SLUDGE BUILD-UP IN SEPTIC TANKS, BIOLOGICAL DIGESTERS AND PIT LATRINES IN SOUTH AFRICA

Report to the Water Research Commission

by

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EXECUTIVE SUMMARY

The objective of this project was to establish sludge build up rates in various on-site sanitation systems under South African conditions. The sludge build up rate is an important design criterion in sizing on-site sanitation systems, for example septic tanks, pit latrines, etc. Comparison of data obtained on various other projects carried out by CSIR Building and Construction Technology (Boutek), indicated that the design criteria currently in use in South Africa were generally inappropriate because they are based largely on experience in other countries. There are many factors affecting the performance of on-site sanitation systems which have not been sufficiently quantified. Climatic and socio-economic factors, for instance, play a major role in the rate of sludge build up, and these differ from country to country. It is not satisfactory, therefore, to simply apply design criteria applicable to other countries. Furthermore, claims by commercial manufacturers of on-site sanitation systems about the design life of their products needed appraisal.

The project commenced with a literature survey which yielded mainly information concerning septic tanks. Less data on pit latrines was available. Factors considered to affect the rate of sludge build up were generally considered to be the number of users, anal cleansing materials used, diet, soil conditions, seasonal effects (temperature, moisture, etc), retention time, influent characteristics and toilet cleaning materials.

Boutek designed a perspex sampling tube which enabled a core to be taken of septic tank and digester contents, from which the depth of sludge could be directly measured and the clarity of the liquid layer established. The contents of VIP latrines were measured by lowering a steel tape with a weight into the pit and measuring the average depth from the toilet seat to the sludge.

The project measured the sludge build up rate in VIP latrines at Constantia Park and Soshanguve (Pretoria), septic tanks at Marselle (Eastern Cape) and Warden (Free State) as well as two kinds of "Loflo" digesters at Umbumbulu (Durban) and Ivory Park (Midrand). Various problems which affected the capture of data were experienced during the monitoring programme; these mostly concerned aspects such as tank emptying routines, reliable information on the number of users, the improper emptying of tanks, as well as political instability. Despite these problems, however, sufficient information was obtained for the purpose of establishing acceptable design guidelines.

The research enabled the following predictions for average sludge build up rates to be recommended:

- VIP latrines: 0.07 litres/person/day
- Septic tanks and "Loflo" systems: 0.08 litres/person/day

It was furthermore possible to suggest that provision for scum accumulation is not necessary. Outlet T-pieces are, however, essential items of equipment.

The research also yielded some important aspects on which recommendations could be made:

- User education is of crucial importance in order to ensure correct operation and maintenance of sanitation systems;

- correct installation of sanitation systems should be enforced by quality control on site;

- tanks connected to Loflo systems should have a minimum volume of 1 000 litres, while tanks receiving sullage in addition to toilet wastes should be at least 1 750 litres; and

- pits for VIP toilets should be as large as possible in order to reduce desludging frequencies, given site and cost constraints.

It is also recommended that further research be conducted into the optimum size for Loflo sanitation systems, as it is suspected that 1 000 litres may be inadequate. Additionally, there is an urgent need for research and information dissemination on low-maintenance sanitation systems, as many local authorities have insufficient funds to carry out maintenance tasks properly.

ACKNOWLEDGEMENTS

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PROJECT TEAM

The following staff from CSIR Building and Construction Technology contributed to this project:

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LIST OF SYMBOLS

ℓ	litre
p	person
d	day
yr	year
k	permeability
n	number of persons
R	retention time
V	volume
q	flow rate
f	sizing factor
r	primary sludge build up rates in litres per person per year
BOD	biological oxygen demand
COD	chemical oxygen demand

LIST OF ABBREVIATIONS

STED	Septic Tank Effluent Drainage
VIP	Ventilated Improved Pit Latrine
LOFLOS	A Low Flow, On-site Sanitation System using a low volume flush, an anaerobic digester to treat the flow, and a soakaway. These are generally sold as package units

THE DETERMINATION OF SLUDGE BUILD-UP RATES IN SEPTIC TANKS, BIOLOGICAL DIGESTERS AND PIT LATRINES IN SOUTH AFRICA

1. BACKGROUND

Efforts to meet the need for basic sanitation facilities in rapidly growing, low income communities have led to an awareness of the necessity to look at alternative means of providing sanitation services. Pit latrines, on-site digesters and septic tank systems are increasingly being installed as appropriate alternatives to water-borne sanitation.

As with any other system, one of the factors that influences the total cost of these systems is the cost of operation and maintenance. In the case of on-site systems this cost is mainly dependent on the life-span of the pit or tank or the emptying frequency thereof.

The bacterial digestion process on which the operation of these systems is based, does not break down one hundred per cent of the tank contents and therefore a layer of partially digested sludge accumulates in the digestion chambers of all three systems. In practice this means that a digestion tank fills up over time and has to be emptied at one stage or another or, if this is not possible, it has to be abandoned. Part of the optimization of the designs of these systems is to design the digestion chamber for a specific economic emptying cycle. For the purpose of optimised design of on-site sanitation systems it is necessary to have a proper indication of the rate of sludge accumulation in a specific type of system operating under certain circumstances.

The CSIR has recently been involved in two research projects that included a study of, in the first instance, the filling rate of a public pit latrine in Constantia Park, Pretoria, and secondly the sludge accumulation rates in biological digesters installed in the township Marselle, near Boesmansriviermond in the Eastern Cape. Both these investigations provided reasons to doubt the figures that are commonly used for digestion chamber design. Although this type of study has been done elsewhere for septic tanks and approximated figures have been published for pit latrines, there is still uncertainty surrounding the performance of biological digesters and as the above mentioned projects showed, there are numerous factors affecting the performance of on-site systems that have not yet been quantified. It is possible that some of these factors pertain to local customs and conditions and therefore the discrepancy between the results of an American study and local phenomena could be ascribed to the effect of local conditions such as diet and cleansing habits.

Other considerations that have brought the importance of sludge build-up rates to the fore are:

- The emergence of the LOFLOS Systems in South Africa and the whole debate on the design principles pertaining to these systems, have highlighted the question of sludge build-up.

- In the past, domestic septic tanks were generally built so excessively big in relation to their loadings that sludge build-up never became a problem. It was only at institutions that accommodated a large number of people (hotels, hostels) or from which large volumes of waste water originated (abattoirs, industries) where regular desludging had to take place.

- The prefabricated tanks of all the commercially available on-site digesters and septic tanks are sized optimally, i.e. as small as possible to minimise costs. Sludge accumulation therefore plays a more important role.

- Since the periodic emptying of any tank based sanitation system has an important bearing on the operation costs thereof, it is important to be able to predict beforehand what the emptying frequency of a particular system would be under certain circumstances.

- Some manufacturers of prefabricated septic tanks and on-site digesters claim very long periods between emptying intervals for their systems, and no substantial evidence is available to contradict these claims. The users of these systems eventually have to bear the brunt of the false claims. It is important to establish proper design figures to give decision makers a factual basis for decisions about systems.

- Septic tank effluent drainage systems (STED systems), also known as solids free or small bore sewer systems are also gaining popularity in South Africa. Sludge build-up in the interceptor tanks is an important factor in the design and operation of these systems.

2. AIMS OF THE PROJECT

- To identify the factors that could possibly affect the sludge accumulation in specific on-site sanitation systems.

- To select a representative sample of on-site systems for the investigation of the factors affecting sludge build-up.

- To determine the sludge build-up rates of a representative sample of specific on-site sanitation systems.

- To quantify the factors affecting the sludge build-up in the named systems.
- To combine the relevant factors in a relation whereby the sludge build-up rate for a specific type of system can be predicted for design purposes.

3. LITERATURE SURVEY

The following information on the topic of sludge build-up has been obtained through the literature survey:

- **Hill, F.G. & Ackers, G.L. 1954. <u>Principles of design for small domestic-sewage-treatment works</u>. Design and operation of septic tanks, World Health organisation Monograph Series, no. 18: 31-57.**

A tank cleaned once a year will require 96 ℓ of scum and sludge storage space per head, whereas by doubling the storage space the frequency of cleansing could be reduced to once in four and a half years.

Small rural plants: The provision to be made for the storage of sludge and scum for a six month period should be 68,2 ℓ per head.

The sludge and scum storage space required for a 12-month de-sludging period amounts to an average of 96 ℓ per head and if allowance is made for seeding sludge, the capacity required for a 12-month interval should be 116 ℓ per head.

- **Drews, R.J.L.C. 1985. <u>A guide to the use of septic tank systems in South Africa</u>. CSIR: Pretoria.**

  This publication concentrates on conventional septic tanks with 9 litre flush toilets. Bath and other grey water is also drained to the septic tank.

Table 1: Rate of sludge and scum accumulation

Years of service	Sludge & scum accumulation (ℓ/person)
1	95
2	120
4	175
6	235
8	305
10	385

The data in Table 1 is represented graphically in Figure 1. A linear regression analysis was carried out on the data. The slope of the straight regression line is the sludge build-up rate. The rate is **32 ℓ/p/yr** or **0.09 ℓ/p/d**.

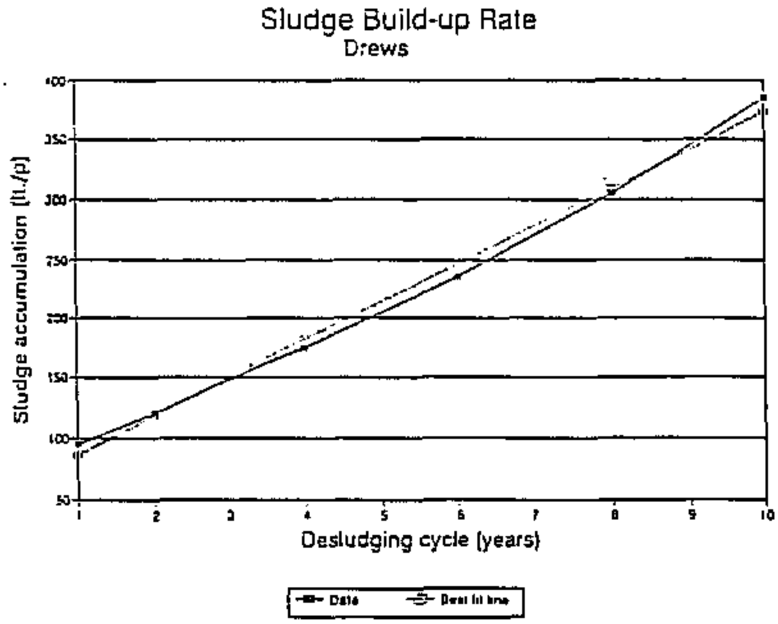

Figure 1. Sludge build-up rates (Drews)

- **Weibel, S.R., Straub, C.P. and Thomas, J.R. 1949. <u>Studies on household sewage disposal systems</u>. US Dept. of Health: Cincinnati, Ohio.**

The sludge build-up rate derived from measurements on 205 American septic tanks is **22 ℓ/p/yr** or **0.06 ℓ/p/d**. Flushing volumes would typically be in the 13-18 litre range.

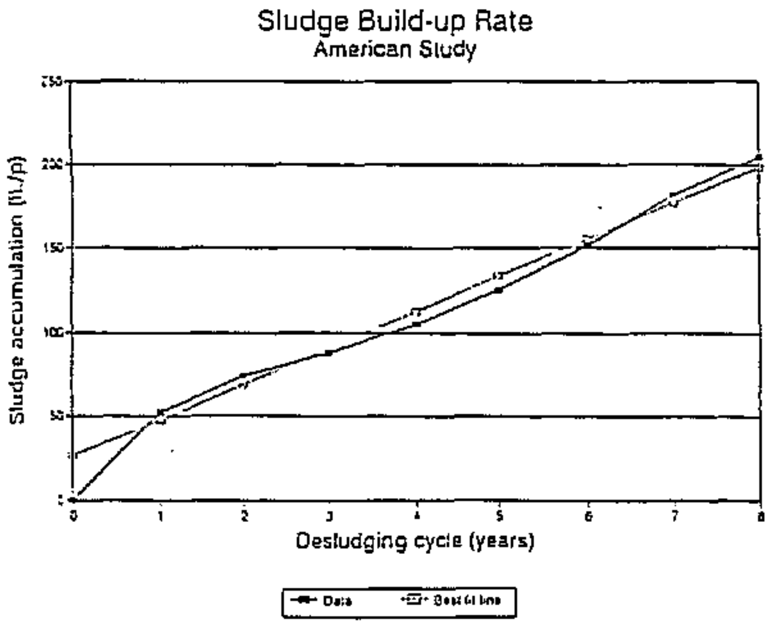

Figure 2. American sludge build-up data

- **ENSIC. 1982. <u>Septic tank and septic systems</u>. Environmental sanitation reviews, no. 7/8.**

In the Indian code the sludge accumulation rate is taken as 77 ℓ/p/yr (0,21 ℓ/p/day).

- **Sewards, G.J., Fimmel, R.J. 1982. <u>On-site wastewater disposal in Perth</u>. Metropolitan Water Authority: Perth.**

Table 2: Results of an Australian survey.

Item	Accumulation in ℓ/p/yr			
	Range	Average	Median	90 Percentile
Sludge	8 - 58	28	27	48
Scum	0 - 45	19	18	32

- **Sahle, H. 1988. <u>Applicability of small bore gravity sewers in Addis Ababa, Ethiopia</u>. Asian Institute of Technology: Bangkok.**

This model combines the effects of temperature, type of cleansing materials used and the source of the waste water. The figure for sludge build-up, given as litres per person per year, is acquired by choosing values for "f" and "r" from Tables 3 and 4 below and then multiplying these two factors, to obtain the sludge build-up rate.

Table 3: Values of sizing factor "f" for stated desludging intervals and temperatures (Sahle 1988:12).

desludging interval (years)	more than 20 °C throughout year	more than 10 °C throughout year	less than 10 °C during winter time
1	1.3	1.5	2.5
2	1.0	1.15	1.5
3	1.0	1.0	1.27
4	1.0	1.0	1.15
5	1.0	1.0	1.06
6+	1.0	1.0	1.0

Table 4: Primary sludge build-up rates "r" in litres per person per year (Sahle 1988:13).

materials used for anal cleansing	water closet or latrine wastes only	household sullage in addition to waste
water, soft paper	25	40
leaves, hard paper	40	55
sand, stone, earth	55	70

- **Brandes, M. 1978. <u>Accumulation rate and characteristics of septic tank sludge and septage.</u> Journal Water Pollution Control Federation, 936 - 943**

Extracts of data from this Canadian study is given in Table 5.

Table 5: Results of a Canadian study.

Location of septic tank	Hawkestone farm	Orilla Hospital house	Whitby experimental
nature of treated waste water	toilet wastewater	toilet, bathroom and kitchen wastewater	toilet, bathroom, kitchen, laundry wastewater
No. of users	3	11	28
Detention time (d)	~9.7	~2.4	~1.9
Sludge build-up rate (ℓ/p/d)	0.18	0.22	0.29

- **Franceys, R., Pickford, J., Reed, R. 1992. <u>A guide to the development of on-site sanitation.</u> World Health Organisation : Geneva.**

According to this publication, very little information is available on sludge accumulation rates. Factors with the biggest effect on accumulation rates in pit latrines are whether decomposition takes place above or below the water table and the type of anal cleaning material used. The suggested rates are shown in table 6. It is also advised that local sludge accumulation rates be measured before designing latrines. In the absence of local data the figures in the table below can be used. Note that the authors consider them to be on the high side.

Table 6: Suggested sludge accumulation rates (Franceys) (Litres per person per year)

	Accumulation rate
Wastes retained in water where degradable anal cleaning materials are used	40
Wastes retained in water where non-degradable anal cleaning materials are used	60
Waste retained in dry conditions where degradable anal cleaning materials are used	60
Waste retained in dry conditions where non-degradable anal cleaning materials are used	90

3.1 Summary of sludge build-up rates

The sludge build-up rates in the literature are given in different units. To aid comparison the results of the literature survey are summarized below with the sludge build-up rates given in litres/person/day, which is the unit used throughout the rest of this document. A year is assumed to comprise 365 days.

Note that the results of the Canadian study in table 5 above indicate that the addition of kitchen and laundry chemicals results in an increase in the sludge build up rate. This may indicate that these chemicals inhibit bacterial activity. However, kitchen wastes result in a greater biological loading and this may also contribute to the higher sludge build up rate.

Table 7: Summary of sludge build-up data in septic tanks reported in literature.

Reference	Country	Type of sanitation system	Sludge build-up rate
			(ℓ/p/d)
Hill & Ackers, 1954	not specific	Septic tank	0.26
Drews, 1985	South Africa	Septic tank	0.09
Wiebel, Stub & Thomas, 1949	USA	Septic tank	0.06
ENSIC, 1982	India	Septic tank	0.21
Sewards & Fimmel, 1982	Australia		0.08
Brandes, 1978	Canada	Septic tank	0.18

Note that all the above studies were for conventional septic tank systems with flush toilets. Franceys suggests figures to use for on-site systems other than septic tanks and this information is quoted in Table 6. The literature survey revealed that very little research on sludge accumulation rates has been undertaken. Most of the literature quotes figures in general use with no attempt to measure local rates.

4. FACTORS AFFECTING SLUDGE BUILD-UP

The following factors were considered to affect the sludge build-up rate in digesters and pit latrines.

4.1 Number of users

The amount of waste entering a pit or digester is obviously dependant on the number of people making use of the sanitation system. If the sanitation system involves flushing, more users means more water going through the system, which will shorten the retention time.

4.2 Anal cleansing material

Two kinds of anal cleansing paper are most popular with the users of on-site sanitation systems, namely conventional toilet paper or newsprint paper. The newsprint paper consists mostly of old newspapers, although magazines are also used.

Newsprint is generally tougher than toilet paper and is therefore expected to take longer to break down than toilet paper. In addition, the ink on these papers may adversely affect bacteria.

4.3 Diet

The nature of the diet will affect the BOD and COD introduced into a pit or digester.

The biological digestion processes are also affected by the proportions of carbon, nitrogen and phosphorous. The optimum BOD:N:P ratio is 100:10:1. These proportions are determined by the protein and carbohydrate intake of the user of the sanitation system. Imbalances in the ratio can lead to an inefficient digestion process and therefore higher sludge build-up rates.

The information required in respect of the diet is therefore the proportion of carbohydrates and proteins. Data obtained from residents, when asked about their diets, was unfortunately not sufficiently reliable to provide a good indicator.

4.4 Soil conditions

Pit Latrines: Soil conditions will have a greater effect on the sludge build-up rate in pit latrines than in digesters. This is so because pit latrines are normally unlined and the flow of water to and from the sludge depends on the permeability of the soil. Soil samples, on which permeability tests were carried out, were taken from each of the pit latrine sites.

Digester systems: For a properly functioning digester with unblocked soakaway, soil will have no effect on sludge build-up rate as the digestion process is isolated from the soil by the tank. The soakaway may fail due to an insufficiently permeable soil, however. As this state of affairs does not represent a functioning sanitation system, soil was considered to have no effect on digesters.

4.5 Seasonal effects

The research team expected to find pronounced seasonal effects on the sludge build-up rates in pit latrines due to effects of rain on the moisture content in the pits. However, no evidence was found to support this theory in the pit latrines monitored.

4.6 Retention time

The retention time (also called detention time) is a measure of the average length of time that the wastewater remains in a digester tank before flowing out of the tank. It depends on the volume of the digester tank and the flow rate of the influent.

$$R = V/q$$

where R = retention time (days)
V = tank volume (litres)
q = influent flow rate (litres/day)

The Canadian research reported in Table 5 seems to indicate that the longer the retention time, the lower the sludge build-up rate.

4.7 Characteristics of influent

The influent may consist of toilet waste only or may include other wastes such as bathroom, kitchen or laundry water. This can be expected to have an effect on the sludge build-up rate. Chemicals in kitchen and bathroom wastes may inhibit bacterial activity in the tank and cause the sludge build-up rate to increase.

4.8 Chemicals used for toilet cleaning

Since some of the commercially available products can harm the biological activity in the tank, the use of these products could be expected to increase the sludge build up rate in the system. However, if these substances are used in small quantities the effect is likely to be minimal. This was evidenced during the project where tanks were seen to be functioning satisfactorily, but on speaking to the residents it was found that these products were used regularly for toilet cleaning.

4.9 Temperature

The temperature in the system can have a marked effect on the sludge build up rate. For every 10 °C rise in temperature the rate of metabolism is expected to increase by a factor of 1,8.

5. METHODS AND EQUIPMENT

5.1 Monitoring of digesters

Figure 3 shows the sludge sampler which was designed to determine the sludge and scum depths in septic tanks and biological digesters. This device is used to core the contents of the tank in order to get an indication of the particular stratification.

The brass rod with the conical plastic stopper is lowered into the tank through the access opening until it reaches the bottom. The clear perspex tube is then inserted into the tank with the brass rod passing through the centre of the tube. The plastic cone will guide the perspex tube onto the rubber sealing ring. The tube is then tightened against the sealing ring by the stopper screwed on at the top of the tube.

This method was found to give a good indication of the sludge and supernatant liquor layers in the tanks. The sludge is of a viscous nature and the plastic cone easily penetrated the sludge layer. The clarity of the supernatant liquor was a good indication of the efficiency of digestion taking place in the tank. The clearer the supernatant liquor, the more efficient the digestion process.

The tanks in Warden, Umbumbulu and Ivory Park were cored using this technique on a cycle of about once every 10 weeks.

5.2 Monitoring of pit latrines

Pit latrines are dry sanitation systems and a different monitoring approach was necessary in this instance. The sludge level was determined by measuring the vertical distance between a fixed datum (top of toilet seat) and the sludge. A steel measuring tape attached to a steel weight was used as the measuring apparatus. The change in the vertical distance then indicates the change in sludge volume.

As the waste material is deposited in the pit from one point, a mound was formed in the pit. Depending on the moisture of the sludge, the steepness of the mound varied, being very steep in the dry season and flatter in the rainy season. The vertical distance to the top of the toilet seat was therefore measured from a point half-way between the top and the base of the mound. The pit latrines were measured about once every 10 weeks.

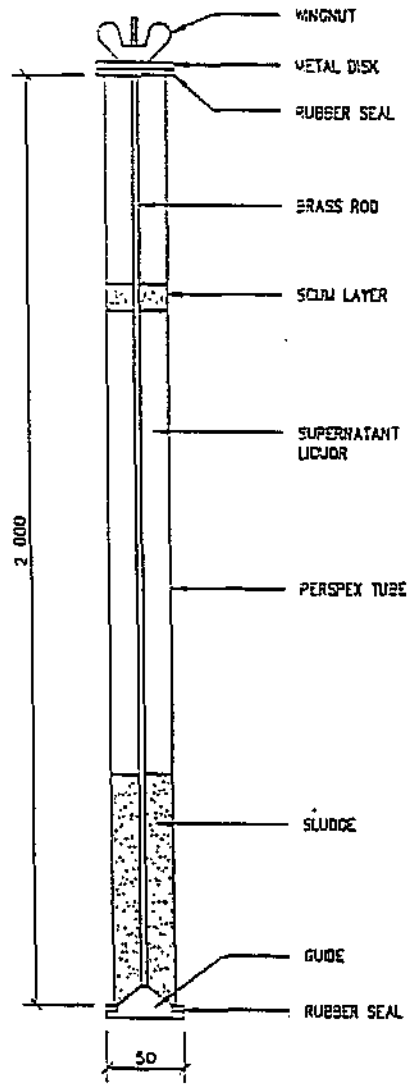

Figure 3. Sludge sampler used for determining sludge and scum depth (Not to scale, dimensions in mm)

6. SYSTEMS MONITORED FOR THIS STUDY

The following on-site sanitation systems were monitored for this study:

- **System A:** Interceptor tanks in a STED system at Marselle township near Boesmansriviermond.
- **System B:** Public VIP latrines at Constantia Park, Pretoria.

- **System C:** Loflo digesters at Umbumbulu near Durban.
- **System D:** Septic tanks at Warden in the Free State.
- **System E:** VIP latrines at Soshanguve north of Pretoria.
- **System F:** Loflo digesters at Ivory Park near Midrand.

These systems are described below:

6.1 System A: Interceptor Tanks at Marselle

Marselle is situated near Boesmansriviermond in the Eastern Cape. Houses are generally of concrete block construction. A STED system was installed by the Cape Provincial Administration in November 1989. Two types of toilets systems, a flush and a non-flush system, were installed in the township. Both systems used a 1750 ℓ polyethylene interceptor tank. The flush system consisted of a conventional P-trap pan with a 5 litre flush. A wash trough with a tap, which also drained into the interceptor tank, was installed on the outside of the toilet hut. Compared with the situation at Warden, this was a low income area with less water passing through the tanks. The non-flush system consists of a ceramic pan without a P-trap that discharges into a long radius bend connected to the interceptor tank below the water level. The water in the long radius bend forms a rough water seal. Waste is either flushed into the tank by pouring a bucket of water into the pan or a plunger with a flexible rod is used to push the waste into the tank. The STED sewers are drained to a series of ponds some distance away from the settlement. Visits to the ponds led to the conclusion that they are much bigger than necessary and also that they are seldom, if ever, maintained.

These systems were monitored by the CSIR, the Cape Provincial Administration and the manufacturer of the interceptor tank. The tank is the same shape as those monitored at Ivory Park and shown in figure 5, the only difference being that the Marselle tanks have a volume of 1 750 litres while those at Ivory Park are 1 000 litres.

During the course of this project the CPA decided to replace the non-flush systems at Marselle with flush toilets. The ceramic pans were removed and replaced with plastic pans and cisterns. The long radius bends were blocked off and conventional connections made to the tank. This effectively converted these systems to the same as the other installations at Marselle. The research team spoke to the engineers at the CPA about the reasons for the alterations to the "dry" systems and this interview is attached in Appendix III. In summary, they found that most of the problems associated with the STED system at Marselle were associated with the "dry" systems. Residents did not like using the plunger to push the waste into the tank. In addition it appeared as if the tanks were never filled with water. The other problems relate to a lack of funds for maintenance at Marselle.

6.2 System B: VIP latrines at Constantia Park

Pit latrines were erected at a bus stop in Constantia Park, a suburb of Pretoria, in 1986 and monitored for a period of 6 years. The latrines were the only public sanitation facility in the area of the bus stop. They were constructed of brick to a standard design as indicated in NBRI information sheets. (X/BOU 2-17: The ventilated improved pit latrine. M A Heap)

Separate pits were constructed for men and women, with volumes of 4,45 m^3 and 3,04 m^3 respectively. Counters were attached to the gates leading to the toilets and urinals so that the exact number of users could be determined. Toilet rolls were contained in special dispensers so that the exact number of toilet rolls used could be determined.

6.3 System C: Biological digesters at Umbumbulu

The digester system used in Umbumbulu consists of a tipping-tray pedestal installed inside the house and a 1 000 litre digester tank made from glass-reinforced plastic (GRP). Waste enters the tank at the centre through a curved funnel-shaped GRP pipe. This pipe is attached to the tank by means of a flexible coupling to allow for differential movement. Effluent is drawn from the centre of the tank via the integral outlet. The tank is covered with a full opening lid. The pedestal is designed to use one litre of water per flush. A cross-sectional drawing of a tank is shown in Figure 4. The tank is drained to an on-site soakaway. Kitchen waste bypasses the tank and goes directly to the soakaway.

Most of the houses were constructed of brick or concrete blocks by Time Housing. Loans were provided to the residents through employee housing schemes. In discussions with residents it was found that most of them were told by agents when they bought their houses that the sanitation system would be replaced within a short space of time with a waterborne sanitation system. The fact that this has not yet happened has given rise to a general non-acceptance of the existing systems.

10 tanks were monitored for this study. A screw cap at the centre of the full opening lid was provided for inserting the sludge monitoring tube.

The tanks at the following houses were monitored:

Tank No.	House No.	Tank No.	House No.
1	C924	6	C905
2	C925	7	C840
3	C926	8	C839
4	C908	9	C834
5	C907	10	C833

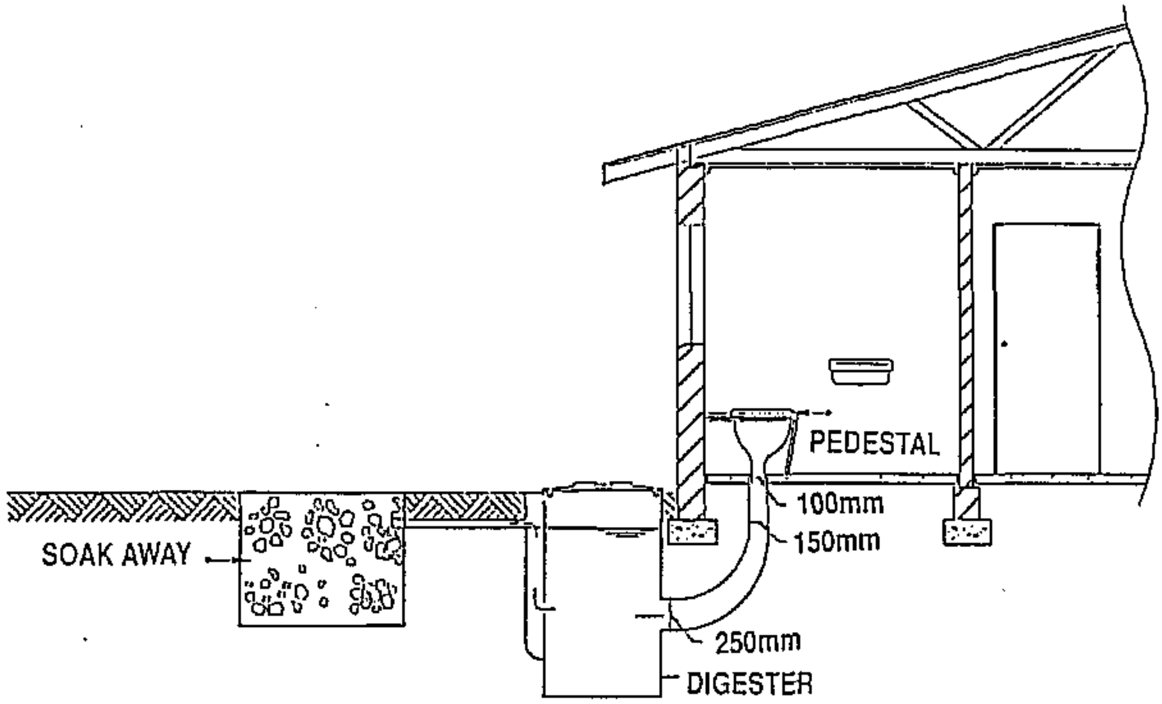

Figure 4. Biological digesters at Umbumbulu.

6.4 System D: Septic tanks at Warden

Warden is a small farming community in the Free State. The houses in Warden used to be served by conservancy tanks which were emptied twice a week. The sanitation system was upgraded in the mid 1990s by connecting the tanks to a STED system. The existing conservancy tanks, with volumes of between 3 500 and 4 000 litres, were not replaced. An outlet T-piece was installed in each tank. The STED sewers drain to the same ponds that were used for the treatment of conservancy tank waste. In discussions with the Town Clerk it was found that the STED system is working very well. The only problems are with the tanks – they are very old, and many of the cover slabs are broken or badly cracked.

6.5 System E: Pit latrines at Soshanguve

The pit latrines at Soshanguve were excavated using a 1m diameter auger. The pits therefore have a round cross-section with a depth of about 2,50 m. The pits were covered with precast concrete slabs, on top of which prefabricated corrugated iron superstructures were installed. The pedestals in the toilets are made from wood. These latrines are not considered to be acceptable. They do not stop the breeding of flies and they tend to smell. The superstructures get very hot in the sun and reverse venting occurs. The superstructures also have large openings between the walls and the roof, resulting in a lot of light falling on the pedestal; as a result, flies are not attracted to the ventpipe where they would be trapped by the flyscreen. The pedestals are made of chipboard which soaks up urine spillage, leading to odours.

Although these are not good examples of VIP latrines, the shortcomings would not affect the sludge accumulation rate.

6.6 System F: Biological digesters at Ivory Park

Ivory Park was one of the first townships in Gauteng to be developed on a site and service basis. Because there is only one standpipe per 20 stands there is no fully waterborne sanitation. Each 200 m^2 stand has one toilet. All of these toilets are on-site sanitation systems. Some of these have very small tanks (~35 litres) and others are anaerobic digesters with 1 000 litre tanks. It was decided that only the 1 000 litre tanks would be monitored. All the toilets are housed in prefabricated corrugated iron huts.

A cross-section of the larger digester tanks monitored in Ivory Park is shown in Figure 5. The cylindrical tank has a conical top section. The tank is 1,20 m in diameter when measured across the bottom surface, with a height of 1,35 m. A T-shaped effluent outlet pipe is positioned 1,0 m above the bottom surface of the tank, inside a cone-shaped baffle protruding 630 mm into the tank. This results in a 1 000 litre liquid capacity and 250 litre free air space.

Sludge readings were taken by inserting the sludge monitoring tube in the manhole at the top of the tank, which is normally covered with a concrete filled lid.

Because the total depth (bottom of tank to outflow level) is 1,0 m the sum of the sludge and fluid level should not exceed this distance. A total depth greater than 1,0 m indicates that either the soak away or the overflow pipe is blocked, resulting in unsatisfactory, and potentially hazardous, operation of the tank.

The digesters were installed in November 1990.

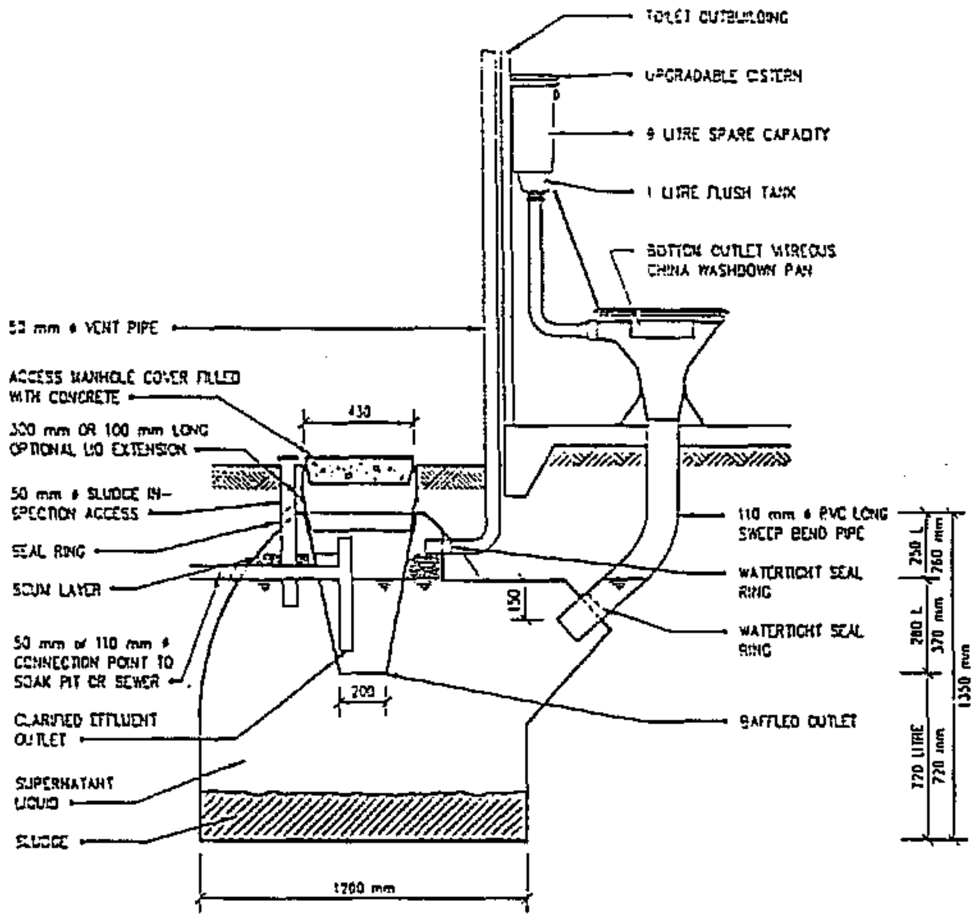

Figure 5. Cross section of digester tank at Ivory Park

7. RESULTS OF INVESTIGATION

7.1 Sludge monitoring

The sludge build-up rates determined by direct measurement are given below. Units are litres/person/day.

Table 8: Sludge build-up rates as determined on site

Description	Range	Mean	# of measurements
Marselle: Non-flush systems	0.087 - 0.247	0.178	26
Marselle: Flush systems	0.074 - 0.140	0.101	24
Umbumbulu: Tipping-tray digesters	0.020 - 0.193	0.074	117
Ivory Park: Anaerobic digesters	0.055 - 0.123	0.083	15
Warden: Septic tanks	0.030 - 0.370	0.149	140
Soshanguve: VIP latrines	0.036 - 0.093	0.066	102

- Constantia park: Public pit latrines:

  Toilet for males: average usage: 765 users per month.
  filling rate: 0,06 ℓ/person/day.

  Toilet for females: average usage: 494 users per month.
  filling rate: 0,80 ℓ/person/day.

7.2 Soil investigations

Soil investigations were only undertaken for on-site sanitation systems where the effluent is discharged to a soil percolation system. The soil property which has the greatest affect on water absorption and soakaway performance is permeability. This was determined in the laboratory using a constant-head permeameter.

Soil samples were taken at the sites listed in Table 8. Constantia Park and Soshanguve sites both have VIP latrines and so the soil permeability can be expected to have a direct influence on the sludge build up rates. Umbumbulu and Ivory Park are Loflo digester systems with on-site soakaways. The results of the soil investigation are summarized in Table 8:

Table 9: Soil permeabilities

Sample	Laboratory permeability k (cm/s)
Umbumbulu, Sample 1	4.19×10^{-5}
Umbumbulu, Sample 2	1.02×10^{-4}
Ivory Park, Sample 1	4.31×10^{-4}
Ivory Park, Sample 2	5.64×10^{-4}
Ivory Park, Sample 3	5.19×10^{-4}
Soshanguve, Sample 1	7.41×10^{-4}
Soshanguve, Sample 2	1.32×10^{-4}
Soshanguve, Sample 3	1.75×10^{-4}

7.3 Socio-economic surveys

Socio-economic surveys were conducted to correlate income levels to the sludge build-up rate. Income level can usually give an indication of diet composition.

7.3.1 Ivory Park

Ivory Park is situated in close proximity to the industrial areas of Midrand and Kempton Park. A relatively large number residents (73%) therefore have full time employment.

7.3.2 Soshanguve

Soshanguve is situated to the north of Pretoria. Although unemployment is relatively high the pit latrines are situated in an area with conventional housing and it seems as if the residents are in regular employment.

7.3.3 Umbumbulu

The area monitored is part of a housing scheme in Folweni. Most of the houses were built by Time Housing for SA Breweries. The owners of these houses are mostly employed at the breweries.

7.4 User Perceptions

As part of the monitoring programme, the users of the toilet systems were asked their opinions on the use of their on-site sanitation systems. Except for the STED system in Warden, most users were negative towards their respective toilets. This is mainly because their demands for full waterborne sewerage had not yet been met and the expectations that this would still be provided. The most common complaints and perceptions are listed below:

- **Smell and flies:** Virtually every user of the VIP latrines in Soshanguve complained about smell and flies. The strongest complaints related to especially large concentrations of flies during summer months. Associated with these complaints were concerns about the health of occupants.

- **Fear of children falling into pits or tanks:** Understandably, these fears were expressed mostly by users with young children.

- **Poor workmanship:** A lot of complaints were received about the flushing mechanisms of the systems installed in Umbumbulu. The complaints were normally in connection with poor quality washers. Other examples of poor workmanship were pedestals not installed horizontally, causing water to leak out of the tipping tray and failed tipping tray mechanisms.

- **Responsibilities not clearly understood:** Users did not understand that they were responsible for looking after their toilets. They also did not fully understand the basic maintenance requirements of the systems. This is probably due to inadequate user training.

7.5 General observations during monitoring

- The septic tanks at Warden usually had well defined separation between the sludge and liquid layers. The liquid layer was very clear.

- There was usually a well defined separation with the LOFLOS systems but the liquid layer was generally much less clear than in the septic tanks.

- There was very little scum accumulation in all the systems monitored.

- Building a cheap VIP latrine is a waste of time and money. The latrines at Soshanguve do nothing to stop the spread of disease carried by flies and they provide an appalling level of service to the user.

- In most of the areas monitored, the residents had been promised that their systems would shortly be upgraded to waterborne sanitation. These unrealistic promises have resulted in dissatisfaction with the present systems.

8. PROBLEMS EXPERIENCED DURING MONITORING PROGRAMME

Some problems occurred in the capture of data. This was mostly due to communication problems

1. **Improper emptying of tanks:** It was often found that tanks showed relatively high levels of sludge after they had supposedly been emptied. It was therefore suspected that the tanks were not being entirely emptied. This suspicion was confirmed by the responsible foreman in Warden, who said that about 200 mm of sludge is normally left behind in the tanks after pumping. In discussion with maintenance personnel at other townships, it transpired that often only the liquids are removed from the tanks, and very little sludge. The emptying is done by contractors with minimal supervision from the local authority. Furthermore, the tanks are usually left empty instead of being filled with water.

2. **Users not home:** Very often users were not home when the survey sites were visited so that information on matters such as the number of users, diet and anal cleansing material could not be updated. In these cases it was assumed, for purposes of the analysis, that the variable had not changed since the last survey for which information was available. Where a change in the number of users occurred, the average number of users was used for the analysis.

3. **Sample size:** Due to cost constraints, the sample sizes chosen were too small. According to CSIR statisticians, a rule of thumb is to choose a sample size of 10 times the number of variables considered.

4. **Inadequate data on tank emptying:** In many cases the users were unable to specify exactly or even roughly when the tanks were last emptied, and the local authority records were also unreliable.

5. **Political instability:** Most of the monitoring work was carried out in politically sensitive areas over a time of political transition. Consequently, toilet systems could not always be monitored at the required intervals.

9. DISCUSSION AND CONCLUSIONS

9.1 Sludge build-up rates

The sludge build-up in litres/person was plotted against time and these graphs are reproduced in Appendix II. A line of best fit was plotted on these graphs and the slope of the line measured, giving the build-up rate in litres/person/day. In this process events such as emptying of the tanks was taken into account. Outlying points that could not be explained were excluded. Table 10 below indicates the total number of measurements taken during this project and the number that could be used to determine the sludge build-up rates.

Table 10: Measurements used to determine build-up rates

Place	# of sites	# of visits	Total measurements	Measurements used
Umbumbulu	10	16	160	117
Warden	14	13	182	140
Soshanguve	11	14	154	102
Ivory Park	9	11	99	15

As can be seen from the table, very few measurements from Ivory Park could be used. The depth of sludge in the tanks showed considerable variation. The tanks were emptied periodically and no record of this emptying could be obtained from the township office or the residents. The emptying was often not done properly and it is believed that, in most cases, only some of the liquid was pumped out and very little, if any, of the sludge. It is also believed that the tanks were seldom filled with water after emptying.

9.2 Accumulation rate versus number of people

When the average accumulation rates are plotted against the number of people resident on the property, no evidence of correlation can be found. This could mean that the number of people contributing waste to the system does not affect the sludge build-up rate.

9.3 Scum accumulation

Several design manuals for septic tanks quote figures for accumulation of scum and thus require designers to allow a volume for the storage of scum. This study, however, revealed that whereas there is a need to design for a floating layer of scum, there is no need to provide additional volume for storage of accumulated scum. The normal practice of placing a T-piece on the outlet to prevent the scum from leaving the tank is sufficient. On tanks with a small surface area the T-piece should be extended higher than normal to allow for the rise in liquid level when a large volume of liquid enters the tank.

9.4 Recommended design criteria

1. The following values are recommended for sludge accumulation in South Africa:

VIP latrines	0.07 litres/person/day
Septic tanks and Loflo systems	0.08 litres/person/day

2. No provision needs to be made for scum accumulation. A T-piece should be placed on the outlet to prevent floating scum from leaving the tank.

10. GENERAL RECOMMENDATIONS

1. **User education:** In many cases toilet systems do not function satisfactorily due to user ignorance. Once a toilet is installed, the correct operating procedures should be explained to the user, in his or her own language, so that there are no misunderstandings.

2. **Correct installation:** Responsibility for correct installation of toilet systems should be clearly defined and the quality of workmanship monitored on site.

3. **Minimum tank size:** Tanks for Loflo digester systems where water is supplied from standpipes should not be less than 1000 litres in volume. If the tanks are to be connected to a STED sewer system then consideration should be given to installing a larger tank, for example 1750 litres. The larger tank is suggested because of the greater volume of water passing through the tank and the impact of kitchen wastes on the rate of sludge build up.

4. **Minimum pit size:** VIP latrines need to be properly designed and constructed. This has a cost implication and would probably mean that one would need to design the latrine for a longer life cycle before emptying is required. It would therefore be best to construct the pit as large as possible, given site and cost constraints. It should be borne in mind, however, that if it is the intention for a VIP latrine be emptied by means of a vacuum tanker, then the depth of the pit should be limited (2 m is suggested as a maximum in this case).

11. RECOMMENDATIONS FOR FURTHER RESEARCH

1. Optimum size for Loflo sanitation systems: Research into this aspect will require a detailed study of the processes inside the tank. During the course of this project, it was seen that the large tanks at Warden operate very well; this leads one to question if the 1 000 litre volume currently used for Loflo systems is adequate.

2. Low-maintenance sanitation systems: It was found that many local authorities have insufficient funds or staff to carry out maintenance tasks properly. Research and information dissemination on low-maintenance systems are required.

12. REFERENCES

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APPENDIX I

Data

SLUDGE MONITORING AT WARDEN

DATE	07/22/93	09/27/93	12/13/93	02/16/94	04/14/94	06/22/94	10/24/94	12/06/94	01/26/95	04/11/95	06/12/95	08/30/95	10/24/95
DAYS	0	68	77	65	58	69	124	43	50	75	62	79	55
CUMULAT. DAYS	0	68	145	210	268	337	461	504	554	629	691	770	825
7DE LAAN NO. 6	ADULTS	CHILDREN		AREA:	4.3								
NO. OF USERS	5	0											
SCUM	0	5	5	10	5	15	5	5	10	5	10	10	10
FLUID	1335	1500	1678	1360	1340	1325	1305	1320	1340	1370	1350	1165	1290
SLUDGE	200	175	165	145	180	190	210	200	180	170	190	180	215
SLUDGE VOL. (L/P)	172	150.5	141.9	124.7	154.8	163.4	180.6	172	154.8	146.2	163.4	154.8	184.9
ST-RATE		-0.3161765	-0.1116883	-0.2646154	0.5189655	0.1246377	0.13871	-0.2	-0.344	-0.11467	0.27742	-0.10886	0.54727
LT-RATE			-0.2075862		0.104878		0.13368		-0.27742		0.06277		0.16045
XLT-RATE				-0.2252381			0.22271			-0.20476			0.19745
7DE LAAN NO 8	ADULTS	CHILDREN		AREA:	3.86								
NO. OF USERS	2	0											
SCUM	0	0	0	0	0	0	0	10	5	5	5	10	15
FLUID	1200	1235	1350	1310	1165	1255	1185	1335	1365	1390	1450	1495	1535
SLUDGE	70	85	75	80	60	70	105	155	155	160	180	200	180
SLUDGE VOL. (L/P)	135.1	164.05	144.75	154.4	115.8	135.1	202.65	299.15	299.15	308.8	347.4	386	347.4
ST-RATE		0.4257353	-0.2506494	0.1484615	-0.6655172	0.2797101	0.54476	2.24419	0	0.12867	0.62258	0.48861	-0.70182
LT-RATE			0.0665517		-0.2353659		0.45		1.03763		0.35219		0
XLT-RATE				0.0919048			0.19223			0.63185			0.19694

SLUDGE MONITORING AT WARDEN

DATE	07/22/93	09/27/93	12/13/93	02/16/94	04/14/94	06/22/94	10/24/94	12/06/94	01/26/95	04/11/95	06/12/95	08/30/95	10/24/95
DAYS	0	68	77	65	58	69	124	43	50	75	62	79	55
CUMULAT. DAYS	0	68	145	210	268	337	461	504	554	629	691	770	825
7DE LAAN NO 10	ADULTS	CHILDREN		AREA:	2.88								
NO. OF USERS	2	0											
SCUM	0	0	0	10	15	40	10	25	25	0	0	5	5
FLUID	840	950	1220	1175	1245	1200	790	810	870	765	750	660	750
SLUDGE	180	90	70	120	155	250	200	170	135	145	75	260	240
SLUDGE VOL. (L/P)	259.2	129.6	100.8	172.8	223.2	360	288	244.8	194.4	208.8	108	374.4	345.6
ST-RATE		-1.9058824	-0.374026	1.1076923	0.8689655	1.9826087	-0.58065	-1.00465	-1.008	0.192	-1.62581	3.37215	-0.52364
LT-RATE			-1.0924138		0.995122		0.33575		-1.00645		-0.63066		1.77313
XLT-RATE				-0.4114286			0.45896			-0.47143			0.69796
7DE LAAN NO 12	ADULTS	CHILDREN		AREA:	2.86								
NO. OF USERS	4	0											
SCUM	0	5	10	20	20	0	25	15	15	10	10	25	50
FLUID	1360	1515	1320	1560	1485	1290	1255	1275	1275	1250	1245	1195	1205
SLUDGE	180	150	150	220	195	170	175	210	200	160	170	210	200
SLUDGE VOL. (L/P)	128.7	107.25	107.25	157.3	139.425	121.55	125.125	150.15	143	114.4	121.55	150.15	143
ST-RATE		-0.3154412	0	0.77	-0.3081897	-0.259058	0.02883	0.58198	-0.143	-0.38133	0.11532	0.36203	-0.13
LT-RATE			-0.147931		0.2615854		-0.07409		0.1922		-0.15657		0.16007
XLT-RATE				0.1361905			-0.12819			-0.06384			0.14592

SLUDGE MONITORING AT WARDEN

DATE	07/22/93	09/27/93	12/13/93	02/16/94	04/14/94	06/22/94	10/24/94	12/06/94	01/26/95	04/11/95	06/12/95	08/30/95	10/24/95
DAYS	0	68	77	65	58	69	124	43	50	75	62	79	55
CUMULAT. DAYS	0	68	145	210	268	337	461	504	554	629	691	770	825
CORNER 7DE + PARK	ADULTS	CHILDREN		AREA:	3.66								
NO. OF USERS	2	0											
SCUM	0	0	10	5	5	0	0	0	5	10	5	0	10
FLUID	0	945	945	1130	845	910	800	805	850	900	860	765	800
SLUDGE	0	95	130	100	180	120	225	220	180	135	180	250	210
SLUDGE VOL. (L/P)	0	173.85	237.9	183	329.4	219.6	411.75	402.6	329.4	247.05	329.4	457.5	384.3
ST-RATE		2.5566176	0.8318182	-0.8446154	2.5241379	-1.5913043	1.5496	-0.21279	-1.464	-1.098	1.32823	1.62152	-1.33091
LT-RATE			1.6406897		0.7439024		0.42668		-0.88548		0		0.4097
XLT-RATE				0.8714286			0.91135			-0.98036			0.70026
CORNER 8STE + PARK(21	ADULTS	CHILDREN		AREA:	2.89								
NO. OF USERS	3	0											
SCUM	0	0	0	0	0	0	5	0	0	0	0	0	0
FLUID	880	1000	1290	1160	780	875	740	770	800	815	550	765	750
SLUDGE	145	175	175	165	180	140	180	185	220	130	120	200	230
SLUDGE VOL. (L/P)	139.6833	168.58333	168.58333	158.95	173.4	134.86667	173.4	178.217	211.933	125.233	115.6	192.667	221.567
ST-RATE		0.425	0	-0.1482051	0.2491379	-0.5584541	0.31075	0.11202	0.67433	-1.156	-0.15538	0.97553	0.52545
LT-RATE			0.1993103		0.0391599		0		0.41434		-0.70316		0.7908
XLT-RATE				0.091746			0.05757			-0.28671			0.4915

SLUDGE MONITORING AT WARDEN

DATE	07/22/93	09/27/93	12/13/93	02/16/94	04/14/94	06/22/94	10/24/94	12/06/94	01/26/95	04/11/95	06/12/95	08/30/95	10/24/95
DAYS	0	68	77	65	58	69	124	43	50	75	62	79	55
CUMULAT. DAYS	0	68	145	210	268	337	461	504	554	629	691	770	825
8STE LAAN NO 15	ADULTS	CHILDREN		AREA:	2.56								
NO. OF USERS	2	0											
SCUM	0	0	0	0	0	0	5	5	5	0	0	20	10
FLUID	1185	1185	1285	1400	1440	1310	1085	1145	1120	1140	1120	1105	1100
SLUDGE	100	125	120	80	115	120	250	135	155	150	120	170	200
SLUDGE VOL. (L/P)	128	160	153.6	102.4	147.2	153.6	320	172.8	198.4	192	153.6	217.6	256
ST-RATE		0.4705882	-0.0831169	-0.7876923	0.7724138	0.0927536	1.34194	-3.42326	0.512	-0.08533	-0.61935	0.81013	0.69818
LT-RATE			0.1765517		-0.0520325		0.89534		-1.30753		-0.32701		0.76418
XLT-RATE				-0.1219048			0.86693			-0.7619			0.32653
8STE LAAN NO 13	ADULTS	CHILDREN		AREA:	3.82								
NO. OF USERS	3	0											
SCUM	0	0	0	5	5	0	5	0	0	0	0	0	0
FLUID	865	1260	1280	1280	340	790	840	830	870	845	865	780	760
SLUDGE	270	155	180	130	160	200	170	170	160	170	120	220	180
SLUDGE VOL. (L/P)	343.8	197.36667	229.2	165.53333	203.73333	254.66667	216.467	216.467	203.733	216.467	152.8	280.133	229.2
ST-RATE		-2.1534314	0.4134199	-0.9794872	0.6586207	0.7381643	-0.30806	0	-0.25467	0.16978	-1.02688	1.61181	-0.92606
LT-RATE			-0.7903448		-0.2070461		0.06598		-0.13692		-0.37178		0.57015
XLT-RATE				-0.8488889			0.20292			0			0.06497

SLUDGE MONITORING AT WARDEN

DATE	07/22/93	09/27/93	12/13/93	02/16/94	04/14/94	06/22/94	10/24/94	12/06/94	01/26/95	04/11/95	06/12/95	08/30/95	10/24/95
DAYS	0	68	77	65	58	69	124	43	50	75	62	79	55
CUMULAT. DAYS	0	68	145	210	268	337	461	504	554	629	691	770	825

8STE LAAN NO 11	ADULTS	CHILDREN		AREA:	3.6								
NO. OF USERS	4	0											
SCUM	5	7	0	5	5	5	10	10	5	10	10	15	10
FLUID	1170	1580	1680	1090	1105	1100	1070	1080	1040	1040	1030	908	1000
SLUDGE	120	120	110	110	185	200	210	170	235	210	235	245	210
SLUDGE VOL. (L/P)	108	108	99	99	166.5	180	189	153	211.5	189	211.5	220.5	189
ST-RATE		0	-0.1168831	0	1.1637931	0.1956522	0.07258	-0.83721	1.17	-0.3	0.3629	0.11392	-0.57273
LT-RATE			-0.062069		0.5487805		0.11658		0.24194		0		-0.16791
XLT-RATE				-0.0428571			0.35857			0			0

8STE LAAN NO 7	ADULTS	CHILDREN		AREA:	3.024								
NO. OF USERS	1	0											
SCUM	0	5	0	5	0	0	10	0	0	0	2	0	0
FLUID	900	1050	1145	1335	1345	1330	800	800	790	845	790	810	725
SLUDGE	110	140	135	120	115	135	190	165	150	150	170	170	230
SLUDGE VOL. (L/P)	332.64	423.36	408.24	362.88	347.76	408.24	574.56	498.96	453.6	453.6	514.08	514.08	695.52
ST-RATE		1.3341176	-0.1963636	-0.6978462	-0.2606897	0.8765217	1.34129	-1.75814	-0.9072	0	0.97548	0	3.29891
LT-RATE			0.5213793		-0.4917073		1.17513		-1.30065		0.44146		1.35403
XLT-RATE				0.144			0.84335			-0.72			1.23429

SLUDGE MONITORING AT WARDEN

DATE	07/22/93	09/27/93	12/13/93	02/16/94	04/14/94	06/22/94	10/24/94	12/06/94	01/26/95	04/11/95	06/12/95	08/30/95	10/24/95
DAYS	0	68	77	65	58	69	124	43	50	75	62	79	55
CUMULAT. DAYS	0	68	145	210	268	337	461	504	554	629	691	770	825
8STE LAAN NO 3	ADULTS	CHILDREN		AREA:	3.483								
NO. OF USERS	2	0											
SCUM	0	0	0	0	0	0	2	0	0	0	0	0	0
FLUID	1030	1010	1010	1030	1105	1015	975	995	1040	980	1000	955	1000
SLUDGE	35	65	60	50	65	75	100	80	75	85	60	90	85
SLUDGE VOL. (L/P)	60.9525	113.1975	104.49	87.075	113.1975	130.6125	174.15	139.32	130.613	148.028	104.49	156.735	148.028
ST-RATE		0.7683088	-0.1130844	-0.2679231	0.4503879	0.2523913	0.35111	-0.81	-0.17415	0.2322	-0.70222	0.66133	-0.15832
LT-RATE			0.3002586		0.0707927		0.31582		-0.46815		-0.19068		0.32491
XLT-RATE				0.1243929			0.34691			-0.15549			0
BOARD. HOUSE	ADULTS	CHILDREN		AREA:	18								
NO. OF USERS	8	30											
SCUM	0	50	45	20	20	0	30	25	0	10	25	50	15
FLUID	0	470	380	300	200	310	400	380	320	350	390	375	400
SLUDGE	0	100	105	180	210	140	60	55	155	150	80	100	90
SLUDGE VOL. (L/P)	0	47.368421	49.736842	85.263158	99.473684	66.315789	28.4211	26.0526	73.4211	71.0526	37.8947	47.3684	42.6316
ST-RATE		0.6965944	0.0307587	0.5465587	0.2450091	-0.4805492	-0.3056	-0.05508	0.94737	-0.03158	-0.5348	0.11992	-0.08612
LT-RATE			0.3430127		0.4043646		-0.36815		0.48387		-0.25932		0.03535
XLT-RATE				0.406015			-0.22646			0.25376			-0.14501

SLUDGE MONITORING AT WARDEN

DATE	07/22/93	09/27/93	12/13/93	02/16/94	04/14/94	06/22/94	10/24/94	12/06/94	01/26/95	04/11/95	06/12/95	08/30/95	10/24/95
DAYS	0	68	77	65	58	69	124	43	50	75	62	79	55
CUMULAT. DAYS	0	68	145	210	268	337	461	504	554	629	691	770	825
7DE LAAN 20	ADULTS	CHILDREN		AREA:	4.4								
NO. OF USERS	3	0											
SCUM	0	0	0	0	0	0	5	0	0	5	5	10	5
FLUID	1075	1445	975	1195	400	1150	1115	1120	970	1130	1085	1010	1010
SLUDGE	90	150	130	145	120	100	125	120	125	100	150	240	200
SLUDGE VOL. (L/P)	132	220	190.66667	212.66667	176	146.66667	183.333	176	183.333	146.667	220	352	293.333
ST-RATE		1.2941176	-0.3809524	0.3384615	-0.6321839	-0.4251208	0.2957	-0.17054	0.14667	-0.48889	1.1828	1.67089	-1.06667
LT-RATE			0.4045977		-0.1192412		0.038		0		0.26764		0.54726
XLT-RATE				0.384127			-0.11687			-0.21825			0.7483
7DE LAAN NO 23	ADULTS	CHILDREN		AREA:	3.465								
NO. OF USERS	3	0											
SCUM	0	0	0	0	0	0	0	0	0	0	0	0	0
FLUID	1000	1155	1200	1220	1170	1145	1190	1170	1145	1155	1170	1155	1230
SLUDGE	60	80	70	75	110	110	90	95	100	120	110	140	140
SLUDGE VOL. (L/P)	69.3	92.4	80.85	86.625	127.05	127.05	103.95	109.725	115.5	138.6	127.05	161.7	161.7
ST-RATE		0.3397059	-0.15	0.0888462	0.6969828	0	-0.18629	0.1343	0.1155	0.308	-0.18629	0.43861	0
LT-RATE			0.0796552		0.3756098		-0.11969		0.12419		0.08431		0.25858
XLT-RATE				0.0825			0.06902			0.20625			0.11786

SLUDGE MONITORING AT UMBUMBULU

BIOTAG DIAMETER *1.0m*
AREA *0.785*

DATE	11/12/92	01/13/93	03/17/93	05/18/93	07/21/93	09/28/93	12/15/93	02/18/94	06/24/94	10/26/94	12/07/94	02/16/95	04/11/95	06/14/95	09/01/95	10/26/95
DAYS	0	62	63	63	64	69	78	65	126	124	42	71	54	64	79	55
CUMULAT. DAYS	0	62	125	188	252	321	399	464	590	714	756	827	881	945	1024	1079
C924	ADULT	CHILDREN		AREA:	0.785											
NO. OF USERS	5	2														
SCUM	30	20	5	10	60	200	130	220	310	-	-	15	5	50	50	100
FLUID	870	1050	920	925	980	900	870	1085	1190	-	-	1215	1155	1105	1100	1000
SLUDGE	380	110	330	360	210	250	260	185	90	-	-	50	105	150	150	270
SLUDGE VOLUME (L)	298.3	86.35	259.05	282.6	164.85	196.25	204.1	145.225	70.65	0	0	39.25	82.425	117.75	117.75	211.95
ST-RATE		-0.488364	0.39161	0.0534014	-0.262835	0.0650104	0.0143773	-0.129396	-0.084552	-0.0814	0	0.07897	0.11422	0.07885	0	0.24468
LT-RATE			-0.044857		-0.105962		0.0381438		-0.099813		-0.0608		0.0942		0.03529	
XLT-RATE				-0.01193			-0.053148			-0.0926			0.07051			0.09345
SLUDGE VOL. (L/P)	42.6143	12.335714	37.007143	40.371429	23.55	28.035714	29.157143	20.746429	10.092857	0	0	5.60714	11.775	16.8214	16.8214	30.2786
CUMLAT. RATE		0.1989631	0.2960571	0.2147416	0.0934524	0.0873387	0.0730755	0.0447121	0.0171065	0	0	0.00678	0.01337	0.0178	0.01643	0.02806
C925	ADULT	CHILDREN		AREA:	0.785											
NO. OF USERS	3	1														
SCUM	0	0	0	0	5	0	10	20	40	0	0	0	0	10	10	20
FLUID	1130	400	900	955	870	670	940	600	500	450	305	1220	1165	1110	1000	915
SLUDGE	150	250	385	290	400	520	300	670	760	800	965	80	125	200	300	360
SLUDGE VOLUME (L)	117.75	196.25	302.225	227.65	314	408.2	235.5	525.95	596.6	628	757.525	62.8	98.125	157	235.5	282.6
ST-RATE		0.3165323	0.4205357	-0.295933	0.3373047	0.3413043	-0.553526	1.1171154	0.1401786	0.06331	0.77098	-2.44621	0.16354	0.22998	0.24842	0.21409
LT-RATE			0.36895		0.0231791		-0.133503		0.472644		0.24236		-1.3188		0.24017	
XLT-RATE				0.1461436			0.0093009			0.31151			-0.7932			0.23292
SLUDGE VOL. (L/P)	29.4375	49.0625	75.55625	56.9125	78.5	102.05	58.875	131.4875	149.15	157	189.381	15.7	24.5313	39.25	58.875	70.65
CUMLAT. RATE		0.7913306	0.60445	0.3027261	0.3115079	0.3179128	0.1475564	0.2833782	0.2527966	0.21989	0.2505	0.01898	0.02784	0.04153	0.0575	0.06548

SLUDGE MONITORING AT UMBUMBULU

BIOTAG DIAMETER *1.0m*
AREA *0.785*

DATE	11/12/92	01/13/93	03/17/93	05/18/93	07/21/93	09/28/93	12/15/93	02/18/94	06/24/94	10/26/94	12/07/94	02/16/95	04/11/95	06/14/95	09/01/95	10/26/95
DAYS	0	62	63	63	64	69	78	65	126	124	42	71	54	64	79	55
CUMULAT. DAYS	0	62	125	188	252	321	399	464	590	714	756	827	881	945	1024	1079
C834	ADULT	CHILDREN		AREA:	0.785	!! TURNED INTO SEPTIC TANK !!										
NO. OF USERS	5	3														
SCUM	0	5	25	5	20	40	25	0	5	5	10	5	10	10	20	10
FLUID	1200	1180	1130	1170	1140	1120	1010	1220	1120	1100	1100	1240	1220	1190	1190	1120
SLUDGE	80	100	175	130	150	170	250	80	140	180	180	40	55	95	75	80
SLUDGE VOLUME (L)	62.8	78.5	137.375	102.05	117.75	133.45	196.25	62.8	109.9	141.3	141.3	31.4	43.175	74.575	58.875	62.8
ST-RATE		0.0316532	0.1168155	-0.070089	0.0306641	0.028442	0.100641	-0.256635	0.0467262	0.03165	0	-0.19349	0.02726	0.06133	-0.02484	0.00892
LT-RATE			0.074575		-0.019316		0.0667517		-0.056512		0.02364		-0.0981		0.04574	
XLT-RATE				0.0260971			0.0558057			-0.0218			-0.0734			0.01239
SLUDGE VOL. (L/P)	7.85	9.8125	17.171875	12.75625	14.71875	16.68125	24.53125	7.85	13.7375	17.6625	17.6625	3.925	5.39688	9.32188	7.35938	7.85
CUMLAT. RATE		0.1582661	0.137375	0.0678524	0.0584077	0.0519665	0.0614818	0.0169181	0.0232839	0.02474	0.02336	0.00475	0.00613	0.00986	0.00719	0.00728
C833	ADULT	CHILDREN		AREA:	0.785											
NO. OF USERS	2	4														
SCUM	80	0	40	50	260	230	325	280	350	-	-	0	0	0	30	25
FLUID	1050	0	935	1020	1030	840	775	1070		-	-	1010	900	855	865	630
SLUDGE	120	0	300	240	200	300	110	170		-	-	170	330	370	370	530
SLUDGE VOLUME (L)	94.2	0	235.5	188.4	157	235.5	86.35	133.45	0	0	0	133.45	259.05	290.45	290.45	416.05
ST-RATE		-0.253226	0.6230159	-0.124603	-0.081771	0.1896135	-0.318697	0.1207692	-0.176521	0	0	0.31326	0.38765	0.08177	0	0.38061
LT-RATE			0.1884		-0.103018		-0.080102		-0.075349		0		0.3454		0.0366	
XLT-RATE				0.0835106			-0.080608			-0.0457			0.25853			0.13215
SLUDGE VOL. (L/P)	15.7	0	39.25	31.4	26.166667	39.25	14.391667	22.241667	0	0	0	22.2417	43.175	48.4083	48.4083	69.3417
CUMLAT. RATE		0	0.314	0.1670213	0.103836	0.1222741	0.0360693	0.0479346	0	0	0	0.02689	0.04901	0.05123	0.04727	0.06426

SLUDGE MONITORING AT UMBUMBULU

BIOTAG DIAMETER *1.0m*
AREA *0.785*

DATE	11/12/92	01/13/93	03/17/93	05/18/93	07/21/93	09/28/93	12/15/93	02/18/94	06/24/94	10/26/94	12/07/94	02/16/95	04/11/95	06/14/95	09/01/95	10/26/95
DAYS	0	62	63	63	64	69	78	65	126	124	42	71	54	64	79	55
CUMULAT. DAYS	0	62	125	188	252	321	399	464	590	714	756	827	881	945	1024	1079
C840	ADULT	CHILDREN		AREA:	0.785											
NO. OF USERS	5	4														
SCUM	0	0	0	0	5	0	0	0	0	15	25	0	0	10	10	10
FLUID	1255	0	1140	1095	1020	990	1000	1025	775	720	800	800	845	855	795	985
SLUDGE	25	0	145	205	270	255	255	230	350	560	480	430	300	350	395	400
SLUDGE VOLUME (L)	19.625	0	113.825	160.925	211.95	200.175	200.175	180.55	274.75	439.6	376.8	337.55	235.5	274.75	310.075	314
ST-RATE		-0.03517	0.2007496	0.0830688	0.0885851	-0.018961	0	-0.033547	0.0830688	0.14772	-0.1661	-0.06142	-0.21	0.06814	0.04968	0.00793
LT-RATE			0.0837333		0.0858486		-0.0089		0.0433828		0.06831		-0.1256		0.05794	
XLT-RATE				0.0835106			0.0206688			0.08445			-0.1358			0.04405
SLUDGE VOL. (L/P)	2.18056	0	12.647222	17.880556	23.55	22.241667	22.241667	20.061111	30.527778	48.8444	41.8667	37.5056	26.1667	30.5278	34.4528	34.8889
CUMLAT. RATE		0	0.1011778	0.0951093	0.0934524	0.0692887	0.0557435	0.0432352	0.051742	0.06841	0.05538	0.04535	0.0297	0.0323	0.03365	0.03233
C839	ADULT	CHILDREN		AREA: !!!	0.785	HORIZONT TANK !!!										
NO. OF USERS	3	3														
SCUM	0	5	40	5	10	7	15	20	40	50	85	25	0	50	50	50
FLUID	640	575	640	570	545	550	555	550	500	400	385	370	350	360	290	335
SLUDGE	0	100	0	175	189	200	190	200	215	330	350	380	400	370	420	370
SLUDGE VOLUME (L)	0	78.5	0	137.375	148.365	157	149.15	157	168.775	259.05	274.75	298.3	314	290.45	329.7	290.45
ST-RATE		0.2110215	-0.207672	0.3634259	0.0286198	0.0208575	-0.016774	0.0201282	0.0155754	0.12134	0.0623	0.05528	0.04846	-0.06133	0.08281	-0.11894
LT-RATE			0		0.1947047		0.00089		0.0171248		0.1064		0.05233		0.0183	
XLT-RATE				0.1217863			0.0093009			0.05815			0.05484			-0.01982
SLUDGE VOL. (L/P)	0	13.083333	0	22.895833	24.7275	26.166667	24.858333	26.166667	28.129167	43.175	45.7917	49.7167	52.3333	48.4083	54.95	48.4083
CUMLAT. RATE		0.2110215	0	0.1217863	0.098125	0.0815161	0.0623016	0.0563937	0.0476766	0.06047	0.06057	0.06012	0.0594	0.05123	0.05366	0.04486

SLUDGE MONITORING AT UMBUMBULU

BIOTAG DIAMETER *1.0m*
AREA *0.785*

DATE	11/12/92	01/13/93	03/17/93	05/18/93	07/21/93	09/28/93	12/15/93	02/18/94	06/24/94	10/26/94	12/07/94	02/16/95	04/11/95	06/14/95	09/01/95	10/26/95
DAYS	0	62	63	63	64	69	78	65	126	124	42	71	54	64	79	55
CUMULAT. DAYS	0	62	125	188	252	321	399	464	590	714	756	827	881	945	1024	1079
C907	ADULT	CHILDREN		AREA:	0.785											
NO. OF USERS	2.5	3														
SCUM	0	15	35	35	20	5	25	5	35	25	10	0	5	0	0	0
FLUID	12280	1200	1250	1145	1120	1100	1040	1260	1210	1230	1070	1095	1215	1135	1050	1000
SLUDGE	0	90	70	160	180	220	260	60	100	80	255	30	110	180	235	270
SLUDGE VOLUME (L)	0	70.65	54.95	125.6	141.3	172.7	204.1	47.1	78.5	62.8	200.175	23.55	86.35	141.3	184.475	211.95
ST-RATE		0.2071848	-0.04531	0.2038961	0.0446023	0.0827404	0.0731935	-0.439161	0.0453102	-0.023	0.5947	-0.4523	0.21145	0.15611	0.09937	0.09083
LT-RATE			0.0799273		0.123622		0.0776747		-0.119562		0.13327		-0.1656		0.12476	
XLT-RATE				0.12147			0.0676433			-0.0816			0.02564			0.11534
SLUDGE VOL. (L/P)	0	12.845455	9.9909091	22.836364	25.690909	31.4	37.109091	8.5636364	14.272727	11.4182	36.3955	4.28182	15.7	25.6909	33.5409	38.5364
CUMLAT. RATE		0.2071848	0.0799273	0.12147	0.1019481	0.0978193	0.0930052	0.0184561	0.0241911	0.01599	0.04814	0.00518	0.01782	0.02719	0.03275	0.03571
C905	ADULT	CHILDREN		AREA:	0.785											
NO. OF USERS	4	0														
SCUM	0	5	30	10	5	0	5	5	0	25	15	30	20	15	30	25
FLUID	1080	950	1050	990	980	920	830	765	890	765	845	810	785	870	790	785
SLUDGE	200	300	130	300	300	350	435	520	360	500	390	460	500	420	400	450
SLUDGE VOLUME (L)	157	235.5	102.05	235.5	235.5	274.75	341.475	408.2	282.6	392.5	306.15	361.1	392.5	329.7	314	353.25
ST-RATE		0.3165323	-0.529563	0.5295635	0	0.1422101	0.2138622	0.2566346	-0.249206	0.22157	-0.514	0.19349	0.14537	-0.24531	-0.04968	0.17841
LT-RATE			-0.1099		0.2626969		0.1802296		-0.077062		0.03547		0.1727		-0.13724	
XLT-RATE				0.1043883			0.1255628			0.0405			0			-0.04956
SLUDGE VOL. (L/P)	39.25	58.875	25.5125	58.875	58.875	68.6875	85.36875	102.05	70.65	98.125	76.5375	90.275	98.125	82.425	78.5	88.3125
CUMLAT. RATE		0.9495968	0.2041	0.3131649	0.233631	0.2139798	0.2139568	0.2199353	0.1197458	0.13743	0.10124	0.10916	0.11138	0.08722	0.07666	0.08185

SLUDGE MONITORING AT UMBUMBULU

BIOTAG DIAMETER *1.0m*
AREA *0.785*

DATE	11/12/92	01/13/93	03/17/93	05/18/93	07/21/93	09/28/93	12/15/93	02/18/94	06/24/94	10/26/94	12/07/94	02/16/95	04/11/95	06/14/95	09/01/95	10/26/95
DAYS	0	62	63	63	64	69	78	65	126	124	42	71	54	64	79	55
CUMULAT. DAYS	0	62	125	188	252	321	399	464	590	714	756	827	881	945	1024	1079
C926	ADULT	CHILDREN		AREA:	0.785											
NO. OF USERS	4	0														
SCUM	0	0	0	0	5	2	5	5	0	0	0	0	0	0	0	5
FLUID	1120	980	1030	985	940	890	970	870	790	825	790	1220	1160	1120	1100	1000
SLUDGE	160	250	190	255	285	340	250	345	430	395	425	10	80	120	125	230
SLUDGE VOLUME (L)	125.6	196.25	149.15	200.175	223.725	266.9	196.25	270.825	337.55	310.075	333.625	7.85	62.8	94.2	98.125	180.55
ST-RATE		0.284879	-0.186905	0.2024802	0.0919922	0.1564312	-0.226442	0.2868269	0.1323909	-0.0554	0.14018	-1.1471	0.2544	0.12266	0.01242	0.37466
LT-RATE			0.0471		0.1468012		-0.046726		0.1849476		-0.0059		-0.5417		0.06176	
XLT-RATE				0.0991689			-0.00465			0.09034			-0.3702			0.14867
SLUDGE VOL. (L/P)	31.4	49.0625	37.2875	50.04375	55.93125	66.725	49.0625	67.70625	84.3875	77.5188	83.4063	1.9625	15.7	23.55	24.5313	45.1375
CUMLAT. RATE		0.7913306	0.2983	0.2661902	0.2219494	0.207866	0.1229637	0.1459186	0.1430297	0.10857	0.11033	0.00237	0.01782	0.02492	0.02396	0.04183
C908	ADULT	CHILDREN		AREA:	0.785											
NO. OF USERS	3	2														
SCUM	0	5	0	0	5	0	0	0	0	10	25	0	0	0	10	20
FLUID	0	1110	1055	1005	1000	960	930	925	790	950	610	1290	1205	1175	1070	1155
SLUDGE	0	170	225	240	270	300	350	350	500	320	700	30	75	170	200	190
SLUDGE VOLUME (L)	0	133.45	176.625	188.4	211.95	235.5	274.75	274.75	392.5	251.2	549.5	23.55	58.875	133.45	157	149.15
ST-RATE		0.4304839	0.1370635	0.037381	0.0735938	0.0682609	0.100641	0	0.1869048	-0.2279	1.42048	-1.48155	0.13083	0.23305	0.05962	-0.02855
LT-RATE			0.2826		0.0556299		0.0854422		0.1232984		0.18916		-0.785		0.13724	
XLT-RATE				0.2004255			0.0818483			-0.015			-0.2303			0.09119
SLUDGE VOL. (L/P)	0	26.69	35.325	37.68	42.39	47.1	54.95	54.95	78.5	50.24	109.9	4.71	11.775	26.69	31.4	29.83
CUMLAT. RATE		0.4304839	0.2826	0.2004255	0.1682143	0.146729	0.1377193	0.1184267	0.1330508	0.07036	0.14537	0.0057	0.01337	0.02824	0.03066	0.02765

SLUDGE MONITORING AT IVORY PARK

CALCAMITE TANKS: *1.2m DIAM*
AREA: *1.130976*

DATE	05/12/93	08/12/93	11/30/93	02/25/94	06/15/94	08/05/94	12/14/94	02/14/95	04/07/95	06/06/95	10/03/95
DAYS	0	92	109	71	110	51	131	62	52	60	119
CUMULAT. DAYS	0	92	201	272	382	433	564	626	678	738	857

1738	ADULT	CHILDREN		AREA:	1.13						
NO. OF USERS	5	1									
SCUM	0	0	0	0	1	0	5	5	5	5	25
FLUID	0	670	855	840	800	530	860	940	800	720	220
SLUDGE	0	215	300	300	265	190	145	170	130	200	30
SLUDGE VOL. (LT/P)	0	40.49167	56.5	56.5	49.908333	35.783333	27.308333	32.016667	24.483333	37.666667	5.65
ST-RATE		0.440127	0.1468654	0	-0.0599242	-0.2769608	-0.0646947	0.0759409	-0.1448718	0.2197222	-0.2690476
LT-RATE			0.2810945		-0.036418		-0.1241758		-0.0247807		-0.1052142
XLT-RATE				0.2077206			-0.0999715			0.0595307	

1739	ADULT	CHILDREN		AREA:	1.13						
NO. OF USERS	4	1									
SCUM	0	0	0	0	0	0	5	5	10	5	5
FLUID	885	770	830	190	535	395	570	860	250	820	190
SLUDGE	225	300	300	320	340	180	350	210	50	115	30
SLUDGE VOL. (LT/P)	50.85	67.8	67.8	72.32	76.84	40.68	79.1	47.46	11.3	25.99	6.78
ST-RATE		0.184239	0	0.063662	0.0410909	-0.7090196	0.2932824	-0.5103226	-0.6953846	0.2448333	-0.1614286
LT-RATE			0.0843284		0.0499448		0.0124176		-0.5947368		-0.0252514
XLT-RATE				0.0789338			0.0232192			-0.3052299	

SLUDGE MONITORING AT IVORY PARK

CALCAMITE TANKS: *1.2m DIAM*
AREA: *1.130976*

DATE	05/12/93	08/12/93	11/30/93	02/25/94	06/15/94	08/05/94	12/14/94	02/14/95	04/07/95	06/06/95	10/03/95
DAYS	0	92	109	71	110	51	131	62	52	60	119
CUMULAT. DAYS	0	92	201	272	382	433	564	626	678	738	857
1740	ADULT	CHILDREN		AREA:	1.13						
NO. OF USERS	2	1									
SCUM	0	0	0	0	0	0	0	0	0	0	0
FLUID	830	760	805	810	905	530	650	700	245	715	30
SLUDGE	195	180	140	200	160	190	220	255	60	90	0
SLUDGE VOL. (LT/P)	73.45	67.8	52.733333	75.333333	60.266667	71.566667	82.866667	96.05	22.6	33.9	0
ST-RATE		-0.06141	-0.1382263	0.3183099	-0.1369697	0.2215686	0.0862595	0.2126344	-1.4125	0.1883333	-0.2848739
LT-RATE			-0.103068		0.0416206		0.1241758		-0.528655		-0.126257
XLT-RATE				0.006924			0.0257991			-0.2814176	
1741	ADULT	CHILDREN		AREA:	1.13						
NO. OF USERS	2	0									
SCUM	0	0	0	0	0	0	20	25	10	10	10
FLUID	950	480	740	800	400	110	320	510	80	235	100
SLUDGE	90	85	240	180	140	65	80	70	25	65	30
SLUDGE VOL. (LT/P)	50.85	48.025	135.6	101.7	79.1	36.725	45.2	39.55	14.125	36.725	16.95
ST-RATE		-0.03071	0.8034404	-0.4774648	-0.2054545	-0.8308824	0.0646947	-0.091129	-0.4889423	0.3766667	-0.1661765
LT-RATE			0.4216418		-0.3121547		-0.1862637		-0.2725877		0.0157821
XLT-RATE				0.1869485			-0.1934932			-0.0487069	

SLUDGE MONITORING AT IVORY PARK

CALCAMITE TANKS: *1.2m DIAM*
AREA: *1.130976*

DATE	05/12/93	08/12/93	11/30/93	02/25/94	06/15/94	08/05/94	12/14/94	02/14/95	04/07/95	06/06/95	10/03/95
DAYS	0	92	109	71	110	51	131	62	52	60	119
CUMULAT. DAYS	0	92	201	272	382	433	564	626	678	738	857

1373	ADULT	CHILDREN		AREA:	1.13						
NO. OF USERS	3	0									
SCUM	0	0	0	0	0	0	0	emptied	0	0	5
FLUID	695	760	875	895	880	830	1110	-	725	1020	125
SLUDGE	365	260	255	230	240	290	25	-	45	150	0
SLUDGE VOL. (LT/P)	137.483	97.93333	96.05	86.633333	90.4	109.23333	9.4166667	0	16.95	56.5	0
ST-RATE		-0.42989	-0.0172783	-0.1326291	0.0342424	0.369281	-0.7619593	-0.1518817	0.3259615	0.6591667	-0.4747899
LT-RATE			-0.206136		-0.0312155		-0.4449634		0.0660819		-0.0946927
XLT-RATE				-0.1869485			-0.2644406			0.2705939	

1374	ADULT	CHILDREN		AREA:	1.13						
NO. OF USERS	5	0									
SCUM	0	0	0	0	0	0	25	emtied	5	0	5
FLUID	800	800	870	875	850	870	300	-	180	500	100
SLUDGE	275	185	200	250	270	240	100	-	55	100	30
SLUDGE VOL. (LT/P)	62.15	41.81	45.2	56.5	61.02	54.24	22.6	0	12.43	22.6	6.78
ST-RATE		-0.22109	0.0311009	0.1591549	0.0410909	-0.1329412	-0.2415267	-0.3645161	0.2390385	0.1695	-0.1329412
LT-RATE			-0.0843284		0.0874033		-0.2110989		-0.0892105		-0.0315642
XLT-RATE				-0.0207721			-0.1160959			0	

SLUDGE MONITORING AT IVORY PARK

CALCAMITE TANKS: *1.2m DIAM*
AREA: *1.130976*

DATE	05/12/93	08/12/93	11/30/93	02/25/94	06/15/94	08/05/94	12/14/94	02/14/95	04/07/95	06/06/95	10/03/95
DAYS	0	92	109	71	110	51	131	62	52	60	119
CUMULAT. DAYS	0	92	201	272	382	433	564	626	678	738	857
1372	ADULT	CHILDREN		AREA:	1.13						
NO. OF USERS	2	1									
SCUM	0	0	0	0	0	0	10	emptied	10	5	0
FLUID	0	600	830	765	740	720	900	-	300	800	145
SLUDGE	0	150	180	215	260	270	124	-	45	60	0
SLUDGE VOL. (LT/P)	0	56.5	67.8	80.983333	97.933333	101.7	46.706667	0	16.95	22.6	0
ST-RATE		0.61413	0.1036697	0.1856808	0.1540909	0.0738562	-0.4197964	-0.7533333	0.3259615	0.0941667	-0.189916
LT-RATE			0.3373134		0.1664825		-0.2814652		-0.2610234		-0.0946927
XLT-RATE				0.2977328			-0.1173858			-0.1385441	
1371	ADULT	CHILDREN		AREA:	1.13						
NO. OF USERS	6	0									
SCUM	0	0	0	0	10	20	10	emptied	50	5	10
FLUID	440	570	645	575	390	-(mixed)	835	-	475	830	110
SLUDGE	570	350	320	360	470	-	130	-	145	120	30
SLUDGE VOL. (LT/P)	107.35	65.91667	60.266667	67.8	88.516667	0	24.483333	0	27.308333	22.6	5.65
ST-RATE		-0.45036	-0.0518349	0.1061033	0.1883333	-1.7356209	0.1868957	-0.3948925	0.5251603	-0.0784722	-0.142437
LT-RATE			-0.2342454		0.1560773		-0.3518315		0.0247807		-0.1209963
XLT-RATE				-0.1454044			-0.1483447			-0.0108238	

SLUDGE MONITORING AT IVORY PARK

CALCAMITE TANKS: *1.2m DIAM*
AREA: *1.130976*

DATE	05/12/93	08/12/93	11/30/93	02/25/94	06/15/94	08/05/94	12/14/94	02/14/95	04/07/95	06/06/95	10/03/95
DAYS	0	92	109	71	110	51	131	62	52	60	119
CUMULAT. DAYS	0	92	201	272	382	433	564	626	678	738	857
1368	ADULT	CHILDREN		AREA:	1.13						
NO. OF USERS	4	1									
SCUM	0	0	0	0	0	0	0	emptied	10	0	10
FLUID	995	540	940	900	875	775	55	-	220	425	50
SLUDGE	165	140	210	100	240	130	35	-	45	80	20
SLUDGE VOL. (LT/P)	37.29	31.64	47.46	22.6	54.24	29.38	7.91	0	10.17	18.08	4.52
ST-RATE		-0.06141	0.1451376	-0.3501408	0.2876364	-0.487451	-0.1638931	-0.1275806	0.1955769	0.1318333	-0.1139496
LT-RATE			0.050597		0.0374586		-0.2545604		0.0198246		-0.0315642
XLT-RATE				-0.0540074			-0.077931			0.0584483	

MONITORING VIP LATRINES AT SOSHANGUVE

Pit size: *1m auger*
AREA: *0.785*

DATE	06/17/93	08/10/93	09/21/93	11/25/93	02/11/94	04/13/94	06/15/94	08/04/94	11/16/94	12/15/94	02/10/95	04/06/95	06/05/95	08/04/95	10/10/95
DAYS	0	53	42	65	78	61	63	50	103	29	57	55	60	60	66
CUMULAT. DAYS	0	53	95	160	238	299	362	412	515	544	601	656	716	776	842
1277FF	ADULT	CHILDREN													
NO. USERS	2	4													
DEPTH	1415	1400	1400	1410	1380	1335	1300	1335	1275	1200	1215	1175	1050	1020	1000
ST-RATE		0.037028	0	-0.02013	0.050321	0.09652	0.072685	-0.09158	0.07621	0.338362	-0.03443	0.095152	0.27257	0.065417	0.0396465
LT-RATE			0.020658		0.018298		0.084409		0.02138		0.09128		0.18772		0.051918
DELTA SLUDGE		1.9635	1.9635	0.6545	4.5815	10.472	15.0535	10.472	18.326	28.1435	26.18	31.416	47.7785	51.7055	54.3235
1278FF	ADULT	CHILDREN													
NO. USERS	2	3		no change											
DEPTH	1495	1405	1315	1285	1240	1190	1200	1130	1075	1070	1070	960	970	900	890
ST-RATE		0.266604	0.336429	0.072462	0.090577	0.12869	-0.02492	0.2198	0.08383	0.027069	0	0.314	-0.02617	0.183167	0.0237879
LT-RATE			0.297474		0.082343		0.050645		0.12827		0.00913		0.13652		0.0996825
DELTA SLUDGE		14.1372	28.2744	32.9868	40.0554	47.9094	46.3386	57.3342	65.9736	66.759	66.759	84.0378	82.467	93.4626	95.0334
1279FF	ADULT	CHILDREN					15-06-94								
NO. USERS	2	2				3	2								
DEPTH	1700	1615	1575	1590	1570	1555	1660	1560	1505	1450	1490	1490	1460	1440	1440
ST-RATE		0.314741	0.186905	-0.04529	0.050321	0.04826	-0.32708	0.3925	0.10479	0.372198	-0.13772	0	0.09813	0.065417	0
LT-RATE			0.258224		0.006862		-0.14244		0.19882		0.03423		0.0512		0.0311508
DELTA SLUDGE		16.68975	24.54375	21.5985	25.5255	28.4708	7.854	27.489	38.2883	49.0875	41.2335	41.2335	47.124	51.051	51.051
1280FF	ADULT	CHILDR	21-09-92												
NO. USERS	2	0	2	1											
DEPTH	1620	1500	1315	1215	1165	1385	1390	1420	1385	1320	1400	1360	1320	1315	1310
ST-RATE		0.888679	1.728869	0.603846	0.251603	-1.41557	-0.03115	-0.2355	0.13337	0.879741	-0.55088	0.285455	0.26167	0.032708	0.0297348
LT-RATE			1.260132		0.411713		-0.7122		0.01283		-0.06846		0.27304		0.0311508
DELTA SLUDGE		47.124	119.7735	159.0435	178.6785	92.2845	90.321	78.54	92.2845	117.81	86.394	102.102	117.81	119.7735	121.737

MONITORING VIP LATRINES AT SOSHANGUVE

Pit size: *1m auger*
AREA: *0.785*

DATE	06/17/93	08/10/93	09/21/93	11/25/93	02/11/94	04/13/94	06/15/94	08/04/94	11/16/94	12/15/94	02/10/95	04/06/95	06/05/95	08/04/95	10/10/95
DAYS	0	53	42	65	78	61	63	50	103	29	57	55	60	60	66
CUMULAT. DAYS	0	53	95	160	238	299	362	412	515	544	601	656	716	776	842
1295FF	ADULT	CHILDREN													
NO. USERS	4	3													
DEPTH	1820	1730	1735	1745	1490	1665	1560	1545	1425	1460	1410	1350	1200	1340	1100
ST-RATE		0.190431	-0.01335	-0.01725	0.366621	-0.32172	0.186905	0.033643	0.13065	-0.13534	0.09837	0.122338	0.28036	-0.26167	0.4077922
LT-RATE			0.100338		0.192133		-0.06331		0.09895		0.01956		0.20478		0.0890023
DELTA SLUDGE		10.098	9.537	8.415	37.026	17.391	29.172	30.855	44.319	40.392	46.002	52.734	69.564	53.856	80.784
1312FF	ADULT	CHILDREN													
NO. USERS	2	2		no change											
DEPTH	1645	1535	1525	1460	1190	1600	1730	1730	1705	1740	1735	1700	1730	1670	1700
ST-RATE		0.407311	0.046726	0.19625	0.679327	-1.31906	-0.40496	0	0.04763	-0.23685	0.01721	0.124886	-0.09813	0.19625	-0.0892045
LT-RATE			0.247895		0.459747		-0.85464		0.03207		-0.06846		0.00853		0.0467262
DELTA SLUDGE		21.5985	23.562	36.32475	89.33925	8.83575	-16.6898	-16.6898	-11.781	-18.6533	-17.6715	-10.7993	-16.6898	-4.90875	-10.79925
1313FF	ADULT	CHILDREN													
NO. USERS	2	2		no change											
DEPTH	2120	2020	1985	1800	1545	2035	2020	1950	1905	1880	1835	1800	1900	1860	1840
ST-RATE		0.370283	0.163542	0.558558	0.641587	-1.57643	0.046726	0.27475	0.08574	0.169181	0.15493	0.124886	-0.32708	0.130833	0.0594697
LT-RATE			0.278882		0.603846		-0.75176		0.14751		0.15974		-0.11092		0.0934524
DELTA SLUDGE		19.635	26.50725	62.832	112.9013	16.6898	19.635	33.3795	42.2153	47.124	55.9598	62.832	43.197	51.051	54.978
1314FF	ADULT	CHILDREN													
NO. USERS	2	1		no change											
DEPTH	1475	1450	1400	1360	1025	1340	1370	1400	1355	1330	1320	1170	1200	1200	1200
ST-RATE		0.123428	0.311508	0.161026	1.123825	-1.35123	-0.1246	-0.157	0.11432	0.225575	0.04591	0.713636	-0.13083	0	0
LT-RATE			0.206579		0.686189		-0.72802		0.02565		0.10649		0.27304		0
DELTA SLUDGE		6.545	19.635	30.107	117.81	35.343	27.489	19.635	31.416	37.961	40.579	79.849	71.995	71.995	71.995

MONITORING VIP LATRINES AT SOSHANGUVE

Pit size: *1m auger*
AREA: *0.785*

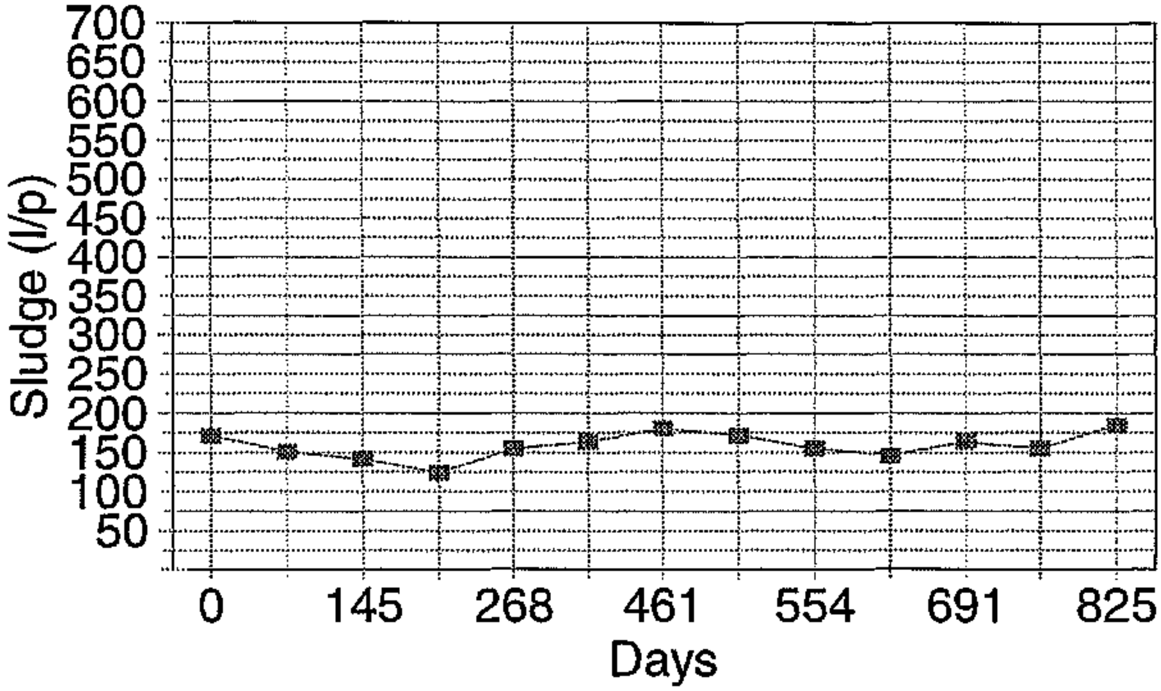
DATE	06/17/93	08/10/93	09/21/93	11/25/93	02/11/94	04/13/94	06/15/94	08/04/94	11/16/94	12/15/94	02/10/95	04/06/95	06/05/95	08/04/95	10/10/95
DAYS	0	53	42	65	78	61	63	50	103	29	57	55	60	60	66
CUMULAT. DAYS	0	53	95	160	238	299	362	412	515	544	601	656	716	776	842
1315FF	ADULT	CHILDREN		21-09-94											
NO. USERS	4	2	2	2											
DEPTH	1005	940	915	925	865	930	910	880	865	860	840	840	840	870	replaced wi
ST-RATE		0.160456	0.077877	-0.02013	0.100641	-0.13941	0.041534	0.0785	0.01905	0.022557	0.04591	0	0	-0.06542	1.7246212
LT-RATE			0.123947		0.045746		-0.04748		0.03848		0.03803		0		0.8722222
DELTA SLUDGE		8.5085	17.6715	15.708	27.489	14.7263	18.65325	24.54375	27.489	28.47075	32.3978	32.39775	32.3978	26.50725	197.33175
1316FF	ADULT	CHILDREN													
NO. USERS	2	3		no change											
DEPTH	1075	1000	1020	985	870	960	1090	1120	1155	1160	1050	945	1030	1080	945
ST-RATE		0.22217	-0.07476	0.084538	0.231474	-0.23164	-0.32397	-0.0942	-0.05335	-0.02707	0.30298	0.299727	-0.22242	-0.13083	0.3211364
LT-RATE			0.090895		0.164685		-0.27855		-0.0667		0.19169		0.0273		0.1059127
DELTA SLUDGE		11.781	8.6394	14.1372	32.2014	18.0642	-2.3562	-7.0686	-12.5664	-13.3518	3.927	20.4204	7.0686	-0.7854	20.4204
292FF	ADULT	CHILDREN													
NO. USERS	1	3													
DEPTH	2700	2570	2500	2100	1300	1480	1560	1730	1735	1180	1890	1560	1800	1950	1985
ST-RATE		0.481368	0.327083	1.207692	2.012821	-0.5791	-0.24921	-0.66725	-0.00953	3.755819	-2.44452	1.1775	-0.785	-0.49063	-0.104072
LT-RATE			0.413158		1.646853		-0.41149		-0.22447		-0.35371		0.15359		-0.2881448
DELTA SLUDGE		25.5255	39.27	117.81	274.89	239.547	223.839	190.4595	189.478	298.452	159.044	223.839	176.715	147.2625	140.39025

APPENDIX II

Graphs

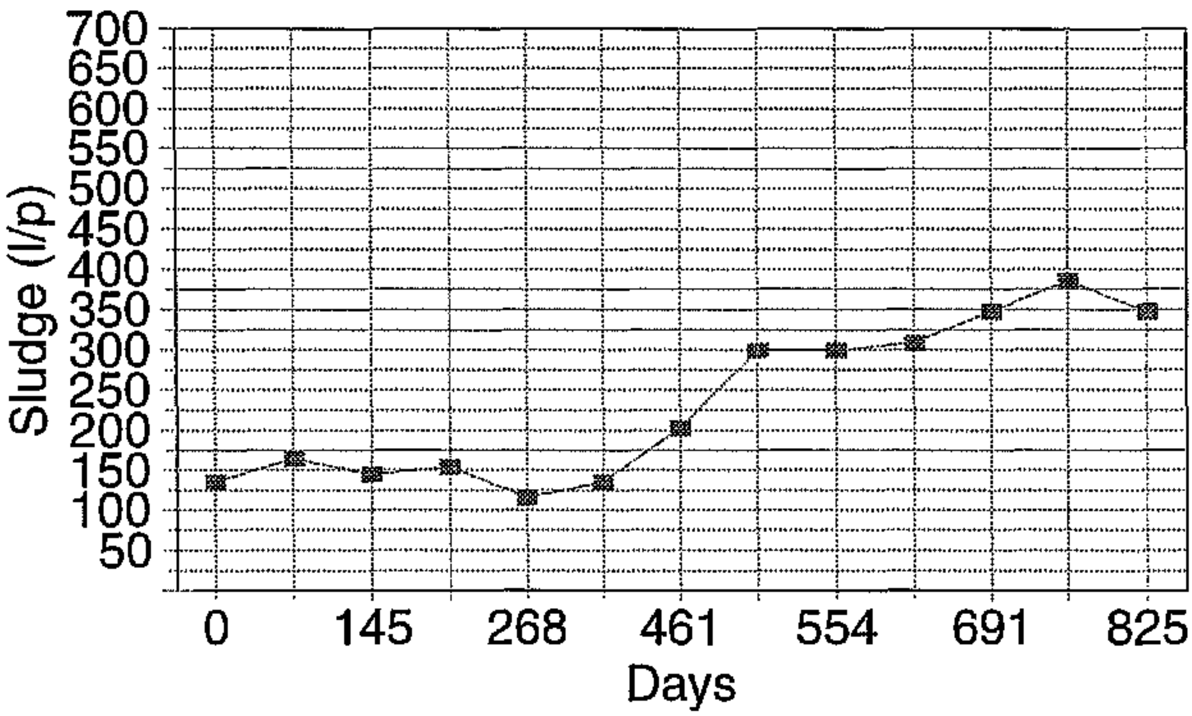
WARDEN: 7de Laan, no. 6

Sludge build up



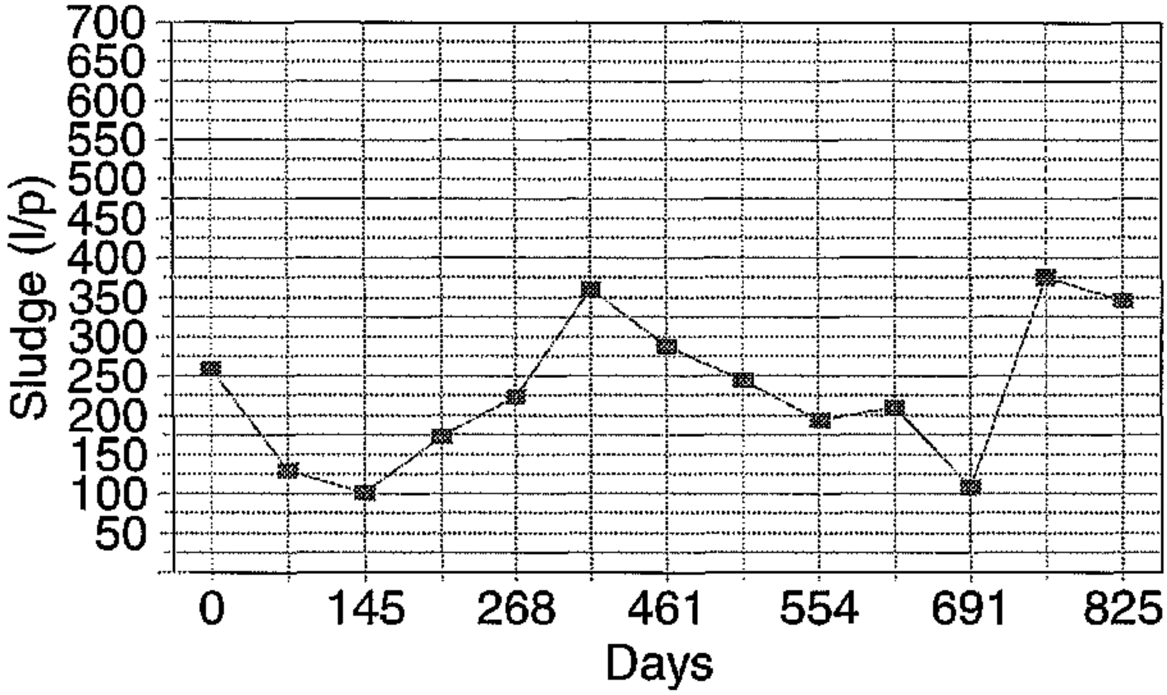
WARDEN: 7th Ave, no. 8

Sludge Build up



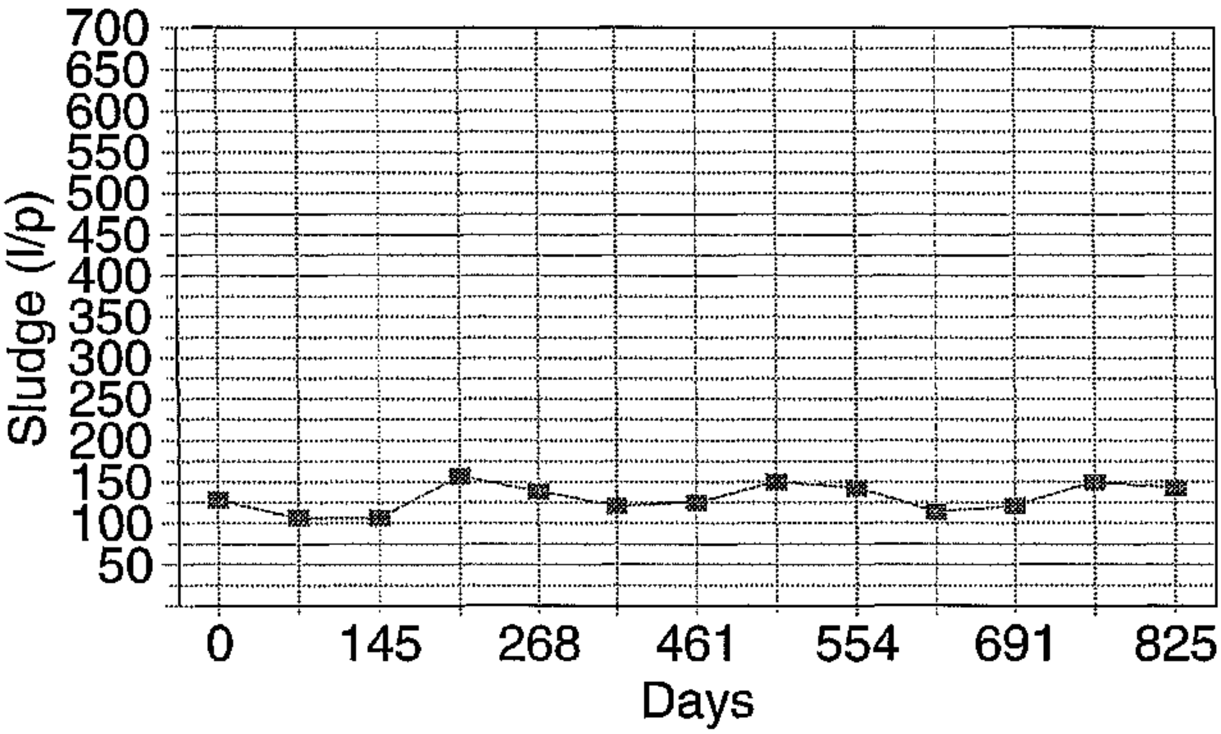
WARDEN: 7th Ave, no. 10

Sludge Build up



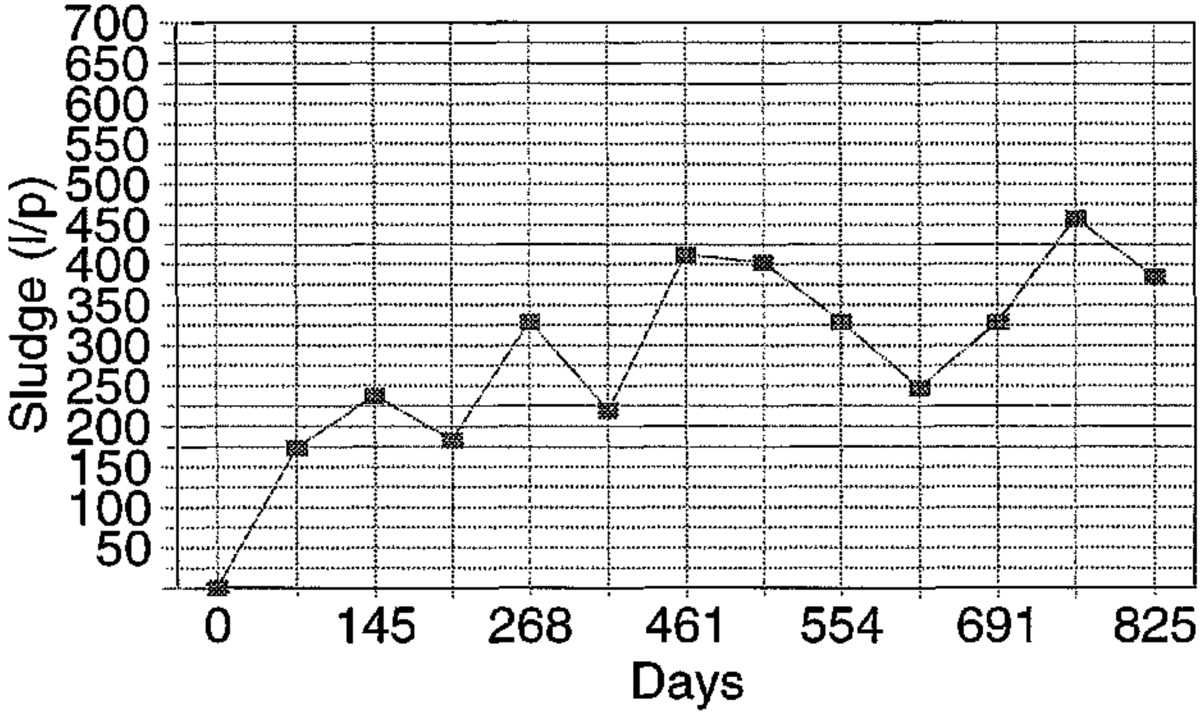
WARDEN: 7th Ave, no. 12

Sludge Build up



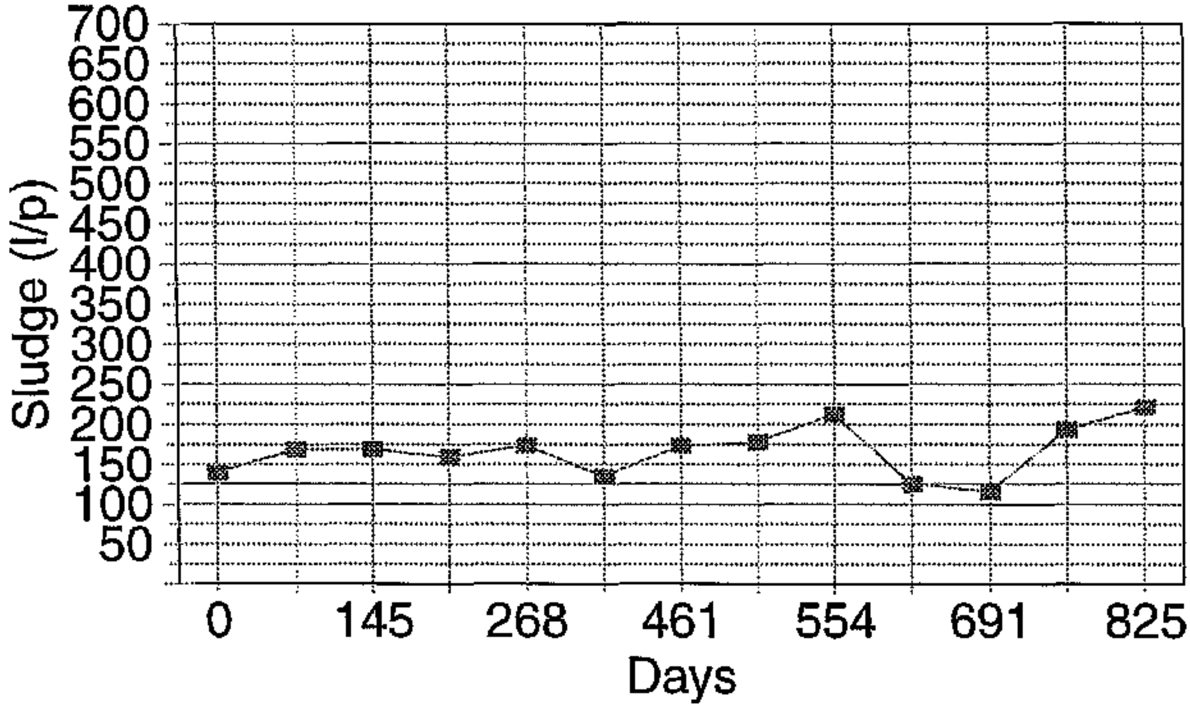
WARDEN: c/o 7th + Park

Sludge Build up



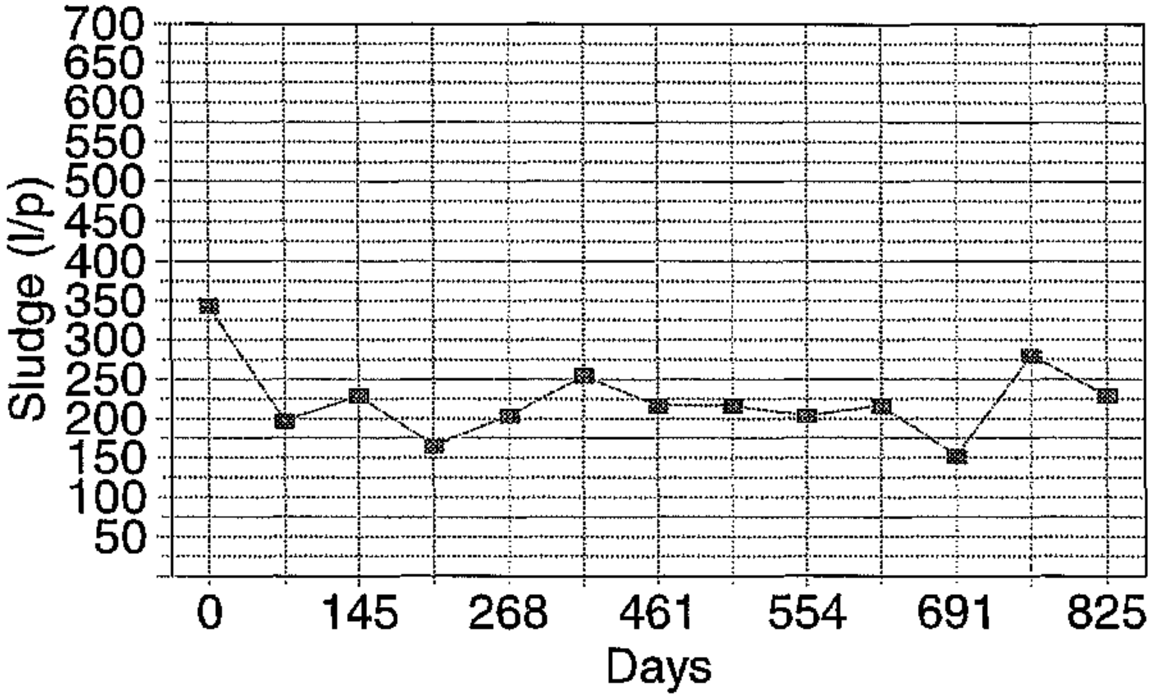
WARDEN: c/o 8th + Park

Sludge Build up



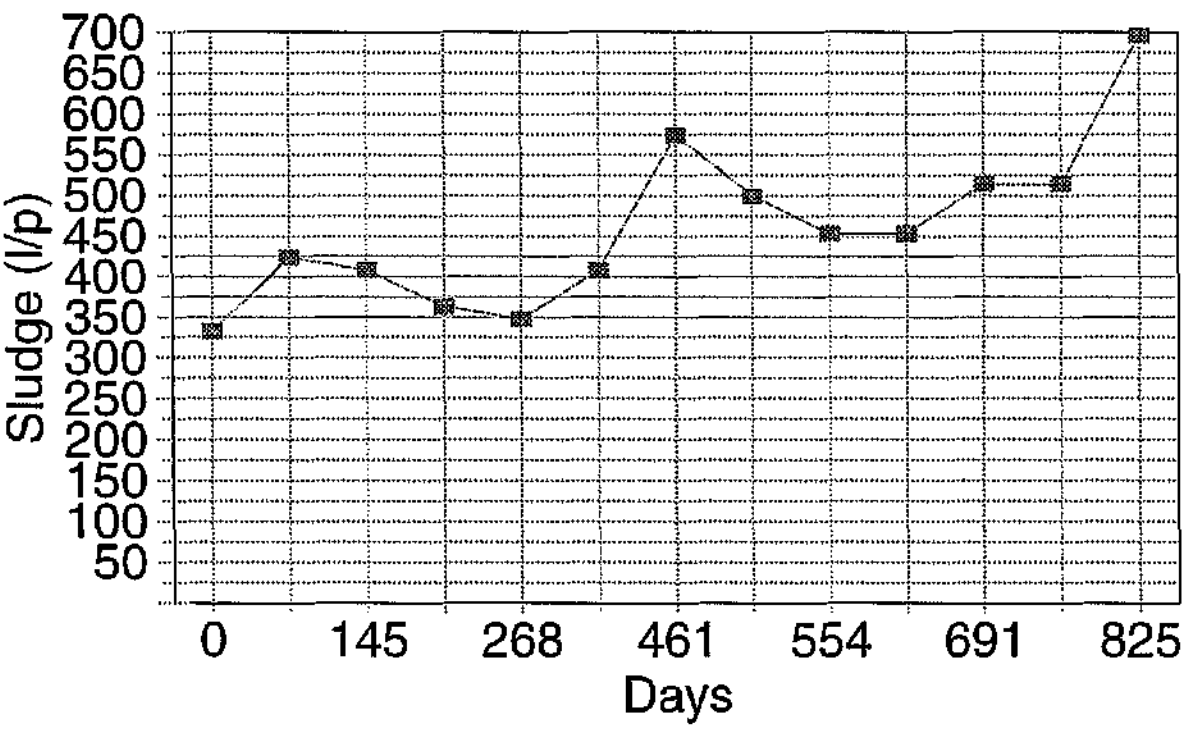
WARDEN: 8th Ave, no. 13

Sludge Build up



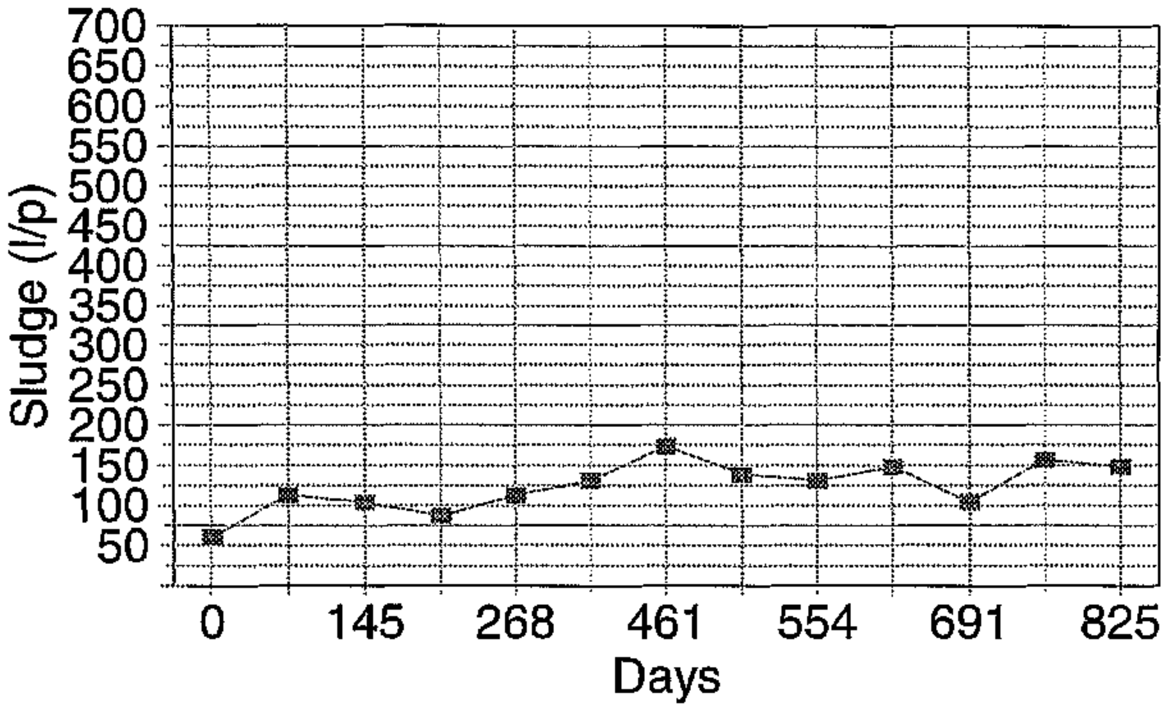
WARDEN: 8th Ave, no. 7

Sludge Build up



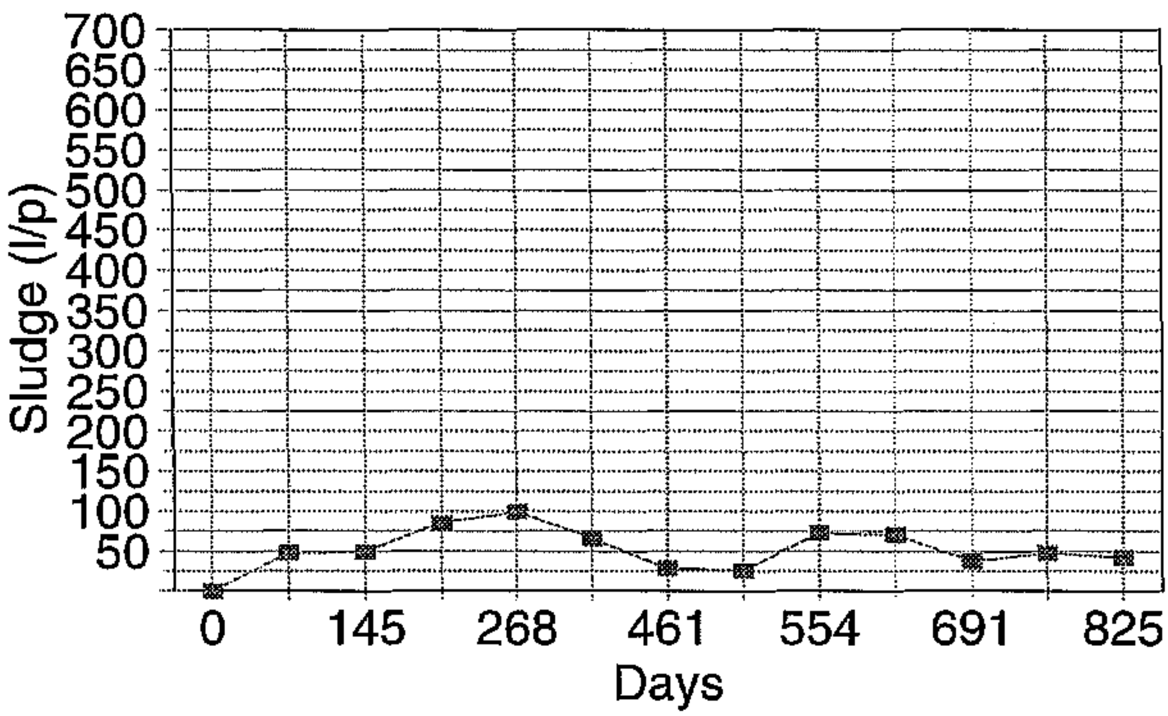
WARDEN: 8th Ave, no.3

Sludge Build up



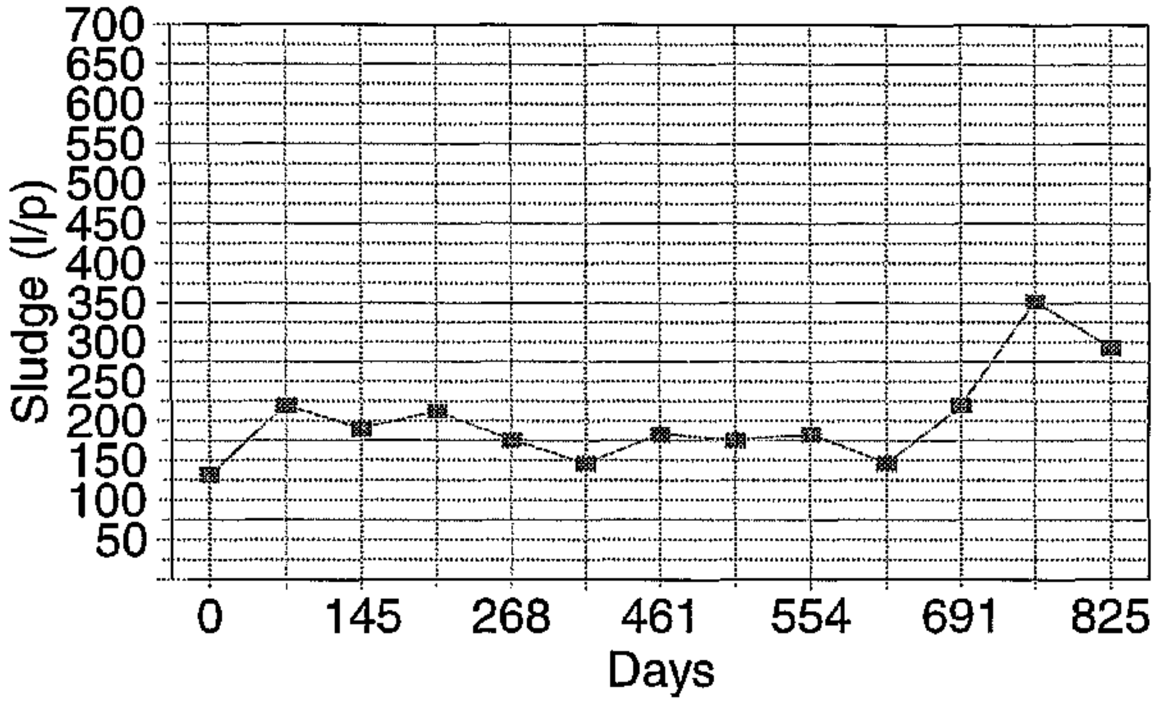
WARDEN: Boarding House

Sludge Build up



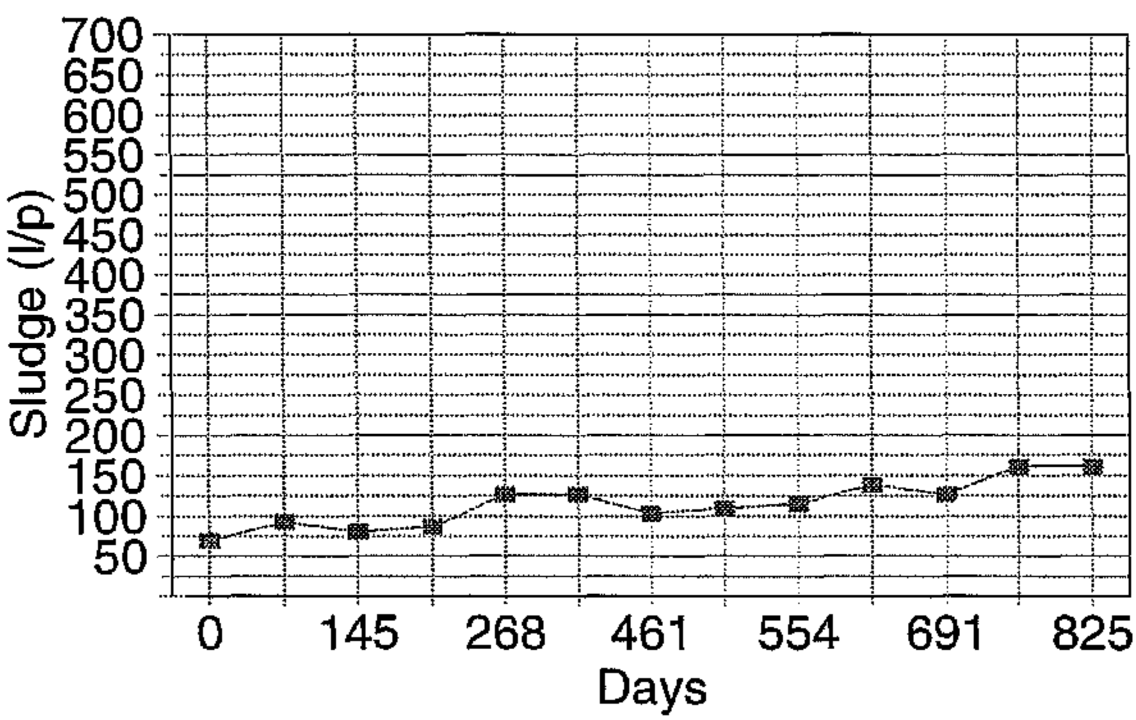
WARDEN: 7th Ave, no. 20

Sludge Build up



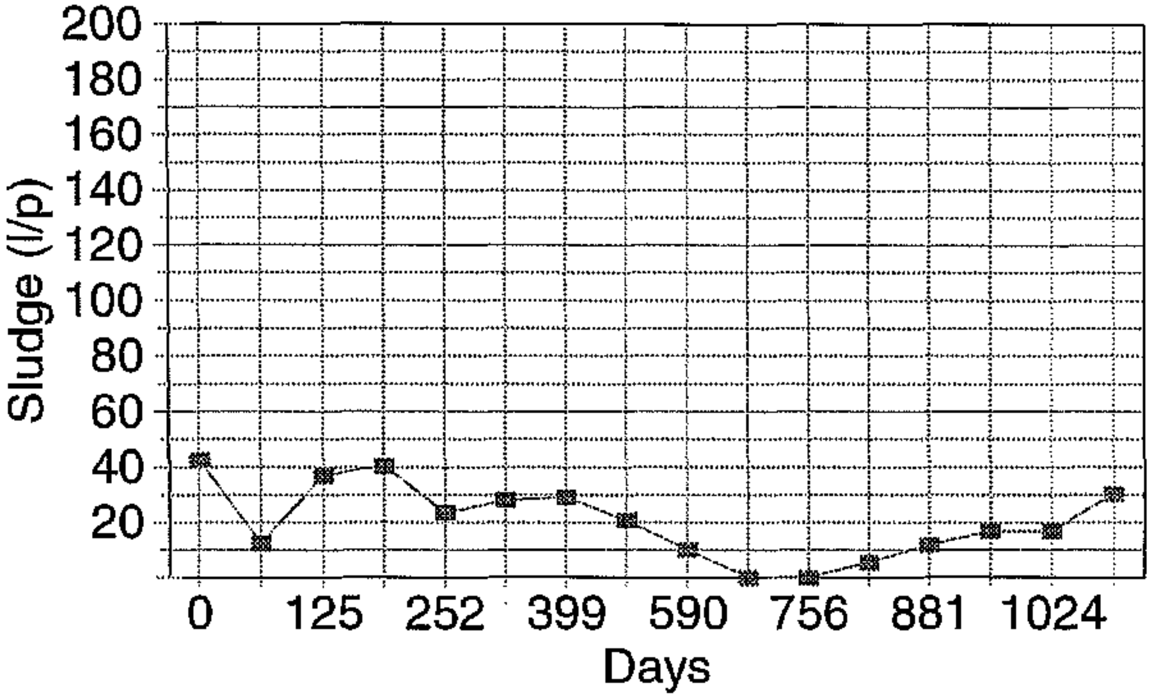
WARDEN: 7th Ave, no. 23

Sludge Build up



UMBUMBULU: C924

Sludge Build up



UMBUMBULU: C925

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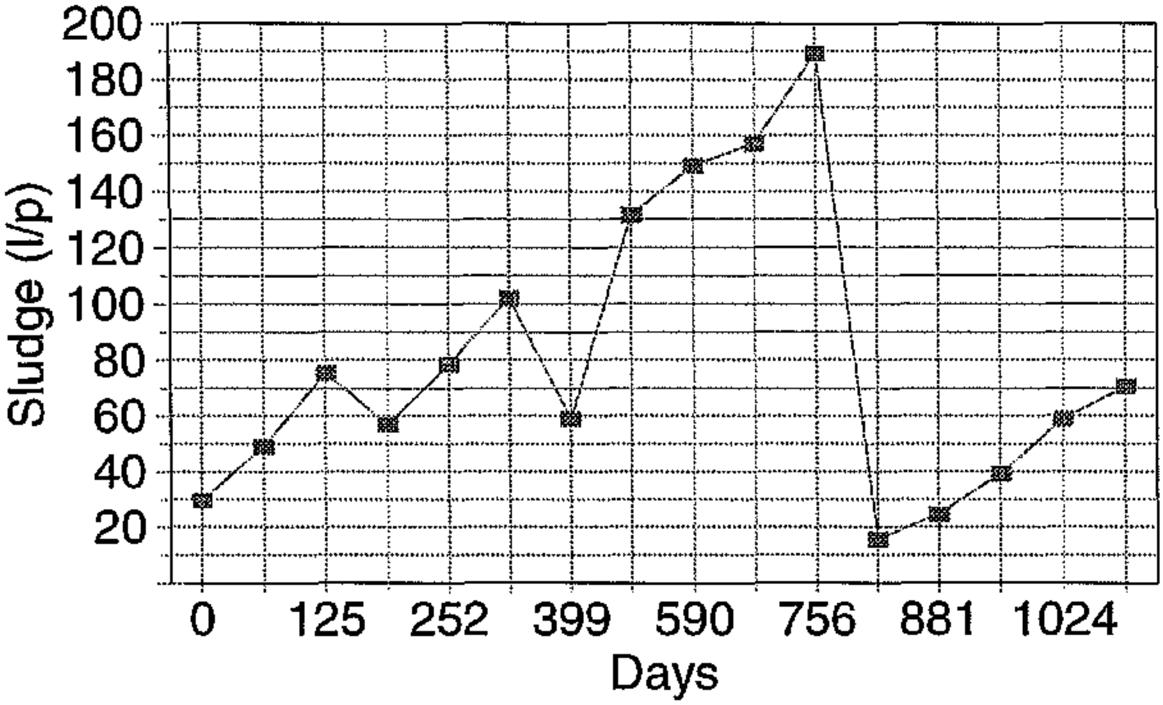

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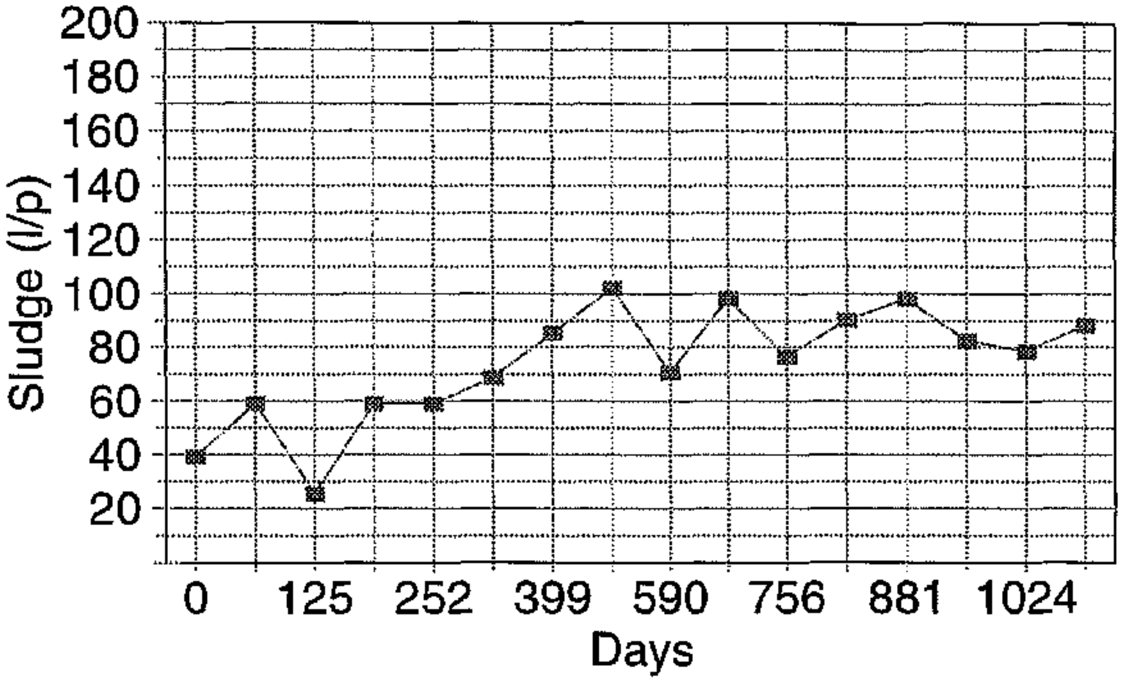
Sludge Build up



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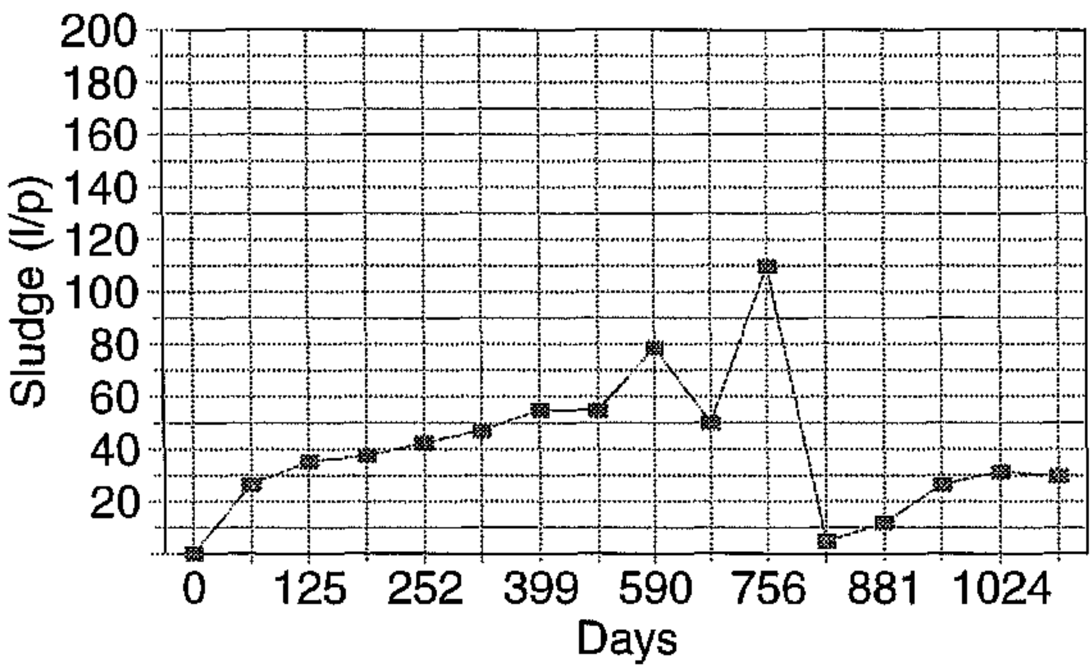
Sludge Build up



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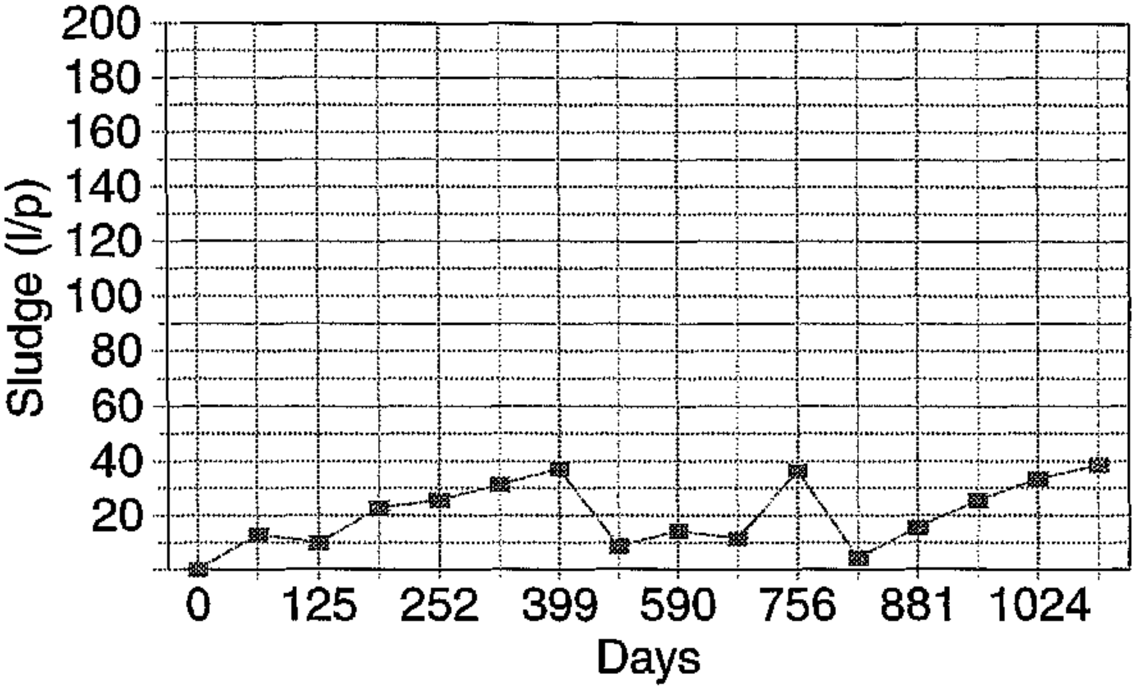
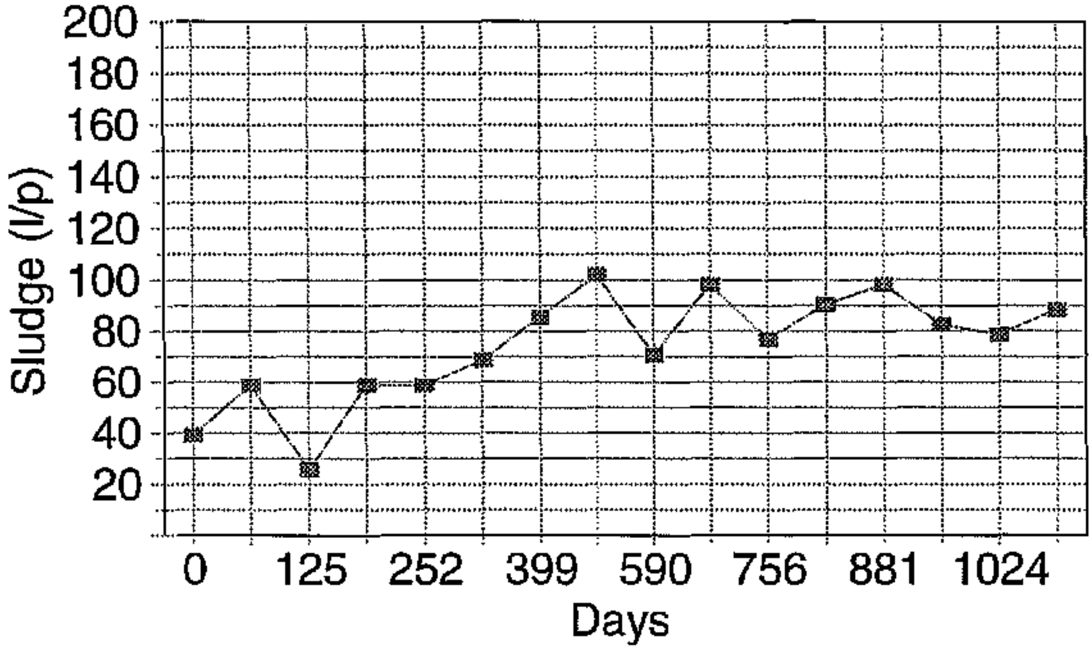
Sludge Build up



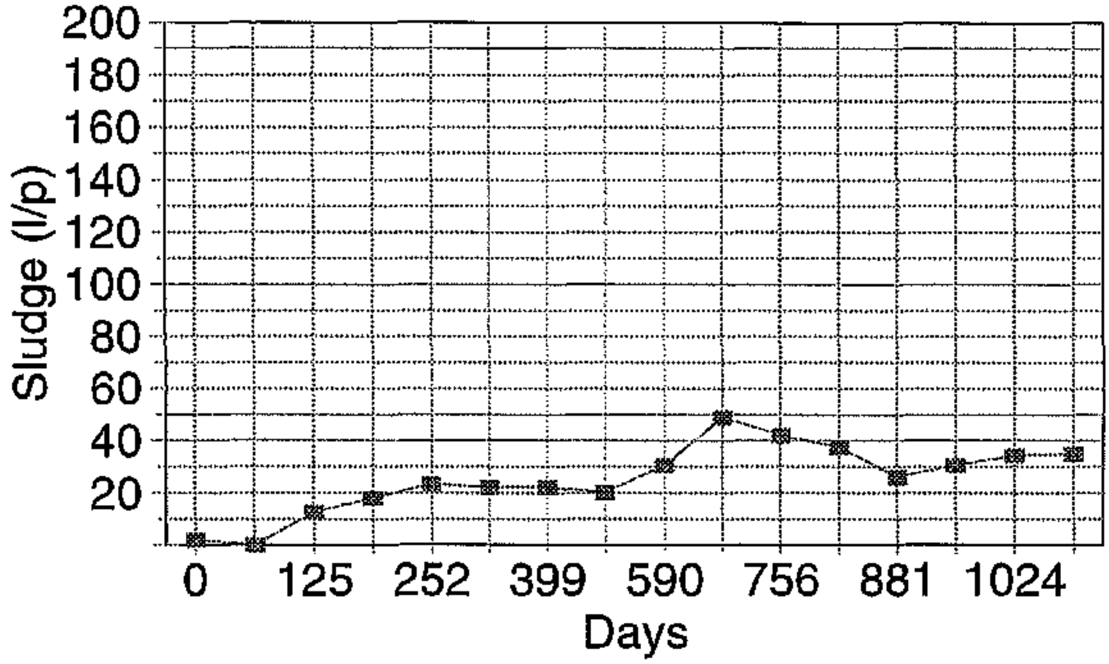
UMBUMBULU: C905

Sludge Build up



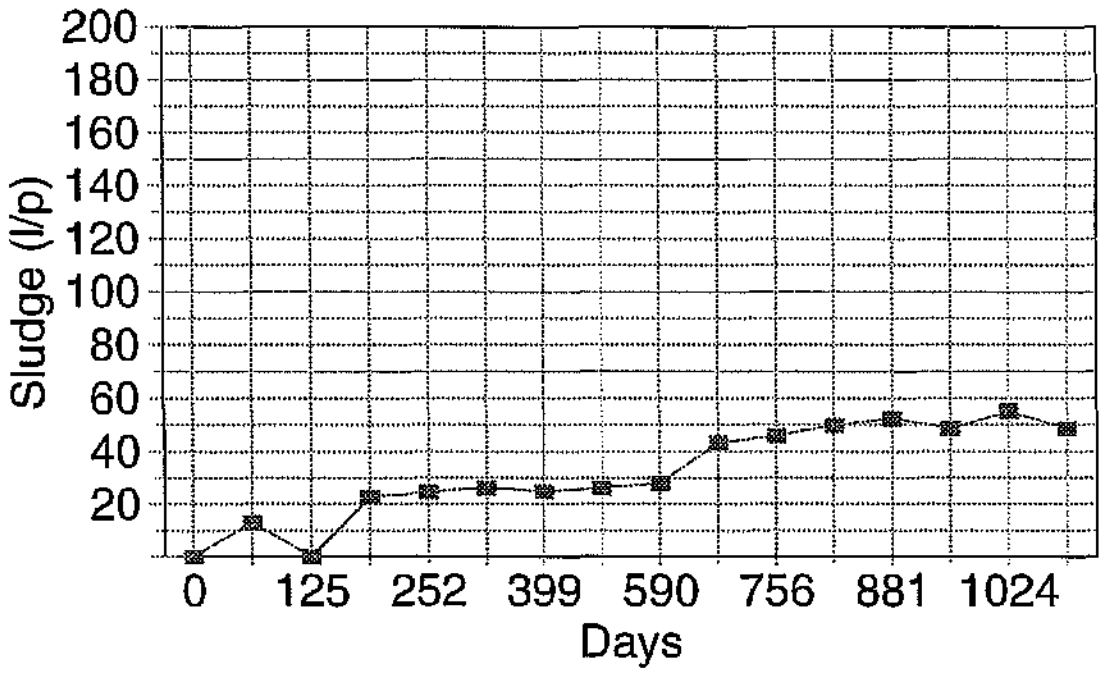
UMBUMBULU: C840

Sludge Build up



UMBUMBULU: C839

Sludge Build up



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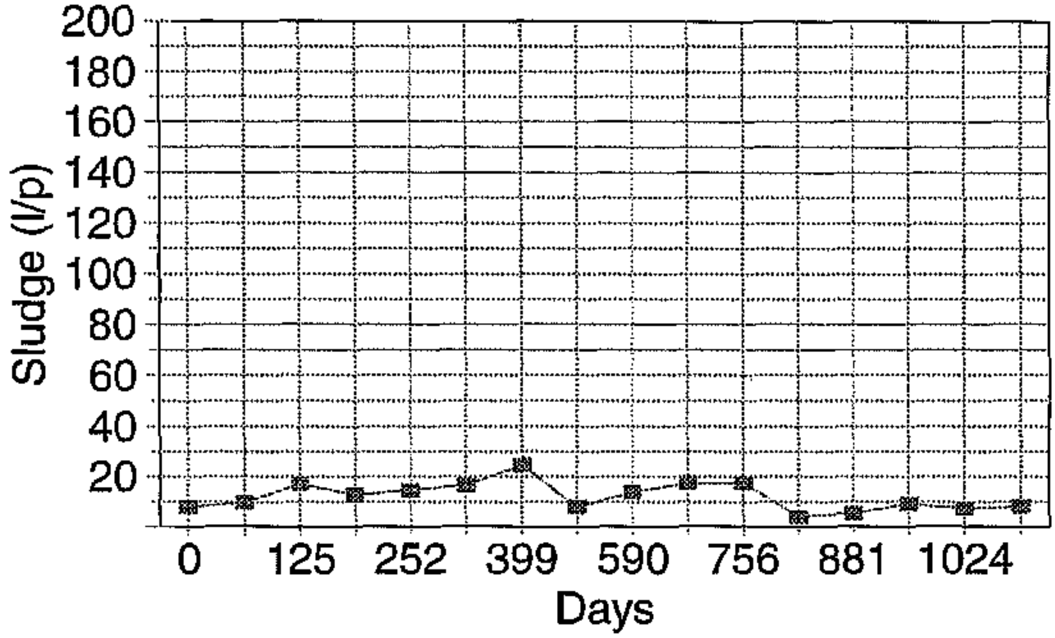
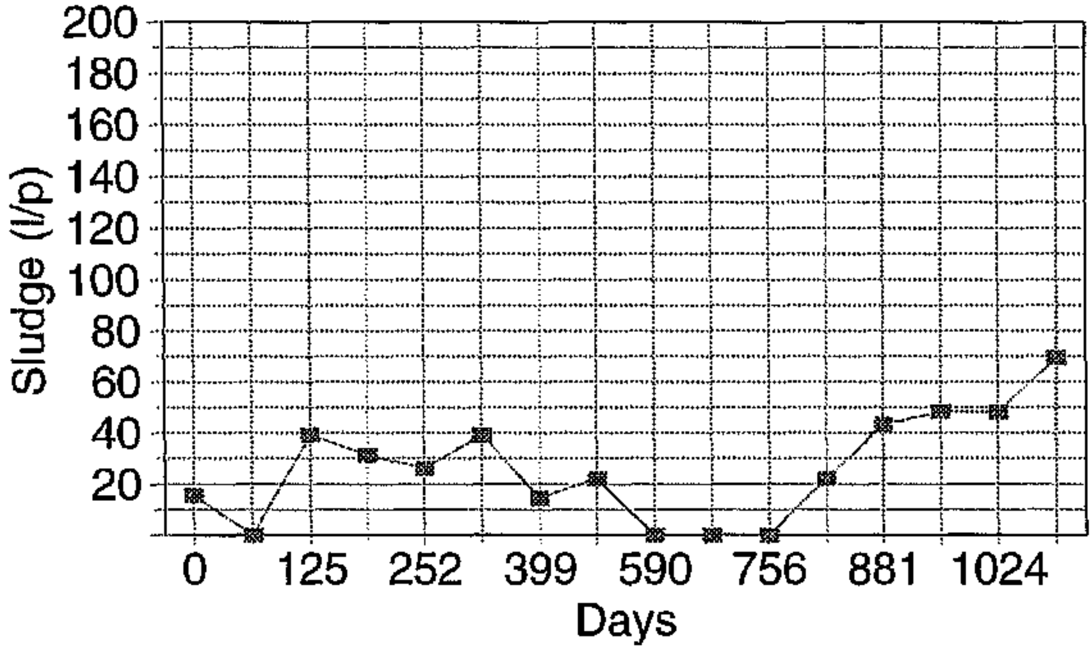
Sludge Build up



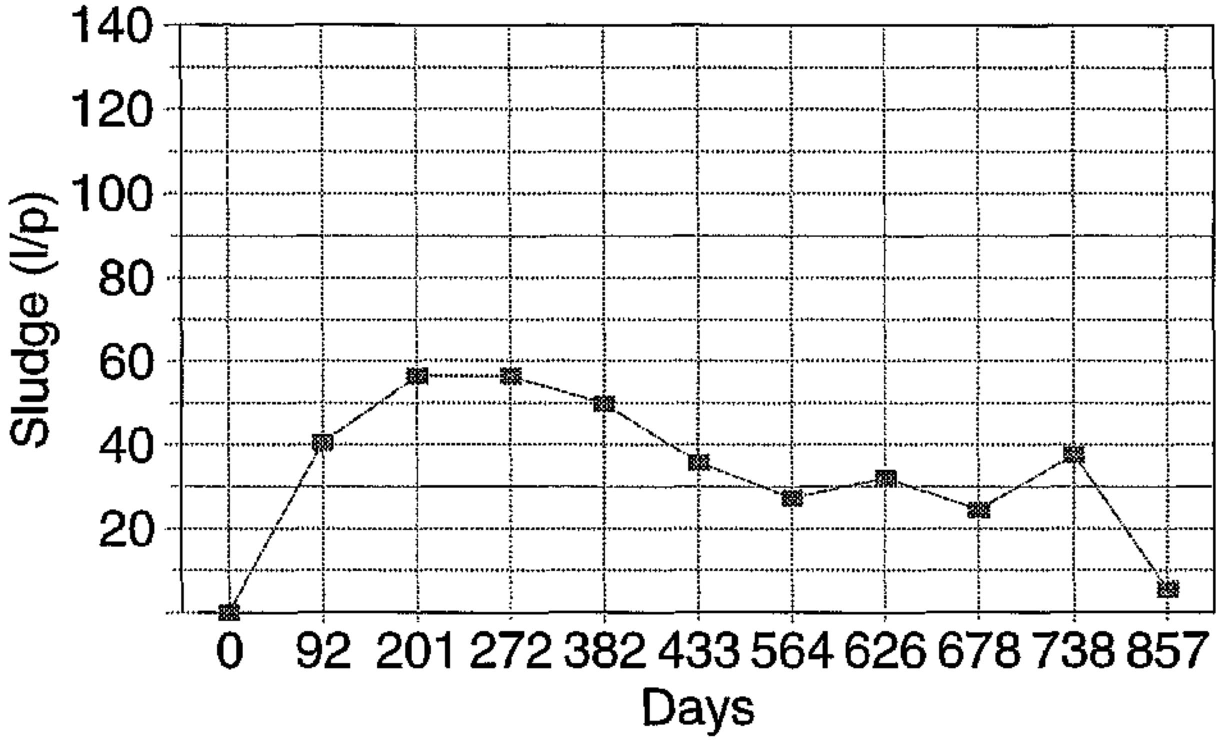
UMBUMBULU: C833

Sludge Build up



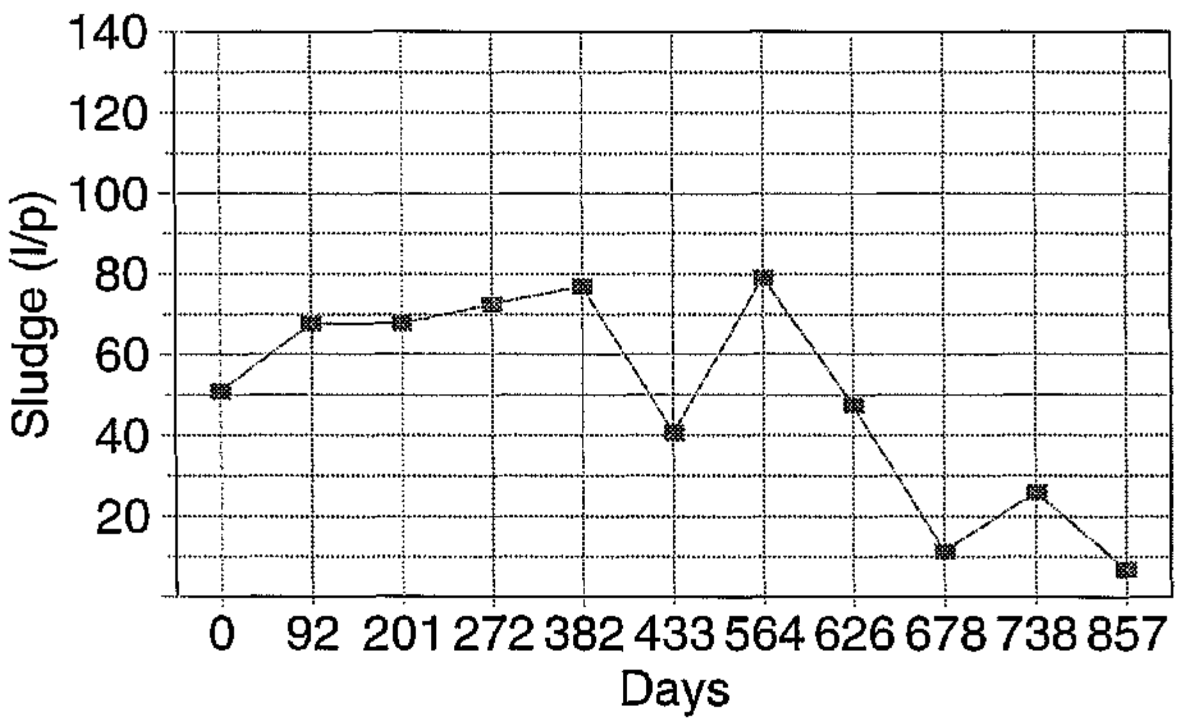
IVORY PARK: 1738

Sludge Build up



IVORY PARK: 1739

Sludge Build up



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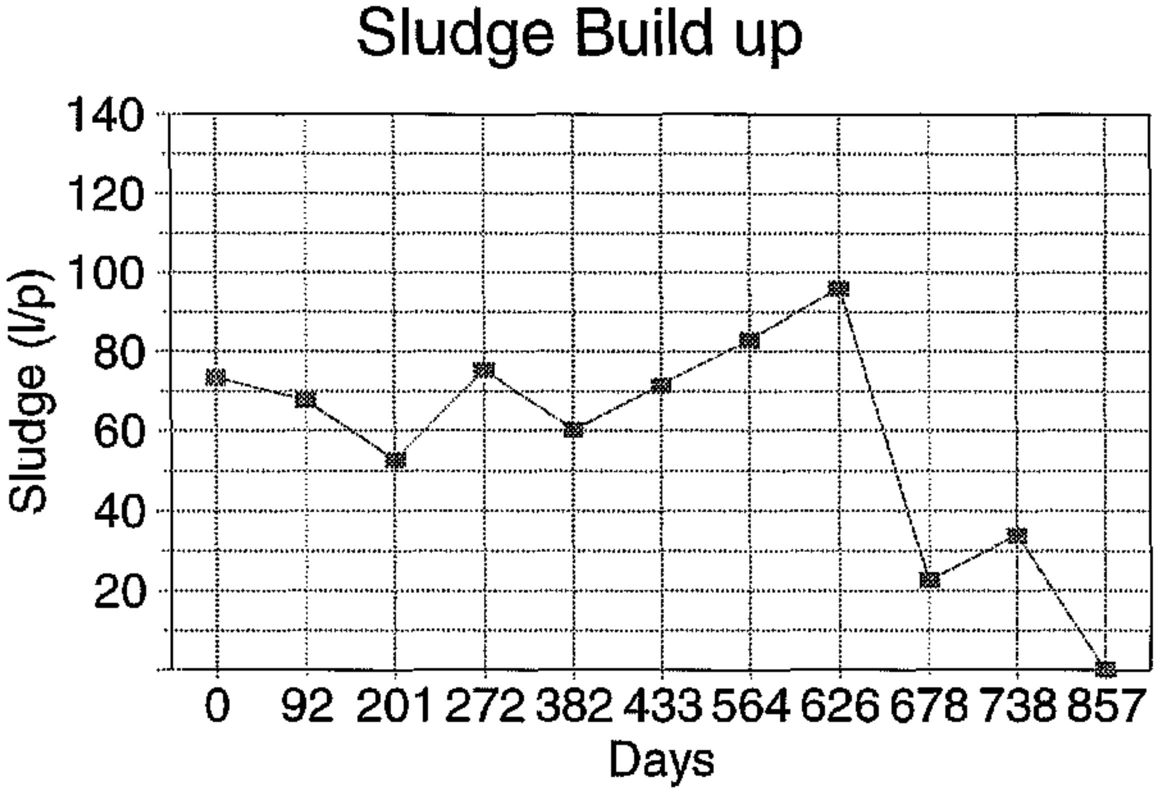

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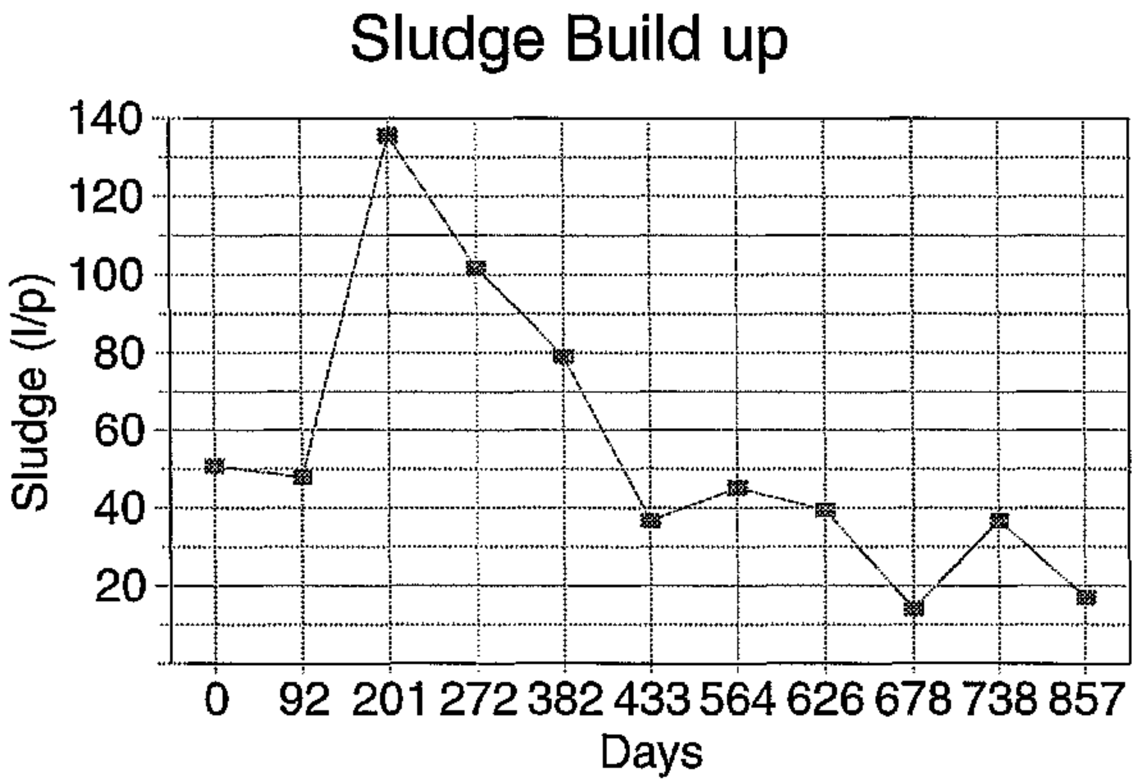
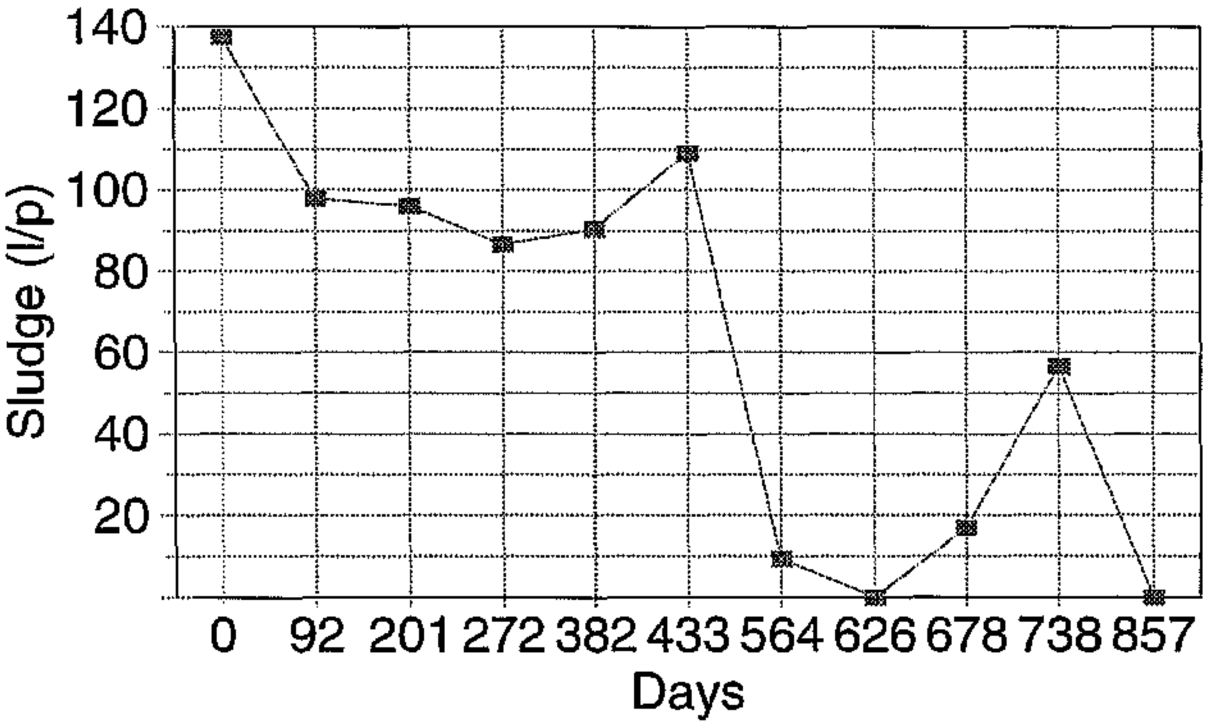


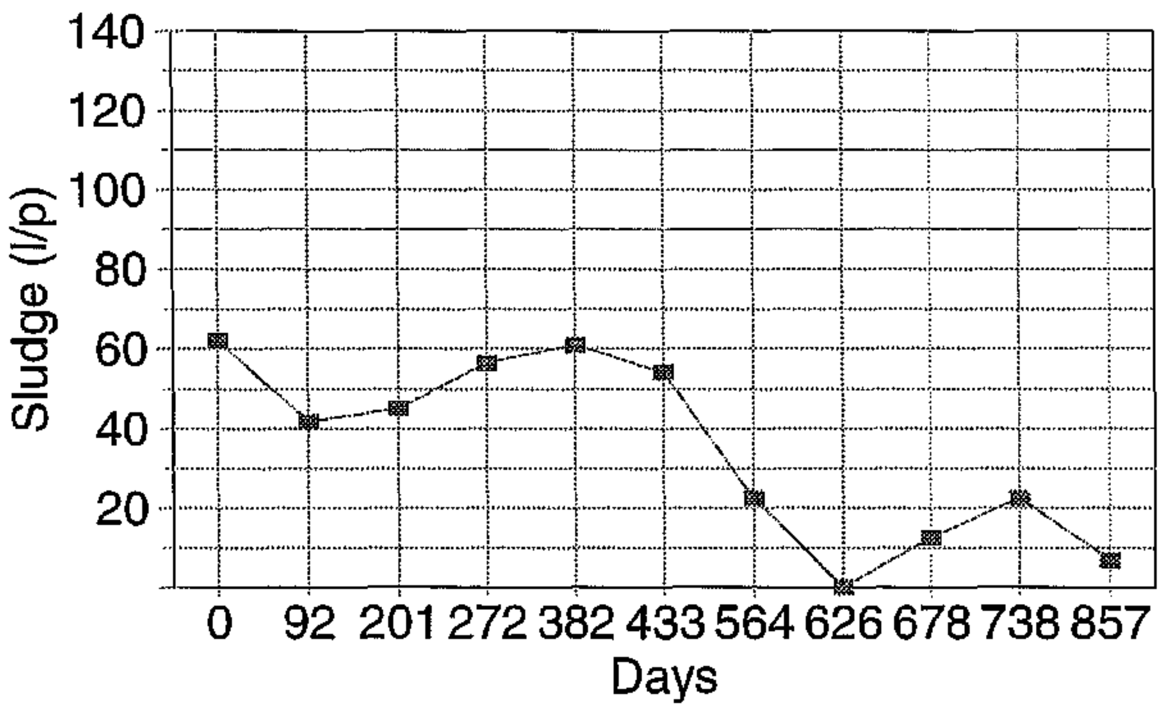
IVORY PARK: 1373

Sludge Build up



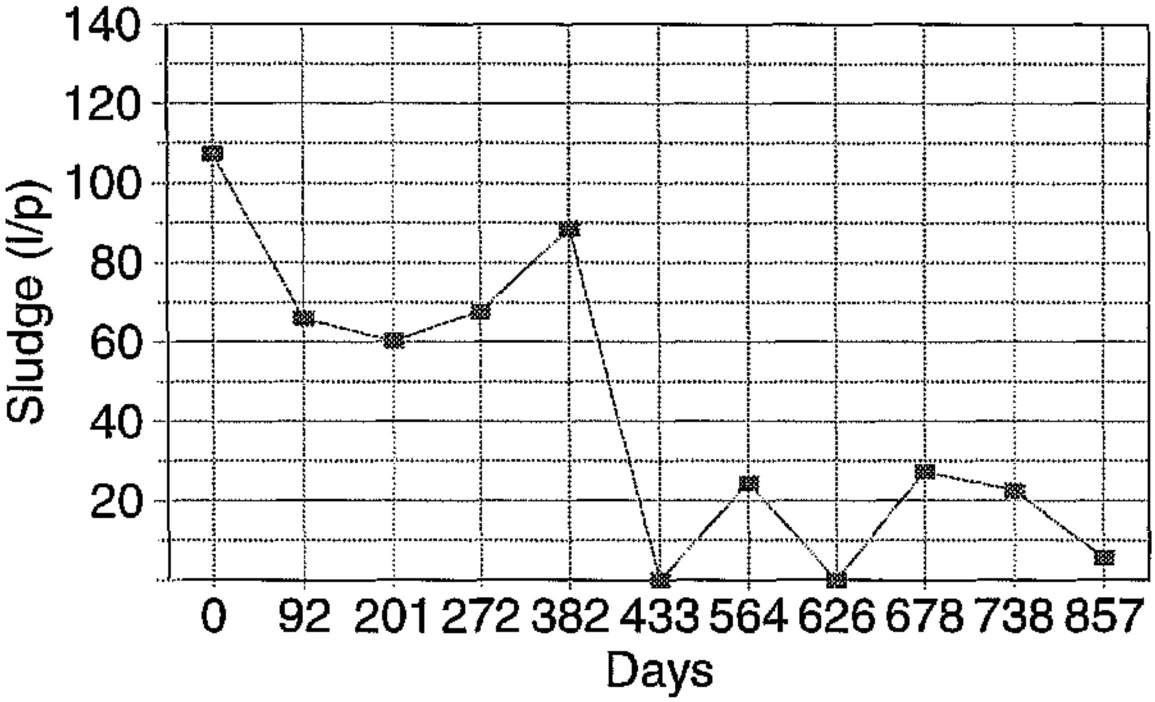
IVORY PARK: 1374

Sludge Build up



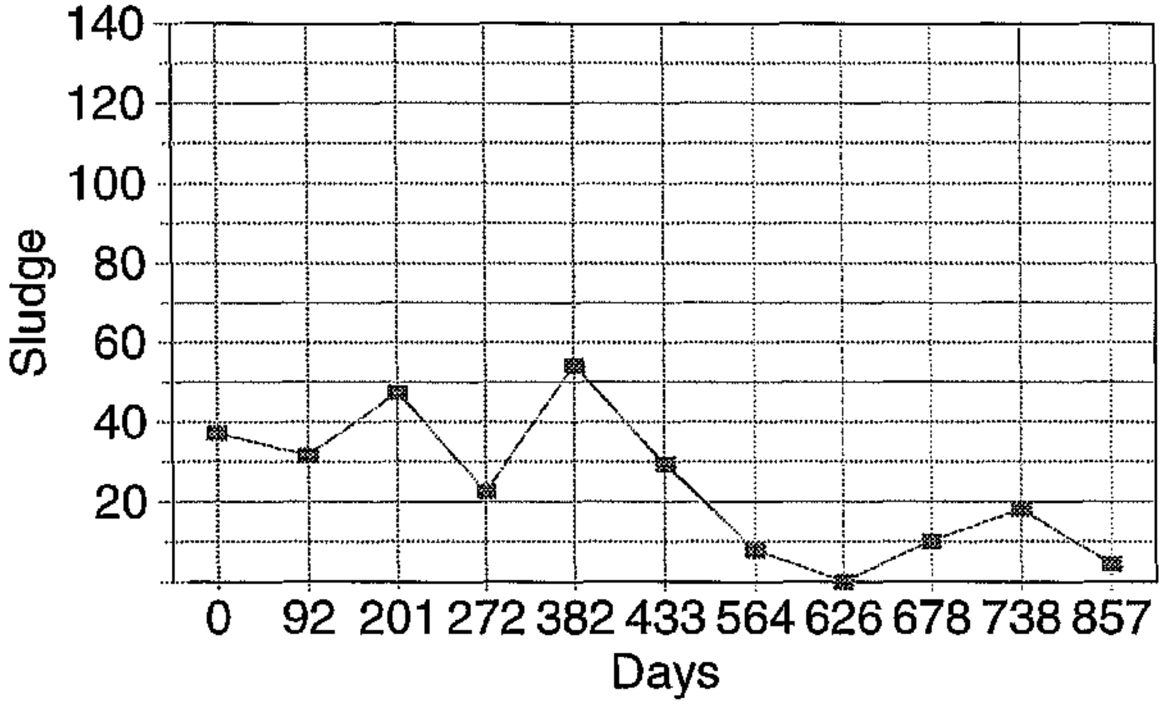
IVORY PARK: 1371

Sludge Build up



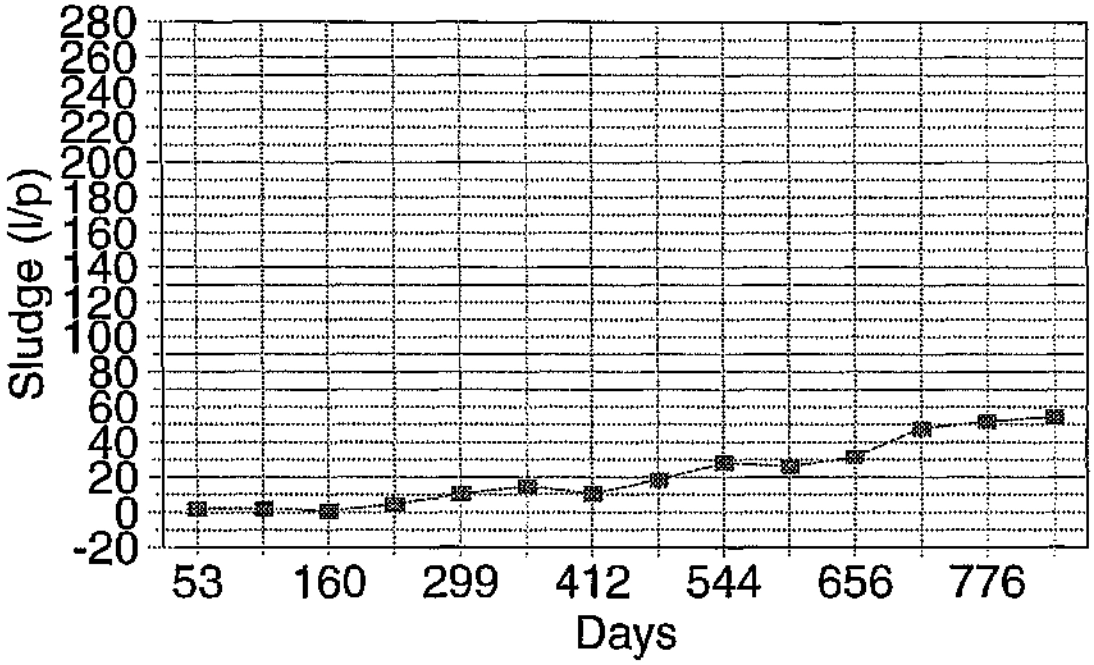
IVORY PARK: 1368

Sludge Build up



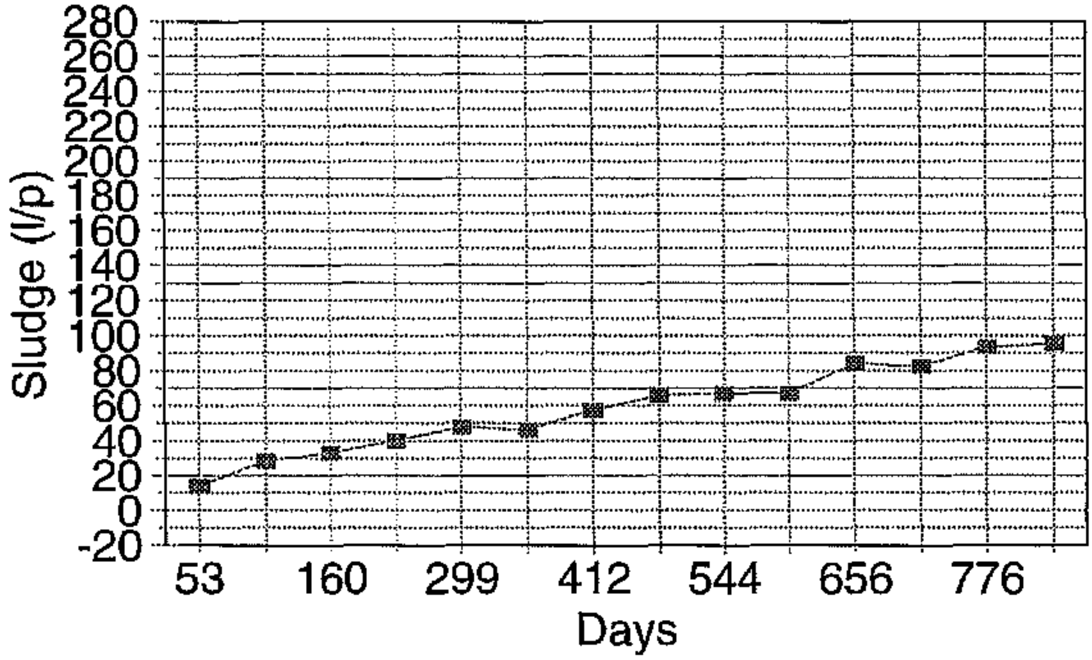
SOSHANGUVE: 1277FF

Sludge Build up



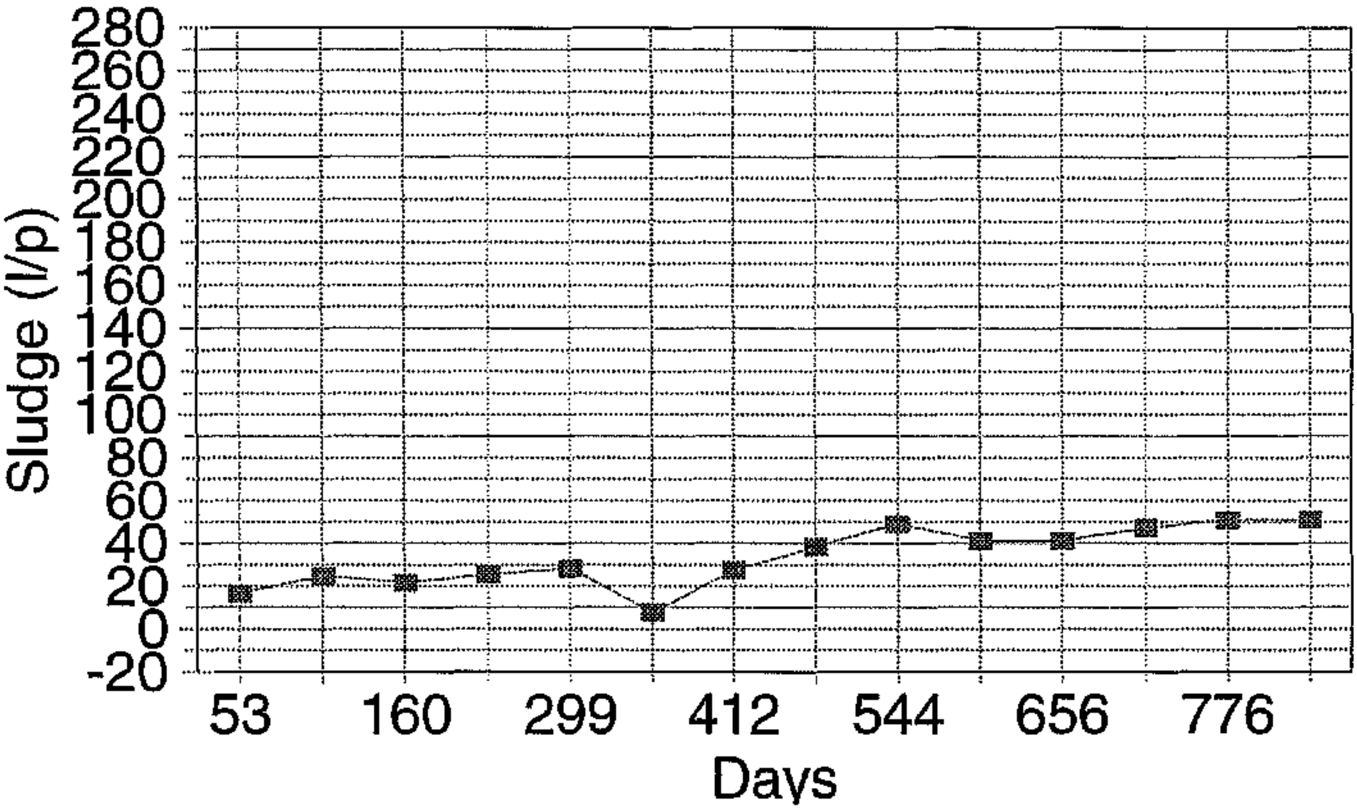
SOSHANGUVE: 1278FF

Sludge Build up



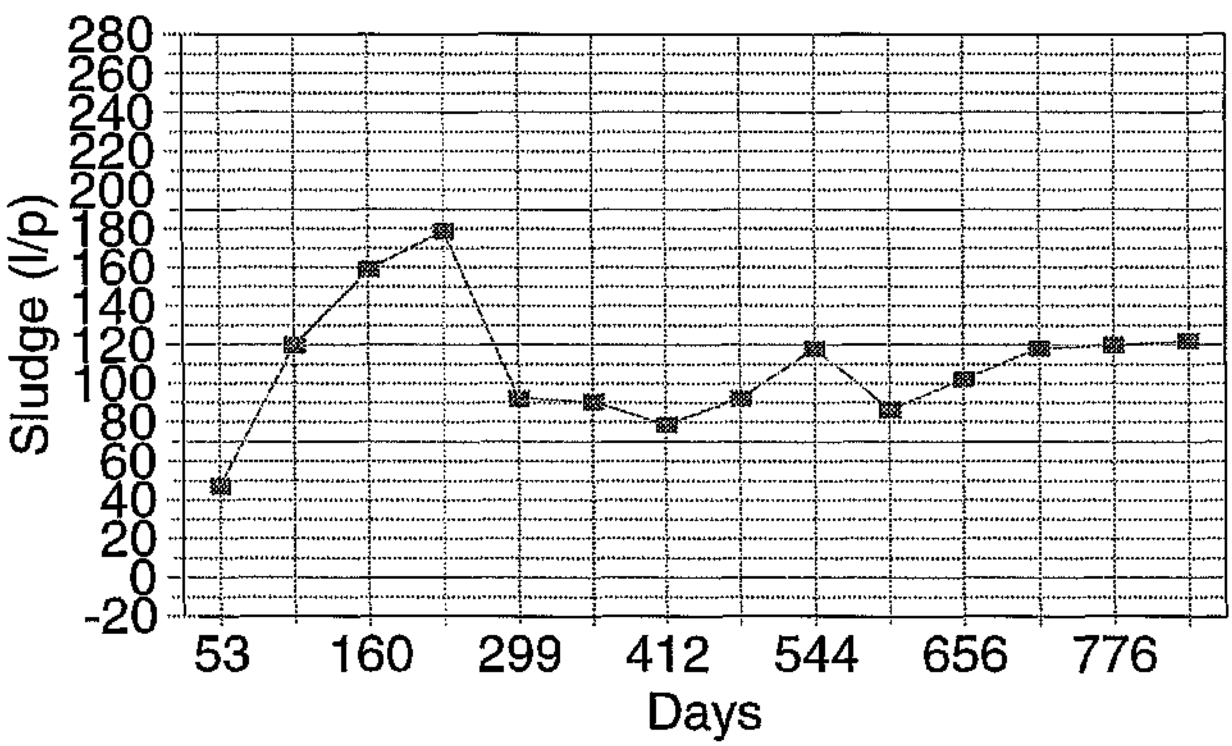
SOSHANGUVE: 1279FF

Sludge Build up

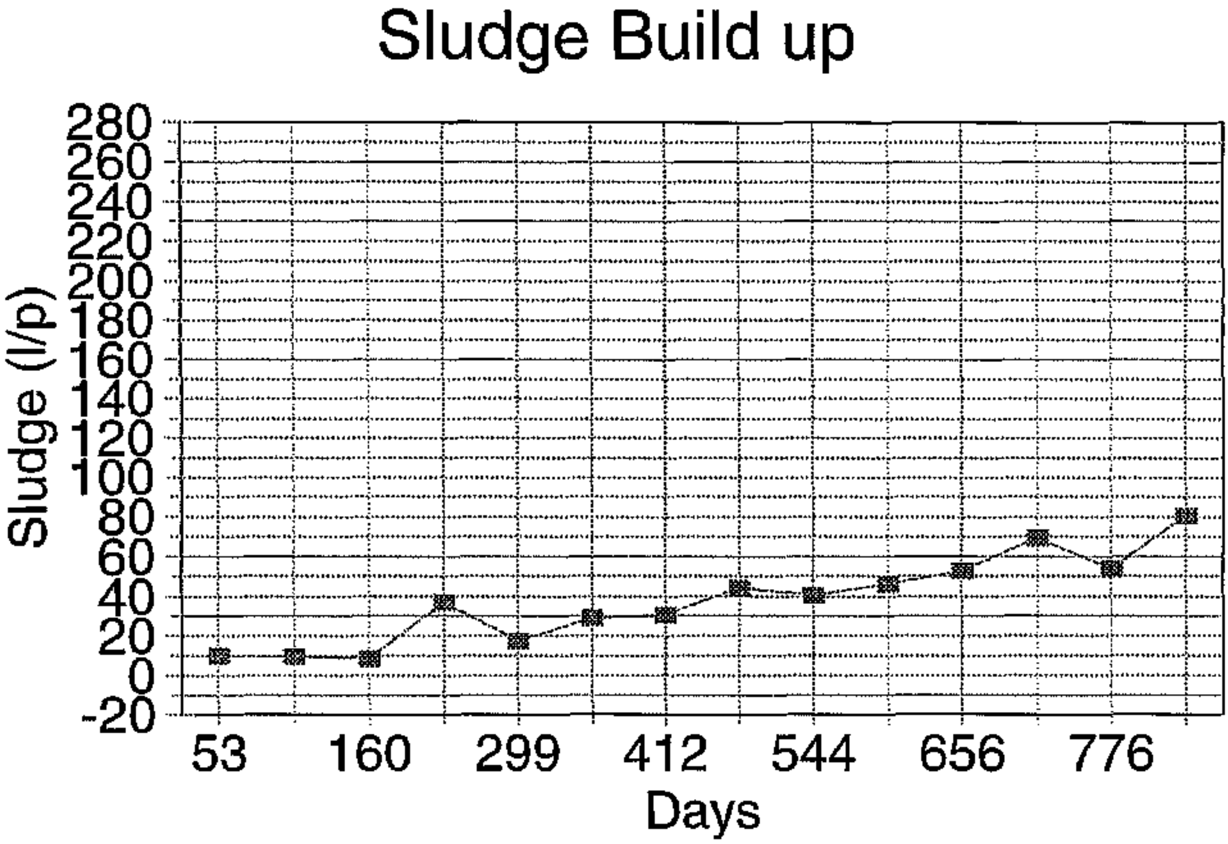


SOSHANGUVE: 1280FF

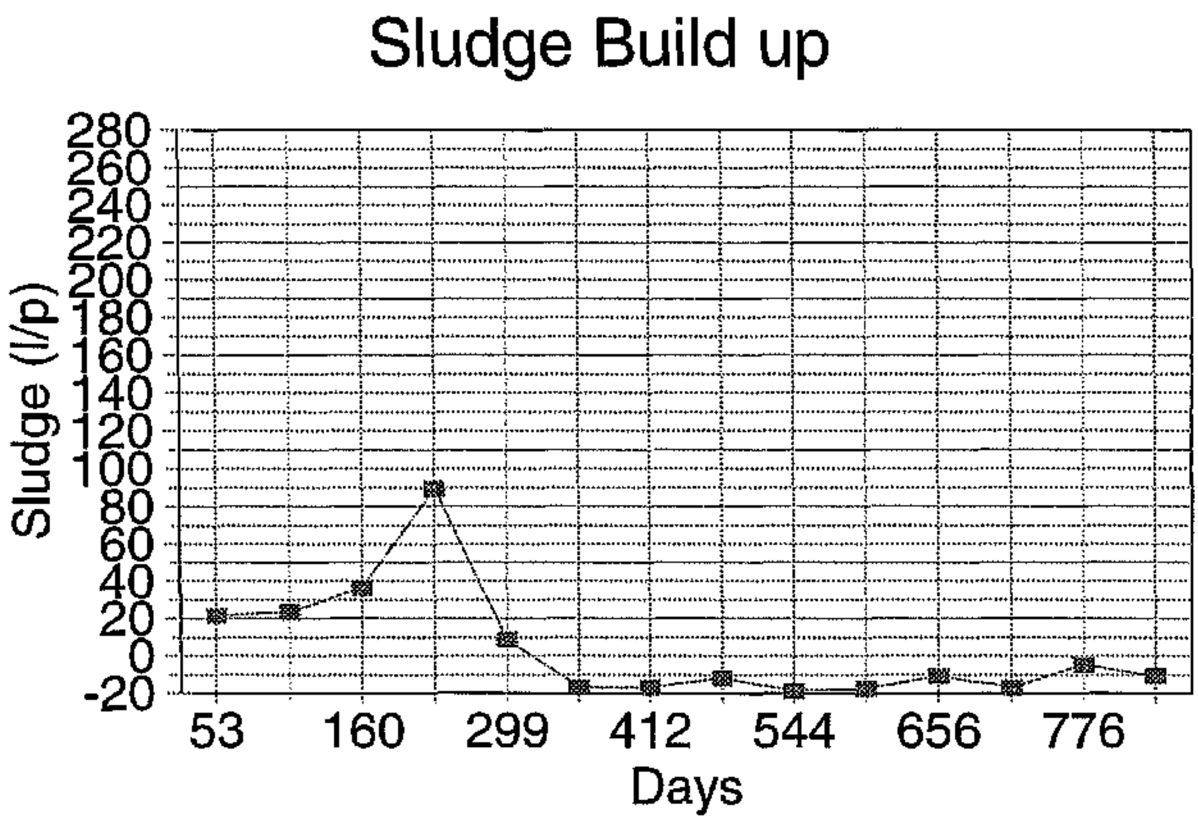
Sludge Build up



SOSHANGUVE: 1295FF

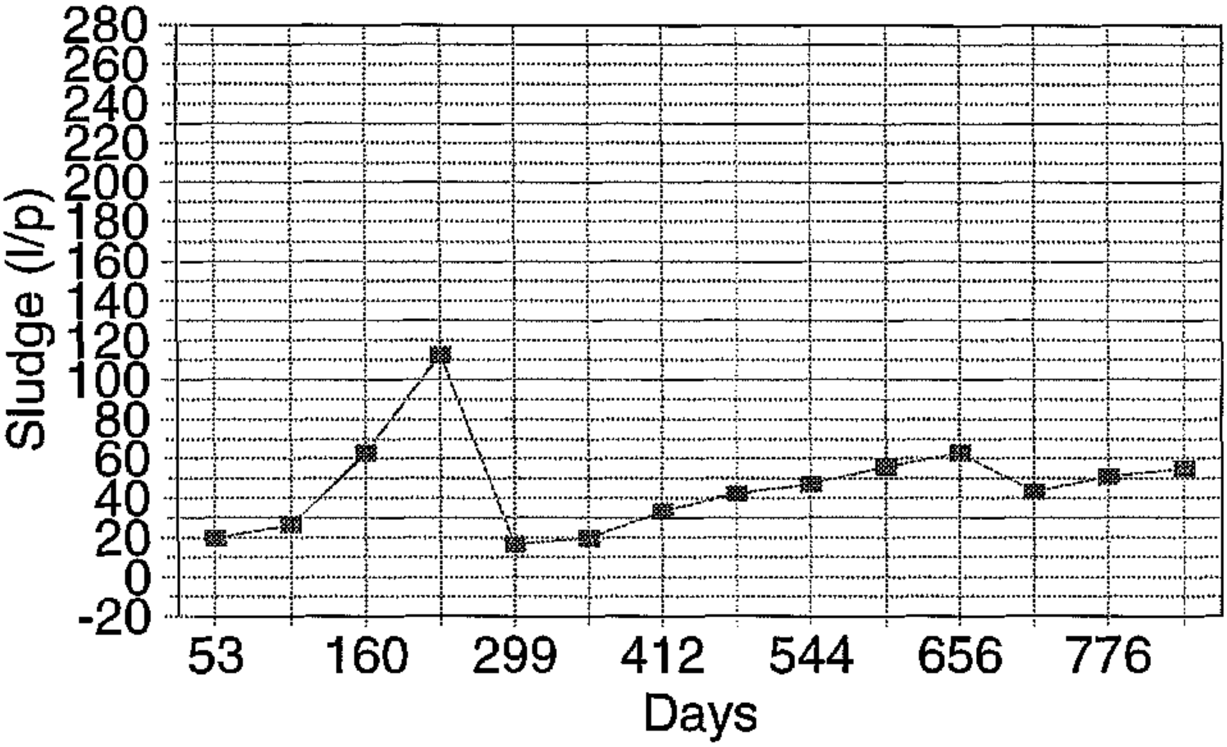


SOSHANGUVE: 1312FF



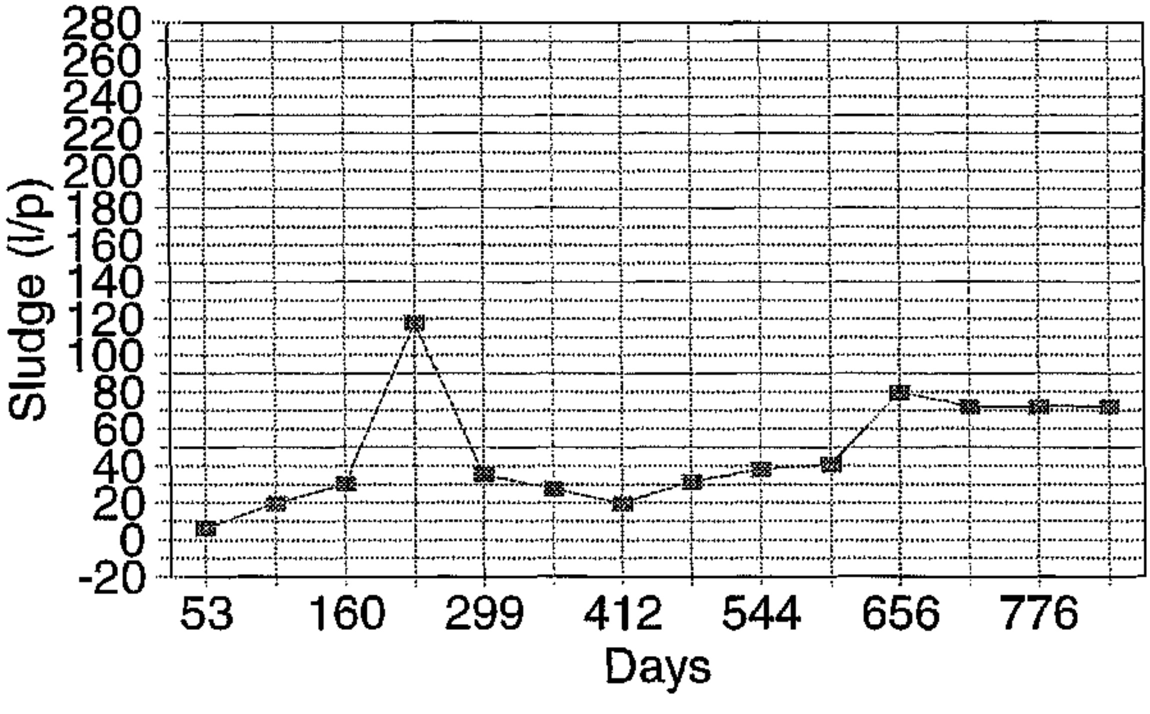
SOSHANGUVE: 1313FF

Sludge Build up



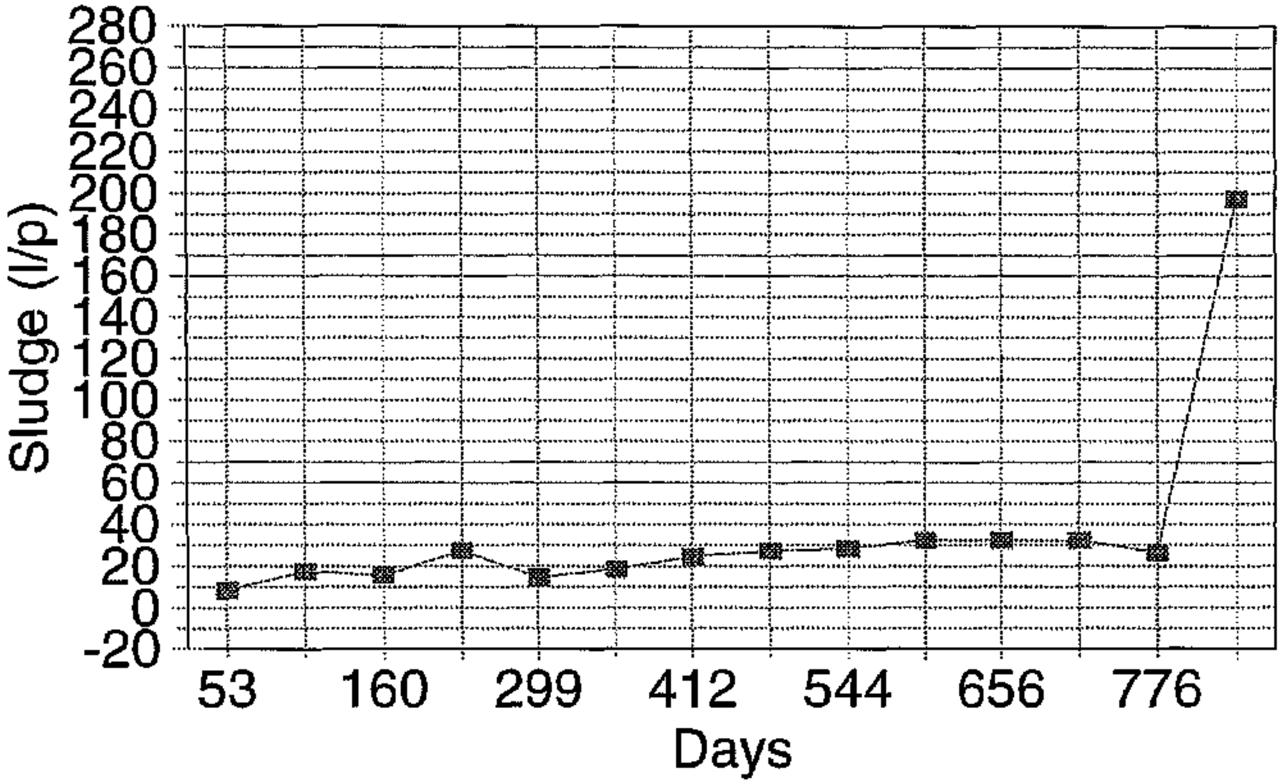
SOSHANGUVE: 1314FF

Sludge Build up



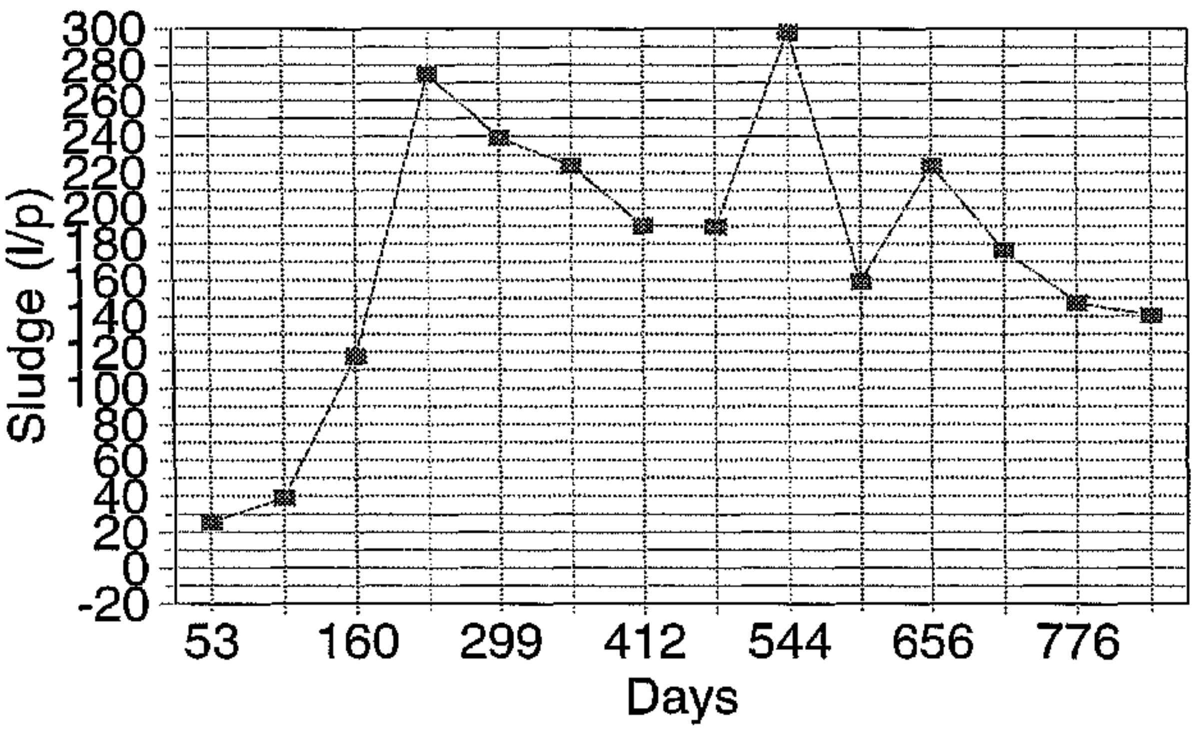
SOSHANGUVE: 1315FF

Sludge Build up



SOSHANGUVE: 292FF

Sludge Build up



APPENDIX III

Notes on some STED systems

Notes taken during discussion with Ronnie Crouse at the CPA offices in PE on 1994/04/03.

Marselle

- Ronnie Crouse direct telephone number; (041)390 2088
- Number of office at Marselle; (0464)81243
- Most of the Municipalities that the CPA deals with have insufficient funds for maintenance of the services infrastructure. Result is that no maintenance is done in these areas.
- In Marselle only one type of tank was installed. Most of the systems that we are monitoring are the so called dry systems. The Pan is a ceramic pan manufactured by Vaal potteries for the system supplier. The pan has no trap and discharges vertically into a curved pipe which enters the tank below the water level. A wash trough was installed on the outside of the toilet building which drained into the tank via the toilet pan. The CPA has found that these systems did not perform satisfactorily at Marselle. There was no problem with the system itself but it seemed as if there was insufficient water for proper operation. The tanks became like Pit latrines with a very thick sludge. In Marselle the people had to fetch water from standpipes some distance away. It is unlikely that people used the wash trough to dispose of water. The result was that only faeces and urine were deposited in the tank. To date 220 sites have been converted from dry to wet systems and all are now working well.
- Before the systems were converted average water consumption in Marselle was only about 10litres per capita per day.
- There were many blockages on the bend into the tank. The dry system is supplied with a plunger rod to assist with getting the solid waste into the tank. They normally recommend that the system is rodded at least once per day. It appears as if even with this rodding the dry systems at Marselle were blocking.
- The residents do not have sufficient money to pay for the emptying of the tank by vacuum tanker so they generally remove the T piece and then empty the tank manually. They then omit to replace the T piece resulting in the scum and floating solids draining into the solids free sewer.
- In Marselle water pumps were installed in the pumpstation. There were a number of problems with these blocking. CPA have now replaced these with sewage pumps and they are now running smoothly. These problems were mainly associated with solids entering the system as a result of the failed dry systems. Ronnie said that the water pumps might have worked if the dry systems had not failed but he would still recommend that sewage pumps are installed in future schemes. He says that you do get some sludge collecting in the sump even now with the dry systems mostly converted to wet systems. This might be suspended solids dropping out in the sump but it could also be slime that might build up in the sewers and then sloughing off the pipes.

- CPA have now bought a high pressure pump to use when cleaning out the tanks. (Kranzle profi-jet) This pump uses a venturi to suck the contents out of the tank. They will also use this to clean the sewer pipes if necessary.
- CPA persons on site: Leon Oosthuizen who runs the office and Dennis Botha who made the changes to convert the systems from dry to wet.
- They are now extending Marselle and installing another 120 new wet systems.
- CPA are now getting applications for developments where applicants would like to apply for housing subsidies. Ronnie is looking for ways to promote STED sanitation with the consulting engineers.
- The town of Hermanus was also on conservancy tanks which will now be converted to STED similar to Warden.
- Aberdeen will also be installing STED sanitation. The tender designs are now being prepared.
-

Cathcart

- CPA is presently installing a STED system in Cathcart.
- Consultants were briefed to prepare two separate designs. One conventional waterborne and the other STED. Steve Landoldt of Cahi de Vries in Bisho did the design. Both schemes went to tender but the STED system was cheaper probably because site is very rocky
- Tender prices as follows; Single toilet block R480+VAT. Septic tank R1203+VAT +toilet pan & washtrough.
-

General notes relating to the site visit at Marselle

- Some of the systems were originally dry systems but the CPA is now replacing them with a plastic toilet pan with a flush of about 3-4 litres. Note that the original tank is left and only the pan and connecting pipework is altered. The original installation was with a ceramic pan.
- The residents say that the tank was emptied when the new pans were installed but in discussion with the CPA labour it seems as if the liquid layer in the tank was pumped to below the level of the outlet T piece so that they could work on the tank pipework. It seems as if the sludge layer was in most cases left undisturbed.
- The reason given for the replacement of the old dry pans was that all the problems with the sewer network were associated with the dry systems. The CPA says that in their opinion based on their experience at Marselle there should be some addition of water to these systems.

GAVIN NORRIS

APPENDIX IV

NOTES ON SANITATION SYSTEMS AT UMBUMBULU

REPORT ON VISIT TO UMBUMBULU IN FEBRUARY 1995

Background

On the 16 & 17 February 1995 a team from CSIR consisting of Gavin Norris and Andy Murdoch visited several houses at Umbumbulu that have Biotag sanitation systems. On the 17th they were joined by Gordon Upton of Shayamanzi, Maurice Curtis of Fibreform and Chris Morris of CSIR. The primary purpose of the visit was to measure the sludge accumulation in 10 of the Biotag tanks in section C Folweni as part of the ongoing monitoring programme for a Water Research Commission project. A secondary purpose was to examine the Biotag systems to see how well they had stood up to several years of use by typical families in Umbumbulu.

Findings

Some of the tanks had been pumped out since our last visit which was on the 8th of December 1994. When asked, the residents said that this was done just before Christmas and that the pumping was done by Kwazulu Finance Corporation. This is a normal operational requirement for on-site sanitation systems. It can be expected that a system such as the Biotag with a 1 000 litre tank would require emptying at least once every five years.

Samples of the tanks' contents were drawn using a transparent tube developed by the CSIR. All of the tanks appeared to be operating very well with a clear separation between the sludge layer at the bottom of the tank and a relatively clear layer of liquid above this sludge layer. Some of the tanks had a floating scum layer forming on the surface of the liquid.

At three of the houses it was noticed that the gulleys were overflowing. Note that this does not indicate any problem with the sanitation system itself because at Umbumbulu only the toilet wastes are drained into the Biotag tanks. Kitchen and bathroom wastes bypass the tanks and drain directly into the soakaways. It would appear as if the fatty wastes, particularly from the kitchens, have caused the soakaways to become blocked. This viewpoint is supported by the fact that one of the residents whose soakaway had been excavated told us that it was filled by a substance that resembled candle wax. The blockage of these soakaways is a cause for concern because the grey water from the kitchens and bathrooms is overflowing from the gulleys and forming puddles on the ground. Since the partially treated effluent from the tanks is also disposed of in the soakaways, this effluent could rise to the ground surface. However, without a more detailed investigation which would include excavation of several blocked soakaways, it is impossible to determine the exact cause for the failure of the soakaways. It would appear at this stage that there are three possibilities for preventing this problem from occurring in the future. The first would be to construct larger soakaways. The second is to install a grease trap between the gulley and the soakaway. This would result in the trap collecting the grease, and if this becomes blocked then it is easily cleaned. Note that if the problem of blocked gullies is more widespread, then this might be a way of rectifying the problem with limited expenditure. The third option would be to put all the wastes through the Biotag tank, which would capture all the greases into a floating scum layer. The writer does not believe that this would have any serious effects on the operation of the tanks but has not yet had the opportunity to test this opinion with a microbiologist. Before this option is tried in practice it needs to be thoroughly discussed.

Most of the pedestals inspected were in good condition. There were no smells coming from any of the toilets. The flap of one of the units had broken. The woman of the house said that she was cleaning the toilet and it just broke. What was noticeable was the fact that even though there was no flap and therefore no water seal, there were still no smells in the bathroom, even though this was a "through the wall" unit.

The washers in some of the cisterns have failed. This means that when the residents fill the cistern, all the water immediately drains through the toilet into the tank. The people are all flushing the toilets manually with small water containers. Replacing these washers is a simple task which should be a normal maintenance operation on standard toilet cisterns.

Residents were unsure of where they could go to obtain advice and assistance when there were problems with the sanitation systems. It seemed as if there was not any functioning local authority responsible for the operation and maintenance of the services in Umbumbulu. For the proper functioning of any sanitation system this is essential. If Umbumbulu were served with waterborne sanitation, there would be a disastrous situation with raw sewage running down the streets.

One of the causes for concern was the apparent lack of user understanding of the operation of the toilet system. Some of the residents were adding chemicals to the unit because they were not aware that with these types of system it was better not to add anything. It is recommended that whatever type of sanitation system is installed, proper user education is carried out and that one of the local residents or the local authority in each area be trained on the systems so that they can answer any queries.

Conclusions

1. On the whole, the Biotag units at Umbumbulu are operating satisfactorily.
2. More user education is required when installing any sanitation system.
3. It is essential that there is a competent local authority to maintain any sanitation system.
4. Fats and greases from the kitchen are causing the soakaways to fail. This can most easily be rectified by installing grease traps.

GAVIN NORRIS

APPENDIX V

Comments received from Allan Batchelor, Environmentek

The observations that you have documented re an inverse correlation between sludge depth and number of users correlates with observations I made in two independent studies, one funded by Calcamite and restricted to Calcamite tanks, and the other funded by TPA through Laubscher, Human & Lombard.

The precise reasons for this apparent anomaly has to my knowledge never been critically examined and as such one can only speculate as to the reason. My own feelings are that:

1. The flush volume is too low given the high organic and ammonia load on systems serving more than three people, and this could effect the biophysical processes including separation of the solid/liquid fraction. Most aquaprivies are fed with both flush water and additional water from washing facilities. I personally feel that the volume of water needed to ensure dilution and methanogenesis has not been evaluated properly, with the focus on our local systems being water conservation rather than a balance between flush volume and process requirements.

1.1 The reasons that I feel this, are anecdotal. As early as 1914 it was found that when buckets containing sewage were introduced into the sewage treatment system at Daspoort, the biological processes were adversely affected unless the bucket emptying was followed by copious washing of the buckets to in effect dilute the effluent.

1.2 The information that I copied to you re piggeries effluent, that solids separation in pig waste failed unless the quantity of water added was "sufficient". (Ref. Separation of Solid and Liquid Parts of Pig Slurry. J C Glerum, G Klomp and H R Poelma. Livestock Waste Management).

2. The tank size is too small for greater than 3-4 users resulting in insufficient residence time for anaerobiasis to develop. My feeling is that all the systems exist in a state of acid fermentation, giving rise to odours.

2.1 The contents of all low-volume flush toilets sampled by ourselves during the surveys and three samples brought to me yesterday, showed o signs of typical anaerobiasis, i.e. there was not the slightest smell of methane or hydrogen sulphide. The samples all smelt of fresh faeces, which to me indicates that the residence time necessary for some form of digestion is simply not being met, although the possibility exists that the digestion process is being inhibited by something (possibly ammonia). This may also influence the settling characteristics of the contents.

Note: This could also be aggravated by the fact that the tanks are emptied fairly often but are never refilled with water afterwards. The only liquid that enters the tanks is flushing/washing water or urine.