TN US SP
TAMIL NADU URBAN SANITATION SUPPORT PROGRAMME

REPORT

SEWAGE AND FECAL SLUDGE TREATMENT IN TIRUCHIRAPPALLI: CURRENT STATUS, PROPOSED PLANS AND RECOMMENDATIONS FOR IMPROVEMENT

December 2017




SEWAGE AND FECAL SLUDGE TREATMENT IN TIRUCHIRAPPALLI: CURRENT STATUS, PROPOSED PLANS AND RECOMMENDATIONS FOR IMPROVEMENT

December 2017

TN US SP
TAMIL NADU URBAN SANITATION SUPPORT PROGRAMME

iihs®
INDIAN INSTITUTE FOR HUMAN SETTLEMENTS

In Association With:
Gramalaya

Sewage and Fecal Sludge Treatment in Tiruchirappalli: Current Status, Proposed Plans and Recommendations for Improvement

December 2017

For Citation: TNUSSP, 2017. Sewage and Fecal Sludge Treatment in Tiruchirappalli: Current Status, Proposed Plans and Recommendations for Improvement.

DOI: https://doi.org/10.24943/tnusspsfst.20171201

This document is produced as part of Tamil Nadu Urban Sanitation Support Programme (TNUSSP). TNUSSP supports the Government of Tamil Nadu (GoTN) and cities in making improvements along the entire urban sanitation chain. The TNUSSP is being implemented by a consortium of organisations led by the Indian Institute for Human Settlements (IIHS), in association with CDD Society, Gramalaya, and Keystone Foundation.

Document Team: David M. Robbins, Sher G. Singh, K.V.Santhosh Ragavan, Vimala P. P., Sasikumar Eswaramoorthy

Editing: Word Lab, IIHS, Bengaluru

Design and Layout: Divya Dhayalan

Production: Shaheena Manoj, Krishnapriyaa P., Govardhan Seshachalam

Team Leader: Kavita Wankhade

Project Director: Somnath Sen

2. BMGF funding acknowledgment: This Research / Work was supported by Bill & Melinda Gates Foundation.

3. Acknowledgement: We thank Rakesh Sharma and J.Androse - TNUSSP Gramalaya for data collection, Shubhra Jain, Consultant, TNUSSP for document review, Manohar for the topo survey, Labs (2), IIT Madras for the flow measurement device.

www.tnussp.co.in | www.iihs.co.in

CONTENTS

Abbreviations vii

Executive Summary E1

E1.1. Sewage Treatment Plant E4

E1.2. Upgrading the STP E4

E1.3. Sewer Network E5

E1.4. Septage Decanting Stations E5

E1.5. Institutional Strengthening E6

E1.6.Review of future plans E6

1. Introduction 1

1.1 Planned investments for wastewater infrastructure 4

1.2 Need for the study 4

1.3 Outputs of the assessment 5

2. Assessment of Current Status 7

2.1 Flow estimates and spatial contribution 9

2.1.1 Sewage flows 11

2.1.2 Fecal Sludge loads 12

2.1.3 Issues and gaps 15

2.2 Infrastructure on wastewater collection and conveyance 15

2.2.1 Network based Infrastructure 15

2.2.2 Non-network based Infrastructure 15

2.3 Infrastructure for decentralised wastewater/sewage treatment 16

2.4 Sewage treatment infrastructure 17

2.4.1 Components of STP 19

2.5 Infrastructure for FS co-treatment in STP 20

2.6 Operation and Maintenance of network, decanting stations and STP 21

2.6.1 O & M of sewerage network 21

2.6.2 O & M of decanting stations 23

2.6.3 O & M of STP 25

2.7 Institutional arrangements 36

2.7.1 Emptying & transportation 36

CONTENTS (Contd)

2.7.2 Treatment 37

2.8 Environmental regulations 37

3. Summary of Recommendations 39

3.1. Proposed solutions for sewerage network 41

3.1.1 Sewerage network 41

3.2. Solutions for decanting stations and co-treatment 44

3.2.1 Implement a manifest system to track loads 45

3.2.2 Safety recommendations 46

3.3. Proposed solutions for the STP 47

3.4. Institutional recommendations 49

3.4.1 Contracting out for O & M services 50

3.4.2 Coordination with other departments 50

3.4.3 Coordination with other TCC public safety and public works 50

3.4.4 Capacity Building: Training 50

3.4.5 Following the rules 51

3.5. Wastewater Reuse 51

4. Future Expansion and Proposed Plans 53

4.1. Sewage flows 56

4.2. Treatment plant suitability 57

4.2.1 Anaerobic ponds 57

4.2.2 Facultative ponds 58

4.2.3 Treating flows beyond 58 MLD 58

4.3. Analysis of draft DPR and implications of future flows 58

4.4. AMRUT: Discussions 59

5. Detailed Action Plan & Recommendations 67

5.1. Action plan description 69

5.2. Action Items 72

5.2.1 AI.1: Servicing the valves at Division Chamber #1 72

5.2.2 AI.2: Flow meter fix or replace 72

5.2.3 AI.3: Repair the bar screen 73

CONTENTS (Contd)

5.2.4 AI.4: Repair the grit chamber 74

5.2.5 AI.5: Service the diversion chamber #2 valves 74

5.2.6 AI.6: Install air vac valve 74

5.2.7 AI.7: Measure sludge depth in AP 1 75

5.2.8 AI.8: Divert wastewater to AP 2 and drain AP 1 pond 75

5.2.9 AI.9: Desludge AP 1 75

5.2.10 AI.10: Install sampling platforms 78

5.2.11 AI.11: Inspect and refurbish outlet structure 78

5.2.12 AI.12: Divert flow to AP 1 79

5.2.13 AI.13: Inspect and service the valves in Diversion Box 3 79

5.2.14 AI.14: Divert flow to FP 2 to dry out FP1 79

5.2.15 AI.15: Remove sludge 80

5.2.16 AI.16: Install outlet structures 80

5.2.17 AI.17: Install sampling platform 80

5.2.18 AI.18: Divert flow to FP 1, dry out FP 2 80

5.2.19 AI.19: Perform dye test on polishing ponds 80

5.2.20 AI.20: Divert flow from PP1 to PP2 and dry out PPI 80

5.2.21 AI.21: Remove sludge 81

5.2.22 AI.22: Install the outlet structures 81

5.2.23 AI.23: Install sampling platforms 81

5.2.24 AI.24: Divert the flow to PP 2 81

5.2.25 AI.25: Install a sampling platform on the discharge pipe 81

5.2.26 AI.26: Install flow-measuring device -Outlet 81

6. Estimation of Costs 83

6.1. Costs and timeframe for achieving current (2008) standards 85

6.2. Additional Costs to achieve October 2017 discharge standards for all parameters 85

7. Recommendation for Future Flows 87

7.1. STP 89

7.2. Upgrading STP effluent-thoughts & strategies 90

7.2.1 Performance assessment tool 90

CONTENTS (Contd)

7.3. Decanting station 92

7.3.1 Upgrading requirements for future flows at decanting stations 92

7.3.2 Locations for new decanting stations 93

8. Conclusions and Next Steps 95

Bibliography 99

Annexures A1

Annexure 1- Wastewater Generation A3

Annexure 2- As Built Drawings and Pond Geometry A5

Annexure 3 - Sampling Analysis Report & Interpretation A7

Annexure 4- Duties and Responsibilities Of Contractor And Supervisor A11

Annexure 5- Commercial Pre-Treatment Program A17

Annexure 6- Best Practices of Operation & Maintenance for Waste Stabilisation Pond A19

Annexure 7- Calibration Procedure for Pumps A33

Annexure 8- Information on Solar Powered Aerators A35

Annexure 9- Case Study- Evaluation of Solar Powered Aerators in STP, at Los Banos, California A39

Annexure 10- Floating Baffles - Proposal and Supporting Information A43

Annexure 11- Information on Surface Aerators A47

Annexure 12- Wastewater Treatment Alternatives A49

Annexure 13- Sampling Plan for STP A53

Tables

Table 1.1: City Profile 3

Table 2.1: Household connection to UGD in different coverage areas 10

Table 2.2: Zone-wise wastewater generation estimate 11

Table 2.3: Fecal sludge generation estimates 13

Table 2.4: Area covered by truck operators 14

Table 2.5: Examples of decentralised wastewater / sewage treatment systems 16

Table 2.6: Inflow and outflow estimated in the pumping stations 23

Table 2.7: Comparison of status of the preliminary treatment units in all decanting facilities 24

Table 2.8: Performance data on Trichy STP-CPCB 2013 report 25

Table 2.9: Removal percentage based on sampling 26

Table 2.10: Preliminary treatment units in need of repair 28

Table 2.11: October 2017 Discharge requirements as they will apply to STP at Tiruchirappalli 37

Table 3.1: Common Sewer Cleaning Methods 43

Table 3.2: Best practices for co-treatment 44

Table 3.3: Best practices for STP operation and proposed changes/solution to issues 47

Table 4.1: Infrastructure of the Four Phases of the AMRUT 58

Table 4.2: Configurations of the existing WSP 64

Table 5.1: Action Plan for STP 69

Table 6.1: Time Based Investment Plan 85

Table 7.1: Number of O & M workers per population served 89

Figures

Figure 2.1: UGD coverage areas in TCC 11

Figure 2.2: Desludging locations 14

Figure 2.3: STP layout 18

Figure 2.4: STP Components 19

Figure 2.5: Electromagnetic Flowmeter 19

Figure 2.6: Screening system at head works 20

Figure 2.7: Sewage flow to STP from pumping stations 22

Figure 2.8: Impact of rainfall on network 23

Figure 2.9: Anaerobic Pond with Surface vegetation 29

Figures *(contd...)*

Figure 2.10: BOD Measurements for Anaerobic Ponds 30

Figure 2.11: Facultative ponds 31

Figure 2.12: BOD5 in Facultative Ponds 31

Figure 2.13: TSS removal from Treatment Train 2 32

Figure 2.14: Facultative pond outlet structure 33

Figure 2.15: Maturation Ponds 34

Figure 2.16: Graph of Nitrogen in Maturation Ponds 34

Figure 2.17: Discharge Pipe for Final Effluent 35

Figure 3.1: Skid Mounted Hydraulic Jetter 42

Figure 3.2: Jet Rodder Truck 42

Figure 3.3: Septage Manifest form 46

Figure 4.1: Area covered by sewerage system under proposed phases- AMRUT 55

Figure 4.2: Estimated TCC Sewage Generation for years 2020, 2035 & 2050 56

Figure 4.3: Trichy Sewage Capacity for Years 2020, 2035, and 2050 60

Figure 4.4: Schematic of Extended Aeration System 61

Figure 4.5: Evaluation of STP Processes from the 2016 DPR 62

Figure 4.6: Schematic of Oxidation Ditch 63

Figure 4.7: Empty oxidation ditch with air diffusers 63

Figure 4.8: Oxidation ditch with 1, 2, and 3 oval channels 64

Figure 5.1: Parshall Flume 73

Figure 5.2: Air vent location 74

Figure 5.3: VAL MATIC air release valve with 2-inch inlet 75

Figure 5.4: EAWAG concept drawing of sludge stockpiling 76

Figure 5.5: Site map showing preferred location of sludge stockpile zone 77

Figure 5.6: Detail of berm and swale to prevent run-on and run-off during storm events 77

Figure 5.7: Pond outlet structure 79

Figure 5.8: Multiple inlet and outlet structures 79

Figure 7.1: WSP Performance assessment tool 91

Figure 7.2: Standard layout of decanting station 92

Figure 7.3: Horizontal flow type and conical sedimentation tank 92

Figure 7.4: Mechanized decanting station using screw press technology in Bekasi City, Indonesia 93

Abbreviations

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BADCT	Best Available Demonstrated Control Technology
BOD	Biochemical Oxygen Demand
BNR	Biological Nutrient Reduction
CNR	Chemical Nutrient Reduction
CPCB	Central Pollution Control Board
CT/PT	Community Toilet/Public Toilet
DO	Dissolved Oxygen
FSM	Fecal Sludge Management
GoTN	Government of Tamil Nadu
HH	Household
HSC	Household Service Connection
MBR	Membrane Bio Reactor
MoEFCC	Ministry of Environment, Forest and Climate Change
MPS	Main Pumping Stations
O & M	Operations and Maintenance
PPE	Personal Protective Equipment
STP	Sewage Treatment Plant
TCC	Tiruchirappalli City Corporation
TN	Total Nitrogen
TNPCB	Tamil Nadu Pollution Control Board
TNUSSP	Tamil Nadu Urban Sanitation Support Programme
TSS	Total Suspended Solids
UGD	Underground Drainage System
UGSS	Underground Sewerage Scheme
WSP	Waste Stabilisation Pond

Measurements

mg/L	milligrams per litre
MLD	million litres per day = 1000 cubic metres per day
MPN/100 mL	Most Probable Number of viable cells in 100 ml
lpcd	litres per capita per day
lps	litres per second
PSI	pound-force per square inch

Executive Summary

E1.1. Sewage Treatment Plant E4
E1.2. Upgrading the STP E4
E1.3. Sewer Network E5
E1.4. Septage Decanting Stations E5
E1.5. Institutional Strengthening E6
E1.6.Review of future plans E6

Executive Summary

The Sewage Treatment Plant (STP) that serves the Tiruchirappalli City Corporation (TCC) is located on 498 acres of land owned by the city. Located at Panjapur, the STP uses Waste Stabilisation Pond (WSP) technology for the treatment of sewage. It has 11 pond cells, of which 6 are currently operational (operational system) while 5 are not (old system). The original design flow was 88.64 million litres per day (MLD) for the 11-pond system, 30 MLD for the old system, and 58 MLD for the operational system. The wastewater flows from the underground sewerage network system (serving approximately 44,000 household connections), are pumped into the STP via two main pumping stations, and proceed for septage disposal (at four pumping/decanting stations).

In October 2017, the Ministry of Environment, Forest and Climate Change (MoEFCC) promulgated the Environmental (Protection) Amendment Rules, 2017, which provide new discharge standards for municipal wastewater treatment plants. Based on these regulations, certain key discharge standards have been identified for STPs. Table E1 presents the effluent discharge requirements for the STP at Tiruchirappalli.

Table E1: **October 2017 Effluent Discharge requirements as they will apply to STP at Tiruchirappalli**

Sl No.	Parameters	Units	*Maximum Permissible Limit (except for pH)
1	pH		6.5 to 9
2	Biochemical Oxygen Demand (BOD)	mg/L	30
3	Total Suspended solids(TSS)	mg/L	100
4	Fecal Coliform	MPN/100mL	1000

*Note: As per the notification for the area/regions other than Metro cities(Mumbai, Delhi, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad and Pune), all state capitals except in the State of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim, Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Union Territory of Andaman and Nicobar Islands, Dadar and Nagar Haveli, Daman and Diu and Lakshadweep

Source: Ministry of Environment, Forest And Climate Change, 2017

The STP at Panjappur was originally designed to meet the discharge standards of 30 mg/L BOD and <100 mg/L for Total Suspended Solids (TSS), which are the same as the October 2017 standards for these two parameters. Therefore, when properly loaded, functioning and maintained, the STP should be able to meet these design standards even when septage is added in. If nutrient compliance ever becomes a problem, TCC could consider either agricultural reuse instead of direct stream discharge, or nutrient reduction technology. Agricultural reuse is the least expensive option which also provides maximum benefit. Careful coordination with the Tamil Nadu Pollution Control Board (TNPCB) will be required to understand the possible limitations of this form of effluent management.

TCC continues to invest in sewerage through a phased approach that will see a significant increase in wastewater generation, collection and treatment. Plans are being made to install a new wastewater treatment system at Keelakalkandarkottai, and eventually, an additional system at Kulumani Road. TCC is exploring ways to improve operations and increase loading for the STP at Panjappur to provide sustainable treatment solutions for current flows and at least a portion of the future flows.

The purpose of this assessment study carried under Tamil Nadu Urban Sanitation Support Programme (TNUSPP) by the TSU was to:

i. assess the effectiveness of the existing STP at the Panjappur site
ii. assess the implications of the proposed development plan

iii. prepare an action plan for upgrading the STP
iv. analyse secondary data pertaining to sewage flows
v. analyse seasonal variations of wastewater flows and
vi. document and analyse the institutional arrangements and protocols for the operations and maintenance (O & M) of the wastewater management programme.

E1.1. Sewage Treatment Plant

The team conducted a full evaluation of the STP to determine the major causes of poor performance as well as identify opportunities for improvement. The analysis identified several reasons for the poor performance of the STP. The main findings are as follows.

- Equipment at the STP, including the flow meter, bar screens and grit chamber, was poorly functioning.

- There were operational problems with the valves on the transmission pipeline, and the settling of the pipeline was interfering with the delivery of wastewater from the head works to the treatment cells.

- There was short-circuiting within pond cells, which reduced both detention time and treatment efficiency. Short circuiting limits the effectiveness of the system. This is a common issue with large sewage lagoons of this type.

- There appeared to be a build-up of excessive sludge and organic matter in the ponds which was being carried over into the following pond and ultimately the effluent discharge.

- There was uneven balancing of wastewater flow throughout the pond system.

- Untreated septage was entering the system, some of which has been documented to contain commercial chemicals which may be toxic to the system.

- There were design flaws in the outlet structures that led to the transfer of algae and scum into the final discharge pipe.

The assessment indicates that while each of these items is of concern, they can all be fixed. Despite gaps in its current performance, the basic design and installation of the STP are sound. Therefore, with minimal O & M, the system can be upgraded to treat wastewater volumes up to the desired design flow, while meeting the October 2017 effluent.

E1.2. Upgrading the STP

Upgrading the STP to meet the stipulated standards and provide continuous service to the TCC will require sustained efforts. First, the existing non-functioning equipment needs to be repaired and maintained through maintenance systematic O & M programme.

This report includes a detailed action plan along with a phased investment strategy. The main elements of this plan include:

- Fixing the flow meter, bar screens and grit chamber;

- Servicing the transmission pipeline valves;

- Checking sludge depth (sludge profiling) and desludging the individual WSP cells as needed;
- Upgrading the outlet structures in all ponds;
- Installing sampling and flow measuring structures at the discharge pipe; and
- Installing baffle walls, aeration equipment, and mixing equipment (Annexure 10 includes useful references for future consideration should TCC ever wish to significantly increase the treatment capacity beyond the initial design limitations).

E1.3. Sewer Network

As the sewer network continues to expand, there is increasing interest in the O & M of the sewer system, including the pumping and decanting stations. As with most cities with underground sewerage networks, the high cost of maintaining the system is of concern to the TCC. Opportunities to improve performance while cutting costs are especially significant. While TCC owns some sewer cleaning equipment, including jet rodding and desilting machines, there is a clear need for additional equipment. The situation is complicated by the fact that some part of the underground network is 5 metres below the ground level, making service both difficult and dangerous. Additionally, there is no commercial pre-treatment programme in Trichy, which means that grease from food service facilities is discharged uncontrolled into the sewer, causing blockages, especially in the central business area of the city. Finally, the discharge of raw and only partially screened and de-gritted septage into the system adds solids to the load that may lead to clogging.

Based on the findings of the assessment, this report makes the following recommendations to address sewer service and maintenance:

- A commercial pre-treatment programme should be implemented.
- A preventative maintenance programme needs to be established.
- Inspections should be carried out more frequently and using best practices, such as CCTV inspections and lamping inspections (a visual method of inspecting sewer lines from one manhole to the next using reflected sunlight or a high-powered light source).
- There is a need for better pre-treatment and ultimately, liquid and solid components of the septage need to be separated prior to its introduction into the sewer system.
- Cleaning should be carried out with proper tools, including high-powered hydraulic sewer cleaning systems.

E1.4. Septage Decanting Stations

In addition to improving the sewer maintenance activities, TCC is also focusing on improving the septage decanting infrastructure at Anna Stadium, Thanjavur Road, Vayalur Road and Vasudevan Street. Each of these stations has a wet well where trucks can discharge their loads. The existing screening and de-gritting facilities are not functioning properly. While each of these stations are attended, there is no control over the type of septage that is received (residential, commercial or industrial). Recordkeeping is minimal as operators only record the number of trucks and not the volume of waste received, and the stations are generally not equipped with the basic required equipment.

Recommendations to improve the functioning of the decanting stations include the following.

- A manifesting system should be implemented where septage truck drivers record the origin of wastewater, time and date of collection, and discharge.

- There should be servicing and better utilisation of grit chambers and screens.

- Liquid and solid components of the septage should be separated through proper co-treatment best practices prior to its introduction into the sewer system.

- Better recordkeeping is required to assess the true volume of septage that is being discharged.

The installation of liquid/solid separation equipment, which will be required as flows approach the design capacity, requires significant capital investment and planning, and should be considered using a phased approach. This would include components such as screw or belt presses, sedimentation tanks, vertical flow and planted or unplanted gravel filters, among others. These are discussed in subsequent sections of this report. The report also provides a detailed assessment of the system design for wastewater and septage loading.

As wastewater flows approach the maximum design flow, BOD loading from raw septage will be greater than can be treated by the STP. The presence of liquid/solid separation equipment at the decanting stations is required to reduce this load, which, in turn, will make co-treatment effective.

E1.5. Institutional Strengthening

Addressing infrastructural aspects alone is not sufficient to solve TCC's wastewater issues. In addition to sustained investment in the upgrading of treatment systems, the institutional arrangements for wastewater management also need due attention. This includes:

i. training and capacity building
ii. augmenting the existing programme to enable sub-contracting firms to provide O & M
iii. inter-agency coordination
iv. coordination with other organisations and the public.

Perhaps the most significant of these is to effectively work with the private sector to conduct O & M services, which will not only protect TCC's significant investments but also help achieve compliance.

At present, TCC engages private players in managing the main pumping stations, the lift and decanting stations, as well as the STP—this will most likely continue as the STP is upgraded. This report suggests how TCC can develop an O & M plan and ensure that it is carried out by their private sector contractors. This report makes recommendations for O & M planning as well as sample forms that can be adapted for use at the STP in Trichy. Additionally, it includes recommendations for a long-term monitoring plan, and plans for health, safety and emergency preparedness.

E1.6. Review of future plans

This report concludes with a summary on review of the Detailed Project Report (DPR) and implications of future flows. Recommendations are provided for the sewer pipe network and manholes, sewage flow estimates and the proposed sewage treatment process that uses Extended Aeration. The draft DPR recommends extended aeration as the treatment process for new STPs. Moving forward, extended aeration may still be a valid option for TCC, although it will not be effective in nutrient reduction.

1

Introduction

1.1 Planned investments for wastewater infrastructure	4
1.2 Need for the study	4
1.3 Outputs of the assessment	5

1. Introduction

The city of Tiruchirappalli, or Trichy, has been served by a combination of networked and non-networked sanitation systems. The non-networked sanitation systems are of many types – the predominant one is individual household connected to On-site Sanitation Systems (OSS) such as pit latrines and septic tanks. The OSSs are desludged as and when the need arises by private operators. The city also has decentralised wastewater treatment systems serving groups of households such as apartments or colonies and community toilets.

The networked based solutions are planned, implemented and maintained by the Tiruchirappalli City Corporation (TCC). About 20-30 per cent (45,000 household service connections out of 2.1 lakh households) of total households in the city are connected to a Underground Sewerage system (UGSS) (alternatively termed as Underground Drainage Network (UGD)) for the collection, conveyance and treatment of domestic wastewater. The city is covered by a sewer network spanning 441.93 km, with 26 lifting stations and 26 sub-pumping stations located across the city. Wastewater from the households and establishments connected to the sewerage system is transported through the sewers, collected at various collection sumps and pumped to the Sewage Treatment Plant (STP) for treatment. The city profile is summarised in Table 1.1

Table 1.1: **City Profile**

Sl No.		
1	Tiruchirappalli status	Corporation in the year 1994
2	Administrative zones	Four zones: Abhishekapuram, Ariyamangalam, Ponmalai, and Srirangam
3	Wards	65
4	Area	167 sq. km
5	Population	9,16,000 (2011 Census)
6	Slums	Estimated population: 2, 30,000; 211 approved and 75 unapproved slums.
7	Altitude	88 m
8	Latitude	10.79 degrees north
9	Longitude	78.70 degrees east
10	Total Annual Rainfall	83.5 cm; (monsoon season: Oct to Dec)
11	Water Source	Cauvery river and groundwater
12	Water Supply	Intermittent

Source: Tiruchirappalli City Corporation

The STP has a design capacity of 88.64 million litres per day or MLD (considering both operational and defunct treatment systems) and is designed on the Waste Stabilisation Pond (WSP) technology. The plant has preliminary treatment facilities and two anaerobic ponds, two facultative ponds and two polishing ponds currently in service. The five additional cells comprising the ‘old plant’ with a capacity of 30 MLD are currently abandoned but could be rehabilitated. The treated wastewater from the STP is discharged into the Koraiyar river and finally flows into river Cauvery. As of 2017, flows ranging from 45,000 to 50,000 m^3 per day (45 – 50 MLD) is received and treated at the operational ponds of WSP.
TCC has also been a model in managing Fecal Sludge (FS) through different decentralised treatment systems and providing decanting facilities as provision to empty the FS collected from OSS by the desludging trucks. There are four decanting stations at Anna Stadium, Thanjavur Road, Vayalur Road, and Vasudevan Street. FS emptied at these decanting stations are conveyed to the STP for further treatment through the sewerage system.

1.1. Planned investments for wastewater infrastructure

The UGSS for the city is proposed in four phases. The following is a summary of the four phases (TCC 2017).

i. the first phase covers the network-omitted area in Srirangam zone
ii. the second covers the network-omitted area in city core and rehabilitate existing STP, expanding the UGSS with an additional STP at Keelakalkandarkottai
iii. the third phase is geared towards expanding the UGSS network with an additional STP at Panjapur
iv. the last phase is geared towards expanding the UGD network with additional STP at Kulumani Road.

1.2. Need for the study

The Bill and Melinda Gates Foundation (BMGF) supports the Government of Tamil Nadu (GoTN) to achieve the Sanitation Mission of Tamil Nadu through the TNUSSP. A component of this programme is to assess the comprehensiveness of the present and proposed plans for FS and sewage treatment in TCC. The rationale for the assessment is:

1. The effluent discharge standards (MoEFCC, 2017) are the governing requirements for the WSP at Panjappur. There is a need to provide TCC with immediate activities such as the physical upgrades and Operation and Maintenance (O & M) improvements required to meet these standards.

2. The WSP capacity may exceed the design capacity when all the household connections to the network are established. The connections will progressively increase and thus there is a need to determine the most effective method of handling incremental increases in the inflow while meeting discharge standards.

3. FS is currently mixed with sewage enroute to the decanting Stations and at the WSP and this potentially adds high solids to the pond(s). Understanding the co-disposal of septage in WSP is important, as there may be a difference in the magnitude of waste characteristics.

4. There is a need to understand the potential for reusing sludge that is periodically removed from the ponds.

Therefore, an assessment of currently operational WSP was carried out under TNUSSP covering the following:

1. Assessment of the coverage and effectiveness of the existing WSP for safe treatment and disposal of sewage and FS for existing and future loads with a view to identify the critical areas of concern.
2. Analyse implications of the proposed projects and plans (for extension of the sewer system in Trichy, under TCC consideration). This analysis must specifically be done with respect to the sewage treatment options proposed for the new connections and an increase in coverage.
3. Preparation of an action plan, outlining clear prioritisation, based on an analysis of benefits and costs.

1.3. Outputs of the assessment

Following are the major outputs of the assessment:

1. An action plan, outlining clear prioritisation, based on the analysis of benefits and costs
2. Analyse secondary data on wastewater flows (wastewater and FS flows) available from TCC over a 3-year period, accounting for all flows at WSP. Include estimate of contribution from each ward to the wastewater flow using data from pumping station records or other similar data sources.
3. Analyse seasonal variation of the flow to STP during dry and wet spells with reference to TCC, and compare this analysis against design requirements
4. Document and analyse institutional arrangements and protocols for O & M – if outsourced, then also document scope of contract and how it is managed. Review national and international best practices on STP (WSPs) O & M practices, sludge withdrawal and reuse

Assessment of Current Status

2.1 Flow estimates and spatial contribution	9
2.2 Infrastructure on wastewater collection and conveyance	15
2.3 Infrastructure for decentralised wastewater/sewage treatment	16
2.4 Sewage treatment infrastructure	17
2.5 Infrastructure for FS co-treatment in STP	20
2.6 Operation and Maintenance of network, decanting stations and STP	21
2.7 Institutional arrangements	36
2.8 Environmental regulations	37

2. Assessment of Current Status

The assessment of present situation or baseline covered the following aspects:

1. **Flow estimates** and spatial contribution of the flows from sanitation system (limited to networked and OSS in combination with FSM)

2. **Infrastructure** for collection, conveyance and treatment

3. **O & M** and performance of collection, conveyance and treatment

4. **Institutional**: Human Resources & Management, O & M Contracting, Environment Regulations, Finance/Expenditure

The baseline assessment covered the status and issues of the infrastructure or the services delivered. In summary, this assessment is developed from:

- Desk study of reports, databases and articles
- Topographic survey of the WSP area in Panjappur
- Site visits to TCC pump and decanting stations including analysis of volumes processed
- WSP field studies of 20 - 31 March 2017 including flow measurements and laboratory analysis
- Interviews with TCC staff

2.1. Flow estimates and spatial contribution

The estimates of sewage and FS generated were obtained using average per-capita water supply and existing number and type of sanitation systems reported under Census and TCC databases. The wastewater and FS generated in a city is dependent on the type of household sanitation arrangements and water supply prevalent in the city.

The existing sewerage system was implemented under two schemes – the first scheme in 1987-1992 and the second scheme of Trichy-Srirangam in 2000-2008 (TCC, 2008). The UGD covers the core area of the city. Although Trichy-Srirangam scheme is the most recently implemented sewerage scheme, covering Srirangam-Golden Rock zone and pockets of non-sewered areas in the city, there are areas on the periphery of the corporation that remain non-sewered and rely on OSS.

TCC maintains records related to household UGD connections and the extent of UGD coverage in each ward. The wards are categorised into three groups based on UGD coverage: Fully Covered (FC), Partially Covered (PC) or Uncovered (UC). The city has 25 FC wards covering an area of 12.95 sq.km, 25 PC wards spread over 51.31 sq.km and 15 UC wards covering 102.97 sq.km as shown in Figure 2.1. The city is spread over an area of 167 sq.km[1].

In the 25 wards that are fully covered by the UGD network, only about 16,500 households are connected to the network. There are about 29,700 household septic tanks, which significantly exceeds the Census figures for these wards (~6,500). According to Census figures, 11.52 per cent, 33.95 per cent and 71.04 per cent of the total households are connected to septic tanks in the wards that are fully covered, partially covered, and uncovered respectively. The reasons for relying on septic tanks in a fully covered

[1] *Based on the area of wards, which are fully covered, partially covered and uncovered, Tiruchirappalli City Corporation*

wards could be, households not connecting to the network, due to technical reasons such as gradient, narrow lanes etc. and due to political reasons of providing the connection by private vendor and concerned implementing/governing department.

Table 2.1 summarises the Household Service Connections (HSCs) connected to UGDs, and household septic tanks for the different UGD coverage categories.

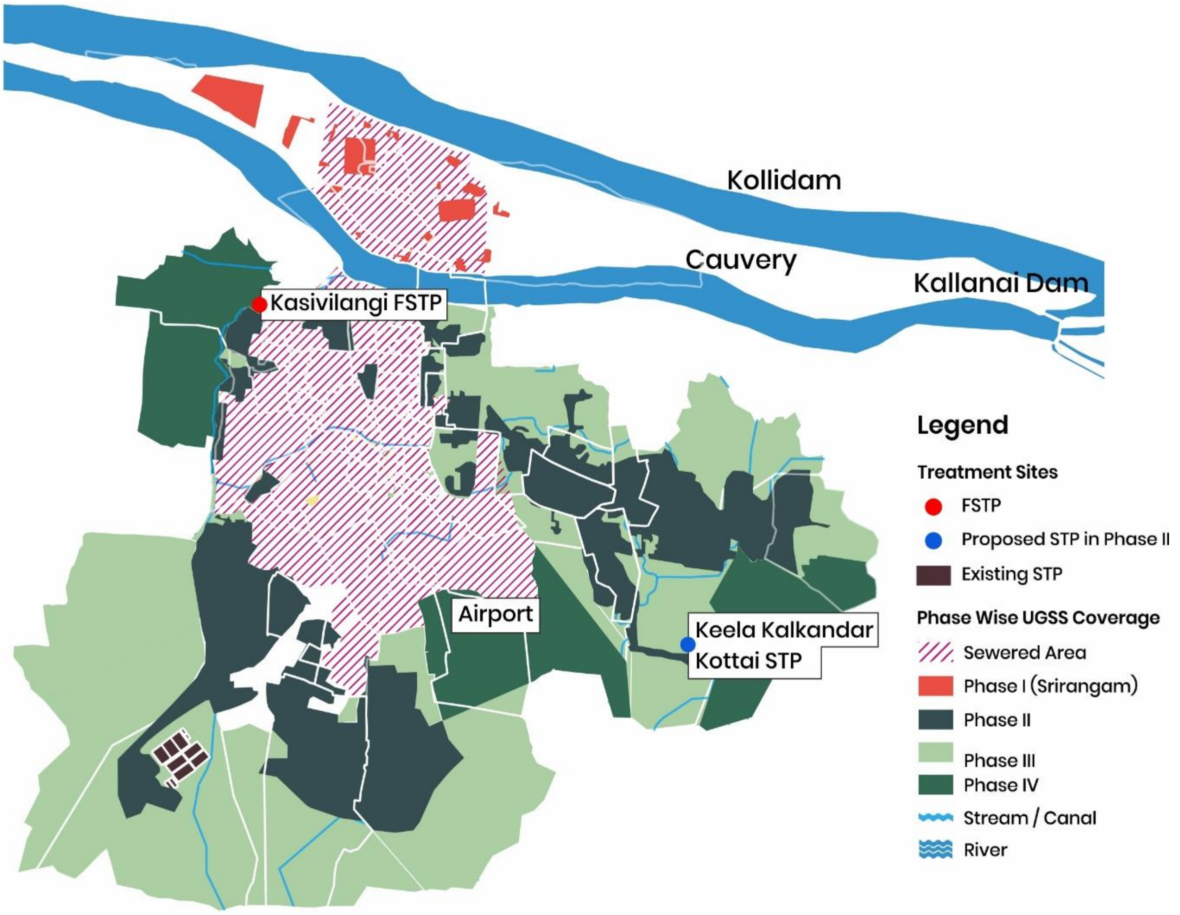
Table 2.1: **Household connection to UGD in different coverage areas**

Sl No.	**UGD Coverage**	**Total No. of Households**	**Number of Wards**	**HH connected to Sewer**		**Variance between Census and Actual UGD connections**	**Household Septic tanks**	
				(Census 2011)	**HSC (TCC Records)**		**(Census 2011)**	**HSC (TCC Records)**
1	FC	56488	25	43,702	16,591	27111	6,506	29,731
2	PC	78559	25	49,378	27,700	21,678	26,670	39,958
3	UC	52010	15	4,976	0	4,976	36,948	38,564
4	**Grand Total**	**187057**	**65**	**98,057**	**44,291**	**53,766**	**70,124**	**108,253**

Source: TNUSSP Analysis 2017

These inconsistencies highlight the need for better data management in urban local bodies. For the purpose of this assessment the data reported by TCC is used.

Figure 2.1: **UGD coverage areas in TCC**



Source: Trichy City Corporation; TNUSSP Analysis, 2017

2.1.1 Sewage flows

Table 2.2 summarises the zone-wise wastewater generation for the population estimated based on the existing number of households connected to UGD network HSCs[2].

Table 2.2: **Zone-wise wastewater generation estimate**

Sl No.	Zone	Length of UGD (km)	Sewered HH (Census 2011)	Domestic HSC Connections (TCC)	Estimated Wastewater generation (per Census HHs) (MLD)	Estimated Wastewater generation from households with HSC (MLD)
1	Abhishekapuram	151.76	30,907	16,068	13.15	6.85
2	Ariyamangalam	93.69	19,141	6,663	8.22	2.85

[2] *Estimated based on a water supply level of 135 lpcd and 80 per cent water supply being generated as wastewater.*

Table 2.2: **Zone-wise wastewater generation estimate**						
SI No.	**Zone**	**Length of UGD (km)**	**Sewered HH (Census 2011)**	**Domestic HSC Connections (TCC)**	**Estimated Wastewater generation (per Census HHs) (MLD)**	**Estimated Wastewater generation from households with HSC (MLD)**
3	Ponmalai	61.5	18,089	5,234	7.98	2.30
4	Srirangam	134.98	29,920	16,326	12.59	6.62
5	**Grand Total**	**441.93**	**98,058**	**44,291**	**41.94**	**18.62**
Source: TNUSSP Analysis 2017						

Given that the city currently has about 44,000 domestic underground drainage HSCs (49,306 reported by the TCC more recently); the estimated domestic wastewater generation will be about 19 MLD. This estimate is exclusive of the wastewater generated from commercial institutions and establishments and other non-domestic connections (at present, there are about 620 non-domestic HSCs connected to the UGD network).

The city's STP receives about 45 MLD (field measurement at the WSP) of wastewater. This is significantly higher than the generation estimate presented in Table 2.2, and indicates one or a combination of the following:

- The household water consumption (used to estimate wastewater generation) is significantly higher than the presumed 135-lpcd water supplied by the TCC through its water distribution network. This could be a result of:
    - Unequal supply of municipal piped water supply, with the sewered areas receiving relatively higher water supply, exceeding the average water supply (of 135 lpcd) provided to the city.
    - Use of supplementary water supply sources such as bore wells or tube wells to augment the municipal water supplied to households.

- Unauthorised connection by households to the UGD network, thereby exceeding the current HSC connections (of ~***44,000*** connections).

2.1.2 Fecal Sludge loads

Table 2.3 summarises the volume of FS expected to be generated, from the existing septic tanks in the city.

Table 2.3: **Fecal sludge generation estimates**							
Sl No.	**Cleaning Frequency (in years)**	**Number of septic tanks**		**Septic tanks to be cleaned daily**		**FS generation (m^3/day)**	
		Household	**CT/PT**	**Household[3]**	**CT/PT[4]**	**Household[5]**	**CT/PT**
1	2 years	108253	190	180	3	576	22
2	3 years			120		384	
3	5 years			72		230	
Source: TNUSSP Analysis 2017							

The FS estimated based on number of OSS and assuming different desludging frequencies is approximately in the range of 344 to 797 m^3/day which is equal to 0.344 to 0.797 MLD.

At present the FS collected from the OSS by the septage trucks is emptied at the four decanting stations located in each of the zones of TCC. These decanting stations maintain a record of the number of truck loads emptied on a daily basis. The record does not capture volume of FS disposed. Analysis of this record indicates that the maximum FS load received is 0.48 MLD (estimated considering an average no. of 80 trucks of 6000L capacity are emptied in the decanting stations). This estimate is comparable to the estimate derived assuming OSS sizes and desludging frequency. The desludging locations reported by the desludging operators as per the TNUSSP survey is shown in Figure 2.2. The areas served by them is listed in Table 2.4.

From the Figure 2.1 and 2.2, it can be seen that largely the desludging locations are marked in those areas where it is non-networked. It is interesting to note that, the desludging trucks frequently visit these locations but there areas which are non-networked and also have rare, or no frequent desludging happening. These areas include Sholanganallur (Ward no. 53), Mela kalakndar kottai (ward no. 30), Adaikala Anna Nagar (ward no. 31), Saravana nagar (Wad no 8), Patel nagar (ward no. 7). The reasons for these areas to have rare desludging could be:

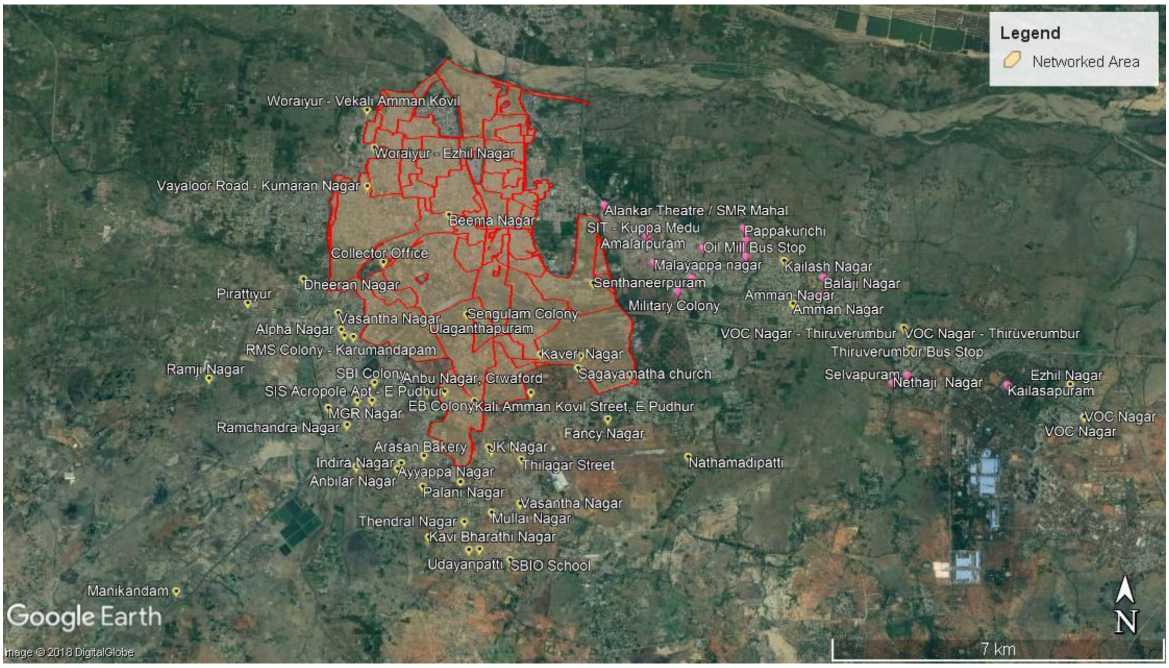
1. The onsite sanitations systems may be unlined pits, with large capacity, for it will take quite a long time to fillup/overflow.

2. They could be using other means of disposal arrangements other than septic tanks or pits, such as toilets directly connecting to the open drains.

3. They could be using other means of desludging other than the desludging trucks

[3] *Estimated based on stated cleaning frequency, and 300 days of operation in a year*
[4] *Calculated based on a presumed tank size of 4 m^3 and that 80 per cent of tank volume is emptied at the time of tank cleaning,*
[5] *CT/PTs are assumed to require cleaning every 6 months and have a volume of about 9 m^3*.

Figure 2.2: **Desludging locations**



Source: Tiruchirappalli City Corporation; TNUSSP Analysis 2017

Table 2.4: **Area covered by truck operators**

Sl.No.	Station name	Area covered	Frequently visited area	Remarks
1	Anna Stadium	1. Kajamalai- JK Nagar 2. Kalkandar kottai 3. G-Corner 4. Subramaniapuram 5. Ponmalapatti 6. Karumandapam 7. KK Nagar 8. Airport 9. Gundur 10. Mathur 11. Puthur	• Kalkandar Kottai, • Ponmalapatti • Karumandapam • KK nagar	Ward numbers as per truck operator, 30, 31, 33 to 39, 47
2	Vayalur Road	1. Srinivasan nagar 2. Uyyakondan thirumalai 3. Woraiyur 4. Thillai nagar		
3	Pookkollai	1. Kattur 2. Thiruvarmbur	Area starting from Milk factory to Thuvakudi,	40,41

Source: Key informant interviews, TNUSSP Analysis, 2017

2.1.3 Issues and gaps

There is a need to undertake a comprehensive survey of the water consumption and household toilet connection arrangements to determine the actual volume of wastewater generated in the city. As the city expands, the growth in population, as well as the increase in coverage of the UGD network will connect increasingly more number of households. It is important to understand the quantity of wastewater being generated to not only plan for the safe conveyance and treatment of the same, but also understand, identify and rectify any leakages in the collection system. Annexure 1 summarises the projected wastewater generation estimates based on projected population and existing levels of domestic water supply. These estimates will need to be revised based on the detailed assessment of actual water consumption figures for the city.

2.2. Infrastructure on wastewater collection and conveyance

The city has a combination of network based and non-network infrastructure for collection and conveyance.

2.2.1 Network based Infrastructure

The collection system consists of a network of 250 to 1100 mm gravity sewers and mains, generally following the roads within the city limits. Network length covered under existing sewerage system is 331 km. Included in the collection system are two main pumping stations, 24 sub pumping stations and 26 lift stations. Sewage is conveyed to the centralised STP at Panjapur, through these sewerage systems. From the MPS 1 and MPS2 connecting to STP, the pumping mains are made of Pre-stressed concrete (PSC) pipes of diameter 1100 mm, running 6.7 km and 4.7 km respectively. The incoming sewers mains to MPSs from the SPSs, are made of Cast iron (CI) pipes of diameter ranging from 500mm to 750 mm. In Srirangam, as the ground water table is high, the depth of excavation were limited to 3 m, while the older scheme of sewerage system, the depth of excavation for laying the sewer lines went upto 5 m (TCC, 2017; TNUSSP Analysis 2017[6]).

The areas not covered under the existing sewerage scheme are proposed to be included under the network through upgrades and improvements in the existing system by implementing it under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT). TCC is planning to expand the sewerage network in phases which is detailed in section 4.

2.2.2 Non-network based Infrastructure

Conveyance and treatment of greywater:

Qualitative information available from the baseline assessment study conducted at specific locations in the city, suggest that the greywater in households having septic tanks or pits and not connected to UGD network, is discharged into open drains flowing outside the house. While this greywater is relatively free from fecal contamination, it will require treatment to remove suspended solids and organic matter before disposal into surface drains or channels.

Conveyance and treatment of septic tank effluent:

Similarly, reliable data is not available for the disposal of effluent from septic tank – which could be discharged into soakaway structures, or open drains. This data may be collected to help develop a detailed action plan to ensure proper treatment and disposal of septic tank effluent.

[6] *Key Informant Interview*

Conveyance and treatment of FS:
Households dependent on septic tanks and pits rely on the cess-pool (desludging truck) operators for emptying their OSSs . This is a demand-based system. There are about 42 private operators providing services for the emptying and conveyance of FS through vacuum trucks of varying capacities. The fees charged to households for emptying ranges from ₹ 1, 000 to ₹ 3,500 per trip. PT/CTs existing in the city limits are emptied by two TCC owned desludging trucks.

The desludging trucks dispose FS into decanting stations. The FS undergoes a preliminary treatment in these stations. There are four decanting facilities within city limits one in each zone of the TCC . They are in Anna Stadium, Vayaloor Road, Thanjavur road (Pookkollai) and Vasudevan Street located in the zones of Ponmalai, K-Abhishekapuram, Aryamangalam and Srirangam respectively. In all these facilities, the existing infrastructure is that of a pumping station, which is a part of the existing UGSS that pumps the sewage to the centralised STP at Panjapur. Vayalur Road and Thanjavur road. These pumping stations were constructed under the 1987 Scheme of UGSS, and Anna Stadium and Srirangam were constructed under 2008 Scheme. Around 2012-2013, the above-mentioned pumping stations were converted to decanting facilities with the addition of a chamber or a storage tank that could receive the FS from septage trucks.

Separate studies on the decanting stations and desludging operators in TCC have been conducted under TNUSSP. These studies detail out the present status, issues, gaps, and recommendations for improvement.

2.3. Infrastructure for decentralised wastewater/sewage treatment

The city relies on large centralised STP for the sewage and FS treatment albeit there are many small to medium sized decentralised treatment systems for treating sewage, community toilet waste, etc. Few examples of decentralised sewage/FS treatment systems is provided in Table 2.5.

Table 2.5: **Examples of decentralised wastewater / sewage treatment systems**

Sl.No.	Location	Treatment system	Details
1	Urban slum at Viragupettai, EB road	Bio methanisation Plant	Bio methanisation plant produces methane from community toilet complex for the urban slum of 2000 residents fuels the community kitchen. 500 users per day for the community toilet. Capacity of biogas reactor : 30 cu.m 250kg per day of vegetable waste It has been functional since February 2016. The toilet complex and kitchen are being managed by Sanitation and Hygiene Education (SHE) team
2	At East Devadanam	DEWATS	The treatment system treats the fecal sludge generated from community toilet (20 seats) serving 460 persons. Capacity: 9 cu.m The treated water from the DEWATS system for irrigation in an area just adjacent to the toilet. SHE team manages the toilet complex and gardening. The DEWATs system is functioning since 2005.

Table 2.5: Examples of decentralised wastewater / sewage treatment systems			
Sl.No.	**Location**	**Treatment system**	**Details**
3	At Ambedkar Nagar (Tamil Nadu Slum Clearance Board housing complex)	Anaerobic baffle reactor	2 numbers of ABRs serves 432 households in the housing complex for treating the black water alone The ABRs were commissioned in 2015. No maintenance apart from pruning plants in the vicinity. Grey water is discharged into the storm water drain.
4	At Rtd Railway colony	Sewage treatment plants for GOC shops	The basic treatment processes includes a collection tank, a sedimentation tank and a filter system. From collection tank to Sedimentation tank, the connection is under ground. From sedimentation tank to filter system, the pipes are laid above ground. The effluent from the filter system, collected in an open channel, surrounded by the unit and it leads to a bigger drain
5	At Yatri nivas	Eco ozotex advanced process	Wastewater generated by the building complex at Yatri Nivas is treated using an advanced oxidation process called Eco ozotex. It treats both black water and grey water . Capacity: 100 cu.m. At present the effluent quantity is 40 cu.m to 60 cu.m
Source: TNUSSP Analysis 2017			

Since STP is playing an important role in catering to the bulk of the treatment of FS and sewage, a detailed assessment of STP infrastructure was carried out.

2.4. Sewage treatment infrastructure

Combined sewage and FS decanting at pumping stations is conveyed to the centralised STP at Panjapur, located about 7 km from the Tiruchirappalli railway station to the east of the Madurai Road. The site is bounded on the west by the Madurai Road and on the east by the Koraiyar River. The site covers about 498 acres of land of which about 30 acres are currently utilised for the disposal of construction and demolition wastes, with the majority of land dedicated to providing sewage treatment facilities.

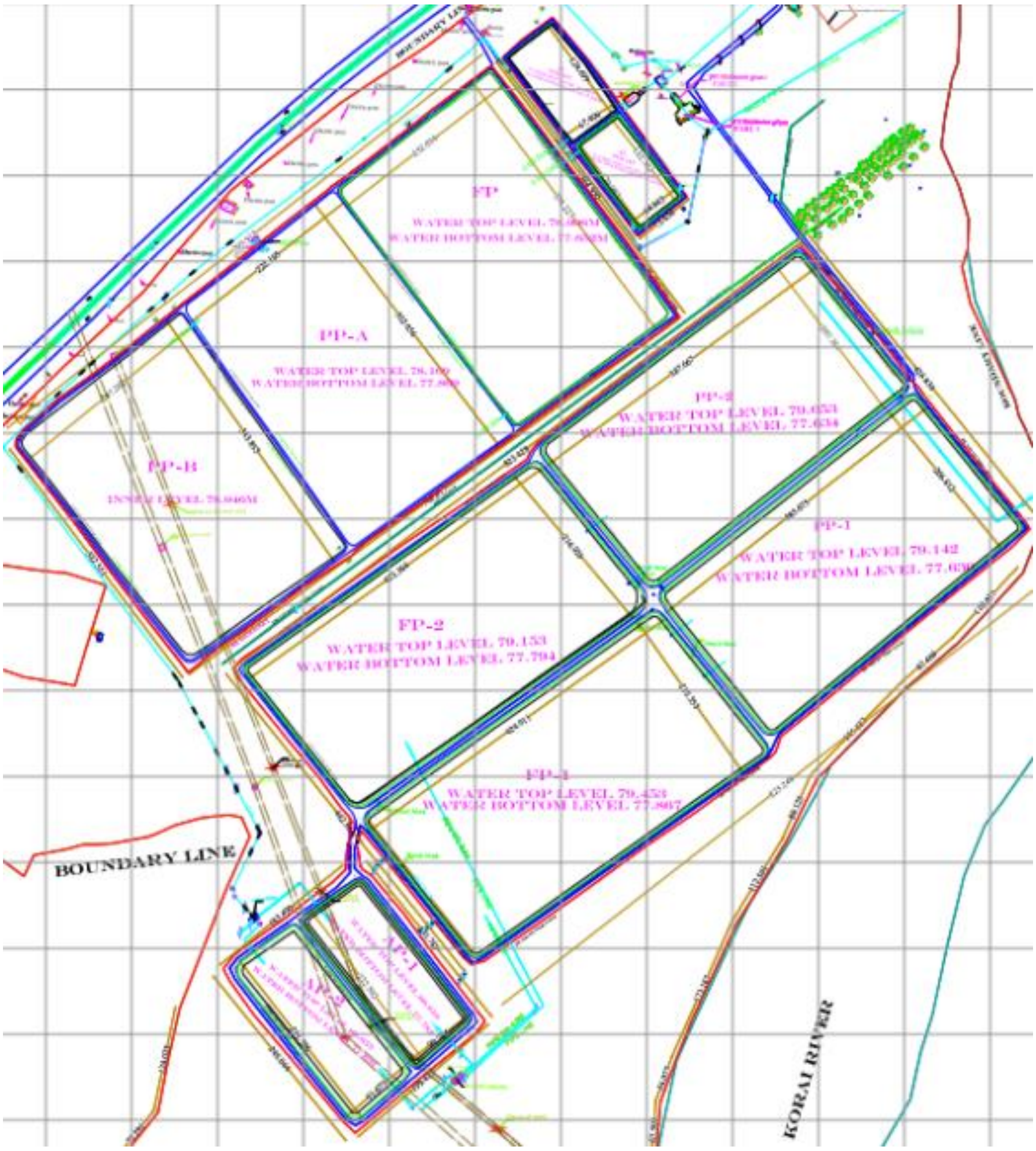
In the existing STP at Panjapur, there are two plants of capacity 30MLD and 58 MLD. The 30MLD plant was constructed in 1987 with lagoon system and augmented later in 2003 under National River Conservation Plan (NRCP) by providing pre-treatment units and anaerobic ponds. Additionally, the 58MLD STP was constructed with WSP process technology. Hence, the total installed treatment capacity is 88 MLD. At present, the 58 MLD plant is functioning while the 30MLD plant is defunct. The defunct 30 MLD STP has two Anaerobic Ponds (APs), two Facultative Ponds (FPs) and one Maturation Pond (MP). The 58 MLD has a screen chamber, grit chamber, two APs, two FPs and two MPs maturation ponds.

The sewage from the city reaches the STP as two separate lines from each of the main pumping stations. Figure 2.3 shows the layout of STP consisting of 58 MLD and 30 MLD ponds. As-built drawings of STP, showing dimensions, geometry and elevation of all components and locations is provided in

Annexure 2. The details of the STP components are shown in Figure 2.4. The figure illustrates the two treatment trains.

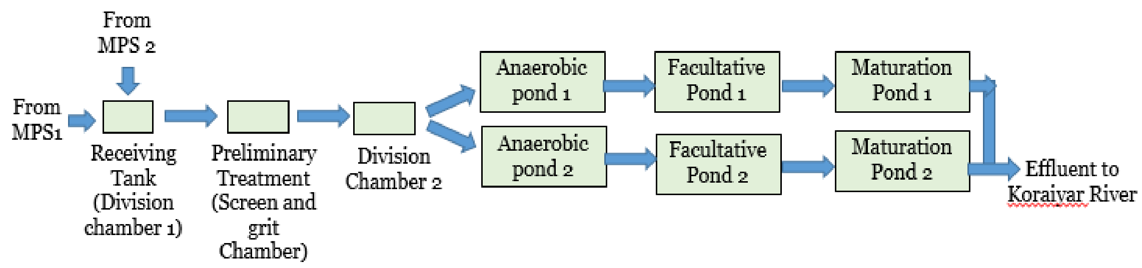
Treatment train 1: AP1 to FP 1 to MP 1.
Treatment train 2: AP 2 to FP 2 to MP 2.

Figure 2.3: **STP layout**



Source: TNUSSP Analysis, 2017

Figure 2.4: **STP Components**



Source: Tiruchirappalli City Corporation, 2008

2.4.1 Components of STP

Division Chamber 1

Division Chamber 1 is a valve control station that sends effluent either to the old treatment plant (head works and three ponds no longer functioning) or to the head works that leads to the six cells that are operational. Valves should be checked for ability to close.

Pre-treatment units

The pre-treatment units, also known as 'head works' include

1. Flow meter: The flow meter is an electromagnetic unit that is non-functional (Figure 2.5). It is unknown where the failure is or why the unit is not working.
2.

Figure 2.5: **Electromagnetic Flowmeter**

Source: TNUSSP Analysis, 2017

3. Screening system: Screening system: The screening system has both coarse and fine bar screens. Coarse screen is manually cleaned while fine screen is a mechanically cleaned (Figure 2.6).

Figure 2.6: **Screening system at head works**

Source: TNUSSP Analysis, 2017

4. The grit chamber collects the grit and then forces it out of the system using a mechanised rake. The rake pushes the grit over the side of the plant where it is collected ideally into containers (mobile storage units) that can be covered and easily moved. The containers are no longer present.

Division Chamber 2

It is a valve box that directs flow to either of the two anaerobic cells or to the bypass line, that sends the wastewater directly to the river with no treatment. Valves in this unit should be serviced so that they open and close freely and tightly.

The current mode of operation is in two parallel treatment trains. AP1, FP1 and MP1 is the first train, AP2, FP2 and MP2 is the second train (Figure 2.4). The function of the division chamber is to split the flows from the head works evenly to the two anaerobic ponds. Indications from the sampling and analysis are that the balance may be off, implying that the flows are not even between the two trains. This is evidenced by the analytical data presented in the annexure 3 and detailed evaluation of components (Preliminary treatment works and the treatment train) is presented section 2.6.3

2.5. Infrastructure for FS co-treatment in STP

FS is received in four designated decanting facilities stations and co-treated in the STP. Decanting stations are provided with screens and grit removal units. These decanting stations are sewage pumping stations, consisting of a collection well, screen and grit removal system and pumping well. As FS is disposed in the collection well sewage is mixed with FS and it passes through the screen chamber where there is a coarse screen and a fine screen and followed by grit removal. It works on simple gravity separation with a mechanical grit removal system. Decanting stations are provided with screens and grit removal units. Finally, from the main pumping well, it is pumped to the STP.

2.6. Operation and Maintenance of network, decanting stations and STP

Operation and Maintenance (O & M) of the network and non-network system are discussed in the following sections. O & M activities relevant for the processes in STP is discussed separately as it covers recommendations, especially for the technology of WSPs.

2.6.1 O & M of sewerage network

O & M of pumping stations

There are 52 pumping station in operation for the underground network in Trichy:

- 10 High Tension (HT) Stations
- 16 Low Tension (LT) Station
- 26 Lifting Stations

TCC contracts out to the private sector for operation of the treatment plants and pump stations. Contracts are given for a period of one year. The pumping stations are maintained by private electrical firms which provide services for motor operation, securing the site and minor repairs (below ₹ 2000). For major problems TCC calls for tenders.

For O & M of pumping stations, TCC has contracted with two private firms: Balajee Electricals which handles 36 pumping stations and Power Electrical Works-which handles the remaining pumping stations. Both firms are employed under electrical contracts as most of the work related to the pumping stations are electrical in nature. Earlier, when centrifugal pumps were used, employees with mechanical backgrounds were required. Civil contracts are required for tasks such as renovation of the pumping stations. Such contracts fall under the responsibility of the TCC Junior Engineers.

In all the pumping stations, a common issue is the poor maintenance of screen and grit removal systems. These are not functioning in most of the pumping stations. Also, provisions for screenings and grit disposal is not organised or absent.

O & M of sewerage network systems[7]

Currently, the TCC staff operate and maintain the sewerage network. The area Junior Engineers (JEs) are responsible for the O & M of the network. The complaints are communicated through telephone or WhatsApp by the local residents. Once a complaint is received, the corresponding zonal JE takes the responsibility in informing Assistant Executive Engineer (AEE, Mechanical) who then gives the permission for dispatching the vehicle or equipment with proper safety measures to resolve the complaint. The predominant reported problem is clogging and blockages of the network. Another problem specific to rainy season is water entering the network through manholes resulting in overloading of the network and overflow.

TCC owns the following equipment:

1. jet rod machines (4)
2. mini jet rod machines (4)
3. desilting machines (4)

The AEE Mechanical is responsible for maintenance of the above equipment.

Issues: Pipes from the jet rod machines might not be long enough to reach the blockage, as sewer lines in some areas are 5 m below ground level. It may also lack sufficient pressure to clean the blockage. After clearing the blockage, the workers face the difficulty of retrieving the pipe back to ground. Current

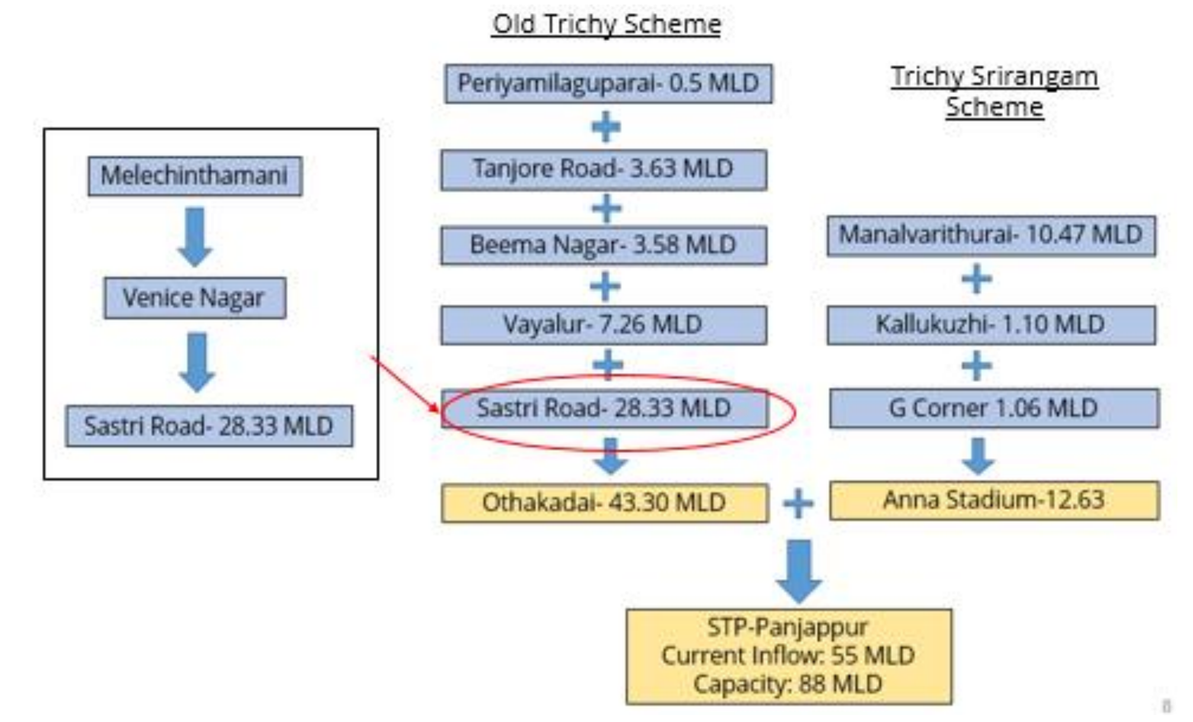
[7] *Key informant interviews, TNUSSP Analysis 2017*

practice to address the blockage involves excavating a considerable quantity of earth. If the blockage is on a highway of two-way traffic, it hinders vehicle movement and cause commotion. Identification of manholes covered under the paved road is also an issue.

An analysis of the sewerage network was done to estimate exfiltration and to assess difference in inflow and outflow of sewage in pumping stations. The city has 52 pumping stations, of which, Shastri Road pumping station receives the highest inflow (Figure 2.7). This pumping station and its stretch of sub pumping stations was taken for analysis. Actual sewage pumped was estimated from the running hour data over two years. A similar analysis was done by comparing the inflow to the sub pumping stations during rainy days for the year of 2015 (subjected to available rainfall data). The findings of the analysis are:

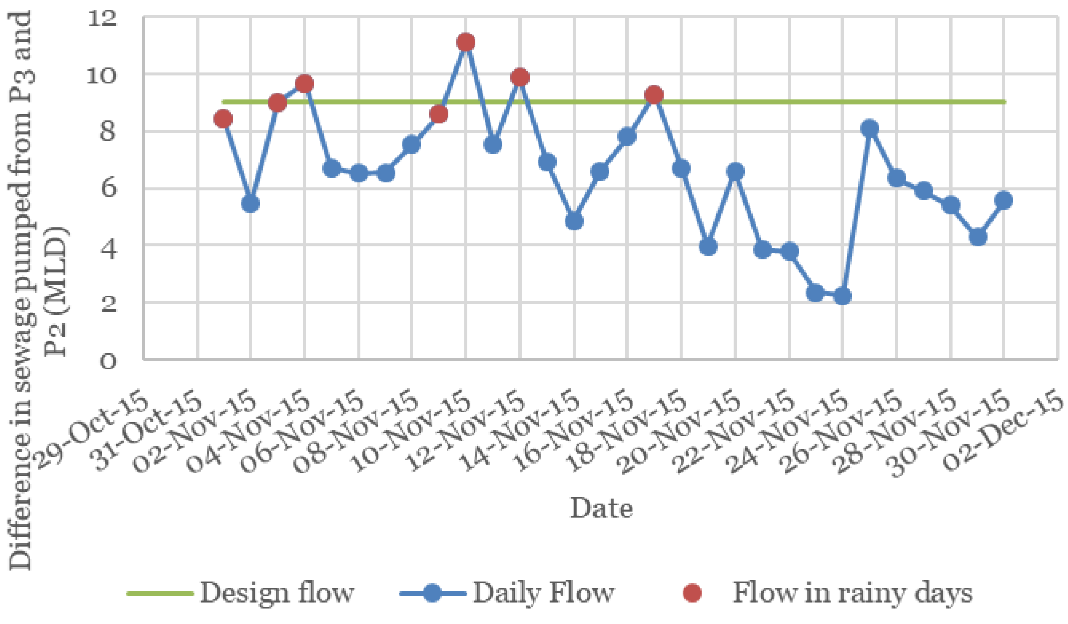
1. Approximately 30% of the untreated sewage is exfiltrating to the environment (Table 2.6)
2. The Shastri Road pumping station is meeting its design outflow only on rainy days (Figure 2.8)

Figure 2.7: **Sewage flow to STP from pumping stations**



Source: Tiruchirappalli City Corporation

Figure 2.8: **Impact of rainfall on network**



Source: Tiruchirappalli City Corporation; TNUSSP Analysis 2017

Table 2.6: **Inflow and outflow estimated in the pumping stations**

Sl No.	Pumping Station	Design flow based on population served	Inflow (MLD)#	Outflow (MLD)*
1	Melechintamani	None	Not known	6
2	Venice Nagar	6	12	12
3	Shastri Road	9	21	14

*Daily Average Flow for the year 2017 calculated (MLD); #calculated'
Source: TNUSSP Analysis, 2017

2.6.2 O & M of decanting stations

In TCC, 41 private vehicles are used for cleaning septic tanks. For regularising these private vehicles as per council resolution no. 20, license fees of ₹ 2,000 is collected per year per vehicle. A tipping fee of ₹ 30 is collected per truck to discharge FS at the four decanting stations.

The total amount collected as license fees for the year 2015-16 was ₹ 62,000; and the tipping fee charged for 2,874 trucks at the above designated locations was ₹ 86,220 (between 01.04.2015 and 31.05.2016). Since the decanting stations are existing pumping stations also, O & M practices are same as that of the pumping stations (as explained in section 2.5.1)

Issues: decanting stations

At the decanting stations: some examples of poor O & M practices include:

1. No usage of Personal Protective Equipment (PPE) for workers or drivers
2. No proper record keeping on septage trucks (number of trucks are identified but not volume)
3. No controls over septage receiving. Anyone can dump anything in the receiving well. There is no manifest system so there is no tracking of waste that might be harmful to the treatment plant
4. Health, safety and hygiene components are lacking. There is no immunisation for septage workers; hand wash station is not properly equipped with soap and towels for drivers; lock out-tag out rules for electrical safety are not followed.

Effectiveness of existing system and operations

Visual observation indicates infrequent screening and grit removal. The vegetation growing in the grit removal basin at Anna stadium indicates that the system has not been used in several months. Field observations and status of the preliminary treatment units at each of the decanting facilities is summarised in Table 2.7.

Table 2.7: **Comparison of status of the preliminary treatment units in all decanting facilities**

Sl.No.	Decanting station	Provision for disposing FS	Screen Chamber	Grit Chamber
1	Anna Stadium	A small inlet chamber was constructed, but at present it is not functional. FS is directly disposed into the collection well	The screen does not seem to be functioning. One of the reasons is that the screens are placed vertically. Vertical placing of screens makes it difficult to manually clean the screenings	Grit chamber works on simple gravity separation. Grit removal system is not functional. Grit pumps are not working.
2	Vayaloor Road	The inlet opening for disposing FS from trucks and intermediate storage tank are both operational.	The screen is poorly functioning. The spacing between the bars is not equal, some are too wide making it easy for the floating debris to pass through. Screens are placed inside the collection well making it difficult to remove the screenings.	Grit chamber works on simple gravity separation. Grit removal system is not functional. Grit pumps are not working
3	Thanjavur road	The provision was permanently closed because of complaints raised by adjacent TNEB[8] office and trucks were advised to discharge in the screen well.	The screen is poorly functioning. Screens are placed inside the collection well itself, which makes it difficult to remove the screenings.	None. Design has a grit chamber, but has not been in use for a long time. There are no grit pumps.

[8] *Tamil Nadu Electricity Board*

Table 2.7: **Comparison of status of the preliminary treatment units in all decanting facilities**				
Sl.No.	**Decanting station**	**Provision for disposing FS**	**Screen Chamber**	**Grit Chamber**
4	Vasudevan Street	None	The screen is functional and maintained	Works on simple gravity separation. Grit pumps are not working.
Source: TNUSSP Analysis, 2017				

2.6.3 O & M of STP

For the STP at Panjappur, the electrical and O & M contract has been out sourced to Power Electrical works. Their scope of work includes labour for:

1. Motor O & M ;
2. Sludge/silt removal; and
3. Pond cleaning and general housekeeping.

In addition, there is a private sector firm contracted for routine O & M activities at the STP. This includes weed and vegetation removal, berm and dyke repair, and general housekeeping. The effectiveness of the existing system and operations was assessed through a combination of field observations, measurements, sampling and lab testing.

Effectiveness of existing system and operations

STP was originally designed to accommodate 2020 lps from main pumping station 1 (MPS1) and 1337 lps from MPS2, as a peak instantaneous flow, or 88 MLD as a peak daily flow (TCC, 2008) for the entire WSP system. Influent BOD was estimated at 270 mg/l and COD at 650 mg/l. Current flows appear to be approximately 45 MLD to the head works, although a large portion of this is diverted to the old treatment system where the effluent ponds on the ground surface. Flows are much lower than would be expected if both pump stations were running full time. Actual performance of the system is not sufficient to meet effluent discharge standards. The Central Pollution Control Board (CPCB) 2013 report (Table 2.8) has performance data on Trichy WSP showing 74% removal for both BOD and COD, but no date is given. In March 2017, the investigating team under this assessment conducted comprehensive sampling and analysis of the STP. The results are summarised in Table 2.9. Key points are the removal efficiency of BOD and COD: 59% removal of BOD and 57% removal of COD.

Table 2.8: **Performance data on Trichy STP-CPCB 2013 report**						
Sl. No	**Inlet**		**Outlet**			
	BOD (mg/L)	**COD (mg/L)**	**BOD (mg/L)**	**% Removal**	**COD (mg/L)**	**% Removal**
1	100	286	26	74%	75	74%
Source: Report on Performance of STP by Central Pollution Control Board 2013t						

Table 2.9: **Removal percentage based on sampling**							
Sl No.	**Parameter**	**Average Results (mg/L)**		**Compliance with Discharge Standards**		**Per cent (%) Removal**	
		Head works	**Final Outlet**	**1986 Standards**	**2020 Standards**	**Expected**	**Actual**
1	Sample Type	composite	grab				
2	BOD @ 20°C for 5 days	103	42	no	no	95% to 97%	59%
3	COD	303	130	yes	no	---	57%
4	Total Suspended Solids (TSS)	163	40	no	no	90% to 95%	76%
5	Ammonia Nitrogen as NH4-N	32	21	yes	no	---	35%
6	Total Nitrogen as N	45	27	yes	no	---	39%
7	Fats, Oil, and Grease (FOG)	not measured		---	---	---	---
8	Fecal Coliform (MPN/100 mL)	1600		none		95% to 98%	0%
Source: Chennai Mettex Laboratory Pvt Ltd 2017, TNUSSP Analysis 2017							

Notes:

- adjusted average results from sampling on March 22, 25, and 27, 2017
- Discharge Standards are listed in Table 2.11
- % Removal Expected from CPHEEO, 2012
- % Removal Actual = (head works - final outlet) / head works
- See Annexure 3 for complete report on sampling and analysis.

Major reasons for unsatisfactory performance of the STP appear to include:

1. Sludge build-up and carry-over of algae between the ponds
2. Short circuiting
3. Uneven distribution throughout the system.

The algae present an issue in achieving regulatory compliance:
'70-90% of the BOD of the final effluent from a series of properly designed WSP is due to the algae it contains, and "algal BOD" is very different in nature to "sewage BOD". Thus, many countries permit a higher BOD in WSP effluents than they do in effluents from other types of treatment plant, or they make some other allowance for WSP effluents. Also, in WSP effluents the algae comprise most (>80%) of the suspended solids.' [Mara, pp 29-30].

Mara explains that 'The algae in WSP effluents readily disperse and are consumed by zooplankton in receiving waters, so they have little chance to exert their BOD, and during daylight hours produce oxygen. In agricultural reuse schemes pond algae are very beneficial: they act as slow-release fertilisers and increase the soil organic matter, thereby improving its water-holding capacity.'

Other observations from site visits and analysis of samples from the inlet and outlet of the plant are as follows:

1. Differences between AP1 and AP2 were also observed, which might be caused by vegetation, which is thick in pond no. 1 but removed in pond no. 2. Differences between ponds may also be due to differences in accumulated solids build up. Short circuiting and uneven distribution between the two ponds may also be a contributing factor.

2. On the third day of sampling (March 27, 2017) grab samples showed unexpected results for BOD_5 and COD. One likely reason is that there is uneven distribution between the cells. This may be due to valves that may not close properly or valve boxes that may have settled. Further review is warranted for the same. Thereafter, these samples from day three could be averaged or discarded.

3. There were significant differences between the BOD values MP1 and MP2 and the outfall, which should have been close in value. The variance may be due to:
   i) unequal flow distribution
   ii) effluent discharge at different elevations within the water column
   ii) uneven sludge volume
   iv) variances within the normal range of accuracy (50% plus/minus) when grab sampling is conducted.

A complete presentation of the analytical data is provided in Annexure 3.
The TNPCB has been collecting and analysing samples for compliance monitoring and the data is available from 2008. Some points to understand:

1. These sampling events are not linked with any flow data. Knowing the flow at the time of sampling is required for proper interpretation of the analytical results of the quality of effluents. This is especially important as there may be flow diversion occurring, as was witnessed in 2017.

2. Effluent coliform counts are quite high indicating that some form of algae reduction in the maturation ponds will ultimately be required (algae can mask the UV radiation which limits natural disinfection capabilities). Even when functioning at peak efficiency, maturation ponds should be expected to remove fecal coliform levels to 1,000 coliforms MPN/100ml. This is sufficient to meet the October 2017 discharge standards. Algae can be controlled by adding aeration and/or improving outlet structures.

3. It should be noted that the analytical results from the 2017 sampling event are also quite different from the analysis performed by the CPCB between 2013 and 2016. Those results were substantially different from what was shown in 2017. Different sampling methods, different laboratories, and the four years of additional sludge and solids accumulation may account for some of the variability.

Moving forward, a long term monitoring programme is essential, including monthly and quarterly sampling and analysis; laboratory Quality Assurance and Quality Control (QAQC).

Under current operating conditions, the coverage and effectiveness of the existing WSP is inadequate for the safe treatment and disposal of sewage and septage for current flows. **However, the underlying components of the system were designed well enough that through i) rejuvenation of the existing components ii) redesign of pond outlet structures and iii) improving distribution of wastewater through the cells to reduce short circuiting and balanced flow, the system can be expected to function as needed to treat current and some future flows including some septage.**

Preliminary treatment works

1. Screen Chamber: Accessibility to for cleaning the coarse screens is in poor condition. One of the fine screens are partly broken.

2. Grit chamber: The grit chamber (Table 2.10) is in poor condition and is not functioning. The issues with the grit chamber include:
    a. non-functioning motors
    b. unlevelled v notch weir with broken teeth
    c. grit accumulation
    d. discharge system and grit collection system absent

Table 2.10: **Preliminary treatment units in need of repair**	
	
V notch weir in need of repair and levelling	Up close image of grit chamber motor. Grit rake is in need of repairing.
Source: TNUSSP Analysis, 2017	

Anaerobic ponds 1 and 2

- Results of sampling and analysis (Annexure 3) shows the poor performance of the APs. It is significant that AP 2 appears to have a higher removal efficiency than AP1. Possible explanations include:

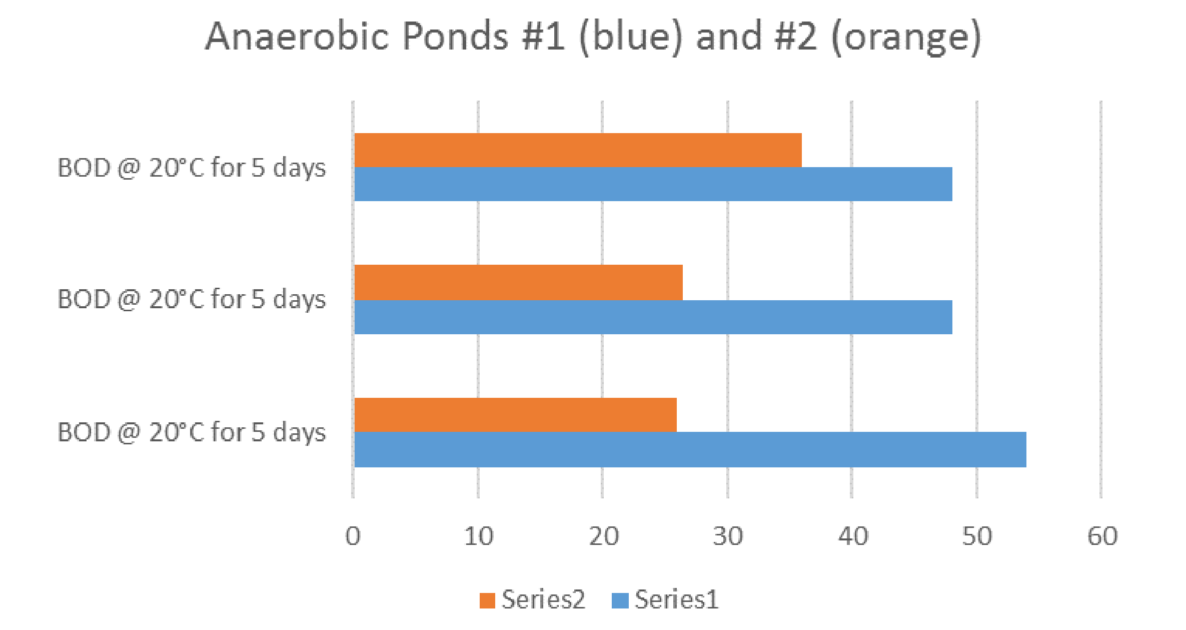
    i. the removal of vegetation from AP 2 while not for AP1 (Figure 2.9)
    ii. different volumes of wastewater entering the ponds due to lack of proper balancing at division chamber 2
    iii. different levels of sludge
    iv. different levels of short circuiting.

Figure 2.9: **Anaerobic Pond with Surface vegetation**

Source: TNUSSP Analysis, 2017

- Figure 2.10 shows the BOD measurements for APs and illustrates the point that AP 2 appears to have a higher removal efficiency than AP1. Over the three-day sampling period, AP 2 consistently outperforms AP1. Again, the most likely explanation is uneven distribution from the division chamber, although other factors may also be involved

Figure 2.10: **BOD Measurements for Anaerobic Ponds**



Source: TNUSSP Analysis, 2017; Chennai Metex Laboratory, 2017

The function of the anaerobic ponds is to reduce organic content of the wastewater – roughly represented by BOD and TSS, hopefully by about 70%. This is not accomplished for the most part in the two anaerobic cells at Panjappur under current operating conditions. As flows increase, the key parameter to look at is loading per cubic metre of pond volume. The United States Environmental Protection Agency (USEPA) recommends a BOD loading of 0.3 kg/m3 day as a design guideline of volumetric loading for anaerobic ponds.

At 58 MLD assuming 270 mg/l, BOD loading = 0.15 kg BOD/m3 per day at 1.61 days detention time

At 88 MLD assuming 270 mg/l, BOD loading = 0.23 kg BOD/m3 per day at 1.06 days detention time

This means that even at 88 MLD, the existing anaerobic ponds (two cells) are sufficient to accommodate loading from sewerage plus some septage, even though the detention time is somewhat less than ideal.

Facultative ponds 1 and 2.

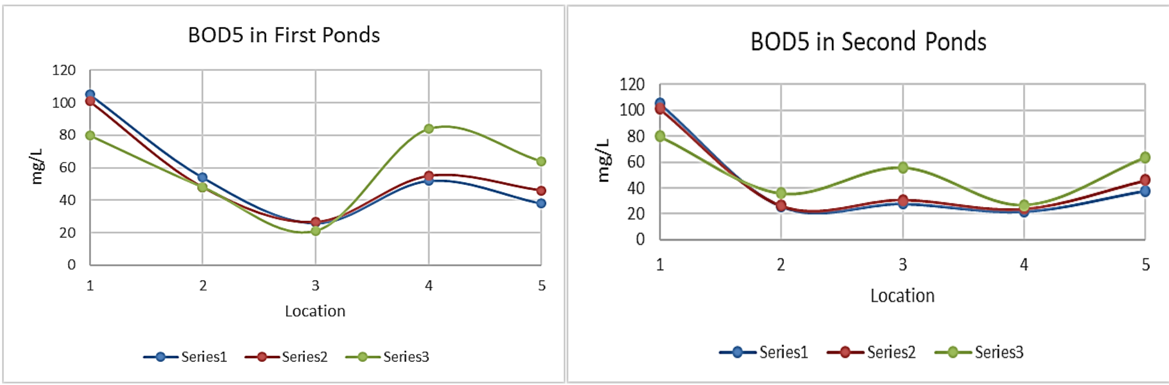
Analytical results from the testing of FPs (Figure 2.11) provide some clues as to each unit's operation. Figure 2.12 illustrates the removal of BOD from treatment train 1 (first ponds) and treatment train 2 (second ponds). Here, location 2 is the outlet of the Aps and location 3 is the outlet of the FPs. Treatment train 1 shows fairly consistent removal efficiency over the three days of sampling. However, there are some anomalies with treatment train 2. In this train, BOD increases slightly indicating the removal mechanism is not functioning properly. The most likely reasons are uneven loading and short circuiting.

Figure 2.11: **Facultative ponds**

Source: TNUSSP Analysis, 2017

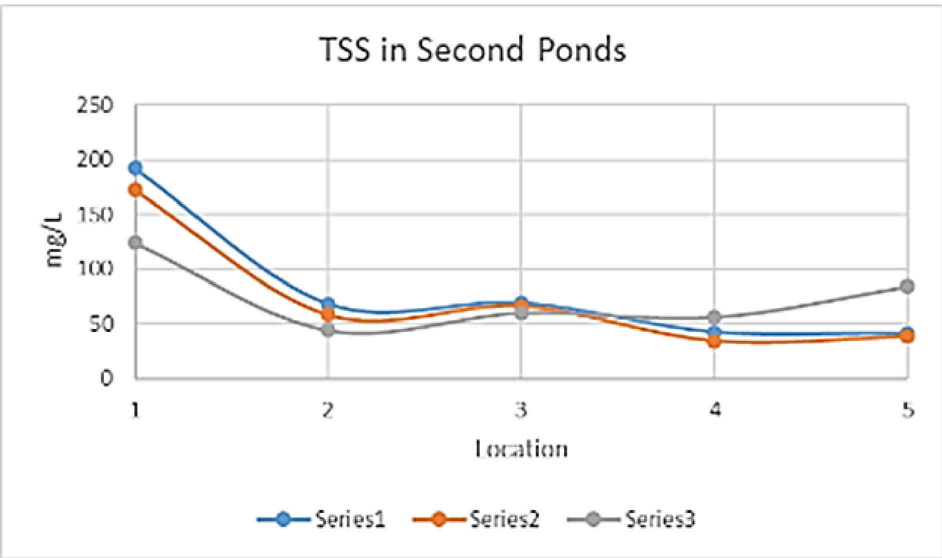
The FPs should achieve significant reductions in BOD, TSS, and ammonia nitrogen. According to the data from the 3-day sampling event, this is not happening currently, especially in treatment train 2. Each of these parameters is only marginally affected. It is a clear sign of short-circuiting.

Figure 2.12: **BOD5 in Facultative Ponds**



Source: TNUSSP Analysis, 2017; Chennai Metex Laboratory, 2017

Figure 2.13: **TSS removal from Treatment Train 2**



Source: TNUSSP Analysis, 2017; Chennai Metex Laboratory, 2017

Figure 2.13 shows TSS removal from treatment train 2. Notice that between the outlet of the AP and outlet of the FP there is no significant TSS reduction. This is an additional indication that the treatment mechanism in the s is not functioning, most likely due to short circuiting.

At current and anticipated flows until 2020, the FPs after the short circuiting issue is addressed, should achieve BOD and TSS of 30 mg/L most of the time (30/30). During the rainy season, this may or may not be possible to achieve. There will be dilution as evidenced by the infiltration rates, but additional loads from non-point source pollution coupled with the lower biological activity in the ponds will likely degrade effluent quality. For FPs to achieve 30/30 all year round, some oxygenation of the ponds through solar powered pond recirculates or other aeration technology will be required. Even baffle walls improve oxygenation in pond systems. If year-round compliance is not required (if rules allow some exceptions during rainy season), no aeration or mixing would be warranted at this time.

Figure 2.14: **Facultative pond outlet structure**

Source: TNUSSP Analysis, 2017

Figure 2.14 shows the outlet structure for the FPs. It satisfies hydraulic requirements but allows surface scum and floating algae to pass through to the next pond.

Maturation ponds 1 and 2

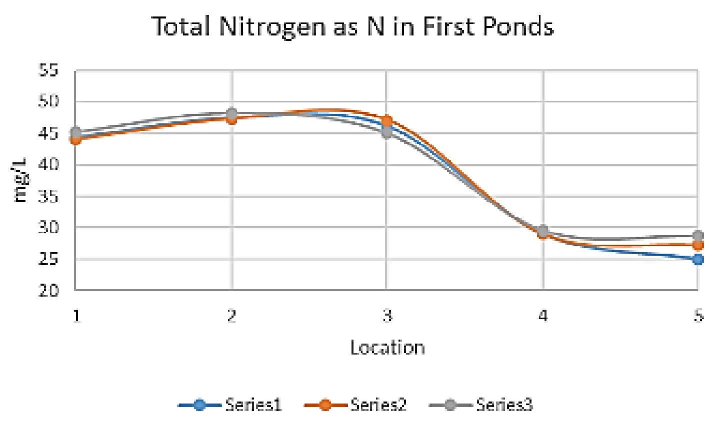
These units are functioning but not nearly as well as they should be. BOD and TSS is being reduced but there should be more nitrogen, TSS, and FC removal. The issue is linked to algae, which are growing robustly in these ponds. This reduces light transmission, which should be throughout the 1.5 m depth of the water column. The maturation ponds are also possibly affected by short circuiting, and accumulation of sludge and scum.

Figure 2.15: **Maturation Ponds**

Source: TNUSSP Analysis, 2017

One area where the MPs (Figure 2.15) appear to be working well is in Total Nitrogen (TN) removal as shown in Figure 2.16. In the figure notice the difference between location 3 (outlet of FPs) and location 4 (outlet of MPs). There is almost a 50% reduction in TN, which is in compliance with the October 2017 discharge standards.

Figure 2.16: **Graph of Nitrogen in Maturation Ponds**



Source: TNUSSP Analysis, 2017; Chennai Metex Laboratory, 2017

Final effluent discharge

Under current conditions, effluent is discharged through a single outlet pipe into the river. Figure 2.17 shows three men standing on the effluent discharge pipe. They are collecting samples for laboratory analysis. Besides showing the pipe and the receiving water this photograph shows the lack of a safe location for sampling. A platform is needed on which a worker can stand to collect samples.

Figure 2.17: **Discharge Pipe for Final Effluent**

Source: TNUSSP Analysis, 2017

Poor operations have a negative effect on the performance and treatment efficiency of STP. The critical areas of concern are listed below:

- Lack of maintenance on existing mechanical equipment has left the equipment non-functional or poorly functional. This includes the flow meter, screens, and grit chambers.
- Lack of monitoring of key operational parameters including influent and effluent parameters, as well as sludge depth in all pond cells means that there is no operational data from which to make operating decisions.
- Excessive sludge accumulation in all pond cells is assumed to contribute to high levels of BOD and TSS in the effluent. Sludge depth profiling has not been performed.
- Design flaws in the pond outlet structures, specifically for the facultative and maturation ponds has resulted in structures that do not provide for adequate separation of algae and scum.
- The transmission sewer line between the head works and the AP has settled below its original grade, which results in an air pocket in the sewer pipe, which must be alleviated by installing a proper air release valve in order to relieve the restriction and enable full flow.
- Valving and flow distribution throughout the WSP are in need of rejuvenation for the operators to be able to i) isolate individual cells for service, and ii) assure even or measured distribution of wastewater loads from one cell to the next. Inability to evenly distribute the wastewater between the two parallel treatment trains is a major concern
- Lack of controls on septage – such as a septage manifesting system, results in inappropriate loads, often containing high levels of fats, oil and grease or commercial and industrial chemicals being discharged at the decanting stations. Implementing an O & M programme for the decanting stations; implementing a manifesting system, taking random and spot checks of septage loads; diverting commercial wastes to stand-alone treatment facilities will be important in addressing this concern.
- Lack of an effective communications procedure for reporting and following up on operational or maintenance issues means that problems go unreported, with little follow up on those problems that are reported.

- Lack of a i) written O & M plan ii) employee health and safety plan and iii) emergency response plan puts workers at risk and leaves the management of the facility without a strategy to achieve compliance when problems occur.

- Short circuiting is a critical issue, which is clearly affecting the performance of both the facultative and maturation ponds and most likely in the APs.

2.7. Institutional arrangements

The following section describes the involvement of essential stakeholders in the service deliveries across the sanitation value chain, which are access and containment, conveyance, and treatment.

2.7.1 Emptying & transportation

Network

When there is reporting of a blockage or overflow or a complaint, the corresponding zonal JE takes the responsibility in informing the AEE mechanical who then gives the permission in dispatching the vehicle or equipment with proper safety measures. Also, each ward has a Sanitary Supervisor (Health), who sometimes conveys the problem to JE through walkie-talkie, who then takes action.

The city has enough t personnel to carry out the work but has issues on efficiency of the equipment that are used (discussed in section 2.4.1). Problems reported are most likely resolved on the same day itself. Problem areas like bus route, bus stand and market places are prioritised. On an average it takes about two hours to resolve the problem.

Pumping station

There are 52 pumping stations. At present, the contract has been given to two private firms. 16 of these are maintained by Power Electrical works and 36 are maintained by Balajee Electricals. They ensure labour engagements for motor operation, carry out repair works and remove silt/sludge and screenings accumulated in the components of pumping stations. The Electrical Line Inspector (ELI) monitors or inspects the pumping station and reports to the AEE, Electrical.

Contracting to the private firms has been made for an estimate of one year. It is extended to two years with 10% increment in payment. After three years, a new estimate is made. From 2001, Balajee Electricals has been maintaining the pumping station. From 2007 Power Electrical Works has been involved. The cost estimate for O & M for 52 numbers pumping stations is approximately ₹ 30 lakh. Any repair work under ₹ 2000 is taken care by the contractor. Any repair work above ₹ 2000 is forwarded to TCC to carry out the work on tender basis. The JE informs the AEE of any other issues which are not part of the contract and is finally approved by the Executive Engineer (EE). TNEB bills are paid by TCC.

Non-Network

Sanitary supervisor under the JE is responsible for maintaining storm water drain. The actual cleaning of the drain is done by the sanitary workers. Each ward has a sanitary supervisor and a number of sanitary workers.

The desludging vehicles obtain license by submitting an application along with vehicle relevant documents to the mechanical department. Thereafter, an agreement needs to be signed between the operator and the TCC ensuring the prohibition of manual scavenging. Following this, the AEE mechanical, verifies all the documents, checks safety gadgets, explains the High court order related to ban of manual scavenging and entry of sanitary workers in to the sewerage system and septic tank. Finally, the Corporation Commissioner approves for the license.

A study conducted under TNUSSP on the desludging operators in TCC had provided an approximate of 69 desludging trucks including two TCC owned vehicles. TCC owned vehicles have two personnel including the driver. In private owned vehicles, the number may vary – on an average there are three people including the driver.

Decanting stations

Since decanting stations are pumping stations, they are maintained by private firms. Duties and responsibilities are similar including labour engagements for motor operation, repair works and silt/sludge and screenings removal.

2.7.2 Treatment

STP

The Sewage Treatment Plant is maintained by Power Electrical Works. Under contract, they provide labour engagements for motor operation. They carry out similar repair work as that of the pumping stations. Additional responsibilities included when the contract is given out for STP are removal of screenings and grit from the inlet works to be done daily without lapse and periodical cutting and removing of grass on the embankments of ponds. There are two security personnel during night hours, who exchange their duties on alternate days and there is one personnel for motor operations. Two personnel are arranged for screenings and grit removal.

Duties and responsibilities of the contractor, supervisor and operator are common across the pumping stations and STP. For the STP, two general maintenance duties are included in addition to that of the pumping stations. General conditions are same for both the STP and pumping stations, but specific duties for each facility differ. The scope of work (SOW) is provided in Annexure 4.

2.8. Environmental regulations

In October 2017, the MoEFCC promulgated the Environmental (Protection) Amendment Rules, 2017, which provides new discharge standards for municipal wastewater treatment plants, breaking down the regulations for metropolitan areas, cities which are provincial capitals, and others. Based on these regulations, the key discharge standards that apply to the STP are provided in Table 2.11.

Table 2.11: **October 2017 Discharge requirements as they will apply to STP at Tiruchirappalli**

No.	Parameters	Units	*Maximum Permissible Limit (except for pH)
1	pH		6.5 to 9
2	Biochemical Oxygen Demand (BOD)	mg/L	30
3	Total Suspended solids(TSS)	mg/L	100
4	Fecal Coliform	MPN/100mL	1000

Source: Ministry of Environment, Forest And Climate Change, 2017

Table 2.11: **October 2017 Discharge requirements as they will apply to STP at Tiruchirappalli**			
No.	**Parameters**	**Units**	***Maximum Permissible Limit (except for pH)**
Other parameters applicable as per General Standards for Discharge of Environmental Pollutants Part A: Effluents			
1	Chemical Oxygen Demand	mg/L	250
2	Ammoniacal Nitrogen (NH_4-N)	mg/L	50
3	Nitrate Nitrogen	mg/L	20
4	Free ammonia (NH_3)	mg/L	5
5	Total Kjedahl nitrogen	mg/L	100
Source: The Environmental Protection Rules, 1986			
*Note: As per the notification for the area/regions other than Metro cities(Mumbai, Delhi, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad and Pune), all state capitals except in the State of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim, Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Union Territory of Andaman and Nicobar Islands, Dadar and Nagar Haveli, Daman and Diu and Lakshadweep			

The STP at Panjappur was originally designed to meet 30 mg/L BOD and <100 mg/L for TSS discharge standards, which coincidentally the same as the October 2017 standards for these two parameters. Therefore, when properly loaded, functioning, and maintained, STP should be able to meet these design standards even when septage are added in. Nutrient compliance may influence the volume of septage liquids that can be received daily as septage has a much greater concentration of nitrogen compounds than sewage. Careful nitrogen monitoring will be required not only for the effluent from the STP but also from the influent wastewater and septage liquids, which will help to understand the loading of nitrogen in the system. The STP is capable of some nutrient reduction, as evidenced by the report provided herein. If nutrient compliance ever becomes an issue, TCC should consider either agricultural reuse instead of direct stream discharge, or nutrient reduction technology. Agricultural reuse would be the least expensive option while maximum benefit. Careful coordination with TNPCB is required to understand the possible limitations of this form of effluent management. (See section 3.3 for details on wastewater reuse).

Summary of Recommendations

3.1. Proposed solutions for sewerage network	41
3.2. Solutions for decanting stations and co-treatment	44
3.3. Proposed solutions for the STP	47
3.4. Institutional recommendations	49
3.5. Wastewater Reuse	51

3. Summary of Recommendations

The previous chapter described the present situation and identified problems/issues of collection, conveyance and treatment. The problems are related to infrastructure, O & M practises and institutions. This chapter summarises potential solutions. These solutions are developed based on the review of best practises, review of literature and the team's experience of working with sewerage and sanitation systems.

3.1. Proposed solutions for sewerage network

The following sections describe O & M activities that meet the definition of best management practices and should be considered for augmenting the existing scope of work.

1. There should be a written O & M plan which the contractors and staff are required to follow.

2. Roles, responsibilities and job descriptions should be clearly identified.

3. All documentation related to the treatment plant including as-built drawings, equipment specific maintenance manuals, and correspondence related to compliance and procedures should be readily available.

4. Lines of communication between contractors and staff should be identified with written work order requests and follow up performed.

5. The senior operator should be responsible for weekly plant inspections where deficiencies are listed. Deficiencies should be prioritised, and budget requests must be made for addressing in writing to the appropriate TCC office. A mechanism for follow up with the contractor should also be in place.

6. An operator's log book should be prepared with daily entries that include
   - pumping volumes from MP1 and MP2
   - number and volume of septage trucks received
   - deficiencies identified and communications or requests for funding made to address
   - any incidents such as accidents, injuries, deliveries, other sub-contractors working at the site
   - any changes in the operations
   - any visual or laboratory analysis.

It is the responsibility of TCC to develop a written O & M plan based on the final configuration of the chosen technology. A sample O & M manual[9] for the central facilities STPs prepared by Idaho National Laboratory (INL- the INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance), February 2011 may be referred.

3.1.1 Sewerage network

Cleaning: Using proper tools for cleaning saves time and money. Table 3.1 summarises different cleaning methods. There many high-pressure hydraulic sewer cleaning systems in the market today. The skid mounted hydraulic jetter (Figure 3.1) has 520 feet of hose and operates at a 4,100 PSI. There

[9] https://inldigitallibrary.inl.gov/sites/sti/sti/4886685.pdf

are also several truck options (see below). In addition to skid mounted units, TCC may consider investing in one modern rodding truck (Figure 3.2).

Figure 3.1: **Skid mounted hydraulic jetter**

Source: http://www.anconservices.com/municipal.php

Figure 3.2: **Jet Rodder Truck**

Source: http://www.anconservices.com/municipal.php

Additional recommendations for sewer line maintenance:

1. Review USEPA best practices guide to municipal sewer O & M[10]

2. Develop a written O & M plan for the sewer system including i) monitoring visually and remotely ii) preventative maintenance and cleaning and iii) implementing commercial pre-treatment programme (see Annexure 5).

3. Ensure budgets are adequate to fund the plan.

Inspection techniques[11]

Inspection programs are required to determine current sewer conditions and to aid in planning a maintenance strategy. Ideally, sewer line inspections need to take place during low flow conditions. If the flow conditions can potentially overtop the camera, then the inspection should be performed during low flow between midnight and 5 a.m., or the sewer lines can be temporarily plugged to reduce the flow. Most sewer lines are inspected using one or more of the following techniques:

1. Closed-circuit television (CCTV)

2. Cameras

3. Visual inspection

4. Lamping inspection which is the use of reflected sunlight or a powerful light beam to inspect a sewer between two adjacent manholes. The light is directed down the pipe from one manhole. If it can be seen from the next manhole, it indicates that the line is open and straight.

Table 3.1: **Common Sewer Cleaning Methods**

Sl.No.	Technology	Uses and applications
		Mechanical
1	Rodding	Uses an engine and a drive unit with continuous rods or sectional rods.
		As blades rotate, they break up grease deposits, cut roots, and loosen debris.
		Rodders also help thread the cables used for TV inspections and bucket machines.
		Most effective in lines up to 300 mm (12 inches) in diameter.
2	Bucket Machine	Cylindrical device closed on one end with two opposing hinged jaws at the other.
		Jaws open, the material is scraped off and deposited in the bucket.
		Partially removes large deposits of silt, sand, gravel, and some types of solid waste.
		Hydraulic

[10] https://www3.epa.gov/npdes/pubs/cmom_guide_for_collection_systems.pdf

[11] USEPA Sewer System Fact Sheet – Sewer Cleaning and Inspection - https://www3.epa.gov/npdes/pubs/sewcl.pdf

Table 3.1: **Common Sewer Cleaning Methods**		
Sl.No.	**Technology**	**Uses and applications**
3	Balling	A threaded rubber cleaning ball that spins and scrubs the pipe interior as flow increases in the sewer line.
		Removes deposits of settled inorganic material and grease build up.
		Most effective in sewers ranging in size from 13-60 cm (5-24 inches in diameter).
4	Flushing	Introduces a heavy flow of water into the line at a manhole.
		Removes floatables and some sand and grit.
		Most effective when used in combination with other mechanical operations, such as rodding or bucket machine cleaning.
5	Jetting	Directs high velocities of water against pipe walls.
		Removes debris and grease build-up, clears blockages, and cuts roots within small diameter pipes.
		Efficient for routine cleaning of lines with small diameter, low flow sewers.
Source: https://www3.epa.gov/npdes/pubs/sewcl.pdf		

For more information on the specific procedures, refer to the full EPA document.

3.2. Solutions for decanting stations and co-treatment

Rehabilitation of valves, screens and grit chamber, along with implementation of a manifest system to track loads. This would provide better accounting for the septage. Table 3.2 summarises the suggested solutions for co-treatment and decanting stations.

Table 3.2: **Best practices for co-treatment**			
Sl.No.	**Best Practice**	**Trichy**	**Remarks**
Truck contents			
1	Best Practice is a manifest system recording source and location of where septage is collected. Industrial septage should not be added.	No manifest system	Establish a manifest system

Table 3.2: **Best practices for co-treatment**			
Sl.No.	**Best Practice**	**Trichy**	**Remarks**
2	Commercial septage with high content of food-oil-grease (FOG) should not be added at the decanting station because it can clog sewer pipes.	No separation; all septage delivered to the decanting station is accepted.	Establish • a monitoring system to assess the quality of FS being discharged at facility • a framework guiding acceptance of FS from different sources and of varying quality • alternative disposal location for commercial septage loads
Decanting Station			
3	Worker health, safety and hygiene	Minimal	see section 3.4.3
4	Pre-treatment of FS: Screening and grit	Not operating, needs maintenance	see section 5.2.3 and 5.2.4
5	FS flow and quality measurement to ensure that volume of load from septage does not exceed STP design loadings for BOD and TSS	Pump capacity multiplied by operating hours measured by a wristwatch or mobile phone	Overtime, pump capacity changes so current capacity should be measured and hour-run meters should be installed
6	O & M of decanting station, presence of trained and qualified operators	See section 2.6.2	See section 3.5
Source: TNUSSP Analysis 2017			

Additional suggestion for co-treatment: Institutional and operations play an important role in effective co-treatment. Septage, especially from commercial sources, may contain chemicals that are toxic to the wastewater treatment process. It is for this reason that every septage load coming into the treatment plant must be evaluated before it is discharged into the system. Checking can be quick, accurate and inexpensive. It involves:

- testing the load for pH, which must be between 6 and 9
- testing the load for conductivity which must be less than 1,000
- looking at the colour, which should be grey, brown or black; and
- noticing if there are odours of hydrocarbons or chemicals in the waste

If any one of these conditions exist, the load must be segregated and discharged into a stand-alone treatment basin specifically for the processing of commercial septage.

3.2.1 Implement a manifest system to track loads

This would provide better accounting for the septage. For septage transportation, the manifest form should include the following information (Figure 3.3):

- Date and time of collection at source
- Address of the place where septage was collected
- The source: residential, commercial, institutional
- If commercial or institutional – describe type of operation of the entity
- Volume of waste collected
- Name and signature of occupant/owner of building where waste was collected
- Name and signature of the driver
- Location of the place where waste is to be delivered
- Date and time of when the waste was delivered for decanting
- Name and signature of the operator at the decanting station

Figure 3.3: **Septage Manifest form**
Part 1: Proposed form-Collection; Part 2: Proposed form-Delivery

TCC SEPTAGE COLLECTION & DELIVERY FORM

COLLECTION

1	DATE		TIME		
2	SEPTAGE SOURCE	RESIDENTIAL		DETAILS	
		COMMERCIAL			
		INSTITUTIONAL			
3	ADDRESS				
4	NAME OF PERSON AT ADDRESS [Owner, Manager, Employee]				
5	VOLUME COLLECTED (cubic meters)				
6	COLLECTED BY				

DELIVERY

7	DELIVERED TO				
8	RECEIVED BY				
9	DATE			TIME	
10	OBSERVATIONS	color			
		odour			
		appearance			
11	REMARKS				

Source: TNUSSP Analysis 2017

3.2.2 Safety recommendations

- A hand wash station should be provided for all drivers and workers along with signage on the rationale for washing hands after handling hoses and equipment.

- There should be incentives for wearing PPE. Drivers could get a cash bonus if they are properly equipped. It should be mandatory for the on-site worker (incentives here can also be very effective).

- Record keeping should be improved. A manifest system would be ideal, but some recording of how large the truck is (how many cubic metres of septage has been discharged) and the source or origin of septage is the minimum information to be maintained.

- Daily tallies of septage discharged at the decanting station should be compiled and sent to the STP operator.

- There are no procedures for sampling a load of septage when it comes into the facility. The manifest system will help to identify the origin of the load. If suspect, operators should i) fill a 2 litres container from the truck ii) observe it for odour of hydrocarbons or other chemicals iii) observe it for high concentrations of grease, check the pH using litmus paper, which should be between 6 - 9. If hydrocarbons, grease or high or low pH is found, the load should not be accepted. If none is found, the load can be discharged. This procedure will require training the operators to implement.

- Night hour monitoring and recording should be established.

3.3. Proposed solutions for the STP

Best practices include i) proper loading to ensure loading does not exceed design capacity ii) O & M of facilities to ensure they are working as designed and iii) desludging, which goes beyond routine O & M and is critical to keep the system functioning properly. Table 3.3 illustrates some of the activities, practices and solutions for the effective outcome of STP operations. Detailed action plan for the issues identified are in chapter 5. Annexure 6 has detailed best practises for O & M of WSP.

Table 3.3: **Best practices for STP operation and proposed changes/solution to issues**

No	Best Practice	Trichy STP	Proposed changes/ solutions
		DESIGN	
1	Measure flow	Flowmeter not working	Fix the existing flow meter ii) install a new flow meter such as a Parshall flume (see discussion below) or iii) first calibrate the pump chambers at the main pumping stations so the operator knows how much volume is pumped per minute, and record volumes daily. A procedure is provided for this in Annexure 7.
2	Remove solids and floating debris before APs to maintain liquid volume capacity.	Mechanical equipment to screen solids and remove grit at facility inlet structure is not operating effectively	Repair or replace bar screens and grit removal system. Provide method (manual or mechanical) to clean the bar screens. Repairs required include: repairing or replacing missing or bent screening components.
3	Ponds in Series provide better treatment	Anaerobic--Facultative--Aerobic	Satisfactory
4	Sets of Ponds allow one to be taken out of service for maintenance	Two sets of ponds	Satisfactory
5	Pond shape rectangular, not square or circular, and with rounded corners to minimise accumulation of floating material.	Rectangular ponds	Confirm corner curvature during pond maintenance

Table 3.3: **Best practices for STP operation and proposed changes/solution to issues**			
No	**Best Practice**	**Trichy STP**	**Proposed changes/ solutions**
6	Pond length to width ratio 3:1 or 2:1 in order to reduce short circuiting and provide time for treatment	Length to width ratio of: i) APs- 2.5 ii) FPs- 2.0 iii) MPs- 1.9	Satisfactory
7	Inlet and outlet positioned to minimize short-circuiting	Unsatisfactory	Position is unsatisfactory. Other factors are likely causing short-circuiting, e.g. temperature differences. Additional inlet and outlet points would help minimize short circuiting if baffle walls are not constructed
8	Pond outlet structures that minimize algae and scum carry-over	Unsatisfactory	Outlet structures should conform to Waste Stabilisation Pond Manual for India, Mara 1999.
9	Facultative Pond: desirable to provide scum guard projecting 150 to 300 mm above water level and tipping about 250 mm below the pond water level.	Overflow weir--good hydraulically but allows surface scum and algae to carry over	Install a scum guard around the existing outlet structures in the FPs
10	Aerobic Pond: Scum guard around the outlet to reduce algae and scum carry-over into effluent discharge.	Aerobic pond outlet allows algae into effluent discharge	Rebuild aerobic pond outlet structure.
OPERATION			
11	Daily report with visual observations and flow measurement	None	Prepare Daily Report
12	Field measurement and laboratory analysis for pH, Temperature, Dissolved Oxygen, BOD, Suspended Solids, and Coliform Group	None	Once or twice weekly: pH, Temperature, and DO. Weekly BOD, SS, Coliform
13	Monthly Reports and Annual Operating Report	None	Volumes treated, average values of measured parameters, estimated pollution removed; operating costs;
MAINTENANCE			
14	Sludge removal (desludging) from ponds	Unsatisfactory	Need to implement a sludge profiling procedure for all cells and desludge as needed

Table 3.3: **Best practices for STP operation and proposed changes/solution to issues**			
No	**Best Practice**	**Trichy STP**	**Proposed changes/ solutions**
15	APs require desludging when they are one third full of sludge (by volume). Typically, this means once yearly.	No desludging done recently	Measure sludge depth and remove sludge as needed. Dispose of sludge properly.
16	FPs require desludging typically once every 5 years.	No desludging done recently	
17	Remove scum from Facultative and maturation pond surfaces	Done regularly	Even though these maintenance activities are carried out, there seems to be scum /weed formation on the surfaces of ponds and equipment not working properly These activities are manually done, providing additional labours and increasing the frequency of activities will help the STP to treat the sewage more efficiently
18	Anaerobic Pond Maintenance	Done regularly	
19	Electrical-Mechanical Equipment in accordance with manufacturer's instructions	Done regularly	
UPGRADES FOR IMPROVED EFFLUENT QUALITY			
20	Baffle Walls in the ponds to reduce short-circuiting	None	Install in all cells or use alternatives such as multiple inlet and outlet structures
21	Balancing flows to achieve even distribution	None	Install valves/repair existing valves that control the flow towards the ponds
22	Installing aeration or mixing	None	If increased loading is anticipated beyond limits allowable under USEPA guidelines
Source: TNUSSP Analysis 2017			

3.4. Institutional recommendations

A wastewater system consists of four main components – collect, move, treat, and dispose wastewater and treat effluents. Each component is essential and needs to operate properly to receive flow from the preceding component and to suitably treat the flow for the succeeding component. Experience in developed countries indicates that this is best accomplished by having one department or management responsible for the entire system with sub-units for each component. Depending on the size of the system there can be further divisions according to geography. The key point is to have one department empowered to coordinate operations, set priorities for maintenance, and allocate resources among the components.

Generally, labourers under trained supervisors and managers are enough to operate and maintain the components. Specialised technical expertise is needed for (a) planning, design, and equipment procurement; for example, electrical and mechanical engineers (b) sampling and laboratory analysis and (c) operations of complex mechanised wastewater treatment systems. These technical experts should be either within the department or on-call as needed. The key points are the availability of this expertise and that the experts support the operating units.

Staff assigned to the wastewater department – labourers, supervisors, managers, experts—need training and tools to do their job effectively. This requires a commitment of time and budget. Consider, for instance, the task of cleaning a blocked sewer line. The staff needs tools and equipment to (a) pry open the manhole cover (b) push through the sewer pipe to clean the blockage (c) gather up the blockage and haul it away. Improper tools can result in worker injury and incomplete cleaning. It is important for the component manager and department manager to periodically review the number/condition of tools and equipment and procure additional when needed.

3.4.1 Contracting out for O & M services.

TCC employs private companies contractually for O & M of pump stations and the WSP. In addition to the expected performance (i.e. complying with regulations for effluent discharge), the terms and conditions of the contract should specify care and maintenance of equipment, health and safety of workers, and reporting inputs such as the format and frequency of labour hours, chemicals, repair parts and outputs such as quantity of wastewater processed. TCC needs to establish a 24-hour hotline for the private operator to report equipment malfunctions, inventory shortages, and other matters requiring immediate attention.

3.4.2 Coordination with other departments

Knowing in advance which roads are to be repaired or repaved, the Wastewater Department could (a) schedule inspection, repair, and replacement of the sewer network before the department of roads starts or completes its work (b) mark manhole covers so they can be easily found after repaving (c) schedule adjusting the manhole, e.g. raising it to the level of the road surface if needed. That can avoid tearing up a newly paved road.

3.4.3 Coordination with other TCC public safety and public works

Workers such as those in the police force, fire department, trash collection and water company might encounter problems such as broken pipes or blockages with the sewer network. They need to know how to report their observations so that the wastewater department can respond promptly.

3.4.4 Capacity Building: Training

Compliance with more stringent wastewater discharge standards requires advanced wastewater treatment. Engineers, operators, and chemists will need training specific to the systems installed. For example, Biological Nutrient Removal (BNR) process uses mechanical and chemical treatment that require measuring and controlling inputs and monitoring outputs to assure that the system is working.
Thus, when the TCC selects wastewater treatment methods it should also identify the staffing requirements, recruit personnel as needed and provide budget and time for training. Training should be done periodically to refresh processes rather than as a one-time activity.

3.4.5 Following the rules

It is common to have a gap between declared rules promulgated by relevant government authorities and actual practice in cities. Reasons for the gap include lack of awareness, cost of compliance, and disagreement with the rule (for instance, know the rule but consider it illogical and unnecessary). Common problems of wastewater systems caused by improper human behaviour include:

- illegal dumping into sewer drains
- building storm water drainage that is connected directly to the sewer system
- unauthorised sewer connections
- discharge of substances harmful to the sewer pipes (cooking oils and grease from restaurants that can cause blockages)
- failure to empty septic tank or using an unauthorised desludging service.

There is no single solution to overcoming these problems. Simultaneous programmes and actions are required, including:

(a) Public education programmes to raise awareness. General awareness is spread through posters, newspapers, and television. It is also useful to have presentations for schools and women's groups.

(b) The government should set an example by making sure its buildings and actions comply with regulations

(c) Pre-treatment programme should be focused on commercial activities whose wastewater discharge is likely to harm the sewer system. For example, restaurants and food processing, automobile service and repair shops

(d) Design of low-cost rainfall capture systems for buildings and incentives for building owners to install

(e) Coordination with the water company to assure that if a building has a water service connection then it also has a wastewater connection

(f) Improved solid waste collection and disposal to keep it out of the sewer and storm drains.

3.5. Wastewater Reuse

Reuse of wastewater for industrial purposes is generally not practical due to the need for further treatment to improve the effluent quality. Reuse for agriculture and landscape irrigation however, is very suitable for wastewater from cities, especially due to the concentrations of nitrogen and phosphorous in the effluent that is beneficial to trees and plants.

An initial investigation indicates that there may be enough land available for agricultural reuse along the Koraiyar river. To determine the suitability of the land for irrigation, it must be: 1) above the elevation of the 100-year flood ii) relatively flat at less than 5% slope and iii) accessible by effluent pipeline. Strategic long-term arrangements between the TCC and property owners for agricultural irrigation would need

Recommendation. *Decision-makers should think in terms of agricultural irrigation for effluent dispersal*. The wastewater effluent from the WSP has value, and could irrigate between 2,000 and 4,000 acres or more of fibre crops (as a rough estimate) such as cotton, hemp or jute (*common crops already produced in Tamil Nadu*). Water requirements for cotton, for example, are between .09 and .3 inches of irrigation water per day. The exact amount of land that can be irrigated by the effluent depends upon the crops and their rotation, as well as the method of irrigation (spray, drip, and furrow). The land along the riverfront on both sides of the treatment plant are prime for this activity.

Future Expansion and Proposed Plans

4.1. Sewage flows 56

4.2. Treatment plant suitability 57

4.3. Analysis of draft DPR and implications of future flows 58

4.4. AMRUT: Discussions 59

4. Future Expansion and Proposed Plans

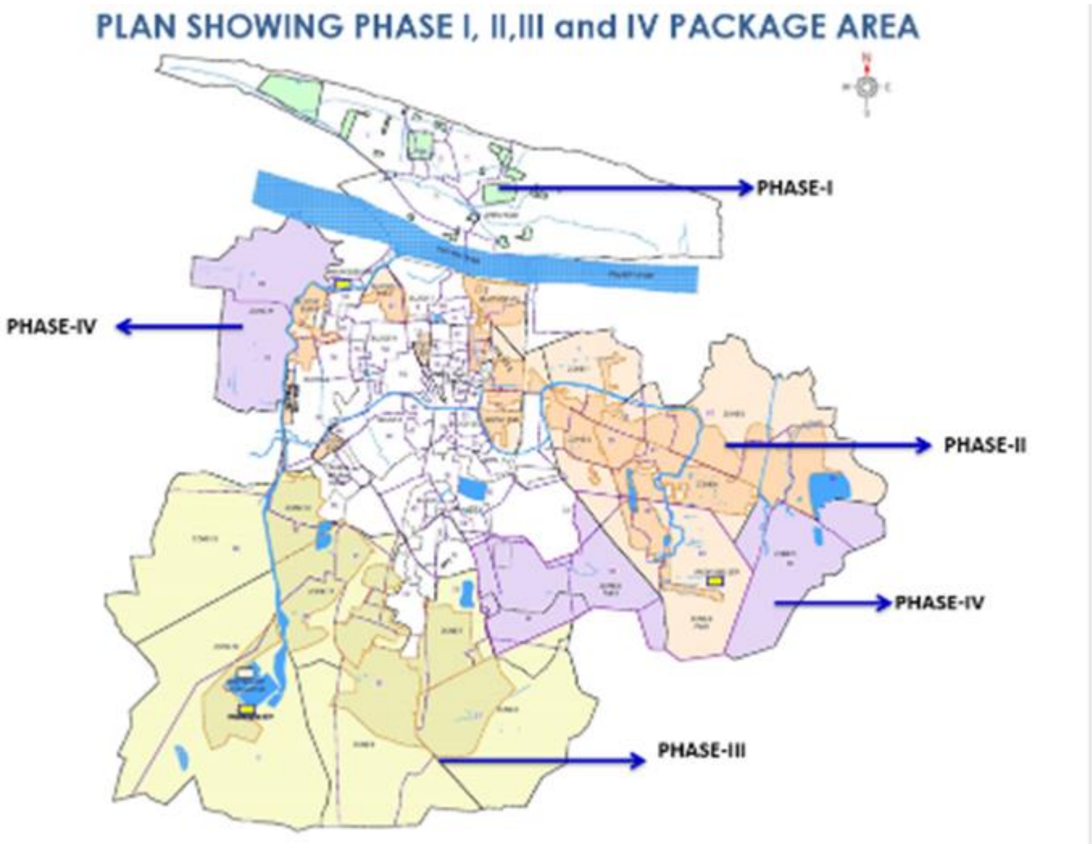
This section describes the analysis of the proposed expansion plan of sewerage system by TCC in a phase wise manner. Figure 4.1 shows the area covered under the proposed phases of the project. The description of the phases included in the proposed plan are as follows:

PHASE II – *Supplying, laying, testing and commissioning of sewer network in the extended area and left out areas in the core area of Tiruchirappalli. This also includes a lifting station, pumping station and proposed Treatment Plants at Kelakalkandar kottai and Panjappur respectively.* Based on the rapid growth, population density and reducing sewage mixing load into river Cauvery, Koraiyaru and Uyyakondan channel, these zones are selected for Phase II: Zones 1, 2, 3, 4, part of zone 6 and B2E1, B2E2, B3E1, B3E2, B4L/o, B5E, B6L/o, GRPS-1-E.

PHASE III – *Supplying, laying, testing and commissioning of sewer network in the extended area of Tiruchirappalli including lifting station, pumping station and proposed Treatment Plant at Panjappur.* Zones 7, 8, 9, 10, 11, 12 and 13

PHASE IV –*Supplying, laying, testing and commissioning of sewer network in the extended area of* Tiruchirappalli (Zone 5, Part of Zone 6 and Zone 14) *including lifting station, pumping station and Treatment Plant at Kulamani.*

Figure 4.1**: Area covered by sewerage system under proposed phases- AMRUT**



Source: Presentation on Providing under ground sewerage scheme to Tiruchirappalli city corporation under AMRUT scheme- Phase-II, TCC

4.1. Sewage flows

Extension of the sewer system in Trichy, will lead to more flows at the WSP. The action plan for upgrading the WSP system will depend upon the population milestones as represented below. Figure 4.2 describes the anticipated flows as reported in the DPR.

Figure 4.2**: Estimated TCC Sewage Generation for years 2020, 2035 & 2050**

Sewage Generation For Tiruchirappalli City Corporation

Year	Stage	Population	Per-capita Sewage Generation In lpcd	Total Sewage Generation
2020	Base	10,93,979	110	120 .5 MLD
2035	Intermediate	14,68,924	110	162.0 MLD
2050	Ultimate	19,72,375	110	217.0 MLD

Sewage Generation - Tiruchirappalli City Corporation Extended Area and left out area in core area – Phase-II

Year	Stage	Population	Per-capita Sewage Generation In lpcd	Total Sewage Generation MLD
2020	Base	257,075	110	28.28
2035	Intermediate	371,541	110	40.87
2050	Ultimate	525,243	110	57.78

Source: Presentation on Providing under ground sewerage scheme to Tiruchirappalli city corporation under AMRUT scheme- Phase-II, TCC

A flow of 135 lpcd is the national standard for water generation. Not all the water delivered to the city ends up in the sewer, some water is consumed by drinking, cooking, cleaning and washing. 81% of the volume of water delivered is assumed to go to the sewer system. This results in a per capita sewage production of 110 lpcd (Figure 4.2).

Population (capita) X Flow (L/cap/day) = Wastewater (MLD).

NOTE: Daily per-capita sewage generation does not present an accurate picture of actual flows. In part this is because all these flows are not collected in the sewer system, while other sources of water that does enter the system via infiltration are not included. For example, in unsewered areas women wash clothes and dishes outside their house and pour the wastewater into the drain. Or they do their washing at water points. However, infiltration and/or leakage from the sewer lines should be considered in assessing total volume of wastewater entering the sewer lines. Over time, as procedures are improved, leakage and infiltration should be reduced.

4.2. Treatment plant suitability

This section will review the WSP sizing to provide a basis of the evaluation of the system's suitability moving forward under this plan:

4.2.1 Anaerobic ponds

The following uses the formula derived by Mara, 1998: $V_a = L_i Q / \lambda_v$

The formula is used to calculate the volume required in an AP

If it is assumed that

- -influent sewage BOD is 270 mg/l (Golden Rock Report)
- -influent septage (upper bound) BOD is 16,038 mg/l (CEEPHO)
- -temperature (mean daily average) is 25 degrees C or higher
- -climate is 75% days sunny

Then, the total flow combined with septage and sewerage = 58 MLD

With 1.9% of the total flow composed of septage, the volume of the APs must be at least 93,000 cubic metres.

The Panjapur WSP anaerobic cells have a calculated volume of 46,800 cubic metres each for a total volume of 93,600 cubic metres, which is just enough for the required volume.
1.9% of 58 MLD is 1.1 MLD of septage liquids. This means that if the APs are functioning at 100% efficiency (no short circuiting and no sludge accumulation), 1.1 MLD of septage liquids can be received safely.

However, short circuiting and sludge accumulation do affect this number. If short circuiting results in pond efficiencies of only 75%, and if 10% of the pond volume is lost to sludge accumulation, the effective volume of the ponds drops to 60,480 cubic metres. Then only 0.35 MLD of septage liquids can be safely added without overloading the ponds. That is the equivalent of 70 five-cubic metre trucks per day.

Three outcomes are likely in this scenario:

(1.) The efficiency of the ponds due to short circuiting is likely less than 75%.

(2.) The amount of septage liquids the plant will need to receive is most likely greater than 0.35 MLD.

(3.) WSPs are known to fluctuate in their overall efficiency during periods of prolonged cloudy conditions or the rainy season.

Therefore, based on these factors, one assessment becomes clear:

The BOD from the septage must be reduced prior to allowing it to enter the sewer system. This can be accomplished by liquids/solids separation at the decanting stations in accordance with best practices for co-treatment.

4.2.2 Facultative ponds

For the FPs, the findings are the same. If the influent to the APs (combined septage and sewerage) are 365 mg/L BOD and the APs reduce the waste load by 70%, then the influent concentration to the FPs will be 109.5 mg/L. This will require FP surface area of 212,700 sq. m. to bring the BOD levels down to less than 30 mg/L. The surface area for the Trichy WSP FPs is 183,345 sq. m. combined, therefore they are inadequate to meet the flows with the septage added. Again, factoring in the potential for short circuiting and variability in pond performance, it is likely that the final effluent limitations will be exceeded, for at least part of the year.

There are two possible solutions:

1. Perform liquid/solid separation of the septage at the decanting stations to reduce the BOD of the incoming septage

2. Install aeration or pond mixing devices in the facultative cells to increase their efficiency and loading potential.

4.2.3 Treating flows beyond 58 MLD

The old three cell WSP at Panjappur can be refurbished and placed into service to address future flows. The original design capacity for the old system is 30 MLD, however, retrofitting can be done to accommodate the following:

(i) deepened cells to hold water up to 5 m deep

(ii) instal baffle walls or floating baffles to control short circuiting

(iii) adding aeration or circulation can significantly increase the capacity

Once a determination is made on how deep the TCC is able to excavate the old cells, volumes can be calculated, and an aeration plan can be proposed which will identify how much additional loading the old cells can handle.

4.3. Analysis of draft DPR and implications of future flows

In Trichy there are several areas without underground sewerage. TCC plans to install sewer pipes in these areas along with sewage pump stations (SPS), Lift Stations (LS), and STPs.

A plan prepared in 2016 described three phases for installation of sewer pipe, construction of SPS and LS, rehabilitation of an existing 30 MLD STP at Panjappur and construction of two new STP at Keelakalkandar Kottai (32 MLD) and Kulumani (22MLD) using Moving Bed Bio Reactor (MBBR).

Following this, a new plan titled 'Providing Under Ground Sewerage Scheme to TCC under AMRUT Scheme' (May 2017) has four phases. Figure 4.1 shows the locations of the four phases and Table 4.1 summarises the proposed infrastructure by phase. Note that Phase 1 is for the omitted areas in Srirangam Zone.

Table 4.1: **Infrastructure of the Four Phases of the AMRUT**

Sl No.	Description	Total	UGD Covered	Phase-II	Phase-III	Phase-IV
1	Area in sq.km	167.23	52.3	27.73	58.01	29.19
2	% of coverage of Area	100%	31%	17%	35%	17%

Table 4.1: **Infrastructure of the Four Phases of the AMRUT**						
Sl No.	**Description**	**Total**	**UGD Covered**	**Phase-II**	**Phase-III**	**Phase-IV**
3	Sewage generation (MLD) Base year-2020	120	63	28	20	10
4	Intermediate year-2035	162	78	41	28	15
5	Ultimate year-2050	217	98	58	39	22
6	Sewer Network Length (Km)	1342	330	318	280	364
7	% of coverage of streets	97%	25%	24%	21%	27%
8	Number of STP		1	2	1	1
UGD = Underground Drainage; Per-capita Sewage Generation = 110 lpcd; STP = Sewage Treatment Plan						
Source: Presentation on Providing underground sewerage scheme to Tiruchirappalli city corporation under AMRUT scheme- Phase-II, TCC						

The proposal under AMRUT in the revised plan proposes extended aeration for the 20 MLD at Panjappur perhaps for the existing WSP.

4.4. AMRUT: Discussions

Sewer Pipe Network

The design criteria and pipe materials shown in the 2017 PowerPoint are satisfactory.

Manholes

Indian Standard (IS) 4111, 'Code of Practice for Ancillary Structures in Sewerage System Part 1 Manholes', 1986 and Reaffirmed 2007

> A manhole is defined as an opening by which a man may enter or leave a drain, a sewer or other closed structure for inspection, cleaning and other maintenance operations, fitted with a suitable cover. On sewers which are to be cleaned manually which cannot be entered for cleaning or inspection the maximum distance between manholes should be 30 m. For sewers which are to be cleaned with mechanical devices, the spacing of manhole will depend upon the type of equipment to be used for cleaning sewers.

Thus, it is important to determine during the design of the sewer pipeline network what equipment will be available for cleaning since that will determine the manhole spacing. Sewer cleaning equipment can be broadly classified as (a) mechanical (rodding or bucket machine) and (b) hydraulic (balling, flushing, jetting). Phase II proposes 318 km of sewer pipe. Manhole spacing of 30m results in over 10,000 manholes while at a spacing of 100m it results in 3,180. The cost savings in manhole construction can pay for the sewer cleaning equipment.

TCC should consider composite manhole covers instead of iron. Composite covers are made of plastic type materials such as Fiberglass Reinforced Plastic (FRP). Some of the advantages of composite covers are:

a. lower weight (about 20% to 40% of the weight of cast iron) making it easier for workers to raise and remove
b. no value as scrap so unlike cast iron covers, composite manhole covers are unlikely to be stolen
c. capable of supporting road traffic
d. much less susceptible to damage from corrosive gases and micro-biological organisms.

Sometimes during road repaving, the manhole cover is paved over. To make it easier to locate composite manholes it is best to install a metal tape or wire across the manhole that can be detected using standard equipment for metal pipe location.

Pre-treatment Before Discharge

TCC sewer maintenance engineers commented that in residential areas the frequency of blockages and clogs is once in three months while in the remaining areas it is once a month. One reason for the increased frequency may be that commercial business are discharging materials that cause blockages and clogs such as FOG from restaurants or cafeterias. The TCC should establish a programme to inspect commercial businesses and enforce pre-treatment of wastewater before discharge into the public sewer.

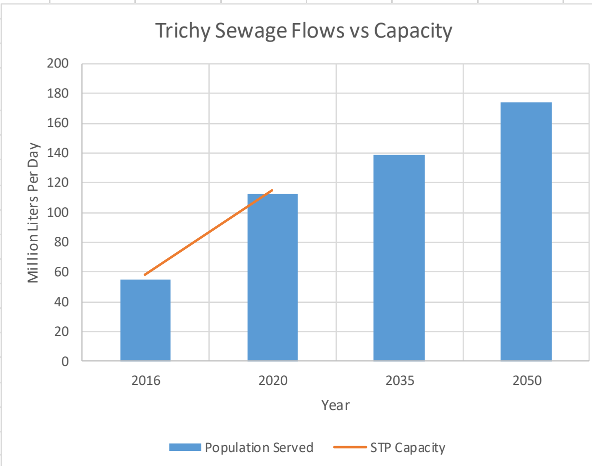
Volume of Sewage Generated and Treatment Capacity

AMRUT estimates 63MLD for the current coverage and an additional 28MLD for Phase II for a total of 91MLD of sewage to be treated. The current WSP is rated at 58MLD and the two STP planned for phase II add 57MLD, that is STP Keelakalkandarkottai at 37MLD and STP Panjappur at 20 MLD. For Phase II, the 115 MLD treatment capacity should be adequate for 91 MLD sewage (80% of capacity). The time frame for the Phase III and Phase IV was not available when this assessment was conducted. Figure 4.3 shows the sewage generated for all four phases for the years 2020, 2035, and 2050 and the STP capacity for year 2016 and 2020.

Figure 4.3**: Trichy Sewage Capacity for Years 2020, 2035, and 2050**

Sewage Flows vs Treatment Capacity

Phase	2016	2020	2035	2050
I	55			
II		28	41	58
III		20	28	39
IV		10	15	22
total sewer	55	112	139	174
total flow		121	162	217
% flow that is sewered		93%	86%	80%
STP Capacity				
WSP (6-cell)	58			
STP Panjapur		20		
STP KK		37	No details in the Amrut PPT	
STP Kulumani				
Total Capacity	58	115		



Source: Presentation on Providing underground sewerage scheme to Tiruchirappalli city corporation under AMRUT scheme- Phase-II, TCC

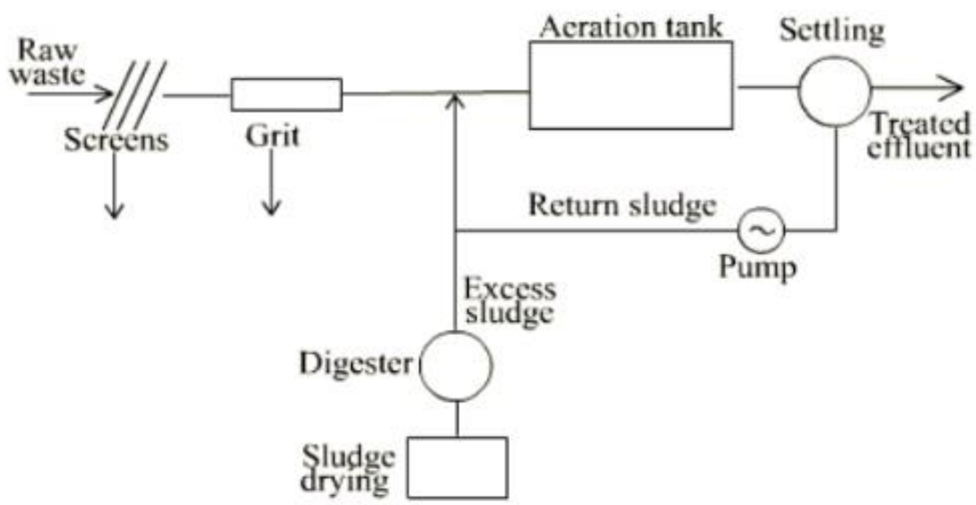
Note that sewage production is very close to available capacity in the year 2020 if the sewage network for Phases II, III, and IV is completed by then.

Sewage Treatment Process

Extended Aeration (EA) is proposed for the STP at Panjappur. In the EA process, raw sewage goes straight to the aeration tank for treatment. The whole process is aerobic. This results in longer aeration time, hence the name 'extended aeration'. The result is that less sludge is produced because of longer aeration.

Figure 4.4 is a process schematic of the extended aeration system. EA is a variation of the activated sludge process. They are both similar to the extent that some sludge is returned to the head of the aeration tank. But note that there is no primary settling tank; the raw waste, after screening and grit removal, goes directly to the aeration tank.

Figure 4.4**: Schematic of Extended Aeration System**



Source: http://www.water-chemistry.in/2009/08/what-is-extended-aeration/

EA is a suitable treatment process because it is effective in reducing BOD and TSS and can provide nitrification (i.e. convert ammonia to nitrate). The Oxidation Ditch (see Annex 1 to this chapter) is proven technology. Compared to other processes EA has high operating costs due to large amounts of electrical power consumption.

The first criterion for evaluating a sewage treatment process is: will it treat the influent to the effluent standards specified by the relevant regulatory authority. Subsequent criteria include evaluations of (a) capital cost and operating cost (b) ability of the responsible agency to operate and maintain (c) environmental impacts (d) any need for resettlement. The people revising the Trichy DPR for sewage system expansion need to apply these criteria and analyse it to justify selecting EA. There are other wastewater treatment options that may be considered. These are represented in Figure 4.5.

Figure 4.5: **Evaluation of STP Processes from the 2016 DPR**

COMPARISON OF TREATMENT PROCESSES FOR SEWAGE TREATMENT

Technologies	Capital cost per MLD (Rs. Lakhs)	Daily power requirement (KW Hr/ MLD)	O&M cost per year per MLD (Rs. Lakhs)	Land requirement (Hectare per MLD)	Remarks
Conventional Activated Sludge Process (ASP)	64	225	4.60	0.25	Conventional ASP with anaerobic sludge digestion: High in power and O&M cost.
Extended Aeration Process	59	270	4.10	0.38	EA Process: High in power, O&M cost and land requirement.
UASB + Polishing Pond	56	78	3.50	0.70	UASB Process: High land requirement, Not a superior quality effluent.
Sequential Batch Reactor ()	89	240	4.35	0.15	Process: High capital cost, power requirement and O&M cost.
Moving Bed Bio Reactor (MBBR)	**78**	**170**	**3.83**	**0.075**	**Medium in capital cost, power requirement, O&M cost and small foot prints. Easy modular construction and expansion.**
Membrane Biological Reactor (MBR)	175	205	6.5	0.05	MBR Process: High capital cost, O&M cost but small foot print.

Source: Presentation on Providing underground sewerage scheme to Tiruchirappalli city corporation under AMRUT scheme- Phase-II, TCC

Impact on Existing WSP

Previous sections of this final report discussed repairs and upgrades (aeration and mixing) to the existing WSP to improve effluent quality. EA was not considered as a method of water treatment because it would require major rebuilding like converting the aerobic ponds to EA reactor, installing sludge recycling system, and adding disinfection equipment.

It would be useful to have a common outfall from the existing ponds and new a STP at Panjappur into the Koraiyar River to blend the two effluent streams.

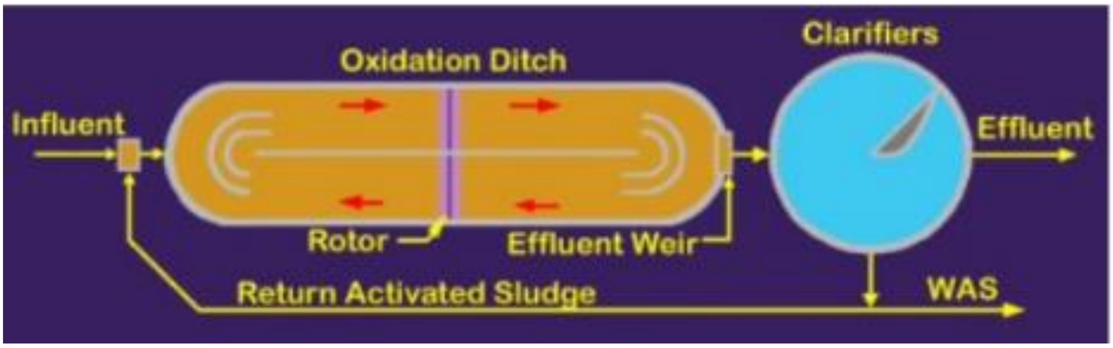
Extended Aeration and the Oxidation Ditch STP

The Extended Aeration process uses low organic loading, long aeration time, high MLSS (mixed liquor suspended solids) concentration and low F/M (food-to-microorganisms) ratio. Because of long detention in the aeration tank, the MLSS undergo considerable endogenous respiration and get well stabilised. The excess sludge production is minimal, does not require separate digestion, and can be directly dried on sand beds. The BOD removal efficiency is high. The oxygen requirement for the process is high so the operating costs are also high. However, operation compared to activated sludge is relatively simple due to the elimination of primary settling and separate sludge digestion.

EA on its own, cannot achieve nutrient reduction. It cannot achieve a final effluent of 10 mg/l of BOD and TSS, unless the detention time in the aeration is between 20 to 40 days[12], which is not possible with the Trichy programme. To achieve denitrification, additional technology is required.

The Oxidation Ditch (OD) is one form of an EA system. The ditch consists of a long continuous channel, usually oval in plan. The channel may be earthen with lined sloping sides and lined floor or it may be built in concrete or brick with vertical walls. The sewage is aerated as it goes around the channel. Figure 4.6 shows a typical layout. The rotor is both a source of aeration and horizontal velocity to the mixed liquor, preventing the biological sludge from settling out. Figure 4.7 is an empty oxidation ditch and Figure 4.8 shows configurations of 1, 2, and 3 channels.

Figure 4.6: **Schematic of Oxidation Ditch**



WAS = Waste Activated Sludge

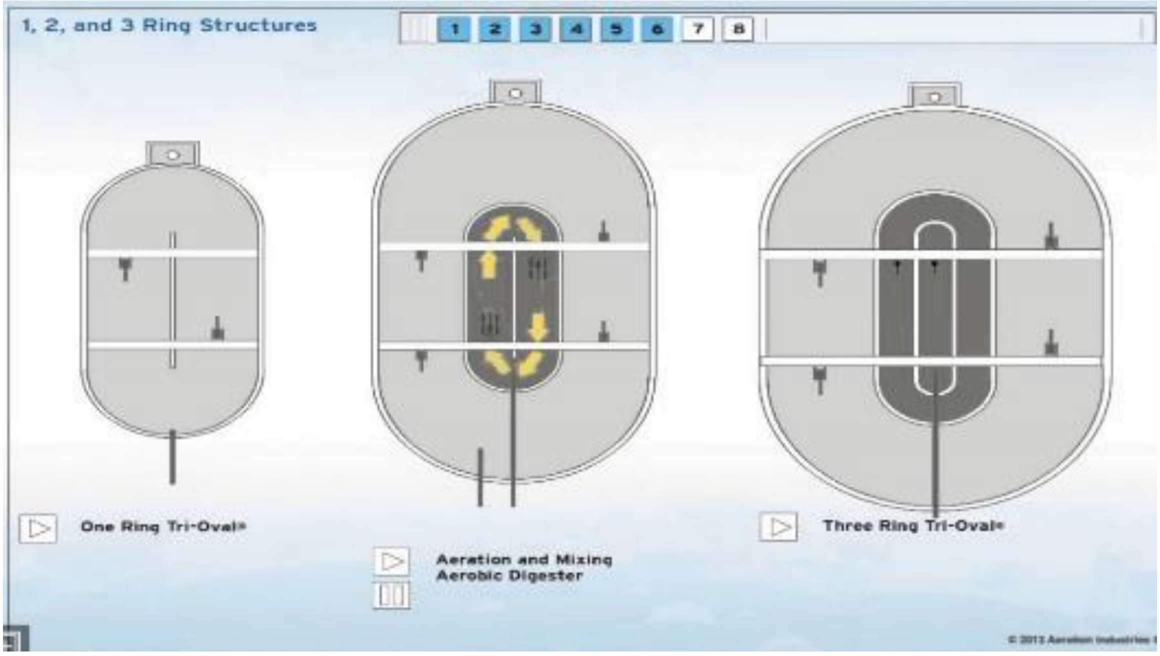
Source: https://i0.wp.com/www.thewatertreatments.com/wp-content/uploads/2009/11/oxidation-ditch1.jpg

Figure 4.7: **Empty oxidation ditch with air diffusers**

Source: https://mixing.com/installations/91-textiles-oxidation-ditch-southeast-usa

[12] *Lagoon Aeration Alternatives: An Overview Posted on February 8, 2013 by Patrick Hill*

Figure 4.8: **Oxidation ditch with 1, 2, and 3 oval channels**



Source: Tri-oval® oxidation ditch system, Aeration industries

Operating data (USEPA, 2000) for the OD STP in a climate similar to Trichy shows a BOD removal of 96%, TSS removal of 97% and Total N removal of 94%.

The source of air for an EA system can be (a) surface aerators (brush rotors, disc aerators, draft tube aerators) or (b) fine bubble diffusers. The aerators add oxygen and are used to circulate the sewage. EA can achieve nitrification. The effluent requires disinfection.

As an alternative to the EA plant, TCC may consider incorporating the three old and unused cells back into the overall WSP programme as described above to treat up to 119 MLD. Once fitted with baffle walls and aeration or mixing, the cells can achieve the 2017 discharge standards (Table 4.2).

Table 4.2: **Configurations of the existing WSP**

Sl No.	Configuration	Standards	Modifications	Flow
1	Existing 6 cells	October 2017	Repairs. No excavation or aeration, but control of short circuiting through inlets and outlets	Up to 58 MLD
2	Existing 6 cells	October 2017	Excavation, baffle walls and some aeration	Up to 119 MLD (estimate) depending upon depth and HP per cell

Table 4.2: **Configurations of the existing WSP**				
Sl No.	**Configuration**	**Standards**	**Modifications**	**Flow**
3	Old 3 cells	October 2017	As designed	30 MLD
4	Old 3 cells	October 2017	Excavate to 5 metres, add oxygenation or mixing	Up to 85 MLD (estimate) depending upon depth and HP per cell.
Source: TNUSSP Analysis 2017				

5 Detailed Action Plan and Recommendations

5.1. Action plan description 69

5.2. Action Items 72

5. Detailed Action Plan and Recommendations

5.1. Action plan description

The Action Plan is organised according to the infrastructure elements of the WSP. The actual work should be contracted according to function. For example, one of the first action items in the plan is to inspect and service the valves located at diversion chamber #1. During execution, operators should consider inspecting and servicing all valves at the same time.

Indicative costs are provided for each action. Prior to engaging work, local costs should be obtained through standard bidding procedures. Following the Action Plan (Table 5.1), each item is explained in detail for rationale and specific activities associated with the action.

Table 5.1: **Action Plan for STP**

Action Item (AI) Number	Location	Action	Time frame (months)	Indicative cost
Division Chamber 1	It 1 is where the wastewater flow first enters the Panjappur plant. Here, by operating the valves, flow can be directed either to the old treatment plant, the current WSP, or a combination of the two.			
AI.1	DC1	Inspect and service the valves	0-3	500 $[13] ₹ 32,235
AI.2	DC1	Flow meter fix or replace	0-3	6,500 $ ₹ 416,000 $
Pre-treatment plant	It is also known as the headworks. Here wastewater is screened and degritted prior to continuing through the WSP cells			
AI.3	PTP	Repair the bar screen	0-3	3,500 $ ₹ 224,000
AI.4	PTP	Repair the grit chamber	0-3	3,500 $ ₹ 224,000
Division Chamber 2	Division chamber #2 immediately follows the PTP. Here, operators can either i) divert the flow away from the treatment plant directly to the river or ii) send the wastewater to the APs.			
AI.5	DC2	Service valves	0-3	500 $ ₹ 32,000
	Transmission pipeline to APs from head works. It is the pipeline that sends wastewater from division chamber 2 to the APs.			

[13] *INR (₹) 64.4 = USD ($) 1*

Table 5.1: **Action Plan for STP**				
Action Item (AI) Number	**Location**	**Action**	**Time frame (months)**	**Indicative cost**
AI.6	PAP	Install air vac valve	0-3	1,800 $ ₹ 117,000
Anaerobic ponds	There are two APs which function through the action of settling and anaerobic digestion. They can reduce the BOD and TSS by about half.			
AI.7	AP 1	First profile sludge. If excavation method	3-6	
AI.8	AP 1	Divert wastewater to AP 2 and drain AP 1		
AI.9	AP 1	Desludge – assumed using a barge or floating desludging unit that can be manufactured locally with the cost amortised over time.		7,500 $ ₹ 480,000 Costs for desludging as shown here may be low. Need to obtain local bids.
AI.10	AP 1	Install the sampling platform		3,500 $ ₹ 224,000
AI.11	AP 1	Inspect and refurbish outlet structure to minimise short circuiting		5,000 $ ₹ 320,000
AI.12	AP 2	Repeat for AP 2	6-9	16,000 $ ₹ 1,024,000
Division chamber 3	Division Chamber number 3 allows the operators to divert the flow from the APs to either of the two FPs.			
AI.13	DC3	Service the valves	0 - 3	
Facultative Ponds	FPs have both aerobic and anaerobic zones. When they operate properly they further reduce the organic matter in the wastewater. They also help to convert the ammonia nitrogen to nitrate through the microbial process of nitrification.			
AI.14	FP 1	First profile sludge depth. If sludge excavation is to be performed, divert flow to FP 2 to dry out FP1.	9 - 12	
AI.15	FP 1	Remove sludge if needed		15,000 $ ₹ 960,000

Table 5.1: **Action Plan for STP**				
Action Item (AI) Number	**Location**	**Action**	**Time frame (months)**	**Indicative cost**
AI.16	FP 1	Install the outlet structures and scum guard around the outlet to minimise algae carryover.		18,000 $ ₹ 1,152,000
AI.17	FP 1	Install sampling platform		3,500 $ ₹ 224,000
AI.18	FP 2	Divert flow to FP 1, dry out FP 2 and repeat the same activities for FP2	12-15	36,500 $ ₹ 4,336,000
Polishing Ponds	These are also called maturation ponds or aerobic ponds. Polishing ponds are shallow basins that allow the sunlight to penetrate throughout the entire water column, which enables natural disinfection. They allow the nitrification to complete and also perform some denitrification – a microbial process that turns nitrate into nitrogen gas.			
AI.19	PP1 and PP2	Dye test – if seepage, add bentonite	15	100 $ ₹ 6,400 If bentonite is to be added, first remove accumulated sludge, then add bentonite. Follow procedures in appendix. Obtain local bids first.
AI.20	PP 1	If sludge excavation is to be performed, divert flow from PP1 to PP2 and dry out PP1. Otherwise use barge method		
AI.21	PP 1	Remove sludge if necessary	15-18	10,000 $ ₹ 640,000
AI.22	PP 1	Install the outlet structure		18,000 $ ₹ 1,152,000
AI.23	PP 1	Install sampling platform		3,500 $ ₹ 224,000
AI.24	PP 2	Divert the flow to PP2 and repeat the above	18-21	31,600 $ ₹ 2,016,000

Table 5.1: **Action Plan for STP**				
Action Item (AI) Number	**Location**	**Action**	**Time frame (months)**	**Indicative cost**
Outlet pipeline	The outlet pipeline collects wastewater from the polishing ponds and sends it to the river. At some time in the future, an additional wastewater plant for Phase II, or additional infrastructure including disinfection and filtration may be required.			
AI.25	OP	Install sampling platform	0-6	3,500 $ ₹ 224,000
AI.26	OP	Simple flow measuring device such as rectangular or triangular notch weir, or Parshall flume	0-6	1,000 $ ₹ 64,000
Source: TNUSSP Analysis 2017				

5.2. Action Items

Following are detailed descriptions of the Action Items (AI) listed in the action plan:

5.2.1 AI.1: Servicing the valves at Division Chamber #1

Valves on the sewer lines throughout the STP must be rehabilitated. Anecdotal evidence from the operators indicates that even when closed, wastewater passes through. This is an indication that the valves have significant scale or debris that is fouling the mechanism.

To rectify this first by pass the sewage as much as possible. It may be required to do this work after midnight when the pumping stations are off-line. Valves may have visible signs of corrosion or the mechanism may be cemented into place by scale (calcium carbonate). Disassemble the valve to the extent possible. Use a water/ascetic acid solution (one part water one part acetic acid) and apply with a brush or sprayer. Use a hammer to loosen large pieces of calcium carbonate. With the valve wheel in place, begin to open and close the valve, adding appropriate grease to the valve mechanism. Keep working the valve back and forth, using the hammer to break up masses of scale.

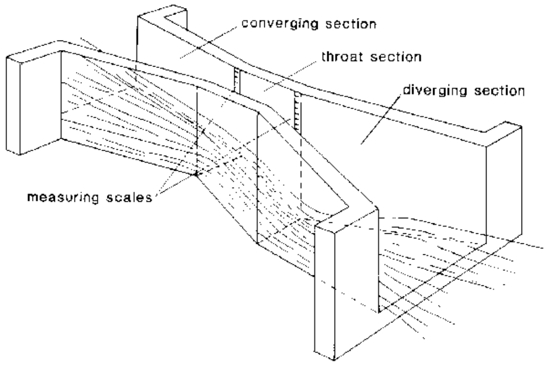
In cases of especially hardened scale, one worker can use a vibrating roto-hammer on the mechanism while the other worker operates the valve. Conduct valve rehab first on the concrete sewer lines and then at the headworks. For safety, a harness and buddy system (straps to secure the worker and at least two people) will be required for workers while performing tasks on the headworks (see Appendix for health and safety requirements).

5.2.2 AI.2: Flow meter fix or replace

There are three options:

i. Fix existing flow meter
ii. Install flow measuring device, for example Parshall Flume at the headworks
iii. Utilise hour logs for daily flow calculation.

A Parshall flume has an advantage over the existing flow meter of no moving parts and is non-electric. Unlike the pump station hour log method of determining flow, the Parshall flume (Figure 5.1) can give instantaneous flow meter readings. They are inexpensive to construct and install and can use local materials and labour.

Figure 5.1: **Parshall Flume**	
	
Parshall Flume	Channels upstream and downstream of the Parshall flume
Source: https://www.jazdesignco.com/blog/flow-monitoring-dirty-water-open-channel/	*Source:* https://tracomfrp.com/parshall-flumes/

Parshall flumes can be read manually by reading the water level against the scale. They may also be fitted with a sensor that reads the water level and records the data on a continuous basis. Parshall flumes can function if there is no backing up of water in the channel (Figure 5.1). For Trichy, the flow meter can be installed at the time when construction is underway. In the meantime, operators should use the daily run logs from the pump stations and calculate the daily flow.

5.2.3 AI.3: Repair the bar screen

This equipment needs to be serviced, which can be done in place. The unit does not function. . The motor and electrical works should be checked, repaired or replaced. The equipment should be sand blasted, painted, and the mechanical parts rehabilitated. The function of the system once operational is adequate for Trichy.

To accomplish this:

i. Divert all flow to the old pond system or conduct work when there is no flow (midnight – 5 a.m.). If the latter, strict lock-out tag-out procedures must be followed to ensure the pumps remain off during servicing of the bar screens;
ii. Empty the wet well. Workers will utilise confined space entry procedures to enter the wet well and conduct work. Trash must be removed first;
iii. Inspect mechanisms and then fully clean and oil all moving parts, with grease applied to all bearings;
iv. Check chains, sprockets and other components for wear; and
v. Replace or repair worn parts as necessary. Metal surfaces should be degreased and painted.

The local maintenance team has done similar work in getting components of the grit chamber to function. Some parts may not be available, and some retrofitting is required. The local crews said they were up to the task.

5.2.4 AI.4: Repair the grit chamber

The grit chamber design appears to be functional. To rehabilitate:

i. Close valves bypassing both sides of the grit chamber. Drain and remove grit manually. Dump over the side in piles, that will later be removed by backhoe
ii. Lock-out all electrical breakers using the lock-out tag-out procedure;
iii. Using confined space and buddy system procedures, workers sand blast or scrape corrosion from metal parts, grease and oil moving components and bearings, and paint metal surfaces
iv. Repair the motors as needed and check the mechanisms that may include chains and sprockets for any wear and tear. Repair or replace components as needed
v. Unlock the electrical breakers, energise and test the system.

5.2.5 AI.5: Service the diversion chamber #2 valves

Refer to AI 1 above

5.2.6 AI.6: Install air vac valve

Install the air vent on the sewer line from headworks to the APs. Use the as-built drawings and land survey to locate the high point on the sewer line.

Figure 5.2: **Air vent location**

Source: TNUSSP Analysis, 2017

Since construction, the sewer line from the headworks to the APs has settled. There is now a high point in the sewer line that traps air and causes a partial blockage of the flow. To alleviate this, an air vent can be installed by drilling a 10 cm hole in the concrete sewer pipe, and installing a vent pipe to an elevation equal to that of the headworks (approximately 3 m). Figure 5.2 shows the location of the air vent.

Recommendation: An alternative to the pipe vent is an air release valve, which can be installed at the same location, but does not require a tall vent pipe. The Val matic[14] (with 2 inch inlet) air release valve is shown, which should be adequate for this purpose (Figure 5.3). It costs ₹52,000 ($800) but similar products may be locally manufactured and available in India.

NOTE: There are many different sizes of air vac valves. The project engineer should determine which size is most appropriate for the project.

Once the air vent pipe is installed it can be supported in place by a tripod or tower. There is no tower required for the air valve. To install:

i. Purchase valve

ii. Drill a hole in the sewer pipe at the correct location as per the survey. Avoid collars where the concrete is thickest

iii. Insert the nipple (stainless steel or galvanised iron is required) concrete into place

iv. Using Teflon plumbers or silicon, screw the valve into place and wrench tighten.

Figure 5.3**: VAL MATIC air release valve with 2-inch inlet**

Source: http://www.valmatic.com/index.html

5.2.7 AI.7: Measure sludge depth in AP 1.

Follow the procedure for measuring sludge depth and performing the sludge profile.

5.2.8 AI.8: Divert wastewater to AP 2 and drain AP 1 pond

Note: This diversion procedure should be followed if desludging will be conducted by excavation, or if the installation or refurbishment of the pond inlet and outlet structures is to be conducted. If simply desludging by dredging, no need to divert flow.

This is the first action item associated with desludging if the excavation method of desludging is to be practiced. To do this, at division chamber #2, close the valve to AP 1 completely and open the valve to AP 2 completely. Then with a skid mounted water pump, begin pumping the liquid from AP 1 over to AP 2. This may take several days depending upon the size of the pump. Operators should monitor the pump to ensure its continuous operation. After the liquid is removed from AP 1, allow it to dry out in the sunshine for at least a week but preferably one or two months.

5.2.9 AI.9: Desludge AP 1

This is done by the excavation method using a backhoe or front-end loader and a dump truck, or the dredging method using a floating barge with sludge pump. The loader uses the front bucket to push

[14] *http://www.valmatic.com/index.html*

the sludge into a pile, and then loads it onto the dump truck with a track hoe working from the embankment and using a large bucket. The dump truck operator brings the sludge to a designated location on-site where it will air dry over the next 3 – 6 months (Figure 5.4).

Figure 5.4**: EAWAG concept drawing of sludge stockpiling**

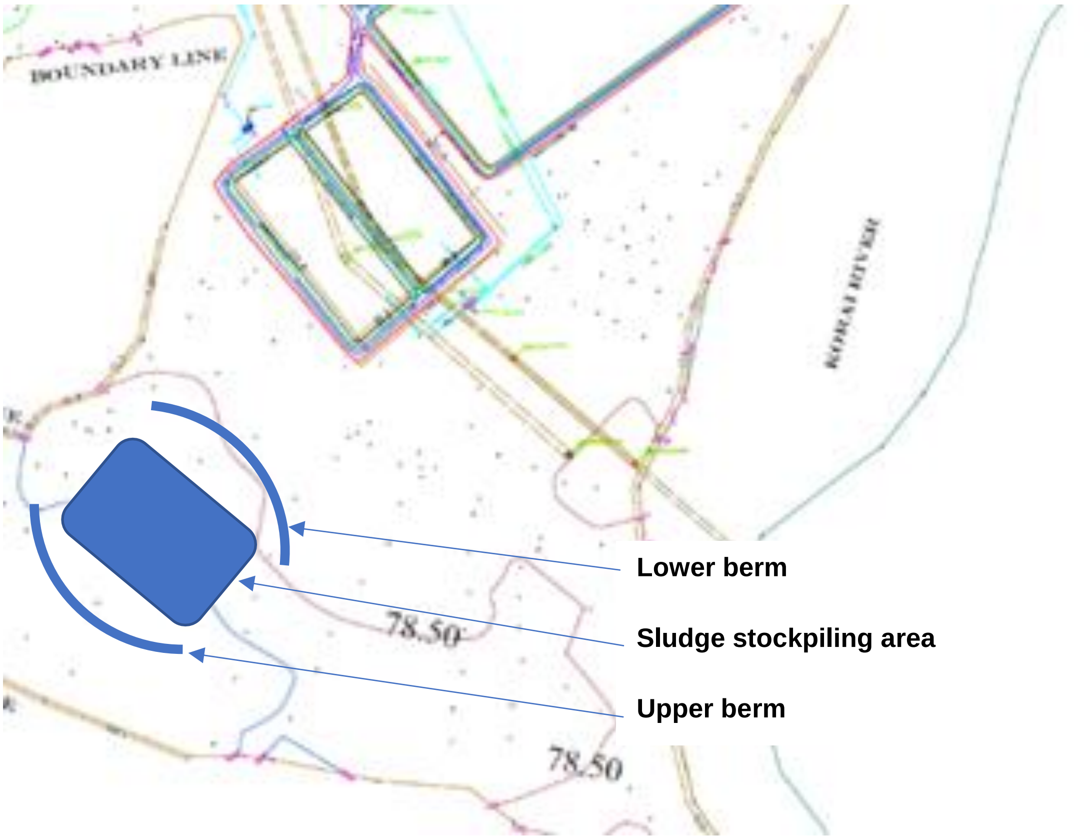
Source: Compendium of sanitation technologies, EAWAG

Once the sludge is removed from the pond, place sludge at a selected location on the 498 acres, as far from houses as possible (Figure 5.5). The sludge will be allowed to air dry using the stockpiling method:

i. Install a berm at the upslope (upper side) of the disposal area as shown to shed storm water around the pile. Then, install the downslope (lower) berm to contain any contaminated water that might run off during storm events. Berms should be constructed as per the drawing and compacted by wheel-rolling or other approved methods.

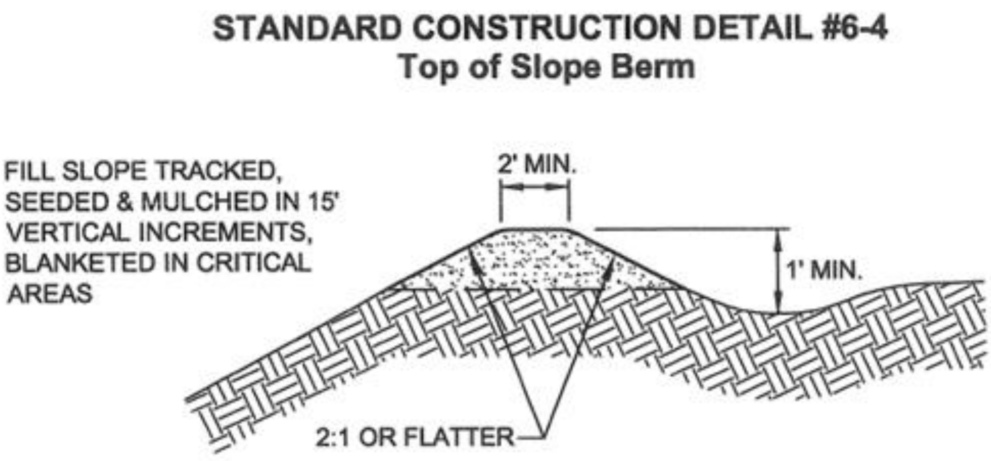
ii. As an alternative, use a floating platform with a sludge pump to directly send the pumped sludge to a tanker truck.

Figure 5.5**: Site map showing preferred location of sludge stockpile zone**



Source: TNUSPP Analysis 2017

Figure 5.6**: Detail of berm and swale to prevent run-on and run-off during storm events**



Source: http://yoeborough.org/wp-content/uploads/2018/08/363-2134-008.pdf

Construct berms (Figure 5.6) using the standard details or something similar. Design berm height to accommodate anticipated maximum 24 hour rainfall event that may occur during the drying period (3 months – 6 months depending upon season).

To enhance air drying if desired, sludge piles should be turned with a backhoe every two weeks. Sludge that is 95% dry is considered safe for all agricultural purposes. Other options for sludge reuse are:

- Composting with the organic fraction of municipal solid waste;

- Composting with crop waste. This requires monitoring to ensure that the co-composting mixture has a carbon to nitrogen (C: N) ratio of between 20:1 and 30:1. Shredded crop waste, food waste, and grease are excellent sources of carbon. Piles should be turned weekly and monitoring to verify that the ideal moisture content of 65% is maintained.

World Health Organisation guidelines for reuse of sludge may be referred[15].

5.2.10 AI.10: Install sampling platforms

A sampling platform is a simple boardwalk that allows the operator to easily take a samples of wastewater at different depths in the pond without using a boat. It should extend 4 metres into the pond cell and ideally have a safety railing.

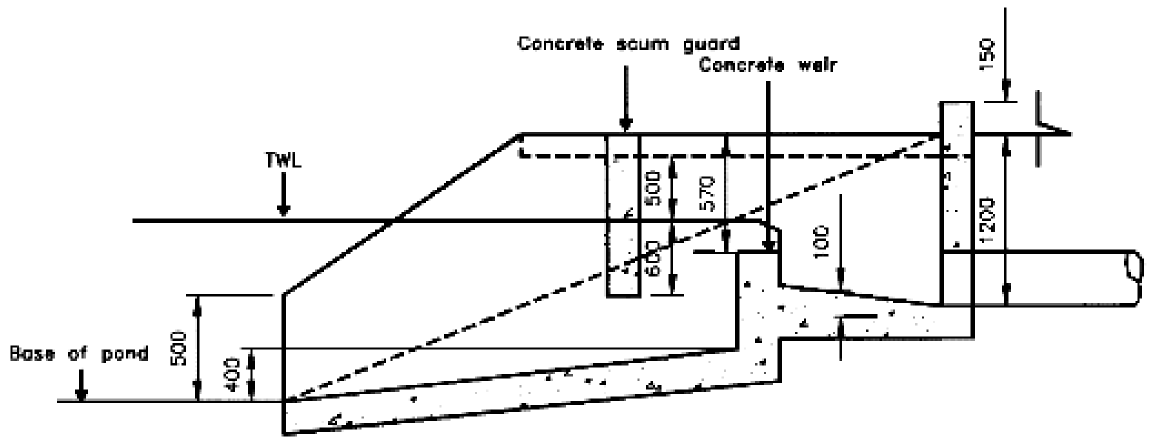
5.2.11 AI.11: Inspect and refurbish outlet structure

Pond outlet structures in the pond cells should be constructed as per Mara 1998 (Figure 5.7) with the following modification:

For the maturation ponds, the same structure is used but placed over the discharge basin. **For both maturation ponds and FPs, the depth of the concrete scum guard should extend into the water to a depth of 0.6 metres below the surface.** This is well below the level occupied by algae.
By collecting the effluent from lower depths, more algae are naturally retained in the pond. Outlet structures can also be fabricated using the floating baffles fitted with discharge windows.

[15] http://apps.who.int/iris/bitstream/10665/41681/1/9241542489.pdf

Figure 5.7**: Pond outlet structure**

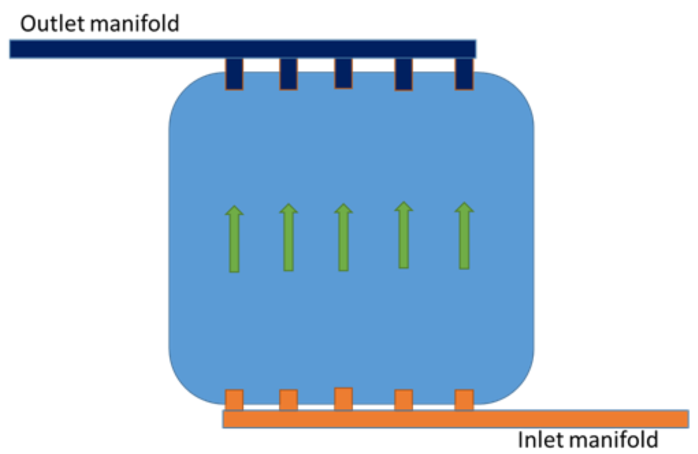


Source: Waste stabilisation ponds manual for India, Mara 1998

NOTE: Addition of one or more inlet and outlet structures in the ponds will help reduce short circuiting. (Figure 5.8)

Multiple inlet and outlet structures can help reduce short circuiting, without baffle walls. Care must be taken to ensure that the manifolds are level. Installation of valves can help operators balance flows for considerable reduction in short circuiting

Figure 5.8**: Multiple inlet and outlet structures**



*Source:*TNUSSP Analysis 2017

5.2.12 AI.12: Divert flow to AP 1

Only divert flow if the excavation desludging method is to be used, as provided above. If diversion is required, close the valve to AP2, open the valve and divert all the sewage to AP 1. Now repeat the process above for AP 2.

5.2.13 AI.13: Inspect and service the valves in Diversion Box 3

Follow the procedures listed in AI 1 above.

5.2.14 AI.14: Divert flow to FP 2 to dry out FP1

Similar procedures that were utilised for the APs will now be conducted for the FPs. Using the valves in Diversion Box 3, close off the flow to FP 1 diverting all the wastewater to FP 2. This will again entail pumping out the liquid from FP 1 into FP 2 and allowing the sludge (if there is any there) to air dry for two weeks.

5.2.15 AI.15: Remove sludge.

Follow the same procedures that were utilised in AI 9.

5.2.16 AI.16: Install outlet structures

Install the outlet structures and scum guard around the outlet to minimise algae carryover. Follow the same procedures as in AI 14.

5.2.17 AI.17: Install sampling platform

Follow same procedures as in AI 10.

5.2.18 AI.18: Divert flow to FP 1, dry out FP 2

For FP 2, repeat the procedures that were utilised for FP 1

5.2.19 AI.19: Perform dye test on polishing ponds

There may be seepage from one or more of the pond cells. Seepage can undermine and erode the berms, contribute to surface and groundwater contamination, and reduce treatment plant effectiveness. A dye test should be performed before emptying the pond to verify if seepage is occurring. After desludging and any needed excavation, inspect the bentonite clay layer and repair and replace it as needed. Local contractors have done this in the past according to anecdotal information. The actual charges of materials used in the past may be used to estimate current costs.

Water tracing dyes[16] are widely used for colour identification in water systems. Its uses include leak detection in closed systems, plumbing tracing, septic system tracing, sewer drain studies, pond leaks, flow and rate studies and more. They can be detected visually or with an ultraviolet light or by a fluorometer. These dyes are safe, non-toxic and biodegradable. Sunlight also breaks down the colour. To use, mix in the required amount of dye solids, wait for 24 hours, and begin to monitor visually or with fluorescent light over the next 7 days. If no color appears in standing water outside of the pond after day 7, there are no leaks. These dyes are used by public works departments, sanitary authorities, engineers and by those who need to trace water. These dyes may be available as powder, tablets or liquid.

Pond Seepage and Groundwater Monitoring

Seal the bottom of the pond to reduce seepage (with bentonite). There is some indication of ponding due to seepage. A simple dye test would help to make a definitive analysis and should be performed prior to contracting the work.

Installation of groundwater monitoring wells (one above the hydraulic gradient of the groundwater as measured through wells in the area, and two below). Monitoring for nitrates and TN would be useful to see long term trends, and to measure the impact upon the environment of the plant over time.

5.2.20 AI.20: Divert flow from PP1 to PP2 and dry out PPI

Using the valves, close off the flow to PP1 diverting all flow to PP2. Dry out the pond cell as with the anaerobic and FPs.

[16] http://prestodye.com/water-tracing-dyes/

5.2.21 AI.21: Remove sludge.

If there is more than 0.25 metres of sludge in the pond, remove it with a front end loader using a procedure to carefully avoid gouging the bottom of the cell and disturbing the bentonite. If there is less than 0.25 metres of sludge on average, let it remain.

If the seepage test indicates a problem, inspect the bottom of the cell near where the seepage is occurring and add bentonite only in those areas.

5.2.22 AI.22: Install the outlet structures.

Follow the same procedures as with the FPs.

5.2.23 AI.23: Install sampling platforms

Follow the same procedures as with the FPs.

5.2.24 AI.24: Divert the flow to PP 2

Open the valve to PP 1, close the valve to PP 2 and repeat the same procedures to rehabilitate PP 2.

5.2.25 AI.25: Install a sampling platform on the discharge pipe.

Use the same procedures that were utilised in the pond cells to install the sampling platform over the discharge pipe. This will make it possible to safely collect samples.

5.2.26 AI.26: Install flow-measuring device -Outlet

Install a flow-measuring device such as rectangular or triangular notch weir, or Parshall flume at the outlet pipe.

6

Estimation of Costs

6.1. Costs and timeframe for achieving current (2008) standards 85

6.2. Additional Costs to achieve October 2017 discharge standards for all parameters 85

6. Estimation of Costs

6.1. Costs and timeframe for achieving current (2008) standards

Table 6.1 shows the suggested time frame for tasks and estimated costs. INR is calculated at exchange rate of INR 64.4 = USD 1. The total cost does NOT include any contingencies.

Table 6.1: **Time Based Investment Plan**

Time Based Investment Plan - WSP										
	MONTH									
	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21- 24	USD	INR
Inspect and service all valves									1,500	96,705
Install or repair flow meter									6,500	419,055
Repair bar screens									3,500	225,645
Repair grit chamber									3,500	225,645
Install air / vac valve									1,800	116,046
Desludge AP 1									7,500	483,525
Install sampling platform in AP 1									3,500	225,645
Inspect and refurbish outlet structure in AP1									5,000	322,350
Repeat for AP 2									16,000	1,031,520
Desludge FP1 (if needed)									15,000	967,050
Install outlet structure in FP1									18,000	1,160,460
Install sampling platform in FP 1									3,500	225,645
Repeat for FP 2									36,500	2,353,155
Dye test PP1 and PP2									100	6,447
Remove sludge from PP1 if needed									10,000	644,700
Install outlet structure in PP1									18,000	1,160,460
Install sampling platform in PP1									3,500	225,645
Repeat for PP2									31,600	2,037,252
Install sampling platform on discharge pipe									3,500	225,645
Install simple flow measuring device outlet									1,000	64,470
TOTAL									**189,500**	**12,217,065**

Source: TNUSSP Analysis 2017

Some of these costs may change because of field evaluations during rehabilitation and construction. For example, it may not be necessary to apply bentonite to the bottom of the pond bottom if the volume of sludge to be removed is less than expected. A two-year time frame is provided if TCC elects to use the excavation desludging method that requires individual pond cells to be dewatered and air dried. If the dredging method is to be used, the activities prescribed above can be accomplished in significantly less time.

6.2. Additional Costs to achieve October 2017 discharge standards for all parameters

To achieve the October 2017 discharge standards, special attention to reducing short circuiting should be prioritised. The use of floating geomembrane baffles is presented in the appendix. Brick baffle walls may also be considered, although the construction will be considerably more complex. These will require the excavation and installation of concrete stem walls to support the brick walls and keep them from settling in the saturated environment. Brick walls will also require reinforcement to withstand incidental contact during desludging procedures.

An alternative is to utilise influent distribution and effluent collection structures that provide a more even distribution of the wastewater throughout the cell. The more distribution and collection points, the less short-circuiting. Professional engineering and strict construction supervision will be required. These may be less expensive (but also less effective) than the baffles.

Recommendation for Future Flows

7.1. STP 89

7.2. Upgrading STP effluent-thoughts & strategies 90

7.3. Decanting station 92

7. Recommendation for Future Flows

7.1. STP

The Action Plan provided herein provides a roadmap and cost estimate for a year-wise investment strategy through 2020 covering the cost of improvements to the STP for up to 58 MLD. The recommended strategy is as follows:

1. Present – 2020. Execute the Action Plan to improve the WSP as directed
2. Post 2020, begin to carefully monitor BOD and TSS at the outlet of the WSP. Begin planning for renovation of old 30 MLD pond system, or consider adding aeration to existing 58 MLD pond system
3. Should TCC abandon the idea of the EA system and opt for treating more of the wastewater at the STP, begin to integrate the old 30 MLD system into the existing pond system as flows increase. Each additional cell will be equipped with baffle walls and aeration as prescribed above and excavated to 5 metres.

To operate the facilities once initial repairs are made as per the Action Plan, Mara (1998) provides the following guidance (Table 7.1):

Table 7.1: **Number of O & M workers per population served**

Sl.No.						
1	Population served	10,000	25,000	50,000	100,000	250,000
2	Foreman/Supervisor	-	-	1	1	1
3	Mechanical Engineer*	-	-	-	1	1
4	Laboratory technician**	-	1	1	1	2
5	Assistant foreman	-	1	2	2	2
6	Labourers	1	2	4	6	10
7	Driver#	-	1	1	1	2
8	Watchman##	1	1	3	5	5
Total		2	6	10	15	23

*Dependent upon amount of mechanical equipment used

**Dependent upon existence of laboratory facilities

#Dependent upon use of vehicle towed lawn mowers etc.

##Dependent upon location and amount of equipment used

Source: Duncan Mara 1998

It is likely that TCC will utilise private sector contractor firms to perform O & M. Such contracts should be performance based. When evaluating proposals, the table above can be used as a guideline. NOTE: The table should be customised based on the actual facilities installed. If mechanical aeration, BNR system, filtration wetlands system, and disinfection system is used, consider adding:

- Trained senior operator
- Electrical technician – start with one and add another as the flows increase
- Mechanical technician – start with two and add additional staff as needed

For specialised equipment such as aeration, the manufacturer may have operations and maintenance crews that can perform services for a nominal price. This is the case with the Aire-O2 surface aerators. They have crews in India that can perform this task.

Contracts should specify:

- PPE, health and safety practices should be followed at all times
- Daily log books should be kept on site and available for inspection
- Insurance for general liability, vehicle liability be kept up to date with TCC registered as 'additionally insured'.

7.2. Upgrading STP effluent-thoughts & strategies

When the effluent from STP exceeds the mandatory discharge requirements for discharge into receiving water, the methods of achieving compliance can be grouped as follows:

1. Administrative compliance by obtaining a compliance schedule for phasing in the interventions (baffle wall, then aeration, then advanced treatment should it ever be necessary). The basis for requesting the compliance schedule is (i) the receiving water is not used for human activities (ii) cost of compliance, and (iii) that earlier interventions may preclude the need for later ones.

2. Stop discharge to the receiving water by (i) total containment by holding the wastewater for evaporation (requires large pond volume) or (ii) discharging to land (for example, agricultural or landscape irrigation, or land application for infiltration). For Trichy, there is not enough land for complete dispersal through agricultural reuse. Cooperative agreements between the TCC and neighboring land owners would be required.

3. Change the influent through a city-wide commercial pre-treatment programme. This is appropriate for industrial and some commercial wastewater discharges such as from restaurants, car repair and service workshops. 80% of this commercial pre-treatment is related to food-waste in an effort to capture fats, oil and grease (FOG). FOG is a valuable feedstock for several commercial products including biodiesel. Such programmes can pay for themselves over time.

   Pre-treatment is best applied where the discharge can adversely affect the wastewater collection system. For example, FOG from food preparation and processing clogs the sewer pipes and creates backup and flooding. The discharger can visually see a direct relationship between their discharge and its impact on the wastewater system and this makes it somewhat easier to get cooperation and support for enforcement.

4. In pond treatment, particularly in the facultative and aerobic ponds, by (i) aeration (ii) mixing (iii) recirculation (iv) biological harvesting of excess algae and (v) adding baffles to increase mixing, a surface can be provided for micro-organisms to grow. In addition, it also reduces short-circuiting.

7.2.1 Performance assessment tool

An excel based performance assessment tool for the WSP has been developed to easily determine the change in quality of effluent from STP based on the given interventions

i. Desludging
ii. Improving outlet structures
iii. Installation of baffles
iv. Providing aeration
v. Deepening the pond

These interventions may or may not be carried out (user is give an option to choose for each). Each chosen option influences the effluent quality (Figure 7.1).

Input assumptions required are

1. Design and observed sewage characteristics
   a. Observed inlet BOD
   b. Inlet Fecal Coliform (FC)

c. Plant flow
d. Maximum sludge build-up in anaerobic tanks
e. Minimum sludge build-up in anaerobic tanks (after desludging)

2. Operational interventions
    a. Initial improvements at WSP
        i. Initiate desludging of APs
        ii. Install baffles in the AP to avoid short circuiting
        iii. Improve outlet structures in maturation pond

3. Increase depth of ponds
    a. Increase depth of FP
    b. Increase depth of AP

4. Provide aeration in FP and MP
    a. Provide aeration
    b. Increase depth in aerated lagoons

With this input data, plant performance will be displayed with the following details

1. BOD in final outlet
2. (FC) in final outlet
3. For APs, FPs , and maturation ponds, details are shown below, under each pond system
    a. BOD loading on the plant
    b. Retention time
    c. BOD of effluent from the pond unit
    d. Adequacy of capacity of the pond

Figure 7.1: **WSP Performance assessment tool**

Input Assumptions		
Design and Observed Sewage characteristics		
Observed inlet BOD	270	mg/L
Inlet Fecal Coliform	5E+07	MPN/100mL
Plant Flow	55	MLD
Maximum sludge buildup in anaerobic tank	30%	
Minimum sludge buildup in anaerobic tank:	0%	
Operational interventions		
1. Initial improvements at WSP		
Initiate desludging of Anaerobic Ponds?	Yes	Realize full volume of AP
Install baffles in anaerobic pond to avoid sh	Yes	Realize 70% BOD remval in AP
Improve outlet structures in maturation por	Yes	Realize 25% BOD removal in MP
2. Increase depth of ponds		
Increase depth of Facultative Pond	Yes	Increase available volume of FP
Increase depth of Anaerobic Ponds	No	Increase available volume of AP
3. Provide aeration in Facultative and Maturation Ponds		
Provide aeration	No	
Increase depth in Aerated Lagoons	No	
Enter data in shaded cells		

Output results		
Plant performance		
Include BOD from suspended solids in outlet?		No
BOD in final outlet	27.24	mg/L
FC in final outlet	133	MPN/100mL
Anaerobic Pond		
BOD loading on the plant	155	$gBOD/m^3.day$
Retention time in AP	1.74	days
BOD in AP effluent	81	mg/L
Adequacy of AP	**Sufficient Capacity**	
Facultative Pond		
BOD loading on the plant	176	$gBOD/m^3.day$
Retention time in FP	6.17	days
BOD in FP effluent	36	mg/L
Adequacy of FP	**Sufficient Capacity**	
Adequacy of FAL	**NA**	
Maturation Pond		
BOD loading on the plant	90	$gBOD/m^3.day$
Retention time in FP	4.09	days
BOD in MP effluent	27	mg/L
Adequacy of MP	**Sufficient Capacity**	
Adequacy of Aerated M	**NA**	

Source: TNUSSP Analysis 2017

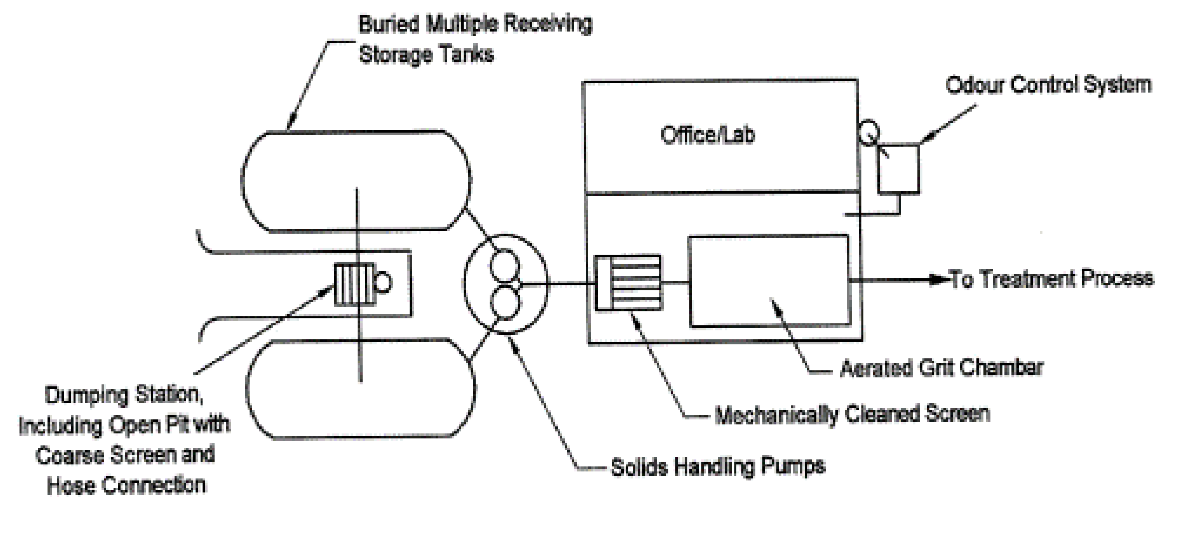
Annexures 8, 9, 10 and 11 have useful information on the interventions of installing baffles and aeration. Annexure 12 provides details on the wastewater treatment alternatives with respect to its reuse and disposal.

7.3. Decanting station

7.3.1 Upgrading requirements for future flows at decanting stations

Figure 7.2 is a schematic representation of a decanting station. Proper screening, grit removal, and diverting commercial and industrial loads of septage will do a lot to reduce organic and toxic loading on the treatment plant. These repairs and upgrades should be made along with the mechanical retrofits at the STP. At the same time, planning for the installation of liquid/solid separation equipment should begin.

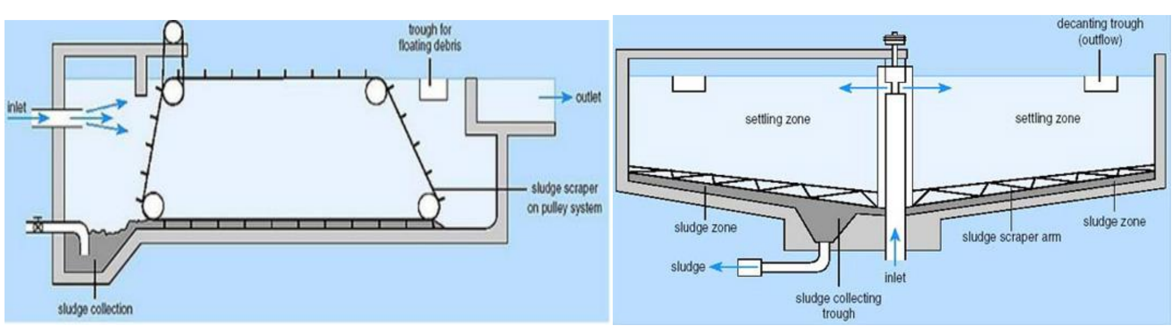
Figure 7.2: **Standard layout of decanting station**



Source: CPHEEO guidelines

Sedimentation is a physical wastewater treatment process using gravity to remove suspended solids from water. Settling basins are ponds or tanks constructed for removing entrained solids by sedimentation. They can be fitted with mechanical means for continuous removal of solids deposited by sedimentation (Figure 7.3). Conical tanks with sludge outlets at the bottom can also be effective.

Figure 7.3: **Horizontal flow type and conical sedimentation tank**



Source: https://theconstructor.org/environmental-engg/types-of-sedimentation-tank/14711/

Figure 7.4 shows a decanting station in Bekasi City, Indonesia. It uses an automated pre-treatment device connected to a screw press for liquid/solid separation. The unit can handle up to 120 cubic metres per day but can be upgraded for doubling the flow to 240 cubic metres per day. It is highly efficient but requires O & M staff that are trained in its use. The cost for this facility is approximately ₹3.2 crore (500,000$).

Figure 7.4: **Mechanized decanting station using screw press technology in Bekasi City, Indonesia**

Source: Image courtsey-David M Robbins

7.3.2 Locations for new decanting stations

Factors to consider in selecting locations for new decanting stations include:

1. Position with respect to large sewer mains (>30 inch diameter) which is necessary to handle the large volume of septage.
2. It should be far from residential and commercial buildings to avoid complaints of odours and noise, but not so far such that it takes a long time to travel from the septic tank to decant station.
3. Access by septage trucks which should include adequate roadway width for large trucks, sufficient space for the truck to turn into and out of the station, and short distance from truck discharge into the receiving pit.
4. Adequate land for pre-treatment and liquid/solid separation equipment.

8 Conclusions and Next Steps

8. Conclusions and Next Steps

The STP at Panjappur is fundamentally sound in terms of size, shape, and sequence of the lagoon cells. The system can achieve the October 2017 discharge standards through i) repairs of existing mechanical equipment, ii) desludging pond cells as needed, iii) installing better inlet and outlet structures that minimise short circuiting and algae carryover, and iv) limiting the amount of BOD introduced into the system through septage by implementing liquid/solid separation at the decanting stations.

The septage decanting programme in Trichy may be improved based on current practices. Recommendations presented herein to improve recordkeeping, initiate a waste load manifesting system, and segregate commercial and industrial septage loads would help considerably. An estimate of the number of trucks that can be accommodated based on different flow and effluent discharge and reuse scenarios at the STP has been provided. Improving on the screening and grit removal is the immediate concern. Adding liquid/solid separation equipment will be required as flows approach the design flow limitations.

The institutional arrangements within the city government are currently insufficient to achieve the compliance goals at the treatment plant at present and in the future. They should be adjusted prior to engaging in significant upgrading of the system. Training and capacity building of TCC and contractor staff is required. A better system for communication and follow through between contractors and TCC engineering staff would be useful in helping to ensure that routine operational and maintenance tasks are performed. Check lists, log books, written work orders and communications logs would be helpful. Placing the entire wastewater programme under one department would also be useful.

Risks

- More volume and different strengths of wastewater than for which the STP was designed (true for any sewage treatment plant)
- Financial constraints of TCC may affect O & M. This is more likely to occur with treatment systems that have high electricity demand

Next steps

- Using the guidelines in this report, prepare a formal O & M plan and implement it
- Using the guidelines in this report, prepare a sampling and monitoring plan that includes daily, weekly, monthly, and quarterly tasks for all aspects of the STP- WSP operations (Annexure 13) .
- Begin working on the initial steps specified in the Action Plan. This includes fixing or repairing the flow meter, fixing the issues identified at the grit chamber and screening system at the WSP headworks, and alleviating the air blockage on the transmission pipeline from the headworks to the APs.
- Start with designs, drawings, and specifications for Action Plan items.

Bibliography

Bureau of Indian Standards, 1987, IS 5611 – Code of Practice for Construction of Waste Stabilisation Ponds (Facultative Type). Bureau of Indian Standards. Second Reprint December 2010.

Kerri, K. D., 1994, *Operation of Wastewater Treatment Plants: A Field Study Training Programme,* Vol.I (4th ed). California State University Sacramento.

Mara, D., 1997, *Design Manual for Waste Stabilisation Ponds in India.* Lagoon Technology International Ltd.

Tiruchirappalli City Corporation (TCC), April 2016, *Detailed Project Report (DPR) on Providing Under Ground Sewerage Scheme to Tiruchirappalli City Corporation using Trenchless Technology, Phase-II*

Tiruchirappalli City Corporation (TCC), 2008, *Details of underground drainage scheme/sewage treatment plant at Panjappur, Golden Rock Sewage Treatment*

Tiruchirappalli City Corporation (TCC), May 2017, *Providing Under Ground Sewerage Scheme to Tiruchirappalli City Corporation under AMRUT, Phase-II*, PowerPoint Presentation

United States Environmental Protection Agency (USEPA), 2011, *Principles of Design and Operations of Wastewater Treatment Pond Systems for Plant Operators, Engineers, and Managers*, EPA/600/R-11/088

United States Environmental Protection Agency (USEPA), September 2000, *Wastewater Technology Fact Sheet Oxidation Ditches, EPA 832-F-00-013*

Annexures

Annexure 1- Wastewater Generation	A3
Annexure 2- As Built Drawings and Pond Geometry	A5
Annexure 3 - Sampling Analysis Report & Interpretation	A7
Annexure 4- Duties and Responsibilities Of Contractor And Supervisor	A11
Annexure 5- Commercial Pre-Treatment Program	A17
Annexure 6- Best Practices of Operation & Maintenance for Waste Stabilisation Pond	A19
Annexure 7- Calibration Procedure for Pumps	A33
Annexure 8- Information on Solar Powered Aerators	A35
Annexure 9- Case Study- Evaluation of Solar Powered Aerators in STP, at Los Banos, California	A39
Annexure 10- Floating Baffles - Proposal and Supporting Information	A43
Annexure 11- Information on Surface Aerators	A47
Annexure 12- Wastewater Treatment Alternatives	A49
Annexure 13- Sampling Plan for STP	A53

Annexure 1- Wastewater Generation

Table A1.1: **Wastewater generation estimates for future population**					
Ward No.	**Wastewater projection (MLD)**				
	2015	**2030 (for population projected by TCC)**	**2030 (Arithmetic Projection)**	**2045 (for population projected by TCC))**	**2045 (Arithmetic Projection)**
1	2.24	3.31	3.05	4.75	4.16
2	1.59	1.91	2.17	2.35	2.95
3	1.51	1.62	2.06	1.76	2.80
4	2.12	2.60	2.88	3.25	3.92
5	2.36	2.84	3.21	3.49	4.38
6	1.96	2.82	2.67	3.97	3.63
7	1.85	2.71	2.52	3.86	3.43
8	1.64	2.28	2.23	3.15	3.04
9	2.02	3.09	2.75	4.53	3.75
10	1.41	1.62	1.92	1.91	2.61
11	0.93	0.99	1.27	1.06	1.73
12	1.54	1.65	2.10	1.80	2.86
13	0.87	1.09	1.19	1.38	1.62
14	1.16	1.22	1.59	1.29	2.16
15	1.66	1.72	2.27	1.79	3.09
16	0.95	1.01	1.30	1.08	1.77
17	1.29	1.32	1.76	1.36	2.40
18	1.26	1.37	1.72	1.51	2.34
19	1.22	1.54	1.66	1.97	2.25
20	0.89	0.94	1.21	1.01	1.65
21	0.99	1.04	1.35	1.12	1.84
22	1.31	1.36	1.78	1.43	2.42
23	1.21	1.29	1.65	1.40	2.25
24	0.77	0.87	1.04	1.02	1.42
25	1.13	1.24	1.55	1.39	2.10
26	1.15	1.36	1.57	1.65	2.13
27	1.98	2.84	2.69	3.99	3.67
28	1.54	2.19	2.10	3.05	2.86
29	1.96	2.77	2.67	3.85	3.64
30	2.14	2.94	2.91	4.02	3.96
31	1.21	2.29	1.65	3.73	2.25
32	0.96	2.30	1.30	4.10	1.77

Table A1.1: **Wastewater generation estimates for future population**					
Ward No.	**Wastewater projection (MLD)**				
	2015	**2030 (for population projected by TCC)**	**2030 (Arithmetic Projection)**	**2045 (for population projected by TCC))**	**2045 (Arithmetic Projection)**
33	1.60	2.03	2.17	2.60	2.96
34	1.20	1.41	1.63	1.70	2.22
35	2.44	3.52	3.33	4.96	4.53
36	1.49	2.57	2.03	4.01	2.77
37	2.21	3.55	3.00	5.35	4.09
38	3.26	4.60	4.44	6.40	6.05
39	2.18	3.25	2.97	4.69	4.04
40	2.93	4.01	3.99	5.45	5.44
41	1.95	2.81	2.66	3.97	3.63
42	1.51	2.31	2.05	3.39	2.80
43	1.52	2.06	2.07	2.77	2.82
44	1.22	2.30	1.66	3.73	2.27
45	2.26	3.06	3.08	4.14	4.19
46	1.83	2.48	2.50	3.34	3.40
47	1.36	1.52	1.85	1.74	2.52
48	1.48	1.64	2.01	1.86	2.74
49	1.87	1.88	2.55	1.90	3.47
50	1.96	2.28	2.66	2.71	3.63
51	1.38	1.49	1.88	1.64	2.57
52	2.93	3.79	4.00	4.94	5.44
53	1.84	2.91	2.51	4.35	3.41
54	1.40	2.05	1.91	2.91	2.60
55	1.55	1.71	2.11	1.92	2.87
56	1.34	1.83	1.83	2.48	2.49
57	2.09	2.42	2.85	2.85	3.88
58	1.46	1.51	1.99	1.59	2.71
59	1.09	1.19	1.48	1.34	2.01
60	2.16	3.23	2.94	4.67	4.00
61	1.73	2.38	2.36	3.24	3.21
62	1.37	2.71	1.86	4.51	2.54
63	2.62	3.96	3.57	5.76	4.86
64	1.29	2.64	1.76	4.43	2.40
65	1.76	2.62	2.40	3.77	3.27
Totals	**107.14**	**143.86**	**145.90**	**193.10**	**198.69**
Source: TNUSSP Analysis 2017, TCC, Census 2011					

Annexure 2- As Built Drawings and Pond Geometry

Table A2.1: **Pond geometry and Volumes**

Sl.No.	Component	Anaerobic pond 1	Anaerobic pond 2	Facultative pond 1	Facultative pond 2	Maturation pond 1	Maturation pond 2
1	Volume of water in the pond from survey (m^3)*	47,803	50,633	136,938	117,631	115,681	109,030
2	Calculated Volume # (m^3)	46800	46800	126688	126688	110531	110531
3	Useful depth (m) as per TCC report	2.5	2.5	1.5	1.5	1.5	1.5
4	High dimensions (Length -m)*	222	225.5	425.5	426	387	386
5	High dimensions (Breadth- m)*	91	91	214	217	214	214
6	Floor dimensions (Length- m)*	206	212.5	414	415	375	375
7	Floor dimensions (Breadth- m)*	75	76	205	204	196	198
8	Dimensions as per TCC report (Length- m)	200	200	413	413	375	375
9	Dimensions as per TCC report (Breadth- m)	75	75	203	203	195	195
10	Water Level Top*	80.6	80.7	79.5	79.2	79.1	79.1
11	Water Level Bottom*	77.8	77.8	77.9	77.8	77.6	77.6
12	Water level depth*	2.8	2.8	1.6	1.4	1.5	1.4
13	Floor type	Soil with clay	Soil with clay	Soil with clay	Soil with clay	Soil with clay	Soil with clay
14	Cell wall	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete
15	Wall slope	1:01		1:01		1:01	

Table A2.1: **Pond geometry and Volumes**							
Sl.No.	**Component**	**Anaerobic pond 1**	**Anaerobic pond 2**	**Facultative pond 1**	**Facultative pond 2**	**Maturation pond 1**	**Maturation pond 2**
16	Freeboard	0.5-1	0.5-1	0.5-1	0.5-1	0.5-1	0.5-1
* from survey							
# Assuming trapezoid with slope 1:1, and taking dimensions as per TCC report							
Source: TNUSSP Analysis 2017							

Annexure 3 - Sampling Analysis Report & Interpretation

There were three sampling evens at Trichy Wastewater Stabilization Ponds: March 22, March 25, and March 27. At the head works, the influent was collected according to time and composited using equal volumes for each time increment. Grab samples were collected at the outlet of each of the Anaerobic, Facultative, and Polishing Ponds (total 6 samples), and at the outlet. Samples were transported in cool boxes by car to Chennai for analysis by Chennai Mettex Lab Private LTD.
Average Results of Laboratory Analysis (mg/L) is in Table A3.1. The analytical results are summarised in Table A3.2.

Table A3.1: **Average Results of Laboratory Analysis (mg/L)**

Sl.No.		**Average Results (mg/L)**		**Compliance with Discharge Standards**		**Percent (%) Removal**	
	Parameter	**Head works**	**Final Outlet**	**1986 CPCB Standards**	**2020 CPCB Standards**	**Expected**	**Actual**
1	Sample Type	composite	grab				
2	BOD @ 20°C for 5 days (mg/L)	103	42	no	no	95% to 97%	59%
3	COD (mg/L)	303	130	yes	no	---	57%
4	Total Suspended Solids (TSS) (mg/L)	163	40	no	no	90% to 95%	76%
5	Ammonia Nitrogen as NH4-N (mg/L)	32	21	yes	no	---	35%
6	Total Nitrogen as N (mg/L)	45	27	yes	no	---	39%
7	Fecal Coliform (MPN/100mL)	1600		none		95% to 98%	0%

Notes:
- adjusted average results from sampling on March 22, 25, and 27, 2017
- Discharge Standards are listed in Table 2.11
- % Removal Expected from CPHEEO, 2012
- % Removal Actual = (headworks - final outlet) / headworks

Source: TNUSSP Analysis 2017

Evaluation of results shows that the WSP is not in compliance with 1986 Standards for BOD5 and TSS. This is due to unsatisfactory operations as evidenced by comparing expected to actual percent removal. From preliminary observations, we believe the reasons for poor operations are (1) sludge build-up in the ponds; (2) outlet structure in facultative ponds that allow algae and solids to be carried over into the maturation pond; (3) outlet structure in the maturation pond that allows algae to be carried over; and (4) scum layer on the surface of the maturation pond that prevents full sunlight for coliform reduction.

Preliminary Evaluation

Differences between Anaerobic Ponds #1 and #2 may be caused by vegetation which is thick in Pond #1 but removed in Pond #2.

Differences between ponds may also be due to differences in accumulated solids build-up.

Third day (27.03.2017) grab samples show unexpected results for BOD5 and COD. One likely reason is that there is not even distribution between the cells. This is due to valves that may not be closing properly or valve boxes that may have settled. Further review is warranted. After which, we may average or discard those data points.

Cannot explain differences in BOD of Polishing Pond #2 and Outfall. Should be close in value. The variance may be due to i) unequal flow distribution, ii) effluent discharge at different elevations within the water column, iii), uneven sludge volume, or iv) variances within the normal range of accuracy (50% plus/minus) when grab sampling is conducted.

Table A3.2: **Analytical Results of 3 days of sampling (22 March 2017)**

FIRST DAY: March 21, 2017 to March 22, 2017

No.	Parameters	Protocol	At Head works (Composite sampling except for No.8)	Anaerobic Pond 1 Outlet	Anaerobic Pond 2 Outlet	Facultative Pond 1 Outlet	Facultative Pond 2 Outlet	Polishing Pond 1 Outlet	Polishing Pond 2 Outlet	Final Outlet
1	pH at 25°C	IS: 3025:Part: 11-1983 (Reaff:2012)	7.37	7.27	7.22	7.75	7.69	8.1	8.03	8.13
2	BOD @ 20°C for 5 days (mg/L)	IS:3025 Part 44-1993 (Reaff:2009)	105	54	26	26	28	52	22	38
3	Chemical Oxygen Demand ()	IS:3025 Part 58-2006 (Reaff:2012)	310	193	133	134	140	184	112	133
4	Total Suspended Solids (mg/L)	IS:3025 Part 17 -1984 (Reaff:2012)	192	98	68	64	69	47	42	41
5	Ammonical Nitrogen as NH4-N (mg/L)	IS:3025 Part 34-1988 (Reaff:2009)	32	34.6	41.2	29.6	29.6	19.5	25.0	19.5
6	Total Nitrogen as N (mg/L)	IS:3025 Part 34-1988 (Reaff:2009)	44.3	47.4	53.3	46.1	44.2	29.0	35.0	25.0

Table A3.2: **Analytical Results of 3 days of sampling (22 March 2017)**										
7	Total Phosphate as P (mg/L)	IS:3025 Part 31-1988 (Reaff:2009)	3.92	4.74	5.47	4.0	4.0	3.7	4.0	3.0
8	Fecal Coliform (MPN/100 mL)	IS 1622:1981 (Reaff:2009)	1600							1600
SECOND DAY: March 24, 2017 to March 25, 2017										
9	pH at 25°C	IS: 3025:Part: 11-1983 (Reaff:2012)	7.38	7.15	7.1	7.6	7.71	7.81	7.85	7.75
10	BOD @ 20°C for 5 days (mg/L)	IS:3025 Part 44-1993 (Reaff:2009)	101	48	26.5	26.5	31	55	24	46
11	Chemical Oxygen Demand (mg/L)	IS:3025 Part 58-2006 (Reaff:2012)	290	158	107	106	140	128	112	109
12	Total Suspended Solids (mg/L)	IS:3025 Part 17 -1984 (Reaff:2012)	172	92	58	56	66	38	34	38
13	Ammonical Nitrogen as NH4-N (mg/L)	IS:3025 Part 34-1988 (Reaff:2009)	31	37.3	43.3	29.6	29	18.6	24	21.4
14	Total Nitrogen as N (mg/L)	IS:3025 Part 34-1988 (Reaff:2009)	44.0	47.3	56.4	47.1	42.6	29	35.0	27.2
15	Total Phosphate as P (mg/L)	IS:3025 Part 31-1988 (Reaff:2009)	3.0	4.1	4.96	4.09	3.8	2.6	3.4	3.08
16	Fecal Coliform (MPN/100 mL)	IS 1622:1981 (Reaff:2009)	1600							1600
THIRD DAY: March 26, 2017 to March 27, 2017										
17	pH at 25°C	IS: 3025 Part: 11-1983 (Reaff:2012)	7.38	7.3	7.2	8.15	7.92	8.26	8.2	8.15
18	BOD @ 20°C for 5 days (mg/L)	IS:3025 Part 44-1993 (Reaff:2009)	80	48	36	21	56	84	27	64
19	Chemical Oxygen Demand (mg/L)	IS:3025 Part 58-2006 (Reaff:2012)	309	173	117	188	220	160	156	149

Table A3.2: **Analytical Results of 3 days of sampling (22 March 2017)**										
20	Total Suspended Solids (mg/L)	IS:3025 Part 17 -1984 (Reaff:2012)	124	64	44	54	60	78	56	84
21	Ammonical Nitrogen as NH4-N (mg/L)	IS:3025 Part 34-1988 (Reaff:2009)	33.5	37.6	43.3	28	33.2	20	26.3	22.2
22	Total Nitrogen as N (mg/L)	IS:3025 Part 34-1988 (Reaff:2009)	45.2	48.2	55.2	45	48.9	29.6	35.7	28.7
23	Total Phosphate as P (mg/L)	IS:3025 Part 31-1988 (Reaff:2009)	3.1	4.0	5	3.7	4.4	2.9	3.3	3.0
24	Fecal Coliform (MPN/100 mL)	IS 1622:1981 (Reaff:2009)	1600							1600

**Additional Parameters*
Source: Chennai Mettex Laboratory Pvt Ltd March 2017

Annexure 4- Duties and Responsibilities Of Contractor And Supervisor[17]

MANDATORY DUTIES OF THE CONTRACTOR

I. GENERAL

1. The entire sewage generated in the area of jurisdiction through the house service connection has to be collected conveyed through the collection system to the sewage pumping station, pumping the sewage by operating the existing Non clog submersible sewage pumping machinery's to the existing treatment plant at Panjappur owned by Tiruchirappalli City Corporation

2. The screens of the wells are to be cleaned in every shift at regular intervals to ensure free flow to prevent back flow and accumulation of sewage in upstream side and to prevent pump failure.

3. Lifting and lowering of submersible pump seta once in fortnight for proper operation and seating.

4. De-silting of wells in the sewage pumping station is to be done periodically by the contractor.

5. Operation of specified shifts/day and ensuring that back up teams would be available to take over during Sundays, Holidays and in the event of regular operator/Labour absence including watch and ward.

6. Making sure that the levels are maintained between safe and low levels, as specified at all times ensuring that the level is always below the incoming sewer lines.

7. Ensuring that the wells are de-silted minimum once a day to handle morning peak flow.

8. Operate and maintain equipment with technical staff so as to safeguard the equipment against single phasing, earth fault, phase reverse etc. in power supply

9. Maintaining all equipment within the station as recommended by the manufacturers, with proper logs and records of the work carried out, as prescribed the City Corporation.

10. Operate and maintain capacitor and allied switch gear so as to maintain a power factor of not less than 0.90 lagging prescribed by TNEB.

11. If any penalty is levied by the TNEB for low power factor, the penalty sum will be recovered from the contractor.

12. The power factor will not decrease or increase suddenly and if the contractor observes daily and finds any decrease in the power factor, it should be informed to the Department engineer in charge. The Department Engineers will take immediate steps in rectifying this.

13. Test run of D.G sets should be carried out for a minimum of 30 minutes per week in idle condition directed by concerned officials. The required lubrication oil and diesel will be supplied by the corporation and contractor should make necessary arrangement for carting the same and maintain

[17] *Source: Trichy City Corporation*

necessary log book and other required documents by the department with the DUE approval and signature of the concerned officials.

14. Keeping all wells, kiosk sheds free from dirt and dust.

15. Ensuring that premises are kept clean and tidy.

16. Maintain the inspection register at the station always

17. Mandatory regulations prescribed by CIEG and inspector of factories shall be followed without any lapse.

18. Carrying out all operations at intervals specified shown on attached sheets for each station.

19. Any repair and replacement works of the HT station should be carried out by the authorised persons as prescribed by CIEG.

20. Each station should be provided with complete set of tools and equipment required for maintaining the station.

21. The following regular equipment maintenance and general maintenance have to be carried out along with those as per preventive maintenance schedule.
    a. De-weeding and cleaning the transformer yard.
    b. Drying and refilling of silica gel in the breather of the transformer.
    c. Regular watering of the earth pits in the transformer yard and maintaining proper earth resistance.
    d. Check for any oil leak in the transformer and top up of oil (transformer oil will be supplied departmentally).
    e. All electric connections have to be checked.
    f. Cleaning of motors, H.t. panel etc. minimum once in a week using air blower
    g. Watering of plants and trees
    h. Check for charging battery including the acidity in cells once in a week so as to start and operate the D.G sets in any emergency requirements.
    i. Replacement of the HG fuse if required.
    j. Replacement of fused out bulbs, chokes, starters etc.

22. The contractor should furnish his local office and residential address along with Telephone nos.

23. Attendance should be maintained in all locations maintained by the contractor and the employee sign it in every shift.

24. Spare (reliever) operator/ labourers should be employed to work in particular station when the person in that station goes on leave, as a substitute.

25. The contractor has to fix leave regulation for the employees and submit a copy to City Corporation.

26. In case of absence of the operator as envisaged the specified amount for that particular shift will be recovered in the monthly bill as per Annexure-II.

27. The contractor has to provide decent uniform with name badge to their staff and if they fail to wear the uniform, penalty at the rate indicated in Annexure II will be recovered from the monthly bill.

28. The contractor has to operate the machineries according to the operating schedule fixed for that particular station and to maintain sewer low-level. The level should not be more or less than that of the operating level fixed during the time of inspection of officials prescribe din the operating schedule. However, tolerance of % (plus or minus) can be allowed. If there is vast difference, unless otherwise specific reasons are not given wages for that particular shift will be recovered as per Annexure-II. Also wages will be recovered, if the reason given by the contractor is not acceptable by the inspecting authority.

29. Maintenance of plant and machineries should be as per the chart given.

30. Whenever an employee of the contractor leaves the job and new person with same qualification is employed or transferred between stations maintained by the contractor it should be informed in writing and with the approval of Engineer and also see that the new persons so employed also have insurance cover.

31. The maintenance gang should possess a register to record their activity in a particular station in a particular day and certified by the corporation officials in charge of that particular station in that book.

32. The contractors are required to operate and maintain the sewage pumping stations continuously during the rainy season by providing additional shifts and man power for the pumping stations operated as per the instruction of Engineer in charge of the station.

33. The contractor should maintain a complaint register in the stations of each zone and also at corporation Mani office and rectify the complaints immediately within 24 hours of receipt of complaints received from public as well as officials.

34. The contractor should make necessary mobile phone arrangements at his own cost for communication purpose.

35. **In view of adhering to the Government policy, the contractor should not engage the manual labour to remove the silt and clog in the manhole strictly**.

36. Following laws shall be adhered to by the contractor wherever applicable
    - 36.1. Workmen Compensation Act, 1923
    - 36.2. Payment of Wages, 1936
    - 36.3. Industries Disputes Act , 1947
    - 36.4. Minimum Wages Act, 1948
    - 36.5. Factories Act, 1948
    - 36.6. Employees PF and Miscellaneous Act, 1952
    - 36.7. Payment of Bonus Act, 1966
    - 36.8. Payment of Gratuity Act, 1972
    - 36.9. Equal Remuneration Act, 1979
    - 36.10. Maternity Benefit Act, 1951
    - 36.11. Contract Labour (Regulation and Abolition Act), 1970
    - 36.12. Industrial employment (Standing orders) Act, 1946
    - 36.13. Trade unions Act, 1926
    - 36.14. Child Labour (Prohibition and Regulation) Act, 1986
    - 36.15. Inter-State Migrant workmen's 9regilation of Employment and Conditions of service) Act, 1979
    - 36.16. The Building and Other Construction workers (regulation of Employment and Conditions of service) Act, 1996 and The Cess Act of 1996

36.17. Employees state insurance Act, 1948

36.18. The Tamil Nadu Manual Workers (Regulations of Employment and Conditions of Work) Act, 1982

36.19. The Bonded Labour system (Abolition) Act, 1976

36.20. The Employer's Liability Act, 1938

II. PROCEDURE FOR CARRYING OUT MINOR REPAIRS

Minor repairs noticed in the equipment should be reported in writing to Official In charge of the station without any time lapse. The rectification works have to be carried out immediately as per the direction of the Official in Charge of the Station. Payment of repair works will be made on actual. Necessary entry for the repairs carried out has to be made in the Log Book.

III. NON- COMPLIANCE TO SCHEDULE OF WORK/MANDATORY DUTIES

If the contractor fails to carry out any work or part of work/mandatory duties, the city corporation shall have the power to carry out such parts of work by engaging private agency and recover such amount including 5 (five) percent of the amount incurred from the progressive bills.

Photo Identify cards have to be issued to the personnel and one set of these identify cards should be furnished to the city corporation and one set displayed in the pumping station.

The responsibility of the contractor to take insurance policy under Workmen's Compensation Act 1923 for each labour and a copy of insurance policy should be furnished to the city corporation. This policy should be kept alive till completion of the contract period.

The name and qualification of the personnel engaged in each Sewage Pumping Station should be prominently displayed in the Pumping Station.

IV DUTIES AND RESPONSIBILITIES OF THE SUPERVISOR OF PUMPING STATION

1. He should be present between 8.30 Am and 5.30 pm in the HT station with one hour lunch intervals
2. He shall hold fully responsibility of maintaining sewer levels as prescribed by the City Corporation.
3. Daily report on flow chart should be sent to office with all activities of the previous day.
4. Inform minor/major/repairs immediately and should be present at site until repair works are completed.
5. He shall have full responsibility for maintaining maintenance schedule such as daily, weekly and monthly programmes.
6. He should organise the silt removal programme and to follow safety rules.
7. He shall keep safety belt, gas mask, gas monitor, and first aid box in his custody and utilize whenever requires.
8. He shall be responsible for overall cleaning and keeping the station neat and tidy.
9. To approach TNEB authority when powers fail in TNEB structure/City Corporation structure and 6 pole structure and do necessary for early supply resumption.
10. He shall check-up power factor every day and to maintain a minimum 0.90 lagging as prescribed by TNEB.
11. In charge shall be sole responsible for carryout mandatory duties of contractor in the individual pumping station and to organise the maintenance gang for routine maintenance work.
12. Up keeping the pumping station such as ait blowing motors, control panels, gland packing, changing engine oil and maintenance of battery.
13. Care has to be taken for workers to avoid double/triple duties as per workmen compensation Act and arrange to renewal the insurance policy.

14. Arrangements shall be made for renewal of insurance policies in time.

V. DUTIES AND RESPONSIBILITIES OF THE OPERATOR OF THE PUMPING STATION

1. Operating the pump set as per the operating rules and maintaining low levels.
2. Recording log book for every hour and including starting/stopping time of pump sets.
3. Check the temperature of running units and control panel.
4. Record daily shift activity in log book.
5. Follow the instruction if any by official in charge of the station or Junior Engineer/Assistant Engineer of the Lifting station regrading lifting
6. Go through previous shift activities and explain the shift activities to the reliever.
7. Arrange for removal of rubbish in the screen well once in the shift with safety precautions.
8. Draw flow chart as per log book in his shift.
9. Operating D.G set when power fails.

VI. GENERAL MAINTENANCE TO BE DONE

1. De-silting of wells.
2. Lifting and lowering of submersible pump sets
3. Drying and refilling of silicon, oil in the breather of the transformer.
4. Check for any oil leak in the transformer and top up oil if necessary.
5. Greasing f bearings and lubricating all moving parts once in a week.
6. Cleaning of motors and lubricating all moving parts once in a week by using air blower.
7. Regular watering of the earth pit in the transformer yard and maintaining proper earth resistance.
8. All electrical connections have to be checked.
9. Lubricating and test operating of the penstock valves for proper seating every week.
10. Check conditions at cabling, motor, and pumps etc.
11. De-weeding and cleaning the transformer yard.
12. Check for tightness of coupling, bolts and nuts and all other fasteners.
13. Overall cleaning and keeping the pumping station neat and tidy.

Annexure 5- Commercial Pre-Treatment Program

What Is "Wastewater Pre-treatment"?

The term "pre-treatment" means the treatment of wastewater by commercial and industrial facilities to remove harmful pollutants before being discharged to a sewer system under the control of a publicly owned treatment works (POTWs).[18]

Objectives of the Pre-treatment Program

By placing controls and/or limits on levels of certain pollutants in wastewater discharged to your sewer system, you:

- prevent interference with the operation of your wastewater treatment plant
- prevent the introduction of pollutants that could pass through your wastewater treatment plant untreated and into the receiving body of water
- improve opportunities for reuse or recycling of wastewater and sewage sludge
- prevent the introduction of pollutants that could cause health or safety problems to the public or the environment

Meeting These Objectives: The Pre-treatment Program

The Pre-treatment Program is part of the local government's regulatory enforcement program to control the pollutants discharged into sewer systems and to reduce the amount of pollutants released into the environment.

Wastewater from homes, commercial buildings, and industrial facilities is collected and transported through a series of pipes—that is, a collection system—to wastewater treatment plants (STPs). These STPs remove harmful organisms and contaminants from the wastewater before discharge into the receiving creek, river, or lake.

Most POTWs are designed to treat sanitary (domestic) wastes from households, but not to treat toxic pollutants from industrial or commercial facilities. The toxic pollutants from industrial and commercial facilities may cause serious problems at POTWs. These problems may be prevented by recycling, waste minimization, chemical substitution, pre-treatment, or other best management practices to reduce or eliminate the pollutants from commercial or industrial facilities.

Outline terms of reference on commercial and industrial pre-treatment programs are available at www.USEAP.gov.

[18] https://www.tceq.texas.gov/permitting/wastewater/pretreatment/pretreatment_definition.html

Annexure 6- Best Practices of Operation & Maintenance for Waste Stabilisation Pond

A6.1 Visual Inspection

Daily Inspection of electrical and mechanical equipment, flowmeter, and ponds for any problems, anything unusual, and to determine when periodic maintenance is needed. Particularly important are visible signs of dike erosion and seepage because that can result in collapse and flooding. Record the date, time, flow, weather (e.g. rain, limited sunshine, very hot, etc.) and observations.

A6.2 Laboratory Sampling and Analysis

Samples for analysis should be collected (a) from inlet control structure for the influent; (b) from each pond at a point about 2 to 2.5 meters from the dike and at a depth of about 0.3 meter; (c) from the outlet discharge point. For safety, there should be at least two people collecting samples. The Laboratory can prepare the sample bottles which should be transported in insulated containers to avoid sunlight and to keep from significant temperature changes.

For pond O & M both grab samples and composite samples should be collected. A grab sample is a single sample collected at a particular time and place and its results are like a photograph. A composite sample is a mixture of individual samples collected according to time, volume, or location. For rectangular or square--shaped ponds, it is better to collect a sample at each of the pond corners or mid-points and combine into a composite sample.

Several times a week (i.e. 2 or 3) measure in each pond the pH, temperature, and dissolved oxygen (DO) (Table A6.1). It is easier and faster to use a pH and a DO meter but if not available then those parameters can be measured chemically. Both pH and DO will vary throughout the day with low readings at sunrise and higher readings in the afternoon. Thus, it is better to measure pH and DO at the same time each day so that time-of-day is not a factor in any variations. Make a graph for each parameter with the date on the x-axis and the amount on the y-axis. The graph quickly shows significant changes from normal. The graph can be done with Microsoft excel or by hand. Useful: measure the DO upstream (about 10 meters) of the effluent discharge and downstream (about 20 meters) to quickly evaluate discharge impacts on the receiving water.

Table A6.1: **Frequency and Location of Lab Samples for Routine O & M**

Sl.No.	Parameter	Frequency	Location		
			Influent	Ponds	Effluent
1	pH	1 to 2 times weekly	X	X	X
2	Dissolved Oxygen			X	X
3	Temperature			X	
4	BOD	Once weekly	X	X	
5	Coliform				X
6	Suspended Solids		X		X

Source: TNUSSP Analysis 2017

A6.3 Periodic Maintenance- done when needed

1. *Bar Screens and Grit Removal.* Do not allow accumulation of material on the screens or removed by the grit system because these materials create odours and block flows. Materials should be collected and buried similar to a sanitary landfill (e.g. cover with a layer of soil).

2. *Scum Control*. Scum on the anaerobic pond is OK because it assists treatment. Accumulated scum on the facultative and polishing (aerobic) pond surface is not OK because the scum reduces penetration of sunlight. Sunlight penetration is needed to reduce fecal coliform and to stimulate algae to produce oxygen. Scum can be broken up manually with rakes or jets of water or rocks tied into netting that are thrown from the shore and then pulled back to the shore.

3. *Weed Control.* Bottom weeds can be controlled by maintaining a depth greater than one (1) meter which is usually sufficient to prevent aquatic weed growth. Any that emerge should be pulled out by hand. Suspended vegetation such as duckweed or water hyacinth can be removed manually, i.e. with hand tools to cut it and pull it to the shore. Shoreline vegetation can be manually cut. Workers need safety equipment and sufficient water to wash after the work. Pesticides are not recommended.

4. *Tree Control*. Do not allow trees to grow close to the ponds. The roots may penetrate the dikes and cause seepage. Fallen leaves into the pond create a breeding location for mosquitoes. Large foliage can block sunlight. Plant trees on the borders of the treatment facility and around occupied buildings but keep distance from the ponds.

5. *Insect Control*. Other animals such as ducks, frogs, fish, and lizards can help control insects. So avoid pesticides and promote animal growth. To prevent habitats for mosquitoes, remove weeds from the pond surface including cuttings from trimming vegetation round the pond edges. In maturation ponds, Gambusa (sp) is the “mosquito fish” that could be introduced. If natural measures are not sufficient, introduction of Bacillus thurengensis (BT) could be used.

6. *Odour Control*. The anaerobic pond is more likely to produce odours than the facultative or aerobic ponds. There is not much that can be done to control odours in anaerobic ponds that are not equipped with recirculation devices. Excessive odours may indicate the need to desludge, or possibly that shock or toxic loads have been allowed to enter the ponds.

7. *Pond Dikes*. Lining the pond with rock, bricks, or cement reduces erosion from wave action. If the dikes are used as roadways then include a crown in the road so that rainfall flows directly into the ponds. For existing concrete lining, inspect weekly and repair cracks with waterproof mortar or tar.

8. *Seepage*. Investigate because if it becomes worse it can cause dike failure. A small amount that does not change may not be a problem but increase in volume and visible leaks can result in catastrophic failure--drain the pond, inspect, repair as needed. Bentonite clay is useful for sealing ponds.

9. *Solids Removal*. Measure depth of pond using a calibrated measuring stick and measure depth of solids using the white towel method (described in appendix). Remove solids when depth of solids is about 20% of pond capacity. Sludge removal can be done by using a raft mounted sludge pump. Alternatively, the flow can be routed around the cell to be desludged, the free liquid can be decanted, and the remaining sludge can be allowed to dry naturally. It is then removed by tractor. The sludge can be discharged into a specially constructed area for air drying or into dump trucks to transport it to a landfill site, agricultural land or other suitable disposal location. It can also be stockpiled with berms to prevent run-on or runoff and allowed to dry for 3 – 6 months. Suggest measuring depth every 6 to 12 months.

A6.4 Safety

- Employees should wear gloves and wash hands after completing work.
- For maintenance of electrical and mechanical equipment (e.g. bar screen, motor, pump) follow lock-out tag-out procedures.
- When using a boat in any of the ponds (a) people in the boat must wear a life vest; and (b) for every person in the boat there must be person on the ground capable of throwing a rope or life buoy.

A6.5 Forms on O & M Activities

Form 1: Equipment maintenance activities

Equipment Name					
Serial Number					
Manufacturer					
Location and Date Installed					
Date	Description of Work Performed	Parts (New or Repaired)	Number and Type of Workers	Man Hours	Checked By
Source: TNUSSP Analysis 2017					

Form 2: Daily Inspection of Trichy Waste Stabilization Ponds

Daily Inspection of Trichy Waste Stabilization Ponds					Date __________	
					BY___________________	
WEATHER						
OBSERVATIONS and MEASUREMENTS						
POND	AP1	FP1	PP1	AP2	FP2	PP2
Colour of water						
Odour						
Surface scum						
Seepage						
Outlet structure						
Other						
Receiving water						
Source: TNUSSP Analysis 2017						

A6.6 Starting a pond

Periodically a pond may be emptied for maintenance, for example sludge removal or sealing the bottom. If possible, schedule the work during a low-flow period so that full flow can go the other 5 ponds. Work on the empty pond should be done by a team; it can be dangerous for one person working by themselves. Provide workers with protective clothing, e.g. rubber boots and gloves, and a supply of fresh water so they can clean up after work is completed for the day.

Following procedure is recommended to be used for re-starting a pond.

Inspect bottom and sides. It is likely there will still be some sludge on the bottom. This is OK as it provides a seed containing many of the beneficial microbes that are an important part of the treatment process.

Remove any vegetation. Repair any visual damage to pond embankments. Confirm inlet and outlet structures are not blocked and make any needed repairs.

For the Anaerobic Ponds, open the inlet to allow sewage to enter. Observe the entrance to notice if any problems with the inlet structure. Make sure the outlet (leading to the Facultative Pond) is open.

For the Facultative Pond, pump water from the other facultative pond that remained in service to a depth of about 0.7 to 1 meter. Then open the outlet of the anaerobic pond and confirm the facultative pond outlet to the aerobic pond is open. Observe to identify any problems with inlet and outlet structures.

For the Aerobic Pond, pump water from the other aerobic pond that remained in service to a depth of about 0.5 meter. Next open the outlet of the facultative pond. Then, make sure the outlet is open AND that there are no obstructions or humans or animals where the pond effluent discharges into the receiving water. Observe to identify any problems with inlet and outlet structures. Remove any surface scum as the pond fills because surface scum blocks sunlight which is the method of disinfection.

A6.7 Logbooks and recordkeeping

There are daily, weekly, monthly, quarterly and annual tasks that must be conducted at the STP, with activities written in the log book. These include:

1. Daily flow – should be calculated daily from running hours of all pumps connected to the WSP. Each pump chamber should be calibrated to verify cubic meters per minute of operation

2. Sampling and analytical results

3. Number of septage trucks per day at each decanting station and at the treatment plant

4. Changes of pond operations

5. Unusual circumstances

6. Employee injury or first response.

The operators log book should be kept at a designated operator station at the WSP.

A6.8 Implement a long-term monitoring plan
The monitoring plan should specify:

1. Daily WSP inspection and monitoring of housekeeping operations by operator and staff

2. Daily flow calculation - from flow meter or hour logs from pumping stations

3. Weekly check on dissolved oxygen (DO), pH, temperature and conductivity, water and depth of each pond. Visual observation of conditions in all ponds

4. Quarterly analytical testing of effluent as per the discharge standards

5. Annual report

Recommendation: Obtain a portable dissolved oxygen (DO) meter to make monthly DO profiles for each pond. DO is a key operational parameter, and can be used to evaluate the effectiveness of aeration devices. Monitor over time, especially before and after aeration devices are installed

A6.9 Implement operation and maintenance plan
An operation and maintenance manual should be prepared for the facility to include at a minimum:

1. Table of Contents/Homepage

2. Historical Background: Provide a narrative on the background and history on the facility

3. Overall Process Description: Briefly describe the type of treatment process employed and the various units or processes incorporated in the facility

4. Plant Layout

5. Design Data Table: Include design population and flows, design efficiency and effluent quality goals (BOD, TSS, ammonia, nutrients, etc.), and design capacity for each process unit

6. Flow diagrams: Include simple schematics showing the individual units and flow sequence

7. Hydraulic Profile

8. Utilities: Include or reference a plan that shows how the plant is served with water, gas, electricity, phone, etc. The map should show the location of isolation valves, access points and other pertinent features

9. Preventative Maintenance & Asset Management Systems
10. Operator and Management Responsibilities breakdown of workhours estimated to operate and maintain the facility. Include job descriptions and roles and responsibilities for all staff

11. Budget. Provide estimated budget costs for operating and maintaining the plant. The estimate should contain a breakdown by major category such as staffing and benefits, training, power,

laboratory, parts, supplies, repairs, chemicals, sludge hauling and disposal costs, grit and screenings disposal

12. Operation and Control of Unit Processes. Each unit process should be under a separate tab. The recommended unit process categories include Influent Pump Station, Head works, Primary, Secondary, Filtration, Disinfection, Recycled Water, Solids Treatment/Storage, and Miscellaneous Equipment. Each unit process should contain the following information;

13. Description of Unit Processes:
    a. Describe each unit mechanically, including each unit component and its function
    b. Describe the feed. Prescribe normal operating positions of all gates and valves (normally open or closed). Provide a flow schematic showing valve, gate and pump locations, and employ and index system for identification
    c. Describe thoroughly the treatment process employed in each unit; chemical, biological, physical or combination
    d. Describe the relationship of each unit to adjacent units in the facility
    e. Describe where and/or how additions or expansions to the plant are intended by the designer
    f. Control of Unit Processes: Describe thoroughly and in detail how each unit process is to be operated and how to control the unit process. Thoroughly discuss all applicable process control parameters and equipment items in detail

14. Preparation of Sewage Treatment Plant O & M plan for pumps, and mixers, valves and screens. Electrical Power draws for each one at startup should be measured and recorded, including normal and shutoff, for future reference

15. Preparation of operational strategy and troubleshooting. Common Operating and Control Problems: Alternate Operational Modes and Emergency Operations and Failsafe Modes

16. Start Up Procedures

17. Equipment Maintenance Summary

18. List all equipment suppliers and service reps telephone numbers and contact information

19. list of critical replacement parts that may have long delivery times associated with them

20. Safety

A6.10 Implement Operator health and safety plan

The operator health and safety plan should include:

1. Prepare a health and safety plan with the following sections and implement the plan:
2. Roles and responsibilities – job descriptions;
3. Hygiene requirements;
4. Health and immunization requirements [mandatory Tetanus vaccination];
5. Personal protective equipment
6. Electrical safety
7. Confined space safety;
8. Drowning prevention;
9. Emergency operations
10. Incident reporting and resolution

Electrical safety
The lock-out tag-out electrical safety programs helps to ensure that the breakers are de-energized and locked in the "off" position before any work can be performed on the equipment. The technician to do the work makes an entry in the log book, affixes the electrical breaker lock and keeps possession of the key until the work is completed. Figure A6.1 shows some of the typical equipment for the lock out tag out program.

Figure A6.1**: Lock-out tags and locks for electrical safety plan implementation**

	
Source: https://www.safetyandhealthmagazine.com/articles/12332-lockouttagout-responsibility:	*Source:* https://www.accidental.com.au/first-aid-supplies/electrical-burns/lockout-tags-danger-do-not-operate-reverse-side-2-striped.html

Figure A6.2**: Aeration and venting of confined spaces help to ensure adequate atmosphere; Example of Sign for Confined Space (left to right)**

	
Source: https://www.worksafeky.com/safety-resources/safety-handouts/confined-space-entry/	*Source:* https://mdasphalt.org/danger-confined-space/

Confined Space Entry Program
Definition of confined space: Contains or has the potential to contain a hazardous atmosphere; i) Contains a material with the potential to engulf someone who enters the space (Figure A6.2); ii) Has an internal configuration that might cause an entrant to be trapped or asphyxiated by inwardly converging

walls or by a floor that slopes downward and tapers to a smaller cross section; and/or iii) Contains any other recognized serious safety or health hazard. All confined spaces at the facility must be labelled through signage (Figure A6.2).

Confined spaces include:

1. Pump system wet and dry wells;
2. Manholes;
3. Tanks;
4. Valve boxes;
5. Piping manifold boxes;
6. Sewer pipes.

Fall Protection

Related to confined space requirements are those for fall protection. There are a number of maintenance tasks that put workers at risk for falls, especially around the headworks and bar screens. Such activities should be identified by senior management. When work is required in these areas, use of the buddy system and proper protective equipment including ropes and harnesses shall be required. Documentation on fall protection can be found at this link: https://www.osha.gov/SLTC/fallprotection/ Management should purchase protective equipment and conduct trainings at regular intervals.

Drowning hazards and protection

Drowning is a real hazard at sewage lagoons, especially as operational tasks involve working from boats. For the Trichy WSP, boats will be used to regularly collect sludge depth and dissolved oxygen data as routine operation and maintenance tasks. Tasks performed from a boat shall:

1. Use the buddy system: two workers on the boat, and two workers on the shore. Workers on the shore will be responsible for holding guy lines or wires (see appendix).

2. Workers on boats will be required to wear life preservers and vests at all times while on the water

3. Training on all aspects of drowning prevention program.

Review the documentation at this website for specific drowning prevention program recommendations: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10669&p_table=STANDARDS

Emergency preparedness plan

The consultants recommend an “all hazards” approach to emergency or contingency management planning. Please review this website for more information:
http://www.awwa.org/portals/0/files/legreg/security/allhazard.pdf

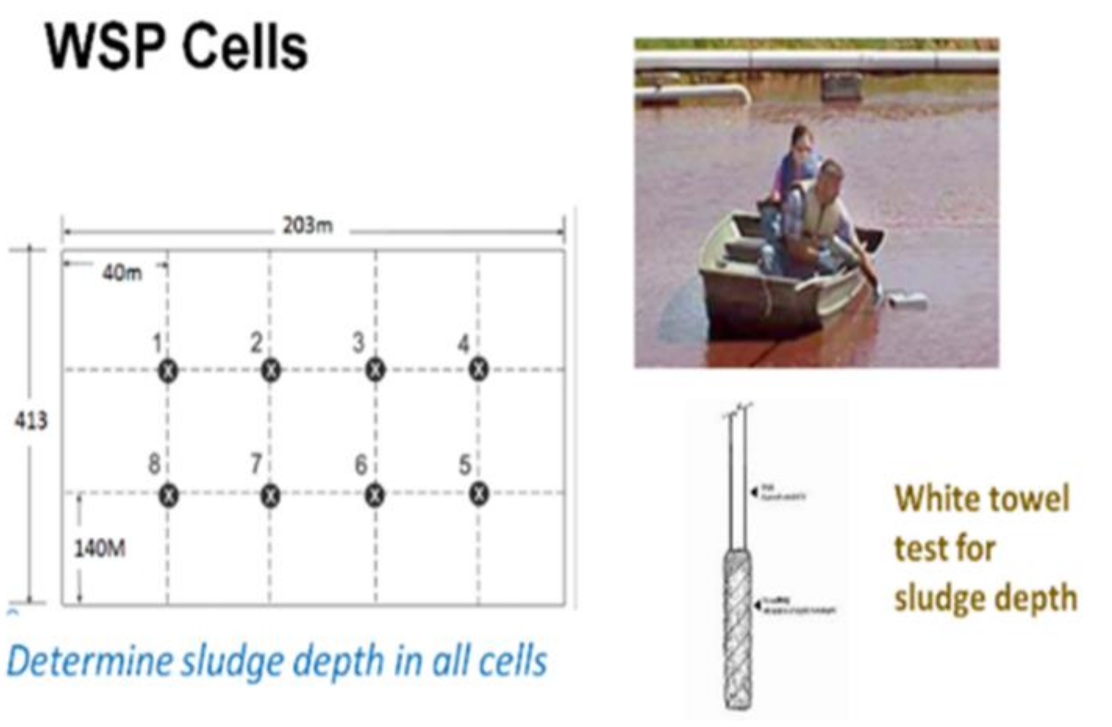
A6.11 Waste stabilization ponds desludging methods

Desludging for WSPs can be accomplished with the ponds full of liquids (dredging) or after the ponds have been drained and allowed to air dry for some time typically 1 or 2 months (excavation). Dredging is used for routine desludging maintenance where desludging is performed regularly and when solids accumulation is not excessive. Excavation is used when there is a heavy sludge accumulation. These terms “not excessive” and “heavy sludge accumulation” are subjective. It will be up to the operator to determine when it is more practical to use the dredging or excavation methods. Presented below is a discussion on both methods that is provided to give the operator more information in choosing which method is best for their specific needs and plant.

First step – sludge profiling

Sludge profiling is accomplished by operators in a boat that probe the sludge depth and record their findings. Safety must be observed. Operators should wear flotation devices and a rope tied from one side of the pond to the other to guide the boat. Mooring posts should be installed to simplify the process Figure A6.3 shows Sludge profiling exercise where the workers in the boat taking sludge depths at different points within the pond cell. The “white towel” method is used, where the towel is affixed to the probe. When the operator pushes the probe to the cell bottom, sludge particles adhere to the white towel, which indicates the depth of the sludge.

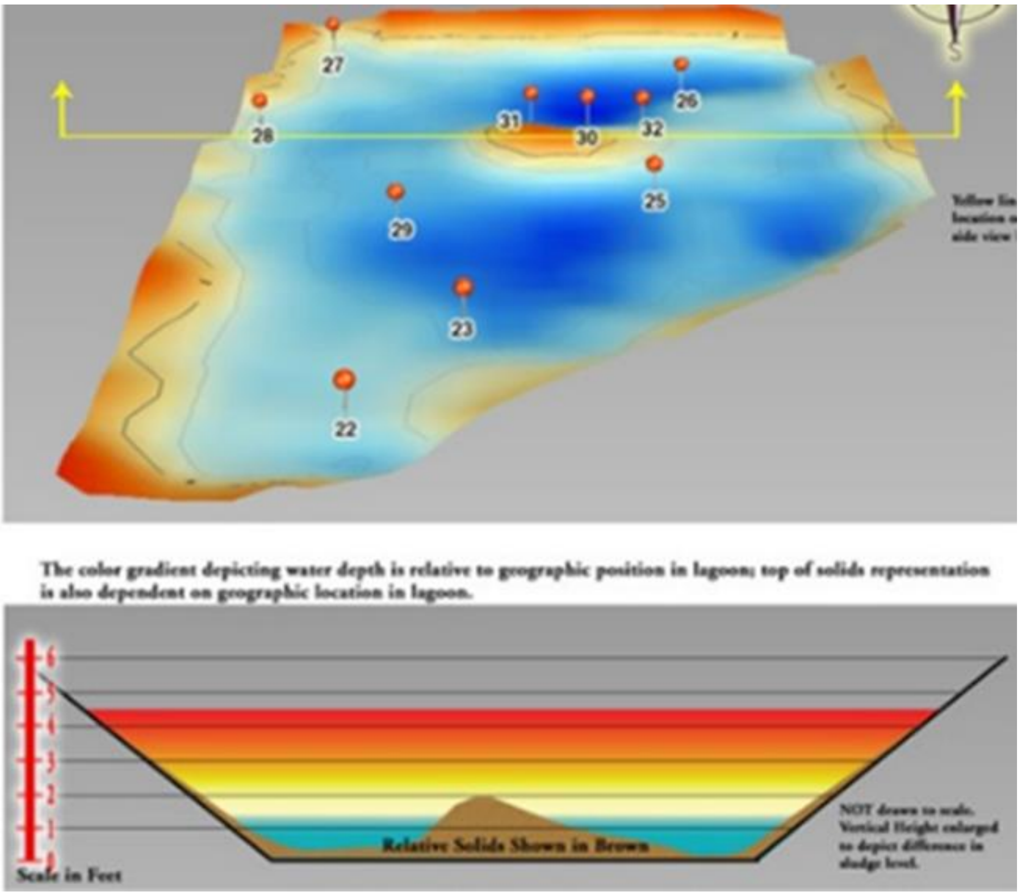
Figure A6.3**: White towel test**



Source: http://www.ncagr.gov/SWC/tech/documents/sludge_survey.pdf

Figure A6.4 illustrates the results of a sludge profile for a hypothetical pond. Sludge is not deposited evenly in a lagoon system. The profiling helps to identify where sludge deposits are located so that desludging using the dredging method can be facilitated.

Figure A6.4**: Sludge profiling**



Source: https://www.lagoonpumping.com/services/mapping/

Dredging

Dredging is accomplished with a floating barge equipped with a sludge pump and long hose that is used to transfer the dredged sludge to a location on shore for sludge disposal, or to a truck that can then haul the dredged sludge to the point of disposal or processing (Figure A6.5). A suction hose is connected to the sludge pump with the suction end set at a depth just above the elevation of the cell bottom. For ponds using clay liners, this helps to ensure that clay liner material is not suctioned out of the pond along with the sludge.

Figure A6.5: **Dredging system for WSPs**

Source:http://www.triplepointwater.com/wastewater-lagoon-sludge-treatment/#.XLXtfDAzapo

Floating barges can be purchased or fabricated using locally sourced materials and labor. The initial expense is high, but over the long-term dredging can be more economical and effective than dry desludging using tractors and excavation equipment.

Excavation using tractors and heavy equipment

Sludge excavation is usually accomplished by first draining the cell to be desludged, and allowing it to air dry for one or two months. A loader or dozer is used to push the sludge to a location near the embankment where it can be removed using a track hoe or other similar device. Excavation can be disruptive to the pond liner if one is present, so care should be exercised if this method is utilized. Figure A6.6 illustrates a track hoe used to remove sludge from pond cell.

Figure A6.6: **Track hoe used for sludge removal from pond cell**

Source: http://www.ulwr-inc.com/lime_lagoon_cleaning.htm

Figure A6.7 illustrates a specialized tractor with a sludge blade used to push accumulated sludge near the embankment where it can be removed by the track hoe.

Figure A6.7: **Specialized sludge tractor**

Source:https://www.tankfarmservices.co.uk/tank_cleaning.html

Figure A6.8 illustrates a dozer performing the sludge stockpiling (pushing the sludge to a location near the embankment where it can be removed. Performing this work once the lagoon has been dewatered will be more effective than the procedure shown. It can also damage clay or plastic liners, so care and inspection of liner after sludge removal is required.

Figure A6.8: **Tractor pushing sludge in pond**

Source: http://easywebmanage.com/krwa/lifeline/1411/72.pdf

A6.12 Installing Bentonite Liners

Soil Testing.

First, conduct soils tests at 1 test every 1,000 square meters. If native soils are less than 65% clay, compact in place using a vibratory roller or similar heavy equipment. If native soils are less than 65% clay, install bentonite clay liner.'

Methods of Applying Bentonite.

Sprinkling Method using Bentonite

Bentonite can be "sprinkled" into the water near areas suspected of leaking in an effort to seal them off. This is rarely effective because of the high probability that the bentonite will not land in the area of the leak.

Mixing in with Native Soil

Bentonite is blended with soil on-site to amend the quality of the soil to reduce water seepage or leaking. In order to determine the amount of bentonite necessary for this method, you will need to have your soil analysed by a soil lab (typical blend is about 5%-10% by weight bentonite/native soil). Once the analysis is complete, you should receive direction on the percent of bentonite necessary to create a seal. This method has a much higher rate of success than the sprinkling method.

Applied as Blanket

Bentonite can also be applied as a blanket over an existing pond surface. Bentonite is typically applied 1" to 4" thick and then covered with a protective layer of soil. Once installed, the entire site will need to be moisturized and compacted.

Best Practices for installing Bentonite Clay Pond liner.

Key steps include: Empty, Spreading, Mixing and Compacting.

To facilitate a proper dry bentonite application, the pond must be drained, dried out, and kept dry during the construction of the liner. Once the soil has been allowed to dry considerably, the mixing phase can begin. The bentonite is spread over the soil at the specified application rate and then the bentonite/soil combination is uniformly mixed. Large scrapers, dozers and discs can be used in combination to efficiently mix the soil.

Once the soil has been well mixed with the bentonite, this combination needs to be hydrated to +/- 2% of optimum moisture content and then compacted. Compaction is necessary to reduce the voids in the soil, and help the clay particles lay flatter together. Compaction is usually done with a sheepsfoot vibratory compactor in combination with whatever other heavy equipment is available onsite. It is very important that no more than 6” layers or lifts be constructed at a time.

Recommendation by the consultant: An on-site supervisor is recommended to oversee each phase for a couple of reasons. Primarily, each soil is unique and therefore responds differently to moisturization and compaction. Having someone with experience to be able to observe the soil and its response will save hours of construction time and years of headaches due to a faulty pond liner. Secondly, the work can be very tedious and there is a tremendous advantage to having someone on the ground observing changes in solid conditions to assist the equipment operators. Most contractors are used to preparing a site for building construction where there is more grace if the soil is not perfectly prepared. Pond water is much less forgiving, and will quickly find the areas that were inadequately constructed. If you want a pond sealed with sodium bentonite, you will need to have a professional apply the materials for the best results. Reference: http://www.bentoniteliner.com/

Other options for pond liner. Bentonite appears to be the best option given previous experience with the product. There are other options for lining ponds:

i. If soils are 65% clay, consider compacting existing clay to form a natural liner;

ii. High Density Polyethylene (HDPE) or Polyvinyl Chloride (PVC) are plastic materials that can be used for pond liners. These may be very expensive. Specialized crews and equipment are required for this option;

iii. Concrete liners. The advantage being that if thick enough to support the weight of a full dump truck, it will facilitation pond desludging in the future. This is also a very expensive option.

Bentonite clay should be applied at a rate of 8 KG per square meter.

Annexure 7- Calibration Procedure for Pumps

1. Calibrate the flow discharge volumes using the following procedures:
    b. Each pump station has a wet well. If we know the volume of the wet well, we can test the amount of effluent each pump can deliver exactly;
    c. Ask the operator to run the level of the water in the wet well down such that the level is about 2 meters above the pump intake;
    d. Now attach a measuring stick or tape to the inside of the wet well. Really you just need a 1-meter increment;
    e. Now have the operator adjust the effluent in the well so that the water level is at the first mark on the measuring stick. If you could coordinate this so it is ready to go by about midnight, there won't be any other sewerage coming in to the well;
    f. Have the operator turn on the pump. Then with a stopwatch, determine how many minutes it takes to pump the level down 1 meter;
    g. Now calculate the volume pumped, and divide by the number of minutes to get a per-minute pumping volume;
    h. With this information, applied to each pump, and assuming we can get a run-time meter on each pump, we can have a very accurate measurement of the inflow to the WSP.

2. If budgets allow, install run time meters on all pumps, and check actual pump discharge monthly as a component of the preventative maintenance program. The log books currently maintained are adequate.

3. This should not be viewed as a substitute for the installation of proper flow measurement devices, such as a Parshall flume, or to fix the existing unit at the headworks of the WSP.

Annexure 8- Information on Solar Powered Aerators

Information in this annexure is provided for consideration of TCC for addressing future flows by adding solar powered mixing units to pond cells. Mixing using this technology can allow for significant increases in organic loading and effluent quality improvements.

A8.1 Description of Facility and Primary Problems

- This is a facultative wastewater lagoon system:
- There are six ponds: two 1.8-hectare anaerobic ponds at 2.5 meters deep, two 8.1-hectare facultative ponds at 1.5 meters deep and two 7.5-hectare polishing ponds at 1.5 meters deep.
- There are also 25 hectares of old ponds that are currently not in use.
- Normal operations are with the flows being evenly split after the head works, into two separate trains (Anaerobic Pond 1 to Facultative Pond 1 to Polishing Pond 1 and Anaerobic Pond 2 to Facultative Pond 2 to Polishing Pond 2). However, the valving of the ponds can be set for two trains or one train; one side of the system can be shut down to desludge an anaerobic pond, which is done every two years.
- Half of the current total flow of 50,000 cubic meters per day goes through each train, 25,000 cubic meters typically going to each train; at times some flow is blocked and is low as 24,000 m3/day.
- The climate is tropical; there is a rainy season, but the sewer system is sanitary; no storm water.
- There is a big problem with algae in the discharge.
- The discharge pipe is near the surface. The discharge requirements are: BOD 10 mg/L and TN 10 mg/L.- Lowering the depth of the discharge pipes is a recommendation being considered for Phase 1 of the project.
- Deepening the ponds is a recommendation that is also being explored. This could be implemented in Phase 2 of the project, which will include provisions for the future flows. The 25 hectares of old ponds that are currently not in use could also be added at an appropriate depth.
- Testing in March 2017 determined that 80 to 100 mg/L influent BOD concentration goes into Anaerobic Ponds 1 & 2.

A8.2 Project Objectives

- Primary Objectives: To provide thorough solar-powered mixing in order to eliminate the need to dredge every two years in the Anaerobic Ponds. In addition, to provide an odor cap of the Anaerobic Ponds.

- To improve treatment in the Facultative Ponds, reducing short-circuiting which in turn increases actual detention time. To improve dissolved oxygen levels, distribute the dissolved oxygen throughout the ponds, and to control blue-green algae.

- The Polishing Ponds will benefit from the increased algae control with less algae in the discharge. Both the Facultative and Polishing ponds will benefit from enhanced sludge digestion as well.

- Solar-Powered Mixing: We recommend the placement of sixteen (16) solar powered aerators, deploying one in each Anaerobic Pond, five in each Facultative Pond, and two in each Polishing Pond.

- Intake Plate Only: Aerators without intake hose due to the shallow depths of the ponds is suggested; the machines will be equipped with a fixed intake place. If the ponds are to be deepened; hose may need to be added.

- Incremental Approach: It is suggested to install the aerators incrementally, observing the performance change by installing in each pond. The recommended number of machines is starting with six units to be deployed in the Anaerobic and Facultative Ponds.

- The full recommendation above is based on an influent flow rate of 40,000 cubic meters per day (20,000 to each train), an influent BOD concentration of 67 mg/L in the Facultative Ponds, and the information provided above in Section 2. (See General Provisions - Assumptions paragraph below.)

A8.3 Proposed Machine

Figure A8.1: Indicative layout and position of the aerators in the ponds

Source: Medora Corporation

The aerators are not drawn to scale, and final placement is to be determined (Figure A8.1).

A8.4 Pricing

Equipment Cost - For Equipment and Option Details, See the Table A8.1.

Table A8.1: **Machine Pricing**			
Quantity	**Equipment Description**	**Cost Each**	**Equipment Total**
6	Solar powered aerators*	$37,900	$227,400
		Equipment Subtotal:	$227,400
Applicable Taxes:			- to be determined -
Total Equipment Cost:			**$227,400**
**Indicative price for the model SB10000 v20 Solar Bee Lagoon Mixers*			
Source: Medora corporation			

Annexure 9- Case Study- Evaluation of Solar Powered Aerators in STP, at Los Banos, California

Trip Report: Los Banos Wastewater Ponds
Purpose of Visit: to learn about Solar Bee use in wastewater treatment
Tuesday, May 2, 2017 by Dave Robbins and Sher Singh
Met with:

- Jeff Bondi, Wastewater Treatment Plant Supervisor

17963 West Henry Miller, Los Banos, California [Merced County]
Cell: 1-209-617-3627 (personal)
and

- Royal Lloyd, City of Los Banos Public Works Operations Officer

A9.1 Location, Climate, Wastewater Service Area, Regulatory Agency
Los Banos is located in Merced County in California's San Joaquin Valley. Climate is typically hot and dry. High temperatures 90 – 100 degrees Fahrenheit (32 to 43 ^{o}C) for about 100 days of the year and low temperatures 30 to 40 ^{o}F (-1 to 4 ^{o}C). Gusty winds year-round. Limited rainfall.

LB has population about 37,000. In addition to typical domestic wastewater, there are four major industries discharging. There is no septage, nor discharge from portable toilets or recreation vehicles. The STP does NOT discharge. Some of the treated wastewater is used for agricultural irrigation. The STP is under the jurisdiction of California Central Valley Regional Water Quality Control Board (RWQCB) http://www.swrcb.ca.gov/rwqcb5/

A9.2 Pond Details
Seven facultative ponds with surface area 520 acres (210 hectares). 4 ponds are treatment and 3 ponds are storage. Pond depth is 6 feet (1.8 meters). Detention Time is estimated to be 30 days. Design capacity is 4.9 million gallons per day (MGD) equivalent to 18.5 million liters per day (MLD). Operating at 2.8 MGD (10.6 MLD). Interior of ponds is lined with rock rip-rap to reduce erosion. Roads atop berms are one-lane, hard-pack dirt with loose gravel as surface.

For purposes of the regulatory permit Pond #1 is designated as influent and Pond #7 as effluent. In fact, there are channels such that all the ponds are inter-connected. Treated wastewater is used for agricultural irrigation.

A9.3 Solar Bee Units
The Solar Bee is a floating, solar powered, mixer-circulating equipment for wastewater treatment. It operates 24 hours a day using solar energy during daytime and a battery to store excess daytime energy for nighttime operation. The Solar Bee circulates water from the bottom of the pond to the surface thus providing an opportunity for natural aeration.

This is different from aerated lagoons where oxygen is supplied mainly through mechanical or diffused aeration, for example by brush (paddle wheel) or static tube aerators or spraying pond contents into the air. In Los Banos, oxygen is provided by algal photosynthesis and by wind action on the pond surface. The Solar Bee (Figure A9.1) provides mixing such that lower water layers with low oxygen come to the surface where they can be aerated by surface algae and wind. The mixing by the Solar Bee is gentle so there is no risk to disrupting the sealed bottom of the lagoon.

Figure A9.1: **Solar Bee**

Source: Image courtesy- David M Robbins

Advantages of the Solar Bee are (a) eliminates stratification (i.e. layers in the pond) which reduces short circuiting caused by temperature stratification; (b) helps with pond turnover which typically occurs twice yearly with change of season (e.g. cold—hot--cold); and increases the aerobic layer in the pond (proven by results of a Dissolved Oxygen Profile in pond with Solar Bee and without.

Los Banos has 20 Solar Bee units with 11 placed in Pond #1 and 9 in Pond #7. Installed April 2008. Units are anchored with adjustable chains and heavy concrete weights. There is additional weight and anchoring due to movement caused by hard blowing winds.

The units are solar powered so there is NO electricity use. The solar panels need to be washed occasionally to remove dust and dirt to maintain full efficiency. On the solar panels are strips of metal with upturned spikes to keep birds from sitting on the panel.

Los Banos contracted with the supplier (Medora Corporation, https://www.medoraco.com/) to provide twice yearly service and repair. Cost is on the order of US$40,000 (INR 2,600,000) per year. Thus, the Los Banos STP staff have no training, tools, or spare parts.

For maintenance, a boat with motor is lowered into the pond. The boat crew ties onto the Solar Bee unit, releases the chains, pulls the unit close to the berm. There a truck with a crane boom lifts the unit out of the pond.

Since installation 9 years ago some motors and some bearings have had to be replaced. Los Banos staff said they are satisfied with Solar Bee and would like to add more. They could not say with certainty that stopping the units would create noticeable changes, for example appearance, odors, effluent quality.

A9.4 Desludging the Ponds

Ponds have been de-sludged once in the past 18—20 years. The pond was drained, semi-solid material collected, disposed on an agricultural field growing alfalfa. The farmer noticed a much better crop after the sludge (rich in nitrogen) was added to the soil and would like to get more.

Sludge depth is measured twice yearly using a “sludge judge” [transparent plastic tube, 2 – 4 inches in diameter, inserted into the lagoon and capped to withdraw a complete vertical layer of water and solids]. The measurement is done by the Solar Bee maintenance crew.

Laboratory Analysis

Three times a week STP staff measure pH, conductivity, settleable solids, and BOD of influent into the ponds and of four large industrial dischargers (Table A9.1) into their collection system in their laboratory (Figure A9.2).

Effluent (Table A9.2) is measured twice monthly by a grab sample from Pond #7 which, for regulatory agency reporting, LB has designated as their discharge pond. In fact there is no discharge.

Table A9.1: Influent

Sl.No.		
1	Date	1 May 2017
2	pH	7.05
3	Conductivity (mmhos/cm)	1702
4	Settleable Solids (mg/L)	30
5	BOD_5 (20°C) mg/L	807

Source: Key Informant Interview

Figure A9.2: **Laboratory**

Source: Image courtsey- David M Robbins

A9.5 Effluent (grab sample from Pond #7 which has 9 Solar Bee Units)

Table A9.2: Effluent characteristics

Sl.No.	Date (2017)	4-Jan	18-Jan	16-Feb	22-Feb	8-Mar	22-Mar	5-Apr
1	Temperature (°C)	9	9	14	12	14	16	17
2	pH	8.23	8.58	8.25	8.56	8.75	8.56	8.63
3	Conductivity (mmhos/cm)	2620	3310	3470	3180	3140	2980	2950
4	Settleable Solids (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5	Suspended Solids (mg/L)	105	139	103	110	126	126	117
6	BOD_5 (20°C) mg/L	41	37	38	48	47	51	41
7	CBOD (20°C) mg/L	---	---	---	---	28	---	---
8	Ammonia as N (mg/L)	---	---	---	---	ND	---	---
9	Total Kjeldahl Nitrogen (mg/L)	---	---	---	---	21	---	---
10	Nitrite as N (mg/L)	---	---	---	---	ND	---	---
11	Nitrate as N (mg/L)	---	---	---	---	1.5	---	---

Source: Key Informant Interview

ND = not detected

TKN = Organic N + Ammonia N

Results are reasonably consistent for the four-month period. Note the significant difference on 8 March 2017 between 5-day Biochemical Oxygen Demand (BOD_5) and Carbonaceous Biochemical Oxygen Demand ($CBOD_5$), 47 mg/L vs. 28 mg/L.

A9.6 Biochemical Oxygen Demand

The total BOD of wastewater is composed of two components: (1) a carbonaceous oxygen demand and (2) a nitrogenous oxygen demand[19]. The carbonaceous demand is proportional to the concentration of the bio-degradable carbon constituents in the effluent while the nitrogenous demand exerted during the 5-day test is proportional to the number of nitrifying organisms in the sample being tested. The $CBOD_5$ is determined by using a nitrification inhibitor[20] in the BOD_5 test.

Los Banos contracts with a private laboratory for effluent analysis and plans to start reporting $CBOD_5$ which show values lower than BOD_5

A9.7 Nitrification--Denitrification

The element Nitrogen is a major component of fertilizers. In large concentrations within lakes or streams, nitrogen increases oxygen demand. Table A9.3 shows the four major forms of inorganic nitrogen and how they progress through a cycle

Table A9.3: Nitrification- Dentrification

Sl. No.								
1	N-cycle	NH_4^+	→	NO_2^-	→	NO_3^-	→	N_2
2	Name	Ammonium		Nitrite		Nitrate		nitrogen
3	electrons	N = -3		N = +3		N = +5		N=0
4	process	Nitrification					Denitrification	
5	conditions	Aerobic					Anaerobic	

Source: TNUSSP Analysis 2017

Ammonium (NH_4^+) coexists with ammonia (NH3) with the ratio determined by pH and temperature. Ammonia is highly toxic to aquatic life. As pH increases (i.e. becomes less acidic and more basic), ratio of ammonia increases. At pH of 8.5 or lower (i.e. more acidic), almost all of the ammonia in solution will exist as the ammonium ion. Also, as temperature increases the ratio of ammonia increases

Nitrification is defined as the oxidation of ammonia to nitrate. The oxidation occurs in two steps – the oxidation of ammonia to nitrite by the bacterium Nitrosomonas followed by the oxidation of nitrite to nitrate by the bacterium Nitrobactor. The Solar Bee increases nitrification by increasing the amount of oxygen through mixing.

A9.8 Advice / Lessons Learned

- Anchor the Solar Bee units
- Get a boat or powerful pump and hose to periodically wash the solar panel
- Consider a maintenance contract

A9.9 Other Comments

LB Staff implement standard safety procedures including electrical lockout.

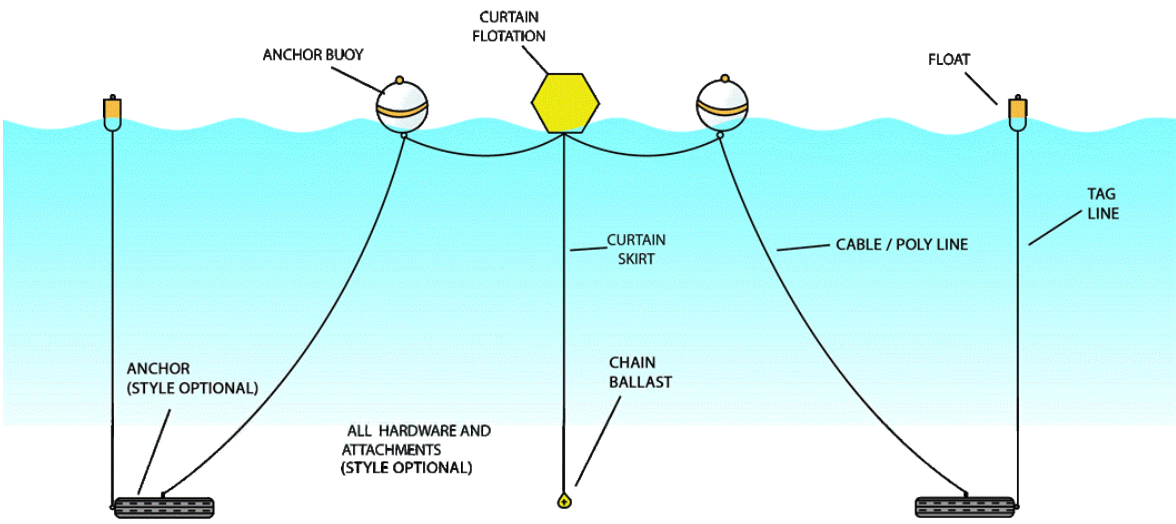
[19] *Linville G. Rich, "Technical Note Number 1 Effluent BOD5 – a Misleading Parameter for the Performance of Aerated Lagoons Treating Municipal Wastewaters", http://www.lagoonsonline.com/technotes.htm*

[20] *Hach Chemical Company's Nitrification inhibitor 2533 (2 chloro 6 (trichloro methyl) pyridine) or equivalent can be used for inhibition during carbonaceous BOD testing.*

Annexure 10- Floating Baffles - Proposal and Supporting Information

Information in this appendix is provided in case TCC would like to consider the use of floating baffles (Figure A10.1) to address short circuiting.

Figure A10.1: **Floating baffles installation schematic and specification**



Specification	
Fabric	Your choice of XR-5/6730, 8130 PW, Urethane, FDA Vinyl
Flotation	Marine grade expanded polystyrene (EPS) or rolled microfoam
Tension	5/16 inch - 3/8 inch stainless steel cable sheathed in vinyl hose
Ballast	3/8 inch - 1/2 inch galvanized steel chain in double layered fabric pocket
End Plates	Stainless steel
Flow-Through Windows	Double layered reinforced hems with bias corners
Construction	Factory assembled continuous length, no field joints
Skirt & Ends	Customized to match bottom and bank topography

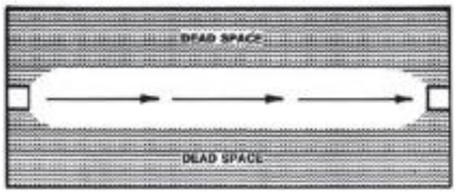
Source: Elastec American marine Innovative Environmental Products

A10.1 Additional information on baffle systems

A10.1.1 Baffle System

Short-circuiting is a common problem in wastewater basins and ponds (Figure A10.2). It is the straight-line flow from inlet to outlet as shown. Short circuiting occurs when wastewater enters a basin at a high velocity or there is stratification caused by salinity or temperature of the influent, which results in "surface streaming" of the flow.

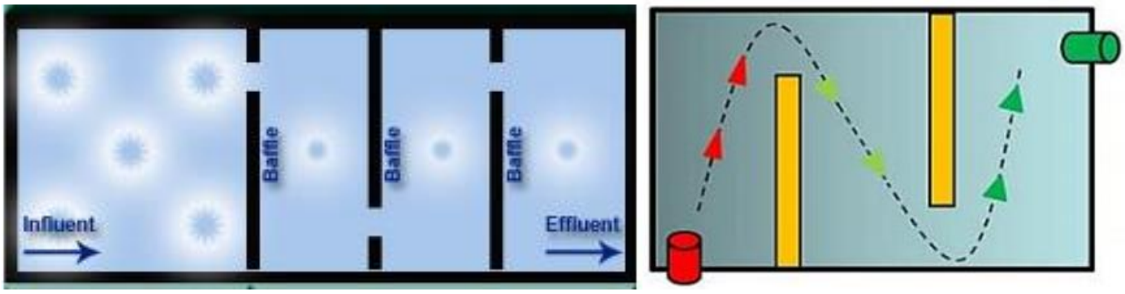
Figure A10.2: **Short Circuiting**



Source: http://www.acmeboom.com/baffle-flow-patterns

A standard solution to reduce short circuiting is to install a baffle wall, also referred to as curtain wall. Baffles are used as vertical walls to redirect flowing water through determined paths to increase the time water is exposed to treatment chemicals or processes. It is a physical system consisting of a flexible geomembrane, stainless steel cables, and mounting hardware. It is. The system creates an extended flow path through the pond and reduces short-circuiting and improves BOD and TSS removal. Figure A10.3 illustrates the concept.

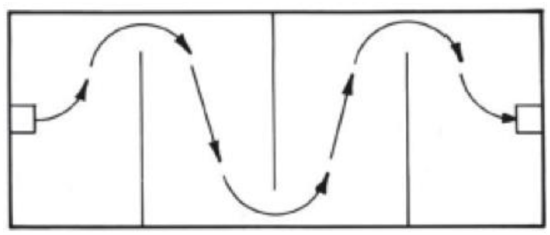
Figure A10.3: **Examples of Baffle (or Curtain) Wall Systems**



Source: http://www.erosionpollution.com/water_baffle.html

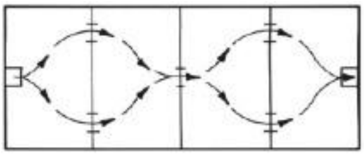
There are different baffle configurations. Side-to-side diversion (Figure A10.4) and flow-thru window diversion (Figure A10.5) increases the retention time of the wastewater. Flow-thru (Figure A10.6) and top-to-bottom promote mixing and require windows in the baffle walls to regulate the flow of the wastewater through the treatment process.

Figure A10.4**: Side-to-Side Diversion**

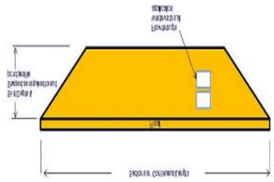


Source: http://www.acmeboom.com/baffle-flow-patterns

Figure A10.5**: Flow-Thru Window Diversion Diagram**

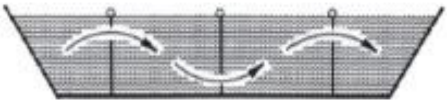


Source: http://www.acmeboom.com/baffle-flow-patterns



Source: https://www.erosionpollution.com/water_baffle.html

Figure A10.6: **Top-to-Bottom Mixing**



Source: http://www.acmeboom.com/baffle-flow-patterns

A10.1.2 Baffle Material

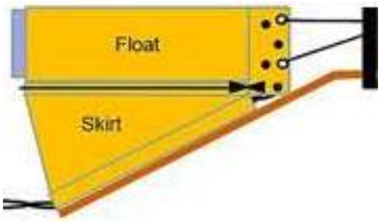
Baffles can be made of wood, concrete, aluminum, geomembrane materials (e.g. Hypalon) or treated fabrics. Manufacturers have their own proprietary materials so the purchaser describes the operating conditions according to the following characteristics:

- chemical composition of the waste water
- exposure to ultra violet light
- temperature range
- hydraulic flows
- wind forces
- temporary or long-term forces

A10.1.3 Baffle Installation

Baffles can be floating with anchorage on the shore or fixed posts placed on the bottom of the pond. Floating baffles can be installed without emptying the pond and provide flexibility of placement and better response to changes in water level compared to a fixed baffle system (Figure A10.7).

Figure A10.7 **: Floating Baffle Anchoring at the Top**



Source: https://www.erosionpollution.com/water_baffles_product.html

Anchor posts are installed on the shore 1 to 2 meters from the edge of the pond or basin. The baffle is secured to the shore anchor posts by stainless steel cable of a suitable length and size to allow the baffles to adjust when the water level changes and to maintain proper tension on the baffle. The anchor points are loops of stainless cable passed through a link in the float. Stainless steel is more expensive but it greatly increases the corrosion resistance of the anchor hardware and therefore increases the life of the baffle.

To keep the floating baffle wall in place it is standard practice to place anchor points through a chain at the bottom of the floating baffle. Anchor points can be placed at any distance along the length of the floating baffle, for example 5 to 10 meters apart. The anchor can be a post installed in the bottom of the pond or a heavy weight at the bottom of the baffle.

A fixed baffle system (Figure A10.8) can be made of concrete or wood walls. For an existing pond, posts (concrete or metal or wood) posts can be installed in the pond bottom and then a geomembrane laced through and attached.

Figure A10.8: **Fixed Baffle System**

Source: TNUSSP Analysis 2017

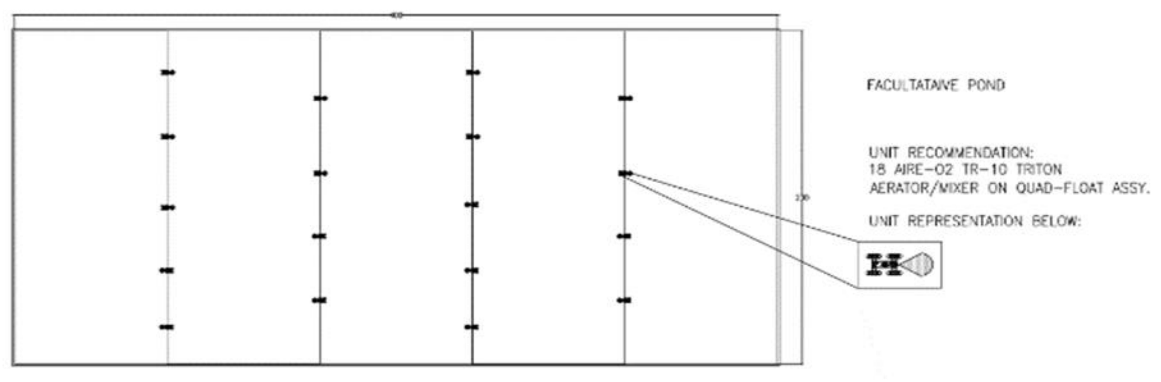
A10.1.4 Baffle Maintenance

Remove floating debris that accumulates along the baffle wall. Make periodic inspections (e.g. once monthly during first six months after installation, then quarterly thereafter) of the baffle material and anchorage system. Items to look for include rips, tears, deterioration of the baffle material and anchorage hardware.

Annexure 11- Information on Surface Aerators

Information in this appendix is provided to TCC in case they would like to consider mechanical aeration a means of providing additional capacity in terms of organic loading and better effluent quality (Figure A11.1).

Figure A11.1: **Layout of Aerators in the Facultative Pond**



Source: Aeration Industries International

The unit selection is based on the depth. Here smaller HP units are used due to the 2m water depth. If anything changes as far as the depth or basin dimensions, power can be increased and offer a few less units.

NOTE from authors: It is suggested that the facultative ponds could be excavated to as deep as 5 meters. This would reduce the cost of aeration, while increasing the organic and hydraulic loading significantly. When the time comes to make a decision, the company indicates that they would work with the design engineers to come up with the optimal pond depth and aeration prescription.

As far as mixing limited, there is two basic criteria to size on for lagoons – mixing and aeration. One will be higher than the other thus choose the higher of the two. Being that this will be a facultative lagoon based on the kinetic calculations; the mixing is the criteria used as the basis for calculations in order to provide the required treatment.

Please find attached calculations for Trichy project based on facultative mix (210 HP) in the facultative lagoon.

The sizing is based on current flow of 45 MLD, flowing in parallel in each of train of lagoons (Anaerobic – Facultative – Maturation). Further equipment can be added for the future loadings as they increase.

Assumed a reduction of 60% in BOD from anaerobic lagoons (40% of 130 ppm, entering the facultative lagoon).

NOTE: Estimated HRT in anaerobic lagoon is only 1.2d, very less for anaerobic reduction to materialize. As well as, shallow for the same purpose.

Settling zone is recommended in the last pond. Additionally, it looks like the discharge is into an adjacent river, so post-aeration certainly adds to the quality of effluent. 3HP/hectare should control algae in the portion of maturation pond.

Flow through lagoon technology has a process effluent limitation of around 20 mg/L effluent BOD. Anything lower than 20 mg/L for consistent figures requires activated sludge or effluent filters. Less than 10mg/L may be achieved, but not consistently.

Lagoon nitrification, conversion of ammonia to nitrate, can occur but it is not reliable due to the slow growth of nitrifying bacteria. Temperature, influent, and alkalinity changes can cause upsets to nitrification.

Having said that, it is recommend supplying an aerated lagoon facultative mix which requires 210 HP in the facultative lagoon. This amount of aeration power provides the minimal recommended mixing for aerated lagoon. The amount of additional BOD treatment with the recommendation is up to 104 mg/L. Assuming the same influent BOD concentration, an estimated increase of 59,650 m3/day in flow would be accommodated. An example of surface aerator is given in Figure A11.2.

Figure A11.2: **Example of surface aerators- Aire-O2 Titron**

Source: Aeration Industries International

Annexure 12- Wastewater Treatment Alternatives[21]

Note on definitions. The term effluent disposal means discharging the effluent into a surface water or onto the land with the associated issues of surface and groundwater pollution. Effluent dispersal refers to evenly applying the effluent into the soil, providing not only important additional treatment but providing for beneficial reuse of the nutrient-rich water by the landscape or agricultural crops.
This section describes alternatives for effluent dispersal using i) agricultural reuse, and ii) treatment and discharge options for non-agricultural systems. Section 8.1 Agricultural Reuse is the primary recommendation. For non-agricultural system, section 8.4 provides recommendations on nutrient reduction using BNR, which is the preferred option.

Modern waste stabilization ponds (WSP) were introduced in India and implemented at scale for small to medium sized cities in the 1990's. However, in 2020, meeting discharge or land disposal standards using waste stabilization pond technology will require nutrient reduction and disinfection. There is a strong incentive for agricultural reuse in the directives which provides that: In addition, Section III of the Directions Under Section 18(1)(b) of the Water (Prevention and Control of Pollution) Act, 1974 regarding treatment and utilization of sewage states:

> (III) Secondary treated sewage should be mandatorily sold for use for non potable purposes such as industrial process, railways & bus cleaning, flushing of toilets through dual piping, horticulture and irrigation. No potable water to be allowed for such activities. They will also digest methane for captive power generation to further improve viability of STPs.

Existing WSPs in Southern India were designed to achieve secondary standards, with BOD and TSS at 30 mg/L and only limited denitrification capability.

Comparison of Commonly Used Wastewater Treatment Technologies
This section is based on data from "Performance Evaluation of Sewage Treatment Plants in India Funded under National River Conservation Directorate (NRCD)" Central Pollution Control Board, Delhi, India, August 2013. This report is based on performance evaluation of 152 Sewage Treatment Plants (STP) in 15 Indian states. Out of the 152 STPs: nine STPs are under construction, 30 STPs are non-operational; and 31 are Waste Stabilization Ponds (WSP).

Wastewater technologies can be broadly classified as:

- Primary (sedimentation to remove settleable solids)
- Secondary (biological treatment to reduce the pollutant loading and volume of solids)
- Nutrient removal of the nutrients Nitrogen and Phosphorus.

Table A12.1 compares the expected effluent concentration for BOD and SS and the removal of fecal coliform bacteria and total nitrogen for six different technologies. The data show that Membrane Bio-Reactor (MBR) and Sequential Batch Reactor (SBR) technologies achieve the best quality effluent and both are considerably better than Waste Stabilization Ponds (WSP). When nutrient removal is added then the effluent concentrations are the same for all technologies.

[21] https://irrigationexpress.co.nz/media/wysiwyg/pdfs/USA_Uniobioline_Waste_Water_PDF.pdf

Table A12.1: **Comparison of Pollutant Removals by Various Wastewater Treatment Technologies**							
	Parameter	**ASP**	**UASB+EA**	**SBR**	**MBBR**	**MBR**	**WSP**
Sl. No	**Type of Treatment**	aerobic	anaerobic-aerobic	aerobic	anaerobic-aerobic	aerobic	anaerobic-aerobic
1.1	Effluent BOD (mg/L)	<20	<20	<10	<30	<5	<40
1.2	Effluent Suspended Solids (mg/L)	<30	<30	<10	<30	<5	<100
1.3	Fecal coliform removal, Log unit	Up to 2<3	Up to 2<3	Up to 3<4	Up to 2<3	Up to 5<6	Up to 2<3
1.4	Total Nitrogen removal Efficiency, %	10 – 20	10 - 20	70 - 80	10 - 20	70 - 80	10 – 20
2	Performance after nutrient reduction						
2.1	Effluent BOD (mg/L)	<10	<10	<10	<10	<10	<10
2.2	Effluent SS (mg/L)	<5	<5	<5	<5	<5	<5
2.3	Effluent NH_3N (mg/L)	<1	<1	<1	<1	<1	<1
2.4	Effluent Total Coliforms MPN/100 mL	10	10	10	10	10	10
Source: Table 6 of "Performance Evaluation of Sewage Treatment Plants in India Funded under National River Conservation Directorate (NRCD)" Central Pollution Control Board, Delhi, India, August 2013							

ASP: Activated Sludge Process	**MBBR:** Moving Bed Biological Reactor
UASB+EA: Upflow Anaerobic Sludge Blanket with Extended Aeration	**MBR:** Membrane Bio Reactor
SBR: Sequential Batch Reactor	**WSP:** Waste Stabilization Pond
Aerobic is with oxygen; anaerobic is absence of oxygen	

Table A12.2 shows percent reduction of the three common pollutants by two-cell waste stabilization ponds.

Table A12.2: **Pollutant Removal In Wastewater Stabilization Ponds**	
Efficiency of Wastewater Stabilization Ponds (two cells)	
Parameter	**Percent Reduction**
BOD	95% to 97%
Suspended Solids	90% to 95%
Total Coliform	95% to 98%
source: CPHEEO, 2012	
Central Public Health and Environmental Engineering Organisation (CPHEEO) [Technical Wing of the Ministry of Urban Development, Government of India]	

Table A12.3 shows the average land area requirements for the six technologies. SBR, MBBR, and MBR have the smallest land area requirements and this makes them quite suitable for urban areas. WSP requires the largest land area and fortunately for Trichy, there is ample empty land available.

Table A12.3: **Area Requirements by Various Wastewater Treatment Technologies**						
	ASP	**UASB+EA**	**SBR**	**MBBR**	**MBR**	**WSP**
Average Area, m^2/MLD including sludge handling	900	1000	450	450	450	6000
Source: Table 6, ibid. 4.1 is the row number in the source table. (m^2 = square meter; MLD = million liters per day)						

Table A12.4 shows the average capital cost in lacs per million liters per day (MLD) and the average Year 2010 treatment cost (INR/m3). Capital cost of MBR is 13 times that of WSP and SBR is 3.2 times. For annual treatment costs, WSP is the least expensive; with SBR 2.6 times more expensive than WSP.

Table A12.4: **Comparison of Average Capital Cost by Various Wastewater Treatment Technologies**							
Sl. No		**ASP**	**UASB+EA**	**SBR**	**MBBR**	**MBR**	**WSP**
1	Average Capital Cost (lacs/MLD	68	68	75	68	300	23
2	Year 2010 treatment cost, INR/m3	3.2	2.8	2.9	3.3	N/A	1.1
Source: Table 6, ibid. 3.1 and 6.7 are the row numbers in the source table.							

N/A = not available; lac = 10,000 Indian Rupee (INR); m3 = cubic meter

Data presented above shows clearly that SBR technology is effective in treating wastewater effluent that meets 2020 standards; and requires a relatively small area of land.

Annexure 13- Sampling Plan for STP

A13.1 Analysis of parameters and frequency (liquid and sludge)[22]

For different technologies of wastewater treatment Centre for Public Health and Environmental Engineering Organisation (CPHEEO) has given the details on the frequency and parameters to be analysed at the STP in the manual on sewerage and sewage treatment. Table A13.1 adapted from CPHEEO, shows the parameters to be analysed for Waste Stabilisation Ponds.

Table A13.1: **Testing parameters at Waste Stabilisation Pond**

No.	Parameter	Sample Type	Remarks
1	Flow	-	Both raw sewage and final effluent flows
2	BOD	C	Unfiltered Samples (A)
3	COD	C	Unfiltered Samples (A)
4	Suspended Solids	C	
5	Ammonia	C	
6	pH	G	Two samples one set each at 8:00-10:00 h & at 14:00-16:00 h
7	Temperature	G	
8	Fecal Coliforms	G	Take samples between 8:00 & 10:00 h
9	Total Nitrogen	C	Only when effluent being used (or being assessed for use) for crop irrigation. Ca, Mg and Na are required to calculate the sodium absorption ratio (SAR) (D)
10	Total Phosphorus	C	
11	Chloride	C	
12	Electrical Conductivity	C	
13	Ca, Mg, Na	C	
14	Boron	C	
15	Helminth Eggs (B)	C	
16	Dissolved Oxygen	-	

Notes:
C = 24 hour flow-weighted composite sample; G = grab sample,
(A) Also on filtered samples if the discharge requirement are so expressed.
(B) Ascaris lumbricoides, Trichuris trichiura, Ancylostoma duodenale and Necator americanus
(D) SAR = (0.044Na)/[0.5(0.050Ca + 0.082Mg)]0.5 where Na, Ca and Mg are in mg/L.

Source: CPHEEO 2013

[22] *Manual on sewerage and sewage treatment plant, Centre for Public Health and Environmental Engineering Organisation (CPHEEO), Part B- Operations and Maintenance,2013*
http://cpheeo.gov.in/upload/uploadfiles/files/operation_chapter7.pdf

TN US SP

TAMIL NADU URBAN SANITATION SUPPORT PROGRAMME

Tamil Nadu Urban Sanitation Support Programme (TNUSSP) supports the Government of Tamil Nadu and cities in making improvements along the entire urban sanitation chain.

The TNUSSP is implemented by a consortium of organisations led by the Indian Institute for Human Settlements (IIHS), in association with CDD Society, Gramalaya and Keystone Foundation.

iihs®
INDIAN INSTITUTE FOR HUMAN SETTLEMENTS

IIHS CHENNAI: Floor 7A, Chaitanya Exotica, 24/51, Venkatnarayana Road, T.Nagar, Chennai-600017.

044-6630 5500 tnussp@iihs.ac.in www.tnussp.co.in www.facebook.com/TNUSSP