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**REPORT ON SEWAGE POLLUTION IN THE KLEIN RIVER: FROM
THE BRIDGE (R43) ON THE KLEIN RIVER AT STANFORD UP TO
SCOUT CAMP (HERMANUS)**

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Investigation requested by Overstrand Municipality, Hermanus

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EXECUTIVE SUMMARY

Regular, long-term environmental monitoring is essential to identify and to act pro-actively in minimising negative human impacts on the environment (e.g. pollution), and in so doing maintain the beneficial value of an area for all its users. This is particularly pertinent to an area such as Klein River and Kleinrivier estuary, which are important for the recreation, tourism and fishing industries.

The importance of ensuring health and safety of water, and especially water in the natural environment are entrenched in all levels of legislation in South Africa. Therefore all levels of society from the resident to the highest authority have to take all necessary steps to ensure that water is not polluted.

From this investigation it became clear that the stream at Stanford and the estuary are polluted considering the high levels of both faecal pollution indicator organisms (*Escherichia coli* and faecal enterococci). It was also proved that the pollution in the estuary has a seasonal trend, but that it quickly regains its polluted status after the water level drops.

A simple procedure is advocated for assessing pollution levels. By using the *E. coli* and faecal enterococci graphs the pollution status can be read off objectively and subjectivity does not play a role. Decisions on when to close a facility can now be made with confidence.

All indications are that the pollution identified is linked to sewerage systems. It originates from old and leaking and/or badly managed and constructed subterranean tanks. The biofilm that develops in such instances supports, harbours and propagates the indicator organisms. A second pollution problem is that bacteria become resistant to disinfectants and become viable when residual disinfectant levels drop. Another possible source of pollution is the old dumpsite.

The increase in construction along the stream, river and estuary calls for drastic re-thinking of the way sewage is managed in areas not linked to water-borne reticulation systems. It will be prudent to put a system in place to have all subterranean tanks of a certain age replaced with pre-fabricated SABS/CSIR approved concrete tanks and to implement stricter inspection regimes. It will also be necessary that DWAF reconsider the requirements for the placing of subterranean septic tanks along natural water bodies.

The Klein River and estuary should continue to be monitored to keep track of the pollution status and the impacts of improvements when implemented.

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1 INTRODUCTION

In the past decade or two the Kleinrivier estuary, previously known as the Kleinriviersvlei, (in the local vernacular as Hermanus Lagoon) became an increasingly important recreational asset. It has currently been upgraded to the 5th most important estuary in South Africa (De Villiers, 2007, pers. comm.). The functioning of the Klein River and its tributaries as ecological corridors and linear open space areas should be protected and managed with conservation objectives in mind (LPL 9; SDF, 2005). In the Planning Principles of the SDF (2005) it is stated that *“The diversity, health and productivity of eco-systems be maintained and environmental and sustainable land use practices promoted. Our goal is to implement an effective management system for the protection of biological diversity and ecosystems through the cooperation of all concerned.”*

As the nearby towns expanded and roads improved the estuary became more and more important. The down side of this was that human pressure on the estuary and river increased as development soared. This is exacerbated during holidays and weekends. As human pressure (residential and tourism) increased so did complaints regarding owners who disregard the activities of others increased. Currently complaints and rumours regarding pollution abound. Europeans (our tourists) are very concerned about water quality in the sea, coasts, rivers and lakes. They put good bathing water quality on the first line when judging their immediate living environment. (EU, 2006).

The problem of sewage pollution of natural waters is nothing new in the current South Africa. Daily in newsprint and on TV shocking images and information on this topic are on display. In this regard the Minister of Water Affairs and Forestry does not build confidence in the system with a statement on pollution in Parliament that *“Our (DWA’s) attitude is: How can you police people when you, yourself, know they actually have no capacity to comply. So we are not going hard on municipalities and taking them to court because of pollution; we are trying to work with them to make sure their systems work”* (SAPA, 15 May 2007).

The Overstrand Municipality, tourists and residents along the estuary and the people using the Kleinrivier Estuary, for recreational purposes are all concerned about the “sporadic” high levels of faecal coli and *Escherichia coli* bacteria in the estuary. This was also a concern 20 years ago. The following statement from Heydorn & Morant (1989) supports this claim. *“In 1986 the Hermanus Municipality embarked on a monthly survey of estuarine coliforms, which are indicators of human faecal contamination, in view of the possibility of seepage from septic tanks along the northern shore.”* If there was this suspicion 20 years ago, one can only imagine what the current situation is!

The general feeling amongst the officials and the public was that the pollution is (a) linked with low water levels and (b) that the pollution originates from Stanford village and agricultural activities in the catchment. The only way to stop rumours and guessing is to provide verified data. To do this an investigation was planned and implemented to determine where this periodic pollution problem originates, how widespread it is and if there are any possible solutions.

Historically samples for bacterial analyses were collected on a monthly basis at seven of the western stations on the estuary - Scout Camp to Maanskynbaai. When “problems” were reported another four stations towards the middle of the estuary at the estates were sampled. Although this sampling process was in place for at least 20 odd years, only records from the last three years were available to study the pollution history of the estuary.

The fact that only data for the last three years are available, the fact that the early history is not available, that the sampling procedure is fragmented and the fact that the data that was collected and still are collected were not interpreted or collated, do not assist in providing answers or in solving the problem.

If for argument’s sake, the historical data was available for 20 years and could be studied, it would have been possible to determine when in the past did this problem start or was exacerbated.

Current data indicates that the only way to evaluate and make decisions on an issue as variable as bacterial counts is to take the history into account. As will be shown later, the method described by Dept of Water Affairs and Forestry (DWAF) in their guidelines and by the Blue Flag organization requires that historical data (the European Union requires data over three years) must be used to “calculate” the hazard level after each new sample has been analyzed. This was not done and decisions were taken, on many occasions, on single samples.

One of the constraints/limitations in a study of this kind is the fact that we have to contend with “diffuse” pollution. Diffuse pollution is *"pollution arising from land-use activities (urban and rural) that are dispersed across a catchment or sub-catchment and does not arise as a process of industrial effluent, municipal sewerage effluent, deep mine or farm effluent discharge"* (D'Arcy *et al*, 2005). These non-point sources of pollution in a catchment area can collectively deliver significant impacts on the environment. Add to this the effect of storm-water run-off and the problem becomes more complicated (DWAF, 2004b).

Examples of minor non-point source (diffuse) pollution include

- ✓ Urban run-off from unsewered urban areas
- ✓ Effluent in areas where septic tank/conservancy/soak-away systems are failing

- ✓ Leaching of septic tank effluents into groundwater sources.

Novotny and Olem (1994. In Davies, *et al.*, 2005) constructed a list of characteristic for diffuse sources. All these are identified in the problems around the river and estuary.

- ✓ Diffuse pollution enters the receiving surface waters in a diffuse manner at intermittent intervals;
- ✓ Diffuse sources are difficult to monitor at the point of origin;
- ✓ Impact on the depression (water body) as a whole;
- ✓ Compliance monitoring is (has to be) carried out on land rather than in water

The most important waste constituents from diffuse sources, subject to management and control, are suspended solids, nutrients, faecal pathogens and toxic compounds.

In order to understand this kind of pollution issue, it was necessary to extensively survey the literature. From this it transpired that this is both a global problem and a very complex one, seldom with clear-cut solutions.

2 HYPOTHESIS & SCOPE

If there is a recurring/cyclic pollution problem in the Klein River and estuary as being indicated by reports, complaints by residents and fragmented historical results, it is important to verify this trend. Only if this is verified then effort can be spent to find a source (diffuse or point) that supplies and supports this cyclic pollution problem.

The aims of this study are therefore

- ✓ To determine if there is a cyclical tendency to the pollution in the estuary and the stream running through Stanford;
- ✓ To determine if any sources exist (can be identified) that can maintain the pollution in these areas;
- ✓ To recommend possible remedies;
- ✓ To propose a method to track the pollution scientifically, and
- ✓ To provide a basis for easier decision making.

3 TERMINOLOGY

Under this heading only a few special terms and concepts will be discussed and highlighted. For the rest of the definitions, descriptions and abbreviations the reader is referred to Chapter 10: Definitions & Abbreviations.

The descriptions “estuary” and “lagoon” are often used in the wrong context. These terms are not synonyms but describe completely different types of natural water bodies.

A **lagoon** is a body of comparatively shallow salt or brackish water separated from the deeper sea by a shallow or exposed sandbank, coral reef, or similar feature (water behind a barrier reef or barrier islands or enclosed by an atoll reef is also called a *lagoon*.)

On the other hand, an **estuary** is a partially enclosed, coastal body of water which is either permanently or periodically open to the sea and within which, there is a measurable variation of salinity due to the mixture of sea water with fresh water derived from land drainage” (Day 1980). The prime difference between a lagoon and an estuary is that the latter receives fresh water from rivers or streams and the other not.

To be termed an estuarine lake or estuarine bay system the surface area of the water body must exceed 1000ha. According to Duvenhage (1983) the Kleinrivier estuary has a water surface of 918ha, which makes it slightly smaller than an estuarine lake, but still one of the largest in South Africa.

Another concept that causes problems is that bacteria are incubated before being counted. Why increase the numbers if you want the smallest number? Bacteria are microscopic (*E. coli* = 1µm in length) and a method is needed to make them visible and easily countable. This is done by incubating the single bacterium cells on a nutrient medium/broth. This means that when cultured each **invisible** single bacterium in a sample will form a **visible** colony. They are then aptly termed a **colony forming unit (cfu)**. They can now be counted in various ways. In microbiology and in this report the number of bacteria cells is expressed as **cfu/100ml**.

4 BACKGROUND

This chapter is included to provide the reader with information on a number of subjects in order relate to the area under investigation and to facilitate the understanding of the contents of and reasoning in this report.

4.1 Characteristics of the Klein River and Estuary

The Klein River has its origin at the confluence of the Hartebees and Steenboks Rivers at *Piet-se-Kraal*, 47-50km upstream from the sea (Figure 1). The latter two rivers have their sources 23km and 15km upstream of the confluence respectively. The Hartebees River drains the valley between Shaw's Mountain and the Kleinriviersberge, while the Steenboks River drains the plains north of the Steenboks Mountain and south-east of Caledon (Overberg). The Klein Steenboks River, which drains the area south of Caledon, joins the Steenboks River 4km upstream of its confluence with the Hartebees River. Other tributaries of the Klein River include the Karringmelks-, Pieters- and Modder rivers, as well as several smaller streams. Approximately 10 streams drain directly from the slopes of the Kleinriviersberge into Kleinriviersvlei (Kleinrivier estuary). From the "mouth" of the Estuary to the source, the Klein River system is approximately 51-60km in length. The estuary measures approximately 10km by 2km and the river, from the estuary up to Stanford another 6km. Another interesting fact about the Klein River is that the origin of the most western and southern stream (Hartebees River) is less than five kilometers from the mouth!

All along its length the river runs through farming communities with a wide range of agricultural interests. A cheese factory is situated south of Akkedisberg. The river meanders through farming communities and approximately 2km east of Stanford the Birkenhead beer brewery is situated. Poultry farms are sited south of Stanford. Downstream from the bridge on the R43 the town of Stanford sits on the eastern and southern banks of the river. From the town up to the estuary, the banks are lined with residences, farms, holiday homes and lodges. With the exception of a few residences in Stanford the rest are all fitted with septic/conservancy sewage tanks and/or soak-aways.

The size of the catchment (Fig. 1) area is between 741 to 906km². An interesting fact is that the Kleinrivier estuary is one of the largest estuaries in South Africa but with the smallest catchment (Heydorn & Morant, 1989).

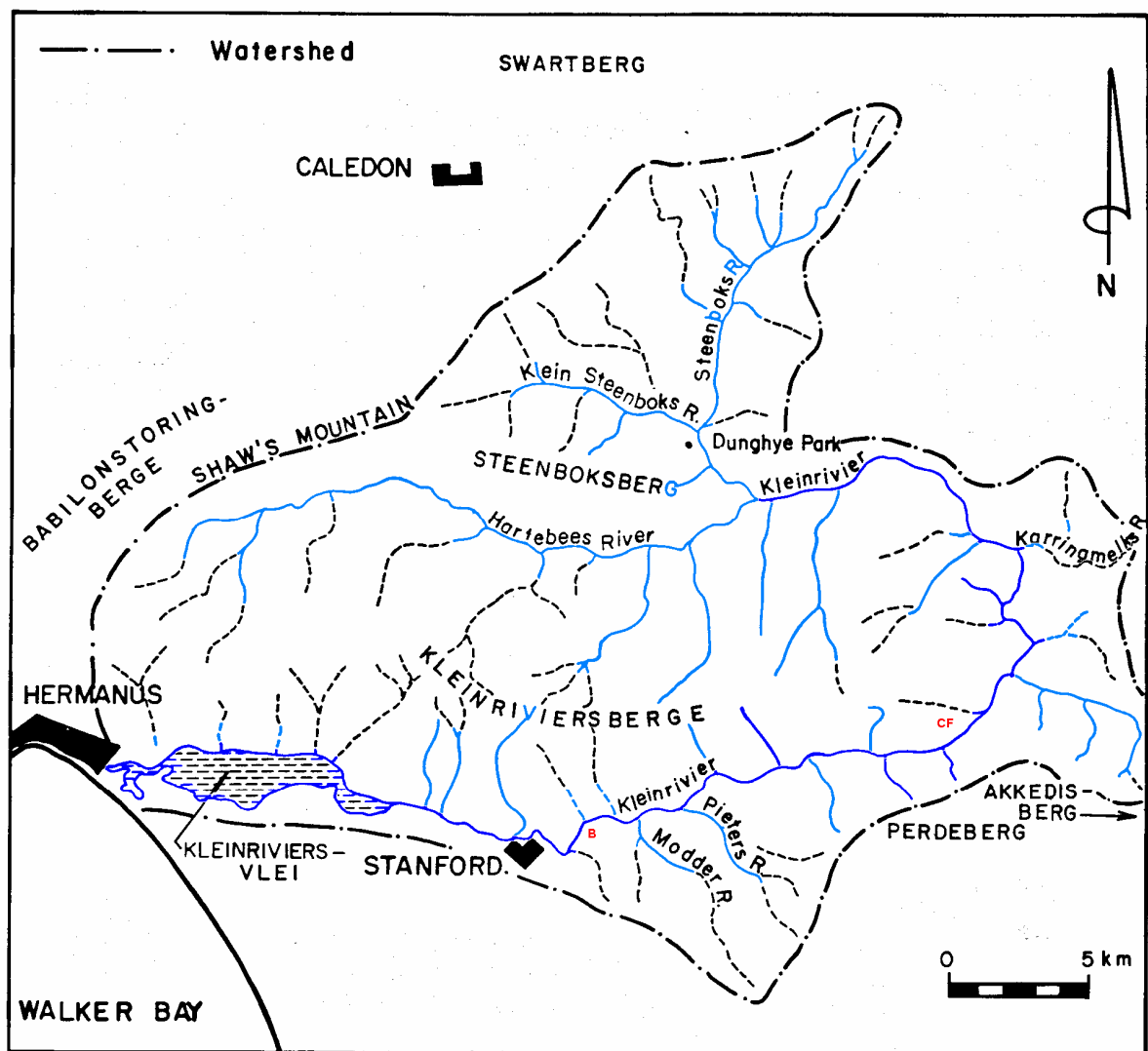


Figure 1. Klein River catchment area and tributaries (From Heydorn & Morant, 1989). Light blue indicates the tributaries and dark blue the Klein River; red “B” = Birkenhead brewery; red “CF” = Cheese Factory.



Figure 2. Topo-cadastral layout depicting the topographic layout of the Kleinrivier estuary from Hermanus (Scout Camp) in the west to the bridge crossing the R43 at Stanford.

4.2 Geology

Klein River and estuary

The information on the geomorphology of Kleinriviersvlei is scarce and what is available has been given by Sloman (1983, In Heydorn & Morant, 1989). The estuary is bounded to the north by the Kleinriviersberge composed of rock of the Table Mountain Group, while its southern shore (Stanford area) is composed of coastal limestones (calcretes). Fringing the southern shore of the estuary, are lithified dunes covered by calcrete caps. The calcrete ends abruptly in a subterranean "cliff", and is replaced on the seaward side by modern sands.

The mountains comprise hard, resistant quartzitic rocks or sandstone of the Table Mountain Series. These ancient, dramatic strata yield humic acid-laden, oligotrophic waters which frequently generate nutrient-laden foams during winter spates, with a pH that rarely approaches neutrality and is often as low as 4.3. (Davies, et al. (1993, p49-57)). The rivers in this area form two groups:

- ✓ Strongly acid (pH 5.0 – 5.9) with unbuffered water, low TDS, and frequently peat stained; and
- ✓ those with a pH between 6.0 – 6.9, with clear water.

Coetzee & Poole (1986) found that the rivers and streams feeding the estuary are acid and stained dark brown by humic substances. Scott *et al.* (1952) measured the pH 5.0 at the inflow and a pH 6.9 - 7.0 at the opposite end of the estuary. When not in flood the pH readings fluctuate between 6.1 – 6.9. Notwithstanding the acidic inflow, the estuary stays alkaline with pH values as high as 8.5 (Coetzee & Poole, 1986).

Stanford

From the schematic cross section in Figure 3 (from Umvoto, 2007) it is clear that all run-off from Stanford along the impermeable Bokkeveld series is towards the Klein River and estuary.

Stanford is situated on the impermeable Bokkeveld Formation of undifferentiated shales and, possibly in some areas, sandstones (Umvoto, 2007). From Stanford stretches the Waenhuiskrans formation, a semi-consolidated aeolian (wind blown) sand with calcrete lenses up to the Table Mountain Group. The general flow direction within the aquifer is towards the Klein River and the Klein River Estuary.

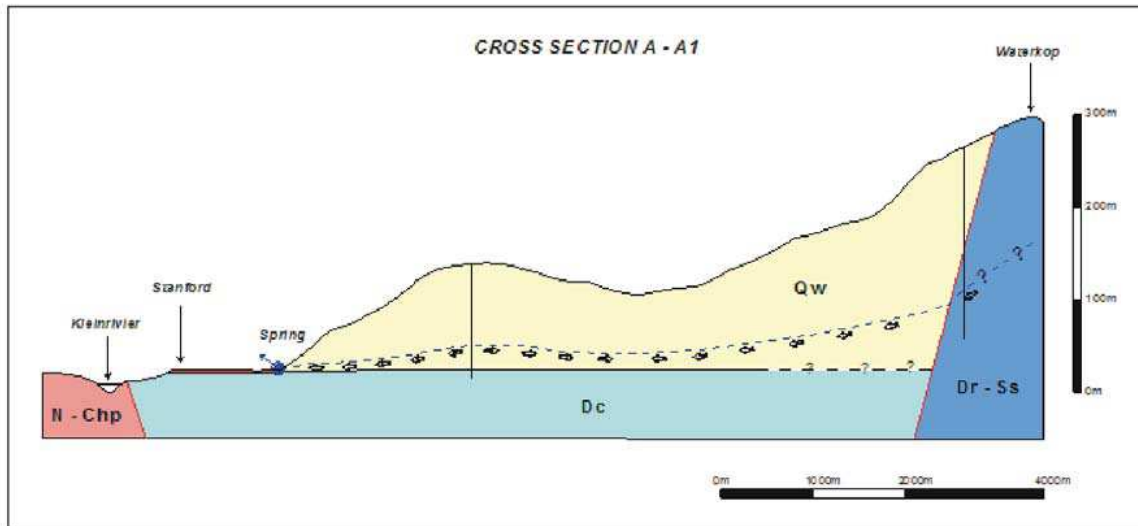


Figure 3: Schematic cross-section through the Stanford Eye, explaining the spring location (Vertical black lines – boreholes, read line – TMG and Qw contact). (From Umvoto, 2007)

4.3 Type and Health of the Estuary

From an ecological point there are two processes which are defined as important “services” provided by estuaries: (A) provision of nursery habitat for marine species and (B) outputs to the marine zone (nutrients and sediment). It is also widely recognized that estuaries are threatened by (a) the activities that occur within and immediately around them, and (b) by activities that reduce the supply of freshwater inputs (Turpie, 2004).

The Kleinrivier estuary has been classified in terms of its physical characteristics as a temporarily open estuary (Harrison, 2004, Whitfield, 2002). This estuary falls within the Warm Temperate zone which extends approximately from Cape Point to the Mbashe River in the Eastern Cape (Harrison 2004). Estuarine temperatures follow the trend for marine coastal waters, being coldest on the west coast. Warm temperate estuaries, such as the Klein River, are characterised by high salinities and low turbidities due to low rainfall and runoff, high seawater input and evaporative loss (Harrison 2004).

There has been concern about the condition of South African estuaries since the 1970s, when it was already noted that few estuaries remained in their natural state (Heydorn 1972, 1973 In Morant & Quinn 1999).

Notwithstanding the statement that “the overall health of South African estuaries is relatively good”, it is also highlighted that the health of the estuaries in our area is only **fair** and that the ecosystems are **vulnerable** (Turpie, 2004).

Estuaries are coming under more and more pressure and are becoming more vulnerable. These pressures include *inter alia* habitat alteration, recreational disturbances and pollution from sewerage systems. It is expected that future pressures in our area will rise sharply (Turpie, 2004).

4.4 Pollution history

Pollution is defined by the United Nations Convention on the Law of the Sea as “*the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of the sea water and reduction of amenities*”. A wide variety of pollutants are generated by man, many of which are discharged to the environment in one form or another (Atkinson, 2006).

Faecal pollution contained in, for example, untreated sewage or storm water runoff, may introduce disease-causing micro-organisms into coastal waters. These pathogenic microorganisms constitute a threat to water users and consumers of seafoods. Bacterial indicators are used to detect the presence of faecal pollution.

According to municipal officials and Johan v Taak (EHO, Overberg District Municipality), the Kleinrivier estuary, was and is every now and then, especially when the water level is low, polluted with *E. coli* and faecal coliforms. This problem generally surfaces during the summer months when large numbers of holidaymakers are around. This pattern has been noted for at least the last 20 years.

4.5 Subsurface Water and Pollution of open water

There are two major influences on the movement of sub-surface water. Firstly, water flows towards the centre of the depression (estuary, lagoon, or river). The second major factor influencing the direction of flow is the hydrological pressure (hydraulic) gradient from the steep mountain structure within one kilometre of these depressions. Water flows down and through a mountain substrate by gravity towards any depression (Parsons 2004). Sub-surface water is therefore the primary channel for transport of nutrients and pollution to the depressions. As a consequence, instead of being washed away, pollutants tend to accumulate in the depressions (Davies & Day, 1998). It has been demonstrated that sub-surface water transports the various pollutants and nutrients through the soil, where some pollutants accumulate and are available for plant absorption (Thomas, 2005).

Stormwater run-off is another of the major non-point sources of pollution. It is, however, very difficult to characterise stormwater run-off because of widely varying contaminant

concentrations (Wanielista *et al*, 1977; In DWAF, 2004b). This, together with large fluctuations in run-off volume and the large number of discharge points, has limited the treatment of such wastewater, which often contains toxic and refractory compounds (Meyer, 1985 In DWAF, 2004b). Stormwater run-off can be divided into two broad categories namely (Hoffman, 1986, In DWAF, 2004b):

- ✓ urban run-off (residential including formal and informal developments, industrial and commercial)
- ✓ rural run-off (e.g. rural settlements, agricultural and forestry areas)

The quality and quantity of stormwater run-off is determined to a large extent by catchment characteristics, rainfall characteristics and antecedent moisture conditions. Stormwater run-off from agricultural catchments was found to contain a high suspended solids load, high iron and manganese concentrations as well as high nutrient (nitrates and phosphates) and pesticide concentrations, while litter, copper, lead, zinc and petroleum hydrocarbons were predominant in run-off from urban (informal) catchments. In most of the latter areas, a low level of sanitary services is provided, with the result that the pollution of stormwater run-off, which usually drains directly into the surf zone and natural surface water is more serious than in formally developed areas (Miles, 1984; In DWAF, 2004b).

The first flush effect, which is evident as a peak of highest pollutant concentrations at the beginning of a storm event, is the result of accumulated materials being washed from the catchment surface. This effect seems to increase in frequency and intensity as the degree of urbanisation increases (Brown *et al*, 1979; Simpson, 1986; In DWAF, 2004b). In general, highly urbanised catchments produce the greatest concentration of pollutants in stormwater run-off and rural catchments the least (Green *et al*, 1986; In DWAF, 2004b).

Concern about the pollution effect of stormwater run-off in South Africa has increased dramatically over the past years. However, the data available on the quantity, and especially the quality, of this run-off is limited. Notwithstanding this limitation, the effect on the problem in the river and estuary must be considered.

Major sources of faecal contamination to marine waters include *inter alia*: sewerage discharges; bathers themselves, especially at densely populated beaches; septic tank seepage; stormwater run-off and contaminated river run-off (DWAF, 2004b).

4.6 Anthropogenic Pressures

Conservancy and Septic tanks (and soak-aways)

The residential estates along the estuary (except Lagoon Edge, where a small scale waste water treatment works (WWTW) is in operation) are not linked to the municipal sewerage

reticulation system and therefore all houses/residences in this area, along the northern and southern bank and in Stanford are fitted with either septic or conservancy tank systems. It is a known fact that sewage tanks do not function properly in areas where the sub-surface water levels are high (Hayes, 2001).

Nitrates and phosphorous are two major pollutants that are released into the sub-surface water due to defective conservancy and septic tanks (Hayes,2001). Nitrates are generally a result of ammonia compounds that are found in household detergents and disinfectants. High concentrations of phosphates are good indicators of pollution caused by domestic effluents (detergents, sewerage etc.). A significant impact of an excess of phosphates and of nitrates (both are natural nutrients) is the 'wild' growth of aquatic plants and algal blooms (Hayes & Winter, 2002). These blooms and unacceptable smells are (sometimes) noticeable at DeMondt and Scout Camp stations.

Domestic sewage contains constituents that may pose a risk to the environment and/or public health, and cause a nuisance. Elements in sewage beneficial to the soil may also produce detrimental effects if applied at excessive rates or under improper conditions and/or locations (SERM, 1999).

Bacteria and viruses absorbed to particulate matter as well as encysted and egg stages of parasites can become concentrated in the sludge phase of septage. Consequently populations of potential human pathogens in sludges such as those in septic tanks are many times greater than that in the sewage entering the septic tank (Fenger, 1973, In (SERM, 1999)).

Land disposal of sewage presents two immediate areas of concern regarding possible health risks: the survival of various infectious agents in soil resulting in contamination of forage and edible crops, and the contamination of water as a result of runoff and percolation (SERM, 1999).

The involvement of micro-organisms in the deterioration of concrete has been studied for a number of years, but only recently have attempts been made to understand the basis of microbiology mediated decay of concrete. A major portion of the work carried out to date on biofilm (refer par. 4.7 Biofilm) formation on concrete and bio-deterioration of concrete pipes has been conducted on sewerage systems, in marine environments (Kulpa & Baker, 1990 In Momba *et al.*, 2000) as well as with underground concrete structures (Tazawa *et al.*, 1994. In Momba *et al.*, 2000). Bio-alteration is part of the weathering process, and concrete is altered by micro-organisms that form a layer called a biofilm on its surface. Although the development of the biofilm can be considered normal due to the fact that it is a natural process, as it occurs on every element in contact with micro-organisms, it can induce an

alteration, such as biological stains on concrete facing, or a degradation of the material (Roux *et al.*, 2007).

Bacteria themselves do not have noticeable effect on concrete. However, anaerobic bacteria (*Thiobacillus* spp.) in untreated sewage tend to produce hydrogen sulfide, which is then oxidized by aerobic bacteria present in biofilm in the oxygen rich areas to sulphuric acid which dissolves the carbonates in the cured cement and causes strength loss. (Diercks *et al.*, 1991; Wikipedia, 2007). Nitrifying organisms (a type of bacteria) have been found in high cell numbers on the surface of concrete structures. The nitric acid, which is excreted by these organisms as a metabolic end-product, also causes severe corrosion (Diercks *et al.*, 1991), failure and inevitable pollution.

4.7 Biofilm

The term “biofilm” is used to describe a layer of micro-organisms in an aquatic environment held together in a polymeric (also known as external polymeric substances (EPS) matrix “slime” attached to any substrate. Attachment is a first step in the process of microbial colonisation (Momba *et al.*, 2000; Ferguson, 2006). Biofilm forms a “pathway” for the sewage pollution (bacteria) to lower lying water resources (depressions). High ground water levels, soil types and gradients increase movement along a biofilm. Many bacteria exist as a biofilm.

Most bacteria in the environment grow in or on a biofilm and forms a community of micro-organisms surrounded by extracellular polymeric substances (EPS). *E. coli*, other coliform bacteria and enterococci are known biofilm producers (Ferguson, 2006). Research indicated that although faecal indicator bacteria cannot multiply in natural water (Momba *et al.*, 1999, Maule, 2000), they can re-grow in biofilm (Ferguson 2006). The process contributing to the increase in microbial numbers, not related to mechanical failure, is described by the terms “regrowth”, “aftergrowth” and “breakthrough” (Momba *et al.*, 2000). The reasons why bacterial numbers increase are due to internal re-growth or after-growth of bacteria and the associated formation of biofilm (Momba *et al.*, 2000). Several investigators have shown that micro-organisms can multiply in biofilm.

Biofilm provides a safe environment for bacterial replication, access to water & nutrients and protection against microbial predators, UV, drying out and disinfectants. Cells detach from the biofilm and enter any water column (trickle, stream, estuary, etc). Natural detachment is related to factors such as water flow velocity & shear forces, nutrient availability, and aging of biofilm (Ferguson, 2006).

Since some bacteria in the environment grow/increase in biofilm, the question is, do *E. coli* and enterococci also survive and grow/increase in biofilm? In a study by Ferguson (2006)

the following was observed when comparing the cfu/100ml counts in water to the those in the biofilm, proving that they increase in numbers.

Bacteria	Surrounding water environment	Biofilm
Enterococci	104	4.6 million
<i>E. coli</i>	400	1.8 million

At soak-away systems (SAS) or leaking systems, a natural biofilm forms in the soil or other absorption systems with time. Such a biofilm harbours and safeguards the bacteria. Under normal conditions this layer is critical in the processing of fine biological solids and pathogens which are in the effluent and without it the septic system would not be adequately treating the effluent. But inadequately-treated effluent released (leaked, spilled) into the ground risks contamination of nearby ponds, wells, streams, etc. (Google Septic Tank Site, 2007).

To summarize this section it is obvious that the indicator organisms form biofilm, survive harsh conditions in the biofilm, use the biofilm as a transport mechanism and can even multiply in the biofilm. Freeing the bacteria in the environment is, as stated, related to water levels and gradients (shear forces), as well as the permeability of the substrate.

4.8 Viable-But-Not-Culturable Bacteria (VBNC) & Bacterial Resistance

A concern was globally raised when it was shown that *E. coli* is highly resistant to treatment processes (Craun, 1991; Craun *et al.*, 1994a, In Momba *et al.*, 1999). It has also been shown that some bacteria can survive and multiply despite the presence of measurable concentrations of disinfectants due to the possible development of resistance towards these compounds. Biofilm cells (extra polymeric substances, EPS) were found to be less susceptible to disinfectants than bacteria (Ridgway and Olson, 1982; Olivieri *et al.*, 1985; LeChevallier *et al.*, 1988a, In Momba *et al.*, 2000).

This form of resistance is often linked to chemical and physical factors which are known to cause a form of sub-lethal and reversible injury (to the bacteria) during disinfection. These factors include chlorine and other biocides, low concentration of metals such as copper and zinc, extremes of temperature, pH and inter-actions with other bacteria. Several investigators have shown that coliforms could survive standard chlorine residuals with subsequent release into natural systems (McFeters *et al.*, 1986, In Momba, *et al.*, 1999).

Their results showed that coliform levels increased as the water moved away from the treatment plant and also showed that maintenance of 1-2 mg/L free chlorine residual was insufficient to eliminate these occurrences of coliforms (Momba, *et al.* 1999).

4.9 The role of cemeteries

According to an article by Harmse & Tumagole (2006) they are of opinion that cemeteries can have fairly severe pollution potentials. They list research by Outfront (2005 *In* Harmse & Tumagole, 2006) that states that cemeteries pose significant contamination threats to groundwater from chemical and micro-organism activities, and by Gregory (2001 *In* Harmse & Tumagole, 2006) who discovered that groundwater was contaminated by faecal and other bacteria of human origin. In a study of a cemetery in the City of Tswane Metropole Municipality they found elevated (400 – 9000 cfu/100ml) faecal coliforms in groundwater from boreholes close to the cemeteries. They also found that this groundwater contamination is generally restricted to the shallow groundwater zone.

4.10 Indicator Organisms.

A range of specific organisms can be used as indicators for the likely presence of pathogens and viruses in the receiving marine environment (Taljaard *et al.*, 2000). In South Africa, faecal coliforms and *Escherichia coli* (as a member of this group) are generally used as indicator organisms. However, new developments in health monitoring propose the expansion of monitoring parameters to include a selection of indicator and/or pathogenic organisms rather than a single indicator organism. These extended surveys need not be conducted frequently, but, for example, could be conducted every three months. In doing so, the assessment of the extended list of parameters assists in detecting anomalies which may otherwise pass undetected when assessing only a single group of organisms. For example, sampling at quarterly intervals for a range of micro-organisms such as *E. coli*, Salmonellae, *Salmonella typhi*, pathogenic staphylococci, shigellae, helminth parasites and faecal streptococci has proved useful for auditing purposes to detect problems which may have passed unnoticed in routine *E. coli* assessments. Measuring more than one indicator for microbiological contamination, together with salinity (as a physical parameter for assessing the dilution or impairment of pristine seawater), has proved valuable for interpretation purposes (Rathbone *et al.*, 1998; CSIR 1999). Other studies that assessed the suitability of indicators for the likely presence of pathogens and viruses in the receiving marine environment along the South African coast include Grabow *et al.* (1989), Idema & Kfir (1990), Genthe (1996) and Grabow *et al.* (1999) (Refer Taljaard *et al.*, 2000 for more detail).

The survival of faecal coliforms in the marine environment is dependent on a variety of variables including temperature, exposure to ultraviolet light, irradiation of sunlight, salinity, osmotic shock, microbiological antagonism, adsorption to solids and sediments and ingestion by molluscs (DWAF, 1995). Research by Maule (2000) indicates that *E. coli* survive less readily in river water where it fell to undetectable levels in 27 days. Air dried deposits on substrates (stainless steel) survived for periods in excess of 60 days. Link this observation to the characteristics of biofilm and one starts to understand this phenomenon. Further it was found that *E. coli* was highly stable at 4°C and viability was only reduced marginally at 18°C. Barnes (2005) states that “*These data (survival rates) indicate the ability of some serious pathogens to persist in the environment beyond the expectations of some engineers*”.

The ideal indicator of faecal contamination of recreational waters would be one of the enteric pathogens, such as ***Salmonella*** or Norwalk virus. However, because these are usually present at low levels and are irregularly distributed, even during disease outbreaks, they are difficult to isolate and quantify. In addition, testing for every possible waterborne disease-causing micro-organism would be prohibitively expensive. For these reasons, it is common practice to monitor the other more plentiful but non-pathogenic bacteria present in human and animal faeces. The presence of elevated numbers of these bacteria in the aquatic environment is **indicative of faecal contamination and the possible presence of enteric pathogens** (DoH+W, 1992).

The best indicators of the presence of enteric pathogens in faecal pollution sources should have the following properties (National Academy of Sciences, 1977; Cabelli *et al.* 1983; Elliot & Colwell 1985, In DoH+W, 1992)):

- ✓ Must be present in faecal-contaminated waters, in large numbers, when enteric pathogens are present;
- ✓ incapable of growth in the natural aquatic environment but capable of surviving longer than pathogens;
- ✓ equally or more resistant to disinfection than pathogens;
- ✓ easily and accurately enumerated;
- ✓ applicable to all types of natural recreational waters (e.g., fresh, estuarine, and marine);
- ✓ absent from non-polluted waters and exclusively associated with animal and human faecal wastes;
- ✓ density of indicator should be directly correlated with the degree of faecal contamination, and

- ✓ density of indicator should be quantitatively related to swimming associated illnesses.

These bacterial indicators, however, only **provide indirect evidence** of the possible presence of water borne pathogens and may not accurately represent the risk to water users (Monteiro *et al.*, 2000). Enterococci cannot multiply in the natural environment and occur normally in faeces. When coliform bacteria are present in the absence of *E. coli*, but in the presence of enterococci, this can be indicative of the faecal origin of the coliform bacteria (Westwood, 2002).

Escherichia coli

E. coli is a coliform bacterium and has historically been regarded as the primary indicator of faecal contamination of both treated and untreated water. As a coliform bacterium it is a member of the family Enterobacteriaceae, and is capable of fermenting lactose or mannitol at 44 °C, usually within 24 hours, and produces indole from tryptophan.

E. coli occurs in the faeces of all mammals, often in high numbers. This widespread faecal occurrence, coupled with methods that for the recovery and enumeration of *E. coli* are relatively simple to conduct, has contributed to the detection of this bacterium as the cornerstone of microbiological water quality assessment for over 100 years (Westwood, 2002).

Enterococci

Of all the micro-organisms considered as suitable recreational water quality indicators, the enterococci most closely satisfy the desirable characteristics presented in the introduction to this chapter. This is supported by epidemiological studies which have indicated that enterococci to be a more reliable indicator of pathogenic pollution in marine waters (Fattal *et al.*, 1983; Prüss, 1998). They grow at temperatures between 10 and 45°C, survive exposure to 60°C for at least 30 minutes, and grow at pH 9.6 and in 6.5% NaCl (DoNH+W, 1992).

- ✓ Enterococci are **exclusively associated** with faecal wastes.
- ✓ They survive much longer than the other indicators in water and sediment (McFeters *et al.* 1974; Lessard and Sieburth 1983).
- ✓ Enterococci are also more resistant to sewage treatment, including chlorination, and thus may be more sensitive indicators of the survival of enteric pathogens and viruses (Cohen and Shuval 1973).

Furthermore, a strong correlation between the concentration of enterococci in marine waters and the risk of gastrointestinal infection has been demonstrated (Cabelli 1983). A membrane filtration method for the enumeration of enterococci in marine waters has recently been described in detail (U.S. Environmental Protection Agency 1985).

Summary

- ✓ In marine waters, the enterococci group is the best available indicator of faecal contamination from warm-blooded animals.
- ✓ Faecal coliforms do not survive well in marine waters and thus may not be reliable indicators of faecal contamination.
- ✓ Enterococci survive longer than faecal coliforms in marine waters and thus are preferred when there is considerable time or distance between the source of faecal pollution and the bathing area.
- ✓ There is a positive correlation between gastrointestinal illness and levels of enterococci in marine waters, but the absence of enterococci does not indicate a lack of risk.
- ✓ Based on the U.S. Environmental Protection Agency epidemiological study, a seasonal geometric mean of 35 enterococci/100ml corresponds to a seasonal gastrointestinal illness rate of 1 to 2 per cent. Because faecal coliforms do not survive well in marine waters, the use of the fresh water maximum limit may increase the risk of illness.

These results support the conclusion (e.g. Prüss, 1998) that enterococcus is a more sensitive indicator of pathogenic pollution for marine environments, especially at low concentration levels (Mardon & Stretch, 2004, Durban beaches).

Coliform bacteria

Several members of the coliform group are known to be present in soil and other environmental materials, and are capable of growth in nutrient-rich water and biofilm. As a result, coliform bacteria are no longer considered to be specific indicators of faecal contamination. However, some species of coliform bacteria, although common in the environment, can be associated with human infection, but rarely with gastro-enteritis (Westwood, 2002). In the presence of enterococci, it is considered indicative of faecal pollution (Westwood, 2002).

4.11 Standards

Water quality and recreation

Water used for recreational purposes should be sufficiently free from microbiological, physical, and chemical hazards to ensure that there is negligible risk to the health and safety of the user. The determination of the risk of disease or harm from microbiological, physical, or chemical hazards is based on a number of factors, including the following:

- ✓ environmental health assessments
- ✓ epidemiological evidence
- ✓ indicator organism limits
- ✓ presence of pathogens.

The decision to post a warning to users of recreational areas or to close an area for public use should only be made by the appropriate authority in accordance with the statutes and standards. This decision will be based on an assessment of existing hazards using available information on the factors. (DoH+W, 1995)

Recreational Water Use

Recreational use of coastal marine waters varies from bathing to mere enjoyment of its scenic aspects. The general public and tourists are very sensitive to any indication of pollution in recreation areas. Recreational use of coastal marine waters is dependent on ambient water quality, since no water treatment or maintenance is practised, except where water is extracted for use in public seawater swimming pools.

As the problems encountered during usage vary as the contact potential with the water changes, it is important to define the different uses. For recreational uses coastal marine waters are divided into three major groups: Full contact recreation; Intermediate contact and Non contact. (DWAF, 1995)

Full contact: This sub-use is characterised by the fact that full body contact, ingestion of water and inhalation of aerosols are likely to occur frequently throughout the activity. Activities include swimming, diving (scuba and snorkling), water skiing, surfing, paddle skiing and wind surfing. This category differs from others in the extent of water contact (full immersion and probability of ingestion), the age group (often include large numbers of children who are more susceptible to health effects – infectious diseases), and the health status of the users (people who are inclined to swim when they are not completely healthy – more susceptible).

Intermediate contact. This sub-use includes activities such as boating, sailing, canoeing, wading, angling and parasailing, where the user may come into contact with the water, inhale aerosols or swallow water, but to a lesser extent than in the case of full contact recreation.

Non contact: Non-contact recreation involves all recreational activities taking place in the vicinity of marine waters, but which do not involve direct contact with the water, such as sightseeing, picnicking, walking, horse riding, hiking, camping, etc. With no contact public health effects are of little relevance here, but aesthetic impacts are very important.

To determine standards/guidelines it is important to consider the norms required for the different impacts. Although all the impacts are discussed (DWAF, 1995), for the purpose of this investigation, only the norms for human health will be highlighted.

Human health

Waterborne diseases:

Water bodies can be the source of infectious diseases as a result of microbial contamination. These diseases are contracted either by ingestion or through skin contact (mucous membranes). A variety of gastro-enteric diseases is caused by the pathogens.

The effects can be acute or chronic depending on how consistent the pollution is or may even cause death

Remedial actions, such as removing or controlling the source of contamination, can either eliminate or mitigate the effects. Banning any activities will have an immediate mitigatory effect.

Skin and ear infections : Contaminated water in contact with the skin or penetrating the ear can cause infections of the skin and/or ear. These infections can also be acute or chronic. Depending on the infections the person may recover, suffer permanent harm or damage.

The use of earplugs will reduce or prevent infections of the outer ear.

4.11.1 Review of water quality guidelines

The reason provided why the standards for South Africa are so fragmented and indecisive, is that information on diseases associated with recreation in marine environments in South Africa is limited. This is due to the absence of a public health infrastructure for epidemiological research (DWAF, 1995).

Table 1: Comparison of world-wide data on Microbiological Standards

Comparison of Water Quality Standards				
Country	Bacteria spp	Excellent cfu/100ml	Acceptable cfu/100ml	Reference
European Union	E. coli	100 [*]	185 [*]	EU-2006/7
	Faecal streptococci	250 [*]	500 ^{**}	EU-2006/7
Blue Flag South Africa	<i>E. coli</i> (Faecal coliforms)	100/100ml 50/100ml (guide line)		Blue Flag Beach Criteria Explanatory Notes. 22 Nov 2006
	Faecal streptococci (faecal enterococci)	100/100ml ⁰ 50/100ml ⁰⁰		

		(guide line)		
USA	E. coli	126 ^{##}		DoH+W, 1992
	Faecal streptococci	35 [#]		
RSA	E. coli	<20% to exceed 100 and/or <5% to exceed 2000	(<5% to exceed 2000?)	DWAf, 1995 (SA Water Quality Guidelines)
	Faecal streptococci	None	None	

⁰ Not to exceed limit >20% of time; sampled twice a month; max 18 days apart

⁰⁰ Not to exceed guideline >25% of time; sampled twice a month, max 18 days apart.

[#] = 30 day geometric mean of minimum five samples

^{##} = For freshwater bodies, geometric mean

^{*} = 90-percentile; GM of previous three years

^{**} = 95-percentile; GM of previous three years.

For coastal waters the EU (EU-2006/7) set the following standards and specify the methods for analyses:

Intestinal Enterococci (cfu/100ml)	100* (Excellent)	185** (Sufficient)
<i>E. coli</i> (cfu/100ml)	250* (Excellent)	500** (Sufficient)

* = 95-percentile evaluation

** = 90-percentile evaluation

The EPA gives a GM limit of 35 cfu/100ml (geometric mean (GM) of five samples, taken within 30 days) in the case of marine waters for enterococcus, but do not specify an *E. coli* limit since they no longer use it as an indicator for marine environments (DoH+W, 1992).

Based on one of the largest investigations of its kind, the U.S. Environmental Protection Agency (EPA) proposed that at freshwater beaches, the 30-day geometric mean should not exceed 126cfu *E. coli*/100ml or 33cfu enterococci/100ml (DoH+W, 1992).

South African water quality (SAWQ) guidelines consider *E. coli* as the only indicator of pathogenic pollution (DWAf 1995) although the Guidelines state that “*Enterococci has been shown to be a valuable indicator for determining the extent of faecal contamination in marine waters*”. In the following section it states that the survival of *E. coli* and other coliforms in the marine environment is *inter alia* affected by salinity, osmotic shock and other conditions. This decision therefore to include *E. coli* as an indicator organism in marine environments, notwithstanding numerous research papers, that demonstrated that *E. coli* does not survive in marine environments, and that enterococci is a “valuable indicator in marine waters” is incomprehensible.

The following standard is specified as limits for *E. coli* for full and intermediate contact recreational waters (DWAF, 1995):

Less than 20% of samples to exceed 100 cfu/100ml

Less than 5% of samples to exceed 2000 cfu/100ml

The SAWQ guidelines do not set limits for enterococcus (faecal streptococci) concentrations, nor do they specify a sampling frequency for the set *E. coli* requirements. It furthermore does not state if one or the other or both are to be used in the final decision. This discrepancy was also identified and addressed by Taljaard *et al.* (2000).

In the light of international trends and to ensure that the pollution can be linked to human sewage (if needs be) it was decided to include faecal enterococci (faecal streptococci) in our sampling and analysis regime and to use the more lenient limit of the Blue Flag standard of 100cfu/100ml for faecal enterococci as standard for marine recreational waters.

5 METHODOLOGY

5.1 Sampling stations

The project started with a discussion with the Area Manager Overstrand Municipality, Mr Dion van Vuuren and Environmental Health Officer, J van Taak, of the Overberg District Municipality in order to understand the reason for the investigation and the existing monitoring programme. A site inspection followed.

As there are stations along the estuary which are sampled continuously and some only where complaints are received, the same stations were marked and others added (Fig. 5) to cover those areas along the estuary with high human impact.

To visit/inspect stations along the Klein River a boat was used (CapeNature, Bredasdorp, Mr Carstens). From the furthest station (K1) up at Stanford down to the sandbank (K14) where the river spills into the estuary, the river was travelled and accessible stations were identified and sampled. The idea was to try and keep these stations approximately 500m apart (Fig. 4). Twenty sampling stations were identified on this stretch of river, including the bridge on the R43, and the stream from the WWTW at Stanford to the river (Fig. 7). The next week the procedure with the boat was re-enacted on the estuary where 16 stations were identified and sampled (Fig 5). These stations included the existing ones and stations corresponding to the residential or recreational sites were added.

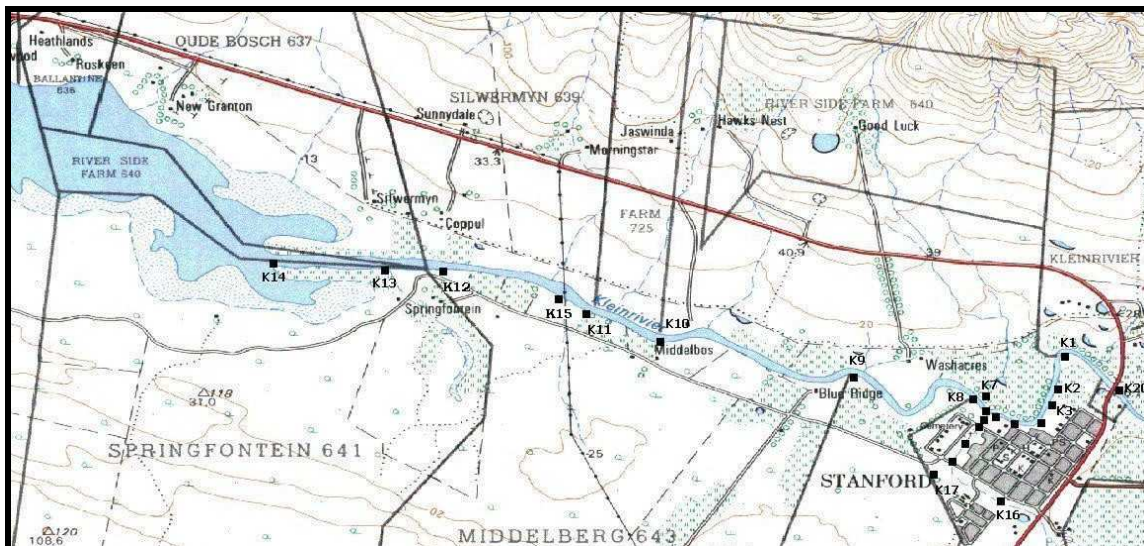


Figure 4: From the estuary (west) to Stanford and bridge in east with sampling stations. The “Stanford area” is enlarged in Figure 6

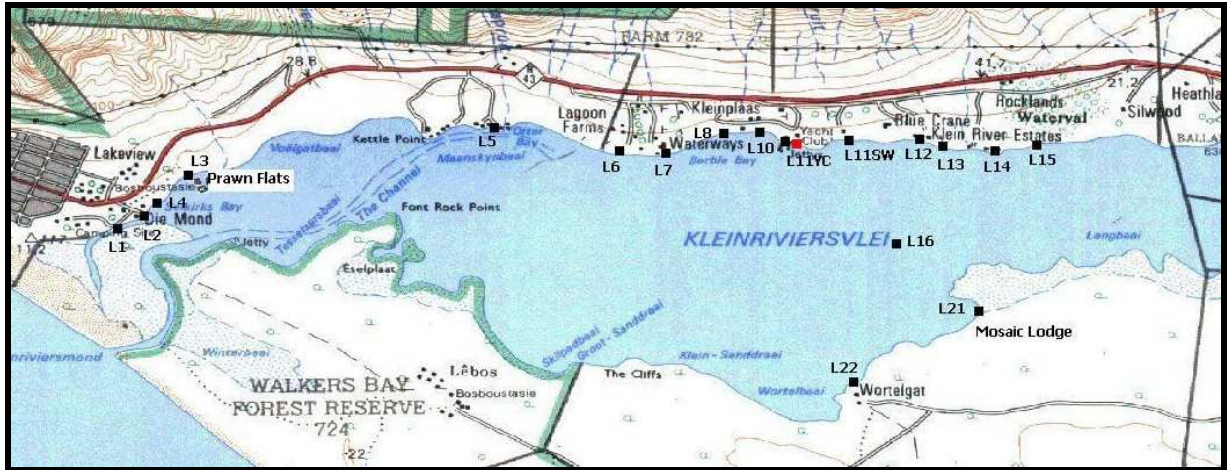


Figure 5: The Kleinrivier estuary with sampling stations.

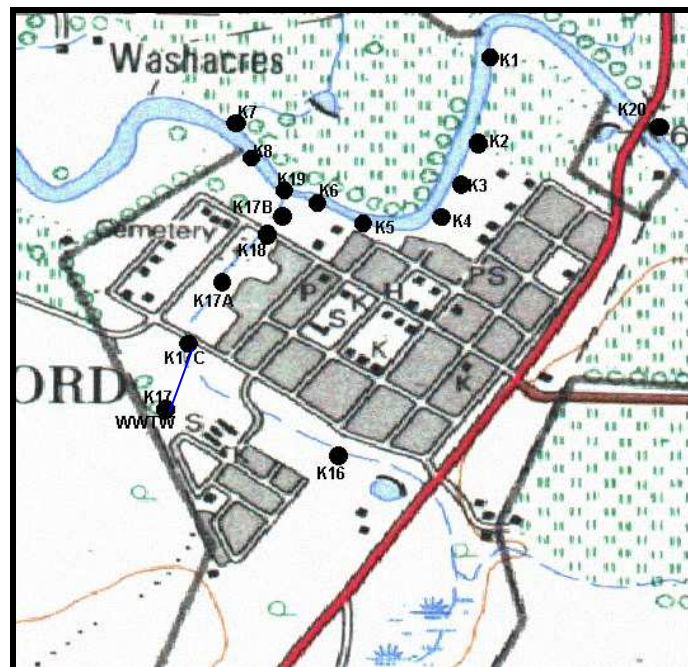


Figure 6: Sample stations in Stanford and from WWTW to bridge

For detailed description of the sampling stations, corresponding GPS references and abbreviations refer to Annexure 1.

From these two excursions it became clear that:

- ✓ It is impossible to sample all sites in one day using a boat;
- ✓ It is impossible to sample from a boat in windy and choppy conditions on the estuary;

- ✓ It is difficult to pinpoint sample stations from the boat (except if a GPS is used);
- ✓ The boat is not always available, and
- ✓ A tight sampling schedule could be put in jeopardy by these limitations.

On the next excursion all the stations were visited and sampled by vehicle. On the south bank/shore of the estuary six additional residences were visited, but only two additional stations at Mosaic Farm and Wortelgat were added. It was only possible to reach the water from these two. To sample the 45 stations in one day it was necessary to use two vehicles.

After the first two complete sets of results, two issues forced a replanning of the process. Cost for 45 samples (R104.50 + R72.10 = R176.60/sample (NHLS, 2007)) and the fact that travel expenses for two vehicles came into play if all stations have to be visited with enough time spare to get to the laboratory in Sea Point. The results (after two cycles) indicated that the stream at Stanford and the northern bank of the Estuary from Scout Camp (L1) to Rocklands (L15) seems to be the stations to focus the effort, time and finances. (Figure 6) It was then decided to limit sampling stations to the stream in Stanford (K17 – K19), and for reference stations K6 and K20, and later also K8. This added up, initially to 22 sample stations, but with the addition of K17A-C the total came to 25 stations. These took 3-4 hours to sample with one vehicle. The stations on the river (K9 – K15) were eliminated as cattle and other farms animals use this stretch extensively. These drinking places were the only places where water is accessible from the bank.

Locked security gates/entrances hampered collecting samples at some stations and this resulted in fragmented data (Broken Yellow line of 28 Feb 2007, Fig. 7). Although phone calls were made, time did not permit the samplers to wait till somebody could open up. Some of the stations (L9, "Stillwaters") were, due to locked gates, eventually abandoned. One new station "South Winds" (L11SW), next door to the Yacht Club was included when it appeared that the latter was locked for three consecutive visits.

Figure 4 demonstrates what the actual (raw) results look like. Very confusing. Historically raw data similar to these were used in decision making. Fragmentation caused various problems when geometric means and logarithmic graphs were generated.

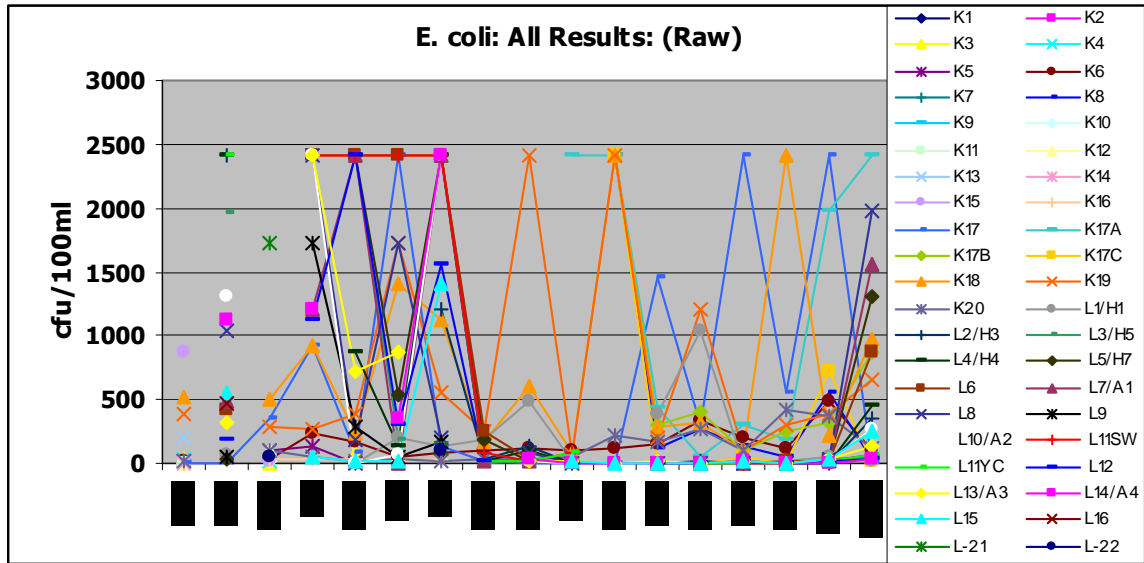


Figure 7: Graph with results from all samples from all stations to demonstrate the confusion that reigns when raw data are used.

5.2 Sampling process

Sterilized autoclaved containers, glass or plastic, were collected from the National Health Service Laboratory (NHLS) in Sea Point each time when samples were delivered. The previous day all containers were labelled and numbered.

The following sampling method was employed: The sampler would walk into the water (where possible) up to a depth of 600mm deep or kneel on a jetty. The container was removed from the sterile packaging and submerged to (ideally) 300mm before being opened upstream (water flow into and past) (EU, 2006). The lid was replaced underwater. This process was repeated at all stations.

The sample was then stored on freezer packs and, if needed, crushed ice.

Where shallow streams and the river (all in and around Stanford) were sampled all kinds of aerobatics had to be employed to get to the water and to be in a position to submerge the container before opening and filling it. In very shallow (<100mm) streams – nearly all the stations on the Stanford stream - the container was opened as close to the water surface as possible and the bottom was slowly pushed (to not disturb the bottom) into the sludge/mud/silt while water flowed past and into the container.

5.3 Analyses

Samples were delivered on ice packs and/or crushed ice and microbiological analyses commenced within 6 hours after sampling started at the NHLS in Sea Point. The NHLS is provisionally accredited to perform this kind of analyses. Other accredited laboratories were

contacted, but in the end costs and the fact that the NHLS performed the analyses on samples from this area for many years, convinced us to stay with them.

The NHLS was instructed to analyze for *Escherichia coli* (*E. coli*), Total coliforms, Total faecal coliforms and Total faecal enterococci. (Reasons discussed in paragraph 4.10). The first three indicator organisms are standard for microbiological analysis of river water.

The procedures followed by the NHLS for the coliforms is an accredited Standing Operational Procedure (SOP): *Determining the microbiological quality of water samples: Collert method for coliforms, E. coli and total bacterial count [SABS 241(221)]* (NHLS, 2006), and to analyze for faecal enterococci SOP GPCPH0047.2.SOP (NHLS, 2005) was followed. Depending on the bacteria species the prepared samples are incubated at specific temperatures for specific periods (refer par. 4.10 and NHLS, 2005 & 2006).

The plate count method is based on the fact that on solid nutrient medium each bacterium under the proper conditions will multiply to form a visible colony. The number of colonies that appear after a suitable period of incubation (species specific) thus represents the number of living cells in the original suspension (Nestor *et al.*, 1983).

The results were faxed from NHLS 5-7 days later. Results was logged in MS Excel tables and graphs were generated. To display the variation in counts from 1 to 2419cfu/100ml, logarithmic graphs were used.

The “level of pollution” was calculated using the standard as stated in the SAWQ Guidelines (DWAF, 1995). First the results for each station was counted. For each station a the percentage samples exceeding the standards (max allowed 20% of the time for 100cfu/100ml, or max allowed 5% of time for 200ocfu/100ml) were calculated. This figure was then used as the “pollution status indicator” and displayed on a graph (Fig. 14).

When microbiological samples are collected to monitor water quality, bacteria concentrations vary considerably from point to point and from day tot day. In our investigation they varied from 0cfu/100ml to 2419 cfu/100ml. This variation of high and low values may bias a normal mean or average value. To dampen the effect of very high and low values, a geometric mean (GM) is calculated to enable meaningful statistical evaluations (Cole, undated). The Canadian standards (DoNH+W, 1992) support this view and advised that the last five samples be used. When the Canadian example was implemented in this investigation and hopefully for future checks, the GM for every last five samples was calculated and logged. These were and can be plotted and used in decision making (Fig. 13, and 17-22).

5.4 Other Data

The Overstrand Municipality and Vogelgat Reserve supplied rainfall data. When DWAF was requested to send rainfall data from this area, they reported that *all stations near G4R004 (estuary) are closed (DWAF, 2007, email)*.

DWAF supplied monthly the river flow data (m³/sec) from Hagedisberg Outspan (G4H006, 34 24 19; -19 35 46) weir and water levels (metres above mean sealevel (mamsl), (34 24 36, - 19 20 54) in the estuary as measured at the Yacht Club (G4H004).

When the project started it was mentioned that it is not necessary to sample salinity and temperature, as these were collected on a weekly basis by CapeNature (Hermanus). Towards the end of the project it was found that, although claims were made that all results were copied to the head office in Jonkershoek, neither the head office nor the local office of CapeNature could provide the results. In the end an ex-employee retrieved some data, 1999 – 2001 from his computer. During this time an employee stated that, for reasons unknown to him, that the sampling was stopped since 2002. The inaccessibility and fragmentation of data reflect badly on the administration of data.

Therefore, as a result of the above, no current physico-chemical data is available! Historical data supplied by DWAF from the Hagedisberg station will be used if necessary.

To display the anthropogenic influence (high, medium, low), mean bacterial numbers and usage (full, intermediate, none) values were linked to each sub-value and these were used to generate GIS-graphs.

6 RESULTS

6.1 Rainfall and flow data

It rained every month with a slow increase in precipitation up to July when 128mm fell in Hermanus and 180mm at Vogelgat (mountains). (Fig 8.)

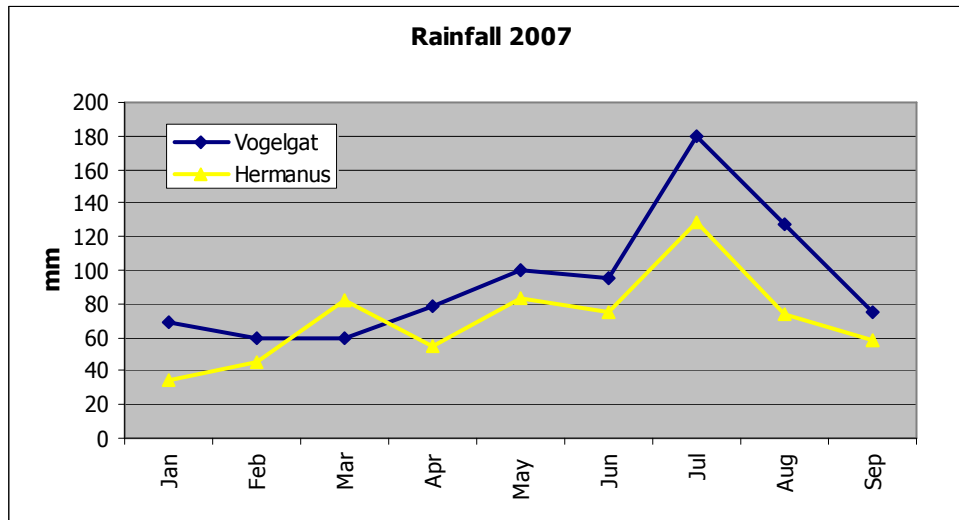


Figure 8. Rainfall data from Hermanus and Vogelgat Reserve.

The rain early in the year in the mountains did not affect the flow of the rivers or the water level in the estuary as the Klein River only started to flow at the weir at Hagedisberg in May 2007 when a 100mm rainfall was measured. The water level in the estuary started to rise at the same time (Fig. 9). When the estuary started to fill up due to heavy down pours, the level increased fast and it breached naturally on August 9, 2007. During the sampling cycle prior to the breaching (July, 25) the bacteria counts showed the first signs of decreasing. Following the breaching the water level oscillated between 2 and 2.5 metres.

6.2 Microbiological results

6.2.1 Historical data on Total coliforms and *Escherichia coli* sampled in 2005.

The available historical data (2003-2005) is fragmented and the estates were only sampled when problems were reported. No useful data are available for the estates during 2005 as there were gaps several months long. Initially this raw and unprocessed set of data was very confusing with no discernable pattern.

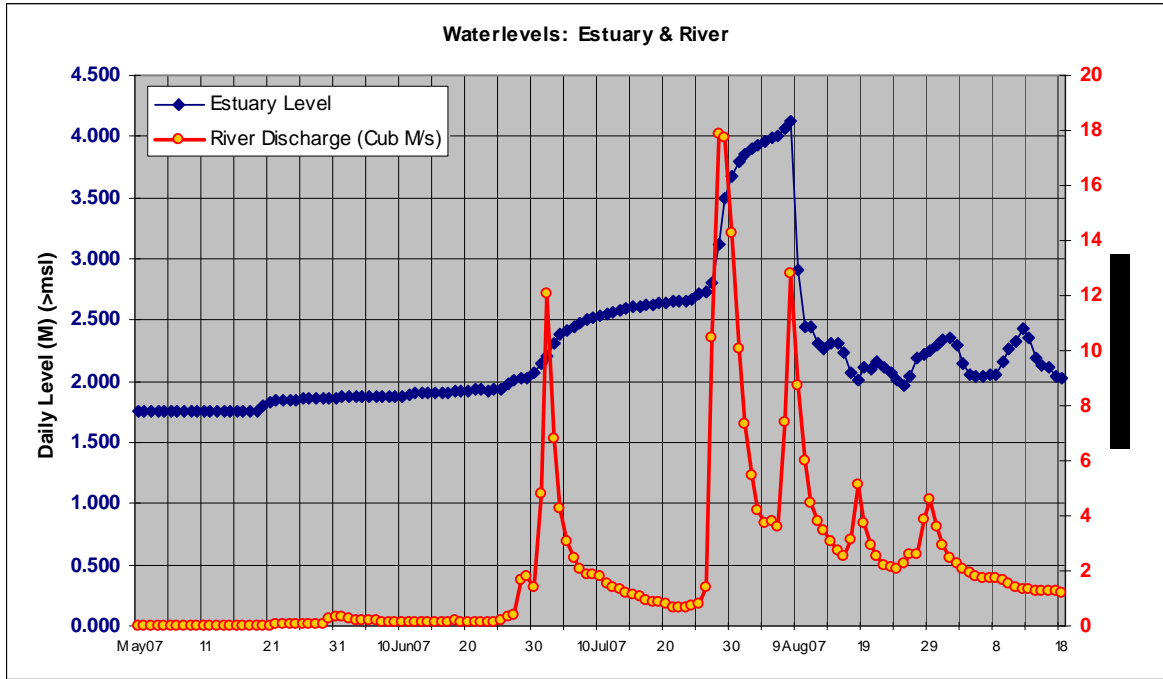


Figure 9: Indicating the influence of the inflow from the Klein River on the water level of the estuary up to Sep. 18, 2007.

To use these data the gaps from the 2005 set were eliminated and the results processed. In order not to labour the issue, the pollution history of the estuary as in 2005 as reflected in the pollution level/status and the calculated geometric mean for *E. coli* will be discussed (Figure 10 + 11).

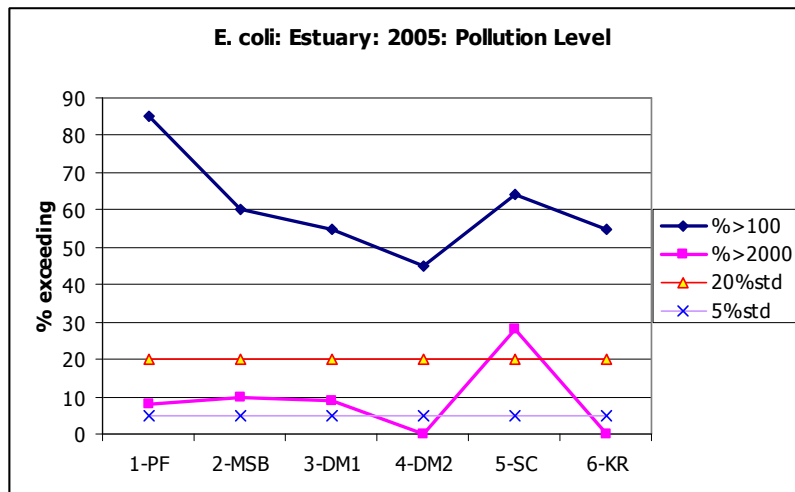


Figure 10: Graph to indicate the condition at the different station in 2005 when the pollution level is calculated according to the SAWQ guidelines (DWAf, 1995).

From Figure 10 it is obvious that all stations exceeded the 100cfu/100ml level far more than the allowed 20%. Although the 2000cfu/100ml level looks better, it is also exceeded.

The verdict will then be, on this standard as prescribed by the SAWQ Guidelines, that the estuary as an entity is polluted.

With new insights the historical data (2005) were revisited and the geometric mean on the “moving 5-result” method calculated. The pattern displayed (Fig. 11) is now similar to the data generated by the current investigation. In summer (Mar-Aug period) the counts are high (outside the acceptable range). When it started to rain in March, the counts started to drop and remained low from Apr-Oct. After the rains stopped, the counts bounced back to pre-rain levels. Attention is drawn to the fact that the counts at Scout Camp (SC) did not drop as low as the other. When the others then started to rise, Scout Camp (5-SC) dropped. This could be due to drying out of the area and no water was available for sampling. Data from DWAF on water levels (2005) indicated that the estuary did not exceed 3 metres and did not breach in 2005.

From this presentation it can be stated that throughout the year of 2005 some of the stations were polluted. The estuary as an entity must however be considered as a unit.

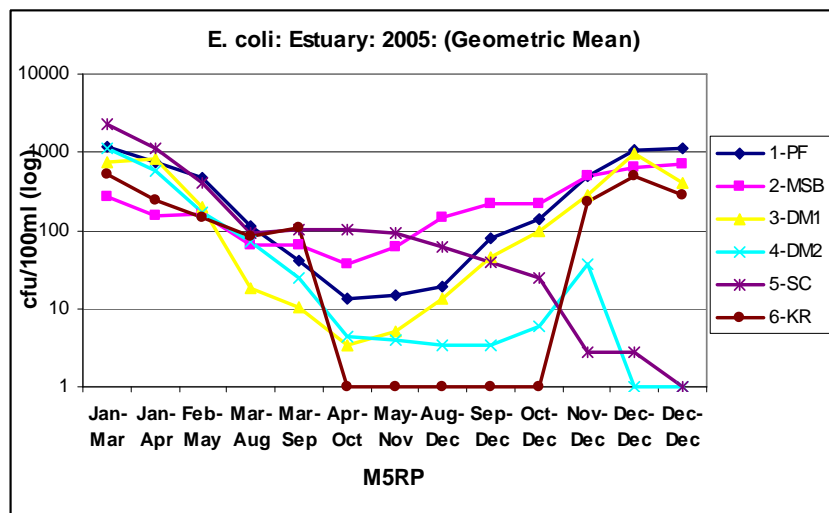


Figure 11: Fragmented data of 2005 has been compressed and a 5-results-period calculated and plotted.

By using the geometric mean calculated with the moving-5-result method or the pollution level method on DWAF it is easier to make a decision than using the single results as in the past. The pollution level method is clear cut and definite. The geometric mean model is clear on when the standard is exceeded, but it also gives you warning of what is going to happen.

For these reasons only the geometric mean calculated with the moving-5-result method and logarithmic displays will be used in the rest of the report.

6.2.2 Results for Current Investigation

As was highlighted earlier, that the characteristics of coliforms render them unsuitable as an indicator organism especially in a marine environment, the results and discussions will only refer to *E. coli* and faecal enterococci.

Stream through Stanford

All stations depicted high bacteria numbers for *E. coli* and faecal enterococci (Fig. 12 - 16). Both indicator organisms presented high numbers during dry and wet periods.

The only stations where counts dropped down below 100cfu/100ml during the wet period was at K17C (culvert where stream crosses De Bruyn St), K6 (slipway) and K8 (500m downstream from slipway) (Fig. 13). This could be attributed to the fact that high ground around this area channelled large volumes of storm water to this culvert while the stations in the river were flooded with clean rain water. A cleaning out process could have occurred.

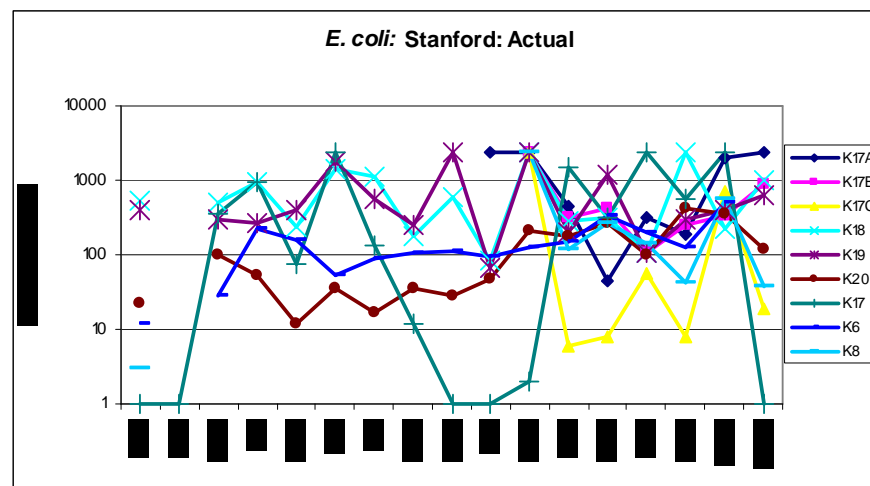


Figure 12: *E. coli* levels in the stream through Stanford for the whole period.

From graphs (Fig. 12 – 16) it is clear that both indicator organisms exceed the 100cfu/100ml level for the most of the time at most of the stations and that an increase in water volume (flood, heavy rain) did not lower the counts significantly. Interesting is that the geometric mean (Fig. 14) indicates that the counts actually rose at the bridge (K20) and slipway (K6) during the rain season. The amount of diffuse pollution due to storm water run-off can attribute to this. A fast flowing stream (storm water in a channel along Queen Victoria St) entering the stream from the WWTW, was observed during the raining season.

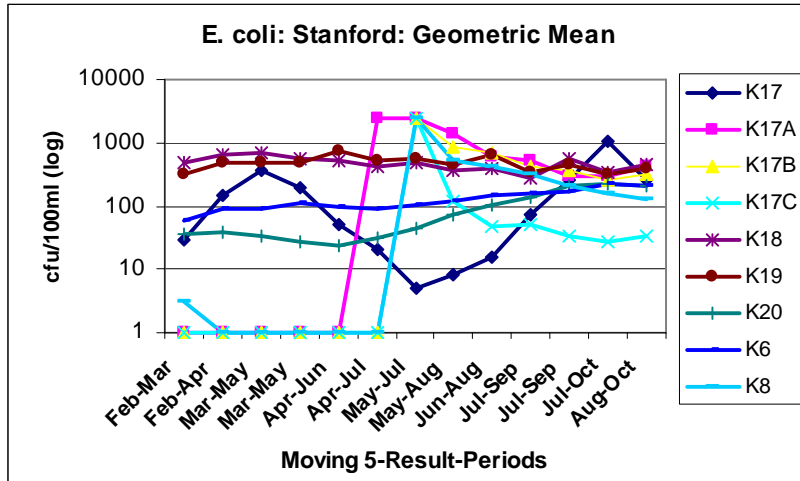


Figure 13: Same data as Fig. 12, but the geometric mean calculated in 5-result-periods.

Furthermore the stream from the WWTW is banked by a cemetery and by residences all fitted with septic and/or conservancy tanks. Taking into consideration the discussion on biofilm and sewage, the possibility of a serious diffuse pollution source can not be excluded. Except for two stations (K6 + K20, Fig. 14) *E. coli* counts did not exceed the 5% limit of the level of 2000cfu/100ml.

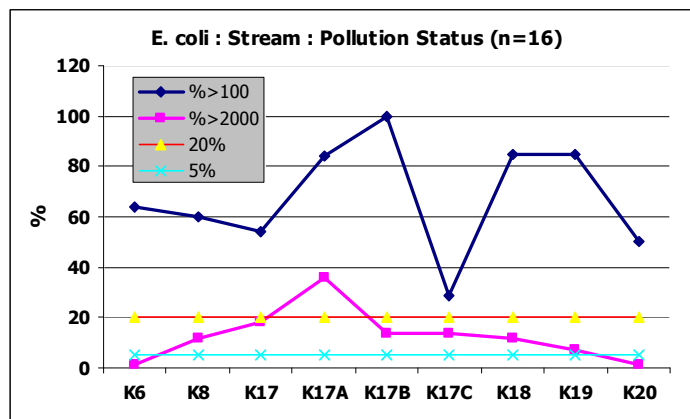


Figure 14: Pollution status of *E. coli* levels in the stream

However, all the stations however exceeded the 20% limit of the 100cfu/100ml (Fig's 14 & 16). Therefore, based on these data, the stream can be classified as polluted. As the flow of the river slows down in the dry season, the area around the slipway becomes more vulnerable to the spread of the bacteria upstream.

It is well known that enterococci do not occur in large numbers in natural conditions, and the fact that enterococci did occur with coliforms in this stream is considered indicative of faecal pollution (Westwood, 2002).

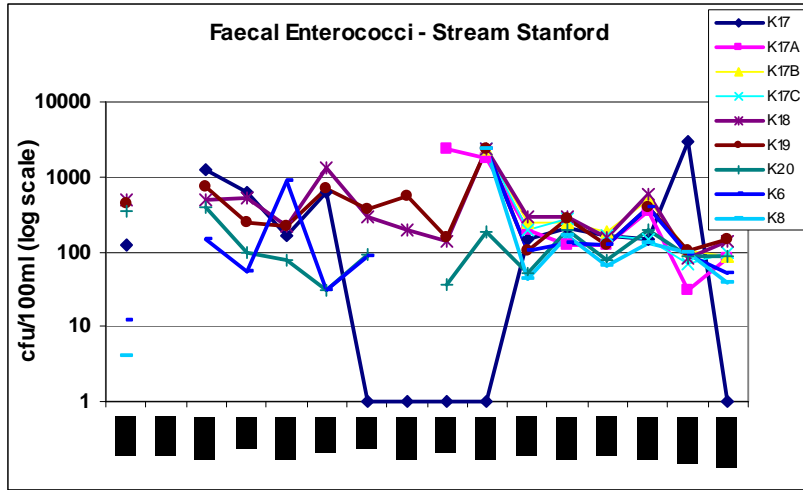


Figure 15: Faecal enterococci counts at all stations in the stream through Stanford for the whole period.

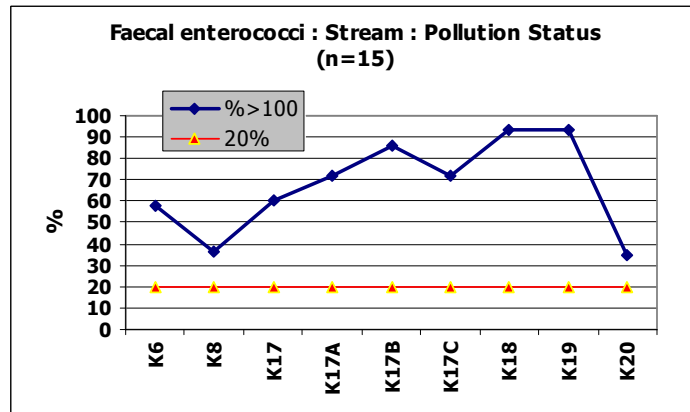


Figure 16. Pollution status of faecal enterococci levels in the Stream

Estuary – from Scout Camp in West to Rocklands in the East.

All data sets (Fig. 17 – 24) demonstrate the decrease in counts when the water level rose and an increase when the water level falls. When the counts showed signs of an increase, sampling was terminated as the cyclic occurrence was observed and proved. When the geometric mean of the data in 5-result periods were calculated (Fig. 17 - 24) the fluctuations are dampened and the data is smoothed and cleared. This procedure makes the data easier to understand and to interpret.

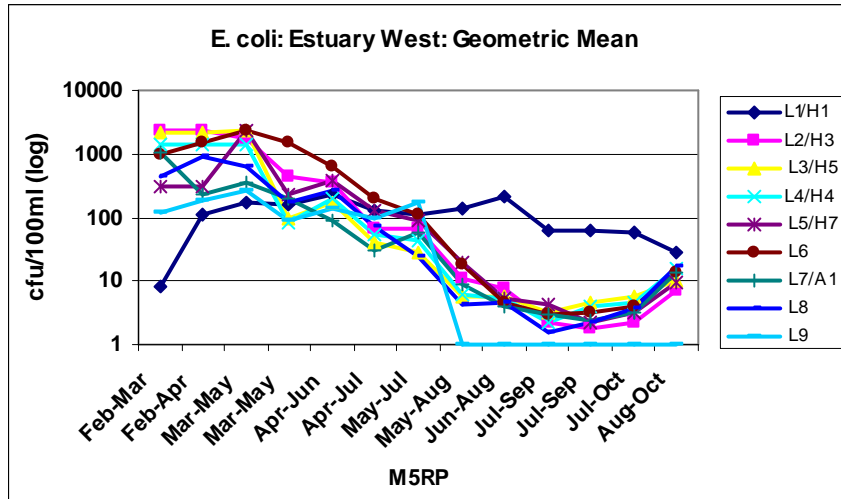


Figure 17: Geometric mean calculated for *E. coli* counts at stations along west of estuary.

During the discussion of the historical data (2005), it was mentioned that Scout Camp (L1/H1) displays high counts of *E. coli* throughout. In the current study this tendency was repeated (Fig. 17 + 20) and highlighted in the calculation of the geometric mean.

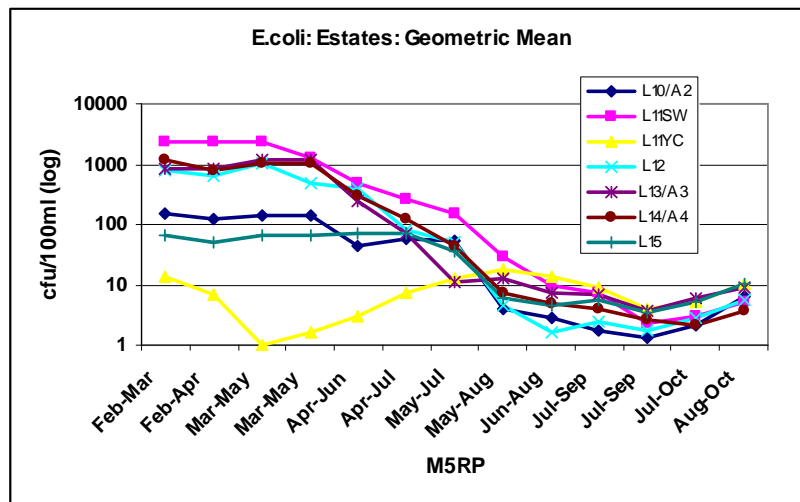


Figure 18: Geometric mean calculated for *E. coli* counts at stations at the estates.

In all the graphs it is also obvious that from the Apr-May period the counts at all stations started to decline. This follows the rise in water level. Along the whole estuary all stations have counts for *E. coli* exceeding the standard before the rains started (Fig. 17 + 18), except Rocklands (L15) and Yacht Club (L11YC). This is reflected in the low pollution level indicators (Fig. 19).

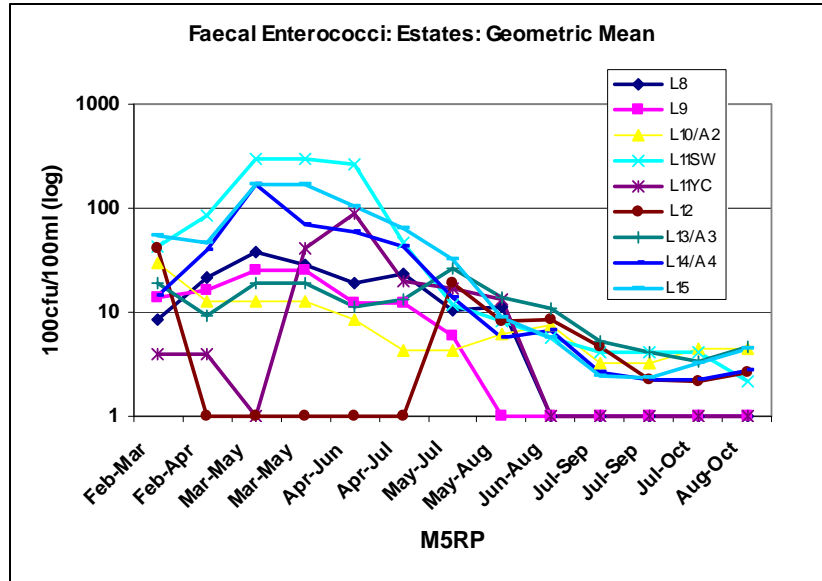


Figure 19: Geometric mean calculated for Faecal enterococci counts at stations at the estates.

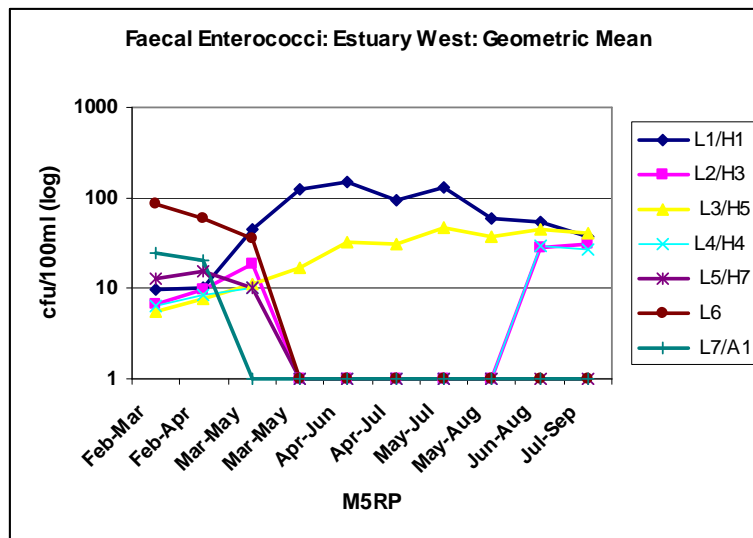


Figure 20: Geometric mean calculated for faecal enterococci counts at stations along west of estuary.

Faecal enterococci show the same pattern before and after the rain season (Fig. 19 + 20). The higher values at Scout Camp (L1) and Prawn Flats (L3) are obvious (Fig. 20). While counts at these two stations gradually declined at the end of the rain season, the counts at all the other stations dropped to zero when the rains started (high water level) and increased when the water level started to drop.

To summarize and to provide an overall view of the findings on the estuary, the geometric mean of all data for *E. coli* and faecal enterococci are displayed in two graphs (Fig. 23 + 24).

It goes without saying that these two graphs mirror the data of the four sets of separate data for the west of the estuary and the estates (Fig. 17 - 20). The relationship between high water levels (volume) and the low counts of the indicator organisms and the bounce back effect (higher pollution levels) when water levels decrease, is demonstrated (Fig. 23 + 24).

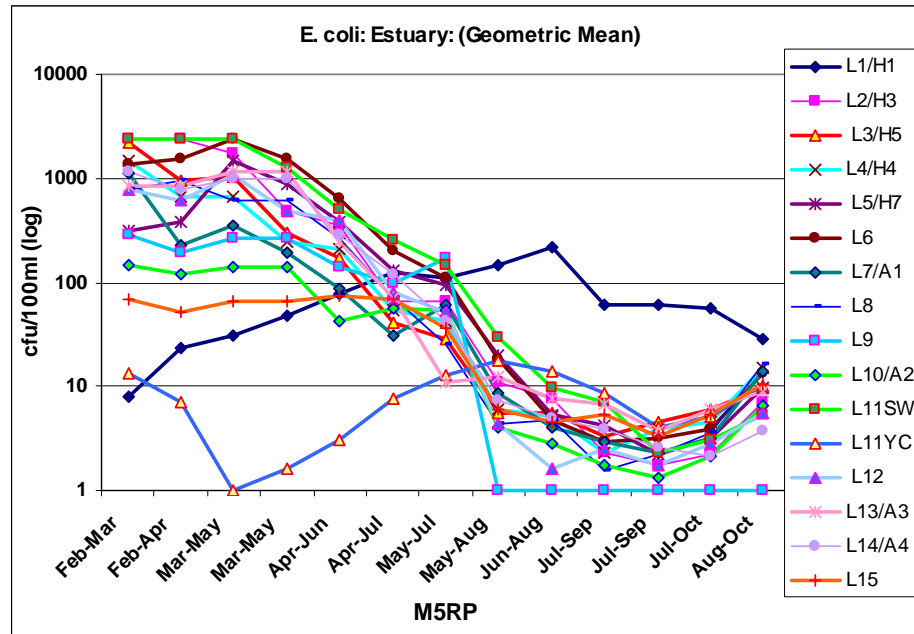


Figure 21: Moving geometric mean calculated for subsequent five results for the whole period using *E. coli* (std.= 100cfu/100ml) data.

The data in Figure 23 indicates that except for Rocklands (L15), Yacht Club (L11YC) and Scout Camp (L1) all the other stations were exceeding the specification (100cfu/100ml) before the rain started. Bacteria concentrations at Rocklands and the Yacht Club stayed below the standard.

Only Scout Camp (L1) deviate for both the indicator organisms from the pattern set at the other stations by decreasing counts. This phenomenon was also observed in the results of 2005. It seems that the bacteria counts at Scout Camp (L1) are actually rising as the estuary fills up (M5RP – May-Jul). Faecal enterococci geometric mean data support the *E. coli* data.

To support an upswing of this magnitude indicates a huge “constant” pollution supply source in along the estuary.

The historical way of operating was to take a sample and, if the results exceeded the standard, another sample was sent for analysis. If this one also had high counts, then the facility or resort was closed. Considering how the counts vary between sample periods for the same station (Fig. 12), this decision process is not very scientific.

When the pollution state of the estuary is calculated according to the specifications set out in the Water Quality Guideline (DWAF, 1995), a different scenario develops. This calls for the calculation of the percentage by which a station exceeds the standards of 100cfu/100ml and 2000cfu/100ml (Fig. 21).

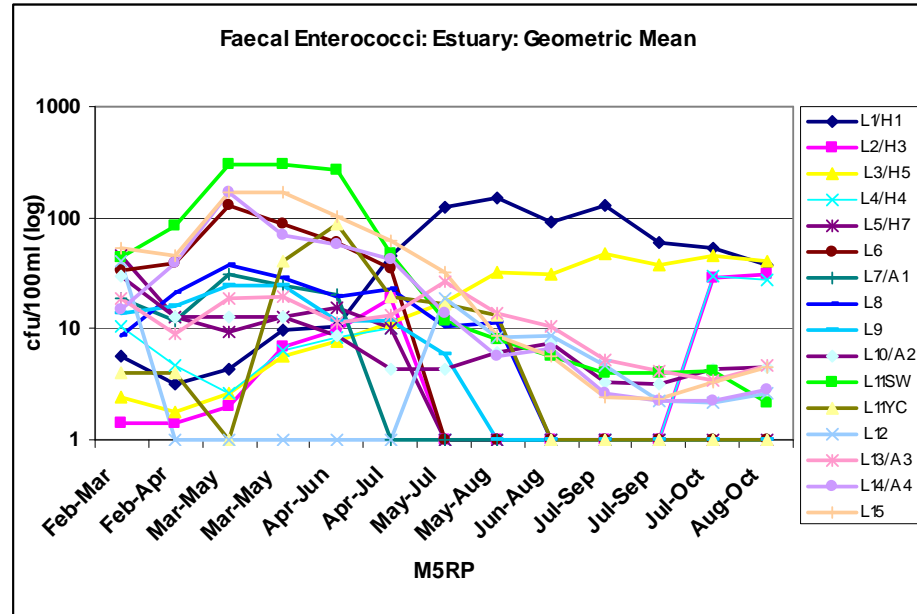


Figure 22: Moving geometric mean calculated for subsequent five results for the whole period using faecal enterococci (std.= 100cfu/100ml) data.

Keeping in mind that the bacteria counts should not exceed the lower limit by more than 20% over time, and by not more than 5% at the maximum limit of 2000cfu/100ml, it is interesting that nearly all stations failed when considering the status of *E. coli* but nearly all stations passed when faecal enterococci was evaluated in the same way (Fig 21 + 22). Actually, it is only Yacht Club station that pass the pollution status test for both the 20% and 5% levels.

Luckily in the South African context, where *E. coli* has a specified limit and faecal enterococci has not (except at Blue Flag beaches), the verdict will lay with the *E. coli* graph. It is further important to look at the estuary as an entity and therefore the estuary will have to be labelled "polluted".

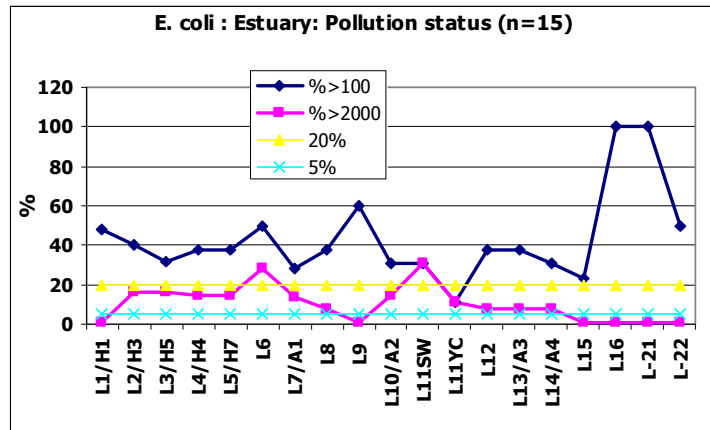


Figure 23: Pollution status of all samples at all stations on the estuary for *E. coli*

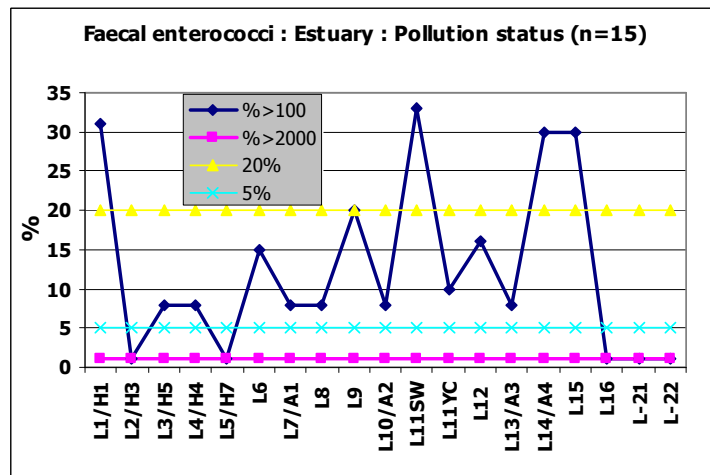


Figure 24: Pollution status of the estuary regarding faecal enterococci.

By using the *E. coli* graphs of the estuary, or any other water body (faecal enterococci graphs for Blue Flag beaches), the pollution status can be read off and subjectivity do not play a role. By this method nobody can query why a resource must be closed or is closed. The main advantage is that the history of a resource can be tracked at the same time and further objectivity is gained. The basic (raw) data are available and are added on a continual basis. To generate both these graphs is very easy, and to use them even easier – no more guessing and trying to convince people! As faecal enterococci is required for Blue Flag beaches, both can be generated. The latter strengthens anthropogenic influence when collected with *E. coli*, although only the *E. coli* graph is needed for the estuary. For now!

7 DISCUSSION

In general it must be stated that it is globally acknowledged that either *E. coli* and/or faecal enterococci are used as indicator organisms of faecal pollution, although they only provide **indirect evidence** and are surrogates for the presence of pathogenic organisms that cause gastrointestinal illnesses (DoNH+W, 1992). Considering that at all stations low to high numbers of faecal enterococci were sampled, it is prudent to state that the presence of enterococci can be furthermore indicative of the faecal origin of the coliform bacteria (Westwood, 2002).

From a legal point of view, it is stated in the Government Notice 180 of Feb. 10, 1967 Part III (Pollution of water) Section 17 that “*no person shall deposit or cause or allow to be deposited in cause or allow to enter or to discharge into any water supply which the public within the district of the local authority has a right to use and does use, any matter, liquid or thing which is infectious to man.*” From it is therefore imperative that action must be taken to remedy the pollution of these natural water resources.

An article by Heydorn & Morant (1989) refers to the fact that the Municipality started in 1986 to “*survey estuarine coliforms in view of seepage from septic tanks....p.38*”. If it was a problem then, maybe a small one then, what has been done the past 20 years? Since septic tanks and sewerage systems were suspect according to officials and articles, the construction of conservancy tanks at five building sites in Onrus, Vermont and Lagoon Farm were studied and compared to specifications supplied by Mr J. Simson (Hermanus Municipality). As waterproofing is important it was checked at these sites. None of the builders could answer the question “*What “waterproof mix” (Hermanus Municipality A & B, undated) was used?*”. An article from the USA states that “*Homemade systems are very likely to be in violation of local plumbing codes and standards*” (Friedman, 2007). Why would we think that the same does not apply in Overstrand?

A letter from DWAF (2002) to the Overstrand Municipality regarding regulations on the use of septic tanks refers to Government Notice 1191 of Oct 8, 1999 and states that septic tanks shall be (a) outside a watercourse; (b) above the 100 year flood-line or alternatively more than 100m from the edge of the water resource/borehole, and (c) on land that is not, or does not overlie a major aquifer. The first problem identified after reading this Notice, is when or how is the 100m determined – in summer or winter? When some of the residences along the river and estuary were visited it was obvious that the position of the tanks do not conform to this Notice. Owners state that they have approved building plans for the positioning of the tanks and buildings.

This Notice further states that the use of septic tanks and French drains are discouraged. The question is then how is it possible that owners and workers indicated that septic tanks and soak-aways are still used? Some of these are obviously below the high-water mark. A map with high-water marks could nevertheless not be obtained.

Considering the acidity/alkalinity of the sewage suspension in these tanks and biofilm effects (if the builder does not remove a brick from the start), it is a fact that with time these tanks will fail and start to leak. While there were a small number of residences it had no effect, but suddenly with the influx of people and more residences, every drop of sewage spilled or leaked becomes important as the principle of cumulative effect is added to the equation.

The interpretation of the results and the decision to close a resource due to pollution, must be made easy. For this reason the “*Moving 5-Result-Period*” method and the calculation of the percentage by which the maximum limit (100cfu/100ml) is exceeded, is advocated. By using both the graphs then generated (where required), the decision is easier and the history can be tracked and it is objective.

In order not to confuse the issues, it will be best to discuss the stream in Stanford and the estuary under separate headings.

7.1 Stream in Stanford.

From the presented data it is obvious that there is a high level of faecal pollution – high numbers constantly - of *E. coli* and enterococci. This level of pollution did not significantly decrease as one would expect when the rain started and the run-off cleaned all the diffuse storm-water sources. Furthermore it is important to remember that when coliform bacteria are present in the absence of *E. coli*, (extremely low counts) but in the presence of enterococci, this can be indicative of the faecal origin of the coliform bacteria (Westwood, 2002).

As the WWTW chlorinates the effluent to kill bacteria before releasing the effluent to the environment, it is important to consider the effect of chlorination on bacteria. The reader is referred to paragraph 4.8 where the issues of viable-but-not-culturable (VBNC) and resistance to chlorination are discussed. From this background information it becomes clear that the sudden increase in bacteria counts further downstream could be attributed to a phenomenon called VBNC. Research indicates that when the chlorine residual falls to 1 ± 2 mg/l free chlorine it becomes insufficient to eliminate coliforms. The chlorine levels along the stream become important and have to be measured. It will therefore be prudent to investigate the issue further before all blame is allocated to the WWTW.

To use of a “reedbed” to further clean the effluent from the WWTW to the river at Stanford, is a positive action. The problem with this stream (“reedbed”) is that it is just a channel

overgrown with kikuyu grass and *Typha* sp. A proper reedbed is constructed with various hydrological systems and populated with specific plants to facilitate the aim of the reedbed, viz chemical removal, bacteria removal, etc.

Considering the geography (paragraph 4.2) of Stanford, the fact that pollution accumulates in depressions and the treatise on biofilm and concrete structures (paragraphs 4.6 - 4.8), all the septic tanks, soak-aways and conservancy tanks in the area must be suspect of faecal pollution. The geology ensures that all groundwater and its 'additives' (this include spills, seepage and leaks from subterranean tanks) trickle to the stream and end up in the river. As stated earlier, biofilm not only corrode concrete structures but also safeguard bacteria against harsh conditions. In soil it develops into a pathway for bacteria to move along to the next depression – in our case the stream.

The maximum bacteria counts the NHLS supplied, is 2419 cfu/100ml – as it is above the upper limit for the standard – 2000cfu/100ml. This maximum number is reached often at the different stations. The question arises where do these high numbers constantly come from? Can these high numbers be attributed that there are leaking septic and conservancy tanks and also to large subterranean structures covered in biofilm? It has been stated that both the indicator organisms occur and survive in biofilm and that they can multiply there. Pollution from subterranean structures must therefore be considered as a possible cause for the constantly high numbers.

In an e-mail (F. Brand, (Asst. Ops. Manager, Stanford) 6 Nov 2007) Mr Brand acknowledges that septic systems along the stream are a problem: *"Our plant is contributing 50% towards the inflow of treated effluent into the Klein River. The other 50% however is of a more serious nature being the untreated effluent seeping from the various riparian owners' properties alongside the river front on both sides. Their "treatment plants" consist of septic tanks where raw sewerage flows into a holding tank, the sludge settles at the bottom and the overflow water seeps into a drainage field.*

Considering all the possible sources of the pollution in this stream it becomes clear that there must be other sources over and above the WWTW. The surprise is that the "50% effluent" is not "treated" anymore if the resistance of bacteria to disinfectants is kept in mind. Although station (K17, 50m below the WWTW) initially presented high counts, these were linked to faulty chlorination equipment. When corrected the counts decreased. Then the counts rose sharply when heavy downpours were measured. This increase could possibly be linked to storm-water entering the WWTW and caused an unintended spill-over – this could however not be verified.

Lastly, attention must be drawn to the fact that this stream is bordered by a cemetery. As stated in paragraph 4.9 cemeteries have serious pollution potential for groundwater and cannot be left out of this equation.

7.2 Kleinrivier Estuary

From the results it was observed that from the end June 2007 (M5RP 5) the counts started to decline. This downward trend was sustained up to end September/beginning of October 2007. The lowest bacteria counts were reached towards the middle of August 2007. Results from the last two samples for this investigation indicated that an increase in counts was underway. This confirmed that pollution in the estuary is cyclical. However, one wonders how it is possible that with this huge volume of “clean” water in the estuary, where the volume of pollution comes from to have such an impact? To increase the bacteria counts so fast and so high in such a body of water requires a potent source or sources.

One of the main problems of interpreting the results is the fact that the estuary is immense and all kinds of currents, channels and wind effects move the water around. Therefore it can, or will be, difficult to pinpoint any pollution source. All pollution sources must therefore be considered diffuse. Biofilm development, and all that goes with it, only exacerbates the problem.

As the indicator organisms do not multiply in natural waters (normally die-off in 27 days), the facts that all storm water inflow with any pollutants stopped with the rains, and that there is no industrial effluent feeding into the estuary, means that the focus to find a source (non-point or point source) shifts to the immediate surroundings of the estuary.

Studying all the samples it was observed that counts for the indicator organisms stay high at the mouth at Scout Camp (L1, Fig. 21 + 23). The history of the estuary (2005) has also shown the same tendency at Scout Camp. Notwithstanding the fact that L1 (Scout Camp) was dry for a long period in 2007, the first time (August 2007) that the station filled up the counts were high and they stayed high, even during the rising of the water level of the estuary and the breaching. According to officials, the Voëlklip sewerage pump-station is sited at this point. No data of spillages or leaks could be obtained. Other reasons could be that this is a natural “depression” due to geological formations and characteristics, where all the surrounding pollution accumulates. Or do we have more pollution sources in this area? Or is it a “concertina-effect” where the pollution from up in the estuary is moved by the currents and wind to this point? Atkinson *et al.* (2006) state that spatial patterns in faecal coliform counts suggest that the water currents and circulation patterns play a large role in determining the concentration and persistence of bacterial indicators in different areas. Considering all the characteristics already discussed for bacteria, all the above is possible.

The scum on the surface of the water is an indication of excess nutrients – viz phosphates and nitrites.

Another source of pollution to consider is the old dumpsite next to the R43 and east of See & Sand. This dumpsite was not constructed along set standards for dumpsites (DWAF, 1998) and a number of pollutants can leach from the site into the estuary. Although the Municipality claims that only garden and building rubble were dumped, this cannot be proved (T. Serfontein, *pers. comm.*). Heydorn & Morant (1989) stated in 1989 that “*it (dumpsite) has been subject of complaints from local residents.*” They did not specify what the nature of the complaints was. The only way to verify if there is seepage and to characterize the seepage from the dump is to sink ground water sampling points (test holes) close to the estuary and to monitor them.

The next, maybe most important, source or sources of pollution are along the estuary are the septic systems along the shore. All indications are that human impact and especially sewage management, must be targeted as the biggest pollution source. Along the estuary it has been ascertained that conservancy tanks are seldom pumped and rumour has it (this could not be confirmed as estate workers and managers would not discuss it) that greywater is dumped in soak-aways and at some stands all sewage is dumped directly into soak-aways.

In order to check how the tanks are managed along the estuary the records on pumping frequency were checked at the Overstrand Municipality. Of the 15 estates where tanks are in place only three had them pumped this year. The only reasonable answer to this is that (a) the tanks are leaking very fast, and do not need pumping as they never fill up; or (b) all tanks are linked to soak-aways. With the number of residences in some areas, drain-fields must have developed over the years.

From the basic data and the subsequent graph a general idea was gleaned as to where the pollution can come from. No point sources could be identified. As all the information types obtained are interrelated, the question what would happen if they were integrated. To investigate this, each of the parameters (anthropogenic pressures, usage of the resource and bacteria numbers) were allocated a weight according to importance or effect. All the relevant data was programmed into an Arcview GIS programme. Then all the parameters were integrated and superimposed in a final map.

To calculate human impact, for instance, the numbers of visitors/residents were checked. At the majority of the estates no formal records are kept on the numbers of residents coming and going. The best data that was obtained stated “*high numbers on weekends, more on long weekends and maximum during holidays*” (*pers. comm.*).

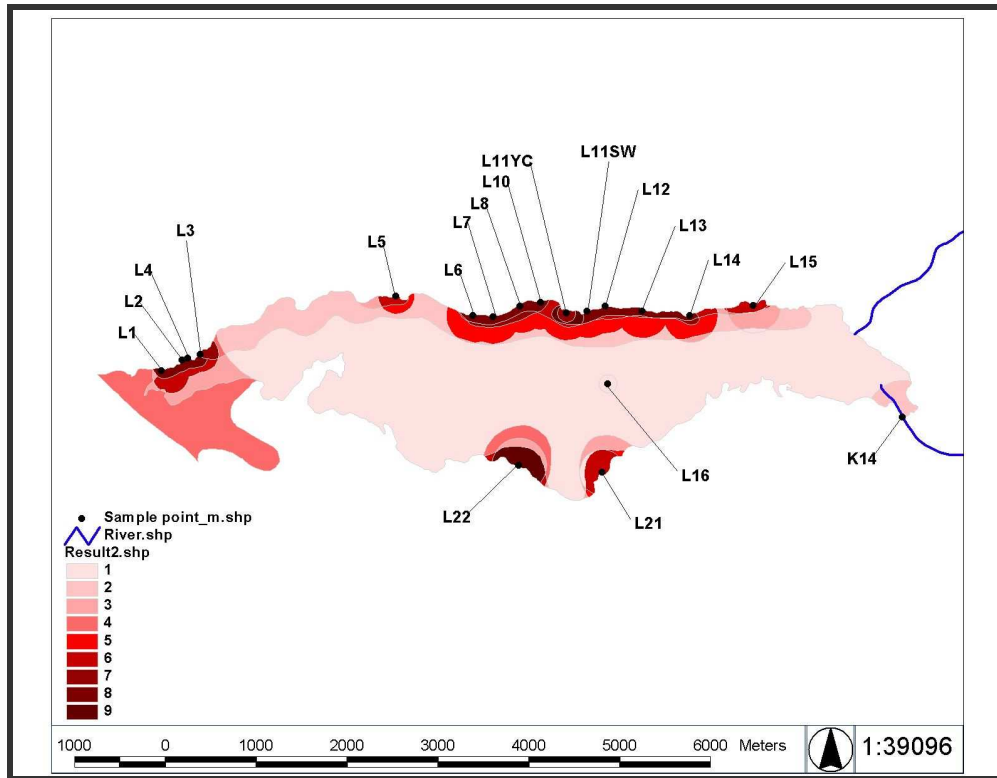


Figure 23: Integration, interactions and superimposed the influence of pollution, human activities and bacteria occurrences. The lighter, the lower the total impact and the darker, the higher the total. (T Dry, 2007)

When all the data from all parameters were integrated and the results mapped, the scale of red from light to very dark indicates the pollution situation along the estuary. It supported all the previous discussions that the main areas where pollution occurs and where the pollution sources (point or diffuse) have to be looked for, are along those areas where human impacts occur and are also the areas where subterranean septic systems occur.

Now that we have all this information, it is indisputable that the estuary, especially along the shore, is polluted. Something has to be done.

With the forthcoming international regatta, the only solace we can offer the competitors and supporters is that the pollution occurs in a relatively thin band along the shore and is within acceptable limits in the deeper water.

8 RECOMMENDATIONS

- ✓ Study viability and resistance of bacteria down-stream from the WWTW at Stanford.
- ✓ Use the “moving-5-sample average” calculation to keep track of bacteria concentration and pollution.
- ✓ Calculate the percentage by which the stations exceed the maximum limit (100cfu/100ml and 2000cfu/100ml) and use this for decisions making.
- ✓ Continue with this sampling regime to build a history.
- ✓ Interpret and use the data.
- ✓ Add to microbiological samples physical-chemical parameters (salinity, temperature, water level, chlorine levels at Stanford and hydrology data.
- ✓ Do a study to determine if chlorination is the best disinfectant for WWTW effluent and if it is not necessary to change to chloramine-based disinfectants.
- ✓ Mount an investigation to check all septic sewerage systems along the stream and estuary. Enforce Government Notice 1191, October 8, 2002.
- ✓ As part of the investigation of the septic systems, test holes for groundwater monitoring along the shore of the estuary would be informative. This could be done with test boreholes along the shore between human activities and the water. Test water in these regularly for the indicator organisms.
- ✓ Consider to change the by-law to force all home owners to install only prefabricated, CSIR/SABS approved subterranean sewage tanks.
- ✓ The owners have to be forced to pump conservancy tanks regularly. – Are there any by-law specifications?
- ✓ Contact DWAF and indicate the gaps in their regulations and request that the positioning of subterranean septic tanks along water bodies, especially where flood plains exist, has to be reconsidered and updated.
- ✓ Obtain high-watermark data and/or maps to validate the positioning of septic systems along the banks and shores.
- ✓ The current water sample regime, analysing fortnightly for faecal coliform, *E. coli* and faecal enterococci concentrations from 15 stations in the estuary, should continue as such with regular analysis and interpretation of data taking place.

9 CONCLUSIONS

More than 20 years ago the Municipality embarked on a monthly survey of estuarine coliforms, which are indicators of human faecal contamination, in view of the possibility of seepage from septic tanks along the northern shore. Today we are again looking at and investigating the same problem. Today the human impact is far more severe, and if the Municipality then suspected “seepage from septic tanks”, there must now be a flood!

Back then the estuary was “just another estuary, but currently *“it is the 5th most important estuary in South Africa.”*, (De Villiers, 2007, pers. comm.). This puts the estuary and our efforts towards eliminating pollution in a total new category. Historically, few people resided around and visited the estuary and Klein River, and the impact was negligible. Today it is different and the pollution potential is more severe. If it is the contention of this Council that the estuary must be a resource to market and to exploit, now is the time to do something and not wait another 20 years. It is now the time to implement and maybe even enforce all legislation, regulations and other requirements to save the estuary.

From the data it is clear that the stream in Stanford and the estuary at Hermanus must be considered polluted as both the indicator organisms occur in high numbers in nearly all samples. For the estuary as an entity a few clean areas are insignificant. There is a significantly high likelihood that the pollution in the stream in Stanford and in the Kleinrivier estuary originates from badly managed subterranean septic tank systems and is propagated in biofilm in the soil between the leaking sewerage systems and the water source. That the WWTW at Stanford contributes to the problem in the stream and river is maybe not purely due to negligence. The fact that indicator organisms are becoming, already are, more resistant to disinfectants can contribute to the level of pollution.

Considering the history of septic systems and the control over these systems, it has to be the debarcation point in finding the pollution sources. For this a complete management and implementation process has to be developed.

In the first paragraph of the Introduction the principles and goal we strive for are listed. Now is the time to start implementing those principles and goals.

Let us not be accused as was the Israelites: Jeremia said to them:

.....; **the whole land will be laid waste because there is no one who cares.** (Jer. 12:11)

10 DEFINITIONS & ABBREVIATIONS

- Aftergrowth** The term aftergrowth consequently denotes growth of micro-organisms native to a water distribution system and the term
- Bacteria** Extremely small, relatively simple prokaryotic micro-organisms.
- Biofilm** The term “biofilm” is used to describe a layer of micro-organisms in an aquatic environment held together in a polymeric matrix attached to a substratum such as pipes, tubercles or sediment deposits. (Miomba, 2000)
- Break-through** Break-through refers to an increase in bacterial numbers in the system after viable bacteria have passed through the disinfection process
- Escherichia coli* (*E. coli*)** Refers to those faecal coliforms which test indole-positive at 44.5°C and generally consists only of *E. coli* which is most definitely of faecal origin. Used to evaluate the possible faecal origin of total and faecal coliforms.
- Estuary** An estuary is defined as “a partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with freshwater derived from land drainage” (with one or more rivers or streams flowing into it) (Day 1980). (Turpie) (Refer also “lagoon”)
- Enterococci (Faecal streptococci)** Refers to bacteria which produce typical reddish colonies on m-Enterococcus agar after 48 hours of incubation at 35°C. These bacteria always appears in human or animal faeces, but in lower numbers than total or faecal coliforms and are **more resistant** than coliform bacteria. Used in the evaluation of treatment processes and **recreational waters**.
- Faecal coliforms** Refers to all bacteria which produce typical blue colonies on m-FC agar within 20-24 hours of incubation at 44.5°C. Indicator of probable faecal pollution of water since this group is more closely associated with faecal pollution than the broader total coliform group. Used to evaluate the quality of waste water effluents, **river water, seawater at bathing beaches**, raw water for drinking water supply, **recreational water**, as well as water used for irrigation, livestock watering and aquaculture.
- Full contact recreational use** This subuse is characterised by the fact that full body contact, ingestion of water and inhalation of aerosols are likely to occur frequently throughout the activity. Activities include swimming, diving (scuba and snorkling), water skiing, surfing, paddle skiing and wind surfing. (SAWGL, 1995)
- Intermediate contact recreational use** Intermediate contact recreation includes activities such as boating, sailing, canoeing, wading, angling and parasailing, where the user may come into contact with the water, inhale aerosols or swallow water, but to a lesser extent than in the case of full contact recreation. (SAWGL, 1995)
- Lagoon** is a body of comparatively shallow salt or brackish water separated from the deeper sea by a shallow or exposed sandbank, coral reef, or similar feature. **Lagoon** refers to both coastal lagoons formed by the build-up of sandbanks or reefs along shallow coastal waters.
- Non-contact recreational use** Non-contact recreation involves all recreational activities taking place in the vicinity of marine waters, but which do not involve direct contact with the water, such as sightseeing, picnicking, walking, horse riding, hiking, camping, etc.
- Pollution** Is the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of the sea water and reduction of amenities. (United Nations Convention on the Law of the Sea)
- Recreational waters** These are all inland waters which are used for recreational purposes. As recreation water is used for a wide variety of activities, it follows that the type of quality requirements for such water represents a synthesis of the needs for various

activities, and that a wide spectrum of problems may be encountered where water does not meet requirements. (DWAF, Vol. 2, p 11).

Regrowth (of bacteria) The term regrowth is used when bacteria injured during the treatment process start to multiply after recovering from a form of reversible injury.

Abbreviations

cfu	colony forming unit
cfu/100ml	(bacteria) colony forming units per 100ml
DEAT	Dept of Environmental Affairs and Tourism
Dc	Bokkeveld Serie
DM1	De Mond Camp 1
DM2	De Mond Camp 2
Dr-Ss	TMG Aquifer in the south
DWAF	Dept of Water Affairs and Forestry.
EHO	Environmental Health Officer
EPA	Environmental Protection Agency of USA
EPS	Extracellular polymeric substances
GM	Geometric Mean (statistical calculation)
KR	Kleinrivier huisies
M5RP	Moving-5-result-period
mamsl	meter above mean sea level
MSB	Maanskynbaai
msl	mean sea level
NHLS	National Health Laboratory Service
PF	Prawn Flats
PH	Pollution history
pH	Numeric value that indicates the relative acidity or alkalinity of a substance of a scale 0-14, with the neutral point at 7.
SAS	Soak-away systems
SAWQ	Sa Water Quality (Guidelines)
SC	Scout Camp
SDF	Spatial Development Framework.
SOP	Standing Operational Procedure
TMG	Table Mountain Group
N-Chp	Cape Granite Suite
VBNC	Bacteria that passed through a reversible injury process are as long as the residual effect last "viable-but-no-culturable".
WWTW	Waste Water Treatment Works

11 LITERATURE CONSULTED

- Atkinson, L., Hutchings, K., Clark, B., Turpie, J., Steffani, N., Robinson, T., & Duffell-Canham, A. 2006. State of the Bay 2006: Saldanha Bay and Langebaan Lagoon. A Technical Report (for) Saldanha Bay Water Quality Trust.
- Barnes, Jo. M. 2005. Health aspects of the re-use of household wastewater (greywater). Dept of Community Health Sciences, Univ. of Stellenbosch, Tygerberg.
- Coetzee, D. J. & Poole, R.C. 1986. Fluctuations in some physico-chemical conditions in Kleinriviersvlei, a south-western Cape coastal lagoon. Bontebok, Vol. 5, p. 24-30
- Costa, J. Unknown date. Geometric Mean Calculations. Article supplied by Dr Jo Barnes, Univ. Stellenbosch, Tygerberg.
- Dept. of National Health and Welfare (DoNH+W) 1992. Guidelines for Canadian Recreational Water Quality.
- D'Arcy B, Campbell, N., Frost, A. , Novotny, V. & Sansom, A. 2005. Diffuse Pollution: An Introduction to The Problems and Solutions. London: WA Publishing.
- Davies, B. R, O'Keefe, JH & Snaddon, CD. 1993. A synthesis of the ecological functioning, conservation and management of South African river systems. Water Research Commission 230pp (ISBN 1-86845-001-3)
- Davies, B, & Day, J. 1998. Vanishing Waters. Cape Town: UCT Press.
- Diercks, M., Sand, W. & Bock, E. 1991. Microbial corrosion of concrete. Cellular and Molecular Life Sciences (CMLS). Birkhäuser Basel; Volume 47, Number 6, June, 1991; pages 514-516
- Dept of Health (DoH), 1967. Government Gazette R180 of 10 Feb. 1967.
- De Villiers, P. 2007. CapeNature Scientific Services, Jonkershoek.
- DWAF (Department of Water Affairs and Forestry). 1995. South African Water Quality Guidelines for Coastal Marine Waters. Volume 2: Recreational Use. 2nd Edition.
- DWAF (Department of Water Affairs and Forestry). 1999. Minimum requirements for waste disposal by landfill. Second edition.
- DWAF (Department of Water Affairs and Forestry), 2002. Regulation pertaining to use of septic tanks. (Reference also to conservancy tanks). Letter 16/2/7/G403/D2, dd 27 May 2002, Mr J Rossouw.
- DWAF (Department of Water Affairs and Forestry), 2004a.. Water Quality Management Series Operational policy for the disposal of land-derived water containing waste to the marine environment of South Africa, Edition 1: Guidance on Implementation. Sub-Series No. MS 13.3 *Section 4: Environmental Quality Objectives*
- DWAF (Department of Water Affairs and Forestry), 2004b. Water Quality Management Series Operational policy for the disposal of land-derived water containing waste to the marine environment of South Africa, Edition 1: Guidance on Implementation. Sub-Series No. MS 13.3. 1st Edition. *Series 5: Activities and waste Loads*
- Duvenhage, I.R. 1983. Getyrvieroppervlaktes van sommige getyrviere van soutmoeras-plantgemeenskappe by twee lokaliteite in Kleinriviersvlei, Hermanus. Unpublished Cape Technikon Rep. 14pp. (IN Heydorn & Morant. 1989)
- European Union (EU). 2006. The management of bathing water quality and repealing Directive 76/160/EEC. ECC DIRECTIVE 2006/7/EC EEC/7/2006; L64/37
- Fattal, B., Vasl, R. J., Katzenelson, E. & Shuval, H. I. 1983. Survival of bacterial indicator organism and enteric viruses in Mediterranean coastal waters off Tel-Aviv. *Water Res.* **17** 397.
- Ferguson, Donna. 2006. Growth of *E. coli* and Enterococci in Storm Drain Biofilm. County of Orange, Health Care Agency Public Health Laboratory
- Friedman, D. 2007. Inspecting, Testing, & Maintaining & Designing Residential Septic Systems - Septic Systems Online Book: Friedman, D. 2007. Google search.

- Harmse, J. T. & Tumagole, K. B. 2006. Groundwater pollution at Ditengeng northern cemetery north of Pretoria, SA. Univ of Johannesburg. Pers. copy of paper presented at conference in Australia.
- Harrison, T.D. 2004. Physico-chemical characteristics of South African estuaries in relation to the zoogeography of the region. *Estuarine, Coastal and Shelf Science* 61: 73–87.
- Hayes, Louise. 2001. Water Quality Monitoring Of Surface Water, Groundwater And Inflowing Streams In And Around Betty's Bay Lakes: Grootrondevlei And Grootwitvlei (unpublished honours dissertation) Depart. of Environmental and Geographical Science, Univ. of Cape Town
- Hayes, Louise & Winter, K. 2002. Surface and groundwater monitoring in and around the lakes at Betty's Bay. Summer 2001/2002 Depart. of Environmental and Geographical Science, Univ. of Cape Town
- Hermanus Municipality-A (no date). Hermanus Municipality conservancy tank details.
- Hermanus Municipality-B (no date). Hermanus Municipality septic tank details.
- Heydorn & Morant. 1989. Estuaries of the Cape. Part II. Synopsis of available information on individual systems. Report No. 40. KLEIN (CSW16). CSIR Report 439. 1989.
- Maule, A. 2000. Survival of verocytotoxigenic *Escherichia coli*)157 in soil, water and on surfaces. Symp. Ser Soc Appl Microbiol (29), 71S – 78S
- Momba, Maggy, N. B., Cloete, T. E., Venter, M. S. N. & Kfir, N. 1999. Examination of the behaviour of *Escherichia coli* in biofilms established in laboratory-scale units receiving chlorinated and chloraminated water. *Wat. Res.* Vol. 33, No. 13, pp. 2937-2940, 1999.
- Momba, Maggy, N. B., Kfir, R., Venter, S. N. & Cloete, T. E., 2000. An overview of biofilm formation in distribution systems and its impact on the deterioration of water quality
- Monteiro, P.M.S, Warwick, P. A., Pascall, A. & FRANCK, M.. 2000. – Saldanha Bay Water Quality Monitoring Programme. Parts 1 & 2. CSIR.
- Morant, P. & Quinn, N., 1999. Influence of man and management of South African estuaries. *In*: Turpie, Jane K., 2004.
- National Health Laboratory Services (NHLS), 2005. The detection of faecal enterococci in food and water samples. GPCPH0047.2.SOP
- National Health Laboratory Services (NHLS), 2006. Determining the microbiological quality of water samples: Colilert method for coliforms and *E coli* and total bacterial count [SABS 241(221)]. Standing Operational Procedure - GPCPH0009.2.SOP
- National Health Laboratory Services (NHLS), 2007. Quotation: Public Health Microbiology 2007.
- Nestor, E. W., Roberts, C. E. , Lindstrom, Mary, E., Pearsall, Nancy, M. & Nestor, Martha, T. 1983. Microbiology. Saunders College Publishing.
- Oelofse, S. H. H., Viljoen, P., Taljaard, Susan & Botes W. A. M. 2000. Discharge of water containing waste emanating from land to the marine environment: A water quality management perspective. 56 ISSN 0378-4738 = Water SA Vol. 30 No. 5 (Special edition) Available on website <http://www.wrc.org.za>
- Overstrand Municipality Wide Spatial Development Framework (SDF), 2005.
- Parsons R , 2004. Surface Water - Groundwater Interaction In A Southern African Context. Pretoria: Water Research Commission.
- Pritchard, D. W. (1967) What is an estuary: Physical viewpoint. p. 3–5 *in*: G. H. Lauf (ed.) *Estuaries*, A.A.A.S. Publ. No. 83, Washington, D.C.
- PRÜSS A. 1998. A review of epidemiological studies from exposure to recreational water. *Int. J. Epidemiol.* **27** 1-9.
- Roux, S., Feugeas, A. & Cornet, A. 2007. The contribution of biofilms in concrete weathering: bioreceptivity of mortars and cement paste in natural fresh water. *Geophysical Research Abstracts*, Vol. 9, 00303, 2007 SRef-ID: 1607-7962/gra/EGU2007-A-00303, European Geosciences Union 2007
- SA Water Quality Guidelines. 1995. Vol.2. Recreational use. Dept of Water Affairs and Forestry.

- SAPA. 2007. Pollution battle 'in stages'. Report from Parliament on water pollution. May, 15, 2007.
- Scott, K. M. F., Harrison, A. D. & Macnae, W. 1952. The Ecology of SA Estuaries. Part II: The Klein River Estuary, Hermanus, Cape. Trans. Roy. Soc. S. Afr. Vol. 33, p283-331
- Saskatchewan Environment and Resource Management (SERM). 1999. An Interim Guide for Disposal of Sewage
- SDF. 2005. Overstrand Municipality Wide Spatial Development Framework (SDF), 2005.
- Sloman, R. J. L. 1983. The sediment distribution of the Klein River estuary. BSc. Hons. Project, Geology Dept, Univ. Cape Town. (In Heydorn & Morant. 1989)
- Taljaard, Susan, Van Ballegooyen, R. C. & Morant, P. D. 2000. False Bay Water Quality Review.. Volume 2: Specialist Assessments and Inventories of Available Literature and Data. Report to the False Bay Water Quality Advisory Committee. CSIR Report ENV-S-C 2000-086/2. Stellenbosch.
- Taljaard, Susan, van Niekerk, L., Huizinga, P. and Joubert, W. 2003. Resource Monitoring Procedures for Estuaries. For application in the Ecological Reserve Determination and Implementation Process. *Water Research Commission Report No. 1308/1/03*. Pretoria
- Thomas, V. 2005. An investigation of diffuse pollution at Betty's Bay. BScHons. Dept. Environmental and Geographical Science. Univ. Cape Town.
- Turpie, Jane K., 2004. South African National Spatial Biodiversity Assessment 2004: Technical Report. Volume 3: Estuary Component. South African National Biodiversity Institute, Pretoria.
- Umvoto Africa. 2007. Stanford regional monitoring: Drilling Phase, May 2007. (LJ Groenewald).
- Westwood, D. (Secretary) 2002. The Microbiology of Drinking Water - Part 1 - Water Quality and Public Health. Methods for the Examination of Waters and Associated Materials. Water Quality
- Whitfield, A. K. 2000. Available scientific information on individual estuarine systems. WRC Report no. 577/3/00.
- Wikipedia. 2007. Search terms "Biofilm, concrete".
- Winter,

12 ANNEXURES

Annexure 1: Description, numbering and GPS references of sampling stations.

Identifiers:

A = Those stations sample additionally when complaints are received

H = Those stations sampled by ODM personnel on monthly basis

K = Stations in Klein River river

L = Stations along the estuary

ID name	ID + Prefix	X	Y	Description
L1	L1/H1	19.30202389	-34.41632812	Scout Camp
L2	L2/H2	19.30344088	-34.41483802	De Mondt 2
L3	L3/H5	19.30557646	-34.41424059	Prawn Flats
L4	L4/H4	19.30406008	-34.41465872	Kleinrivierhuisies
L5	L5/H7	19.32899076	-34.40840632	Maanskynbaai
L6		19.33820049	-34.41034961	Lagoon Farm
L7	L7/A1	19.34057893	-34.41044889	Waterways
L8		19.34385026	-34.40935387	Maanskijnkop
L9				Stillwater (Locked)
L10	L10/A2	19.34631792	-34.40901257	Pennant 9
L11YC		19.34936068	-34.41006828	Yacht Club
L11SW		19.35185292	-34.4098482	South Winds
L12		19.35400206	-34.40937366	lagoon Lodge
L13	L13/A3	19.35845378	-34.40980467	Lagoon Edge
L14	L14/A4	19.36419164	-34.41024677	Lagoon Rock
L15		19.37175657	-34.40925094	Rocklands
L16		19.35434236	-34.41706162	Middle of Estuary
L21		19.35369137	-34.42584961	Mosaic Farm
L22		19.3437479	-34.4251945	Wortelgat
K1		19.45866349	-34.43129631	Upper end Stanford
K2		19.45788158	-34.43455971	Jetty - last house upstream
K3		19.45745014	-34.43592034	Jetty - opposite Adderley St
K4		19.45686563	-34.4369649	Jetty - opposite Quick St
K5		19.45447742	-34.43664207	African Queen anchorage
K6		19.45376778	-34.43639745	Slipway

K7	19.45141327	-34.43436849	Storm water stream
K8	19.44602595	-34.43632535	Melkbos Res. East jetty
K9	19.44129938	-34.4331242	Blue Ridge - jetty
K10	19.42438031	-34.42938751	Middelbos - jetty
K11	19.41093696	-34.42463575	Watering place - animals
K12	19.40628474	-34.42434267	Springfontein - jetty
K13	19.39847806	-34.42409775	Side stream
K14	19.38962708	-34.42024296	Upper station at estuary
K15	19.41820591	-34.42643047	Slipway - Mr Finch
K16	19.4537877	-34.44304067	Containment dams SF
K17	19.44845331	-34.44186874	WWTW outflow
K17A	19.45141485	-34.43808486	100m south QVB
K17B	19.45278	-34.43652	100m north QVB
K17C	19.44988506	-34.44032122	Culvert DeBruin St
K18	19.45211301	-34.43716595	Queen Vic Bridge (QVB)
K19	19.45291418	-34.43607438	Stream in river
K20	19.4628561	-34.43412706	Bridge on R43