1

DEVELOPMENT OF A COMPUTER PROGRAMME FOR THE DESIGN OF MUNICIPAL WASTEWATER TREATMENT FACILITIES
Part 5: Secondary Clarifier

by

Amat Sairin B. Demun
Dept. of Hydraulics and Hydrology
Faculty of Civil Engineering

ABSTRACT

A computer programme was developed using Fortran programming language utilizing IBM-PC compatible microcomputers to design a secondary clarifier in a centralised municipal wastewater treatment plant. The programme is used to design the dimension and capacity of four circular secondary clarifiers including the influent and effluent structure to satisfy the specified design criteria such as the detention time, the overflow rate, solid-loading rates and weir loading. The programme was written in a subroutine called from the main prógramme which also be able to call other subroutines for designing other facilities in the treatment plant. The programme runs successfully given the right input data. The results are easy to interpret and automatically appear either on the computer screen or in an output file.

INTRODUCTION

Secondary clarifier or secondary sedimentation basin is normally the fifth unit after the aeration basin in a centralised municipal wastewater treatment plant. The purpose of secondary clarifier is to provide further removal of suspended solids that escape from the primary sedimentation basins to provide well clarified effluent. Beside removing suspended solids from the wastewater, the secondary clarifier must be able to provide thickening of the settled solids. Therefore circular clarifier is the best shape for thickening purpose. Secondary clarifier may remove more than 85% of the suspended solids [1]. However it does not remove significant amount of nitrogen, phosphorous, heavy metals, bacteria and viruses and therefore they need further removal.

2

THE DESIGN CRITERIA

The computer programme was written to design four circular secondary clarifiers in which each clarifier can operate independently with respect to the aeration basin upstream. One clarifier can be taken out of service for maintenance. The clarifiers are designed to handle average design flow plus the return flow. To achieve the function of the secondary clarifiers, they must be designed to provide sufficient detention period which is not less than 1.5 hour at peak design flow plus recirculation. The clarifier depth must be sufficient for solids not to flow with the effluent and also to provide storage for the settled solids for thickening purpose. Qasim [1] suggested that the overflow rate at average design flow and at peak design flow should not exceed 15 and 40 m³/m².day respectively while the solid loading rates at average and peak design flow condition should not exceed 50 and 150 kg/m².day respectively. The weir loading at the effluent weir should not exceed 124 m³/m.day at average design flow.

THE DESIGN OF CLARIFIER

The flow pattern in a circular clarifier is radial. Therefore the influent must be a central feed type. The design flow, Q in m³/s flowing into the four clarifier is the average design flow plus the return sludge flow and minus the mixed liquor suspended solid (MLSS) wasted. The average design flow is calculated in the main computer programme which is based on the number of population served for the treatment plant. The return sludge flow, Q_r and the MLSS wasted are calculated in SUBROUTINE AERAT which is a subroutine to design aeration basin. SUBROUTINE AERAT was discussed previously in Part 4.

The surface area of each of the circular clarifier is computed using equation:-

$$A = \frac{3600 Q_1 X}{S} \qquad (1)$$

where	Q_1	=	the design flow to each clarifier (m³/s)
		=	$Q/4$ (there are four circular clarifiers)
	X	=	MLSS concentration
		=	3.75 kg/m³ [Qasim, 1985]
	S	=	limiting solid flux value
		=	2.0 kg/m².hour [Qasim, 1985]

From the value of surface area, the diameter of each circular clarifier can be determined. The actual overflow rate, V in m³/m².day at average design flow

(and when all four clarifiers operate) and at critical flow condition (at peak flow and when only three clarifiers operate) is computed using equation:-

$$V = \frac{uQ_i}{n} \qquad (2)$$

where u =   unit conversion (86400 second/day)

                       Q_i =   average or peak flow plus return sludge flow (m^3/s)

                       n =   number of clarifiers operating (3 or 4)

This actual overflow rate must satisfy the design criteria which is not less than 15 m^3/m^2.day for average flow and 40 m^3/m^2.day for critical or emergency flow condition. If the calculated value of the actual overflow rate does not satisfy the design criteria, the computer programme is designed to request the user to input the new increased value of the clarifier's diameter in meter. This request value will be repeated until the final diameter satisfy the overflow rates with respect to the specified design criteria.

Based on the final diameter of each clarifier, the solid loading, L_s in kg/m^2.day can be computed using equation:-

$$L_s = \frac{uQ_iX}{nA_1} \qquad (3)$$

where A_1 =   the surface area of the circular clarifier (m^2) which is computed based on the final clarifier's diameter.

The actual value of solid loading must also satisfy the specified design criteria and if it does not satisfy the design criteria, the computer programme will again request the user to input the new increased clarifier's diameter.

The side depth of the clarifier is determined using a basic formulation which is equal to the depth of clear water zone plus the depth of thickening zone and the depth of sludge storage zone and plus a 0.5 meter freeboard for safety. The clear water and settling zone is taken generally to be 2.0 meter while the depth of thickening zone is equal to:-

4

$$t_z = \frac{S_c}{X_t A_1}$$ (4)

where X_t =   concentration of the thickened sludge.

                         =   7.0 kg/m^3 [Qasim, 1985]

              S_c =   total solids in the clarifier (kg)

                         =   30% of m_s

              m_s =   total mass of solids in each aeration basin which is equal to:-

$$m_s = X y L w$$ (5)

where y =   water depth in the aeration basin (meter)

              L =   length of the aeration basin (meter)

              w =   width of the aeration basin (meter)

The dimensions (y, L and w) of the aeration basin was computed previously in SUBROUTINE AERAT. The sludge storage zone is computed using equation:-

$$t_s = \frac{S_s + S_c}{X_t A_1}$$ (6)

where S_s =   solids stored in each clarifier (kg).

The detention time of the wastewater in the clarifier is calculated based on the volume of the clarifier and the design flow rate. The computer programme calculates the detention time under average design flow plus recirculation, under peak design flow plus recirculation and under emergency condition (peak flow plus recirculation when only three clarifiers operate) and they must satisfy the specified design criteria. Figure 1 shows the detail of the secondary clarifier.

INFLUENT AND EFFLUENT STRUCTURE

The influent structure is located at the centre of each clarifier. The structure is called the central feed well influent structure. An influent pipe will be installed across the clarifier (at the bottom side) which discharges the wastewater from the aeration basin into the clarifier through the influent riser pipe and the central feed well. The central feed well will distribute the wastewater evenly and under quiescent condition throughout the clarifier. The diameter of the centre feed well is typically between 15 to 20 percent of the total diameter of the clarifier which range from 1 to 2.5 meters [2].

The effluent structure consists of several components which include effluent baffle, effluent launder, effluent box, 90° V-notch weirs and a pressure outlet pipe. The width of the effluent launder is designed to be 0.5 meter which is located around the circumference of each circular clarifier. The weir plate length can be calculated based on the diameter of the clarifier and the width of the effluent launder. The 90° V-notch is 8 cm deep at 39.5 cm centre-to-centre. From the dimension of the V-notch and the length of the weir plate, the total number of V-notches can be computed. The head over the V-notch is computed using equation:-

$$H = \left[\frac{15}{8} \frac{Q}{c_d\sqrt{2g}\ \tan 45°} \right]^{2/3} \qquad (7)$$

where

c_d = 0.60 (weir coefficient)

Q = flow through each V-notch at average design flow and at peak design flow when only three clarifiers operate (m³/s).

If the head over weir, H at both design flow conditions is greater than the notch depth (8 cm), the notch depth should be increased. The actual weir loading at average design flow and at emergency flow condition can be computed which is equal to the design flow divided by the length of the weir plate. The weir loading at average flow must satisfy the design criteria which is not more than 124 m³/m.day. The computer programme also calculates the depth of the effluent launder which is based on the characteristics of the effluent box and the hydraulic profile in the clarifier, in the effluent launder and in the effluent box. Clarifiers with diameter between 3.6 to 9.0 meter is equipped with sludge removal facility supported on beams across the clarifier while clarifiers with

diameter of 10.5 or larger must have a central pier that supports sludge scraper blade [2]. The clarifier is built with a walkway travelling bridge equipped with handrailing. The detail of the effluent structure with the hydraulic profile is shown in Figure 2.

THE PROGRAMME STRUCTURE

The computer programme was written using Fortran programming language utilizing IBM-PC compatible microcomputers. The structure of the programme for the design of secondary clarifier is outlined in a flowchart shown in Figure 3. The programme was written in a subroutine named SUBROUTINE SECOND. The subroutine is called from the main programme which also be able to call other subroutines to design other units in a municipal wastewater treatment plant. SUBROUTINE SECOND must be run after SUBROUTINE AERAT is run. This is because some output data from SUBROUTINE AERAT is needed to run SUBROUTINE SECOND.

RUN EXAMPLE AND RESULTS

The computer programme runs easily after the DOS command A:>WWTREAT which stands for WasteWater TREATment. Input data file is not needed to run the programme. Some of the input data are obtained after running the main programme and some are obtained after running SUBROUTINE AERAT. The input data obtained from the main programme is only the peak design flow rate while the data obtained from SUBROUTINE AERAT are the return sludge flow, the MLSS wasted, the average and peak flow plus the recirculation, the BOD_5 flowing out from the aeration basin and the dimensions of the aeration basin. Appendix 1 shows the run example for the secondary clarifier for a local municipal wastewater treatment plant which serves a total population of 170.45 thousand people.


CONCLUSION

The calculations for the design of the secondary clarifier actually use a simple method and technique provided a clear design criteria. However the process of calculations might consume much time if it is done manually. Trial and error procedure is involved in the design of the clarifier to satisfy the given design criteria. Therefore for convenience and best results, such calculation can be easily performed using a computer programme. This particular computer programme has a capability to design a secondary clarifier. It is guaranteed to be accurate and faster compared to manual calculation. It is more versatile and easier to use. The results are easy to interpret and automatically appear either

on the computer screen or in an output file and it is ready to be included in any
design report of a centralised municipal wastewater treatment plant.

REFERENCES

[1]   Qasim, R.S (1985). Wastewater Treatment Plant - Planning, Design
        and Operation. CBS Publishing, Tokyo, Japan.

[2]   Tchobanohlous, G. and Burton, F.L. of Metcalf & Eddy, Inc (1991).
        Wastewater Engineering - Treatment, Disposal, and Reuse. Third
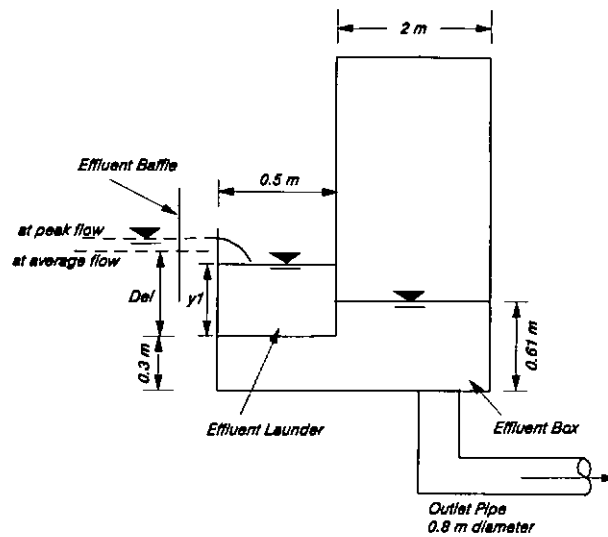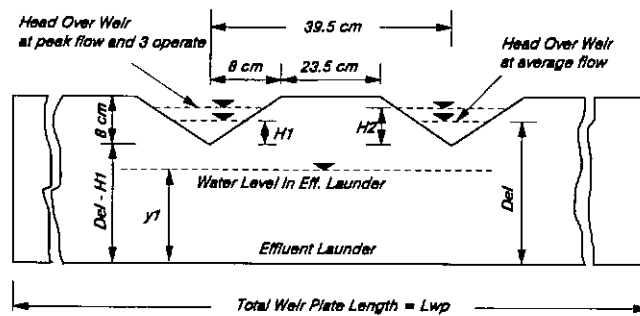   Edition. McGraw-Hill Inc, Singapore.
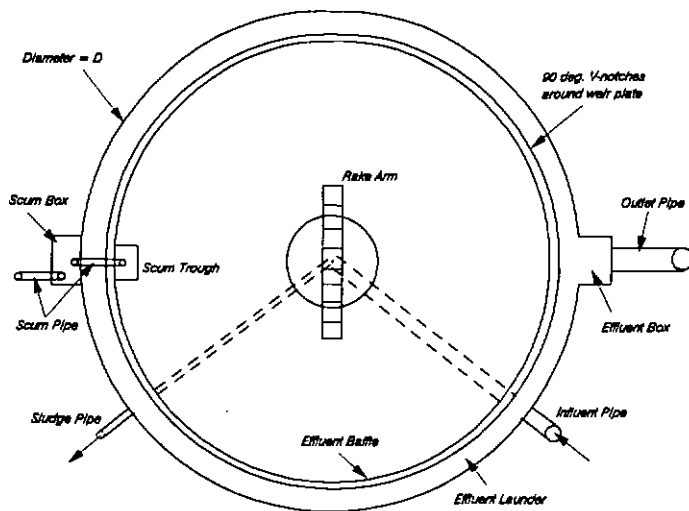
(a) Plan View
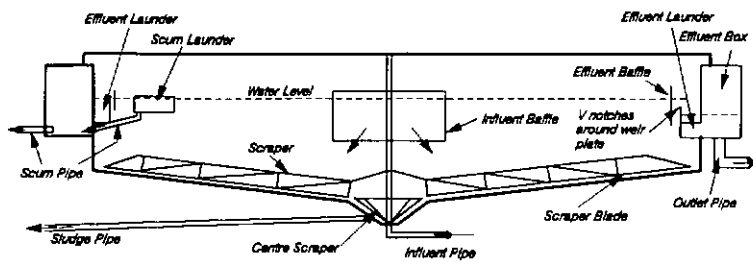
(b) Elevation View

FIGURE 1: Secondary Clarifier

(a) Detail of Effluent Structure and Hydraulic Profile

(b) Detail of Weir Plate and V-notches

FIGURE 2: Detail of Effluent Structure
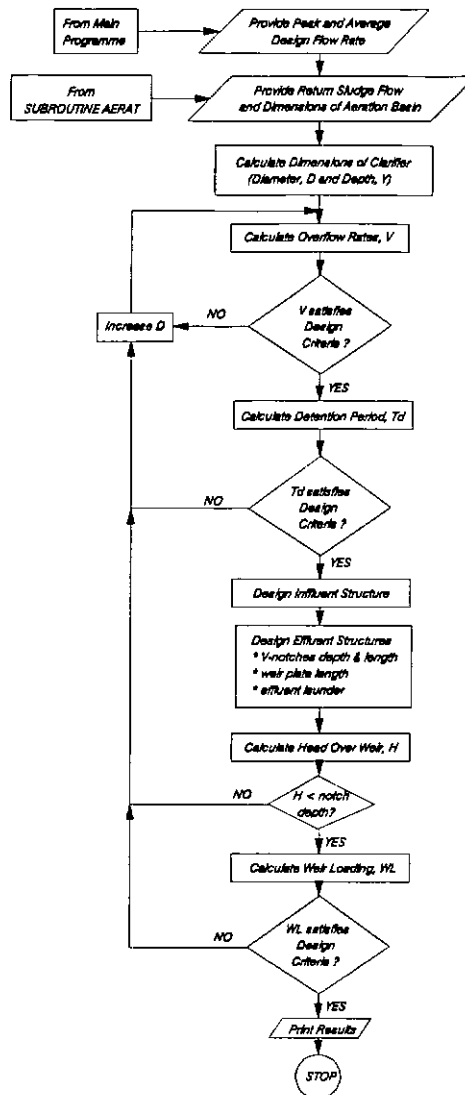(Length Symbols = See
Programme Output File)

10

FIGURE 3: Flowchart for the Design
of Secondary Clarifier
(Subroutine SECOND)

APPENDIX 1

-- OUTPUT FILE --

```
W       W   W      W  TTTTT  RRRR   EEEEE    A     TTTTT
W   W   W   W   W   W    T    R   R  E       A A     T
W   W   W   W   W   W    T    RRRR   EEE    A   A    T
  WW WW       WW WW      T    R  R   E      AAAAA    T
   W  W        W  W      T    R   R  EEEEE  A   A    T
```

```
*>>>>>>   DESIGN OF MUNICIPAL WASTEWATER     <<<<<<*
*           TREATMENT PLANT FACILITIES             *
*                                                  *
*                 programmed by                    *
*               AMAT SAIRIN DEMUN                  *
*            Universiti Teknologi Malaysia         *
***************************************************
```

Project Name   : Wastewater Treatment for the City of XYZ
Program run by : Amat Sairin Demun
Organization   : Universiti Teknologi Malaysia
Date   : 21 st March 1997
Output Filename : A:OUTPUT.OUT

DESIGN INFORMATION
==================

1. Number of Population Served, P   =   170.450 thousand
2. Peak Design Wastewater Flow, Qpk   =   1.185 m3/s
3. Average Design Wastewater Flow, Qav =   .444 m3/s
4. Minimum Design Wastewater Flow, Qmn =   .200 m3/s

- -

```
****************************************************
5.0  SECONDARY CLARIFIER / SOLID SEPARATION FACILITY   .
****************************************************
```

Purpose: To provide further removal of suspended solids.

5.1 DESIGN CRITERIA
    ===============

1. Provide four circular clarifiers, each have independent
   operation with respect to the aeration basins.
2. The clarifiers are designed for average flow plus the
   recirculation.
3. Check the hydraulic performances of the influent and
   the effluent structures at peak design flow when one
   clarifier is out of service.

12

4. The return sludge from each clarifier must have an
   independent sludge withdrawal arrangement with flow
   flow measurement devices.
5. The overflow rate at average flow < 15 m3/m2.day and at
   peak flow < 40 m3/m2.day.
6. The solids-loading rates at average flow < 50 kg/m2.day
   and at peak flow < 150 kg/m2.day.
7. Scum baffles and scum collection system must be provided.
8. Weir loading < 124 m3/m2.day at average design flow

5.2 DIMENSION OF THE CLARIFIER
    ============================

```
 1. Design flow to the clarifiers           =    .780 m3/s
 2. Design flow to each clarifier (4 nos) =    .195 m3/s
 3. Diameter of each clarifier, D          =    40.9 m
 4. Overflow rate @ average flow           =    12.8 m3/m2.d
 5. Overflow rate @ peak flow & 4 operate =    24.3 m3/m2.d
 6. Overflow rate @ peak flow & 3 operate =    32.4 m3/m2.d
 7. Depth of the clarifier, Dp             =     3.9 m
 8. The overflow rates satisfy the design criteria ==> OK
 9. Detention time @ average flow          =     6.4 hr
10. Detention time @ peak flow & 4 operate =     3.4 hr
11. Detention time @ peak flow & 3 operate =     2.5 hr
```

5.3 INFLUENT STRUCTURE
    ==================

The influent structure consists of a central feed well. An
influent pipe must be installed across the clarifier that
will discharge into the central feed well.   The influent
should pass under the baffle and then distribute uniformly
throughout the clarifier.

5.4 EFFLUENT STRUCTURE
    ==================

1. The effluent structure consists of:-
   o effluent baffle
   o V notches
   o effluent launder
   o effluent box
   o a pressure outlet pipe
2. Provide 90 deg V notches on the weir plate on one side
   of the effluent launder
3. Provide width of the effluent launder = 0.5 m
4. Provide 8 cm deep notches at 39.5 cm centre to centre.
5. Length of effluent weir plate, Lwp   = 125.4 m
6. Total number of notches   = 317
7. Head over notch @ average flow, H1   = 3.8 cm
8. Head over notch @ peak flow & 3 operate,H2 = 6.1 cm
9. H1 and H2 is less than notch depth (8 cm) ==> OK

Appendix 1 continued

10. Weir loading @ average flow   =   83.3 m3/m2.d
    Weir loading < 124 m3/m2.d (design criteria) ==> OK
11. Weir loading @ peak flow & 3 operate =   272.2 m3/m2.d
12. Effluent Launder:-
    o Provide effluent box of 2 m x 2 m
    o Provide at least 0.8 m diameter outlet pressure pipe.
    o The pipe is an inverted syphon connected to a common
      junction box.
    o The water level in junction box is kept such that the
      depth of flow in the effluent box at peak flow is kept
      at 0.61 m.
    o Provide invert of the effluent launder 0.3 m above the
      invert of the effluent box.
    o Depth of effluent launder @ ave flow, Del =   .77 m
    o Water Depth in Effluent Launder, yl   =   .45 m

END OF OUTPUT FILE