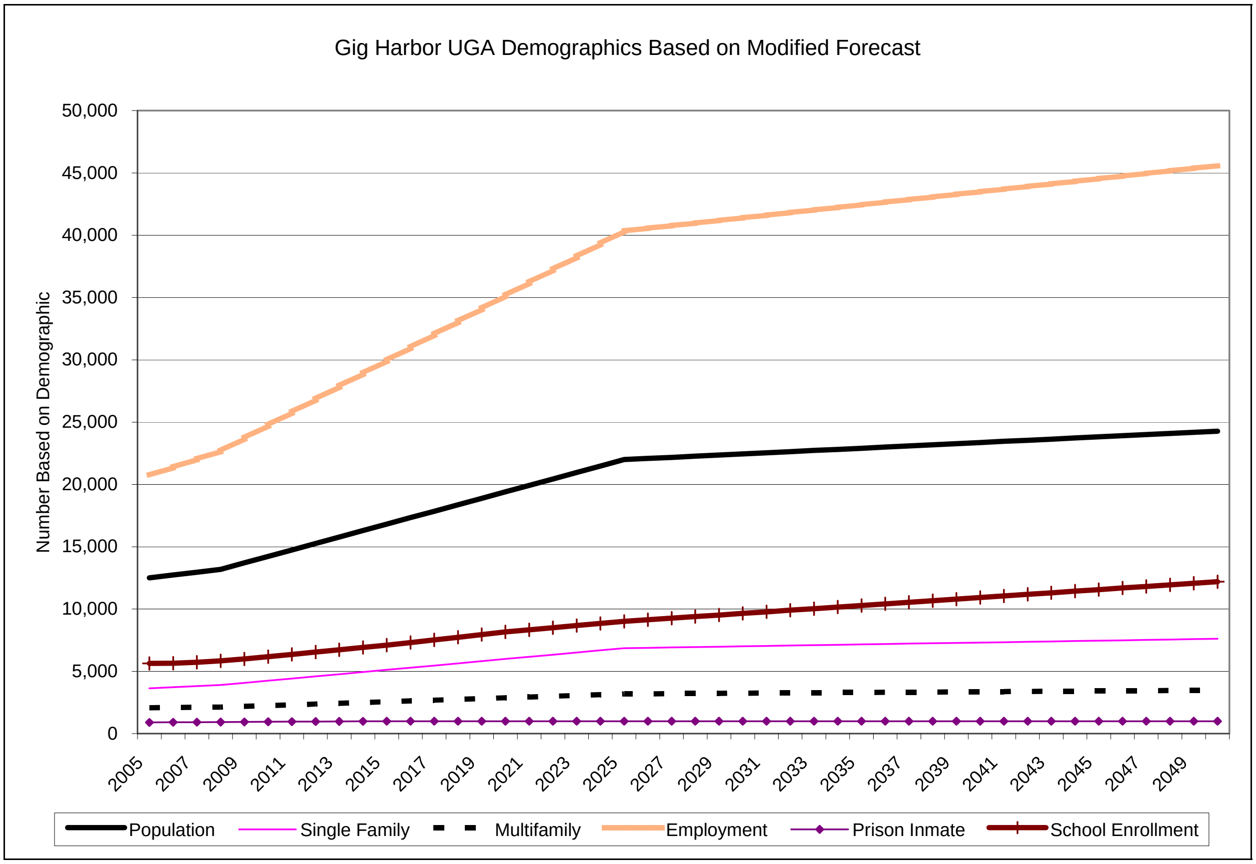
Table 3-4. Gig Harbor UGA Demographics Based on Adjusted Growth Rates

Year	Population	Households		Employment	Prison Inmates	School Enrollment
		Single Family	Multi-family			
2005	12,494	3,632	2,073	20,727	896	5,625
2010	14,223	4,244	2,250	24,748	946	6,172
2015	16,813	5,116	2,562	29,949	996	7,098
2020	19,404	5,987	2,873	35,150	996	8,160
2025	21,994	6,858	3,185	40,351	996	9,007
2030	22,450	7,008	3,243	41,398	996	9,644
2035	22,906	7,158	3,302	42,445	996	10,282
2040	23,363	7,308	3,360	43,492	996	10,919
2045	23,819	7,458	3,418	44,539	996	11,557
2050	24,275	7,608	3,477	45,586	996	12,194

Table 3-5. Gig Harbor UGA Demographics Based on Adjusted Growth Rates by Sewer Connection

Year	Single Family Households		Multifamily Households		Employment	
	Sewered	Non-Sewered	Sewered	Non-Sewered	Sewered	Non-Sewered
2005	1,324	2,308	848	1,225	14,530	6,197
2010	1,910	2,334	1,102	1,148	16,976	7,771
2015	3,006	2,110	1,507	1,054	20,936	9,012
2020	4,298	1,689	1,999	875	26,015	9,135
2025	5,787	1,071	2,575	610	32,213	8,138
2030	6,132	876	2,745	498	34,704	6,694
2035	6,486	672	2,920	382	37,280	5,165
2040	6,851	457	3,098	262	39,941	3,551
2045	7,225	233	3,280	138	42,686	1,853
2050	7,608	0	3,466	10	45,517	69

Figure 3-4. Gig Harbor UGA Demographics Based on Adjusted Growth Rates



3.4. Current and Future Wastewater Flow Estimates

3.4.1. Average Wastewater Unit Flow Rates

Based on the City's historic wastewater flow data and published literature, the average wastewater unit flow rates were estimated and refined during DFAM-WW simulations in an effort to correlate the total historic and calculated flows. The average wastewater unit flow rates used in the DFAM-WW are presented on Table 3-6.

Table 3-6. Average Wastewater Unit Flow Rates

Demographic	Average Wastewater Unit Flow Rate
Single Family Household (1)	134 gallons per household per day
Multi-Family Household (1)	134 gallons per household per day
Commercial Population	18 gallons per person per day
School Population	20 gallons per person per day
Prison Population	100 gallons per person per day

1. The City estimates 2.19 people per household.

DFAM-WW has the capability to modify the average wastewater unit flow rates for further refinement and correlation if required. These modifications can vary over time within the capability of the DFAM-WW to account for such activities as conservation measures implemented by the City and its customers.

3.4.2. Wastewater Flow Projections

Before future flows were estimated, the average sanitary and sanitary peak flows were calculated using a quantity of sewered units calculated in the Demographic Forecast Allocation Model-Wastewater (DFAM-WW). This data is shown on Table 3-7.

Table 3-7. Average Sanitary and Peak Flow Estimates

		2005		2025		2050	
Category	**Unit Wastewater Flows**	**Qty. of Sewered Units**	**ADWF (GPD)**	**Qty. of Sewered Units**	**ADWF (GPD)**	**Qty. of Sewered Units**	**ADWF (GPD)**
Single Family Residential	134 gpd per unit	1,324	177,414	5,787	775,392	7,608	1,019,472
Multi Family Residential	134 gpd per unit	848	113,614	2,575	345,098	3,466	464,444
Employment	18 gpd per person	14,530	261,534	32,213	579,838	45,517	819,306
Prison	100 gpd per person	896	89,600	996	99,600	996	99,600
School	20 gpd per person	5,625	112,504	9,007	180,134	12,194	243,886
	Subtotal		754,665		1,980,062		2,646,708
Canterwood			40,000		40,000		40,000
Wollochet Harbor			11,000		11,000		11,000
	Total		2,031,062		805,666		2,697,708
Average Dry Weather Flow (MGD)			0.75		1.98		2.65
Sanitary Peak Flow (MGD)			1.13		2.97		3.97

The ADWF value for 2005 correlates to the ADWF value calculated from historic WWTP flows. The sanitary peak flows equals the ADWF multiplied by a sanitary peak factor of 1.5 (Table 3-1).

The projection of future flows were estimated based on observed impacts from rainfall. The 8 acre equivalent I&I factor and estimated current and future ADWF values described above were applied to the average annual, maximum month, and maximum day flow projections. The 8 acre equivalent I&I factor and estimated current and future sanitary peak flow values were applied to the peak hour flow projections. These wastewater flow projections are shown in Table 3-8.

Note that the projected current maximum month, peak day, and current peak hour flow correlate to historic WWTP flow data using the 8 acre equivalent I&I factor and the historic maximum month, peak day, and peak hour rainfalls, respectively.

In addition, these projections include estimating I&I to remain constant in the future. This assumes that new sewers will not increase I&I and that as existing sewers may continue to deteriorate, they will be replaced over time. If the City observes increased I&I in the future, it may be due to rainfall events or they can make the decision to study the cost/benefit of increasing capacity or performing I&I reduction projects.

In order to distribute I&I temporally (throughout time) and spatially (throughout the wastewater basins in the UGA), the total I&I quantity was distributed based on the percentage of dry weather flow in each basin over time.

Table 3-8. Wastewater Flow Projections

Year	ADWF	SPF	Equiv. I&I Factor		AWWF			MMF			MDF			PHF		
	Ave. Dry Weather Flow (MGD)	**Sanitary Peak Flow (MGD)**	**Equiv. I&I Area (Acres)**	**Equiv. I&I Flow Coeffi-cient**	**Ave. Annual Precip. (Inch)**	**Ave. Annual I&I (MGD)**	**Average Wet Weather Flow (MGD)**	**Max Month Precip. (inch)**	**Max Month I&I (MGD)**	**Max Month Average Flow (MGD)**	**Max Day Precip. (inch)**	**Max Day I&I (MGD)**	**Max Day Flow, (MGD)**	**Peak Hourly Precip. (inch)**	**Peak Hourly I&I (MGD)**	**Peak Hourly Flow (MGD)**
Historic	**0.74**	**1.11**				0.09	**0.83**		0.37	**1.11**		1.29	**2.03**		2.09	**3.2**
2005	**0.75**	**1.13**	8	1.00	52.4	0.03	**0.79**	22.0	0.16	**0.91**	6.0	1.30	**2.06**	0.4	2.09	**3.2**
2025	1.98	2.97	8	1.00	52.4	0.03	2.01	22.0	0.16	2.14	6.0	1.30	3.28	0.4	2.09	5.1
2050	2.65	3.97	8	1.00	52.4	0.03	2.68	22.0	0.16	2.81	6.0	1.30	3.95	0.4	2.09	6.1
Notes	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*

1. 2005 ADWF from historic data. Demographic data used to estimate unit flow factors. Future ADWF multiplied future demographic estimates by unit flow factors.
2. Sanitary peak flow equals ADWF times peaking factor of 1.5 (Refer to Table 3-7)
3. Area estimated from analysis of daily flow and daily precipitation data.
4. Coefficient estimated from analysis of daily flow and daily precipitation data.
5. Annual average precipitation from Western Regional Climate Center, Wauna 3 SW Minter Creek WA station, 1948 to 2007. Maximum annual precip was 69.58" in 1950.
6. Average Annual Inflow equals impervious area times runoff coefficient times precipitation.
7. Average wet weather flow is equal to average dry weather flow plus average annual inflow.
8. Maximum month precipitation from Western Regional Climate Center, Wauna 3 SW Minter Creek WA station, 1948 to 2007. Maximum month precip was November 2006
9. Maximum Month Inflow equals impervious area times runoff coefficient times precipitation.
10. Maximum month average flow is equal to average dry weather flow plus maximum month inflow.
11. Maximum day precipitation from Gig Harbor WWTP data between June 2003 to Nov 2006 occurred on Oct 20 2003. Max day from WRCC is 5.06" on Oct 21, 2003.
12. Maximum Day Inflow equals impervious area times runoff coefficient times precipitation.
13. Maximum day flow is equal to average dry weather flow plus maximum day inflow.
14. Maximum hourly precipitation estimated from Type 1A Hyetograph. Appx 5.4% of max day rain falls in peak hour (6.0 inches * ~5.4%). (1-hour rainfall data not available
15. Peak Hourly Inflow equal impervious area times runoff coefficient times precipitation.
16. Peak hourly flow equals sanitary peak flow plus peak hourly inflow.