WATER RESEARCH COMMISSION PROJECT NO. 201

TREATMENT OF INORGANIC BRINES AND CONCENTRATES

APPENDIX 1

Explosive and Chemical Production by AECI at Modderfontein and Zomerveld

Summary of a Visit on 8 July 1987

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INTRODUCTION

The Pollution Research Group has been contacted by AECI to investigate pollution abatement, resource conservation and effluent treatment at the Modderfontein and Zomerveld factory sites.

This report describes a recent visit to the Zomerveld factory site (8/7/87). Observations and recommendations concerning this factory have been made. In addition knowledge acquired as a result of discussions concerning the Modderfontein factory have been summarised. Proposed action at both Zomerveld and Modderfontein has been listed.

1. VISIT TO AECI EXPLOSIVE FACTORY AT ZOMERVELD, OFS

1.1 General

The AECI explosive factory at Zomerveld produces an ammonium nitrate based mining explosive called 'Powergel' principally for the supply to the OFS gold mines.

The factory site consists of :

(i) an office block
(ii) two production houses (further expansion is envisaged)
(iii) a tank farm for raw chemical storage
(iv) a pumphouse and associated water storage facilities
(v) two lined dams for effluent buffering
(vi) site for liquid effluent disposal
(vii) burning site for solid waste disposal
(viii) magazines for product storage
(ix) explosive testing sites

The Zomerveld factory commenced production in the early part of 1987. At present, there are approximately 300 employees operating on a basis of three 8 hour shifts per day, 6 days per week.

Figure 1 shows a schematic of the factory site. The various production and water consuming processes, together with effluent arisings and existing treatment facilities are discussed below.

1.2 Raw Materials : Supply and Storage

1.2.1 Chemicals

The explosive base, ammonium nitrate is delivered to the site in tankers as an 88% solution (ANS). Approximately 30 000 kg of this solution is delivered daily and stored, initially, in one of two 100 ton tanks on the tank farm.

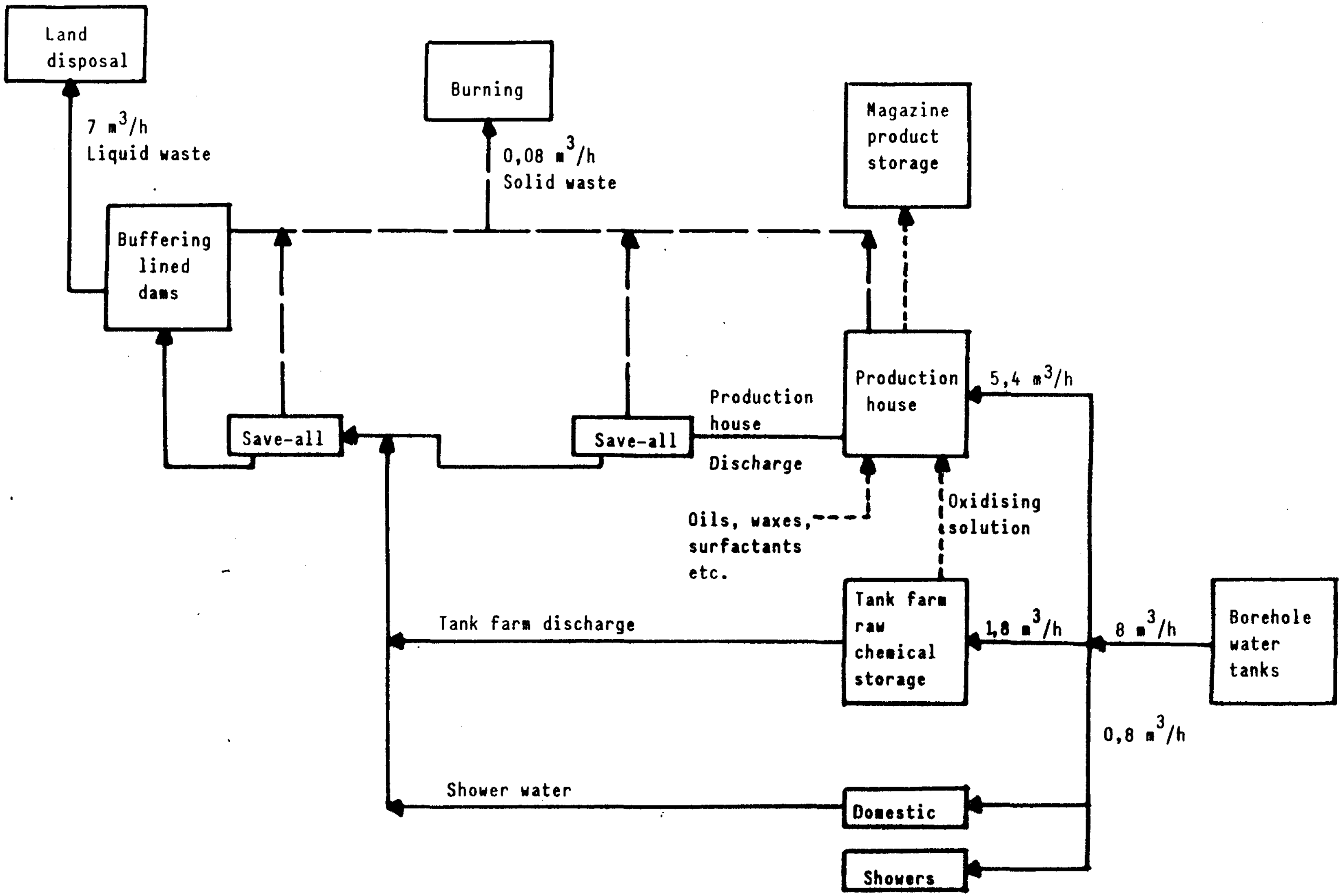

FIGURE 1 : Schematic of Zomerveld Plant

This stock solution is then mixed with sodium nitrate and water and stored in one of four 20 ton tanks on the tank farm. The fudge point of this so-called 'oxidising solution' must be carefully controlled to ensure that the final product is explosive.

1.2.2 Water

Water is not used directly in the production process but it is used mainly for cleaning and cooling. Minimal amounts are used for domestic purposes.

All water consumed at the site is pumped from a borehole into one of four 14 000 l storage tanks from where it is drawn directly as required. This water has a TDS level of 1 200 mg/l and some of it is demineralised before use in the boilers and other specialised applications.

The water consumption at the site has been estimated at 63 000 l per shift (approximately 8 m^3/h).

1.3 Process Description

The oxidising solution is pumped from the tank farm to the production houses as required.

In the production houses, sausage-shaped explosive cartridges are produced by the following route :-

(i) the oxidising solution is mixed with oil and wax and emulsified to produce a waxy white base.

(ii) an aluminium sensitiser is mixed in with this base.

(iii) the base is then gassed to create 'hot-spots'. A mixture of thiourea and sodium nitrate is used during gassing which liberates nitrogen gas.

(iv) the gassed product is then extruded into a sausage shape contained in a plastic cover, cut into lengths and clipped at each end.

(v) the cartridges then pass along a conveyer belt, and up through a cooling tower, where they are continuously sprayed with a detergent solution.

(vi) the cartridges leave the cooling tower, are sorted, packed and stored in magazines.

The machine which extrudes, cuts and clips the cartridges is lubricated with spindle oil and sprayed with cleaning water. Approximately 600 to 800 l of spindle oil is used on this machine each week.

Approximately 10% of the product is wasted ; either due to broken cartridges or due to spillages.

1.4 Water Usage and Effluent Arisings

Water is consumed :-

(i) for domestic uses eg showers, toilets, drinking.

(ii) at the tank farm :
- all spillages during transfers from tankers and tanks are washed away with water.
- water is used to flush all hoses and pipes conveying ANS and oxidising solution after contact to prevent solidification of the chemicals. The hoses used for pumping ANS and oxidising solution are flushed daily and the pipes conveying oxidising solution are flushed after each transfer to the production site (tank farm records indicated hourly transfers).

(iii) in the production houses :
- to wash the floor.
- to clean the extruding, cutting and clipping machine.
- to cool the cartridges.

The cooling water is recycled through the cooling tower and changed each shift. There is a small continuous overflow from the tower.

It has been estimated that of the 63 000 l of water consumed per shift, approximately 40 000 l is used in the production houses and approximately 15 000 l is used at the tank farm. The remainder is used domestically.

The various waste water streams can be characterised as follows :

(i) the streams arising at the tank farm. These are generally oil free, fairly concentrated solutions of ammonium nitrate, with or without sodium nitrate and any other process chemicals used.

(ii) the streams discharged from the production houses. At present, a single stream is discharged from each house which is a composite of all cleaning and cooling waters used in production. These streams are contaminated by :
- dissolved solids, mainly ammonium and sodium nitrate.
- suspended solids, mainly product waste.
- detergent from the cooling tower water.
- spindle oil from the extruding, cutting and clipping machine.

(iii) domestic water, an insignificant volume with minimum chemical contamination.

Tables 1, 2 and 3 give the average composition of the discharges from both production houses and the average composition of the contents of the lined dams over the 6 month production period. It will be noted that the concentration of the liquid in the dams is generally 4 to 8 times the concentration of the production house effluents. This illustrates the large effect of tank farm discharge onthe composition of the dam contents.

TABLE 1 : Average composition of effluent discharge from Production House No.1

DATE	NH_3-N	NO_3-N	TOTAL N	TDS	COND	PH
4/2/87	—	—	—	—	—	—
23/2/87	130	140	270	1580	2200	7.3
9-13/3/87	210	200	410	1930	3000	8.5
16-20/3/87	1400	1600	3000	8690	13500	7.8
23-27/3/87	90	110	200	1380	2100	8.5
30-3/4/87	110	110	220	1440	2200	8.4
7-10/4/87	170	220	390	1970	3000	8.1
13-16/4/87	130	180	310	1710	2600	7.2
27-30/4/87	160	220	380	1970	3000	7.9
4-8/5/87	610	700	1310	4600	7000	7.4
~~11-15/5/87~~	~~120~~	~~200~~	~~320~~	~~1770~~	~~2700~~	~~7.8~~
18-22/5/87	210	290	500	2350	3500	7.6
1-5/6/87	150	240	390	1840	2800	7.7
8-12/6/87	580	810	1390	4600	7000	7.6
15-19/6/87	180	220	400	2070	2900	8.3
22-26/6/87	100	120	220	1500	2100	7.1
29-3/7/87	200	250	450	2360	3300	7.6

TABLE 2 : Average composition of effluent discharge from Production House No. 2

DATE	NH_3-N	NO_3-N	TOTAL N	TDS	COND	[illegible]
4/2/87	1000	990	1990	5840	10000	7,5
23/2/87	100	110	210	1330	2300	7,7
9-13/3/87	200	240	440	2120	3300	8,2
16-20/3/87	260	270	530	2570	4000	8,1
23-27/3/87	100	130	230	1440	2200	8,5
30-3/4/87	390	500	890	3280	5000	8,4
7-10/4/87	190	240	430	2100	3200	8,1
13-16/4/87	120	140	260	1580	2400	7,7
27-30/4/87	180	240	420	2100	3200	7,9
4-8/5/87	280	340	620	2630	4100	7,6
11-15/5/87	130	160	290	1610	2500	7,9
18-22/5/87	210	280	490	2350	3500	7,7
1-5/6/87	240	360	600	2550	3800	7,9
8-12/6/87	640	770	1410	4790	7200	7,5
15-19/6/87	550	640	1190	4290	6000	7,9
22-26/6/87	80	220	300	1500	2100	8,3
29-3/7/87	550	630	1180	4290	6000	7,7

TABLE 3 : Average composition of dam contents before discharge to land

DATE	NH_3-N	NO_3-N	TOTAL N	TDS	COND	pH
4/2/87	680	610	1290	4670	8000	8,0
23/2/87	1600	1800	3400	8490	14000	7,2
9-13/3/87	1700	1900	3600	8400	13000	7,4
16-20/3/87	900	1000	1900	5150	8000	7,6
23-27/3/87	800	1000	1800	5580	8500	5,6
30-3/4/87	800	850	1650	4600	7000	5,6
7-10/4/87	1600	1800	3400	9900	15000	7,2
13-16/4/87	800	900	1700	4600	7000	6,0
27-30/4/87	1000	1500	2500	7900	12000	7,7
4-8/5/87	700	900	1600	4930	7500	7,6
11-15/5/87	1200	1500	2700	7720	11800	7,4
18-22/5/87	1600	1900	3500	8000	12000	7,6
1-5/6/87	1900	2400	4300	10500	16000	7,5
8-12/6/87	1800	2100	3900	9200	14000	7,3
15-19/6/87	1000	1000	2000	7870	11000	7,9
22-26/6/87	1000	1200	2200	6440	9000	7,8
29-3/7/87	1500	1400	2900	11400	16000	7,5

Composites

1.5 Existing Waste Treatment

At present all the waste water streams originating at the tank farm and in the production houses are conveyed by means of concrete channels towards two lined buffering dams. The shower water and any laboratory waste water are also discharged into these dams.

Save-alls, which effect liquid-solid separation, based on density differentials, are situated :

(i) immediately outside each production house.
(ii) immediately before discharge into the dams.

The aim of the save-alls is to remove all suspended, waxy and oily contaminants from the waste streams to ensure that only dissolved solids enter the dam. The solids are removed from the save-alls outside the production houses each shift and from the save-all before the dams each week. Approximately 12 x 50 l drums of solid waste are produced during each shift (1,8 m^3/day).

1.5.1 Solid waste disposal

The solid waste is transported to the burning enclosure where it is mixed with wood and firelighter, covered in paraffin and ignited. The ash is dumped. This burning process is a daily operation and is extremely expensive since the solids are too wet to burn efficiently and significant amounts of wood and fire lighters are required to effect burning.

The waste product from burst cartridges is also burnt in the enclosure.

1.5.2 Liquid waste disposal

The liquid fractions of the effluent streams pass into one of the two lined buffering dams.

Each dam has a capacity of 55 000 l and can hold the waste water produced during one shift. At the end of each shift the liquid discharge is directed into the second empty dam and the contents of the full dam are pumped through pipes to a disposal site where it is discharged at a rate of 7 m^3/h and seeps into the ground.

The solids which manage to pass through the save-alls, into the dams, are shovelled from the dams weekly and burned at the burning site.

It was originally proposed that the liquid waste would be irrigated. However, the high levels of nitrogen in this discharge killed the receiving vegetation and this irrigation practise has been suspended until a suitable solution has been found.

1.6 Recommendations

It is the policy of the Pollution Research Group (PRG) to prevent or minimise pollution by in-house modifications to existing processes. Where pollution problems cannot be totally engineered out of a process, only then will the Group consider the alternative approach of effluent treatment.

Where effluent treatment is considered necessary, the Group is committed, where possible, to the recovery and total recycle of water, process chemicals and heat energy within the production process. In addition the Group has adopted the approach that the segregation of effluent streams is essential. In this approach, the effluent streams containing high pollution loads or undesirable and toxic wastes may be preferrentially treated without dilution by or contamination of less polluted streams.

With these policies in mind, the following recommendations were made by both AECI and PRG personnel after visiting the Zomerveld production site.

1.6.1 Tank farm

(i) the waste streams from the tank farm produced by flushing pipes and hoses should be recycled back to the chemical storage tanks. If these streams are too dilute for direct recycle, the installation of a small concentration plant (reverse osmosis, evaporation) should be investigated to enable the chemicals to be returned to their desired concentration and to enable the water to be reused.

(ii) mixing of waste streams from the tank farm with other factory waste streams should be prevented since the former stream is up to 15 times the concentration of the production house discharge. Without contamination by the tank farm discharge, it is possible that the liquid waste from the production house could be sufficiently low in nitrogen for safe irrigation.

1.6.2 Production houses

(i) all waste streams within the production house should be segregated i.e. floor washings, machine washings, cooling water.

(ii) the oil and water in the machine washings should be separated in an oil separator and reuse of the water should be investigated.

(iii) the nozzel used for floor spraying should be redesigned to enable more effective and efficient cleaning.

(iv) the addition of increased surfactant levels to the cooling water should be investigated to prevent free oil.

(v) the possibility of using hot soapy water for removing excess oil from the cartridges before cooling should be investigated. This will increase oil removal efficiency and possibly enable longer cooling water cycles to be used with fewer dumpings.

(vi) the installation of a wedge wire screen immediately before the save-all will remove large suspended matter and reduce the solids loading on the existing save-alls.

(vii) the save-alls immediately after the production houses could possibly be cleaned more regularly to prevent excess solid build-up and increased leaching of salts from the solids.

(viii) the capture and reuse of the underflow from the save-alls as floor wash water should be investigated.

1.6.3 Water related operations

(i) the reuse of regeneration liquors in the ion-exchange demineralization plant should be investigated.

(ii) water meters should be installed to monitor the flow from the borehole and the flows to the tank farm and to each of the production houses (separate water meters to monitor cooling water and water used in floor and machine washing would be preferred).

(iii) a figure relating water consumption to production should be monitored on the regular basis.

1.6.4 Solid waste disposal

(i) the reuse of product from burst cartridges should be investigated.

(ii) the viability of burning the suspended matter with pulverised coal as opposed to with wood and firelighter could be investigated.

1.6.5 Liquid waste disposal

(i) the disposal of this stream should only be considered when its volume, composition and concentration has been optimised by carrying out the recommendations above. The final arisings could be so reduced that they are suitable for evaporation and not chemical treatment. In addition, irrigation as a means of dispersal could become viable.

(ii) laboratory bench tests will be conducted by the Pollution Research Group, pending the decision in (i) above. Effluent will be supplied to the Pollution Research Group on request.

1.6.6 General

(i) It is recommended that the AECI Modderfontein laboratories perform solubility experiments on 'Powergel' to determine the effect that immersion in water has on the product. These tests should be performed using both hard and soft water.

(ii) A detailed survey should be conducted at the factory to monitor dam and effluent stream concentrations on an hourly basis using conductivity measurements. In this manner, the impact of various operations on site (e.g. pipe flushing at the tank farm) on the effluent composition and volume can be determined. The Pollution Research Group will investigate the employment of a student for this purpose.

(iii) It was agreed that the Zomerveld factory manager will organise a design body for carrying out the recommended work.

(iv) The Pollution Research Group requested :

- a complete borehole water analysis.

- specifications of the demineralisation plant, and details of the destinations and volumes of demineralised water.
- specifications of all surfactants and soaps used to enable compatibility with existing effluent treatment membranes to be determined.

(v) The Pollution Research Group recommended various organisations for the supply of wedge wire screens and oil separators and for project management.

CONCLUSIONS

Successful implementation of the recommendations given would :

(i) significantly reduce product, water and chemical wastage.

(ii) enable effective and efficient monitoring of the water and chemical reticulation systems within the plant.

(iii) enable the recycle and reuse of large proportions of water, raw chemicals and oils.

(iv) enable the production of a small volume, high concentration effluent containing minimum suspended matter, which could be treated, concentrated or discharged.

The theoretical recycle/reuse system envisaged is shown in Figure 2. In the system :

(i) the tank farm flushing water is recycled, as is or after concentration.

(ii) the streams from the production houses are segregated and individually treated and recycled :
- machine washings are separated into their oil and water components for reuse or discharge.
- floor washings are passed through a wedge wire screen and partially recycled.
- cooling water is passed over a wedge wire screen before passing into a save-all. Some cooling water is recycled for floor washing and the rest is discharged to the dams for land disposal or further treatment.
- the waste product is recycled.

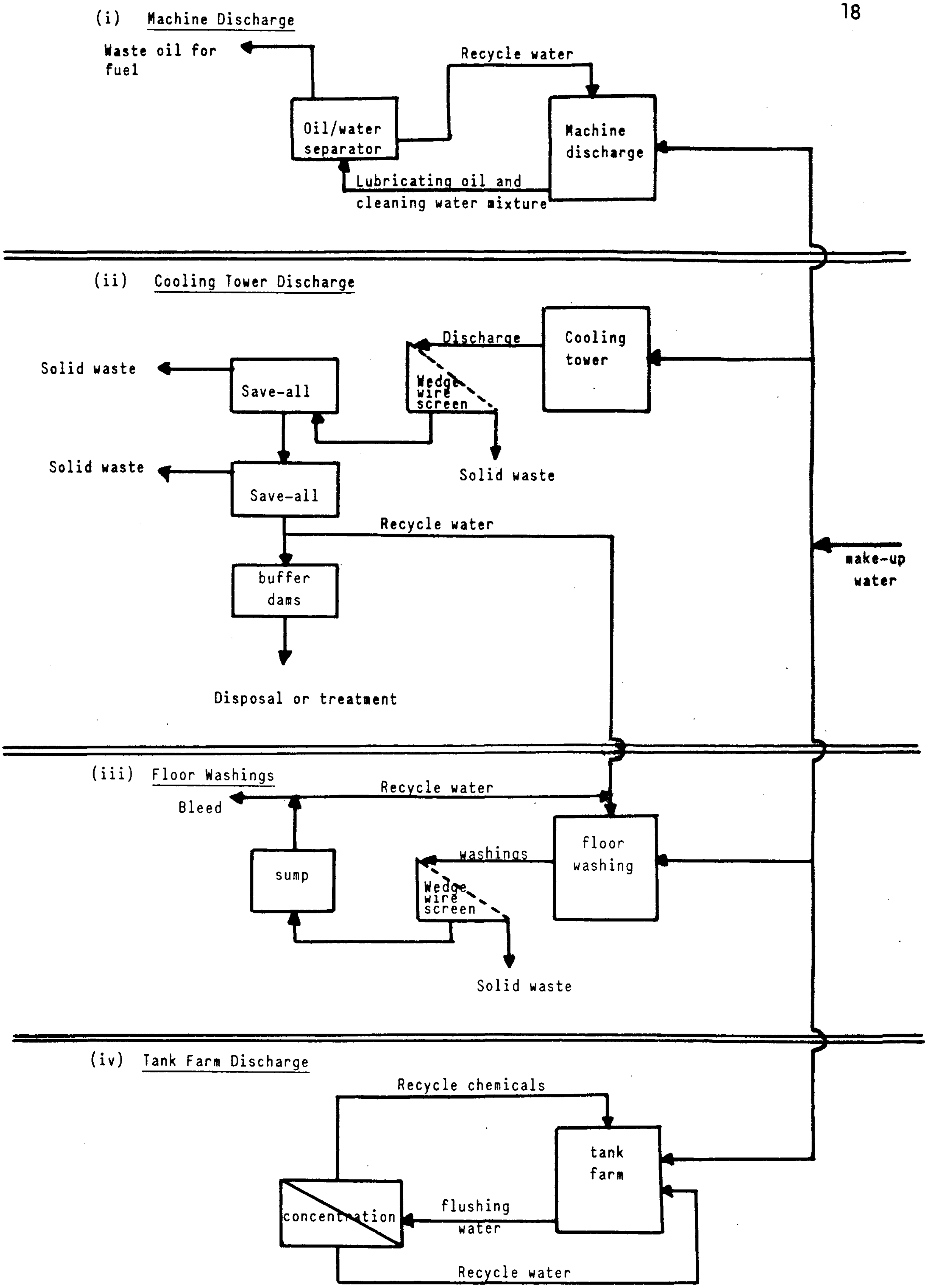

FIGURE 2 : Schematic of Proposed Water and Chemical Reticulation

2. MODDERFONTEIN CHEMICAL AND EXPLOSIVES PRODUCTION - DISCUSSION

At Modderfontein both chemicals and a wide range of nitroglycerine based and ammonium nitrate based explosives are manufactured.

The factory consumes approximately 30 Ml/day of water supplied by the Rand Water Board. In addition, 50 m^3/h (1,2 Ml/day) of sewage effluent from each of the Modderfontein and Johannesburg sewage works is consumed. A recycle system within the factory enables a further reuse of approximately 8,4 Ml/day of weak effluent.

There are two effluent discharges :

Weak effluent which is discharged into a holding dam (residence time 2 to 4 weeks) before flowing into the Yukskei River at a rate of 1 000 m^3/h. This effluent has a pH of 1 to 13 and is not limed before discharge.

Strong effluent which is irrigated at a rate of 20 m^3/h. The TDS of this stream is 10 to 15 g/l and the contaminants of major concern are N (3 to 4 g/l in the form of NH_4^+, NO_3^-), Cl^-, $SO_4^=$ (3 g/l) and F^-. This effluent is made up of streams from chemical production and explosive production. The pH ranges from 1 to 6 and the effluent is limed before storage and irrigation in order to deactivate residual nitroglycerine.

Approximately 75% of the volume of the strong effluent originates in the chemical production plant.

The cost of irrigation is forcing AECI to investigate alternate methods of disposal/treatment of the strong effluent.

After discussions it was decided that :

(i) The Pollution Research Group would visit Modderfontein (planned date 20/7/87).

(ii) AECI would supply the Pollution Research Group with 5 l samples of the following streams :

- weak effluent
- strong effluent component from chemical plant before liming.
- strong effluent component from chemical plant after liming.
- strong effluent component from explosive plant after liming.
- combined strong effluent.

The Pollution Research Group would conduct evaporation trials on all samples to determine the type and amount of chemical precipitation as a function of water recovery. This information is important in predicting scale formation and solid deposition if water recovery technology is implemented.

Facilitated transport and electrolysis experiments will be conducted on the unlimed samples of the strong effluent component from the chemical plant on a laboratory scale to determine the feasibility of a one stage process to neutralise the strong effluent, remove sulphates/nitrates and precipitate and separate calcium sulphate.