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# SEWAGE TREATMENT PLANT
# AT
# BRAMPTON FARMS, ST. CATHERINE

FCS # 0853/76/C

# ENGINEERING REPORT

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## Overview

This engineering report describes the sewerage treatment designs for the proposed sewage treatment plant at Brampton Farms St. Catherine. This sewage treatment plant is intended to serve two (2) housing developments; one at The Whim consisting of 1380 houses and the other at Brampton Farms consisting of approximately 900 houses. The Whim development will be constructed first with the Brampton Farms development to follow shortly after. The proposed capacity of the sewage treatment plant will be $2771m^3$/day. This is based on 1.17 of the expected sewage generated by both.

## Sewage Treatment Design

### Design References

The sewage treatment design was prepared with reference to the developers manual Volume 3 Section 4 “Minimum Requirements for Waste Water Treatment Systems and Excreta Management in Jamaica” provided by the Ministry of Health & Environment – Environmental Health Unit; EPA Technology Assessment: Subsurface Flow – Constructed Wetlands for Wastewater Treatment - EPA/832-R-93-008, and Waste Stabilization Ponds and Constructed Wetlands Design Manual by UNEP-IETC with the Danish International Development Agency (Danida).

### Design Criteria

The basic criteria used in the design is that influent to the treatment plant is typical of medium strength domestic sewage. The treatment plant effluent will meet NEPA 2004 standards for direct discharge.

**Table 1: Sewage Treatment Plant Wastewater Characteristics**

| Parameter | Units | Influent | Effluent |
|---|---|---|---|
| COD | mg/l | 500 | 100 |
| BOD | mg/l | 250 | 20 |
| TSS | mg/l | 220 | 20 |
| TKN | mg/l | 40 | 10 |
| P | mg/l | 8 | 4 |
| FC | MPN/100ml | $10^7$ -$10^8$ | 200 |

## Sewage Treatment Plant Components

The sewage treatment plant consists of the following components:

1. Grit removal chamber
2. Anaerobic Ponds
3. Distribution box
4. Constructed Wetlands (Scirpus, Typha, phragmites)
5. Chlorination chamber

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**Table 2: Sewage Treatment Plant Components**

| Brampton Farms Sewage Treatment Plant | | | |
|---|---|---|---|
| **Anaerobic Pond, Constructed Wetland and Chlorination Chamber** | | Qty | Unit |
| 1 | Headworks including grit removal structure | | |
| 2 | Average Daily flow | 2771 | $m^3$ |
| 3 | Hydraulic retention time for Anaerobic Ponds | 1.5 | Days |
| 4 | Required pond capacity | 4,157 | $m^3$/d |
| 5 | Number of ponds | 2 | No. |
| 6 | Dimensions of each pond, Depth | 4 | m |
| 7 | Width (mid depth) | 16.6 | m |
| 8 | Length(mid depth) | 34 | m |
| 9 | Volume of each pond | 2,257 | $m^3$ |
| 10 | Total pond volume | 4,514 | $m^3$ |
| 11 | Effluent from septic tank flows into a distribution box that spreads flow into four constructed wetlands | | |
| 12 | Constructed Wetland loading rate | 90 | L/$m^2$ |
| 13 | Constructed Wetland size - Required | 30,788.89 | $m^2$ |
| 14 | Constructed Wetland depth | 0.7 | m |
| 15 | Voids in bed | 0.38 | |
| 16 | pore volume | 8189.84 | $m^3$ |
| 17 | Retention Time (required) | 2.96 | Days |
| 18 | Number of wetland trains | 4 | |
| 19 | Area of each bed (required) | 30,788.89 | $m^2$ |
| 20 | Length | 161 | m |
| 21 | Width | 48 | m |
| 22 | L/W | 3.35 | # |
| 23 | Total Constructed Wetland area (provided) | 30,912 | $m^2$ |
| 24 | Contact Chlorine chamber HRT | 25 | min |
| 25 | Volume required | 48 | $m^3$ |
| 26 | D | 0.9 | m |
| 27 | W | 2 | m |
| 28 | L | 27 | m |

# Biochemical Processes

## Anaerobic Ponds

Anaerobic ponds are commonly 2 – 5 m deep and receive wastewater with high organic loads. The retention time is generally 1-1.5 days although they can be designed with up to 6 days retention. In anaerobic ponds, BOD removal is achieved by sedimentation of solids, and subsequent anaerobic digestion in the resulting sludge. The removal rates for anaerobic ponds are temperature dependent. The Brampton Farms site is expected to have a minimum air temperature of 23$^{o}$C. As such the permissible loading rate for BOD is 330 g/m$^{3}$ day with a removal rate of 66%.

The anaerobic ponds require a minimum hydraulic retention time of 1 day; approximately 1.6 days have been provided at this site. Based on the removal efficiency of the proposed pond the COD and BOD will be reduced to 180 and 85mg/l respectively. The ponds will also remove the majority of the TSS and fecal coli form by about 1 log.

**Table 2.7 Design value of permissible volumetric BOD loadings on, and percentage BOD removal in, anaerobic ponds at various temperatures (from Mara and Pearson, 986; Mara *et al.* 1997)**

| Temperature (°C) | Volumetric loading (g/m$^3$.day) | BOD removal (%) |
|---|---|---|
| < 10 | 100 | 40 |
| 10 - 20 | 20T – 100 | 2T+20 |
| 20-25 | 10T+100 | 2T+20 |
| >25 | 350 | 70 |

**Figure 1: Anaerobic Pond Design formula**

**Table 3: Constructed Wetland Waste Water Characteristics**

| Parameter | Units | Influent | Effluent |
|---|---|---|---|
| COD | mg/l | 190 | <100 |
| BOD | mg/l | 85 | 20 |
| TSS | mg/l | 110 | 20 |
| TKN | mg/l | 45 | 10 |
| P | mg/l | 8 | 4 |
| FC | MPN/100ml | 1.9x10$^{6}$ | 1.9x10$^{4}$ |

## Constructed Wetlands

Constructed wetlands are engineered systems designed and constructed to utilise wetland vegetation to assist in treating wastewater in a more controlled environment than occurs in natural wetlands. The type of wetland chosen for sewage treatment at this site is subsurface flow. In subsurface flow systems, water flows though a porous media such as gravels or aggregates, in which the plants are rooted

Subsurface flow systems are most appropriate for treating primary wastewater, because there is no direct contact between the water column and the atmosphere. There is no opportunity for vermin to breed, and the system is safer from a public health perspective. The environment within the subsurface flow bed is mostly either anoxic or anaerobic. Oxygen is supplied by the roots of the emergent plants and is used up in the Biofilm growing directly on the roots and rhizomes, being unlikely to penetrate very far into the water column itself. Subsurface flow systems are good for nitrate removal (denitrification), but not for ammonia oxidation (nitrification), since oxygen availability is the limiting step in nitrification.

This constructed wetland is designed to have a minimum hydraulic retention time of 3 days; this is required to reduce the oxygen demand and nutrient levels to NEPA standards. The reeds in the constructed wetland should be planted with one reed per square foot to ensure an adequate plant density.

The BOD removal follows the 1st order plug flow reaction

$$L_t=Le^{-kt}$$

where $L_t$ is the concentration of BOD at any time.
The reaction constant $k_T = k_{20}\,\Theta^{(T-20)}$
where $k_{20}$ = Rate Constant at $20^{o}$ C

$k_{20}$ = = 1.104

$\Theta$ = 1.06

$k_T$ = 1.31

$$L_e = L_i \, e^{(-k_T t)}$$

The average temperature for this site is 23 degrees Celsius. COD removal is at the same rate as BOD removal and COD is generally twice the BOD concentration. The expected BOD concentration ($C_e$) will be approximately 1.7mg/l

The TSS will be removed within the first few metres of the wetland (EPA/832-R-93-008).

The removal of TSS can be predicted by

$$TSS_e = TSS_i \, [0.1058 + 0.0011(100 * Q/A_s)]$$

Where Q is the average daily flow rate through the wetland and $A_s$ is the required surface area. The total area required for a wetland with 3 day retention time is 1,520 $m^2$ while 30,900 $m^2$ has been provided.

The nitrogen entering wetland systems can be measured as organic nitrogen and ammonia (expressed as TKN), or as nitrate, or a combination of both nitrogen measurements. The organic N entering a reed bed is typically associated with particulate matter such as organic wastewater solids. Decomposition and mineralization processes in the wetland will convert a significant part of this organic N to ammonia (EPA/832-R-93-008).

Nitrogen removal by wetland plants ranges from 0.2 to 2.25 g/($m^2$.day). Using a removal rate of 1.1 g/($m^2$.day) over the total area (30, 912 $m^2$) the effluent concentration should be about 9 mg/l.

Hydraulic retention time = 3 days
Total daily nitrogen load; 45g x 2771$m^3$ ÷3 = 41565g
Removal by plant uptake; 1.1g x30912 $m^2$ =33211 g/
Effluent concentration; (41565-33211) g/day ÷ (2771 $m^3$÷3) = 9.0 g/$m^3$

Phosphorous removal by wetland plants ranges from 0.05 to 0.5 g/$m^2$/day. Using an average of 0.25/$m^2$/day, the phosphorous will be below acceptable levels within the 3 days of retention. Phosphorous reduction will occur via plant uptake and sedimentation of PO4.

Alternatively Nitrogen and Phosphorous removal can also be predicted by the following formula developed in North America. The removal is temperature sensitive but there are no published values for adjusting the rate constant.

$$\frac{A_s = \frac{365Q}{k}\ln\left(\left(C_i - C*\right)\right)}{\left(C_e - C*\right)}$$

Where C* the background concentration, 0.02 for TP
Q = 2771÷3 $m^3$/day
$k_{20}$ = 12 m/yr for TP

Required surface area for phosphorus removal, $A_s$ = 19,544 $m^2$.

Fecal coliform levels are expected to have a 1.5 log reduction in 3 days. Chlorination for 25 minutes in a contact chamber will reduce FC to acceptable levels.

Discharge from the chlorination chamber will be to the Fraser's Gully

## Conclusion

Anaerobic Ponds are suitable for primary treatment of domestic and municipal sewage. They are easily maintained with low energy requirements. Constructed wetlands are an “eco-friendly” alternative for secondary and tertiary domestic and municipal wastewater treatment. Constructed wetlands are practical alternatives to conventional treatment of domestic sewage.

When the same biochemical and physical processes occur in a more natural environment, instead of reactor tanks and basins, the resulting system often consumes less energy, is more reliable, requires less operation and maintenance and, as a result costs less.

The chosen system, anaerobic ponds followed by constructed wetlands, incorporates natural biochemical processes which are time and temperature dependent. As such it is suitable for subtropical regions such as Jamaica. The sewage treatment plant as designed is expected to meet the effluent standards required by NEPA.

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## APPENDIX

1. Estimate of Water Usage

2. Layout of Sewage Treatment Plant

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| Gore Whim and Brampton Water Demand Estimate | | | |
|---|---|---|---|
| **Item** | **Description** | **Qty** | **Unit** |
| 1 | **Number of residential lots** | 2,250 | No |
| 2 | Estimate of the number of persons per lot | 4.50 | No |
| 3 | Population Estimate | 10,125 | No |
| 4 | Average per capita consumption per household resident | 227 | Liters |
| 5 | Estimate of domestic water use | 2,298,375 | Liters |
| 6 | | | |
| 7 | **Commercial and Light Industry** | | |
| 8 | Commercial and shopping area | 78,768.00 | $m^2$ |
| 9 | Usage per unit area commercial space | 14.68 | $L/m^2$ |
| 10 | % Area used for commercial floor space | 20% | |
| 11 | Estimate of floor space | 15,753.60 | $m^2$ |
| 12 | Water for commercial and light Industry | 231,265 | L |
| 13 | | | |
| 14 | **Basic School** | | |
| 15 | Student Population | 250 | No |
| 16 | Staff Population | 25 | No |
| 17 | Total Basic School population | 275 | No |
| 18 | | | |
| 19 | **Primary School** | | |
| 20 | Student Population | 1,800 | No |
| 21 | Staff Population | 144 | No |
| 22 | Total primary school population | 1,944 | No |
| 23 | | | |
| 24 | Per Capita demand for each head of school population | 57 | Liters/day |
| 25 | Estimate of Basic School demand | 15,675 | Liters/day |
| 26 | Estimate of Primary School demand | 110,808 | Liters/day |
| 27 | | | |
| 28 | **Other water use** (5% domestic use) | 114,918.75 | Liters |
| 29 | **Average day demand** | **2,771,041.46** | **Liters** |
| 30 | | **2,771** | **$m^3/d$** |
| 31 | sewage generation factor | 0.85 | |
| 32 | **Average daily sewage generation** | **2355** | **$m^3/d$** |
| 33 | Safety factor | 1.17 | |
| 34 | **Required STP capacity** | **2771** | **$m^3/d$** |