Chapter 4 - Waste Load and Flow Projections

Purpose

The purpose of this chapter is to:

- Present population trends and projections
- Evaluate water consumption within the service area and compare to wastewater treatment needs
- Develop wastewater flow and loading projections for the planning period

Population Trends and Projections

Current Population

The estimated year 2000 populations of Washington County and Springfield are 10,916 and 2,634, respectively.

An estimate was made of the 1999-2000 wastewater system service population based on the estimated number of residential wastewater system customers, and census-derived persons per housing unit. In 1999-2000, the Springfield sewer system served 1,042 residential customers in single family homes. In addition, it served approximately 10 percent of that population number residing in apartments (estimated from water usage bills). This corresponds to a service population of approximately 3,200, based on 2.8 persons per household (1990 U.S. Census data).

Given an estimated service population of 3,200 in the year 2000 (number of people currently provided with Springfield wastewater collection and treatment service), and an estimated Springfield population of 2,634, as shown in Table 2-1, 566 persons living outside Springfield are provided with Springfield wastewater collection and treatment service.

The Planning Area does not coincide with any census or other jurisdictional boundaries. However, it does fall totally within the boundaries of Census Tract (CT) 9802. According to the 2000 census, the portion of CT 9802 in Washington County had a population of 6,195. Thus, 3,200/6,195, or approximately 52 percent of the census tract population, was served by the Springfield sewer system.

For the purposes of this study, the year 2000 Planning Area population is estimated to be 75 percent of the census tract population, or 4,650 residents. This represents 43 percent of the year 2000 county population.

Population Projections

Population projections are based on the Kentucky State Data Center's projection of county population. This agency is the official source for population data/projections for Kentucky. It forecasts population county-wide only and, therefore, projections for areas within the county must be estimated.

Washington County population projections for the years 2000, 2010, and 2020 were used as the basis for projecting planning area and wastewater system service populations as follows:

- The percentage of county population residing within the planning area in the year 2000 was estimated to be 43 percent. This percentage of county population in the planning area was assumed to remain constant throughout the planning period.

- The service population in the planning area was estimated to be 3,200 in year 2000, or about 69 percent of the 4,650 planning area population. This percentage was increased to 75 percent in 2010 and 85 percent in 2020. The rational for this is that as the sewer system expands to serve future development, it will pick up currently unserved development in the process.

The resulting planning area and service population projections are shown in Table 4-1. As indicated in Table 4-1, the service population is expected to grow from an estimated 3,200 persons in year 2000 to 4,255 persons in 2020, which is a 33 percent increase.

Table 4-1
2000-2020 County, Planning Area, and Wastewater Service Populations
Springfield Facilities Plan Update

Year	*Washington County Population*[1]	*Planning Area Population*	*Planning Area Population Increase*	*Service Population*	*Service Population Increase*
2000	10,916	4,650	0	3,200	0
2002	11,008	4,698	48	3,294	94
2010	11,378	4,892	484	3,669	375
2020	11,644	5,006	114	4,255	586

Note: [1] Source: Kentucky State Data Center

Base Wastewater Flow

The total wastewater flow received at the typical wastewater treatment facility represents a combination of several sources including:

- Wastewater purposely discharged to collection system
- Groundwater infiltration
- Surface water inflow

To determine the per capita wastewater contribution, it is first necessary to quantify the flow without the influences of extraneous water. Therefore, base flow is the amount of wastewater discharged directly to the collection system, excluding the contribution by infiltration/inflow (I/I).

The base flow for the SWSC system has been determined by reviewing flow records for days in which the effects of I/I were considered negligible. WWTP operating records were used to select non-rainfall days.

During three separate extended time periods in 1999, there was little or no rainfall recorded at the Springfield WWTP. Those periods are summarized as follows:

8/21- 9/13: rainfall = 0.17 in. total; average WWTP flow = 0.249 MGD
10/11- 11/1: rainfall = 0 in. total; average WWTP flow = 0.293 MGD
11/3 - 11/19:rainfall = 0 in. total; average WWTP flow = 0.325 MGD

The average flow during these three dry weather periods totaling 63 days, was approximately 0.3 MGD. Therefore, 0.3-MGD flow is considered the "base flow" to the Springfield Wastewater Treatment Plant (WWTP).

Base Wastewater Flow Components

A breakdown of the 0.3-MGD base wastewater flow into two components - "significant industrial" flows, and "domestic strength " flows (which includes residential, commercial, institutional and insignificant industrial flows) - is useful for projecting future flows and loads to the WWTP.

Significant industrial flows are wastewater flows having an organic strength significantly higher than typical municipal wastewater strength. Only two industries - Bluegrass Dairy and GSAFI (formerly Armour Foods) - discharge significant industrial flows to the Springfield wastewater system. According to water billing records, these industries discharged an estimated combined annual average flow of 75,000 gallons per day (gpd) to the Springfield WWTP.

The remaining base wastewater flow component is the domestic strength flow. This flow component includes flows from residential, commercial, institutional, and low-strength-industrial sources. The domestic strength flow component is calculated as follows:

Domestic Strength Base Sewage Flow:

= Total Base Flow - Significant Industrial Flow
= 0.300 - 0.075 = 0.225 MGD

As previously stated, the approximate population of residential single and multi-family domestic customers is 3,200 persons. Therefore, the per capita domestic strength base sewage flow is:

Per Capita Domestic Strength Base Sewage Flow:

= 0.225 MGD/3,200 persons
= 70 gallons per capita per day (gpcd)

The portion of the domestic strength base sewage flow attributable solely to residential customer use ("residential base flow") is comprised of sewage from all residences, i.e. single family and multi-family homes. This flow can be estimated using water consumption records, and assuming that 95 percent of the water consumed is discharged to the sewer system.

Using this approach, the residential base sewage flow is calculated as follows:

Annual Residential Water Consumption, million gallons (MG),7/99-6/00:

Apartments:	5.836
Single Family Homes	46.496
Total	52.332 MG (annually), or 0.143 MGD

The total and per capita residential base sewage flows are calculated as follows:

Total Residential Base Sewage Flow:

= (0.143 MGD x 95 percent)
= 0.136 MGD

Per Capita Residential Base Sewage Flow:

= 0.136 MGD/3200 persons
= 42 gpcd

The estimated average day commercial base sewage flow (which includes commercial, small industrial, and institutional flows) is the difference of the Domestic Strength Base Sewage Flow and the Residential Base Sewage Flow, as follows:

Total Commercial Base Sewage Flow:

= 0.225 MGD - 0.136 MGD
= 0.089 MGD

Per Capita Commercial Base Sewage Flow:

= 0.089 MGD/3,200 persons
= 28 gpcd

Infiltration/Inflow Analysis

Planning and design of sanitary sewer collection and treatment systems must take into account extraneous water components which enter the sanitary sewer system. The two major sources of extraneous water are I/I. Infiltration is groundwater which enters the collection system through pipe joints, broken or cracked pipe, openings in manholes, and other subsurface imperfections. Inflow is the flow component which enters the collection system immediately following a rain event. Typical points of inflow include leakage through manholes covers, roof drain connections, and storm water inlet connections. Because infiltration and inflow each represent a different flow component, it was necessary to calculate the respective flow separately.

Maximum inflow occurs during periods of high intensity precipitation which may be accompanied by isolated flooding. An evaluation of the SWSC collection system indicates significant inflow occurs during high intensity storm events. According to a 1982 sewer system evaluation (SSES) study, the Springfield sewer system has the following average annual inflow rates; and inflow rates for 2-year, 24-hour and 2-year, 4-hour storm peaks[1]:

Average Annual:	0.06 MGD
2-Yr., 24-Hr. Storm Peak:	1.47 MGD
2-Yr., 4-Hr. Storm Peak:	3.51 MGD

These inflow rates were compared to historical plant flow data which indicated that in the time period 1993-present, the maximum recorded plant flow was 4.04 MGD (January 27, 1994). For this study, the actual recorded plant flow of 4.04 is assumed to be a valid peak flow number, and is generally consistent with the 1982 SSES inflow rates.

From WWTP data for the years 1999-2000, the daily flow rate to the Springfield WWTP averaged 0.47 MGD, and the peak flow was 2.47 MGD. Subtracting the average Domestic Strength Base Sewage Flow; average Significant Industrial Flow; and average inflow from the total average flow rate, provides an estimate of the year 2000 average infiltration rate, as follows:

Year 2000 Average Infiltration Rate:

= Average Annual WWTP Flow - Domestic Strength Base Sewage Flow - Significant Industrial Flow - Average Inflow
= 0.470 MGD - 0.225 MGD - 0.075 MGD - 0.06 MGD
= 0.110 MGD

The year 2000 peak infiltration rate was determined in a similar manner, with the assumption that the peak Domestic Strength Base Flow and Significant Industrial Flow rates are 50 percent higher than the average flow rate:

Year 2000 Peak Infiltration Rate:

= Peak WWTP Flow - Peak Domestic Strength Base Sewage Flow - Peak Significant Industrial Flow - 24-Hr. Peak Inflow
= 2.470 MGD - 0.338 MGD - 0.113 MGD - 1.47 MGD
= 0.549 MGD

As noted previously, there is an estimated service population of 3,200 for the Springfield sewer system. Utilizing water usage data from SWSC, the calculated City of Springfield population equivalent (PE) for the wastewater system for the year 2000 is as follows:

- Number of people (residential) served by sewer system: 3,200
- Per capita residential base sewage flow: 42 gpcd
- Year 2000 PE: 225,000 gallons per day[1] ÷ 42 gpcd = 5,357 people

U.S. EPA guidelines for determining excessive I/I are defined as follows:

- Infiltration - If the average daily flow to the WWTP is 120 gpcd or less, infiltration is considered non-excessive. If the average daily flow is greater than 120 gpcd, further investigation of flows is required.

[1]Domestic strength base sewage flow rate

- Inflow - If the rainfall induced peak hydraulic flow rate at the WWTP exceeds 275 gpcd, the city shall perform a study of the sewer system to determine the quantity of excessive inflow and propose a rehabilitation program to eliminate excessive inflow.

The per capita average daily flow rate based upon a PE of 5,357 people is determined by dividing the average daily wastewater flow rate for 1999 and 2000 by 5,357 people, or 88 gpcd. Since this calculated per capita daily flow rate is less than the allowable 120 gpcd, the SWSC sewer system is considered to have nonexcessive infiltration.

The peak 24-hour hydraulic flow rate recorded at the Springfield WWTP during the period January 1999 through December 2000 was 2,470,000 gpd. The peak daily hydraulic flow rate is therefore, 2,470,000 gpd divided by 5,357 PE, or 461 gpcd which is greater than the allowable 275 gpcd. The SWSC sanitary sewer system is, therefore, considered to be subject to excessive inflow. However, this was one event which occurred during an extremely high intensity rainfall. Normal yearly peaks average 1.9 MGD or 355 gpcd.

No known bypasses occur in the collection system. The existing collection system is maintained on a regular basis to minimize any potential overflows; however, during short, high intensity rainfall periods, overflows occur one to two times per year. These occur in the older part of the town but not always in the same location. The durations are generally short. It is recommended that an I/I investigation be completed to try to eliminate all occurrences.

Wastewater Flow Projections for 20-year Planning Period

Table 4-2 presents a summary of the previously calculated wastewater flows for the year 2000 and projected wastewater flows for the 20-year planning period. Wastewater flow projections for the years 2010 and 2020 include the following considerations:

- New residential customers are based on service population projections, which consider population growth in the current service area, as well as extension of the service area.

- Per capita wastewater contribution for residential and commercial will not change significantly; however, low strength industrial flows will increase by an additional 0.485 mgd by 2010, and 0.908 mgd by 2020.

- Significant industrial flow will not change.

- Design flow represent the average daily flow during the maximum flow month of each year, and results from higher infiltration/inflow than is experienced during the average month of the year.

- Peak flow rates for the year 2000 are based on the historical peak flow rate recorded on January 27, 1994 (4.04 MGD). Peak flow rates for the years 2010 and 2020 are based on formula prescribed by "Recommended Standards for Wastewater Facilities, Great Lakes - Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers", p. 10-5, 1997 Edition; and service populations as follows: year 2010 - 3,669; and year 2020 - 4,255.

Table 4-2
***Design Wastewater Flows*[1]**
Springfield Facilities Plan Update

Year	*Type*	*Wastewater*		
		Average Annual Flow	***Design Flow*[2]**	***Peak Flow Rate*[3]**
2000 Existing	•Residential	0.136	0.136	
	•Significant Industrial[4]	0.075	0.075	
	•Commercial[5]	0.089	0.089	
	•Infiltration	0.110	0.220	
	•Inflow	0.060	0.180	
	Total	**0.470**	**0.700**	**4.04**
2010 Projected	•Residential	0.154[6]	0.154	
	•Significant Industrial	0.075[7]	0.075	
	•Commercial	0.588[8]	0.588	
	•Infiltration	0.121[9]	0.363	
	•Inflow	0.030[10]	0.120	
	Total	**0.968**	**1.300**	**4.40**
2020 Projected	•Residential	0.179[11]	0.179	
	•Significant Industrial	0.075[7]	0.075	
	•Commercial	1.027[12]	1.027	
	•Infiltration	0.133	0.399	
	•Inflow	0.030	0.120	
	Total	**1.444**	**1.800**	**6.00**

Notes:
[1]All flows in million gallons per day (MGD)
[2]Assumes residential, significant industrial and commercial/industrial flow components are same as average day flow; infiltration is increased by 200 percent over average annual flow; and inflow is increased by approximately 300 percent over annual average flow.
[3]Year 2000 peak flow based on January 27, 1994 plant record. Year 2010 and 2020 peak flow projections are calculated per "Recommended Standards for Wastewater Facilities, Great Lakes - Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers," p. 10-5, 1997 Edition; with service populations as follows: Year 2000 - 3,200; Year 2010 - 3,669; and Year 2020 - 4,255.
[4]Bluegrass Dairy and GSAFI
[5]Includes commercial, normal-strength industrial, and institutional wastewater
[6]3,669 persons x 42 gpcd
[7]Assumed same as present day
[8]3,669 persons x 28 gpcd plus 0.485 mgd additional low-strength industrial flow
[9]10 percent higher than year 2000 infiltration due to aging and increased sewer length
[10]50 precent lower than year 2000 inflow due to rehabilitation efforts
[11]4,255 persons x 42 gpcd
[12]4,255persons x 28 gpcd plus additional 0.908 mgd low strength industrial flow

Wasteload Projections

In Chapter 3, it was shown that the Springfield WWTP treats a medium strength wastewater. In the period January 2001 through June 2002, the average influent five-day biochemical oxygen demand (BOD_5) concentration was 160 milligrams per liter (mg/L). In that same period, the average influent total suspended solids (TSS) concentration was 230 mg/L. These values are characteristic of a medium strength wastewater, and wastewater flows from all sources including Bluegrass Dairy and GSAFI, Inc. after pretreatment in the trickling filter at the Springfield WWTP.

Influent ammonia-nitrogen (NH_3-N) averaged approximately 14.9 mg/L during the same 18-month period. Total Kjeldahl Nitrogen (TKN) includes ammonia and organic nitrogen species, and is typically 1.6 times the ammonia-nitrogen values in municipal wastewater. Thus, the historical TKN value is calculated to be 1.6 x 14.9 mg/L, or 23.8 mg/L.

Wasteload projections must take into account not only the nature and quantity of existing wastes, but also the possibility that the existing waste characteristics will change as major customers change their process, or expand or close their operation. The nature of future development and their wastes must also be taken into account. Therefore, future waste loads have been projected using reasonably conservative wastewater strengths. The following factors were considered in projecting future wasteload strength:

- GSAFI Inc., a major sewer customer with a high-strength waste, is in the process of phasing out its operation in Springfield.

- The future of the WWTP trickling filter, which provides pretreatment to the Bluegrass Dairy and GSAFI wastes, is uncertain; however, the Springfield WWTP cannot adequately handle the high strength waste of either or both of these customers without some form of pretreatment. It is assumed that the wastes of these and any future high-wastewater strength customers will receive some form of pretreatment.

- The City desires to provide an environment that will attract relatively clean industry and jobs to the area. Thus, waste from new industries will be medium strength.

Given the above, wasteloads for the Springfield WWTP have been projected assuming a similar, although slightly more conservative wastewater strength, than the plant is currently receiving. Table 4-3 summarizes the projected flows, concentrations and mass loading of the sewered portion of the planning area for the years 2010 and 2020.

Table 4-3
Wasteload Projections
Springfield Facilities Plan Update

Constituent	*Design Flow Rate (MGD)*[1]	*Peak*[2] *Concentration (mg/L)*[3]	*Design Concentration (mg/L)*	*Design Load (lbs/day)*[4]
Year 2010	1.3			
BOD_5[5]		400	220	2,385
TSS[6]		500	220	2,385
TKN[7]		45	25	271
NH_3-N[8]		25	15	--
P[9]		9.0	5.5	60
Year 2020	1.8			
BOD_5		400	220	3,303
TSS		500	220	3,303
TKN		45	25	375
NH_3-N		25	15	--
P		9.0	5.5	83

Notes: [1]MGD - Million gallons per day
[2]Peak concentration is used for design of aeration system only and will be confirmed during design development
[3]mg/L - Milligrams per liter
[4]lb/day - Pounds per day
[5]BOD_5 - Five-day biochemical oxygen demand
[6]TSS - Total suspended solids
[7]TKN - Total Kjeldahl nitrogen
[8]NH_3-N - Ammonia
[9]P - Phosphorus

The numbers in Table 4-3 are based on the assumption that industrial pretreatment will be provided, either by the existing pretreatment trickling filter, or by each industry. The age, uneven loading, and low performance of the existing trickling filter in cold weather, suggest that consideration be given to removing it from service. Pretreatment requirements would be imposed on industries discharging waste in a strength that the wastewater treatment plant is unable to accept. A cost-benefit analysis should be performed by the city to determine its options for continued pretreatment versus imposing stricter pretreatment requirements on individual customers.

Capacity of Existing Facilities and Projected Growth

As noted in Chapter 3, the existing Springfield WWTP is operating well and consistently meets its effluent permit limits. However, the existing facilities are designed to meet a 0.88 MGD average flow and are not capable of meeting treatment requirements for the flows and loads projected in this chapter.

Flow and load projections presented in this chapter indicate that design flow will increase to 1.8 MGD within 20 years, which is more than a 100 percent increase in flow compared to present conditions. Waste loads will also increase by approximately that amount. Therefore, it can be concluded that the existing wastewater treatment facilities are not capable of meeting future load conditions, and therefore need to be expanded and upgraded.