Samoa Water Authority

Apia Water Supply Consolidation Project

Water Treatment Plant Operations Manual

by

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APPENDICES

1. INTRODUCTION

1.1. OVERVIEW

The objective of the water treatment plants at Alaoa, Fulu'asou and Malololelei, is to remove contaminants in order to provide a safe water supply to the population they serve, ie urban Apia.

There are community expectations on the operating authority to supply high quality water, while minimising costs to consumers. Consequently for any operations team there is an emphasis on providing a good service, which may be achieved in part by maintaining and optimising the existing systems and assets (and implementing any improvements which might be identified as necessary to achieve objectives in the future).

This document describes the unit processes used at each of Apia's treatment plants, how they work, and the purpose they serve. It also outlines monitoring of water quality, why we sample, using the analytical results and other observations to optimise water treatment plant performance, troubleshooting if problems should arise and how to recognise the problems.

The design and actual flows for each of the three water treatment plants are as follows:

	ALAOA WTP		FULU'ASOU WTP		MALOLOLELEI WTP	
	Flow L/s	Flow m^3/day	Flow L/s	Flow m^3/day	Flow L/s	Flow m^3/day
Design Flow	106	9,125	69	5,950	22	1,900
Actual Typical Flow	137	11,800	105	9,100	33	2,850

1.2. WATER QUALITY

Potable water is water fit for drinking and is the key to life. Water, which is fit for human consumption, is clear, colourless, free from objectionable odour and taste, and does not contain dangerously high levels of contaminants.

Treatment systems remove contaminants - particles or solids, micro-organisms and other contaminants. The purpose of these is to produce water to a level, which does not present a risk to human health, and thereby fit for human consumption.

Although water must taste good - the main control to be provided by the operators of the Apia water Supply Authority is in the removal of solids (via settling and filtration) and the removal of bacteria.

The proposed Samoa Standards for Drinking Water include the following parameters :

- Bacteriological 0 Total Coliforms / 100 mL sample
  0 *Escherichia Coli* / 100 mL sample

- Chemical Arsenic 0.01 mg/L

Cadmium	0.003 mg/L
Chromium	0.05 mg/L
Copper	2.0 mg/L
Cyanide	0.07 mg/L
Lead	0.01 mg/L
Manganese	0.5 mg/L
Mercury	0.001 mg/L

- Physical & aesthetic parameters

Turbidity *(nephelometric turbidity units)*	5 NTU
Ammonia	1.5 mg/L
Iron	0.3 mg/L
pH	6.5 - 9.5
Total Dissolved Solids	1000 mg/L
Chlorine	0.6 - 1 mg/L

2. WATER TREATMENT PLANT AS A SYSTEM

2.1. GENERAL

The treatment process train at each of the plants is made up of a series of individual processes, as follows:

- raw water intake screen
- settling tank
- roughing filters
- slow sand filters
- balancing tank

The treatment system is basically arranged so that progressively more advanced systems from coarse solids entrapment to fine are in place. Each unit essentially acts as a pre-treatment unit of the other leading on to the slow sand filters, which are the final polishing system. The units are arranged to allow total gravity flow. Process flow diagrams of the plants are contained in Appendix A. Appendix B contains the flow diagrams for overflows and cleaning of units.

Hydraulic profiles of the plants are shown in Appendix C.

Appendix D contains the criteria sheets for each of the 3 WTP's, that show tank dimensions and loading rates calculated for the design and actual average flows. The latter were recorded at October 1999.

Units may be isolated or taken off-line to allow for clean out (to remove blockages) or allow cleaning. This is achieved by using the inflow and outflow valves, which are provided for each unit.

2.2. SUMMARY OF TREATMENT PROCESS UNITS DESIGN CRITERIA

The table below summarises the design criteria for each of the individual units which make up the treatment train :

Treatment Unit	DESIGN CRITERIA	Units $m^3 / m^2 . hour$
SETTLING TANKS	Loading rate (based on surface area)	1.0
ROUGHING FILTERS	Loading rate (equivalent to velocity)	1.5
SLOW SAND FILTERS	Loading rate (based on area, velocity)	0.20

The table below shows the operating criteria based on actual average flows :

Treatment	ALAOA WTP LOADING, m/h	FULU'ASOU WTP LOADING, m/h	MALOLOLELEI WTP LOADING, m/h

Unit	All units operating	One unit off-line	All units operating	One unit off-line	All units operating	One unit off-line
SETTLING TANKS	0.99	1.98	1.11	2.22	1.09	only 1 unit available
ROUGHING FILTERS	1.25	1.67	1.48	1.96	1.43	2.85
SLOW SAND FILTERS	0.16	0.20	0.18	0.24	0.17	0.24

Areas of most concern are considered to be as follows :

- settling tanks if 1 unit is off-line
- roughing filters at Fulu'asou and Malololelei if 1 unit is off-line
- slow sand filters at Fulu'asou and Malololelei if 1 unit is off-line

The above assumes there is even flow to the units. An example is presented below if this is not the case.

Please note that the above criteria are not strict rules - they are the adopted loading rates. The process units at the 3 WTP's would seem to be coping reasonably well. However, sustained loading at significantly higher rates than the design criteria is not recommended. This will lead to a deterioration in water quality. If a high loading is necessary (through a tank having to be taken off line) for extended periods, either a reduced flow might be considered or allowance for additional solids loading on downstream units should be made (which would entail additional cleaning).

2.3. EVEN FLOW DISTRIBUTION

To demonstrate the effect of loading rates evenly between the filters, a theoretical example is presented for the slow sand filters at Malololelei. There are 3 SSF's at the plant.

Say 45 % of flow goes through SSF No. 1, 35 % through No. 2 and the rest through No. 3.

Each SSF has a surface area of 238 m^2.

TOTAL Flow = 33 L/s x 3600 s/h x 1 m^3/1000 L = 119 m^3/hour

45 % of the flow = 0.45 x 119 m^3/hour = 53.5 m^3/hour

$$\text{Loading} = \frac{53.5\ m^3/\text{hour}}{238\ m^2} = \mathbf{0.22\ m^3/\ m^2.\ hour\ (No.\ 1)}$$

35 % of the flow = 0.35 x 119 m^3/hour = 41.6 m^3/hour

$$\text{Loading} = \frac{41.6\ m^3/\text{hour}}{238\ m^2} = \mathbf{0.17\ m3/\ m2.\ hour\ (No.\ 2)}$$

20 % of the flow = 0.20 x 119 m^3/hour = 23.8 m^3/hour

3.4. SETTLING TANKS

3.4.1. General

The purpose of these tanks is to remove the heavy settleable solids from the source water from turbid sources to lessen the load on downstream treatment processes (usually with a screen upstream). Raw water enters the tanks via a central well and solids settle out. The settled water (outflow) flows over a weir at the periphery (circumference) of the tank.

The design criteria for these tanks (i.e., the basis of design) is loading rate, which is a function of flow and surface area of the tank. Typical design criteria is 1 m^3/m^2.hour (or m/h), which allows time and area for the solids to settle adequately.

Withdrawal of sludge should be frequent and controlled. Otherwise if sludge becomes too thick, the flow may "pipe" through to the drain valve leaving the bulk of the solids on the sides of the tank base. Frequent removal of solids may disrupt density currents and improve performance.

The loading rates of the settling tanks at each of the plants is summarised in the table below. The rate is calculated for two flows, that of design flow through the WTP and actual average flow. The calculation of the loading rate is as follows:

LOADING RATE = Flow / (surface area of tanks)

11,856 m^3/D

E.g., ALAOA, average flow = 137 L/s = 494 m^3/hour

2 settling tanks, each 249 m^2 surface area; total surface area = 498 m^2 23 m^3/m^2.D

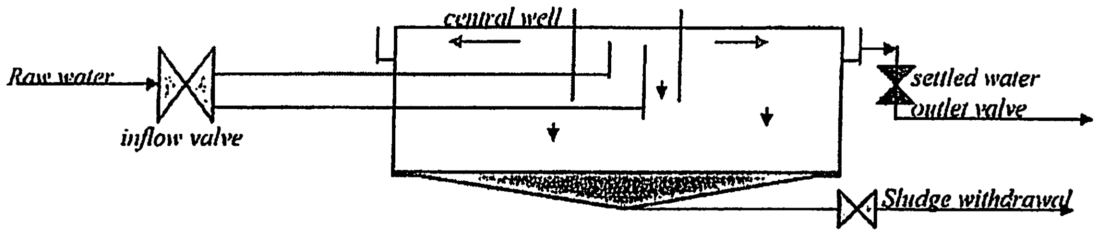
LOADING RATE = 494 m^3/hour / (498 m^2) = 0.99 m^3/m^2. hour

	ALAOA WTP		FULU'ASOU WTP		MALOLOLELEI WTP	
	Flow L/s	Loading m/h	Flow L/s	Loading m/h	Flow L/s	Loading m/h
Design Flow - *all units operating*	106	0.76	69	0.73	22	0.73
Design Flow - *one unit off line*	106	1.52	69	1.46	-	only 1 unit available
Actual Average Flow - *all units operating*	137	0.99	105	1.11	33	1.09
Actual Average Flow - *one unit off line*	137	1.98	105	2.22	-	only 1 unit available

As can be seen from the table, the loading of the settling tanks during design flow, for all units on line (and assuming even flow distribution), is less than the normal design load of 1 m^3/m^2.hour. Even at the average actual flow the loading is around 1 m/hour. However, there may be performance problems during the times when one tank is taken off-line, since the loading would be significantly greater than 1 m/h.

3.4.2. Operation

Raw water enters the tanks through one central pipe per tank and feeds to a central well (baffle) which directs solids towards the base. Settleable (heavy) solids settle out, assisted by the long retention time of over 3 hours in the settling tanks. The settled water (outflow) flows over a weir at the periphery (circumference) of the tank. The circular weir has 25 mm dia. discharge holes located evenly around it. A moderate reduction in turbidity is achieved over the settling tanks. Even flow rates through the two tanks during normal operation should be maintained. The system is designed so while one tank is out of service for maintenance, or the level in the tank is lower than the weir during sludge withdrawal, the other tank can provide settled water to all roughing filters (there is a balance line between the two tanks).



The inflow valve to the tanks needs to be adjusted to restrict the required flow to the WTP as well as maintaining an even flow distribution between the 2 settling tanks (at Alaoa and Fulu'asou). The outflow valves should be maintained at 100 % open.

3.4.3. Cleaning of Settling Tanks

SLUDGE REMOVAL

The base of the settling tanks is sloped towards the sludge washout pipe in the centre.

Raw water contains sediment which is removed in the settling tank (sediment load is typical increased after rain). Sludge build up in the tanks will result. Sludge should be withdrawn separately from the tanks at least every week (although it is suggested that daily cleaning is undertaken - this will help prevent consolidation and potential for blockages in the take-off pipe - which would reduce the efficiency of the sludge withdrawal system and so the effectiveness of the settling).

If sludge withdrawal is infrequent, sludge may become too thick, and the flow may "pipe" through to the drain valve leaving the bulk of the solids on the sides of the tank base. Frequent removal of solids should maintain the sludge layer away from the outlet and prevent solids overflow.

Procedures

a) Open drain valve to allow draw down of sludge.

b) Run the sludge out until the water becomes clear (this should not be done at too fast a rate, to avoid rat-holing).

c) Close drain valve.

TAKING TANK OFF-LINE

d) Closing inlet and outlet valves on tank is not required unless the tank is to be fully drained and cleaned to undertake maintenance. If the tank is to be taken off-line then the inlet valve on the other tank will need to be adjusted to maintain the required flow through plant.

e) If required, allow all excessive algae on the tank walls to dry out and scrub the walls discharging all water and dead algae to waste.

f) Close drain valve.

g) Refill tank via inlet valve with clean raw water.

h) Once the water level reaches weir overflow level adjust the inlet valves of both tanks to the required operating setting.

i) Open the outlet valves.

WEIR OUTLETS
The 25 mm diameter weir outlet holes will need to be regularly inspected and cleaned to maintain the correct flow balance around the tank.

3.5. *ROUGHING FILTERS*

3.5.1. General

Roughing filters are used as pre-treatment to slow sand filters to reduce sediment loading to them. A coarse media (gravel) is used to filter out larger particles from the water. Particles are trapped within the voids in the media. Gravel size is graded in direction of flow (i.e. the flow enters the bed at the coarse layers and leaves the media from the finer media) so are usually upflow type filters.

Water enters at the base of the media and flows up through the bed of gravel. Filtered water is collected from the tank by a peripheral weir.

Depending on the type of particles present in the water, removal rates may be 70 - 90 % over the roughing filter.

LOADING RATE (or velocity) = Flow / (surface area of tanks)

E.g., ALAOA, average flow = 137 L/s = 494 m^3/hour 11.856

4 roughing filters, each 98.5 m^2 surface area; total surface area = 394 m^2

LOADING RATE = 494 m^3/hour / (394 m^2) = 1.25 m^3 /m^2 . hour

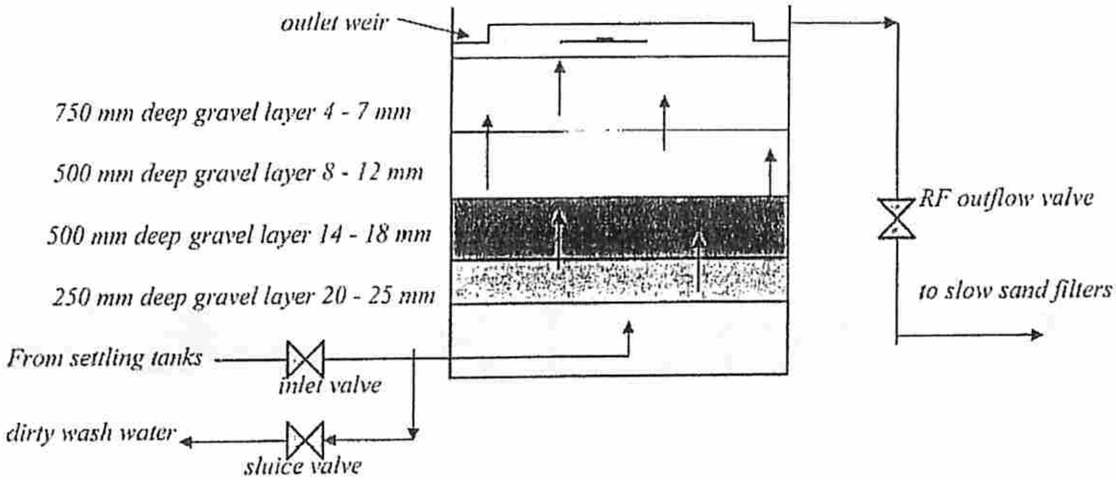
30m. 80m 90 → 100m.

	ALAOA WTP		FULU'ASOU WTP		MALOLOLELEI WTP	
	Flow L/s	Loading m/h	Flow L/s	Loading m/h	Flow L/s	Loading m/h
Design Flow - *all units operating*	106	0.96	69	0.97	22	0.95
Design Flow - *one unit off line*	106	1.29	69	1.29	22	1.90
Actual Average Flow - *all units operating*	137	1.25	105	1.48	33	1.43
Actual Average Flow - *one unit off line*	137	1.67	105	1.96	33	2.85

As can be seen from the table, the loading of the roughing filters during design and actual average flow for all units on line (and assuming even flow distribution) is within the normal design load (of say 1.5 m^3 /m^2.hour). However, there may be performance problems during the times when one tank is taken off-line, since the loading would be significantly greater than 1.5 m/h (and so well above what would be considered typical design criteria).

3.5.2. Operation

Settled water enters up through the roughing filter underdrain system at the base of the media and flows up through the 2 metre bed of gravel entrapping sediment in the process. Filtered water flows over a circular weir within the tank walls (about 1 m above the last gravel layer).



The inflow valve to the roughing filters needs to be adjusted to provide an even flow distribution between all the operating units. The outflow valves should be maintained at 100 % open.

HEADLOSS INDICATOR PIPE

There is a 25 mm diameter headloss indicator pipe located in each tank and running from the inflow channel vertically up the basin wall. It is understood this is not currently operating. However, this is considered useful to measure the headloss across the filter bed.

Each filter should be cleaned fortnightly or more regularly if the gauge indicates so, or if there is breakthrough of solids occurring.

3.5.3. Cleaning of Roughing Filters

Cleaning of the filters is done by providing an additional head of water to the filter, then dumping the contents into the underdrain system when the inlet valve is closed and the sluice valve opened. Cleaning of the filters should only be done with clean settled water. (Heavy solids have been removed in the settling tanks so the light material captured is easily carried out by the high velocities).

Procedures

a) Shut the outlet valve of the roughing filter to be cleaned.(the remaining filters should automatically balance, although the rate via the remaining units may need to be increased to maintain the required plant flow - check overflow and meter reading).

b) Allow an increase to maximum water height (about 800 mm) in the tank, then close the tank's inlet valve.

c) rake the accumulated sludge and brush algae from walls.

d) Open the sluice valve fully and dump the contents to waste. (Check the discharge via the manhole). The above procedure may need to be repeated 3 times until the effluent runs clear.

e) When the filter bed is exposed after dumping the contents inspect the gravel layer and remove any leaves or growing plants etc. Any algae growths on the walls should also be allowed to dry then be scraped off the walls and removed from the tanks.

f) Once cleaning is complete, close the sluice valve and refill the tank via the inlet valve. Set the outlet valve back to normal operating setting. Re-adjust inlet valve position to achieve even flow between filters.

A siphon arrangement has been tested at ALAOA, whereby a 50 mm pipe (with valves) is placed in the roughing filter to suck and clean the solids into the drain line prior to backwash. This should be considered for the other plants (although a larger pipe may be better - allowing faster removal of surface solids). Brushing down walls prior to this or during the suction operation would be preferred. This procedure is undertaken prior to opening sluice valve. All material removed by the siphon is discharged to the sluice line via the manhole,

Chlorine dosage (once the disinfection system become available at the WTP) may be applied on an annual basis (possibly at the end of the wet season) to kill any residual biological growth in the roughing filters. Again this should be tested and procedures developed.

3.6. SLOW SAND FILTERS

3.6.1. General

Slow sand filters involve a bed of fine media through which water is passed in a downward direction. The sand media is supported on a layer of gravel, which allows water to pass through without entraining the sand particles, and migrating to block the drains below the bed. With slow sand filters, the main mechanism of particulate removal is entrapment (rather than attachment) at the surface of the media bed. The media depth is 1.0 m, and this is placed above a gravel support layer about 0.5 m deep). At the Apia water treatment plants, the gravel media is graded 25 mm down to 4 mm size. The sand media size used for slow sand filtration should be 0.15 - 0.4 mm.

During the initial operation (after washing) the separation of organic matter and other solids generates a layer of biological matter on the surface of the filter media. Once established, this layer (sometimes referred to as a bio-layer or the "schmutzedecke") is the predominant filtering mechanism. It has also been found that some biological activity extends into the bed where particulate removal is achieved by bio-adsorption and attachment to the sand grains. The presence of dissolved oxygen (DO) is critical for stimulating the health of the bio layer. Typically this should be greater than 6 mg/L.

A level of water is maintained above the sand media to provide the driving head across the filter bed. When the filter is clean a lower head is required. As the filter develops a bio-layer and more particles are trapped, then more head is needed to drive the water through the filter. The terminal head loss (i.e. when the filter needs cleaning) is 1.4 m head.

Typically an average filter run (i.e. the period of time the filter operates before cleaning is required) is 45 - 60 days, although runs greater than 6 months have been reported. However, the filter run depends on the quality of water (extent of solids concentration) and the loading.

Slow sand filters remove iron and manganese (contaminants) via precipitation on the sand surface (which forms as a scale), but iron should be less than 1 mg/L to avoid forming an iron precipitate that could clog the filters.

Slow sand filtration is known to be able produce a high quality of effluent and effectively remove many microbial contaminants. They are capable of reducing turbidity to less than 1 NTU and reducing Coliforms by between 10 to 1000 times (1 - 3 log units).

As with the other units, the basis of design is loading rate or filtration rates, and is based on flow and surface area. A typical design criteria for the slow sand filters is between 0.1 - 0.2 m/h.

LOADING RATE = Flow / (surface area of tanks)

e.g., ALAOA, average flow = 137 L/s = 494 m^3/hour
5 sand filters, each 616 m^2 surface area; total surface area = 3080 m^2
LOADING RATE = 494 m^3/hour / (3080 m^2) = 0.16 m^3 /m^2. hour 3.84 m/d

	ALAOA WTP		FULU'ASOU WTP		MALOLOLELEI WTP	
	Flow L/s	Loading m/h	Flow L/s	Loading m/h	Flow L/s	Loading m/h
Design Flow - *all units operating*	106	0.12	69	0.12	22	0.11
Design Flow - *one unit off line*	106	0.15	69	0.16	22	0.16
Actual Average Flow - *all units operating*	137	0.16	105	0.18	33	0.17
Actual Average Flow - *one unit off line*	137	0.20	105	0.24	33	0.24

As can be seen from the table, the loading of the slow sand filters during design and actual average flow for all units on line (and assuming even flow distribution) is less than the normal design load (0.2 m^3 /m^2.hour). However, there may be performance problems during the times when one tank is taken off-line, since the loading (for Fulu'asou and Malololelei) is significantly greater than 0.2 m/h.

3.6.2. Operation

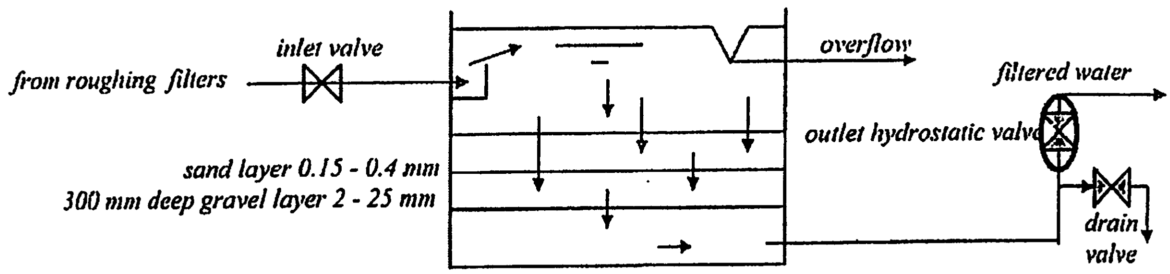
Pre-filtered water from the roughing filters enters the slow sand filters via the inlet chamber. The slow sand filters, correctly operated will further reduce turbidity and bacteria levels. The normal slow sand filter operating level is 2 mm above overflow (up to 5 mm is acceptable). A level of water is maintained above the sand media to provide the driving head across the filter bed. When the filter is clean, a lower head is required. As the filter develops a bio-layer, more particles are trapped, and more head is needed to drive the water through the filter.

The media within the tank consists of a 300 mm depth of gravel, which covers the underdrain systems. This gravel layer supports the 1m depth of 0.15 - 0.6 mm graded sand media. Accumulated biological matter creates a bio-layer at the surface of the sand, and this creates the main method of entrapment of fine solids (although some filtering also takes place within the upper layers of the bed). Once a bio-layer has been formed it is termed as RIPENED.

Development of the bio-layer normally takes 1-3 days. Water is "filtered to waste" until this is established. Once ripening has been established the filter drain valve can be closed and the hydrostatic valve adjusted to allow water filter . The head difference at the start of the run may be as low as 30 mm, but increases over the filtering period reaching a total headloss of 1400 mm (at which point the hydrostatic valves are fully opened).

Correct filter operation and filtration rates must be maintained to obtain full filter running periods. Although the inlet valves might be used to adjust flow into the filters, in this case the hydrostatic valves actually are needed to adjust the head. Consequently, it is suggested that the inlet valve be opened 100 % and the outlet hydrostatic valves be adjusted as required to provide even flow distribution through the slow sand filters. The hydrostatic valve will need to be adjusted regularly to maintain required evenly distributed flow rates (check at least twice daily).

Once the filter unit has reached the terminal head loss (1400 mm) the unit shall be taken out of service, cleaned and then "ripened" again. Only one filter should be out of service for cleaning at a time. HIGH TURBIDITY LOADINGS WILL REDUCE FILTER RUNS.



3.6.3. Cleaning of Slow Sand Filters

When the headloss has reached the permissible limit, the filter must be taken out of service and cleaned. Cleaning is done manually. The filter is drained to expose the surface, which is allowed to dry.

The biological layer is scraped off along with 5 to 10 mm of sand. The removed sand should be washed and replaced in the filter.

Irrespective of head loss, the original designers of the WTP's suggested a design criteria of 400 m^3/m^2 per filter run for the slow sand filters. Using the example of Alaoa, the length of time between filter cleaning may be calculated :

Design flow of Alaoa is 106 L/s (9158 m^3/day),

SSF area is 3080 m^2, 3m/b.

Period of time between cleaning $= \frac{400\ m^3/m^2 \times 3080\ m^2}{9158\ m^3/day}$ = 134 days = 4.5 months

However, for loads about 40 % above the design flow, the filters should be washed every 3 months.

The table below provides a guide for period of time suggested for washing based on the design.

% of DESIGN FLOW	No. of days between SSF cleaning	Months
75 %	179	6
95 %	143	4.8
104 %	130	4.3
114 %	119	4
123 %	110	3.7
133 %	102	3.4
142 %	95	3.2
152 %	89	3
161 %	84	2.8
170 %	79	2.6
180 %	75	2.5
190 %	71	2.4

As a general rule, based on the current loadings, it is recommended that the program for washing SSF's be every 3 months.

Procedures

a) Close the inlet of the filter to be cleaned. Raise the filter's hydrostatic valve and open the filter drain valve.

b) Close filter drain valve (water should be 150 mm below sand level during cleaning).

c) Allow spent biological layer to dry. (overnight drying allows for a complete day's scraping).

d) Scrape biological layer off sand bed (plus about 5 - 10 mm of surface sand). The layer is removed manually using scraper, shovels, planks and barrows etc).

e) Remove sand from filter and arrange washing (OR arrange new sand).

f) Evenly spread the cleaned sand onto the sand bed and rake level.

g) Refill the tank slowly initially (so as not to damage the filter bed) using water from the filters inlet valve. Fill to overflow level.

h) Open the cleaned filters 'drain valve' one and a quarter turns. This flow is estimated at the one quarter normal flow rate for an overnight re-ripening period.

i) Adjust cleaned filter inlet valve to prevent excessive filter overflow.

j) The filter is now establishing another biological layer. Test the water from the drain valve and compare to other filters. Filtered water results will indicate the ripening process has occurred.

k) Close the filter drain valve and slowly over a period of 24 hours introduce the cleaned filter to the flow rate required via the hydrostatic valve.

Other important procedures are as follows :

- Record activities in log book.

- Prior to any person entering the filter tank for cleaning purposes that person should walk through a footbath of disinfected water to avoid contaminating bio-layer.
- All algae attached to inside walls of the tanks should be allowed to dry during the cleaning process then scraped off.

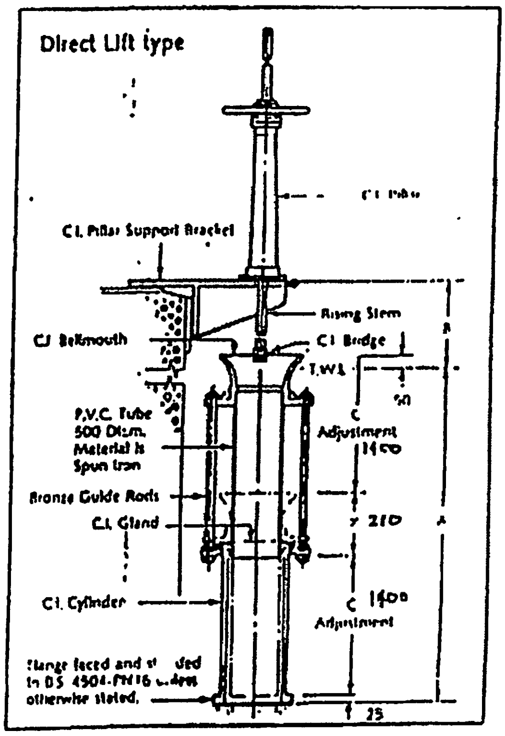
DAILY CLEANING
Large floating leaves should be skimmed off the surface of the water daily. In addition any floating algae should be discharged down the overflow pipe by increasing the flow of water over the overflow.

3.7. *HYDROSTATIC VALVES*

Filtered water from each slow sand filter is collected in the hydrostatic valve chamber.

Each of the five hydrostatic valves controls the flow output of one filter. The operator should regularly adjust these valves to maintain an equal flow between the filters and to be constant with the increasing filter headloss. (i.e.. as the biological layer builds up the hydrostatic valve shall be lowered to maintain correct flowrates).

The headloss should be checked and recorded daily.



3.8. *BALANCE STORAGE RESERVOIR*

The reservoir acts as a storage of the treated water. This provides about one hours storage to allow treated water to build up at the WTP prior to distribution to the reticulation system network.

Metering is installed downstream of the reservoir to allow measurement of the flow production from each plant (and so the operations personnel may calculate loading rates to the process units).

There may be occasions when the balancing reservoir overflows at the treatment plants. While this is not desirable, there are certain aspects to consider, include the following:

- What the flow is from the treatment plant
- The balance tank storage is equivalent to less than one hours detention
- What the likely pattern of demand is expected to be in the following 2 – 3 hours
- The extent of the overflow.

The basic rule, should be that when the balancing reservoir is full, the inflow should be turned down. However, there may be some mitigating reason why this should not be undertaken. Repeating notes from Session 6 of the course, it is important for the operator to build up a picture of how his plant performs and also the water demand flow pattern. Certainly this will be helped by the installation of metering, but the operator should ferquently check levels in the balance reservoir and WTP output flow to allow graphing of these and so provide a pattern of demand. Below are three scenarios related to this matter, and suggested actions :

- *Balance tank is overflowing, the demand is low, and the predicted pattern for this particular time of the day is tending towrads continuing low demand for over 2 - 3 hours.* The plant flow should be reduced (by partially closing the settling tank inflow valves). The operator should then check his flow meter and the level in the balancing reservoir every 20 – 30 minutes. Depending on what these show he may need to adjust the inflow.
- *Balance tank is overflowing (only slightly). The demand is low now, but is expected to climb rapidly within the next hour.* In this case the inflow valves should not be adjusted.
- *Balance tank is overflowing (significantly). The demand is low now, but is expected to climb rapidly within the next 1 – 1 ½ hours.* In this case, the operator should adjust the inflow valves, by closing partially, but should closely check the level in the tank and the flow demand very frequently. It would be likely that the operator will need to re-adjust the inflow valves to allow more flow through the plant within 1 hour.

Frequent checking and adjustment of the inflow to match the demand might be regarded as some considerable trouble for a small volume of water, which has overflowed the balance reservoir. However, what must also be considered is not only the need to conserve water, but also the fact that an unnecessary volume of water has been put through the treatment plant. With the latter, there is the potential to :

- Overload the units
- Provide for additonal solids capture in the process units
- This in turn necessiattes additonal cleaning.

3.9. DISINFECTION

It should be noted that chlorination of the treated water for the 3 water treatment plants is currently under consideration. The purpose of this process will be to kill any micro-organisms which may be present in the treated water produced by the slow sand filters and in the reticulation / distribution network.

This step involves addition of chemical to the treated water to kill pathogenic bacteria. Chlorine based chemical is the most common form of disinfectant used in water treatment. A residual of chlorine is produced and this is used as an indication of disinfection effectiveness.

At present, calcium hypochlorite powder is proposed for installation at the three WTP's. The powder will be mixed in a holding tank (with treated water) and the hypochlorite solution dosed to the filtered water.

3.10. OTHER PROCEDURAL ASPECTS

As stated previously an even balance should be maintained between all operating units. It is suggested that this be applied using simple visual inspections of the levels inside the weir walls in the settling tanks and roughing filters. Extent of flow from each of the slow sand filters may be checked for the hydrostatic valve output, since they are adjacent to each other.

Levels within the balance storage tank should be regularly checked and so the plant operator may make any required adjustments to plant flow rates.

Metering (downstream of the reservoir) allows measurement of the flow production from each plant and this should be checked at least twice daily.

Maintenance of all valves and intake stop gates should be programmed to ensure that all equipment is in good operating order. Failure to do this might impact on ability to adjust flow, which might affect water quality.

3.11. DISPOSAL OF SLUDGE AND COLLECTED MATERIAL FROM CLEANING

Typically this would be either returned to the river (screenings, sludge from settling tanks and roughing filter backwash) or left to dry and buried (slow sand filter sludge and algae mats).

4. TROUBLESHOOTING

4.1. GENERAL

Troubleshooting is learning to recognise problems and then taking some actions / steps to overcome these. The objective is to maintain the process at optimum performance. Early recognition of situations will often avoid major efforts to rectify the situation.

This Section deals with problems that could arise, how to recognise them and what action to take. Generally there are two methods of recognising when there is a problem - visual and laboratory testing / monitoring.

4.2. CHECKING AND MONITORING

Monitoring of the treatment plants is important in providing an understanding of the performance of the system. Certainly the testing of the treated water is compulsory in order to provide records of attainment of water quality, but monitoring of the different units is necessary to understand the system and where the problem might lie if quality drops off. Monitoring systems (through arranging lab testing and graphing the results) are used to indicate trends of the plant, ie., how it performs over time. The type of things to look for include :

- whether there is a deterioration in water quality,
- what is the water quality of the raw water,
- performance of the unit processes (individual tanks)
- whether the systems are being maintained / cleaned frequently enough.

Visual observations are very useful in terms of immediate recognition. This is the operator's early warning sign of potential problems. Consequently, the operator must include a check of all tanks and outflows in his daily routine - how do they look compared to usual operation, is flow evenly distributed.

Visual checks are typically used in conjunction with monitoring of the plant to provide an understanding of how the plant is going. Section 5 will deal with laboratory testing and reporting, and this session outlines warning signs (and also aspects of water quality achievement) and what to do when performance drops off.

4.3. BASIS OF CONTROL

The broad potential problem areas for normal operation of the WTP's are regarded as :

- insufficient flow to WTP and / or units
- high through put through individual units (overloading)
- high turbidity in water (and other contaminants); and

- blockages in pipes / valves - restricting flow.

A summary of the required unit loading and water quality (which have been covered in the previous sections) is contained in the table below:

Unit	Maximum Criteria	
Settling Tanks	1.0 m^3/m^2. hour	
Roughing Filters	1.5 m^3/m^2. hour	
Slow Sand Filters	0.2 m^3/m^2. hour	
Treated water	Turbidity	5 NTU
	Iron	0.3 mg/L
	pH	6.5 - 9.5
	Total Coliforms	0 / 100 mL sample

In terms of being able to control the situation, there are limited options. The operator has no means to change or control the size of the tanks or the raw water characteristics - although new tanks may be built to provide for higher loading and a new intake may improve water quality - but for operations, only optimisation of the existing assets can be considered. So on this basis there are two broad control mechanisms :

- Flow distribution to process units through adjustment of valve position
- Removal of collected solids either by withdrawal of sludge (settling tanks) or instigation of filter cleaning (to overcome high headloss) for both roughing and slow sand filters.

A summary of the problems that could be expected and the recommended course of action to overcome them are listed in the following sections.

4.4. IN-TAKE AREA

PROBLEM	RECOMMENDED ACTION
(a) Insufficient flow	Check for blockages / restrictions. Clean screen / remove sediment build-up.
(b) Sudden on-set of poor water quality	Look at upper catchment - check for any run-off / discharges - and stop.
(c) On-going poor water quality	Look for new intake site - protected catchment

4.5. SETTLING TANKS

PROBLEM	RECOMMENDED ACTION
(a) High turbidity	check raw water quality check inflow (if overflowing from settling tanks - high inflow may be disturbing sludge blanket)
(b) High sludge blanket	Withdraw sludge (slowly to avoid rat-holing) until off-take becomes clear. Repeat later and following days to reduce.
(c) Inflow water flowing over central well wall	Check overflow and WTP flow meter. Flow too high - Reduce inflow by closing inlet valves (to required extent) - ensure balanced flow between settling tanks
(d) Solids flowing from tank into outflow weir	Sludge blanket is too high - withdraw sludge (slowly to avoid rat-holing) until off-take becomes clear. Repeat later in day. Also check overflow - reduce intake as necessary.
(e) Clear water in 1 tank, turbid in other	Uneven loading. Use inlet valves to balance flow between tanks (because of the positioning of tanks in relation to pipe, this may involve different settings of valves - visual check of inflow)
(f) No sludge coming out when opening withdrawal pipe	Blocked pipe - use compressor to shift blockage (take tank off-line). Increase sludge withdrawal frequency.
(g) High overflow from tank	Check WTP throughput - reduce inflow if required. Check for restriction in outflow valve (valve to be 100 % open) and / or downstream unit pipe.
(h) Low flow into settling tanks (& WTP)	Check WTP meter. Open inflow valves to achieve required flow. If little change - check intake area and clear.

4.6. ROUGHING FILTERS

PROBLEM	RECOMMENDED ACTION
(a) High turbidity in outflow water	Check settled water quality Check inflow rate (to calculate loading - reduce inflow if required), adjust flow distribution if necessary.
(b) High water level in 1 to 2 roughing filters	Check outflow valves in these (to be 100 % open) Adjust inflow valves of all filters to ensure even flow.
(c) Clear water in 1 or 2 filters, turbid in others	Uneven loading. Use inlet valves to balance flow between filters (because of the positioning of the filters in relation to the inflow pipes, this may involve different settings of valves - visual check at outlet weir).
(d) A lot of algae and growth at surface	Clean / scoop, or siphon If significant, may be time to backwash (check headloss)
(e) Solids travelling upward from filter	May be high flow velocity - check evenness of flow distribution between filters. May be solids breakthrough (so filter bed is full of solids / sediment) - time to backwash.
(f) On-going poor capture of solids	Check flow to filters - check loading (compare to design criteria). If still okay, check media bed - size of surface layer - replace media if required
(g) Washing - waste water not clear even after several dumps.	May be high sediment load in filter (check lab tests from previous days). Continue to wash / waste. May be inefficient cleaning caused by underdrain failure / blockage - clean out tank - take off-line.

4.7. SLOW SAND FILTERS

PROBLEM	RECOMMENDED ACTION
(a) Low flow going through SSF, with hydrostatic valve low	High head loss - time for cleaning
(b) Low flow going through filters	Check overflow - if high, lower hydrostatic valves. Check filter inflow valves open 100 % Check flow going through WTP (meter). If low, open up settling tank inflow to allow more flow through WTP.
(c) High overflow from filter tanks	Lower hydrostatic valves (ensuring loading to filters is okay). Check WTP flow, control plant inflow if necessary.
(d) High flow from 1 - 2 slow sand filters only	Check Inflow valves (to be 100 % open). Adjust hydrostatic (outflow) valves (upwards) for the high flow filters. Adjust other hydrostatic valves (down) if necessary to ensure even flow between all filters.
(e) Turbid effluent	Check inflow quality. Should achieve about 70 % reduction in turbidity. If not achieving this, check bio-layer intact. If problem restrict flow until filter develops full bio-layer - may need to test and compare all filters). May be time for cleaning - may be blockage in underdrains - restricting flow over most of SSF area and channeling flow through one small section
(f) Bio-layer unhealthy (black - odours)	Ensure Dissolved Oxygen (DO) entering the tanks is > 6 mg/L
(g) A lot of algae / scum on surface	Scoop / clean. Slightly increase overflow. If very bad could clean one filter at a time - increase individual filter flow through inflow valve (while restricting flow to others) to release to overflow

4.8. TREATED WATER

PROBLEM	RECOMMENDED ACTION
(a) Poor water quality (failure to meet Water Quality Guidelines - Turbidity, solids, *Coliforms*	Check raw water quality Check loading rates of all units - provide even distribution (optimise loading to all tanks) Check bio-layer in SSF's May need to reduce flow to WTP *Introduce disinfection of treated water.*
(b) Low water - insufficient to meet demand	Adjust inflow valves to settling tanks to allow more water into WTP. Check for overflows in units - adjust as required. Check hydrostatic valves set correctly with only 2 mm overflow in slow sand filters - adjust as required.

5. MONITORING AND REPORTING

5.1. GENERAL

The objective of the water treatment plants at Alaoa, Fulu'asou and Malololelei, is to remove contaminants in order to provide a safe water supply to the population they serve, ie urban Apia. Testing of the treated water is compulsory in order to provide records of achievement of water quality. However, if quality drops off, we should want to know why. So monitoring of the different units is necessary to understand the system and where a problem might lie.

Monitoring of the treatment plants is important in providing an understanding of the performance of the system. In order to be able to optimise the WTP's, we want to understand the individual processes that make up the WTP. And to do that we need to monitor and test the inflows and outflows of the individual process units. Monitoring systems (through arranging lab testing and graphing the results) are used to indicate trends of the plant, ie., how it performs over time. The type of things to look for include :

- whether there is a deterioration in water quality,
- what is the water quality of the raw water,
- performance of the unit processes (individual tanks)
- whether the systems are being maintained / cleaned frequently enough.

In this section, the following are considered:

- ➢ the frequency of monitoring,
- ➢ parameters to test and location
- ➢ reporting of results and how they will be used.

5.2. PARAMETERS TO TEST

Operational testing should be carried out routinely to test performance of units. The basic purpose of the units is to remove solids. Consequently, suspended solids (SS) and turbidity should be done as a basic routine. An advantage of these tests are that they are fast and they will provide a rapid answer of performance. In addition to removal of solids, the slow sand filters also remove microbial contaminants. So the outflow should be tested for these.

TURBIDITY - is a measure of the clarity of water. It is aesthetically important for drinking water to be clear. It is measured by a Turbidimeter, which consists of a nephelometer with a light source for illuminating the sample, plus a photo-electric detector. The measurement basically shows the reduction in light intensity. It is important for glass ware to be clean and that there be no lumps of sediment. Turbidity should be measured soon after sampling as colour may change over time. (Similarly pH should also be measured very soon after sampling).

SS - is a measure of particulate solids. The sample is passed through a filter paper (pre-weighed), which is then dried paper and weighed again. The mass is divided by the volume of sample put through the paper --> mg/L SS. When analysing for SS (and any parameter) it is important to shake the bottle to re-suspend any solids - again to achieve a representative sample.

Total Coliforms - test involves applying small sample of water to a cultured plate, incubating and counting numbers. As stated in Section 1 these are used as an indicator of potential presence of pathogens. Based on the Water Quality Guidelines, 0 is the appropriate standard for potable water. However, results for the 3 WTP's show that there are occasions that Total Coliforms are present in the treated water. It is also considered important to monitor reduction of these over the WTP. To accurately measure Coliforms, the sample should be refrigerated to slow any additional growth on the way to the laboratory.

The above is considered to be the basic routine testing required, other basic parameters which are typically used to characterise water (and covered in the Standards) should also be included - pH, Suspended Solids (SS), Total dissolved solids (TDS), Faecal Coliforms and iron.

It is considered appropriate to record percentage % removal over the :

- settling tanks,
- roughing filters
- slow sand filters,

and this should be done for both SS and turbidity.

5.3. *SAMPLING POINTS*

5.3.1. Intake - raw water

It is important to sample raw water to gain idea of performance of the plant as a whole as well as individual units. At Fulu'asou and Malololelei the intake is remote from the WTP. Consequently sampling from inlet to settling tanks is okay - except for access to the middle of the central well. It is understood that a sample point valve is being arranged for installation at the treatment plants. When sampling, the operative must open the valve for several seconds before taking a sample to ensure a fresh sample is obtained (without debris, which might be stuck in the valve).

5.3.2. Settling tanks

The purpose of these tanks is to remove the heavy settleable solids from the source water from turbid sources to lessen the load on downstream treatment processes. Therefore we should monitor for SS and turbidity, since this is it's function. Depending on the type of solids / sediment present in the water, 40 - 60 % solids removal might be achieved. However, distributing flow evenly, loading at or below design loading, the operator will be able to build up a picture of the actual performance for the given characteristics.

5.3.3. Roughing filters

Again, this unit's main purpose is to act as a pre-treatment for SSF's - removing larger particles from water stream. Therefore we should similarly test for SS and turbidity. Depending on the type of particles present in the water, removal rates may be 70 - 90 % over the roughing filter. However, quality of water is good in Samoa, - turbidity removal may not be as high as this - again through sampling regularly a picture may be build up - the operator will come to know his plant's capability.

5.3.4. Slow sand filters

Main mechanism of the slow sand filters is entrapment in bio-layer - we would expect good turbidity removal and micro-organisms. The presence of dissolved oxygen (DO) is critical for stimulating the health of the bio layer.

Slow sand filters also removes iron via precipitation on the sand surface.
Determination of Turbidity and total coliforms removal over the SSF's is very useful.

5.3.5. Disinfection

When this is introduced, Total Coliforms should be measured (to determine effectiveness), but a more regular check would be to measure residual chlorine. This may then be used as an indication of disinfection effectiveness.

5.4. FREQUENCY OF TESTING AT WTP's

The following monitoring frequency is proposed based on providing some statistical validation of results and appropriate frequency to determine performance of the WTP.

Parameter	Raw Water	Settling Tank Effluent	Roughing filter Effluent	Treated water (slow sand filter effluent)
Turbidity	2w	2w	2w	2w
SS	2w	2w	2w	2w
pH	2w	2w	2w	2w
DO	2w		1 - 2 w	
TDS	2w	2w	2w	2w
Inorganic characteristics (iron)	m			m
Microbiological characteristics	w			2w

Notes : *w = weekly; 2w = twice weekly; m = monthly*

This proposed regime is certainly considered appropriate for the larger plants of Alaoa and Fulu'asou. However, given the small size of Malololelei, the sampling may be halved to that outlined above.

If anything looks unusual - the operator should sample and arrange testing. To handle the proposed additional sampling, may necessitate sampling and delivery by Headworks personnel, but this should be worked out between the two groups, with clear procedures identified.

The following Sections discuss how operational personnel might use the results to build up a picture of performance for the plant.

5.5. *MONITORING PERFORMANCE*

5.5.1. Individual units

First we will consider the monitoring of the individual units. Results for Alaoa WTP as tested in May 1999 for turbidity are presented below. Averages over the tanks are shown.

Sample Location	Turbidity (NTU)	% Removal
Raw Water	18.4	-
Settling tank outflow	20.6	0 %
Roughing Filter outflow	11.6	43 %
Slow Sand Filter outflow	0.5	96 %
Overall	-	97.3 %

Fulu'asou WTP was tested in October 1999 for turbidity. The samples were composited between the tanks. The results were as follows:

Sample Location	Turbidity (NTU)	% Removal
Raw Water	Not measured	-
Settling tank outflow	0.52	estimate 10 - 20 %
Roughing Filter outflow	0.47	10 %
Slow Sand Filter outflow	0.16	66 %
Overall	-	75 %

As can be seen from the two sets of results, the slow sand filters achieve the bulk of the removal performance. This is also true for other parameters, including iron and bacteria (settling tanks and roughing filters would not be expected to remove any significant proportion of pathogens). Total dissolved solids would not be expected to change from the raw water (since the existing units rely on particle capture).

5.5.2. Overall plant

The following table summarises the overall results based on raw and final treated water sampling.

Parameter	ALAOA WTP treated water	% reduction	FULU'ASOU WTP treated water	% reduction	MALOLOLELEI WTP treated water	% reduction
Turbidity, NTU	0.8	74 %	0.6	65 %	1.1	49 %
Iron, mg/L	0.1	47 %	0.1	36 %	0.1	31 %
Total Coliforms, no. / 100 mL	5	99.8 %	26	98.7 %	51	99.1 %

Results and statistical assessment of removal capability from the year 1998 – 1999 is contained in Appendix E. While it can be seen that the % reduction for all plants is good, the important parameter of 0 Total Coliforms has not been met. So while % reduction is a very good performance indicator for the plant, the final level is probably more of an issue for the overall treated water.

5.6. RECORDING AND REPORTING

As discussed above, appropriate working relationships need to be established between the laboratory staff and Headwork's group.

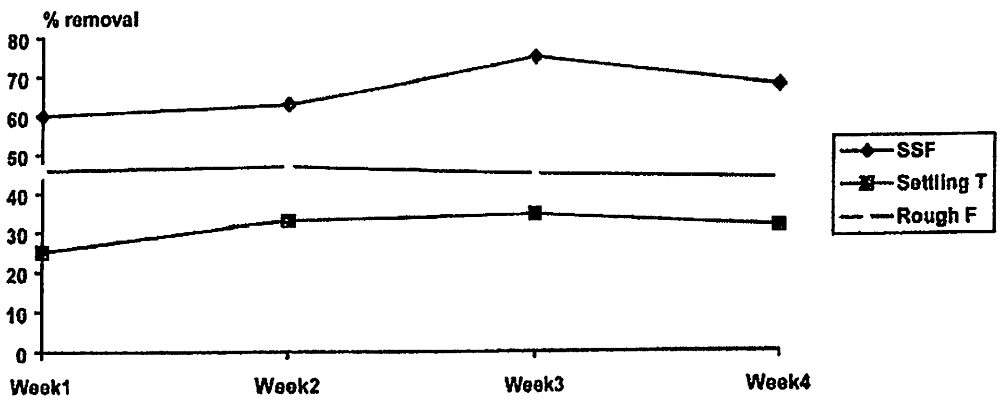
Two kinds of report need to be provided to Headworks management. The first is the results from the laboratory testing (from Environmental Services Group), as outlined above. In addition to these the plant operators should fill a weekly plant operational log sheets out daily and copies handed to Headworks Supervisor of SWA upon completion of the full report.

Operator Log sheets are contained in Appendix F.

Operator Reporting should entail :

- WTP flow - instantaneous and total day
- notes / records of cleaning / of intake screen and adjusting valves (for operational procedure)
- length of time sludge withdrawal takes
- records of which filters were cleaned during the week

As discussed above, routine operational testing should involve sampling raw water, settling tank outflow, roughing filter outflow and final treated water then testing for turbidity and suspended solids. Percentage removal should then be calculated and graphed against time and also against unit loading. For example the graph might look something like the following:



The graphing / reporting should also be done for loading rate versus % removal.

The first thing which needs to be considered is the flow: Reading might be 137 L/s. To convert his to m^3/hour, is as follows. There 3600 s / hour. There are 1000 L / m^3. So ....

$$m^3/\text{hour} = \frac{137\ \text{L}}{\text{s}} \times \frac{3600\ \text{s}}{\text{hour}} \times \frac{1000\ \text{L}}{m^3} = 494$$

The calculation of the loading rate is as follows:

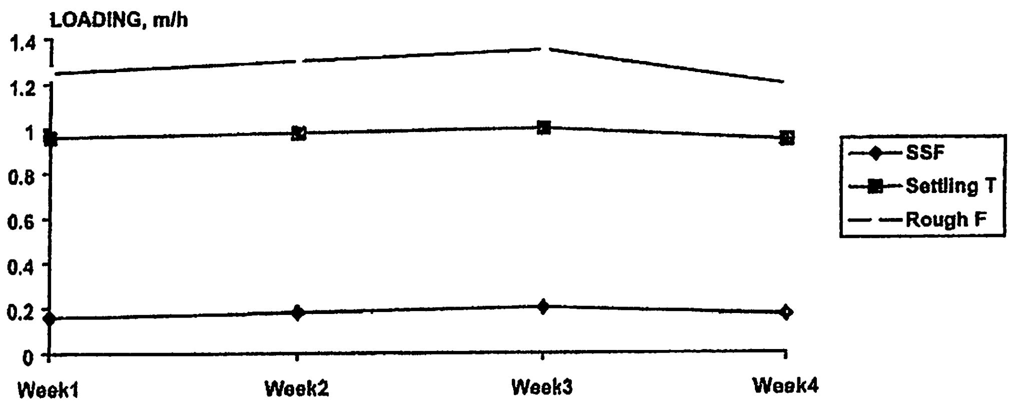
LOADING RATE = Flow / (surface area of tanks)

eg, 2 settling tanks, each 249 m^2 surface area; total surface area = 498 m^2
LOADING RATE on settling tanks = 494 m^3/hour / (498 m^2)
= 0.99 m^3 /m^2. hour

4 roughing filters, each 98.5 m^2 surface area; total surface area = 394 m^2
LOADING RATE (or velocity) through RF's = 494 m^3/hour / (394 m^2)
= 1.25 m^3 /m^2. hour

5 sand filters, each 616 m^2 surface area; total surface area = 3080 m^2
LOADING RATE on SSF's = 494 m^3/hour / (3080 m^2)
= 0.16 m^3 /m^2. hour

This should be calculated on a weekly basis to allow a picture to be built up for each unit at the WTP's. Example might look something like the following graph :



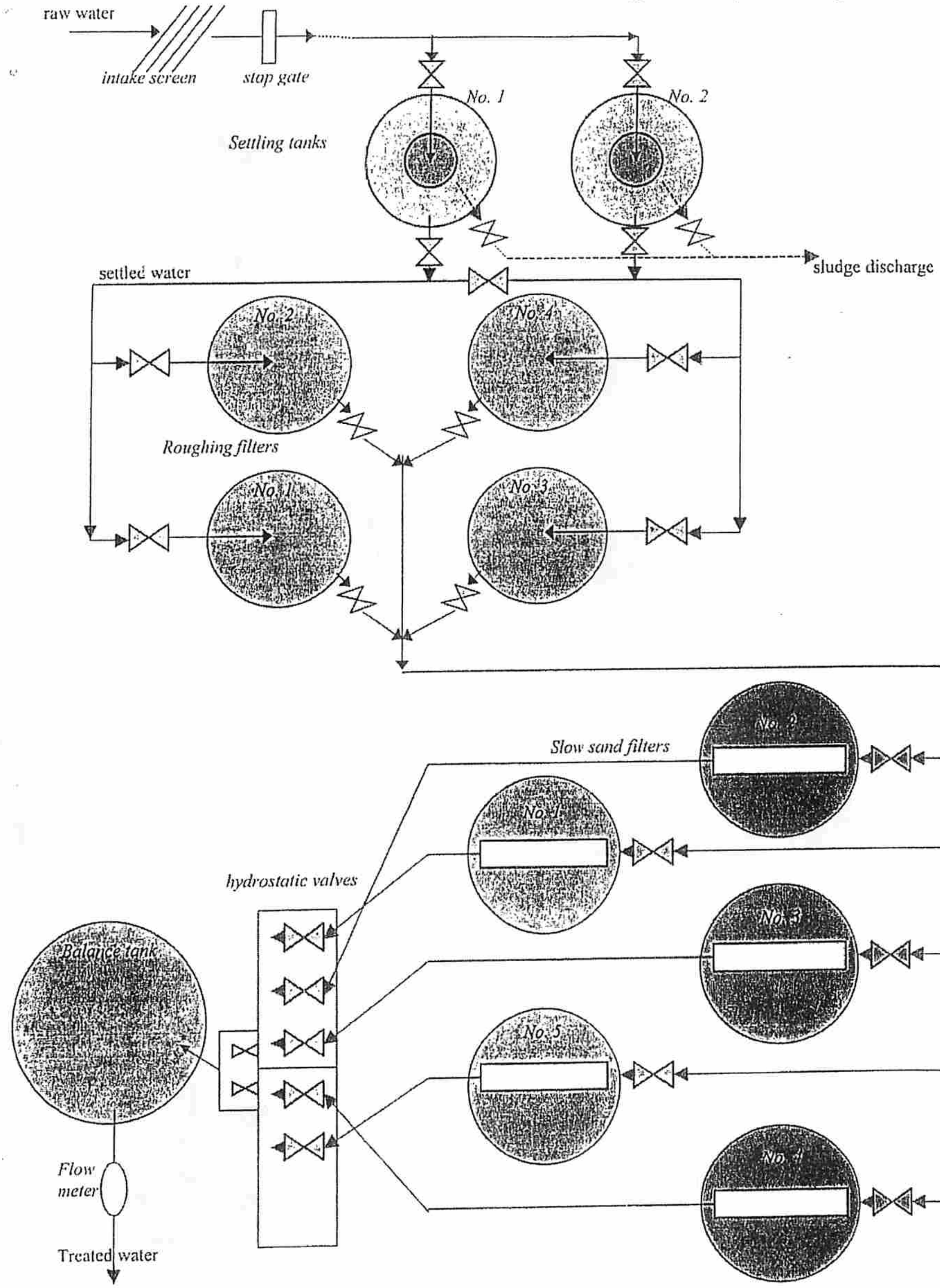
The graphs might then be combined showing % removal and loading rates for individual units. As the weeks continue, the operator might review the performance and should be able to recognise whether there is any deterioration over time or at certain loadings. Some checking should then be undertaken to determine the cause (high influent load or other). Total Coliform removal / levels should also be graphed to determine trends in terms of reduction and in relation to raw water concentrations.

The records should be accessible to all Headworks personnel to allow review.

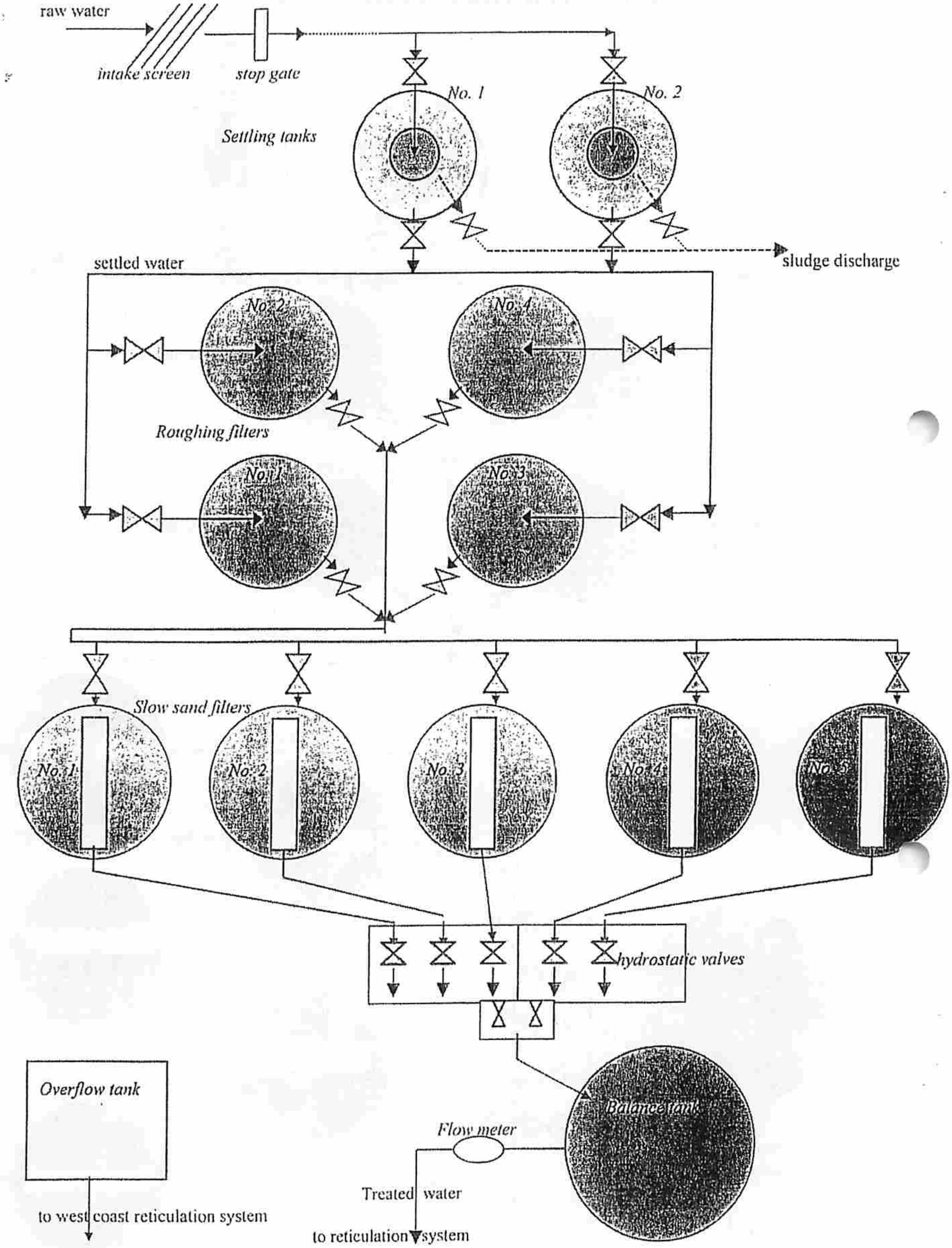
APPENDIX A

Water Treatment Plant PROCESS DIAGRAMS

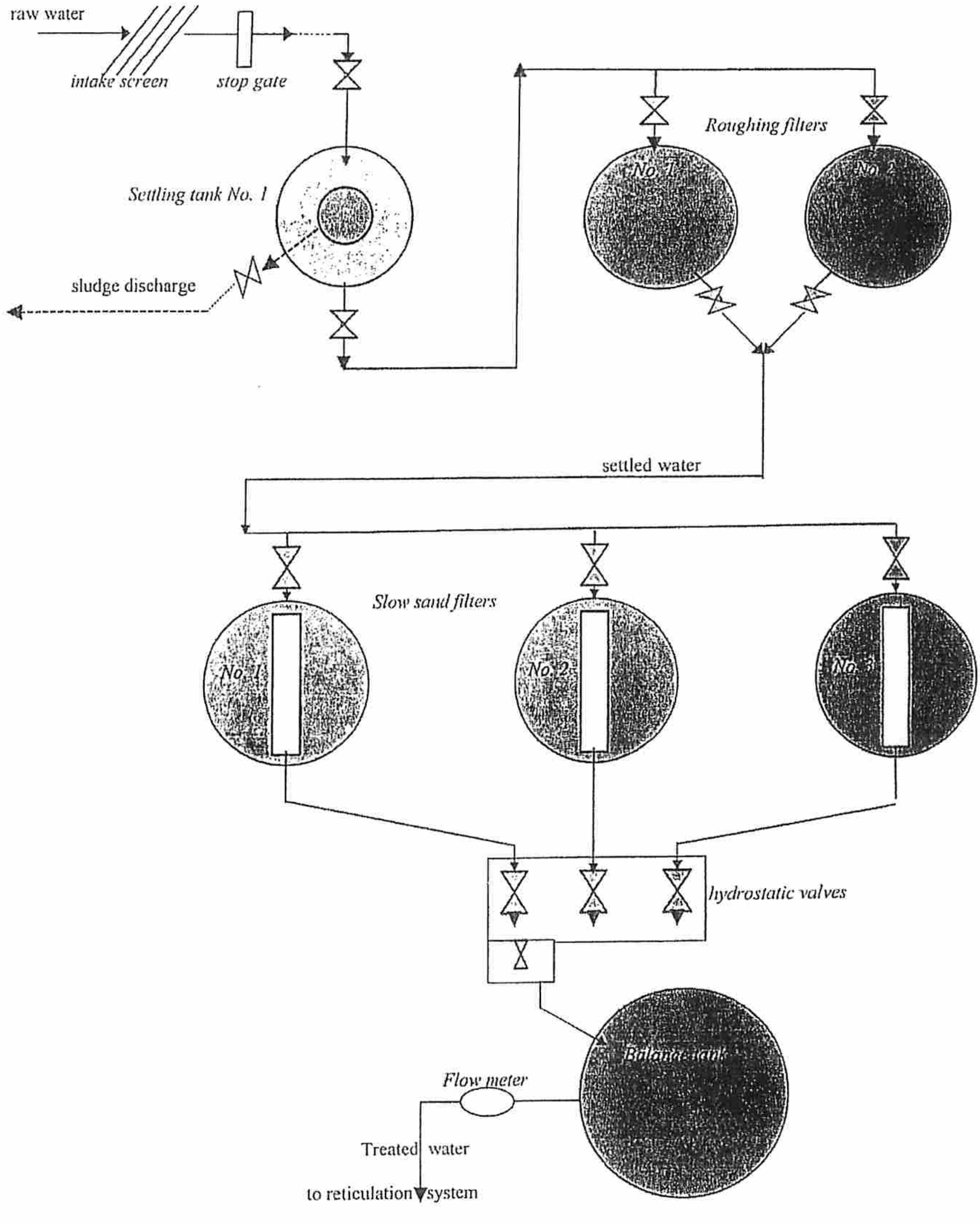
ALAOA WATER TREATMENT PLANT - Figure 1a - processing



FULU'ASOU WATER TREATMENT PLANT - Figure 2a - processing



MALOLOLELEI WATER TREATMENT PLANT - Figure 3a - processing



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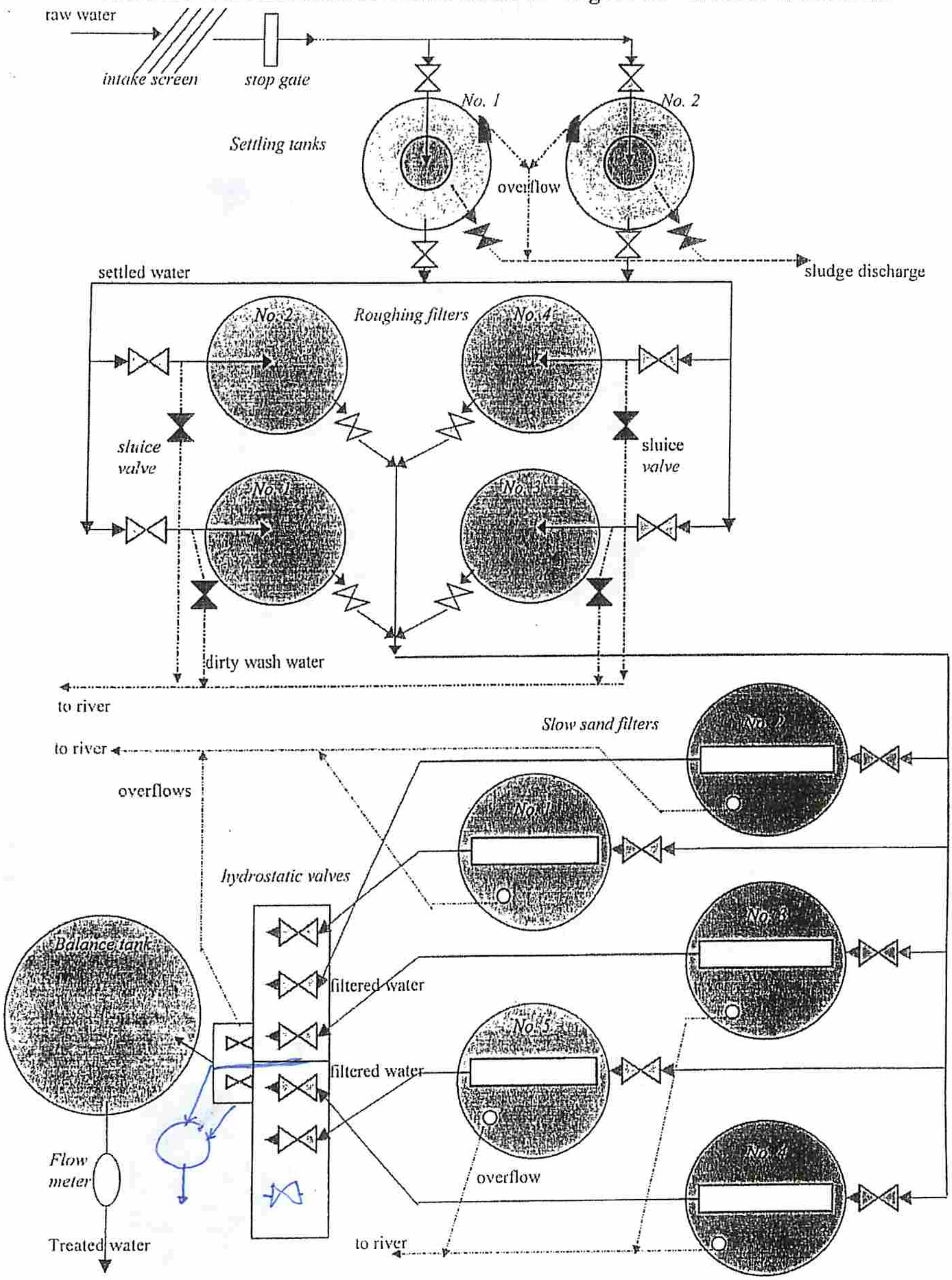
APPENDIX B

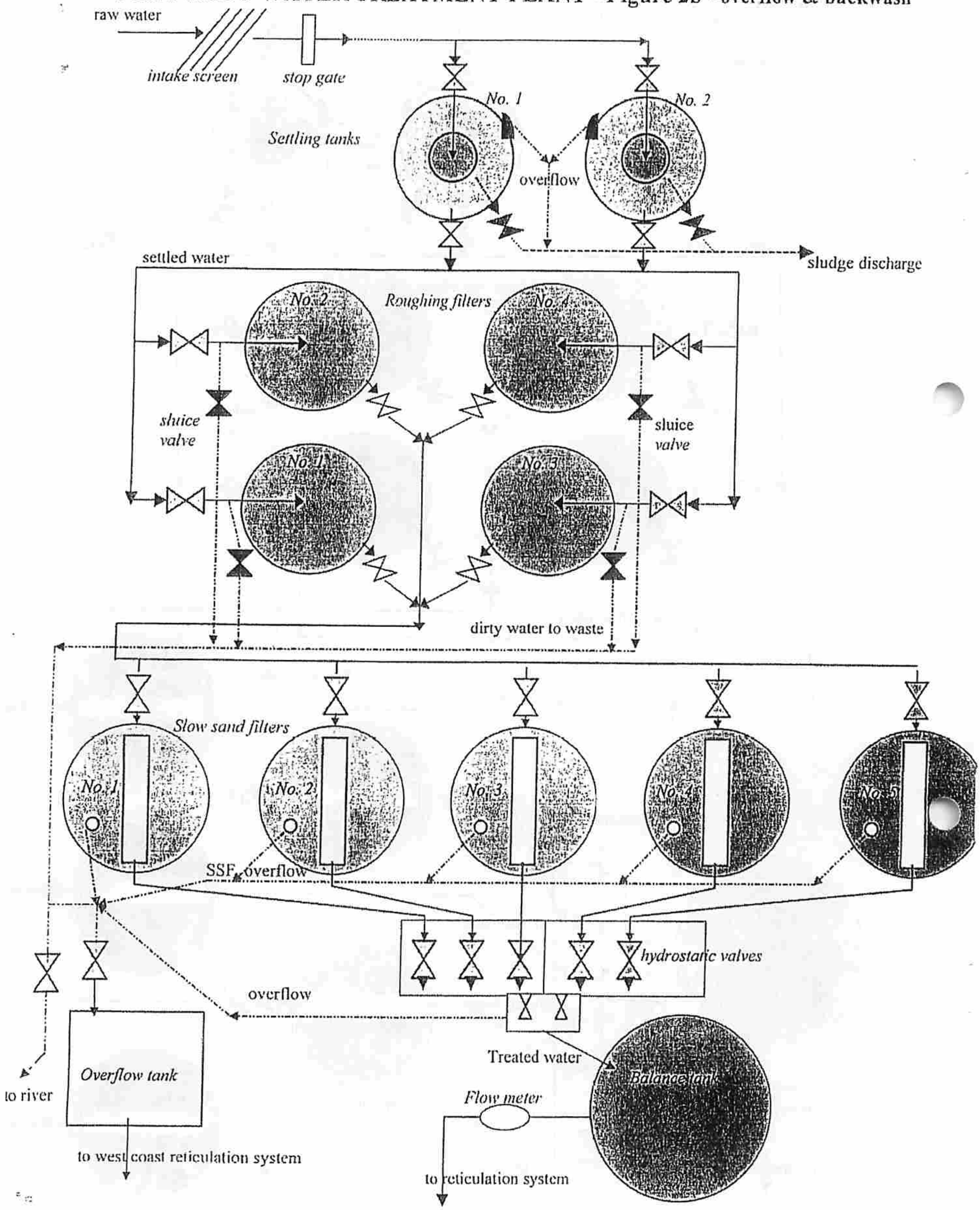
Water Treatment Plant - DIAGRAMS FOR OVERFLOWS AND CLEANING CYCLES

6

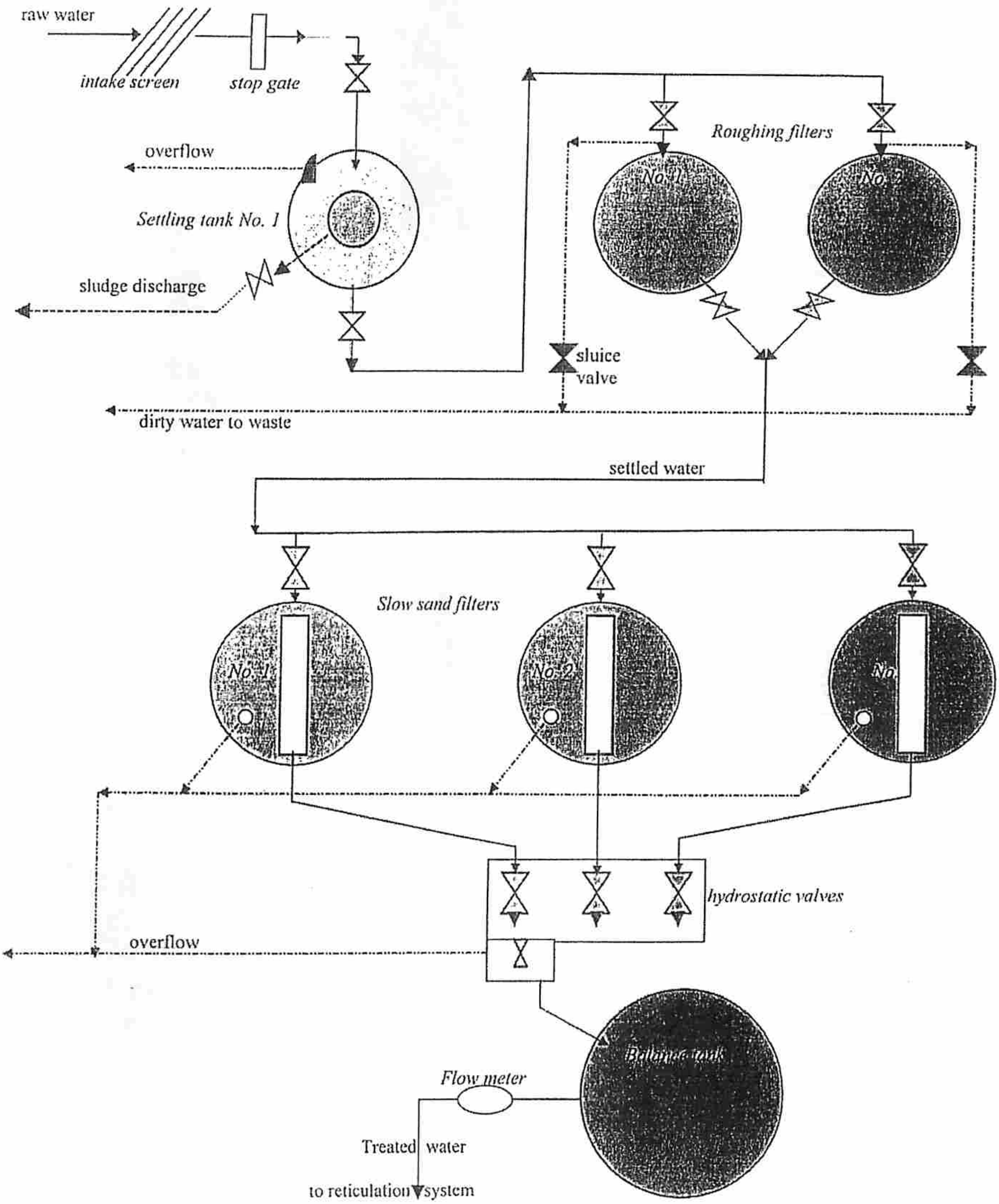
ALAOA WATER TREATMENT PLANT - Figure 1b - overflow & backwash



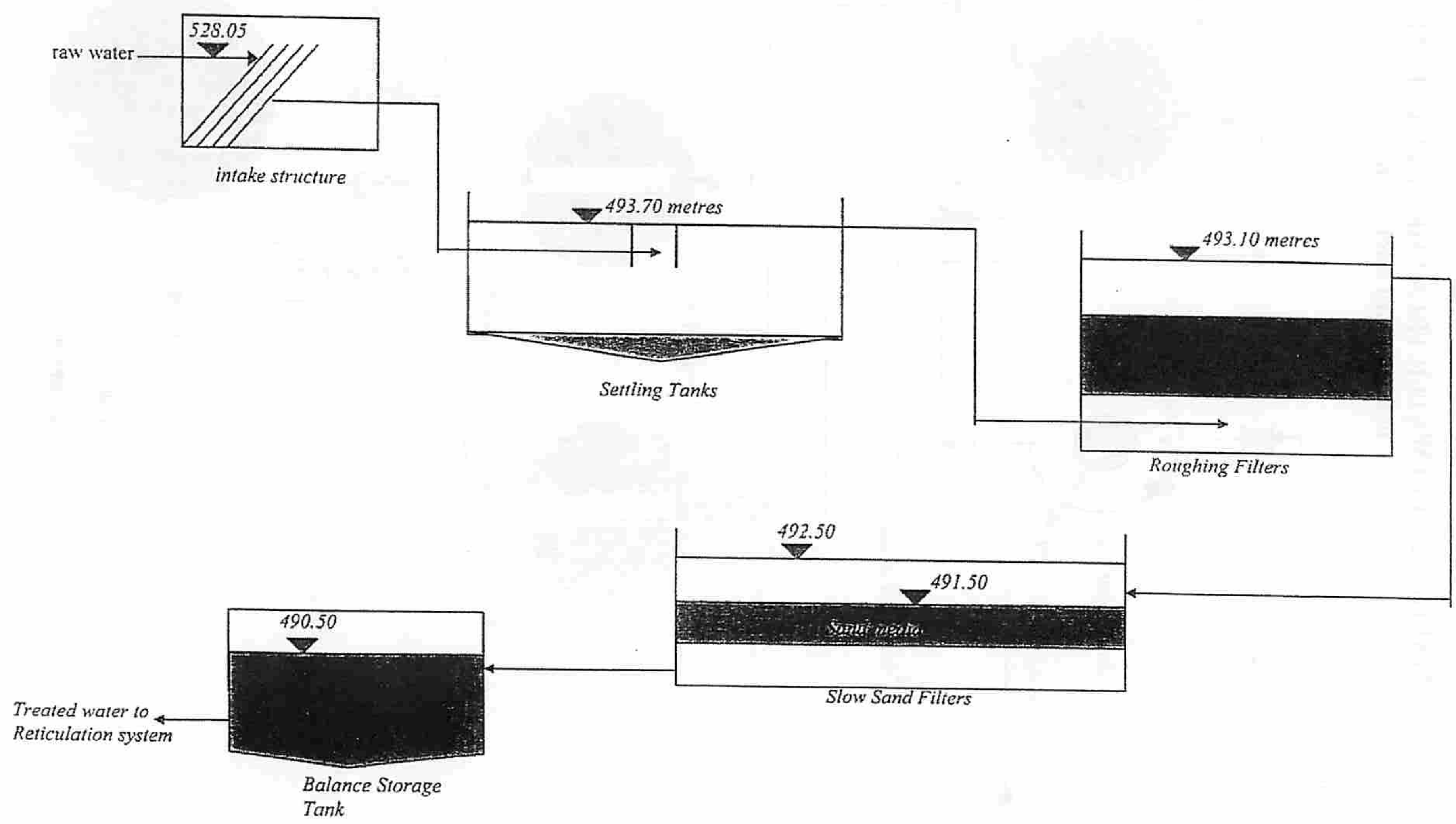
FULU'ASOU WATER TREATMENT PLANT - Figure 2b - overflow & backwash



MALOLOLOLEI WATER TREATMENT PLANT - Figure 3b - overflow and backwash



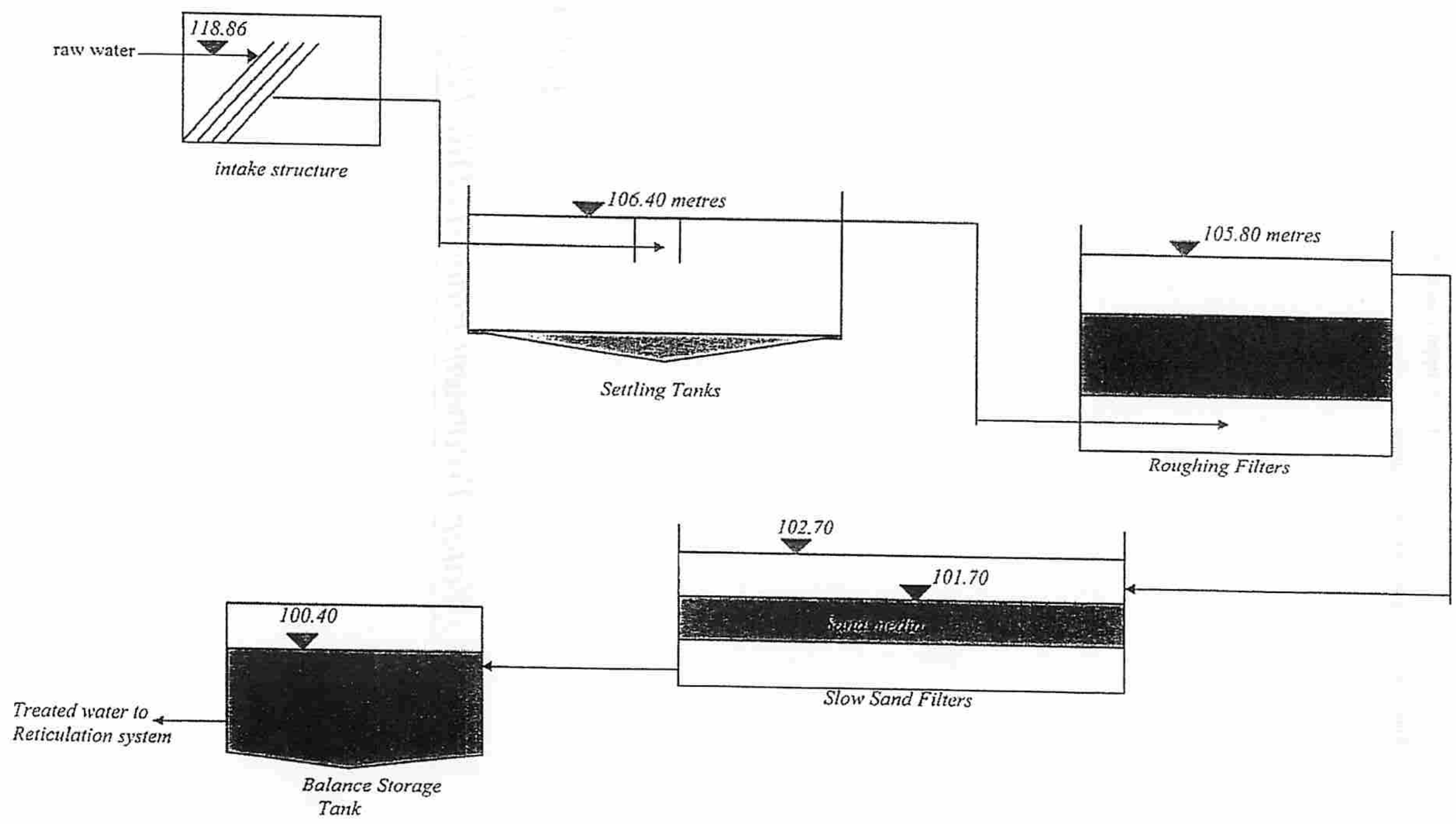
MALOLOLELEI WATER TREATMENT PLANT - Figure 3.6 - HYDRAULIC PROFILE



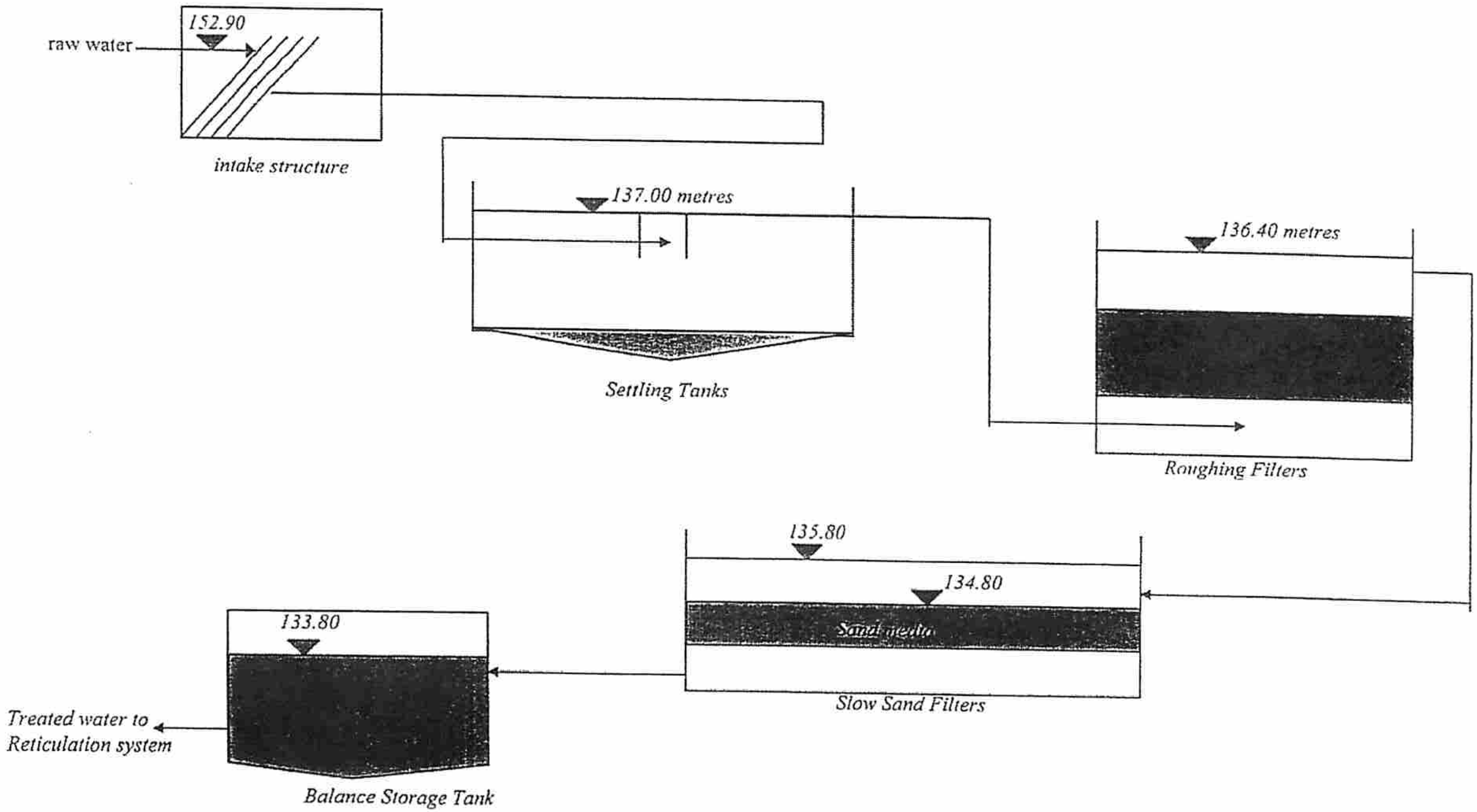
APPENDIX C

Water Treatment Plant HYDRAULIC PROFILES

ALAOA WATER TREATMENT PLANT - Figure 3.4 - HYDRAULIC PROFILE



FULU'ASOU WATER TREATMENT PLANT - Figure 3.5 - HYDRAULIC PROFILE



APPENDIX D

WATER TREATMENT PLANT DESIGN CRITERIA SHEETS

ALAOA / VAISIGANO WTP

FLOWS AND LOADING

Design Flow Ml./day	9.125		Actual Average Ml./day	12.096
m^3/hour	380		m^3/hour	504
L/s	105.6		L/s	140
			% increase over design	33

TREATMENT SYSTEM

Raw Water Intake Bar screen

No. of units			1
Width	m	approx	1.25
Bar Aperture	mm		25

Settling Tank

No. of tanks		2
Diameter	m	17.8
Surface Area	m^2	248.8
Side Water Depth	m	2.5
Tank volume	m^3	622.1139
Overflow Rate @ Design Flow	m^3/m^2.hour	0.76
Overflow Rate @ Actual Average Flow	m^3/m^2.hour	1.01
Detention time @ Design Flow	hours	3.3
Detention time @ Actual Average Flow	hours	2.5
Outlet Weir length (per tank)	m	53.7

ROUGHING FILTERS *(Gravel media)*

No. of tanks		4
Diameter	m	11.2
Surface Area	m^2	98.5
Media Depth	m	2
Media volume	m^3	197.0407
Surface Loading Rate @ Design Flow	m^3/m^2.hour	0.96
SLR / design flow / 1 filter off-line	*m^3/m^2.hour*	*1.29*
Surface Loading Rate @ Act. Avg Flow	m^3/m^2.hour	1.28
SLR / actual average flow / 1 filter off-line	*m^3/m^2.hour*	*1.71*
Detention time @ Design Flow	hours	2.1
Detention time @ Actual Average Flow	hours	1.6
Backwash	Once every 2 weeks	

Gravel	
size (mm)	depth (mm)
4 - 7	750
7 - 10	500
12 - 18	1000
20 - 25	250

SLOW SAND FILTERS *(Sand mono-media)*

No. of tanks		5
Diameter	m	28
Surface Area	m^2	616
Media Depth	m	1
Media volume	m^3	616
Surface Loading Rate @ Design Flow	m^3/m^2.hour	0.123
SLR / design flow / 1 filter off-line	*m^3/m^2.hour*	*0.154*
Surface Loading Rate @ Act. Avg Flow	m^3/m^2.hour	0.164
SLR / actual average flow / 1 filter off-line	*m^3/m^2.hour*	*0.205*
Detention time @ Design Flow	hours	8.1
Detention time @ Actual Average Flow	hours	6.1
Cleaning	Once every 3 months	

	size (mm)	depth (mm)
Sand media	0.15 - 0.60	1000
Supporting Gravel	2 - 4	100
	4 - 10	100
	10 -25	100

BALANCE TANK

No. of tanks		1
Diameter	m	17.8
Side Water Depth	m	1.8
Active volume	m^3	447.9
Retention time @ Design Flow	hours	1.2
Retention time @ Actual Average Flow	hours	0.9

$$V = \frac{\pi r^2}{4} \times H = \frac{\pi \times \left(\frac{17.8}{2}\right)^2}{4} \times 1.8m = 447.9 m^3$$

FULU'ASOU WTP

FLOWS AND LOADING

Average flow	ML/day	5.915	Actual Average ML/day	9.072
	m^3/hour	246	m^3/hour	378
	L/s	68.5	L/s	105
			% increase over design	·53

TREATMENT SYSTEM

Raw Water Intake Bar screen (approx. 2 km from plant)

No. of units			1
Width	m	approx	1.5
Bar Aperture	mm		100

Raw Water Mesh screen at intake

No. of units			1
Width	m	approx	3
Mesh Aperture	mm		12

Settling Tank

No. of tanks			2
Diameter	m	approx.	14.7
Surface Area	m^2		169.7
Side Water Depth	m		2.5
Tank volume	m^3		424.2917
Overflow Rate @ Design Flow	m^3/m^2.hour		0.73
Overflow Rate @ Actual Average Flow	m^3/m^2.hour		1.11
Detention time @ Design Flow	hours		3.4
Detention time @ Actual Average Flow	hours		2.2
Outlet Weir length (per tank)	m		44.0

ROUGHING FILTERS *(Gravel media)*

No. of tanks			4
Diameter	m	approx.	9
Surface Area	m^2		63.6
Media Depth	m		2
Media volume	m^3		127.2345
Surface Loading Rate @ Design Flow	m^3/m^2.hour		0.97
SLR / design flow / 1 filter off-line	*m^3/m^2.hour*		*1.29*
Surface Loading Rate @ Act. Avg Flow	m^3/m^2.hour		1.49
SLR / actual average flow / 1 filter off-line	*m^3/m^2.hour*		*1.98*
Detention time @ Design Flow	hours		2.1
Detention time @ Actual Average Flow	hours		1.3
Backwash	Once every 2 weeks		

Gravel	
size (mm)	depth (mm)
4 - 7	750
7 - 10	500
12 - 18	1000
20 - 25	250

SLOW SAND FILTERS *(Sand mono-media)*

No. of tanks			5
Diameter	m	approx.	22.5
Surface Area	m^2		397.6
Media Depth	m		1
Media volume	m^3		397.6078
Surface Loading Rate @ Design Flow	m^3/m^2.hour		0.124
SLR / design flow / 1 filter off-line	*m^3/m^2.hour*		*0.155*
Surface Loading Rate @ Act. Avg Flow	m^3/m^2.hour		0.190
SLR / actual average flow / 1 filter off-line	*m^3/m^2.hour*		*0.238*
Detention time @ Design Flow	hours		8.1
Detention time @ Actual Average Flow	hours		5.3
Washing	Once every 3 months		

[redacted]	size (mm)	depth (mm)
Sand media	0.15 - 0.60	1000
Supporting Gravel	2 - 4	100
	4 - 10	100
	10 -25	100

BALANCE TANK

No. of tanks			1
Diameter	m	approx.	14.5
Side Water Depth	m		1.8
Active volume	m^3		297.2
Retention time @ Design Flow	hours		1.2
Retention time @ Actual Average Flow	hours		0.8

MALOLOLELEI WTP

FLOWS AND LOADING

Design flow ML/day	1.86		Actual Average ML/day	2.8512
m^3/hour	78		m^3/hour	119
L/s	21.5		L/s	33
			% increase over design	53

TREATMENT SYSTEM

Settling Tank

No. of tanks			1
Diameter	m	approx.	11.6
Surface Area	m^2		105.7
Side Water Depth	m		2.5
Tank volume	m^3		264.2079
Overflow Rate @ Design Flow	m^3/m^2.hour		0.73
Overflow Rate @ Actual Average Flow	m^3/m^2.hour		1.12
Detention time @ Design Flow	hours		3.4
Detention time @ Actual Average Flow	hours		2.2
Outlet Weir length (per tank)	m		34.2

ROUGHING FILTERS *(Gravel media)*

No. of tanks			2
Diameter	m	approx.	7.2
Surface Area	m^2		40.7
Media Depth	m		2
Media volume	m^3		81.43008
Surface Loading Rate @ Design Flow	m^3/m^2.hour		0.95
SLR / design flow / 1 filter off-line	*m^3/m^2.hour*		*1.90*
Surface Loading Rate @ Act. Avg Flow	m^3/m^2.hour		1.46
SLR / actual average flow / 1 filter off-line	*m^3/m^2 hour*		*2.92*
Detention time @ Design Flow	hours		2.1
Detention time @ Actual Average Flow	hours		1.4
Backwash	Once every 2 weeks		

Gravel	
size (mm)	depth (mm)
4 - 7	750
7 - 10	500
12 - 18	1000
20 - 25	250

SLOW SAND FILTERS *(Sand mono-media)*

No. of tanks			3
Diameter	m	approx.	17.4
Surface Area	m^2		237.8
Media Depth	m		1
Media volume	m^3		237.7871
Surface Loading Rate @ Design Flow	m^3/m^2.hour		0.109
SLR / design flow / 1 filter off-line	*m^3/m^2.hour*		*0.163*
Surface Loading Rate @ Act. Avg Flow	m^3/m^2.hour		0.167
SLR / actual average flow / 1 filter off-line	*m^3/m^2.hour*		*0.250*
Detention time @ Design Flow	hours		9.2
Detention time @ Actual Average Flow	hours		6.0
Washing	Once every 3 months		

	size (mm)	depth (mm)
Sand media	0.15 - 0.60	1000
Supporting Gravel	2 - 4	100
	4 - 10	100
	10 -25	100

BALANCE TANK

No. of tanks			1
Diameter	m	approx.	8
Side Water Depth	m		1.8
Active volume	m^3		90.5
Retention time @ Design Flow	hours		1.2
Retention time @ Actual Average Flow	hours		0.8

APPENDIX E

WTP ANALYTICAL TEST RESULTS FOR 1998 - 99

APPENDIX F

WTP OPERATOR REPORTING SHEETS

SAMOA WATER AUTHORITY SWA

APIA WATER SUPPLY CONSOLIDATION PROJECT

DORSCH CONSULT Ingenieurgesellschaft mbH

ALAOA WTP - OPERATOR LOG SHEET

GENERAL DATA				ANALYSIS / TESTING											DAILY OPERATIONAL PROCEDURES													
WEEK ENDING	WTP Flow	WTP Total Flow	Rainfall	Raw Water Intake		Settled tank Effluent		Settled Sludge	Roughing Filter Effluent		SSF Inflow	Slow Sand Filter Effluent		Raw Water Screen	Settling tank Inlet Valves - adjusted		Settling tank - sludge cleaned / minutes		Roughing filter Inlet Valves - adjusted / check for even flow				Slow Sand Filter Hydrostatic Valves - adjusted / check for even flow				
....../....../......	L/s	m³ / day	mm	Turbidity NTU	SS mg/L	Turbidity NTU	SS mg/L	SS mg/L	Turbidity NTU	Total Coliforms	DO mg/L	Turbidity NTU	Total Coliforms	Cleaned	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2	No. 3	No. 4	No. 1	No. 2	No. 3	No. 4	No. 5
Monday AM				cleaning OO cm																							
PM																											
Tuesday AM																											
PM																											
Wednesday AM																											
PM																											
Thursday AM																											
PM																											
Friday AM																											
PM																											
Saturday AM																											
PM																											
Sunday AM																											
PM																											
WEEKLY TOTAL																											
WEEKLY AVERAGE																											

FILTER CLEANING

FILTER TYPE	☐ Roughing Filter ☐ Slow Sand Filter	FILTER Number	
PROCEDURE			
Date undertaken		Period of time filter off-line	

REMARKS (details of any problems, adjustments, tanks off-line, etc)

Operator: ....

SAMOA WATER AUTHORITY SWA

APIA WATER SUPPLY CONSOLIDATION PROJECT

DORSCH CONSULT Ingenieurgesellschaft mbH

FULU'ASOU WTP - OPERATOR LOG SHEET

GENERAL DATA / ANALYSIS / TESTING

WEEK ENDING	WTP Flow	WTP Total Flow	Rainfall	Raw Water Intake		Settled tank Effluent		Settled Sludge	Roughing Filter Effluent		SSF Inflow	Slow Sand Filter Effluent	
...../...../.....	L/s	m^3 / day	mm	Turbidity NTU	SS mg/L	Turbidity NTU	SS mg/L	SS mg/L	Turbidity NTU	Total Coliforms	DO mg/L	Turbidity NTU	Total Coliforms
Monday AM													
PM													
Tuesday AM													
PM													
Wednesday AM													
PM													
Thursday AM													
PM													
Friday AM													
PM													
Saturday AM													
PM													
Sunday AM													
PM													
WEEKLY TOTAL													
WEEKLY AVERAGE													

DAILY OPERATIONAL PROCEDURES

	Raw Water Screen	Settling tank Inlet Valves - adjusted		Settling tank - sludge cleaned / minutes		Roughing filter Inlet Valves - adjusted / check for even flow				Slow Sand Filter Hydrostatic Valves - adjusted / check for even flow				
	Cleaned	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2	No. 3	No. 4	No. 1	No. 2	No. 3	No. 4	No. 5
Monday AM														
PM														
Tuesday AM														
PM														
Wednesday AM														
PM														
Thursday AM														
PM														
Friday AM														
PM														
Saturday AM														
PM														
Sunday AM														
PM														

FILTER CLEANING

FILTER TYPE	☐ Roughing Filter ☐ Slow Sand Filter	FILTER Number	
PROCEDURE			
Date undertaken		Period of time filter off-line	

REMARKS (details of any problems, adjustments, tanks off-line, etc)

Operator

SAMOA WATER AUTHORITY SWA

APIA WATER SUPPLY CONSOLIDATION PROJECT

DORSCH CONSULT
Ingenieurgesellschaft mbH

MALOLOLELEI WTP - OPERATOR LOG SHEET

GENERAL DATA				ANALYSIS / TESTING										DAILY OPERATIONAL PROCEDURES								
WEEK ENDING	WTP Flow	WTP Total Flow	Rainfall	Raw Water Intake		Settled tank Effluent		Settled Sludge	Roughing Filter Effluent		SSF Inflow	Slow Sand Filter Effluent		Raw Water Screen	Settling Tank			Roughing filter Inlet Valves - adjusted / for even flow		Slow Sand Filter Hydrostatic Valves - adjusted for even flow		
...../...../.....	L/s	m³ / day	mm	Turbidity NTU	SS mg/L	Turbidity NTU	SS mg/L	SS mg/L	Turbidity NTU	Total Coliforms	DO mg/L	Turbidity NTU	Total Coliforms	Cleaned	Inlet flow adjusted	Sludge cleaned	No. of minutes	No. 1	No. 2	No. 1	No. 2	No. 3
Monday AM																						
PM																						
Tuesday AM																						
PM																						
Wednesday AM																						
PM																						
Thursday AM																						
PM																						
Friday AM																						
PM																						
Saturday AM																						
PM																						
Sunday AM																						
PM																						
WEEKLY TOTAL																						
WEEKLY AVERAGE																						

FILTER CLEANING

FILTER TYPE	☐ Roughing Filter ☐ Slow sand filter	FILTER Number	
PROCEDURE			
Date undertaken		Period of time filter off-line	

REMARKS (details of any problems, adjustments, tanks off-line, etc)

Operator