SECTION 2.0
PLANNING APPROACH

2.1 INTRODUCTION

This section discusses three key issues related to the approach adopted in this phase of the Nitrification Study. The approach used to develop the future diurnal daily, weekly, monthly, and seasonal flows and loads to be treated, the approach used in the process modeling work to predict the performance of various treatment process options, and the methods used for development of the cost estimates for the potential upgrades of the City of Winnipeg's three Water Pollution Control Centres (WPCCs) are described in the following sections.

2.2 FLOWS AND LOADS

2.2.1 Preamble

An initial assessment of the flows and loads projected to be discharged to each of the City's three WPCCs was developed in Section 2.0 of the Preliminary Design Study. This initial assessment has been used as the basis to develop a detailed profile of the flows and loads to be used in the process modeling of the three WPCCs. Additional plant data has been incorporated into the projections of flows and loads, resulting in a refined set of values.

Nitrification at wastewater treatment plants is influenced by seasonal and daily variations in the influent flow and load. A representative approach to modeling for the evaluation of nitrification alternatives requires input data that reflect these seasonal and diurnal variations. For this reason, a synthetic flow and load pattern was developed for each of the three plants. These patterns are based on hourly estimates of primary effluent flow and the contaminant concentrations. Hourly flow and load data were developed independently for each of the WPCCs by adjusting the previously documented seasonal flows and loads and incorporating a number of assumptions that allowed for future growth in the related catchments. The adjustments to the flows and loads, assumptions, and the associated procedure to derive the hourly flows and loads are outlined for each WPCC in the sections that follow.

2.2.2 North End Water Pollution Control Centre (NEWPCC)

The synthetic database for the NEWPCC was constructed after examining existing information obtained from plant records and new information obtained during specific sampling periods undertaken to characterize diurnal fluctuations.

Seasonal Variations

The synthetic databases were configured with four seasons – summer, fall, winter, and spring. Each season was assumed to have a duration of 90 days, so the synthetic annual database represented 360 days in total. The assumed pattern was based on several assumptions, as follows:

1. From an examination of the historical records at the NEWPCC, the following seasonal designations were made:
   - Summer June, July, and August
   - Fall September, October, and November
   - Winter December, January, and February
   - Spring March, April, and May
2. Each 90 day season is comprised of three 30 day periods. The first and third 30 day periods are assumed to be "average" periods while the middle 30 day period is a assumed to be the maximum month condition.
3. The maximum week flow is assumed to occur during the maximum month period. The maximum day flow is assumed to occur during the maximum week period.
4. The flow during the two average periods (i.e., first and third 30 day period) is equal to the average flow for the season minus an adjustment that accounts for the higher flows during the 30 day maximum period.
5. The maximum month flow, during the 23 days when it is not maximum week, is equal to the predicted maximum month flow minus an adjustment that allows for the higher flows during the maximum week period.
6. The maximum week flow, during the six days when the flow is not equal to the maximum day flow, is equal to the predicted maximum week flow minus an adjustment to allow for the higher flows on the maximum day.
7. The loads are adjusted in a manner similar to that employed for the flows. The loads during the first and third 30 day periods are equal to the predicted average seasonal loads minus an allowance for the maximum month loads.
8. Loads during the maximum month period are adjusted downward to allow for a maximum 7 day span.
9. No specific maximum day loads were incorporated in the synthetic database. As discussed later in this subsection, maximum day loads were assumed to be a multiplier of maximum week loads.
10. For the NEWPCC, maximum week loads were assumed to occur so that they are not coincident with maximum week flows.

The assumption that maximum week flows and loads are not coincident is based on a detailed evaluation of the 1996 to 1999 plant data. In general, this assessment indicates that the maximum loads occur when the flow rates are less than the maximum flow conditions for all four seasons. More specifically, the following is observed by examining the plant data:

- During the spring season, maximum week loads occurred when the flow was only about 12 percent greater than average spring flow. The maximum week flow is 81 percent greater than the average spring flow.
- During the summer season, the maximum week load occurred when the flow was only about 21 percent greater than the average summer flow. The maximum week flow is 54 percent greater than the average summer flow.
- During the fall season, the maximum week load occurred when the flow was only about 3 percent greater than the average fall flow. The maximum week flow is 46 percent greater than average fall flow.
- During the winter season, the maximum week load occurred when the flow was only about 6 percent greater than average winter flow. The maximum week flow is 18 percent greater than the average winter flow.

Maximum daily loads could not be inferred from the data available from the plants. There was considerable scatter and some of the maximums were likely due to sampling or laboratory inconsistencies. For this reason, the maximum day load in secondary influent was assumed to equal the maximum week load in primary effluent multiplied by a peaking factor or 1.3. This relationship was used to establish projected secondary influent loads listed in Table 2.3. As with the maximum week flows and loads, the maximum day flows and loads are not coincident. A review of the data indicated that maximum day loads during any season occurred at flows that were 3 to 21 percent higher than average flows. As a result, it was assumed that the maximum day loads occurred during the maximum week loads, which were assumed to occur during a period of maximum month flows.

Table 2.1 presents the projected Year 2041 seasonal flows and loads for the NEWPCC. The table lists flow and load values for average month, maximum month, maximum week and maximum day for each season.

Table 2.1: Projected Seasonal Flows and Loads to NEWPCC for the Year 2041

Periods	Flow (ML/d)	TSS (kg/d)	BOD (kg/d)	COD (kg/d)	TKN (kg/d)	TP (kg/d)
Winter						
Average	211	58,750	54,660	109,320	9,820	1,365
Maximum Month	237	72,410	65,970	131,930	11,260	1,535
Maximum Week	250	123,640	78,450	156,900	12,620	1,835
Maximum Day	260	--	--	--	--	--
Spring						
Average	390	84,400	56,900	113,790	10,730	1,595
Maximum Month	571	128,490	75,070	150,130	12,490	1,990
Maximum Week	705	206,470	97,550	195,110	14,800	2,470
Maximum Day	710	--	--	--	--	--
Summer						
Average	291	71,070	51,120	102,240	9,270	1,390
Maximum Month	381	105,090	62,910	125,820	10,700	1,680
Maximum Week	449	131,050	90,280	180,560	14,860	2,305
Maximum Day	686	--	--	--	--	--
Fall						
Average	250	51,170	51,630	103,260	9,360	1,240
Maximum Month	312	74,390	61,840	123,670	10,950	1,525
Maximum Week	364	81,340	71,440	142,880	11,420	2,025
Maximum Day	526	--	--	--	--	--

Primary Treatment Removals

Modeling of the NEWPCC secondary treatment processes was based on primary effluent values. Primary treatment removes a significant fraction of the influent contaminants prior to secondary treatment. To determine the likely removals, plant records from 1996 to 1999 were examined and algorithms were developed to predict TSS and BOD removals. The algorithms are as shown in Table 2.2.

Table 2.2: NEWPCC Primary Clarifier Removals

Season	TSS Removal	BOD Removal
Winter	$\frac{TSS_e}{TSS_i} = \frac{177.03\, OFR^{0.435}}{TSS_i^{\;0.707}\; T^{1.557}}$	$\frac{BOD_e}{BOD_i} = 0.708\left(\frac{TSS_e}{TSS_i}\right)^{0.124}$
Summer/Fall	$\frac{TSS_e}{TSS_i} = \frac{0.794\, OFR^{0.165}\; T^{0.437}}{TSS_i^{\;0.464}}$	$\frac{BOD_e}{BOD_i} = 0.705\left(\frac{TSS_e}{TSS_i}\right)^{0.181}$
Spring	$\frac{TSS_e}{TSS_i} = \frac{0.382\, OFR^{0.345}\; T^{0.350}}{TSS_i^{\;0.404}}$	$\frac{BOD_e}{BOD_i} = 0.727\left(\frac{TSS_e}{TSS_i}\right)^{0.222}$

Notes:
- Subscript “e” indicates primary “effluent”
- Subscript “i” indicates primary “influent”
- “OFR” indicates primary clariafier surface overflow rate
- “T” indicates wastewater temperature in degress Celsius

These algorithms were applied to the average, maximum month, and maximum week plant raw wastewater loads to determine the residual load after primary treatment under those conditions. It was assumed that primary treatment efficiencies would not vary over the course of a day.

Primary treatment was assumed to also remove a fraction of the influent TKN and total phosphorus (TP). It was assumed that this fraction would represent the insoluble fraction of these compounds that is removed with the TSS. The insoluble fraction of TKN was assumed to be 25 percent of the influent TKN and the insoluble fraction of the TP was assumed to total 20 percent of the influent TP.

The projected seasonal flows and loads to the secondary treatment process for the NEWPCC are summarized in Table 2.3.

Table 2.3: Projected Seasonal Flows and Loads to Secondary Treatment at the NEWPCC, Design Year 2041

Periods	Flow (ML/d)	Flow Used in Load Calculation (ML/d)	TSS (kg/d)	BOD (kg/d)	COD (kg/d)	TKN (kg/d)	TP (kg/d)
Winter							
Average	211	211	22,809	34,414	68,828	8,862	1,245
Maximum Month	237	237	27,682	41,475	82,950	10,144	1,398
Maximum Week	250	223	32,335	47,053	94,106	11,373	1,650
Maximum Day	260	211	42,036	61,169	122,338	14,785	2,145
Spring							
Average	390	390	34,905	33,969	67,938	9,672	1,443
Maximum Month	571	571	59,670	46,023	92,045	11,249	1,827
Maximum Week	705	437	89,107	58,968	117,936	13,322	2,228
Maximum Day	710	390	115,839	76,658	153,317	17,319	2,896
Summer							
Average	291	291	27,674	30,380	60,761	8,352	1,251
Maximum Month	381	381	40,424	37,338	74,676	9,639	1,524
Maximum Week	449	352	52,800	53,856	107,712	13,376	2,042
Maximum Day	686	291	68,640	70,013	140,026	17,389	2,654
Fall							
Average	250	250	21,100	30,975	61,950	8,425	1,125
Maximum Month	312	312	29,640	36,941	73,882	9,890	1,373
Maximum Week	364	258	34,248	43,003	86,005	10,300	1,828
Maximum Day	526	250	44,522	55,903	111,807	13,390	2,377

Diurnal Variation

Recorded flows for January to August 1999 were retrieved from the plant data acquisition system. The flow data were available for six minute intervals. A typical diurnal curve for flows entering the plant during a dry period (January 1999) is shown in Figure 2.1.

This curve illustrates the typical dry period flow pattern measured at the discharge of the raw sewage pumps during the period of record. The pattern is a function of the influent pump control strategy and the large flow buffering capacity of the incoming interceptor system. The flow remains relatively constant from about 2:00 p.m. until about 3:00 a.m. At that time, it falls dramatically to a value that is less than half of the average flow prior to that point. At about 8:00 a.m. in the morning, it rises somewhat and then later in the morning, the peak flow for the day occurs.

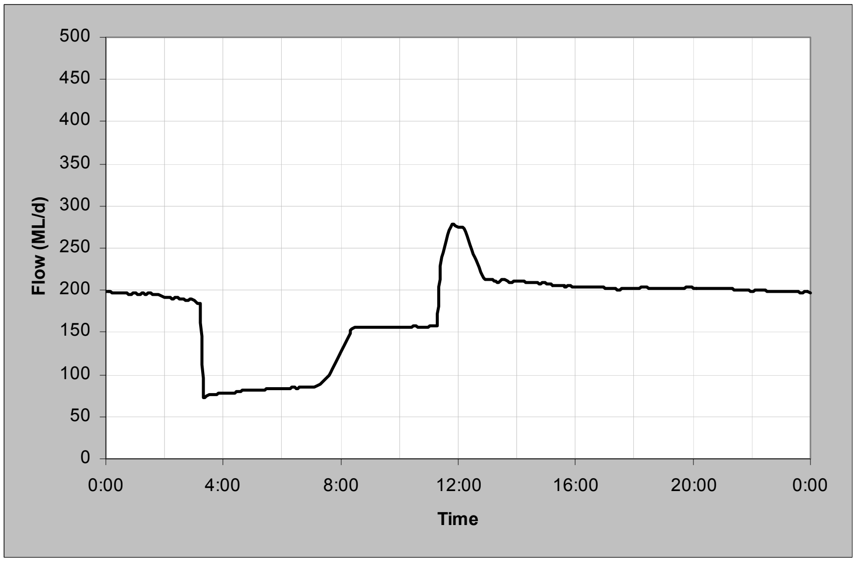


Figure 2.1: Diurnal Flow Variation at NEWPCC on January 13, 1999

The pattern can be explained by the pump operating pattern. For most of the day, one large pump, operating at near maximum, is able to maintain reasonable levels in the incoming interceptor system. During the night when the flows drop, the large pump is able to draw down the interceptor. At 3 a.m., the large pump is stopped and a smaller pump starts. At about 8:00 a.m., the larger pump re-starts and then slowly increases speed until it is again running at maximum output. Sometime during the morning as influent flows continue at their normal daily high, the water level rises to a level that initiates the start of a second pump. The second pump operates for one or two hours until the water levels again recede.

This pattern is consistent through dry periods of the year. During wet periods, the pumping pattern constantly changes depending upon the snow melt or rain storm characteristics. At the other plants, it will be shown in latter sections that during wet periods the diurnal variation can be overlain on a raised base flow that is a function of the storm. For simplicity, this same assumption has been used for the NEWPCC. During wetter periods of the year, wet weather flows are added to the base flow and the diurnal curve remains constant. These patterns are illustrated in Figure 2.2.

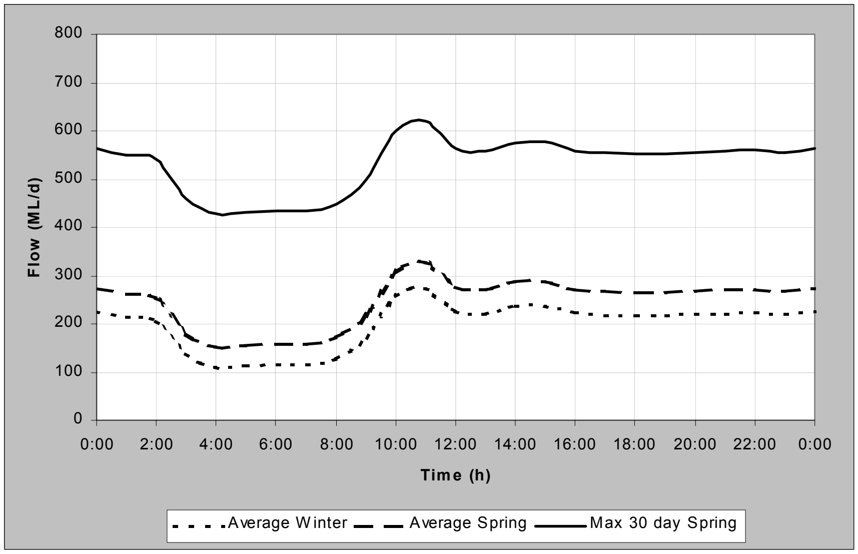


Figure 2.2: Predicted 24 hour Flow Patterns at NEWPCC

The load rate also varies during the day. Between September 26 and September 30, 1999, samples were taken at one hour intervals and tested for COD, soluble COD (sCOD), TSS, VSS, TKN, NH_3-N, and TP. These values were then used to derive load variation ratios for each hour during the day. A comparison of the load ratio and the flow ratio during the day is illustrated in Figure 2.3.

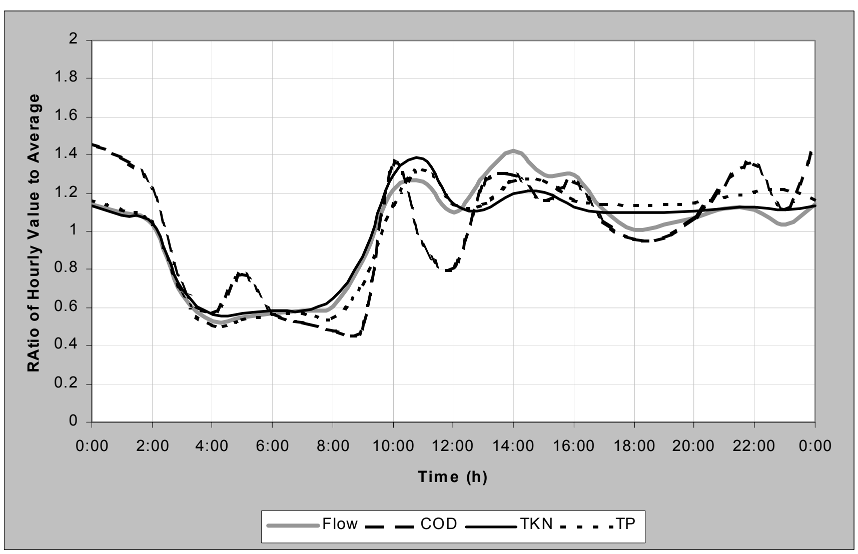


Figure 2.3: Comparison of 24 hour Load and Flow Variations at NEWPCC

Generally, the morning peak values for load are greater than the flow peak at the same time. This characteristic is consistent with findings in other catchments. Table 2.4 presents the diurnal flow and load peaking factors that were used for the synthetic 2041 secondary influent database.

Table 2.4: Diurnal Flow and Load Peaking Factors - NEWPCC

Hour	Peak Factors			
	Flow	COD	TKN	TP
0	1.137	1.458	1.141	1.164
1	1.084	1.384	1.099	1.114
2	1.045	1.226	1.032	1.039
3	0.698	0.716	0.669	0.662
4	0.561	0.569	0.531	0.507
5	0.571	0.774	0.548	0.533
6	0.581	0.573	0.572	0.560
7	0.588	0.519	0.586	0.572
8	0.649	0.477	0.603	0.542
9	0.868	0.484	0.845	0.716
10	1.299	1.352	1.216	1.140
11	1.382	0.922	1.261	1.324
12	1.144	0.811	1.097	1.140
13	1.115	1.250	1.292	1.139
14	1.194	1.299	1.421	1.262
15	1.204	1.160	1.297	1.266
16	1.124	1.262	1.295	1.160
17	1.101	1.059	1.114	1.142
18	1.099	0.960	1.007	1.134
19	1.097	0.964	1.032	1.139
20	1.107	1.078	1.069	1.150
21	1.119	1.243	1.120	1.175
22	1.125	1.349	1.115	1.201
23	1.110	1.110	1.038	1.219
Averages	**1.000**	**1.000**	**1.000**	**1.000**

The hourly variation in load was superimposed on the predicted loads during the various seasons to obtain the predicted contaminant concentrations through the synthetic year.

Projected Diurnal Flows and Loads for the NEWPCC

Projected diurnal primary effluent flows and loads for NEWPCC during year 2041 are shown in Figures 2.4 to 2.8. Temperature variation is presented in Figure 2.9.

Figure 2.4 shows the projected 2041 primary effluent flow rates plotted at hourly intervals. The dark green line represents a 7-day running arithmetic average for the flow. The average seasonal flow in each season increases to a maximum month flow in the middle of that season. The flow pattern during the maximum month has a depression that is related to the flows corresponding maximum week loading conditions. The flows corresponding to maximum week loads are higher than average seasonal flows, but lower than maximum month flows. The lowest depression point in

Figure 2.4: NEWPCC 2041 Primary Effluent Flowrate
[Used for Correponding AD, MM, MW & MD Loads in Simulation Work]

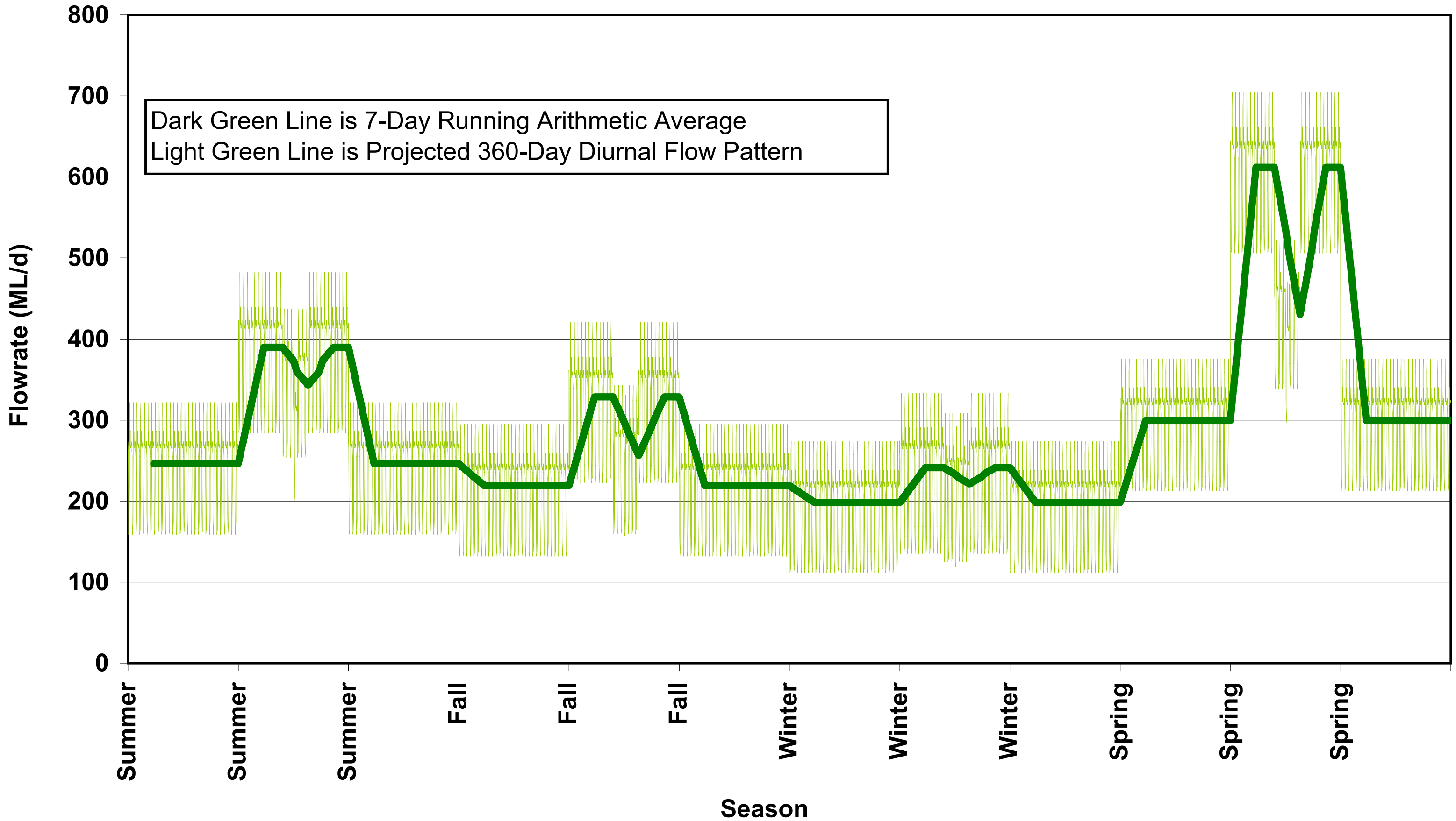


Figure 2.8: NEWPCC Primary Effluent Inert Suspended Solids Projection

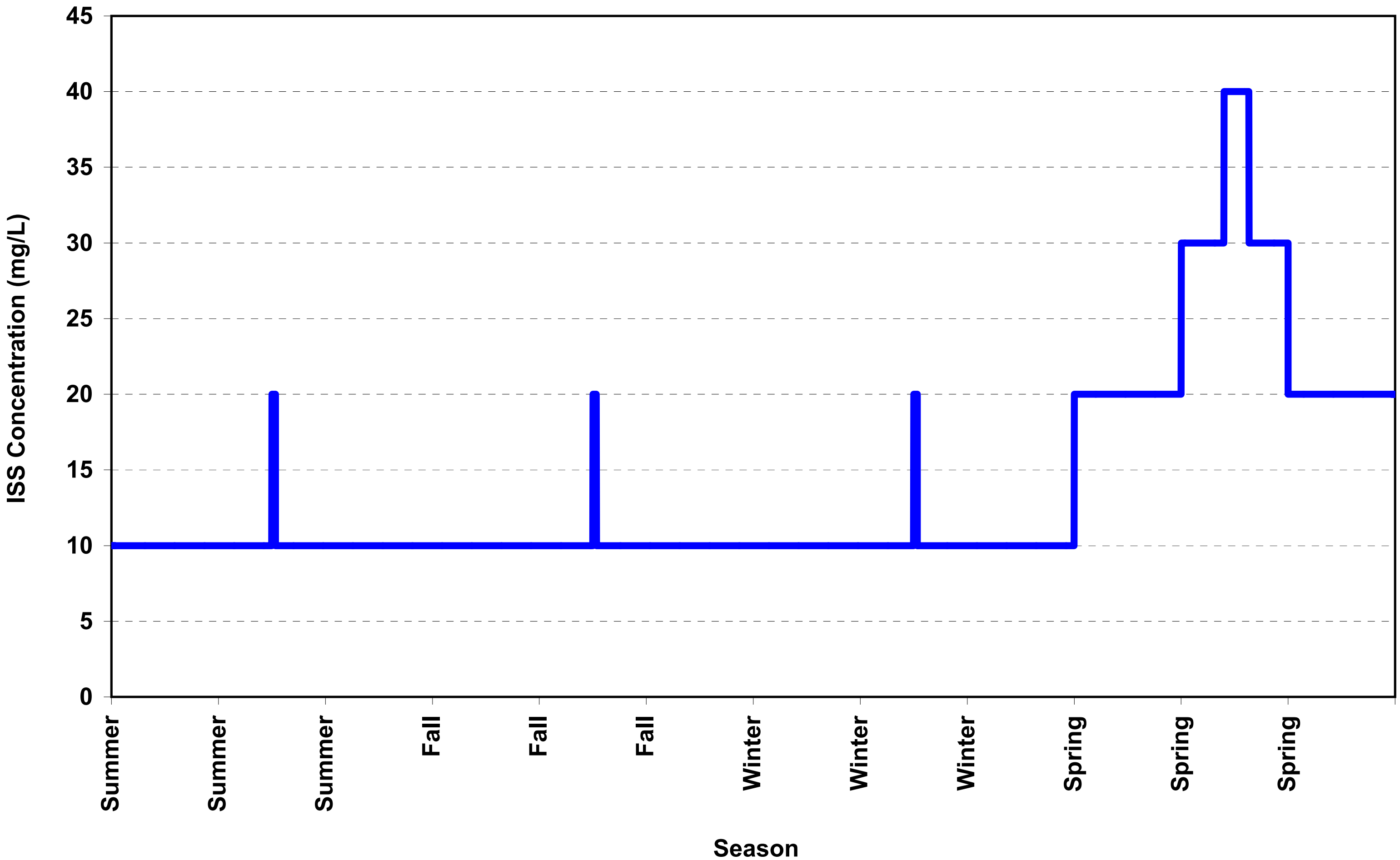


Figure 2.7: NEWPCC 2041 Primary Effluent Total P

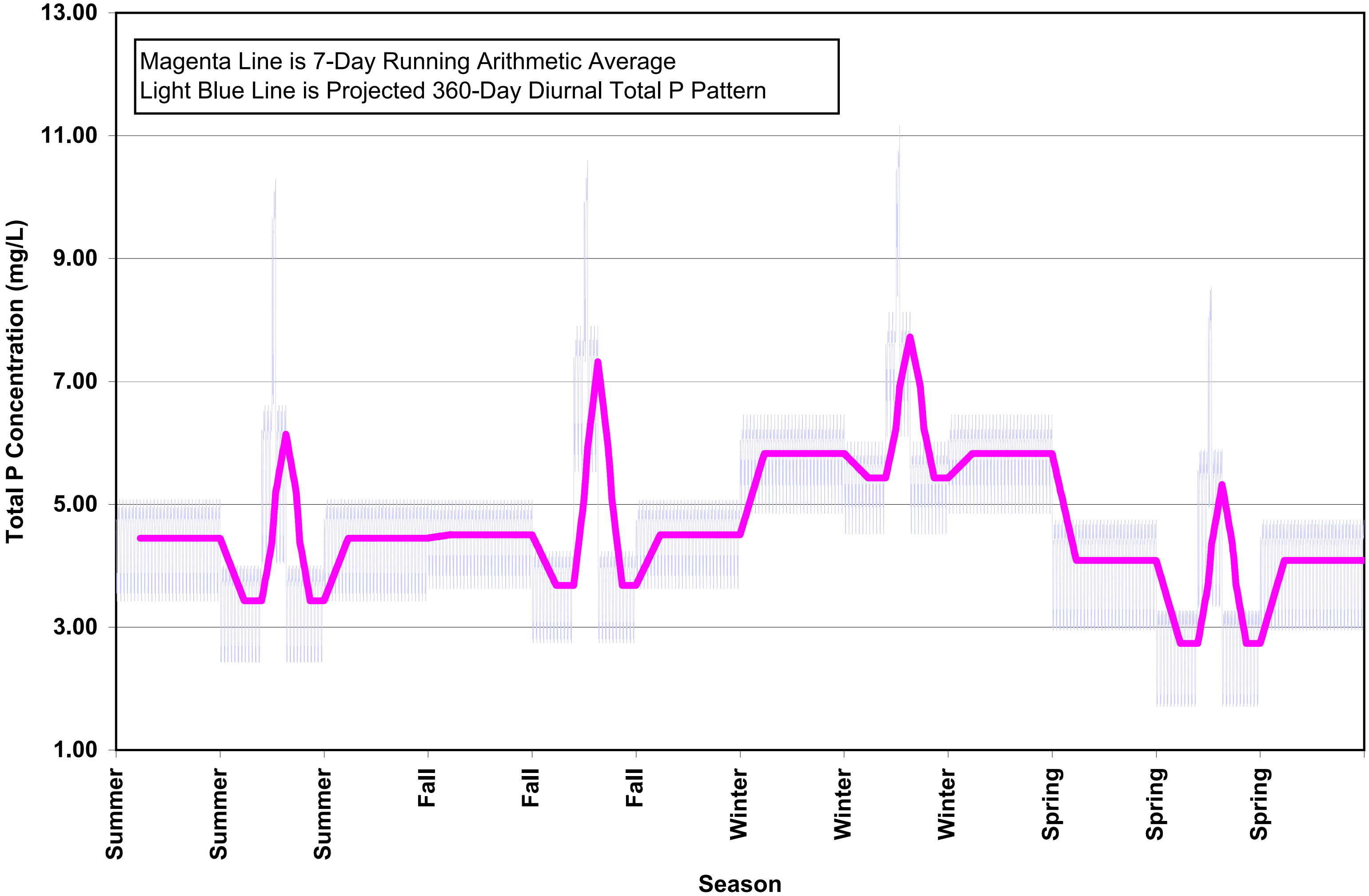


Figure 2.6: NEWPCC 2041 Primary Effluent TKN Projections

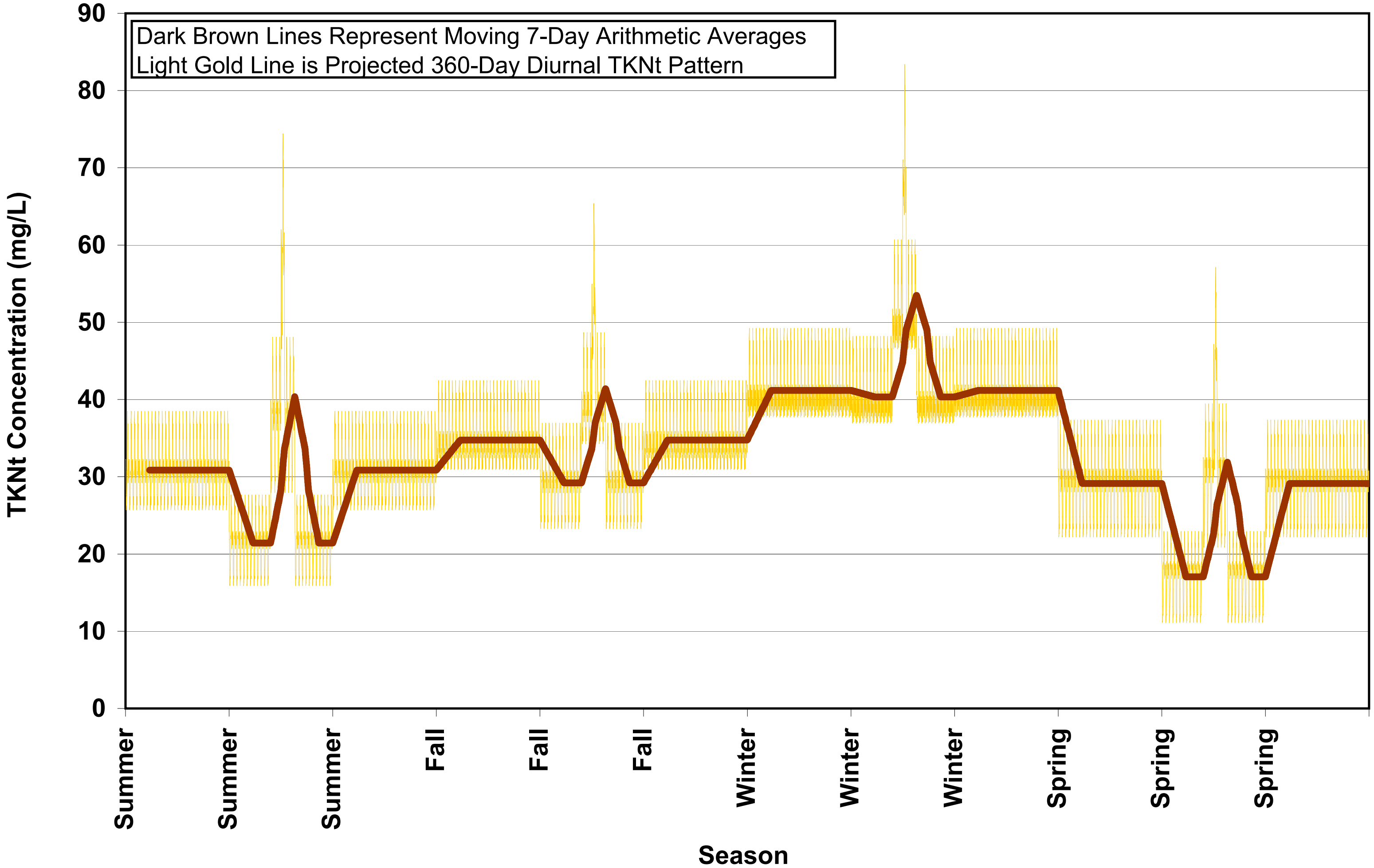


Figure 2.5: NEWPCC 2041 Primary Effluent CODt Projections

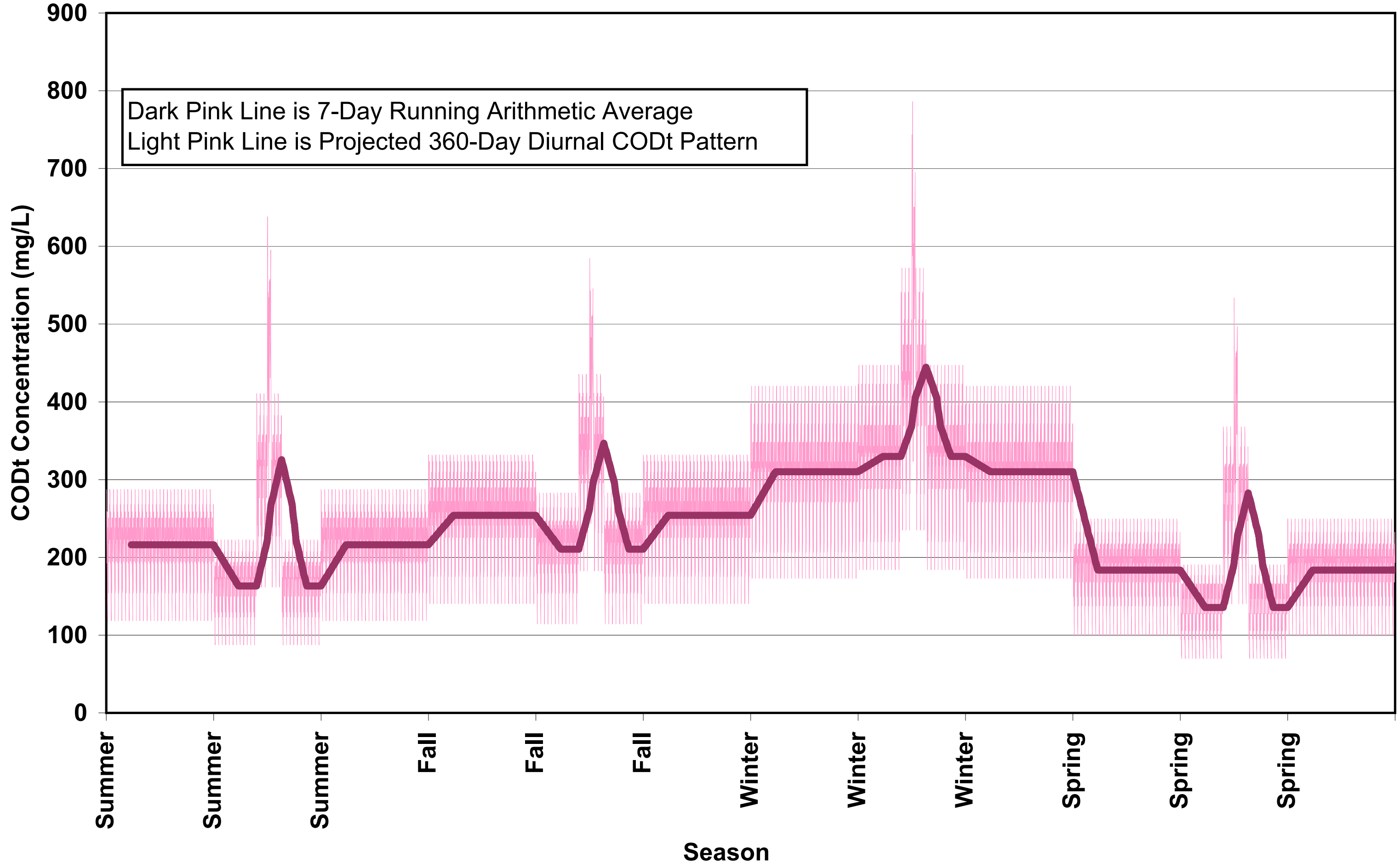
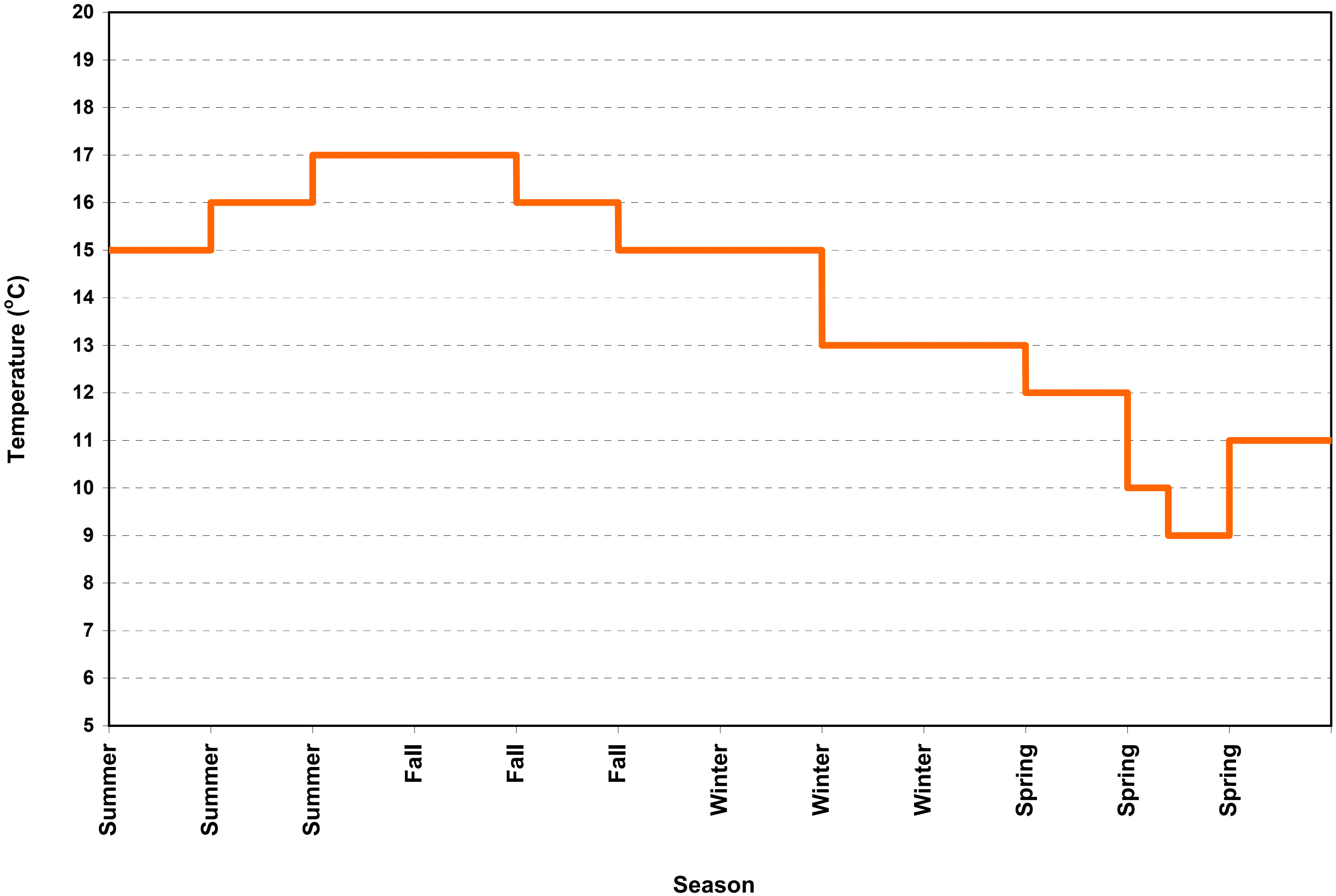


Figure 2.9: NEWPCC Influent Wastewater Temperature



a maximum month flow pattern represents the flow corresponding to maximum day load. As indicated previously, this flow was assumed to be the same as the average seasonal flow and occurs in the middle of the maximum week in each season.

Figures 2.5, 2.6, and 2.7 present projections of NEWPCC primary effluent total COD (CODt), total TKN, and TP concentrations, respectively. These concentrations are estimated by combining the flows plotted in Figure 2.4 with the appropriate loads from Table 2.3 and appropriate peaking factors representing the diurnal loading pattern in Table 2.4.

There is a common trend among the hourly variations of COD, TKN and TP concentrations for the NEWPCC. During the early period of summer, fall, and spring maximum months, the average concentration of pollutants drops considerably followed by a sharp increase during the maximum week and maximum day. Following the maximum week, the concentrations decrease until the end of the maximum week when the average seasonal concentration is resumed. The first drop of pollutant concentrations observed during the initial period of the maximum month for the summer, fall, and spring seasons is due to the dilution effect of rainfall or snow melt. During this period, the increase in wet weather flow is likely not sufficiently high to have a flushing effect on the sewer sediments. Therefore, the high flow mainly has a dilution effect and causes a drop in concentrations to below average seasonal values for non-maximum months. During maximum week and maximum day, however, the flow is in such quantity that it flushes roads and sewer sediments resulting in an increase in concentrations of pollutants. Following the maximum weekly flows, the sewers are clean and the flows return to the maximum month values. As a result, wastewater pollutants approach their typical maximum month concentrations shown by the second drop of the curve during the latter part of the maximum month. Average day concentrations are resumed after the maximum month period because of the re-establishment of average flows.

The trend observed in winter concentrations for the NEWPCC is somewhat different than for other seasons. In winter, the concentration of pollutants in the early and late portion of the maximum month period is slightly greater than the average seasonal concentration. This is because there is no significant rainfall or snowmelt to dilute the sewage. This minimizes the variations in concentrations. However, similar to other seasons, a sharp increase is observed during the maximum week and the maximum day of the winter season.

In general as can be seen from Figure 2.4, the flow to the NEWPCC is highest during spring and decreases during summer and fall, and reaches its minimum during winter season. Conversely, concentration ranges of pollutants are highest during winter months and lowest during spring months with fall and summer concentrations being next to the highest and lowest ranges, respectively.

Inert Suspended Solids (ISS)

The ISS content of wastewater can be a significant factor in the behaviour of the wastewater treatment system, particularly if large variations in ISS occur. Such large variations can occur during periods of storm runoff when excess quantities of grit and fine silt can gain access to the sewage collection system through inflow and infiltration. This will be particularly significant in a combined sanitary/storm sewer system such as that which feeds the NEWPCC. One of the inputs to the mathematical models used to simulate the performance of a wastewater treatment plant is the ISS. Therefore, it is important to have some knowledge of this variable to achieve reliable modeling results.

The City of Winnipeg records only the total suspended solids (TSS) content in the raw and primary effluent streams. There is evidence of improved mixed liquor settleability at the NEWPCC during spring snowmelt/runoff periods. It is reasonable to expect that the improved settleability is due to the "weighing down" of the biological floc by fine ISS particles in the incoming wastewater that become enmeshed in the floc. This would indicate that the incoming wastewater's ISS content is elevated on these occasions compared to other times of the year. Therefore some means of inferring the variations in ISS concentration in the wastewater throughout the year must be devised so that appropriate values for ISS can be used in the modeling work.

The default value used for the ISS of raw sewage in BioWin™ is 15 mg/L. A typical value for ISS in the primary effluent during dry weather flow at a municipal wastewater treatment plant would be 10 mg/L. Several monthly average plant performance datasets for 1999 and 2000 were used in a series of steady state simulations. By employing a trial and error approach to match simulated with actual nitrogen and solids balances around the existing HPO process, estimates of the seasonal variation of ISS in the primary effluent stream were inferred to be as follows:

Season	Loading Condition	Corresponding ISS (mg/L)
Summer	AD/MM/MW/MD	10/10/10/20
Fall	AD/MM/MW/MD	10/10/10/20
Winter	AD/MM/MW/MD	10/10/10/20
Spring	AD/MM/MW/MD	20/30/40/40

AD = Average Day MM = Maximum Month
MW = Maximum Week MD = Maximum Day

The 360-day annual plot of the projected 2041 ISS concentration at the NEWPCC is presented in Figure 2.8.

Temperatures

The influent wastewater temperatures influence primary treatment performance and the rate of nitrification in the biological process. Influent temperatures are no longer recorded at the NEWPCC. However, temperature records are available for 1984 to 1987. In addition, some SEWPCC temperature records are available. These records were used to develop a temperature variation pattern that is considered to be reasonable for the NEWPCC. Figure 2.9 illustrates the temperature variation through the year. Temperature variations can be classified into three ranges:

- **The maximum range (15 to 17°C).** This temperature range occurs during the June to December period with its highest value (17°C) in August and September.
- **The middle range (12 to 15°C).** This temperature range is associated with the flows of January and February.
- **The minimum range (9 to 12°C).** This range occurs during March to June. The lowest temperature is 9°C and occurs during a portion of the month of April and is due to the impact of inflow and infiltration during the snowmelt period.

Nitrification is a biological process that is strongly impacted by temperature. Nitrifying organisms are very sensitive to low temperatures and their growth rates become significantly limited at temperatures below 12°C. Springtime is the most critical period of year for the nitrification process at the NEWPCC because snowmelt and rainfall create influent conditions that are high in flow and low in temperature.

2.2.3 South End Water Pollution Control Centre (SEWPCC)

Section 2.2.2 described the derivation of a synthetic flow and load database for the NEWPCC. Using a similar approach, a synthetic influent database was constructed for the SEWPCC. This construction was undertaken after examining existing information obtained from plant records and new information obtained during specific sampling periods done to characterize diurnal fluctuations.

Seasonal Variations - SEWPCC

The synthetic databases were configured with the same four seasons as for the NEWPCC – summer, fall, winter, and spring. Each season was assumed to have a duration of 90 days, so the synthetic annual database represented 360 days in total. The assumed pattern was based on the same assumptions as for the NEWPCC. The only exception was that for the SEWPCC, maximum week loads were assumed to be coincident with maximum week flows.

The assumption that maximum week flows and loads are coincident was considered appropriate for this plant.

Maximum daily loads could not be inferred from the data available from the plants. There was considerable scatter and some of the maximums were likely due to sampling or laboratory inconsistencies. For this reason, the maximum day load in secondary influent was assumed to equal the maximum week load in primary effluent multiplied by a peaking factor of 1.3.

Table 2.5 presents the projected Year 2041 seasonal flows and loads for the SEWPCC. The table lists flow and load values for average month, maximum month, maximum week and maximum day for each season.

Table 2.5: Projected Seasonal Flows and Loads To The Primary Treatment Process of the SEWPCC For The Year 2041

Periods	Flow (ML/d)	TSS (kg/d)	BOD (kg/d)
Winter			
Average	75	23,260	20,720
Maximum Month	79.3	32,355	24,425
Maximum Week	81.5	47,815	35,265
Maximum Day	125		
Spring			
Average	112.6	34,055	26,195
Maximum Month	151.6	49,175	35,075
Maximum Week	205.3	64,285	56,670
Maximum Day	270		
Summer			
Average	94.2	31,335	23,465
Maximum Month	109.9	61,845	47,210
Maximum Week	144.5	79,295	61,690
Maximum Day	270		
Fall			
Average	84.5	24,395	22,230
Maximum Month	105.1	34,535	26,220
Maximum Week	119.9	45,910	32,370
Maximum Day	200		

Primary Treatment Removals - SEWPCC

Modeling of the SEWPCC was based on primary effluent values. Primary treatment removes a significant fraction of the influent contaminants prior to secondary treatment. To determine the likely removals, plant records from 1996 to 1999 were examined and algorithms were developed to predict TSS and BOD removals. Unlike the NEWPCC, different algorithms were not developed for the various seasons.

Seasonal variations in primary clarifier performance were not as pronounced at the SEWPCC, likely because of the predominantly separate collection system. Best fit power functions were derived for TSS and BOD, as follows:

TSS removal $$\frac{TSS_e}{TSS_i} = \frac{234.8}{OFR^{0.143} * TSS_i^{0.1.066} * T^{0.0983}}$$

BOD removal $$\frac{BOD_e}{BOD_i} = 0.707\left(\frac{TSS_e}{TSS_i}\right)^{0.3675}$$

Notes:

- Subscript “e” indicates primary “effluent”
- Subscript “i” indicates primary “influent”
- “OFR” indicates primary clarifier overflow rate
- “T” indicates wastewater temperature in degress Celsius

The BOD algorithm suggested relatively low primary effluent concentrations after primary treatment (35 to 40 percent of influent). These low predictions were considered optimistic; hence, the less aggressive algorithms derived for NEWPCC were used for the prediction of primary effluent BOD at the SEWPCC. This approach resulted in concentrations that were 20 percent higher than would have been predicted using the BOD algorithm derived from the SEWPCC data.

These algorithms were applied to the average, maximum month, and maximum week plant raw wastewater loads to determine the residual load after primary treatment under those conditions. It was assumed that primary treatment efficiencies would not vary substantially over the course of a day.

Primary treatment also will remove a fraction of the influent TKN and total phosphorus (TP). It was assumed that this fraction would represent the insoluble fraction of these compounds that is removed with the TSS. The insoluble fraction of TKN was assumed to be 25 percent of the influent TKN and the insoluble fraction of the TP was assumed to total 20 percent of the influent TP.

The projected seasonal flows and loads to the secondary treatment process for the SEWPCC are summarized in Table 2.6.

Table 2.6: Projected Seasonal Flows and Loads To The Secondary Treatment Process of the SEWPCC For The Year 2041

Periods	Flow (ML/d)	Flow Used for Load Calculations (ML/d)	TSS (kg/d)	BOD (kg/d)	COD (kg/d)	TKN (kg/d)	TP (kg/d)
Winter							
Average	75	75.0	6,050	12,415	24,830	2,637	478
Maximum Month	79.3	79.3	6,390	14,140	28,280	2,800	522
Maximum Week	81.5	81.5	6,045	19,320	38,640	3,328	704
Maximum Day	125	81.5					
Spring							
Average	112.6	112.6	9,515	14,350	28,700	2,538	542
Maximum Month	151.6	151.6	12,230	18,725	37,450	3,065	768
Maximum Week	205.3	205.3	16,045	30,275	61,550	4,218	1,210
Maximum Day	270	265.3					
Summer							
Average	94.2	94.2	7,825	12,870	25,740	2,317	427
Maximum Month	109.9	109.9	8,620	23,300	46,600	2,537	684
Maximum Week	144.5	144.5	10,795	30,315	60,630	3,171	843
Maximum Day	270	202.0					
Fall							
Average	84.5	84.5	7,195	12,565	25,130	2,426	433
Maximum Month	105.1	105.1	8,600	14,375	28,750	2,730	488
Maximum Week	119.9	111.9	8,945	16,975	33,950	3,064	539
Maximum Day	200	138.8					

Diurnal Variation - SEWPCC

Recorded flows for April to September 1998 were retrieved from the plant data acquisition system. The flow data were available for ten minute intervals. A typical diurnal curve for flows entering the plant during a dry period (September 1998) is shown in Figure 2.10.

This curve illustrates the typical dry period flow pattern measured at the discharge of the raw sewage pumps during the period of record. At the SEWPCC during dry periods, flow is generally pumped at the rate at which it arrives at the plant. Unlike the NEWPCC, dry weather flows into the plant are not substantially affected by the pump operation strategy.

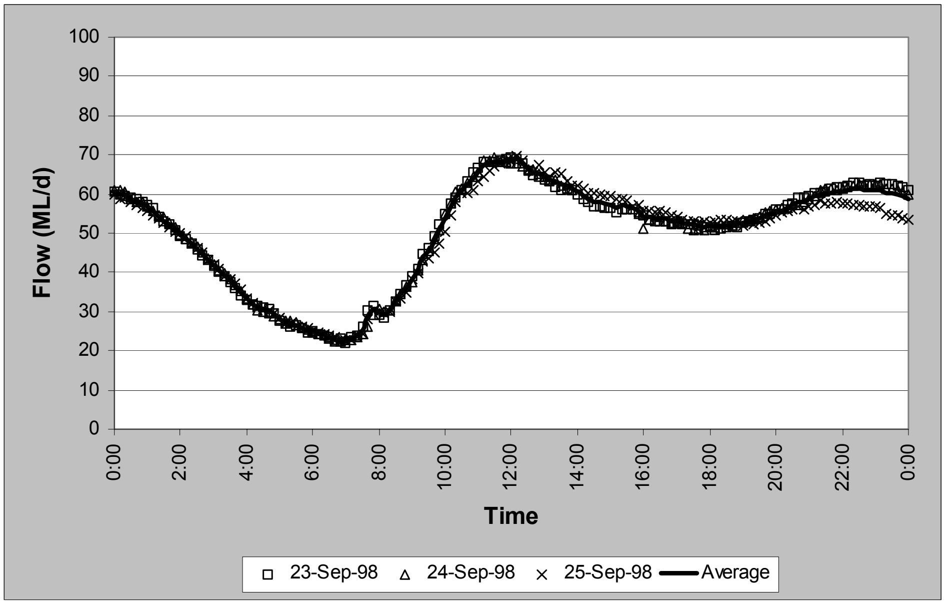


Figure 2.10: Dry Weather Diurnal Flow Variation at SEWPCC in September, 1998

This pattern is consistent through dry periods of the year. During wet periods, the pumping pattern changes depending upon the snow melt or rain storm characteristics. During these wet periods, the diurnal variation can be overlain on a raised base flow that is a function of the storm. This characteristic is illustrated in Figure 2.11 where measured flows during a wet period (May 1998) are compared to synthetic curves constructed by adding a constant amount to the average dry weather diurnal pattern shown above in Figure 2.10.

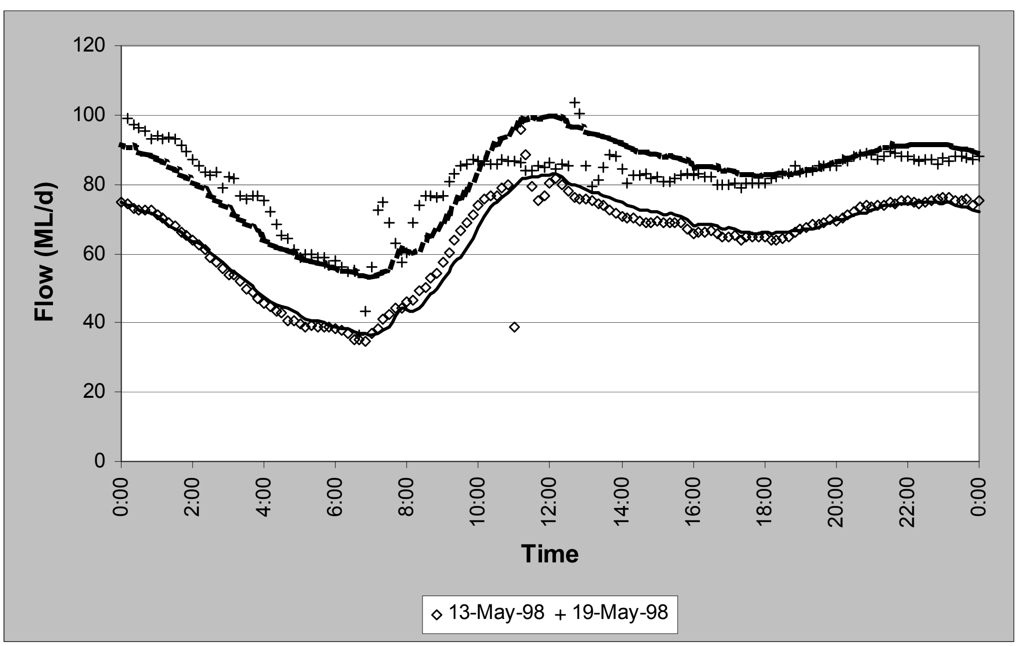


Figure 2.11: Wet Weather Diurnal Flow Variation at SEWPCC in May, 1998

The darker solid lines indicated in Figure 2.11 are derived by adding about 14 ML/d to the dry weather diurnal flow on May 13 1998, and about 31 ML/d on May 19 1998. As indicated in Figure 2.11, the darker lines are very close to the measured flows which are represented by the individual points.

The loading rate also varies during the day. From September 19 to September 22, 1999, samples were taken at one hour intervals and tested for COD, soluble COD (sCOD), TSS, VSS, TKN, NH_3-N, and TP. Through the day at the SEWPCC, measured concentrations for TSS, COD, TKN, and TP were relatively consistent. Some anomalies existed. On September 21 and September 22 during early morning hours (4:00 and 5:00 am), extremely high concentrations of TSS, TKN, and TP were measured. High concentrations were not evident for the soluble constituents – sCOD and NH_3-N. Figure 2.12 illustrates the measured concentrations during the test period for COD while Figure 2.13 illustrates the measured concentrations for soluble COD.

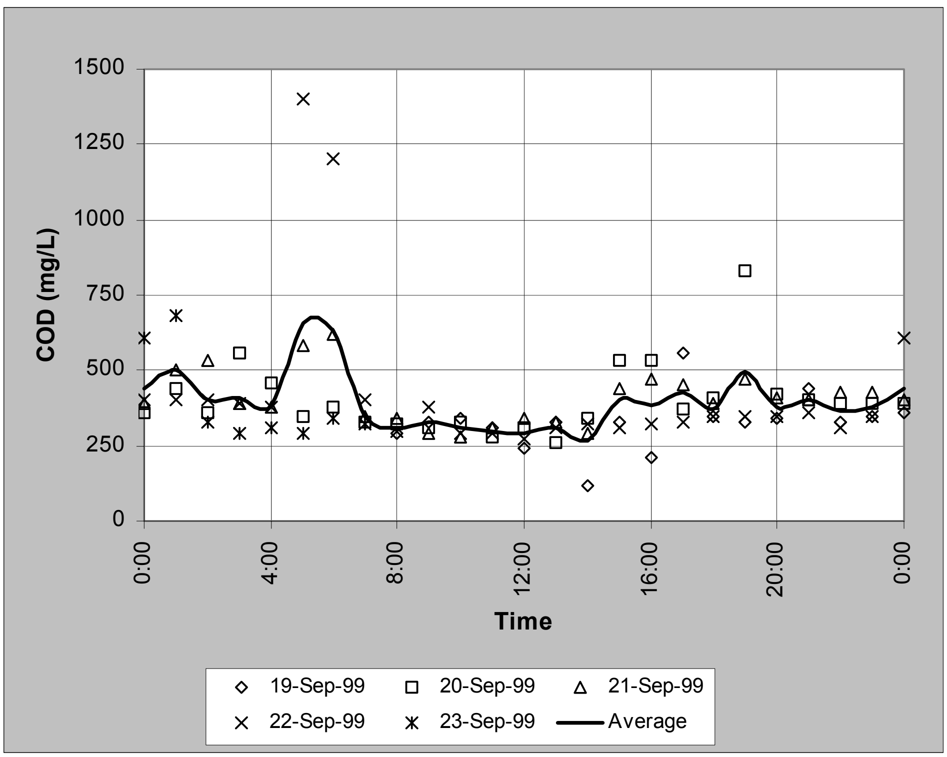


Figure 2.12: Diurnal COD Variation at SEWPCC in September, 1999

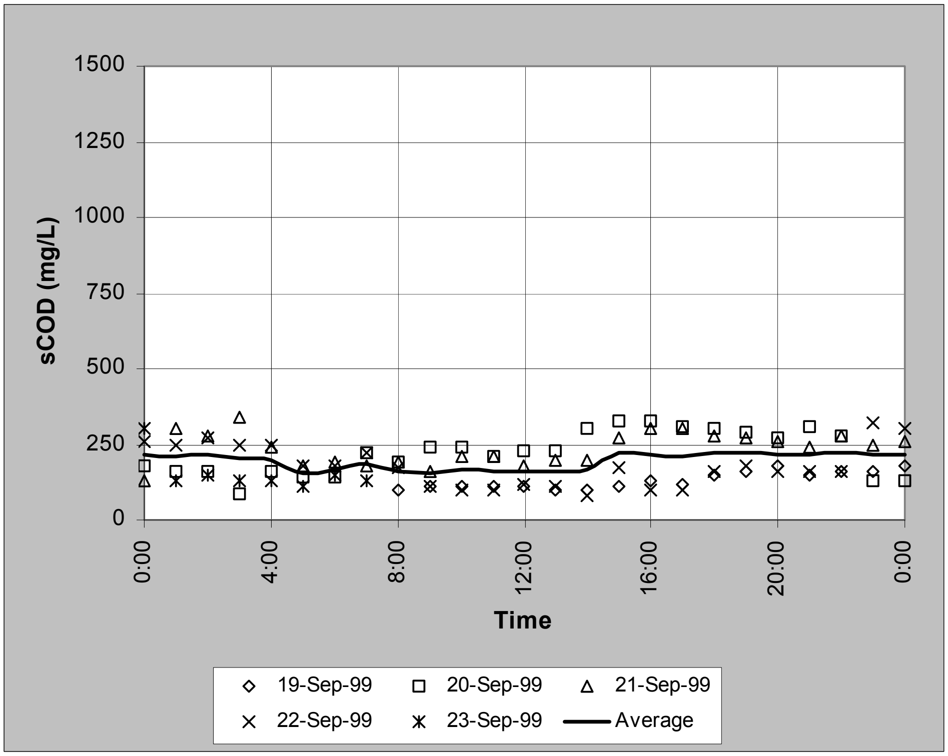


Figure 2.13: Diurnal sCOD Variation at SEWPCC in September, 1999

The concentrations obtained for each hour were multiplied by the flow measured for each of those hours to obtain hourly loads. These values were then used to derive load variation ratios for each hour during the day. These normalized values are illustrated in Figure 2.14.

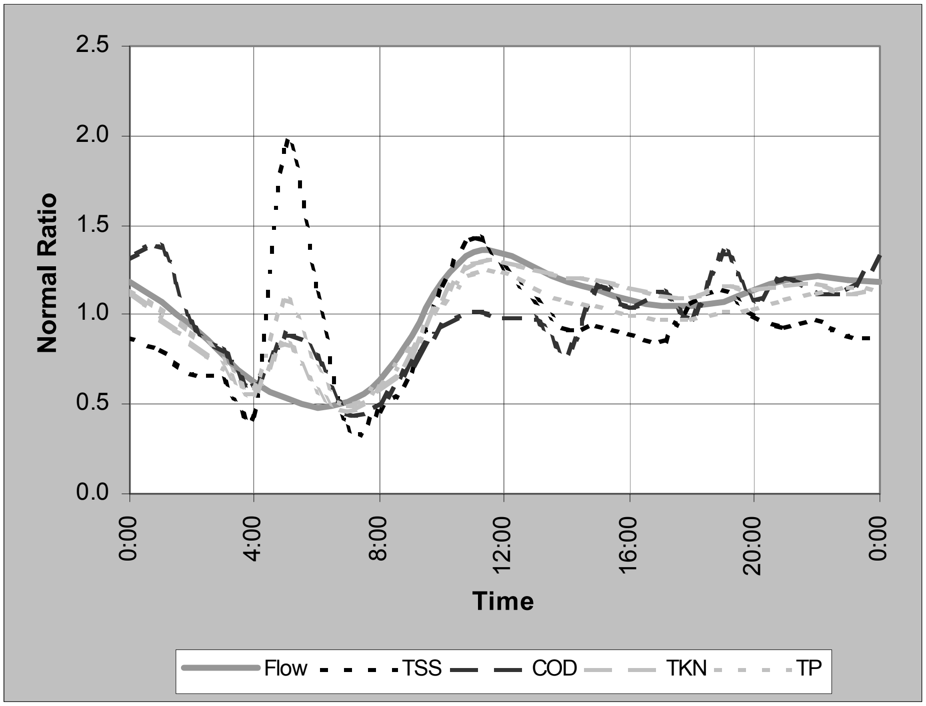


Figure 2.14: Hourly Load and Flow Variations at SEWPCC

At the SEWPCC, there is a peak in the early morning hours, possibly caused by upstream operating practices. Table 2.7 presents the diurnal flow and load peaking factors that were used for the synthetic 2041 secondary influent database.

Table 2.7: Diurnal Flow and Load Peaking Factors - SEWPCC

Hour	Peak Factors			
	Flow	COD	TKN	TP
0	1.182	1.308	1.133	1.140
1	1.077	1.368	0.977	1.039
2	0.934	0.952	0.847	0.901
3	0.771	0.791	0.686	0.741
4	0.622	0.598	0.561	0.593
5	0.533	0.878	0.838	1.078
6	0.476	0.760	0.573	0.690
7	0.509	0.448	0.456	0.489
8	0.641	0.504	0.582	0.619
9	0.885	0.729	0.772	0.815
10	1.187	0.926	1.090	1.077
11	1.351	1.011	1.287	1.230
12	1.343	0.980	1.295	1.242
13	1.262	0.976	1.253	1.153
14	1.185	0.797	1.210	1.074
15	1.141	1.155	1.198	1.051
16	1.079	1.038	1.146	0.998
17	1.048	1.126	1.107	0.969
18	1.044	0.985	1.097	0.973
19	1.074	1.337	1.165	1.012
20	1.135	1.085	1.134	1.025
21	1.193	1.200	1.157	1.086
22	1.213	1.113	1.170	1.113
23	1.195	1.142	1.118	1.152
Averages	**1.000**	**1.000**	**1.000**	**1.000**

The hourly variation in load was superimposed on the predicted loads during the various seasons to obtain the predicted contaminant concentrations through the synthetic year.

Projected Diurnal Flows and Loads - SEWPCC

Projected diurnal primary effluent flows and loads for SEWPCC during year 2041 are shown in Figures 2.15 to 2.18. Wastewater temperature variation at the SEWPCC is based on the same derivation as noted in the section regarding the NEWPCC, as shown in Figure 2.19.

Figure 2.15 shows the projected 2041 primary effluent flow rates plotted at hourly intervals. The dark green line represents a 7-day running arithmetic average for the flow. The average seasonal flow in each season increases to a maximum month flow in the middle of that season.

Figure 2.15: SEWPCC 2041 Primary Effluent Flowrate

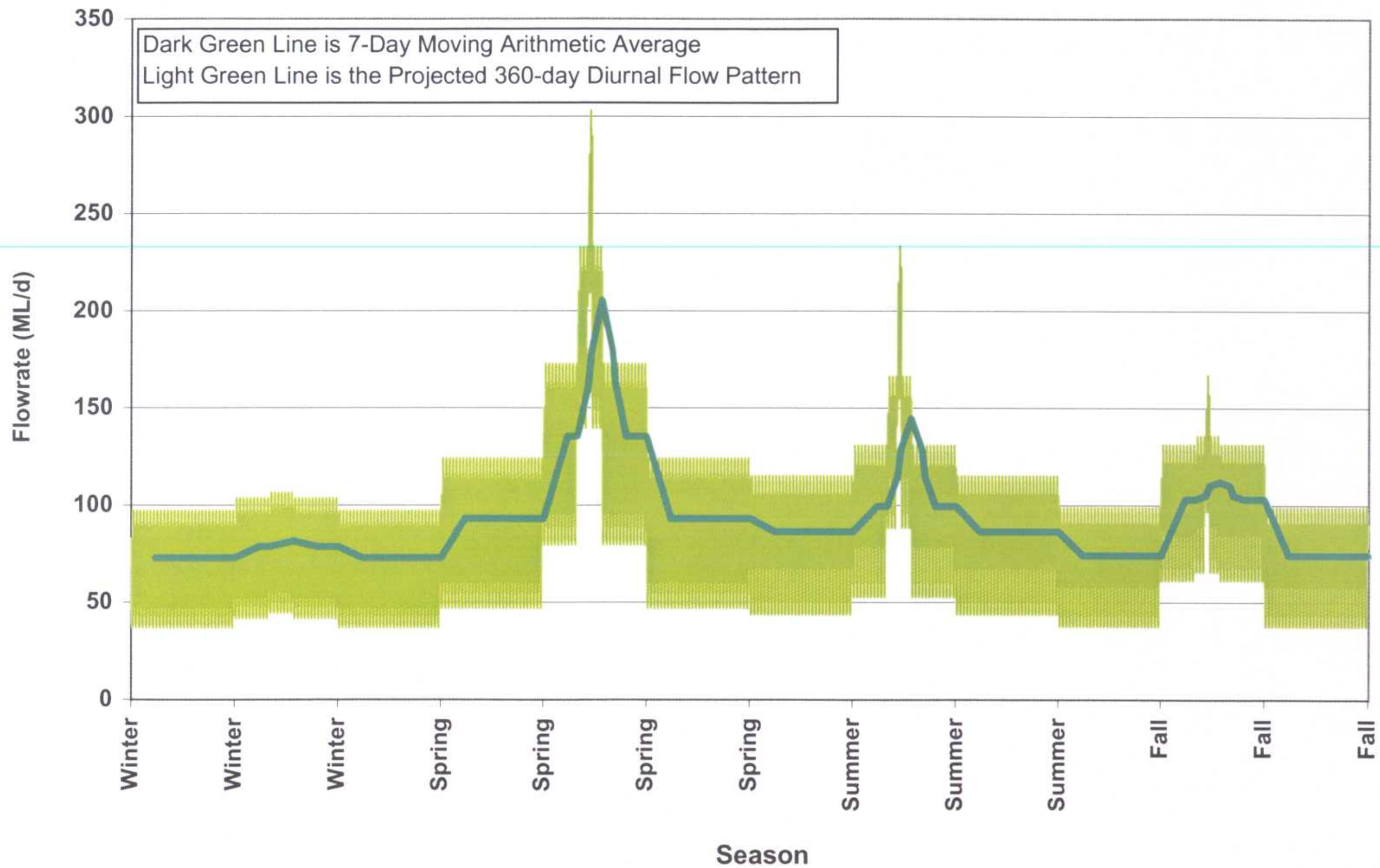


Figure 2.16: SEWPCC 2041 Primary Effluent Total COD Projection

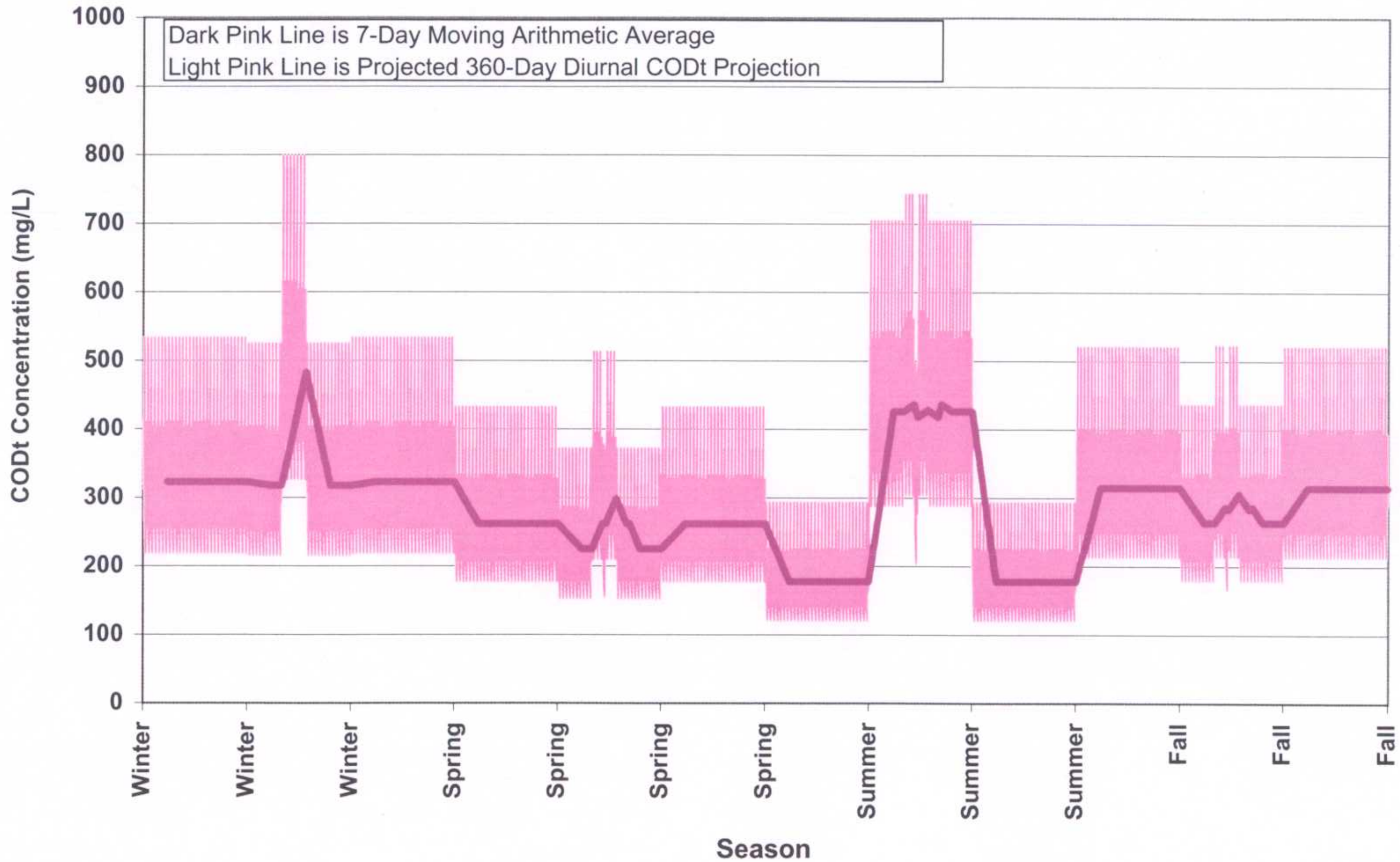
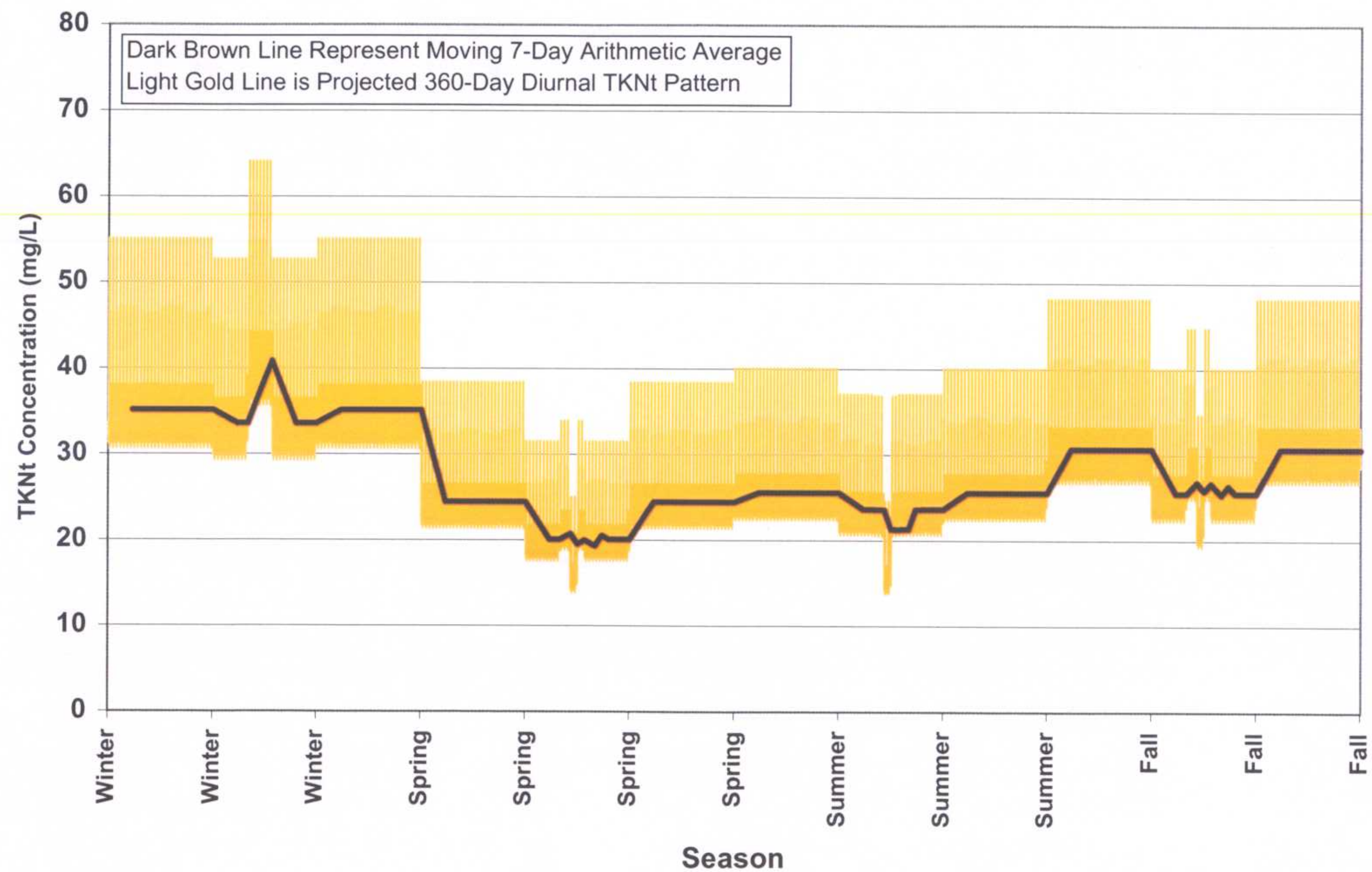


Figure 2.17: SEWPCC 2041 Primary Effluent Total TKN Projection



H:\p..\wat\6234000\02\SEWPCC_Biowin_June_00\step14-SD-2041 Flow and Loads Plots.xls2041Total TKNProjectn Fig 2.17

Figure 2.18: SEWPCC 2041 Primary Effluent Total Phosphorus

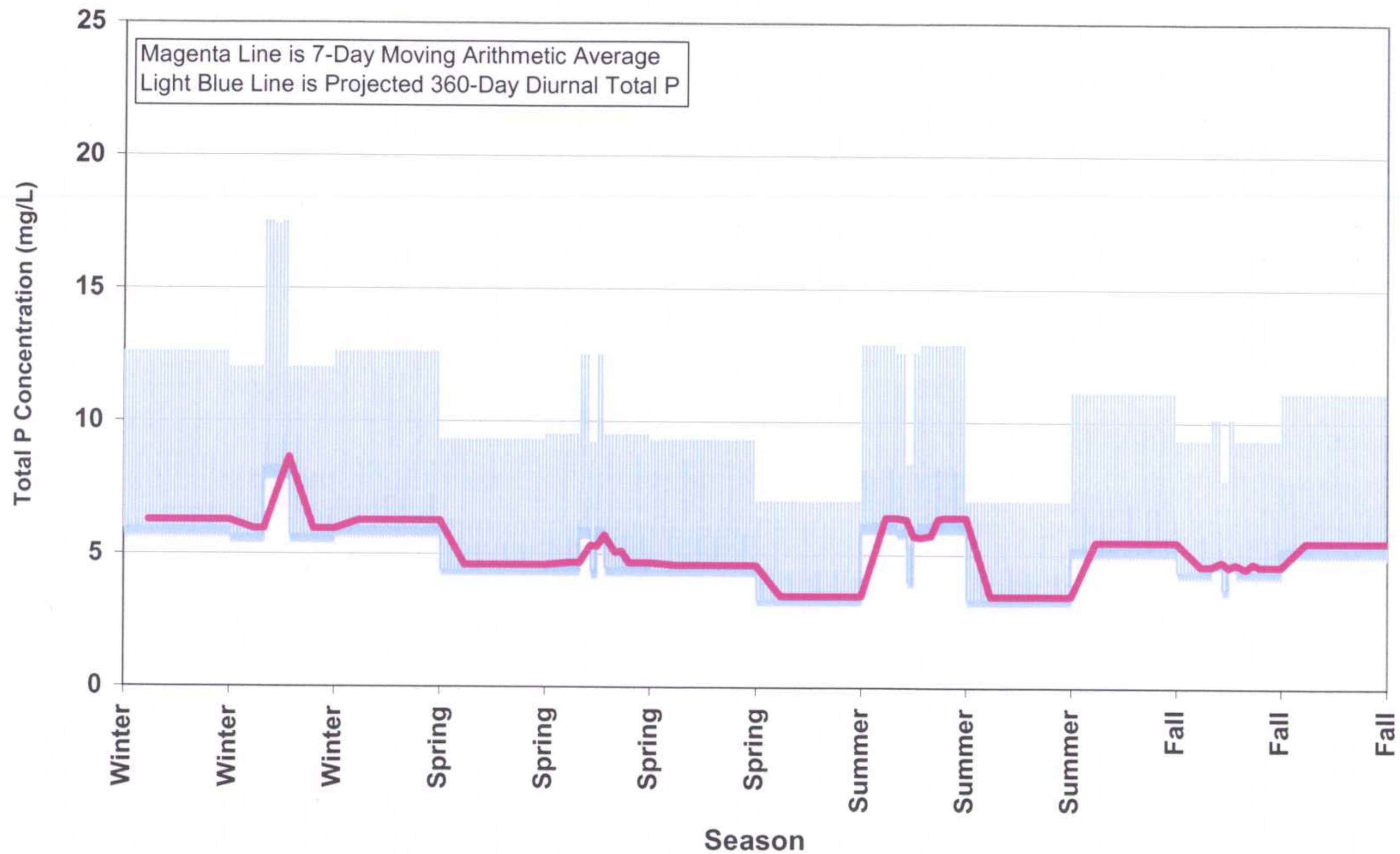
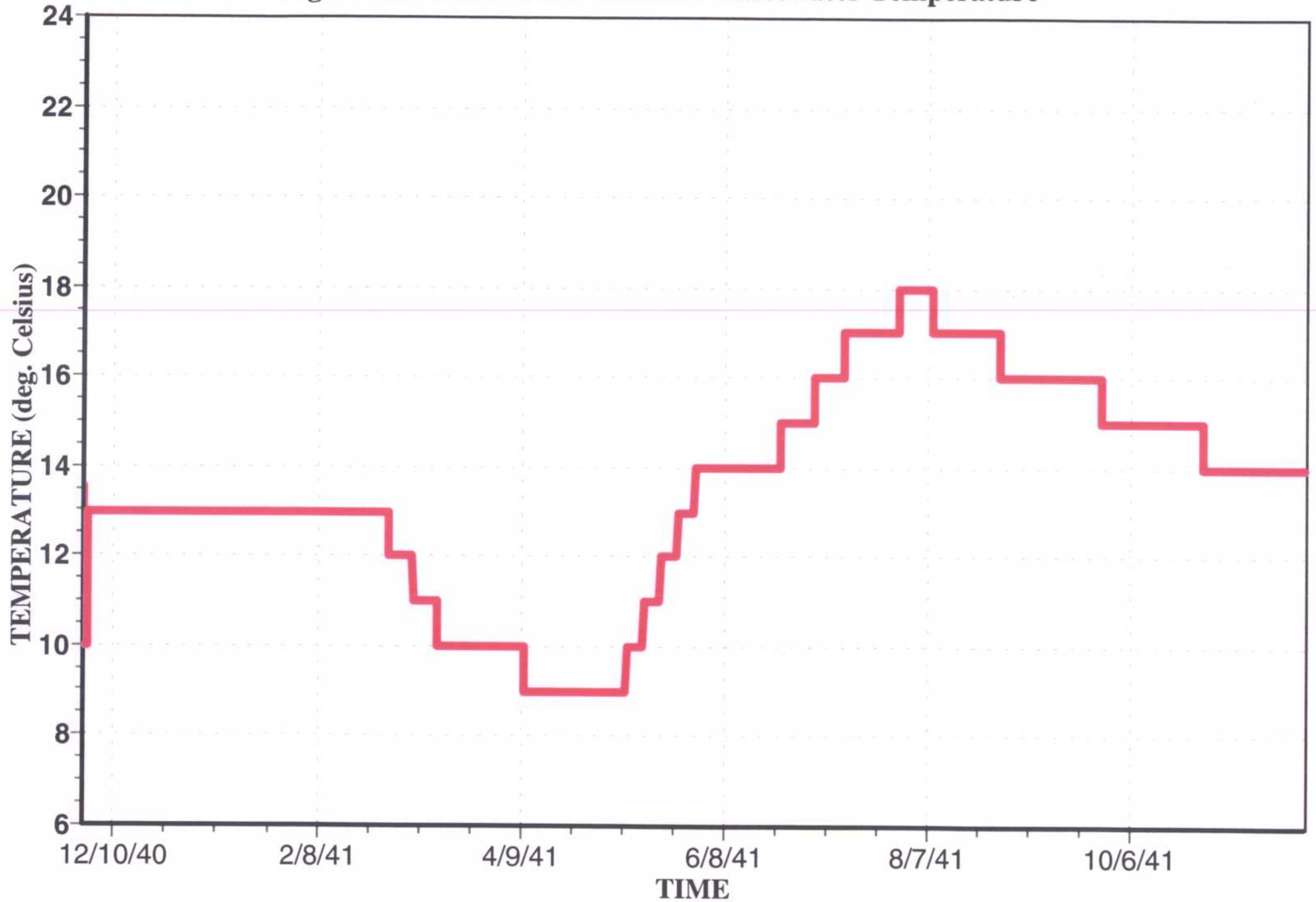


Figure 2.19 : SEWPCC Influent Wastewater Temperature



Figures 2.16, 2.17, and 2.18 present projections of NEWPCC primary effluent total COD (CODt), total TKN, and TP concentrations, respectively. These concentrations are estimated by combining the flows plotted in Figure 2.15 with the appropriate loads from Table 2.6 and appropriate peaking factors representing the diurnal loading pattern in Table 2.7.

The hourly variations of COD, TKN, and TP concentrations display a similar pattern that is described as follows:

- During the early period of summer, fall, and spring maximum months, the average concentration of pollutants drops. The concentration eventually levels off.
- The drop of pollutant concentrations observed during initial period of the maximum month of the summer, fall, and spring seasons is due to the dilution effect of rainfall or snowmelt. During this period, the increase in wet weather flow will have a moderate flushing effect on the sewer sediments. The flushing effect, however, is less than the dilution factor and the concentrations of the pollutants go down. Therefore, the high flow mainly has a dilution effect and causes a drop in concentrations to below average seasonal values for non-maximum months.
- There are, however, instances were the situation described above does not occur. These include the TP concentrations during spring and summer and COD concentrations during summer. In these cases, a positive slope is observed at the beginning of the maximum month signifying that the pollutant concentrations are increasing. The flushing effect is therefore greater than the dilution factor. During maximum month, the flow is in such quantity that it flushes roads and sewer sediments resulting in substantial increases in pollutants. This results in an increase in concentration and a positive slope is observed in the average concentration curve corresponding to the maximum week.
- There are some instances, however, where the increase in pollutants was overpowered by the dilution factor. For example, during the maximum week periods for TP and TKN summer concentrations, a negative slope is observed. For the majority of the maximum day periods, a negative slope is observed signifying that the effect of the increase in pollutants was not as great the dilution factor.
- This was not the case for COD concentration in the spring and fall and TP concentration in the spring where the average concentration curve corresponding to the maximum month experiences a positive slope. Following the maximum week flows, the sewers are clean and the flows return to the maximum month values. As a result, wastewater pollutants approach their typical maximum month concentrations during the late part of the maximum month. Average day concentrations are resumed after the maximum month period because of re-establishing of average flows.

- The trend of change observed in winter concentrations is somewhat different than for other seasons. In winter, there is no significant drop in the concentration of pollutants in the early and late maximum month periods. The concentrations during these periods are slightly greater than the average seasonal concentration. This is because there is no rainfall or snowmelt to dilute the sewage. This minimizes the variations in concentrations. However, similar to other seasons, a sharp increase is observed during maximum week of winter season.

In general, the flow to the SEWPCC is highest during spring and decreases during summer and fall, and reaches its minimum during winter season. Conversely, concentrations of pollutants are highest during winter months and next to highest during the fall months. Due to the great variations in loading distribution during the spring and summer, pollutant concentration is not indirectly proportional with flow. In the case of TP and COD, spring concentrations are greater than summer concentrations. TKN concentrations are lowest in the spring and next to lowest in the summer.

Inert Suspended Solids (ISS) - SEWPCC

The ISS content of wastewater can be a significant factor in the behaviour of the wastewater treatment system, particularly if large variations in ISS occur. Such large variations can occur during periods of storm runoff when excess quantities of grit and fine silt gain access to the sewage collection system through inflow and infiltration. One of the inputs to the mathematical models used to simulate the performance of a wastewater treatment plant is the ISS. Therefore, it is important to have some knowledge of this variable to achieve reliable modeling results.

The City of Winnipeg records only the total suspended solids (TSS) content in the raw and primary effluent streams. Therefore some means of inferring the variations in ISS concentration in the wastewater throughout the year must be devised so that appropriate values for ISS can be used in the modeling work.

The default value used for the ISS of raw sewage in BioWin™ is 15 mg/L. A typical value for ISS in the primary effluent during dry weather flow at a municipal wastewater treatment plant would be 10 mg/L. This value was used in the BioWin modeling done for the SEWPCC. Several monthly average plant performance datasets for 1999 and 2000 were used in a series of steady state simulations.

2.2.4 West End Water Pollution Control Centre (WEWPCC)

Section 2.2.2 described the derivation of a synthetic flow and load database for the NEWPCC and Section 2.2.3 described the derivation of a synthetic database for the SEWPCC. Using a similar approach, a synthetic influent database was constructed for the WEWPCC. This construction was undertaken after examining existing information obtained from plant records and new information obtained during specific sampling periods done to characterize diurnal fluctuations.

Seasonal Variations - WEWPCC

The synthetic databases were configured with four seasons – summer, fall, winter, and spring. As with the other two plants, each season was assumed to have a duration of 90 days, so the synthetic annual database represented 360 days in total. The assumed pattern was based on several assumptions, as described in Section 2.2.3 for the SEWPCC.

The assumption that maximum week flows and loads are coincident was considered conservative for this plant. As noted for the NEWPCC, maximum loads generally occur when the flow rates are less than the maximum flow conditions for all four seasons.

Maximum daily loads could not be inferred from the data available from the plant. There was considerable scatter and some of the maximums were likely due to sampling or laboratory inconsistencies. For this reason, the maximum day load in secondary influent was assumed to equal the maximum week load in primary effluent multiplied by a peaking factor of 1.3. This relationship was used to establish projected primary influent loads.

Table 2.8 presents the projected Year 2041 seasonal flows and loads for the WEWPCC. The table lists flow and load values for average month, maximum month, maximum week and maximum day for each season.

Table 2.8: Projected Seasonal Flows and Loads To The Primary Treatment Process of the WEWPCC For The Year 2041

Periods	Flow (ML/d)	TSS (kg/d)	BOD (kg/d)
Winter			
Average	29.6	7,070	6,585
Maximum Month	31.3	7,260	6,550
Maximum Week	32.2	9,035	7,920
Maximum Day	34.0		
Spring			
Average	43.7	8,805	5,760
Maximum Month	60.4	12,115	7,130
Maximum Week	80.2	18,085	10,015
Maximum Day	112.5		
Summer			
Average	37.7	7,315	5,580
Maximum Month	42.5	9,505	6,490
Maximum Week	57.0	12,560	8,545
Maximum Day	82.2		
Fall			
Average	32.7	7,135	6,315
Maximum Month	38.1	8,165	7,155
Maximum Week	44.1	10,240	8,255
Maximum Day	54.3		

Primary Treatment Removals - WEWPCC

Modeling of the WEWPCC was based on primary effluent values. In a manner similar to that employed for the SEWPCC, the likely primary treatment removals were derived based on plant records from 1996 to 1999. Best fit power functions were derived for TSS and BOD, as follows:

TSS removal
$$\frac{TSS_e}{TSS_i} = \frac{629 * OFR^{0.00445}}{TSS^{0.662} * T^{1.314}}$$

BOD removal
$$\frac{BOD_e}{BOD_i} = 0.726\left(\frac{TSS_e}{TSS_i}\right)^{0.184}$$

Notes:

- Subscript “e” indicates primary “effluent”
- Subscript “i” indicates primary “influent”
- “OFR” indicates primary clarifier overflow rate
- “T” indicates wastewater temperature in degress Celsius

These algorithms were applied to the average, maximum month, and maximum week plant raw wastewater loads to determine the residual load after primary treatment under those conditions. It was assumed that primary treatment efficiencies would not vary substantially over the course of a day.

Primary treatment also will remove a fraction of the influent TKN and total phosphorus (TP). It was assumed that this fraction would represent the insoluble fraction of these compounds that is removed with the TSS. The insoluble fraction of TKN was assumed to be 25 percent of the influent TKN and the insoluble fraction of the TP was assumed to total 20 percent of the influent TP.

The projected seasonal flows and loads to the secondary treatment process for the WEWPCC are summarized in Table 2.9.

Table 2.9: Projected Seasonal Flows and Loads to the Secondary Treatment Process of the WEWPCC for the Year 2041

Periods	Flow (ML/d)	TSS (kg/d)	BOD (kg/d)	COD (kg/d)	TKN (kg/d)	TP (kg/d)	Temp. (°C)
Winter							
Average	29.6	2,010	3,794	7,588	913	158	12 to 13
Maximum Month	31.3	2,085	3,694	7,388	930	166	
Maximum Week	32.2	2,266	4,566	9,131	1,014	192	
Maximum Day	34.0						
Spring							
Average	43.7	3,383	3,508	7,016	912	172	10 to 11
Maximum Month	60.4	4,674	4,346	8,691	1,032	193	
Maximum Week	80.2	6,891	6,092	12,184	1,233	236	
Maximum Day	112.5						
Summer							
Average	37.7	1,975	3,184	6,369	821	147	16 to 18
Maximum Month	42.5	2,339	3,641	7,282	891	171	
Maximum Week	57.0	2,835	4,719	9,439	1,049	188	
Maximum Day	82.2						
Fall							
Average	32.7	1,781	3,554	7,109	892	150	16
Maximum Month	38.1	2,066	4,034	8,069	961	164	
Maximum Week	44.1	2,457	4,611	9,222	1,039	177	
Maximum Day	54.3						

Diurnal Variation - WEWPCC

Recorded flows for January to May 1996 and for January 1999 were retrieved from the plant data acquisition system. The flow data were available for ten minute intervals. A typical diurnal curve for flows entering the plant during dry periods (January 1996 and January 1999) is shown in Figure 2.20.

This curve illustrates the typical dry period flow pattern measured at the discharge of the raw sewage pumps during the period of record. At the WEWPCC during dry periods, flow is generally pumped at the rate at which it arrives at the plant. Unlike the NEWPCC, dry weather flows into the plant are not substantially affected by the pump operation strategy.

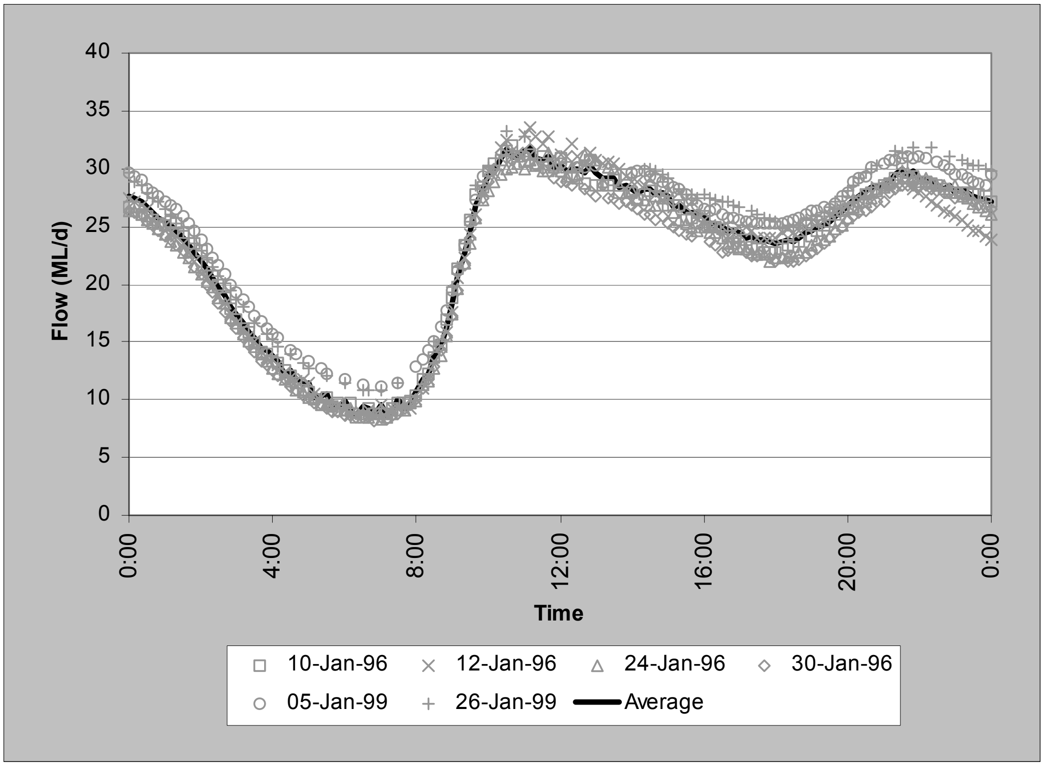


Figure 2.20: Dry Weather Diurnal Flow Variation at WEWPCC in September, 1998

This pattern is consistent through dry periods of the year. During wet periods, the pumping pattern changes depending upon the snow melt or rain storm characteristics. During these wet periods, the diurnal variation can be overlain on a raised base flow that is a function of the storm. This characteristic is illustrated in Figure 2.21 where measured flows during a wet period (May 1996) are compared to synthetic curves constructed by adding a constant amount to the average dry weather diurnal pattern shown above in Figure 2.20.

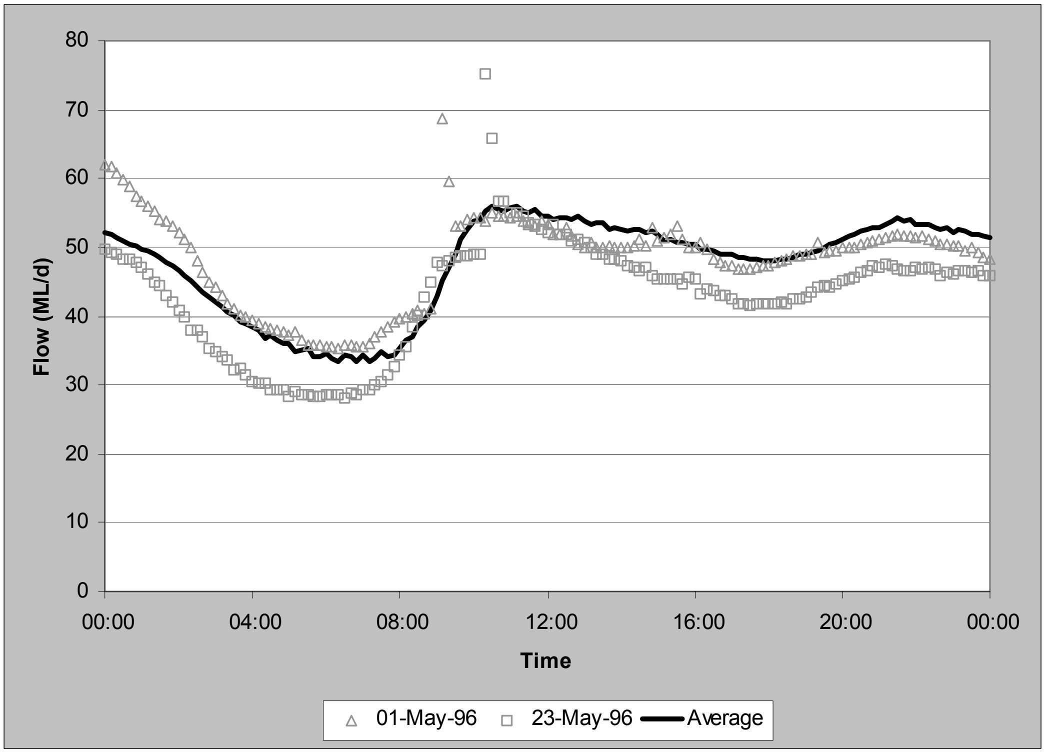


Figure 2.21: Wet Weather Diurnal Flow Variation at WEWPCC in May, 1998

The darker solid line indicated in Figure 2.21 are derived by adding about 22.5 ML/d to the dry weather diurnal flow on both May 1 1996 and on May 23 1996.

The loading rate also varies during the day. From September 13 to September 17, 1999, samples were taken at one hour intervals and tested for COD, soluble COD (sCOD), TSS, VSS, TKN, NH_3-N, and TP. Through the day at the WEWPCC, measured concentrations for TSS, COD, TKN, and TP were relatively consistent. Concentrations were generally lowest in the early morning hours, rising to a maximum in the early evening hours. Figure 2.22 illustrates this pattern for the measured COD concentrations.

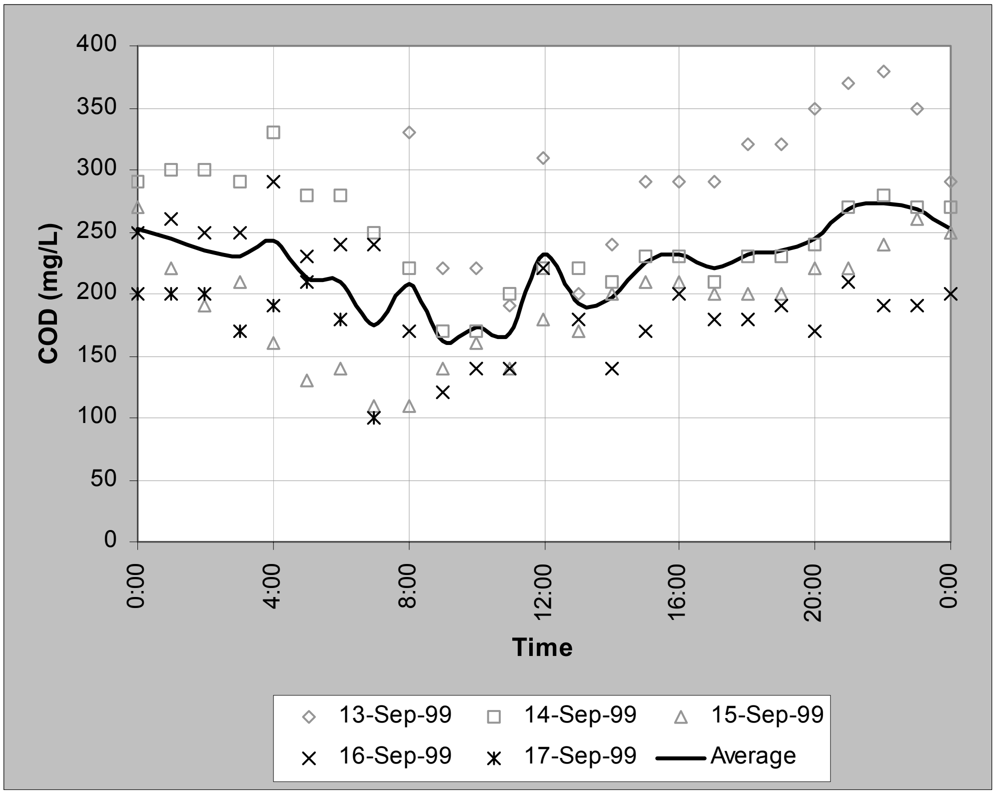


Figure 2.22: Diurnal COD Variation at WEWPCC in September, 1999

The concentrations obtained for each hour were multiplied by the flow measured for each of those hours to obtain hourly loads. These values were then used to derive load variation ratios for each hour during the day. Table 2.10 presents the diurnal flow and load peaking factors that were used for the WEWPCC synthetic 2041 secondary influent database.

Table 2.10: Diurnal Flow and Load Peaking Factors - WEWPCC

Hour	Peak Factors			
	Flow	COD	TKN	TP
0	1.130	1.112	0.957	0.963
1	1.021	1.276	0.905	0.963
2	0.880	1.023	0.905	0.963
3	0.728	1.029	0.888	0.960
4	0.603	0.966	0.900	0.952
5	0.565	1.655	1.570	2.020
6	0.502	1.604	1.203	1.448
7	0.507	0.884	0.894	0.960
8	0.623	0.789	0.905	0.963
9	0.870	0.827	0.871	0.920
10	1.100	0.783	0.917	0.906
11	1.298	0.752	0.951	0.909
12	1.333	0.733	0.963	0.924
13	1.285	0.777	0.991	0.913
14	1.231	0.676	1.020	0.906
15	1.196	1.017	1.049	0.920
16	1.117	0.966	1.060	0.924
17	1.082	1.080	1.054	0.924
18	1.062	0.947	1.049	0.931
19	1.096	1.251	1.083	0.942
20	1.151	0.960	0.997	0.902
21	1.205	1.011	0.968	0.909
22	1.216	0.922	0.963	0.916
23	1.199	0.960	0.934	0.963
Averages	**1.000**	**1.000**	**1.000**	**1.000**

The hourly variation in load was superimposed on the predicted loads during the various seasons to obtain the predicted contaminant concentrations through the synthetic year.

Projected Diurnal Flows and Loads - WEWPCC

In general, the flow to the WEWPCC is highest during spring and decreases during summer and fall, and reaches its minimum during winter season. Conversely, concentrations of pollutants are highest during winter months and next to highest during the fall months. Due to the great variations in loading distribution during the spring and summer, pollutant concentration is not directly proportional with flow. In the case of TP and COD, spring concentrations are greater than summer concentrations. TKN concentrations are lowest in the spring and next to lowest in the summer.

Inert Suspended Solids (ISS) - WEWPCC

The City of Winnipeg records only the total suspended solids (TSS) content in the raw and primary effluent streams. Therefore some means of inferring the variations in ISS concentration in the wastewater throughout the year must be devised so that appropriate values for ISS can be used in the modeling work.

Primary effluent generally has a VSS:TSS ratio of 75 percent at the WEWPCC. The average primary effluent TSS concentration through the synthetic database is about 63 mg/L. Accordingly, an ISS of concentration of 16 mg/L was selected for use in the modeling work done for the WEWPCC.

2.3 APPROACH TO MODELING

2.3.1 Model Description

The BioWin™ wastewater treatment process simulator has been used in this work to model the proposed nitrification upgrading options and to project their performance for the estimated 2041 flow and loading conditions. The BioWin™ simulator is a Microsoft Windows-based simulator used world-wide in the analysis and design of wastewater treatment plants. The package was developed specifically for the computer-based modeling of biological nutrient removal processes and it is an ideal tool to use for the design, analysis and optimization of these systems.

The simulator allows the designer to predict how a wastewater treatment plant of a specified size and process configuration will respond to different wastewater flow and loading conditions. In this manner, a computer can be used to run several scenarios covering various plant design and operating conditions for different flow and loading situations.

A key component of the simulator is the bioreactor model which is based on the use of the International Association of Water Quality (IAWQ) Model, modified according to the results of numerous laboratory and full scale tests to include the biological reactions responsible for biological nutrient removal. The model describes the changes that occur to carbon, nitrogen and phosphorus species as they are processed by the numerous complex biochemical reactions in a bioreactor. Every element in the bioreactor configuration can be modeled to provide a mass-balance on many variables including, among others, oxygen, carbon, nitrogen, and phosphorous species as well as solids and flows. Another key component of the simulator that, together with the bioreactor model enables the user to simulate the activated sludge process, is a layered one-dimensional final clarifier model.

2.3.2 Use of BioWin™ for Modeling

BioWin™ must be calibrated to result in realistic output projections for the flows and loads of the plant under consideration. The simulator contains default values for the influent wastewater characteristics and for the various kinetic and stoichiometric parameters associated with the biochemical models, as well as operational conditions such as temperature, dissolved oxygen set-points, air flow, etc. These default values are appropriate for instructional and demonstration purposes.

For application to a specific treatment plant, however, the simulator must be calibrated on the basis of the existing physical/environmental/operational conditions and the wastewater characteristics, as far as they are known. Final calibration adjustments are made on a trial-and-error basis by comparing simulator projections to a selected period of plant performance.

The following steps were taken in customizing the simulator to the specific circumstances of each of the City's WPCCs:

1. The simulator was calibrated for each of the City's WPCCs. Calibration of the model was mainly based on a detailed review of four years (1995 to 1998) of plant records on flow, COD, TSS, TKN, NH3-N, TP, temperature, and DO. Moreover, the experience of the team members and the literature data were other significant assets considered in this task. In general, the calibration of the simulator included:

   - Configuration of the various process options for upgrading each plant using the simulator's "drawing board" to create the desired process flow diagrams.
   - Change in default environmental and operational conditions to represent the existing conditions. For example, the wastewater temperatures developed in Section 2.2 were used. Also, bioreactor dissolved oxygen and final clarifier RAS pumping rates were modified to represent the recorded data.
   - Appropriate modifications to selected kinetic and stoichiometric parameters. A very important kinetic parameter in nitrifying systems is the maximum specific growth rate of the autotrophic organisms (μ_{max}). This parameter determines the nitrification rate in the bioreactor. For the NEWPCC, a value of 0.55 d^{-1} was assigned to this parameter based on previous research work at the University of Manitoba. For the SEWPCC and the WEWPCC, a value of 0.50 d^{-1} was allocated to μ_{max}. A limited amount of research done at the SEWPCC has indicated that the value might be as high as 0.55 d^{-1}. The slightly lower value used in the modeling mandates the adoption of slightly longer system SRTs to achieve the same nitrification performance and will produce a

conservative result. Further site specific testing prior to final design will allow more accurate selection of the value of this parameter.

- Specify various organic and nitrogen fractions, the inert suspended solids (ISS) and the total phosphorus (TP) of the wastewater input streams. The partitioning factors used to describe wastewater characteristics necessary for the biochemical model in the simulator are summarized in Table 2.11. The values for the ratios were developed to ensure that the BOD, TSS, and VSS values calculated by the program closely resembled the actual values. The F_{xsp}, ISS, and F_{up} values are critical to the VSS:TSS ratio and have a substantial impact on bioreactor sizing.

Table 2.11: Values Specified for the Primary Effluent Wastewater Characteristics

Parameter	Description	Value		
		NEWPCC	SEWPCC	WEWPCC
COD/BOD_5	COD to BOD_5 ratio	2.00	2.00	2.00
F_{bs}	Fraction of COD that is readily biodegradable.	0.20	0.07	0.07
F_{ac}	Fraction of readily biodegradable COD that is VFA.	0.20	0.25	0.25
F_{xsp}	Fraction of slowly biodegradable COD that is particulate.	0.45	0.35	0.40
F_{us}	Fraction of COD that is soluble and not biodegradable.	0.05	0.13	0.13
F_{up}	Fraction of COD that is particulate and not biodegradable.	0.08	0.08	0.08
F_{na}	Fraction of TKN that is ammonia.	0.75	0.69	0.69
F_{nox}	Fraction of particulate organic nitrogen that is biodegradable.	0.50	0.50	0.50
F_{nu}	Fraction of soluble organic nitrogen that is not biodegradable.	0.00	0.00	0.00
F_{upN}	Nitrogen in biomass.	0.068	0.068	0.068
F_{upP}	Phosphorous in biomass.	0.021	0.021	0.021

2. Input data for BioWin™ dynamic simulations were prepared. These data included hourly flows and loads (COD, TKN, TP) to the secondary treatment process. The use of hourly flows and loads in computer simulations will cover seasonal and diurnal variations so that a realistic annual pattern can be input to the computer model. Details on the derivation of hourly flows and loads were discussed previously in Section 2.2.

3. Following calibration of the model and data input, and prior to the final simulation, several initial simulation runs were conducted to determine the appropriate SRT settings. Sufficiently high SRTs are required to ensure that nitrification remains stable.

4. Important variables to monitor during the course of the simulation runs include MLSS and MLVSS, oxygen uptake rates, and the surface overflow rates and solids load rate in the final clarifiers. If any of these vary beyond an acceptable range during the course of a simulation, then adjustments are made to the process design and operating configuration on the simulator's "drawing board" to refine the design and the simulation is re-run.

The outputs of the final run represent the projections of the treatment performance for the selected treatment option.

2.3.3 Version of BioWin™ Used in This Report

The simulation work for the Best Practicable Level of Ammonia Control at the NEWPCC employed Version 4.4 of BioWin™. Part way through this assignment, a newer version of the simulator called BioWin32™ Version 1.1.0 became available and this was used for the balance of the simulation work on this assignment. A major difference between the older version and the newer version of BioWin™ is in the graphical presentation observed on the computer screen. This difference will be readily apparent in the figures presented in this report that show process configuration and predicted model outputs from the simulator.

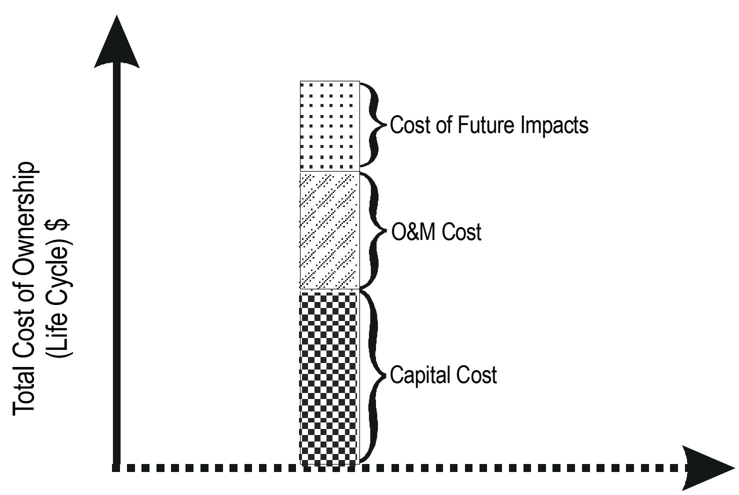
2.4 DEVELOPMENT OF COST ESTIMATES

2.4.1 General Approach

The overall objective of the Nitrification Study is to develop relationships between the total cost of plant upgrades versus the various levels of ammonia control that could be provided. These relationships will provide the costing information that the City will use in its discussions with Manitoba Conservation.

Total Cost of Ownership

The cost of the plant upgrades to meet the various levels of ammonia control must represent the total cost of ownership – a complete representation of all costs that will be associated with the provision of the ammonia control option. The various components of the total cost of ownership can be described as follows:



- **Capital Cost** – The cost of building the facilities and bringing them on line including construction cost, start-up and commissioning, engineering, administration, burdens, and overheads.
- **Operations and Maintenance (O&M) Cost** – The cost of running the facilities over their lifetime including such items as labour, power, chemicals, materials, parts, and other consumables.
- **Cost of Future Impacts** – Includes the cost of all impacts that will occur as a result of implementing the upgrades for nitrification. A global perspective has to be taken so that true cost of ownership is presented.

In presenting the costs, effort has been made to indicate only costs directly related to a decision to implement ammonia control. Expenditures that the City would incur in order to maintain the current levels of secondary treatment until the year 2041 have been identified wherever possible and excluded from the cost estimates for provision of nitrification.

2.4.2 Cost Information Sources

The information sources used to generate conceptual level capital cost estimates include the following:

- Conceptual level engineering of each alternative
- Budget prices for major components of the plants, such as budget quotations for electrical and process equipment and unit prices for concrete in place
- Cost data from actual recent projects
- Trends in recent construction contracts and bid prices for other facilities

Wherever possible, operations and maintenance costs have been estimated based on the details available in the conceptual design (e.g. power costs based on equipment required for various processes). Additional information sources were also drawn upon to help to generate and validate the O&M costs, including the following:

- Cost data from the City's existing plants were used to define the general magnitude of the O&M costs and also help to set unit costs, such as labour rates and maintenance effort (man-hours) for specific functions.
- Data obtained from other plants, particularly those in Western Canada. A database of existing costs from other facilities was drawn upon to help establish some of the estimating parameters.

The impacts due to the decision to implement nitrification is considered to be a critical issue in generating estimates that represent the true total cost of ownership. All current and future impacts were identified and included in the cost analysis.

Further detail regarding the cost estimating approach for each of the three components of the total cost are set out in the following paragraphs.

2.4.3 Capital Costs

The following method was employed for preparing the capital costs:

- Conceptual engineering drawings were prepared for each upgrade alternative identified for each level of control for each plant. These drawings included site locations, general arrangements, and process flow diagrams. In several cases, hand drawn cross sections and details were also developed.
- Quantities were taken off based on the available conceptual engineering information and entered into a spreadsheet for each component or discipline.
- Wherever sufficient detail was generated in the conceptual designs, unit construction costs were entered into the spreadsheet to derive the capital cost for that component. For equipment, budget quotations were obtained from manufacturers wherever possible and used in the calculations.
- Where there was insufficient detail available from the conceptual designs, data from other recent construction projects were used. For example, if any option required a pump house and the pumping capacity had been determined but a layout was not available, a reasonable estimate was generated based on the costs of similar facilities completed at other locations.
- Other items included in the capital costs were contingencies, contractors' overheads and profits, engineering costs, City finance and administration costs, overhead burdens, and taxes.

When undertaking the capital cost estimates, particular attention was paid to the following factors:

- Market conditions were taken into account to the degree possible when preparing the estimates. There are a number of indices published that report cost trends on a regular basis. These publications provided the cost estimating team with a general guide as to what is happening in the market, what direction trends are taking, and hence what type of market the projects might be tendered in. Information sources include the Consumer Price Index, Canadata, prime interest rates, construction cost trends, labour wage rates, Statistics Canada information, the construction associations, and Engineering News Records. It is recognized that market conditions at the actual time of tendering will have an impact on the capital costs.
- The more complex a project is to build, the more it will cost. For instance, undertaking modifications to an existing plant component will be typically more costly than a new construction as the schedule and productivity will be impacted by the operation constraints imposed.

Some specific parameters used in the capital cost estimates are as follows:

• General Conditions, Contractor Overheads, etc.	12% - 20% of total cost
• Concrete:	$\$400/m^3$ - $\$700/m^3$
• Piles:	$900 - $1,00- each
• Excavation:	$\$18/m^3$ - $\$25/m^3$
• Backfill:	$\$12/m^3$ - $\$25/m^3$
• Building Envelope:	$\$600/m^2$ - $\$800/m^2$
• Process Mechanical:	Equipment costs depend on type of equipment under consideration. Typically they are based on budget estimates from suppliers and data from other plants completed in western Canada.
• Electrical & Mechanical (E&M) Building Services:	Allowance included depends on the size of the building considered. Typically approximately 10% of the building cost is included to cover E&M Building Services
• Electrical & Instrumentation and Controls:	Allowance of 15% - 25% of total cost
• Siteworks and Miscellaneous:	The costs included depend on the facility under consideration. Typically no more than 5% of the construction costs is allowed for options involving extensive utility and siteworks.
• Other allowances include:	- Contingency 20% - Engineering 15% - City Administration 3%

2.4.4 Operating and Maintenance Costs

The following method was adopted for preparing the annual operating and maintenance (O&M) costs:

- The O&M costs were estimated under several headings including: labour (salaries and benefits), power consumption (electricity and natural gas), utilities (telephone, etc.), consumables (chemicals, oils, grease, etc.), total maintenance services (materials related to electrical, mechanical, and instrumentation items), and miscellaneous.
- Wherever sufficient detail allowed, the costs under the various headings were calculated based on quantities and unit prices. For example, an estimate of

operating staff requirements was generated in the conceptual designs and labour unit costs were applied to generate a reasonable estimate of this component.

- Where insufficient detail has been generated, data from the City's records and other facilities was used to provide guidance.
- Consideration was given to increases in certain costs over time. For example, power costs will increase as the loading to the plant increases over the life of the facility. Maintenance costs will increase over time as mechanical equipment wears and eventually must be replaced.

Some specific parameters used in the O&M cost estimates are as follows:

- Labour: $30/hr. which includes salaries and all burden costs
- Power: $0.05/kWh including demand charge
- Utility: Gas usage @ $24/m^2 of building space
- Consumables: Types and amounts depend on facility under consideration
- E&M Materials: Amount estimated depends on type of equipment included

2.4.5 Future Impact Costs

The following method was adopted for preparing the future impacts cost estimates:

- Possible future impacts were identified based on each of the upgrade alternatives proposed.
- The timing of the impacts were identified and were used in the net present value calculations.
- Each impact was costed using the information and data as described for the capital and O&M costs.

2.4.6 Net Present Value (NPV) Costs

Present value calculations were carried out so that all costs (capital, O&M, and future impact costs) are discounted over time to the present date. This method was used to derive a single monetary value that permits a direct comparison between options. The following assumptions and approach were used:

- Discount rates of 4%, 7%, and 10% were used for the NPV calculations. This will cover low, medium, and high inflation scenarios. The key purpose of using different rates is to test the sensitivity of the cost estimates and determine if the use of any particular rate will alter the ranking of the options.

- Life for civil engineering construction work was assumed to be 50 years.
- Life for electrical and mechanical installations was assumed to be 15 to 25 years, depending on the particular component.
- Costs and timing of replacement components that have a useful life expectancy shorter than the period of analysis were included.
- Final salvage value of the plant at the end of the planning cycle was included.

2.4.7 Range Estimating

The cost data used and the assumptions made in any cost calculations are typically taken as the best available at the time. In practice, however, much of the data used in economic analysis is uncertain in varying degrees, either because of the nature of the data itself, or because of the difficulties in interpretation.

A technique known as "Range Estimating" was applied to provide an indication of how the cost estimates generated in this study might change from now until implementation due to uncertainties such as described above. The fundamental concept in this type of analysis is to break the cost estimate down into independent categories, and then to define the statistical distribution type (typically normal distribution) of the estimated costs for each category.

For each category or cost item, a low estimate and a high estimate of expected total cost was generated, in addition to the most likely value. These values were generated by viewing the details of the estimate to define the items that have a good probability of changing between the time of the estimate and actual implementation. For example, for construction costs:

- Equipment budgetary prices obtained from different manufacturers often vary from source to source, and a range of prices can be developed.
- Quoted unit construction prices will vary. For example, for cast-in-place concrete, references can be made to previous tenders to establish the range of prices. Another good source of information is the community of contractors and suppliers who are most up to date not only on material and labour costs, but also on the cost trends.
- Power and chemical consumption could vary from the conceptual level estimates.

Once the range in likely values was generated, the following statistical relationship was used to obtain an estimate of the expected value and values at different confidence limits:

$$E = \text{Expected Value} = \frac{L + 4M + H}{6}$$

L = Optimistic or low estimate

H = Pessimistic or high estimate

M = Most likely estimate

s = Standard deviation = $\frac{H-L}{6}$ (Individual Activity)

S = Standard deviation = $\sqrt{\sum(s^2)}$ (Whole Project)

From statistical theory, it can be assumed that the expected value will fall within ± one standard deviation two-thirds of the time (i.e., 67 percent confidence limit) and within two standard deviations within 95 percent of the time (i.e., 95 percent confidence limit).

With the foregoing approach, an indication of how the estimates of total cost of ownership might change over time and what range in values might be expected has been generated.