2.0 METHODOLOGY

2.1 INTRODUCTION

EPA evaluated potential water quality effects of discharges of conventional pollutants from meat and poultry processing (MPP) facilities on receiving streams in a national analysis of direct and indirect discharges[1]. Specifically, EPA used the National Water Pollution Control Assessment Model (NWPCAM version 1.1) to model the change in reach specific instream concentrations of total suspended solids (TSS), fecal coliform bacteria (FCB), ultimate carbonaceous biochemical oxygen demand (CBODu), and dissolved oxygen (DO) concentration. Total Kjeldahl nitrogen (TKN) was also modeled to account for oxygen depletion through nitrogenous biochemical oxygen demand (NBOD).

The modeled changes in these concentrations were then used to identify changes in use categories ranging from the least desirable of no use, to boatable, to fishable, to the most desirable of swimmable.

In the following sections, EPA presents the water quality assessment approach, the NWPCAM model, the pollutants evaluated, and water use support determinations.

2.2 OVERVIEW OF WATER QUALITY ASSESSMENT APPROACH

The main purpose of the Water Quality Environmental Assessment (WQEA) is to estimate changes in water quality conditions resulting from adoption of new limitations and

---

[1] Direct discharge facilities are those which discharge effluent directly into water bodies, usually following on-site wastewater treatment. Indirect discharge facilities are those which discharge effluent into a publicly owned treatment works (POTWs), which provides subsequent effluent treatment prior to discharge.

standards as established by the proposed rule. Developing these estimates involves a multi-step process that begins with the analysis presented in the MPP Technical Development Document (TDD) and ends with the MPP Economic Analysis. The first four steps, which are covered in the TDD, are:

1. Identify the universe of MPP discharging facilities
2. Differentiate MPP direct dischargers from MPP indirect dischargers
3. Characterize the technology in place for each of the MPP facilities being evaluated
4. Characterize effluent discharges from each of the MPP facilities being evaluated with baseline and various regulatory options being proposed.

The next three steps, which are the focus of this WQEA, are:

5. Identify and characterize the receiving water body for each direct discharger, and identify the associated POTW for each indirect discharger.
6. Estimate water quality conditions under current discharge conditions and under regulatory alternatives.
7. Quantify changes in water use categories (i.e., fishable, boatable, swimmable)

The final step, covered in the Economic Analysis, is:

8. Monetize changes in environmental benefits associated with changes in water use categories.

Even though the characterization of the MPP effluent discharges (step 4) is covered in the MPP TDD, a quick summary of the process is presented below. The rest of Section 2 presents EPA's methodology used to complete steps 5 through 7.

2.2.1 Characterize Effluent Discharges

EPA estimated baseline and treatment option loadings on a facility-specific level. The baseline loadings were based primarily on data provided in the 2001 MPP Detailed Survey. Where data for specific pollutants could not be obtained from the survey or facility compliance reports, EPA used surrogate data, so that each facility could be modeled for the full suite of pollutants of concern addressed by NWPCAM.

EPA estimated the treatment option loadings for each facility, based upon expected pollutant removals from implementation of the proposed effluent guideline. The evaluated treatment options are presented in Table 2-1.

Table 2-1: Regulatory Treatment Options

Regulatory Option[1]	Technical Component
BAT2	Dissolved Air Flotation (DAF) (advanced oil/water separation), Lagoon, and Disinfection (Oil and Grease, BOD$_5$, TSS, Pathogen removal) + Nitrification (NH$_3$ removal)
BAT3	BAT2 + Denitrification (Nitrate removal)
BAT4	BAT3 + (Phosphorus removal)
PSES1	DAF, Equalization (Oil and Grease, TSS, removal) phorus removal

[1] BAT = Best Available Treatment (covers existing Direct Dischargers)
PSES = Pretreatment Standards for Existing Sources (covers existing Indirect Dischargers)

EPA only applied those BAT/PSES controls that would achieve pollutant concentration levels at least equal to the facility's current treatment in place. Under this approach, a facility that was characterized as having equivalent BAT2 technology in place would only obtain reduced pollutant concentrations levels under more stringent technology options (i.e., BAT3 or BAT4 controls).

2.2.2 Ensure MPP Survey Data is Model Ready

EPA performed several additional steps to ensure that the facility information provided through the MPP Survey, as well as the loadings data generated by the other analyses, could be successfully entered into the NWPCAM model. For example, data on facility specific location information provided in the survey had to be matched with NWPCAM location data for receiving water bodies. In cases where Survey respondents did not identify discharge location (direct dischargers) or associated POTW (indirect dischargers), EPA staff made follow-up calls to the facility operators to ensure that estimated discharges were allocated to the correct water body or POTW, respectively. The Agency made additional modifications to the facility loadings data set to ensure proper data formatting for use in the NWPCAM model. Once EPA entered the facility loadings into the NWPCAM model, EPA combined facility impacts with existing stream reach conditions to estimate water quality under both baseline and regulatory options.

2.3 OVERVIEW OF NWPCAM 1.1

NWPCAM is a national-level water quality modeling system and policy analysis tool. It incorporates a national-scale water quality model into a system designed for conducting policy simulations and benefits assessments. The core of NWPCAM is its water quality modeling system. The system is built on a surface water routing framework that covers virtually the entire inland region of the continental United States. This framework catalogs where surface waters are located and how they are interconnected, and it characterizes the dimensions and flow of water through this network. It is through this routing framework that the hydrological, hydrodynamic, and surface water transport components of the system are integrated into NWPCAM.

A second major component of the modeling system is the pollutant loadings data. This component defines the location and magnitude of discharges to the nationwide surface water network for a selected number of conventional and nutrient pollutants. These loadings are defined for both point and nonpoint sources of water pollution.

The kinetics component of the modeling system then incorporates information from the previous components and simulates how the selected pollutants are dispersed and transformed throughout the surface water network. The primary output of these integrated modeling components are water quality estimates, primarily measured as in-stream pollutant concentrations, across this network.

2.3.1 Types of water pollution problems and policies that can be analyzed with NWPCAM

NWPCAM was originally developed and designed to conduct retrospective analyses of Clean Water Act policies, but has been adapted for conducting prospective analyses of new or proposed regulations. As the model has been expanded and refined, it has become suitable for analyzing an increasingly diverse set of water pollution problems and policies.

Because of its large scale, the development of NWPCAM's water quality modeling and policy evaluation system has been incremental. The scope of the model has been gradually expanded to include more pollutants, more pollutant sources (point and nonpoint), more water bodies, and more water quality measures. For instance, the first version of this model (the CWAEM) incorporated only two "conventional" pollutants (CBODu and TSS), and it included urban and rural nonpoint sources, municipal point sources, and "major" industrial point sources. A subsequent version (NWPCAM Version 1.0) added modeling capability for two additional conventional pollutants (FCB and DO) and added Combined Sewer Overflows (CSOs) and approximately 20,000 "minor" industrial dischargers. The entire model has been reimplemented from its original location on the EPA IBM mainframe running under SAS to a PC-based platform under Microsoft Access.

NWPCAM 1.1 models four conventional pollutants: DO, CBOD, TSS, and FCB. TKN is also included to support the modeling of DO and BOD. These pollutants have been the primary focus of federal water pollution control policies under the Clean Water Act and have the following advantages for modeling purposes:

- They can be characterized by first-order kinetics.
- Data is widely available to estimate point and nonpoint source loadings of these constituents.
- Existing surface water quality indices are based, at least in part, on these parameters.

For this analysis, NWPCAM 1.1 was further modified to also model total nitrogen and total phosphorous. However, only the four conventional pollutants were employed in use support determinations.

2.4 POLLUTANT PARAMETERS MODELED USING NWPCAM 1.1

2.4.1 Dissolved Oxygen (DO)

Levels of DO in surface water are commonly used as an indicator of aquatic health. High levels of oxygen are characteristic of good water quality that can support a high-quality fishery and diverse aquatic biota. Conversely, low or depleted oxygen concentrations indicate poor water quality and an inability to support a diverse population of aquatic biota. DO is added to water through photosynthesis and aeration from turbulent mixing, and is removed through respiration and sediment oxygen demand.

In NWPCAM 1.1, oxygen production from photosynthesis (P) and consumption from respiration (R) were assumed to balance (i.e., P = R or P – R = 0). Increases in DO concentration due to atmospheric reaeration were accounted for by water temperature, velocity, and depth of the river channel. The additional atmospheric oxygen that can be contributed to a free-flowing stream falling over a dam or waterfall was not represented.

2.4.2 Biochemical Oxygen Demand (BOD)

Biodegradable organic materials, such as plant, fish, or animal matter, consume DO during decomposition. The level of organics in wastewater and natural water bodies has historically been assessed using BOD, which measures the pollutants' potential to remove oxygen from the receiving waters. BOD is a primary determinant of DO concentrations in surface water.

Both the carbonaceous and nitrogenous components of the ultimate BOD (CBODU and NBODU, respectively) are needed to model DO. The decomposition of organic carbon was represented by the decay of CBODU as an oxygen equivalent measure of the amount of organic carbon. The labile/refractory and dissolved/particulate fractions of total organic carbon were not differentiated. Eutrophication was not considered in this model, so the contributions of algal respiration, algal mortality, and zooplankton grazing to organic carbon concentrations were also not represented.

Loadings of CBODU occur from both point (e.g., municipal and industrial dischargers) and nonpoint sources (e.g., urban runoff). Since effluent loading data for these sources are typically characterized as the 5-day BOD or CBOD (BOD5 and CBOD5, respectively), conversion factors were used to obtain CBODU for input to the model. BOD5 data obtained from literature was assumed to represent CBOD5 because of uncertainty related to the interpretation of BOD5 measurements (Hall and Foxen, 1984). The magnitude of the conversion factors for municipal dischargers depend on treatment level as the relative proportion of easily degraded materials in the effluent declines as the efficiency of waste treatment improves (Leo et al., 1984; Thomann and Mueller, 1987).

The sequential nitrogen-cycle processes of hydrolysis of organic nitrogen to ammonia, oxidation of ammonia to nitrite, and oxidation of nitrite to nitrate (nitrification) were simplified by combining these steps into a single NBOD representation. Because organic nitrogen in wastewater can be hydrolyzed to ammonia and thus contribute to the eventual oxygen demand in a receiving water, the total NBOD is determined as the oxygen equivalent of the sum of organic nitrogen and ammonia (see Equation 1). Total Kjeldahl nitrogen (TKN) represents the sum of organic nitrogen and ammonia.

$$NBOD = \frac{O_2}{N} * TKN \qquad (1)$$

where:

O_2/N = stoichiometric equivalent of 4.57 g oxygen per 1 g nitrogen consumed in the stepwise nitrification process of ammonia to nitrate, and

TKN = total Kjeldahl nitrogen.

Although the use of a lumped NBOD approach to account for the oxygen consumption component of the nitrogen cycle has known shortcomings in representing the lag time needed to initiate nitrification (Chapra, 1997), the approach adopted is consistent with other components of the simplified model framework.

2.4.3 Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl nitrogen (TKN) is the sum of organic nitrogen and ammonia. It is the key pollutant in modeling DO. Sources of TKN include municipal and industrial discharges, combined sewer overflows, and urban and rural runoff. It is routinely measured in water and wastewater monitoring programs. Under aerobic conditions, nitrification occurs as described in Section 2.1.2 and results in DO consumption. Under anaerobic conditions, the reverse process (denitrification) occurs. During denitrification, nitrate is reduced to nitrite, nitrate is converted to free nitrogen, and the free nitrogen is either assimilated by nitrogen-fixing, blue-green algae, or released to the atmosphere as a gas.

In the absence of a national database to characterize benthic regeneration rates for ammonia, a stoichiometric weight ratio for oxygen to nitrogen of 15.1:1 (Redfield, Ketchum, and Richards, 1963) was used to define the equivalent amount of ammonia nitrogen released by decomposition of organic carbon in the sediment bed. The benthic release of ammonia to the water column was estimated from the reach-dependent parameter values assigned for sediment oxygen demand (Di Toro, 1986; Di Toro et al., 1990).

2.4.4 Total Suspended Solids (TSS)

Total suspended solids (TSS) are used as a surrogate indicator of water transparency to characterize recreational service flows provided by a water body. Low TSS concentrations are associated with a high degree of water clarity. High concentrations of TSS are generally associated with murky or turbid waters and are therefore important contributors to perceptions of poor water quality. The assessment of economic benefits is, in part, dependent on changes in water transparency (as assessed by TSS) and corresponding improvements that result from implementing controls to reduce TSS loadings.

In NWPCAM 1.1, no distinction is made between the relative fractions of cohesive (clays and silts) and noncohesive (sands) particle sizes that contribute to deposition processes from the water column or the sediment bed concentration of solids that contributes to the resuspension of solids back into the water column. A simple net settling velocity was used to parameterize the interactions of particle size distributions with deposition and resuspension.

2.4.5 Fecal Coliform Bacteria (FCB)

In accordance with the practices of the EPA and other public health officials, the NWPCAM 1.1 model uses FCB as a surrogate indicator for waterborne pathogens that are known to cause a variety of human illnesses. Low densities of FCB are characteristic of good water quality and low risk of waterborne diseases. High concentrations of FCB indicate poor water quality and a high risk of waterborne diseases. Using typical water quality standards for primary contact recreation (swimming) and secondary contact recreation (boating), the concentration of FCB is directly related to service flows and economic benefits. The assessment of economic benefits, in part, depends on changes in FCB concentrations and improvements in service flows that may result from implementing controls to reduce FCB loadings.

FCB are introduced into natural waters by municipal and industrial wastewater discharges, combined sewer overflows, and urban and rural runoff. Animal feedlots in rural areas also contribute high loading rates of bacteria. High loading rates are most commonly associated with untreated or poorly treated human sewage or animal waste. Bacteria are lost from the water column by mortality, adsorption to particles, and settling. The mortality of coliform bacteria can be functionally related to salt content, water temperature, and incident solar radiation (Mancini, 1978). In shallow waters, bacteria can be reintroduced back into the water column by resuspension of particles under high flow conditions. In NWPCAM 1.1, the components of the mortality and net settling loss rate for FCB were parameterized by a lumped temperature-dependent net loss rate.

2.4.6 Nutrients (Total Nitrogen and Total Phosphorous)

Total nitrogen (TN) and total phosphorous (TP) are present in wastewater, surface runoff, rainwater, groundwater, and surface waters. They exist in organic and inorganic forms and in both dissolved and particulate fractions.

Elevated nutrient concentrations can affect a number of different water quality processes and endpoints. Perhaps the most direct impact of nutrient loading is the toxicity of ammonia and nitrate to aquatic and human populations. Ammonia, particularly the un-ionized form (NH3), is highly toxic to aquatic organisms. Nitrates are considered a potential health concern for humans, particularly for infants.

Excessive enrichment with phosphorous and/or nitrogen is also associated with the process of cultural eutrophication, the anthropogenically induced acceleration of natural aging in aquatic systems. Symptoms include shifts in ecological processes (e.g., carbon, nitrogen, phosphorus, and oxygen cycling rates and dynamics) and plant and animal species. In the extreme state of "hypereutrophy," a system may suffer extensive DO depletion, wide diurnal shifts in oxygen corresponding with photosynthesis and respiration cycles, extreme bloom events, noxious and undesirable algal species, fish kills, foul odors, and turbidity.

Total nitrogen and total phosphorous were modeled using first order kinetics. Decay coefficients were obtained from the SPAtially Referenced Regressions On Watershed (SPARROW) study (Smith, Schwarz, and Alexander, 1997).

As mentioned above, nutrient concentrations were not considered in use support determinations. However, the development of regional nutrient criteria makes this a possibility for the future.

2.5 WATER QUALITY MODELING

NWPCAM 1.1 has the capability to model water quality in a stream reach after inclusion of all source loadings. A change of loadings from one source is realistically considered in comparison with the total loadings to a stream reach. NWPCAM 1.1 contains information on approximately 8,000 municipal facilities and 23,000 industrial facilities. It can be run on any scale, ranging from a basin to the entire United States.

Municipal and industrial select tables contain all loading information. Each discharger is associated with identification information (name and NPDES number), receiving water (as identified by CU, segment number, and distance along the stream reach), loading data (flow rate and concentrations), and a sequence number to identify the order in which stream reaches are modeled. The municipal and industrial select tables are generated each time the study area is selected. After the model is run, each stream reach is associated with steady-state flow rate and concentration information.

2.6 WATER USE SUPPORT DETERMINATIONS

In order to quantify the economic benefits associated with improved water quality, a modified Vaughn water quality ladder is used to associate water quality and designated uses (Vaughn, unpublished). NWPCAM 1.1 compares the concentrations of BOD5, TSS, FCB, and percent DO saturation (DO_{PCT}) to benchmark values associated with swimming, fishing, and boating uses (see Table 2-2). Swimming is associated with the most stringent water quality criteria, and boating is associated with the least stringent water quality criteria. For BOD5, TSS, and FCB, the in-stream concentration must be below the benchmark value to attain a given use. For DO_{PCT}, the in-stream value must be greater than the benchmark value to meet the criterion for that use. If even one parameter does not meet its benchmark value, the stream is not considered to support that use. If the stream reach does not attain any of the three uses, it is designated as "not supporting."

Table 2-2: Water Quality Criteria Threshold By Use

USE Supported	Water Quality Index (WQI) Criteria	BOD_5	TSS	DO_{pct}	FCB
Swimming	99	1.5	10	83	200
Fishing	94.4	3	50	64	1000
Boating	79	4	100	45	2000

Note:
BOD_5 = 5 day Biochemical Oxygen Demand (mg/L)
TSS = Total Suspended Solids (mg/L)
DO_{pct} = percent of DO Saturation
FCB = Fecal Coliform Bacteria(MPN/100ml)

This approach is somewhat problematic since water quality improvements are considered to not occur unless movements result in migrating from one use category to another, e.g., fishing to swimming. The implication of this is that the baseline condition for a given stream reach must be just below the break point between categories so an improvement will result in the water quality conditions moving beyond the breakpoint. Furthermore, this also implies that no within use category movements have any value associated with them..

As an alternative to the stepwise ladder approach, EPA evaluated all water quality changes. To accomplish this a continuous Water Quality Index (WQI) was constructed. The WQI combines information from four water quality measures rather than using only the limiting lowest quality criterion to define use category. For this benefit valuation, NWPCAM compiled a WQI from turbidity, BOD, fecal coliforms, and dissolved oxygen indexes based on work by McClelland (1974). Since the baseline distribution of use categories is well understood and generally accepted, it is desirable for the distribution based on WQI to match the existing distribution of use categories in the baseline. EPA derived WQI values to represent the breakpoints on the water quality ladder based on empirical observation of the WQI distribution among use categories in the baseline data. EPA calculated the mean and standard deviation of WQIs for the reaches in each use category in the baseline population of reaches. If reaches are normally distributed within each use category, 84 percent of observed WQI for each category should be less than the mean WQI plus one standard deviation (SD). The Mean + SD value serves as the criterion for the boundary with the next higher use category. Table 2-3 shows the calculation and the resulting criteria.

Table 2-3: Empirical Calculation of Criteria from the Baseline Scenario

Use Category	Mean (WQI)	Standard Deviation (WQI)	Criterion (Mean + SD) (WQI)
No Use, 0	54.1	24.8	79.0
Boatable, 1	84.9	9.5	94.4
Fishable, 2	92.5	6.5	99.0
Swimmable, 3	98.5	2.3	

Source: EPA analysis of Baseline Access database, 10/2/2001

2.7 FACILITY EFFLUENT DATA INPUTS FOR NWPCAM

Effluent data extracted from the MPP Detalied Surveys were entered into NWPCAM model for the 97 meat-processing facilities evaluated for the benefit analysis. As described below, some adjustments were required, because not all facilities collected data for all parameters evaluated in the environmental assessment.

Each facility's effluent was characterized by flow rate and the six water quality parameters discussed in section 2.0 (BOD5, TSS, FCB, TN, TKN, and TP). The current effluent quality at each facility was defined at the "baseline average concentration" (BAC). Direct discharge facilities were also associated with a maximum of three alternative effluent qualities that would result upon implementation of a Best Available Technology (BAT) control. Indirect discharge facilities were associated with one alternative effluent quality that would result upon implementation of the Pretreatment Standard for Existing Sources (PSES).

The facility effluent data were modified prior to use in NWPCAM. The type of discharger (i.e., direct or indirect) was changed for four industrial facilities based on the NWPCAM model. Of the 97 total facilities, 36 were direct dischargers and 61 were indirect dischargers. When facilities lacked data for one or more control options, the effluent quality was assumed to be identical to the baseline average concentration. The original data contained some instances of TKN concentrations that were larger than corresponding TN concentrations. In these instances, TN was set equal to TKN. The modified data was reformatted and inserted into NWPCAM as two tables (TTMunSelect and TTIndSelect).

2.8 MODEL RUNS

EPA performed nine model runs to estimate baseline conditions and water quality changes for various combinations of regulatory controls. They correspond to the following scenarios shown in Table 2-4.

BAT options were applied to direct dischargers and PSES options were applied to indirect dischargers. It should be emphasized that differences between baseline loadings and technology treatment options were calculated prior to input into NWPCAM. As described in detail in the MPP Technical Development Document, facility loadings under alternative technology options were derived based on technology performance of model facilities for each MPP industry subcategory. The NWPCAM model used these estimates to model water quality changes in affected receiving water bodies on a facility-by-facility basis.

Table 2-4: Benefits Scenarios Modeled

Model Run	Regulatory Options[1]
1	Scenario 0: Baseline
2	Scenario 1: BAT2
3	Scenario 2: BAT3
4	Scenario 3: BAT4
5	Scenario 4: BAT2 + PSES1
6	Scenario 5: BAT3 + PSES1
7	Scenario 6: BAT4 + PSES1
8	Scenario 7: BAT3 (meat, poultry), BAT2 (Rendering)
9	Scenario 8: BAT3 (meat, poultry), BAT2 (Rendering) + PSES1

[1]

BAT:	Best Available Treatment (for Direct Discharges)
BAT2:	Dissolved Air Flotation (DAF) (advanced oil/water separation), Lagoon, and Disinfection (Oil and Grease, BOD_5, TSS, Pathogen removal) + Nitrification (NH_3 removal)
BAT3:	BAT2 + Denitrification (Nitrate removal)
BAT4:	BAT3 + Phosphorus removal
PSES	Pretreatment Standards for Existing Sources (for Indirect Dischargers)
PSES1:	Dissolved Air Flotation (DAF) , Equalization (Oil and Grease, TSS removal)

2.9 CREATING MUNICIPAL AND INDUSTRIAL SELECT TABLES

To perform the nine model runs, one municipal select and nine industrial select tables were needed. The original NWPCAM model was run over the entire United States to generate one municipal and one industrial select table containing information on the facilities originally contained in NWPCAM. Nine copies were made of the industrial select table to correspond with baseline and Model Runs 2-9. Records for 151 facilities (36 direct industrial dischargers, 61 indirect industrial dischargers, and 59 municipalities) were inserted or updated using the facility specific data generated from the MPP Survey and other compliance reports. The specific approach to update the loadings data was dependent on the facility type (i.e., direct industrial discharger, indirect industrial discharger, municipal discharger). However, in each case a module was used to automatically update the appropriate table. Appendix A contains the code used in the modules.

2.10 DIRECT INDUSTRIAL DISCHARGERS

Data for the 36 direct discharge facilities were inserted in the industrial select tables without any modification.

2.11 INDIRECT INDUSTRIAL DISCHARGERS

The original version of NWPCAM did not include records for indirect dischargers, because their loadings were captured through the corresponding municipality. For this analysis, flow rates from the meat-processing facilities and municipalities were separated. This approach permitted adjustment of the loadings from the meat processing facilities without affecting the municipalities. New records were inserted into the industrial select tables for each indirect discharger. Pollutant concentration data were then multiplied by a factor to account for the treatment received prior to discharge (see Table 2-5). The fractions estimate the proportion of pollutant retained based on level of municipal treatment. The module linked the indirect discharger to its municipality through the NPDES number. The treatment level of the municipality was used to determine the appropriate multiplication factors for updating the industrial select tables.

Table 2-5: Fraction of Pollutant Retained as a Function of Treatment Level

Treatment Type	Level	Fraction Retained					
		BOD_5	TSS	FCB	TKN	TN	TP
Primary	2	0.70	0.50	0.65	0.78	0.78	0.87
Advanced Primary	3	0.50	0.30	0.65	0.78	0.78	0.87
Secondary	4	0.08	0.08	0.005	0.55	0.61	0.42
Advanced Treatment I	5	0.03	0.03	0.005	0.43	0.61	0.06
Advanced Treatment II	6	0.02	0.02	0.0000032	0.12	0.48	0.06
Default	9	0.08	0.08	0.005	0.55	0.61	0.42

Notes: BOD_5 = Five-day biochemical oxygen demand
TSS = Total suspended solids
FCB = Fecal coliform bacteria
TKN = Total Kjeldahl nitrogen
TN = Total nitrogen
TP = Total phosphorous

2.12 POTWs

Mass and flow balances were developed to calculate new effluent information for the municipal facilities (see Equations 2 and 3). Appendix B contains full details on how the equations were developed.

$$Q_{mun,new} = Q_{mun,old} - Q_{meat} \tag{2}$$

$$C_{mun,new} = \frac{1}{Q_{mun,new}}\left[Q_{mun,old} C_{mun,old} - Q_{meat} C_{meat} f_{retained}\right] \tag{3}$$

where

Qmun,new = updated municipal flow rate (MGD)
Qmun,old = original municipal flow rate (MGD)
Qmeat = flow rate from the meat-processing facility (MGD)

Cmun,new = updated municipal concentration (mg/L)
Cmun,old = original municipal concentration (mg/L)
Cmeat = concentration in the meat-processing facility's effluent (mg/L)
fretained = fraction of pollutant retained after treatment.

Two municipalities received flow from multiple meat-processing facilities. For this situation, equations were developed to calculate total flow and average concentrations to use for Qmeat and Cmeat in Equations 2 and 3 (see Equations 4 and 5).

$$Q_{meat} = Q_{meat,1} + Q_{meat,2} \tag{4}$$

$$C_{meat} = \frac{C_{meat,1} Q_{meat,1} + C_{meat,2} Q_{meat,2}}{Q_{meat,1} + Q_{meat,2}} \tag{5}$$

where

Qmeat = total flow rate from all meat-processing facilities (MGD)
Qmeat,1 = flow rate from meat-processing facility 1 (MGD)

Qmeat,2 = flow rate from meat-processing facility 2 (MGD)

Cmeat = average concentration in effluent from all meat-processing facilities (mg/L)
Cmeat,1 = concentration in effluent from meat-processing facility 1 (mg/L)
Cmeat,2 = concentration in effluent from meat-processing facility 2 (mg/L).

There were nine meat-processing facilities that had a flow equal to or larger than their corresponding municipalities. For these treatment plants, the flow rate was divided in half and the original concentration values were retained.

Analysis using these equations revealed that there were 15 wastewater treatment plants that had negative concentrations for one or more parameters. This occurred when the meat facilities comprised a large fraction of the total municipal flow and/or when the meat facility effluent concentration was much larger than the municipal concentration. Negative concentrations were replaced by default concentration values based on treatment level (see Table 2-6).

Table 2-6: Default Effluent Characteristics by Treatment Level

Treatment Type	Level	Effluent Characteristics					
		BOD_5	TSS	FCB	TKN	TN	TP
Primary	2	143.5	107.5	2.06E+06	23.4	23.4	5.2
Advanced Primary	3	102.5	64.5	2.06E+06	23.4	23.4	5.2
Secondary	4	16.4	17.2	1.58E+03	16.5	18.3	2.5
Advanced Treatment I	5	6.2	6.5	1.58E+03	12.9	18.4	0.4
Advanced Treatment II	6	4.1	4.3	1.00E+01	3.6	14.4	0.4
Default	9	16.4	17.2	1.58E+03	16.5	18.3	2.5

Notes: BOD_5 = Five-day biochemical oxygen demand (mg/L)
TSS = Total suspended solids (mg/L)
FCB = Fecal coliform bacteria (MPN/100 mL)
TKN = Total Kjeldahl nitrogen (mg/L)
TN = Total nitrogen (mg/L)
TP = Total phosphorous (mg/L)