THE REVIEW OF INDUSTRIAL EFFLUENT TARIFF STRUCTURES IN SOUTH AFRICA AND GUIDELINES ON THE FORMULATION OF AN EQUITABLE EFFLUENT TARIFF STRUCTURE

Des Kerdachi

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EXECUTIVE SUMMARY

BACKGROUND AND MOTIVATION

Industrial effluent tariffs in South Africa are characterised by a wide variety of formulae that have been illogically designed, and have no sound financial and technical basis. Sufficient evidence is available from numerous presentations and discussions on the subject matter to confirm that many industrial effluent tariffs in South Africa are unrealistic with the resultant effect being that the financial shortfall has to be obtained from other sources, usually at the expense of domestic ratepayers. A correct formulation will allow for an equitable proportion of finance to be derived from industry for the services provided. These services are the acceptance, conveyance and treatment of industrial effluent. Such a formulation must lend itself to application in any size town or metropolitan area such that transparency, equity, and sustainability are prevalent.

The National Water Act, 1998(Act 36 of 1998) (hereafter referred to as NWA) promotes the polluter must pay principle and also implies that the polluter must pay for any damages to the environment and for any clean up operation resulting from illegal discharges.

In the absence of any incentive for industrialists to allocate finance towards improving the quality of their effluent it is more convenient to let the controlling authority incur the expenditure. Inevitably this expenditure is never fully recovered. If proper effluent charging systems are in place, industry will devote more attention to effluent management, and many financial benefits will accrue to all users.

Therefore there is a need for a guideline document that provides a systematic methodology on how to formulate and implement a tariff structure that allows for an equitable proportion of finance to be provided by industry for their contribution towards the cost of effluent treatment to the required liquid and solid phase standards and guidelines of the Department of Water Affairs and Forestry (hereafter referred to as DWAF) and the Department of Health (hereafter referred to as DH) respectively and for the installation of an adequate sewerage system. This mode of operation is essential and preferable to the system of punitive measures that are not easily enforceable, nor understood by the legal fraternity usually ending up in a no win situation after months and years of protracted legal proceedings.

OBJECTIVES

Following the submission of a research proposal to the Water Research Commission in 1996, the project titled "Review of Industrial Effluent Tariff Structures in South Africa and Guidelines on the Formulation of an Equitable Effluent Tariff Structure" was approved on a two year basis commencing in 1997.

The objectives of the project were as follows:

- Review the status of industrial effluent tariffs in South Africa
- Produce guidelines on the formulation of an equitable industrial effluent tariff structure applicable on a national scale
- Provide a sound, rational basis for the essential elements that contribute to or influence the compilation of an industrial effluent formula
- Examine current Municipal By-Laws and National Legislation that directly and indirectly influences the extent of effluent charges
- Simplify current systems in use in order that they are easily understood and can be administered without much difficulty
- Define clearly the interacting role's of industry, commerce and the householder with respect to their financial contribution

METHODOLOGY USED

Ten local authorities were chosen throughout South Africa on the basis of their variation in size, industrial activities, known availability of reliable analytical, operational, and industrial effluent data and records. Some of the ten local authorities (e.g. Durban Metropolitan Council, Greater Johannesburg Metro Council, Cape Town Metropolitan Council) consisted of large operational areas with many wastewater treatment facilities included within their boundaries. Within these integrated schemes, there were areas of overloaded treatment facilities with substantial industrial effluent contributions while within the same areas of jurisdiction there were areas of "low key " industrial activity.

The data supplied was for the financial period 1996-1997 and overlapped with 1997-1998. Since Metropolitan schemes had not yet been fully operational to provide the requisite information, the data used to assess the areas of Cape Town and Durban was based on the operational activities within the pre-Metro boundaries. The Greater Johannesburg Metro sub structure was able to provide operational and industrial effluent data for a full financial year operating as a Metropolitan council. (1997-1998) The methodology used to obtain data that would allow for an appraisal and evaluation of industrial effluent tariff structures in South Africa was to provide a checklist of information required viz. Operational, financial, industrial and legislatory. This was combined with a personal site visit to enable explanatory discussions and verbal interaction with senior personnel involved in the subject matter. Additional meetings were also held with senior staff from the service providers; Umgeni Water, East Rand Water Care Company (ERWAT), and East Gauteng Services Council (EGSC).

The executive summary is presented in three parts consistent with the format of the document.

Part I – **Overview.** The overview sketches the background to industrial effluent tariffs in South Africa. An outline is provided on the relevant principles, impacting legislation, water quality standards and formulae fundamentals that form the basis for the Guidelines presented in Part III. This section also introduces the reader to GAMAP (generally accepted municipal accounting practices) and the application of depreciation in the calculation of effluent tariff charges. It's use to establish a cash reserve fund and obtain a return on assets is unique in a municipal context.

Part II - **Review.** The review presents the results and interpretations of the processed data extracted from the checklist. The information has been presented in a manner that allows for meaningful comparisons to be made between local authorities of different size.

Part III – **Guidelines.** The guidelines take cognisance of all the principles outlined in Part 1.This information is used to present a systematic methodology to derive an equitable effluent tariff structure that can be applied anywhere.

PART I - OVERVIEW

PRINCIPLES, LEGISLATION, STANDARDS AND FORMULAE FUNDAMENTALS

The underlying principle is that industry and the other users of the sewerage and treatment system must pay for the services rendered by the local authority. When discharges of industrial effluent are made into a municipal sewer and conveyed to the treatment works for purification the local authority becomes the direct polluter of the receiving water.

The project directs attention to the NWA, and the Water Services Act, 1997(Act 108 of 1997) (hereafter referred to as WSA). These Acts of 1997 and 1998, are consistent with the principles of the new Constitution, which are to ensure that water is available to everyone on an equitable basis, and that our water resources which are scarce, are managed and protected in a sustainable manner.

The NWA reinforces the polluter must pay principle and makes provision for the protection of our scarce water resources by limiting water use in terms of the "Reserve". Other measures which will improve the allocation and selection of water resources are the classification system and the management strategies proposed for future implementation. In terms of tariffs the emphasis is on full cost recovery which represents a move away from the traditional approach of capital funding. The above Acts provide the basis for the roles to be played by local authority, industry, and service providers and their relationship with DWAF with respect to the construction and operation of wastewater treatment works, and the conditions and standards permitting discharge of purified effluent into the water resource. Other local legislation such as Municipal By-Laws, Ordinances, and Transitional Acts are briefly referred to because of their relevance to the subject. While the Water Act, 1956 (Act 54 of 1956) (hereafter referred to as WA) has been entirely repealed, it was noted that some of the regulations are still in use. In particular, the General and Special Standards where contained in existing permits still apply until a new permit is issued. The important role of DWAF is highlighted with respect to the protection of water resources, interaction with the local authority, and catchment management. As a result of the NWA, all users of water must now register with DWAF and be licensed. To ensure that the water resources are preserved and protected, DWAF are in the process of compiling a new set of standards for discharge of effluents to receiving waters with cognisance being given, ***inter alia,*** to the nature of the use of the water downstream of the discharge point.

In order that the sewer system can be protected and that the treatment works can function biologically, effluent By-Laws are compiled by the Water Services Authority stipulating the hydraulic and concentration limits of different pollutants and parameters of significance that can be discharged into the sewer. The tariff formula is also contained in the By-Laws. It is essential that a legally binding agreement is concluded between the service provider and the discharger of the effluent. In most cases the service provider is the Water Services Authority.

The use of the Chemical Oxygen Demand (COD) analytical test as an indicator of the organic strength is justified and compared to the other tests such as the Biochemical Oxygen Demand (BOD) and the Permanganate Value (PV). While all the tests have advantages and disadvantages, the COD is the preferred test. The use of the COD to model and quantify the activated sludge process including sludge production has been ably demonstrated by the UCT research team. The response of the 3 tests to different well known organic compounds is shown and supports the choice of the COD over the PV which does not even respond to some organic compounds such as acetic acid and acetone.

The influence of the Mogden Formula is illustrated by the existence in South Africa of a variety of formulations which bear close resemblance to modifications of the original. Irrespective of the formulations used, certain information is required and is common to all of them. The AHC (average historic costs) must be based on actual expenditure records for the conveyance and treatment systems. Reliable analytical data based on a statistically acceptable number of samples, together with accurate flow data from the discharger and the service provider are essential. Furthermore the volume of effluent based on water consumption must be calculated as prescribed.

The most understated aspect concerning effluent tariffs relates to sampling. Procedures for sampling: sample point: the type of sampling: the frequency and the number of samples that should be taken with due regard to the precision and relative error: are all discussed with references. Without sufficient attention given to these items, there can be major variations in the amount of finance recovered.

Effluent tariffs and their formulae are all structured to recoup an equitable proportion of finance from industry and therefore it is important that financial aspects are put in perspective. Costing procedures as recommended by the Institute of Municipal Financial Officers (IMFO) are shown and different costing methods such as the fixed-variable method, the design-causative method and the functional method are detailed for the benefit of the reader. Attention is drawn to the fact that the National Treasury have introduced new regulations relating to GAMAP (generally accepted municipal accounting practices). These regulations are due to be introduced in July 2002. One of the main features of the new accounting system will be the use of depreciation which is considered to be an expense. This depreciation must be applied on a straight line basis over the useful life of any particular structure and the fixed assets revalued at regular intervals by competent persons. It is important for the sake of transparency and understanding that the recording of expenditure is consistent with GAMAP and an indication provided to the user of these guidelines on how this information is used in the tariff derivation.

Consideration was given to all the systems, and it was decided that the fixed variable method represented the best compromise between simplicity, ease of administration and the correct fundamentals with due respect to the inherent deficiencies of each component. The basic tariff system recommended is

Charge = conveyance + treatment (variable) + fixed costs

where treatment embraces both liquid and solid phase while fixed costs represent the O&M expenditure which is independent of strength or volume and includes depreciation and a return on assets.
The presence of heavy metals and the problems with the sludge disposal guidelines are elaborated upon and an explanation given why heavy metals should not ideally be incorporated into the effluent charging formula. Technology is available to treat the solid phase in such a manner as to inactivate pathogens, fixate heavy metals and render the sludge environmentally friendly, particularly as a soil conditioner.

PART II - REVIEW

EFFLUENT TARIFF PRACTICE BASED ON THE ASSESSMENT OF THE CHECK LIST DATA FOR THE PERIOD 1996 - 1998

- Wide variations exist in the cost of water for industrial purposes where more than 30 kℓ per month are used. The costs varied from 72 cents per kilolitre in Estcourt to R4,70 in the Johannesburg Metro Substructure. Both of these costs were reflected in the 1996 – 1997 financial year. The reason for the very low cost of 72 c/kℓ is due to the raw water being abstracted directly from the river, purified and then distributed by Estcourt Town Council. These values do have a very large impact on cost economic considerations when examining the feasibility of water re-use, and industrial effluent tariffs. Ultimately the cost of water for industrial purposes influences the final decision.

- The project indicated a definite trend towards under – recovery in effluent income. In two instances the under – recovery was very pronounced. Under-recovery is illustrated in the case of one of the larger Metro authorities where the income from the monitored industries for both conveyance and treatment is 28,72 million, whereas the calculated revenue due from industry for treatment alone is R29,44 million. If the contribution from conveyance is similarly calculated, then it is anticipated that a figure of R50 million should have been recouped via the tariff instead of the R28,72 million.

- The situation was distorted with respect to sewerage expenditure since many local authorities were not able to supply the requisite sewerage data related to each specific industry. This deficiency is attributed to a common weakness found *in most of the participating local authorities i.e. an abundance of data is available*, but not processed in a form that readily lends itself to meaningful use. From the few instances where sewerage tariff contributions from industry were available, it is evident that as in the case of treatment, there is also a significant under-recovery.

- There is a tendency for the industrial effluent hydraulic contribution to be lower on a percentage basis as the area served gets larger, while the carbon load contribution is much higher. This is exemplified in the Johannesburg Metro Substructure where the hydraulic contribution from **the monitored industries** is only 1,58% of the total influent, while the COD load is 16,5% of the total COD received when the weighted COD is taken into consideration. The contribution to this observation by the larger local authorities is illustrated hereunder.

	%HYDRAULIC LOAD	%COD LOAD	FLOW $M\ell d^{-1}$
Johannesburg Metro	1,58	16,5	769
Cape Metro	11,0	22,0	289
Durban Metro	7,7	14,9	343
Pietermaritzburg L.A	8,8	36,9	60

- A variety of formulae are in use, some of which have recently been reviewed to reflect more realistic financial returns, and with a trend towards simplicity and ease of understanding.
  There is no transparency, and using one of the participating organisations as an example the effluent formula allows for a significant amount of revenue to be recouped from industry, but it is not clear how all the constants are derived. It is inadequate for these formulations to be comprehended by only a few staff within a local authority. Industry require a clear understanding of the basis of the tariff which should lend itself to easy interpretation. Nearly all the formulae in use, if properly updated with revised constants and accurate reliable data, are capable of producing a good return.

- It was observed, that while hundreds of industries operating within the area of the organisations involved in this project discharge effluent into the sewer, more than 75% of the industrial effluent income is derived from only a handful of industries in each instance. This is exemplified in one of the large Metro Councils where one industry provides 52,6% of all effluent income received.

- Where such a few industries contribute the bulk of the effluent income, additional attention should be given to the statistical approach to determine the number of samples to be taken; frequency of such and due regard given to the precision and error of the analytical method. In such instances small errors can lead to large amounts of income being lost.

- It was observed that some By-Laws do not stipulate a limit for the COD concentration, and even where there was limit, there seems to be no enforcement. The limits varied from 1000 $mg\ell^{-1}$ to 10000 $mg\ell^{-1}$.

- The project has indicated that there is a definite need for more internal communication and liaison between the different Departments within a local authority involved in such a multidisciplinary subject as industrial effluent tariffs. The abundance of accumulated data, and the observed wealth of specific expertise within different departments/sections of the organisations concerned could be more effectively utilized if a co-ordinated approach was used.

PART III – GUIDELINES

RECOMMENDED GUIDELINES FOR THE IMPLEMENTATION OF AN EQUITABLE INDUSTRIAL EFFLUENT TARIFF STRUCTURE

- The guidelines are presented such that **PART III** can be used as a stand alone document.
- The recommended methodology separates and defines fixed and variable costs. Depreciation forms part of the fixed expenditure. Attention is drawn to the impending use of depreciation instead of redemption once GAMAP becomes fully operational. This will also allow for the accumulated depreciation to be used for the provision of finance for asset replacement of wastewater infrastructure and to serve as a basis for calculating a return on the assets. Both flow and concentration are actively involved in the calculation of the unit variable treatment cost.
- The format in which income and expenditure are reflected is consistent with the recommended methods of IMFO and is also illustrated as recommended in terms of GAMAP which is due to be introduced by the Department of Finance on July 1,2002. For ease of understanding a real set of data from a medium size town which is heavily industrialised and has three separate wastewater treatment works in 3 separate catchments, is presented in the old and the new financial format. The financial and technical data are used in the new format to illustrate the derivation of the tariff formulation.
- The emphasis is on full recovery and this is in line with the principles of the NWA. Straight line depreciation over the useful life of infrastructure and assets is recommended. All infrastructure and fixed assets must be revalued at regular intervals to allow for adjustments for commodity price increases.
- The recommended analytical method to assess the organic strength is the COD test. Two accredited methods are provided in the appendix together with the coefficient of variation for each method.
- A statistical procedure is provided for estimating the number of samples which should be taken to ensure minimum charging error, and consistent with the precision, standard deviation, and the confidence level. While recognising that the more frequently samples are taken, the greater is the precision, there is no point in spending money on sampling and analysis in order to get a precision no better than that of the method of analysis or where the cost of sampling and analysis is greater than the probable error in the industrial effluent charge.

In order that the formulation can produce the desired results attention must be given to the following:

- Ensuring accurate assessment of the effluent volume.
- Utilizing sampling procedures that are in accordance with the recommended code of practice.
- Ensuring that the number of samples taken are compatible with statistical acceptability.
- Following the recommended analytical procedures for the COD test.
- Utilizing financial data based on either the average historic cost (AHC) or the budgeted expenditure for the sewerage and treatment system. The budgeted expenditure can always be reconciled with AHC data at a later stage.

Basic principles and potential benefits of an equitable industrial effluent tariff formula are detailed, as well as a brief reference to the legislatory basis for effluent treatment cost recovery. Definitions of the terms used are carefully delineated to ensure that there is clarity in understanding of all the components involved.It is recommended that only effluents of significant volume and load should be sampled. However a minimum charge based on the fixed costs as defined is applicable to everyone that discharges to the sewer provided that the effluent is classified as an industrial effluent by definition.

- While no method is devoid of weaknesses and structural deficiencies, the fixed-variable cost proportionation methodology using AHC together with the COD and flow data, provides a charging formula that has elements of simplicity without compromising any essential principles. Since costs are based on average historic costs (AHC) the costs are exact and have automatically accommodated any inflationary consequences, except for capital costs.
- Conveyance is calculated in a geographically unbiased manner.

Much attention and deliberation was given to the validity of expressing the fixed costs per kilolitre. From the service provider's point of view the

$$\frac{\text{total expenditure}}{\text{total flow at works}} = \text{“x” c/k}\ell$$

which is the overall "bottom line" unit cost for the conveyance and treatment of one kilolitre of wastewater. Now this "x" c/kℓ consists primarily of three components as follows:

$$\text{X c/k}\ell = \underset{\text{conveyance}}{X_a} + \underset{\text{treatment (variable)}}{X_b} + \underset{\text{fixed costs}}{X_c}$$

Thus for purposes as shown there is no apparent reason why the fixed expenditure can't be expressed as a fixed cost component for every kilolitre arriving at the works, just as the conveyance and variable treatment costs are shown. It does allow for the proportionate fixed cost contribution by industry to be retrieved using the volume parameter. Alternatively, each industrial discharger can be allocated a fixed sum (to cover fixed costs) at the outset based proportionately on their assessed volume of effluent.

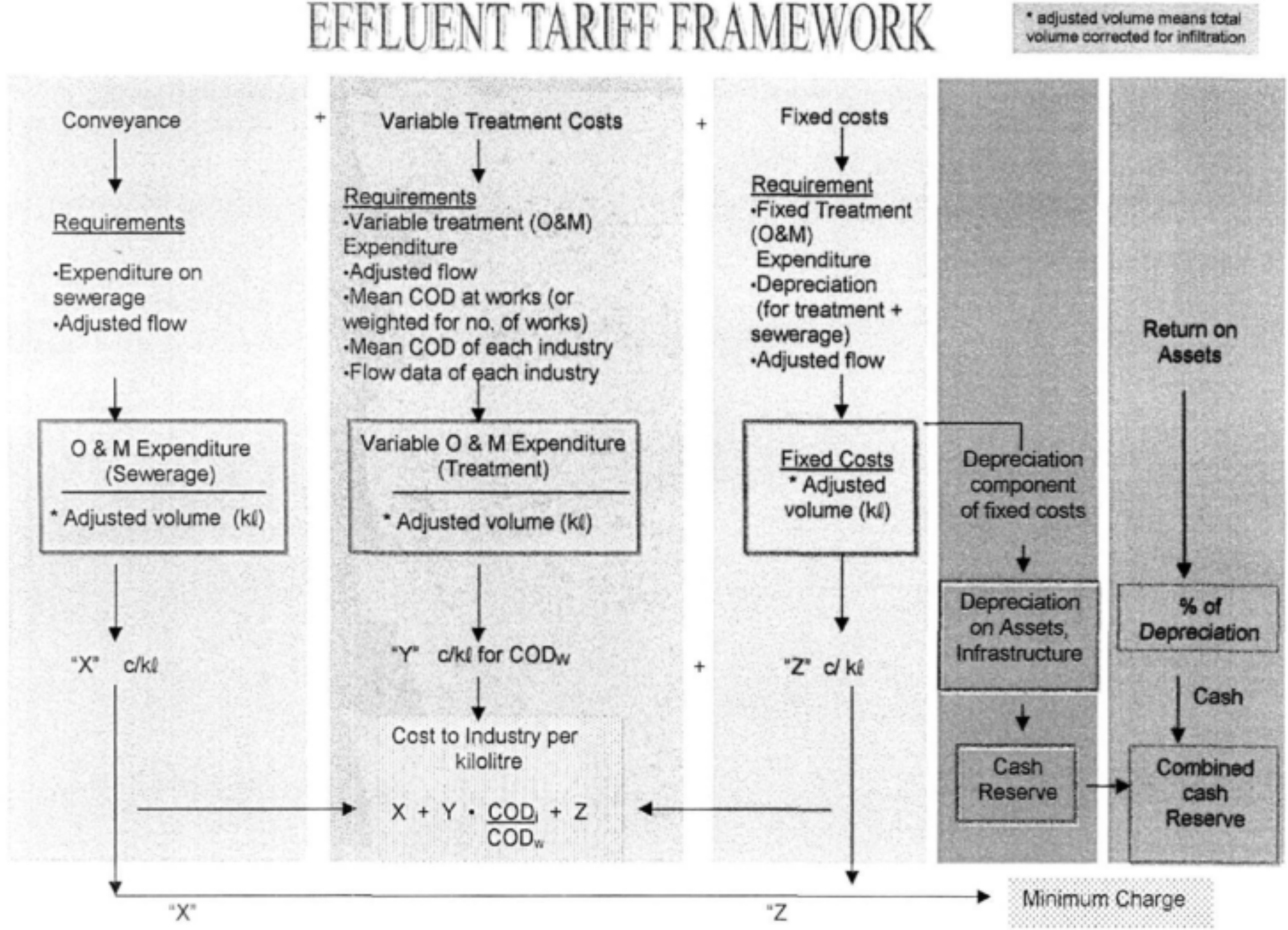
A systematic procedure is provided to illustrate how the relevant data can be used to perform the requisite calculations. The outlined methodology can be applied to all sizes of operational systems and municipal boundaries and will allow for a uniform tariff formulation in Metro operational areas.

In accordance with the guidelines provided in the NWA the end objective is for full cost recovery and a return on assets (wastewater infrastructure). This will allow for the creation of a dedicated cash reserve fund to be used for the sole purpose of asset replacement as well as for augmenting and upgrading sewers and treatment works.

Justification is provided to support the recommendation that no provision should be made in the general tariff formulation for the charging of heavy metals. The problem of heavy metals entering the sewer and its impact on sludge disposal must be dealt with in terms of the By-laws and the consent agreement between industry and the service provider. The same applies to parameters such as pH , colour , and conductivity. Emphasis is placed on treatment at source in harmony with source directed measures in the NWA.

The unique features of the recommended tariff structure are; the emphasis on full cost recovery, combined with a reasonable return on assets; the utilization of depreciation to achieve these benefits; the use of variable and fixed cost apportionation of the O&M expenditure: and the combination of the liquid and solid phase operating expenditure into one treatment component.

EFFLUENT TARIFF FRAMEWORK



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GLOSSARY OF ACRONYMS AND DEFINITIONS

ACRONYMS

AHC	Average Historic Cost
BOD	Biochemical Oxygen Demand
CMA	Catchment Management Agency
CM	Catchment Management
COD	Chemical Oxygen Demand
CPI	Consumer Price Index
DEAT	Department of Environmental Affairs and Tourism
DH	Department of Health
DWAF	Department of Water Affairs and Forestry
GAAP	Generally Accepted Accounting Practices
GAMAP	Generally Accepted Municipal Accounting Practices
ICM	Integrated Catchment Management
IMFO	Institute of Municipal Financial Officers
IMTA	Institute of Municipal Treasurers and Accountants
NWA	National Water Act,1998(Act 36 of 1998)
OA	Oxygen Absorbed
O & M	Operation and Maintenance
PPP	Polluter Pays Principle
PV	Permanganate Value
RBCOD	Rapidly Biodegradable Carbon

RDM	Resource Directed Measures
ROA	Return on Assets
RQO	Resource Quality Objectives
RWQO	Receiving Water Quality Objective
WA	Water Act,1956(Act 54 of 1956)
W E & T	Water Environment and Technology
WLA	Waste Load Allocation
WSAU	Water Service Authorities
WSA	Water Services Act,1997(Act 106 of 1997)
WSP	Water Services Provider

DEFINITIONS

Arithmetic Mean	The sum of the values obtained divided by the number of observations $X = \frac{\sum X}{N}$ (Willemse 1990)
Capital charges	Interest and redemption charges on capital borrowed
Capital funding	Refers to the financing of capital infrastructure, primarily the borrowing of money e.g. loans or bond issues on the capital market, to fund capital infrastructure development.
Coefficient of variation	This is the ratio, expressed as a percentage of the standard deviation to the mean. It is used for the comparison of the variation of two sets of data with different means, sample sizes or measurement units.
Conveyance	The transport of effluent or any liquid waste in the sewer network from the point of discharge to the inlet of the treatment works.

Depreciation	Depreciation is the real cost of operating water infrastructure in that it represents the loss in value of facilities not restored by current maintenance, that occurs due to wear and tear, decay, inadequacy and obsolescence due to technological advancement.
	Or alternatively,
Depreciation	The systematic distribution of the cost price of a fixed asset over its useful life and is applied on a straight line basis viz equal amount over the useful life of the assets.
Dry Industry	An industry whose manufacturing process does not produce an effluent of any significance e.g furniture and engineering fabrications.
Economic Value	The cost that represents the scarcity value of a good which would prevail in competitive markets.
Expenses	Outflows of economic benefits or depletions of assets or increases in liabilities that reduce own capital
Externalities	These are essentially activities whose full cost or benefit are not incorporated into an economic decision; hence they lead to sub-optimal social allocation.
Fixed Costs	These costs are defined as expenditure that does not vary significantly during a particular financial year and which is not affected by the **COD** loading.
Geographically unbiased	The same for all users of the sewer network irrespective of their proximity to the treatment works.
Industrial Effluent	Any liquid, whether or not containing matter in solution or suspension, which is given off in the course of or as a result of any industrial, trade, manufacturing, mining or chemical process or any laboratory, research , service or agricultural activities
Industrial sewerage tariff	This tariff is to accommodate the domestic effluent from staffing on the industrial site and is separate from the assessed industrial effluent portion.
Marginal Cost	This is the unit cost of treatment of the next (major)

increase in treatment capacity.

Median .... This is the value that occupies the middle position of a group of numbers in a numerical order.

Half of the terms lie above this point and the other half below it.

$$\text{Median} = \frac{N + 1}{2}$$

If there is an odd number of items the middle item of the array is the median. If there is an equal number of items, the median, is the average of the two middle items.

Opportunity Costs .... The benefit forgone by using a scarce resource for one purpose instead of for its next best alternative use.

Precision .... This is a measure of the closeness with which multiple analyses of a given sample agree with one another.

Return on Assets .... Allows for the earning of a specific rate of return on the total financial investment used to finance the facilities used to convey and treat wastewater.

Reserve .... The quantity and quality of water required to satisfy basic human needs by securing a basic water supply and to protect aquatic ecosystems in order to secure ecologically sustainable development and the use of the relevant water resource.

Revenue .... Inflows of economic benefits or enhancement of assets or reduction of liabilities that increase own capital

Sewerage system .... The network of piping, pump stations, and all equipment associated with the transporting of liquid waste from all types of users to the treatment works.

Sewage .... This is the liquid waste that emanates from residential areas and is of a domestic nature and is conveyed to the treatment works. Sometimes referred to as domestic wastewater. Domestic wastewater only

Standard Deviation .... This is a measure of dispersion about the mean. It measures the square root of the average squared distances of the observations from the mean. The larger the standard deviation in comparison with the data size, the wider the spread of data around the mean value.

Treatment Charges .... Cost to treat one kilolitre of wastewater of a specified COD which can be one individual result or the mean of a number of results.

Treatment Works .... The facility where the wastewater is treated to the prescribed DWAF standards and DH guidelines for the liquid and solid phase respectively.

Wastewater .... The combined liquid waste from all users of the sewerage system and includes domestic wastewater and industrial effluent.

Water Service Authorities ..... The NWA identifies Water Service Authorities as the local government responsible for service provision in terms of the constitution.

Water Service Providers .... The NWA identifies Water Service Providers as the body actually providing the service, including the day to day activities needed to keep a water supply and/or a sanitation system running effectively.

Wet Industry .... Any industry that produces a liquid effluent arising from the manufacturing process and whose volume and/or strength are likely to have an impact on the operation of the treatment works.

Weighted Mean .... This is a measure which enables the calculation of an average that takes into account the importance of each value to the overrall total.

$$\overline{X}_v = \frac{\sum X \bullet V}{\sum V}$$

PART I - OVERVIEW

1. MOTIVATION, OBJECTIVES AND BACKGROUND

1.1 Motivation

Industrial effluent tariffs in South Africa are characterised by a wide variety of formulae that have been illogically designed, and have no sound financial and technical basis. Sufficient evidence is available from numerous presentations and discussions on the subject matter to confirm that many industrial effluent tariffs in South Africa are unrealistic with the resultant effect being that the financial shortfall has to be obtained from other sources, usually at the expense of domestic ratepayers. A correct formulation will allow for an equitable proportion of finance to be derived from industry for the services provided. These services are the acceptance, conveyance and treatment of industrial effluent. Such a formulation must lend itself to application in any size town or metropolitan authority which usually includes many towns such that transparency, equity, and sustainability are prevalent.

The National Water Act, 1998(Act 36 of 1998) (hereafter referred to as NWA) promotes the polluter must pay principle and also implies that the polluter must pay for any damages to the environment and for any clean up operation resulting from illegal discharges.

In the absence of any incentive for industrialists to allocate finance towards improving the quality of their effluent it is more convenient to let the local authority, health committee or any other controlling authority incur the expenditure. Inevitably this expenditure is never fully recovered. If proper effluent charging systems are in place, industry will devote more attention to effluent management, and many financial benefits will accrue to all users.

Therefore there is a need for a guideline document that provides a systematic methodology on how to formulate and implement a tariff structure that allows for an equitable proportion of finance to be provided by industry for their contribution towards the cost of effluent treatment to the required liquid and solid phase standards and guidelines of the Department of Water Affairs and Forestry (hereafter referred to as DWAF) and the Department of Health (hereafter referred to as DH) respectively and for the installation of an adequate sewerage system. This mode of operation is essential and preferable to the system of punitive measures that are not easily enforceable, nor understood by the legal fraternity usually ending up in a no win situation after months and years of protracted legal proceedings.

1.2 Objectives

Following the submission of a research proposal to the Water Research Commission in 1996, the project titled "Review of Industrial Effluent Tariff Structures in South Africa and Guidelines on the Formulation of an Equitable Effluent Tariff Structure" was approved on a two year basis commencing in 1997.

The objectives of the project were as follows:

- Review the status of industrial effluent tariffs in South Africa
- Produce guidelines on the formulation of an equitable industrial effluent tariff structure applicable on a national scale
- Provide a sound, rational basis for the essential elements that contribute to or influence the compilation of an industrial effluent formula
- Examine current Municipal By-Laws and National Legislation that directly and indirectly influence the extent of effluent charges
- Simplify current systems in use in order that they are easily understood and can be administered without much difficulty
- Define clearly the interacting role's of industry, commerce and the householder with respect to their financial contribution

1.3 Background

The subject matter of industrial effluent tariffs has an interesting history in South Africa. The first charge on record for industrial effluent treatment was made by the City of Germiston in 1920 (Barnard 1961) for the discharge of effluent from a starch factory on to a slop farm.
Two local authorities i.e. Germiston and Johannesburg, pioneered the levying of a charge for the disposal of industrial effluent. Johannesburg's first industrial effluents officer was only appointed in 1950 and was engaged in preliminary survey work until 1952 when the Industrial Effluent By-Laws were gazetted. The first charges were actually levied in 1954.
After much deliberation during the period of 1950-1954, the formula finally adopted was:

$$\text{Charge in cents per k}\ell = 2 + 1.25\left(\frac{OA_{MAX} - 100}{100}\right) \quad \text{(Barnard 1961)}$$

This formula provided an incentive for industrialists to reduce the strength of their effluents. Application of this formula ran into trouble two years, after initial implementation. From accurate records available on flow, strength and costs of operating the sewerage and treatment system it was possible to establish fairly reliable figures for the unit cost of conveyance and treatment of industrial effluents. These were found to constitute only 5% of the total flow and something like 40% of the total load. Agreement was reached on a formula that allowed for a 50% rebate, in order that industrial expansion would be encouraged.

The subsidized formula adopted was

$$\text{Charge in cents per k}\ell = 3 + 0{,}01\ \text{OA}$$

A minimum charge of 3 cents per kℓ was proposed. Concern was also expressed at the limitations of the use of OA to measure strength and eventually it decided to stay with the OA because of no better substitute i.e. COD also having it's limitations. South African industrial effluent tariff formulations have been strongly influenced by developments in the UK where the "Mogden Formula" as a basis for industrial effluent charging has been in use for 60 years (Ingold and Stonebridge 1987, Griffiths and Kirkbright 1959). Following reorganisation of the water industry in 1974, the new Regional Water Authorities, in conjunction with the Confederation of British Industry (CBI), agreed upon guidelines (CBI 1976) which included the adoption of a Mogden type formula as a basis for industrial effluent charges nationally. They were reviewed and revised in 1986 by the Water Authorities Association with little significant alteration (WAA 1986).
The Mogden Formula (Ingold and Stonebridge 1987) split the cost of treatment into three elements.

a). Preliminary treatment and miscellaneous operations, mainly proportional to volume (V)
b). Biological treatment, which is proportional to both volume and strength (B)
c). Sludge treatment and disposal which is proportional to the amount of solids in the effluent (S)

The Confederated British Industries guidelines (CBI 1976, WAA 1986) incorporating a Mogden type formulation were adopted with the object being to ensure that the industrialist paid a fair charge for the service and for the final disposal of the liquid phase as was required by the UK Water Act of 1973.
The formula which basically is

$$\begin{array}{ccccccc} \text{Charge} & = & \text{reception} & + & \text{biological treatment} & + & \text{sludge treatment} \\ X & = & R & + & B & + & S \end{array}$$

was developed around conventional treatment of wastewater using sedimentation, followed by biological filtration and anaerobic digestion of solids to CO_2 and CH_4. One weakness associated with the Mogden formula was that it made no provision for conveyance (Ingold and Stonebridge 1987).

Activated sludge systems and variations of such systems to account for phosphate and nitrogen removal were not yet in operation in South Africa, prior to 1960, and the most used system at the time was that of the conventional sedimentation, biological filtration, anaerobic digestion type. Hence it is observed that industrial effluent formulae in South Africa and the UK were designed around the above systems and very little effort was made over the following 35 years to review the situation in keeping with advances in wastewater treatment and technology.

Activated sludge systems treating unsettled and settled wastewater are now the norm and it would be most unusual to use conventional type biological filters to treat industrial wastewaters with a high percentage of COD load. Furthermore, developments in the understanding of growth kinetics, population dynamics (biological) and the mathematical modelling of activated sludge systems allow for quantitative predictions to be made on sludge production. Biological process performance and sludge production can now all be quantified in terms of the COD (chemical oxygen demand), (WRC Nutrient Removal Guide 1984).

As technical developments progressed in wastewater treatment the numerous variations of the Mogden formula and adaptations of such, were left unmodified. Funke 1980, and Louw 1990 highlighted the variety of formulae in existence in South Africa and the confusion as a result of such a situation. Whenever the finances did not balance, a further factor was added. In many cases these "further factors" were required to satisfy political decisions which took no cognisance of the underlying factors in the formula. Such practices over the years have resulted in a situation in South Africa where so many of the formulae in use are clumsy, outmoded and in need of wholesale revision to adequately serve their purpose. Even the industrialists are confused and very few are aware of the significance of the various components in such formulae.

With the political transition and transformation well in progress particularly with Unicities and Metropolitan type structures of local government being regarded as the way forward, the subject of industrial effluent tariffs along with other sanitation tariffs – (Palmer Development Group 1998) is receiving much attention. This is seen as necessary to eliminate cross-subsidization, ensure that the price paid for the service reflects the scarcity of the resource (i.e. water) and promote the principle of the "Polluter Must Pay" in order to recoup the proportionate costs from industry for services rendered by the local authority. The Water Act, 1956 (Act 54 of 1956) (hereafter referred to as WA) which has provided the guidelines to local authority over the past 40 years, is no longer applicable. The NWA has now replaced the WA, and will have a strong impact on future trends and direction in water resource management with water regarded as a scarce resource. Not only is water quality under consideration, but more attention is now directed to the aquatic habitat, ecosystem and the Reserve in the Catchment area. The recent legislation, furthermore, places strong emphasis on equitable pricing strategies with a significant departure from the previous financing and accounting methods used by DWAF. The emphasis is on full cost recovery in accordance with generally accepted accounting principles (hereafter referred to as GAAP) and charges for water resource management and catchment management will have to be borne by all users of the

system (DWAF 1998 – Pricing strategy document).
Most efforts and legislative directives have in the past been devoted to ensuring that the liquid phase conforms to rigid chemical and microbiological standards. Over the past 10 years, the situation has changed dramatically resulting in local authorities having to now also treat their sludge to acceptable disposal quality in accordance with the permissible guidelines, (Permissible Utilization and Disposal of Sewage Sludge WRC TT 85/97) and in such a manner that the sludge is not detrimental to the environment. Operating expenditure for wastewater treatment has, under the circumstances, also risen steeply reflecting the above changes.
Since all the new legislation promotes enhanced resource management, equitable cost distribution and revised tariffing strategies, one can expect treatment costs including capital charges to impact on effluent tariffs. This is unavoidable, because the pollutional load from industrial sources is high and the proportionate direct and indirect impact cost must be recouped.
The need for an improved tariff structure formulation that will meet the above requirement and which can be universally applied without difficulty was recognised by the Water Research Commission. This project **concerning effluent discharges to the municipal sewer** endeavours to meet the challenge of reviewing the current situation and providing guidelines on an equitable effluent tariff structure. Very relevant topics that are essential to this project and which are addressed in the presentation include:

- Role of Department of Water Affairs and Forestry;
- Water Quality Standards (local and national);
- Financial expenditure and full cost recovery;
- Sludge disposal and the DH guidelines:
- Relevant national legislation and the use of market and economic forces to protect and sustain our water resources.

The challenge in this project is to produce guidelines that not only take cognisance of the above factors but which will also be easy to understand, implement, and administrate. If attention is not given to these factors, then the chances of a practical and useful document being produced will be diminished.

2 LITERATURE SURVEY

2.1 National Policy

The NWA and the WSA provide the basis for gradual implementation of the new water related policies. The financial impact of water resource management and water resource costs will be borne by all water users. The emphasis will be on full cost recovery and revised accounting procedures consistent with GAAP– (Pricing Strategy Document – DWAF 1998). The basis of the new Act is provided by the contents of "Fundamental principles and objectives for a New Water Law in South Africa (1996). DWAF, who are charged with the responsibility of implementing and administrating the provisions of the Act have stated their general approach towards water supply protection, financing and pricing, pollution control and water resource management (Management of the Water Resources of the Republic of South Africa1986). This direction has not changed, but actually has been confirmed with additional improvements. In keeping with international practice DWAF has adopted the principle that the polluter must pay for the abatement of his own pollution (WA and NWA Appendix II).

2.2 Water Quality and Standards

The protection of our limited water resources is a key point in the new legislation and emphasises the importance of the "Reserve" and the "Eco-Habitat." (Water Act News – April 1999) The General and Special Standards gazetted in terms of the WA (**Appendix II)** and which have been the cornerstones of water quality maintenance and sustenance for the past 40 years are not applicable as from October 1999 except where already contained in an existing permit. New general and special limits for treatment plants with a capacity of less than 2000m^3/d have been gazetted (Ref: Gov Gazette No. 20526 1999).

While DWAF are developing a revised set of standards, RWQO (receiving water quality objectives) and WLA (waste load allocation) are being applied as interim measures and will serve to dictate the allowable concentrations of certain pollutants which will be permitted (Van der Merwe and Grobler 1990; DWAF 1991).

The WSA stipulates that access to water for industrial purposes requires a license from the water services authority. The disposal of industrial effluent requires approval by the area water services provider (WSA Section9 (1b)).

The Health Act, 1977(Act 63 of 1977) is concerned with health matters related to handling and disposal of wastewater and sewage sludge, while the Environmental Conservation Act,1989(Act 72 of 1989) is concerned with environmental pollution particularly in relation to the control and management of disposal sites. At a local level, the promulgation of By-Laws provides the rules for acceptance of an effluent into the sewer system to be conveyed to the treatment works. These rules are designed primarily to protect the sewer infrastructure, the biological functioning of the works and the safety of the workers. Industrial effluent tariffs are incorporated in these By – laws.

2.3 Guidelines

There is a dearth of information on industrial effluent tariff guidelines. The Water Industry in the UK following the reorganisation and privatization in 1974, produced guidelines (CBI 1976) which only provided a minimum amount of information with no justification for the parameters used and the choice of formula. These guidelines were reviewed and published by the Water Authorities Association in 1986 without any significant changes (WAA 1986).
Through personal communication with the secretary of the Australian Water Works Association it was established that there are no effluent guidelines in Australia but that some of the states e.g. New South Wales, are giving attention to pollutant discharge limits on a mass basis.

2.4 Economics

The Department of Environmental Affairs and Tourism (hereafter referred to as DEAT) 1994 indicates how the use of economic tools can ensure that future policy reflects sound environmental and economic principles, as well the realities of the situation in South Africa. The role and use of market forces, economics and fiscal instruments (such as cost-benefit analysis) are illustrated in a series of reports commissioned by the DEAT (EPR1993).

The determination of all Government bodies to ensure that the "polluter pays principle" is applied is indicated in nearly all reports and documentation related to charges, tariffs and pollution. Department of Environmental Affairs (1993) – Managing South Africa's Environmental Resources - A possible new approach. (WRC 793 progress report 1997) (EPR 1993),(WA)and (NWA).

2.5 Analytical Methods

The chemical oxygen demand (COD), biochemical oxygen demand (BOD), and the permanganate value (PV) have been the preferred analytical tests to assess the organic load. (Simpson 1967) evaluated these methods and outlined the advantages and disadvantages of each. None of the methods are ideal but as the chemical interaction and understanding improved over the years, there has been a distinct swing to the use of COD. (Wilson 1960) provided information confirming the varied response of the 3 tests to pure organic substrates. (Dart 1977, Micklewright 1986), both reviewed the use of COD in the effluent formulae in preference to the BOD and the PV.The PV test found favour in South Africa in the earlier years because at the time it was regarded as simple and easy to undertake, whereas COD analysis was still in its infancy of development (Osborn 1954, part of Heynike 1959).

2.6 Analytical Errors and Sampling Errors

The effects of any analytical errors on single COD determinations are incorporated within the uncertainties surrounding the estimates of "the average COD of industrial effluent" – Hulme et al (1985). Balinger , Jamison , and Kemsley (1982) whilst considering the effect of variations in analytical methods on industrial effluent quality data, pointed out that the precision of the analytical method is less important than the precision of the actual COD of the sample. As the number of samples on which the COD strength estimate are based increases, the effect of random analytical errors diminishes considerably.
Few analysts are aware that the sealed tube variation of the COD test is different to the standard reflux in its response to chloride interference (Balinger et al 1982). Considerable and expensive refinement of analytical precision may be a poor strategy to employ when trying to reduce the uncertainty in industrial effluent charges. The uncertainty can be reduced by taking more samples. (Dart 1977)

2.7 Sampling Procedures, Number of Samples, Frequency of Sampling

Sampling techniques and procedures for liquid samples, and liquid samples containing suspended matter, are well documented. The procedures in the American Standards Methods (1994 20th edition) are very comprehensive. (Montgomery and Hart, 1974) provide a very good example of how to design a sampling programme for effluents. Once an estimate of the standard error of charge is available, the technique first expounded in the water industry by Montgomery and Hart, may be used to estimate the future sampling frequencies required to satisfy a particular precision. Dart (1977) indicated that less thought has been given to devising sampling schemes which ensure that the load on a treatment plant (e.g. COD) can be estimated with reasonable accuracy. The number of samples (N) which must be taken to estimate the mean of a set of values with a normal distribution to a precision "P" is given by

$$N = \left(\frac{KS}{P} \right)^2$$

"P" = precision

"S" = standard deviation of the set of values about the mean

"K" = coefficient which depends on the confidence level required and which has a value of 1,64 for a confidence level of 90%.

Gaillard (1959) suggested that only a few of the strongest industrial effluents need to be assessed, since most effluent admitted to the sewer contributes but only a small fraction of the total load handled at a treatment works. This suggestion is borne out by **Project K5/854** and is illustrated in **Table 19** of this report.

Hulme (1985) expressed concern with how the results of applying the formula that establishes the number of samples to be taken (**Table 1a**) can be fair and reasonable bearing in mind cost of sampling/analyses portion and effects of random sampling errors on the precision of the estimated charge.
Louw (1990) highlighted the importance of sampling and the various aspects such as where to sample; number of samples to be taken; the frequency of sampling, and how sampling needs to be undertaken.

2.8 Flow Measurement

Experience in the metering of sewage and sewerage effluents (Gaillard 1959) at a number of sewage works has shown that unless frequent and expert servicing of meters is undertaken, misleading results are sometimes obtained. For purposes of calculating the charge it will be more satisfactory in many cases to make use of metered water consumption less deductions for domestic sewage; non-condensed steam produced during process; and for water leaving the premises in the form of product sold. Harkness (1984) stated that direct measurement of industrial effluent discharge is often fraught with difficulties.

2.9 Effluent Tariff Formulae

The Mogden Formula and its variations have been used in the UK since 1937 (Ingold et al 1987, Griffiths 1959). The Mogden Formula has a weakness in that it does not allow for conveyance but has an element for preliminary treatment (Barnard 1961). The Confederated British Industries (CBI 1976) produced a set of guidelines for effluent tariff as follows:

$$C\ (\text{charge}) = R + V + \frac{O_t}{O_s} \bullet B + \frac{S_t}{S_s} \bullet S$$

where R = reception and conveyance cost per kilolitre.

It should be noted that this was an improved modification to the original formula, and is still used in the UK at present and was last confirmed by the Water Authorities Association (WAA 1986). A succession of municipal engineers, scientists, and consulting engineers have attempted to adapt the formula to South African conditions.
Vosloo (1979) was commissioned by the Transvaal Provincial Administration to produce a tariff structure that could be used throughout the province. His proposal was rejected primarily because he added availability charges (i.e. even if there was no flow from a property, he suggested that the developers should pay an assumed availability charge).

$$C = \left(\frac{a}{\sum a} \bullet R\right) + \left(\frac{b}{\sum b} \bullet S\right) + \left(\frac{b}{\sum b} \bullet \frac{O}{O_s} \bullet T\right)$$

C = annual sewerage charge per erf

a = area of erf

Σa = total area of all connected ervens

R = annual capital charges for sewer reticulation

b = assessed flow from erf in question

Σb = total measured flow from all developed erven

S = annual capital charges for sewers, trunk mains + annual maintenance costs + pumping

T = annual capital charges and running costs for treatment

O_s = COD mgℓ^{-1} of sewage averaged to all treatment works in the area of local authorities.

O = COD mgℓ^{-1} of wastewater discharged from industrial erf.

Osborn (1954) (part of Barnard 1961) proposed a methodology for effluent tariff calculations very similar to that being considered for the WRC Project K5/854 in 1999.

Local drainage By-Laws governing acceptance of industrial effluent into sewerage systems are by no means uniform, and tariffs charged for the acceptance, conveyance and treatment differ widely from town to town (Funke 1980). The calculation is usually based on one organic pollutant parameter with the result that no consideration is given to the presence of excessive concentrations of inorganic pollutants such as heavy metals or sodium. Impact of industrial discharges can be judged only by taking load as a parameter (Funke 1980). Load parameters for individual dischargers should be used in preference to concentration limits. Charges for heavy metals should only be implemented with discretion (Roets 1978). There have been many endeavours to provide rational effluent tariff formulae in South Africa (Cowan 1989, van Niekerk, and Wagner 1988, Vosloo 1979). However their proposals which were sound were generally not implemented by the water industry. Most endeavours fail because they do not tend towards simplicity and ease of understanding without compromising principles. (Kerdachi 1997) proposed a simple formulation based on COD and designed to recoup costs without any compromise on basic principles. The emphasis is on accurate data revised annually. (Van Niekerk and Wagner 1988) presented a rational approach based on cost allocation amongst the unit processes and used a mass basis of charging for the COD parameter. However the final formulation is unwieldy and does not lend itself to easy day to day application. (Funke 1980) placed much emphasis on using mass

loadings to limit the pollutants discharged into the receiving water. (Rhoades 1997 and Ingold et al 1987) proposed 3 alternative systems for charging : 1) Charges based on the types/groups of similar industries 2) Charges based on a "Rolling average" for the previous 18 months 3) Charge bands. It should be noted that charge bands are very logical especially when the water and wastewater industry is privatized as in the UK since 1974. This method is not in use in South Africa. (Bolitho 1975), estimated that the additional cost of biological removal of N to $< 5\ mg\ell^{-1}$ and P to $< 1 mg\ell^{-1}$ was ca. 20% for capital expenditure and 20% running cost.
Pitman & Boyd (1997) proposed a formulation that is simple and which lends itself to understanding and ease of interpretation. Provision has been made for an incentive scheme which allows rebates of up to 50% for beneficial substrates. e.g. Volatile Fatty Acids produced from yeast waste are an excellent substrate for biological phosphate removal.

3. LEGISLATION

3.1 Introduction

The use of water anywhere in the Republic of South Africa is subject to the requirements of the NWA. This replaces in total the WA. The WSA which complements the 1998 Act, provides the basis for ensuring how water services and related activities will meet the basic needs of the nation. While other Acts such as the Health Act, 1977(Act 63 of 1977) and the Environment Conservation Act, 1989 (Act 73 of 1989) are important and play a significant role, most attention will be focused in the ensuing paragraphs on the salient features and key points contained in the NWA and WSA. A brief reference is made to the WA, because some regulations are still being applied. Reference is made to recent sludge utilization legislation, and to local By-Laws and Ordinances both of which are essential in implementing an industrial effluent policy.

3.2 National Legislation

1994 saw the dawn of a new South Africa and a new Constitution which demanded a review of National Water Policy and the Water Law, on the basis of equity and fairness, values which are enshrined as cornerstones of our new society. The existing law did not provide for adequate sustainable management and conservation of a scarce resource in a semi-arid country with increasing demand for water, thus necessitating a thorough review of the country's water law.
The following key points incorporated in the NWA, and which will guide water management in South Africa in the future are relevant to the project and industry in particular. (SECTION 56 (2a) & (2c) of NWA).

- Users will be charged for the full financial costs of providing access to water, including infrastructure development and catchment management activities, on an equitable basis.

- All water use, wherever in the water cycle it occurs will be subject to a catchment management charge which will cover actual costs incurred.

- The use of rivers and other water resources to dispose of wastes will also be made subject to a catchment management charge which will cover actual costs and a resource conservation charge where there are competing beneficial uses for such use and/or such use significantly affects other users.

The NWA specifies that government as the public trustee of the nations' water resources must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner. The NWA does not indicate how to implement all of its components, but does specify that the various components of the Act must be developed in a progressive manner over time with stakeholder consultation. Eleven uses of water are specified under the Act. Of these the following relate directly to the project and will impact on effluent tariffs. (SECTION 21(e) (f) (g) of NWA.

- discharging waste such as releasing water containing waste into a river through a pipe, canal, or sewer
- waste disposal in a manner which may detrimentally impact on a water resource
- disposal of wastewater from industries or power stations

All water uses under the above Act are subject to the requirements of the "RESERVE". A combination of source- directed and resource- directed measures as illustrated in the boxes on the next page will provide a measure of protection to the water resource. (Herbst 1999) provided an insight into how these measures are likely to be implemented in practice.

RESOURCE DIRECTED MEASURES	SOURCE DIRECTED CONTROLS
These measures are directed at the water resource itself. They focus on the water resource as an ecosystem. ❑ a national classification system for water resources ❑ determining a management class for each resource ❑ determining the "Reserve" ❑ setting resource quality objectives which represent the desired level of protection of a water resource.	These will control the impacts that different kinds of users of water will have on water resources. ❑ standards to regulate the quality of waste discharges to water resources (the so-called end-of-pipe quality) ❑ requirements of on-site management practices (e.g. to mining waste at source and to control diffuse pollution) ❑ requirements to minimise impacts of water use generally, not just water quality aspects ❑ requirements for clean-up and rehabilitation of water resources that have already been polluted.

Other protection measures include both mandatory and voluntary demand management (water conservation) and economic incentives to foster the development of low-waste and non-waste technologies and to reduce pollution.
The WSA provides the basis from which to ensure that all South Africans will be able to meet their basic needs for water supply and sanitation with dignity and equity. Of particular interest is the allocation of responsibilities at local government level for the provision of water-related services and the new role of Water Boards as service providers to Water Services Authorities.
Key relevant points contained in the WSA are:

- Access to water for industrial use requires the approval of the water services authority serving the area.
- The disposal of industrial effluent requires approval by the water services provider nominated by the water services authority having jurisdiction in that area.
- Any person who, at the commencement of this Act, was using water for industrial use or disposing of industrial effluent, in a manner which required the approval of a water services authority, may so continue but must apply for approval within 5 years from the date of commencement of this WSA.

  No approval given by a water services authority under this section relieves anyone from complying with any other law relating to
  - a) abstraction
  - b) disposal of effluent

3.3 Other Related Acts

- **The Health Act, 1977 (Act 63 of 1977).**

  Administered by the Department of Health (DH) . This Act outlines duties, responsibilities and powers of local authorities with respect to the handling and disposal of wastewater, sewage sludge and solid waste collection, treatment, and management, all from a health point of view.

- **The Environment Conservation Act,1989(Act 73 of 1989)**

  Administered by the Department of Environmental Affairs and Tourism (DEAT). This Act is concerned with the protection of ecological processes, natural systems and the preservation of biotic diversity in the natural environment.
  Economic measures must be undertaken for the effective conservation of the environment. The environmental resource measures are, inter alia,

  - promoting the reduction of waste streams and pollution to levels that can be naturally absorbed without deleterious effects on the environment
  - promoting the usage of innovative technologies that can make a specific contribution towards sustainable developments
  - internalising external environmental costs as part of the exploitation and production costs, having due regard to the economic implications.

  The requirements and conditions with regard to the control and management of disposal sites and the procedures to be followed to ensure compliance form an important section of the Act. It should also be noted that no person can establish or operate any disposal site without a permit from the Minister of Water Affairs and Forestry.

- **The Conservation of Agricultural Resources Act,1983 (Act 43 of 1983)**

  Administered by the National Department of Agriculture(NDA).
  The scope of this Act is very broad, but the strongest implication is that the beneficial use of appropriate quality sewage sludge in agriculture is indirectly encouraged because it promotes conservation and fertility of agricultural soil.

3.4 Local Legislation

Municipal Ordinance

The Municipal Ordinance No. 20 of 1974, provides all local authority in South Africa with the local legal framework and authority to compile rules for the acceptance of sewage, protection of the sewerage system, and industrial effluent measurement and charging. This ordinance also allows the local council to delegate powers to various

Committees and Officials.

By-Laws

Under the same Municipal Ordinance No 20 of 1974, the local authorities are empowered to make suitable laws that, inter alia, govern the quality, quantity, and conditions of acceptance of industrial effluent into the sewer system. At local level, these By-Laws provide the legal framework to allow industry to discharge its waste effluent into the sewer; subject to prescribed conditions. . In terms of these By-Laws, the industrialist becomes the polluter of the sewer system and his effluent impacts on the treatment works as well as the final effluent. The polluters of the conveyance and treatment system are industrial, commercial and residential users.
The industrialist enters into an agreement with the local authority on the conditions under which industrial effluent can be discharged. A charge is made for the conveyance and treatment of this effluent. The charge is made in terms of a prescribed tariff formula which is designed to recover from industry the cost of conveying and treating the pollution load. The By-Laws are designed to protect and regulate the sewer infrastructure; to ensure continuity in the biological functioning of the treatment works; ensure safety of the workers active in the sewer system and to ensure that the local authority is adequately compensated for the service provided.

Local Government Transition Act,1993(Act 209 of 1993)

This Act allows a municipality to levy fees, taxes and tariffs in respect of any function or service provided by the municipality. It also provides the authority for obtaining finance and the raising of loans for capital expenditure.

3.5 Repealed Legislation and Regulations in Transition .

Water Act, 1956 (Act 54 of 1956)

The key features of this Act, which was totally repealed in October 1999, were as follows:

- It was a basic requirement of the legislation on pollution control that effluent purification be an integral part of industrial processes and that the producer of the effluent must provide all the resources required to purify his own effluent to DWAF prescribed standards before the purified effluent was returned to its stream of origin.

- An industrialist required a permit from the Minister of Water Affairs and Forestry to use more than 150m^3 of water for industrial purposes on any one day.

- The purification of effluent resulting from the use of any water for industrial purposes was obligatory.

- A permit was required from DWAF whether the aim was to build, augment and/or to operate the works.

- The treatment plant required, process design and the extent of its sophistication was dictated by the prescribed standards set by DWAF with due consideration given to the location, sensitivity and status of the receiving water and its catchment.

- Discharges of industrial effluent into the sewer of a local authority were not subject to the requirements of the WA.

- Two standards were applicable: the General and the Special Standards as promulgated and gazetted in Terms of Section 21 of the above WA.

4. UNDERLYING PRINCIPLES GOVERNING PAYMENT FOR EFFLUENT DISCHARGES

4.1 'The Polluter Pays Principle'

DWAF has always adopted the principle that the polluter must pay for the abatement of his own pollution. This approach has been reinforced in the NWA under the Section of Water Use Charges (NWA chapter 5, Part 1 Section 56) to ensure compliance with prescribed standards and water management practice.
Legislation on pollution control requires that effluent purification be an integral part of industrial processes. The underlying philosophy of the "polluter pays principle" is to get the tariff system to reflect the true costs of the service provided including all activities involved in delivering the service (Herold et al. 1998).
The discharge of industrial effluent into the sewer is subject to the requirements of the NWA and WSA. The local authority assumes responsibility for the purification and disposal of effluent in accordance with the requirement of the Act. In the process of undertaking the responsibility the local authority or the service provider which may be the local authority incurs expenditure to provide a sewerage network and treatment/purification facilities to meet the additional hydraulic, and COD load contribution to the system, and to ensure that the standards prescribed by DWAF are attained. The local authority uses a tariff structure designed to ensure that the costs incurred will be proportionately recovered from industry for the services provided.
If the water resource is treated as free goods, then it leads to abuse and exploitation of the natural resource. One method of reducing the above externality is to force the polluter to internalise the cost of his externality - by making the polluter pay i.e. making sure that the polluter internalises not only the production or marginal costs of producing an extra unit, but the marginal environmental costs of production as well.

This approach mirrors the understanding of the "polluter pays principle" by the OECD countries policy document of 1975. (OECD 1975)
The polluter pays principle is being addressed in detail by other researchers.(WRC Project 793, Herold and Taviv 1997)

4.2 Who is the polluter?

Static statements such as the polluter will pay are an over simplification of the real situation. The prime polluter of the receiving water is the local authority. Although DWAF stipulates the pollutant limits in the effluent discharge permit, the effluent discharged will still impose an additional load on the water resource and this could have a detrimental impact on the water resource and the ecosystem. The DWAF pricing strategy in terms of the NWA promotes charging for the point and diffuse sources of pollution with a view point to internalizing the cost of water pollution as well as economic incentives and disincentives to promote the reduction of waste discharge.
These charges over and above the direct operating expenses of the sewerage and treatment systems, will have to be sustained partially by industry. Since the domestic householder also contributes to the final pollution load discharged into the water environment, they will also have to bear their share on a proportionate basis. Industry are the secondary polluters. Before any effluent discharges are accepted into the sewer system for treatment, specific binding legal agreements and documentation must be completed between industry and the local authority. By taking on this responsibility the local authority will have to acquire capital, sustain all purification costs, and pay for water resource and catchment management charges. These will then be apportioned to all users of the system.

4.3 Catchment Management

Integrated Catchment Management (ICM) is a systems approach to the management of natural resources (DWAF,1996). The ability of all nations or societies to develop and prosper is directly related to their ability to properly develop, utilize, protect and sustain their water resource. Since water resources of South Africa are recognised as a critically important national asset (DWAF 1986), they must be managed effectively and efficiently so as to maximize long-term benefits to the country as a whole and ensure sustainability. Management of any catchment will entail planning and execution of actions designed to maintain the system at a particular agreed status of water quality.
At local level, a catchment management agency (CMA) will be formed, representing each water use sector in the catchment and will be responsible for executing the management plan under DWAF supervision. In terms of the NWA , a catchment management agency must be funded from water use charges and it can raise any funds required by it for the purpose of exercising any of its powers and duties.

4.4 Water Resource Protection

The main purpose of catchment management strategies is to achieve sustainable use of water in each catchment. To do this catchment management strategies must balance the eleven recognised uses of water in the catchment while protecting the catchments' water resources (National Water Act News – DWAF 1999).
Resource Directed Measures (hereafter referred to as RDM) are fundamental to catchment management strategies.
The first stage in the protection process is to develop a system which classifies the nations water resources. This system must establish guidelines and procedures for determining different classes of water resources and associated with each class, procedures to determine the Reserve, and to set objectives which will satisfy users water quality requirement as far as possible. MacKay 1998 provided an insight into how such a system could operate in practice. DWAF(1999)have used the MacKay 1998 document as a basis of RDM for protection of water resources. It indicates the procedures to be followed in undertaking preliminary determination of the class , Reserve , and resource quality objectives for water resources as specified in Sections 14 and 17 of the NWA. It must also be noted that in terms of the NWA no water use license may be issued without at least a preliminary determination of the Reserve having been undertaken .DWAF is in the process of finalising a classification system for different classes of water resources.(Water Act News 1999)
Table 0 (MacKay 1998) provides an illustration of the classification process in action.

Table 0 A classification approach to balancing the requirements of protection and utilisation

Water resource	Ecosystem protection class	Desired status for domestic use	Desired status for agricultural (irrigation) use	Desired status for recreational use	classification
River X, reach 1	A	Class I	Class II	Full contact	$Ad_{I}a_{II}r_{f}$
River X, reach 2	B	Class II	Class III	intermediate contact	$Bd_{II}a_{III}r_{I}$
River X, reach3	B	Class II	Class IV	Intermediate Contact	$Bd_{II}a_{IV}r_{I}$

Thus River X, reach 2 would have a classification of $Bd_{II}a_{III}r_{I}$. This means that

B: the ecological integrity status of that reach would be maintained at class B

d_{II}: the water quality would be fit for domestic use with conventional treatment

a_{III}: the water quality would be fit for irrigation of moderately tolerant crops, depending on site-specific soil conditions.

R_{I}: the water resource would be fit for intermediate contact recreation.

4.5 Interaction between Local Authority, DWAF, Industry and Service Providers

The local authority usually acquires finance on the capital markets to build a conveyance and treatment infrastructure. Once GAMAP is operational this finance

could come from internal cash funds. Those local authorities that cannot set aside cash in their AFF (asset finance fund) will have to rely on external finance to fund development. The depreciation on capital as well as the operating expenditure of both systems are initially sustained by the local authority and passed on to industry proportionately. It should be noted that the polluter of the receiving water will be the local authority. The local authority has to be licensed to use water and operate a treatment works and has to ensure that the treatment infrastructure is adequate to achieve the requisite standards (Section 21(e) NWA).
In the processing of such an application, attention is given via Receiving Water Quality Objective (RWQO) studies to the status of the river or receiving water and its ability to assimilate limited pollution without detriment to aquatic life as well as to downstream users. The results of the RWQO study dictate the concentrations of certain pollutants which will be permitted and the conditions of the permit.

5 EFFLUENT STANDARDS AND SLUDGE DISPOSAL GUIDELINES - DWAF AND DH

5.1 Introduction

DWAF is the custodian of a limited national resource in a society with a growing, diversified and competitive economy (DWAF 1986). Its major objective is to ensure the provision of adequate quantities and qualities of water to all competing users with the emphasis on water resource protection, equity and sustainability. Therefore it is obliged to set the standards required to ensure that the above objectives are met.

5.1.1 Effluent Discharge Permit – Standards

All water users will have to be registered and licensed in terms of the NWA. The authorisation stipulates the conditions under which the treatment system will be allowed to operate and the standards required for the effluent quality prior to discharge into the receiving water.
The special and general standards under the Water Act of 1956 are no longer applicable from October 1999 and all new permits for effluent discharge into the water resource will be subject to appropriate standards set by DWAF. However, the Department is working on the compilation of a new set of standards. The new approach is to use receiving water quality objectives (RWQO) methodology to set a Waste Load Allocation (WLA).
Attention must be given to the water quality requirements of downstream users, the assimilative capacity of the water resource and the impact on the aquatic habitat and ecosystem. This approach was introduced in 1991 (DWAF 1991) and in general, attempts to ensure that the quality specifications of the receiving water are not exceeded.
Permits which were issued in terms of the WA and which contain either the General or Special Standards as illustrated for ease of reference in **Appendix II** will remain valid until the expiry date of the permit.

5.1.2 Protecting Water Quality Standards

Maintaining water resource quality depends on the combined use of a number of regulatory mechanisms.
Resource directed measures: These define a desired level of protection for a water resource and on that basis set clear numerical goals for the quality of the resource. (Resource Quality Objectives)
Source directed controls: These control the impacts on the water resource through statutory requirements for meeting effluent discharge standards and the use of regulatory measures such as registration, permits, directives and prosecutions, and economics in order that the RQO's are met.
Monitoring: This entails monitoring the status of the country's water resources on a continual basis in order to ensure that the RQO's are being met.

5.1.3 Impact on Design and Costs of Treatment Works

While the general parameters governing the design of wastewater treatment works are the carbon and nitrogen loadings such that the effluent must comply with a Chemical Oxygen Demand (COD) concentration of < 75 mgℓ$^{-1}$ and a NH_3/N concentration of < 10 mgℓ$^{-1}$, DWAF may impose specific restraints on other pollutants. These may, for e.g. include sodium, colour from dye-material, total dissolved solids, conductivity or phosphate. Should any of these pollutants either individually or collectively require to be reduced to environmentally acceptable concentrations, then advanced tertiary treatment will be required. It is well known that such treatment irrespective of whether it be membrane technology, use of activated carbon or ozone, or similar types of technology, will result in exorbitant capital and operating costs. The direction being promoted by DWAF embraces waste minimization and treatment at source. Once the standards of effluent quality required are specified, the effluent producer will have to commission a treatment system that will produce an effluent that complies with the above standards. The effluent producer who is the local authority or the service provider will have to implement tariffs for industrial effluent such that the costs associated with the pollutional load from industry will be fully recovered. The DWAF standards impact significantly on the level of capital and operating expenditure, as well as the tariff settings for all users of the above system.

5.1.4 Wastewater Sludge Utilization and Disposal

5.1.4.1 Guidelines

Guidelines on the permissible sludge utilization and disposal have been developed by the Department of Health (DH 1991, 1997). These guidelines provide a classification system in terms of 4 types of sludge. Types A, B and C are classified in a decreasing order of potential to cause odour, nuisances, and fly-breeding as well as to transmit pathogenic organisms to man and his environment. The type D sludge is of similar hygienic quality to type C, but the metal and inorganic content are limited to acceptable low concentrations.

The greatest potential health hazard appears to be the danger of transmission of heavy metals and pathogenic organisms from the sludge-treated soil to crops, grazing animals (food chain) and humans. Therefore it is essential to minimize the accumulation of heavy metals in the soil and in this regard DH have provided maximum metal and inorganic concentrations allowable in soil. The permissible application rate to the soil is also given.

5.1.4.2 Limitations

However before such an exercise can be put into operation, a sludge analysis is required to assess sludge quality in terms of heavy metal concentrations. This will then govern the options open for its utilization or disposal. A complication with heavy metal analysis is the interpretation of the data. Total metal results do not indicate what transformations take place at various pH levels, and how much is available. A further limitation is the scarcity of accredited laboratories with the requisite expertise to undertake such analytical tests. (Ekama 1993)

5.1.4.3 Heavy metals

The South African Sludge Disposal Guidelines (DH 1997) incorporate a permitting framework which is very sophisticated with conservative limits set for the total content of trace elements in the sludge and in soils, rather than the amount that is extractable or bio-available. Cadmium and mercury are the metals that are of most concern. Many are of the opinion that it is best to prevent the metals from getting into the sludge by implementing industrial effluent By-Laws which regulate the amount of metals that can be discharged (Ekama1993). If a good system is in place with regular inspection and monitoring, there should be no difficulty in maintaining metals at an acceptable level.

5.1.4.4 Technology

Prior to the 1980's most sludge was biologically digested as a means to stabilize the sludge organics producing methane and carbon dioxide in the process. Pathogens were also partially destroyed at the same time. However since the 1980's advanced technologies for sludge treatment have emerged. These are capable of producing a pathogen-free product, stabilized organic matter and fixated heavy metals in an inert form. The two most widely used approaches are biological composting and advanced alkaline stabilization (Logan 1995, Burnham et al 1992). While composting relies on biological degradation, heat and drying to kill pathogens and stabilize organic matter, advanced alkaline stabilization using lime or kiln-dust (Biofix 1994 and Burnham et al 1992) utilizes a combination of high pH (>12), heat (52^0C – 62^0C) and drying to achieve the same purpose.

Although guidelines are available (DH 1991,1997) and have been recently augmented by the Water Research Commission document (WRC TT 85/97, August 1997), there is still much debate and deliberation on these guidelines by a national working group. The main concern is related to the ultraconservative metal limits which are considered to be unrealistic and impractical.

5.2 Effluent Standards – Local authority

5.2.1 Introduction

Industry generally, discharges it's effluent to the municipal sewer for treatment at the purification works. In special cases, industry may have its own treatment facility, and will then, subject to obtaining a permit to discharge from the relevant authority, will discharge treated effluent directly to the receiving water.
Before the local authority accepts any industrial effluent into its sewer system, a legally binding agreement must be signed, stipulating the conditions under which this effluent may be discharged as well as the maximum acceptable pollutant limits. However, just as DWAF sets the standards for discharge into the receiving water so does the local authority compile a set of By-Laws. Parts of these By-Laws relate to industrial effluent tariffs and stipulate the requirements that need to be complied with before discharging into the sewer. A typical example from one of the local authorities participating in the project is shown in **Appendix III**, illustrating prohibited and limiting pollutants. It should also be noted that the Chief Executive Officer or anyone with delegated authority can in liaison with any industry, relax or even intensify the concentrations of selective pollutants if in their opinion they are likely to be inhibitory or detrimental to the functioning of the biological processes at the treatment works. **(Appendix III)**

5.2.2 Protection of the Sewer System and the Treatment Works

One of the main aims of the By-Laws is to protect the sewerage infrastructure from damage due to corrosive and acidic substances, and to prevent any fires or explosions from combustible material. Of concern is the protection of the health and well-being of the workers that maintain the sewerage infrastructure. A similar situation exists at the treatment works where the biological processes promoting the synthesis of microorganisms that utilize and remove carbon and nitrogen are extremely sensitive to toxic material. In situations where inhibition takes place or biological malfunction occurs due to toxic substances which have exceeded the threshold toxicity limits, the resultant effect can be very costly with implications to all concerned. It is important to note that the local authority is not obliged to accept an effluent from industry if it considers that the effluent will be detrimental to any functioning of the sewer or treatment system.
The extent of the pollution load is assessed by the water quality officers in terms of volume of effluent calculated from the water consumption with approved allowances

and the measured strength in terms of COD. These two parameters i.e COD and Volume, generally dictate the ultimate cost of effluent treatment.

6. INDUSTRIAL EFFLUENT TARIFF FORMULAE

6.1 Introduction:

Since this research project is all about industrial effluent tariffs, it is considered as appropriate that the history and development of the South African formulae are traced, and also to show the large influence that the United Kingdom (UK) Water Industry has had on the general direction taken by South Africa. Until the formation of the Water Institute of Southern Africa (WISA) in 1987, the local water industry was very much influenced by the direction of the Institute of Water Pollution Control (UK). The South African chapter of the IWPC was a branch of the IWPC (UK). This situation had promoted a strong water and wastewater technology interaction between officials from the UK and South Africa who were involved with water and wastewater practice.

6.2 Tariff formulae:

The "Mogden formula" has been in use in the UK since 1937 as the basis for trade effluent charging. The Public Health (Drainage of Trade Premises) Act 1937 was the first Act which gave traders in England and Wales (except London) the right to discharge trade effluent into the public sewer. Mogden Wastewater Treatment Works was the largest activated sludge plant in the world when it was commissioned in December 1935.

The "Mogden formula" split the cost of treatment into 3 elements:

a) Preliminary treatment and miscellaneous operations, mainly proportional to volume (V)
b) Biological treatment, which is proportional to both volume and strength (B)
c) Sludge treatment and disposal which is proportional to the amount of solids in the effluent. (S)

If V, B, and S are expressed as the cost/m^3 of sewage treated, then total cost of treatment / m^3 $C = V + B + S.$

In the case of trade effluent, V is constant and a function of volume only.
At that time (1937), the McGowan figure (M) was considered to be the best basis of comparison of the strength of trade effluent and sewage.

For sewage,

McGowan strength = 4,5 (Ammoniacal N + Organic N) + 6,5($\frac{N}{8}$ Permanganate Value)

$$\text{Total charge (C)} = V + \frac{M_t}{M_s} \bullet B + \frac{S_t}{S_s} \bullet S$$

where M_t and M_s are McGowan strengths of settled trade effluent and settled sewage respectively. S_t and S_s are settleable solids of trade effluent and sewage respectively.

In 1936,the simplified formula became

$$C = 1 + \frac{M_t}{75} + \frac{S_t}{60}$$

and was used from 1937 – 1951. However the effects of inflation required that it be changed more frequently and in 1957 – 1958 it had become

$$C = 1{,}3 + \frac{M_t}{34{,}8} + \frac{S_t}{35}$$

In 1965 the Mogden Works was transferred to the Greater London Council, and in 1970 the London Formula was used.

$$C\ (c/m^3) = R + X + \left(\frac{M}{M_1}\right)Y + \left(\frac{S}{S_1}\right)Z$$

where

R	=	one sixth of the amount of the average cost of receiving into the sewers and conveying of sewage to the treatment works (c/m^3)
X	=	the average cost of primary treatment of sewage (c/m^3)
Y	=	the average cost of biological treatment of sewage (c/m^3)
Z	=	the average cost of sludge treatment and disposal of sewage (c/m^3)
M	=	strength of settled trade effluent discharged to the sewer (McGowan figure in $mg\ell^{-1}$)
M_1	=	mean strength of settled sewage (McGowan figure $mg\ell^{-1}$)
S	=	settleable solids of trade effluent discharged to sewer ($mg\ell^{-1}$)
S_1	=	mean settleable solids of sewage ($mg\ell^{-1}$)

Since April 1975, COD has been adopted as the strength parameter instead of McGowan strength.

N.B. Some water authorities use SS (suspended solids) instead of settleable solids.

When the CBI/NWC Guidelines were published in 1976 (Confederation of British Industry 1976) it was recommended that trade effluent should be charged on the following type of formula using average flow conditions:

$$C = R + V + \left(\frac{O_t}{O_s}\right)B + \left(\frac{S_t}{S_s}\right)S$$

where

C	=	total charge per m^3 of trade effluent
R	=	Reception and Conveyance charge per m^3
V	=	Volumetric and primary treatment cost per m^3
O_t	=	COD in $mg\ell^{-1}$ of the trade effluent after 1 hr of quiescent settling at pH 7.
O_s	=	COD in $mg\ell^{-1}$ of settled sewage
B	=	biological oxidation cost per m^3 of settled sewage
S_t	=	total suspended solids in $mg\ell^{-1}$ of trade effluent at pH 7
S_s	=	total suspended solids in $mg\ell^{-1}$ of crude sewage
S	=	treatment and disposal cost of primary sludges per m^3 of sewage

The 1976 guidelines were reviewed in 1986 by the Water Authorities Association in liaison with the British Industries(Water Authorities Association 1986). They agreed to continue to use the Mogden type formula recommended in 1976.

The unit cost for item "R" (reception and conveyance) is calculated by taking a proportion of the net annual current expenditure, including financing charges on capital, on all sewers and pumping stations in the Authority's area or in a Divisional catchment area, other than those used solely for surface water and those pumping stations with rising mains discharging directly to sewage treatment works. It was suggested that the proportion taken be one third, divided by the average flow.
The unit cost for the term "V" (volumetric and primary treatment) is derived from the net annual revenue expenditure including financing charges on capital on:

a). all pumping stations with rising mains discharging directly to sewage treatment works
b). all inlet works, including screenings, comminution, grit removal and pre-aeration
c). all primary settlement units other than storm treatment works
d). tertiary treatment for reduction of the concentration of residual suspended solids
e). all outfalls for treated sewage

The unit cost for term "B" (biological treatment) is derived from the net annual revenue expenditure including financing charges on capital on:

a). biological filtration plants and humus tanks, including recirculation, alternating double filtration and humus sludge pumping,

b). activated sludge plants and final settling tanks, including returned sludge pumping,

c). the proportion of total sludge treatment and disposal costs associated with secondary sludge treatment and disposal.

The unit cost for term "S" (primary sludge treatment and disposal only); is derived from that portion of the total net annual revenue expenditure including financing charges on capital related to primary sludges on:

a). pumping or otherwise conveying (e.g. by tanker) sludge to treatment and disposal,

b). sludge dewatering and treatment, including digestion, conditioning, consolidation, drying, storage, incineration and disposal.

Otherwise unallocated charges, such as site charges, administration and indirect costs should be allocated over the treatment stages in proportion to the expenditure under each heading.
Further additions to the guideline formula were made to accommodate a charge for heavy metals and cyanides in the formula.
An example of one such formula is as follows:

$$C = V + \left(\frac{X}{W} + \frac{Y}{20} + \frac{Z}{7}\right)B + \left(\frac{Q}{R}\right)S$$

where

C	=	total unit charge for trade effluent (c/m^3)
V	=	volume charge for conveyance, reception and preliminary treatment (c/m^3)
X	=	COD of trade effluent after 2 hr settlement (ℓ)
Y	=	total toxic metals in trade effluent ($mg\ell^{-1}$)
Z	=	cyanogen compounds (as CN) which on acidification liberate HCN, in the trade effluent ($mg\ell^{-1}$)
W	=	COD of settled sewage ($mg\ell^{-1}$)
B	=	unit cost of biological purification of settled sewage (c/m^3)
Q	=	SS of trade effluent after adjustment to pH of 7,5
R	=	SS of sewage treated at the works ($mg\ell^{-1}$)
S	=	unit cost of sludge disposal (c/m^3)

The metal and cyanide charges were added to the biological treatment charge, as inhibition of the process was a major problem in this case. The policy had the desired effect as the metal burden of the influent wastewater (sewage) dropped significantly. There was much opposition to the levying of an additional charge for heavy metal pollution and other toxic constituents such as cyanide. Many authorities shared the view that such a move would mean that industrialist who could afford to do so would be able to buy an unfair share of the environment. It also provides an unfair disadvantage over their competitors who do take a responsible attitude and comply with the limit. A further complicating factor is that the mechanisms and conditions under which heavy metals become inhibitory towards the biological processes are poorly understood.
The first formula used in South Africa was devised by Murray (1942) and is represented as follows

$$G + \left(\frac{d+1}{3}\right) + \frac{O}{36} + \frac{S}{300}$$

where

G	=	basic Germiston charge
d	=	difference between pH measured and that of pH 7,0
O	=	OA in parts per 100 000 of supernatant
S	=	total volatile solids in parts per 100 000

The formula was only applied to one factory in 1945. However the charge was not recognised as a true reflection of actual costs to purify wastewaters from industry. A new formula was promulgated in 1950 and has basically been used until recently. Its basis was as follows:

"The monthly handling and treatment charges shall be the summation of"

a) The assessed cost of pumping the trade effluent after it has been discharged into the Councils' sewer.
b) The assessed cost of treatment of the supernatant liquid constituent of the trade effluent
c) The assessed cost of treatment of the settleable sludge content of the trade effluent.

The "Germiston formula" had much in common with the "Mogden formula". But both of them made no provision for a conveyance charge. It was only in 1956 that a full time industrial effluents inspector was appointed and the formula really put into practice. Similarly Johannesburg's first industrial effluent officer was appointed in 1950, but the first charges were only levied in 1954. After agreeing to a 50% subsidy to industry to encourage further expansion, the following formula was adopted. Charge in pence per m^3 = 1,3 + 0,004 OA

Actual disposal costs at the time were as follows:

Conveyance :	2,75 pence per m^3	**N.B. [1 pence = 2cents**
Treatment :	11,0 pence per kg OA	**at the time]**

The basis for calculating the unit cost of conveyance and treatment in 1954, was as follows:
Records relating to the volume and strength of industrial effluents had been accumulated over a period of 4 yrs. It was thus possible to calculate the percentage of the total hydraulic and pollution load contributed by industry. These were found to be 5% hydraulically and 40% of total carbon load. Knowing the cost of running all the Johannesburg sewage works and the cost of maintaining the sewer system, it was possible to establish reliable figures for the cost of conveyance and treatment of industrial effluents. The OA in the above formula was based on an average of 4 snap samples in 6 months.
The "1954" Johannesburg tariff as illustrated above remained in force until July 1969 when it was replaced by the new "1969" Tariff designed on the basis of the investigation undertaken by Bolitho (Bolitho 1970).

The formula adopted by Johannesburg in 1969 was

$$\text{Cents per cubic metre} = 3{,}75 + 0{,}022\,(OA - 80)$$

In devising the new formula two principles directed at reducing administrative work to a minimum were adopted

1. No charge was made for suspended solids, as the level of organic suspended solids in industrial effluent in Johannesburg was not sufficiently above the norm to affect the cost of purification sufficiently to justify a separate suspended solids charge.

2. To avoid unnecessary sampling and analysis no surcharge was made against industrial discharges of lesser volume than $90m^3$ per month, or lower OA strength than 80 $mg\ell^{-1}$.

The trend set by Johannesburg provided the direction for local authorities in the former PWV area. This can be seen from a survey in 1979 (Funke 1980) where the similarities were observed.

e.g.

Pretoria: $\left[7 + 0{,}047\,(OA - 80)\right]$ c/kℓ

Springs: $\left[6{,}5 + 0{,}081\,(PV - 80)\right]$ c/kℓ

Witbank $\left[5{,}0 + 0{,}05 \ (OA - 50)\right]$ c/kℓ

Johannesburg $\left[10{,}6 + 0{,}055\,(PV - 80)\right]$ c/kℓ

Cape Town $\left[R + T\left(\frac{1}{3} + \frac{COD - 75}{1350}\right)\right]$ c/kℓ

where R = conveyance charge 7,1 c/kℓ
T = treatment charge 6,42 c/kℓ

Any COD of less than 1500 $mg\ell^{-1}$ attracted no treatment charge.

Durban $\left[X + Y\frac{A}{30} + Z\frac{B}{9}\right]$

where X = conveyance = 12,31 c/kℓ
Y = 0,79
A = OA over past 12 mths, revised every 3 months
Z = 3,56
B = settleable solids over past 12 mths, revised every 3 mths.

In the early 70's it was government policy to encourage the establishment of border industries, as a means to providing employment to the local population away from the main towns and cities and at the same time providing incentives to industry via tax benefits to relocate. Government financed organisations also provided a service at unrealistically low effluent rates. One such example was the Isithebe Industrial Township *in* Natal *where the prevailing tariff was*

$[1 + 0{,}0425PV]$ c/kℓ

By comparison with the data in the previous passages it can be seen that this service was provided very cheaply to industry.
Durban realised in the late sixties that the gazetted tariff had not been raised over a few years, and with the infrastructural augmentation to wastewater treatment in the Southern and Coastal Area of Durban making a huge financial impact on costs, the tariff was hiked significantly. This was phased in over a 5 yr period. It was also noticed that most of the local authorities in the PWV area (now called Gauteng) followed the direction in tariff structure given by Johannesburg at that time.
At this time the treatment costs in most of the effluent tariff formulae included both the liquid and solid phases. Only Durban had a formulation which still had a separate solid phase cost. Certainly Johannesburg, Cape Town, Port Elizabeth, East London

had regarded the treatment cost for purposes of effluent charging as one overrall cost. Thus the treatment cost reflected the unit cost to treat 1 kilolitre of wastewater to the liquid and solid standards required by the DWAF and DH respectively.
Roets 1978, established a rate of charge for the acceptance of heavy metals, over and above the effluent formula which was :

$$\text{Cost in c/k}\ell \quad = \quad 7{,}0 + 0{,}047(\text{PV} - 80)$$

where the cost for treatment of domestic raw sewage was 47c/kg PV treated to a final PV value of 10 $mg\ell^{-1}$ in the effluent.
The additional cost for heavy metals was

$$\text{Cost in c/k}\ell \quad = \quad 5{,}75\left(\frac{\text{M} - 20}{\text{pH}}\right)$$

where M is the aggregate total concentration of Zn, Cr as CrO_3 , Cu, Ni, Cd, Fe, Co, As, B and Pb.
Roets(1978) however did suggest that a charge for heavy metals should only be implemented with great discretion and only in cases where the acceptance of such has genuinely resulted in additional costs.
Van Niekerk and Wagner (1988) produced a tariff structure based on earlier work by Cowan (1986), and which embraced 3 principles.

- Every individual unit treatment process has a specific function
- Every unit treatment process has a quantifiable capital redemption and operational and maintenance cost associated with it.
- Correlation of the specific function (related to a raw sewage constituent) and the cost of a unit treatment process should form the basis for the derivation of a sewage purification charge.

The tariff structure which allows allocation of the cost to each individual contributor in proportion to the relative flow and relative mass contribution of the selected sewage constituent is as follows:

$$T_i = C_t \bullet A_1 \bullet \frac{Q_i}{Q_t} + A_2 \bullet \frac{M_{CODi}}{M_{CODt}} + A_3 \bullet \frac{M_{ssi}}{M_{sst}} + A_4 \bullet \frac{M_{ni}}{M_{nt}} + A_5 \bullet \frac{M_{pi}}{M_{pt}}$$

where T_i = Total charge to the effluent contributor (R/annum)
C_t = Total purification cost (R/annum)
A_i = Cost allocation factor to sewage flow and sewage constituents; where $A_1 + A_2 + A_3 + A_4 + A_5 = 1{,}0$
Q_i = Sewage flow from an individual contributor (Ml/d)
Q_t = Total plant sewage flow (M1/d)
M_{CODi} = Settled COD mass contribution from an individual contributor (kg/day)

M_{CODt} = Total plant settled COD mass (kg/day)
M_{ssi} = SS mass contribution from an individual contributor (kg/d)
M_{sst} = Total plant influent SS mass (kg/d)
M_{ni} = Ammonia mass contribution from an individual contributor (kg/d)
M_{nt} = Total plant influent ammonia mass (kg/d)
M_{pi} = Phosphate mass contribution from an individual contributor (kg/d)
M_{pt} = Total plant influent phosphate mass (kg/d)

The rationale for the allocation of cost on the basis of mass of sewage constituents contributed is important. Each industrial unit treatment process must be analyzed and the cost associated with such a unit treatment process allocated to sewage flow and the selected sewage quality parameters. This is very onerous, and subject to plenty guesswork and not very practical in a Metro network where there can be up to 45 treatment works using different treatment processes and different background financing for capital expenditure.
Cowan (1989) attempted to improve on both his 1986 version and that of Van Niekerk and Wagner (1988). He emphasised, in particular, that the greatest requirement of any tariff formula is simplicity – cost-effective simplicity. The capital and O&M costs are allocated to the unit processes by % volume and composition. Here again the procedure becomes onerous and relies on plenty guesswork. His formula for assessing the effluent charge in cents per kilolitre was presented as follows:

$$\frac{\text{Annual revenue (R)} \bullet 100}{\text{m}^3/\text{a}} = 100\left(\frac{\text{Flow related costs (R)}}{\text{m}^3/\text{a}} + \frac{\text{composition related costs (R)}}{\text{units of composition /a}}\right)$$

where the unit of composition is the COD.
Further simplification where COD load = kg COD $= \frac{\text{mg COD/k}\ell}{1000}$ results in

$$\text{cents/kilolitre} = V + T \bullet \frac{\text{COD}}{100}$$

where V = flow related charge from $\frac{\text{annual flow related cost}}{\text{estimated m}^3/\text{a}}$

T = composition related charge calculated from $\frac{\text{annual composition related cost}}{\text{estimated kg COD/a}}$

Here again the formulation did not capture the imagination of the authorities.

Pitman and Boyd (1997) highlighted the new approach to industrial discharges to sewer, by using the rebate system for the Greater Johannesburg Metropolitan Council for illustrative purposes. Subject to certain screening procedures, industrialists can obtain up to a 50% rebate in effluent charges if their effluent is beneficial to the operation of the treatment works. In the above scenario, the discharge of yeast waste has proved to be very successful for the biological nutrient removal (BNR) process.

The general formula on which charge is based is as follows:

$$c/k\ell = C + T\left(\frac{COD}{700}\right)$$

$$= \text{unit conveyance cost} + \text{unit treatment cost}$$

It should be noted that the conveyance and treatment cost calculations are different in this application compared to that by Cowan 1989.
There are a variety of practices concerning the charging for industrial effluent discharged to the sewer to be treated to a determined standard by the authority in charge. Besides the UK where guidelines along the lines of the "Mogden variation" are in use, it is found that Switzerland and Sweden do not have effluent charges while in the Netherlands all wastewater dischargers are required to pay (Meijer 1983) a levy, regardless of whether the sewage is treated or not. The principle of the charging system being that the costs of preventing, reducing or controlling water pollution must be borne by the polluter.
Industrial dischargers are charged as follows:

$$P = \frac{Q\,(COD + 4{,}57N)}{180}$$

where

P	=	pollution load (p.e)	pe = population equivalent
COD	=	chemical oxygen demand ($mg\ell^{-1}$)	
N	=	organic N + Ammonia/ N-content ($mg\ell^{-1}$)	
Q	=	rate of discharge (m^3/d)	

A levy is also charged on the amount of heavy metals discharged per annum.

6.3 The Strength Parameter

6.3.1 Introduction

Over the years recommendations have been made locally and abroad for the use of PV (Permanganate Value), BOD (Biochemical Oxygen Demand) and COD

(Chemical Oxygen Demand) as the ideal parameter providing the best indication of strength. Recently there has been a swing towards the use of COD. The COD together with the volume are the two parameters which make a large impact on the final effluent charge billed to each industry. It is considered as important to this document and its value to it's readers, that the main arguments for and against each of these three strength parameters are outlined. The information provided justifies the choice of the COD test.

6.3.2 COD (Chemical Oxygen Demand)

- This is a chemical and not a biological test and is carried out using a boiling mixture of dichromate and concentrated sulphuric acid.

- While a value will be obtained, there is absolutely no indication of what proportion of this value is biodegradable.

- The use and understanding of COD in wastewater treatment kinetics and design is well documented and universally utilized together with the BOD_5 which is still used in Europe for design purposes. (Metcalf and Eddy 1991)

- The solids production can be calculated from COD data. This has been ably demonstrated by the UCT Pollution Research Team. (WRC Nutrient Removal Guide 1984)

- The COD analytical test provides an absolute value and within the same method it has precision. However there are now a number of different COD analytical procedures including the microwave digestion technique, which show significant variations in the results obtained using the same sample. (Balinger et al 1982) (Slatter N P and Alborough H 1992)

- Nuisance organic compounds such as oil, fat and grease are totally oxidized by the dichromate method and measured in terms of oxygen consumed for oxidation. (Degremont Handbook 1991)

- COD test requires careful technician skills and takes ± 2 hrs.

The following illustration in **TABLE 1** indicates why the COD is the preferred test, and at the same time highlights the shortcomings in the use of the permanganate test which displays no reaction towards Benzene Sulphonic acid , Acetic acid and Acetone and Toluene.

TABLE 1 : Comparison of Analytical Data illustrating the response of BOD, PV, COD, to pure organic compounds (Wilson 1960)

Substrate	Values as per cent of theoretical		
	BOD	**PV**	**COD**
Benzene Sulphonic Acid	63,6	0	91,6
Acetic Acid	58,0	0	93,5
Phenol	69,7	80,1	96,0
Ethyl Alcohol	69,9	4,7	95,9
Acetone	67,5	0	92,2
Toluene	39,2	0	60,0
Diphenyl Guanidine	2,3	59,6	101,6

6.3.3 PV (Permanganate Value)

- PV is defined as the oxygen absorbed from acid potassium permanganate and thus it is sometimes referred to as OA. The standard test specifies the use of $\frac{N}{80}$ potassium permanganate with a contact time of 4 hrs at 27^0C.

- It is the oldest test for assessing the strength of pollution now in use and is considered to be simple and requiring little skill to produce results in a relatively short time.

- The test is empirical because it measures only the fraction of the organic matter that can be oxidized by acid permanganate, with no indication of whether this organic matter can be metabolized in biological wastewater treatment systems.

- It's limitations are shown in **Table 1** (Wilson 1960) where it can be seen that the PV test does not react with some organic compounds. Furthermore tertiary alcohols and similar saturated structures do not react significantly with permanganate.

- PV tests do not indicate what proportion of the biologically degradable matter will be oxidized or synthesised nor do they yield information on the reaction rates.

- For a particular organic substrate, the PV obtained can vary over a wide range depending on the size of the sample.

- While many have chosen the PV test as a parameter for strength assessment, some researchers have concluded that the PV test is not as simple, quick and reproducible as many suppose.

- Severe distortions of the PV are experienced when inorganic oxidizing agents are present.

6.3.4 BOD (Biochemical Oxygen Demand)

This test is defined as the amount of oxygen used by the bacteria in the process of stabilizing organic matter under aerobic conditions, and serves as a good indicator of the quantity of organic pollution present.

- The test is carried out over 5 days and called the BOD_5, but represents only approximately 60% of the theoretical ultimate BOD.

- The BOD is time consuming; and it is not easy to obtain reliable results in the presence of certain organic and toxic material.

- It does come the closest to replicating actual biological degradation.

Since plant design data is presented in terms of BOD_5, particularly in the UK, and Europe, the BOD value has meaning to design engineers with specific reference to the synthesis and respiration kinetics of biological systems.

6.4 Volume Assessment

6.4.1 Introduction

The volume assessment is often taken for granted but in practice is subject to many problems. Since this parameter governs the overrall amount that the industrialist will have to pay the service provider for accepting and treating the waste, the method used to assess the volume must be carefully considered and agreed to by both parties. i.e. the discharger of the effluent and the service provider.
Two methods are recommended. Either by direct meter measurement or by the system of using water consumption data together with borehole information, and then providing allowances as illustrated in **Appendix V.** The difference is considered to be effluent. This approach encourages industry to use good water management practice. The preferred method is the one where the effluent volume is calculated from the metered water consumption (including boreholes), as recorded by the local authority.
Effluent volume readings whether calculated from water consumption or direct from the meter must be taken at regular weekly or monthly intervals, preferably in the presence of on-site employees.

6.4.2 Total Flow Received at the Works

This figure is the summation of influent over a defined period (12 months) of all the measured flow that has been received at the works. Infiltration always contributes to an inflated value for this parameter, but in the light of information such as rainfall, knowledge of the extent of infiltration, and the hydraulics under such conditions, a reasonable allowance can be deducted. Readings are usually taken daily and the flow is recorded on a continuous basis.

6.5 Sampling

6.5.1. Introduction

Sampling is an important part of any effluent monitoring programme especially when charges are involved. It is undertaken for two principal purposes.

1) Compliance with consent conditions
2) To enable the charges to be calculated

Unfortunately this key aspect of any industrial effluent charging system has never received sufficient attention with respect to

- Procedures and sample storage/preservation
- Nature of the sampling (composite, random, snap, weighted)
- No. of samples to be taken in accordance with statistical acceptability
- Sample point
- Frequency of the sampling

Different requirements do exist in respect of sampling for charging purposes where charges are related to strength and volume being discharged and treated on the one hand and monitoring of compliance with consent conditions on the other. Samples taken for charging purposes need to be as representative of the composition of the effluent flow as is reasonably practicable without incurring disproportionate expenses. It will need to take into account fluctuations in output and the nature of the products manufactured on-site. Each industrial premises is likely to have its unique set of diurnal, weekly and seasonal fluctuations.

6.5.2 Sampling Procedures, Frequency of Samples and Number of Samples Required

Before an analysis can be undertaken to determine the COD concentration of the sample, it is necessary to obtain a good representative sample where representative means reflecting the true characterisation of the effluent strength on a continuous basis. In keeping with good sampling code of practice, and for purposes of legal compliance when there is a dispute, specified procedures must be followed. This also

includes the preservation of sample/s. These procedures and techniques are well documented. (Standard Methods 1999)
Once this aspect is in place, a sampling strategy must be devised. This strategy must be compiled after consultation with the personnel processing the data; and with the effluent staff who have a good knowledge of the potential variation in effluent quality with certain types of key industries, and the temporal distribution of such over 24 hours during the weekday mode of operation.
A procedure is required to determine the number of samples to be taken, the frequency and the time interval. The recommended statistical approach allows for a rational decision to be made and eliminates unnecessary numbers of samples and frequency of analysis when there is no justification for such in terms of the accuracy, precision and standard deviation of the COD test itself. The number of samples that are required can be calculated using the formulation of (Dart 1977).
The number of samples (N) required is calculated as follows:

$$N = \left(\frac{KS}{P} \right)^2$$

P = precision which is a measure of the closeness with which multiple analysis of a given sample agree with one another (Standard Methods 1992)
Precision is specified by the standard deviation of the results

S = standard deviation of the set of values about the mean

K = co-efficient which depends on the confidence level required and which has a value of 1,64 for a confidence level of 90% or 1,96 for a confidence level of 95%

N = number of samples which must be taken to estimate the mean of a set of values with a normal distribution to a precision "P"

Obviously the more frequently samples are taken, the greater the precision. The precision should be sufficiently high to avoid the risk of substantial overpayment or underpayment of the industrial effluent charge, but it is obviously not acceptable to spend money on sampling and analysis in order to get a precision no better than that of the method of analysis or where the cost of the sampling and analysis is greater than the probable error in the industrial effluent.
The number of samples, related to confidence limits, precision and standard deviation are shown in **Table 1a.**

Table 1a: Relationship between the number of samples taken, the variability of the industrial effluent and the relative precision (Dart 1977)

NUMBER OF SAMPLES (N)	RELATIVE PRECISION (P)		
	S = 0,1	S = 0,5	S = 1,0
4	0,082	0,410	0,820
9	0,0547	0,274	0,547
16	0,041	0,205	0,410
25	0,0328	0,164	0,328
36	0,0273	0,137	0,273
49	0,0234	0,117	0,234
64	0,0205	0,103	0,205
81	0,0182	0,091	0,182
100	0,0164	0,082	0,164
121	0,015	0,075	0,150
144	0,0137	0,069	0,137

Illustration using Table 1a

Consider an industrial effluent with a standard deviation of 0,5, a true effluent charge of R100 000 per annum, and 4 samples taken per year, then the relative precision is 0,41.

$\therefore$ for 90% of the time (k = 1,64 for a confidence level of 90%) an error of about R40000 could be expected. This is substantial. To reduce the error to about 10%, 64 samples would need to be taken during the year within the same standard duration and confidence limit.

The key decision facing those officials in management will be to evaluate whether additional expenditure on sampling and analysis is justified in terms of the extent of the benefit to be derived from such an exercise. While it may not at first glance seem significant in most cases, it certainly will be very relevant when applied to major industrial effluent contributors with large effluent expenditure. Thus a basis is presented to indicate the degree of sampling attention that should be devoted to industrial effluent discharges with large effluent charges. In such circumstances decisions need to be made based on valued judgement .

The relatively simple task of taking regular representative samples at acceptable intervals is a task most underestimated.

6.5.3 Nature of the sampling

Each industrial operation has a different type of process which can be continuous, intermittent or limited to a batch basis. A further variant is that the effluent quality could vary from one extreme to another and in order to obtain a fairly representative sample the time of sampling during the processing cycle is critical. There are ways to overcome these constraints and these include automatic sampling for short and extended periods. Alternatively it could be agreed upon in the interests of both parties that all effluent goes to a holding tank before discharge at time intervals mutually agreed upon. For some industries the magnitude of the COD plays a major role in dictating the extent of finance to be paid by industry to the service provider.

7. FINANCE RELATED ASPECTS

7.1 Introduction

The guideline national approach for setting tariffs is full cost recovery including a return on assets (NWA) which will provide a fair rate of return on the total capital investment required to finance wastewater infrastructure. A rate of return on assets can be justified from the point of view of there being an opportunity cost associated with the utilization of scarce capital resources for the development of conveyance and treatment infrastructure and this cost should be reflected in the tariffs. The members of the Steering Committee strongly supported the need to incorporate a mechanism into the tariff formulation that will allow for the creation of a dedicated cash reserve fund that can be used to finance asset replacement and new infrastructure. This new approach represents a step towards compliance with Generally Accepted Accounting Practice (GAAP).

A brief reference is made at the end of this chapter, to the generally accepted municipal accounting practices (hereafter referred to as GAMAP). As a constitutional requirement this new municipal accounting system will apply to all municipal bodies and is due to be implemented on July 1, 2002. For purposes of this project, users should be aware of the impending changes which will come into effect. Where considered necessary, such as in the **Part III guidelines**, examples of data utilization are presented in the current municipal format and the anticipated new format.

This is very important with respect to the replacement of redemption with depreciation and its identification as an expense. It could alter the bottom line expenditure if the depreciation is different from the redemption on the loan.

The principles in the ensuing paragraphs have been adapted from the water pricing strategy document since they also apply to wastewater treatment (DWAF 1998).

7.2 Different Funding Methodologies

Three approaches can be used to determine the capital portion of the unit cost of conveyance and treatment of wastewater which includes industrial effluent.

- Funding Approach
- Depreciation Approach
- Rate of return Approach

Funding Approach

Basic feature of this approach is that revenues must be adequate to cover debt service obligations (interest charges) and the redemption of loans. This approach is the traditional approach used by local authorities and Governmental Departments.

Depreciation Approach

In this approach fixed assets are depreciated over their useful lives. Depreciation is calculated on a straight line basis over the assessed useful life of the asset. However assets must be regularly revalued so that the depreciation is based on the current replacement value.

Rate of return approach

This method allows for the earning of a specific rate of return of the full investment used to finance the facilities provided to convey and treat wastewater. In order that costs for financing the relevant infrastructure are fully recovered, the capital component of the unit cost of water is determined by a depreciation charge and a return on assets charge. Depreciation is applied on a straight line basis which means that the depreciable amount is allocated in equal amounts over the useful life of the assets. The depreciable portion and useful lives over which the asset is depreciated are determined by professional engineers. A guide to the portion of depreciation applicable is shown in **Table 2.**

Table 2 : Asset Depreciation

Component	Depreciable portion %	Estimated Total Useful Life (year)
Pump stations	40	30
Pipelines	75	30
Wastewater Treatment Works	100	20

The return of assets charge will be determined by applying an acceptable interest rate to the current cost (i.e. depreciated replacement value) of the wastewater infrastructure asset. When full cost recovery is achieved, the depreciation and return of asset charges will result in a cash reserve fund being built up over time. These reserve funds are to be used specifically to fund asset replacement and for new sewerage and wastewater infrastructure.

7.3 Financial Costs of Service Provision

In terms of the Local Authority Transition Act 1993, Act No 209 of 1993 (as amended), Section 10 G, 7(a) ii reads as follows. "A municipality may by resolution supported by a majority of the members of the council levy and recover levies, fees, taxes, and **tariffs** in respect of any function of the municipality"

An integral component of any effluent tariff structure is the calculation of the annual unit cost at the works to treat a kilolitre of wastewater at a certain derived strength based preferably on the mean of all the analysis undertaken.
In order that this unit cost can be calculated, one must have accurate expenditure (O&M expenditure + depreciation) records. The costs of service provision must be known to the service provider in order to determine revenue requirements and thus to set tariffs in such a way that financial viability is ensured.
The procedures on costing in the following paragraphs have been adopted for illustrative purposes from "Management Guidelines for Water Service Institutions" – Palmer Group WRC Report TT 98/98. Where possible every endeavour has been to accommodate depreciation since this will be the future mode of municipal accounting.

7.3.1 Classification Of Costs

Three kinds of costs have been identified : average historic costs, replacement costs and marginal costs.

Average historic costs

These are the costs incurred and include operating and maintenance costs plus interest and redemption payments (to be replaced by depreciation on assets when GAMAP is introduced) on past investments.

$$\text{AHC per unit (kilolitre) of wastewater} = \frac{\text{O\&M + depreciation}}{\text{Volume of wastewater}}$$

Replacement costs

When infrastructure reaches the end of its economic life it needs to be replaced, and these costs are referred to as the replacement costs. This expenditure is financed by drawing on accumulated cash reserves. One of the reasons for making cash contributions to reserves is, therefore, to make provision for asset replacement.

Marginal Costs

The cost of most interest for this project is the long-run marginal cost.
Capacity generally needs to be expanded at irregular intervals and at a fairly high (construction) cost. The expansion can be financed by drawing on accumulated reserves. These payments along with the additional operating and maintenance costs of the new infrastructure are experienced by the service provider as the marginal costs.

7.3.2 Expenditure

Service providers (or the local authority of which they form a part) prepare budgets and financial statements every year that account for both expenditure and income. **Table 3** shows the standard breakdown of expenditure recommended by the Institute for Municipal Treasurers and Accountants (IMTA 1994). IMTA is now called IMFO

(Institute of Municipal Finance Officers). Also shown is the type of expenditure and cost each item represents.

Table 3 : Breakdown of expenditure

Expenditure item	Type of expenditure	Type of cost
Salaries, wages and allowances	Operating and maintenance	Historic cost
General expenses, including bulk water, electricity and chemicals	Operating and maintenance	Historic cost
Repairs and maintenance	Operating and maintenance	Historic cost
Depreciation *	Capital-related	Historic cost
Interest	Capital-related	Historic cost
Return on asset *	Capital-related	Historic cost

* Redemption has been substituted by depreciation in accordance with GAMAP and return on assets included

Attention is again directed to the implications of GAMAP. When GAMAP is fully operational, redemption payments will be replaced by depreciation which will be recorded as an expense. Furthermore local authorities will not be required to make contributions to statutory funds but must budget for working capital reserves which will be derived from depreciation. Therefore **Table 3** has been modified to resemble the anticipated format of recording expenditure after July 1, 2002.

7.3.3 Fringe operating and maintenance expenditures

Operating and maintenance (O&M) expenditures are those expenses incurred by the service provider while providing a wastewater service to customers. O&M expenses include items such as:

- salaries and wages;
- benefits paid to staff;
- power (electricity);
- rent;
- insurance;
- chemicals;
- general overheads;
- vehicle running costs; and
- inter-departmental charges – that is, support rendered by the local authority to the water service provider or vice versa, such as computer facilities, laboratory services, and administrative services.

A real expenditure report from one of the participating organisations is shown in the **APPENDIX VI.**

Expenditure on small equipment that does not extend the useful life of major facilities should be classified as O&M expenditure. O&M expenditures are estimated in the annual budgets of local authorities and service providers. Actual expenditure is recorded in the financial statements for each department.

7.3.4 The costs of service provision

Financial cost refers to money actually spent.

The costs of service provision must be known to the service provider for three reasons: (1) to determine revenue requirements and thus to set tariffs in such a way that financial viability is ensured; (2) to ensure fairness and transparency in setting tariffs; and (3) to predict increases in future tariffs – which is important for achieving tariff stability and financial sustainability in the longer term.

7.3.5 Expenditure breakdown

Expenditure is commonly broken down further into operating and maintenance expenditure, together with depreciation and interest. These categories are discussed further in the following sections.

Table 4 Illustrates typical O&M expenses associated with a municipal sanitation service.

Table 4 : Typical O&M expenses associated with municipal sanitation

On-site expenses	Sewerage & conveyance system	Wastewater treatment expenses
• Pit emptying • Tanker service • Sludge handling • General repairs and maintenance • Education and public awareness	• Operation supervision • Operation labour • Operation supplies and expenses • Maintenance of sewer • Inspection of sewer connections • Pumping (lift station) labour • Power for pumping • Pumping station supplies and • Maintenance of pumping station structures and equipment • Transportation • Insurance on pumping	• Operation supervision • Labour • Power • Chemicals • Fuel • Maintenance of structures and equipment • Transportation • Sludge disposal • Insurance on plant structures and equipment • Laboratory and scientific services

Accounting and Collecting expenses	Consumer service expenses	Admin. and general expenses
• Meter reading • Strength sampling • Consumer billing • Accounting • Collections • Cashiers • Payment processing	• Consumer enquiries • New service requests • Education and capacity	• Administrative salaries • Other general office salaries • General office supplies and expenses • Special services (engineering, legal) • Employee insurance • Vehicle insurance • Other employee costs (workman's compensation) • Special requirements of grant programmes • Miscellaneous general expenses.

7. 4 Components of Capital Expenditure for Waterborne Systems

Capital-related expenditure for a waterborne service is associated with:

- The construction of new works, such as sewerage networks, pumping stations and treatment plants;

- Asset replacement of ageing equipment and plant to keep systems functioning properly;

- Upgrading of infrastructure to provide a higher level of service; and

- Routine capital purchases.

7.4.1 Methods of Expenditure Allocation

- Functional cost method;
- Fixed-variable cost method;
- Design cost-causative method.

7.4.1.1 Functional cost method

The functional cost method provides a relatively simple breakdown of a sanitation service providers expenditure. However, it does not recognise expenses associated with peak flows.

7.4.1.2 Fixed-variable cost method

With this method, expenditure (both operating and depreciation) is categorised as either fixed or variable, [1] and is then further divided into system components:

- The sewerage system
- Treatment plant
- Billing and consumer costs
- Administration

Most of the local authorities in South Africa incorporate administrative charges in their operating expenditure and use inter-departmental charges for consumer billing services.
An advantage of this method is that because expenditure is divided into fixed and variable categories the impact on revenues of significantly changing volumes is shown.

7.4.1.3 Design cost-causative method

The design cost causative method is the most commonly used in the USA but hardly at all in South Africa, and is the alternative method of expenditure analysis used to illustrate tariff-setting for this project. It allocates capital and O&M expenditure to cost-causative elements of the sanitation system and then distributes these costs to consumer classes on the basis of their responsibility due to their specific service requirements. The distribution of total cost of service to consumer classes is done by first identifying the type of service and the consumer category. Next the units of service for each consumer class are determined. The unit costs for each system component can then be calculated, based on the total units of service for each system component and the total O&M and capital-related expenditure. Cost responsibility is then distributed to the various consumer classes based on the unit costs determined in the previous step and the units of service previously assigned to the consumer classes.
The method thus provides a direct way of apportioning cost responsibility to customers, and a sufficiently detailed analysis of the cost structure of a sanitation service provider for tariff-setting purposes. It is presented in more detail in the next section.

[1] Fixed expenditure refers to those expenses that remain relatively unchanged for the year, and variable expenditure are expenses that change with fluctuations in volume or strength of wastewater treated.

7.5 The Cost-Causative Method for Allocating Sanitation Service Expenditure

7.5.1 Introduction

The cost-causative method of expenditure allocation consists of the following key steps:

- Collection and analysis of billing and budgetary data;
- Allocation of annual expenses to the system components and cost functions; and
- Distribution of the component costs to consumer classes.

7.5.1.1 The allocation of costs to system components

Once all available data are available the expenses are classified according to O&M and capital-related expenditure and then categorised according to system components. Following this, the expenditure associated with each of the system components is apportioned to the cost-causative functions:

- Volume (relates to average wastewater flow);
- Capacity (relates to peak flow);
- Wastewater strength; and
- Consumer services

The degree to which expenses are apportioned to these functions is determined by the extent to which the component of the system (such as internal reticulation) relates to the cost functions (such as volume, capacity, strength and consumer services). The procedure for the allocation of both O&M and capital-related expenditure is explained in more detail in the following sections.

7.5.1.2 Allocation of Operation and Maintenance Expenditure

O&M expenditure is a major part of a sanitation service provider's total expenditure. An example of the allocation O&M costs is shown in **Table 5.**

Table 5 : Allocation of operation and maintenance expenditure (example)

SYSTEM COMPONENTS	TOTAL CAPITAL RELATED COSTS	COST FUNCTION			
		Volume	Capacity	Strength	Consumer
On-site Sanitation Services					
Vacuum tanker Services	124 400				124 400
Sludge treatment and handling	115 000			115 000	
Community awareness programme	80 000				80 000
Customer Billing	28 146				28 146
Administrative and General	75 915			50 104	25 811
Total O&M Costs - Onsite	256 903			165 104	258 357
Waterborne:					
Internal Reticulation	185 000				185 000
Outfall Sewers	90 210		90 210		
Pumping Stations	4 400	1 100	3 300		
Conservancy Tank	231 482		231 482		
Treatment Plants					
Inlet Works	79 460	79 460			
Reaction Tanks	326 660			326 660	
Settling Tanks	88 290	88 290			
Tertiary Treatment	97 115	97 115			
Sludge Handling	238 375			238 375	
General	52 970	16 950		36 020	
Customer Billing	80 650				80 650
Administrative and General	217 529	34 805	93 537	54 382	34 805
Total O&M Costs – Waterborne	1 692 141	317 720	418 529	655 437	300 455
Total O&M Costs	2 115 601	317 720	418 529	820 540	415 909

Source : (WPCF et al, 1984)

- Pumping expenses are not allocated entirely to the capacity cost function. This is because the power costs for pumping vary principally with the volume of wastewater pumped, while other pump-station O&M expenditure is related to peak flows. Therefore, in the example, 25% of the annual pumping expenditure is assumed to be related to power costs and is allocated to the volume cost function, and the remaining 75% of pumping expenditure is allocated to the capacity cost component.

- O&M expenditure associated with the inlet works and chlorination facilities at the treatment plant is more dependent on the volumes of wastewater handled than the peak flow rates and is therefore allocated to the volume cost function, and not the capacity cost function as was done with capital-related expenditure.

- Expenditure relating to treatment plant administration and general activities is allocated to cost functions in proportion to the ratio of expenditure on the other components of the treatment plant, less costs for chemicals and power. If the information required for a detailed breakdown of the treatment plant operation and maintenance costs is not available, an assumed proportional breakdown of the expenditure may be used as is given in **Table 6**, which was compiled based on typical operations at an activated sludge treatment works.

Table 6 : Typical % proportion of O&M costs for an activated sludge treatment works

System component	Operating staff	Maintenance	Electricity	Chemicals	Total % cost breakdown
Inlet works	15	6	5	5	9
Reaction tanks	20	42	80	5	37
Settling tanks	10	17	5		10
Tertiary treatment	10	3		60	11
Sludge handling	35	27	10	30	27
General and Administration	10	5			6
Overall % of total cost	**40**	**30**	**20**	**10**	**100**

Source : Estimates based on experience in the field (Ian Palmer)

From this table, a ratio for allocating general and administration expenditure to cost functions can be derived. In this case it is 32:68 to *volume : strength* cost functions

- Consumer billing costs are directly proportional to the number of customers served and are thus allocated to the *consumer* cost function in full.
- Expenditure relating to general and administrative operations or overheads is allocated to cost functions in proportion to the ratio of expenditure on the other components of the whole system.

Once the O&M and capital-related expenditure has been allocated to system components and cost functions, it is possible to determine the level of costs attributable to each customer class. This process of distributing expenditure to customers is discussed in the following section.

Distribution of costs to customer classes

The method for distributing the total cost of service to customers comprises four steps:

- classification of customers into categories or customer classes;
- the determination of the units of service for the system;
- the determination of the unit cost of service; and
- the distribution of costs to customer classes.

Table 7 a : Units of Service

		RESIDENTIAL								
Item	**Units**	Onsite Septic	Onsite: LOFLOS	Onsite: Dry	Waterborne: Low income	Waterborne: Middle income	Waterborne: High income	Commercial	Industrial	TOTAL SYSTEM
Wastewater Volume										
Contributed	kℓ/year	n/a	n/a	n/a	162 640	328 059	419 212	48 552	180 000	1 138 464
Infiltration/Inflow	kℓ/year	n/a	n/a	n/a	32 528	65 612	83 842	9 710	36 000	227 693
Total wastewater Volume	kℓ/year				195 168	393 671	503 055	58 263	216 000	1 366 157
Wastewater Capacity										
Contributed	kℓ/day	n/a	n/a	n/a	446	899	1 149	133	493	3 119
Infiltration/Inflow	kℓ /day	n/a	n/a	n/a	178	360	459	53	197	1 248
Total wastewater Capacity	kℓ/day				624	1 258	1 608	186	690	4 367
Strength										
COD	kg/year	27 959	6 990	12 505	97 584	196 836	251 527	2 402	108 000[a]	702 573
Consumer										
Bills	Number	9 670	4 452	15 490	45 539	22 980	12 487	2 402	670	104 020

[a] Includes 3600 kg from surcharge consumers

7.5.2 Units of service

Once customers have been classified into classes, the service costs can be distributed to each class on the basis of their proportionate responsibility that each class bears for the costs. This is determined by first identifying an appropriate unit for each cost function (wastewater volume, capacity, strength, and customer services) that is representative of the cost-causing agent for each component of the system. Once this is done units of service attributable to each customer class for each component are determined.

(a) Volume

The volume cost function relates to the average annual flow of wastewater of the sanitation service.

(b) Capacity

As with the volume cost function, the capacity cost function is not used to analyse on-site service because it relates to wastewater flows. System capacity costs depend on the estimated peak flow rates for both wastewater and infiltration/inflow water attributable to each customer class.

(c) Strength

The strength cost function is relevant to the analysis of both waterborne and on-site sanitation services. The unit of service used to determine responsibility of each consumer class for the strength of wastewater or sludge is the daily organic load as measured by the chemical oxygen demand (COD). The units of service for customers with a waterborne service are based on an estimate of average COD concentrations and contributed volume for each class. Typical COD concentrations and average COD load per capita figures for residential and commercial customer classes in South Africa are given in **Table 7b**

Table 7 b : Typical COD loadings of wastewater digester/pit sludge entering a treatment works

Consumer class	Typical COD concentrations ($mg\ell^{-1}$)	Typical COD load per capita (grams COD/person/day)
Residential – on site – dry	-	16
Residential – on site – wet	-	20
Residential – low income	1200	80
Residential – middle income	800	100
Residential – high income	600	150
Commercial	1000	-

The figures in **Table 7b** compare favourably with a survey conducted in the city of Belo Horizonte, Brazil (Camps et al, 1996). The survey determined BOD concentrations for residential customers to be in a range of 472 mg BOD/1 for middle-income households to 249 mg BOD/1 high-income households. The equivalent COD concentrations are determined by doubling the BOD concentrations (pers. com. Mark Wentzel, UCT Civil Engineering Department), and thus the range for COD concentrations is 498 mgCOD/1 for high-income households and 944 mg COD/1 for middle-income households.

Table 8 : Unit cost of service

			COST FUNCTION			
Line No.	**Item**	**Total cost**	**Volume**	**Capacity**	**Strength**	**Customer**
1	System Units of Service		kℓ	kℓ/day	kg COD	Bills
2	Onsite Services					
3	Number of units		n/a	n/a	47 453.47	29 612.0
4	Operation & Maintenance Expense					
5	Total (R/year)	423 460.29	n/a	n/a	165 103.61	258 356.6
6	O&M Unit Cost (R/unit/year)		n/a	n/a	3.48	8.7
7	Capital Related Costs					
8	Total (R/year)	256 903.25	n/a	n/a	32 817.37	224 085.8
9	Capital-related unit cost (r/unit/yr)		n/a	n/a	0.69	7.57
10	**Total Unit Costs of Onsite Services**		**n/a**	**n/a**	**4.17**	**16.29**
11	Waterborne Services					
12	Number of units		1 366 157	4 367	683 079	84 078
13	Operation & Maintenance Expense					
14	Total (R/year)	1 692 141.00	317 720.04	418 529.47	655 436.85	300 454.64
15	O&M Unit Cost (R/unit/year)		0.23	95.85	0.96	3.57
16	Capital Related Costs					
17	Total (R/year)	1 075 220.20	63 787.14	256 667.46	202 995.81	551 769.79
18	Capital-related unit cost (r/unit/yr)		0.05	58.78	0.30	6.56
19	**Total Unit Costs of Waterborne Services**		**0.28**	**154.62**	**1.26**	**10.14**

7.6 Generally Accepted Municipal Accounting Practices (GAMAP)

7.6.1 Introduction

Section 216(1) of the Constitution requires the National Treasury to develop and prescribe generally recognised accounting practice for all spheres of the government. In accordance with this requirement GAMAP (Department of Finance 1999) has been devised. GAMAP requires that transactions be disclosed in the financial statements of the municipality in a consistent manner, using recognised principles. This will ensure that municipalities in South Africa use accounting principles that are recognised nationally and internationally (GAAP).

7.6.2 GAMAP: framework, benefits and implications

GAMAP consists of an accounting framework that defines assets, liabilities, revenue, expenditure, and own capital and sets out the criteria for including them in their financial statements of a municipality. This framework is based on internationally recognised accounting principles that apply in both the private and public sectors.

Definitions

Element	Definition	Examples
Assets	An asset is a resource controlled by a municipality which will result in future economic benefits (usually cash) or will enable the municipality to provide services in the future	
Liabilities	A liability is an obligation of the municipality that will result in an outflow of future economic benefits or for which service delivery must still be provided.	
Own Capital	The difference between assets and liabilities.	
Revenue	Inflows of economic benefits or enhancement of assets or reduction of liabilities that increase own capital.	• Rates and service charges received in cash or which increase assets (debtors) where cash is still to be received.Interest received as this resulted in cash being received or if the interest was capitalised, and increase in assets (investments).

Expenses	Outflows of economic benefits or depletions of assets or increases in liabilities that reduce own capital	• Salaries, wages and other personnel costs as these resulted in outflows of cash • Purchases of goods and services as these resulted in the outflow of cash or an increase in liabilities (trade creditors). • Depreciation because there is usually a reduction in the value of an asset over time and when it is used.

Key benefits of GAMAP:

- Consistency in the accounting principles applied
- Harmony with internationally recognised accounting standards
- Promoting a better understanding of the operating results, financial position and cash flows of local authorities .
- Facilitates comparisons between local authorities, all using the same accounting principles.

Implications of GAMAP

- Fixed assets will now be depreciated and disclosed in the financial statements at historical depreciated values.
- Loan repayments (redemption) are not considered to be an expense and will no longer be included as expenditure.
- Interest capitalization is no longer permitted and interest paid is an expense and must be included in the income statement in the period that such interest was incurred.
- Internal interest is no longer permitted as an expense.
- Local authorities will not be required to make compulsory contributions to statutory funds. .
- Local authorities must budget for working capital reserves. These reserves cannot be included in the financial statements. The reason is that the working capital reserve is effectively a budgeted bad debt provision. The actual bad debt provision must be included in the financial statements instead of a working capital reserve.

7.6.3 How does GAMAP affect this project?

A time frame for the implementation of GAMAP has been devised by the Public Services Accounting Practices Board appointed by the Minister of Finance in terms of the Public Finance Management Act. Local authorities can expect GAMAP to be implemented on July 1,2002. This will allow staff to become familiar with the changes from fund accounting to depreciation accounting and the format of financial statements under this system. The capacity of local authorities to implement these changes is a matter of concern. At present local authorities are still using the traditional municipal accounting system while staff are being trained in the application of the new system. In the guidelines contained in PART III financial expenditure for a full financial year is presented in the present format and also in the GAMAP format. This is particular relevant for the substitution of depreciation for redemption and it's use in the creation of a cash reserve fund.

7.7 Depreciation Substitution For Fixed Redemption Charges

In terms of GAMAP these fixed capital charges will be replaced by depreciation which will be recorded as an expense. The depreciation will be undertaken on a straight line basis over the useful life of the asset. The depreciation must be undertaken on the current replacement value of the asset. IMFO has produced a schedule of estimated useful lives of infrastructure assets, as shown in **Table 8a**

TABLE 8a Useful lives of infrastructure assets

ASSETS	USEFUL LIFE (yrs)
Sewerage:	
Sewers	20
Outfall	20
Purification works	20
Sewerage pumps	15
Sludge machines	15
Plant and Equipment :	
Graders	10-15
Tractors	10-15
Mechanical horses	10-15
Farm equipment	5
Lawnmowers	2
Compressors	5
Laboratory equipment	5
Radio equipment	5
Telecommunication equipment	5
Office Equipment:	
Computer hardware	5
Computer software	3-5
Office machines	3-5
Air conditioners	5-7
Buildings	30

7.8 Creation of a cash reserve fund

Local authorities will have to create non-distributable reserves, and any other reserve required by law. Non-distribultable reserves can either be statutory or voluntary. Non-distributable reserves generally arise as a result of a management decision that profit from an extraordinary transaction should not, according to sound accounting practice, be available for distribution. e.g. profit arising from the revaluation of fixed assets is regarded as unrealised and therefore not available for distribution. Such profit is retained as a reserve and must be shown as such in the balance sheet. A portion of available profit can be set aside for a specific purpose. e.g. Cash reserve for increased replacement costs of fixed assets or transfer to a general reserve.
In practice this cash reserve will be realised from the depreciation component and will be supplemented by a " return on asset "charge based on a predetermined percentage of the depreciation amount.

7A SEWERAGE SYSTEM AND CONVEYANCE

7A.1 Introduction

There are two distinct parts to any industrial effluent tariff charging system. In the first instance the effluent must be conveyed to the treatment works through a network of piping which is called the sewerage system, and then it must receive the appropriate treatment which is usually biological to obtain a effluent quality that conforms to DWAF requirements.
However, on each industrial site there is a domestic component of wastewater derived from the number of staff on site and who contribute to the sewerage system and the treatment works on a daily basis. These contributions can be substantial depending on the size of the particular industry. The confusion arises from the manner in which local authorities attempt to recover the costs for such a service, and in many cases this results in a double charge.
The financing of a network of sewers to serve a town or city is an expensive undertaking which is even more so when the area of operation is heavily industrialized. The following paragraphs and subsections will discuss the terminology used in conveyance, the costing of sewer networks, and address the problem of double charging via the sewerage tariff in conjunction with the normal rates contribution. This will provide the user of this document with a broader insight into the purpose, financing and cost recovery of the conveyance component of effluent tariffs.

7A.2 Terminology

The terminology used in describing sewerage systems, the nature of effluent transported in these systems, and the conveyance of all effluent to the treatment works, requires clarification. This is necessary since many of the terms are incorrectly used and convey a confusing picture to those persons not directly involved in wastewater and effluent activities.

Sewer:

Length of pipe of adequate diameter that allows liquid wastes to be transported to the treatment works or to a marine outfall for treatment and disposal respectfully.

Sewerage System:

Network of piping, pump stations, and all equipment associated with the transporting of liquid waste from all types of users to the treatment works or marine outfall.

Sewage:

This is the liquid waste that emanates from residential areas and is of a domestic nature and is transported to the treatment works via the sewerage network.

Wastewater:

This is the combined liquid waste which will include sewage, industrial effluent, and other similar type of wastes. Domestic wastewater and sewage both have the same meaning in the context of the project.

Sewerage tariff:

This tariff is specifically designed to cover the costs of installing and operating a conveyance and treatment system to treat all **domestic wastewater**.

N.B. Some local authorities incorporate this cost in the rates and do not have a special sewerage tariff for cost recovery. It is viewed as a obligatory service in view of the rates paid.

Conveyance:

The transportation of liquid waste through the sewerage system to the destination point

7A.3 Principles

- The amount of rates one pays and the calculation of the sewerage tariff for industry is generally based on land value and area, or the floor space of the buildings. Proximity to the treatment works is therefore not a deciding factor when considering potential sites to locate an industrial concern.

- The provision of sewerage and wastewater treatment services for handling domestic wastewater is regarded basically as a public service similar to electricity supply, with tariffs based on a "cost for service" principle. However if it is regarded as conferring diffused benefits throughout the community, like a public health service, different charging systems arise and it then becomes necessary to decide what proportion of revenue should be recovered by users directly and non users (through taxation or rates). Whether it is the householder, industry or commerce, all of their discharges into the sewerage system have to be transported to the treatment works, independent of strength. It is clear that conveyance is volume dependent.

- A sewerage system is installed with a useful life of at least 30 years but is never at full hydraulic load in the early stages of it's life span. This leads to a situation of unavoidable overcapitalization and underutilization in the short term. This situation accounts for the relatively high unit conveyance cost in the early stages of the useful life of the sewerage infrastructure. While these costs will be high they are incurred annually and must be recovered.

- In view of the complexities that will arise from attempting to accommodate industries located at varying distances from the treatment works **the best approach is to adopt a geographically unbiased** method of calculating the cost to convey one kilolitre of wastewater to the treatment site such that the cost is the same for every user of the system. For purposes of practicality the costs are all regarded as fixed.

7A.4 Sewerage expenditure and the cost of conveyance

Sewerage expenditure which is incurred annually does not differ much in nature from the treatment expenditure, and is detailed similarly to the manner in which the data is shown in **Appendix IV.** While the type of detail against various cost codes and cost centres may differ, the broad categories as recommended by IMFO are the same as for treatment expenditure.

Staff Expenses……………………………

Repair and Maintenance …………………

General Expenses …………………………

Depreciation + interest ……………………

Depreciation is on a straight line basis and over a period of 30 yrs as recommended by IMFO. It should be noted that in terms of GAMAP depreciation is an expense and replaces the traditional redemption of loans.
In order that a geographically unbiased unit cost can be established for conveyance, the volume of wastewater that flows through the sewer network is required. This figure can be obtained from the cumulative daily flow data recorded at the treatment works. This figure will include any infiltration and is likely to be inflated.

The effect of this infiltration will result in a lower unit cost for conveyance. In order that this value is correctly reflected allowance must be made for infiltration based on data provided by the hydraulics department of the local authority.

The unit cost for conveyance (as a separate component) is calculated as follows:

$$\frac{\text{O \& M expenditure including depreciation + interest (Rand)}}{\text{Adjusted Volume (kilolitres)}}$$

= cents/kilolitre

When the conveyance is combined with the variable treatment and the fixed costs, then the depreciation component of the sewerage expenditure is combined with the fixed costs.

Total unit cost = conveyance + variable treatment cost + fixed cost

7 A 4.1 Recovery of conveyance cost from industry

Having established a unit cost for conveyance, one needs to know the volume of effluent discharged from each industrial site. This information is processed in the normal course of industrial effluent activities and is calculated by using the water consumption data plus any borehole utilization and then allowing for approved deductions as illustrated in a typical assessment shown in **Appendix V.**

∴	Water consumption + borehole data	=	"x" kilolitres
	Less approved deductions	=	"y" kilolitres
	∴ Effluent	=	(x – y) kilolitres
∴	Conveyance charge for each industry	=	(Unit Cost • (x-y) kilolitre)

7 A 4.2 Significance of the conveyance unit cost

- **Minimum charge:**

  Many industries are small with no COD load of significance, but still discharge a fair volume of effluent. These types of industries are not monitored, analysed, or visited often, but still must be charged the conveyance and fixed cost charges by virtue of their contribution to the overall wastewater volume and expenditure.

- **Data Retrieval**

  It provides the local authority with the financial implications and significance of the conveyance aspect of the industrial effluent tariff system. One can calculate in advance the amount of revenue that is due from industry for the conveyance aspect on its own.
  By combining the depreciation with the treatment infrastructure depreciation under fixed costs, it facilitates the setting aside of finance from depreciation for the purpose of building up cash reserves to service future requirements for asset replacement and additions to the sewerage and treatment facilities. This depreciation also provides the basis for a % return on assets calculation applicable to all dischargers to the sewerage system. This is illustrated under the effluent tariff framework in **Part III** guideline.

7A.5 Element of double charge

A sewerage tariff is usually charged by many local authorities to cover the cost for the conveyance and treatment of domestic wastewater. This cost is alternatively incorporated by other local authorities in the rates and is regarded as one of the services provided in lieu of the rates finance received. The choice of option depends on the policy of the particular local authority.
The element of double charge arises when the sewerage tariff is applied as above and then having the same tariff included in what is termed the "basic tariff". The basic tariff is derived by dividing the total sewerage and treatment expenditure by the volume recorded at the treatment works. This gives a basic tariff per kilolitre used as a starting point and paid by everyone. Industry then pay proportionately on the strength of the effluent based on COD as follows:

$$\left(\text{Basic charge (c/k}\ell\text{)} \bullet \frac{COD_I}{COD_m} \right) \quad \text{Over and above the sewerage tariff}$$

Note that the conveyance cost is included in the basic charge. Under these circumstances there should be no sewerage tariff applicable unless a deduction is made for such, as indicated by Durban Metro in the **Part II** review.

PART II

REVIEW OF EFFLUENT TARIFF PRACTICE

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PART II

REVIEW OF EFFLUENT TARIFF PRACTICE

8. INTRODUCTION

8.1 Basis of Review

A number of local authorities (some of which were then Transitional Councils and others Metropolitan Councils) throughout South Africa were chosen as suitable for the project. The size, as gauged by the daily influent received at the wastewater treatment works, varied from 7,6 Mld^{-1} to 769 Mld^{-1}. The main criteria for their specific choice was that significant industrial activity resulting in the discharge of effluent into the municipal sewer, is ongoing in the area of jurisdiction.

The methodology used was to obtain relevant data via a checklist **(Appendix I)** that would enable meaningful comparisons of similar information; allow for an evaluation of each local authority's industrial effluent tariff and all the factors associated with such, and finally to gain a good insight into the "status quo" of industrial effluent tariffs in South Africa with reference to industrial effluent discharges into the municipal sewer. An important component of the exercise was to personally visit each organisation involved and to inform them of the purpose, motivation and objectives of the Water Research Commission project. This type of contact and verbal exchange with senior professional personnel involved in effluent tariff related activities, formed a key element of the information and technology transfer. In many instances, multiple visits were made to some of the participating local authorities.

8.2 Participating Organisations

A Greater Johannesburg Metropolitan Council
B Estcourt Town Council
C Port Elizabeth Transitional Local Council
D Cape Metropolitan Council
E East London Local Council
F Pietermaritzburg Transitional Local Council *
G Durban Metropolitan Council
H Springs Town Council
I Umgeni Water
J Pinetown Town Council

* In the case of Pietermaritzburg, the industrial effluent control, monitoring, and tariff implementation and administration is undertaken by Umgeni Water.

Therefore in this instance discussions were with officials from Umgeni Water who provided all the required data.

8.3 Limitations

- Many of the organisations involved were themselves in transition, and temporary legal problems hindered the full implementation of the Metropolitan status and its benefits, at the time of the data compilation.
  i.e. Durban Metropolitan Council now operates over a very enhanced area involving an integrated sewerage scheme of approx. 40 treatment works varying in size from one extreme to another. A similar situation exists in the Cape Metropolitan Council. Problems with Metro By-Laws overlapping with the By-Laws of Local Councils that form part of the Metro have been resolved.

Under the circumstances, the data retrieved was confined to the 1996-1997 and in three instances to the 1997-1998 financial year. With respect to the Durban Metro and Cape Metro the data is confined to the pre-Metro areas. However, it is anticipated that when the Metropolitan areas are fully operational there will be financial benefits derived due to the large operational base.

The essential ingredient of success in this type of project is the availability of good, reliable data. As such the choice of the participating organisations was made with the above thoughts in mind. While a larger number of participants would have been statistically preferable it was considered that those chosen, and their specific internal composition, would suffice.

9. INDIVIDUAL TARIFF STRUCTURES AND COMMENTS

9.1 Greater Johannesburg Metropolitan Council
Organisation A

Effluent tariff charge in cents per kilolitre = $C + \left[\frac{COD}{700}\right] \bullet T$

where C = conveyance cost in cents per kilolitre
T = treatment cost in cents per kilolitre
COD = chemical oxygen demand of the effluent sample in $mg\ell^{-1}$

The constants C and T are 115 and 130 respectively for the period under consideration. (1997 – 1998)

The previous formula was $C + T \left[\frac{PV - 80}{80}\right]$ where C and T had the same meaning as shown above, but the values of C & T were different. PV represents the Permanganate value expressed in $mg\ell^{-1}$.

Minimum charge:

There was a minimum charge previously. This is no longer applicable. However when the volume is less than 100 kℓ per month, as assessed from computerized water consumption data then the domestic tariff as prescribed in the By-Laws, is applicable i.e. R 5 per kilolitre.

Sewerage Tariff

There is an industrial effluent sewerage tariff of R5 per kilolitre of assessed liquid volume.

Additional effluent charges for heavy metals

In addition to the effluent tariff charge which is $\mathbf{C} + \left[\frac{COD}{700}\right] \bullet T$,

the following charges for heavy metals are applicable, and are illustrated in **TABLE 9.**

TABLE 9 : Additional charge formula for heavy metals

Charge Formula Expressed in c/kℓ	Excess Metal Concentration In mgℓ$^{-1}$
1. $T\left(\frac{Cd - 2,0}{2,0}\right)$	Cd > 2
2. $T\left(\frac{Co - 20}{20}\right)$	Co > 20
3. $T\left(\frac{Cr - 20}{20}\right)$	Cr > 20
4. $T\left(\frac{Cu - 10}{10}\right)$	Cu > 10
5. $T\left(\frac{Hg - 2,0}{2,0}\right)$	Hg > 2
6. $T\left(\frac{Mo - 5,0}{5,0}\right)$	Mo > 5
7. $T\left(\frac{Ni - 10}{10}\right)$	Ni > 10
8. $T\left(\frac{Pb - 2,0}{2,0}\right)$	Pb > 2
9. $T\left(\frac{Zn - 10}{10}\right)$	Zn > 10
10. $C(3,0 - pH)$	Where pH < 3,0

Where:

Cd = Cadmium;
Co = Cobalt;
Cr = Chromium;
Cu = Copper;
Ni = Nickel;
Zn = Zinc;
Pb = Lead;
Hg = Mercury
Mo = Molybdenum

Where:

C & T have the same value as in the main formula.

Rebates

The following rebates are granted subject to specific conditions stipulated by the Metropolitan Council:

a). 10% if discharge occurs at specified times only.

b). 15% if flow is balanced and discharged evenly over 7 days at specified times only.

c). 20% if effluent contains readily biodegradable carbon beneficial to the Councils treatment process
and

d). 50% maximum if (c) occurs with (a) and (b).

In order to assess the eligibility of the industrial effluent discharges for the rebates mentioned above a screening process is used. This screening process takes into account – *inter alia* , the following :

- balancing of load
- significant rapidly biodegradable carbon load
- favourable TKN/COD and TP/COD ratios

where TKN = total kjeldahl nitrogen
TP = total phosphate

The rebate system is intended to make it financially attractive to discharge effluents conforming to the above criteria, to sewer. A good example is the effluent from the yeast industry. It contains significant amounts of rapidly biodegradable COD (RBCOD) which is an excellent source of carbon substrate for the biological removal of phosphate.
The above approach has so far been applied to 5 discharges. Further refinements are under consideration to restrict effluents that have a negative impact on the treatment process and to provide more incentives for the discharge of effluents which could promote the biological process.

Analysis and Comment

The Johannesburg formula viz. :

Charge in cents per kilolitre : $C + \left[\frac{COD}{700}\right]T$

where C = conveyance cost in cents per kilolitre.
T = treatment cost in cents per kilolitre

COD = chemical oxygen demand in $mg\ell^{-1}$ of the industrial effluent

- The above formula is simple and easy to administrate.
- Using the data provided it was established that the values of C and T as presented, are very inflated. The reasons for this situation were not identified.
- The 700 in the formula is a fixed assumed concentration of COD for a typical influent wastewater. This should be the average COD over 1 yr at the treatment works or the weighted COD where many works are combined into one scheme.
- Examination of the effluent income based on conveyance and treatment indicates that there is an under recovery in comparison to the anticipated amounts which should be recovered according to the calculations.

9.2 Estcourt Town Council
Organisation B

The monthly charge in cents per kilolitre = $A + \left(\frac{COD}{1000}\right) \bullet B$

Where A = the basic conveyance tariff in cents per kilolitre and determined annually in advance by the Council

B = the basic treatment tariff expressed in cents per kilogram of COD, determined annually in advance by the Council

COD = chemical oxygen demand expressed in milligram of COD per litre of effluent

The Council bases its monthly charge on the **highest** COD of one or more samples collected from the trade effluent sampling point. Where an industry has been allocated a maximum COD load and the load has been exceeded, the charge shall be calculated by the following formula.

$$R = A + \left\{\left(\frac{L_1}{L_2}\right) \bullet L_1 \bullet B\right\}$$

Where L_1 is the calculated load expressed in metric tons of COD for the month. L_2 is the maximum allocated load expressed in metric tons of COD for the month.

Previous formula was $55 + \frac{OA}{4}$ where 55 is the conveyance cost expressed in cents per $k\ell$ and OA is the permanganate value expressed in $mg\ell^{-1}$

Sewerage costs are incorporated in the conveyance cost.

Minimum charge

This is a nominal R5 per month, and is applicable where the monthly charge is less than five rand.

Comment

Estcourt is the only participating local authority that uses a COD mass for the basic treatment tariff which is expressed in cents per kilogram COD.
The formulation used by Estcourt, and provided to them by a firm of consulting chemists, is a good example of an effective charge system, which is easy to administrate and is effective in ensuring that an appropriate financial contribution from industry is obtained. The use of maximum C O D to calculate effluent charges places the onus on the effluent dischargers to manage their effluent system in an economically responsible manner. A further unusual feature is that the charge is on a monthly basis. Estcourt does not have many industries to monitor and therefore have no difficulty in charging on a monthly basis. This approach may be problematic in a metropolitan area.

There is no separate sewerage tariff applicable for industry.

9.3 Port Elizabeth Transitional Local Council Organisation C

Treatment charge per kℓ = C x V x K x T

where C = factor expressed in cents per kilolitre and which incorporates total annual expenditure for treatment. For the period 1996/97, the value of C was 62 cents per kilolitre. This cost of treating wastewater is calculated each year and is based on actual costs and flows received at the treatment works.

V = metered volume of <u>water</u> entering the premises in kilolitres

K = fraction of incoming water discharged to sewer

T = strength of effluent discharged to sewer

where $T = \frac{1}{3}\left[\left(\frac{2PV-160}{80}\right)+\left(\frac{S-10}{10}\right)\right]$

where PV = Permanganate Value in $mg\ell^{-1}$

S = Settleable Solids in $mg\ell^{-1}$

The factor C which is 62 c/kℓ^{-1} for the period 1996/97 is the calculated treatment costs for domestic wastewater at an assumed strength of PV = 80 mgℓ^{-1}, but based on actual operating treatment plant data.
For calculation purposes it has been assumed by Port Elizabeth officials that the average cost of treatment for industrial effluent is twice that of treating domestic wastewater.
The manner in which T is calculated, is not desirable. It was mentioned in the preceding paragraph that to obtain C an assumption was made that the industrial treatment cost is twice the domestic treatment cost. If one now examines the formula for T, any effluent with a PV of less than 80 and a settleable solids of less than 10 mgℓ^{-1} will attract no charge for treatment. However this is not entirely correct since the basic wastewater treatment charge is included in the rateable value of the premises and therefore all dischargers pay something for treatment. Up until June 1998 all rate-payers, domestic, commercial and industrial paid a sewerage tariff which was based on the rateable value of the buildings.
As from 1 July 1998 this has changed and all water consumers now pay a sewerage charge based on water consumption and cost of conveyance and treatment.

For industry : Sewerage charge = tariff x V x K

Where the tariff for 1998/99 = R2,20 kℓ^{-1} (exc VAT)

V = volume of water entering the premises

K = fraction of incoming water discharged to the sewer

The trade effluent tariff is applied to industry in addition to the sewerage tariff.

Notwithstanding deficiencies in the formulation used to assess the charges for effluent disposal from industry, this formula i.e. C x V x K x T,
has been in use for the past 22 years.

A minimum charge is applicable and is based on a water consumption of 11 kℓ per month.
In order that cross subsidization of the wastewater tariff from other sources is eliminated, the method of charging has been changed since 1 July 1998 and both conveyance and treatment charges are based on water consumption.

9.4 Transitional Metropolitan Substructure of Cape Town Organisation D

Effluent tariff formula : $$VE\left[\frac{COD - L}{3A} + \frac{2}{3}\right]$$

where V = Vol. of effluent in kilolitres
E = 1,1244 rands – cost of conveying and treating one kilolitre of sewage
A = 900 mgℓ$^{-1}$ - average COD arriving at the Councils' sewage treatment works
L = 75 mgℓ$^{-1}$ - statutory limit in terms of the permit issued by DWAF
COD = chemical oxygen demand based on the median of 4 samples in the 6 month cycle and 4 samples in the previous 6 month cycle.

Previous industrial effluent formula : $$V\left\{R + T\left[\frac{1}{3} + \frac{COD - 75}{1350}\right]\right\}$$

Where R = 0,4000 rands per kilolitre (conveyance cost)
T = 0,6746 rands per kilolitre (treatment cost)

Minimum charge

R10 per cycle	where the discharge is < 25 kℓ per cycle
R25 per cycle	where the volume exceeds 25 kℓ per cycle

Penalties

In the By-Laws under Section 4 it states that any person who discharges industrial effluent into any sewer in contravention of Section 5(2) shall in addition to any other penalty which may be imposed, pay to the Council a surcharge calculated by means of the following formulae :

i). $\frac{E}{45}$ for every completed 5^{0}C whereby temperature exceeds 45^{0}C plus

ii). $\frac{E}{45}$ for every completed 1,0 whereby the value of $\left(\frac{6,2 - pH}{10}\right)$

exceeds zero for pH value, below 5,5 plus iii). $\frac{E}{45}$ for every completed 5^0C whereby the flash point falls below 60^0C, plus

iv). $\frac{E}{45}$ for every completed 5 $mg\ell^{-1}$ whereby the cyanide content in such effluent exceeds 20 $mg\ell^{-1}$ plus

v). $\frac{E}{45}$ for every completed 5 $mg\ell^{-1}$ whereby the sulphide content in such effluent exceeds 20 $mg\ell^{-1}$ plus

vi). $\frac{E}{45}$ For every completed 300 $mg\ell^{-1}$ whereby the sulphate content in such effluent exceeds 1500 $mg\ell^{-1}$ plus

similar calculations for excesses of heavy metals in group 1, group 2, and group 3.

N.B. "E" has the same meaning as defined at the beginning.

A rebate of 50% of the charge, calculated as prescribed in the opening paragraphs and not including the penalty clauses, shall be granted in respect of all industrial effluent discharged during off-peak hours, provided that such discharge takes place in accordance with the requirements as determined by the Council in respect of :

a) Off peak hours
b) The holding facilities provided
c) The rate of discharge and the metering, recording and sampling thereof and
d) The returns to be submitted to Council

Sewerage Tariff

Industrial effluent dischargers pay the minimum charge or the formula charge where conveyance charges are incorporated in the E factor.

The domestic component is recovered from the rates.

Water Cost for Industry

Flat rate per kilolitre – R2,27

Comment

Whenever a figure such as "E" based on annual estimates of conveyance and treatment expenditure for the ensuing year is used in an effluent formulation, a (dimension of) financial stability is added to the charging system :
By using the actual or estimated conveyance cost per kilolitre, there is no need for an industrial sewerage tariff since the conveyance cost is calculated on the total combined domestic and industrial volume .The situation also becomes more well defined and lends itself to easy interpretation and understanding.
If (COD –L) is equivalent to the "A" which is the average COD value of raw sewage arriving at the Council's sewage treatment works, then

$$VE\left(\frac{COD-L}{3A}+\frac{2}{3}\right)=VE\left(\frac{1}{3}+\frac{2}{3}\right)$$

$$= VE$$

9.5 East London Local Council
Organisation E

Charge in cents per kilolitre = K1 + K2A + K3B + K4C + K5D

Where A is the volume in millilitres of settleable matter in one litre of trade effluent up to a volume of 10 millilitres

B is the volume in millilitres of settleable matter in one litre of trade effluent in excess of 10 millilitres

C is the Permanganate Value of settled trade effluent in excess of 30 $mg\ell^{-1}$ and up to 1000 $mg\ell^{-1}$

D is the Permanganate Value of settled trade effluent in excess of 1000 $mg\ell^{-1}$

The Permanganate Value being the oxygen absorbed expressed in $mg\ell^{-1}$ from acidic 0,0125 N Potassium Permanganate in 4 hrs at $27^{0}C$ and being determined on the trade effluent after settlement of solid matter for one hour.
The arithmetic values of K1 K2 K3 K4 and K5 are determined by the Council from time to time.The terms K2A and K2B are only applied if the service includes settlement or any other form of sludge treatment, while the terms K4C and K5D are only applied if the service includes treatment of the aqueous phase. In the absence of analytical results to determine SS or PV , or where SS and PV are found to be less than 10 and 50 respectively , these shall be deemed to be 10 and 50 respectively.

For example, the value of the above constants for the period 1 July 1998 – 31 December 1998 were

K1 = 121,0
K2 = 2,85
K3 = 2,85
K4 = 1,075
K5 = 1,075

There are different categories for charges for a variety of services which include

i) The conveyance, screening and disposal to the surf zone (West Bank) where the charge for any volume less than 50 kℓ per month is R82,28 which represents the minimum charge and above 50 kℓ per month is (**volume x 164,56 ckℓ^{-1}**). The volume is assessed as a percentage of the metered water consumption.

ii) The tariff for conveyance, full treatment and disposal, other than West Bank, is 171,00 ckℓ^{-1}, with a minimum charge of R85,50 for any month.

iii) All areas other than West Bank, where the volume is in excess of 50 kℓ per month and requires conveyance , full treatment and disposal are charged as (**volume x tariff**) where the tariff is 171,00 ckℓ^{-1} or greater depending on effluent strength and applying the formula. A minimum monthly charge of R85,50 is applicable.

iv) Miscellaneous sites where the effluent volume is in excess of 50 kℓ per month and a variety of services are available. The charge applicable is the (**volume x tariff**). In this case the tariff will be 171,00 ckℓ^{-1} or greater. The formula will apply and the volume is assessed by direct effluent measurement or other means.

v) Provision is made for a surcharge on the monthly effluent account if there is a repeated non-compliance with the City By-laws.

Comments and Analysis

The formula used for effluent tariff calculation apparently was devised a few years ago by a consultant. The rationale behind this formulation was not at all clear.
Communication between the project leader and senior staff from East London resulted in the following explanation.
The Sewerage Branch Engineering Staff supply data spreading the % costings between area, volume, and strength

i.e.	Total Area Cost	34,5%
	Total Volume Cost	33,5%
	Total Strength Cost	32,0%

These include overheads of 11% allocated proportionately for purposes of trade effluent, the overheads are separated as follows:

	Basic	Overhead	Total
Total Area Cost	30,7	3,8	34,5
Total Volume Cost	29,8	3,7	33,5
Total Strength Cost	28,5	3,5	32,0
	89,0	**11,0**	**100,0**

The domestic sewerage tariff will recover the area cost in respect of trade effluent and therefore the volume cost and the strength cost need to be readjusted to total 100% for trade effluent purposes.

Volume costs	29,8	45,5
Volume cost overheads	3,7	5,6
Strength cost	28,5	43,5
Strength cost overheads	3,5	5,4
	65,5	**100**

A similar exercise is done with the strength cost where the basic comprises of both solid phase and liquid phase treatment cost. These must be further allocated according to the following Sewerage Branch estimate.

Volume cost : basic	45,5
Volume cost: overheads	5,6
Solid phase cost 16%	7,0
Liquid phase cost 84%	36,5
Strength cost: overheads	5,4
Total	**100**

Summarising the split needed for use in determining the trade tariff constants is thus

Volume + overheads term	56,5
Solid phase strength term	7,0
Liquid phase strength term	36,5
Total	**100,0**

The above split determines the arithmetic values of constants K_1 to K_7 every six months, in order to recover costs as fairly as possible.
This formulation does not readily lend itself to easy explanation to industrialists how the overall formula is derived. This formula could be simplified a great deal, and still ensure that adequate income in proportion to the pollutional load is derived for the conveyance and treatment.

9.6 Pietermaritzburg Transitional Local Council Organisation F

Effluent tariff charge = 55 + 0,039 (OA – 70)
(cents per kilolitre)

Previous tariff = 44 + 0,031(OA – 70)

The structure of the effluent tariff used in terms of the By-laws has remained largely unchanged for the past 20 years. The factors used in the formula have been revised on a random periodic basis. OA is the oxygen absorbed in $mg\ell^{-1}$ and essentially the same as the PV (Permanganate Value) except with respect to the temperature at which the test is carried out in the laboratory. The 55 expressed in $ck\ell^{-1}$ is a factor defining a basic tariff which is related to the fixed treatment and conveyancing cost. The factor 0,039 is a factor for converting OA into variable treatment costs in $ck\ell^{-1}$. It was until recently believed that the "55 $ck\ell^{-1}$ " was a conveyance charge which was supposed to be revised annually. However it was established that this is not the case. The officials at one time in the past must have taken the total cost of treatment and sewerage maintenance and after dividing by the flow, reached the basic value of 55 $ck\ell^{-1}$. Incidentally this was at 44 ckl-1 until January 1997.
In addition to the above industrial effluent charge, industries in Pietermartizburg also pay a "sewerage tariff" similar to that paid by the householder. This tariff is based on clean water consumption and is calculated on a sliding scale, currently as follows:

- 0 to 400 kℓ/mth : R1,42 $k\ell^{-1}$
- 401 to 1000 kℓ/mth: R1,30 $k\ell^{-1}$
- > 1000 kℓ/mth: R1,09 /kℓ
- Maximum = R5690 per month

The minimum charge is R421,80 per six month period.

Shortcomings with the Pietermartizburg formula are as follows:

The treatment portion is totally unrealistic and implies that any industry with an OA of less than 70 $mg\ell^{-1}$ will pay nothing for treatment except for the basic 55 $ck\ell^{-1}$. Furthermore even if an effluent is analysed as very high e.g. 1000 $mg\ell^{-1}$ OA, then the additional figure over and above 55 will be 0,039 x (1000 – 70), and this is equivalent to 36,27 cents per kilolitre. For such a strength, experience and examples from elsewhere in South Africa indicate that a charge of approximately R10 per kilolitre would be more realistic.

- It does not include a defined conveyancing cost, and bears very little relationship to the operating costs at the Darvill Wastewater Treatment Works since it has not been properly reviewed for at least 20 years.

- There is an element of double charging which is evident from expecting industry to pay an industrial effluent tariff incorporating elements of conveyance as well as a sewerage tariff.
- The sewerage tariff based on water consumption decreases with increasing water consumption.
- The minimum charge needs to be upgraded considerably.

Comments and Analysis

The situation within this local authority at the time of review provides a good example of significant under-recovery in effluent and sewerage income from industry. For the year under review industrial effluent income of R1,2 million was derived instead of a calculated R7,2 million .For the sewerage expenditure only an additional R2,15 million was received

Therefore, out of a total expenditure of R34,57 million for conveyance and treatment, only R3,35 million was derived from effluent charges **and** sewerage rates from industry.
The main reasons for this are out of date data (constants) used in the formula and a weak formulation that has not been reviewed for years. This is coupled with the cumulative effect of political decisions in the late 70's and early 80's to deliberately keep effluent tariffs low so as to encourage industry to come to Pietermaritzburg.

However, the Pietermaritzburg Transitional Local Council in conjunction with Umgeni Water have formulated new effluent charges. These new charges take cognisance of all the previous deficiencies and have been approved by the Pietermaritzburg Council with effect from January 1st, 2000 to be phased in over a period of time.

9.7 **Durban Metropolitan Council–** prior to Metropolitan Status **Organisation G**

General formula for trade effluent expressed in cents per kilolitre is as follows:

$$X + V\left(\frac{C}{R}\right) + Z\left(\frac{B}{S}\right)$$

where

a). X = prescribed rate for the conveyance and preliminary treatment of sewage and shall include all operational repair and maintenance and annual capital costs less an authorised allowance in respect of the sewerage rates contribution.

b). V = prescribed rate for the treatment in the treatment works of the Council of Standard domestic effluent having a prescribed chemical oxygen demand value and shall include all operational, repair maintenance, and annual capital costs.

c). R = prescribed chemical oxygen demand value referred to in (b)

d). Z = prescribed rate for the treatment in the treatment works of the Council of standard domestic effluent having a prescribed settleable solids value and shall include all operational, repair, maintenance, and annual capital costs.

e). S = prescribed settleable solids value referred to in (d) as expressed in millilitres per litre.

C = chemical oxygen demand being the value of the amount of oxygen from potassium dichromate that reacts with the oxidizable substances contained in 1 litre of the settled trade effluent and expressed in $mg\ell^{-1}$.

f). B = volume of settleable matter in one litre of the trade effluent, measured after settlement in the laboratory for one hour.

Minimum charge

A minimum charge is applicable and equivalent to the charge for the disposal of standard domestic effluent.

Additional charge for high strength sewage:

The rate in cents per kilolitre for the additional charge for the disposal of high strength sewage to the sewage disposal system shall be determined in accordance with the following formula:

$$V\left(\frac{C}{R}-1\right)+Z\left(\frac{B}{S}-1\right)$$

where V,C,R,B,Z and S are defined as in the previous section.

Sewerage Tariff

This is applied separately by the different substructures within the Metropolitan area.

Example:

Calculating Sewerage Rates in South Central and North Central

Land Value x 1,092 (cents for every rand value)
Building Value x 0,091 (cents for every rand value)

Total sewerage rates = rates for land + buildings.(as calculated above)

Inner West Local Council

Land: 4,8096 cents in the rand.
Building: 0,6012 cents in the rand.

Comments:

The formulation is very similar to that recommended by the Water Authorities in the United Kingdom and has been in operation for the past 40 years with annual revision. In the case of **Organisation G** ,the sewerage rates contribution is deducted to eliminate any element of double charge. While there are heavy metal limits, there is no provision to include an additional charge for them. Durban is one of the few large organisations that still bases its effluent charge on a formula that contains settleable solids. It would seem that industrialist pays a sewerage tariff, and this is deducted from the formula applied to trade effluent. A further query is directed to the use of standard domestic sewage. The constants in the formula are revised annually based on actual sewerage and treatment expenditure. This approach has contributed to the revenue derived from industry being consistent with the calculated amount.

9.8 **Springs Town Council** within the umbrella of "ERWAT" **Organisation H**

This town council provides a good representation of many of the East Rand Town councils whose wastewater treatment activities fall under ERWAT (East Rand Water Care Company).The wastewater treatment service is provided by ERWAT who then bill the Springs Town Council on a commercial basis for services rendered.

Industrial effluent charge formula for the period 1996-1997.

$$\text{Charge in cents per kilolitre} = X\left[54{,}67 + 68{,}71\left(\frac{COD}{1000}\right)\right]$$

Where COD = chemical oxygen demand of a settled industrial effluent sample. The actual COD used in the formula is an average of 4-6 samples taken in a 6 month period.

54,67 = The conveyance cost for the 96/97 financial year in cents per kℓ.

68,71 = The treatment cost for the 96/97 financial year in cents per kℓ.

The Springs Council decided to change from OA to COD in 1995, but realised that there would be a big change in effluent expenditure for industry. To minimize the impact it was decided to incorporate a factor "X" on an annual diminishing scale. For the year 1996-1997 the value of "X" was 0,37. The "X" can be considered to be a normalisation factor.

Minimum charge

There is no minimum charge applicable in Springs.
Sewerage Tariff

A tariff is applicable such that the 1st 2500 m^2 : → R22,80
(up to 300 m^2) + additional tariff for 12 mths : → R97,20
(greater than 300m^2) + additional tariff for 12 mths: → R163,44
TOTAL **R283,44** per annum

This very small amount is for the domestic on-site component at each industrial site.

An additional charge for heavy metals is applicable but it is not very clearly defined.

Comments

The general effluent tariff structure is consistent with, a conveyance and treatment structure, but the constants in the formula need to be reviewed. However it highlights the need to use the chosen parameter (either OA, PV or COD) consistently. This implies that if, for example, the COD is the chosen parameter for industrial effluent strength assessment, then the treatment works data must be processed in terms of COD. If this is done, there should be no problem when a change in analytical test procedure is effected. Essentially, if you use the OA or PV for assessing the strength of the industrial effluent then one must also use the same analytical test for assessing the influent wastewater at the treatment works.

9.9 Umgeni Water
Organisation I

Hammarsdale was developed as an industrial area under the Government policy of decentralization advocated in the 1960's and 1970's. The aim was to provide industrial employment opportunities for the local population, while providing industry with many benefits and tax advantages. The Department of Water Affairs and Forestry commissioned a Wastewater Treatment Works in 1974 to treat an anticipated 27Mℓ/day of primarily industrial wastewater. For a variety of reasons, beyond the scope of this project, the envisaged/anticipated industrial development never materialised and in November 1998, only 11 industries contribute an average of 10 Mℓ/day of high strength industrial waste such that although the plant is at 40% design hydraulic load, it is at 90% of the design COD load. It is estimated that in excess of 95% of the total volume treated on a daily basis is derived from industry.

A unique feature of this industrial township with respect to industrial effluent charges has been the use of water consumption to assess the charge for effluent disposal. No attention has ever been given to the COD load of each effluent contributor. This situation which was introduced by DWAF **and** accepted **by industry (reluctantly)**

has been maintained even after Umgeni Water purchased the works from DWAF in 1983. This situation still remains intact, although under review.
The annual operational costs plus the relevant capital charges are proportionately allocated to the 11 industries on the basis of water consumption. While this type of effluent charging system is easy to administrate, it is not equitable and fair to the industrialists because the aspect of strength which plays a major role in determining the effluent cost, is given no consideration. All the industries are very close to the treatment works, and the sewerage system administered by the Development and Services Board has never been a factor in the assessment of effluent charges.

A further observation is the high uniform treatment charge per kilolitre for all industry in Hammarsdale. This is due to very high strength waste and relative low volumes. If this was reversed and low strength waste with higher volumes prevailed then the treatment charge would be more in line with the other 9 organisations.

9.10 Pinetown Local Council
Organisation J

Effluent tariff charge in cents per kilolitre = $\left(60 + \frac{OA}{1,02}\right)$

Where the OA represents the strength of a well shaken effluent sample.
The 1,02 is an arbitrary factor which is adjusted annually to ensure that the treatment cost $\left(\frac{OA}{1,02}\right)$ together with the conveyance cost (60 cents per kilolitre) recovers the proportionate cost from industry. The guideline being that the assumed OA strength of domestic wastewater (i.e. 70mgℓ$^{-1}$) divided by 1,02 resulted in an acceptable treatment cost for 1 kilolitre of domestic wastewater.
This type of formulation for industrial effluent charging has been in use since 1985.
Where the six monthly water consumption exceeds 25000 kilolitres, the formula is as follows: $(60 \bullet 0{,}9) + \frac{OA}{1{,}02}$

The minimum charge for the discharge of industrial effluent into the sewer, per half year is : R500
In addition a charge for heavy metals is applicable under the following conditions:

Metals

a) 15 parts or less per million	No charge
b) In excess of 15 parts but not > 20 parts per million	R0,20 kℓ$^{-1}$
c) In excess of 20 part but not > 25 parts per million	R0,47 kℓ$^{-1}$
d) Over 25 parts per million for each part where by the number of parts exceeds 25.	R0,59 kℓ$^{-1}$

For purposes of these charges, the flow per day is calculated on the average daily water consumption averaged over the preceding two months.

Capital Contribution

A feature of Pinetown's industrial effluent charges is the requirement of a capital contribution of R2000 (inc VAT) multiplied by the number of kilolitres per day based on the estimated maximum daily amount of water likely to be used, with due allowance being given for the volume of water used in products and not discharged to the sewer.

Comments

Pinetown has one integrated sewerage scheme that includes the three treatment works. The industrial effluent formula has been easy to administrate, but contains an element of duplicate charging in that a capital contribution is required and the interest charges on capital are incorporated in the conveyance and treatment cost. The formula also does not try to split the treatment costs into liquid and solid phase, but rather uses treatment costs that include all operations on site. It could be improved upon by using the actual annual treatment costs and its associated average strength of the wastewater.

10. SUMMARY OF SELECTED DATA FROM THE RETURNED INFORMATION ACCORDING TO THE CHECKLIST

The checklist **(APPENDIX I)** was given to all concerned, together with an explanation of the data required. The information provided was then processed, verified, and utilized as is evident in this WRC Project.

Industrial effluent tariff processing involves effluent and analytical scientific staff; wastewater treatment operations and engineering staff, sewerage maintenance and engineering staff; data processing personnel; financial accounting input; administration of the receipt of payments and cross-referencing against users of the system. This multidisciplinary composition of staff that contributes to the overall success or failure of any industrial effluent system, also places a restraint on obtaining a cohesive approach to the subject.

However, in general, a sizeable amount of valuable information relevant to the checklist was obtained. The information was not always in a useful form and in some instances had to be checked many times to ensure correctness.

A summarized version of this information is shown in **TABLE 10 (a)** and **(b)**, and will allow users of the document to undertake other calculations specific to their need. Much of the information is shown in bar chart form to highlight variations and similarities on various parameters. **TABLE 10 (c)** provides a summarized version of the different tariff structures.

One deficiency was the dearth of satisfactory data confirming the rationale behind the different sewerage tariff formulations.

Table 10 (a) Summary Of Checklist Data

Local Authority		A		B	C	D		E	
Works Influent	$M\ell\,d^{-1}$	769		7,6	119,3	289		38,8	
COD	$mg\ell^{-1}$	571		790	1136	1000		750	
Industrial Effluent Portion % of Total	%	1,58		35,5	25,4	11		8,0	
Industrial Effluent COD Load % of Total	%	16,5		73,0	44,80			19,8	
Industrial Effluent Income	Rands $\bullet 10^6$	28,72		0,473	2,216	10,20		4,614	
Sewerage Income Rates	Rands $\bullet 10^6$	5,38							
Treatment O&M Expenditure	Rands $\bullet 10^6$	190,13		1,864	27,72	141		8,4	
Sewerage O&M Expenditure	Rands $\bullet 10^6$					incorporated		19,3	
Monitored Wet Industries (excluding min charge)		358 (including 186 garages		4 main industries	141	1100		70	
Average Industrial COD	$mg\ell^{-1}$	-		-	1978			1860	
Weighted Industrial COD	$mg\ell^{-1}$	5954		1462	-			-	
Treatment Costs	$R\,k\ell^{-1}$	0,68		0,67	0,62	0,68		0,79	
Sewerage Costs	$R\,k\ell^{-1}$					0,44			
No. of Industries providing major source of income		24	1	4	20	18	64	7	1
% of Total Effluent Income		73,4	52,6	>95	>80	52	68	72,5	42,4
Cost of water for Industrial use	$c\,k\ell^{-1}$	470		72	195	227		196	

Table 10 (b) Summary of Checklist Data

Local authority		F	G	H	I	J
Works Influent	$M\ell d^{-1}$	60	343	43,7	10,5	29,84
COD	$mg\ell^{-1}$	436	667	538	1400	790
Industrial Effluent Portion % of Total	%	8,84	7,66	20,19	95	23
Industrial Effluent COD Load % of Total	%	36,90	14,9	52,7	99	57,5
Industrial Effluent Income	Rands $\bullet 10^6$	1,20	15,02	2,55	8,93	5,31
Sewerage Income Rates	Rands $\bullet 10^6$	2,15				
Treatment O&M Expenditure	Rands $\bullet 10^6$	19,70	92,84	7,40	9,59 inc H/O copies	11,74
Sewerage O&M Expenditure	Rands $\bullet 10^6$	14,87		4,97		4,36
Monitored Wet Industries (excluding min charge)		82		51	11	120
Average Industrial COD	$mg\ell^{-1}$	1821	1343	3012	6109	1710
Weighted Industrial COD	$mg\ell^{-1}$	1674	1405	1405	2432	-
Treatment Costs	$R\ k\ell^{-1}$	0,87	0,74	0,55	2,49	1,07
Sewerage Costs	$R\ k\ell^{-1}$	0,68				
No. of Industries providing major source of income		10	111	4	11	17
% of Total Effluent Income		85,4		82,7	100	85,3
Cost of water for Industrial use	$ck\ell^{-1}$	350	213	279	236	213

Table 10 (c) Summary of Tariff Structures

Local Authority	Effluent Tariff Structure from checklist	Explanatory Notes
A.	$C+\left[\frac{COD}{700}\right]\bullet T$	where C = Conveyance = c/kℓ T = Treatment = c/kℓ
B.	$A+\left[\frac{COD}{1000}\right]\bullet B$	where A = Conveyance = c/kℓ B = Treatment = c/kℓ
C.	C•T	where C = Treatment cost (unit) $T=\frac{1}{3}\left(\frac{2PV-160}{80}\right)+\left(\frac{S-10}{10}\right)$
D.	$E\left(\frac{COD-L}{3A}+\frac{2}{3}\right)$	where E = 1,1244 c/kℓ to convey and treat wastewater
E.	$K_1 + K_2 + K_3 B + K_4 C + K_5 D$	K_1 recovers 56,5% of industrial effluent income K_2 and K_3 recover 7,0% of industrial effluent income K_4 and K_5 recover 36,5% of industrial effluent income
F.	E + (0,039 • (OA – 70)	where E = 55 cents to convey and treat 1 kℓ of wastewater at a strength of OA = 70
G.	$X\left[A+B\left[\frac{COD}{1000}\right]\right]$	where A = 54,67 = conveyance in c/kℓ B = 68,71 = treatment in c/kℓ X = normalisation factor to allow for change over from PV to COD
H.	$X+V\left(\frac{C}{R}\right)+Z\left(\frac{B}{S}\right)$	where X = conveyance and reception charge V = basic treatment charge (liquid) Z = basic treatment charge (solid)
I.	$\frac{\text{O\&M Expenditure}}{Q}$ = c/kℓ	where O&M = operating costs + finance charges Q = annual flow to the works
J.	$[A+B]$	where A = conveyance = 60 c/kℓ B = treatment = $\frac{OA}{1,02}$

N.B. I = Water Board

11. SELECTED DATA ON SOME OF THE TREATMENT FACILITIES WITHIN THE LARGER LOCAL AUTHORITIES

- **Greater Johannesburg Metropolitan Substructure**

Total flow at treatment works 769 Mℓ d^{-1} July 97 – June 98

Table 11 : Treatment Works Data (Johannesburg)

Names of Works	Design Capacity Mℓ d^{-1}	Actual flow Mℓ d^{-1}	COD mgℓ$^{-1}$
Bushkoppie	150	206	890
Driefontein	15	12	400
Ennerdale	6,5	3	670
Goudkoppies	150	129	390
Northern Works	320	268	540
Olifantsvlei	220	141	390
Sebokeng (Lekoa Water Company)	-	10	-
Total Flow **Average COD** **Weighted COD***		**769**	 **546** **571**

* The weighted COD average was done by calculation using flow and strength data

COD = 571 mgℓ$^{-1}$

With respect to the Johannesburg sub-structure there are 4 major treatment works of significance with the COD strength varying from 390 mgℓ$^{-1}$ to 890 mgℓ$^{-1}$. The weighted COD is 571 mgℓ$^{-1}$, and it is essential when quoting a treatment cost constant for the year that it is noted that the overall treatment cost per kilolitre was for a weighted COD of 571 mgℓ$^{-1}$.This weighted COD value and the significance of it, is not understood by all concerned in effluent tariff discussions.

- **Transitional Metropolitan Sub-structure of Cape Town**

  Total flow of treatment works   289 $M\ell\ d^{-1}$ July 97 – June 98

Table 12 : Treatment Works Data (Cape Town)

Name of Works	Actual Flow $M\ell\ d^{-1}$	COD $mg\ell^{-1}$
Athlone	96	930
Cape Flats	139	1000
Mitchells Plain	28	1160
Marine Outfalls	26	700
Total Flow	**289**	
Average COD		**948**
Weighted COD		**965**

Similarly with respect to the Cape Town Metro Sub-structure, 3 treatment works and a marine outfalls contribute to the total of 289 $M\ell\ d^{-1}$ which is operated as an integrated sewerage/sewage scheme.
While the COD's vary from 700 – 1160 $mg\ell^{-1}$ the weighted COD is 965 $mg\ell^{-1}$.

Table 12a: Treatment Works Data (Durban)

- **Transitional Metropolitan Substructure for the City of Durban**

  Total flow received at Works 343 $M\ell\ d^{-1}$

  Durban's Wastewater Scheme consisted of 5 treatment works viz.

  Southern
  Central
  Northern
  Kwa Mashu
  Phoenix
  } 343 $M\ell\ d^{-1}$

  The average COD of the above 5 works was 667 $mg\ell^{-1}$

  The data to calculate weighted COD's was not readily available.

- **Pinetown Local Council**

Total flow received at 3 works 29,8 Mℓ d^{-1}

Table 13 : Treatment Works Data (Pinetown)

Name of Works	Actual Flow Mℓ d^{-1}	COD mgℓ$^{-1}$
Umbilo	19,4	600
Umhlatuzana	9,5	1175
Umlaas	0,95	770
Total Flow	**29,8**	
Average COD		**848**
Weighted COD*		**790**

*Weighted COD 790 mgℓ$^{-1}$
Average COD 848 mgℓ$^{-1}$

The integrated wastewater scheme of Pinetown consists of 3 treatment works varying in size from 0,951 Mℓ d^{-1} to 19,4 Mℓ d^{-1}.
The weighted COD was 790 mgℓ$^{-1}$ while the average COD was 848 mgℓ$^{-1}$.
Pinetown is a very good illustration of how economy of scale distortions can be smoothed out by combining everything into one scheme.

e.g. Wastewater treatment costs

Umbilo Treatment Works - treatment cost ⟶ R0, 87 /m^3
Umhlatuzana Treatment Works - treatment cost ⟶ R1,22 /m^3
Umlaas Treatment Works - treatment cost ⟶ R4,04 /m^3

∴ Combined treatment cost on a weighted basis ⟶ **R1,07/m^3**

12. VARIATIONS IN THE TARIFF OF POTABLE WATER FOR INDUSTRIAL PURPOSES

A surprising feature amongst the data obtained was the wide variation in the cost of water for industry. The range was 72 cents per kℓ for Estcourt at the bottom up to 470 cents per kℓ for Johannesburg at the top for the time periods 1996 – 1997 and 1997 – 1998 as shown in **Table 14** and which illustrates the divergence amongst all the participating authorities.
The variations in the cost of water for industrial purposes are attributed to the following:

- Large local authorities acquire their water in bulk from Water Boards e.g. Rand Water and Umgeni Water. The unit cost per kilolitre for water for industrial purposes is set by the local authority who have added on their costs over and above the purchase price from the Water Boards. Furthermore consideration has been given to lifeline tariffs and sliding scale tariffs depending on the amount of water used

e.g. As from 22nd April 1998, the following charges apply within the Durban Metro area:

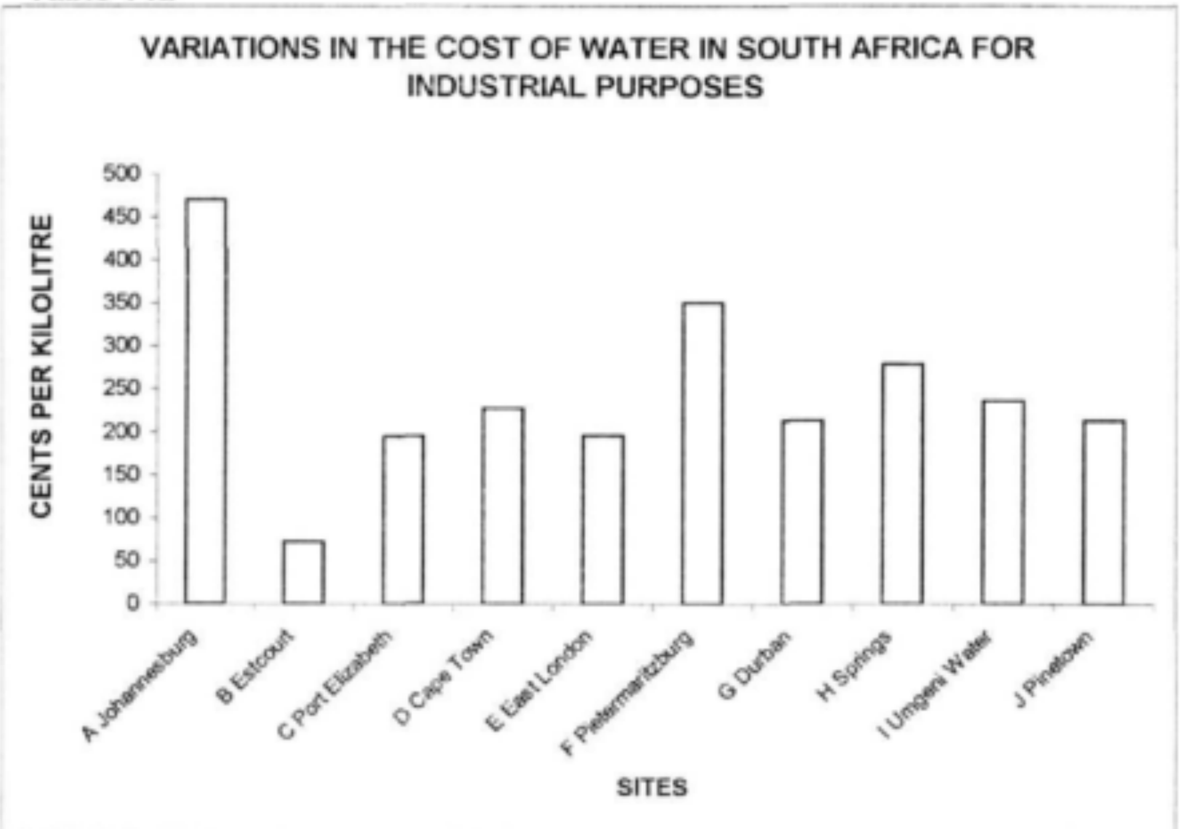
Type	Volume used	Charge c/kℓ
Domestic	0 kℓ to 6 kℓ	nil
Domestic	6 kℓ to 30 kℓ	R2,53
Domestic	30 kℓ →	R5,06
Industrial		R2,53

However the bulk cost of the water to Durban Metro from Umgeni Water was only R1,30 cents/kℓ. In the case of Estcourt, the local authority obtains its water from the river and does not pay for any bulk supply.
DWAF encourages water re-use, and the concept has been revitalised following recent statements by the Minister of Water Affairs and Forestry that our surface water resources will be depleted by the year 2020. In any cost economic exercise to ascertain the viability of using advanced technology for on-site effluent treatment e.g. membrane technology, the cost of municipal water will be a key factor influencing the outcome of the exercise. As long as water is very cheap, there is little incentive to using advanced treatment technology for effluent treatment or to consider the re-use option. Water in South Africa is a very undervalued commodity compared to countries in Europe such as Germany where water is approximately R10 per kilolitre.

Table 14: Supply cost of water for Industrial purposes

Year	Local Authority	Cents per kilolitre
97/98	A	470
96/97	B	72
96/97	C	195
96/97	D	227
96/97	E	196
96/97	F	350
97/98	G	213
96/97	H	279
96/97	I	236
96/97	J	213

Table 14a



13. HYDRAULIC AND COD LOADING

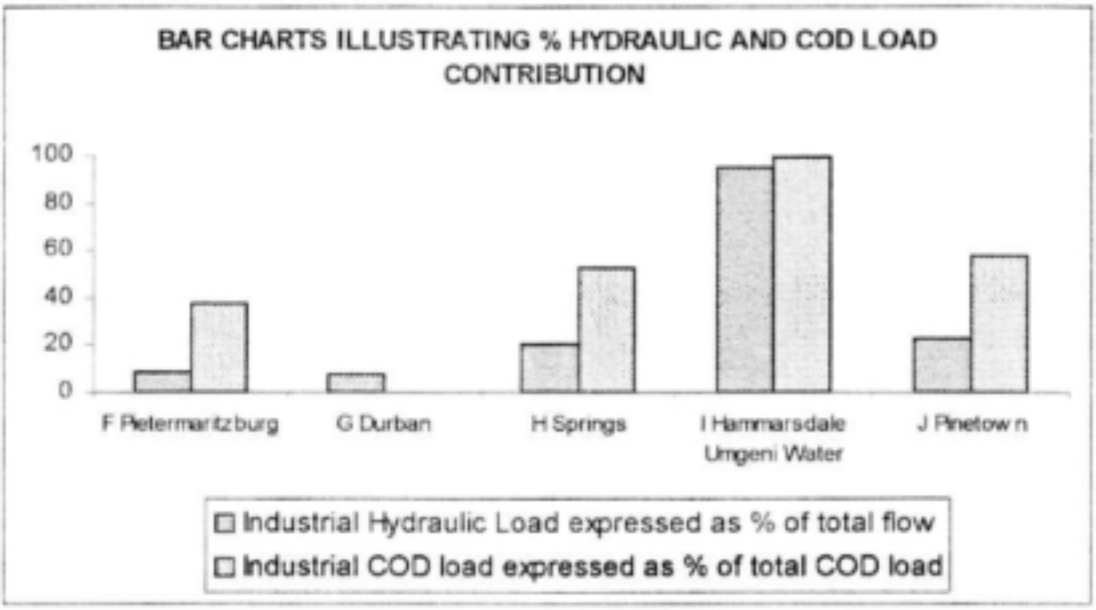
The data shown in **Table 15** and the bar charts in **Table 16** illustrate the overall impact of the % hydraulic and COD loadings relative to the total flow and total COD load respectively.

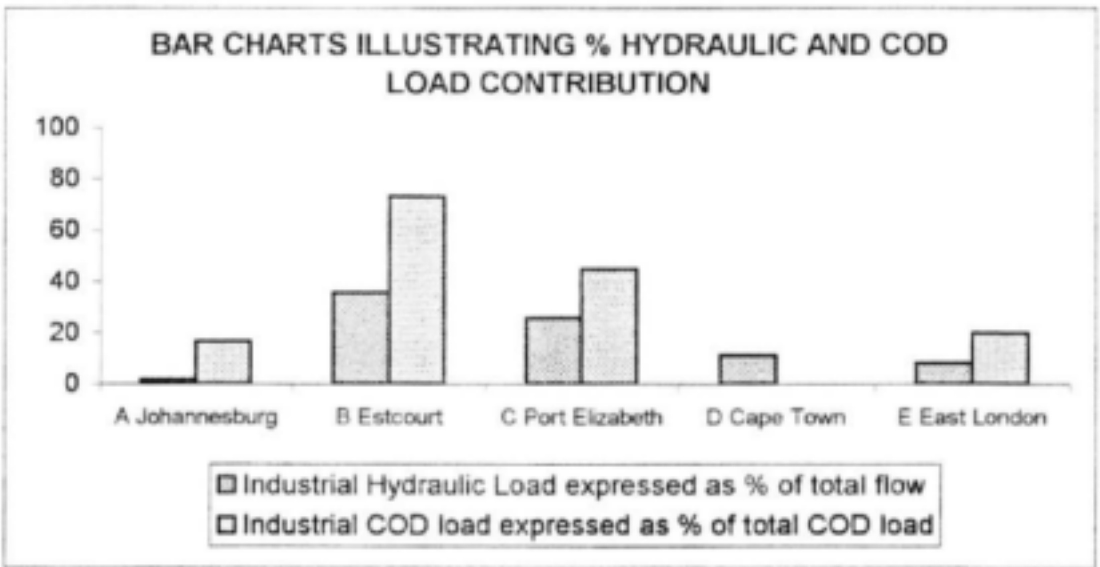
Table 15 : Proportion of Industrial Effluent on a Hydraulic and COD load Basis

Local Authority	Flow (Mℓd)	COD Arriving at works (mgℓ$^{-1}$)	% (hydraulic basis	% (COD load basis)
A	769	571	1,58	16,5
B	7,6	790	35,5	73,0
C	119,3	1136	25,4	44,8
D	289	1000	11,0	est. 22,0
E	38,8	750	8,0	19,8
F	60	436	8,84	36,9
G	343	667	7,66	est. 14,9
H	43,7	538	20,19	52,7
I	10,5	1400	95,0	99,0
J	29,84	790	23,0	57,5

The above data is based only on the monitored industries which are considered by the local authority to be of significance in terms of hydraulic and COD loading. Industries which have no known toxicity towards biological processes and contribute only a small volume are not monitored. In the case of **local authority A** it has been estimated that the hydraulic contribution could be as much as 20% of the total hydraulic load if all the small industries are collectively taken into consideration (Pitman 1997)

Table 16 : Bar Charts illustrating % hydraulic & COD load contribution





While in general the hydraulic loading tends to be on the low side, the mass loading when taking the COD concentration into consideration becomes very significant. This finding is consistent with the United Kingdom experiences **(Micklewright 1986).** The COD load is a good indicator of the amount of revenue which should be derived from industry for treatment alone.

e.g. Johannesburg contributes a very low hydraulic load of 1,58%(based on the data of the monitored industries) of the total flow,but a 15,5% COD load.

This implies that 15,5% of all the COD load arriving at the treatment works is from industrial sources based on the data of the monitored industries. In a large Metropolitan area there must be many hundreds of small industries that collectively contribute significantly to the hydraulic load. The above information can be used for calculation purposes to approximate the amount of revenue due from industry for treatment alone. In the above instance this amounts to R29,44 million. This amount is what the Metro Council should have received from industry for **treatment alone,** notwithstanding the conveyance contribution which should result in a further similar amount in addition to the R29,44 million.

- In Estcourt 73% of the treatment costs should be derived from industry. Similarly **Table 15** and bar charts in **Table 16** highlight the significance of the COD loading relative to proportionate cost assessment for industry. Continual reference is made only to treatment costs, because the project leader experienced much difficulty in obtaining sewerage tariff and sewerage operating expenditure from most of the participating local authorities. However it can be inferred or assumed with confidence that sewerage operating costs and interest on capital charges are in general of a similar order of magnitude to the treatment costs.

- In the case of Pietermaritzburg it should be noted that while industry only contributes 8,84% of the hydraulic load, it takes up 36,9% of the treatment capacity of the treatment plant at the Darvill Treatment Works based on the COD loading.

14. TREATMENT COSTS

This parameter displayed a large degree of consistency, particularly with the larger local authorities and those with a Metropolitan status. The treatment costs shown in the third column of **Table17** were calculated from the data provided.

Table 17 : Wastewater Treatment Costs in South Africa

Local Authority	Year	Treatment Cost Rand per kilolitre
A	97/98	0.68
B	96/97	0,67
C	96/97	0,62
D	96/97	0,68
E	96/97	0,79
F	96/97	0,87
G	97/98	0,74
H	96/97	0,55
I	96/97	2,49
J	96/97	1,07

Where treatment cost includes all O&M expenditure and capital charges.

e.g.

Johannesburg Greater Metropolitan Council	68 c/kℓ
Durban Metropolitan Council	74 c/kℓ
Transitional Metropolitan Substructure of Cape Town	68 c/kℓ
Port Elizabeth Transitional Local Council	62 c/kℓ

Hammarsdale is an exception and has a treatment cost of R2,49 per kℓ. This figure is derived by simply dividing the total treatment annual cost by the amount of wastewater reaching the works over the year. There is very little infiltration experienced in this industrial area which is in close proximity to the works. It should be noted that the influent wastewater at the Hammarsdale Treatment Works is characterised by high strength and low volume. If there was more volume and reduced strength the treatment cost per kilolitre would be very much lower than R2,49. The high overall treatment cost of R1,07 per kℓ for Pinetown is due to the imbalance created by the Umlaas Treatment Works where the cost is R4,04 per kℓ.

It is a very small works where the operating costs per kℓ are distorted by the economies of scale normally associated with small works of similar size. The overall treatment cost for Pinetown is a combination of the three treatment facilities in the area, and indicative of the potential financial benefit from effluent tariffs calculated on a uniform basis in a Metropolitan size area.

15. ACTUAL vs CALCULATED EFFLUENT INCOME BASED ON TREATMENT ALONE

This comparison provides a good reflection of whether sufficient income is being obtained from industry or whether the formulation is at fault.
Based on the % industrial COD load shown in **Table 10 (a) and (b)** and using the actual total treatment expenditure, it was possible to calculate the proportion of the operating expenditure due from industry. The actual income vs calculated income based on treatment expenditure alone is illustrated in **Table 18**.

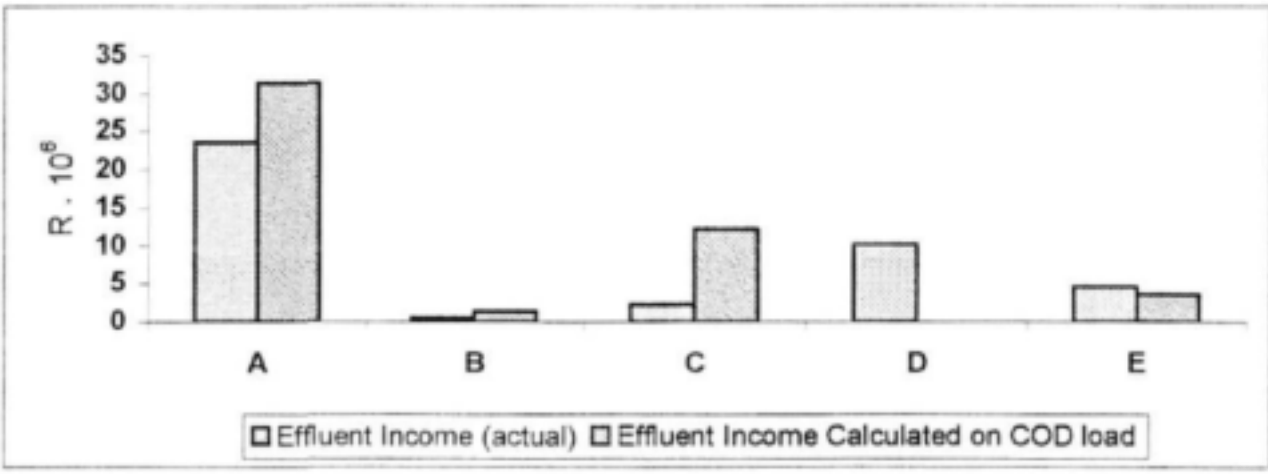
Explanatory Notes:

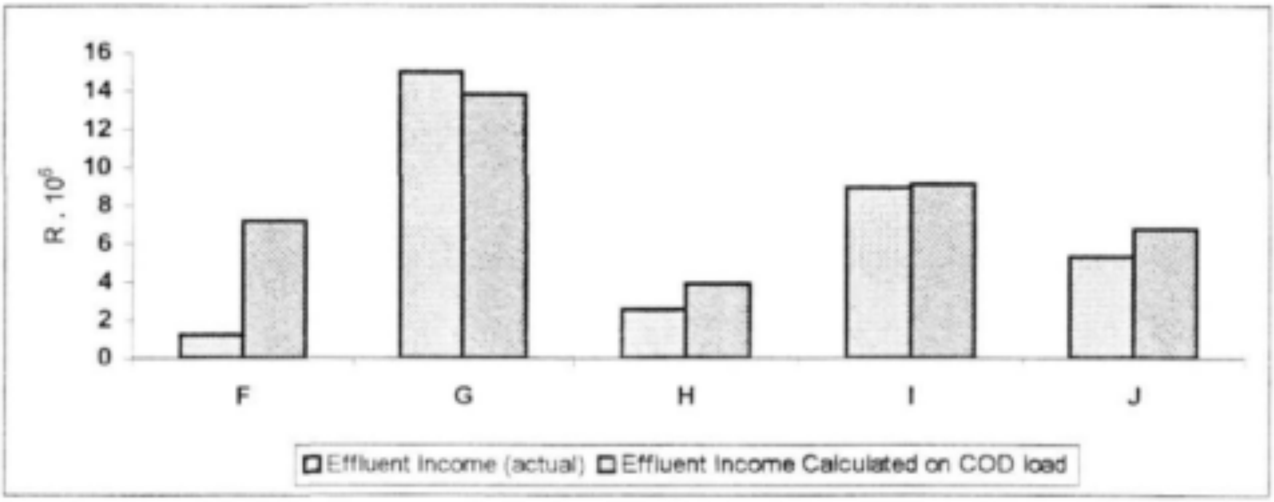
Actual effluent income is based on combined conveyance and treatment charges and therefore it is not expected that this figure would be lower than the calculated effluent income based on COD load and on treatment alone. A cursory glance at **Table 18** shows striking under recoveries within some of the local authorities.
The under recoveries as shown in **Table 18** indicate a need for all local authorities to review their effluent tariff charging procedures such that the actual income for conveyance and treatment is in line with the calculated estimates. In just about every organisation involved in this project, the effluent section does not concern themselves with sewerage tariff income. While this data is certainly available in one form or another, it needs to be part of the routine data retrieval process. This again directs attention to the need for effluent personnel to liaise with engineering staff from the sewerage division and to acquire a familiarity with all costs and income related to the operation of the sewerage system. This is what "conveyance" is all about.

Table 18 : Actual vs Calculated Income on treatment expenditure

	Effluent Income (actual) R•10⁶	Effluent Income Calculated on COD load R • 10⁶ excl. conveyance
A	28,72	29,44
B	0.473	1.36
C	2.216	12.14
D	10.2	-
E	4.614	3.58
F	1.2	7.2
G	15	13.83
H	2.55	3.9
I	8.93	9.1
J	5.3	6.75

Where:
$R \bullet 10^6$
= R 1000 000





16. INCORPORATION OF SLUDGE DISPOSAL INTO THE TREATMENT COMPONENT

It was noted that, with the exception of Durban, there has been a shift away from the classical type formulation (shown below) incorporating a separate sludge handling/disposal component viz.:

charge per kilolitre = Conveyance + Treatment

Treatment → Liquid phase, Solid phase

= X + V + Z

X → conveyance; V → liquid; Z → solid

$$= X + V\left(\frac{C}{R}\right) + Z\left(\frac{B}{S}\right)$$

The general formula most in use is

Effluent charge c/kℓ = Conveyance + Treatment

$$X + V \bullet \left(\frac{COD_l}{COD_b}\right)$$

Where X = unit conveyance cost c/kℓ
V = unit treatment cost c/kℓ for a COD value of COD_b

For purposes of the objectives of this project there is no justification for splitting the liquid and solid handling operational costs on sites where staff are interchanged and the allocation of load and solids production to different phases is a daunting task. With the type of activated sludge systems in operation and now being designed, and the ability now to calculate solids production from a COD mass balance, (WRC Nutrient removal guide 1984) there is only a need for one treatment cost that includes liquid and solid. That is the bottom line.

Some of the local authorities use internal cost allocation methodologies to split the expenditure between the liquid and solid phases.

17. MAJOR SOURCES OF REVENUE FOR EFFLUENT TREATMENT

With the exception of the Hammarsdale industrial area and its unique circumstances, it was evident in every other instance that a small number of industries provide the bulk of the effluent income as in shown in the pie charts on the next 4 pages and tabulated in **Table 19.**

Table 19 : Financial Impact of Major COD Load Contributors

Local Authority	No. of major Industries	Effluent income from specific industries (rand $\bullet 10^6$)	Contribution (%)	Total effluent income (rand $\bullet 10^6$)
A example 1	24	21,07	73,4	28,711
A example 2	1	15,106	52,6	28,711
B	4	0,449	95	0,473
C	20	1,772	80	2,216
D example 1	18	5,304	52	10,20
D example 2	64	6,936	68	10,20
E example 1	7	3,365	72,5	4,614
E example 2	1	1,938	42,4	4,614
F	10	1,024	85,4	1,200
H	4	2,110	82,7	2,550
I	11	8,93	100	8,93
J	17	4,529	85,3	5,31

- Most of the By-Laws of the above local authorities stipulate limiting COD concentrations yet there is no indication of any of these limits being adhered to. One benefit of high COD concentrations particularly those with a significant biodegradable component is its application as an essential substrate for biological phosphate removal. This has been successfully applied within the Johannesburg Metro Substructure with rebates of up to 50% subject to certain conditions.

- Due to the extent and significance of their contribution there is ample justification to ensure that certain industries are sampled, monitored and analysed more frequently.

- Unless there is knowledge of toxic discharges from certain industries, time and effort should not be wasted on small contributors of effluent load.

Illustration 1 Local Authority A

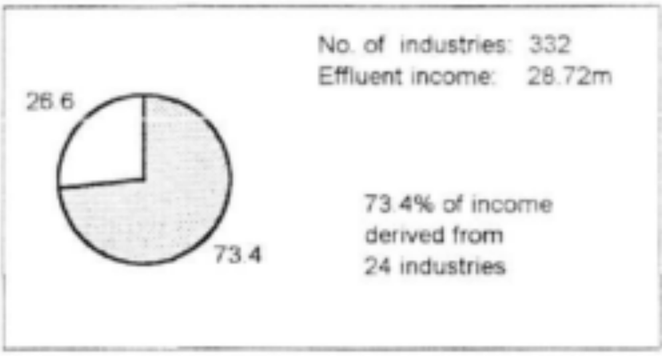


Illustration 2 Local Authority A

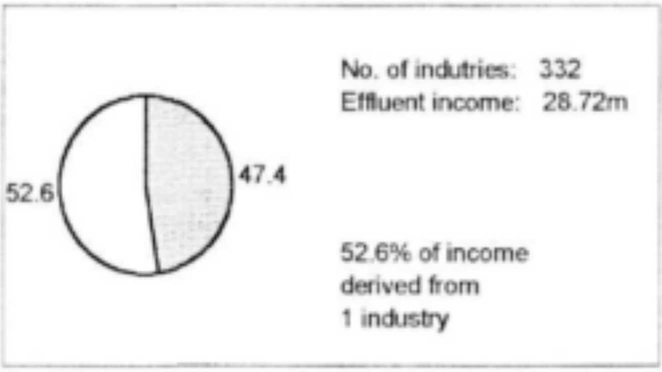


Illustration 3 Local Authority B

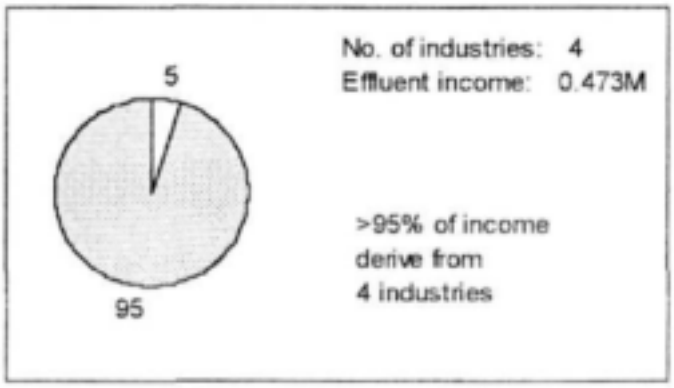


Illustration 4 Local Authority C

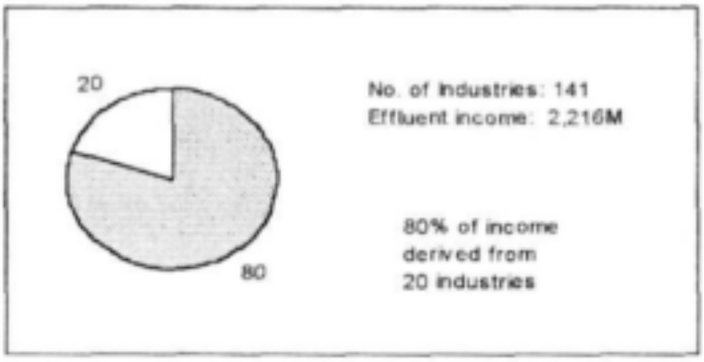


Illustration 5 Local Authority D

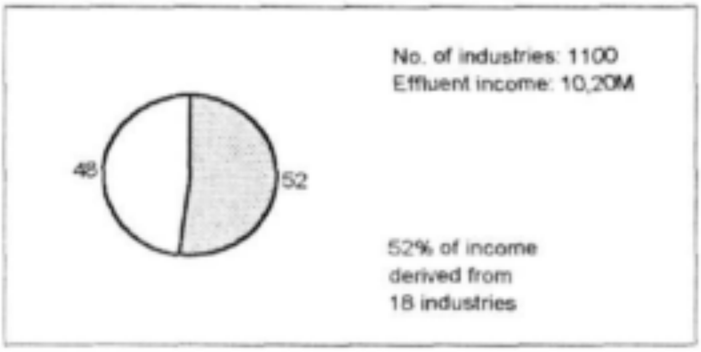


Illustration 6 Local Authority D

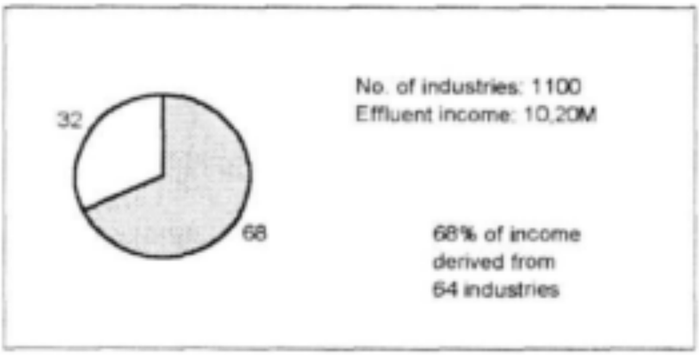
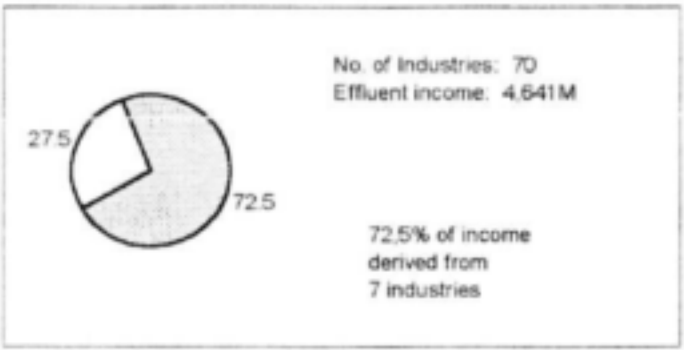


Illustration 7 Local Authority E



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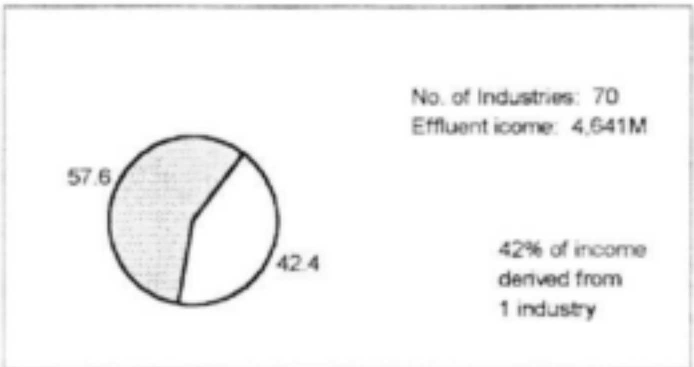

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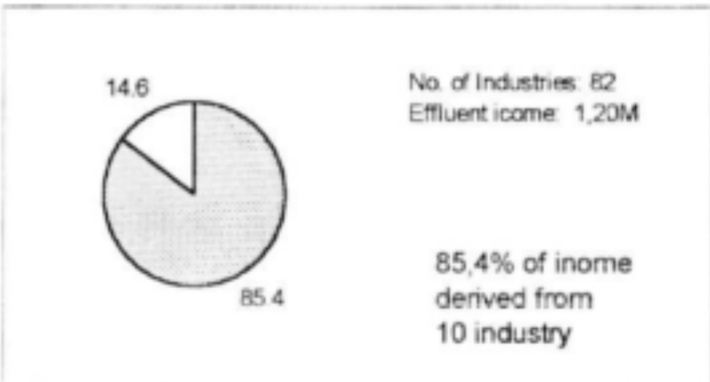

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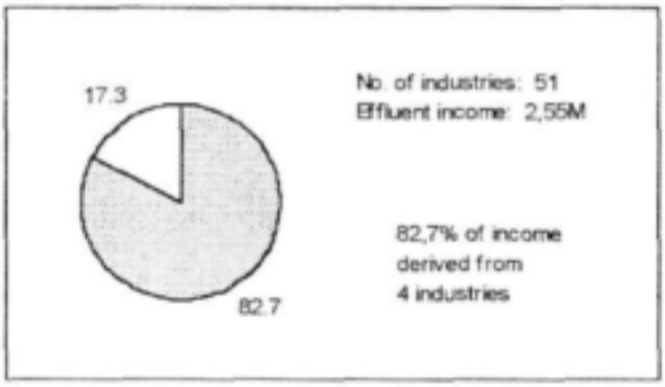
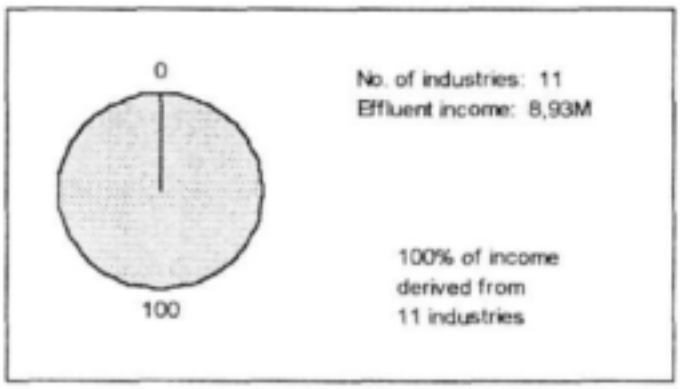


Illustration 11 Water Authority I



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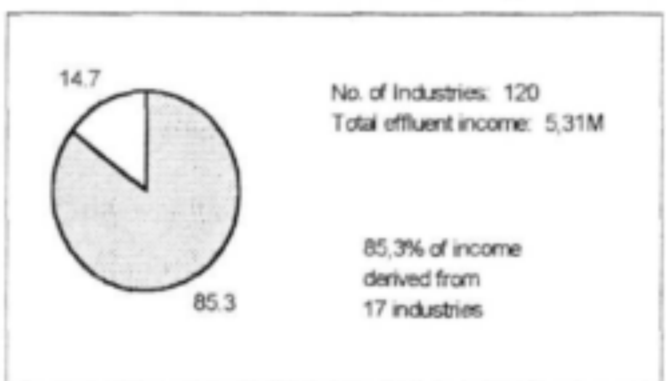

18. SEWERAGE TARIFFS AND CONVEYANCE CHARGES

This important component of any industrial effluent formulation has not received the attention it deserves, even though on the surface its application looks relatively simple. It could be that within all organisations, there is little enthusiasm to change a formula whose structures have been used for years.
Therefore new proposals are accepted and added to previous poor systems in operation, without a total review and overhaul of the system under investigation.

It is not surprising therefore to find that:

- Pinetown, Johannesburg, Port Elizabeth and Springs charge industry a sewerage tariff, over and above the conveyance and treatment charge.

- Pietermaritzburg has an element of double charge.

- It was only in Cape Town, Estcourt , that there is no sewerage tariff applicable to industry.

- Even after discussions with officials from all of the above organisations, it was not always clear how the factors or constants are derived from time to time to ensure that they are accurate, reliable, and reflect the correct financial situation.
  If all of the expenditure for sewerage is divided by the total annual influent wastewater at the treatment works, less an estimated amount for infiltration, then a conveyance rate per kilolitre is obtained. This rate in cents per kilolitre is the same for everyone; domestic, industry, and commerce. It is geographically unbiased and will, if implemented at least provide a more realistic picture of an equitable sharing of the sewerage costs amongst all users of the system.
  Should industry be required to contribute a capital contribution such as in the Pinetown Local Council, then it should rebated accordingly, since the capital charges are incorporated in the sewerage operating expenditure.

PART III

GUIDELINES ON THE FORMULATION OF AN EQUITABLE EFFLUENT TARIFF STRUCTURE

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GLOSSARY OF ACRONYMS AND DEFINITIONS

ACRONYMS

AHC	Average Historic Cost
BOD	Biochemical Oxygen Demand
CMA	Catchment Management Agency
CM	Catchment Management
COD	Chemical Oxygen Demand
CPI	Consumer Price Index
DEAT	Department of Environmental Affairs and Tourism
DH	Department of Health
DWAF	Department of Water Affairs and Forestry
GAAP	Generally Accepted Accounting Practices
GAMAP	Generally Accepted Municipal Accounting Practices
ICM	Integrated Catchment Management
IMFO	Institute of Municipal Financial Officers
IMTA	Institute of Municipal Treasurers and Accountants
NWA	National Water Act,1998(Act 36 of 1998)
OA	Oxygen Absorbed
O & M	Operation and Maintenance
PPP	Polluter Pays Principle
PV	Permanganate Value
RBCOD	Rapidly Biodegradable Carbon
ROA	Return on Assets

RDM	Resource Directed Measures
RQO	Resource Quality Objectives
RWQO	Receiving Water Quality Objectives
WA	Water Act,1956(Act 54 of 1956)
W E & T	Water Environment and Technology
WLA	Waste Load Allocation
WSAU	Water Service Authorities
WSA	Water Services Act,1997(Act 106 of 1997)
WSP	Water Services Provider

DEFINITIONS

Arithmetic Mean	The sum of the values obtained divided by the number of observations $X = \frac{\sum X}{N}$ (Willemse 1990)
Capital charges	Interest and redemption charges on capital borrowed
Capital funding	Refers to the financing of capital infrastructure, primarily the borrowing of money e.g. loans or bond issues on the capital market, to fund capital infrastructure development.
Coefficient of variation...........	This is the ratio, expressed as a percentage of the standard deviation to the mean. It is used for the comparison of the variation of two sets of data with different means, sample sizes or measurement units.
Conveyance	The transport of effluent or any liquid waste in the sewer network from the point of discharge to the inlet of the treatment works.
Depreciation...........................	The real cost of operating wastewater infrastructure in that it represents the loss in value of facilities not restored by current maintenance, that occurs due to wear and tear, decay , inadequacy and

	obsolescence due to technological advancement. **Or alternatively,**
Depreciation...........................	The systematic distribution of the cost price of a fixed asset over its useful life and is applied on a straight line basis viz equal amount over the useful life of the assets.
Dry Industry...........................	An industry whose manufacturing process does not produce an effluent of any significance e.g furniture and engineering fabrications.
Economic Value	The cost that represents the scarcity value of a good which would prevail in competitive markets.
Expenses	Outflows of economic benefits or depletions of assets or increases in liabilities that reduce own capital
Externalities...........................	These are essentially activities whose full cost or benefits are not incorporated into an economic decision; hence they lead to sub-optimal social allocation.
Fixed Costs	Expenditure that does not vary significantly during a particular financial year and which is not affected by the **COD** loading.
Geographically unbiased.......	The same for all users of the sewer network irrespective of their proximity to the treatment works.
Industrial Effluent	Any liquid, whether or not containing matter in solution or suspension, which is given off in the course of or as a result of any industrial, trade, manufacturing, mining or chemical process or any laboratory, research , service or agricultural activities
Industrial sewerage tariff	This tariff is to accommodate the domestic effluent from staffing on the industrial site and is separate from the assessed industrial effluent portion.
Marginal Cost	This is the unit cost of treatment of the next (major) increase in treatment capacity.
Median	This is the value that occupies the middle position of a group of numbers in a numerical order. Half of the terms lie above this point and the other half below it. $\text{Median} = \frac{N+1}{2}$

	If there is an odd number of items the middle item of the array is the median. If there is an equal number of items, the median, is the average of the two middle items.
Opportunity Costs	The benefit forgone by using a scarce resource for one purpose instead of for its next best alternative use.
Precision	A measure of the closeness with which multiple analyses of a given sample agree with one another.
Return on Assets	Allows for the earning of a specific rate of return on the total financial investment used to finance the facilities used to convey and treat wastewater.
Reserve	The quantity and quality of water required to satisfy basic human needs by securing a basic water supply and to protect aquatic ecosystems in order to secure ecologically sustainable development and the use of the relevant water resource.
Revenue	Inflows of economic benefits or enhancement of assets or reduction of liabilities that increase own capital.
Sewerage system	The network of piping, pump stations, and all equipment associated with the transporting of liquid waste from all types of users to the treatment works.
Sewage	This is the liquid waste that emanates from residential areas and is of a domestic nature and is conveyed to the treatment works. Sometimes referred to as domestic wastewater.
Standard Deviation	A measure of dispersion about the mean. It measures the square root of the average squared distances of the observations from the mean. The larger the standard deviation in comparison with the data size, the wider the spread of data around the mean value.
Treatment Charges	Cost to treat one kilolitre of wastewater of a specified COD such that it complies with the effluent discharge requirements of the Department of Water Affairs and Forestry and the Department of Health.
Treatment Works	The facility where the wastewater is treated to the prescribed DWAF standards and DH guidelines for the liquid and solid phases respectively.

Wastewater	The combined liquid waste from all users of the sewerage system and includes domestic wastewater and industrial effluent.
Water Service Authorities	The NWA identifies Water Service Authorities as the local government responsible for service provision in terms of the constitution.
Water Service Providers	The NWA identifies Water Service Providers as the body actually providing the service, including the day to day activities needed to keep a water supply and/or a sanitation system running effectively.
Wet Industry	Any industry that produces a liquid effluent arising from the manufacturing process and whose volume and strength are likely to have an impact on the operation of the treatment works.
Weighted Mean	This is a measure which enables the calculation of an average that takes into account the importance of each value to the overall total.

$$\overline{X}_v = \frac{\sum X \bullet V}{\sum V}$$

PART III - GUIDELINES

19. GUIDELINES – BROAD OUTLINE

19.1 Introduction

The guidelines presented in this section of the project are intended to assist all personnel who are responsible for or involved in the implementation of an industrial effluent policy. The nature of the multiplicity of activities associated with industrial effluent tariffs is multidisciplinary and as such these guidelines will be beneficial to all parties involved.

The approach adopted has been to identify current practices, take cognisance of recent developments towards costing and financing and then to provide a systematic methodology which results in a tariff formulation that lends itself to at least full cost recovery. This tariff structure and the components that make up the formula reflect the principles highlighted in **Part 1** particularly the 'polluter pays principle', and is sufficiently flexible to allow for the incorporation of water use charges within the catchment to ensure that the Reserve and the aquatic ecosystems are protected. The structure also provides a means via the depreciation component to create a cash reserve fund dedicated to financing asset replacement and infrastructure upgrade.

These guidelines are to be used with discretion and have no statutory implication. However they have been compiled following input and discussion with a variety of involved and interested parties who are either directing, managing, or actively engaged in effluent tariff activities.

19.2 Methodology

The methodology recommended is the fixed – variable system where the fixed costs (which include depreciation and return on assets) and the variable costs are separated. These costs are used in conjunction with the effluent volume and the COD concentration to arrive at unit costs for the various components. It can be viewed as a positive attempt to concisely describe, clarify, simplify, and define all the components that contribute to the formulation of a tariff structure that is equitable.

A distinct tendency towards simplicity and ease of understanding without compromising any of the principles involved has been adopted. The background discussions on principles, alternate costing methodologies and financing methods are presented in **Part 1** of the project report.

It is accepted that other methodologies to breakdown costs are available and these are described elsewhere in the document. Careful examination of these alternatives did not indicate that they would yield any better basis for tariff charging than the procedure recommended.

19.3 Target Users

These guidelines are directed to engineers, consultants, scientists, technicians, industrial effluent personnel, managers, financial accountants, wastewater treatment operational staff and water quality officers. All of these multidisciplinary personnel are involved in the overall spectrum of activities related to industrial effluent tariffs.

19.4 Special Features of the Recommended Tariff Formula

- The fixed - variable costing method for expenditure allocation is based on the average historic cost, (hereafter referred to as **AHC**) but can also apply to budgeted expenditure depending on policy towards billing and time frames allowed for payment. There is a legislatory obligation to inform industry in advance of the tariff to be applied for the forthcoming period. This is usually advertised in the news media 3 months prior to the commencement of the application of the new tariff. However budgeted expenditure can always be reconciled at a later stage with **AHC** expenditure and the impact on final cost adjusted.

- The tariff structure has three basic components.

Conveyance - Treatment - Fixed costs

Where treatment = unit treatment cost (variable) • $\frac{COD_i}{COD_w}$

- The liquid and solid phase expenditures are combined into one unit treatment cost (variable).
- Depreciation has been removed from the O&M expenditure of both sewerage and treatment and shown under fixed costs. This depreciation will be based on current replacement value to ensure full cost recovery and escalated marginally to ensure a return on assets in keeping with generally accepted accounting practice (hereafter referred to as **GAAP**).
- The formulation allows for a cash reserve to be created to fund asset replacement and future augmentation schemes.
- It meets the guidelines of the **NWA** with no compromises on fundamentals yet displays an element of simplicity and lends itself to ease of understanding.

20. FUNDAMENTAL PRINCIPLES

The guidelines proposed are based on fundamental principles that need to be understood and comprehended by the users of this document. The following aspects have been taken into consideration.

- **Cost recovery**

  The purpose of an industrial effluent charge is to enable the relevant authority to recoup the proportionate costs from industry in accordance with their hydraulic and organic load contribution. These costs are part of the total expenditure incurred annually to operate and maintain the sewerage system and the treatment works in such a manner that they are able to comply with the defined standards and guidelines set by the Department of Water Affairs and Forestry (hereafter referred to as **DWAF**) in consultation with the Department of Health (hereafter referred to as **DH**) respectively and other relevant Government departments. These standards take cognisance of all the principles embodied in the **National Water Act ,1998 (Act 36 of 1998)** and the **Water Services Act ,1997 (Act 108 of 1997)** (hereafter referred to as **NWA** and **WSA** respectively).

- **Charges must be Fair and Equitable**

  Fair and equitable implies that the method of charge assessment will withstand scrutiny by industry, and that the same basis for charging can be equitably applied to all of the users of the conveyance infrastructure and the treatment works. There must also be a strong degree of transparency and the method of charge calculation seen to be fair by industry.

- **The "polluter pays" principle will apply**

  The local authority is the direct polluter of the receiving water, whereas industry is the direct polluter of the sewerage system. Thus industry is required to pay a charge commensurate with the degree of pollution discharged. This charge incorporates all the costs incurred to meet the environmental and legislatory standards required by DWAF.
  While the general norm for pollution assessment is provided by the chemical oxygen demand (hereafter referred to as **COD**) test, the local authority can legally agree by negotiation with industry in specific circumstances on the use of an alternate means of pollution assessment. However, it must be recognised that effluent is part of the production process, and the producer of this effluent must pay the proportionate cost. The principle of the "polluter must pay" is strongly emphasised and reinforced in the revised Water Law and the NWA .

- **Simplicity, ease of understanding and administration**

  The tariff formula and its structure must be such that it is simple to implement and lends itself to ease of understanding and administration, whilst also reflecting actual costs incurred to meet the requisite standards.

- **Conveyance geographically unbiased**

  The conveyance cost is geographically unbiased to eliminate arguments by users of the system with reference to their proximity to the treatment works. The resultant effect is that the rate per kilolitre for conveyance from the point of discharge to the treatment works will be the same for industry, commerce and the householder.

- **No "magic" formulae to suit all situations**

  A recognition and acknowledgement that it is not possible to compile a formulation that will provide the final answer to all industrial effluent charging problems.
  The bewildering complexity of the wide variety of industrial treatment process effluents combined with the heterogeneous nature of the wastewater which is a mixture of industrially and domestically derived effluent precludes exactness.

- **Provision for the implementation and administration of the effluent charging policy**

  Provision must be made in the administrative cost for the implementation, processing, monitoring and management of the industrial effluent policy. This includes adequate staffing at all times. This aspect is crucial to the success of any industrial effluent monitoring and charging system.

- **Level of expenditure to reflect legal compliance**

  The capital and operating costs incurred must be commensurate with legislatory compliance. This ensures that the inherent principles in Integrated Catchment Management (hereafter referred to as ICM), NWA, and WSA are satisfied.

- **No provision is made for any form of subsidization.**

  The true cost for the service provided is distorted when elements of subsidization and cross-subsidization are included in a tariff.

- **Industrial effluent tariff formula must not be seen as a substitute for adequate staffing, monitoring, sampling and on – site inspections.**

  The temptation to misuse the industrial effluent tariff formula as reflected above must be resisted at all costs. A good set of By-Laws which needs to be rigorously enforced with punitive penalties for non-compliance is the essence of preventing undesirable pollutants from entering the sewer.

- **Integrated scheme must apply when many treatment works are involved**

  Where more than one works are in operation in the area of jurisdiction, it is desirable that all costs are combined to form one integrated operating account. Similarly with the sewerage system. The procedures to arrive at the unit cost for conveyance and treatment remain the same based on the fixed – variable method, and it is the responsibility of each authority to determine and allocate the fixed and variable portions of the total expenditure. Such an approach will allow for a uniform tariff to be derived and applied within the operational area.

21. BENEFITS OF THE INDUSTRIAL EFFLUENT TARIFF FORMULA

- Provides a solid motivational basis towards ensuring that there is adequate staffing of the effluent inspectorate and laboratory since the cost to implement and manage an industrial effluent policy (including tariff of charges) is incorporated in the tariff formulation.

- Automatically caters for inflation because exact expenditure is used in the AHC approach, except for capital cost. The use of budgeted expenditure to approximate the AHC must be applied with caution.

- The role of the various components of the formulation can be readily gauged, and their derivation readily understood. The methodology of tariff calculation and the data used for such purposes will be transparent and available to all of the parties involved.

- There will be potential for improved water management within industry. This will lead to a greater awareness and appreciation by all levels of personnel involved, of the financial and environmental impact of proper effluent management and control.

- Industry will be encouraged to investigate the potential for water reuse. Such an approach is encouraged by DWAF, and will assist in the conservation of our precious water resources which are limited.

- The principle of the "polluter must pay" is reinforced and this highlights to industry the need for good effluent management practice on a continuous basis.

- Provides industry with scope to incorporate effluent expenditure into the cost of its product. This principle is in accordance with the NWA that recognises that effluent production is part of the manufacturing process, and is consequently a legitimate tax expense.

- Contributes towards ensuring that proportionate finance for services rendered is received from all users of the sewerage and treatment system.

- Allows local authorities to contribute towards the fulfillment of the aims and principles of the NWA and WSA resulting in full cost recovery and compliance with the DWAF Standards

- Provides a mechanism by which a local authority can establish a cash reserve, in keeping with the principles of GAMAP, for asset replacement and future infrastructure upgrade or augmentation, with respect to wastewater sewerage and treatment facilities.

- Addresses mechanisms that ensure that double charging is eliminated.

22. LEGISLATORY BASIS FOR EFFLUENT TREATMENT COST RECOVERY

The Water Services Act 1997, (Act 108 of 1997) (hereafter referred to as WSA) provides the legislatory basis for effluent cost recovery and revenue requirements by a Water Services Authority. In terms of Section 10(1) of WSA in respect of tariffs, the following is applicable:

- **Revenue requirements**

  A Water Services Authority must, when determining its revenue requirements on which tariffs for water services are based, take into account
  1) Recovery of overheads, operational and maintenance costs
  2) Cost of capital and
  3) Depreciation

- **Disposal of industrial effluent discharged via a municipal sewer to a wastewater treatment plant**

  Tariffs set, by a Water Services Authority, for the disposal of industrial effluent discharged to a wastewater treatment plant must be based on
  a) Volume discharged to a treatment works
  b) An estimate of the cost that will be reasonably incurred in collecting, conveying , treating and disposing of the effluent to comply with quality standards set for discharge to a water resource, including additional costs related to the treating of specific pollutants and
  c) Any costs that may be payable for discharge to a water resource e.g. water resource management charge in terms of **Section 56 (2) (c) of the NWA.**

23. BASIS FOR THE EXCLUSION OF POLLUTANT PARAMETERS SUCH AS HEAVY METALS, pH, PHOSPHATE, SETTLEABLE SOLIDS AND NITROGEN FROM THE GENERAL EFFLUENT TARIFF STRUCTURE

23.1 Introduction

When compiling a tariff structure it is always tempting to incorporate as many parameters as possible into the formulation. This very dilemma has led to the downfall of many theoretically and technically sound formulations and in the process rendered them as impractical and being permanently confined to the library shelf. Since one of the objectives of this project is to simplify, rather than complicate tariff structures, it is essential to examine the tariff structure and to delineate the balance between limiting pollutants by consent agreements, good monitoring practice and regular visits to each industry rather than adding many parameters into the formula rendering it clumsy, not easy to administrate, difficult to explain to industry, and impractical. Pollutants are preferably regulated at source, as promoted by DWAF in accordance with the NWA, and should be supplemented by a good set of By-Laws which carry punitive charges for excess pollutant discharges.
The parameters which were considered were chemical oxygen demand (COD) , phosphate(PO_4), heavy metals, pH , nitrogen and settleable solids.

23.2 Heavy metals

The charging for heavy metals is controversial judging from the literature and from the results of the survey in **Part II**. One school of thought is of the opinion that the concentration of heavy metals entering the sewer should be limited by the consent agreement between the service provider and the industries concerned. Furthermore the essence of any industrial effluent policy is good monitoring and inspection at frequent intervals in terms of the By-Laws to ensure that the limiting concentrations of the pollutants are not exceeded. It was noted that the UK guidelines (WAA 1986) do not recommend charging. Their approach is to limit heavy metals to concentrations that do not pollute directly or indirectly and that do not inhibit treatment processes and that if heavy metals do not pollute then their presence cost nothing and no charge should be made.

Roets (1978) cautioned that a tariff comprising of an additional charge for heavy metals should be implemented with great discretion and authorities should use it only in cases where significant additional costs are experienced in accepting these wastes. Ekama (1993) urged the management and operators of larger wastewater treatment plants in the metropolitan areas to examine carefully their By-Laws regulating metals discharges to the sewer. One of the best preventative measures is to prevent the metals from getting into the sludge.

Lotter (1991) emphatically recommends the removal of heavy metals at source, and is of the opinion that punitive tariffs will ensure effectiveness in controlling specific discharges.

This once again directs attention to proper staffing of the industrial effluent section. Competent personnel can identify, quantify, and in liaison with industry control the amount of heavy metals being discharged into the sewer. Cadmium appears to be the heavy metal of most concern because it can be accumulated from the soil by certain food plants (Bitton et. al 1980). Soils mixed with sludge containing metals should be monitored and treated with lime to keep the pH (water) above a level of 6,5. With respect to procedures considered necessary to monitor and control toxic metal additions to land, the most important control parameter is the soil analysis. Once the analysis is known then calculations can be made to determine the application rate to land in a manner such that the permissible limits (DH1993) are not exceeded.

23.3 Other parameters

pH

This is best limited in terms of the industrial effluent By-Laws with heavy penalties for any transgressions. It is virtually impossible to fully assess the overall effects of pH on a biological system when effluent that is outside of a pH range of 5,5 – 9,5 enters the main aeration tank for limited periods.The buffering capacity of the biological system is able to provide a barrier to any major biological malfunction when high acidity or high alkalinity prevails for periods of a short duration. While it is known that growth and synthesis of microorganisms are at a maximum when the pH environment is close to 7,0, it will take a very significant amount of highly acidic effluent, sustained for quite a few hours to result in the whole aerated system being severely affected. The aerated system assumes a type of activated sludge treatment process. The answer lies in consent agreements, heavy penalties for transgressions, and frequent random visits by effluent officers. This approach will compel industry to ensure that good effluent management practice is on-going. The main concern is related to situations where chemical addition using $FeCl_3$ or $Al_2(SO_4)_3 \cdot 14\,H_2O$ has been implemented to remove phosphate as either $A\ell PO_4$, $FePO_4$, or other similar type of solid precipitates. Highly acidic conditions will result in the solubilization of phosphate which is chemically bound in the sludge. In such cases, the penalties must allow for full cost recovery of all expenditure (involved to rectify the situation). It is also recommended that where pH plays such an important role, early warning systems that inform the controlling operators of acidity or alkalinity problems timeously, should be installed.

Settleable solids

There has been a trend observed within effluent tariff practice in South Africa, that the liquid and solid phase treatment costs are combined into one treatment operating expenditure account. There does not seem to be sufficient grounds for incorporating a settleable solids into the formulation. A further objection to the use of this parameter is that the result on its own does not provide any information on it's capability to undergo biodegradation.

Phosphate and Nitrogen

Existing legislation requires that a wastewater treatment works discharging to a water resource situated in a designated sensitive area must comply with a 1 $mg\ell^{-1}$ as "P" phosphate standard. This has been in force since 1984 (DWAF 1984), whereas the nitrogen standard now required under the general limits of the authorisations in terms of the NWA is < 3 $mg\ell^{-1}$ NH_3 and < 15 $mg\ell^{-1}$ NO_3/NO_2 (Government Gazette No 20526 1999). The removal of nitrogen and phosphate via biological means and sometimes supplemented with chemical addition, is closely related to the COD. The presence of COD in domestic wastewater nearly always has sufficient phosphate and nitrogen associated with it to ensure that the biological mechanisms of N and P removal can take place. Most industrial wastewaters do have nitrogen and phosphate but not necessarily in balanced proportions; and in many cases are deficient of N and P. It should be accepted that N and P are necessary and desirable components of the effluent and should not be regulated through a tariff formula.

If any industry has an effluent whose N and/or P concentration significantly affects the overall cost of treatment, or compliance with the standards promulgated, then the problem should be addressed at source rather the through effluent tariff.

Allowing for the fact that only the variable expenditure will be involved in calculating the treatment cost, the COD parameter provides the best compromise of blending all the requirements for an equitable tariff structure; and these are mentioned elsewhere in this project.

24. GENERALLY ACCEPTED MUNICIPAL ACCOUNTING PRACTICES (GAMAP)

24.1 Introduction

The accounting principles used by local authorities in South Africa differ significantly from those that are generally recognised internationally. To promote transparency and allow for comparisons between local authorities, GAMAP has been introduced by the Department of Finance. This is a requirement in terms of **Section 216(1)** of the Constitution

24.2 GAMAP Framework

GAMAP consists of an accounting framework that defines assets, liabilities, revenue, expenditure, and own capital and sets out the criteria for including them in the financial statements of a local authority. This framework is based on internationally recognised accounting principles that apply in both the private and public sectors.

Definitions

Elements	Definition	Example
Assets	An asset is a resource controlled by a local authority which will result in future economic benefits (usually cash) or will enable the local authority to provide services in the future	
Liabilities	A liability is an obligation of the local authority that will result in an outflow of future economic benefits or for which service delivery must still be provided.	
Own Capital	The difference between assets and liabilities.	
Revenue	Inflows of economic benefits or enhancement of assets or reduction of liabilities that increase own capital.	• Rates and service charges received in cash or which increase assets (debtors) where cash is still to be received. • Interest received as this resulted in cash being received or if the interest was capitalised, and increase in assets (investments).
Expenses	Outflows of economic benefits or depletions of assets or increases in liabilities that reduce own capital	• Salaries, wages and other personnel costs as these resulted in outflows of cash • Purchases of goods and services

		as these resulted in the outflow of cash or an increase in liabilities (trade creditors). • Depreciation because there is usually a reduction in the value of an asset over time and when it is used.

24.3 Key benefits of GAMAP:

- Consistency in the accounting principles applied
- Harmony with internationally recognised accounting standards
- Promotes a better understanding of the operating results, financial position and cash flows of local authorities.
- Facilitates comparisons between local authorities, all using the same accounting principles.

24.4 Implications of GAMAP

- Fixed assets will be depreciated and disclosed in the financial statements at historical depreciated values.
- Internal charges will no longer constitute expenditure. Contributions to reserves and statutory funds will no longer be included in the income statement as an expense.
- Loan repayments (redemption) are not regarded as an expense and will no longer be included as expenditure.
- Interest capitalization is no longer permitted and interest paid is an expense and must be included in the income statement in the period that such interest was incurred.
- Local authorities must budget for working capital reserves. These reserves cannot be included in the financial statements. The reason is that the working capital reserve is effectively a budgeted bad debt provision. The actual bad debt provision must be included in the financial statements instead of a working capital reserve.

24.5 How does GAMAP affect this project?

A time frame for the implementation of GAMAP has been devised by the Public Services Accounting Practices Board appointed by the Minister of Finance in terms of the Public Finance Management Act. Local authorities can expect GAMAP to be implemented on July 1,2002. This will allow staff to become familiar in the interim period with the changes from fund accounting to depreciation accounting and the format of financial statements under this system. The capacity of local authorities to implement these changes is also a matter of concern. At present local authorities are still using the traditional municipal fund accounting system and are likely to continue in such a manner until GAMAP is fully operational. To avoid confusion the present costing system is used in the first two examples given and compared with the anticipated format of the same data (**TABLES 25, 25a, 26, and 26a)** using depreciation while attention is drawn to the key changes that will impact on the recording and presentation of expenditure information. This is particularly relevant to the use of depreciation and it's use to create a cash reserve fund.

24.6 Depreciation substitution for fixed redemption charges

In terms of GAMAP, fixed redemption charges will be replaced by depreciation which will be recorded as an expense. The depreciation will be undertaken on a straight line basis over the useful life of the asset. The depreciation must be undertaken on the current replacement value of the asset. ImfoPro in a presentation to the Institute of Municipal Financial Officers (ImfoPro 1999) produced a schedule of estimated useful lives of infrastructure assets, as shown in **Table 20 .**

TABLE 20: Useful lives of infrastructure assets

ASSETS	USEFUL LIFE (yrs)
Sewerage:	
Sewers	20
Outfall	20
Purification works	20
Sewerage pumps	15
Sludge machines	15
Plant and Equipment :	
Graders	10-15
Tractors	10-15
Mechanical horses	10-15
Farm equipment	5
Lawnmowers	2
Compressors	5
Laboratory equipment	5
Radio equipment	5
Telecommunication equipment	5
Office Equipment:	
Computer hardware	5
Computer software	3-5
Office machines	3-5
Air conditioners	5-7
Buildings	30

In the financial statements the depreciation will be shown at the historic cost.

24.7 Establishment of a cash reserve fund

Local authorities will have to create non-distributable reserves, and any other reserve required by law. Non-distributable reserves can either be statutory or voluntary. Non-distributable reserves generally arise as a result of a management decision that profit from an extraordinary transaction should not, according to sound accounting practice, be available for distribution. e.g. profit arising from the revaluation of fixed assets is regarded as unrealised and therefore not available for distribution. Such profit is retained as a reserve and must be shown as such in the balance sheet. A portion of available profit can be set aside for a specific purpose. e.g. Cash reserve for increased replacement costs of fixed assets or transfer to a general reserve. In practice this cash reserve will be realised from the depreciation component and will be supplemented by a "return on asset" charge based on a predetermined percentage of the depreciation amount.

25. DEPRECIATION AND RETURN ON ASSETS

25.1 Introduction

Depreciation is the process whereby the cost price of a fixed asset is systematically distributed over its useful life, in order that the cost of use may be appropriately matched or measured against the income generated by that use, (**or alternatively**).

Depreciation is a real part of the cost of operating wastewater infrastructure, in that it represents the loss in value of facilities not restored by current maintenance, that occurs due to wear and tear, decay, inadequacy and obsolescence due to technological advancement (Faul et al 1992).

A compilation of an inventory of assets relating to existing wastewater infrastructure and the evaluation of current and depreciated replacement value for each item of significant infrastructure with its useful life is necessary and essential at specified intervals. The technical life span, determined by factors pertaining to the technical nature of the asset concerned, terminates when the asset can no longer provide the service for which it was required, maintenance costs notwithstanding. Of all the aspects relating to depreciation, cost price alone can be determined with certainty. Sound clear judgement and skill must therefore be used in determining the other factors in order to arrive at a reasonable depreciation cost.

25.2 Methods of calculating depreciation

The most generally used methods are the following (Faul, Pistorius and van Vuuren 1988).

1) **Fixed instalment method**

According to the method (also known as straight-line method) depreciation is regarded as a function of time. An equal portion of the amount subject to depreciation is allocated to each accounting period over the lifespan of the asset. This method is illustrated in the example provided.
Using this method, 1) the annual provision for depreciation remains the same 2) the accumulated depreciation is increased annually by an equal amount 3) the net book value is decreased annually by the same amount until the estimated trade-in value is reached at the end of the last year of the assets lifespan.

2) **Diminishing amount methods**

These methods are known as accumulated methods of calculating depreciation and are based on the premise that the decrease in an asset's value is greater in the first years of use than in later years. These methods usually result in depreciation which decreases constantly from year to year.

3) **Production methods**

These are based on the premise that depreciation should be linked to the use of the asset and time is not a determining factor.

Fixed instalment Method

<u>EXAMPLE</u>: Fixed – instalment method (also known as straight-line method) of depreciation

Cost price of a plant item: R16 000 000
Estimated scrap value at end of 10th year: R500 000
Life span of asset: 10 yrs

Table 20a Asset and Depreciation schedule:

Date	Cost Price	Annual provision for depreciation	Accumulated depreciation	Net book value
Date of purchase	16 000 000	-	-	16 000 000
End of year 1	16 000 000	1 550 000	1 550 000	14 450 000
End of year 2	16 000 000	1 550 000	3 100 000	12 900 000
End of year 3	16 000 000	1 550 000	4 650 000	11 350 000
End of year 4	↓	-	-	↓
↓	↓	↓	↓	↓
End of year 10	16 000 000	1 550 000	15 500 000	500 000

Total depreciation R15 500 000

In the above example the R15500000 is not the replacement value since in a dynamic and inflationary environment prices of equipment will most certainly increase over 10 years and hence the necessity for regular re-valuation. This supports the need for the establishment of a renewal or replacement fund. The accumulated depreciation costs based on current replacement value will allow for the provision of realistic asset replacement funding. With depreciation the emphasis is on the systematic and realistic apportionment of the expenses involved in using the fixed assets. Accordingly, the balance sheet does not show the current market value of fixed assets nor does the depreciation provided measure the decrease in value over a period. Depreciation is simply a process of apportionment and not a process of valuation. Assets shown at AHC are frequently undervalued.

25.3 Value of Assets

The value to an organisation of any of it's assets is the loss the organisation would suffer if it were deprived of the asset. In the great majority of cases this is equal to the amount it would cost the organisation to replace the asset in its existing condition. It will therefore normally be appropriate to value assets in the balance sheet by reference to their current replacement cost (allowing for depreciation where appropriate) taking any holding gains which may arise to a fixed asset revaluation reserve.

In a proper current cost accounting system, the increased charge for depreciation is intended to increase the historic cost charge to that of a new asset of similar technology (purchased at the end of the year). Therefore, if these suggested indices are used, the depreciation adjustment will give an approximate reflection of the loss of service potential, in replacement cost terms, of the existing assets if no major technological changes took place. If replacement cost is used, without allowing for technology innovation the assets may be overvalued in comparison with new assets with similar productive capacities.

25.4 Return on Assets

Section 56 (2) (b)(v) of the NWA makes provision for a return on assets. The return on assets is intended to pay the annual interest cost of debt capital and provide a fair rate of return for the total capital employed to finance wastewater infrastructure. A rate of return on assets can be justified from the point of view of there being an opportunity cost associated with the utilization of scarce capital resources for the development of wastewater infrastructure and that the cost should be reflected in the tariffs.

Traditionally local authorities charge users for their share of operating costs, including operations and maintenance (O&M), debt service, and replacement costs. Legislative amendments are required to allow local authorities to charge tariffs that not only reflect the operating costs but also provide a return on investment based on the value of the sewerage and treatment infrastructure. **Such amendments should specify that the additional funds accumulated in the above manner will be for a specifically defined purpose.** It has been suggested that water pollution control and prevention should be viewed as a local investment in environmental protection and ratepayers and the communities will be the beneficiaries.(WE&T –USA 1999)

In keeping with the depreciation and return on assets rationale as described in the preceding paragraphs the proposed formulation will allow for full cost recovery (O&M expenditure + depreciation at current replacement cost) and provide a return for investors – the local community. Provision is made under fixed costs for the incorporation of a return of assets charge by inflating the depreciation amount by a predetermined percentage authorised and approved by the executive management. This value could, **inter alia,** be the official inflation rate.

26. ESTIMATION OF INDUSTRIES' SHARE OF COSTS (USING COD LOADINGS) FOR TREATMENT AND CONVEYANCE

Before setting out guidelines on the overall conveyance and treatment tariff structure a brief presentation is made on how to approximate the share of the costs due from industry using COD loading as the main criteria. Such an exercise must be realistic in terms of effort, and the use of manpower effectively. There is little point in devoting plenty of time and energy to hundreds of small enterprises that do not produce more than a few kilolitres of effluent daily. Of course if there is knowledge of any toxic material present in the effluent then it will warrant attention in proportion to its evaluated potential impact to the system.

Regular monitoring of each significant "wet" industry within each local authority provides data on the strength of their waste as well as the volume of effluent which is assessed either by direct measurement or calculated from water consumption including the contribution of boreholes, less allowable deductions for boilers, cooling systems, water in product, staff on site etc. Similarly, data is available at the treatment works on the total flow arriving at the works; the average strength of the influent; and the total costs to operate the sewerage and treatment systems. Thus for each twelve month period, one can calculate the proportion of industrial effluent with respect to the total flow (including infiltration) that was conveyed to the works. Similarly by multiplying the volume of effluent by the average industrial effluent strength, and by multiplying the total flow received at the works by the average strength expressed as mgℓ$^{-1}$ COD , one can calculate the total load received at the works and the approximate proportion contributed by industry based on COD mass load.

Since the total expenditure (staff, overheads, maintenance, electricity, depreciation) for the sewerage system as well the treatment works, will be known, the hydraulic and organic load contributions and their relationship to the total expenditure can be calculated.

This provides a guide in terms of the expenditure that is incurred by the local authority in conveying and treating industrial effluent and the approximated amount that should be recouped from industry by the particular tariff system in use.

Data required (12 month period)

a) Collective assessed volume from "wet" industry: ...."a"..............kℓ
b) Weighted COD of all these industries : ...."b"..............mgℓ$^{-1}$
c) Volume arriving at the works (metered) : .... "c"..............mgℓ$^{-1}$
d) Average COD at the works: .... "d"............. mgℓ$^{-1}$

- Hydraulic loading due to monitored industry $= \left[\frac{a}{c} \bullet \frac{100}{1}\right]\%$

  Approximate income due to conveyance of industrial effluent to the treatment works

  $= \left[\frac{a}{c} \bullet \frac{100}{1}\right] \bullet$ Z <u>(rands)</u>

  where $Z = \frac{\text{sewerage expenditure}}{100}$

$= \text{"S" Rands}$

COD mass load due to industry (monitored wet industry) $= \sum (\text{Flow} \cdot \text{COD})$ for each industry

$= (a \cdot b)$ kg

COD mass load arriving at the works $= \text{flow} \cdot \text{avg COD}$

$= (c \cdot d)$ kg

Estimated income for treatment due from industry $= \left[\frac{a \bullet b}{c \bullet d} \bullet \frac{100}{1}\right] \bullet \; W \; \text{(rands)}$

where $W = \dfrac{\text{treatment expenditure}}{100}$

$= \text{"T" Rands}$

∴ Total calculated amount due from the monitored industries for conveyance and treatment of industrial effluent .

$= (S + T)$ Rands

In the examples above treatment expenditure includes all O & M expenditure + depreciation.

27. BASIC TARIFF STRUCTURE AND COMPONENTS

27.1 Definitions

TARIFF STRUCTURE consists of 3 primary components:

- Conveyance
- Treatment
- Fixed costs

CONVEYANCE is the transport of the industrial effluent from the discharge point to the inlet of the treatment works via a sewer network.

TREATMENT is the purification and disposal of the liquid and solid phases to the prescribed standards and guidelines of DWAF and the Department of Health(DH) respectively.

FIXED COSTS are items of expenditure that do not vary with COD load and remain relatively constant throughout the year.

VARIABLE COSTS are defined as items of expenditure that vary significantly with volume and COD loading.

SEMI-VARIABLE COSTS are costs which consist of fixed as well as variable cost elements and which do not vary in direct proportion to changes in production levels e.g maintenance costs

TARIFF UNIT CHARGE is the summation of the three component unit costs expressed in c/kℓ.

$$\textbf{TOTAL COST} = \left(\underset{(c/k\ell)}{\text{conveyance}} + \underset{(c/k\ell)}{\text{treatment}} + \underset{(c/k\ell)}{\text{fixed costs}} \right) \bullet V\,(k\ell)$$

where V = the volume of effluent assessed from the water consumption using the recommended procedure in **Appendix V** and expressed in kilolitres.

The derivation of the unit cost of each component will be illustrated in the following paragraphs.

Unit conveyance cost - this is the unit geographically unbiased cost to transport 1kℓ of effluent from the industrial site to the treatment works via the sewer network.

Unit treatment cost - this is the cost to treat 1 kℓ of industrial effluent to the requisite standards and guidelines of DWAF and DH respectively

Unit Variable Treatment Cost

- this is the unit cost to treat one kilolitre of wastewater at a specified COD concentration, based on the variable portion of the treatment expenditure.

Unit fixed cost - this is the portion of each kilolitre of the total unit cost that is due to fixed expenditure independent of the strength of the wastewater

COD_i - this is the mean chemical oxygen demand of a number of samples from the industrial contributor and is expressed in $mg\ell^{-1}$

COD_m - this is the mean chemical oxygen demand of a number of samples taken at the works over 1 yr period and is expressed in $mg\ell^{-1}$

COD_w - this is the weighted mean and is applicable where a number of treatment works are in operation e.g. Metro or Unicity

Examples of fixed and variable costs

Fixed: redemption
depreciation + interest
permanent staff salaries
vehicles
repair and maintenance
administration

Variable: chemicals
electricity (power)
sludge production
&
disposal

Semi - variable
Some maintenance costs are incurred irrespective of whether the equipment is used. These constitute the fixed cost element. However, if it happens that the more the equipment is used in the operating process, the greater the maintenance costs incurred; this is the variable cost element of maintenance costs. In the final analysis it will be up to each local authority and their officials to assess and allocate the expenditure into fixed, variable and semi-variable categories. Some allocations will be subjective.

27.2 FIXED COSTS

Fixed costs are defined as items of expenditure that are not likely to vary significantly during a particular financial year and which are not affected by the **COD** loading. These costs include depreciation. Since these are part of the overall expenditure they can be used in conjunction with flow data to calculate the fixed proportion of each kilolitre of the bottom line unit cost to the service provider. This section will indicate how the depreciation shown in the fixed cost data is used to create cash reserves for asset replacement and to fund future capital works.

The appearance of a fixed costs component which includes depreciation in the tariff structure is unique to the Southern Africa experience with respect to local government.

If all expenditure including depreciation is divided by the total flow then the overall **bottom line unit cost** to the service provider to convey and treat 1 kilolitre of combined effluent/wastewater is obtained. One component of this bottom line unit cost will be the fixed cost contribution i. e. every kilolitre treated at the works has a fixed cost component of which the depreciation is a significant portion.. This serves the purpose of separating different contributions to the overall bottom line unit treatment cost. Depreciation plus interest is currently denoted as interest and redemption in the fund accounting system. Once GAMAP is in operation redemption will fall away and will be replaced by depreciation. The depreciation value used will be based on the current replacement value and the asset will be depreciated over the useful or remaining useful life of the wastewater infrastructure.

By having a fixed cost a dimension of stability is given to the tariff structure in that each user contributes a fixed amount by virtue of his kilolitre usage using the unit fixed cost rate. Thus while the rate is the same for **everyone** the total amount due by each contributor will differ in proportion to the water utilization consumption.

The use of depreciation in terms of GAMAP will allow for the accumulation of a cash reserve fund dedicated to financing asset replacement and for upgrading of sewerage and treatment infrastructure. An additional contribution to this fund will be a % return on total wastewater assets. To ensure that the amounts reflected are realistic, all assets as per inventory are to be revalued at regular intervals, and the useful life of the asset reassessed.

The return on assets portion is incorporated in the depreciation component of the fixed cost. In practice this involves inflating the actual depreciation based on replacement value, by a marginal percentage to be agreed upon by the authority concerned and within the legislative financial guidelines. It has been suggested (DWAF 1998) that this percentage could be the **CPI**.

When effluent income is retrieved at defined intervals, a specific amount based on accumulated depreciation and return on assets must be deposited in a dedicated cash reserve fund.

Summation of the three components

Total bottom line unit cost = [unit conveyance cost] + [unit treatment cost (variable)] + [unit fixed cost]

27.3 Recovery of fixed costs

There is a concern that by using a fixed rate per kilolitre methodology there may be a major under or over – recovery if the predicted water usage does not materialise and/or if the projected growth is not achieved. This deficiency can be overcome by allocating a fixed cost amount to each user of the system. The basis for each fixed cost allocation will be apportionment using water consumption data. This approach must be applied to every metered user of the system to ensure equity.

It should be noted that while the fixed cost per user will be different in proportion to their water usage **the total fixed costs for the service provider remain constant in any chosen time frame.**

28. SEWERAGE SYSTEM AND CONVEYANCE

28.1 Introduction

There are two distinct parts to any industrial effluent tariff charging system. In the first instance the effluent must be conveyed to the treatment works through a network of piping which is called the sewerage system, and then it must receive the appropriate treatment which is usually biological to obtain a effluent quality that conforms to DWAF requirements.

However, on each industrial site there is a domestic component of wastewater derived from the number of staff on site and who contribute to the sewerage system and the treatment works on a daily basis. These contributions can be substantial depending on the size of the particular industry. The confusion arises from the manner in which local authorities attempt to recover the costs for such a service, and in many cases this results in a double charge.

The financing of a network of sewers to serve a town or city is an expensive undertaking which is even more so when the area of operation is heavily industrialized. The following paragraphs and subsections will discuss the terminology used in conveyance, the costing of sewer networks, and address the problem of double charging via the sewerage tariff in conjunction with the normal rates contribution. This will provide the user of this document with a broader insight into the purpose, financing and cost recovery of the conveyance component of effluent treatment tariffs.

28.2 Terminology

The terminology used in describing sewerage systems, the nature of effluent transported in these systems, and the conveyance of all effluent to the treatment works, requires clarification. This is necessary since many of the terms are incorrectly used and convey a confusing picture to those persons not directly involved in wastewater and effluent activities.

Sewer:

Length of pipe of adequate diameter that allows liquid wastes to be transported to the treatment works or to a marine outfall for treatment and disposal respectfully.

Sewerage System:

Network of piping, pump stations, and all equipment associated with the transporting of liquid waste from all types of users to the treatment works or marine outfall.

Sewage:

This is the liquid waste that emanates from residential areas and is of a domestic nature and is transported to the treatment works. Sometimes referred to as domestic wastewater.

Wastewater:

This is the combined liquid waste which will include sewage, industrial effluent, and other similar type of wastes. Domestic wastewater and sewage both have the same meaning in the context of the project.

Sewerage tariff:

This tariff is specifically designed to cover the costs of installing and operating a conveyance and treatment system to treat all **domestic wastewater**.

N.B. Some local authorities incorporate this cost in the rates and do not have a special sewerage tariff for cost recovery. It is viewed as a obligatory service in view of the rates paid.

Conveyance:

The transportation of liquid waste through the sewerage system to the destination point

28.3 Principles

- The amount of rates one pays and the basis of the sewerage tariff for industry is based on land value and area, or the floor space of the buildings. Proximity to the treatment works does not provide any benefit with respect to the conveyance tariff.

- The provision of sewerage and wastewater treatment services for handling domestic wastewater is regarded basically as a public service similar to electricity supply, with tariffs based on a "cost for service" principle. However if it is regarded as conferring diffused benefits throughout the community, like a public health service, different charging systems arise and it then becomes necessary to decide what proportion of revenue should be recovered by users directly and non users (through taxation or rates). Whether it is the householder, industry or commerce, all of their discharges into the sewerage system have to be transported to the treatment works, independent of strength.

- A sewerage system is installed with a useful life of at least 20 years but is never at full hydraulic load in the early stages of it's life span. This leads to a situation of unavoidable overcapitalization and underutilization in the short term. This situation accounts for the relatively high unit conveyance cost in the early stages of the useful life of the sewerage infrastructure. While these costs will be high they are incurred annually and must be recovered.

- In view of the complexities that will arise from attempting to accommodate industries located at varying distances from the treatment works **the best approach is to adopt a geographically unbiased** method of calculating the cost to convey one kilolitre of wastewater to the treatment site such that the cost is the same for every user of the system. For purposes of practicality the O&M costs are all regarded as fixed.

28.4 Sewerage expenditure and the cost of conveyance

Sewerage expenditure which is incurred annually does not differ much in nature from the treatment expenditure, and is detailed similarly to the data shown in **Appendix VI.** While the type of detail against various cost codes and cost centres may differ, the broad categories as recommended by IMFO are the same as for treatment expenditure.
O&M expenditure based on average historic costs (hereafter referred to as AHC) shown in **TABLE 21,** is expressed in the broad categories, of expenditure in accordance with the recommendations of the Institute Of Municipal Financial Officers (IMFO 1999).

TABLE 21: O & M sewerage expenditure (AHC)

SALARIES	....
REPAIRS AND MAINTENANCE	....
GENERAL EXPENSES	....
DEPRECIATION + INTEREST	....
	TOTAL ....

Depreciation is on a straight line basis and over a period of 20 yrs as recommended by IMFO. It should be noted that in terms of GAMAP depreciation is an expense and replaces the traditional redemption of loans.
In order that a geographically unbiased unit cost can be established for conveyance, the volume of wastewater that flows through the sewer network is required.

The metered volume is the amount of wastewater expressed in kilolitres arriving at the treatment works for the 12 mth period. This volume is likely to be inflated due to infiltration from rainfall, and can be dealt with in two ways.

1. The metered volume can be used without adjustment. This will mean a marginally lower unit cost for the conveyance and will be favourably biased to all users of the conveyance system, or

2. The metered volume can be adjusted for an assessed % of infiltration by competent persons, if the data is available. This will yield a unit cost more representative of the true situation.

3. Typical breakdown of the sub-categories of each of the cost centres shown in **TABLE 21**, is illustrated in the **Appendix VI**. This data is a true representation of the present municipal system of expenditure recording and has been extracted from the official records of one of the participating organisations.

The unit cost for conveyance (**as a separate component**) is as follows:

$$\frac{\text{O \& M expenditure including depreciation (Rand)} \bullet 100}{\text{Volume (kilolitres)}}$$

$$= \quad \text{"X" c/k}\ell$$

When the conveyance is combined with the variable treatment and the fixed costs, then the depreciation component of the sewerage expenditure forms part of the fixed costs.

Total unit cost = conveyance + variable treatment cost + fixed cost

Additional notes:

- The conveyance charge is geographically unbiased and independent of strength.
- Depreciation has been separated from the O & M expenditure and now forms part of the fixed costs.
- Conveyance should be viewed as a "user charge" no different from the conveyance of electricity.
- This conveyance unit cost is the same for all users of the sewer system. Therefore the domestic ratepayer should also be charged a conveyance cost at the same unit cost as industry. The key difference being in the manner in which the volume component is calculated for the domestic user e.g. % of the total metered water consumption.
- If the conveyance is calculated on its own in isolation from the treatment data then the depreciation must be included in the sewerage expenditure to enable calculation of the true unit conveyance cost.

28.5 Significance of the conveyance cost

Having established a unit cost for conveyance, one needs to know the volume of effluent discharged from each industrial site. This information is processed in the normal course of industrial effluent activities and is calculated by using the water consumption data plus any borehole utilization and then allowing for approved deductions as illustrated in a typical assessment shown in **Appendix V.**

∴ Water consumption + borehole data = "x" kilolitres

Less approved deductions = "y" kilolitres

∴ Effluent = (x – y) kilolitres

∴ Conveyance charge for each industry = (Unit Cost • (x-y) kilolitre)

Minimum charge:

Many industries are small with no COD load of significance, but still discharge a fair volume of effluent. As a norm these types of industries are not monitored, analysed, or visited often, but still must be charged the conveyance and a portion of the fixed cost charges by virtue of their contribution to the overall wastewater volume. "The volume to calculate minimum charge can be based on a fixed percentage of the water consumption figure as recorded by the local authority".

Data retrieval

It provides the local authority with the financial implications and significance of the conveyance aspect of the industrial effluent tariff system. One can calculate in advance the amount of revenue that is due from industry for the conveyance aspect on its own.

By combining the depreciation with the treatment infrastructure depreciation under fixed costs, it facilitates the setting aside of finance derived from the depreciation component of the fixed costs for the purpose of building up cash reserves to service future requirements for asset replacement and additions to the sewerage and treatment facilities.

This depreciation also provides the basis for a % return on assets calculation applicable to all dischargers to the sewerage system.

28.6 Element of double charge

A sewerage tariff is generally charged by many local authorities to cover the cost for the conveyance and treatment of domestic wastewater. This cost is alternatively incorporated by other local authorities in the rates and is regarded as one of the services provided in lieu of the rates finance received. The choice of option depends on the policy of the particular local authority.

The element of double charge arises when the sewerage tariff is applied as above and then having the same tariff included in what is termed the "basic tariff". The basic tariff is derived by dividing the total sewerage and treatment expenditure by the volume recorded at the treatment works. This gives a basic tariff per kilolitre used as a starting point and paid by everyone. Industry then pay proportionately on the strength of the effluent based on COD as follows:

$$\left(\text{Basic charge (c/k}\ell) \bullet \frac{COD_i}{COD_m} \right) \text{ over and above the sewerage tariff.}$$

Note that the conveyance cost is included in the basic charge. Under these circumstances there should be no sewerage tariff applicable unless a deduction is made for such.

29 KEY PARAMETERS INVOLVED IN TREATMENT COST CALCULATIONS

29.1 Introduction

To calculate the variable treatment unit cost and then the charge applicable to each industry the following information for the defined twelve month period is necessary.

1. Actual O&M expenditure for treatment excluding fixed costs
2. Metered volume arriving at the works
3. The assessed volume of effluent for each industry that discharges effluent
4. The mean of all the COD analyses on the influent wastewater
5. The mean of all the COD analyses from each industry

Explanatory notes on each of the above parameters are described in the ensuing paragraphs.

29.1.1 Volume of wastewater arriving at the works

The volume of the wastewater arriving at the treatment works is a critical value and as such regular calibration of the metering device in use is necessary. This metered volume is the cumulative amount of wastewater expressed in kilolitres arriving at the treatment works for the 12 mth period. This volume is likely to be inflated due to infiltration from rainfall, and can be dealt with in two ways as was mentioned in earlier paragraphs. This will result in a unit cost more representative of the true situation. The adjusted volume (compensated for infiltration) allows all the requisite hydraulic and COD load calculations and the apportionation to industry to be calculated.

29.1.2 Volume Assessment of Industrial Effluent Discharge

The volume assessment is often taken for granted but in practice is subject to many problems. Since this parameter governs the overall amount that the industrialist will have to pay the service provider for accepting the waste, it must be carefully assessed and agreed to by both parties. i.e. the discharger of the effluent and the service provider. Experience has shown that scant attention is given to the effluent meters and this usually results in problems with the meters and the recorded volumes.

Two methods are recommended. Either by direct meter measurement or by the system of using water consumption data together with borehole information, and then providing allowances as is illustrated in **Appendix V.** The difference will be considered to be effluent. This approach encourages industry to use good water management practice and is the preferred method.

29.1.3 Analytical Method

The recommended analytical method to assess the organic strength is the COD. The merits of the strength parameter are discussed in **Section VI, Part I** and are reproduced here for ease of reference.

- The use and understanding of COD in wastewater treatment kinetics and design is well documented and universally utilized together with the BOD_5 which is still used in Europe for design purposes (Metcalf and Eddy 1991).

- The solids production can be calculated from COD data. This has been ably demonstrated by the UCT Pollution Research Team (WRC Nutrient Removal Guide 1984).

- The COD analytical test provides an absolute value and within the same method it has precision. However there are now a number of different COD analytical procedures including the microwave digestion technique, which show significant variations in the results obtained using the same sample (Balinger et al 1982), (Slatter, NP and Alborough,H 1992).

- Nuisance organic compounds such as oil, fat and grease are totally oxidized by the dichromate method and measured in terms of oxygen consumed for oxidation(Degremont Handbook 1991).

The illustrations in **TABLE 22** substantiate why the COD is the preferred test, and at the same time highlight the shortcomings of the permanganate test which displays no reaction towards Benzene Sulphonic Acid, Acetic acid, Acetone and Toluene.

TABLE 22 : Comparison of Analytical Data illustrating the response of BOD, PV, COD, to pure organic compounds (Wilson 1960)

	Values as per cent of theoretical		
Substrate	**BOD**	**PV**	**COD**
Benzene Sulphonic Acid	63,6	0	91,6
Acetic Acid	58,0	0	93,5
Phenol	69,7	80,1	96,0
Ethyl Alcohol	69,9	4,7	95,9
Acetone	67,5	0	92,2
Toluene	39,2	0	60,0
Diphenyl Guanidine	2,3	59,6	101,6

Two accredited methods used by leading service provider laboratories in South Africa are illustrated in the **Appendix IV.** The final choice is at the users discretion.

The COD concentration together with the assessed or metered volume (whichever is applicable) has a major impact on the final charge for effluent billed to industry.
It should be noted that the COD test must be undertaken on a well shaken unsettled sample. This is important because treatment represents the combination of the solid and liquid phases. Furthermore it will enable the COD mass balances and the calculation of sludge production..from the COD data. (X)
(WRC Nutrient Removal Guide 1984)

29.1.4 Number of samples required, sample point, sampling procedures, and frequency of samples

Before an analysis can be undertaken to determine the COD concentration of the sample, it is necessary to obtain a good representative sample where representative means reflecting the true characterisation of the effluent strength on a continuous basis.
In keeping with good sampling code of practice, and for purposes of legal compliance when there is a dispute, specified procedures must be followed. This also includes the preservation of sample/s. These procedures and techniques are well documented. (Standard Methods 1999). It is good practice to split the sample volume in the presence of a representative from the industry concerned so that they may also be able to undertake an analysis of the key parameters involved e.g. COD. Once this aspect is in place, a sampling strategy must be devised. This strategy must be compiled after consultation with the personnel processing the data; and with the effluent staff who have a good knowledge of the potential variation in effluent quality with certain types of key industries, and the temporal distribution over 24 hours during the weekday mode of operation.
A procedure is required to determine the number of samples to be taken, the frequency and the time interval. The recommended statistical approach allows for a rational decision to be made and eliminates unnecessary numbers of samples and frequent analysis when there is no justification for such in terms of the accuracy, precision and standard deviation of the test itself. The number of samples that are required can be calculated using the formulation illustrated below (Dart 1977).

The number of samples (N) required is calculated as follows:

$$N = \left(\frac{KS}{P} \right)^2$$

P = Precision which is a measure of the closeness with which multiple analysis of a given sample agree with one another (Standard Methods 1992)
Precision is specified by the standard deviation of the results

S = Standard deviation of the set of values about the mean

K = co-efficient which depends on the confidence level required and which has a value of 1,64 for a confidence level of 90% or 1,96 for a confidence level of 95%

N = number of samples which must be taken to estimate the mean of a set of values with a normal distribution to a precision "P"

Obviously the more frequently samples are taken, the greater the precision. The precision should be sufficiently high to avoid the risk of substantial overpayment or underpayment of the industrial effluent charge, but it is clearly not acceptable to spend money on sampling and analysis in order to get a precision no better than that of the method of analysis or where the cost of the sampling and analysis is greater than the probable error in the industrial effluent.
The number of samples required is related to confidence limits, precision and standard deviation and its determination is illustrated in **Table 23.**

TABLE 23: Relationship between the number of samples taken, the variability of the industrial effluent and the relative precision (Dart 1977)

NUMBER OF SAMPLES (N)	RELATIVE PRECISION (P)		
	S = 0,1	S = 0,5	S = 1,0
4	0,082	0,410	0,820
9	0,0547	0,274	0,547
16	0,041	0,205	0,410
25	0,0328	0,164	0,328
36	0,0273	0,137	0,273
49	0,0234	0,117	0,234
64	0,0205	0,103	0,205
81	0,0182	0,091	0,182
100	0,0164	0,082	0,164
121	0,015	0,075	0,150
144	0,0137	0,069	0,137

Illustration using Table 23

Consider an industrial effluent with a standard deviation of 0,5, a true effluent charge of R100 000 per annum, and 4 samples taken per year, then the relative precision is 0,41.

∴ for 90% of the time (k = 1,64 for a confidence level of 90%) an error of about R40000 could be expected. This is substantial. To reduce the error to about 10%, 64 samples would need to be taken during the year within the same standard deviation and confidence limit.

The key decision facing those officials in management will be to evaluate whether additional expenditure on sampling and analysis is justified in terms of the extent of the benefit to be derived from such an exercise. While it may not at first glance seem significant in most cases, it certainly will be very relevant when applied to

major industrial effluent contributors with large effluent expenditure. Thus a basis is presented to indicate the degree of sampling attention that should be devoted to industries with large effluent charges. The relatively simple task of taking regular representative samples at acceptable intervals is a task most underestimated.
The sample point must be well defined and particular care must be taken to ensure that the chosen sample point reflects the combined industrial effluent leaving the industrial site.

30. THE DERIVATION OF THE VARIABLE UNIT TREATMENT COST AND IT'S USE

30.1 Introduction

The calculation of the effluent treatment cost for each industry discharging into the sewer is dependent on the availability of the variable unit treatment cost ("Y" c/kℓ) for a defined COD, and then this is further used to establish the treatment charge.

$$\text{Treatment charge} = \left(Y\ c/k\ell \bullet \frac{COD_I}{COD_m} \right) \bullet \underset{(k\ell)}{\text{volume}}$$

Thus it is essential that all treatment expenditure must be separated into the respective categories, so that the variable and fixed unit costs can be established in conjunction with the respective volumetric and strength data.

30.2 Treatment O&M expenditure

The first requisite is the treatment data expressed in the general manner and showing the overall cost. **Table 24** indicates the general categories of expenditure as recommended by IMFO.

TABLE 24 : Treatment O&M expenditure

Salaries	....
Repairs and Maintenance	....
General Expenses (where general expenses includes chemicals, transport, electricity, vehicles etc.)	....
Depreciation + interest	....
	TOTAL ....

Itemize all treatment expenditure and then separate the expenditure into fixed and variable portions as illustrated in Section 27.1.

Variable Unit Treatment Cost

$$= \frac{\text{variable expenditure}}{\text{works metered flow (adjusted for infiltration)}} = Y \quad c/k\ell$$

for a mean COD_m of .... $mg\ell^{-1}$ **or**
a weighted COD_w of ....$mg\ell^{-1}$

This variable unit treatment cost at the works is an exact calculated number (constant **Y**) and based on actual expenditure. This is the variable treatment cost per kilolitre to the authority providing the treatment service. It provides a solid basis for calculating the cost of industrial effluent, besides the fixed costs. If budgeted expenditure is used initially for convenience this must be reconciled at a later stage with the actual expenditure incurred.

30.3 Calculation of cost to treat industrial effluent from individual industries

In this instance the industrial effluent has a mean COD concentration based on many samples taken and analysed during the twelve-month period.

$$\text{Industrial effluent treatment cost} = \left(Y \ (c/k\ell) \bullet \frac{COD_I}{COD_m} \right)$$

where Y is the variable unit treatment cost for a specified mean COD_m calculated from all COD data of the works influent during the defined period.
COD_I is the mean COD of all the industrial effluent samples taken within the defined period.
From the variable unit treatment cost one can calculate the unit cost for an industrial discharge of a particular strength assessed in terms of COD.

31. APPLICATION OF EFFLUENT TARIFF STRUCTURE

31.1 Introduction

An example is provided on the application of the above procedure to a medium size local authority that has three wastewater treatment facilities which vary significantly in size. There is much industrial activity within the area of jurisdiction but most of the industrial effluent is treated at only one of these works.
The data used is based on actual historic costs for a defined period of one year. The O&M expenditure for sewerage and wastewater treatment is shown in two

formats. One format is the present expenditure system as used by local government while the other format is what can be expected when depreciation accounting is used. The expenditure has been separated into fixed and variable categories as described earlier.
This local authority has been operating an integrated wastewater scheme which combines sewerage and treatment expenditure for all three treatment facilities into one operating account and thus lends itself to illustrating the implementation of the recommended tariff structure.

31.2 Outline of the procedure

Using all the principles and methodologies outlined in the earlier paragraphs of Part III (Guidelines), the following stepwise procedure is recommended:

- Assets registry must be compiled. This will initially be a very onerous task particularly for the Metropolitan and Unicity Authorities. Once each fixed asset has been itemized and recorded, a value must be assigned to each item.
- Establish the value of all sewerage and treatment works infrastructure of a capital nature. This value must be at current replacement cost and undertaken by professional engineers with competency in this type of activity.
- Once an assets registry has been compiled and a current value (replacement) attached to items of a capital nature the depreciation process can proceed on a straight line basis and continue for the number of years assigned to each item in terms of useful lifespan remaining. Guidelines with respect to sewerage and treatment works equipment, and the number of years of useful life and the depreciable portion have been provided by IMFO and IMPRO.
- For each financial year, there will be a calculated depreciation which is considered to be an expense in terms of GAMAP and thus must be included along with staff remuneration, general expenses, repair and maintenance, as part of the overall expenditure.
- All O & M expenditure must then be grouped into the categories as shown and then treatment expenditure is divided into variable and fixed costs as shown earlier in this section of the project. The depreciation contribution of the sewerage O & M expenditure is shown as part of fixed costs to facilitate easy application of depreciation towards a cash reserve fund.

- Further additional information required is as follows,
  - total volume of wastewater received by the Authority concerned
  - the individual contribution of industrial effluent from each industry. This information is calculated from water consumption data as shown in **Appendix V.**
  - the weighted COD corresponding to the total volume of wastewater within the operational area
  - the mean COD for each industrial concern

- Tariff structure application

$$c/k\ell = \text{conveyance} + \underset{\text{(variable)}}{\text{treatment}} + \text{fixed costs}$$

  It should be noted that depreciation and return on assets are incorporated in the fixed cost component.

- Establish the unit cost for each component

$$\frac{\text{sewerage expenditure}}{\text{vol. of wastewater}} + \frac{\text{variable treatment expenditure}}{\text{vol. of wastewater}} + \frac{\text{fixed costs}}{\text{vol. of wastewater}}$$

= " X " + " Y " + " S "

  for a COD_m or COD_w of .... $mg\ell^{-1}$

- Variable unit treatment cost " Y " for a strength of " .... " $mg\ell^{-1}$ COD_{m} or $_{w}$

- Actual cost to industry for treatment $= \left(\text{" Y "} \bullet \frac{COD_I}{COD_w} \right)$ $c/k\ell$

  Therefore it is clear that industries that have a very high COD will have a high unit charge for their specific type of effluent. Note that in some cases it could be much lower than " Y ", typical of the textile industries characterised by high volumes and low strength.

- **Fixed costs**

  For every kilolitre of wastewater entering the combined treatment facilities, there is a portion that is independent of strength and indicative of costs that would have to be met even if all industry disappeared overnight. However recovering the fixed cost requires careful application. When using AHC and other relevant data from a time frame that has just been completed, the information is exact. This information also provides the basis for setting a tariff for the next period, and for fulfilling legal requirements to inform consumers timeously of the new tariff.

N.B.

The fixed cost rate is the same for everyone, except that the individual contribution will vary due to the variation in water consumption / industrial effluent in each separate instance. In any time frame, the overall fixed cost component of all the expenditure is constant, but individual amounts will vary in proportion to their hydraulic contribution.

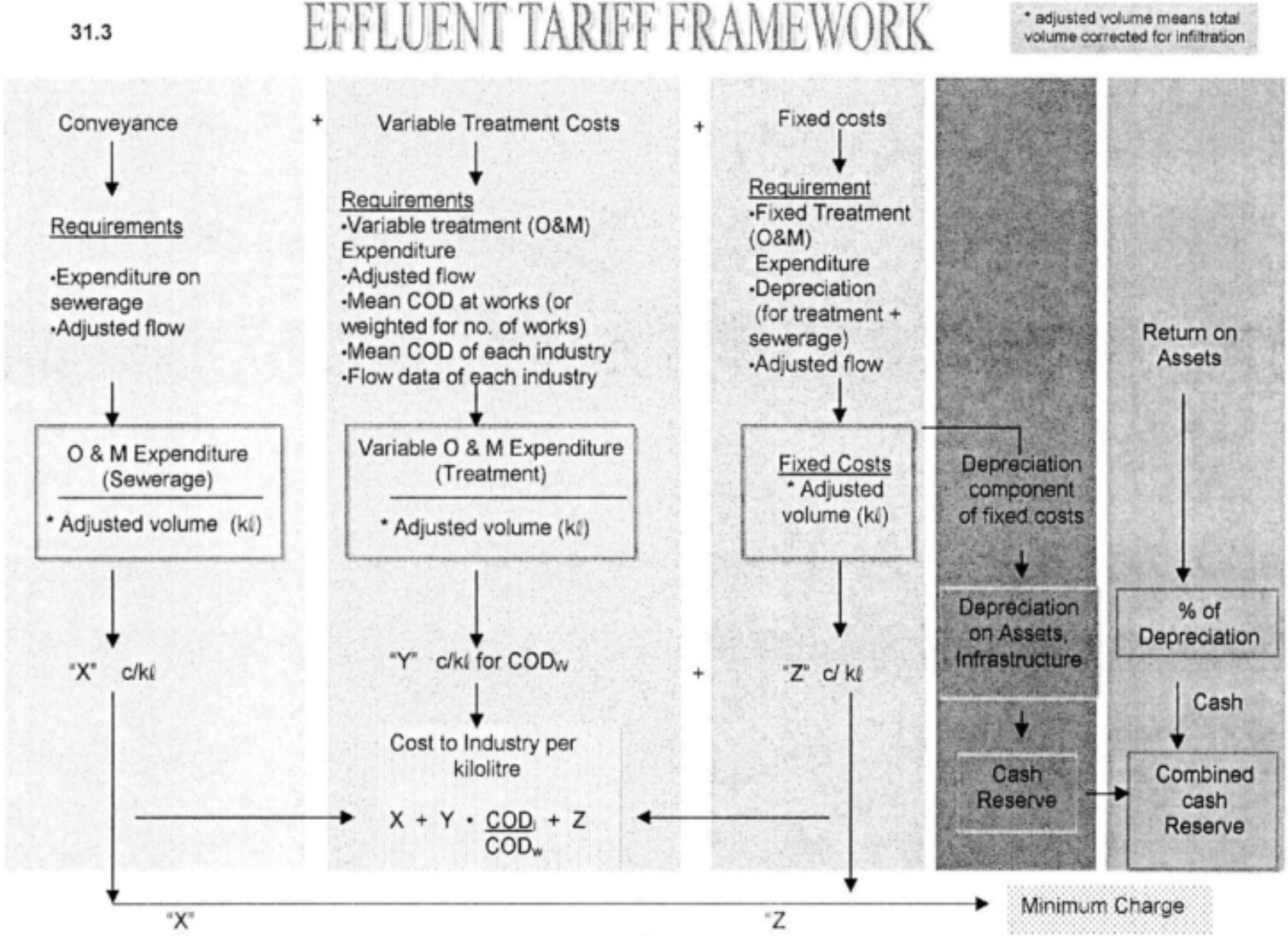
- Sewerage is shown on its own to indicate the conveyance contribution separate from treatment. However the depreciation has been removed and added to fixed costs even though the bulk of the sewerage expenditure can also be considered to be of a fixed nature, except for pumping.

- Depreciation must be isolated as this is the amount that must be set aside in a cash reserve fund. This cash reserve fund will at any given time reflect the accumulated depreciation less any amounts used for asset replacement.

- The amount set aside for depreciation is used to calculate an additional amount which is termed "return of assets" and is based on an agreed percentage of the depreciation. Policy decisions made by the authority concerned will determine the precise % to be used for calculation purposes.

31.3

EFFLUENT TARIFF FRAMEWORK



32. CASE STUDY

32.1 Introduction

This case study represents a local authority which operates three wastewater treatment facilities which are situated in three different catchments. All expenditure is combined into one wastewater scheme for purposes of setting annual wastewater and effluent tariffs. Each treatment works, however, has its own budget and operating cost centres.
Treatment works No 1 has been in operation the longest and has recently been augmented. Works No 3 is a small works and receives no industrial effluent.

All the relevant financial and operational data necessary to perform the calculations are presented in the following paragraphs.

32.2 Flow and Strength Data

	WORKS NO 1	WORKS NO 2	WORKS NO 3
Volume (kℓ)	19 392	9 482	951
Strength (COD in $mg\ell^{-1}$)	600	1 100	793

Weighted mean $(19\,392 \bullet 600) + (9\,482 \bullet 1\,100) + (951 \bullet 793) = (29\,826 \bullet (X))$

$$11\,635kg + 10\,431kg + 755kg = 29\,826k\ell \bullet X$$

$$22\,821kg = 29{,}826\ M\ell \bullet X$$

$$COD = 765\ mg\ell^{-1}$$

whereas the average would have been 823 $mg\ell^{-1}$

32.3 Financial data

As mentioned earlier in **PART III** the operation and maintenance expenditure for the sewerage and treatment systems will be presented in the old and new format for purposes of illustration. **Table 25** and **Table 25a** represent the treatment expenditure in both formats using the general categories recommended by IMFO.

TABLE 25 : O&M treatment expenditure using fund accounting

	WORKS NO1	WORKS NO 2	WORKS NO 3	LAB. SERVICE
Salaries	**1 454 000**	**867 610**	**456 130**	**1 064 980**
General * Expenses	**1 395 290** Admin 272600 Electricity 364570 Cl_2 170000 Salary recharge 313310	**2 182 010** Admin 280 100 Electricity 440 470 Salary Recharge 296 160 Marine Disposal 1000 000 Cl_2 50 000	**535 410** Admin 90620 Electricity 54900 Salary recharge 36000	**297 990**
Repair & Maintenance	165 990	50 510	21 190	36 000
Capital Charges: Interest Redemption	 2 161 040 332 130	 439 660 71 760	 251 850 17 290	 152 190 210 890
Consolidated Capital Development Fund	234 880	67 520	34 338	-(730 200) Salary recharge
TOTAL EXPENDITURE	**5 743 330**	**3679070**	**1316208**	**1031850**

- The main cost contributions to the overall total in "general expenses" are shown under the total in bold figures.

TABLE 25 (a): O&M treatment expenditure using depreciation accounting

	WORKS NO 1	WORKS NO 2	WORKS NO 3	LAB SERVICES
Salaries	1454000	867610	456130	1064980 - (730200)
General Expenses:	1395290	2182010	535410	297990
Repair & Maintenance	165990	56510	21190	36000
Depreciation	750000	175000	62500	240890
Interest	2161040	439660	251850	152190
TOTAL	**5926320**	**3720790**	**1327080**	**1061940**

Table 26 and **Table 26a** represent the sewerage expenditure in both formats using the general categories recommended by IMFO.

TABLE 26: O&M sewerage expenditure using fund accounting

	WORKS NO 1	WORKS NO 2	WORKS NO 3	PUMP STATION
Salaries	1 017 370	-	-	174 310
General Expenses	**439 580**	**103190** Including salary recharge	**82 660** Including salary Recharge of 64 380	**176 100**
Repair & Maintenance	291 400	175 000	59 000	35 000
Capital Charges: Interest Redemption	587 380 86 630	689 710 105 260	210 520 27 720	- -
Consolidated Capital Development Fund	281770	36760	-	36630
Contribution to Capital outlay	82 000	55 000	65 000	-
Less – charged out labour plant vehicles	421 000	-	-	-
TOTAL EXPENDITURE	**2365130**	**1164920**	**444 900**	**422 040**

TABLE 26 a: O&M sewerage expenditure using depreciation accounting

	WORKS NO 1	WORKS NO 2	WORKS NO 3	PUMP STATION
Salaries	1017370 - 421000	-	-	174310
General Expenses	439580	103190	82660	176100
Repair & Maintenance	291400	157000	59000	35000
Depreciation	500000	231000	103000	39000
Interest	587380	689710	210520	-
Total Expenditure	**2414730**	**1180900**	**455180**	**424410**

- It should be noted that the depreciation shown in **TABLES 25a and 26a** is based on replacement value and accounts for the higher total expenditure in comparison with the total expenditure shown in **TABLES 25 and 26.**

- Within these groupings are more detailed information on individual cost centres similar to the example in **APPENDIX VI**

- Out of each total the fixed and variable costs must be allocated.

  e.g. Depreciation is an expense and is considered to be a fixed cost
  External interest is also considered to be an expense and a fixed cost
  Permanent staff will be a fixed cost
  Power consumption is primarily due to load and is considered variable since in any activated sludge system, aeration contributes substantially to the total power cost
  Chemicals will vary with the load which depends on flow and strength.
  Return on assets is accommodated by inflating the depreciation figure

Once the costs have been categorised into fixed and variable, then the next step is to calculate the unit fixed and variable cost for the combined integrated treatment system. In the above case this will consist of the expenditure due to Treatment Works 1, 2 and 3 together with the laboratory services.
It should be noted that when the above concept is applied to a metropolitan area or a megacity or unicity, there will be many treatment works using different types of treatment systems. However, in the end, the calculation will be no different from the illustration using 3 treatment works. Whereas the fund accounting system was relatively easy with respect to the interest and redemption charges, the depreciation accounting system will initially require much effort to ensure that a fixed asset register is compiled, and that all structures are valued at current replacement value by competent persons, with attention being given to the assessment of the remaining useful life of each item of capital infrastructure. This will be a onerous task for larger authorities such as Durban, Cape Town and Johannesburg Metro Authorities, although this information should be known from updated asset inventories that are currently in use
The depreciation figure is vital and must reflect with reasonable accuracy and confidence the true financial situation. This value which is part of the fixed costs provides the basis for calculations to obtain funding for asset replacement, cash reserve accumulation, and for future works or structural upgrade. The return on assets calculated by applying an acceptable/approved % of the amount of depreciation is also important to the successful implementation of the new funding concept.

32.4 Apportionment of treatment expenditure into fixed and variable components

The relevant financial data that enables the above apportionment is shown in **Table 27.**

TABLE: 27 O&M treatment expenditure using depreciation accounting

	Works1	Works 2	Works 3	Lab Services	Totals
Salaries	1 454 000	867 610	456 130	1 064 980 - (730200)	3112520
General Expenses	1 395 290	2 182 010	535 410	297 990	4410700
Repair & Maintenance	165 990	56 510	21 190	36 000	279 690
Depreciation	750000	175000	62500	240890	1228390
Interest	2161040	439660	251850	152190	**3004740**
Total					**R12036040**

The return on assets contribution is accounted for by inflating the depreciation by 6%.

Fixed and variable components are separated as shown in **Table 28**

Table 28: Fixed and variable treatment expenditure

FIXED EXPENDITURE	RAND	VARIABLE EXPENDITURE	RAND
80% of salaries	2490 016	20%	622 504
20% of general expenses	882 140	80%	3 528 560
60% of repair & maintenance	167 814	40%	111 876
100% of depreciation	1 228 390	0%	
6% of depreciation (Return on Assets)	73 703	0%	
100% Interest	3 004 740	0%	
TOTAL	**7 846 803**		**4 262 940**

The depreciation component of the sewerage expenditure is also added to the fixed expenditure total and provision once again made for a return on assets of 6% of the sewerage depreciation. This is illustrated in the next paragraph.

32.5 Calculation of the 3 unit costs:

- **Calculation of unit conveyance cost**

In order that the unit conveyance cost can be calculated it is required that the total sewerage expenditure less depreciation be calculated as follows:

TABLE 29 Sewerage Expenditure

Item	Total Expenditure A	Depreciation B	A – B
Works 1	2 414 730	500 000	1914730
Works 2	1 180 900	231 000	49 900
Works 3	455 180	103 000	352 180
Pump station	424 410	39 000	385 410
TOTAL	**4 475 220**	**873 000**	**3 602 220**

Unit conveyance cost = $\frac{R3\,602\,220}{29826.365}$

= R0,33 / kℓ

- **Calculation of unit variable treatment cost and fixed cost**

	Rand
Fixed treatment expenditure	7 846 803
sewerage depreciation	873 000
6% return on assets	52 380
TOTAL	8 772 183

Volume of effluent (daily) 29 826kℓ /d

Volume of effluent (annual) (29 826 • 365) kℓ / yr

Applying the tariff structure as outlined in **Section 31.2** and using the data in **Table 28** showing the fixed and variable expenditure the following is obtained.

$$c/k\ell = \text{conveyance} + \text{treatment (variable)} + \text{fixed costs}$$

$$= \frac{3\,602\,220}{29\,826 \cdot 365} + \frac{4\,262\,940}{29\,826 \cdot 365} + \frac{8\,772\,183}{29\,826 \cdot 365}$$

$$= R0{,}3309 + R0{,}3915 + R0{,}8057$$

for a weighted COD of 765 $mg\ell^{-1}$

∴ For each kilolitre of industrial effluent, the industry concerned will have to pay: **R0,33** for conveyance
R0,81 for fixed costs
R0,39 $\cdot \frac{COD_I}{COD_W}$ for the variable treatment

One can assess the effect of a high COD concentration as follows. Assume the mean COD for the particular industry was 4310 $mg\ell^{-1}$, then the variable treatment charge will be

$$\frac{R0{,}39 \cdot 3410}{765}$$

$$= R1{,}74 \text{ per kilolitre}$$

∴ The overall charge will be : R(0,33 + 1,74 + 0,81)

$$= R2{,}88 / k\ell$$

The system allows for easy identification of how the charges are derived and directs attention to reducing the COD load, which in turn will reduce the unit cost for treatment and the overall effluent charge.

e.g. If the mean COD was 470 $mg\ell^{-1}$ instead of 3410 $mg\ell^{-1}$, the variable charge will be

$$\left(\frac{0{,}39 \cdot 470}{765}\right) = R0{,}24$$

In this case, the overall charge will now be

R(0,33 + 0,24 + 0,81)

= R1,38 / kℓ

32.6 Contribution towards Cash Reserve Fund

Within the total fixed expenditure, a specific amount representing depreciation and return on assets is contained.

i.e.	1 228 390	(treatment depreciation
	73 703	(return on assets)
	873 000	(sewerage depreciation)
	52 380	(return on assets)
	R2 227 473	

When all the effluent income is received from industry, an amount of

R2 227 473 must be transferred to the cash reserve fund. This will continue annually and eventually a substantial cash reserve will be available.

Minimum Charge

The minimum charge will apply to all industries that discharge a liquid effluent. The volume assessment must be based on water consumption and the method of assessment discussed with the industrialist. Small industrial operations are the most problematic because they are usually part of a number of mini factories on a particular site and usually do no have their own water meter. Agreement by both parties involved is important when minimum charges are applied in the above manner.
Using the data above the minimum charge applicable will be as follows.

[conveyance cost + fixed cost]

= R(0,33 + 0,81)

= R 1,14 / kℓ

32.7 Supplementary notes to be used in conjunction with the guidelines

- The COD test must be carried out on a representative unsettled sample of industrial effluent taken at an agreed and well defined sample point.

- The recommended guidelines are applicable to a private company in the same manner as applicable to any local authority. Their charges for undertaking the role of a service provider are included as part of the operational expenditure and must be allocated under the appropriate cost centre e.g. fixed or variable.

- Successful application of these guidelines will only be possible if attention is given to all aspects mentioned.

- Time frames for the application of the tariff formulation and for the billing and recovery of costs, depend on the financial operating policies of each local authority. Therefore although the AHC is the basis for the financial calculations , budget costs can be used for interim practical purposes and reconciled at a later stage.

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33 TECHNOLOGY TRANSFER ACTIONS

Presentations by Des Kerdachi were made as follows :

- Paper entitled "Guidelines in the formulation of an equitable industrial effluent tariff structure", at the Industrial Effluent Management Seminar.
  Port Elizabeth Technikon.
  23 April 1997
  Eastern Cape Branch of WISA

- Similar, but more advanced version of the above paper to the bimonthly WISA General Meeting of the Kwa-Zulu Natal Branch.
  Pinetown, Pinecity , 1998

  Both presentations were well attended with representatives from Local authorities, Industry, DWAF and consulting engineers. Lively discussion took place and many interesting and useful points, of benefit to the project, emerged.

- To the professional staff at Talbot and Talbot in Pietermaritzburg, local industrialists were invited to attend. Progress on the above project was outlined.

- Two meetings to the Eastern Gauteng Services Council (EGSC) working group on Sanitation and Water in Germiston.

- Two meetings to the EGSC working group on industrial effluent tariffs at the H/O of ERWAT at Kempton Park.

  At all the above meetings the purpose was to keep all the Local authorities under the ERWAT umbrella fully informed of the WRC Project, progress and development.

  It is further recommended that subject to finance from the WRC, being available presentations be made at selected venues in South Africa to promote the final version of the guidelines.

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The Water Act No.54 of 1956(also referred to as WA)

Water Services Act No 108 of 1997. (also referred to as WSA)

CHECK LIST

APPENDIX 1

1 Total flow received at Works. (Wet and Dry weather flow)

2 Population served

3 Contribution by industry (hydraulically m^3) + (carbonaceous load) kg per six month billing period

4 Data on all industries: Water consumption (Potable + Borehole)
Effluent assessment
Strength / Suspended Solids

4 (a) Strength of the wastewater arriving at the works. (average over 6 months or 1 yr)

5 Income derived from industrial effluent

6 Total capital and Revenue expenditure (including interest and redemption charges) on the sewerage system and the treatment system.

7 By-laws in operation – copy required

8 Sludge disposal: Method
Data on heavy metals

9 Current and previous industrial effluent formula

10 Minimum charge

11 Method for strength assessment PV or COD

12 Basis for both 10 and 11

13 No. of samples taken and method of statistical appraisal

14 Nutrient removal or other special conditions required by DWAF

15 General standards or RWQO

16 Penalising clauses or any punitive measures

17 Overall treatment cost in R/kℓ

18 Current cost of water for householder and industrialist

19 Single authority or part of Metro

20 Integrated treatment systems

21 Prosecuting authority

22 Industrial representation or liaison

23 Sewerage tariff for all types of users

24 Is this included in the industrial effluent tariff?

25 If not in the effluent tariff, then how much finance is derived from industry for sewerage/conveyance annually?

APPENDIX II

REGIONAL (DWAF) STANDARDS FOR WASTEWATER OR EFFLUENT IN TERMS OF THE WATER ACT NO 54 OF 1956

The following are the requirements to which wastewater or effluent produced by or resulting from the use of water for industrial purposes shall conform after purification:

1 Special Standard

Quality standards for wastewater or effluent arising in the catchment area draining water to any river specified in **Schedule I** or a tributary thereof at any place between the source thereof and the point mentioned in the Schedule, in so far as such catchment area is situated within the territory of the Republic of South Africa.

1.1 Colour, Odour or Taste:
The wastewater or effluent shall not contain any substance in a concentration capable of producing any colour, odour or taste.

1.2 PH:
Shall be between 5,5 and 7,5.

1.3 Dissolved Oxygen:
Shall be at least 75 per cent saturation.

1.4 Typical (faecal) Coli:
The wastewater or effluent shall contain no typical (faecal) coli per 100 $m\ell$.

1.5 Temperature:
Shall be a maximum of $25^{0}C$.

1.6 Chemical Oxygen Demand:
Not to exceed 30 $mg\ell^{-1}$ after applying the chloride correction.

1.7 Oxygen Absorbed:
The oxygen absorbed from acid **N**/80 potassium permanganate in 4h at $27^{0}C$ shall not exceed 5 $mg\ell^{-1}$.

1.8 Conductivity:

1.8.1 Not to be increased by more than 15 per cent above that of the intake water.

1.8.2 The conductivity of any water, wastewater or effluent seeping or draining from any area referred to in section 21 (6) of the aforementioned Water Act shall not exceed 250 mS/m (determined at $25^{0}C$).

1.9 Suspended Solids:
Not to exceed 10 $mg\ell^{-1}$.

1.10 Sodium Content:
Not to be increased by more than 50 $mg\ell^{-1}$ above that of the intake water.

1.11 Soap, Oil or Grease:
None.

1.12 Other Constituents:

1.12.1 Constituents:

Constituents	Maximum concentration in milligrams per litre
Residual chlorine (as Cl)...	Nil
Free and saline ammonia (as N) ...	1,0
Nitrates (as N) ...	1,5
Arsenic (as As) ...	0,1
Boron (as B) ...	0,5
Total chromium (as Cr) ...	0,05
Copper (as Cu) ...	0,02
Phenolic compounds (as phenol) ...	0,01
Lead (as Pb) ...	0,1
Soluble ortho phosphate (as P) ...	1,0
Iron (as Fe) ...	0,3
Manganese (as Mn) ...	0,1
Cyanides (as CN) ...	0,5
Sulphides (as S) ...	0,05
Fluoride (as F) ...	1,0
Zinc (as Zn) ...	0,3
Cadmium (as Cd) ...	0,05
Mercury (as Hg) ...	0,02
Selenium (as Se) ...	0,05

1.12.2

The wastewater or effluent shall contain no other constituents in concentrations which are poisonous or injurious to trout or other fish or other forms of aquatic life.

2 Special Standard for Phosphate

Wastewater or effluent arising in the catchment area within which water is drained to any river specified in **Schedule II** or a tributary thereof at any place between the source thereof and the point mentioned in the schedule, in so far as such catchment area is situated within the territory of the Republic of South Africa shall not contain soluble ortho phosphate (as P) in a higher concentration than 1,0 $mg\ell^{-1}$.

3 General Standard

Quality standards for wastewater or effluent arising in any area other than an area in which the SPECIAL STANDARD is applicable, as described in paragraph 1.

3.1 Colour, Odour or Taste:

The wastewater or effluent shall not contain any substance in a concentration capable of producing any colour, odour or taste.

3.2 PH:

Shall be between 5,5 and 9,5.

3.3 Dissolved Oxygen:

Shall be at least 75 per cent saturation.

3.4 Typical (faecal) Coli:

The wastewater or effluent shall not contain any typical (faecal) coli per 100 mℓ.

3.5 Temperature:

Shall be a maximum of 35^0C.

3.6 Chemical Oxygen Demand:

Not to exceed 75 $mg\ell^{-1}$ after applying the chloride correction.

3.7 Oxygen Absorbed:

The oxygen absorbed from acid N/80 potassium permanganate in 4 h at 27^0C shall not exceed 10 $mg\ell^{-1}$.

3.8 Conductivity:

3.8.1 Not to be increased by more than 75 mS/m (determined at 25^0C) above that of the intake water.

3.8.2 The conductivity of any water, wastewater or effluent seeping or draining from any area referred to in Section 21 (6) of the aforementioned Water Act shall not exceed 250 mS/m (determined at 25^0C).

3.9 Suspended Solids:

Not to exceed 25 $mg\ell^{-1}$.

3.10 Sodium Content:

Not to be increased by more than 90 $mg\ell^{-1}$ above that of the intake water.

3.11 Soap, Oil or Grease:

Not to exceed 2,5 $mg\ell^{-1}$.

3.12 Other Constituents:

3.13 Constituents:

Constituents	Maximum concentration in milligrams per litre
Residual chlorine (as Cl)	0,1
Free and saline ammonia (as N)	10,0
Arsenic (as As)	0,5
Boron (as B)	1,0
Hexavalent chromium (as Cr)	0,05
Total chromium (as Cr)	0,5
Copper (as Cu)	1,0
Phenolic compounds (as phenol)	0,1
Lead (as Pb)	0,1
Cyanides (as CN)	0,5
Sulphides (as S)	1,0
Fluoride (as F)	1,0
Zinc (as Zn)	5,0
Manganese (as Mn)	0,4
Cadmium (as Cd)	0,05
Mercury (as Hg)	0,02
Selenium (as Se)	0,05

3.12.2 The sum of the concentrations of the following metals shall not exceed 1 $mg\ell^{-1}$: Cadmium (as Cd) chromium (as Cr), mercury (as Hg) and lead (as Pb).

3.12.3 The wastewater or effluent shall contain no other constituents in concentrations which are poisonous or injurious to humans, animals, fish other than trout, or other forms of aquatic life, or which are deleterious to agricultural use.

4 Methods of Testing

All test shall be carried our in accordance with methods prescribed by and obtainable from the South African Bureau of Standards, referred to in the **Standards Act, No 30 of 1982**, as listed in Schedule III.

APPENDIX IIA

GENERAL AND SPECIAL LIMITS FOR WASTEWATER EFFLUENTS FROM TREATMENT PLANTS DISCHARGING LESS THAN 2OOOm^3/d

As illustrated in Government Gazette No20526 Oct 1999 (Government notice DWAF No. 1191 8th Oct 1999)

Wastewater limit values applicable to discharge of wastewater into a water resource (DWAF 1999)

SUBSTANCE/PARAMETER	GENERAL LIMIT	SPECIAL LIMIT
Faecal Coliforms (per 100 mℓ)	1000	0
Chemical Oxygen Demand (mgℓ$^{-1}$)	75*	30*
PH	5,5-9,5	5,5-7,5
Ammonia (ionised and un-ionised) as Nitrogen (mgℓ$^{-1}$)	3	2
Nitrate/Nitrite as Nitrogen (mgℓ$^{-1}$)	15	1,5
Chlorine as Free Chlorine (mgℓ$^{-1}$)	0,25	0
Suspended Solids (mgℓ$^{-1}$)	25	10
Electrical Conductivity (mS/m)	70 mS/m above intake to a maximum of 150 mS/m	50 mS/m above background receiving of 150 mS/m
Ortho-Phosphate as phosphorous (mgℓ$^{-1}$)	10	1 (median) and 2,5 (maximum)
Fluoride (mgℓ$^{-1}$)	1	1
Soap, oil or grease (mgℓ$^{-1}$)	2,5	0
Dissolved Arsenic (mgℓ$^{-1}$)	0,02	0,01
Dissolved Cadmium (mgℓ$^{-1}$)	0,005	0,001
Dissolved Chromium (VI) (mgℓ$^{-1}$)	0,05	0,02
Dissolved Copper (mgℓ$^{-1}$)	0,01	0,002
Dissolved Cyanide (mgℓ$^{-1}$)	0,02	0,01
Dissolved Iron (mgℓ$^{-1}$)	0,3	0,3
Dissolved Lead (mgℓ$^{-1}$)	0,01	0,006
Dissolved Manganese (mgℓ$^{-1}$)	0,1	0,1
Mercury and its compounds (mgℓ$^{-1}$)	0,005	0,001
Dissolved Selenium (mgℓ$^{-1}$)	0,02	0,02
Dissolved Zinc (mgℓ$^{-1}$)	0,1	0,04
Boron (mgℓ$^{-1}$)	1	0,5
***After removal of algae**		

APPENDIX III

PROHIBITED DISCHARGES

1. No person shall without the permission of the Council in writing discharge into or cause or suffer to enter any sewer, any sewage or industrial effluent which -

a) has a temperature exceeding 45^0 centigrade at the point of entry to the sewer;

b) has a pH value less than 6,5 or greater than 10 units;

c) Contains any calcium carbide or any other substance whatsoever liable to give off explosive or offensive gases or vapours in the sewer;

d) Contains any substance which has an open flash point of less than 65^0 centigrade or which gives off a poisonous vapour below 65^0 centigrade;

e) Includes any substance in concentrations expressed as milligrams per litre by weight greater than those specified and listed below:

	Milligrams per litre
Total sugars and starch (expressed as glucose)	1000
Solids in suspension (dried at 105^0)	1000
Grease and mineral oil, tar and tar oils not dissolved in the aqueous phase	20
Animal and vegetable oils and fats	200
Total sulphates (expressed as SO_4)	500
Sulphides (expressed as S)	25
Copper (expressed as Cu)	25
Nickel (expressed as Ni)	25
Zinc (expressed as Zn)	25
Cadmium (expressed as Cd)	25
Chromium (expressed as CrO_3)	25
Hydrocyanic acid and cyanides or other cyanogen compounds (expressed as HCN)	10
Calcium Carbide	Nil

f) contains any substance which, whether alone or in combination with other matter, may in the opinion of the Council cause a nuisance of any kind to the public or, in particular, injury to, or danger to the health of, persons entering sewers or manholes or carrying out any work in connection therewith or working at the sewage purification works, or which may be injurious to the sewers, treatment plants or any land used for disposal of sewage, or which shall in any way injuriously affect any of the processes whereby sewage is treated or the re-use of treated sewage effluent.

2. Any person who discharges or causes or suffers to be discharged into the sewer any substance which he knows or ought to know to be one, the said discharge of which is prohibited by subsection (1) and any person who, after receiving from the Council an order in writing prohibiting the discharge from any date of any substance to the sewer, continues so to discharge it or to cause or suffer such a discharge thereof after that date shall be guilty of an offence

RECOMMENDED METHOD NO. 1

1. INTRODUCTION

The chemical oxygen demand (COD) of a sample is a measure of the oxygen equivalent of the organic matter content that is susceptible to oxidation by a strong chemical oxidant. This method uses potassium dichromate as the oxidant and this gives 95-100% of the theoretical oxidation value for most organic compounds.

The sample is heated by microwave radiation in a strongly acidic solution with a known excess of potassium dichromate. After digestion the remaining unreduced potassium dichromate is titrated with standard ferrous ammonium sulphate (FAS) using an autotitrator or a burette. COD is expressed in units of mg O_2/ℓ.

2. SCOPE

The method may be used to determine COD for both clean water and wastewater samples.

3. INTERFERENCES

3.1 Straight chain aliphatic compounds resist oxidation and silver sulphate is added to the digestion mixture to catalyse the oxidation of these organic compounds.

3.2 The silver sulphate that is added reacts with halides to produce precipitates that are only partially oxidised. The difficulty caused by the presence of halides may be largely overcome (up to a maximum of 2000 mg/ℓ) by complexing with mercuric sulphate before the digestion procedure.

3.3 Reduced inorganic species e.g. Fe^{2+}, Mn^{2+} and S^{2+} give rise to positive errors.

3.4 Pyridine and related compounds resist oxidation.

3.5 Volatile organic compounds are only oxidised to the extent that they remain in contact with the oxidant.

4. HAZARDS

Potassium dichromate.
Sulphuric acid.
Mercuric sulphate.

Ensure that you are familiar with the dangers and treatment associated with each of the above substances. (See Appendix 1 in the Methods Manual).

5. SAMPLE COLLECTION AND PRESERVATION

Samples are collected in glass bottles or plastic containers. For preservation purposes, section 10.1 must be performed within 24 hours of the samples being received in the laboratory.

6. APPARATUS

Autotitrator or burette.

250mℓ autotitrator cups or suitable titration vessels.
Laboratory microwave digestion oven.
120mℓ teflon PFA pressure digestion vessels, digestion carousel and capping station.
Cooling bath.
Volumetric equipment.
A Grade glassware.

The instrument manuals should be studied thoroughly before using any equipment.

7. REAGENTS

Ferrous ammonium sulphate.$6H_2O$ (FAS).
Potassium dichromate.
Sulphuric acid.
Silver sulphate.
Mercuric sulphate.
Potassium hydrogen phthalate.
1,10 phenanthroline monohydrate.
Ferrous sulphate.$7H_2O$.
Use only AR grade reagents unless otherwise specified.
Use only distilled (or better quality) water.
All prepared solutions are made up to volume in volumetric flasks and are stored in glass containers, unless otherwise indicated.

7.1 Sulphuric acid/silver sulphate

Very cautiously add 25g of silver sulphate powder or crystals to a 2.5ℓ reagent bottle filled with concentrated sulphuric acid.
Allow the solution to stand for two days before use.

Prepare this solution at least every 2 weeks.

7.2 Ferroin Indicator

Weigh 1.485g 1,10 phenanthroline monohydrate and 0.695g ferrous sulphate.$7H_2O$ and dissolve in approximately 20mℓ distilled water and dilute to 100mℓ.
Prepare this solution at least every month.

7.3 Mercuric sulphate (crystals or powder)

Once open, the contents are stable for three years.

8. PREPARATION OF STANDARDS

8.1 Ferrous ammonium sulphate working solution (~ 0.13N)

Weigh 52g FAS and dissolve in approximately 700mℓ distilled water.
Cautiously add 26mℓ concentrated sulphuric acid.
Allow to cool and dilute to 1ℓ with distilled water.
Store the solution in an amber bottle
Prepare this solution at least every 2 weeks.

8.2 Potassium dichromate working solution (0.250N)

Accurately weigh out 12.2588g of potassium dichromate (previously dried to constant weight at 105°C ± 5°C, cooled and stored in a desiccator).
Dissolve in distilled water and dilute to 1ℓ.
Store the solution in an amber bottle.
Prepare this solution at least every 2 weeks.

9. PREPARATION OF AQC

9.1 Stock COD solution (2 000mg O_2/ℓ)

This solution is prepared by the Senior Technician or Scientist.

Accurately weigh out 1.7007g potassium hydrogen phthalate (previously dried to constant weight at 105°C ± 5°C, cooled and stored in a desiccator). Dissolve in distilled water and dilute to 1ℓ. Store the solution in an amber bottle and discard if any biological growth is observed. Prepare this solution at least every 3 months.

9.2 Working solution (200mg O_2/ℓ)

Pipette 100mℓ of stock solution into a 1ℓ volumetric flask and make up to the mark using distilled water. Store the solution in an amber bottle and discard if any biological growth is observed.
Prepare the working solution at least every 2 weeks.

AQC results are deemed acceptable if their values are within a maximum allowable limit of ± 5% of the true value of the working solution. All results associated with any AQC outside these limits must be reanalysed.

10. ANALYTICAL PROCEDURE

Exercise caution when handling wastewater samples that pose serious health risks. It is recommended that gloves be worn. Do not inhale or ingest. Upon ingestion, proceed to hospital immediately.

10.1 Preparation of samples

Add approximately half a spatula (at least 0.4g) mercuric sulphate to each of the 120mℓ teflon PFA pressure digestion vessels. This amount is sufficient for 20mℓ of sample. A ratio of approximately 10Hg : 1 Cℓ should be maintained to complex chloride in the sample (up to a maximum of 2 000 mg Cℓ/ℓ . A slight precipitate will not affect the determination adversely.

Add a suitable volume (up to a maximum of 20mℓ) of sample which has been well shaken or homogenised with a high speed blender if necessary. If less than 20mℓ of sample is used, then sufficient distilled water must be added to make this volume up to 20mℓ.
Preliminary dilutions of samples with high COD concentrations may be necessary.

Some suggested sample volumes:

Sewage treatment plant:	Influent	1-5mℓ
	Settled	10mℓ
	Biofilter effluent	20 mℓ
	Humus tank effluent	20 mℓ
	Final	20 mℓ
Clean water samples:		20 mℓ
Other wastewater samples: discretion.		At analyst's

If a filtered COD is required, the sample is filtered through Whatman No.2 (or equivalent) filter paper and the filtrate is analysed. A blank and a standard must also be filtered.

Cautiously add 30mℓ sulphuric acid/silver sulphate reagent (with mixing to prevent local overheating and loss of sample). Carefully add 10 mℓ 0.25N potassium dichromate solution.

10.2 Preparation of standard and blank solutions

Prepare at least one standard and one blank daily. In each case, 20 mℓ of distilled water is treated as in 10.1 above.

10.3 Preparation of AQC solution

Prepare at least one AQC per tray of samples. 20 mℓ of the AQC working solution is treated as in 10.1 above.

10.4 Microwave digestion and titration of prepared samples

Microwave radiation is potentially hazardous. Study the operating manual thoroughly before using the oven. Do not operate the oven with a partially full carousel. If necessary, fill the carousel with blanks.

Close the digestion vessels using the capping station. Microwave the samples according to the procedure. After digestion, the digestion vessels may be cooled in the cooling bath and must only be opened when the contents are at, or below, room temperature.
Quantitatively transfer the digestion vessels' contents to suitable titration vessels. When the residual dichromate is titrated against FAS, the titration end point is indicated potentiometrically, or by the digested samples' colour change from green to reddish brown after the addition of 3 -4 drops of ferroin indicator. If there is no residual dichromate after digestion, the digestion must be repeated using a smaller volume of sample.

11. CALCULATION OF RESULTS

Standardisation of FAS working solution (8.1) and the calculation of COD results are performed by the autotitrator, or manually using the following equations:

11.1 Concentration of FAS (N) $= \frac{0.25\ (N) \times 10\ (m\ell)}{Titre_{std}\ (m\ell)}$

where:

$Titre_{std}$ = Volume (mℓ) of FAS used in titration against 10 mℓ standard potassium dichromate.

11.2 COD mg O_2/ℓ $= \frac{(Titre_{blank} - Titre_{sample})\ m\ell \times Conc.\ FAS\ (N) \times 8000}{Sample\ volume\ (m\ell)}$

where:

$Titre_{sample}$ = Volume (mℓ) of FAS used in titration against samples/AQC.

$Titre_{blank}$ = Volume (mℓ) of FAS used in the blank titration.

NB: The calculated COD value must be multiplied by the dilution factor from any preliminary dilutions.

12. SOURCES OF ERROR

12.1 Ensure that samples are well mixed.

12.2 Preliminary dilutions for wastewaters with suspected high COD levels are made to reduce error inherent in measuring small sample volumes.

13. REFERENCES

- Standard Methods for the Examination of Water and Wastewater, 18th edition.
- Slatter, NP and Alborough, H (1992) Chemical Oxygen Demand using microwave digestion: A tentative new method, Water SA. Vol. 18, No 3.

RECOMMENDED METHOD NO. 2

CHEMICAL OXYGEN DEMAND

Scope

This method is applicable to the determination of the chemical oxygen demand, in water and wastewater. Measurement range: HR = 10 – 2000 $mg\ell^{-1}$
LR = 10 – 150 $mg\ell^{-1}$

Principle:

Most types of organic matter are oxidised by a boiling mixture of chromic and sulphuric acids. A sample is refluxed in strongly acid solution with a known excess of potassium dichromate ($K_2Cr_2O_7$). After digestion, oxygen consumed is measured against standards at 600 nm using a spectrophotometer.

Interference's

Volatile straight-chain aliphatic compounds are not oxidised to any appreciable extent. Straight-chain compounds are oxidised more effectively when silver sulphate (Ag_2SO_4) is added as a catalyst. However, Ag_2SO_4 reacts with chloride, bromide, and iodide to produce precipitates that are oxidised only partially. The difficulties caused by the presence of the halides can be overcome largely, though not completely, by complexing with mercuric sulphate ($HgSO_4$) before the refluxing procedure. Nitrite (NO_2) exerts a COD of 1,1 mg O_2/mg NO_2 –N. Because concentrations of NO_2 in waters rarely exceed 1 or 2 mg NO_2 –N/ℓ , the interference is considered insignificant and usually is ignored. To eliminate a significant interference due to NO_2, add 10 mg sulfamic acid for each mg NO_2 –N present in the sample volume used; add the same amount of sulfuric acid to the reflux vessel containing the distilled water blank.

Equipment

- Where applicable use only class A volumetric glassware
- A 2 ml Fixed pipette
- Borosilicate tubes (100 nm x 10 nm), with screw cap
- Digestion block, to operate at 140-155^{0}C.
- Hach DR/2000 Spectrophotometer, for use at 600 nm with access opening for tubes.

Reagents and Standard Solutions:

1. Distilled / deionised water. Conductivity should be less than 3 mS/m.

2. Potassium dichromate digestion solution:

   a. Potassium dichromate, $K_2Cr_2O_7$
   b. Concentrated sulphuric acid, conc.H_2SO_4.
   c. Mercuric sulphate, $HgSO_4$.
   d. Dissolve 20,43 g $K_2Cr_2O_7$, primary standard grade, previously dried at 103^0C for 2 hrs, in 500 ml distilled water.
   e. Carefully add 167 ml conc. H_2SO_4 to the $K_2Cr_2O_7$ solution in a 1 litre erlenmeyer flask, in a fume cupboard, then add 33,3 g $HgSO_4$. Use a stirring bar and stirrer in a fume cupboard to dissolve $HgSO_4$

   Caution: The fumes from $HgSO_4$ and H_2SO_4 are toxic.

   f. Cool to room temperature, and dilute to 1 litre.

3. Sulphuric acid / Silver sulphate solution:

   a. Sliver sulphate, Ag_2SO_4.
   b. Concentrated sulphuric acid, conc. H_2SO_4.
      Add 5.5g Ag_2SO_4 to 1 kg conc. H_2SO_4.
      Let stand 1 to 2 days to dissolve Ag_2SO_4

NOTE: A QC solution is to be run at the start of the analysis and then after each batch, a batch being 25 samples. In the event of there being less than 25 samples, a QC solution will be run after the last sample.
All QC and standards to be weighed accurately to 3 decimal places.

4. Potassium hydrogen phthalate (KHP) QC:

   a. Potassium hydrogen phthalate (KHP), ($HOOCC_8H_4COOK$).
   b. Distilled water.

5. Lightly crush and then dry KHP to constant weight at 120^0C.

6. Dissolve 0,425 g in distilled water and dilute to 500 mℓ.

   KHP has a theoretical COD of 1,176 mg O_2/mg and this solution has a theoretical COD of 1000 mg O_2/ mℓ. This solution is stable for up to 3 months when refrigerated at $4^0C \pm 2\ ^0C$.

Dilute 25 ml from the 1000 mg/ℓ stock standard in a 250 mℓ A grade volumetric flask. This solution has a theoretical COD of 100 mg O_2/ mℓ. This solution is stable for up to 1 month when refrigerated at $4^0C \pm 2\ ^0C$.

7. Low range COD digestion vials, 0 to 150 mgℓ$^{-1}$ COD (Hach cat. No. 21258-15).

Sampling and Storage

Preferably store samples in glass bottles. Test unstable samples without delay. If delay before analysis is unavoidable, preserve sample by acidification to **pH ≤ 2 using** conc. H_2SO_4. Blend samples containing settleable solids with a homogeniser to ensure representative sampling. Make preliminary dilution's for wastes containing a high COD to reduce the error inherent in measuring small sample volumes.

Analytical procedure:

Sample with low COD values (<150mgℓ$^{-1}$) must be digested in the low range reagent vials. High range COD reagent tube can be prepared as follows:

- Measure 2 mℓ of the potassium dichromate digestion solution into a borosilicate tube.
- Measure 2 mℓ of the sulphuric acid / silver sulphate solution into a tube.
- **Pipette 2 ml of the sample into a tube**.
- Prepare a blank and one or more standard in the same manner. Prepare standards for the high and low range.
- Close the tube tightly and invert each tube several times to mix well. CAUTION: Wear eye and hand protection against heat and possible tube explosion!
- Digest on a preheated digestion block for 2 hours at 140-155^{0}C.
- Remove carefully from heating block, and allow to cool. CAUTION: Hot surfaces, wear hand protection!
- Clean tube surface by wiping with a damp towel, followed by a dry one. Read on spectrophotometer at 600 nm for high range COD (method 952) and 420 nm for low range COD (method 430). The following procedure should be followed.

DR/2000 Spectrometer procedure.

- Put spectrometer on by pressing POWER switch
- Enter stored program number for COD. For Low Range press 430 READ/ENTER display will show DIAL nm TO 420.
- Rotate the wavelength dial until the small display shows : 420 nm.
- For High Range press 952 READ/ENTER.

- Rotate the wavelength dial until the small display shows : 600 nm.
- Press READ/ENTER. The display will show : $mg\ell^{-1}$ COD.

- Ensure COD Vial adaptor is placed into cell holder with the marker to the right.
- Place blank into the **adaptor** with the Hach logo facing the front of the instrument. Place the cover on the adapter.
- Press ZERO. Display will show WAIT, then : 0/$mg\ell^{-1}$ COD.
- Place sample into the adaptor with the Hach logo facing the front of the Instrument. Place the cover on the adapter.
- Press READ/ENTER. Display will show WAIT, then : the result in $mg\ell^{-1}$ COD will be displayed.
- Dilution of sample may be necessary if concentration level is higher than 1200 COD as mg O_2/l.

Calculation of results:

Direct reading from Hach spectrophotometer.

Reporting of results:

- Express results as COD, to the nearest 10 $mg\ell^{-1}$.
- Example: COD as mg O_2/l = 50 $mg\ell^{-1}$.

References:

- American public health association – American Water Works Association – Water Environmental Federation. (1985) Standard Methods for the Examination of Water and Wastewater, 13th Edition, Washington DC
- Hach Company (1993). DR 2000 Spectrophotometer Procedures Manual Loveland, Colorado.

APPENDIX V

A typical information sheet used to assess the volume of effluent.

PART I

INFORMATION REGARDING PERSONS EMPLOYED AND WATER CONSUMED ON THE PREMISES

1. Nature of the industry concerned
   ………………………………………………

2. Name under which the industry is trading
   ………………………………………

3. Address of the industry ………………………………
   ………………………………………

   If the business or industry is carried on by a company, state the name of the secretary and if it is a partnership state the names of the partners

   ………………………………………………………………………………………………

4. Description of the process by which the effluent will be produced
   ………………………………………………………………………………………

5. Information relating to employees:

Office/Factory

(1) Total number of daily employees (not to include (4)) ………………………………

(2) Number of shifts worked per day ……………………

(3) Number of days worked per week ……………………

(4) Number of persons resident on the premises ……………………

(5) Is a canteen provided: ……………………

6. Information relating to water consumption:

Kilolitres/Month

(1) Approximate average monthly quantity of water purchased from the Local authority for use on the premises ……………………

(2) Approximate average monthly quantity of water obtained from any borehole or other source ……………………

(3) Quantity of water in the end-product ……………………

(4) Quantity of water lost by evaporation ……………………

(5) Quantity of water used as boiler make-up ……………………

(6) Is water used on the premises for any, and if so, which, of the following purposes : cooling, the cleaning of utensils, floor-washing, any other industrial purpose, and subsequently discharged to sewer?

……………………………………………………………………………

7. If the answer to the question in paragraph 6 (6) is "yes", Part II of this form must be completed.

Applicant's Signature : ………………………………………………

PART II

INFORMATION REGARDING THE CONSUMPTION OF WATER

The following information is required for the purpose of estimating the quantity of industrial effluent discharged into the Local authority's sewer, and all figures given shall relate to the quantity of water taken over a period of six months.

Name of consumer

……………………………………………………………………………

1. Stand No: ……………Township:

Total number of kilolitres of water consumed in six months

	Meter No.	Meter No.	Meter No.	Meter No.
Water purchased from the Service provider				
Water from borehole or other source				
Water entering with raw materials				
Section of plant served by meter				
Total quantity of water consumed				

2. For the purposes of this estimate the total number of kilolitres of water used in six months for any of the purposes below mentioned may be left out of account.

(1) Water used by staff for domestic purposes:

	Number	Shifts per day	Days per week	Allowance kilolitres/head/day	Total
Daily employees (excluding residents) Office .... Factory					
Resident Persons .... Canteen					
Total water used (in kilolitres)					

(2) Water used in the operation of boilers:

	Boiler 1	Boiler 2	Boiler 3	Total
Type of boiler				
Rating (kg steam/hr (kilowatt)				
Hours steamed per month				
Total evaporation per month				
Condensate returned (in kilolitres)				
Percent of unreturned condensate discharged to sewer				
Coal burned – kg per month				
Water used for coal wetting (in kilolitres)				
Water used for ash quenching (in kilolitres)				
Quantity of blowdown (in kilolitres)				
Does blowdown enter sewer?				

Quantity of softener back-wash water per month (in kilolitres)				
Total quantity of water used (in kilolitres)				

(3) Water absorbed by the goods manufactured on the premises in six months:

(a) Expressed as a percentage of the total consumption of water less the allowance for staff use.

(b) Expressed as kilolitres per six months contained in the finished product*:

(i) ……………………………………………………………………

(ii) ……………………………………………………………………

(iii) ……………………………………………………………………
Kilolitres per six months

(iv) ……………………………………………………………………

(v) ……………………………………………………………………

(4) Kilolitres of water lost in six months by evaporation to the atmosphere:

(a) By units of plant other than cooling towers ……………… Kilolitres per six months.

(b) By cooling towers: …………………………………………… Kilolitres per six months.

* Example: Soap factory; Yellow soap, 4 000 metric tons manufactured at 50 per cent moisture content-water in product 2 000 kilolitres (in six months).

N.B. All deductions need to be justified.

	1	2	3	Total
Type of Tower				
Quantity of water circulated per six months (in kilolitres)				
Temperature drop (C^0)				
Estimated loss by evaporation (in kilolitres)				
Metered water fed to cooling towers (in kilolitres)				
Quantity of refrigerant in circulation in six months (in kilolitres)				
Total quantity of water lost by evaporation (in kilolitres)				

(5) Quantities of water lost in six months from miscellaneous cause:

(a) ……………………………………………………………………

(b) ……………………………………………………………………

(c) ……………………………………………………………………

Total deduction (in kilolitres) ……………… grand total of deductions to be made in terms of subparagraphs (1) to (5) of this paragraph ………………

* Example: Soap factory: Yellow soap, 4 000 metric tons manufactured at 50 per cent moisture content – water in product 2 000 kilolitres (in six months).

Estimated process water discharge to sewer (arrived at by deducting the total quantity of permissible deductions shown in sub-paragraphs (1) to (5) of paragraph 2 from total water consumed as shown in paragraph 1.

SIGNED: ……………………………………………………
By or for the Applicant

……………………………………………………
By or for the City/Town Engineer

DATE : ……………………………

APPENDIX VI

SPECIMEN ANNUAL BUDGET
DETAILED EXPENDITURE REPORT

DIRECT EXPENDITURE	RAND
MANPOWER HIGHER GRADES	
Salaries – Normal	268971
Salaries – Overtime	63646
Shift Allowance	0
Annual Bonus	22414
Housing subsidies	45600
Pension Fund contribution	47204
Medical Aid contributions	16507
UIF contributions	3145
Sale of Leave	0
Five Year bonus	1827
Interpreters Allowance	360
Standby allowance	10060
TOTAL	**479734**
MANPOWER LOWER GRADES	
Salaries – Normal	282725
Salaries – Overtime	62206
Shift Allowance	5009
Bonus & other	23560
Housing subsidies	64500
Pension Fund contribution	49618
Medical Aid contributions	51000
UIF contributions	3472
Five Year bonus	16337
Temporary Staff	**25000**
TOTAL	**583427**
TOTAL MANPOWER COSTS	**1063161**
PURIFICATION COSTS	
Alum/Liquid – usage	489956
Chlorine – 1 ton	16970
Chlorine – 70 kg	588
HTH – usage	0
Line – usage	290
Chloride of lime – usage	1698
Zetafloc CB 5157	99242
TOTAL	**608744**
INDIRECT EXPENDITURE	
Internal – Mobile Plant	179093
Transport – Internet Vehicles	102079
Transport – Hired Vehicles	240000
Rates	0
Rent	8160
Security services	43293
Insurances	118056
Admin & Technical – Indirect	1201387
Interest – external	2710694
Redemption – external	125509
SUB TOTAL	**4728271**

DIRECT EXPENDITURE	RAND
GENERAL	
Subsistence and Transport	1150
Transport – Non External Vehicles	26000
Conference – Local	1500
Electricity & Water	583500
Staff Recreation	613
Plant/Equipment – Hired	2500
Materials – Consumables	23000
Materials – Small Tools	4100
Safety	11500
Printing & Stationery	750
Telephone, Telex & Postage	12500
Advertising	0
Repairs, Maintenance & Renewals	3000
Hire of Office Equipment	2250
Fuel & Lubricants	3000
Annual Maintenance Contracts	45000
Canteen Services	8000
Library Books & Publications	150
Institutions – Membership Fees	250
Property Services	6570
TOTAL DIRECT EXPENDITURE	**2407238**
MAINTENANCE	
Workshop – Mechanical (1)	507111
Workshop – Electrical (1)	139499
Workshop – Instruments (1)	38391
Workshop – Civil (1)	226541
Workshop – Vehicle (1)	6666
Garden Maintenance Services	11590
TOTAL	**929798**
TOTAL INDIRECT EXPENDITURE	**5658069**
NET REVENUE/DEFICIT	**494693-**
All the above can be grouped under the following headings	
Salaries (manpower costs)	1063161
Repair & Maintenance	929798
General expenses	2407238
Depreciation + interest	3665110
TOTAL	**8065307**

N.B. Each treatment facility has a specific cost centre, and a variety of cost codes for various items of expenditure.

Other related WRC reports available:

Estimation of the Residential price elasticity of demand for water by means of a contingent valuation approach

GA Veck & MR Bill

An important factor in being able to manage metered water effectively is knowledge of its price elasticity of demand. However, no recent research effort has been undertaken in South Africa regarding this subject.
The objective of this research study is to estimate the residential price elasticities of demand for water for different income groups by means of the contingency valuation method (CVM).

The literature on this subject shows that CV values are good surrogates for actual behaviour and that CV measures from surveys can be compared directly with economic values attained from trends in the market place.

This study was undertaken in the residential areas of Alberton and Thokoza. The methodological approach was undertaken by means of a two-stage interview survey.

Survey No 1: Consisted of establishing a water usage profile for different income groups in Alberton and Thokoza
Survey No 2: Consisted of a CV experiment and analysis.

During these surveys, it was found that people were not aware of how they used water, nor were they aware of how they could save water. Consequently, it was necessary to design an educational programme as part of the complete process in order to arrive at a meaningful result. Surveys 1 and 2 were, therefore, used in conjunction with each other, and the end result of the analysis yielded defensible estimates of the price elasticity of demand for domestic water usage amongst residential consumers in Alberton and Thokoza. From the results it can be seen that the price elasticity of demand for total water usage in Alberton and Thokoza is -0.17. It, therefore, follows that if the price of metered water for residential use is increased by 10%, the total quantity of water demanded would be reduced by 1.7%

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