DESIGN GUIDELINES
FOR
WASTEWATER FACILITIES

MARYLAND DEPARTMENT OF THE ENVIRONMENT
ENGINEERING AND CAPITAL PROJECTS PROGRAM

2021

Purpose:

- *Recommended Standards for Wastewater Facilities* for Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (10-State Standards) will continue to be the main source of guidance for the program's design review and construction permit functions.

- These guidelines are intended to serve as addenda to supplement the 10-State Standards.

- The 10-State Standards (as revised) and these guidelines supersede all other design guidelines for wastewater (sewerage facilities) previously issued by MDE.

- At the appearance of conflicting information, these guidelines supersede the 10-State Standards as they intended to provide further clarifications specific to MDE.

- Additional requirements beyond these guidelines and the 10-State Standards can be added by the facility's discharge permit and/or consent order or decree issued by MDE.

- If a local jurisdiction has more stringent requirements for any specific item, the more stringent requirements must be used for that item.

ADDENDUM TO CHAPTER 10
ENGINEERING REPORTS AND FACILITY PLANS

HYDRAULIC CAPACITY

Terminology and Typical Use:

Term	Description	Typical Design Use
Average Daily Flow (Current or Initial)	For existing facility, it's the current average daily flow based on the last three years data. This is done by averaging the daily flow for each year, then averaging the three years. For a proposed facility, it's the project initial flow.	To evaluate and address low flow conditions (minimum flows)
Design Average Flow (Design Capacity)	Average daily flow a facility is designed to successfully process	To develop maximum flowrates and peaking factors to be used for the design of equipment and unit processes.
Approved/Permitted Design Capacity	A treatment plant design flow approved by the County Water and Sewer Plans and permitted by the discharge permit with certain limits and conditions. It must be greater than or equal to a proposed design flow.	The maximum flow that can be evaluated to become the facility's new design capacity.
Diurnal Flow Pattern	The typical daily flow pattern for domestic wastewater with usually peaks occurring in the morning and evening.	Important in developing process control strategies for managing high flows.
Peak Hourly Flow	The largest volume of flow occurring within 1-hour period in the record examined.	Sizing of pumping facilities and conduits, sizing physical treatment units (ie grit chambers, screens, sedimentation tanks, filter hydraulic capacity). Sizing chlorine or other disinfection contact tanks. Also important in developing process control strategies for managing high flows.
Maximum or Peak Daily Flow	The largest volume of flow occurring within a 1-day period in the record examined.	Sizing of equalization tanks Sizing of sludge pumping system Sizing of chemical feed system
Maximum Monthly Flow	The average daily flows for the month with the highest total flow in the record examined.	Sizing of the bioreactor Sizing of the chemical storage tank Sizing of denitrification filter

Peaking Factor:

The peaking factor is used to forecast the maximum/peaking flows for the new proposed design capacity. The above average and maximum/peak flows are highly impacted by inflow/infiltration (I/I) and wet weather events. Therefore, the preferred method of estimating these values is by using actual data, which can account for any excessive I/I in the system and yield higher peaking factors than those of a typical system. When available, a record of three or more consecutive calendar years should be examined at an existing facility. Peaking factors should be calculated independently for each full consecutive calendar year examined, and then the highest of each type (hourly, daily, monthly) is selected.

$$\text{Peaking Factor (PF)} = \frac{\text{peak flow for the calendar year (hourly, daily, monthly)}}{\text{average daily flow for the calendar year}}$$

The following typical peaking factors (PF) should be used if there is not sufficient historical data available:

Design Capacity Range	Hourly PF	Daily PF	Monthly PF
0 to 0.25 MGD	4	3	2
0.25 to 16 MGD	$\frac{3.2 \times \text{Design Capacity}^{5/6}}{\text{Design Capacity}}$	75% of Hourly PF	50% of Hourly PF, but not below 1.2
More than 16 MGD	2	1.5	1.2

Peak Flow = PF calculated above X Proposed Design Capacity

Proposed Design Capacity:

Proposed Design Capacity = Current Average Daily Flow (0 for new facilities) + Projected Future Flow

Projected Future Flow:

Future flows are projected based on 100 gallons per day per person, or 250 gallons per day per Equivalent Dwelling Unit (EDU). In addition, the following are the flow projections for different establishments:

Table I - Flow Projection Based Upon Gallons Per Person Per Day

Airports (per passenger)	5
Apartments-multiple family (per resident)	60
Bathhouses and swimming pools	10
Camps:	
Campground with central comfort stations	35
With flush toilets, no showers	25
Day camps (no meals served)	15
Resort camps (night and day) with limited plumbing	50
Luxury camps	100
Cottages and small dwellings with seasonal occupancy	50
Country clubs (per resident member)	100
Country clubs (per non-resident member present)	25
Dwellings:	
Boarding houses	50
additional for non-resident boarders	10
Luxury residences and estates	150
Multiple family dwellings (apartments)	60
Rooming houses	40
Single family dwellings	75-100
Factories (gallons per person, per shift, exclusive of industrial wastes)	35
Hospitals (per bed space)	350
Hotels with private baths (2 persons per room)	60
Hotels without private baths	50
Institutions other than hospitals (per bed space)	125
Laundries, self-service (gallons per wash, i.e., per customer)	50
Mobile home parks (per space)	250
Motels with bath, toilet and kitchen wastes (per bed space)	50
Motels (per bed space)	40
Picnic Parks (toilet wastes only) (per picnicker)	5
Picnic Parks with bathhouses, showers and flush toilets	10
Restaurants (per seat)	25
Restaurants (toilet and kitchen wastes per patron)	10
Restaurants (kitchen wastes per meal served)	3
Restaurants, additional for bars and cocktail lounges	2
Schools:	
Boarding	100
Day, without gyms, cafeterias or showers	15
Day, with gyms, cafeterias and showers	25
Day, with cafeterias, but without gyms or showers	20
Service Stations (per vehicle served)	10

Swimming pools and bathhouses	10
Theaters:	
Movie (per auditorium seat)	1
Drive-in (per car space)	5
Travel Trailer Parks without individual water and sewer hook-ups (per space)	50
Travel Trailer Parks with individual water and sewer hook-ups (per space)	100
Workers:	
Construction (at semi-permanent camps)	50
Day, at schools and offices (per shift)	15

An alternative method used to project average daily flows generated from commercial establishments, public service buildings, or dwelling units can be figured on the basis of total floor area, number of building units, or service seats multiplied by a statistical factor. Guiding factors are given in Table II.

Table II - Guiding Factors for Flow Projection Related with Commercial Establishments, Public Service Buildings, or Dwelling Units

Office Buildings	Gross Sq. Ft. x 0.09 = gpd
Medical Office Buildings	Gross Sq. Ft. x 0.62 = gpd
Warehouses	Gross Sq. Ft. x 0.03 = gpd
Retail Stores	Gross Sq. Ft. x 0.05 = gpd
Supermarkets	Gross Sq. Ft. x 0.20 = gpd
Drug Stores	Gross Sq. Ft. x 0.13 = gpd
Beauty Salons	Gross Sq. Ft. x 0.35 = gpd
Barber Shops	Gross Sq. Ft. x 0.20 = gpd
Department Store with Lunch Counter	Gross Sq. Ft. x 0.08 = gpd
Department Store without Lunch Counter	Gross Sq. Ft. x 0.04 = gpd
Banks	Gross Sq. Ft. x 0.04 = gpd
Service Stations	Gross Sq. Ft. x 0.18 = gpd
Laundries & Cleaners	Gross Sq. Ft. x 0.31 = gpd
Laundromats	Gross Sq. Ft. x 3.68 = gpd
Car Wash without Wastewater Recirculation Equipment.	Gross Sq. Ft. x 4.90 = gpd
Hotels	Gross Sq. Ft. x 0.25 = gpd
Motels	Gross Sq. Ft. x 0.23 = gpd
Dry Goods Stores	Gross Sq. Ft. x 0.05 = gpd
Shopping Centers	Gross Sq. Ft. x 0.18 = gpd

Flow projection for country clubs or public parks may be made on the basis of plumbing fixtures. The related statistical flow figures per unit of plumbing fixture are shown in Table III and Table IV.

Table III - Flow Projection for Country Clubs

	Gallons Per Day Per Fixture
Showers	500
Baths	300
Lavatories	100
Toilets	150
Urinals	100
Sinks	50

Table IV - Flow Projection for Public Parks
(During hours when park is open)

	Gallons Per Day Per Fixture
Flush toilets	35
Urinals	10
Showers	100
Faucets	15

ORGANIC CAPACITY
(For Wastewater Treatment Plant)

For existing facilities, 3-year data, if available should be evaluated, and average concentration is calculated in the treatment plant influent, primary effluent, and secondary effluent. For new wastewater treatment plant typical values are used or values from equivalent existing facility of similar capacity.

Average Organic/Mass Loading (Lbs/Day)
= Design Capacity (MGD) X Average Concentration (mg/l) X 8.34 (Conversion Factor)

Sustained Mass Loading (Lbs/Day)
= Average Mass Loading X PF (hourly, daily, monthly depending on the unit process being sized)

Computer Simulations:

Computer simulations have become more common in recent years, especially in the design of Biological and Enhanced Nutrient Removal processes. Simulators use mathematical models to allow designers to study kinetic as well as time-based solutions while determining the total mass balances of many constituents. Simulation results must be interpreted carefully given the potential limitations inherent in the calibration and validation of the computer model.

ADDENDA TO CHAPTER 30
DESIGN OF SEWERS

38.21 Minimum Distance from Water Supply Wells and other Water Supply Sources or Structures *(New Added Paragraph)*

To be consistent with COMAR 26.04.04.05, the proposed sewer line shall satisfy the following minimum horizontal distance from a water supply well and other water supply sources or structures:

(1) 100 feet from well utilizing unconfined aquifer, and surface water supply with "P" designation.

(2) 50 feet from well utilizing confined aquifer, or covered reservoir.

When it is impossible to obtain proper distance as stipulated above, the minimum horizontal separation can be reduced to 10 feet if one of the methods in Paragraph 38.4 (added below) is used, and the selected provision is extended 100 feet on both sides of an unconfined aquifer well or surface water supply with "P" designation (stream embankment may also be required), and 50 feet on both sides of a confined aquifer well or covered reservoir.

38.31 Horizontal and Vertical Separation *(Added to the Existing Paragraph)*

In addition to the above, one of the other methods in Paragraph 38.4 can be used if it is impossible to obtain the proper horizontal and vertical separation between the water and sewer lines.

38.32 Crossings *(Added to the Existing Paragraph)*

In addition to the above, one of the other methods in Paragraph 38.4 can be used if it is impossible to obtain the proper horizontal and vertical separation between the water and sewer lines. The selected provision shall be extended 10 feet on both sides of the crossing, measured perpendicular to the water main.

38.4 Methods to Address Minimum Separation Issues *(New Added Paragraph)*

When it is impossible to obtain proper horizontal and/or vertical separation as stipulated in the added 38.21 Paragraph above, and Paragraphs 38.31, and/or 38.32 of the 10-State Standards, one of the following methods can be used:

a. The sewer shall be designed and constructed equal to water pipe, of slip-on or mechanical joint pipe complying with Section 8.1 and Section 8.7 of the *Recommended Standards for Water Works*, and shall be pressure rated to at least 150 psi (1034 kPa) and pressure tested to ensure watertightness.

b. The sewer can be continuous, fused, or welded as long as it is equal to water pipe as described above.

c. Either the water main or the sewer line may be encased in concrete or other watertight carrier pipe as approved by MDE.

ADDENDUM TO CHAPTER 40
WASTEWATER PUMPING STATION

EMERGENCY OPERATION

Additional Measures for Facilities Located within Certain Critical Water Uses:

Per Paragraph 47.3 of Chapter 40 of the Recommended 10-State Standards (under Emergency Operation), the Maryland Department of Environment (MDE) hereby establishes the following supplemental design guidelines for wastewater pumping stations that can have a potential overflow that may affect public water supplies and other critical water uses identified by MDE. These supplemental guidelines apply to any existing station where pumping capacity is being increased to accommodate increased flows due to growth, and for proposed new pumping stations (not for the purpose of functional replacement); AND fall under at least one of the following categories:

1. Existing or new within 3 miles of a shellfish water

2. Existing or new within 3 miles of a bathing beach water

3. Existing or new within 3 miles of public water supply (“P” designation surface water)

4. Existing pumping stations within 3 miles of bacteria impaired water and has one or more overflow event(s) over the past 3 years that is/are attributable to a power outage, mechanical failure or human error

A. Case I

The wastewater pumping station is missing one of the four essential items: a telemetering alarm system, a standby pump unit, a stationary auxiliary power source, or a pump-around connection.

- MDE may allow a 24-hour emergency wastewater storage capacity as a substitute for the missing essential item.

B. Case II

The wastewater pumping station provides all four essential items:

1. A telemetering alarm system
2. A standby pump unit (internal)
3. A stationary auxiliary power source connected to a separate power feed substation or stationary generator
4. A pump-around connection coupling facility

AND

(a) For Pumping Capacity (Q_p) ≤ 150 gallons per minute (gpm), or serving Equivalent Dwelling Units (EDU) ≤ 200, no additional measure is required.

(b) For Pumping Capacity (Q_p) > 150 gallons per minute (gpm), or serving Equivalent Dwelling Units (EDU) > 200, one of the following items must be provided in addition to the four essential items listed above:

Option 1: A third power source must be provided by a separate feed line to a new power substation, by providing a new stationary generator, or by a stationary independently-powered pumping unit(s) with adequate capacity to maintain proper operation.

Option 2: An additional 2-hour wastewater storage capacity shall be provided for emergency need, based on the newly projected design average daily flow.

Emergency Wastewater Storage:

For existing wastewater pumping station, MDE may approve a wastewater emergency storage capacity with a detention time less than 2 hours, provided that all of the following circumstances are substantive and evidenced:

(1) Options 1 and 2 above are also not feasible;

(2) There is no physical means to provide the required storage capacity due to site restriction at the premise of the pumping station;

(3) The pumping station has had excellent operation records without Overflow of wastewaters at the premise of the station in the past five years; and

(4) An emergency plan ensuring that the maximum response time will be less than one hour to remedy the malfunction of the pumping station.

Emergency wastewater storage capacity defined as detention time is determined by the following:

Total Wastewater Storage Time + Wastewater Traveling Time = 2 Hours

(1) The traveling time of land overflow wastewaters will be calculated at 1 foot per second (fps).

(2) In water, the traveling time overflow wastewater will be calculated at 2 feet per seconds (fps).

(3) The wastewater storage time will be calculated by dividing the total storage capacity with the design average daily flow (Q_a).

Where, Q_a = design average daily flow, in gpm
Q_p = pumping capacity, in gpm

If Q_p = 0 to 694 gpm ➔ $Q_a = 0.25 \text{ X } Q_p$
If Q_p = 695 to 22,384 gpm ➔ $Q_a = 0.0668 \text{ X } Q_p^{1.2}$
If Q_p > 22,384 gpm ➔ $Q_a = 0.5 \text{ X } Q_p$

(4) The total storage capacity includes:

1. the available excess storage in the wet well above the elevation of high water alarm to the elevation where the first sewer service connection is made or the sewer system's lowest ground elevation, and

2. the storage basin provided.

AMENDMENT TO CHAPTER 40
WASTEWATER PUMPING STATION

49.61 Friction Coefficient *(Amended Paragraph)*

Friction losses through force mains shall be based on the Hazen-Williams formula or other acceptable methods. When the Hazen-Williams formula is used, the value for "C" shall be 100 for unlined iron or steel pipe for design. For other smooth pipe materials such as PVC, polyethylene, lined ductile iron, etc., a higher "C" value may be allowed for design. Frictional loses should be evaluated over the life of the pipe.

ADDENDUM TO CHAPTER 50
WASTEWATER TREATMENT FACILITIES

ESSENTIAL FACILITIES

Special Requirements for Facilities Discharge to Shellfish Harvesting Waters:

Per COMAR 26.08.04.04.C (2) (c), these facilities shall incorporate a bypass control system, including a minimum 24-hour emergency holding facility,

- The facility shall provide for biocide residual control.
- The 24-hour emergency holding facility must be sized based on the design average flow of the plant.
- Retention or holding time of other unit processes used for other purposes cannot be counted toward this 24-hour emergency storage.
- Section 93.4 shall be used for pond construction details.
- Minimum freeboard shall be 3 feet. For small ponds of 5 acres or less, 2 feet may be acceptable.

ADDED CHAPTER 120
SUPPLEMENTAL DESIGN GUIDELINES FOR DRIP DISPERSAL OF TREATED WASTEWATER

Scope:

Drip dispersal is a method used to discharge treated wastewater by distributing it over an area of land at root zone depth for final polishing, reuse, and/or recharge of groundwater. The proposed drip dispersal system shall be capable of uniformly distributing the wastewater effluent over the required area of application.

Applicability:

These guidelines are applicable to the design of wastewater systems that receive discharge permits from the Maryland Department of the Environment (Department) and that employ drip dispersal discharge systems.

The Department's discharge permit must be issued and its limitations set before a construction permit can be reviewed and issued.

As for any construction permitted facility, the drip dispersal system design plans submitted to the Department for construction permit shall be signed and sealed by a Professional Engineer licensed by the State of Maryland. The system design engineer shall follow these guidelines and incorporate necessary manufacturing product specifications into the design document to ensure satisfactory performance of the drip dispersal system.

Pre-Treatment:

Wastewater effluent dispersed through this method must be treated to meet the water quality standards within the issued discharge permit limitations. The treatment process will be reviewed and approved for construction in accordance with the Department's Design Guidelines and the Recommended 10-State Standards.

Nitrogen removal capability by the vegetation planted at a drip irrigation field or other means is determined by the discharge permitting process and is accounted for in the set discharge permit limitations. The vegetation planted on the drip dispersal field shall provide a comparable nitrogen uptake rate as used in the Nitrogen Balance Calculation for achieving a zero nitrogen percolate concentration during the growing season.

Wastewater Effluent Dosing and Equalization Tank:

The treated wastewater effluent shall be discharged to the drip disposal system through a dosing tank that has sufficient volume to provide flow equalization. Storage requirements within the treatment and dispersal system shall be at least one full day-storage located between the treatment and dispersal systems.

The Wastewater Effluent Dosing and Equalization Tank will be reviewed and approved for construction in accordance with the Department's Design Guidelines and the Recommended 10-State Standards.

Drip System Dosing Pump and Filter:

The system is to be designed with the pumps, filters, and dispersal area to accommodate the following conditions:

1. Filter flushing
2. Zone dosing
3. Tubing network flushing

Dosing pump selected for the dispersal system shall be capable of delivering the design hydraulic flow. At least one standby pump must be provided and available for service at all times.

The filters shall be included as part of the drip dispersal system and meet the manufacturer's specifications as approved by the design engineer.

Wastewater Effluent Loading Rate:

The wastewater effluent loading rate will be determined and provided by the issued discharge permit and shall not exceed an annual average loading rate of two inches per week.

2 inch per week = 0.18 gal/ft^2/day

Dispersal Area Sizing:

The size of the required dispersal area is determined by the daily design flow (gpd) and the loading rate stipulated in the issued discharge permit.

Zone Layout:

Dispersal Zone, as defined by the National Onsite Wastewater Recycling Association (NOWRA), is the smallest unit of a drip dispersal system, consisting of a supply manifold, return manifold, drip laterals, and associated appurtenances, which can be loaded independently of all other parts of the dispersal system.

Zone width across contour is typically from 50 to 300 feet. Zone width is delineated by the following factors:

1. Site and soil evaluation.
2. Available distance down slope
3. Maximum linear feet of drip tubing as provided by the manufacturer

Drip Tubing (Dripper line) Runs and Laterals:

A length of dripper line across the contour is defined as a "run." The tubing should be installed on contour and laid out to drain itself through the emitters as evenly as possible so as not to cause localized overloading.

Typical Run Length = 50' to 300'

Lateral is a dripper line consisting of a run or series of runs extending from the supply manifold to the return manifold of a single dispersal zone. Lateral length is dependent on head loss, and the drip system design (i.e. dosing pump and filter).

Typical Dripper line Depth = 6 to 12 inches

Percent Run Time:

Each manufacturer offers different models with various dispersal dosing capacities. The selected model must be capable to accommodate the peak day flow within the desired Percent Run Time of less than 50%.

$$\text{Percent Run Time} = \frac{\text{Peak Day Flow (gpd)}}{\text{Dispersal Dosing Capacity (gpm)} \times 1440} \times 100\%$$

Dripper line Spacing:

Typical manufacturer recommendations call for drip tubing to be spaced 1 foot to 3 feet on center (2' o.c. is the most common).

Zone Dosing:

- A pressure regulator is required to maintain adequate residual pressure during dosing.
- The control system must allow for variable loading rate and/or dosing time at the individual zones.
- Individual zones shall be designed to be easily taken in and out of service for maintenance or repair.

Zone Forward Field Flushing:

Each drip zone must automatically undergo a periodic forward field flushing usually every 25 cycles or 15 days, whichever occurs first. Other flushing frequencies can be considered if recommended by the manufacturer. Control system must allow for adjustable flushing frequency.

A minimum velocity of 2 ft/sec should be used in the zone flushing.
A minimum velocity of 1 ft/sec is acceptable if the drip tubing is manufactured with antimicrobial inner lining to inhibit adhesion of biological growth on the inside walls of the tube and emitters.

Flush Residuals Required Treatment:

All filter flush and tubing network forward flush residuals are to return to the head of the pre-treatment system, or be treated by an acceptable side-treatment system before returning to the dosing station.

Air Release Valve:

An air release valve shall be provided for each zone at the highest elevation of the zone.

Minimum Required Horizontal Separation:

The following are the minimum horizontal separation distances required between the Drip Dispersal Area and other land features or components. Any exception may be considered by the Department using the Department's Design Guidelines and the Recommended 10-State Standards.

Land Feature or Component	Minimum Required Horizontal Separation Distances (in feet)
A flowing body of water	50
Well or suction line	100
Water service line	50
Occupied building	50
Property line	50
In-ground Swimming Pool	50

ADDED CHAPTER 130
RECOMMENDED BNR/ENR DESIGN CRITERIA

BNR TYPICAL DESIGN CRITERIA:

Usually two-stage reactor (anoxic/aerobic) would be sufficient to achieve BNR level of 8 mg/l TN.

Typical Design Criteria for Two-Stage BNR:

Parameter	Recommended
MLSS (mg/l)	3000-4000
Total HRT (hr)	12-16
Anoxic	2-4
Aerobic	8-12
MCRT (d)	15-40
F/M (g BOD/g MLVSS/d)	0.05-0.2
RAS (%Q)	50-100
Internal Recycle (%Q)	100-400
Anoxic Mix Power (hp/MG)	40-70

Typical Design Criteria For SBR BNR System:

Parameter	Recommended
BOD Load (Lbs/d/ft^3)	0.005-0.015
Cycle time (hr): Fill Settle Draw	 1-3 0.75-1 0.5-1.5
MLSS (mg/l)	3000-5000
HRT (hr)	~6 per cycle per reactor
MCRT (d)	20-40
FM (g BOD/g MLVSS/d)	0.05-0.2

Additional Criteria:
Post-equalization basin with a storage capacity adequately for two decants should be provided for flows of 2.0 mgd or less, or when the total SBR system less than four (4) units.

BIOLAC Wave Oxidation Reactor BNR System:

- Nominal Hydraulic Detention Time = 36 hours
- Side-Water-Depth = 8 feet
- Free Board = 2 feet
- Aeration system and automatic control air valves shall be capable of achieving BNR.
- The reactors are earth structure lined with high quality of liners.

Typical Design Parameters for BNR Orbal/Oxidation Ditch:

Flow (mgd)	BOD Load (Lbs/d/ft^3)	MLSS (mg/l)	MCRT (d)	HRT (hr)	Side-Water Depth (ft)
<0.2	0.012	4000-5000	31-38	24	8-13
0.2 to 0.499	0.015	4000-5000	26-32	20	8-13
0.5 to 0.999	0.015-0.018	4000-5000	20-32	16.6-20	8-13
1.0 to 2.0	0.018	4000-5000	21-27	16.6	8-13
>2.0	0.02	5000-6000	24-29	15	8-13

Secondary Sedimentation Tanks for Conventional BNR:

Parameter	Recommended
Side Water Depth (ft)	12 to16
Hydraulic Overflow Rates (gpd/sq. ft.)	
Average Design Flow	400 to 700
Hourly Peak Flow	1000 to 1600
Solids Loading Rate (lbs/sq. ft.-day)	
Average Solids Loading Rate	24 to 36
Peak Solids Loading Rate	43

Secondary Sedimentation Tanks for Extended Aeration BNR:

Parameter	Recommended
Side Water Depth	12 to16
Hydraulic Overflow Rates (gpd/sq. ft.)	
Average Design Flow	200 to 400
Hourly Peak Flow	600 to 800
Solids Loading Rate (lbs/sq. ft.-day)	
Average Solids Loading Rate	15
Peak Solids Loading Rate	34

ENR TYPICAL DESIGN CRITERIA:

To achieve ENR, in general a four-stage reactor, or two-stage with denitrification filter would be needed. The biological process should be sized at 12° C will be funded

Four-Stage Bardenpho Process for ENR:

- The proposed four-stage Bardenpho process is intended to meet 3 mg/l TN. However, facilities for supplemental carbon and/or a conventional filtration process for polishing may be required to meet the nutrient goals of 3 mg/l TN and 0.3 mg/l TP.
- The width to length ratio of the reactor: 1:5
- Side-water-depth = 18 feet
- Free Board = 2 feet

Parameter	Recommended
MLSS (mg/l)	3000-5000
Total HRT (hr)	16-23 (~23 is used when high BOD with no primary)
1st Anoxic	2-4
Aerobic	8-12
2nd Anoxic	2-5
Re-aeration	0.5-1
MCRT (d)	10-40
F/M (g BOD/g MLVSS/d)	0.1-0.2
RAS (%Q)	100
Internal Recycle (%Q)	400-600
Anoxic Mix Power (hp/MG)	40-70

Carrousel Process for ENR:

- Nominal Hydraulic Detention Time = 21 hours
  - 1st Anoxic Zone = 3 hours
  - Aerobic Zone = 15.5 hours
  - 2nd Anoxic Zone = 2 hours
  - Re-aeration Zone = 0.5 hour
- Reactors are reinforced concrete structures.
- Side-Water-Depth = 14 feet
- MLSS = 4,000 mg/l

Conventional Filters

- The conventional filtration process is designed for polishing purpose.
- Filter Media Depth = 4 feet
- Hydraulic Loading Rate: 2.5 gpm/sq. ft. at average daily flow
- Hydraulic Loading Rate: 4.0 gpm/ sq. ft. at maximum month
- A conventional filtration process following the four-stage Bardenpho process may be required to achieve the level of 3 mg/l of TN and 0.3 mg/l of TP.

Denitrification Filters

I. Deep Bed Downflow Denitrification Filter:

Parameter	Recommended
Filter Depth	6 feet media depth plus 1.5 feet support gravel depth
Temperature	12 º C
Filter Influent DO (mg/l)	< 6 mg/l or as recommended by filter manufacturer
Nitrogen Volumetric Loading Rate for Annual Average	50 lbs NOx-N/1000 ft^3/day
Empty Bed Detention Time for Annual Average	20 minutes
Empty Bed Detention Time for Maximum Month	15 minutes
Hydraulic Loading Rate for Annual Average	2.2 gpm/ft^2
Hydraulic Loading Rate for Maximum Month	3.0 gpm/ft^2

II. Continuous Backwash Upflow Denitrification Filter:

Parameter	Recommended
Filter Depth	80 inches
Temperature	12 º C
Filter Influent DO (mg/l)	< 4 mg/l or as recommended by filter manufacturer
Nitrogen Volumetric Loading Rate for Annual Average	40 lbs NOx-N/1000 ft^3/day
Empty Bed Detention Time for Annual Average	20 minutes
Empty Bed Detention Time for Maximum Month	12 minutes
Hydraulic Loading Rate for Annual Average	2.2 gpm/ft^2
Hydraulic Loading Rate for Maximum Month	4.0 gpm/ft^2

Membrane Bioreactor (MBR)

Membrane Bioreactor (MBR) is a combination of suspended-growth activated sludge biological treatment and membrane filtration equipment performing the critical solid/liquid separation function that is traditionally accomplished using secondary clarifiers. To achieve ENR level of treatment, MBR needs to include a high performing nitrogen removal system such as Bardnepho, Johannesburg process, etc. MBR operates at high MLSS concentration almost double or triple the conventional activated sludge system, thereby allowing a smaller bioreactor to achieve the same level of treatment as the conventional system.

Typical MBR Design Parameters:

Parameter	Recommended
BOD Loading (Lbs/1,000 ft^3/day)	30-60
MLSS (mg/l)	8,000-15,000
F/M (g BOD/g MLVSS/day)	0.05-0.2
MCRT (day)	12-20
HRT (Hour)	6-15
Flux (gpd/ft^2)	8-15 (Temperature-Corrected at 12º C)
DO (mg/l)	Anoxic 0-.5 Aerobic 1.5-3 Membrane 2-6
Pore Size (μm)	0.1-0.4
RAS (Q)	3-6
Energy Consumption (KWh/1,000 gal)	0.1
Membrane Replacement	Every 3 to 5 years (Flux rate gradually declines overtime)
Pretreatment Requirements	1. Flow Equalization for peaking factor over 1.5-2.0 2. Fine Screening: 1-3 mm (0.04-0.12 in)

Facilities for Chemical Additions (Including Supplemental Carbon Source and Facilities for Phosphorus Removal):

- Chemical feed pumps shall be sized based on peak daily flow.
- Chapter 110 of the 10-State Standards shall be used for phosphorus removal by chemical treatment.
- In funding facilities for chemical addition, up to 30 days in storage capacity would be allowed for grant participation.