FINAL PROJECT REPORT

to the

WATER RESEARCH COMMISSION

RESEARCH INTO THE EFFECTS OF REDUCED WATER CONSUMPTION ON DOMESTIC SEWER SYSTEMS

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* Joint Acceptance Scheme for Water Installation Components

AIMS OF THE PROJECT

The aim of the project is to provide information, relating to the effect of reduced water consumption on domestic sewer systems, that will;

(i) Enable local authorities to evaluate the merits of approving low volume WC flushing systems

(ii) Assist in the planning of domestic water use systems

(iii) Facilitate the design and maintenance of building drainage and sewer systems

(iv) Enable the effects of severe water restrictions on building drainage and sewer systems to be evaluated.

EXECUTIVE SUMMARY

This research project stems from the concerns of municipal authorities about the possible negative impacts that water economy measures may have on drains and sewers.

The aim of the research project is to provide information, relating to the effect of reduced water consumption on domestic sewer systems, that will enable local authorities to evaluate the merits of approving low volume WC flushing systems, assist in the planning of domestic water use systems, facilitate the design and maintenance of building drainage and sewer systems and enable the effects of severe water restrictions on building drainage and sewer systems to be evaluated.

A study on the effects of reducing the flush volume of the toilets from 9 litres to 6 litres was undertaken at the Rooiwal township near Pretoria. No overall water saving resulted from the reduction of the WC flush volumes by 33% and the blockage rate was not noticeably affected. Blockages were attributed to the introduction of in-appropriate materials to the drainage installation, root intrusion, displaced joints and broken pipes, and no relationship between blockages and average water consumption was detected. Factors that could explain the 3.2% increase in the average water consumption were:

a) Induced flushing inefficiency as a result of the reduced flush volumes
b) Removal of water restrictions

In Mamelodi, 6-litre flush toilets were installed in a block of six stands at the head of the sewer system. The reduced flush volume toilets accounted for about 15% of the total water consumption, but did not have a significant effect on the water consumption pattern. This was attributed to the stronger influences of several other factors that also helped to determine water demand.

The average daily water consumption of above 1000 litres per stand was adequate to keep the drain and sewer clean, even after the flush volumes were reduced to 4.5 litres for one month. Unless the water consumption reduces by at least 30%, the risk of low flush toilets affecting the performance of the Mamelodi sewer system is insignificant.

A survey of twelve local authorities in Natal was conducted in October 1988 to obtain their opinions on the effects of the 1982/83 water crisis in Natal and what effect drastically reducing the water content of domestic sewage would have on the corrosion and maintenance of sewer systems and on sewage treatment processes. In their experience, an increase in blockages at the head of household drains was caused by the abnormal conditions pertaining at the time. Septicity was not an important factor, no long-term changes in preventative and other maintenance work took place during the water restriction period and there was no negative changes in the operating efficiency of the treatment plants. Gains of about five years in their capital expenditure programmes were reported by most of the local authorities.

In Port Elizabeth, the effects of reduced water consumption during the 1989 drought were monitored. The reduction in the water content of domestic sewage did not have a significant effect on the frequency of blockages in the sewer system, although blockages on drains increased by about 18.4%.

While root intrusion accounted for 60% of blockages, paper blockages increased by 50% to 33.8% of the total in the second half of 1989. The reduction in sewer flow, as a result of the drought, was estimated to be about 30 to 40% in the residential areas, which was not considered to be drastic. No increase in septicity was observed and the performance of the sewage treatment processes was not affected.

Overseas, Building Research Establishment in the UK found that a 6 litre flush WC did not increase the amount of deposition or in the number of blockages in the drain. They also found that 3 litre flush volume Swedish toilets performed well with no adverse effects on the drainage system, although below 4 litres some restrictions on length and grade may be necessary for isolated WCs.

Four and a half litre prototype flush toilets in Botswana achieved an 18% water saving over a control group installed with 10 litre flush volume toilets with no detrimental effects in the drains. Norwegian studies showed that the WC causes the most problems in a waste water system, which should be designed for a specific flush volume.

In conclusion, blockages were generally attributable to the introduction of in-appropriate materials to the drainage installations, or root intrusion, possibly coupled with irregularities in the pipeline, such as displaced joints and broken pipes. No definitive relationship between blockages and water consumption was detected and given normal levels of water consumption, reducing the WC flush volume to 6 litres should have no effect on the performance of the drainage installation, or the sewer system.

However, reducing the flush volume, without maintaining an acceptable level of flushing performance from the WC will be counter-productive in terms of efficient use of water and water economy and user satisfaction.

It is recommended that reduced flush volume cisterns and water closets may be accepted by local authorities if it can be shown that the overall flushing performance of the water closet system is maintained at, or above, an acceptable standard of efficiency.

Other recommendations are:

a) establish a database on the behaviour and design of existing drainage and sewer systems,
b) include the effect of groundwater and stormwater infiltration when evaluating the effect of reduced water consumption on sewers,
c) consider what steps municipalities and pipe manufacturers can take to reduce or eliminate the problem of root intrusion and
d) address the problem of in-appropriate materials and items being able to find their way into drains and sewers.

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INTRODUCTION

During the 1980 decade, severe droughts were experienced over large areas of the country and many communities suffered harsh water restrictions. The CSIR, SABS and the WRC were involved in a joint research project aimed at introducing water economy measures to urban areas and improving the utilisation of scarce water resources. [Malan,1983]. The project considered many aspects of urban water use and led to changes in specifications, new guidelines and regulations and improvements in the efficiency of water use of many commercial plumbing products.

Local authorities, while welcoming the potential of water economy measures to reduce the level of water consumption in the urban environment, were concerned at the possible negative impacts of such measures. One major area of concern was the effect of reduced water consumption on the performance of domestic drainage and sewer systems. [JASWIC,1985]

Overseas research on water economy measures and the components of domestic water use, noteably in the USA and the UK, identified the water closet as one area where significant water savings could be achieved. Another area was showering and bathing. Comparisons of the breakdowns of the internal domestic water consumptions between USA (California), UK and RSA are given in Table 1 below. [Malan,1983]

TABLE 1 : COMPARISON OF INTERNAL WATER CONSUMPTIONS

COMPONENT	WATER USE - l/c/d			PERCENT OF TOTAL		
	USA	UK	RSA	USA	UK	RSA
Bath & Shower	73	22	65	32	21	41
Water Closet	95	37	48	42	34	30
Clothes washing	32	12	23	14	11	14
Other	27	36	24	12	34	15
Total	227	107	160			

Since baths, showers and water closets were identified as the main areas of water use, they were seen as potential targets for reductions in water consumption. One of the effects of the project was a reduction in the WC nominal flush volume from 11 litres to 9 litres, which was introduced through SABS specifications.

In respect of baths and wash basins, the project recommended that the advantages of moderate capacity fixtures should be stressed through water economy education programmes, rather than try to legislate for volumetric limits. However, the recommendation for showers was to limit the flow rate to a maximum of 10 litres/minute, through the National Water Regulations.

The percentages given in Table 1 applied to middle income housing at the time. It can be deduced that, in a country where the majority of the population fall into the lower income groups and have access to limited water using facilities, the use of water in toilet flushing should be proportionately higher[1]. There is therefore an incentive to reduce the WC flush volume as much as possible, but the concern is that at some point in the overall water reduction process, the drains and sewers could fail to function and result in an unacceptably high level of blockages and corresponding maintenance work.

This research project was instituted to consider such aspects as the effect of reduced flush volumes on;

a) Blockage frequency
b) Concentration of sewage
c) Lower velocities
d) Retention time
e) Septicity
f) Corrosion
g) Cost of maintenance
h) Effects on sewage treatment works.

The work involved in the project was considered to fall into specific tasks, taking into account the "worst state" conditions of severe water restrictions, infrequent use, the flushing of inappropriate sanitary materials and the diversion of wash water out of the system, as follows;

1. Investigate the effect of low-volume WC cisterns and water conserving showers on water consumption and on drain and sewer performance.

2. Investigate the relationship between water consumption and drainage blockages

3. Investigate the effects of drastically reducing the water content of domestic sewage on the corrosion and maintenance of sewer systems and on sewage treatment processes.

In each of these tasks, the common denominator is the quantity of water drawn from the supply system and discharged into the sewer system, via water closets and other drainage fixtures. This water consumption can be affected by changes in product designs and water restrictions. Since the purpose of introducing water to the drainage system is to convey waste products to the treatment works, the quantity and nature of the waste products are relevant to the situation.

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1 The Mamelodi data, given later, tends to refute this, possibly due to higher population densities, resulting in more use of the facilities for washing purposes.

ROOIWAL TOWNSHIP TRIALS

General

The 128 staff houses at the Rooiwal power station were selected for a study on the effects of reducing the flush volume of the toilets from 9 litres to 6 litres. The houses are under the control of the Pretoria City Council and water for external garden use is supplied separately from the metered in-house water supply, thus avoiding the need to instal meters on garden taps. The water meters are read monthly by the Council and the occupants billed for the water consumed.

Initialisation Phase

The water supply system to each house was checked and rehabilitated where necessary, to ensure that there were no leaks and the the water meters, toilet cisterns and other components were functioning correctly. All the cistern inlet valves were replaced with new float valves[2] before setting the flush volumes of the low-level cisterns to 9 litres. The water levels in the 11 litres (2.5 gallon) high-level siphonic cisterns, found in most of the outbuildings, were set to the level-mark and were not adjusted again during the course of the trials.

From plans of the township, it was established that the ground slopes along house drains were typically 1 in 70 with drain runs up to 30 metres long. Drain gradients vary in general between 1 in 30 to 1 in 50. It was claimed that there was approximately one house drain blockage per month.

Fixtures contributing to the sewage flow from each property consist of a sink, wash trough, bath, wash basin and a water closet in the house and a water closet and shower in the servants quarters. The houses were constructed in between 1962 and 1984, but most houses date from 1962.

First Year of Monitoring

The first set of water meter readings were taken at the beginning of November 1987. Thereafter, meter readings were taken once a month for a full twelve month period to the 10th November 1988. Unfortunately, staff changes occurred in both the NBRI and the municipality, which led to a breakdown in communications and no blockage records for the year.

Second Year of Monitoring

During November and December 1988, the 143 flush valves in the low level cisterns were replaced by new direct outlet flush valves[3] and the water levels adjusted so that the flush volumes were reduced to 6 litres. It should be noted that in adjusting the flush volumes, an allowance of 0.5 litres was made for inflow during flushing. Thus the stored volumes, set in each yearly period, were 8.5 litres and 5.5 litres respectively.

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[2]"Kleanflo" float valves manufactured by NI Plastics to SABS 752. This note indicates the origin of the valves and is not a product endorsement.

[3]"Thru-flush" valves manufactured by NI Plastics. This note indicates the origin of the flush valves and is not a product endorsement.

Monitoring of the water consumption re-commenced early in January 1989 and continued until 10 January 1990. Maintenance staff at Rooiwal were of the opinion that the blockage tempo remained much the same after the flush volume changes as before. The available data on blockages in 1989 are;

DATE	HOUSE	POSITION	CAUSE	WATER l/day
31/01	127	bathroom basin	Deposit in pipe	327
09/02	133	Drain d/s of pan	Nappy liner	403
12/02	166	Drain d/s of pan	Nappy liner	1002
17/02	105	Basin in bathroom	Deposit in pipe	896
29/06	113	Outbuilding pan	Rubbish in pan	321
04/07	198	Drain d/s of pan	Nappy liner	757
-/12	-	Connection	Roots	

Each of the recorded blockages can be attributed to the introduction of in-appropriate materials to the drainage installation, or root intrusion, possibly coupled with irregularities in the pipeline, such as displaced joints and broken pipes. There appears to be no relationship between the blockages and the average water consumption for the month in question under these specific operating conditions.

Water Consumption Analysis

The monthly water consumption in litres per household per month were calculated from meter readings and dates of readings. Previous records have shown that internal water consumption is relatively constant during the year [Malan,1983], provided the occupancy level is maintained. Thus seasonality can be ignored and the data lumped together for analysis purposes. The statistics for the full set of internal water consumption data is presented in columns (1) and (2) of Table 2 for 1988 and 1989 respectively.

TABLE 2 : ANALYSIS OF ROOIWAL'S MONTHLY WATER CONSUMPTION DATA

VARIABLE	(1) FULL DATA SET 1988	(2) FULL DATA SET 1989	(3) REDUCED DATA SET 1988	(4) REDUCED DATA SET 1989
Sample size	1524	1518	677	678
Average	508	544	559	577
Median	465	486	526	525
Variance	122,577	155,381	55,748	65,235
Standard deviation	350	394	236	255
Standard error	8.97	10.12	9.07	9.81
Minimum	0	0	131	135
Maximum	3492	7483	1697	2265
Lower quartile	301	324	394	389
Upper quartile	636	683	673	710
Skewness	2.21	4.85	1.21	1.42
Standardized skewness	35.20	77.20	12.9	15.1
Kurtosis	11.33	66.78	2.4	3.9
Standardized kurtosis	90.28	531.14	12.5	20.8

If a meter change occurred in a month, the data for the month and the previous month does not represent the true consumption and must be deleted from the record. Thus the sample sizes are different.

There are significant differences between the two sets of data. Firstly, the average and median for 1989 is larger than for 1988. Skewness, a measure of the asymmetry of the distribution, and kurtosis, a measure of the steepness of the distribution and the length of the tails with respect to the normal distribution, both increase. Both standardised coefficients show a significant change in the water consumption distribution pattern and indicate that the data are not normally distributed.

An analysis of water consumption records revealed two factors that could invalidate the use of data in determining the effect of the reduced flushes on water consumption and hence drainage performance;

a) Changes in occupancy at several houses resulted in a significant change in their water consumption pattern.

b) Several monthly periods when houses were not occupied resulted in reduced water consumption which was not related to the reduced flush volumes.

Other factors which tended to cause a general increase in the level of water consumption were:

- the relaxation of water restrictions in 1989
- the periodic failure of the water supply for external garden watering, leading in some instances to greatly increased monthly water use from the domestic (internal) water supply.

The records were inspected and where evidence of (a) and (b) was found in either of the annual records, the record for the house was removed from the data. A maximum of one monthly discrepancy was allowed in the annual record, so that after this datum was removed, at least eleven data remained in the annual record.

The statistics for the reduced data set are given in columns (3) and (4) of Table 2. This data set represents the houses that were assumed to be fully occupied by the same occupants for the duration of the trials. Even so, the figures show an overall increase in the average water consumption of 3.2%, indicating that the other factors mentioned above had a stronger influence on water consumption than the change in the WC flush volume.

Difference between 1988 and 1989 Average Water Consumption

A two-sample analysis of the reduced data set resulted in the following;

	1988	1989	Pooled
Number of Observations	677	678	1355
Average (Mean)	559	577	568
Variance	55748	65235	60495
Standard Deviation	236	255	246
Median	526	525	525

The difference between the means is -17.29 and the confidence interval for the difference is (-43.5 to 8.9) at 95%. In testing the hypothesis that there is no significant difference between the averages for the two years, we find that the computed t statistic is -1.2935 with a significance level of 0.19606. Since we are looking for Alpha = 0.05, we cannot reject the hypothesis and must conclude there is no difference between the two means.

However, if the flush volume is reduced from 9 to 6 litres, a water saving of 3 liters per flush should occur. Since the number of flushes are not expected to change, the overall reduction in WC water use is expected to be in the order of 33.3%. Assuming the proportion of water used by the toilet was 0.3, it should reduce to 0.2 thus resulting in an overall 10% water saving, all other things being equal. The expected mean water consumption would be 503 litres/house/day. Similarly, if the entire water consumption was due to WC flushing, the average water consumption should drop by 33.3% to 373 litres/house/day.

The ratio between 1988 and 1989 consumption was calculated for each house in the reduced data set and ranked. The result is shown in Figure 1.

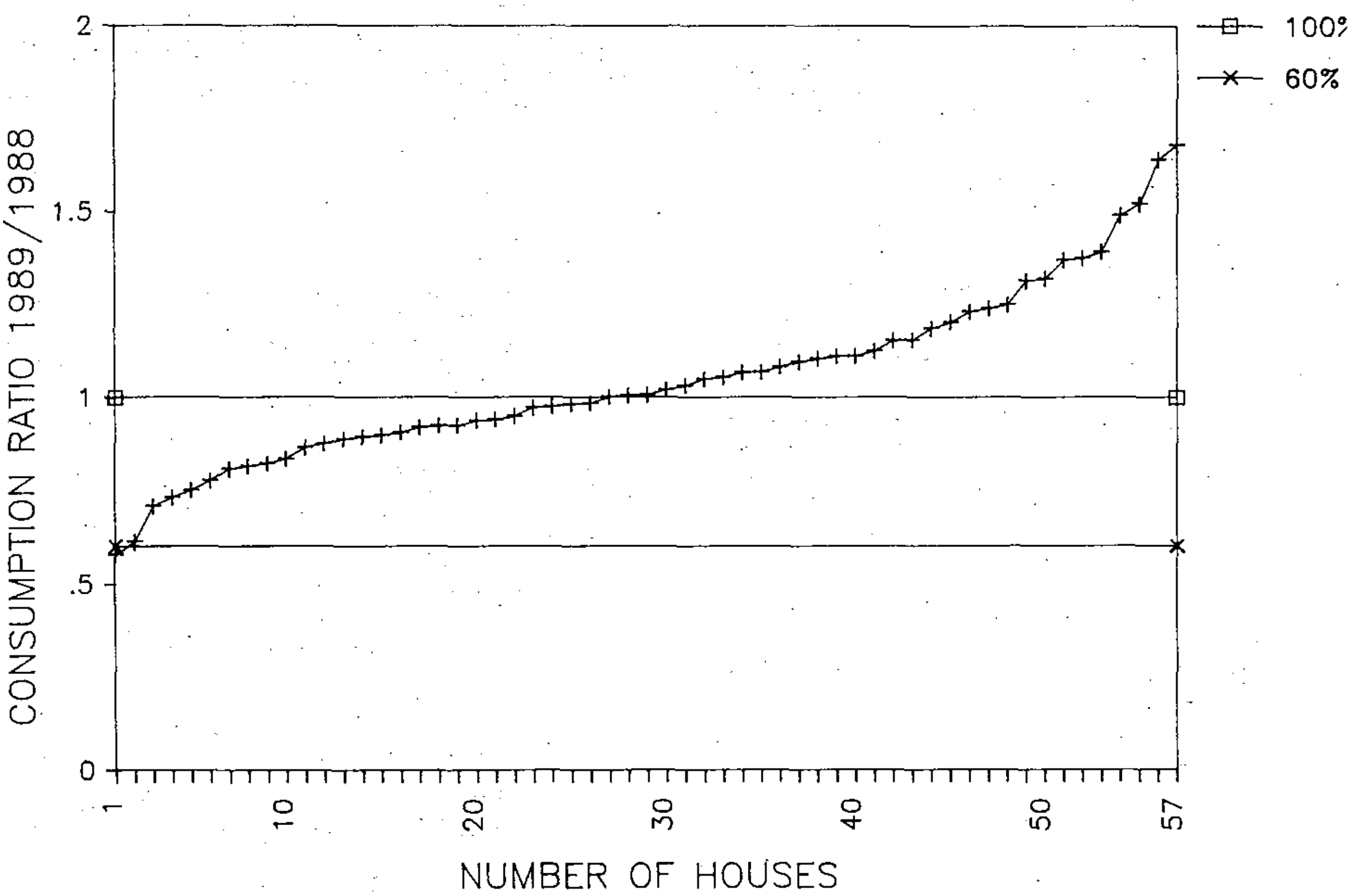

Figure 1 : Rooiwal Houses - Change in Annual Water Consumption

Effectiveness of Reducing the WC Flush Volume

The above results could mean that no overall water saving resulted from reducing the WC flush volumes by 33%, or else the measure was in fact responsible for more water being used.

This possibility can be explained as follows. Previous research carried out by the CSIR has demonstrated the inter-dependability of the components of the water closet system. [Simpson,1983]. Ideally, the flow hydrograph from the cistern must be optimised for each pan design. Factors and combinations of factors, such as lowering the cistern and the water level in the cistern, changing flush valves, or converting from low level to close-coupled cisterns, can radically affect the shape and duration of the inflow hydrograph and hence undermine the performance of the pan.

Given a particular WC system configuration, the relationship between the flush volume and the overall WC water consumption is illustrated in Figure 2. An event is defined as a single use of the WC as distinct from the number of flushes needed to clear the pan. An event could result in water consumption greater than or less than the flush volume. The optimum flush volume is defined as the minimum flush volume required to clear the pan efficiently with a single flush.

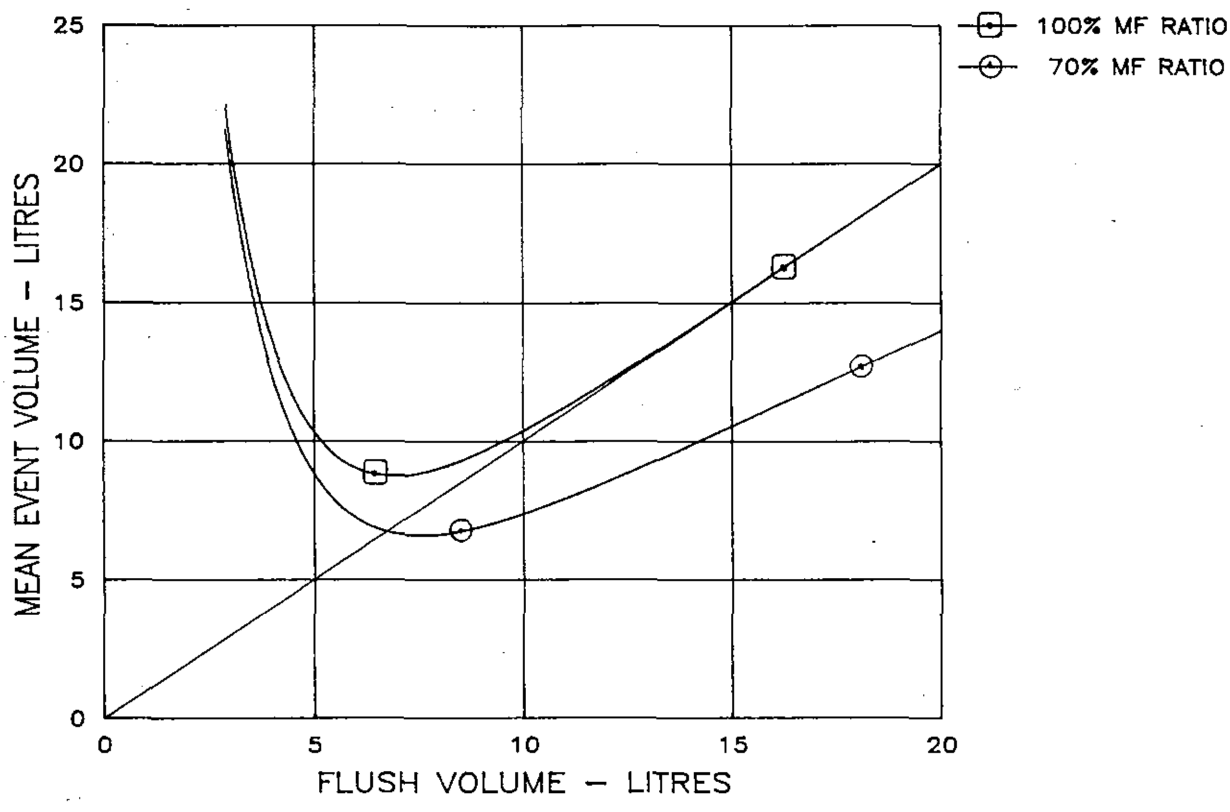

Figure 2 : Flush Volume and Mean Event Volume Relationship

At flush volumes higher than the optimum flush volume, the ratio between mean-event water use and the flush volume will be equal to one, if part flushes are prohibited. The use of part-flushes will cause the ratio to be less than one, provided the part flushes are successful. However as the flush volume is reduced, a region of the curve is reached where the number of repeat flushes needed to clear the pan increases and this causes the mean event volume to increase, due to the reduced system efficiency.

Therefore, if the flush volume is reduced below the optimum flush volume for the pan, the water savings will be small and may even be negative. This concept should also be viewed together with the effect of not providing the optimum flow hydrograph, in particular a lack of duration of the peak flow rates required to rinse the pan and generate sufficient flow through the trap to clear the contents from the pan. [Simpson,1983].

The increase in water consumption at Rooiwal could have been due, in part, to an induced flushing inefficiency as a result of the reduced flush volumes. It is more likely, however, that other factors, such as the removal of water restrictions, had a greater impact on the overall water consumption at Rooiwal. Nevertheless, Figure 2 shows that the flushing efficiency of the WC system is an important factor to consider when reducing flush volumes. More attention should be paid to efficient WC pan designs and methods of evaluating WC component and system performance.

PRETORIA MIDDLE INCOME HOUSES

The three houses, which are described below, were identified from the records of a local plumber as having a history of drain blockages. The houses were to be monitored for a year after which time the flush volumes would be reduced and water conserving shower heads fitted. After a further 12 months, the drains would be relaid at minimum grades, using different pipe materials.

However after 12 months it was clear that the blockage rates had remained the same and that the causes were invariably root penetration. Furthermore, to relay the drains would have caused substantial damage to the existing gardens and the reinstatement costs were beyond the project's budget.

These properties would not have yielded meaningful results in terms of the project objectives and alternative possibilities were sought. A block of six stands at the head of a sewer in Mamelodi was identified as being of potential use to the project. The work that was done at the three houses is described below for completeness of the record.

Erf 649/1 Silverton

Six water meters, additional to the Municipal water meter, were installed at the start of the experiment. These were monitored from December 1987 to November 1988. An investigation of the drainage system revealed that the system was in good condition generally, with three problem areas causing all of the blockages experienced in the past.

The problems in all three areas were found to be caused by root intrusion. Root intrusion occurs near the municipal connection and also, unfortunately, at a point where the drain is shallow, within two metres of each of the two pans at the heads of the drain on the property. The intruding roots trap solids and paper close to the WCs, which are pivotal to the experiment, so that only water passes through.

The house connection had not blocked again since the preliminary clean out. However, the drains near the WCs are prone to blockages at three to four month intervals. The drains are cleared each time by tearing the roots out of the pipes.

The owner, an Architect, did not want the ivy, which causes the blockages, to be removed, so nothing could be done to reduce the blockage frequency.

<u>Erf 269 Brooklyn</u>

Nine water meters, additional to the municipal water meter, were installed at the start of the experiment. These were monitored from December 1987 to November 1988.

On investigation, the drainage system was found to be in fair condition with two problem areas, both caused (coincidently) by the intrusion of ivy roots. These roots cause blockages every five to six months.

The first problem area was in a flower bed, where eight metres of Salt Glazed Earthen Ware (SGEW) pipes had been laid under shallow cover in a flower bed. It is thought that these pipes were cracked in numerous places by the combined effects of gardening work in the bed, expansion and contraction of the pipeline with rigid caulked joints and by ground movements. This pipe could be replaced if the whole flower bed was dug up. However the second problem area is of a more serious nature in that the root intrusion occurs somewhere in a cast iron pipe, laid under the building, where we cannot gain access to replace the pipes.

Three of the four WCs in this household are upstream of the adjacent blockage areas with the fourth WC, a guest toilet, hardly being used. Consequently, the length of drain from the house to the boundary, which was supposed to be the test section, often receives no solids and was not suitable for the experiment.

<u>Erf 522 Brooklyn</u>

Six water meters, additional to the municipal water meter, were installed at the start of the experiment. These were monitored from December 1987 to November 1988.

This house is old, but the drain is in good condition and had not blocked once since it was cleaned out at the beginning of the experiment. The drain was laid before the 2nd World War and a waste disconnection gully, as was the practice then, is installed near the bathroom with an unventilated 110 mm waste drain eleven metres long running from the kitchen gully to the waste disconnection gully.

The blockages prior to the cleaning out of the system all occurred in the waste drain between the kitchen and bathroom. All household waste water enters the drain upstream of the house WC, so that reducing the flush volume of the WC would have a minimal effect on the solids carrying capacity of the drain.

The section of drain as selected on the drawings cannot be easily relaid as it passes under at least three mature 15 - 20 metre high blue gum trees which the owner wants to remain. The trees were planted over the drain many years ago and have grown into massive trees without causing damage to the drain underneath. Tunneling under the trees is a possibility but any contractor quoting on the job of relaying a pipe under a tree with a trunk of more than a metre or so in diameter will load his price to provide for all the roots he is bound to encounter.

MAMELODI HOUSES

General

The main objective of the Mamelodi tests was to determine the effects of installing 6 litre flush toilets in a block of six stands at the head of the sewer system. The site was selected from an older part of Mamelodi, where monitoring could determine:

a) if there were any blockages in the sewer as a result of a reduction in the flush volumes
b) if there was a significant water saving as a result of the installation of 6 litre WC units.

The objectives included measuring the rate of deposition of solids in the sewer, corresponding to the reduced water consumption from the toilets.

The wet services at each site consist of a toilet in the rear corner of the stand with a wash-tub and tap mounted on the outside wall of the toilet building. There are no wet services inside the dwellings. The toilet building is constructed of brick with a corrugated iron roof and door. The water supply is metered by the Council.

The pre-monitoring conditions of the toilets were as follows:

STAND No.	FLUSH VOLUME	TOILET INSTALLATION DETAILS
1637	10 litres	High level cast iron cistern
1638	9 litres	High level cast iron cistern, leaking pan connector
1639	9 litres	High level plastic cistern with plastic Beta valve
1640	9 litres	High level plastic cistern with plastic Beta valve
1641	7 litres	High level plastic cistern with plastic Beta valve
1642	-	High level cast iron cistern and badly cracked pan. The cistern was found to be rusted through and the residents were flushing the pan using a bucket filled at the wash-tub.

The Council provided the water meter readings for these stands for the pre-monitoring period January 1989 to May 1989.

Monitoring period

The gradient of the 150 mm sewer, over a length of 90 metres between manholes, was measured as 1:37,8. An inspection of the sewer, using mirrors and a sewer camera, revealed that there were 5 displaced joints, 1 cracked pipe, 1 fractured pipe and root penetration at one point, although the general condition could be described as good and representative of an old sewer.

All the toilet units were replaced with new six-litre flush volume pans and cisterns, with the installation being done by a local contractor. At the time of installation, an additional water meter was placed on the supply pipe to the cistern to measure the quantity of water used for toilet flushing. Each unit was set to flush a total of 6 litres.

The installation of the new toilet pans and cisterns was completed in June 1989 and the initial meter readings were taken on the 20th June which was then considered as the start of the monitoring period. The sewer was cleaned on the 20th June. Thereafter the site was visited each month and the following tasks undertaken;

a) Both the toilet and the council water meters on each stand were read.
b) The sewer was inspected to see if any material had settled.
c) The flush volume of each cistern was checked.

To obtain additional information on the pattern of water consumption, the bulk meters at stands 1637 and 1642 were replaced for a short period with 15mm Kent water meters, geared to trigger an event datalogger at 1.1 litre increments[4].

The water consumption patterns at these two stands were monitored from the 8 August to 22 August 1989. At the end of this period, the registers of the original bulk meters were adjusted to account for the consumption measured by the triggering meters and reinstated.

Water Consumption Analysis

A summary of the water consumption data is given in Table 3 below. It will be seen that after the WC units had been replaced, water consumption dropped at only two of the stands. Given that the toilets use about 20% of the total water, the expected water reduction is in the order of 7%. The recorded changes are considerably in excess of this figure, suggesting that unforeseen factors contributed to the changes in water consumptions.

In Table 3, the water consumption attributed to the toilets is based on actual meter readings taken after the changes in the plumbing were made. Prior to the changes, only the total water consumption records were available and it was therefore not possible to isolate the proportion of water used by the toilet.

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4 The meters were supposed to trigger every 0,5 litres, but an assembly error led to the wrong gearing being installed in the meter. This was corrected later for other water-use monitoring in the Pretoria area.

TABLE 3 : ORIGINAL WATER CONSUMPTION DATA FOR MAMELODI HOUSES

STAND No.	APPROX. No. OF PEOPLE	LITRES/HOUSE/DAY BEFORE CHANGE	AFTER CHANGE	TOILET USE %	LITRES/CAPITA/DAY BEFORE CHANGE	AFTER CHANGE	TOILET USAGE	CHANGE IN WATER USAGE
1637	22	884	1138	15.6%	40	52	8.1	28.7%
1638	5	272	372	11.7%	54	74	8.7	36.5%
1639	7	1261	764	17.6%	180	109	19.2	-39.4%
1640	12	1441	1861	38.5%	120	155	59.7	29.1%
1641	10	1097	777	14.9%	110	78	11.6	-29.2%
1642	27	1324	1803	21.8%	49	67	14.6	36.2%
Totals		6279	6715					6.9%

<u>Changes in Population</u>

It is thought that the main cause for the water consumption changes could be changes in the resident population. Unfortunately, the number of occupants on each property during each month was not recorded and the only population count was taken during November 1989. At the beginning of the project no back yard shacks were noticed on stand 1642 whereas the population count received on the 20th November 1989 indicated an 11 member family and 16 tenants. It would seem, therefore, that the population on this stand may have increased from 11 to 27 during the project period. Similarly, the population at stands 1639 and 1641 could have decreased.

<u>Leakage of Valves</u>

Another important contributing factor was the leakage of valves in the cisterns, noteably at stand 1640 and 1642. Corrections were made to the outliers in the monthly toilet water consumption data and the adjusted data are given below in Table 4.

TABLE 4 : ADJUSTED WATER CONSUMPTION DATA FOR MAMELODI HOUSES

STAND No.	APPROX. No. OF PEOPLE	LITRES/HOUSE/DAY BEFORE CHANGE	AFTER CHANGE	TOILET USE %	LITRES/CAPITA/DAY BEFORE CHANGE	AFTER CHANGE	TOILET USAGE	CHANGE IN WATER USAGE
1637	22	884	1138	15.6%	40	52	8.1	28.7%
1638	5	272	372	11.7%	54	74	8.7	36.5%
1639	7	1261	764	17.6%	180	109	19.2	-39.4%
1640	12	1441	1387 *	17.0%	120	116	20.2	- 3.7%
1641	10	1097	777	14.9%	110	78	11.6	-29.2%
1642	27	1324	1619 *	13.0%	49	60	7.7	22.3%
Totals		6279	6057					- 3.5%

The adjustments have not significantly improved the results in terms of percentage change in usage, but have led to consistency in the proportion of water used by the toilet. The mean proportion of toilet water to total water use is 15% with a standard deviation of 2.28%. The t value for a 95% confidence interval is 2.571.

Hence, for similar stands at Mamelodi, we can expect the proportion of water used by the WCs to lie between 21% and 9% of the total water use.

From an analysis of the differences in Tables 3 and 4, it would seem that leaking valves in the cistern at stand 1640 were responsible for a 32.8% increase in the water consumption.

Changes in Occupants' Habits

It is worth noting that the daily water consumption at Stand 1638 increased by 36.5 % and yet the proportion of water used in the toilet was the lowest at 11.7%. This indicates that the tap water consumption increased, possibly as a result of additional laundry and washing activities.

Results of Flow Monitoring at Stand 1637

The total number of flow data recorded from 14:21:45 on the 08/08/89 for a period of 9 days and 0.9 hours was 10491. The mean flow rate was 12.9 litres/minute, with a standard deviation of 34.9 litre/minute. The standard error of the mean was 0.3 litre/minute. The frequency distribution of the flow data is shown in Table 5. Each flow-rate datum also represents a water consumption of 1.1 litres.

The high frequency of 1097 events in Class 1 (10.5% of total) does not indicate a large proportion of the flow occurred at very low flow rates. These events indicate two things:

a) the number of periods (of duration more than 1 minute) that the water supply was not in use. By adding up the time intervals preceding these events, the "down-time" of the water supply can be estimated.
b) the number of times the supply was used, or the user activity.

The size of Class 1 in Table 5 suggests that this water supply was used relatively frequently by the estimated 22 residents.

Theoretically, every class can contain a certain number of events that indicate inactivity, rather than water flow, but in practice the length of the periods of inactivity between events will tend to be relatively long. Hence with the exception of Class 1 in Table 5, the frequencies reasonably reflect the true distribution of flow rates. The flow monitoring method is discussed in more detail in a report by the author [Simpson,1990a].

One method of correcting the distribution would be to eliminate Class 1 and redistribute the 1097 data proportionally among the other classes. The 147 events above Class 24 were due to switch-bounce and other error sources in the data record and do not represent real flow rates, hence they can be ignored.

It will be seen that there are 2 modes, one at Class 3 and the other at Class 15. These correspond to the cistern inflow rate of approximately 3.0 litres/minute and the tap discharge rate of about 15 litres/minute. Classes 2.3 and 4 can be taken to represent toilet water use and the sum of the relative frequencies for these classes is 15.8%, which corresponds closely with the 15.6% given in Table 3.

TABLE 5 : FLOW FREQUENCY DISTRIBUTION FOR STAND 1637

Class	FLOW (litres/min)		1.1 litre Unit Volumes		
	From	To	Frequency	Rel.Freq.	Cum.Rel.Freq.
1	0.00	0.99	1097	0.105	0.105
2	1.00	1.99	383	0.037	0.141
3	2.00	2.99	756	0.072	0.213
4	3.00	3.99	518	0.049	0.263
5	4.00	4.99	172	0.016	0.279
6	5.00	5.99	147	0.014	0.293
7	6.00	6.99	158	0.015	0.308
8	7.00	7.99	196	0.019	0.327
9	8.00	8.99	161	0.015	0.342
10	9.00	9.99	185	0.018	0.360
11	10.00	10.99	169	0.016	0.376
12	11.00	11.99	315	0.030	0.406
13	12.00	12.99	854	0.081	0.487
14	13.00	13.99	1156	0.110	0.597
15	14.00	14.99	1711	0.163	0.760
16	15.00	15.99	1598	0.152	0.913
17	16.00	16.99	683	0.065	0.978
18	17.00	17.99	28	0.003	0.981
19	18.00	18.99	27	0.003	0.983
20	19.00	19.99	5	0.000	0.984
21	20.00	20.99	13	0.001	0.985
22	21.00	21.99	7	0.001	0.986
23	22.00	22.99	5	0.000	0.986
24	23.00	23.99	1	0.000	0.986
			No. of Values beyond class 24 = 147		

<u>Results of Flow Monitoring at Stand 1642</u>

The population on this stand was estimated to be 27. The total number of flow data recorded from 14:31 on the 8 August 1989 for 8 days was 10634, representing 11.7 kilolitres. The mean flow rate was 9.3 litres/minute, with a standard deviation of 8.1 litre/minute. The standard error of the mean was 0.1 litre/minute. The frequency distribution of the flow data is shown in Table 6 and is very similar to that obtained for Stand 1637. The daily per-capita water consumption for the period was 54 litres, compared with 67 litres from Table 3.

TABLE 6 : FLOW FREQUENCY DISTRIBUTION FOR STAND 1642

Class	FLOW (litres/min) From	To	1.1 litre Unit Volumes Frequency	Rel.Freq.	Cum.Rel.Freq.
1	0.00	1.09	1045	0.098	0.098
2	1.10	2.19	483	0.045	0.144
3	2.20	3.29	911	0.086	0.229
4	3.30	4.39	314	0.030	0.259
5	4.40	5.49	262	0.025	0.284
6	5.50	6.59	263	0.025	0.308
7	6.60	7.69	354	0.033	0.342
8	7.70	8.79	387	0.036	0.378
9	8.80	9.89	635	0.060	0.438
10	9.90	10.99	935	0.088	0.526
11	11.00	12.09	931	0.088	0.613
12	12.10	13.19	1135	0.107	0.720
13	13.20	14.29	1363	0.128	0.848
14	14.30	15.39	1098	0.103	0.951
15	15.40	16.49	395	0.037	0.988
16	16.50	17.59	112	0.011	0.999
17	17.60	18.69	8	0.001	1.000
			No. of values beyond class 17 = 3		

Water Saving Effects

The reduced flush volume toilets accounted for 15% of the total water consumption, but did not appear to have a significant effect on the total water consumption. This can be attributed to the effects of several unforeseen factors that could also have influenced water consumption.

It was not possible to determine the true impact of the low flush volume toilets, since there was no control group and various other factors were not included in the monitoring plan.

For example, regular complaints were received about the flushability of the toilets on stands 1641 and 1642, but the extra water drawn from the taps and used to bucket-flush the toilets when they failed to clear properly could not be measured. Neither could the changes in occupancy, or usage patterns be monitored.

Effect on Sewer Performance

It is clear that the flow in the sewer was adequate to maintain the pipeline in a clean condition. No deposits were found in the sewer during the monthly inspections and no blockages were recorded, even after the flush volumes were reduced to 4.5 litres for one month at the end of the project.

Tables 3 and 4 show that the average daily water consumptions per stand are relatively high and the overall average is above 1000 litres per stand per day. Since almost all of this volume is discharged into the sewer, the sewer flow is more than adequate to maintain the pipeline in a clean, deposit free condition and is far from being a "worst case" condition.

Consider houses in Pretoria which are situated on larger erven and have proportionately longer drains and sewers than those in Mamelodi. The mean internal water consumption for houses in Pretoria was determined as 763 litres [Simpson,1990b:21] and most blockages occur as a result of root intrusions and in-appropriate materials flushed down the drain. If this represents a "normal" situation, it also suggests that to achieve this "normal" situation in Mamelodi, we would need to reduce the water consumption for the Mamelodi houses by more than 30%.

It is concluded that low-flush toilets are unlikely to affect the performance of the sewer system in areas such as Mamelodi, because the relatively high water consumption per stand (due to high population densities) should ensure drains and sewers are maintained in a clean condition. Low-flush toilets cannot be attached to the issue of flushing drains and sewers under "worst case" scenarios, unless the scenario provides for a reduction in water consumption exceeding about 80 to 85 percent. ie. the point where the toilet becomes the only contributor to the flushing of the drains.

EFFECT OF DRASTICALLY REDUCING WATER CONTENT OF DOMESTIC SEWAGE

A survey of twelve local authorities in Natal was conducted in October 1988 to obtain their opinions on the effects of the 1982/83 water crisis in Natal and what effect drastically reducing the water content of domestic sewage would have on the corrosion and maintenance of sewer systems and on sewage treatment processes. A summary of the findings, based on the opinions of the interviewees, is given below.

Effect on the Frequency and Causes of Blockages in Sewer Systems

Eleven of the twelve local authorities interviewed had sewage systems in operation during the water restriction period. Unfortunately, the second largest municipality could provide no information on their experiences of sewer blockages during this period.
Five of the ten remaining authorities reported no increase in the blockage rate of the sewers in their areas during the water restriction period. The other five reported increased blockage rates, but two of these could provide no data, with the remaining three reporting 29%, 90% and 100% increases in their sewer blockage rates.

Five of the twelve local authorities did not know what the household drain blockage situation was in their areas during the water restriction period. Two municipalities reported that there was no change in the household drain blockage rate in their areas during the water restriction period. Three stated that there was an increase but could quote no figures. The last two reported a 100% and a 10 to 15% increase in blockage rate in their areas.

All members of maintenance sections who had experienced the water restriction period expressed the view that, apart from the normal causes of blockages, i.e. roots, broken pipes, lips and bad joints, etc, additional blockages were being caused by the abnormal conditions pertaining at the time. The additional blockages occurred most often at the head of household drains where the flushed paper and solids were relatively fresh and firm.

A factor which contributed greatly to the abnormal condition pertaining during the restriction period was that caused by a build-up of urination into the WC during the day without flushing the pan, with the commensurate build-up of unflushed paper in the pan. When the pan is flushed eventually, with just enough water to clear the pan, the paper wad is transported to just beyond the turbulent area in the drain pipe at the foot of the soil stack where it remains. The paper wad either breaks up with successive flushes and dissipates, or builds up and causes a blockage. Most waste gullies contributed no water that would aid in the rinsing out of the drain during the restriction period.

As these solids move further down the drain they are softened and break up through the action of water absorption and turbulence. By the time the solids reach the house connection and the sewer this type of blockage no longer contributes any significant amount to the total blockage rate in some areas. Other areas did experience this type of blockage near the heads of their sewers, but in the cases of all eleven contributing local authorities the incidence had dropped off completely by the time the solids had reached the main sewers.

Increase in Septicity and Corrosion in the Sewer Systems

Seven out of eleven areas reported no changes in septicity, corrosion, or smell in their sewer systems.

Two municipalities reported an increase of odour at their pump stations, but no changes otherwise.

The last two areas both reported no increase in septicity but one reported an increase in the corrosion of steel and the other an increase in the corrosion of concrete. Both stated that the corrosion rate returned to normal after the drought.

Most of the respondents believed that septicity was not an important factor in their areas, because with a detention time of two to five hours in the sewers their sewage remains relatively fresh.

Effect on Increase and Cost of Preventative and Other Maintenance Work

All eleven contributors reported that no long-term changes took place during the water restriction period. Three councils reported a short-term increase in maintenance costs. One council reported a reduction in pumping costs during the water restriction period.

Effect on Grease Traps, Oil and Petrol Interceptors

Four contributors reported that they have no grease traps or petrol interceptors in their areas. Seven contributors reported that there was no effect on the grease traps or petrol interceptors in their areas.

One municipality reported a decrease in the frequency of cleaning out of petrol interceptors.

Effect on Transportation of Sand and Gravel

Seven contributors reported no change in the deposition characteristics of their sewer systems. Three reported an increase in the silting of sewers. One reported increase in deposition in grit traps. Two reported less sand in the systems.

Effect of Reduced Discharges from Individual Fixtures

Six contributors did not think that there would be any adverse effects on the performance of the drainage or sewage systems if the water content was reduced moderately. The interviewer was not able to quantify what was meant by moderately, but an interpretation of the attitudes suggests a reduction of about 30% to 40% in the water consumption of individual fixtures.

Two contributors foresaw no adverse effects in the sewers but had reservations about the effect on household drains especially if the reduction was excessive. For example, if all the waste water was diverted for irrigation purposes, the soil water in the drains may be insufficient to prevent blockages. In this case "excessive reduction" would mean a reduction in normal water consumption of about 75 to 85 percent.

One respondent did not wish to see any changes and two of the contributors did not wish to express an opinion.

Effect on Performance of Sewage Treatment Process

The eight local authorities that had sewage works operating at the time of the water restrictions all reported that there was virtually no negative changes in the operating efficiency of their plants. The activated sludge plants on the whole in fact seemed to benefit by having less water to deal with, even though the biological load, for which the plant was designed, remained the same.

The biological filters continued to deliver reasonable effluent even though there was concern about the fact that there were low water periods, especially during the early hours of the morning, when no water at all was flowing through the works and the filters started drying out.

All twelve contributing local authorities reported having gained at least a five year breathing space in their capital expenditure programmes. Potable water consumption and sewage flow rates are today still slightly below the pre-water restriction levels in most cases, and no extensions to the plants have been required. One of the works was being extended to handle a greater biological load, but not a greater hydraulic load.

More details from the individual municipalities are given in Appendix C.

REDUCED WATER CONSUMPTION IN PORT ELIZABETH IN 1989

General

The 1989 drought in the Eastern Cape affected the catchment areas of the major water supply dams serving the Port Elizabeth area. The city itself did not suffer from a lack of rain and this helped to reduce the pressure on the water supply for external garden watering requirements.

Measures had to be taken to control water utilisation during 1989 and these were phased in as the drought worsened. Details are given later in the report. Good rains fell in the catchments during October and November 1989 and the restrictions were finally repealed on the 22nd November.

Effect on the frequency of blockages

Drastically reducing the water content of domestic sewage did not have a significant effect on the frequency of blockages in the sewer system, although the data indicated that blockages on drains increased.

The incidence of blockages is generally very small compared to the size of the sewer system in Port Elizabeth. The older parts of the sewer system are laid in salt glazed earthen-ware (SGEW) and the newer parts are laid in fibre cement pipe with uPVC pipe being used for drains. The blockages in the main sewers usually occur in the older 150 mm diameter SGEW pipes, due to cracked lips.

Before the drought, no dry blockages were reported on the main sewer lines, but by September 1989 approximately two per week were being cleared in certain parts of the system. With a dry blockage, the solids are not transported in the pipe, instead they build up at a point and dry out. Subsequent flushes provide insufficient moisture to break down the accumulated material and a blockage is created. The occurence of these blockages is thus a function of the pipe gradient (and condition) and the amount of moisture in the pipe. Thus the best conditions for dry blockages will occur where the pipe gradient is shallow and the air in the pipe is dry and warm.

A charge is levied for blockages cleared on the consumer side of the connection, otherwise the Council accepts the costs. Blockages were estimated by Council staff to have increased by about 30%, due to the drought. The causes were generally attributed to bad pipelaying, roots and manholes, where the junctions with uPVC pipes are not sealable. The use of saddles on main sewers leads to ragged edges protruding into the pipe and these snag paper and rags, etc. The Council now provides a "Y" branch to eliminate this problem.

Analysis of blockage records

Records of blockages are kept by the municipality for the purpose of calculating tariffs. Most of the municipal maintenance truck records, which logged the sites and causes of blockages attended to by the maintenance crews were available for the period from January 1987 to

December 1989, although it was found that much of the data for 1988 was missing. Requests for blockage records for the private plumbers were made, but it was found that private plumbers do not generally keep such records because it is not required and it would be an administrative burden.

A summary of the records indicating the position and frequency of blockages is given in Table 7 and the causes of the blockages are given in Table 8. The total number of blockages given in Table 7 is less than the total number of causes given in Table 8, because the records often indicated more than one cause of a blockage. Another feature of the tables is that they reflect the available data for each month. In most cases, all the records were available, but there were months when either a truck record was missing or entire records were missing for particular days. The effect can be seen in the records for January, February and June in 1988.

TABLE 7 : POSITION OF BLOCKAGES FOR PORT ELIZABETH

MONTH	YEAR	CONN	DRAIN	MAIN	TOTAL
1	87	112	217	125	454
2	87	128	184	125	437
3	87	146	184	142	472
4	87	166	214	182	562
5	87	175	239	156	570
6	87	201	282	173	656
7	87	192	257	149	598
8	87	192	187	142	521
9	87	157	216	143	516
10	87	117	198	121	436
11	87	117	212	123	452
12	87	124	226	136	486
1	88	58	84	46	188
3	88	86	159	81	326
4	88	124	167	109	400
5	88	87	126	56	269
6	88	25	33	19	77
2	89	111	91	92	294
3	89	229	163	184	576
4	89	237	175	168	580
5	89	301	153	182	636
6	89	331	165	195	691
7	89	292	122	158	572
8	89	256	156	186	598
9	89	276	167	180	623
10	89	245	183	178	606
11	89	219	225	198	642
12	89	118	153	100	371

The data in Table 7 was used to determine the relative frequencies for blockages in main sewers, drains and at connections. These are shown in Figure 3. There appears to have been an increase in the number of blockages at connections and a corresponding decrease in the number of blockages in drains. However, it was stated that where there was doubt, or a case for leniency, the point of blockage was recorded as being at the connection, thus there could be a bias in the data, the extent of which cannot be determined.

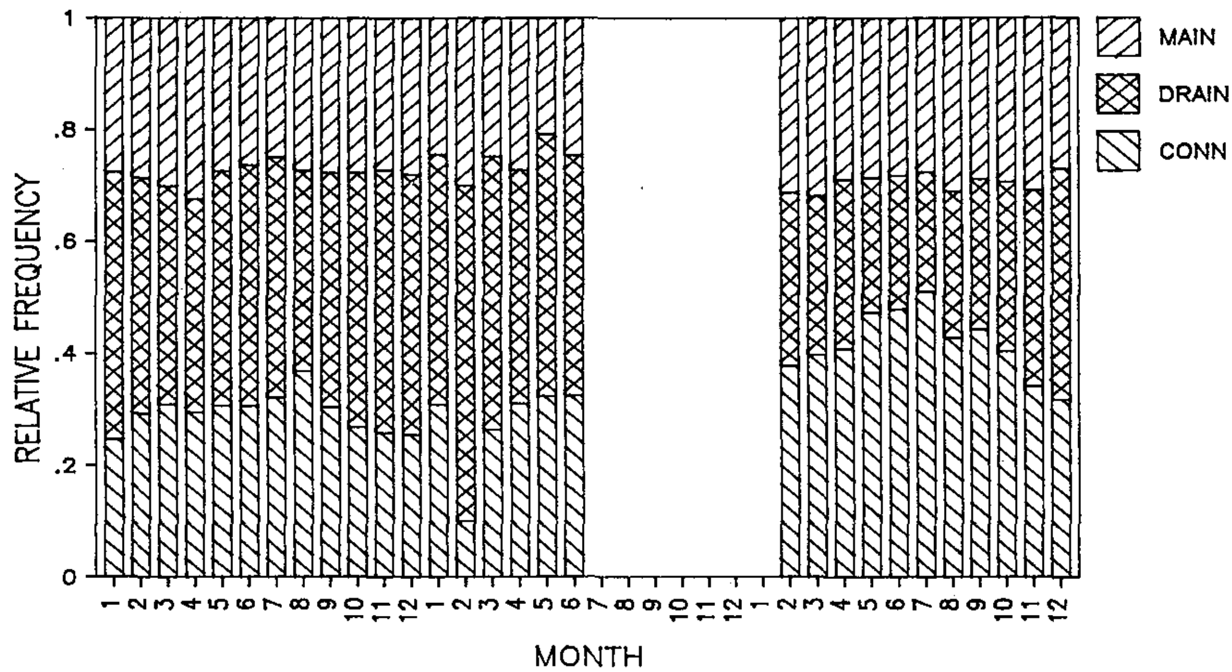

Figure 3 : Relative Blockage Frequencies by Position

The record appears to be fairly consistent between March and November for both 1987 and 1989. This period also corresponds to the drought period in 1989 and the total blockages for this period were 5220 in 1987 and 5524 in 1989. The increase in blockages in 1989 compared to 1987 was only 5.8%.

In Table 9, the causes of blockages and their positions are summarised for the first half of 1989. Where two or more causes were given, the one thought to be the predominant cause was chosen, so that the totals of the causes correspond to the total blockages.

Similarly, the summary for the second half of 1989 is given in Table 10.

The data in Table 11 reveal that roots at connections are the most common cause of blockages. A reduction in water consumption in drains should lead to an increase in blockages due to paper, which is confirmed by comparing the data for drains given in Tables 9 and 10. Paper blockages rose from 22.5% of the total in the first half of 1989 to 33.8% of the total in the second half of 1989, which is a 50% increase.

TABLE 8 : MONTHLY RECORD OF BLOCKAGE CAUSES FOR PORT ELIZABETH

DATE	ROOTS	RAGS	PAPER	FAT	STONES	SAND	STICKS	PLASTIC	MISC.	TOTAL CAUSES
1/87	266	106	104	57	44	8	5	12	35	637
2/87	266	104	101	57	23	5	1	25	34	616
3/87	318	91	82	59	29	11	3	14	27	634
4/87	366	88	103	74	32	8	10	11	53	745
5/87	361	129	147	79	20	10	2	14	33	795
6/87	399	179	196	107	25	8	3	10	44	971
7/87	359	144	180	79	36	14	5	18	38	873
8/87	269	89	187	41	28	10	4	12	64	704
9/87	292	117	199	45	22	4	6	17	65	767
10/87	229	107	138	37	30	10	5	17	57	630
11/87	219	110	122	44	26	13	5	20	69	628
12/87	267	128	160	42	40	12	11	18	52	730
1/88	87	54	63	23	9	3	1	15	13	268
2/88	4	3	3	0	4	0	0	1	2	17
3/88	192	90	82	39	22	4	2	17	47	495
4/88	228	115	74	44	17	1	4	22	58	563
5/88	156	78	63	23	14	1	3	13	40	391
6/88	52	21	16	5	1	0	3	4	8	110
2/89	160	71	54	17	16	3	6	24	34	385
3/89	349	130	119	20	28	5	3	32	52	738
4/89	358	120	105	25	26	4	7	27	51	723
5/89	439	98	73	16	22	9	8	16	57	738
6/89	458	94	83	21	16	4	4	21	88	789
7/89	387	64	112	18	15	7	4	15	46	668
8/89	367	93	117	16	20	5	7	18	57	700
9/89	376	121	159	21	29	5	3	14	59	787
10/89	349	92	125	20	23	10	3	25	94	741
11/89	303	155	146	35	34	22	0	19	107	821
12/89	183	68	85	19	20	10	3	11	65	464

TABLE 9 : CAUSES OF BLOCKAGES FOR PERIOD 31 JAN TO 30 JUNE 1989

CAUSES	CONNECTIONS	DRAINS	MAINS	TOTALS
Roots	1136	202	414	1752
Rags	23	176	212	411
Paper	13	169	17	199
Sludge	0	44	47	91
Other	24	35	15	74
Stones	5	22	42	69
Fat	3	50	14	67
Tins	0	9	16	25
Plastic	2	26	6	34
Sticks	0	3	17	20
Sand	4	5	6	15
Bricks	0	2	11	13
Wire	0	7	3	10
TOTALS	1210	750	820	2780

TABLE 10 : CAUSES OF BLOCKAGES FOR PERIOD 1 JULY TO 18 DECEMBER 1989

CAUSES	CONNECTIONS	DRAINS	MAINS	TOTALS
Roots	1292	141	512	1945
Rags	28	184	267	479
Paper	30	340	46	416
Other	32	116	23	171
Sludge	9	73	39	121
Fat	4	68	17	89
Stones	4	33	50	87
Sand	3	19	14	36
Plastic	2	15	12	29
Tins	1	4	7	12
Bricks	1	5	5	11
Sticks	0	4	6	10
Wire	1	4	3	8
TOTALS	1407	1006	1001	3414

TABLE 11 : BLOCKAGE CAUSES FOR THE YEAR 31/1/89 TO 18/12/89

CAUSES	CONNECTIONS	DRAINS	MAINS	TOTALS	PERCENTAGE
Roots	2428	343	926	3697	60%
Rags	51	360	479	890	14%
Paper	43	509	63	615	10%
Other	56	151	38	245	4%
Sludge	9	117	86	212	3.4%
Stones	9	55	92	156	2.5%
Fat	7	118	31	156	2.5%
Plastic	4	41	18	63	1.0%
Sand	7	24	20	51	0.8%
Tins	1	13	23	37	0.6%
Sticks	0	7	23	30	0.5%
Bricks	1	7	16	24	0.4%
Wire	1	11	6	18	0.3%
TOTALS	2617	1756	1821	6194	

Some of the increases in blockages due to other listed causes are significant, in particular sludge, sand, stones and "other" causes. The latter would be due to the disposal down the drain of many less common items, such as glass bottles and other in-appropriate articles. While sufficient water is flushed down the drain, these articles tend to be scoured clean of other debris, but with a reduction in discharge water, paper and other material tend to clog on these articles and eventually cause a blockage.

The data indictate that the frequency of blockages caused by paper, sludge, sand, stones or "other" causes did increase significantly when discharges into the drains were reduced as a result of the water restrictions imposed during the drought. To illustrate this more clearly, the data in Tables 9 and 10 were converted to daily blockage rates and are given in Table 12. The percentage differences between the rates for the first and second periods were calculated and these are given in Table 13.

Table 13 shows that there was an overall increase in the blockages rate of 18.4% on drains and if roots were eliminated from the analysis, the differences would become more pronounced. The decrease in blockages due to roots, particularly in drains, may be due to local rain and a reduction of flow in the sewer system, which resulted in a higher level of moisture outside the pipes, thus discouraging root intrusion.

However, in real terms the blockage rates given in Table 12 show that the incidence of blockages is very low compared to the size of the sewer system and the number of drainage installations. From this perspective, the change in the blockage rates is not considered to be significant.

When the 1987 data were compared to the 1989 data on a monthly basis, it was observed that more blockages occurred on sewer mains and connections in 1989 than in 1987 and less on drains. This is illustrated in Figure 4 and the primary causes of blockages are compared in Figure 5.

TABLE 12 : DAILY BLOCKAGE RATES

	31 January to 30 June				1 July to 18 December			
	Conn	Drain	Main	Total	Conn	Drain	Main	Total
Roots	7.52	1.34	2.74	11.60	7.56	.82	2.99	11.37
Rags	.15	1.17	1.40	2.72	.16	1.08	1.56	2.80
Paper	.09	1.12	.11	1.32	.18	1.99	.27	2.43
Other	.16	.23	.10	.49	.19	.68	.13	1.00
Sludge	.00	.29	.31	.60	.05	.43	.23	.71
Fat	.02	.33	.09	.44	.02	.40	.10	.52
Stones	.03	.15	.28	.46	.02	.19	.29	.51
Sand	.03	.03	.04	.10	.02	.11	.08	.21
Plastic	.01	.17	.04	.23	.01	.09	.07	.17
Tins	.00	.06	.11	.17	.01	.02	.04	.07
Bricks	.00	.01	.07	.09	.01	.03	.03	.06
Sticks	.00	.02	.11	.13	.00	.02	.04	.06
Wire	.00	.05	.02	.07	.01	.02	.02	.05
Totals	8.01	4.97	5.43	18.41	8.23	5.88	5.85	19.96

TABLE 13 : PERCENTAGE INCREASE IN DAILY BLOCKAGE RATE

Cause	Conn	Drain	Main	Total
Sand	-33.8	235.6	106.0	111.9
Other	17.7	192.7	35.4	104.1
Paper	103.8	77.7	138.9	84.6
Sludge		46.5	-26.7	17.4
Fat	17.7	20.1	7.2	17.3
Stones	-29.4	32.5	5.1	11.3
Rags	7.5	-7.7	11.2	2.9
Roots	.4	-38.4	9.2	-2.0
Plastic	-11.7	-49.1	76.6	-24.7
Bricks		120.8	-59.9	-25.3
Wire		-49.5	-11.7	-29.4
Sticks		17.7	-68.8	-55.8
Tins		-60.8	-61.4	-57.6
Overall	2.7	18.4	7.8	8.4

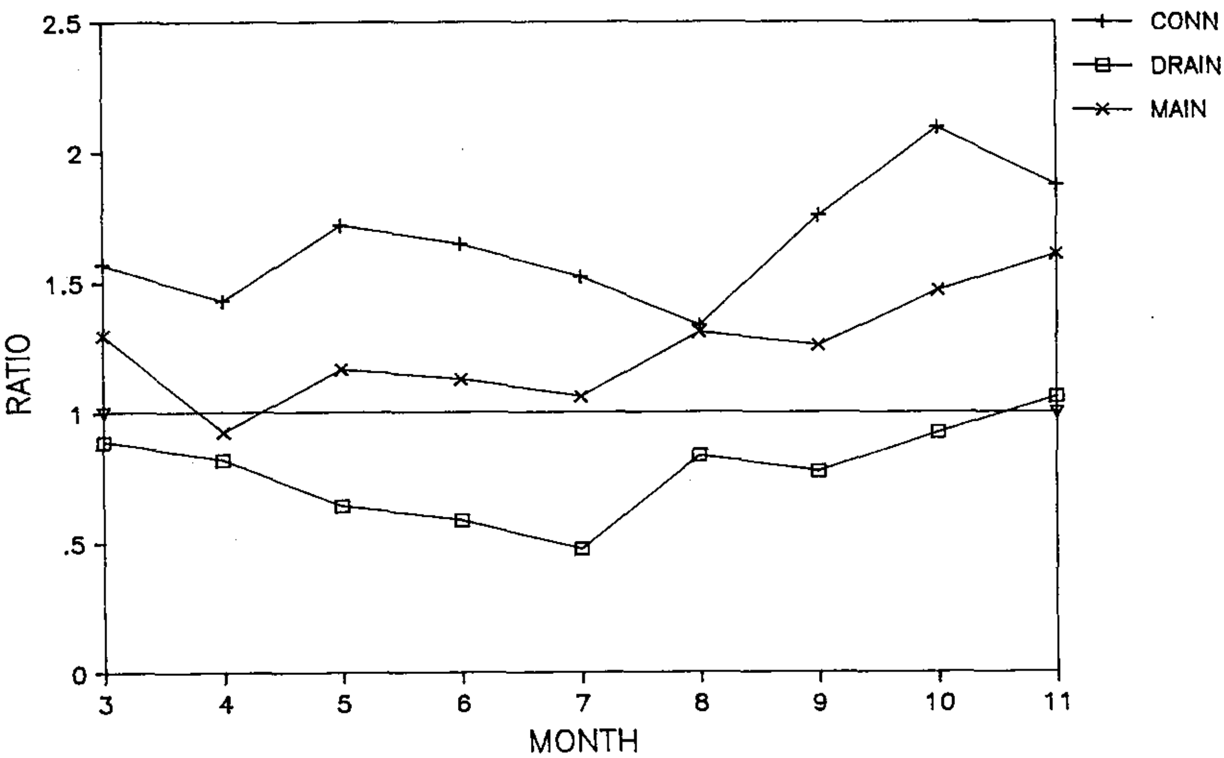

Figure 4 : Comparisons of Blockage Positions for 1987/1989

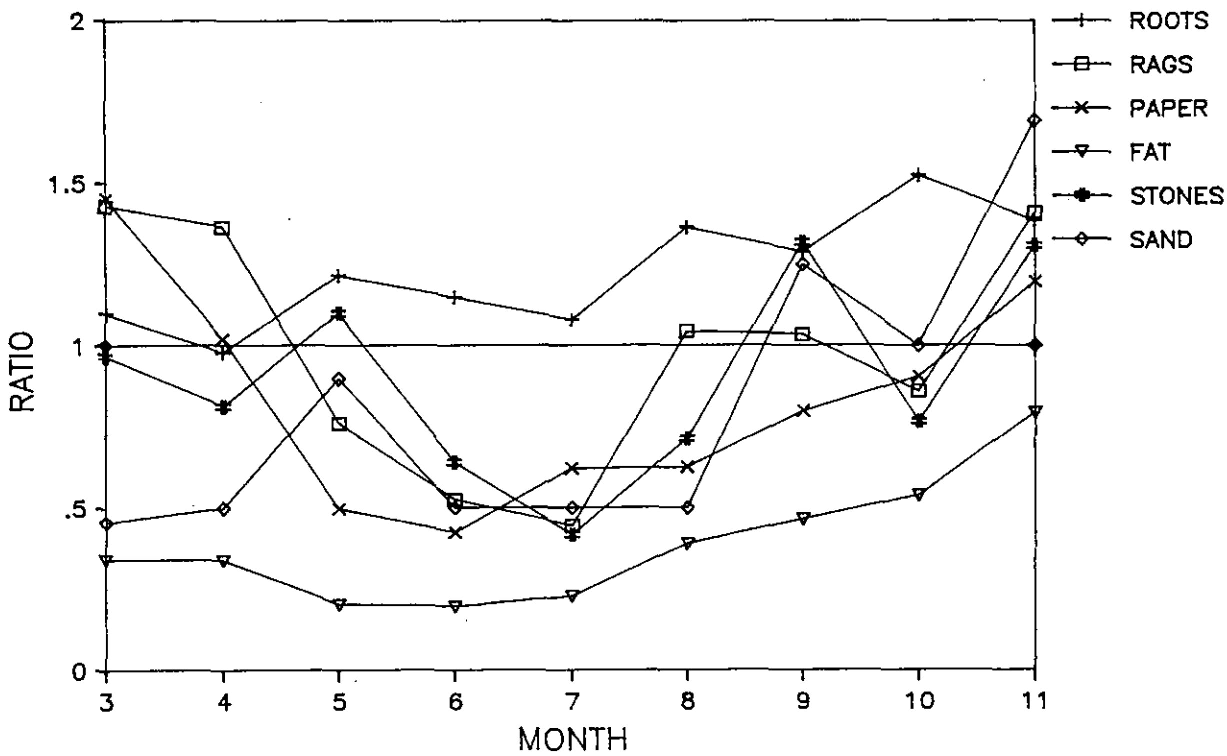

Figure 5 : Comparisons of Primary Blockages Causes for 1987/1989

Other Causes of Blockages

Table 14 on page 27 illustrates the number of times (N) that in-appropriate materials and items were found to have caused blockages in the Port Elizabeth sewer system during 1989. The incidence of blockages due to "other causes" was relatively high for drains, showing a 193% increase between the two halves of the 1989 year. Sand, although not a main cause of blockages, showed the highest increases of 236% for drains and 112% for the system as a whole. However, sand blockages may be related to the seasonal stormwater infiltration.

Water Consumption and Sewer Flow

The water consumption pattern for the metropolitan area of Port Elizabeth is shown in Figure 6, together with the original budget consumption and stages in the regulation of water use imposed by the municipality. The water utilisation control measures were implemented as follows:

27 February	**Restrictions prohibiting the use of hosepipes, sprinklers,** automatic flushing and washing systems, as well certain other limitations.
1 April	Introduction of stepped tariff: 52.7 cents/kilolitre up to 400 litres/day 96 cents/kilolitre for the next 600 litres/day 120 cents/kilolitre for the next 1000 litres/day 150 cents/kilolitre for additional consumption.

(Continued on p28)

TABLE 14 : OTHER CAUSES OF BLOCKAGES JAN 89 TO SEP 89

N	DESCRIPTION OF ITEM	N	DESCRIPTION OF ITEM
1	BLOCK	1	PLASTIC BUCKET
2	BONES	1	PLASTIC CONTAINER
1	BONES, SHOES, ETC.	5	PLASTIC CUP
1	BOTTLE TOP	1	PLASTIC HOLDER
1	BOTTLE, ETC.	1	PLASTIC HOSE
7	BROKEN GLASS	3	PLASTIC MUG
8	BROKEN PIPE	1	PLASTIC TOP
3	BRUSH	1	PLASTIC TUBE
1	CARDBOARD	1	PLUG SPANNER
1	CARROTS & POTATOES	1	PLUMBERS RODS
7	CEMENT	1	PLUNGER
1	CEMENT & WOOD	4	PULP
3	CUTLERY	1	PVC & HOSE
1	CUTLERY & SCOOP	1	RAKE
1	DOOR LATCH	1	RICE
1	GALVANISED PIPE	1	RINGS
1	GLASS	1	RINGS & PIPE
1	HAIR	1	ROLLERSKATE WHEEL
3	HOSE	4	RUBBER
1	HOSE & PLUNGER	1	RUBBLE
3	IRON	6	SHOE
3	IRON ROD	1	SOAP
1	IRONS	1	SOFT BOARD
4	LEAVES	3	SPOON
1	MEAT	1	SPOON & FORK
1	MOUSE	1	SPOON & NEWSPAPER
1	MUG	1	SPRAY CAN
1	NEWSPAPER	1	STAKE
1	PAINT	1	STEEL PLATE & SPRINKLER
1	PEN & TOILET ROLL	1	STRAP
1	PIECE OF PLYWOOD	1	STRAPS, PVC, ETC.
1	PIECE OF CHROME	1	TAP
3	PIECE OF HOSE	2	TEASPOON
2	PIECE OF METAL	2	TENNIS BALL
3	PIECE OF PIPE	1	TENNIS RACKET
1	PIECE OF PIPE & CEMENT	1	TIN LID
1	PIECE OF PLANK	1	TOYS
1	PIECE OF TIMBER	3	TWINE
1	PIECE OF WOOD	1	WHEEL
2	PLANK	1	WOOD
7	PLASTIC BOTTLE		

<u>1 June</u>	Notice of a water supply crisis.
<u>1 September</u>	Notice of a water shortage emergency, effective from August. Water consumption quotas for residential properties introduced. R24/kl penalty tariff.
<u>13 September</u>	Harsher restrictions imposed.
<u>1 November</u>	Harshest restrictions lifted, including R24/kl penalty tariff for daily consumption in excess of 500 litres.
<u>22 November</u>	Water restrictions repealed.

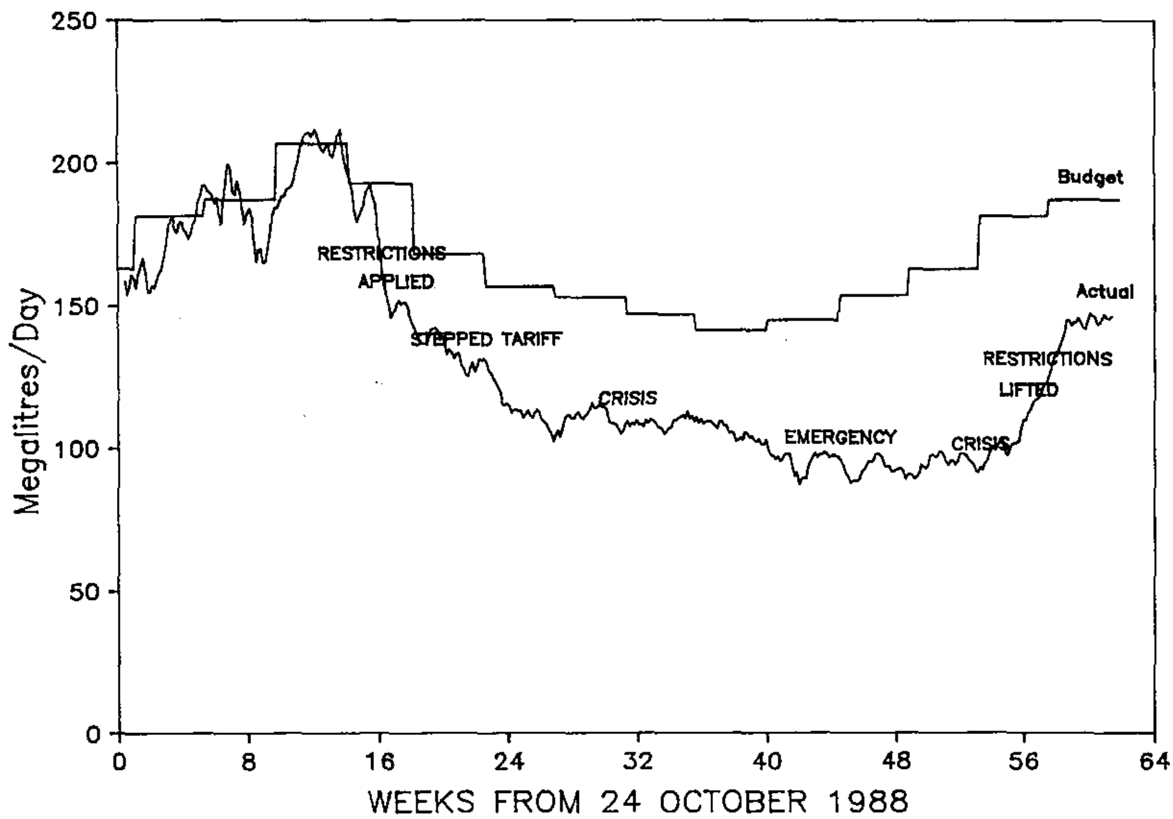

Figure 6 : Water Consumption for Port Elizabeth Metropolitan Area

The weekly sewer flow records for the inflow to the works at Fish Water Flats (FWF), Cape Receife and Driftsands are illustrated in Figure 7. This figure shows that there was a gradual reduction in sewer flow until June 1989, when infiltration caused the flow to increase, particularly from the domestic areas. This may explain why the blockage rate on mains and connections did not increase as much as on drains.

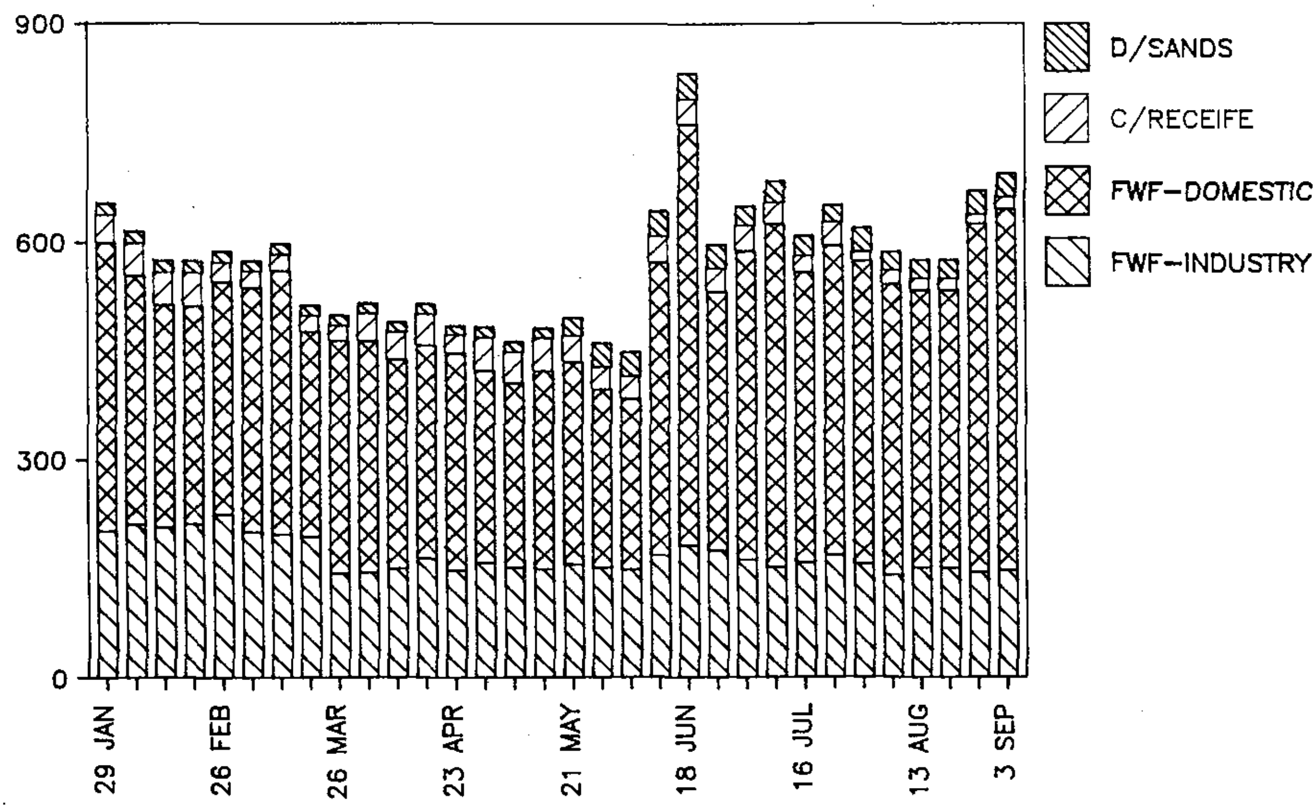

Figure 7 : Weekly Sewer Flows to Sewage Treatment Works

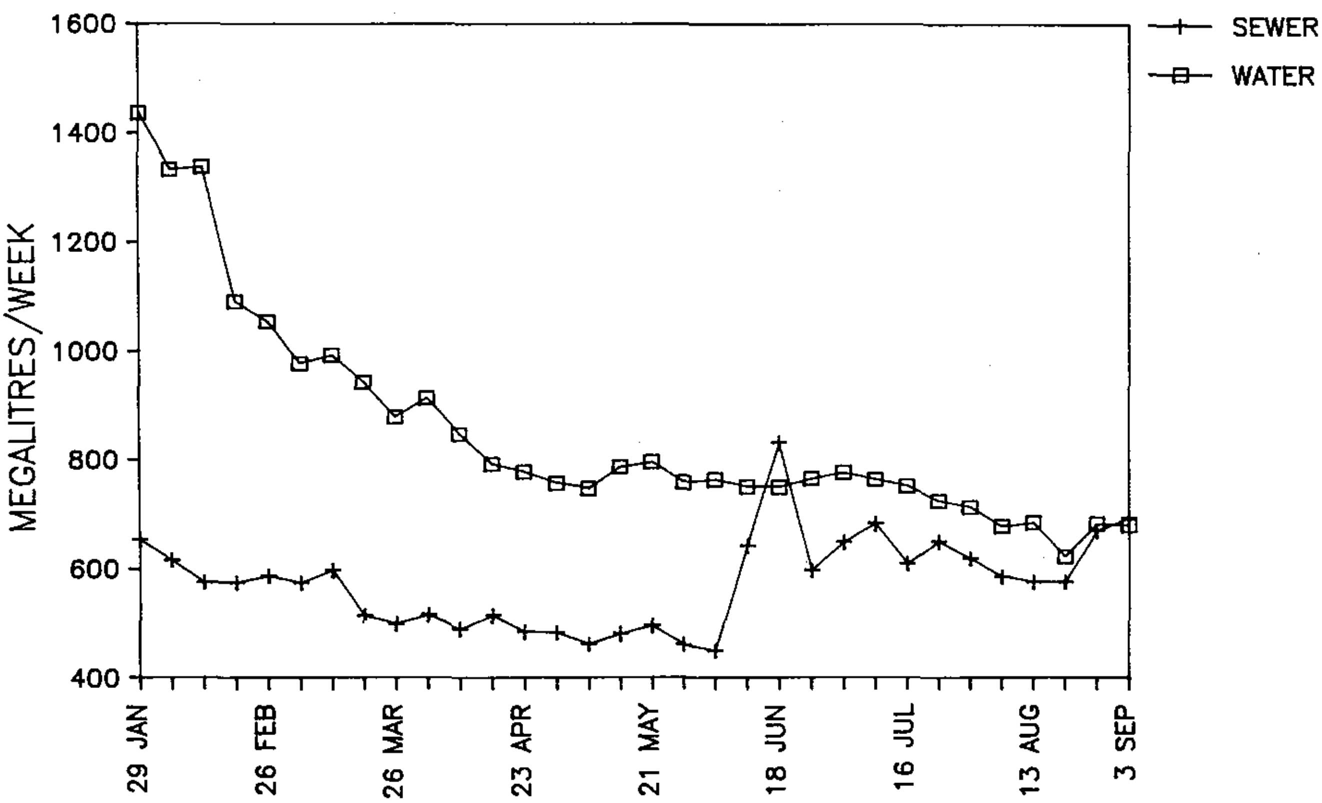

Figure 8 : Relationship between Sewer Flow and Water Consumption

The relationship between the total sewer flow and metropolitan water consumption is shown in Figure 8, where the effect of infiltration can be seen from June onwards. Generally, the ratio of sewer flow to water consumptions lies between 50% and 60%. External garden watering lowers the ratio in the summer months.

Concentration of sewage, septicity and corrosion in the system

The chemical oxygen demand of the inflow to the Fishwater Flats treatment works is normally between 500 and 700. An increase in this parameter was expected, as the water restrictions became effective in reducing water consumption, but the increase never occurred, possibly because infiltration and stormwater ingress through gullies helped to flush the system. No increase in septicity was observed, but sand and grit build-ups did increase, particularly in the black township areas.

Effect on preventative and other maintenance work

The municipality does not believe a drastic reduction in the water content of domestic sewage would not have an effect on preventative and other maintenance work.

Grease traps, oil and petrol interceptors

In Port Elizabeth, grease traps, oil and petrol interceptors are usually located on private property. These are checked regularly by the trade effluent inspectors. All industries must provide and maintain a trap to ensure no grease, oil or petroleum is discharged with the effluent. A standard design is available from the Council if needed.

During the drought, the effluent from these traps could not be sampled. Periodic checks made by officials show that there is a lack of maintenance of traps by the property owners.

Transportation of sand and gravel

The municipal view was that a drastic water reduction in the sewer flow may lead to increased siltation, but this would only be detected once sewer flows return to normal. The reduction in sewer flow, as a result of the drought, was estimated to be about 30 to 40% in the residential areas, which was not considered to be drastic. The business areas were largely unaffected by the restrictions.

Reduced discharges from individual fixtures

According to the municipality, there should be no problem with reduced discharges from individual fixtures, such as the bath, WC, shower, washing machines and dishwashers, provided the velocities are high enough to ensure self-cleaning of the drains and sewers.

Manholes are preferred to a closed system, because they would ensure access when blockages occur.

Effect on performance of the sewage treatment process

The reduction in the water content of domestic sewage had no significant effect on the performance of the sewage treatment processes in Port Elizabeth. There was a decrease in use of plant capacity and this was a benefit, since it extended the period to the next expansion of facilities.

UITENHAGE DURING THE 1989 DROUGHT

Uitenhage claimed that blockages increased drastically (about 100%) due mainly to roots in the older earthern pipelines. Usually, work that could be done by the private plumbers was farmed-out and only after hours was a mix of private and municipal maintenance work undertaken by the municipal maintenance crews.

The source of Uitenhage's water is 30% from PE, 15% from artesian wells and 55% from the local dam and water consumption is split 27% to 73% between industry and private consumers. Up to July 1989, the savings in these areas had been about 5% and 20% respectively, while the municipality was trying to achieve a target 30% saving.

HUMANSDORP

Stormwater infiltration into the sewers is a problem in Humansdorp, due mainly to low house gullies. Blockages tend to occur at a rate of about 2 per day and most of these are due to roots and paper. Disposal of bottles down public toilets is a recurring problem for the maintenance crews. In the past, the local abattoir had been responsible for several blockages on the main sewer, but they took steps to trap the solids, after being charged by the municipality for clearing blockages that were clearly due to specific wastes disposed down the sewer from the abattoir.

Fountains provide an average of 1640 kl of water per day to the town. The lowest recorded flow was 700 kl on 15 August 1989 and the peak flow was 1750 kl on the 21 August 1989.

The drought has not affected the water availability and hence the operation of the sewer system has not been affected.

OVERSEAS RESEARCH FINDINGS

In a number of trials carried out by Building Research Establishment (BRE) in the United Kingdom, 9 litre dual flush WCs achieved reductions in WC water consumption of up to 40%, without any increases in the amount of deposition or in the number of blockages. [Webster & Davidson,1982]. Trials with 6 litre flush WCs also showed no adverse effect on the drainage system, but some surface fouling in the pan was observed.

In studying the effects of flush volumes below 6 litres, BRE found that 3 litre flush volume Swedish toilets performed well with no adverse effects on the drainage system. [Lillywhite, Webster and Griggs,1987].

However it was noted that with flush volumes below 4 litres, some restrictions on length and grade may be necessary for isolated WCs. For example, the researchers found that with flush volumes of 3 litres and a shallow gradient of 1 in 120, deposition occurred within 4 metres of the drain inlet. Subsequent transportation distances were correspondingly low and eventually multiple stoppages formed in the pipework, leading to blockages. The shortcoming in their report is the lack of information on the relationship between drainage slope, length of drain and flush volume, as well as the solids to fluid ratio of the discharges.

Swaffield et al.[1987] carried out similar work in Botswana and Lesotho between 1985 and 1987. The installation of 4.5 litre prototype flush toilets in Gaborone achieved an 18% water saving over a control group installed with 10 litre flush volume toilets. The prototype group accounted for approximately 19% of the water consumption, while the corresponding figure for the control group was 37%. Monitoring of the drains showed no detrimental effects, but it was noted that water use in Gaborone was rising in general.

These records are the more recent of a number of studies that have been done in various parts of the world on the transportation of wastes in drains. It seems that the BRE research was undertaken on working drains laid at 1 in 40 and at 1 in 120 and focused on the interaction between the WC and the drain without additional inflows to complicate the analysis. Because of this, the BRE research is considered significant in terms of the effects of reduced flush volumes on drains.

The results obtained by Swaffield et al. in Gaborone are similar to those obtained at Rooiwal and Mamelodi, but their value is enhanced by the presence of a control group.

The following research findings may be of interest and can provide more detailed background information into the international research being conducted in the building drainage field.

Norwegian studies showed that the WC causes the most problems in a waste water system, the WC must be designed for the flush volume used and the transport capacity from a 3 litre WC connected to a 63 mm diameter pipe was better than that from a 6 litre WC connected to a 110 mm network. [Olsson,1985:3]. Olsson describes a method of increasing the volume of the discharges in the drain by using a siphon tank. The tank accumulates waste discharges until a sufficient quantity is available to ensure adequate flushing of the downstream drain.

Work done by Swaffield and Wakelin identified three transportation zones in a drainage pipe and laid down some basic equations to describe the nature of the flow, related to the slope of the drain, pipe diameter flush volume and the amount of solids. [Swaffield and Wakelin,1977].

At the same time Rosrud looked at user requirements regarding drainage pipework and provided some guidelines towards the development and use of performance specifications.[Rosrud,1977]

CONCLUSIONS

1. Blockages were generally attributable to the introduction of in-appropriate materials to the drainage installations, or root intrusion, possibly coupled with irregularities in the pipeline, such as displaced joints and broken pipes. No definitive relationship between blockages and water consumption was detected.

2. The use of reduced flush volume toilets did not have a significant effect on the water consumption patterns. This was attributed to other factors, such as changes in occupancy and the removal of water restrictions, having a stronger influence on water consumption than changes in the WC flush volume. In some cases, it is possible that the reduced flush volume caused a reduction in WC system efficiency, which led to an increase in water consumption.

3. For properties similar to those at Mamelodi, the proportion of water used by WCs is expected to lie within a 95% confidence interval of between 21% and 9% of the total water use.

4. Flow frequency distributions, determined from datalogger records, can be used to indicate the proportion of water used by a WC. Based on a cistern inflow rate of approximately 3.0 litres/minute at Mamelodi, it was found that the WC accounted for 15.8% of the total water consumption.

5. Based on the available information, the reduction of the WC flush volume to 6 litres has no effect on the performance of drainage installations that have been installed in compliance with accepted regulations and guidelines, including the SABS-0400 Code of Practice for the application of the National Building Regulations.

6. Assuming a normal soil waste composition and no other contributing factors, blockages can be expected to occur when flush volumes of less than 4 litres are discharged from isolated toilets into long drains laid at gradients of 1 in 120. With gradients of 1 in 60 or steeper, flush volumes down to 4 litres should not increase the incidence of blockages in the drain.

7. The Port Elizabeth blockage records showed that a reduction in water consumption can lead to an increase in blockages in drains due to paper. However, in real terms the blockage rates show that the incidence of blockages is very low compared to the size of the sewer system and the number of drainage installations. From this perspective, the change in the blockage rates is not considered to be significant.

8. Reducing the flush volume has no effect on the sewer system, since the quantity of water concerned is not likely to be significant in terms of the total quantity of water discharged to the sewers.

9. Reducing the flush volume, without maintaining an acceptable level of flushing performance from the WC will be counter-productive in terms of efficient use of water and water economy and user satisfaction.

10. The connection of one or more waste discharge pipes from baths, showers, sinks and basins at or near the soil pipe from a low-flush WC should be sufficient to prevent blockages in the drainage installation.

11. The surveys in Natal and the Eastern Cape indicate that water restrictions did not adversely affect the performance of the building drainage and sewer systems, including the various treatment works. However, in both cases, the magnitude of the reduction in sewer flow was not regarded as drastic, even if the water supply cuts were regarded as very severe.

12. Logic tells us that an efficient reduction in a WC flush volume must save water, however the experimental design of the Rooiwal and Mamelodi trials did not take into account changes in other factors that, as it turned out, had a significant effect on water usage. Therefore the water conservation effects of reduced flush volumes in toilets cannot be quantified from the results.

13. A reduction in water usage as a result of performance changes to water installation components (eg. low flow rate showers) should not affect drain and sewer performance significantly, since the total water discharge from these devices should invariably exceed that of a low-flush water closet.

RECOMMENDATIONS

1. Reduced flush volume

   Reduced flush volume cisterns may be accepted by local authorities if it can be shown that the overall flushing performance of the water closet is maintained at, or above, an acceptable standard of efficiency.

2. Acceptable Standards

   A flush volume of 6 litres should not affect the performance of the average drainage and sewer systems, but not all the makes and designs of water closets on the local market are suitable for flushing with 6 litres. It is recommeded that, where it is possible to mix-and-match the cistern, pan and other components, proof must be submitted to show that the toilet system will function to an acceptable standard.

3. Flushing Efficiency Tests

   The current SABS test procedure, based on a single ball with a specific gravity greater than one, is not adequate to test the efficiency of low flush volume WCs. The flushing efficiency tests developed by the CSIR should be incorporated into a new specification for low flush volume toilets. Proposed tests for the sanitary performance of water closet pans are given in Appendix D. It would be necessary to phase these in over a period, or else make provision for an efficiency grading system, because it is possible that about 60% of local WC pan production would not comply with the test requirements.

4. Establishment of database

Steps should be taken to establish a uniform method of collecting the relevant data and establishing a database that will enable the behaviour of the drainage and sewer systems to be monitored more effectively in times of reduced water consumption. In many cases, this should require minor changes to the forms currently used to record operational information, but a more disciplined approach is needed to ensure data is collected, transmitted and processed. Private plumbers should be included in the data collection system.

5. National Performance Ratios

If recommendation (4) can be implemented, the data should be used to generate performance ratios for the systems run by each municipality. The comparison of these ratios on a National basis would enable relative performance to be determined and would enable municipalities to identify areas where improvements should be made.

6. Ventilation Valves on Drainage Installations

The correct use of two-way and one-way vent valves on drainage installations would enable the drainage system to be closed to the atmosphere under normal operating conditions. This should help to maintain the humidity in the drain at close to 100% and thus prevent dry blockages in building drains.

7. Stormwater Infiltration

Potential infiltration and ingress of stormwater into sewers should be taken into account when evaluating the effect of reduced water consumption on sewers.

8. Root Intrusion

Root intrusion has been identified as the major cause of blockages in all the main centres. Information on what steps the individual municipalities and the pipe manufacturers are taking to reduce or eliminate the problem should be obtained and disseminated.

9. Misuse of Drains and Sewers

The industry should address the problem of in-appropriate materials and items being able to find their way into drains and sewers. Where possible, entry points should be identified and steps taken by engineers responsible for the design and operation of the systems, together with the product manufacturers, to reduce the potential for the misuse of the systems.

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APPENDIX A

AVERAGE DAILY WATER CONSUMPTIONS FOR ROOIWAL HOUSES

The average water consumption was calculated for each month from the differences in the meter readings and the number of days between readings. The results are given in the tables below in litres per house per day. The house number is given at the top of each column, with summary statistics at the bottom of the columns.

EFFECTS OF REDUCED WATER CONSUMPTION ON DOMESTIC SEWERS
ROOIWAL WATER CONSUMPTION DATA

END DATE	DAYS	198	199	200	201	205	206	209
10-Dec-87	31	615	532	415	502	496	160	531
11-Jan-88	32	820	774	398	443	685	156	781
16-Feb-88	36	604	528	414	461	530	301	629
10-Mar-88	23	693	851	424	530	505	318	555
11-Apr-88	32	752	561	412	636	506	278	419
10-May-88	29	609	511	272	722	595	362	476
10-Jun-88	31	641	396	417	565	715	432	501
12-Jul-88	32	704	382	247	544	486	332	359
11-Aug-88	30	662	382	606	471	770	318	424
12-Sep-88	32	1068	472	397	475	727	287	451
11-Oct-88	29	944	571	405	600	753	492	392
10-Nov-88	30	662	462	474	521	682	393	481
11-Dec-89	32	637	383	220	559	779	281	494
10-Jan-90	30	447	273	321	538	881	338	386
09-Feb-89	30	862	309	362	868	525	376	554
15-Mar-89	34	742	465	330	697	611	408	525
10-Apr-89	26	714	399	341	591	636	437	519
09-May-89	29	721	402	345	598	643	442	524
12-Jun-89	34	651	309	287	448	599	520	505
10-Jul-89	28	757	307	301	402	952	459	510
10-Aug-89	31	640	463	275	570	661	414	378
11-Sep-89	32	606	494		572	657	340	511
09-Oct-89	28	883	478	387	519	725	446	476
09-Nov-89	31	682	419	308	550	500	333	458
Data in 1988		12	12	12	12	12	12	12
Data in 1989		12	12	11	12	12	12	12
Average 88		731	535	407	539	621	319	500
Average 89		695	392	316	576	681	399	487
% Change		95.1%	73.2%	77.7%	106.9%	109.7%	125.1%	97.4%
Variance 88		19289	19586	7391	6089	11396	8740	12219
Variance 89		12373	5345	1887	12747	16518	4185	2731

EFFECTS OF REDUCED WATER CONSUMPTION ON DOMESTIC SEWERS
ROOIWAL WATER CONSUMPTION DATA

END DATE	DAYS	158	159	163	169	170	174	175	176	178	194
10-Dec-87	31	576	536	236	250	383	682	503	396	487	939
11-Jan-88	32	479	131	259	241	235	749	479	591	433	779
16-Feb-88	36	561	289	247	476	349	709	900	998	449	1050
10-Mar-88	23	511	344	260	555	339	771	517	878	401	842
11-Apr-88	32	541	296	297	477	495	560	489	749	389	869
10-May-88	29	560	339	294	478	636	761	473	655	438	942
10-Jun-88	31	527	269	281	263	819	747	519	510	392	703
12-Jul-88	32	624	297	347	237	503	763	502	457	455	516
11-Aug-88	30	694	286	492	254	782	794	635	480	562	829
12-Sep-88	32	677	342	374	289	403	802	490	521	618	1096
11-Oct-88	29	600	340	314	338	411	817	501	540	608	1697
10-Nov-88	30	549	349	386	332	406	760	519	522	474	838
11-Dec-89	32	446	361	406	277	661	744	676	1087	326	1334
10-Jan-90	30	491	403	368	269	790	724	769	1259	419	1332
09-Feb-89	30	665	299		260	497	707	681	690	500	845
15-Mar-89	34	483	272	374	290	429	634	728	510	451	384
10-Apr-89	26	517	253	336	299	430	636	724	850	430	1510
09-May-89	29	523	255	340	302	435	643	732	859	435	1527
12-Jun-89	34	560	240	404	304	397	657	370	607	523	482
10-Jul-89	28	547	210	371	297	473	519	1101	697	428	572
10-Aug-89	31	501	179	396	319	430	633	676	922	339	630
11-Sep-89	32	588	325	424	260	407	660	703	1096	448	692
09-Oct-89	28	922	319	420	254	567	490	775	1363	375	706
09-Nov-89	31	237	323	443	259	724	680	689	939	330	1117
Data in 1988		12	12	12	12	12	12	12	12	12	12
Data in 1989		12	12	11	12	12	12	12	12	12	12
Average 88		575	318	316	349	480	743	544	608	475	925
Average 89		540	286	389	282	520	644	718	907	417	928
% Change		93.9%	90.0%	123.3%	80.9%	108.3%	86.7%	132.1%	149.1%	87.7%	100.3%
Variance 88		3775	7559	4970	12179	29451	4310	13134	30022	5826	75542
Variance 89		22777	3749	1076	438	16588	5111	23288	62083	3713	156978

EFFECTS OF REDUCED WATER CONSUMPTION ON DOMESTIC SEWERS
ROOIWAL WATER CONSUMPTION DATA

END DATE	DAYS	130	131	132	138	139	140	147	149	151	155
10-Dec-87	31	394	484	602	672	788	195	586	569	248	556
11-Jan-88	32	528	496	658	482	1009	278	572	876	248	628
16-Feb-88	36	380	422	470	748	965	289	687	917	287	639
10-Mar-88	23	353	486	443	754	669	327	613	626	290	584
11-Apr-88	32	355	498	272	693	767	279	602	350	377	583
10-May-88	29	273	453	689	765	669	274	554	399	340	448
10-Jun-88	31	176	348	748	754	740	262	596	505	391	569
12-Jul-88	32	263	410	625	806	734	303	510	535	365	616
11-Aug-88	30	241	449	640	788	628	328	429	594	280	706
12-Sep-88	32	222	618	639	693	667	313	301	388	330	553
11-Oct-88	29	348	519		499	1030	321	451	368	326	541
10-Nov-88	30	257	281	787	760	948	276	437	411	452	473
11-Dec-89	32	322	420	723	879	952	233	640	328	312	346
10-Jan-90	30	390	468		491	802	291	654	481	310	765
09-Feb-89	30	301	301	900	803	968	296	473	284	386	388
15-Mar-89	34	225	294	907	758	804	281	467	260	332	459
10-Apr-89	26	218	382	941	663	884	230	345	301	340	332
09-May-89	29	221	386	952	670	894	232	349	304	344	335
12-Jun-89	34	186	312	790	759		234	600	274	341	486
10-Jul-89	28	272	404	824	814	905	234	734	284	292	403
10-Aug-89	31	244	357	781	773	570	204	788	285	358	579
11-Sep-89	32	357	245	633	774	641	267	811	267	360	531
09-Oct-89	28	377	135	537	818	916	304	667	362	323	562
09-Nov-89	31	381	757	658	796	968	317	604	359	317	493
Data in 1988		12	12	11	12	12	12	12	12	12	12
Data in 1989		12	12	11	12	11	12	12	12	12	12
Average 88		316	455	598	701	801	287	528	545	328	575
Average 89		291	372	786	750	846	260	594	316	335	473
% Change		92.1%	81.6%	131.5%	106.9%	105.6%	90.7%	112.6%	57.9%	102.1%	82.3%
Variance 88		8431	6741	20076	10286	19687	1236	10373	32665	3454	4543
Variance 89		4888	20680	16946	9378	15904	1240	22345	3486	615	14621

EFFECTS OF REDUCED WATER CONSUMPTION ON DOMESTIC SEWERS
ROOIWAL WATER CONSUMPTION DATA

END DATE	DAYS	106	107	109	113	115	117	118	119	120	129
10-Dec-87	31	497	351	324	442	408	547	517	908	862	566
11-Jan-88	32	239	434	282	453	392	556	439	1110	869	657
16-Feb-88	36	230	291	433	412	408	575	361	989	721	550
10-Mar-88	23	281	281	453	446	288	541	375	1060	589	587
11-Apr-88	32	359	302	434	400	271	581	307	891	699	578
10-May-88	29	579	316	807	387	412	612	282	1065	610	665
10-Jun-88	31	388	304	468	348	407	557	292	1101	494	630
12-Jul-88	32	275	277	400	235	389	558	402	831	613	590
11-Aug-88	30	262	446	391	354	380	545	326	574	581	520
12-Sep-88	32	209	438	450	460	230	573	336	627	544	554
11-Oct-88	29	249	227	405	285	610	611	347	583	539	598
10-Nov-88	30	238	249	456	392	406	572	410	624	539	564
11-Dec-89	32	591	390	576	353	410	536	334	656	401	744
10-Jan-90	30	650	266	362	352	479	537	266	922	305	686
09-Feb-89	30	243	235	458	383	438	542	361	544	657	695
15-Mar-89	34	562	172	521	320	256	540	269	590	678	686
10-Apr-89	26	615	614	357	302	461	550	198	593	498	661
09-May-89	29	622	620	361	305	466	557	201	599	503	669
12-Jun-89	34	586	693	452	328	449	596	322	420	588	670
10-Jul-89	28	520	637	496	321	493	576	417	604	669	649
10-Aug-89	31	472	699	505	286	494	516	600	491	657	659
11-Sep-89	32	525	501	471	277	545	581	408	636	737	625
09-Oct-89	28	483	492	407	398	491	621	338	535	809	689
09-Nov-89	31	521	637	512	479	479	729	356	1199	712	721
Data in 1988		12	12	12	12	12	12	12	12	12	12
Data in 1989		12	12	12	12	12	12	12	12	12	12
Average 88		317	326	442	385	383	569	366	864	638	588
Average 89		532	496	456	342	455	573	339	649	601	679
% Change		167.9%	152.1%	103.3%	88.9%	118.7%	100.8%	92.6%	75.1%	94.2%	115.5%
Variance 88		12499	5156	14982	4422	8324	515	4216	40969	14195	1738
Variance 89		10469	32200	4679	2935	4636	3004	10781	40875	19913	926

EFFECTS OF REDUCED WATER CONSUMPTION ON DOMESTIC SEWERS
RODIWAL WATER CONSUMPTION DATA

END DATE	DAYS	77	79	81	82	87	89	91	92	103	105
10-Dec-87	31	606	543	690	270	398	500	645	517	696	477
11-Jan-88	32	671	810	747	262	393	435	514	690	345	281
16-Feb-88	36	654	587	868	278	605		949	817	846	589
10-Mar-88	23	655	591	660	292	479	492	289	505	857	618
11-Apr-88	32	576	781	751	305	465	391	562		711	572
10-May-88	29	624	752	590	280	453	418	667	732	790	615
10-Jun-88	31	549	939	639	288	512	459	525	543	710	589
12-Jul-88	32	523	504	666	308	771	447	286	618	745	636
11-Aug-88	30	604	742	526	221	642	498	538	659	887	575
12-Sep-88	32	640	642		278		738	363	730	738	605
11-Oct-88	29	748	1006	683	367	933	784	356	570	860	444
10-Nov-88	30	604	675	741	308	578	402	336	520	866	702
11-Dec-89	32	772	592	389	422	430	497	802	725	1060	806
10-Jan-90	30	710	995	504	442	531	561	666	851	1025	500
09-Feb-89	30	614	500	625	368	550	617	443	509	905	824
15-Mar-89	34	582	486	717	351	613	547	663	474	912	896
10-Apr-89	26	583	817	497	420	544	470	756	901	1273	832
09-May-89	29	589	826	502	425	574	476	764	911	509	841
12-Jun-89	34	504	564	456	419	626	482	714	743	820	687
10-Jul-89	28	433	797	402	393	471	507	758	747	774	834
10-Aug-89	31	409	832	506	519	572	510	700	628	879	718
11-Sep-89	32	483	858	373	618	739	702	748	480	916	675
09-Oct-89	28	802	1364	411	643	610	842	803	960	905	816
09-Nov-89	31	801	848	465	645	420	537	578	445	919	762
Data in 1988		12	12	11	12	11	11	12	11	12	12
Data in 1989		12	12	12	12	12	12	12	12	12	12
Average 88		621	714	687	288	566	506	502	627	754	559
Average 89		607	790	487	472	557	562	700	698	908	766
% Change		97.7%	110.6%	70.9%	164.0%	98.3%	111.2%	139.3%	111.2%	120.4%	137.1%
Variance 88		3230	21927	7500	1088	25036	15844	34388	10138	19741	11196
Variance 89		17513	54222	9138	10470	7311	11157	9777	32136	29634	10571

EFFECTS OF REDUCED WATER CONSUMPTION ON DOMESTIC SEWERS
ROOIWAL WATER CONSUMPTION DATA

END DATE	DAYS	59	61	64	65	66	67	73	74	75	76
10-Dec-87	31	343		434	1156	498	450	1013	976	782	406
11-Jan-88	32	454	1225	580	1372	638	381	953	1056		581
16-Feb-88	36	439	860	527	1299	508	464	710	1377	827	683
10-Mar-88	23	177	1166	307	1262	587	441	580	1693	673	638
11-Apr-88	32	282	854	401	1321	519	452	615	1364	601	575
10-May-88	29	331	1144	417	1306	571	448	635	1084	560	584
10-Jun-88	31	347	970	428	1322	493	456	658	869	658	665
12-Jul-88	32	337	810	173	1263	409	435	751	876	671	554
11-Aug-88	30	289	989	454	1280	290	437	788	822	751	594
12-Sep-88	32	358	856	456	1390	531	443	792	975	692	539
11-Oct-88	29	349	966	481	1361	764	494	750	1190	757	664
10-Nov-88	30	315	890	458	1301	547	490	687	746	685	411
11-Dec-89	32	326	766	414	1224	784	476	791	1007	654	564
10-Jan-90	30	344	465	368	1397	666	355	916	1597	492	581
09-Feb-89	30	262	883	408	1390	507	479	634	1045	640	963
15-Mar-89	34	248	793	367	1237	539	523	859	845	669	558
10-Apr-89	26	273	625	308	1326	682	465	1011	751	554	659
09-May-89	29	276	632	311	1341	690	470	1022	759	560	666
12-Jun-89	34	325	501	355	1245	773	460	1004	763	567	468
10-Jul-89	28	338	450	370	1229	562	413	948	736	544	639
10-Aug-89	31	332	509	465	1300	654	419	765	780	483	903
11-Sep-89	32	343	417	430	1320		484	681	1205	559	995
09-Oct-89	28	382	671	380	952	1422	537	710	2265	551	
09-Nov-89	31	270	466	401	1439	735	585	968	1360	712	849
Data in 1988		12	11	12	12	12	12	12	12	11	12
Data in 1989		12	12	12	12	11	12	12	12	12	11
Average 88		335	975	426	1303	530	449	744	1086	696	574
Average 89		310	598	381	1283	729	472	859	1093	582	713
% Change		92.5%	61.3%	89.5%	98.5%	137.6%	105.1%	115.4%	100.6%	83.6%	124.2%
Variance 88		4704	18582	9901	3479	12253	761	15631	70155	5588	7433
Variance 89		1631	21837	1914	14635	55573	3314	17649	195496	4606	30077

APPENDIX B - WATER CONSUMPTION DATA FOR MAMELODI HOUSES

Adjusted with original data shown in brackets

Stand 1637 (26) Date	Days	Total l/day	Toilet l/day	Toilet as % of total	Litres/capita/day Total	Litres/capita/day Toilet
21-Feb-89	32	875			34	
23-Mar-89	30	833			32	
14-Apr-89	22	818			31	
20-Jun-89	67	932			36	
20-Jul-89	30	912	91	10.0%	35	4
22-Aug-89	33	822	151	18.4%	32	6
26-Sep-89	35	1251	190	15.2%	48	7
23-Oct-89	27	1173	164	13.9%	45	6
13-Nov-89	21	1280	261	20.4%	49	10
22-Nov-89	9	1479	238	16.1%	57	9
20-Dec-89	28	1242	187	15.1%	48	7
22-Jan-90	33	1237	199	16.1%	48	8

Stand 1638 (5) Date	Days	Total l/day	Toilet l/day	Toilet as % of total	Litres/capita/day Total	Litres/capita/day Toilet
21-Feb-89	32	344			69	
23-Mar-89	30	267			53	
14-Apr-89	22	364			73	
20-Jun-89	67	211			42	
20-Jul-89	30	223	52	23.4%	45	10
22-Aug-89	33	228	31	13.8%	46	6
26-Sep-89	35	471	0	.0%	94	0
23-Oct-89	27	380	7	1.9%	76	1
13-Nov-89	21	383	58	15.1%	77	12
22-Nov-89	9	485	66	13.5%	97	13
20-Dec-89	28	326	59	18.1%	65	12
22-Jan-90	33	538	95	17.7%	108	19

Stand 1639 (7) Date	Days	Total l/day	Toilet l/day	Toilet as % of total	Litres/capita/day Total	Litres/capita/day Toilet
21-Feb-89	32	1250			179	
23-Mar-89	30	1400			200	
14-Apr-89	22	1318			188	
20-Jun-89	67	1186			169	
20-Jul-89	30	598	129	21.6%	85	18
22-Aug-89	33	654	113	17.3%	93	16
26-Sep-89	35	899	112	12.5%	128	16
23-Oct-89	27	846	63	7.4%	121	9
13-Nov-89	21	809	403	49.7%	116	58
22-Nov-89	9	894	101	11.3%	128	14
20-Dec-89	28	700	71	10.2%	100	10
22-Jan-90	33	807	135	16.8%	115	19

Stand 1640 (12) Date	Days	Total l/day	Toilet l/day	Toilet as % of total	Litres/capita/day Total	Toilet
21-Feb-89	32	1750			146	
23-Mar-89	30	1733			144	
14-Apr-89	22	1773			148	
20-Jun-89	67	1053			88	
20-Jul-89	30	1047	210	20.1%	87	18
22-Aug-89	33	[3023]	[1930]	[63.8%]	[252]	[161]
		1338	245	18.3%	112	20
26-Sep-89	35	[1766]	[617]	[34.9%]	[147]	[51]
		1399	250	17.9%	117	21
23-Oct-89	27	1635	242	14.8%	136	20
13-Nov-89	21	1419	240	16.9%	118	20
22-Nov-89	9	1746	273	15.6%	146	23
20-Dec-89	28	[1612]	[468]	[29.0%]	[134]	[39]
		1409	265	18.8%	117	22
22-Jan-90	33	[2244]	[1087]	[48.4%]	[187]	[91]
		1392	235	16.9%	116	20

Stand 1641 (10) Date	Days	Total l/day	Toilet l/day	Toilet as % of total	Litres/capita/day Total	Toilet
21-Feb-89	32	1281			128	
23-Mar-89	30	1167			117	
14-Apr-89	22	1182			118	
20-Jun-89	67	951			95	
20-Jul-89	30	591	101	17.1%	59	10
22-Aug-89	33	656	108	16.5%	66	11
26-Sep-89	35	692	105	15.2%	69	10
23-Oct-89	27	853	130	15.3%	85	13
13-Nov-89	21	1002	137	13.7%	100	14
22-Nov-89	9	952	153	16.1%	95	15
20-Dec-89	28	816	109	13.4%	82	11
22-Jan-90	33	872	117	13.4%	87	12

Stand 1642 (27) Date	Days	Total l/day	Toilet l/day	Toilet as % of total	Litres/capita/day Total	Toilet
21-Feb-89	32	1281			47	
23-Mar-89	30	1533			57	
14-Apr-89	22	1409			52	
20-Jun-89	67	1223			45	
20-Jul-89	30	[2735]	[1539]	[56.3%]	[101]	[57]
		1406	210	14.9%	52	8
22-Aug-89	33	1118	171	15.3%	41	6
26-Sep-89	35	1832	259	14.2%	68	10
23-Oct-89	27	1844	240	13.0%	68	9
13-Nov-89	21	1952	269	13.8%	72	10
22-Nov-89	9	2020	195	9.7%	75	7
20-Dec-89	28	1713	175	10.2%	63	6
22-Jan-90	33	1502	159	10.6%	56	6

APPENDIX C

REPORTS FROM SPECIFIC AREAS ON THE EFFECT OF THE NATAL DROUGHT OF 1982/83 ON BUILDING DRAINAGE AND SEWER SYSTEM PERFORMANCE

These are the views given by the interviewees and do not necessarily reflect the official view of the municipality or the views of the researchers.

Clermont

Water was supplied by Pinetown and the Umgeni Water Board. There was no data to indicate a change in the blockage rate or the pattern of blockages. Only the Kwadabegka Sections A & B are sewered, the rest of area has pits and septic tanks. There are no sewage works and the digestion tanks worked as usual during the drought. Sewage goes into digestion tanks (septic tanks) and the effluent from these flows into small bore pipe, to sewers and the sewage works downstream at Durban.

A 6 litre WC flush would be acceptable.

A point of interest is that the water consumption in parts of this area increased during the restriction periods. A large portion of this area is supplied by un-metered standpipes in the streets and it is presumed that employees, who were refused permission to wash at work due to the restrictions, were obliged to wash in a bucket at home.

No routine maintenance is undertaken.

Durban

Normally there were about 40 sewer blockages per day. When the water restrictions were applied, this figure rose to between 75 and 80 blockages per day. There seemed to be more blockages at the tops of ramp junctions (house connections) and these were mostly caused by roots.

The design flow used is 1 000 litres/property/day. Maintenance had to be increased. With low water had egress of water at rubber O-ring joints. Did AC pipes or O-rings dry out and shrink?

There was an increase in the deposition in grit traps, as well as a packing of sedimentation in bottom of pipes which was hard to remove.

Problems arose with a full day's solids and paper from the whole household being removed with one small flush per day. As a result, blockages occurred mostly in house drains and connections.

Routine maintenance was undertaken at trouble spots in the main sewers. The worst spots required desilting once every two weeks with bucket winch.

There was no change in sulphides recorded at the treatment works. The levels are generally between 4 mg/l in winter to 3 mg/l in summer.

Domestic sewage flow to treatment works

108	litres/capita/day	North and KwaMachu (new works)
265	litres/capita/day	Central Works
400+	litres/capita/day	Downtown Durban
204	litres/capita/day	South Works
218	litres/capita/day	Average for whole of Durban

Westville

There was no change in the performance of the sewer system. A major blockage tends to occur approximately every 6 months. The blockages occurred predominantly in private drains and about 1% of households had blockages during the restriction period. In normal times, there are very few blockages and these are caused mostly by roots.

Where there was a build-up of paper, due to un-flushed urination, individual WCs with long runs before the gully did tend to block more frequently.

No change in the operation of the treatment works was observed. Incoming sewage was fresh and age on arrival was from 2 hours to a maximum 13 hours.

Preventative maintenance for the whole system is undertaken approximately once a year. There was an increase in deposition of fats in pipelines.

Low shower flows coupled with no discharges from a bath may result in inadequate flushing of house drains. Low flush volumes from WCs will not carry solids as far and this could increase the number of blockages.

The annual water consumption for the whole area was 360 megalitres before the drought, but only recovered to 300 megalitres per year after the restrictions were lifted. Houses use typically 0,8 - 1,1 kl/day. Durban received 98% of Westville's sewage, which was generated by about 1800 houses. The remaining 2% was pumped to Pinetown, a new arrangement since the drought.

A point of interest is that Westville did not like the concept of a closed drainage system or rodding eyes and preferred manholes in order to check for illegal connections such as sauna baths and car washes.

Umhlanga

During the period of water restrictions from July 1982 to July 1983, water consumption averaged about 10 kl per household per month.

It was claimed that blockages increased, although the extent could not be quantified since house drains were cleaned by private plumbers. The sewers blocked mainly on bends and sewer flows were about half of what they were before the drought, thus the concentration of the sewage was doubled. An increase in the smell at pump stations was noted.

Running costs decreased at twenty-six sewage pumping stations, compared to normal times and electrical charges fell by R7 000 per month, although maintenance costs remained the same.

The treatment works apply the activated sludge process with maturation ponds. No changes in the operation of the works was observed and odours were at normal levels.

Pinetown

There were much fewer septic tank and soakage pit failures and some septic tanks suffered from being too dry. Blockages on domestic drains increased mainly due to root intrusions. These drains are predominantly caulked salt glazed earthenware (SGEW) that were laid in the 1960s. Some of the main sewers and a number of factories also experienced blockages. Although an increase in the blockage rate was perceived to have occurred, no data was available to indicate the magnitude of the increase.

There is a lot of industrial activity in Pinetown and corrosion in pump houses is common, increasing slightly during the drought. A lot of steelwork in the pump houses was replaced at the time, but which was due for replacement.

Pump blockages increased, mainly as a result of the paper load and the life of a pump-seal was reduced to half the normal life-span. Less sand was deposited in sewers, due to the reduced ingress of water.

In the Umbilo treatment works the biofilter mass stayed the same, but volumes dropped to a half. Water was re-circulated to keep the biofilters wet. There was no change in the quality of the final effluent and in general the system worked better during the drought period.

An activated sludge process is used in the Umhlatuzana Works. The bio-mass stayed same, but the effluent volume dropped. Consequently, pump sumps took too long to fill before discharging, resulting in septicity problems and necessitating an increase in the pump cycles. Due to the low volume, alkalinity of the sewage dropped while the BOD remained the same. There was no bulking and no change in the final effluent.

New Germany

The normal house drain blockage rate of 12 per year increased to about 25 during the drought. Blockages were caused mainly by roots and paper. There was no real increase in blockages in the main sewers, although there was an increase in the deposition of fine particles, due to lower velocities in the pipelines.

Factories and domestic sources contribute 70% and 30% of the sewage respectively. The decrease in flow caused no problems at the activated sludge treatment plant. The plant was designed for 7 Ml/day but was operating at 2,2 Ml/day. Nothing changed during the drought and the effluent quality remained good. The plant is easier to run in winter, since algal growth in the summer causes bulking. There is one pump sump with a maximum retention of 10 hours.

Kloof

An increase of 10% to 15% in house drain blockages occurred mainly in the upper parts of the installation. There was no increase in sewers blockages.

Blockages in sewers	During drought	After drought
For ±500 Indians' houses	7 per year	6 per year
For Whites' houses	1 per year	2 per 5 years

There was an increase in corrosion at the soffit of the 150 mm diameter concrete pipelines at the lower end of system, in the Indian area. Most of sewers are laid in PVC and Vitro clay pipes of 150 mm diameter. Regular maintenance of the whole system, consisting of some 10 to 12 kilometres of pipelines, is undertaken once per month.

No treatment works were in operation during the drought and all sewage was drained to Pinetown. A new, small works, involving biofiltration into soak-pits, is fed by 120 houses.

Amanzimtoti

The following table indicates the number of blockages on sewers and the inflow to the treatment works at Amanzimtoti from 1982.

Year	Sewer blockages per year	Flow rate to works
1982	18	16 Ml/day
1983	29	7.5 Ml/day
1984	16	-
1987	12	12 Ml/day

In 1987, 3.8 to 4.5 Ml/day of the total 12 Ml/day was from the industry.

The number of house blockages did not increase. The area is serviced mostly by new asbestos cement pipelines, installed between 1972 and 1988. The beachfront is serviced by very old caulked SGEW bedded in sand. The installations are stable and the pipes are not subject to breakages, so there are no problems. It was noted that some of the pipelines, up to 150 mm in diameter, are laid at very flat grades of up to 1:180.

Most blockages occur at property connection manholes where the PVC house drain is cemented into an asbestos sewer connection. There is no bond, thus roots can penetrate easily and cause blockages. To eliminate this problem, an earthenware or asbestos channel is required in the manhole.

The primary cause of blockages at hotels, cafes, Vetkoek Plaza, etc., are due to fat solidification. Other blockages are caused by sand deposition, in sandy areas, and newspaper and plastics at the pump house grid screens.

Odour increased during the drought since most of the sewage is pumped 15 km, through three pump stations, hence there is a long retention period. No change in the corrosion rate was observed.

The lack of rain reduced the amount of sand washed into the sewer system. The outflow from the activated sludge plant is polished with pressure sand filters and passes through a chlorine contact tank. The effluent quality was not affected during drought. Water was re-circulated at 360 cubic metres per hour during night, due to the low water level in the activated sludge plant, but with hindsight this was not necessary

In general the drought provided a breathing space in the capital expansion programme. The works have since been extended to handle more solids, but it has not been necessary to increase their hydraulic capacity.

Kingsburgh

Five hundred to six hundred houses were sewered in 1983, with another eight hundred more added in 1985. No major problems were experienced in approximately 50 km of sewers. Before regular maintenance was introduced there were about 10 blockages per year, but no blockages had occurred since introducing a regular six-monthly maintenance cycle.

PVC and asbestos pipelines are in service and there are seven sewage pump stations with rising mains to an activated sludge treatment works and pacifier ditch. Oxygen is injected at peak season and the effluent is polished in an oxidation pond.

Before the drought, the plant was operating at about 2000 Ml/day. In October 1988, it was operating at between 1000 to 2000 M/day. The plant was originally designed to service a population of 9000 and was being extended to serve a future population of 20 000.

Queensburgh

On average, sewer blockages occur at a rate of 3 per week. There was no change in this rate during the drought. Most blockages occur during the rainy season and are caused by fig tree roots.
A reduced volume of water consumption was not expected to affect the drains and sewers and would help to alleviate water supply problems.

The sewer maintenance programme is based on a 3 monthly cycle. There are about 50 km of sewers that are at least 15 years old. The sewers are constructed with cement caulked salt-glazed earthen-ware pipes. There were three pump stations with rising mains in operation as follows:

60 m long serving 120 houses
3 000 m long serving 1 000 houses
2 000 m long serving the industrial area

The treatment process includes an activated sludge plant and a chlorine contact tank. The load averages 500 kl/day of the domestic sewage only. No change in operations were necessary during the drought. Measuring flumes are installed at 5 points where sewage is discharged into other municipal areas.

Pietermaritzburg

At the time of this survey there were about 40 household blockages and 50 sewer blockages per month. All the maintenance staff had changed since the drought and there was no record of what happened. If the reduction of water-use through reduced flow showers and low flush volume toilets is not excessive, there should be no effect on the drains and sewers.

The system consists of 917 km of sewers, constructed with caulked SGEW and asbestos pipes and ranging in size from 150 to 1700 mm diameter. In addition, some brick barrel sewers, about 100 years old, are still in service. There are 9 pump stations and about 2 km of rising mains. The detention period of the sewage is less than 5 hours and there is a high level of infiltration.

During October 1988, the biofilter plant at the treatment works was operating at 10 Ml/day. The capacity of the activated sludge plant was 54 Ml/day. During the drought the biofilters were closed down, but no figures on performance were available.

The effluent flows into oxidation ponds and then into a chlorine contact tank. Detritus at the works was less than normal during the drought.

Howick

Practically only the CBD was sewered by a new system, which was commissioned in February 1982 and consisted of 4 to 5 km of Vitro sewer pipes with Hepsleeve joints. There have been no sewer blockages and no maintenance programme is in operation. Domestic blockages are cleared by private plumbers.

The pre-drought water consumption was 100 000 Ml per annum. Water use after the drought had recovered to between 80 000 to 85 000 Ml per annum water by October 1988.

APPENDIX D

TESTS FOR THE SANITARY PERFORMANCE OF WATER CLOSET PANS

1. TEST ARRANGEMENTS

Set up the pan and flushing apparatus in the normal operating position ensuring that the top of the pan is horizontal and the outlet can discharge freely.

2. DETERMINATION OF THE WATER SEAL VOLUME

2.1 Washdown pans

Remove all the water from bowl Pour measured volumes of water into the bowl until the water level just begins to overtop the weir in the trapway. Measure to the nearest 0,01 litre and record the volume of water added. This is the water seal volume.

This determination may be made once only.

2.2 Siphonic pans

Ensure that the trapways are fully charged with water. Remove all the water from the bowl by means of a pipette or siphon. Measure to the nearest 0,01 litre and record the volume of water thus removed. This is the water seal volume.

This determination may be made once only.

3. SOLIDS REMOVAL TEST

3.1 Ball test

3.1.1 Test media

Fifty balls of diameter 19 ± 0,5 mm, of non-absorbent durable material having a relative density of between 0,85 and 0,88.

3.1.2 Procedure

Place the balls in the bowl of the pan ensuring that no balls escape into the trapway. Initiate the flush and count the number of balls flushed out of the pan. Record the number of balls remaining in the pan (X) i.e. fifty minus the number of balls flushed out.

Without adding balls, repeat the flush until all the balls have been flushed from the pan or a maximum of four times whichever is attained first and record the number of additional flushes (Y).

Carry out the test five times.

3.1.3 Performance requirement

Calculate the means of X and Y for the five tests ($\bar{X}$ and $\bar{Y}$) and obtain the rating value for the pan (R) from the formula:

$$R = 100 - 2\bar{X} - 7\bar{Y}^2$$

The pan shall be deemed to have passed the test when the value of R is equal to or greater than 60. Alternatively, R may be used to grade the pan in terms of flushing efficiency.

3.2 Paper test

The paper test is a two part test.

3.2.1 Test media

The test media shall consist of two types of paper, one type being used for each of the two tests.

Paper type I : single ply commercial toilet paper conforming to SABS 648.

Paper type II : locally available used newspaper.

3.2.2 Procedure

Part 1 : Tear off six double sheets of paper type I at the perforations (a sheet is the portion between consecutive perforations), loosely crumple each double sheet and drop it into the bowl followed by the next in quick succession until all six pieces have been deposited in the bowl. Initiate the flush within ten seconds of the last piece of paper being deposited and record whether or not any paper remains visible in the bowl.

Part 2 : Cut six A5 size (148 x 210 mm) sheets from paper type II and carry out the test as for Part 1. Record whether or not any paper remains visible in the bowl.

Carry out the test five times ensuring each time that any paper remaining in the pan after the preceding test is removed.

3.2.3 Performance requirement

The pan shall be deemed to have passed the test when all the pieces of paper are flushed from the visible portion of the trap as follows:

Paper type I : in not less than four out of five tests.

Paper type II : in not less than three out of five tests.

4. SURFACE WASH TEST

4.1 Test media

A broad point fibre-tip marking pen with water soluble ink.

4.2 Procedure

Clean the internal surface of the bowl thoroughly and wipe with a clean cloth dampened with alcohol. When the surface of the bowl is completely dry draw a line around the full circumference of the bowl at a level of 25 mm below the underside of the flushing rim. Immediately initiate the flush and record the lengths of line remaining on the surface of the bowl.

Carry out the test three times ensuring each time that the surface of the bowl is clean and dry.

4.3 Performance requirement

The pan shall be deemed to have passed the test when the mean for all three tests of the total lengths of line added together after each test does not exceed 50 mm and no individual segment of line remaining after any test exceeds 10 mm in length.

5. REMOVAL OF LIQUID WASTES

The removal of liquid waste test comprises a dye test and splash test, both of which may be conducted simultaneously.

5.1 Dye test

5.1.1 Test media and apparatus

Sufficient powdered water soluble ERIONYL BLUE BUFF dye. A suitable container of 1 litre minimum capacity for preparing the concentrated dye solution (5.1.2). A pipette and 100 millilitres measuring cylinder. A suitable container for preparing the comparator solution (5.1.3). Two identical measuring cylinders of 200 mm to 250 mm depth.

5.1.2 Preparation of the concentrated dye solution

Heat a suitable quantity of water to 80°C in a clean container and add powdered dye to achieve a concentration of 30 gallons per litre. Stir and allow the solution to cool to room temperature.

5.1.3 Preparation of the colour comparator

Prepare a comparator solution by adding 0,25 millilitres of the concentrated dye solution (5.1.2) to 1 litre of water drawn from the test supply and carefully stir. (The comparator solution is equal to 7,5 mg of dye powder to one litre of water.)

Fill one of the two identical measuring cylinders with the comparator solution and retain as the colour comparator.

5.1.4 Procedure

Remove 1/40 of the volume of the water seal (determined from 2) from the bowl using the pipette and replace carefully with an equal quantity of concentrated dye solution (5.1.2). Stir carefully avoiding any spill over into the trapway.

Initiate the flush, and when the water seal has stabilised remove sufficient water from bowl to fill the second of the two identical measuring cylinders.

Place the cylinder next to the colour comparator on a piece of white paper and observe by looking downward into the two cylinders whether or not the colour intensity of the residual solution is lighter than the comparator. Record the result of the observation.

Carry out the test three times ensuring each time that before commencing the test all traces of dye have been removed from the bowl and the water seal is recharged with fresh water from the test supply.

As an alternative to the use of identical cylinders for colour comparison, a laboratory type colour comparison, a laboratory type colour comparator may be used.

5.1.5 Performance requirement

The pan shall be deemed to have passed the test if the colour intensity of the solution drawn from the water seal after each of the three tests is less than that of the comparator.

5.2 Splash test

5.2.1 Apparatus

A sheet of clear acrylic 1,5 to 3,5 mm thick and of sufficient size to completely cover the bowl at the top surface. Three cubes of sides 20 ±1 mm of a hard durable material.

5.2.2 <u>Procedure</u>

Having mixed the dye solution in the water seal in the bowl (5.1.4) place the cubes equidistant around the top of the rim of the bowl and rest the acrylic sheet on the cubes.

Initiate the flush and without removing the acrylic sheet observe the drops of dye-coloured water adhering to the underside of the sheet. Record the number of dye-coloured drops 3 mm and greater across.

Carry out the test three times ensuring that the acrylic sheet is clean and dry before commencement.

5.2.3 <u>Performance requirement</u>

The pan shall be deemed to have passed the test when the total number of drops recorded for all three tests does not exceed 18.

6. WATER SEAL TO BE SELF RESTORING

After each and every flush carried out in terms of the tests described in 3 to 5 the water seal in the pan shall fully restore itself.
