THE APPLICATION OF INTEGRATED ENVIRONMENTAL MANAGEMENT TO IMPROVE STORM WATER QUALITY AND REDUCE MARINE POLLUTION AT JEFFREYS BAY (SOUTH AFRICA)

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TABLE OF CONTENTS

ABSTRACT

It is projected that by 2025 three-quarters of the world's population will live in the coastal zone. This is an alarming statistic, with a consequently significant impact on small coastal towns and the adjacent marine environments. Developing communities within the coastal zone of South Africa have proved to be a significant pollution source of storm water. Studies have shown that storm water that is deposited in the ocean will be trapped in the near shore marine environment causing poor seawater quality over a large distance. Furthermore, this can pose a significant threat to the health of recreational users and important marine ecosystems. In Jeffreys Bay storm water quality is thought to pose a threat to the maintenance of the international Blue Flag status for its beach. The aim of the current project was to investigate the main sources of storm water and subsequent marine pollution at Jeffreys Bay and to develop an appropriate management strategy using the integrated environmental management framework. In order to achieve this objective, it was also necessary to determine the current quality of water at various points within the catchment and near shore marine environment. Even though the storm water was found to be severely contaminated no evidence existed for a negative impact on the marine environment. None the less, a precautionary approach was adopted and a risk assessment employed in order to consider potential impacts on the marine and aquatic environment, human health and socio-economic welfare within the town. Significant sources of storm water contamination included grey water, domestic solid waste disposal and informal ablution. These significant aspects were investigated further and it was found that solid waste management in the catchment was poor with significant quantities of waste, primarily (76%) from domestic sources, being disposed of illegally. A study of sanitation management showed inadequacies where up to 58% of the residents from the informal settlements disposed of their grey water into open spaces. The ratio of residents to toilets in these areas was 28:1, therefore supporting the outcome of the risk assessment. Due to the fact that all the significant aspects were related to anthropogenic waste, an integrated waste management plan (IWMP) was developed that would not only facilitate the reduction of pollution of storm water, but would also allow for sustainable community-based development.

ABBREVIATIONS

COD	Chemical oxygen demand
Comm	Community-based intervention
DEAT	Department of Environmental Affairs and Tourism
DWAF	Department of Water Affairs and Forestry
EcoSan	Ecological sanitation
Ed	Educational intervention
EHO	Environmental health officer
EIA	Environmental impact assessment
EMP	Environmental management plan
En	Engineering intervention
EPA	Environmental Protection Agency (United States)
I&APs	Interested & affected parties
IEM	Integrated environmental management
IPWM	Integrated pollution and waste management
IWMP	Integrated waste management plan
MARPOL	International convention for the prevention of pollution from ships
NGO	Non-governmental organisation
NHLS	National Health Laboratory Service
NSW EPA	New South Wales Environmental Protection Authority
POPs	Persistent organic pollutants
RA	Risk assessment
SS	Suspended solids
UNEP	United Nations Environmental Program
UNEP - IETC	United Nations Environmental Program - International Environmental Technology Centre
WESSA	Wildlife and Environmental Society of South Africa
WHO	World Health Organization
WRC	Water Research Commission
YWAM	Youth with a Mission

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LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

GENERAL INTRODUCTION

1.1 BACKGROUND

Genesis 1:21 of the Bible (New International Version) says, "God created the great creatures of the sea and every living and moving thing with which the waters teem according to its kind and every winged bird according to its kind. And God saw that it was good." Today the coast is appreciated as a special and exceptional part of earth that contains many unique ecosystems. The marine environment offers significant benefit to humans, including nutritional resources, recreational opportunities and potential treatment for diseases. This has lead to coastal areas growing in popularity but, regrettably, also a gain in the quantity of toxic effluent and solid waste from human activities reaching the ocean. Some pollutants are able to biodegrade while others accumulate and cause short- and long-term harm to the marine environment (DEAT, 2001).

It is projected that two-thirds of the world's population live within the coastal zone and that this figure could increase to three-quarters by the year 2025 (DEAT, 2001). Furthermore, population growth in the coastal zone is twice that of the global trend (Farmer & Garcia, 2002). This is an alarming tendency, with a consequently huge impact on a relatively small coastal area and its adjacent marine environment. In the developing world coastal population growth and coastal urbanization is of an even greater concern (UNEP, 2000a). As this trend of population growth in the coastal zone continues, so will the threat of inshore marine pollution from land-based activities.

It was as late as the 1950's when concern for pollution to the sea was first raised (Albaiges, 1989). Radioactive tracers were found in seawater, sediment and biota samples and this indicated that pollution in the world's oceans had the capability to disperse proving that international cooperation was essential to combat the threat (Albaiges, 1989). One of the earliest attempts to establish international law relating to land-based marine pollution was the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 better known as the London Convention, which was amended in 1996. At around the same time, the International Convention for the Prevention of Pollution from Ships (MARPOL) was established in order to reduce marine pollution from ships (Fanshawe & Everard, 2002). Despite the development and ratification of international agreements and policies to protect the marine environment from pollution, little is being done in developing countries to understand and reduce anthropogenic land-based marine pollution. When taking into consideration the population growth in coastal areas and the importance of marine resources to developing economies, it is clear that new and sustainable initiatives are necessary to find solutions to the problems that coastal and marine management is facing. Before developing appropriate and sustainable solutions, the categories and effects of land-based marine pollution need to be better understood.

1.2 THE MAIN CATEGORIES AND EFFECTS OF LAND-BASED MARINE POLLUTION

Marine pollution can be defined as "…the introduction by humans directly or indirectly, of substances or energy into the marine environment that cause harm to living resources, are hazardous to human health, hinder marine activities including fishing, or impair the quality of sea-water or coastal amenities" (DEAT, 2001). Either land-based activities or activities at sea can be responsible for the pollution of the marine environment. Although events such as oil spills from maritime vessels result in much publicized disastrous effects, it is often sources that receive less public and local government attention that contribute the most to pollution of the marine environment (DEAT, 2001).

Statistics show that land-based pollution is responsible for 75% to 80% of all the pollution that ends up in the worlds oceans, this compared to only 10% that originates from the maritime industry (Dittke, 2000). Others argue that over 80% of the pollution to the ocean comes from land (Global Environmental Facility, 2000). Pipelines, land-use runoff, storm water discharge, submarine groundwater and atmospheric fallout are the main contributors (DEAT, 2001; Finkl & Krupa, 2003). Visible marine pollution such as litter, oil and sediments are evidence of human impact on the marine environment. Other contaminants of the marine environment such as heavy metals and persistent organic pollutants are not as visible, but they are still detrimental. Similarly, some of the effects of marine pollution, for example oiled marine animals, are more obvious than other effects such as the heavy metal bioaccumulation within marine organisms (DEAT, 2001). The main categories of land-based marine pollution, according to UNEP (1995), are sewage, persistent organic pollutants, heavy metals, oils, nutrients, sediment, litter and radioactivity. These marine contaminants can originate from human activities such as mining, agriculture, industry and urban settlements. The following sections will describe the main categories of marine pollution and their effects in more detail.

1.2.1 Sewage

The flushing of urine and faeces down a pipe with water creates what is called sewage (Austin & van Vuuren, 2001). This is one of the most problematic pollutants of the marine environment, due to the fact that it is often discharged in great quantities directly into the ocean and may contain polluting agents such as pathogens, nutrients and heavy metals (Islam & Tanaka, 2004). The problem is further complicated by the discharge of chemicals, for example detergents, into the sewage system that prevents microbiological processes from breaking down sewage during treatment operations.

In large cities, huge volumes of sewage are generated and then require disposal. In the developed world it used to be standard practice to dump sewage in the ocean although this practice has now been discontinued or is in the process off being phased out (Clark, 1992). Nevertheless, raw sewage still finds its way into the ocean (UNEP, 2000b) as a result of spills, leaking sewers and septic tanks as well as sewer overflow during times of heavy rain (UNEP, 1995; Dorfman, 2004). In the United States of America the Environmental Protection Agency (EPA) reported that over 1.3 trillion gallons of raw sewage enter the environment and receiving water bodies due to combined storm water and sewer overflow each year (Dorfman, 2004). They attributed this to ineffective sewage systems, population growth, increased storm water runoff due to urban sprawl and global climate change that has resulted in more rainfall.

The picture in the developing world is, however, very different since a significant proportion of sewage that is generated in these countries is discharged untreated or only partly treated into receiving water bodies (UNEP, 2001). Where sewage treatment plants exist, their operation is usually inadequate (UNEP, 2000b; UNEP, 2001). In the Caribbean it was found that less than 2% of urban sewage was treated before disposal, with the percentage in the rural areas even lower. The lack of sanitation in these areas leads to marine pollution, primarily through contamination of surface water runoff (UNEP, 2001).

Sewage-contaminated marine environments pose significant health threats to users. UNEP (2000b) stated that one out of every twenty people swimming in water only somewhat polluted with sewage later become sick. Pathogens usually enter the human body through the mouth, broken skin, nose, ear, eyes, anus or genitourinary tract and wave action can allow for certain contaminants to become airborne resulting in people inhaling disease-causing agents and toxins. Chemicals or toxins from algal blooms found in the ocean due to marine pollution can also cause skin irritations and various other diseases (Dorfman, 2004). Filter feeders such as mussels and clams harvested from sewage-contaminated waters are another threat to human health because they can accumulate human pathogens, and consumption of infected shellfish may result in diseases such as hepatitis (Clark, 1992; Dorfman, 2004). Globally, at least 50 000 to a 100 000 people die every year due to the consumption of infected seafood (UNEP, 2000a), and this is one of the reasons why the United Nations has placed sewage discharges to sea on top of their list of concerns regarding the marine environment (Clark, 1992).

The negative impact on public health as a result of consumption of contaminated seafood and bathing in polluted seawater also has negative economic implications. UNEP (2000b) stated that global social costs due to sewage pollution have reached US$ 1.2 billion a year. It is further estimated that globally, 3 000 000 years of man-hours are lost every year due to disability after consuming polluted seafood or using polluted waters for recreational purposes (Farmer & Garcia, 2002). Apart from negative impacts on humans, sewage also poses a direct threat to marine ecosystems. Cetaceans and other marine mammals are also vulnerable to bacteria and viruses from human sewage. Viruses such as influenza, herpes and measles as well as bacteria for example *Escherichia coli*, *Mycobacterium tuberculosis*, *Vibrio cholera* and *Salmonella* sp. are zoonic and capable of infecting marine mammals (Islam & Tanaka, 2004). These mammals represent the top of marine food chains and therefore disturbance of the health of these animals may impact on entire ecosystems. The nutrient content of untreated sewage is also of concern to the health of marine ecosystems and is discussed in detail in the following section.

1.2.2 Nutrients

Nutrients such as nitrogen and phosphorus compounds can enter the marine environment from land-based sources by means of point and diffuse sources, both atmospheric and by means of surface water runoff. A major source of nutrients to the marine environment is sewage from coastal communities, while other sources include nutrient-enriched effluent from industries, such as food processing plants, and nitrogen originating from vehicle emissions (UNEP, 2001). Cultivated lands may also contain excessive phosphates and nitrates from fertilizers and livestock manure causing nutrient enrichment of surface waters, which ultimately flow into the ocean (Islam & Tanaka, 2004). In the developed world, large water drainage basins, for example the Mississippi watershed, transport one million tons of nitrates to be deposited into the sea each year, mainly due to agricultural activities (Walsh, 2004). In developing countries, the nutrient load entering the marine environment is increased by lack of sanitation, specifically in those catchments supporting dense informal settlements (Wright *et al.*, 1993).

From as early as the 1970's scientists have been reporting that the chemistry of the oceans is changing due to human impact. These changes have resulted in alterations of the marine food web structures with far reaching effects on marine biota (Singer, 1970). One of the most conspicuous changes is the eutrophication pattern found in some of the world's oceans. Due to excessive inputs of nutrients into the oceans, the growth of phytoplankton can be over-stimulated causing harmful algal blooms and eutrophication. In serious cases, red tides can occur. These phytoplankton blooms are of such intensity that discolouring of the ocean is caused. Bacteria feeding on dead alga from red tides severely deplete the oxygen in the water (Clark, 1992; UNEP, 2000b). This loss of oxygen and other effects arising from red tides, such as toxic release and the clogging of gills and other structures, can result in the death of numerous marine organisms.

1.2.3 Persistent organic pollutants

Persistent organic pollutants (POPs) can be defined as "fat-soluble toxic chemicals that do not easily degrade, persist for many years in the environment and concentrate up the food chain" (UNEP, 2000b). POPs, found in industrial waste and some pesticides (e.g. DDT), mainly gain access to the environment through careless disposal of hazardous waste, leaks and spills or through careless use in agriculture and pest control (UNEP, 1995). Even though the use of DDT in first world countries has been banned, there is still an estimated 28 000 000 tons of DDT being produced globally of which 25% is presumed to reach the oceans (Islam & Tanaka, 2004). POPs then gain access to the marine environment by means of surface water and the atmosphere (Singer, 1970). When POPs have been released into the environment, remediation will pose a near impossible task (UNEP, 1995).

Concentration of POPs within food chains happens by means of bio-concentration and biomagnification. With bio-concentration, chemicals and pesticides concentrate in the fatty tissue of an organism through lipophilicity, while biomagnification is the accumulation of toxins within an organism by means of digesting contaminated foodstuff (Islam & Tanaka, 2004). Of concern is the uptake of POPs into marine plankton, which then allows entry into the marine food chain. Those at the top of the food chain, which include humans, can show signs of large concentrations of these chemicals and pesticides (Islam & Tanaka, 2004). Toxins originating from POPs can also harm the habitat of fish and other marine organisms. Live coral reefs, sea grass beds, and other marine vegetation can decrease due to toxins, such as herbicides, which originate from land-based sources (UNEP, 2001). This could indirectly result in the loss of marine biodiversity.

1.2.4 Heavy metals

Heavy metals are found as natural elements within the earth, but where their biochemical and geochemical cycles have undergone changes due to anthropogenic activities, abnormal quantities of heavy metals can be released into the environment. The problem with the release of excessive heavy metals into the environment lies with their persistent nature which, in return, results in a continuous threat to the marine environment (UNEP, 1995). Although metals such as manganese, iron, copper and zinc are needed for metabolic processes in different forms of life, these metals can however become toxic if organisms absorb excessive amounts. The toxic nature of heavy metals is due to cations that combine short carbon chains within organisms, which subsequently interferes with a range of the organisms' metabolic processes. The fact that heavy metals are not biodegradable, allows for these elements to concentrate within organisms and food chains as time progresses (Islam & Tanaka, 2004). A second group of heavy metals including lead, mercury, chromium and cadmium can however be toxic even if low quantities are consumed, making the monitoring of the environment essential if exposure to these heavy metals is expected (Fatoki & Mathabatha, 2001).

Natural phenomena, for example weathering, erosion, volcanoes and fires that involve rocks that contain metals, can facilitate release of heavy metals to the environment (Clark, 1992). However, a number of anthropogenic sources such as industrial activities, mining, sewage discharge, metal piping, and the burning of fossil fuels can contribute to heavy metal pollution. As with POPs, heavy metals can then find their way into the ocean by means of the atmosphere or surface water runoff (UNEP, 2000b). Clark (1992) argues that the main path for heavy metals to reach the ocean is the atmosphere while Fatoki and Mathabatha (2001) have stated that the main contributors of heavy metals to ports are storm water drains and tributaries that drain industrial and urban areas. Once in the ocean, heavy metals are absorbed in the sediments where accumulation takes place in the ocean floor. If the sediment is then disturbed, heavy metals may be released into the seawater where they pose a threat to marine life (Clark, 1992).

A tendency exists for heavy metal pollution and industrialization to occur concurrently (Islam & Tanaka, 2004; UNEP, 2001). Bioaccumulation of heavy metals can take place which can lead to disease in marine organisms and which in return can affect public health. For example, the consumption of heavy metal-contaminated seafood has been shown to result in higher-than-normal concentrations of methyl mercury in maritime communities such as those in Canada. These toxins can have serious public health implications such as effects on the immune system, brain development, and fertility (Farmer & Garcia, 2002).

1.2.5 Sedimentation

It is currently estimated that 8 billion tons of sediment enters the world's oceans per year (UNEP, 2001), which is predicted to increase to 20 billion tons per year towards the middle of this century, mainly due to human activities (Islam & Tanaka, 2004). Human activities that have a widespread sediment distribution potential include dredging, mining, land filling, urbanization, deforestation and agriculture (Clark, 1992; UNEP, 2001). Sediment loads can then increase in the marine environment by means of direct input or via streams and rivers (UNEP, 2001).

Certain coastal habitats, for example estuaries, require sediments for their development and maintenance, but an overload of sediments can have negative impacts on the marine environment (UNEP, 1995). For example, sediment can be responsible for smothering of juvenile coral and increased turbidity can block light needed for photosynthesis by marine flora (UNEP, 2001). Consequently, the habitat for many other marine organisms becomes affected leading to a loss of biodiversity in the marine environment. Sediments also play a role in distributing pollution loads in the marine environment, for example where certain inorganic pollutants are attracted to clay particles by means of ion exchange processes. Organic pollutants on the other hand are associated with "…organic carbon that is transported as part of the sediment load in streams and rivers" (Islam & Tanaka, 2004). In this way inorganic and organic pollutants are dispersed exposing different organisms in the marine environment to potential contamination (UNEP, 2001).

1.2.6 Oils (Hydrocarbons)

Various oils can be found in different physiological forms in the natural environment. In more refined forms, petroleum hydrocarbons used for various human activities, for example engine fuel, is a large source of land-based marine pollution (UNEP, 1995). As with many other pollutants, hydrocarbons can reach the ocean via the atmosphere, surface water runoff or deliberate discharge. The largest percentage of oil or hydrocarbon pollution in the ocean is derived from industry and urban runoff with only 12% from maritime operations at sea (UNEP, 2000b). Big oil spills from vessels in distress receive significant attention in the media while the more chronic land-based oil pollution often goes unnoticed due to its less visible effect (DEAT, 2001). Marine terminals where oil tankers discharge their cargoes are a potential source of contamination. Human error and breakages can lead to accidents at these sites resulting in oil leaking into the marine environment (DEAT, 2001). Coastal oil refineries are also a large potential source of marine oil pollution. These refineries store and process millions of tons of crude oil and regular leakages, spills and breakages occur. Water that is polluted in the different refinery procedures can also be a pollution risk if discharged untreated (Islam & Tanaka, 2004).

It is not only the oil industry that contributes significantly to pollution of the marine environment by hydrocarbons. Untreated domestic- and industrial effluent can contain petroleum hydrocarbons in various forms, even after treatment. Highly developed storm water catchments also facilitate entry of oil into the ocean. This is due to vehicles depositing oil on roads and paved surfaces, which is subsequently washed into surface water drainage canals and eventually the ocean during rainstorms. The illegal discharge of used oil by industry, vehicle repair shops or the public directly into storm water drains also contributes to the above-mentioned predicament (Clark, 1992). Apart from these inputs, vehicles and industrial emissions release hydrocarbons into the atmosphere that may eventually reach the ocean directly or indirectly by means of storm water runoff (Singer, 1970). Statistics from Australia show that 16 000 tons of oil enter the ocean as a result of run-off and waste from land-based activities (Islam & Tanaka, 2004). Petroleum hydrocarbons can have toxic effects on marine biota, and plankton is particularly susceptible to these toxins (DEAT, 2001). Plankton is also the first link in the marine food web and by depleting this resource all marine life in the ocean can be affected negatively. Toxins found in oil can also lead to increased infections, tumours, reproductive disorders, disease and even death of marine organisms (Attwood *et al.*, 2000; Islam & Tanaka, 2004).

1.2.7 Litter

Litter in the marine environment can be seen as any "…solid material from human origin that has been discarded of at sea or has reached the sea through waterways or domestic or industrial outfall" (Williams *et al.*, 2000). Even though marine litter is made up of many different materials, plastic is the most common (UNEP, 2000b; Islam & Tanaka, 2004), followed by glass with other items such as metal, rubber, textile and organic matter also prevalent (UNEP, 2000b). Plastic represents between 60% and 80% of all the litter found in the marine environment (Derraik, 2002). Apart from being the most common among marine litter, it is also the most problematic. This is due to plastic's ability to float, allowing it to distribute over a very wide area, as well as the prolonged existence of plastic in the marine environment due to its durability (Derraik, 2002). For example, plastic bags can take up to 12 years to degrade while plastic foam containers will take considerably longer to degrade (DEAT, 2001).

According to Fanshawe and Everard (2002), the major land-based sources of marine litter are: "sewage treatment works, combined sewer overflows, industrial discharge, urban runoff, shipping, defence munitions, piers, agricultural waste, fishing, fly tipping, aquaculture, municipal and recreational." The list shows that most litter originates directly from coastal settlements. Once in the ocean, tides, currents, and winds determine the spreading of litter, which eventually accumulates at different locations known as sinks (Fanshawe & Everard, 2002). Litter or marine debris can pose a direct and indirect threat to marine biodiversity. Marine animals can become entangled in litter such as plastic lines and packaging material with consequent negative effects for example drowning, suffocation or starvation (Derraik, 2002; Fanshawe & Everard, 2002). Litter items can also be mistaken for food and primary ingestion or secondary (through co-ingestion of prey and litter) ingestion can occur. Once plastic accumulates in an animal's stomach it usually results in death (DEAT, 2001; Derraik, 2002).

Floating litter can contribute to the spread of invasive marine organisms over long distances, which can have significant adverse consequences for marine ecosystems (Derraik, 2002; Fanshawe & Everard, 2002). When litter sinks to the bottom of the ocean floor, smothering of, in particular, biotic communities but also other marine fauna and flora can occur. Over a long period of time litter starts breaking down and may release toxic chemicals and particles into the ocean causing secondary negative impacts to the marine environment. A possible indirect impact of marine litter is the harmful effect on habitats when mechanical machinery is used to clean the litter that has washed up on the beach (Fanshawe & Everard, 2002). Solid waste found in marine waters also poses a potential risk to public health as items such as glass, tins, or needles on beaches can cause injury.

Divers can become entangled in marine litter and large floating marine litter is a safety risk to those using watercraft (Fanshawe & Everard, 2002).

Marine litter can also have significant economic impacts. Fanshawe and Everard (2002) stated that the public perceives visible pollution such as litter as an indicator of water quality. Consequently, the closing of beaches due to pollution or the loss of tourism from aesthetically unpleasing occurrences such as beach litter has large social and economic implications for coastal towns that depend on tourism for an income (Dorfman, 2004). In an attempt to keep coastal areas litter free, local councils in the United Kingdom have spent up to £7 205 489 annually on clean-up costs (Fanshawe & Everard, 2002). Damage to watercraft and fishing gear can require expensive repair and there may be costs associated with the loss of productive working time in both the fishing and in the mariculture industries (Fanshawe & Everard, 2002). DEAT (2001) stated that in South Africa in 1985, insurance claims by fishing and maritime companies amounted to hundreds of millions of US dollars, which was due to marine litter clogging up engines and equipment that lead to repair costs and a loss of productivity.

1.2.8 Radioactive Substances

Radioactive substances are materials that include radio nuclides (UNEP, 1995) and were first detected in fish from the open ocean after weapon testing at sea during the Second World War (Albaiges, 1989). This has left signs of radioactivity in all parts of the world's oceans, even up to depths of 4 kilometers (Albaiges, 1989). Much government concern was raised as a result, which led to an increase in research in this area. The super powers of the time eventually realized the danger of radioactivity in the environment upon which they agreed to sign treaties regarding weapon testing. The result was a steep decline in levels of radioactivity in marine waters (Singer, 1970).

New concerns are however becoming more apparent with the siting of nuclear reactors in the coastal zone. Radioactive substances, found in cooling water discharge and waste produced by nuclear power plants, can find their way into the ocean (Clark, 1992). Furthermore, nuclear power plants also have the potential risk of releasing dangerous amounts of radioactive fall-out in the case of an accident. Other potential sources of radioactive contamination include activities such as recycling of fuel, the discarding of radioactive waste, certain medical wastes and some industrial processes. The transport of radioactive waste can also pose a risk of radioactive release (UNEP, 1995). The impacts associated with radioactive substances are long-term and the effects of the Chernobyl nuclear power plant accident of 1986 are still evident with an increase in the number of thyroid cancer patients in the affected areas (Talerko, 2004). This accident stressed the dangers associated with nuclear power plants within the environment at large.

A variety of land-based pollutants can have serious negative impacts on the marine environment with subsequent social and economic implications for those who rely on the marine environment, either for their livelihood or recreation. As can be seen from the above, while some contaminants reach the marine environment directly, the majority find their way to the ocean through indirect routes including storm water (Fuggle & Rabie, 1992; Wright *et al.*, 1993; Bay *et al.*, 2003). The degree of contamination of storm water shows significant spatial and temporal variation and therefore, before it can be managed, the origins and cause of variation of storm water quality needs to be explored and understood.

1.3 STORM WATER AND MARINE POLLUTION

When rain falls within a catchment, some of the precipitation will be "…intercepted by vegetation, and lost through evaporation, infiltrate through the soil surface, or collect in surface depressions." If the precipitation exceeds the interception and penetration capability within a catchment, overland flow begins which collects in a stream or canal and is known as surface runoff or storm water (Wright *et al*., 1993). Although storm water itself is not a pollutant, it acts as a carrier of pollution, and has received attention from a number of researchers (Wright *et al*., 1993; Berry, 2000; Lee & Bang, 2000; Taebi & Droste, 2004). It has been recognised that rainwater run-off during the early stages of a rainfall event is responsible for the suspension of pollution particles lying on solid surfaces. This results in what is called the "first flush" of storm water, which is characterised as being of very poor quality (Wright *et al*., 1993). MacKay (1994) states that storm water from urban catchments is considerably more polluted than that produced in undeveloped areas.

The type of pollutants found in storm water may vary greatly, and include nutrients, suspended solids, heavy metals, pathogens, hydrocarbons, persistent organic pollutants and litter (Wright *et al.*, 1993; Fanshawe & Everard, 2002; DiGiacomo *et al.*, 2004). The characteristics of storm water may vary greatly between developed and developing countries. Urban storm water runoff plays a very large part in the contamination of Southern California's coastal waters, where a comprehensive study showed toxic plumes due to storm water discharged up to 4km offshore on some occasions. The main pollutants were heavy metals more particularly, zinc and pesticides (Bay *et al.,* 2003). In the developing world, the main pollutants in storm water seem to be nutrients and microbiological pollution, for example studies in Iran showed that oxygen-demanding matter found in storm water exceeded that of raw sewage (Taebi & Droste, 2004). Furthermore, pollutants such as heavy metals have been found to be relatively low in developing community catchments, possibly due to the lack of vehicles and industry within the catchments (Wright *et al.*, 1993).

Studies have shown that storm water that is deposited in the ocean will be trapped in the near-shore marine environment causing poor seawater quality over a large distance (Wright *et al.,* 1993). This can pose a significant threat to the health of recreational users of the coastal zone and economically important marine ecosystems. The problem is of such a magnitude that DEAT (2001) has warned the public not to bathe or collect seafood near storm water discharge points. Valuable research has been done in the area of storm water pollution from coastal urban catchments (Wright *et al.*, 1993; MacKay, 1994; Berry, 2000). Informal settlements have the potential to grow extremely fast resulting in a lack of basic service delivery with minimal waste and sanitation management. The storm water originating from these urban catchments is thus often highly contaminated with nutrients, bacteria, and viruses (Berry, 2000) and becomes a difficult problem to manage. These contaminants are commonly linked to sewage and it has been found that in developing countries, sanitation facilities are often misused which, in turn, contributes to storm water pollution. Broken and blocked sewer pipes, due to vandalism or flushing of non-perishable items down sewers, facilitates the spill of raw sewage into urban water ways (Pretorius & de Villiers, 2003). Interestingly, combined sewer overflow during periods of high rainfall has also proven to be a significant source of diffuse pollution in the United States of America (Dorfman, 2004).

Solid waste and litter can also reduce the quality of storm water and where the 'skip method' of solid waste management exists, problems seem to be considerable (Pretorius & de Villiers, 2003). The primary reason is that communities perceive that the skips are too far from their homes so they tend to discard household waste a more convenient distance from their homes. Another reason for misuse of the system is that often the skips are full or too high for children to reach. All of the above result in people dumping solid waste in open spaces, rivers, or storm water canals on a regular basis (Pretorius & de Villiers, 2003). Grey water, which is "…wastewater from kitchens, baths and laundries" (Winblad & Simpson-Hébert, 2004), may include solid waste, oils, and faecal matter (UNEP, 2000a). Due to an absence of effective drainage in disadvantaged communities, grey water may pool around water supplies and form contaminated torrents, which feed into storm water canals (Wood *et al.*, 2001). Informal settlements may also contribute large amounts of suspended solids to surface waters (Berry, 2000; Wright *et al.*, 1993). The contribution is either direct through surface erosion or indirect through increased volume of surface water runoff. This is mainly due to the destruction of vegetation cover and poor storm water drainage within the catchment of these highly populated urban areas (Berry, 2000).

From the above, poor sewage disposal practices, solid waste disposal, grey water disposal, and erosion have been identified as having the biggest effect on storm water quality within an urban catchment, especially in lower income or developing communities. Developing communities are seen in the contexts of this study as people that are "under-developed," "poor" or "unsophisticated" (Swanepoel, 1993). However, to date approaches and examples of addressing the root causes of storm water and subsequent land-based marine pollution from developing world urban catchments, as suggested by (DEAT, 2000), are scarce. The relevance and application of an integrated waste management approach needs to be investigated, particularly in poorer communities, whereby the root causes of storm water pollution are identified and addressed.

1.4 INTEGRATED POLLUTION AND WASTE MANAGEMENT INITIATIVES IN DEVELOPING COUNTRIES

The previous section illustrated the unique pollution problems associated with developing community storm water catchments. These problems appear to require a combination of both short- and long-term interventions. An example of the former would be the prevention of polluted storm water from reaching the marine environment by physical means. Potential interventions are described by Mackay (1994) and include buffer strips, gross pollution traps and bypass sumps. These measures will however not address the root causes of land-based marine pollution in a holistic way, and by doing so contribute to the vision of sustainable development which "…meets the needs of the present without compromising the ability of future generations to meet their own needs..." which involves the "…integration of environmental, social and economic factors" (De Beer, 2002). Furthermore the above physical measures, described by DEAT (2000) as 'end-of-pipe' type of controls, are contrary to the aim of 'Integrated Pollution and Waste Management' (IPWM). IPWM gives priority to prevention and minimization through the integration of different sectors and the enhancement of public participation.

This functional approach is one of source-based controls aimed at good practice regarding the production and disposal of waste (DEAT, 2000). Managing diffuse sources of water pollution can be a complex and daunting task for various reasons (Schoeman, 1997). Table 1.1 provides a short summary of the different barriers facing the management of pollution at source in developing communities. In South Africa, the Department of Water Affairs and Forestry (DWAF) combined different management strategies for pollution originating from disadvantaged communities, although these strategies have met with varying success (World Summit Publication, 2002). As polluted storm water is largely anthropogenic in nature, a community-based participatory approach is needed to ensure the sustainability of any proposed solutions (Schoeman, 1997; Wood *et al.*, 2001). Through such an approach, concrete targets can be met with long-term abstract gains such as "…self-sufficiency, self-reliance and dignity ..." (Swanepoel, 1993).

Table 1.1: General barriers to the reduction of pollution in developing countries.

Barrier	Explanation	Reference
Education	Communities have a lack of knowledge regarding the efficient use of technologies and the pollution dangers associated with use.	Pretorius & de Villiers, 2003; Morel & Forster, 2002
Finances	Communities as well as local authorities lack sufficient finances in order to implement and maintain pollution reduction initiatives.	Sawman & Lirqhart, 1998; UNEP, 2004
Technical	Communities and local governments often lack the necessary technical equipment in order to provide sufficient waste management services.	Kaseva & Mbuligwe, 2005
Social	People within communities oppose pollution reduction through illegal actions e.g. vandalism and illegal dumping.	Clark, 1992; Pretorius & de Villiers, 2003

In the previous section poor sewage disposal, solid waste disposal, grey water disposal, and erosion were identified as the main sources of storm water pollution from informally developed areas. It is therefore appropriate to review recent initiatives from both developed and developing countries aimed at addressing these potential pollution sources. Emphasis will be placed on good practice and incentive-based waste management seeking ways where pollution prevention and reduction can be linked to the economic empowerment of the underprivileged.

1.4.1 Sewage

As the size of a community will directly influence the volume of sewage that has to be disposed of, the option of source reduction is not viable. Instead, sewage must be managed in such a way so as to prevent contamination of the environment. In the developed world water-borne sanitation is the preferred technology This system is, however, not always the best option in the developing world since it requires skilled personnel as well as large funds to initiate and manage (Sawman & Lirqhart, 1998; UNEP, 2004). Furthermore, misuse and poor maintenance of such water-borne systems can result in environmental pollution and degradation of water resources (Sawman & Lirqhart, 1998; Austin & van Vuuren, 2001). Alternative methods to treat sewage are available and the following sewage treatment processes are considered to be suitable for developing countries (Koné & Strauss, 2004):

- "Solids-liquid separation;
- Settling/ thickening tanks or ponds (non-mechanized, batch-operated);
- Unplanted drying beds;
- Constructed wetlands;
- Pond treatment of faecal sludge supernatants or percolates;
- Combined composting ("co-composting") with organic solid waste, and
- Anaerobic digestion with biogas utilization."

In certain developing communities, water-borne sewage systems are used and it is essential to educate the users on the correct use of the systems (Pretorius and de Villiers, 2003). Education should be focused on explaining to the community that their health can become affected if sewers become blocked or vandalized. Specific issues that can be addressed in such educational programs are the flushing of solid waste and utensils down the sewer as well as the use of alternatives to toilet paper, for example plastics and newspaper (Pretorius & de Villiers, 2003), which can result in broken or blocked sewers. Prevention of the spillage of sewage into storm water canals during times of excessive rain or overload is a costly process requiring engineering intervention. An end-of-pipe solution employed in a developed country by the council of Milwaukee (United States) was to build an underground sewage storage tunnel, which was designed to take the full volume of rainwater of the largest recorded rainstorm in that location (Dorfman, 2004).

In South Africa, the provision of sewage disposal to low-income communities within the coastal zone seems to be very challenging. The reason is due to the high level of the coastal aquifers making the popular pit latrine system unsuitable (Wright *et al.*, 1993; Berry, 2000). Furthermore, it has been attested that water-borne systems are not always the best option in developing countries. Other systems such as bucket latrines and chemical toilets are also widely used in South African townships (Berry, 2000). These options, even though more economical than water-borne systems, can also involve high cost and have negative environmental impacts (Wright *et al.*, 1993). In many townships the use of communal sanitation facilities also create problems such as misuse and cleanliness (Berry, 2000; Wood *et al.*, 2001). A case study from India showed that a pay-and-use public latrine was a viable option. However, with this option the needs of the community involved must be well defined for it is they who will manage and employ the caretaker. An added benefit of such an intervention is that it can be used as an economic empowerment project (Wood *et al.*, 2001).

Sewage systems that have potential for onsite treatment should also be considered, for example digestive septic tanks and small-bore sewers (Berry, 2000). A new sanitation approach called ecological sanitation that can "…save water, prevent pollution, and recycle the nutrients in human excreta" has recently become a very popular alternative (Winblad & Simpson-Hébert, 2004). One such ecological sanitation on-site system that has proven to be successful in both developed and developing countries is the urine diversion sanitation system (Austin & van Vuuren, 2001). With the urine diversion toilet, urine is separated from faecal matter from which compost can be generated. Compost from urine diversion toilets is suitable to be used for food gardening, or agriculture (Austin & van Vuuren, 2001) and the selling of the compost can be a profitable enterprise (World Summit Publication, 2002). In addition, the manufacturing and selling of toilet components also holds potential for the creation of micro enterprises in developing communities. Efficient training and development of entrepreneurial skills is however vital for the success of such initiatives (Holden, 2003).

1.4.2 Solid waste

Solid waste management in developed and developing countries varies extensively. In developed countries sophisticated and costly technologies are often employed with the emphasis on waste minimization, community participation, and strict legislation (Palmer Development Group, 1996). In contrast, priorities in developing countries lie with meeting basic human needs when it comes to waste management, which results in a need for more public participation, prevention, minimisation and economic empowerment (Palmer

Development Group, 1996). In developing communities, even where formal waste removal services exist, the problem of informal dumping and littering can still persist (Palmer Development Group, 1996; Pretorius & de Villiers, 2003). The change of the community's attitudes and views are essential to prevent the above-mentioned problem (Pretorius & de Villiers, 2003). Furthermore, the use of community-based education in addressing pollution problems should not be underestimated, and could be more effective than law enforcement (Derraik, 2002). Focusing environmental educational activities, including solid waste management, on children has proven to be effective since their habits can still easily be changed and the children then take their newfound knowledge to their families and into wider social circles (Derraik, 2002).

An innovative project in Bangkok, that made children aware of 'magic eyes' that were 'watching them' if they littered reduced litter by up to 90% (Palmer Development Group, 1996). In South Africa the school-based 2020 Vision for Water program, aimed at empowering children with knowledge of water conservation, has had a nationwide effect (World Summit Publication, 2002). Other innovative ways of raising awareness to curb solid waste pollution include beach clean-up days, competitions, the use of slideshows, or videos, or the media, and the distribution of pamphlets (Zurbrügg & Ahmed, 1999). Where solid waste management systems are non-existent or ineffective, alternative solutions need to be considered. Zurbrügg and Ahmed (1999) stated that in certain areas in the developing world, community-based self-help projects are the only solution to solid waste management problems. There may be a need for economic incentives to ensure success of any solid waste program (Derraik, 2002). Community-contract solid waste management where a member from the community is employed to remove solid waste is one potential option. There are two different approaches to this system, the first of which is where the community themselves pay contractors to remove solid waste (Kaseva & Mbuligwe, 2005). This approach is often overseen by a volunteer community committee (Zurbrügg & Ahmed, 1999; Dahiya, 2003). The second approach is where the local government contracts people from within the community to remove solid waste (Palmer Development Group, 1996; Wood *et al.*, 2001).

To date, there have been no South African examples where low-income communities themselves were paying for solid waste removal (Palmer Development Group, 1996). Regardless of this general lack of concern in South Africa, Wood *et al.* (2001) reported that a community group of a Cape Town informal settlement introduced fines to those who littered and did not use the waste skips, which resulted in an almost unpolluted informal settlement. The trend in community-contracting solid waste management in South Africa seems to be all government funded. These systems, if managed correctly, can however be more effective than municipal solid waste management. By means of example, the 'Clean and Green' community-based waste management project in South Africa has led to improved waste management and has simultaneously contributed to poverty relief through the creation of jobs. ‘Clean and Green’ employs “…micro enterprises, project leaders, supervisors, and one-person contractors…” to keep the township areas litter-free (Earthyear, 2001).

The ‘one-man-contract’ involves an unemployed resident of a community who is given the task of collecting solid waste from a designated group of residences on foot. By travelling on foot he or she can easily move between dense squatter houses from where waste is taken to a central point for final removal (Wood *et al.*, 2001). The ‘one-man-contract’ system can also involve contractors paying for refuse bags, which they then distribute within the community. Contractors will then collect the full bags, which are then bought back at a higher price by the local authority (Palmer Development Group, 1996). Other innovative ‘waste exchange’ systems include ‘garbage for eggs’ in Yala, Thailand. Residents are encouraged to bring recyclable materials in exchange for eggs on a monthly basis (Mongkolnchaiarunya, 2003). In Curti, Brazil, residents can exchange their bags of garbage for bus fares and agricultural and dairy products. These systems have been tried in South Africa with varied success. In Doornkop, Wallacedene and Khayelithsha food parcels were handed out after a certain amount of refuse bags were received. The instances where these projects failed were due to a lack of funding and dishonesty from the community (Palmer Development Group, 1996).

Encouraging recycling also has the potential to improve solid waste management and create economic empowerment. A very successful recycling and waste management program in Suryapet, India, resulted in a town free of roadside waste bins. After the local government removed all the roadside waste bins that proved to be ineffective, residents were provided with a red bin for recyclables and a green bin for organics. The waste was collected door-to-door daily by municipal workers. This not only resulted in a cleaner Suryapet but also municipal cost recovery by being able to sell the recyclables and compost made from the organics (UNEP, 2000a). In other places in the developing world, recycling initiatives are more scavenger-based. A study in Tanzania showed that what scavengers earn on average in a month could exceed the country's official minimum wage. This has proven to be a way of economic empowerment for the scavengers in order for them to provide for their families (Kaseva & Gupta, 1996).

In South Africa, informal resource recovery is a very widespread activity. In the Johannesburg area 'Pikitup' recycling buy-back centres are joint ventures between local authorities, major recycling companies, and local entrepuneurs. These centres accept recyclable waste such as paper, glass, plastic, cans, and aluminium. This provides informal waste recovers with easy access to a market for their goods. In the future 'Pickitup' intends to develop a "…recycling park where recycling initiatives include a plastic recycling factory, permaculture projects such as vegetable gardens, composting, muti-herbs, and vermiculture…." (World Summit Publication, 2002). A major need is still to find more sustainable markets for recyclable items in South Africa (Palmer Development Group, 1996). Based on the above it can also be concluded that there is a need to encourage source separation and collection incentives.

Composting initiatives provide potential opportunities to both reduce informal disposal of organic solid waste while at the same time providing economic empowerment and job creation. In South Africa, only a few local authorities, mainly in the Western Cape, have composting operations. While these do not tend to be economically viable, their value is rather to extend the life of local landfills (Palmer Development Group, 1996). In other places in the developing world, composting has proven to be a sustainable option for the reduction of solid waste pollution. For example, in Shri Shankara Nagar, India, a vermi-composting operation run by a local woman's organization has reduced waste generated in the region by more than 80% (Dahiya, 2003). Another example is of a successful community-composting project in Dhaka, Indonesia, where a labour-intensive aerobic and thermopilic technique is used. The success of this project is attributed to the correct composting technique, sound financial management, and a good marketing strategy (Zurbrügg *et al.*, 2002). The above-mentioned case studies show that community involvement can be highly beneficial in the management of solid waste and therefore the reduction of potential environmental pollution.

1.4.3 Grey water

Many people do not see grey water as a hazard even though it is polluted with pathogens and chemicals (Morel & Forster, 2002). As such, education regarding the dangers and disposal of grey water is important. As mentioned previously, the collection of grey water around standpipes poses a significant environmental and health threat. More technologically focused solutions to address this issue would be to supply households with water directly. For example, eThekwini Municipality in South Africa started to supply water to homes from an outside ground-level water tank connected to the home with a pipe. There is a connection fee involved and a monthly cost to have the tank filled on a daily basis. This system provides households with a water supply and reduces the use of communal standpipes and the possible abuse thereof (Wood *et al.*, 2001).

Effective drainage was essential to solving grey water problems in Paarl, South Africa, where a temporary drainage system in a densely- populated informal settlement provided some relief from grey water pooling between homes. This system involved soak-ways, which allowed household grey water to gravitate through concrete trenches to a central drainage canal from where the mixed grey water and storm water flowed to the municipal sewage treatment plant (Wood *et al.*, 2001). Where grey water diversion to the sewage system is not possible, the construction of an artificial wetland is recommended. Berry (2000) describes artificial wetlands as "…cost-effective alternative for dealing with wastewater treatment." Wastewater treated by artificial wetlands can have many different uses for example the watering of food gardens or the practicing of aquaculture. In Midrand, South Africa, the local community along the Kaalspruit and Jukskei rivers have, with the help of local government and non-governmental organisations (NGO), established food gardens that include artificial wetlands for the treatment of grey water (Wood *et al.*, 2001).

Other potential uses of grey water include groundwater recharge, landscaping, flushing toilets, and industrial applications (Midmore & Jansen, 2003; Al-Jayyousi, 2004).

1.4.4 Suspended solids

The improvement of storm water drainage in high-density developing communities will reduce erosion and the quantity of suspended solids entering receiving waters. According to Berry (2000), the collection of storm water in concrete trenches can help reduce erosion of earth canals, and a community and local government project undertaken in Soweto-on-Sea, South Africa, to line storm water canals with concrete proved to be a means of job creation and a self-improvement scheme (Wood *et al.*, 2000). Gabions of stones can also be built to prevent erosion in drainage canals (World Summit Publication, 2002), while the construction of artificial wetlands has the potential to reduce the amount of suspended solids in surface water and mitigate the effects of flooding (Berry, 2000).

Since the destruction of vegetation in and around informal settlements contributes to erosion (Berry, 2000) the greening of open spaces in high-density areas that have lost their vegetation cover could reduce erosion and mitigate the flow of suspended solids to water bodies during periods of high rainfall. For example in Botshabelo, South Africa, the community transformed a desolate open space into a green and productive area by building stone bunds to stop erosion and planted indigenous vegetation (Wood *et al.*, 2001). While the hierarchical integrated waste management approach has merit, without participation of all stakeholders, it is unlikely to achieve its full potential. Therefore one needs to combine knowledge of potential waste management solutions with an integrated environmental management approach (IEM) to find sustainable solutions.

1.5 INTEGRATED ENVIRONMENTAL MANAGEMENT AS A TOOL FOR IMPROVING STORM WATER QUALITY

Many different conceptual frameworks exist to address pollution reduction. For example, Integrated Catchment Management (Mardon & Stretch, 2004), Integrated Pollution and Waste Management (DEAT, 2000) and Integrated Coastal Management (Bowen & Riley, 2003). Researchers however agree that the most suitable system to address matters of environmental concern is IEM (MacKay, 1994; Schoeman, 1997; Antunes & Santos, 1999; Margerum, 1999; Berry, 2000). IEM provides a conceptual framework to address environmental issues through inclusion of all the different role players and by doing so, increases the quality of life for those concerned (Berry, 2000).

DEAT (1998) describes IEM as an, "…integrated approach for environmental assessment, management, decision making, the promotion of sustainable development, and the equitable use of resources." In South Africa the National Environmental Management Act 1998 makes provision for IEM to which planning and development projects must adhere (Berry, 2000). Plans that aim to sustainably manage water resources need to be developed within a framework of IEM in order to make the best possible decisions regarding the environmental impact of a project. The following principals underline IEM (Schoeman, 1997):

- "informed decision-making;
- accountability for information on which decisions are taken;
- accountability for decisions taken;
- a broad meaning given to the term environment (i.e. one that includes physical, biological, social, economic, cultural, historical and political components);
- an open, participatory approach in the planning of proposals;
- consultation with interested and affected parties;
- analysis of alternative options;
- an attempt to mitigate negative affects and enhancement of positive aspects of proposals;
- an attempt to ensure that the 'social costs' of development proposals (those borne by society, rather than the developers) be outweighed by the 'social benefits' (benefits to society as a result of the actions of the developers);
- democratic regard for individual rights and obligations;
- compliance with these principals during all stages of the planning implementation and decommissioning of proposals (i.e. from 'cradle to grave'), and
- the opportunity for public and specialist input in the decision-making process."

Mackay (1994) stated that IEM could be very useful in water quality management by forming a framework for problem solving, research and implementation of issues raised by those concerned and affected. IEM requires integration of ecological, social and economic perspectives, which can be applied at different levels to different problems (Antunes & Santos, 1999). However, no specific examples of the application of IEM in storm water management could be found in literature. Taking into account the complexity of the barriers associated with waste management and the potential success of community-based initiatives, the need for public participation in pollution reduction is evident. The following sections will describe the basic steps within the IEM process that should be followed in addressing an issue such as storm water pollution.

1.5.1 Impact assessment

Identifying environmental impacts that could effect the environment in a negative way would be the first task in the IEM process (Antunes & Santos, 1999). DEAT (1998) describes the environmental impact assessment (EIA) process in detail. In brief, a description of the study area is needed that includes baseline environmental information and a list of potential negative and positive environmental impacts. Then, an appropriate environmental assessment method needs to be used to determine the extent of each impact and to rank the significance thereof. Many different methods exist to assess the impact of anthropogenic activities on the environment. One such method, which is rapidly growing in its own right, is risk assessment (RA) (Morris & Therivel, 2001). RA is a method used to analyse the probability of any potential negative effect in the future (Lohani *et al.*, 1997). This is done by evaluating the probability of occurrence of potential impacts as well as the consequence if the impact is not mitigated (Morris & Therivel, 2001). According to Jooste *et al.* (2000) RA can be effective in managing water resources in a sustainable way. RA allows for the identification of significant aspects by means of a systematic approach that will aid in planning for effective environmental management. It can therefore be concluded that RA is an appropriate approach to identify and address the root causes of land-based marine pollution associated with a coastal community's storm water discharge.

1.5.2 Decision

At this stage a decision needs to be taken regarding the acceptability of proposed plans (Fuggle & Rabie, 1992). This decision is based on input from interested and affected parties, which include the community and the local authority. The public participation process is not only included in the final stage but needs to be integrated throughout the IEM process (Berry, 2000). According to Schoeman (1997) the core community participative elements regarding programs to address diffuse sources of water pollution include the following:

- allowing people to make decisions regarding their own welfare;
- forming of community-accountability structures (i.e. water committees), and
- utilizing community resources to contribute on an ongoing basis, for example community monitoring groups.

1.5.3 Implementation

After the decision has been made to go ahead with the project the proposal can be implemented. An environmental management plan (EMP) can be used to give direction regarding the execution of the project (Fuggle & Rabie, 1992). The EMP aids in making sure that the environment is protected and that the environmental benefits of the project are maximised (Sawman & Lirqhart, 1998). The EMP is compiled out of various mitigation measures, which are structured into an organized plan that cover the whole duration of the project (Fuggle & Rabie, 1992). Throughout the implementation phase, regular monitoring should take place to see if mitigation measures are effective and adhered to. More formal intermittent audits can help in determining the environmental adequacy of the development (Fuggle & Rabie, 1992).

As discussed previously, the marine environment is of significant economic importance to many developing countries, primarily as a result of the provision of natural resources and the development of tourism. Both could be adversely affected by the discharge of highly polluted storm water, which is often exacerbated by poor waste management in disadvantaged communities. The South African coast is recognised internationally as an attractive holiday destination and many small coastal towns in South Africa are reliant on tourism as the primary source of income. However, the future of tourism in the region may well be determined by the ability of coastal towns to effectively manage their growing waste streams so as to reduce the pollution of storm water and the near-shore marine environment. The application of IP&WM and IEM may offer a potential solution.

1.6 THE APPLICATION OF IP&WM AND IEM TO THE REDUCTION OF LAND-BASED MARINE POLLUTION FROM SOUTH AFRICAN COASTAL COMMUNITIES

Statistics in South Africa show that one-third of the population live within 60km of the ocean (O'Donoghue & Marshal, 2003). O'Donoghue and Marshal (2003) have examined the trends in marine pollution research in South Africa over the last 40 years and state that there has been a remarkable decline in the amount of research in this area over the last twenty years and an increased effort is necessary to ensure that our marine resources are protected. Apart from the London Convention and MARPOL, more general and regional conventions pertaining to South Africa include the Convention for the Cooperation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region 1981 and the Convention for the protection and Management of the Marine Environment in Eastern African Region 1985 (Fuggle & Rabie, 1992).

In South Africa there are around 60 pipelines that release 800 million litters of effluent into the ocean every day, of which a significant component is sewage (DEAT, 2001). Mardon and Stretch (2004) found the microbiological water quality of Durban's beaches poor according to international standards due to polluted water from rivers and storm water canals. This could pose a serious threat to the health of people using Durban's beaches for recreational purposes. Based on the results of local studies, the primary sources of land-based marine pollution in South Africa are similar to those from other parts of the world and are often linked to the presence of dense, poor communities.

Recent studies in South Africa have shown that anthropogenic activities can lead to heavy metal contamination of sediments within ports, and that the situation at these sites requires careful monitoring to reduce the threat to mariculture and recreational activities (Fatoki &

Mathabatha, 2001). It is estimated that 2.5 million tons of oil enter the South African coastal waters annually (DEAT, 2001) of which 4000 tons consist of hydrocarbons entering the ocean due to the burning of petroleum products (Dittke, 2000). A study done by Wright *et al.* (1993) showed that an urban catchment in the Western Cape of South Africa, produced storm water with very high nutrient and organic concentrations, which was subsequently discharged into the marine environment at False Bay. They attributed this to the growth of informal settlements with little to no basic services such as sanitation and solid waste removal. The 'red tide' blooms found in the Western Cape of South Africa, potentially a result of excessive nutrient input, can have a devastating consequence to marine life (Attwood *et al,* 2000), could have significant socio-economic impacts and could pose public health risk.

Sedimentation due to inputs from poor agricultural practices is of great concern in South Africa, especially in fragile estuarine environments (DEAT, 2000). A study conducted by Wright *et al.* (1993) in False Bay (South Africa) on storm water pollution in a third world-type catchment showed that erosion facilitated the movement of considerable quantities of sediment into the marine environment. Berry (2000) stated that the high levels of erosion in these urban storm water catchments was due to the high population density and the destruction of vegetation cover. DEAT (2001) reported that as much as 80% of plastic found on South African beaches is from land-based sources, which is in line with global estimates (Fanshawe & Everard, 2002). According to DEAT (2001), it is costing the South African taxpayer up to R8 million per year to clean littered beaches. A number of towns along the South African coast depend on tourism to drive and support their economies and stabilization of the South African economy has meant that significant development, including golf estates, retirement villages etc. are taking place in the coastal zone. More people in these areas means that businesses are growing to support them resulting in unemployed and unskilled individuals moving into the area to find work. As a consequence of the above, the quantity of waste being produced in the South African coastal zone and, therefore, the threat to the local marine environment, is likely to increase.

Many coastal towns are looking for ways to increase the revenue that they generate through tourism and one such initiative is for local beaches to attain Blue Flag status. The

Blue Flag is an annual international award only given to beaches that sustain high standards in the areas of safety, facilities, cleanliness and environmental management (Wildlife and Environmental Society of South Africa, 2004). South Africa is the first country outside of Europe to have achieved this award for some of its beaches (WESSA, 2004). As many international tourists choose Blue Flag beaches as their holiday destination, it is of significant economic importance to local coastal communities. While coastal towns have little alternative to the discharge of storm water directly to the marine environment, the discharge of polluted storm water close to bathing beaches could jeopardize the award of Blue Flag status. Thus, the root causes of storm water pollution and appropriate mitigation measures need urgent consideration.

Along the southern and eastern coasts of South Africa dramatic development has taken place over the last few years. Jeffreys Bay's growth started after 1985 when the Chokka fishing industry gained momentum (Hift, 1998). Soon after this Jeffreys Bay became a very popular tourist destination and developers started investing millions of rands in timeshare and retirement homes. In 2004 property prices in Jeffreys Bay escalated by up to 300%, which triggered the launch of numerous new property developments (Weistra pers. comm., 2005). The work opportunities created by the Chokka fishing and the building industries drew people from all over the country to Jeffreys Bay. This has led to a growth in the township and informal settlements beyond the point where the municipality could keep up with sufficient service delivery. Currently the problem of insufficient waste and sanitation service delivery is of great concern to the community of the affected areas (Our Times, 2004b; Randall, 2004).

Fuggle and Rabie (1992) report that informal settlements within the coastal zone of South Africa have proved to be a significant pollution source of storm water. In Jeffreys Bay urban runoff from both the township and light industry collects in a storm water canal which discharges on the south side of Main Beach. Residents often complain of raw sewage and "hazardous" waste such as glass being deposited onto the Main Beach after rainfall via the storm water canal (Arnolds, 2004; Williams 2004). Surfers and bathers from the previously disadvantaged community mainly use this part of Main Beach and health problems after rainfall have been reported (Williams, 2004). Furthermore, this source of pollution is an important stumbling block with regards to Jeffreys Bay's intention of maintaining Blue Flag status for its beach (Oldman, 2004; Our Times, 2004a). Taking the population growth within the coastal zone into consideration, increased effort is needed to sustainably manage and protect the marine environment from anthropogenic land-based pollution. It is predicted that by applying the conceptual framework of IEM, both pollution reduction and empowerment of the underprivileged can be achieved in a small coastal town such as Jeffreys Bay.

1.7 HYPOTHESIS AND RESEARCH OBJECTIVES

Based on the above it can be concluded that storm water originating from coastal communities poses a pollution risk to the marine environment. This is due to anthropogenic activities that contribute significantly to pollution of the storm water. This gave rise to the primary objective for the study, which was to investigate the main sources of storm water and subsequent marine pollution at Jeffreys Bay and to develop an appropriate management strategy using the IEM framework. In order to reach the primary objective the following hypothesis and research objectives were identified.

1.7.1 Hypothesis

Environmental management within the storm water catchment at Jeffreys Bay, South Africa, is inadequate and therefore poses a pollution threat to storm water and subsequently, the local marine environment. Furthermore, an IEM approach would facilitate identification of appropriate and sustainable strategies to mitigate these pollution related impacts.

1.7.2 Research objectives

- To identify the significant sources of storm water pollution within the Jeffreys Bay storm water catchment;
- To determine the state and underlying causes of and attitudes of stakeholders to the identified significant pollution sources, with a emphasis on the sources thought to pose the greatest threat to storm water quality;

- To use an IEM approach to develop an appropriate strategy for improved storm water quality management in Jeffreys Bay;
- To identify possible implications of the current project for storm water quality management in other small coastal towns that rely on tourism for a significant proportion of their income.

CHAPTER 2

IDENTIFICATION AND ASSESSMENT OF POLLUTION SOURCES WITHIN THE JEFFREYS BAY STORM WATER CATCHMENT

2.1 INTRODUCTION

Various natural factors, for example rocks and soils, can influence the storm water quality within a catchment (MacKay, 1994). However, it is often human activities within a storm water catchment that have the most profound impact on water quality (Wright *et al.,* 1993; MacKay, 1994; Berry, 2000; DiGiacomo *et al.*, 2004). Commercial, industrial and domestic activities result in the production of waste and different pollutants within storm water catchments. These anthropogenic activities can result in both point source and diffuse (non-point source) discharge to the receiving waters (Taebi & Droste, 2004). Diffuse pollution does not originate from a single point (Schoeman, 1997), but can simply be described as water that "…flows on the surface, dissolving and washing away pollutants and soil sediments along its path and finally discharging in receiving waters" (Taebi & Droste, 2004). Wright *et al.* (1993) state that up to 80% of the pollution found in storm water in urban catchments originates from diffuse sources. Recently it has been recognized that this contaminated urban storm water is a major source of marine water pollution (DiGiacomo *et al.*, 2004).

Storm water catchments that consist of formal housing found in higher income areas in South Africa generate very little pollution (MacKay, 1994) but include faecal contamination (mostly from domestic animals, unless a sewer has overflowed) and vehicle by-products for example oils and heavy metals that are washed off the roads. The legacy of South Africa's political policies of the past have resulted in informal settlements where people live in extreme poverty coupled with inappropriate basic service delivery with consequently high levels of pollution (Berry, 2000). The pollution that originates from these high-density residential areas and informal settlements within South African urban catchments has captured the attention of a number of South African researchers (Wright *et* *al.*, 1993; MacKay, 1994; Schoeman 1997; Berry, 2000; Wood *et al.*, 2001; Pretorius & de Villiers, 2003). Research has shown that the main sources of pollution in catchments characterised by informal housing are sewage, solid waste and grey water (Wright *et al.*, 1993; MacKay, 1994; Berry, 2000; Wood *et al.*, 2001; Pretorius & de Villiers, 2003).

Berry (2000) states that in many coastal settlements of the South-Eastern Cape of South Africa, there are little to no sanitation facilities available and people do not understand the basic principals associated with hygiene. Wood *et al.* (2001) agreed and stated that in South Africa 50% of informal settlement residents have no sanitation facilities and have to use open spaces for ablution. At night, residents use buckets out of safety fears and the night soil is then discarded on rubbish heaps, open spaces or in storm water canals. During periods of high rainfall this faecal matter pollutes storm water systems.

In the Eastern Cape of South Africa only 5,9% of the population have access to solid waste removal by the local authority at least once a week (Statistics SA, 2001). Uncollected garbage is one of the most serious contamination risks to urban storm water systems (Palmer Development Group, 1996). Pretorius and de Villiers (2003) remarked that the number of informal dumps in certain developing communities is unacceptable. This informal dumping can cause storm water canals to become blocked resulting in storm water not draining away but collecting in pools, which can then become contaminated by solid waste. Contaminated water and large proportions of uncollected waste eventually end up in surface water bodies (Palmer Development Group, 1996; Pretorius & de Villiers, 2003) or are discharged to the ocean (Derraik, 2002) where they pose a threat to the inshore marine environment, as is the case at many coastal towns, including Jeffreys Bay (South Africa). The previous chapter described the process of Integrated Environmental Management (IEM) wherein Risk Assessment (RA) may be incorporated into the impact assessment process. The objective of this initial part of the study was to make use of the tools of RA to investigate and develop a preliminary descriptive model of the main sources of storm water and subsequent marine contamination at Jeffreys Bay. In order to achieve this objective the following questions were identified:

- Which aspects (activities and services) in the catchment posed the most significant risk to storm water quality, marine ecology, human health and the socio-economic status of the community?
- To what extend did rainfall influence the probability of aspects having a negative impact on receptors?
- What was the current quality of storm water within the catchment?
- Was there evidence that direct discharge of storm water had a negative impact on the water quality of the near shore marine environment at Jeffreys Bay?

2.2 METHODOLOGY

2.2.1 Description of the study area

2.2.1.1 Location

"Jeffreys Bay is a coastal town developed to the south-west of the Kabeljous River mouth, in the southern part of the Eastern Province (Figure 2.1). This town forms part of the Kouga Municipality, and is located about 85km south-west of Port Elizabeth and about 16km east of Humansdorp" (Biopite, 2004). More specifically the study area is situated in the southwestern region of Jeffreys Bay and comprises a section of Ward 2 of the Municipality. The study area consists of a storm water catchment of approximately 2.2km^2 in which formal and informal residential developments, as well as light industry, is found. Towards the north, the study area is bordered by central Jeffreys Bay, consisting of small businesses and residential developments. The Main Beach of Jeffreys Bay and the Indian Ocean lie towards the east. South of the study area the previously disadvantaged residential areas of Pellsrus and Tokyo Sexwale can be found. The area towards the immediate west consists of a new low-income housing development and private agricultural land.

2.2.1.2 Topography

The study area elevates from a barrier beach to a miocene marine terrace in a northwesterly direction. The gradient of the slope towards the ocean is less than 2º. At its highest point the study area is approximately 65m above sea level. The gentle gradient results in drainage canals that feed into the storm water system (Biopite, 2004).

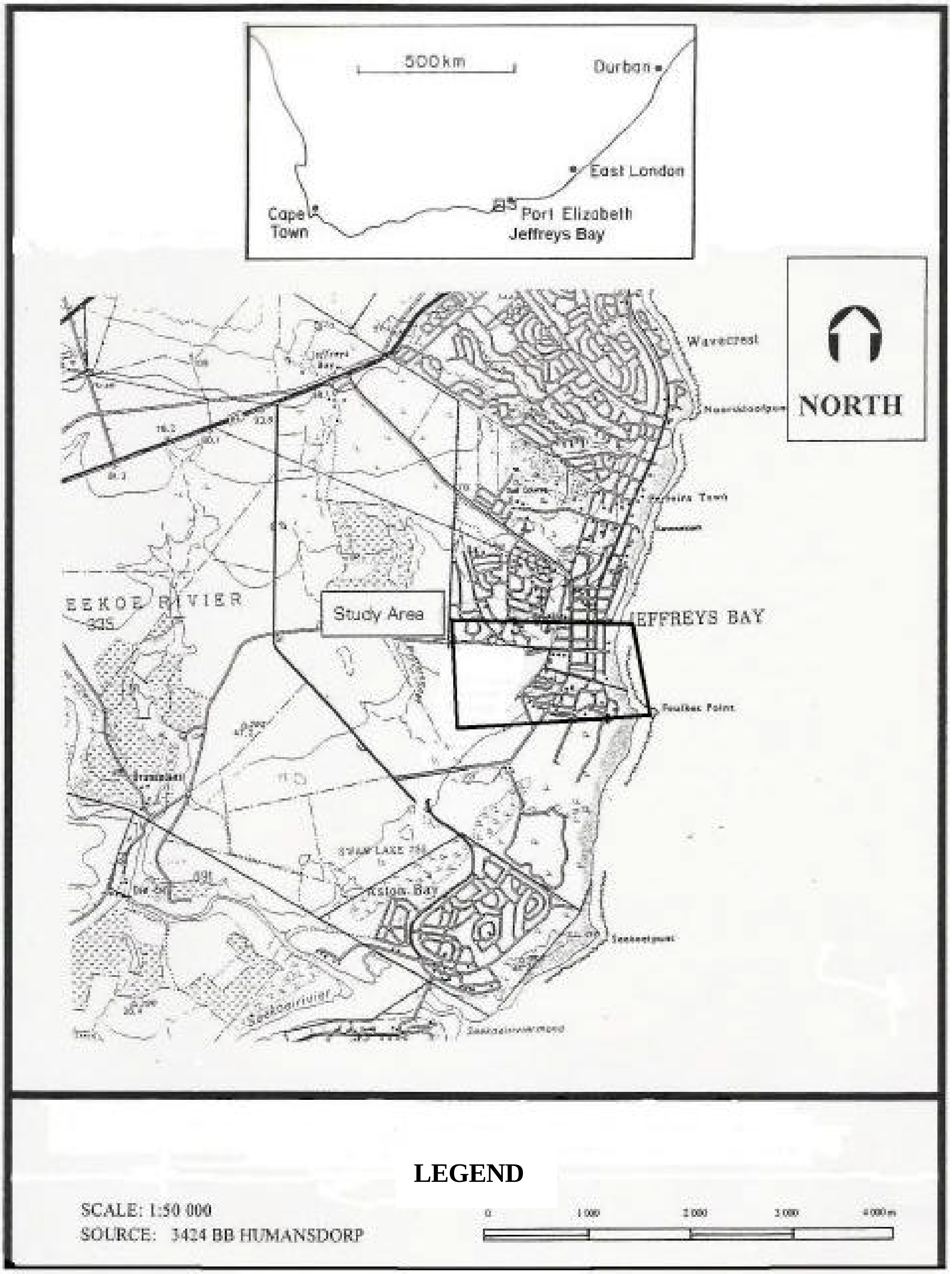


Figure 2.1: Map of Jeffreys Bay showing the location of the study area (adapted from Biopite, 2004). The insert shows Jeffreys Bay's location along the South African coastline (adapted from Mackay, 1994).

2.2.1.3 Climate

Jeffreys Bay has a moderate climate and experience year-round rainfall of between 600 and 680mm (Biopite, 2004). The average temperatures vary between 18ºC and 23ºC in summer and 11ºC to 18ºC in winter. The predominant wind direction is southwest (Biopite, 2004).

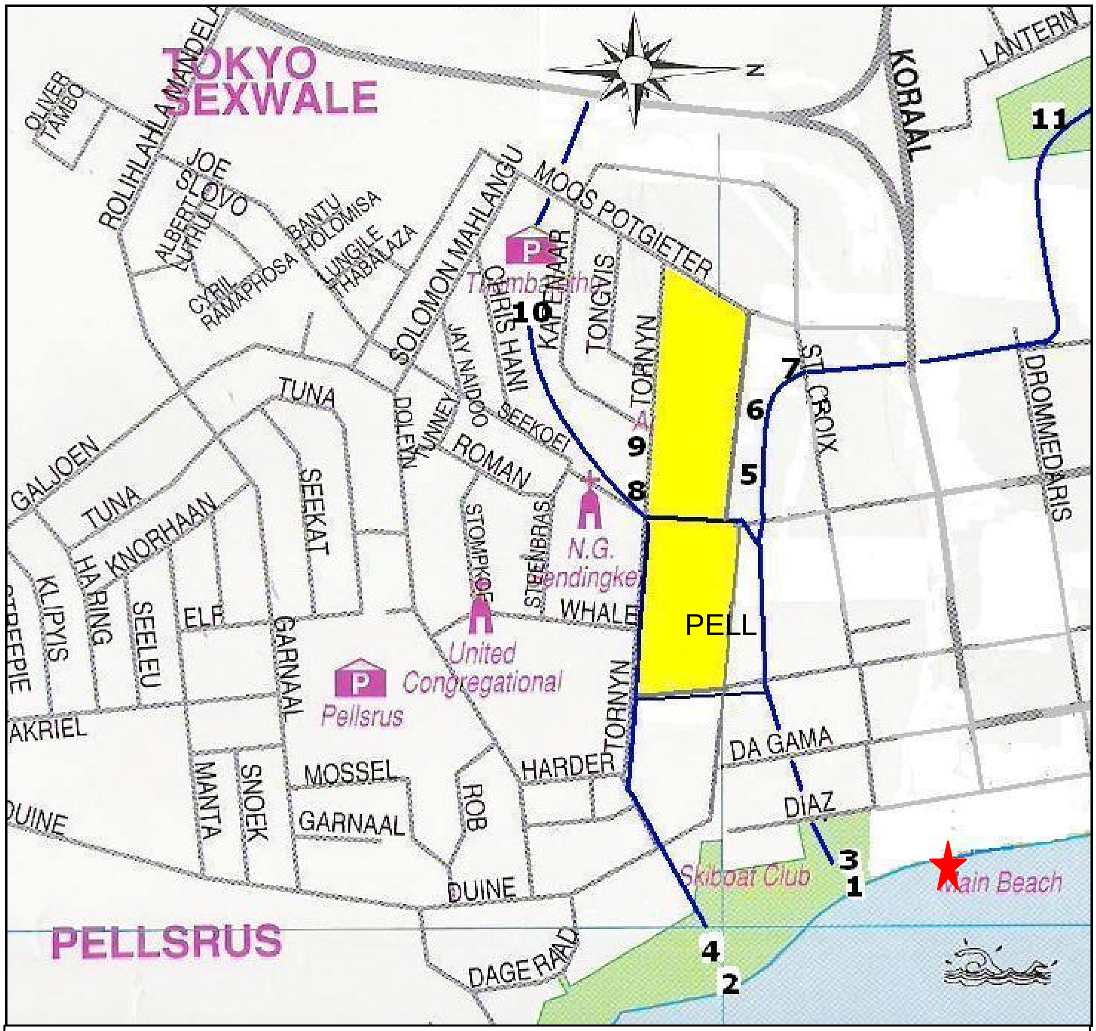
2.2.1.4 Geology

This coastline of the study area consists of a rocky shore towards the south and a sandy shore towards the north, backed by stabilized dune fields. Geologically, the study area is "…underlined by undifferentiated shale and sandstone" (Biopite, 2004). The shale and sandstone originate from the Ceres Subgroup, Bokkeveld Group and Cape Super Group (Biopite, 2004). There are two types of soil groups in the Bokkeveld shales of which the first group includes superficial duplex soils and a second group includes deeper well-drained soils (Cowley, 1984 cited in Berry, 2000).

2.2.1.5 Hydrology

According to the 1:2000 Pellsrus services map (SW45) published by the Jeffreys Bay municipality, surface water that is generated within the study area during wet periods flows into ephemeral drainage canals that discharge into two main storm water canals (Figure 2.2). The one storm water canal runs from a small wetland (marked as 10 on Figure 2.2) that lies towards the center of the study area. Up to this point the canal is open but splits (at point 8 marked on Figure 2.2) into two separate collector drains that are entirely below ground.

The first collector drain empties on the southern part of the Main Beach (marked as 4 on Figure 2.2). The second collector drain runs from C-Place (marked as 11 on Figure 2.2) and meets up with the second main storm water canal, which drains the northwestern part of the catchment. The collector drains are also linked further down. The second collector drain then leads to a storm water outfall pipe that empties on Main Beach (marked as 3 on Figure 2.2) towards the north of the first collector drain. The current along Main Beach moves in a northerly direction.



LEGEND

(grey line)	Road	(red star)	Marine water sampling point
(blue line)	Storm water canal	(yellow box)	Survey sampling area

Monitoring stations

1	North Beach	5	Scrap Yard	9	Waste Skip
2	South Beach	6	Informal Dump	10	Wetland
3	Northern Outlet	7	Industrial Area	11	C-Place
4	Southern Outlet	8	YWAM		

Figure 2.2: The Jeffreys Bay study area and the storm water canal (adapted from the Jeffreys Bay tourist information map which can be obtained from the Jeffreys Bay Tourism Information Centre).

All along the main storm water system, secondary collector drains allow for further general drainage of the study area. The drainage system only flows during periods of moderate to high rainfall but small pools in the wetland and in different sections of the drainage canal hold water year round. Grey water from informal settlements feeds into the storm water system at various points along its length.

2.2.1.6 Land-use

The land in the study area is mainly used for industrial, residential and recreational purposes. A municipal waste disposal site and a graveyard are situated in the northwestern part of the study area and a green space, including a wetland (marked as 10 on Figure 2.2) that is mostly overgrown with alien vegetation, exists in the center of the study area. The industrial zone (area around St. Croix Street on Figure 2.2) that falls within the study area consists of light industry such as surfboard factories and vehicle repair shops.

2.2.1.7 Socio-economic factors

According to Statistics SA (2003), Ward 2 of the Kouga Municipality, which includes the greater part of the study area, has a population of approximately 7 815 people. The population increased by 60% since the last census of 1996. The Coloured group represents 50.9%, Blacks 48.2%, Whites 4.7% and Asians 4.1% of the population. The unemployment rate calculated from the total labour force for this Ward is 36.7%, which is a 180% increase since the last census of 1996. 20.7% of the people of this Ward work for private households, 18.4% in retail and 16.8% in the construction industry.

The dwelling types within the study area are predominantly informal (51.4%) followed by 41.8% formal homes with the rest of the housing having been constructed from traditional materials of an unspecified type (Statistics SA, 2003). Informal or squatter housing predominates in what is known as ‘Toksville’ (Tokyo Sexwale township), which lies north of Joe Slovo Road. Housing in the extension between Tornyn and Pell Streets is characterized by a combination of informal and formal dwellings. The latter has water-borne sewage, on-site water and a formal storm water system. Homes of this type can be found in the remaining parts of Tokyo Sexwale and Pellsrus within the study area’s boundaries.

In terms of solid waste removal, the municipality services 79.8% of the total households in Ward 2 on a weekly basis while 20.1% make use of a communal dump (Statistics SA, 2003). It is stated that 98.2% of residents have access to full water-borne toilets, while the rest make use of flush-septic tanks or ventilated-pit-latrines (Statistics SA, 2003). A limited number of communal water supply points exist and there is no formal drainage infrastructure for grey and storm water. The higher income housing that exists in the northwestern and western part of the study area (marked as 11 on Figure 2.2) is provided with all the necessary on-site services including door-to-door solid waste removal, water-borne sewage and a formal storm water drainage system. In general, the infrastructure of Jeffreys Bay is good with a well maintained access route, namely the N2 (National Road) and a major airport and harbour approximately 70km's away in the city of Port Elizabeth. A coastal community such as Jeffreys Bay is unique in that tourism causes a seasonal influx of people resulting in similar fluctuations in waste and sewage volumes. Tourism is the main driving force behind the economy of the town, with local and international visitors taking pleasure in the beautiful beaches and world renowned surf of Jeffreys Bay.

2.2.2 Identification and prioritisation of pollution sources

The purpose of this initial component of the study was to use RA methodology (Lohani *et al.*, 1997; Guild & Marais cited in Guild, *et al*. 2001; Mentis, 2004) to determine which aspects (activities and services) within the selected catchment posed the most significant threat to storm water quality, marine ecology, socio-economic status and health of the community and to what extent the presence of storm water influenced the probability of aspects having a negative impact on receptors. It was intended that this information would be used to select which aspects required further detailed investigation prior to the development of an integrated pollution management plan. Information pertaining to the RA was gathered through a process of site visits during June 2004, informal interviews with interested and affected parties (I&APs) and by reviewing available literature. The methodology employed during this phase of the study is described in detail below.

Upon initiation of the study, the entire catchment, including the storm water canal, was surveyed on foot to identify aspects that could potentially have contributed to the pollution of the local storm water. The location and extent of legal and illegal dumping sites, evidence of informal ablutions and grey water disposal and community behaviour were all noted. The risks associated with each aspect were then determined by considering the potential receptors and the potential impact on each receptor. As discussed above, impacts of primary concern were storm water quality, marine ecology, human health effects and socio-economic effects. The risk associated with each aspect was calculated according to the following equation:

Risk = (likelihood of occurrence + detection) x consequence (Mentis, 2004)

"Occurrence" referred to how regular the aspect was likely to have had an effect, while "detection" referred to the probability of detecting the effect of the specific contaminant on the potential receptors (storm water, marine ecology, human health and socio-economic). Occurrence and detection were scored according to the ratings described in Table 2.1. which were based on a worst-case scenario. The higher the probability of occurrence the higher the rating and if the effect was unlikely to be detected a higher rating was awarded. "Consequence" referred to the potential result or severity of the effect due to a specific aspect. "Consequence" was rated as described in Table 2.2. with a more severe consequence receiving a higher rating. The rating system was based on the precautionary principle, stating that if there was uncertainty about the ability to detect an impact or the likelihood of occurrence, the risk rating was high.

The mean value of the four impacts (storm water, marine ecology, human health and socio-economic status) for each specific aspect represented the overall risk rating for each aspect. The significance of the calculated risk for each aspect was determined from the overall risk rating as described in Table 2.3. An aspect was considered significant and required further investigation and mitigation if the risk rating was higher than 50.

2.2.3 Water quality studies

The purpose of this section of the study was two-fold, namely to obtain a "snap shot" of the quality of the storm water at various parts within the drainage system and to determine whether there was evidence of a negative impact of storm water on the near shore marine system. Due to the risk associated with informal ablution, focus was placed on indicators of faecal contamination, specifically faecal coliforms, which are a general indicator for faecal pollution, and *Escherichia coli* (*E. coli*), which is a very precise indicator for faecal contamination (DWAF, 1995).

Table 2.1: Likelihood of occurrence and detection rating (Mentis, 2004).

Likelihood of occurrence	Rating	Likelihood of detection
Don't know/ very high (occurs every day of the year)	5	Don't know/ very low (undetectable)
High (occurs every week but not every day of the week)	4	Low (detection through a specialist study)
Moderate (occurs every month but not every week in a month)	3	Moderate (detection through scientific testing)
Low (occurs every semester but not every month in a semester)	2	High (detection by means of a survey)
Very low (occurs every year but not every semester of a year)	1	Very high (detection by trained observer)
None (never occurs)	0	Certain (detection by untrained observer)

Table 2.2: Severity of consequence rating (Mentis, 2004).

Severity of consequence	Rating
None (neutral)	0
Minor (not measurable)	2
Low (just measurable)	4
Moderate (stress, safety)	6
High (well being, sustainability)	8
Very high (illegal, unsustainable)	10

Table 2.3: Risk rating (Mentis, 2004).

Risk	Significance
>50	significant environmental effect
30<50	moderate environmental effect
<30	low environmental significance

2.2.3.1 Storm water quality

The water quality assessment of the complete storm water system was conducted on the 20th June 2005 and the 6th October 2005. The purpose of these assessments were not to address spatial or temporal variation in storm water quality but rather to confirm the importance of the aspects identified as priorities through the RA process and to assist in the identification of additional contaminant sources not detected previously. As such, an extensive monthly monitoring programme was not deemed necessary. As the quality of the water within the storm water canal was expected to show temporal variation, related primarily to the timing of rainfall and subsequent "first flush" events, the sampling events were scheduled seven days after the most recent rainfall, when it was expected that the water within the canal represented the poorest quality.

500ml grab samples were taken at 07h00 on the 20th June 2005 and 17h00 on the 6th October 2005 at the following locations within the catchment: Northern Outlet (1), Industrial Area (7), YWAM (8), Wetland (10) and C-Place (11) (numbering refers to locations on Figure 2.2). These sites were chosen due to the fact that pools of water can be found at these stations year round. The samples were stored in sterile plastic sample bottles in a cooler box and delivered within three hours to the Environmental Biotechnology laboratory (Rhodes University) for analyses. The samples were analysed to determine the levels of ammonia, chemical oxygen demand (COD), indicator organisms, nitrate, pH, total phosphorous and suspended solids (SS).

All chemical analyses were conducted using Merck Spectroquant test kits (ammonia-4500-NH_3-C; COD-5220-D, Nitrate-4500-NO_3; Phosphorus-14543). The standard method 2540-D was used to determine SS (APHA, 1998). Commercially available (Sigma) Mac

Conkey Agar with crystal violet, sodium chloride and 0.15% bile salts was used as a medium for the detection of indicator organisms. The medium was incubated for 48 hours at 35°C as per the manufacturer's instructions. The pH of the samples was determined using a Cyberscan 2500 pH meter.

Historical storm water quality sampling data was obtained from the Kouga Municipality's Department of Health and Community Services. The data was limited to samples taken at the Northern Outlet (marked as 3 on Figure 2.2) between 9 October 2004 and 21 June 2005 and only included *E. coli* counts. An environmental health officer (EHO) from the municipality collected the samples approximately every 14 days and they were analysed by the National Health Laboratory Service's (NHLS) regional laboratory in Port Elizabeth. The storm water quality data was compared to the South African water quality guidelines for recreational use (DWAF, 1996b) in order to obtain an estimate of the risk that the water posed to human health.

2.2.3.2 Marine water quality

If storm water at Jeffreys Bay had a significant negative impact on the quality of marine water in the near-shore environment, it was expected that a decline in marine water quality would have coincided with local rainfall events i.e. peak discharge of storm water. Marine water quality data was obtained from the Kouga Municipality's Department of Health and Community Services for the period of 3 October 2002 to 21 June 2005. An EHO from the municipality collected marine water samples every 14 days around midday at the Main Beach at a depth of approximately 0.3m. The exact location of the sampling point is indicated on Figure 2.2 and was approximately 40m north of the Northern Outlet. Water samples were only analysed for *E. coli* also by the NHLS regional laboratory using standard techniques.

Rainfall data for Jeffreys Bay for the period 3 October 2002 to 30 June 2005 was obtained from the South African Weather Service (2005). In order to provide indirect evidence for the relationship between storm water discharge and the marine water quality, a Spearman rank correlation analyses was conducted using KyPlot 2.0 statistical software. The

Spearman rank test provides a robust estimation of correlation and was chosen due to the non-parametric nature of the data (Kanistanon, 1997).

2.3 RESULTS AND DISCUSSION

2.3.1 Identification and prioritisation of pollution sources

All aspects in the catchment considered to have posed a direct or indirect threat to marine ecology, storm water quality, socio-economic status and health of the community are indicated in Table 2.4. The potential impacts of some of the identified aspects were considered to depend to a greater or lesser extent on the presence of rainfall and these are also indicated. The nature of the identified aspects, in particular those that where considered to pose a significant threat to the marine environment in Jeffreys Bay, are discussed below.

2.3.1.1 Solid waste disposal

Three communal waste collection points in the form of waste disposal skips existed in the catchment in the Pellsrus and Tokyo Sexwale townships. Even though the skips were emptied once a week, the areas around the skips were littered with solid waste (Figure 2.3). Apart from the areas around the waste skips, bags filled with refuse are also dumped in other places in the catchment (Figure 2.4). Refuse dumping was observed to occur continually in the storm water canal and in the wetland, which was also reported for other areas within South African developing communities (Wright *et al.*, 1993; Wood *et al.*, 2001; Pretorius & de Villiers, 2003). Although the RA only involved a single formal visit to the study site, the storm water catchment was visited regularly and the level of informal dumping observed during the formal visit was considered representative of the normal situation within the catchment. As such, the likelihood of occurrence was considered to be high.

The accumulation of solid wastes in residential areas is aesthetically unpleasing and considered an environmental and human health hazard (Dahiya, 2003). Solid waste that enters the marine environment could be fatal to marine life (Derraik, 2002; Fanshawe &

Table 2.4: Risk rating of the aspects considered to threaten storm water quality, marine ecology, human health and have local socio-economic impacts within the study area.

Aspect	Occurrence	Detection	Consequence	Risk rating	Rainfall influenced
1. Solid waste disposal				**54**	
Storm water quality	5	3	10	80	
Marine ecological effect	4	4	8	64	v
Human health effect	4	2	6	36	
Socio-economic effect	4	2	6	36	
2. Erosion				**35**	
Storm water quality	3	3	6	36	
Marine ecological effect	3	4	8	56	v
Human health effect	3	5	2	16	v
Socio-economic effect	3	2	6	30	v
3. Grey water disposal				**58**	
Storm water quality	5	3	8	64	
Marine ecological effect	3	4	8	56	v
Human health effect	5	2	8	56	
Socio-economic effect	5	2	8	56	
4. Informal ablution				**54**	
Storm water quality	3	3	8	48	
Marine ecological effect	3	4	8	56	v
Human health effect	5	2	8	56	
Socio-economic effect	5	2	8	56	
5. Sewage pump overflow				**44**	
Storm water quality	3	2	8	40	
Marine ecological effect	3	4	8	56	v
Human health effect	3	2	8	40	
Socio-economic effect	3	2	8	40	
6. Sewer overflow				**42**	
Storm water quality	3	1	8	32	
Marine ecological effect	3	4	8	56	v
Human health effect	3	2	8	40	
Socio-economic effect	3	2	8	40	
7. Operation of waste disposal site				**22**	
Storm water quality	1	1	6	12	
Marine ecological effect	1	4	8	40	v
Human health effect	1	2	6	18	
Socio-economic effect	1	2	6	18	

Figure 2.3: Communal waste skip (marked as 9 on Figure 2.2) showing large volumes of solid waste outside the skip.

Figure 2.4: Informal waste dump (marked as 6 on Figure 2.2) showing the problem of illegal littering within the catchment.

Everard, 2002) and litter, such as glass, on beaches is considered a human safety risk. Furthermore, it has been shown that the public associates littered beaches with poor water quality (Fanshawe & Everard, 2002), which may have a negative socio-economic impact through a loss of tourism (Dorfman, 2004). Litter, particularly plastic, is prone to be blown into the ocean at Jeffreys Bay with the predominant and strong southwesterly winds which blow offshore every week. Light industry seemed to be responsible for solid waste pollution in the storm water canal adjacent to the industrial zone. After inspection and informal interviews with I&APs, the primary pollution from this source seems to be deliberate dumping of industrial solid waste in the storm water canal (marked as 5 and 7 on Figure 2.2). According to survey and initial site assessment, quantities of solid waste disposed of into the storm water system are small but required further investigation. For this reason, the consequence and detection ratings of this aspect was considered low and the occurrence specifically for marine ecology, was considered to depend to some extent on rainfall. Storm water is recognized as a vector for the removal of solid waste after a significant rainfall event (Marais *et al.*, 2004). The overall mean risk rating of solid waste disposal was 54 and was regarded as significant.

2.3.1.2 Erosion

Due to the high density of people of approximately 1954/ km² in Ward 2 (adapted from Statistics SA, 2003), many footpaths and stretches of land existed where the vegetation cover was completely or partially absent. Research in similar catchments supported this observation and indicated that this could contribute to high-suspended solid loads in surface water runoff (Wright *et al.*, 1993; Berry, 2000). Sediments could have a smothering effect on marine biota (UNEP, 2001) and potentially a moderate socio-economic and human health effect by causing discolouring of beach and bathing waters which could cause injury due to unseen submerged objects (DWAF, 1995). Sediment input can only occur during periods of rainfall, which is normally every month but not every week of the month. The overall risk rating was 35 was and regarded as insignificant.

2.3.1.3 Grey water disposal

Wastewater produced during washing or cooking in the informal settlement was disposed of in the passages between the informal homes, and then flowed along informal drainage canals to the storm water system. This wastewater was regarded as highly polluted (UNEP, 2000a). Grey water can also originate due to the misuse of water standpipes where water collects in pools and is contaminated by wastewater and solid waste sources (Wood *et al.*, 2001). Foul smelling grey water that pooled within the catchment was aesthetically unpleasing and could therefore have had a negative socio-economic effect. The potentially high nutrient load of grey water (Eriksson *et al.*, 2002) could have had a negative effect on marine ecology (Islam & Tanaka, 2004) and the pathogens often found in grey water could have a significant negative impact on human health (UNEP, 2000b). The occurrence of grey water reaching the inshore marine environment was believed to have be moderate, as the quantity of grey water produced was considered insufficient to reach the marine environment in the absence of rainfall. For this reason, although the grey water could have posed a threat to marine ecology, it was considered less frequent than the potential impact on human health and socio-economics status of the community. The overall risk rating was 58 and was regarded as significant.

2.3.1.4 Informal ablution

The provision of sanitation within the catchment was, on the whole, considered representative of the situation in other developing communities where communal toilets are badly maintained (Morel & Forster, 2002) and sewers regularly overflow (Pretorius & de Villiers, 2003). Based on a site assessment and informal discussions with I&APs, communal toilets were considered to be constantly in an unhygienic and badly maintained state. The communal toilets were recently supplemented with chemical toilets in an attempt to make sanitation more accessible. Due to a lack of sanitation facilities, residents made use of the green area in the central part of the wetland and storm water canal for their sanitary requirements.

The occurrence of faecal contamination reaching the inshore marine environment was rated as moderate as rainfall was considered necessary to wash the faecal matter into the storm water canal and then carry it to the ocean. Pathogens associated with faecal matter have a potential to affect the health of humans (Dorfman, 2004) and marine life (Islam & Tanaka, 2004). Furthermore, the higher nutrient load due to sewage contamination can cause harmful red tides that deplete oxygen and affect marine life negatively (Clark, 1992). The above may be associated with negative socio-economic impacts resulting from a loss of tourism (UNEP 2000b; Farmer & Garcia, 2002). The overall risk rating was 54 and was regarded as significant.

2.3.1.5 Sewage pump overflow

A sewage pump station is located approximately 30m fom the storm water outlet on Main Beach. This facility pumps the total sewage flow from Jeffreys Bay along a main line to the sewage treatment plant which is located approximately 4 000m west of the pump station. On occasion, during peak holiday periods when the flow of sewage is very high or during periods of high rainfall (Botha pers. comm., 2004), the system malfunctions resulting in the overflow of raw sewage onto Main Beach via the storm water outlet. The likelihood of occurrence was considered low. As described under 'informal ablution', sewage has a harmful effect on humans (Dorfman, 2004) and marine life (Clark, 1992; Islam & Tanaka, 2004) with a potential negative socio-economic effect due to a loss of tourism (UNEP 2000b; Farmer & Garcia, 2002). However, due to the low occurrence, the overall risk rating was 44 and regarded as insignificant.

2.3.1.6 Sewer overflow

During periods of high rainfall, sewers overflow into the storm water system. As with the sewage pump, this is particularly problematic during peak holiday periods when the population in Jeffreys Bay can triple, causing overloading of the sewerage infrastructure (Botha pers. comm., 2004). The main contributor to raw sewage in the storm water outfall is, however, considered to be the sewage pump (Botha pers. comm., 2004). The overall risk rating was 42 and regarded as insignificant.

2.3.1.7 Operation of waste disposal site

The municipal waste disposal site towards the north of the catchment received solid waste from Jeffreys Bay and the surrounding area. Through observation it was apparent that the site was not well fenced and it was possible for litter to blow towards the ocean in times of strong south-westerly winds, even though the distance between the waste disposal site and the storm water canal was considered to be too far to have any real impact (approximately 1000m). The overall risk rating was 19 and regarded as insignificant.

From the risk assessment it was concluded that solid waste disposal, grey water disposal and informal ablution posed the most significant risk within the Jeffreys Bay storm water catchment. The situation appeared to be similar to that in other South African coastal communities where informal settlements contribute substantially to pollution (Mackay, 1993; Wright *et al.*, 1993; Berry, 2000). All of the three significant aspects were considered to pose a significant threat to the marine ecosystem although the relatively high ratings were partly due to the difficulty associated with the detection of negative impacts. Only grey water disposal and informal ablution were considered to have significant direct impacts on human health.

As discussed previously, storm water has proven to be an important contact between the original pollution source and the final receptors (Clark, 1992; Wright *et al.*, 1993; Berry, 2000; Lee & Bang, 2000; Taebi & Droste, 2004) and a major route for solid waste to enter receiving water bodies (Derraik, 2002; Fanshawe & Everard, 2002). Even though most developing communities, including that in Jeffreys Bay, have some sort of rudimentary solid waste disposal system in place, informal waste disposal can be considered a persistent problem (Wood *et al.*, 2001; Dahiya, 2003). Insufficient sanitation and disposal of sewage sludge (UNEP, 2001), as well as leaking and overflowing sewers (Dorfman, 2004), are also of growing concern as coastal populations expand (Farmer & Garcia, 2002). Interestingly, grey water may not be perceived as a significant problem by local communities (Morel & Forster, 2002) even though research has shown that it may contain high concentrations of various pollutants (Wood *et al.*, 2001; Källerfelt & Nordberg, 2004).

The RA provided an initial estimate as to the most likely sources of pollution of storm water and subsequently, the marine environment, within the catchment and suggested that both storm water and marine water were likely to exhibit faecal and nutrient contamination. Detection of these contaminants within the storm water or near-shore marine system would lend support to the finding that sanitation (incorporating disposal of human excreta and grey water) within the catchment was of concern and should be addressed as a priority to decrease the likelihood of potential negative impacts.

2.3.2 Water quality studies

2.3.2.1 Storm water quality

The results of the first assessment of water quality within the storm water canal are summarized in Table 2.5. When comparing the storm water quality results with that of the South African water quality guidelines for aquatic ecosystems (DWAF, 1996a) and fresh water recreational use (DWAF, 1996b), it was evident that the water did pose a threat to human and environmental health at certain points. Although the quality of the storm water was expected to gradually decrease from the top of the catchment (C-Place) to the

Table 2.5: Jeffreys Bay storm water quality data for 20 June 2005 compared to South African water quality guidelines (DWAF, 1996a; DWAF, 1996b). All values given in mg/l unless otherwise specified. Those values exceeding the South African water quality guidelines are in bold font.

	Monitoring Stations					
Water Quality Constituent	**Northern Outlet**	**YWAM**	**Wetland**	**Industrial Area**	**C-Place**	**South African Water Quality Guidelines**
Suspended solids	**120**	**116**	**100**	96	84	<100 (DWAF, 1996a)
COD	**1160**	**765**	<100	<100	<100	12.77 Variance: 80%-120% (DWAF, 1996a)
Phosphorous	0.3	**6.3**	0.23	0.09	0.12	<5 (DWAF, 1996a).
Ammonium	<0.05	<0.05	<0.05	<0.05	<0.05	0.007 (DWAF, 1996a).
Nitrate	**4.5**	**5.2**	**1.6**	**1.5**	**2.3**	<0.5 (DWAF, 1996a).
PH	7.85	7.86	7.71	8.46	8.44	6.5-8.5 (DWAF, 1996b)
E. coli	0 cfu/ml	**18 000 cfu/ml**	0 cfu/ml	0 cfu/ml	0 cfu/ml	0-130 cfu/ml (DWAF, 1996b)
Faecal coliforms	0 cfu/ml	**105 000 cfu/ml**	0 cfu/ml	0 cfu/ml	0 cfu/ml	0-150 cfu/ml (DWAF, 1996b)

discharge points (Northern Outlet) due to the collection of contaminated run-off and leaching of potential contaminants from solid waste within the system, this was not the case. The most polluted site was mid-way along the southern leg of the storm water canal at YWAM (marked as 8 on Figure 2.2), with the water at the Northern Outlet showing limited pollution.

Water quality at C-Place and, surprisingly, at the Industrial Area was not highly polluted. The elevated nutrient levels at these two sample points could have been due to decomposing organic matter (DWAF, 1996a) rather than faecal pollution since no pathogen indicators were detected. The pH at both of these sights was slightly elevated, possibly due to the fact that the water at these sites originates directly from a highly vegetated stream and physiological activities such as photosynthesis and respiration can affect water pH (DWAF, 1996a). Despite the large quantity of solid waste in the wetland, the water was relatively unpolluted, although the suspended solids were at the maximum level as stipulated in the guidelines and nutrients exceeded the level. Once again, the absence of indicator organisms pointed towards organic decomposition rather than sewage pollution. Therefore, water at these three sites did not appear to pose a threat to human or environmental health, at least not during June 2005. It was predicted that, as the period between significant rainfall events increased, pollution would accumulate on surfaces adjacent to the storm water canal. During rainfall events, any run-off would convey this pollution into the canals, resulting in an elevation of pollution levels of water within the canal and, consequently, increase the threat to human and environmental health after the following rainfall event.

Storm water at the YWAM site was highly contaminated with respect to both chemical and potential pathogen loads. At this site, a storm water outlet fed water from a road where people regularly discarded their grey water, suggesting that the grey water was the primary source of both nutrients and potential pathogens. SS exceeded the target water quality, which could be due to input from the kitchen and laundry water component of the discarded grey water. Furthermore, the high COD level (765mg/l) could have been due to chemicals found in domestic cleaning detergents as well as organic material (food scraps, oil etc) in the grey water from household kitchens. The general COD of grey water from lower income communities in South Africa has been reported as between 530mg/l and 3520mg/*l* (Eriksson *et al.,* 2002).

Phosphorous levels in the storm water at the YWAM site also exceeded the target water quality level. Carden *et al.* (2005) stated that high levels of phosphorous could be expected where low-cost detergents are being used and again, this was expected to have been related to the disposal of grey water. Although nitrate levels of grey water are not usually expected to be very high (Eriksson *et al.,* 2002) the high nitrate figure at YWAM suggested that urine was either being deposited in grey water due to a lack of sanitation facilities or that the community was urinating directly into the storm water system at that point. The high microbial counts at the YWAM monitoring station also reflected the documented microbiological properties of grey water (Eriksson *et al.,* 2002; Källerfelt & Nordberg, 2004; Carden *et al.*, 2005).

At the Northern Outlet, SS and COD values exceeded the target water quality range and, as with the YWAM site, may have been as a result of disposal of grey water higher in the catchment and/ or deposition of material as a result of erosion (DWAF, 1996a). Interestingly, no evidence of faecal contamination was detected at the Northern Outlet suggesting that grey water, with its potential faecal contamination, may not have been the primary cause of the high COD and SS levels. No explanation for this apparent contradiction could be found. In general, the level of detection of the tests was not able to fully determine whether ammonium levels were below the required limit, but the concentrations of this contaminant was lower than 0.05 mg/l at all sites.

According to the storm water quality analyses, there was indirect evidence of pollution from grey water and municipal wastewater to the storm water system, although the results may not have represented a worst-case scenario. Indeed, rainfall data for a six-month period obtained from the South African Weather Service (2005) showed that the storm water quality assessment in June (Figure 2.5) fell at the end of a high rainfall period (April) and therefore it is possible that many of the potential pollutants had been flushed from the catchment and canal. However, the highly polluted nature of the water at the YWAM site indicated that this was a point where contaminants entered the storm water system regularly and in sufficient quantities to increase the level of pollutants to above the maximum allowable levels specified by water quality guidelines. At this site the water commonly pooled until rainfall flushed the contaminated water towards the storm water outlets and into the marine environment.

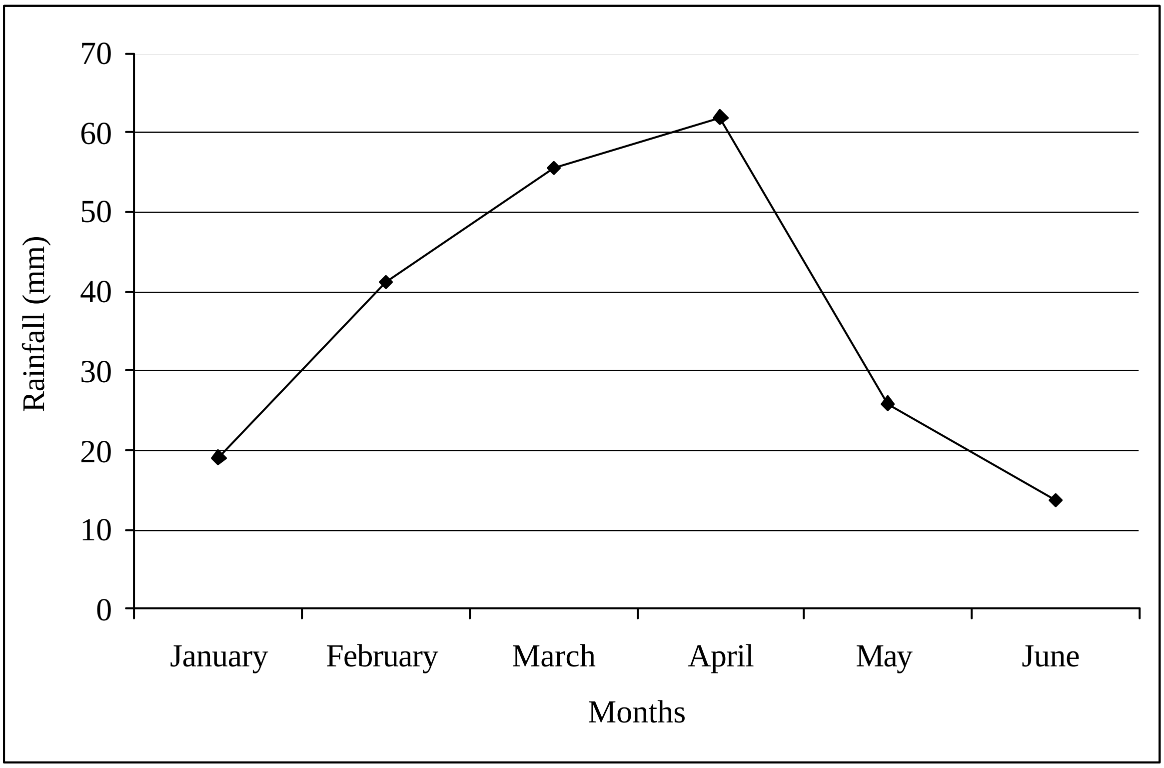


Figure 2.5: Monthly rainfall for Jeffreys Bay for the period January 2005 to June 2005.

In order to determine whether the levels of faecal contamination obtained during the first sample were an accurate representation of the normal state of the storm water, the data was compared to municipal data for storm water quality at the Northern Outlet (Figure 2.6). According to the data E. *coli* counts in the storm water exceeded those stipulated in the standard on all occasions from November 2004 to June 2005 and therefore posed a threat to the quality of water at Main Beach. The municipality's storm water quality data showed that the day after the first water quality analyses (21 June 2005), the *E. coli* count at the storm water outlet was 649 cfu/ 100ml. This appeared to contradict the data obtained from the previous day's analyses when no *E. coli* were detected at the same site. However, shortly after the first sampling, 0.6mm of rainfall was recorded (South African Weather Service, 2005). This rain may have been sufficient to move faecally contaminated storm water from the YWAM monitoring station to the Northern Outlet, which could justify the higher *E. coli* counts on 21 June.

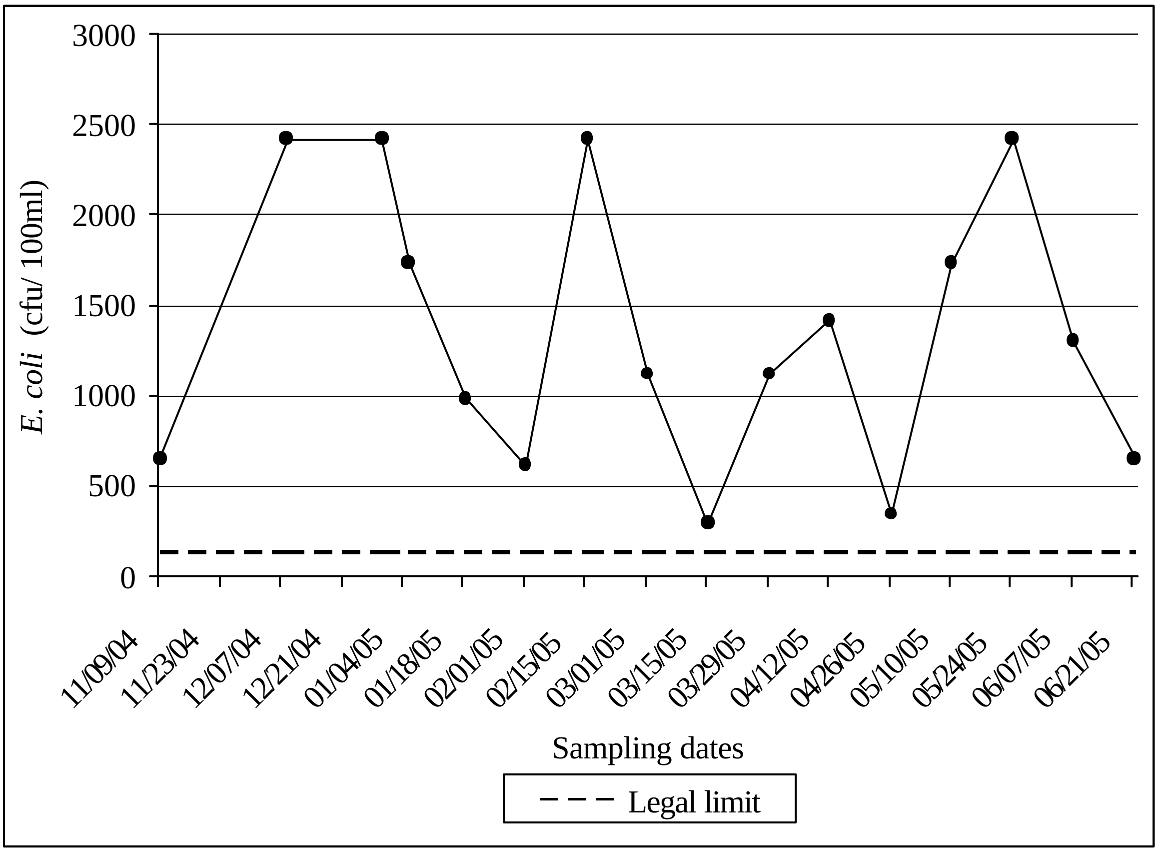


Figure 2.6: Storm water quality (*E. coli* counts) at the Northern Outlet in comparison to the South African water quality guidelines for recreational use. The legal limit is 130 cfu/ 100m*l* (DWAF, 1996b).

A second water quality analysis was conducted on 7th October 2005 (Table 2.6). The water quality findings of this analyses were significantly worse than that of the previous analyses. COD levels exceeded the target range at all the sites. This could have been because the water had been standing in the canal for a longer period than before, and the high COD was the result of degradation of organic waste within the canal. The high ammonium levels at the YWAM site which could have contributed to elevated ammonium levels at the Northern Outlet, was again attributed to the input of grey water into the storm water at that point as grey water has been shown to contain cleaning compounds with high concentrations of ammonia or ammonium salts (DWAF, 1996a).

Table 2.6: Jeffreys Bay storm water quality data for 7 October 2005 compared with South African water quality guidelines (DWAF, 1996a; DWAF, 1996b). All values given in mg/l unless otherwise specified.

	Monitoring Stations					
Water Quality Constituent	**Northern Outlet**	**YWAM**	**Wetland**	**Industrial Area**	**C-Place**	**South African Water Quality Guidelines**
Suspended solids	1	2	2	1	23	<100 (DWAF, 1996a)
COD	**120**	**1260**	**135**	**185**	**2310**	12.77 Variance: 80%-120% (DWAF, 1996a)
Phosphorous	0.18	**9.38**	0	0	0	<5 (DWAF, 1996a).
Ammonium	**0.02**	**0.14**	0	0	0	0.007 (DWAF, 1996a).
Nitrate	**5.6**	**55.3**	**37.4**	**13.9**	**35.5**	<0.5 (DWAF, 1996a).
PH	7.18	7.21	8.05	7.77	8.2	6.5-8.5 (DWAF, 1996b)
Faecal coliforms	**60 000 cfu/ml**	**1 290 000 cfu/ml**	0 cfu/ml	**660 000 cfu/ml**	**50 000 cfu/ml**	0-150 cfu/ml (DWAF, 1996b)

As was the case during the first sampling, nitrate levels exceeded that of the target water quality range at all the monitoring sites although at most sampling stations, the concentrations were 10 times higher than previously recorded. DWAF (1996a) state that surface runoff that is contaminated with faecal matter or fertilizers could be the cause of high nitrate levels. If faecal matter was responsible for high levels of nitrates at these sites then it would be expected that faecal coliform counts would also be high at these sites. This was infact the case except at the wetland monitoring station which was surprising since this site showed the second highest of level of nitrates and initial site surveys revealed a great deal of open defecation in the area. At the industrial site the microbiological levels were also high which pointed to the overflow of sewers or use of the canal itself for ablutions. The only explanation that could be given for the high microbial counts at the C-Place site, since the water originated from a densely vegetated wetland area, was that open defecation occurred next to the footpath at this monitoring site.

The mean level of potential faecal contamination of Jeffreys Bay storm water (Northern Outlet and YWAM) was compared to that of other sites with catchments that contained developing communities (Table 2.7). It was revealed that many storm water and river systems in coastal regions of South Africa exhibited higher faecal contamination than the Jeffreys Bay system. Nevertheless, the storm water at Jeffreys Bay system was still considered a health hazard and the sources of contamination needed further investigation prior to the development of a management plan. Interestingly, the other highly contaminated systems either received treated sewage or flowed past large poor urban settlements (Mackay, 1994; Berry, 2004). There was thus further indirect evidence to support the findings of the current study that these settlements contributed to the poor quality of surface water in coastal regions, even in the case of Jeffreys Bay where the population is relatively small.

Table 2.7: A comparison between water quality assessments in the South African coastal zone (adapted from Berry, 2004).

Sampling site	**Sampling station**	**Mean *E. coli*/ 100ml**
Jeffreys Bay	Northern Outlet	1 300
	YWAM	18 000
Port Elizabeth	Motherwell Canal	390 000
	Chatty River	320 000
	Chatty River Mouth	97 000
	Swartkops Estuary	230 000
Plettenberg Bay	Gansvlei Stream Downstream 1	2 200 000
	Gansvlei Stream Downstream 2	7 969
Knysna	Ouplaas River Downstream	2 286

2.3.2.2 Marine water quality

Based on the initial risk assessment process and the level of contamination of storm water within the Jeffreys Bay catchment, it was expected that discharge of the storm water into the marine environment would have had a detectable negative impact on the quality of near-shore waters at the economically important Main Beach. Furthermore, it was expected that marine water quality would be lowest immediately after rainfall events due to the "first flush" phenomenon and the potentially high volumes of storm water.

Monthly rainfall and seawater quality data (*E. coli*) for Jeffreys Bay are shown in Figure 2.7. A correlation analyses (KyPlot 2.0) was conducted in order to determine whether there was a statistically significant relationship between storm water discharge (rainfall) and marine water quality. The timing of rainfall events was compared with fluctuations in *E. coli*, and no significant interactions were found ($P>0.05$). Although there was no statistical correlation it was interesting that the five highest *E. coli* counts did appear to coincide with peaks in rainfall. However as high *E. coli* counts were detected on days where rainfall was not recorded (Figure 2.7), another source (other than storm water) was possibly responsible for the contamination of the water off Main Beach. It has been found that surface runoff plumes of 20mm precipitation can have a shore length of up to 10km's and that the influence of ocean currents and wind play a major role in the distribution of storm water plumes (DiGiacomo *et al.,* 2004). Thus, possible sources of pollution included the Seekoei and Kromme Rivers approximately 2km and 10km south, respectively.

Water quality data for the Kromme and Seekoei Rivers was obtained from the Department of Water Affairs and Forestry (Pumsa pers. comm., 2005), and showed faecal pollution levels above that of the limits set in South African water quality guidelines (DWAF, 1996b) only on 10 February 2004 (12 200 faecal coliform/ 100ml for the Kromme River and 2000 faecal coliform/ 100ml for the Seekoei River) and 6 March 2004 (200 faecal coliform/ 100ml for the Kromme River). Again, none of these high and sporadic contamination levels coincided with reduced marine water quality at Jeffreys Bay Main Beach. Despite the negative correlation, it was still possible that storm water had a negative impact on marine water quality, but that the timing of the fortnightly municipal

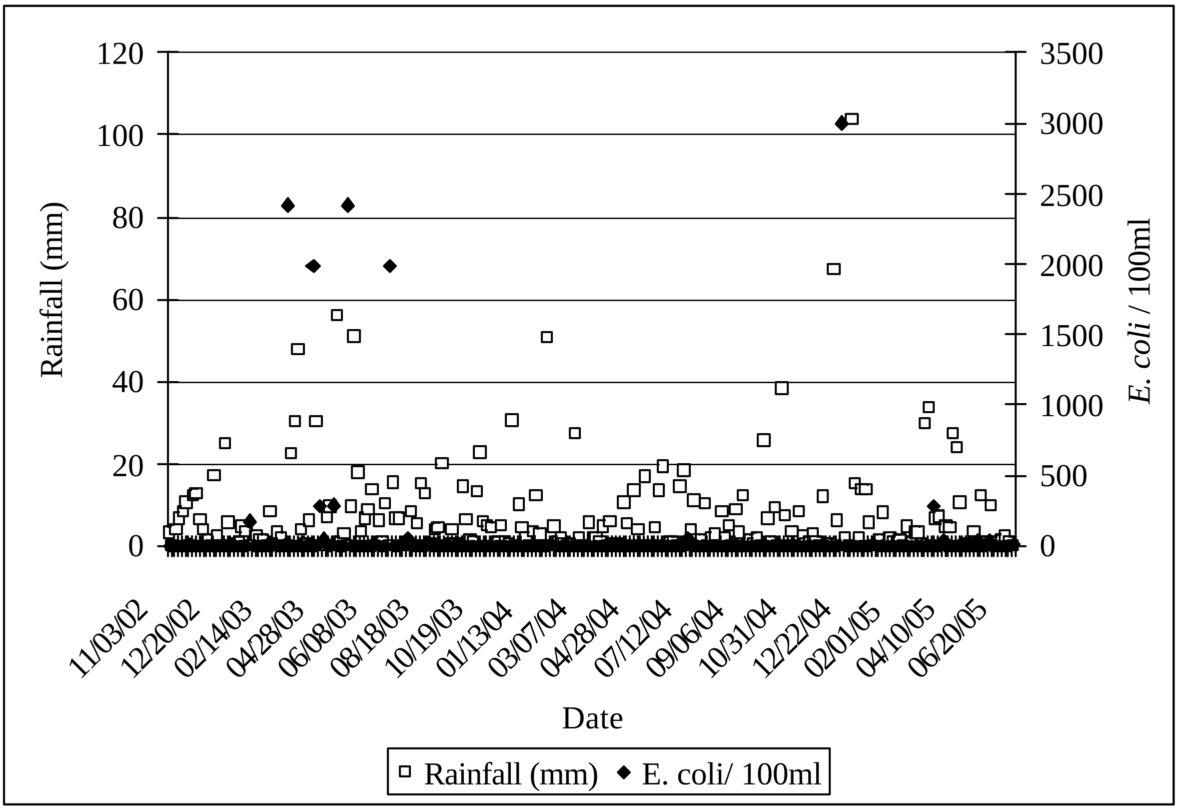


Figure 2.7: Jeffreys Bay seawater quality (*E. coli*) and rainfall data for the period November 2002 – June 2005.

sampling events missed peak *E. coli* levels. Indeed, marine *E. coli* data only existed for 10 of the 179 days on which rain fell. An alternative explanation for the negative correlation was that despite the level of contamination of the storm water within the Jeffreys Bay system, it was diluted sufficiently during rainfall events and through mixing with marine waters that the actual impact on marine water quality was negligible.

Based on the above, further detailed studies, with more frequent sampling, are required to determine with certainty whether discharge of contaminated storm water had a significant negative impact on marine water quality at the study site. This considered, the relatively high-risk values assigned to the various land-based pollution sources with respect to their possible impact on the marine environment may have been too high. Nevertheless, until such time as a more detailed study is conducted on the impact of contaminated storm water on the marine environment, it would be appropriate to adopt a precautionary approach. Part of this approach would be to address priority waste management issues.

One of the problems with trying to limit or prevent contact between pollution sources and receptors is that there are often more than one receptor for a pollutant, and the timing and duration of contact may be influenced by natural vectors such as wind and rain. For example, grey water can collect in hollows and may be released during rainfall to the main storm water system (Wood *et al.,* 2001). Rainwater can furthermore act as a vector for secondary input of faecal matter to reach the storm water canal from open spaces surrounding the canal (Wright *et al.*, 1993). Solid waste not discarded of in the appropriate way can also spread within the catchment by means of wind and rain (Marais & Armitage, 2004) eventually reaching the storm water system. While it would be possible to reduce contact between the pollution sources and receptors with a subsequent reduction in risk, it would be more appropriate to tackle the issue of pollution at its source with effective mitigation measures (DEAT, 2000).

The pollution management models described in the literature are predominantly focused on engineering interventions, runoff cycles and catchment processes (Wright *et al.*, 1993; Morris & Therivel, 2001). Jooste *et al.* (2000) suggested, however, that a balance needs to be found between the "hard sciences" (i.e. toxicology) and the "soft sciences" (i.e. social issues) within risk assessment models in order to formulate appropriate and effective management strategies. A good example of such a balanced pollution management model is that of Marais and Armitage (2004) where planning controls, source controls and structural controls are combined to formulate an integrated catchment management strategy for litter. It is suggested that the same route needs to be followed in Jeffreys Bay in order to reduce pollution within the storm water catchment. This requires a more detailed understanding of the factors that have resulted in the current poor state of management of potential sources of pollution in the Jeffreys Bay catchment, with particular attention being paid to sanitation and solid waste management.

2.4 CONCLUSIONS

Due to the potentially complex interaction of abiotic, biological, economic and social factors, the identification and prioritisation of those aspects within a storm water catchment that contribute to environmental pollution can be complex and time-consuming. By using a risk assessment process, it was possible to screen a wide range of potential sources of contamination and identify those which were likely to have had the most significant impacts, and therefore required further investigation prior to the development of a management plan. The key findings of this chapter may be summarized as follows:

- Within the Jeffreys Bay storm water catchment, solid waste disposal and sanitation (grey water disposal and informal ablution) were considered to be key sources of pollution;
- While the impact of poor solid waste management and sanitation on human health was not considered reliant on the presence of rainfall, rain may have facilitated the movement of contaminants from land into the storm water system and was considered essential for transport of pollutants to the marine environment;
- The first analyses of the quality of the storm water within the catchment complied with the DWAF standards for recreational use, although where grey water entered the system, the storm water exhibited unacceptably high contamination in the form of faecal matter and nutrients. A second analyses at a later stage showed a marked deterioration of water within the system above acceptable levels. Storm water at the point of discharge was also unacceptable over an extended period;
- Although storm water was severely contaminated, no evidence existed for a negative impact on marine water quality. It was proposed that polluted storm water might have resulted in periodic and short-lived reduction of marine water quality following rainfall events.

The sources of contamination identified in the current study are not unique to coastal communities and are common in those areas characterized by informal housing and limited municipal waste management infrastructure. However, in coastal areas, the marine environment is often the primary economic support of the community and therefore requires protection from land-based pollution. Sustainable pollution management strategies require an in depth understanding of the root causes of the pollution and the subsequent chapters will examine solid waste management and sanitation within the Jeffreys Bay storm water catchment.

CHAPTER 3

ASSESSMENT OF SOLID WASTE MANAGEMENT WITHIN THE STORM WATER CATCHMENT

3.1 INTRODUCTION

The results of the risk assessment (RA) demonstrated that the management of solid waste was perceived as a significant threat within the Jeffreys Bay storm water catchment. International best practice and national policy favours prevention and minimization over end-of-pipe alternatives, but in order for this to be achieved, it is necessary to understand in more detail the magnitude and causes of the problem as well as the willingness of the local population to address the issue.

The main sources of solid waste generation within urban storm water catchments have been described as "…residential, commercial, institutional, construction/ demolition, agricultural/ animal husbandry, industrial, and special" (Buenrostro *et al.*, 2001). Volumes and composition of solid waste are highly variable, both spatially and temporally. Both Mohee (2002) and Metin *et al.* (2003) stated that seasonal variations were observed in the generation and composition of solid waste within their respective study areas. Reasons given for such variations included the influx of tourists into specific areas during certain seasons, the burning of waste as fuel during winter months and a potential decrease in gardening waste during the winter. Contrary to these findings Mbande (2003) reported no seasonal variation of solid waste generation within a developing community of South Africa.

According to recent research, the generation and density of solid waste is highly dependable upon the socio-economic activity within an area, with factors such as the income group, culture, population demographics and the pattern of consumption playing a major role (Kaseva & Gupta, 1996; Ojeda-Benitez *et al.*, 2003). Studies show that the higher the income group the greater the volume and lower the density of the solid waste produced (Kaseva & Mbuligwe, 2005). Contrary to the above, Metin *et al.* (2003) and

Mbande (2003) stated that income level or lifestyle do not play a major role in the generation and density of solid waste within a developing community. The difference in waste composition between developed and developing countries can be found in the volume of the organic waste. People in the developed world tend to consume more processed foodstuff, resulting in less organic waste and more inorganic waste (Mohee, 2002) although Mbande (2003) found no significant difference in the composition of household waste of low and high-income groups in South Africa. Based on the above there does not appear to be a reliable relationship between the socio-economic status of a community and waste generation, and therefore each situation requires separate investigation.

By obtaining a better understanding of the type and volumes of solid waste being produced it might be possible to identify opportunities for reduction, recycling and reuse. Information regarding the original source of solid waste often provides a useful indicator of the type and hazardous properties of the waste. Literature shows that household waste is mostly comprised of organic matter followed by paper, plastic, glass and metals (Mbande, 2003; Ojeda-Benitez *et al.*, 2003), all of which can be regarded as economically valuable resources (Kaseva & Gupta, 1996).

With regards to solid waste disposal, it is necessary to determine whether existing infrastructure is sufficient and used optimally, as well as the possible reasons for any misuse. Various methods have been described for the removal and disposal of solid waste within developing urban areas (Palmer Development Group, 1996; Mongkolnchaiarunya, 2003; Kaseva & Mbuligwe, 2005). However, despite having solid waste management systems in place, problems have been experienced with the removal and disposal of solid waste in developing communities, leaving large amounts of solid waste to pollute the environment and storm water catchment areas (Wright *et al.*, 1993; Wood *et al.*, 2001; Dahiya, 2003). Different reasons have been attributed to these problems, and can be categorised as institutional, physical or social.

Institutional problems include insufficient service delivery by municipalities which can result in the insufficient clearing of communal waste disposal areas with consequent solid waste pollution (Wood *et al.*, 2001). Physical reasons include factors such as waste collection skips too far and too high for correct use by children and elderly people, resulting in informal dumps (Pretorius & de Villiers, 2003). Pretorius and de Villiers (2003) regarded people's attitudes and perceptions as a major stumbling block in sufficient solid waste management. People believe that it is the municipality's responsibility to keep the surrounding area clean and once a polluted environment persists, local communities become more and more desensitised, which in turn amplifies the problem.

The magnitude of the solid waste management and associated constraints in the Jeffreys Bay catchment were not known and needed to be determined before they could be overcome. Furthermore the study of potential incentives to all role-players would help ensure sustainable solid waste management. Consequently the objective of this part of the study was to assess the current status of solid waste management within the storm water catchment. This was done by answering the following key questions:

- Where were the main solid waste disposal areas within the catchment?
- Were there any significant spatial and temporal changes in the quantity of solid waste at key points within the catchment?
- What were the main sources of solid waste pollution within catchment?
- Were there any signs of reuse or recycling of the solid waste within the catchment?
- What was the local perception of the current status of solid waste management and the potential impacts on human and environmental health within the storm water catchment?

3.2 METHODOLOGY

A range of techniques exist by which to assess the quantity and distribution of solid waste within coastal areas. The basis of most of these methods amounts to physical counting, weighing and identification of solid waste items within a specified area (Velander & Mocogni, 1999; NSW EPA, 2003; Silva-Iñiguez & Fischer, 2003). However, none of the documented methods were appropriate for use within the Jeffreys Bay catchment due to the fact that the largest part of the catchment was within a high crime zone which was regarded as unsafe for prolonged sampling and research. Thus, the time-spent sampling in these areas had to be minimized. Added to this was the large volume of waste produced within the catchment which precluded removal for detailed separation at a safer location. For these reasons, the development of a rapid semi-quantitative photographic method of solid waste assessment was thought to be the most appropriate to rapidly determine if there was any significant spatial and temporal changes in the quantity of solid waste at key points as well as the most likely sources of waste within the catchment.

While the photographic analysis of the solid waste provided information regarding the quantity, quality and sources of solid waste, it did not provide any information on the underlying causes of poor solid waste management or the attitude of the community to the problem. Based on the integrated environmental management (IEM) approach it was thus necessary to conduct a community survey to determine the factors that influenced the distribution and fate of solid waste within the catchment, and the local perception of the current status of solid waste management and its potential impacts on human and environmental health. This information was thought to be essential for the development and effective implementation of a waste management plan in the area. A detailed description of methodology involved in the photographic assessment method and community survey is provided below.

3.2.1 Photographic solid waste assessment method

3.2.1.1 Sample sites

Eleven solid waste monitoring stations were chosen for the study, and their locations are indicated in Figure 2.2. Stations 1 to 4 were chosen on the points of discharge of the storm water canal and stations 5 to 11 were chosen as points close to expected sources of storm water contamination. Below is a brief description of each sampling station:

Station 1: *North Beach*. The beaches in front of the Northern Outlet, where storm water is discharged after a rainfall event.

Station 2: *South Beach*. The beach in front of the southern storm water outlet, where storm water is discharged after a period of heavy rain.

Station 3: *Northern Outlet*. Storm water outlet that empties on Main beach that is used for bathing and recreation.

Station 4: *Southern Outlet*. Storm water outlet opposite Pellsrus, which only flows after heavy rainfall.

Station 5: *Scrap Yard*. The storm water canal next to a scrap metal yard in Pell Street. An initial survey indicated that this site was a regular dumping ground for solid waste from the industrial area.

Station 6: *Informal Dump*. The community uses this area in Pell Street as an informal dumping site.

Station 7: *Industrial Area*. This site was situated adjacent to a section of the storm water canal on St. Croix Street.

Station 8: *YWAM*. This site included the section below the storm water headwall opposite the Youth with a Mission (YWAM) base on Seekoei Street where informal dumping and littering persisted and where grey water from the Extension 25 informal settlement entered the storm water canal.

Station 9: *Waste Skip*. This area was situated at the waste skip in Tornyn Street, which was mainly used by the residents of Extension 25.

Station 10: *Wetland*. This area included the wetland opposite Makukanje Primary School and Chris Hani Road. This site holds water year round and flows during periods of rainfall.

Station 11: *C-Place*. This area included a section of the storm water canal in C-Place, a high-income residential area.

3.2.1.2 Photographic survey: semi-quantitative assessment of solid waste

Digital photographs were taken once a week for a period of three months (16 November 2004 - 17 February 2005) at each of the above 11 sites. Prior to the first photo "sampling", a quadrat was marked out at each site based on physical reference points to ensure that the same area was monitored at each successive sample time (Figure 3.1). At the monitoring stations on the beach physical reference points were used to identify the location from which to take the photos, but no reference points were possible to determine the size of the quadrat. Therefore, all photographs were taken at the same angle and camera setting to ensure that the size of the quadrats were consistent. While it would have been preferable

Figure 3.1: Quadrats for the photographic surveys were based on features such as vegetation dumps, outcrops etc. represented in these photographs by red dots.

to demarcate the quadrats with permanent stakes in the ground, these would have been removed frequently and would thus have been unreliable.

Photographs were taken using a Photosmart 320 digital camera at exactly the same location and angle. The photographs were taken around midday to ensure the best possible light and lessen the effect of shadows in the photographs. The quality of the pictures was 2.1 mega pixels taken at normal magnification. The distance from the theoretical quadrat was such that the area of the quadrat approximately filled the area of a standard photograph.

While approximately the same size quadrat was photographed each time at each monitoring station, the square quadrats at the various sampling sites were not all the same size and depended on the extent of the area thought to be representative of each particular sample point. For example, larger quadrats were required at the beach sites compared with the YWAM sample point. The size of the quadrats used in the study were: North Beach 3m x 58m, South Beach 3m x 58m, Northern Outlet 3m x 30m, Southern Outlet 3m x 12m, Scrap Yard 3m x 5m, Informal Dump 3m x 14m, Industrial Area 3m x 3m, YWAM 3m x 5m, Waste Skip 3m x 22m, Wetland 3m x 12m and C-Place 3m x 5m.

More traditional beach litter quantification methods (Velander & Mocogni, 1999; Tudor, *et al.*, 2002, Silva-Iñiguez & Fischer, 2003) may have been more appropriate to use on the beach, but due to cleaning of the area every morning by municipal workers, it was unlikely that any litter would have been detected. Instead, the survey of the solid waste at the storm water outlets probably provided a more accurate picture of the quantity of waste that was likely to have washed onto the beach.

Photographs of quadrats were viewed using Microsoft Power Point 2000. A grid of 16 equally sized squares was digitally overlaid on each photo in order to facilitate estimation of the percentage cover of solid waste within the quadrat (Figure 3.2). The four corners of the digital grid were placed over the corners of the theoretical quadrat based on physical features. The photographic data from each solid waste assessment station was evaluated according to an estimate of the percentage of the surface area that was covered with solid waste. This value was then multiplied by an estimated waste depth factor. For example, if the coverage of waste in a particular quadrat was 75% and the estimated depth was 20cm (0.2m) then the solid waste coverage index would be 75 x 0.2 = 15. By determining the waste index for each of the sample points over a period of time, it was possible to assess intra-site temporal variation and to a limited extent inter-site spatial variation over the three-month study period. Due to the difference in the size of quadrats at the different sites, the method did not allow for a comparison of the absolute quantity of solid waste at the various sites. However, it did indicate relative differences in waste coverage.

3.2.1.3 Photographic survey: identification of sources of solid waste

In order to identify the sources of solid waste pollution within the catchment, a method involving the use of indicator items was used. This method involved the association of certain waste items with specific waste sources and has been used by previous researchers (Tudor *et al.*, 2002; Silva-Iñiguez & Fischer, 2003). Again, in order to allow for rapid assessment, the study was based on the same photographs as used for the semi-quantitative study. All waste was divided into three broad source categories namely marine, domestic and commercial/ industrial. The chosen indicator item classes for each of these categories are listed in Table 3.1.

Figure 3.2: A grid of 16 squares was used to estimate the percentage cover of solid waste in each quadrat.

Table 3.1: Indicator item classes (modified from Buenrostro *et al.*, 2001; Tudor *et al.*, 2002 and Silva-Iñiguez & Fischer, 2003).

Marine	Domestic	Commercial / industrial
Fragmented plastic	Glass bottles	Building rubble/ waste
Secondary use container	Plastic bottles	Scrap metal
Synthetic sponges	Plastic bags	Processed wood
Fishing gear	Food cartons	Commercial plastic
Shipping items	Tin cans	Vehicle repair waste
Marine organic material	Domestic organic material	Bulk organic material

For the marine category, indicator classes as described by Tudor *et al.* (2002) and Silva-Iñiguez and Fischer (2003) were used. The classes were defined broadly, for example 'shipping gear' included items such as buoys and fenders. There was, however, limited literature describing specific indicator items from terrestrial sources (Buenrostro *et al.*, 2001) and therefore only broad categories were used (Table 3.1).

Based on preliminary investigations it was realized that organic waste at many of the sites were from two potential sources and that for the purpose of the current study, it was necessary to separate these. Small piles of organic material or industrial items were considered to have come from a domestic source while larger piles (>0.5m^3) were considered to have been commercial in origin where sources could include garden services. ‘Domestic organic material’ would include kitchen waste as well as small piles of garden refuge. ‘Vehicle repair waste’ would include items such as oily rags or motor parts.

The photographs from each station were analysed by means of the dot-grid photographic method. A variation of the method has previously been used for ecological quantification surveys (Hill & Wilkinson, 2004; Macyk & Richens, 2004). Each photograph was overlaid with a grid containing 50 randomly placed points using Microsoft Power Point 2000 (Figure 3.3). As it was impossible to determine the most likely origin (domestic, industrial, commercial or marine) of every item of waste, the random ‘dot’ method was used to randomly ‘select’ a sub-sample. Once the overlay with 50 randomly placed dots had been placed over the theoretical quadrat in a photograph, all items touched by a dot were categorized by source, based on the indicator items shown in Table 3.1. If two or more dots ‘landed’ on a single item, this item was only categorised once. Based on the data collected by this method, it was possible to determine the most common source of the solid waste (marine, domestic or commercial / industrial) at the various sites and identify what proportion of the solid waste could potentially be recycled.

As no previous use of such a photographic method for the assessment of solid waste could be found in literature, it was considered appropriate to validate the method. The validation test only focused on the dot-grid method since the grid method was only used to provide a rapid semi-quantitative method for assessment of the relative change in the quantity of waste at the various sites. The dot-grid method was tested by collecting approximately one cubic meter of mixed solid waste (including garden waste and a few items to represent the waste from a marine source). Each item was then physically sorted by source based on the indicator items (marine, industrial/ commercial, domestic) and the number of items from each source recorded.

Figure 3.3: A grid consisting of randomly placed dots was used to determine the types and sources of solid waste.

A 1m x 1m quadrat was then marked out and the solid waste tipped into the quadrat. One photo was then taken from the same distance and angle used during the original study. The same garbage was then mixed up, twice more and put into a pile and two more photos were taken. The photos were analysed by means of the dot-grid method based on indicator items. The mean proportion of items from each of the three source catagories based on the actual count was then compared to the estimated distributions based on the photographic dot-grid method (Figure 3.4). A statistical analysis of the data revealed that there was no significant difference (Mann-Whitney U Test; $P>0.05$) between the two methods.

Despite the statistical validity of the method some problems have been identified (Table 3.2) with the proposed photographic method. When compared to physical collection and sorting techniques, it was still considered a valuable semi-quantitative tool when physical collection was not possible. However, the method should be subjected to detailed calibration and validity tests as part of future studies.

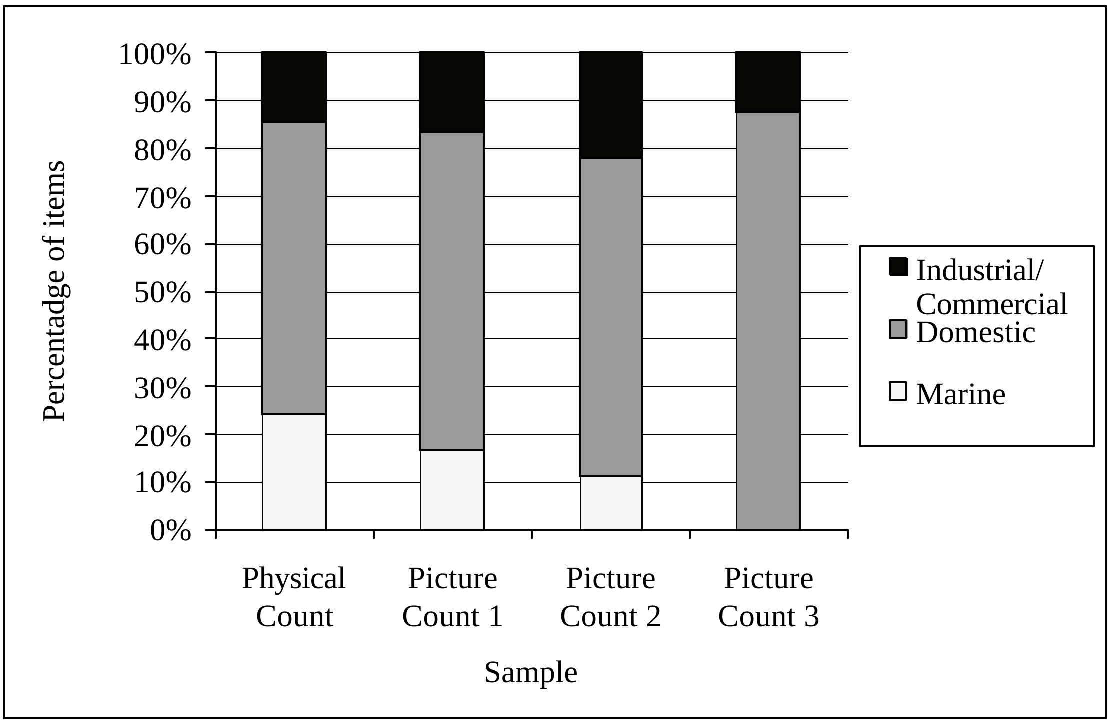


Figure 3.4: The reliability of the dot-grid method was tested by comparing the percentage of items in each category.

Table 3.2: Advantages and disadvantages of the photographic solid waste assessment method.

Advantages	**Disadvantages**
Sampling is rapid	Small items are unaccounted for
Sampling is very simple	Distant items were unidentifiable
Increased safety of researcher	Can give falsely lower numbers of litter
	At times insufficient light resulted in unidentifiable items
	Unable to distinguish between hazardous and non-hazardous material

3.2.2 Survey

3.2.2.1 Questionnaires and interviews

In order to determine the local perception of the current status of solid waste production, disposal (reuse or recycling) and management, as well as its potential impacts on human and environmental health, it was decided to engage with interested and affected parties (I&APs) by means of semi-structured interviews. It was expected that the data gathered during these interviews would be essential when developing an integrated strategy for managing potential land-based marine pollution at source.

The interviews involved the use of questionnaires incorporating a combination of closed- and open-ended questions according to the method described by Cronje (2000). Such semi-structured interviews have been described as one of the best techniques to gain insight from a community (Fuggle & Rabie, 1992; Swanepoel, 1993; DWAF, 2001a). According to DWAF (2001a) the advantages of using semi-structured interviews include the gain of valuable opinions and perspectives from I&APs, which can result in high-quality information. The disadvantages are high cost, that they are time consuming and that interviewees might feel intimidated which could result in biased information. For logistical reasons, it is often not possible to conduct interviews with the entire affected community, and it was thus necessary to interview a sub-sample of the population. Cronje (2000) stated that an available sample could be used instead of a statistically valid sample size if specific reasons were provided as to why a statistically-valid sampling technique was not chosen. For this study an available sample was chosen for the following reasons:

- The population from the available sample had a direct influence on the monitoring stations, specifically the Waste Skip, Informal Dump, Scrap Yard and YWAM sites;
- From the photographic assessment and preliminary informal site assessment it was concluded that the chosen residential cluster was likely to have had a direct impact on the storm water canal through illegal waste disposal practices and grey water discharge;

- As the researcher already had a good working relationship with the target community, this area was considered safer to work in relative to other informal settlements within the greater storm water catchment, and
- This community had already been identified as a likely location for the implementation of a pilot project addressing the issue of waste management.

The available sample consisted of residents living in Extension 25 in the center of the catchment between Tornyn and Pell Streets (Figure 2.2). Families in this area lived in a mixture of low-cost formal and informal housing that was characteristic of a lower income group. The aim was to interview an adult from each of 30 households, which represented 1.4% of the households of Ward 2 of the Kouga municipality (Statistics SA, 2003), which formed the largest part of the storm water catchment. The questionnaire itself is provided in Appendix A.

In order to obtain a more balanced perspective of attitudes towards waste management in the Jeffreys Bay catchment, other I&APs were also identified and interviewed using similar structured questionnaires. Interviewees included a key representative from the Kouga Municipality who was involved in solid waste management (Appendix B), and a key representative from the Jeffreys Bay business community (Appendix D). The questionnaires did not only contain questions regarding solid waste, but also covered other issues such as sanitation and environmental management that were relevant to this study. Personal information regarding the respondent's household was gathered by means of questions 1 to 7 (Appendix A) in order to assist with interpretation of the other data and the development of appropriate waste management strategies. Such demographic data (education levels, age, gender, income group etc.) has been linked to patterns in both production and management of solid waste (Kaseva & Gupta, 1996; Ojeda-Benitez *et al.*, 2003). Questions 8 to 11, 16 and 17 (Appendix A) as well as questions 1, 2, 6 to 8, 11 and 12 (Appendix B) were aimed at examining the production and the disposal (signs of reuse or recycling) of solid waste within the catchment. Questions 12 to 15 (Appendix A), questions 4 to 6, 10, 13, 14 and 16 (Appendix B) and questions 1 and 2 (Appendix D) were aimed at assessing the I&APs attitudes and concerns regarding solid waste management within the catchment.

3.2.2.2 Ethical considerations and good practice

The means by which one conducts an interview and the use of the data obtained has a number of ethical implications, which need to be addressed. Some ethical considerations deployed during the interview procedure were to maintain the anonymity of the interviewees and assure them that all information would be treated as confidential (Swanepoel, 1993). Furthermore, it was deemed important to inform the interviewees of the purpose of the interview and study, in order to gain their trust. Open-ended questions were used at the beginning of the interview in order to put the interviewee at ease. A conscious attempt was made not to doubt or argue with the interviewee (Swanepoel, 1993).

3.3 RESULTS AND DISCUSSION

3.3.1 Current state of solid waste management

3.3.1.1 Quantification of solid waste

Figure 3.5 shows the mean waste coverage indices for each monitoring station over the 3-month sampling period. Analysis of the data revealed that there was significant difference between the means for the different monitoring stations (Kruskal-Wallis; $P<0.05$). The South Beach monitoring station showed the least (mean: 0.01 ±0.02) solid waste pollution. This site only received storm water during periods of high rainfall and was regularly cleaned by municipal workers. The C-Place monitoring station situated in the middle-class housing development at the upper end of the storm water catchment also showed very little solid waste in open areas (mean: 0.02 ±0.02). This sample site was along a footpath that was regularly used by individuals walking towards the township and it was suspected that the litter at this site was primarily deposited by those who made use of this footpath.

The mean waste index for North Beach monitoring station (mean: 0.05 ±0.07) was marginally higher than that for South Beach, possibly due to the higher number of beach-users and greater volume of storm water. The mean waste index for the two outlet stations were also low with the value for the Northern Outlet (mean: 0.21 ±0.24) being slightly lower than that of the Southern Outlet (mean: 0.27 ±0.2). This result was surprising since, according to a spokes person for the municipality, the Northern Outlet received more storm water and therefore potentially more solid waste than the Southern Outlet. This result could

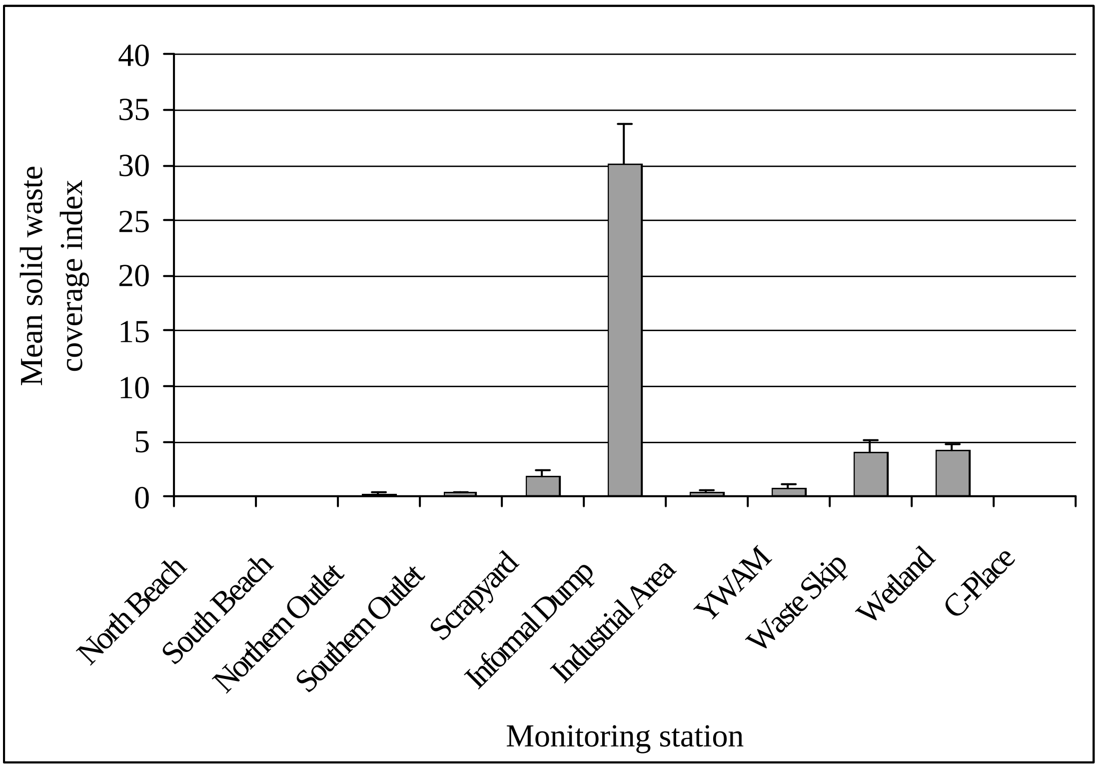


Figure 3.5: Spatial variability of solid waste at 11 monitoring stations within the Jeffreys Bay storm water catchment from 16 November 2004 to 17 February 2005 (vertical bars indicate standard deviations).

however have been due to daily clean up of North Beach and the associated outlet by the 'Blue Flag beach clean-up team', whereas cleanup of the Southern Outlet by municipal workers was less frequent. This result showed that clean-up teams were effective regarding the reduction of solid waste and should be considered as part of the larger waste management strategy for the catchment.

Despite the apparent positive impact of the cleanup teams, litter deposition on beaches was still evident after rainfall events (Figure 3.6). It is proposed that while some of the litter was transported and subsequently deposited directly onto the beach by storm water flows, a significant proportion was probably first deposited into the near-shore marine environment, thus the period from initial release from the storm water system until final deposition on the beach may be extended, hampering cleanup operations. Figure 3.6 illustrates the

Figure 3.6: Solid waste discharged on Main Beach after rainfall.

accumulation of solid waste on a stretch of beach directly down stream of the Northern Outlet after a large rainstorm event. As this stretch of beach is the main section of the Jeffreys Bay Blue Flag beach, it is evident that inadequate solid waste management within the storm water catchment could pose a threat to the Blue Flag Status of the beach.

Surprisingly, the quantity of waste at the Industrial Area (mean: 0.41 ±0.72) and the YWAM site (mean: 0.81 ±1) were also relatively low. The latter was situated directly in the storm water canal and it was expected that the solid waste pollution would be high due to the observation of regular littering and illegal dumping. This was not the case and could be due to regular clean up by the 'Coast care clean-up team' and removal of solid waste during the flow of storm water. The quantity of solid waste at the four remaining sample sites were relatively high. The mean waste index values were 1.89 (±1.55) for the Scrap Yard site, 4.03 (±3.47) for the Waste Skip, 4.19 (±1.88) for the wetland and 30.02 (±12.82) for the Informal Dump. During the monitoring it was observed that the inputs at these monitoring stations were due to illegal dumping of solid waste and littering (Figure 3.7). This finding was consistent with literature where it has been pointed out that illegal dumping of solid waste and littering in and around storm water canals has proven to be a

Figure 3.7: Illegal solid waste dumping and littering within the storm water catchment.

significant problem in South African developing communities (Wright *et al.*, 1993; Wood *et al.*, 2001; Pretorius & de Villiers, 2003). Figure 3.8 and 3.9 illustrate the temporal variation at the different solid waste monitoring stations. From Figure 3.8 it is evident that solid waste at the Informal Dump exhibited a significant increase over the Christmas and New Year holiday season (22/12/04-17/02/05) and while this trend was evident to a lesser degree at the Waste Skip, the quantity of solid waste at the other sites remained consistently low. During the holiday season it is expected that people consume more and that a more careless attitude by the public and the municipal workers responsible for cleanliness and waste management prevails. Both could have contributed to the increased levels of waste deposited illegally in certain of the communal areas.

This finding was inconsistent with that of Mbande (2003), who found that there was no seasonal increase in the production of solid waste within a South African developing community. Although the quantity of solid waste at the two beach and two outlet monitoring stations was relatively low, quantities did vary with time (Figure 3.9), with peaks around the 9^{th} and 30^{th} of December 2004 and the 27^{th} January 2005. As was expected, the quantity of waste at the outlets was almost always lower than on the

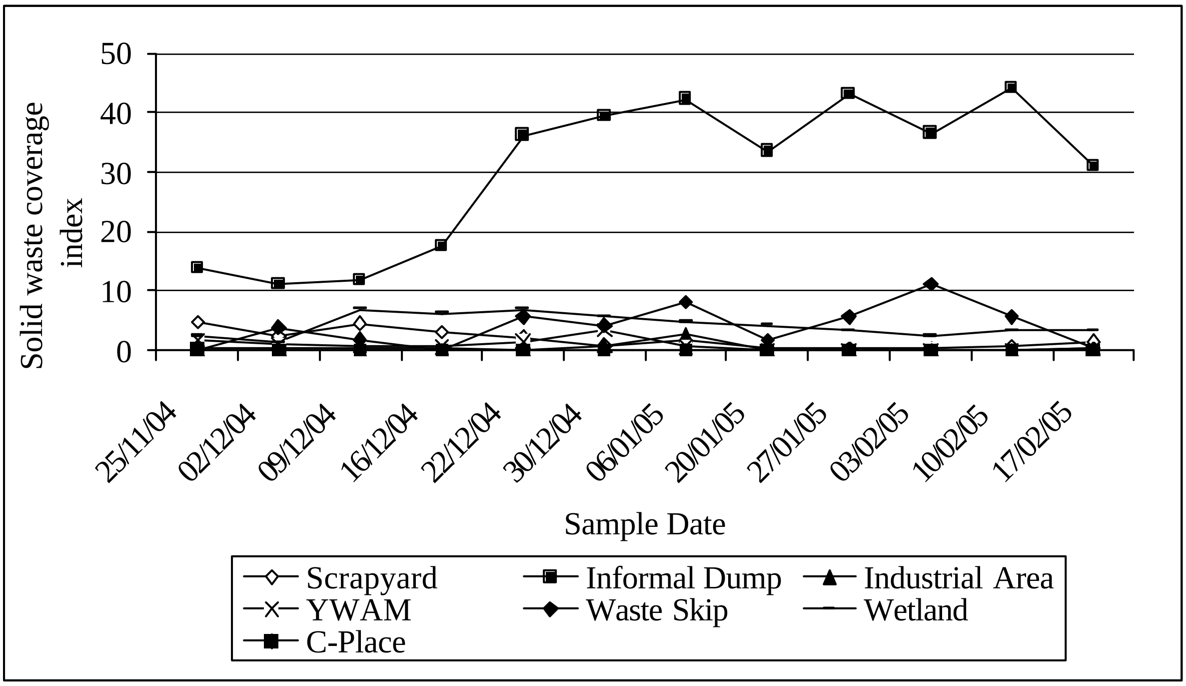


Figure 3.8: Temporal variation of solid waste at the inland monitoring stations within the Jeffreys Bay storm water catchment.

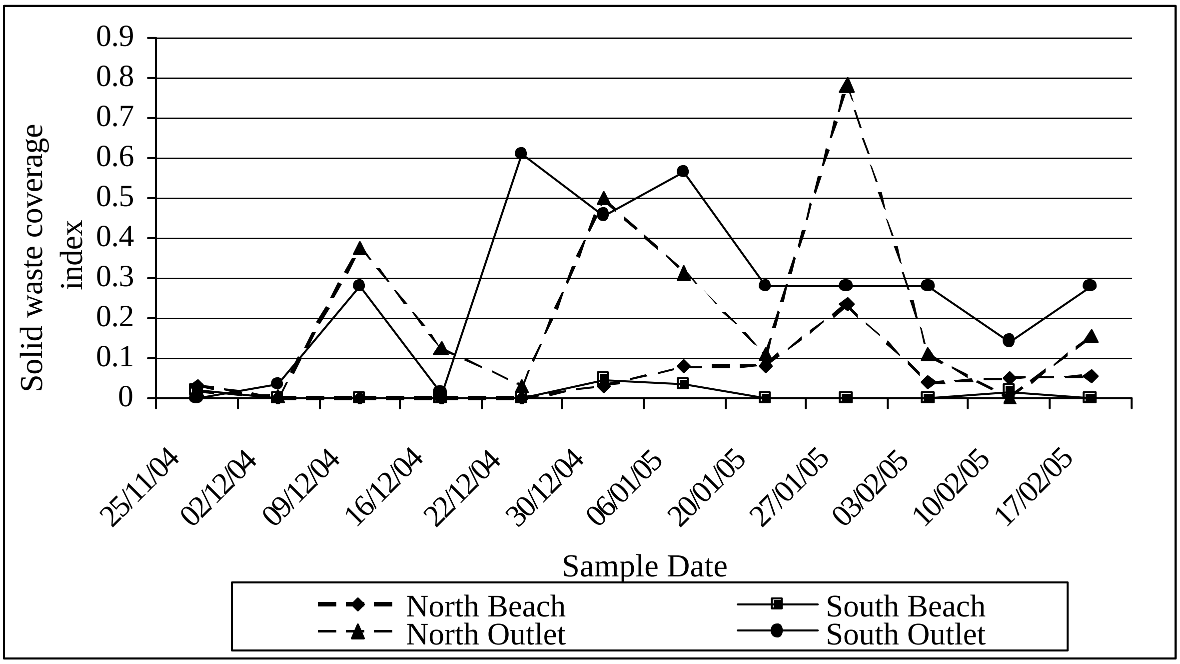


Figure 3.9: Temporal variation of solid waste at the storm water outlet and the beach monitoring stations.

corresponding beaches. A Spearman Rank Correlation Coefficient confirmed that there was not a statistically significant correlation between the quantity of waste at either the Southern (rs: 0.29; P>0.05) or Northern (rs: 0.12; P>0.05) storm water outlets and the corresponding beaches. However, the peak in the quantity of solid waste at both the North Beach and Northern Outlet on the 27st of January 2005 suggested that there was at least some evidence that the solid waste found on the beach was deposited by storm water and that it may have originated within the storm water catchment system.

In order to further investigate the possibility that rainfall was responsible for the transportation of solid waste from the catchment to the beach, rainfall data (South African Weather Service, 2005) and solid waste coverage index data from a monitoring station within the catchment, YWAM, and on the beach, namely the North Beach monitoring station, were compared (Figure 3.10). It was expected that solid waste within the storm water canal would have decreased and that solid waste coverage on the beach would have increased after a rainfall event. A Spearman Rank Correlation Coefficient did not however show any significant association between rainfall and the solid waste coverage index at the YWAM monitoring station (rs: 0.5; P>0.05) or the beach (rs: -0.87; P>0.05).

This result was most likely due to a combination of the relatively low waste coverage index values for both sites and the low resolution of the sampling technique. It was expected that if a more reliable quantitative waste quantification methodology such as total mass or volume of waste had been employed, that significant correlations between rainfall events and the quantity of solid waste in the storm water canal or on the beach may have been found. Interestingly, based on the peaks in rainfall and the solid waste coverage index for YWAM around the 22/12/04 and the 31/12/04 (Figure 3.10), there did seem to be some relationship between rainfall and the transportation of solid waste within the catchment. The fate of the waste requires further study, specifically to determine what proportion finds its way into the marine environment.

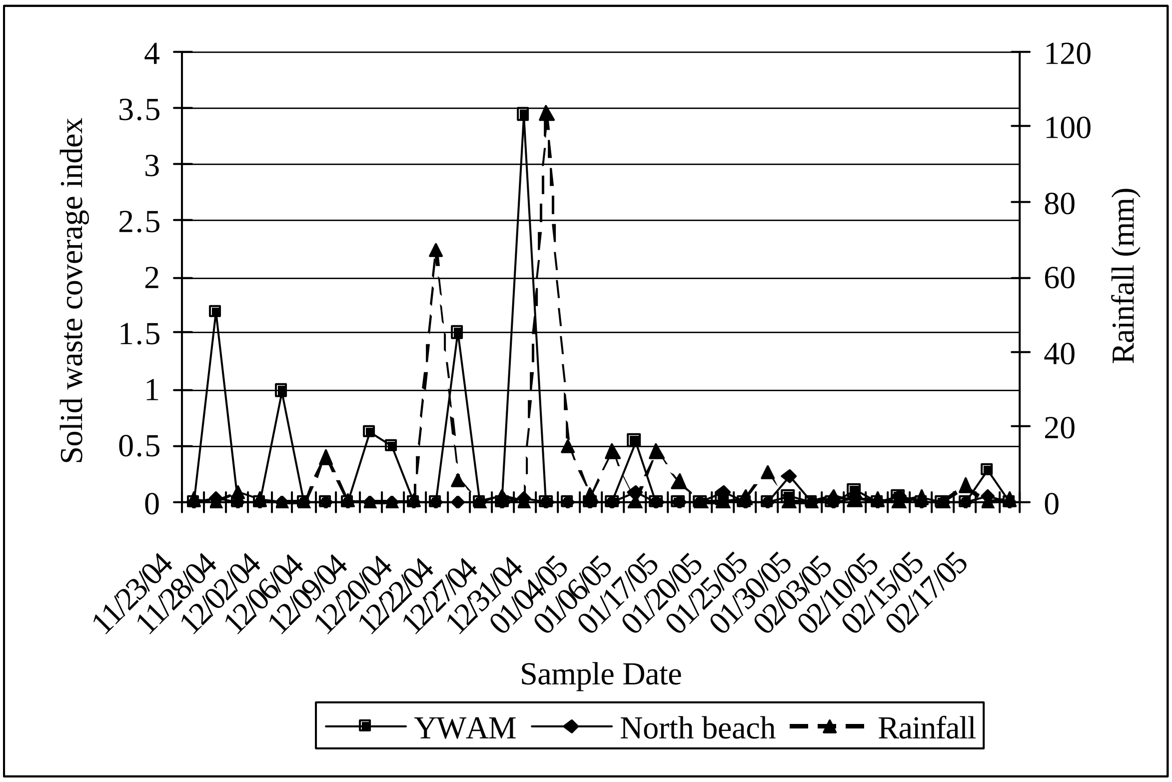


Figure 3.10: A temporal comparison of rainfall and solid waste coverage index data for Jeffreys Bay storm water catchment.

3.3.1.2 Sources of solid waste

Using the photographic method, a total number of 919 items were categorised over the three-month period. Theoretically, the maximum number of items that could have been identified was 6600, but due to more than one dot falling on a large item and open spaces without solid waste coverage, this actual number was approximately 14% of the theoretical maximum. The highest proportion of solid waste disposed of informally or illegally was of domestic origin (Table 3.3 and Figure 3.11). Industry accounted for 24% of the solid waste disposed of illegally/ informally and only one item was identified on the beach that could have come from marine activity. This result was as expected, and confirmed that almost all solid waste on the beach was terrestrial in origin and that waste management efforts needed to concentrate on land rather than behaviour at sea. It is worth nothing that due to the method employed, the data could not be used to estimate the volume or mass of solid waste from each source but nevertheless provided usefull management data.

Table 3.3: The origin of illegally or informally disposed of solid waste within the Jeffreys Bay study area.

Source	Number of items	% Sample
Marine	1	0.1
Domestic	701	76.3
Industrial/ Commercial	217	23.7
Total	**919**	**100**

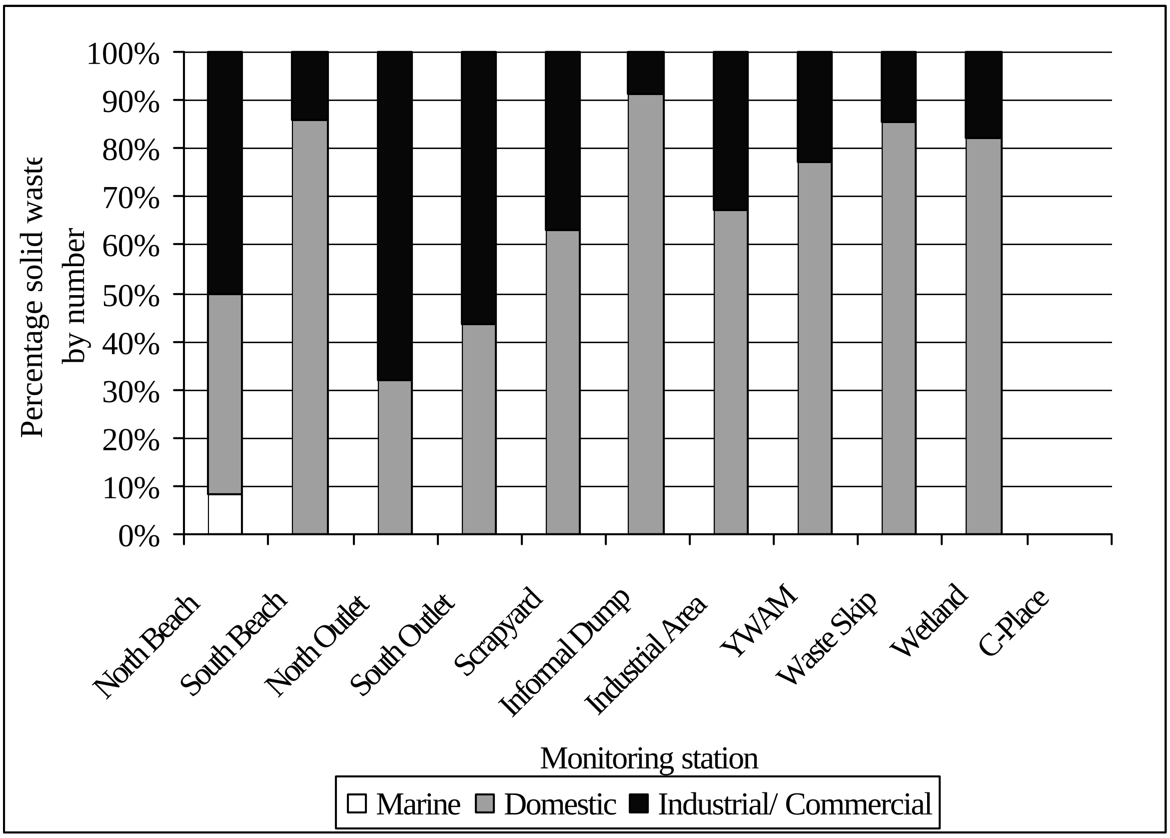


Figure 3.11: Sources of solid waste at various monitoring stations within the Jeffreys Bay storm water catchment from November 2004 to February 2005.

At all the sites, except for the Northern and Southern Outlets, more than 50% of the items 'sorted' were classified as having originated from domestic sources (Figure 3.11). The highest percentage of domestic waste was found at the Informal Dump (92%) and the South Beach (80%) sampling site. Surprisingly, the number of items from industrial sources was highest at the storm water outlets, which was due to a large amount of building rubble (pieces of brick and cement) found at these sites after a period of high rainfall. This rubble appeared on the 9th of December 2004 and remained at the sites for the rest of the monitoring period. As very little rubble was found at other sites within the storm water catchment, it was not clear whether this material was deposited by storm water or whether it was simply exposed when storm water cleared away the sand layer covering it.

Other areas that showed significant input from industrial/ commercial sources were the Scrapyard (36.8%) and the Industrial Area (32.8%). Items such as plastic cable covers, wood off-cuts and building rubble pointed towards industrial/ commercial sources of pollution. Within the rest of the catchment the presence of solid waste items such as plastic containers and food waste, confirmed that the local community contributed significantly to solid waste pollution within the catchment. It has been estimated that informal settlements can contribute up to 6000 kg/ha/yr of litter to the proximity of drainage canals (Marais *et al.,* 2004). Based on the results above, the main source of solid waste pollution in Jeffreys Bay was considered to have been the local residential community of Pellsrus and Tokyo Sexwale and potential management interventions should focus on the prevention of solid waste pollution from these areas.

When considering solid waste management, issues such as potential reuse and recycling are important. For this reason, further examination of the 919 items identified during the solid waste source classification exercise was required in order to assess the recycling potential. The analysis revealed that approximately 36% of the items were considered to be made from recyclable material. According to a breakdown of those items considered recyclable (Figure 3.12), the predominant recyclable material was plastic, which was inconsistent with literature which showed organic material to be the most prevalent (Mohee, 2002; Metin *et al.,* 2003; Mbande, 2004). This was due to the fact that studies in literature were focused on weight and not number of items, which pointed towards a weakness in the methodology employed in the current study, since piles of organic waste (i.e. pile of grass cuttings) were counted as one item. Thus, the total mass of organic material available for recycling in the Jeffreys Bay storm water catchment may have been higher than expected based on count data.

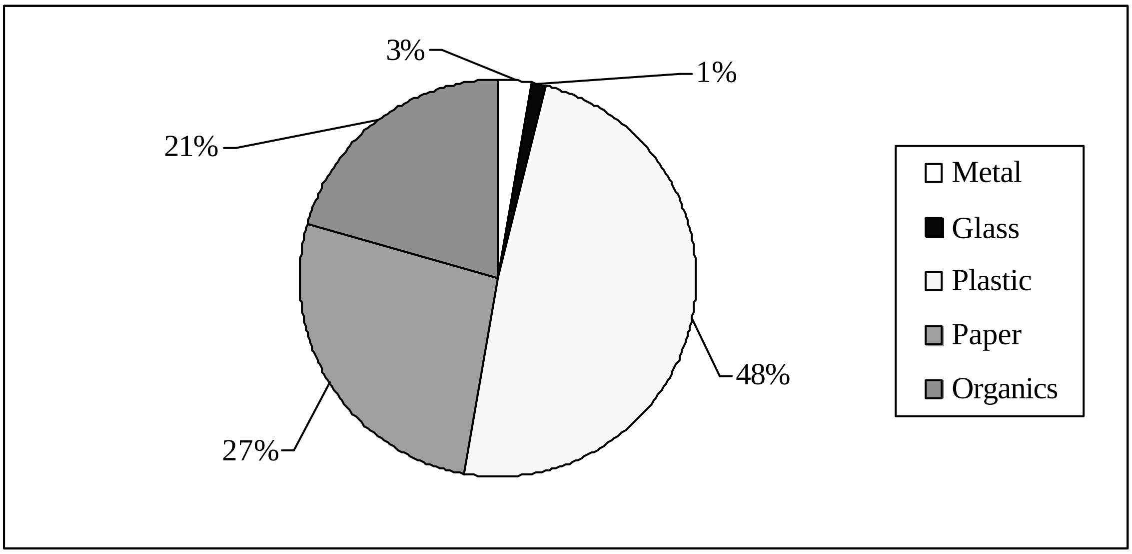


Figure 3.12: The classification of that proportion of the illegally dumped solid waste in the Jeffreys Bay catchment that was considered to have recycling potential.

This result was most likely due to a combination of the relatively low waste coverage index values for both sites and the low resolution of the sampling technique. It was expected that if a more reliable quantitative waste quantification methodology such as total mass or volume of waste had been employed, that significant correlations between rainfall events and the quantity of solid waste in the storm water canal or on the beach may have been found. Interestingly, based on the peaks in rainfall and the solid waste coverage index for YWAM around the 22/12/04 and the 31/12/04 (Figure 3.10), there did seem to be some relationship between rainfall and the transportation of solid waste within the catchment. The fate of the waste requires further study, specifically to determine what proportion finds its way into the marine environment.

Thus, once potential for recycling had been identified using the photographic method, more detailed follow-up analysis would then be required in order to assess the actual quantity (mass) of recyclable material in the various classes prior to the commencement of any formal recycling initiatives. The semi-quantitative nature of the photographic dot-grid method may explain why the estimated percentage of solid waste available for recycling in the Jeffreys Bay catchment was so much lower than the 61% estimated by other studies

(Ojeda-Benitez, 2003). Nevertheless this study indicated that local communities were discarding waste that could have been recycled, although some individuals may have been already involved in some form of reuse or recycling initiatives.

3.3.2 Community perception of solid waste management

Of the individuals that were interviewed, 70% were female between the ages of 16 and 55, and 30% male between the ages of 17 and 34. As the survey was undertaken during working hours, most of the men were at work. Those men that were not at work were students, casual workers, shift workers or unemployed. The sample population that was interviewed was representative of 101 household members. Of these members 14.9% were younger than five years of age, 13.9% were between the age of 6 and 15, 50.5% were between 15 and 35 and 20.8% between 35 and 60 (Figure 3.13). The community therefore consisted of mostly families with young children and young adults. Most of the interviewees (66.7% of sample) had obtained secondary level education while only one person did not attend any schooling (Figure 3.14). None of the sample population had received any tertiary education. All of the interviewees worked in the non-professional sector that ranged from domestic work to security with only three people claiming to be unemployed. The most common occurring household income (33.3%) was less than R2400 per month (Figure 3.15). Of the individuals that were interviewed, 86% lived in informal homes made from non-recognized building material for example corrugated iron and cardboard, with the remainder living in formally constructed homes.

Information from the survey showed that on average it was estimated that households produced two (±1.23) standard black municipal plastic bags of solid waste per week with the highest estimate being five bags per week. Paper/ cardboard was regarded as the most commonly disposed of waste type followed by, in order of estimated volume, plastic/ rubber, organic matter, metal, glass, wood, garden waste and other items. Once again, these findings contradict those of Mbande (2003) who reported finding of organics followed by paper, plastic, glass, metal and other items. This could be explained by either a lack of accurate knowledge on the part of the interviewees regarding the quantities of the various waste types being disposed of or a genuine difference in the composition of the solid waste streams at the two sites. As waste composition is known to be affected by age profile of communities, social and

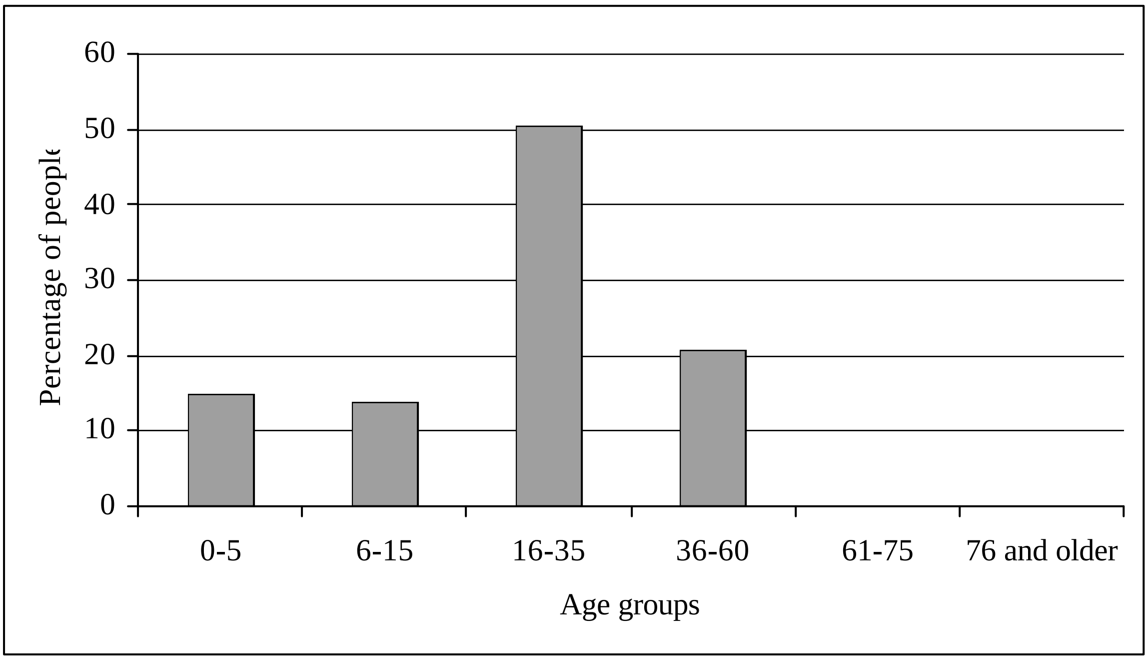


Figure 3.13: Age distribution within the households of the sample population (n=30).

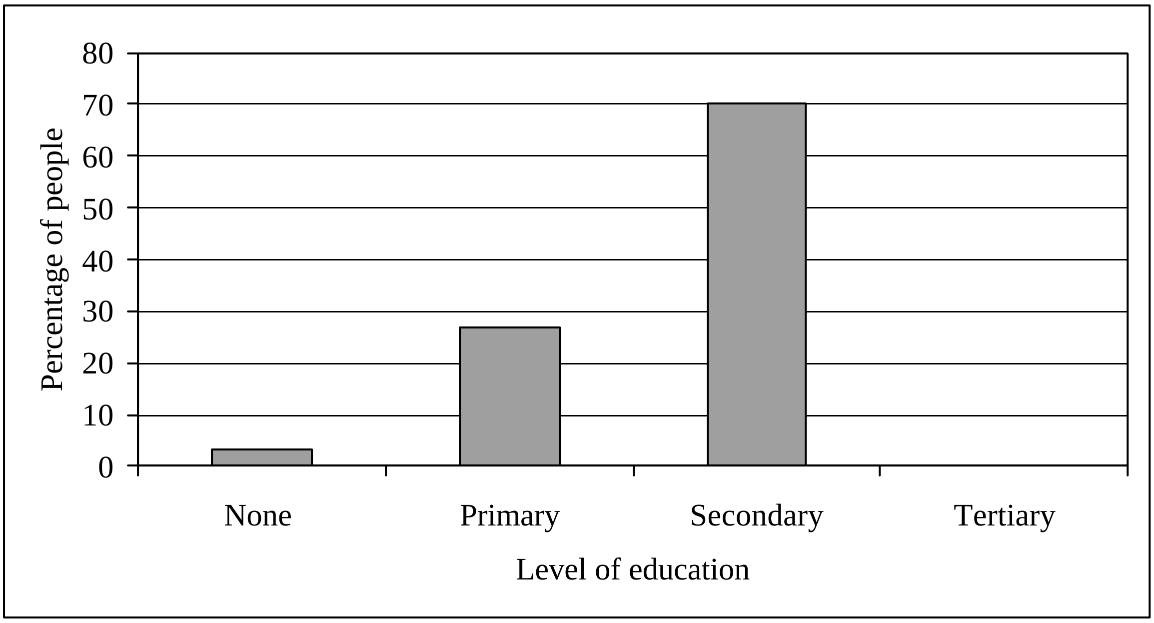


Figure 3.14: Respondents' level of education (n = 30).

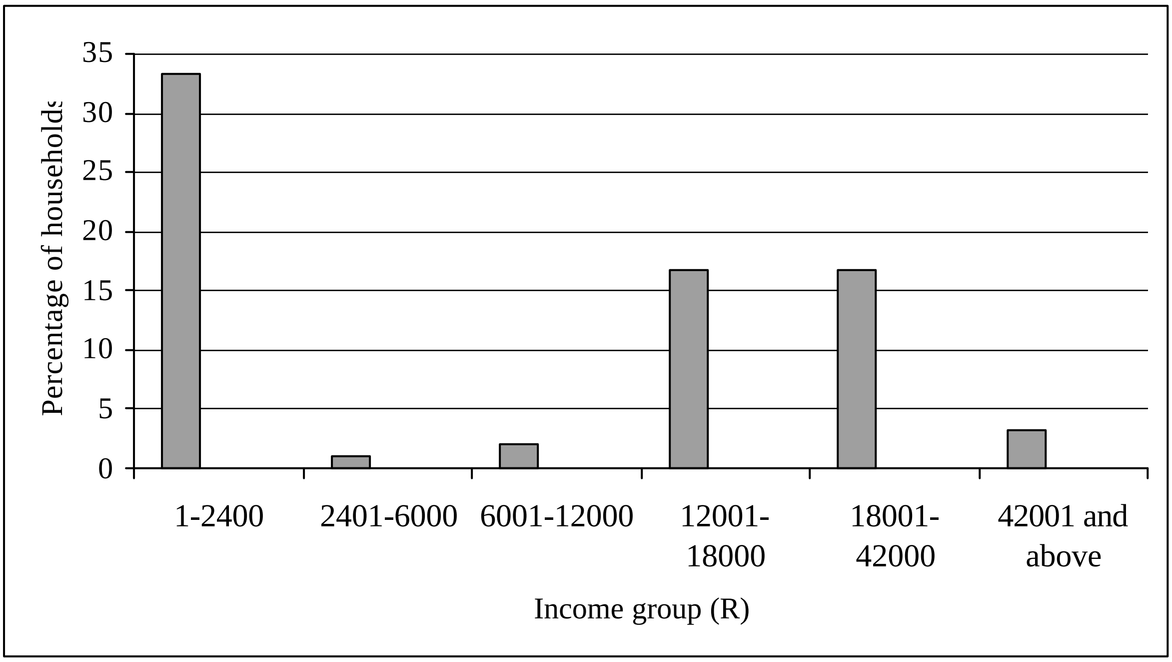


Figure 3.15: Annual household income of the sample population (n = 30).

economic factors (Kaseva & Gupta, 1996; Ojeda-Benitez *et al.*, 2003) as well as the seasons (Mohee, 2002; Metin *et al.*, 2003), it is possible that the latter explanation is valid.

33% of the interviewees remarked that they reused or recycled certain items, specifically glass bottles, plastic bottles and plastic bags. Tin, plywood and cardboard were also reused as building material for informal homes. Within Jeffreys Bay, formal recycling of solid waste from domestic sources only focused on glass bottles and scrap metal. None of the interviewees had a composting facility at their house even though it has been shown that up to 60% of the material within the municipal solid waste stream could be reduced if household composting was to take place (Mohee, 2002). The Kouga municipality representative stated that composting was potentially a viable option for municipal solid waste reduction, but indicated that recycling had not proven to be economically viable in Jeffreys Bay since the distance for transporting recyclables from Jeffreys Bay to recycling factories was too large.

Every household within the catchment had the option of curbside solid waste collection provided by the municipality (black plastic bags were not provided for refuse removal) at identified central points, once a week. Those living in the informal community who did not choose to make use of the curbside collection had the option of using the waste skip for their solid waste disposal. Those nearer to the waste skip were disposing of their waste at the skip while people further away from the skip made use of the weekly curbside municipal waste collection service. Marais and Armitage (2004) stated that the distance people have to walk and the height of the waste skip contributed to the efficiency of this method. People who have to walk far to dispose of their solid waste or children who cannot reach to dispose of their waste inside a skip tend to dump their waste informally. It was estimated that residents of Pellsrus and Tokyo Sexwale township had to walk up to 200m to the nearest solid waste disposal point (curbside and/ or waste skip) which could have been a reason why so much informal dumping of solid waste was found within the Jeffreys Bay catchment. In Extension 25 residents had to walk up to 100m to the nearest waste skip, however no interviewees in Extension 25 admitted to discarding of waste next to an empty skip and rather blamed people from other areas who were not supposed to be using the local waste skip. Those picking though the trash, were observed to be mainly children who, based on informal interviews, were looking for items to play with as opposed to scavenging for economic gain. Only one person admitted to regular dumping of solid waste on an informal dump.

The survey revealed that 60% of the interviewees were unhappy with the way solid waste was managed, with 77% of those using the waste skip method expressing dissatisfaction (Figure 3.16). Problems with the current state of solid waste management included physical nuisance (bad smell, flies & rats), the wind blowing the litter around, dead animals, the waste skip filling up quickly, people digging through the trash and throwing trash out of the skip and the effect on their children's health. Few interviewees (3%) expressed concern for the impact on 'nature'. This was consistent with the findings of Rahardyan *et al.* (2004) that people have not much concern about the effect of solid waste management facilities on the natural environment. This information would be valuable when putting together educational and anti-litter campaigns, which should include issues such as impacts on public health and ecosystem goods and services. More importantly, an understanding of the affected community's primary concerns can be used to formulate and develop incentives for improved waste management.

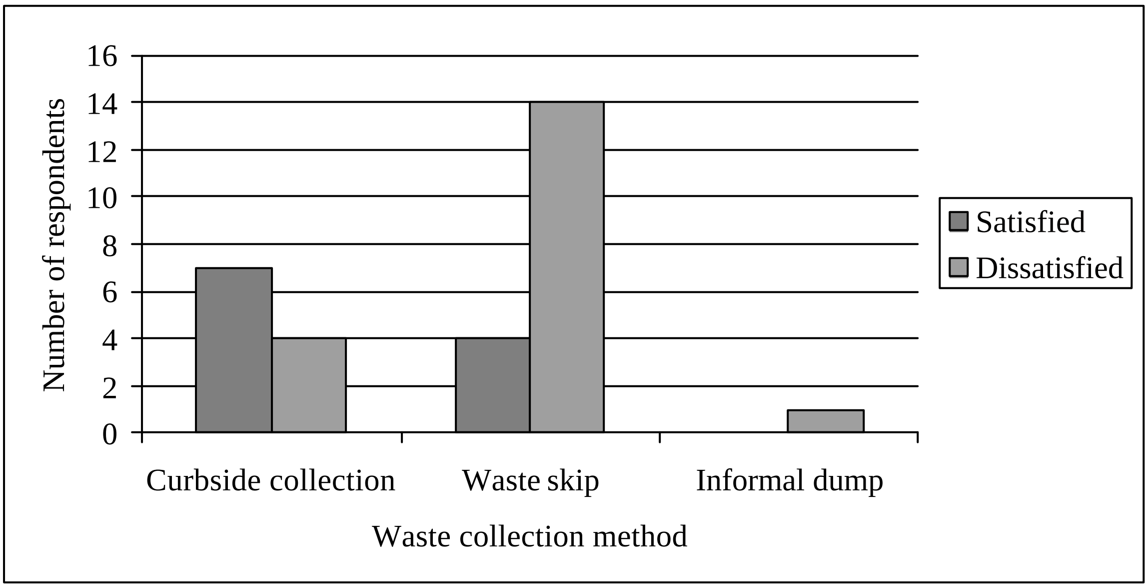


Figure 3.16: Community attitude regarding solid waste disposal in the Jeffreys Bay storm water catchment (n=30).

The Kouga Municipality's representative stated that the inadequate solid waste management in the catchment was not due to a deficient solid waste management system. His concerns were focused on insufficient technical equipment and staff. Kaseva and Mbuligwe (2005) stated that the condition and the availability of solid waste removal equipment had a direct link to problematic solid waste management. The municipal representative also mentioned that deficient social cooperation lead to a near impossible task in keeping the catchment pollution free. In a sense this expectation was not realistic if the institutional arrangements around solid waste removal were not ideal. For example, the relatively far distance from some homes to formal disposal points, whether skips or curb-side collection points, would not facilitate correct disposal by children and the elderly. Subject to budget allowances, it would be beneficial to increase the number of available skips although the location of these skips would need to be carefully considered to ensure maximum use. Furthermore, the municipal representative's solutions were all short term and considered 'end-of-pipe'. Instead, solutions should include ways of minimizing waste production or increasing opportunities for recycling and reuse as prescribed by the National Waste Management Strategy (DEAT, 1999) and the White Paper on Integrated

Pollution & Waste Management (DEAT, 2000). This would not only reduce pressure on existing skips but could generate income.

Even with sufficient skips, abuse of the formal waste management system through illegal dumping may still be problematic, and effective incentives and "policing" would be required. The Kouga Municipality's representative stated that the local government's law enforcement division was responsible for the issuing of fines for those who were dumping illegally, although no fines had been issued for illegal dumping of solid waste. Marais *et al*. (2004) stated that the level of exercising legislation with regard to illegal dumping and littering is one of the major contributing factors for the state of pollution in storm water catchments, and therefore issuing of fines for illegal dumping in Jeffreys Bay could potentially improve local solid waste management.

Other suggestions offered by the Kouga Municipality were to increase involvement of local councillors who could encourage local communities to abide by the waste management legislations, as well as to increase the number of waste skips and the digging of trenches in which to place waste skips. The latter solution would hopefully overcome the issue of skips being too high for convenient deposition of waste. Interestingly, none of the interviewees indicated that skip height was a problem which could be due to the fact that the waste skip nearest to those that were interviewed had a embankment which increased accessibility, although this was not the case at all the waste skips in Jeffreys Bay. Privatisation of the solid waste management service was also suggested and was considered the only option for effective solid waste management due to the current shortage of equipment and staff. This suggestion was in line with literature where it has been proven that privatisation is a more viable option than municipal solid waste removal (Palmer Development Group, 1996; Earthyear, 2001; Wood *et al.*, 2001; Kaseva & Mbuligwe, 2005).

The Municipality was of the opinion that local industrial operations did not pose a problem with respect to solid waste management. The only hazardous wastes that the representative was aware of within Jeffrey Bay's commercial and industry sector were vehicle batteries, motor oil and computer parts which, according to him, did not reach the municipal solid waste stream but were being recycled. Buenrostro *et al.* (2001) stated however that hazardous waste from light industry in developing countries did reach the municipal solid waste stream illegally and stated that this practice was impossible to prevent. Results from the current study also showed that industry and commerce did contribute towards solid waste pollution although the quantity of waste, specifically building rubble, was not considered significant. The local community and the Kouga Municipality's concerns were echoed by other I&APs. A representative for the Jeffreys Bay business community stated that the Jeffreys Bay business sector was not satisfied with the state of solid waste management within the town and that they had brought this issue before council as it was thought to threaten local economic development.

3.4. CONCLUSIONS

In general, solid waste management within the Jeffreys Bay storm water catchment was poor, with significant quantities of solid waste, primarily from domestic households, being disposed of illegally. The Informal Dump and the area around the waste skip, as well as the wetland, showed particularly high quantities of solid waste. The quantity of waste at many of the sites, based on a waste coverage index, varied with time, probably as a result of a combination of periodic removal by collection services and flushing during rainfall events. The data to support the hypothesis that solid waste from the storm water catchment was transported to the marine environment was, however, inconclusive and required further detailed investigation.

A significant proportion of the I&APs expressed dissatisfaction with the state of waste management and the investigation revealed that a combination of institutional, technical and social aspects were considered to have contributed to the dilapidated state of the catchment in terms of solid waste pollution. While a lack of municipal resources and a disregard for pollution-related legislation were both thought to contribute to the situation, there was no evidence that legal avenues had been employed to improve waste management. It was thus suggested that incentive-based initiatives should be explored. Based on the concerns of the community, these could potentially include a reduction of nuisance and health risks. While solid waste was of significant concern, waste streams related to sanitation were also identified as potentially threatening during the initial RA and therefore also required more detailed investigation prior to the development of an integrated waste management strategy.

CHAPTER 4

ASSESSMENT OF SEWAGE AND GREY WATER DISPOSAL WITHIN THE STORM WATER CATCHMENT

4.1 INTRODUCTION

A basic sanitation service is defined within the Strategic Framework for Water Services (DWAF, 2003) as the "…provision of a basic sewage disposal facility which is easily accessible to a household, the sustainable operation of the facility, including the safe removal of human waste and wastewater from the premises where this is appropriate and necessary, and the communication of good sewage disposal, hygiene and related practices." The risk assessment (RA) described in Chapter 2 indicated that sanitation, specifically sewage and grey water disposal, were potential sources of storm water contamination within the Jeffreys Bay storm water catchment, and therefore required more detailed investigation.

The World Health Organization (WHO) estimated that 60% of the world's population does not have access to appropriate sanitation (WHO, 2000 cited in Källerfelt & Nordberg, 2004). The problem of lack of ablution facilities is of particular concern in growing urban areas within developing countries (Austin & van Vuuren, 2001) and is recognized as a major cause of degradation of the environment and, in particular, receiving waters. It is estimated that on average humans produce "…500*l* of urine and 50*l* of faeces per year" (Austin & van Vuuren, 2001). Faecal matter may contain various bacteria, viruses, heavy metals and nutrients (Islam & Tanaka, 2004) while urine, on the other hand, is rich in elements such as nutrients, ammonia, phosphates and potassium (Austin & van Vuuren, 2001). As the world's population grows the safe disposal of human waste will become a growing problem that needs to be addressed if significant environmental degradation is to be avoided.

Closely related to sewage disposal and also problematic in developing communities is grey water, which is defined by Ottoson and Stenström (2003) as "…wastewater without input from toilets (i.e. wastewater from laundries, showers, bathtubs, hand basins and kitchen sinks)". Wastewater from toilets is generally referred to as black water (Källerfelt & Nordberg, 2004). The volume of grey water produced differs greatly between developed and developing communities. In Sweden various studies found the production of grey water to be between 108*l* and 133*l* per person per day (Källerfelt & Nordberg, 2004), while Carden *et al.* (2005) estimated that in South African informal settlements, the water use per person is 24*l* per day of which approximately 75% to 80% is released as grey water.

The quality of grey water also differs between developed and developing countries. Källerfelt & Nordberg (2004) remarked that the most significant difference was in high chemical oxygen demand (COD) levels from developing community's grey water, pointing towards surplus discharge of oxygen demanding substances such as fat. They also remarked that the high microbiological count in the grey water from developing communities could be due to the washing of baby's nappies and the preparation of traditional African food such as 'afval', which makes use of digestive organs of animals. Carden *et al.* (2005) stated that the use of inexpensive cleansing chemicals in underprivileged communities might also have contributed to the poor quality of grey water.

Sanitation in South Africa can comprise of anything from full waterborne sewage disposal to ventilated improved pit latrines (VIP) (Austin & van Vuuren, 2001). Where water-borne facilities exist, the grey water is mostly discarded into the main sewer stream. In non-sewered informal settlements the grey water is mostly thrown on the ground resulting in a potential pollution threat (Carden *et al.*, 2005). Carden *et al.* (2005) have also called for Government to include grey water when addressing the environmental needs of poor communities. A report produced by the Water Research Commission of South Africa (WRC), Department of Water Affairs and Forestry (DWAF), Department of Agriculture, as well as the Department of Health and Sludge Consult (2002), described the acceptable guidelines for the use and disposal of sewage sludge. However, for the disposal and use of grey water there are no detailed guidelines or dedicated legislation even though the White

Paper on basic household sewage disposal (DWAF, 2001b) stated that communities need to have access to a system for the safe disposal of grey water.

Census data (Statistics SA, 2003) indicated that 98% of the population in the study population had access to sanitation, but this figure did not represent the sufficiency of sanitation services. The true status of sanitation provision within the Jeffreys Bay storm water catchment was not known and as it was identified as a potentially significant threat during the RA, a more detailed investigation was required. The objective of this part of the study was therefore to assess the current status of sewage and grey water management in the storm water catchment by answering the following questions:

- How much grey water was produced in the non-sewered area of the catchment and what was the fate of this grey water?
- What was the status of sewage disposal in terms of availability and functionality of infrastructure in the catchment?
- What was the extent and primary causes of informal sewage ablution in the catchment?
- Did the status of grey water and sewage disposal pose a threat to human and environmental health?

4.2 METHODOLOGY

4.2.1 Survey

The semi-structured interview method and sample population described in the previous chapter was used to assess the current status of grey water management and sewage disposal within the Jeffreys Bay storm water catchment. The questionnaires to the residents and municipality are provided in Appendices A and C, respectively. Questions 19, 20 and 21 of the community questionnaire (Appendix A) were aimed at examining the production and the disposal of grey water within the catchment. In order to obtain an estimate of the amount of grey water being produced in the catchment, the sample population were asked to estimate their daily household production based on the number of buckets of water used in a single day (Carden *et al.*, 2005). Evidence of re-use of grey water was also a focus of the study. The availability and functionality of sewage disposal infrastructure was determined by questions 25 and 26 of the community questionnaire (Appendix A), and questions 3 to 12, and 14 of the municipal questionnaire (Appendix C).

Insight into the extent and the primary causes of informal ablution was obtained through question 27 of the community questionnaire (Appendix A) and question 13 of the municipal questionnaire (Appendix C). Questions 1, 2 and 17 of the latter were aimed at determining whether or not the current status of grey water and sewage disposal within the catchment was perceived to pose a threat to human and environmental health. Data obtained during the survey was analysed and compared with that of literature to gain a fundamental understanding of the state of sewage disposal in the Jeffreys Bay storm water catchment, which was necessary for the formulation of an effective integrated pollution management strategy.

4.2.2 Grey water monitoring

A single storm water outlet in the catchment was monitored to provide additional information regarding input of grey water to the storm water system. This storm water outlet was considered to be the main link between the street where people from Extension 25, an informal housing area, were regularly observed discarding grey water, and the main storm water canal. The quantity of grey water entering the storm water canal is evident from Figure 4.1. The storm water outlet was monitored over a three-month period to determine the regularity with which grey water entered the storm water canal. The outlet was situated at the YWAM monitoring station (indicated as number 8 on Figure 2.2) and monitoring took place once a week at midday between 4 October 2004 and 12 February 2005. A 'yes' was recorded if discharge was visible and a 'no' if there was no visible discharge.

4.3 RESULTS AND DISCUSSION

4.3.1 Grey water disposal

The survey revealed that the mean water use within the sample population was 27*l* (±23) per person per day, which was only slightly more than the 24*l* per person per day reported

Figure 4.1: A section of the storm water canal at the YWAM monitoring site (indicated as number 8 on Figure 2.2) where grey water drains from a street next to an informal settlement into the storm water canal.

by Carden *et al.* (2005) but a great deal lower than in a developed country such as Sweden (200*l* per person per day) (Källerfelt & Nordberg, 2004). Of the 27*l* of water used per person per day, based on the values provided by Carden *et al.* (2005), it was estimated that the mean production of grey water within the catchment was 21*l* per person per day (Figure 4.2), or a total of 95m^3 of grey water per day for those who live within the non-sewered areas of the catchment. This figure was based on 1134 households (Statistics SA, 2003) with an average of 4 people per household (±2.3). The majority of residents (57%) disposed of their grey water directly into the environment, either in open spaces (26%) (backyards, parks, side walks etc.) or on the road (31%) (Figure 4.3). Therefore, the estimated amount of grey water that was discarded directly into the environment and potentially reached the storm water system in the Jeffreys Bay catchment and, subsequently, the marine environment was estimated as 54m^3 per day.

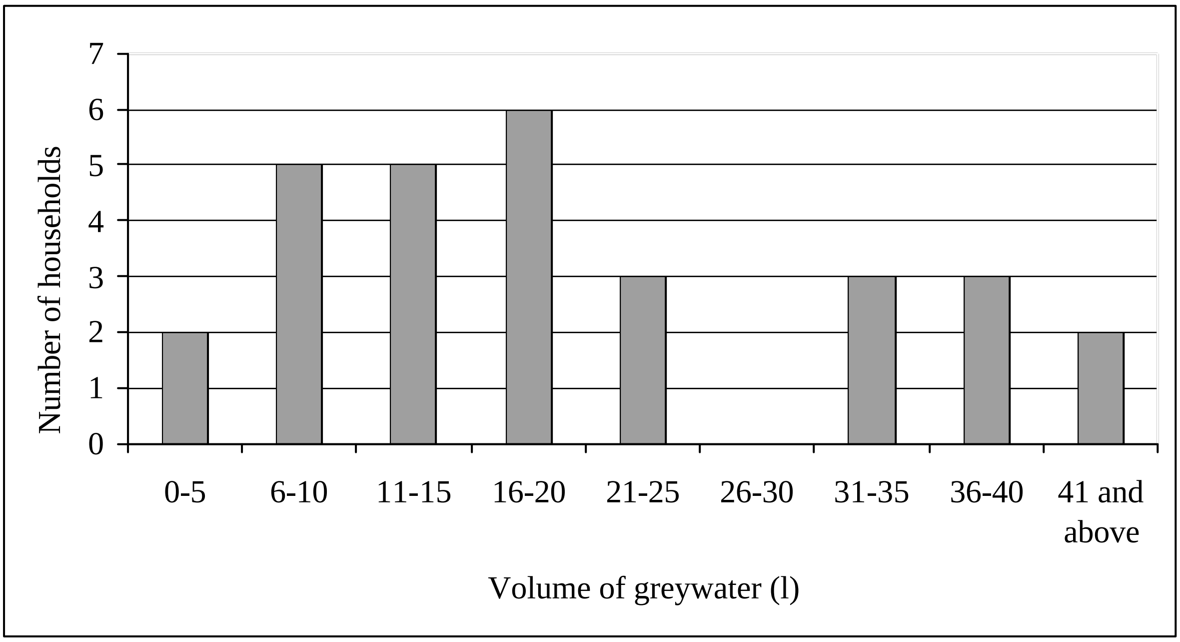


Figure 4.2: Estimated volumes of grey water produced per person (n = 29).

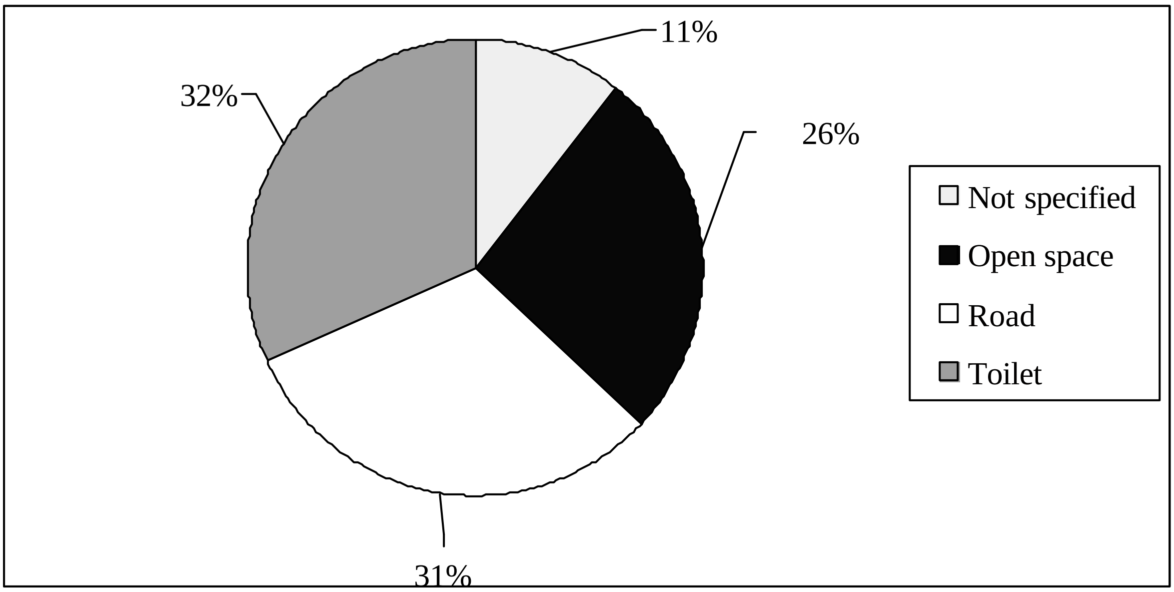


Figure 4.3: Disposal routes for grey water from the sample population within the non-sewered areas of the study area (n=30).

The average nutrient (Total Kjeldahl Nitrogen, phosphate and ammonia) load of grey water from developing communities was reported to be 78.7mg/l by Carden *et al.* (2005).

Therefore, according to the estimated volume of grey water discarded into the open environment of the catchment (54.3m³/ day), it was predicted that 4.27kg of nutrients could potentially enter the local environment per day. Wood *et al.* (2001) however stated that where grey water was mainly discarded into the open environment, it would either infiltrate the ground or flow into surface water bodies. In surface water bodies some of the nutrients could be taken up by natural processes such as algal blooms (Finkl & Krupa, 2003; Dorfman, 2004), and therefore not all of the estimated 4.27kg of nutrients that entered the open environment would necessary reach the marine environment. Nonetheless, this was considered as an indication of the pollution potential of grey water to the near shore marine environment. Another popular (32%) route for the disposal of grey water was via the communal waterborne toilets (Figure 4.3). Since the grey water was being diverted to the sewer, this could be considered an safer option with respect to human and environmental health compared to discarding of grey water into open areas or the road where it poses a potential public health and storm water contamination risk.

Eriksson *et al.* (2002) however warned that pathogens contained in grey water could become airborne and pose a health risk if grey water is used during the flushing of toilets. Typical pathogens found in grey water include *Salmonella* and *Campylobacter,* which may cause gastro-intestinal diseases (Ottoson & Stenström, 2003). This was one of the reasons why grey water received a significant rating during the RA which was supported by high microbiological counts (18 000 cfu/ml *E. coli* and 105 000 cfu/ml faecal coliforms on the 20^{th} of June 2005 and 1 290 000 cfu/ml faecal coliforms on the 7^{th} of October 2005) where grey water entered the storm water canal (YWAM monitoring station indicated as number 8 on Figure 2.2). An additional problem associated with the disposal of grey water via communal toilets is that these facilities are often blocked (Pretorius & de Villiers, 2003) and therefore users may be exposed to pathogens from waste water when the units overflow. Thus, while disposal of grey water into the toilet system may be preferable to disposal into public spaces, there are certain potential hazards associated with this practice that need to be considered when developing a waste management plan for the catchment area.

During the survey the Kouga Municipality's representative remarked that there were no procedures in place for the management of grey water and the representative did not consider grey water to be an environmental or health problem. Contrary to the representative's statement, the monitoring of the grey water outlet revealed that grey water flowed into the storm water canal 82% of the time and, taking into account the estimated grey water discarded into the environment (54m³/ day) and the water quality at the YWAM monitoring station, it can be concluded that grey water disposal practices in the non-sewered areas posed a significant potential pollution threat to storm water and potentially the marine environment. Only two of the residents mentioned that they reused grey water to wash the floor of their homes before discarding it into the environment. This practice could result in a further increase of polluting agents in grey water even though the practice of reuse could result in a reduced volume of grey water being produced by households. Other practices of grey water reuse mentioned in literature included the reuse of grey water for toilet and urinal flushing (Eriksson *et al.*, 2002) as well as "…washing of vehicles and windows, fire protection, boiler feedwater and concrete production…" (Santala *et al.*, 1998 cited in Eriksson *et al.*, 2002). However, treatment of grey water before reuse is suggested and could include the removal of solids by means of filtration and the reduction of pathogens by means of storage in detention ponds and/ or chlorination (Al-Jayyousi, 2004).

The re-use options from developed countries are, however, probably not applicable to less developed communities, such as that in the Jeffreys Bay storm water catchment, due to the cost of the treatment of the grey water prior to reuse. Perhaps more appropriate is the use of grey water for irrigation and the growing of food (Al-Jayyousi, 2004) although Carden *et al.* (2005) stated that people distrust the use of grey water to irrigate gardens due to the perceived low quality of the water. This was in line with the Jeffreys Bay study where none of the interviewees was using grey water as a means of irrigation and 57% of the respondents stated that they would not consider using grey water on a garden because the water was perceived to be 'dirty'.

4.3.2 Sewage disposal

The survey revealed that 87% of the sample population were using communal flush toilets, 10% were using private flush toilets and 3% of the sample population were using a bucket inside their home (Figure 4.4). The survey also revealed that 69% of those using the communal toilets experienced problems with these facilities. This was consistent with literature where it was stated that many townships experience constant problems with communal ablution facilities (Berry, 2000; Wood *et al.*, 2001). The problems the local community experienced with the public ablution facilities included the following (listed in order of significance according to the sample population's response):

- the toilets were always dirty (31%);
- the toilets were regularly broken (16%);
- the toilets were always wet inside (13%);
- there were not enough toilets for everyone (13%);
- the toilets were frequently blocked with newspaper and rocks (9%);
- the toilet doors could not lock (6%);
- the toilets were unsafe to use especially at night (6%);
- the toilets were cold in winter due to broken windows (3%), and
- the toilets smelled (3%).

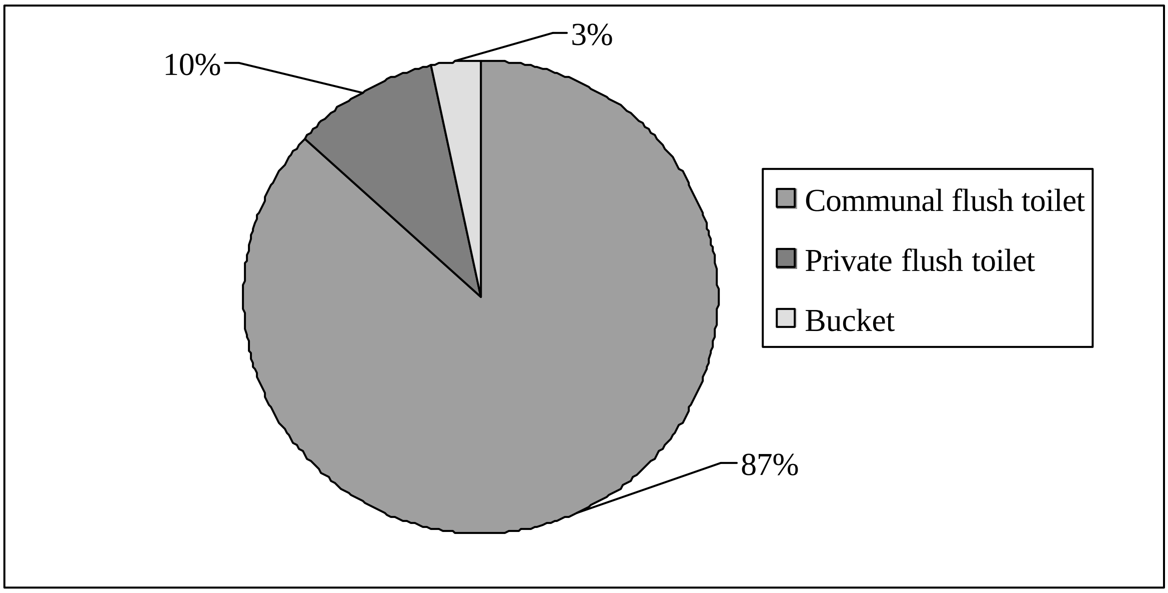


Figure 4.4: Types of toilets used by the sample population in the storm water catchment (n=30).

Pretorius and de Villiers (2003) stated that many of the problems associated with broken and blocked toilets within the underprivileged communities could be overcome with sufficient education. Community education needs to focus on the risks involved with insufficient sewage disposal as well as the correct use of facilities. The Kouga Municipality's representative remarked that there were currently around 40 communal toilets within the informal sector of the storm water catchment. Currently these toilets (20 flush and 20 chemical toilets) were the only communal sewage disposal technology being used in the informal settlements within the catchment. The representative stated that the municipality inspected these toilets once a day during which time they normally found approximately five toilets that were broken. The most common causes for broken toilets were considered to have been vandalism and the use of newspaper or solid objects instead of toilet paper. He further stated that they did not have a vehicle to regularly remove the full buckets from the chemical toilets and that the roads separating the informal homes made accessibility very difficult. This, according to the representative, resulted in buckets not being regularly collected, which was the main complaint that they received from the community.

Based on data from the current study, the ratio of toilets to households living in non-sewered areas was estimated at 28:1 and the representative agreed that the ablution facilities were not sufficient to serve the community. This situation did not conform to the first goal of the 'Strategic framework for water services' (DWAF, 2003), which states that "All people living in South Africa have access to an appropriate, acceptable, safe and affordable basic water supply and sewage disposal service." The only possible solution the representative saw to the sewage disposal dilemma was the provision of homes and waterborne sewage disposal for all the residents. Their short-term mitigation included the provision of chemical toilets, which was very costly (R10 000 per month), and at present the municipality did not have sufficient funding to expand or even continue this service. The representative did not know if sewage disposal could be provided for half the residents of the informal settlements by 2015 as required by the United Nation's millennium development goals. The progress on meeting this millennium development goal in Sub-Saharan Africa received a "no access and no change" status with the latest United Nations progress report (United Nations Department of Economic and Social Affairs & United

Nations Department of Public Information, 2004) which was reflected in the state of Jeffreys Bay's sewage disposal.

Even though no one that was interviewed in the community admitted to the use of open areas for ablution, 23% of the sample population stated that when the communal toilets were broken or very dirty they would use a bucket at home, walk to communal toilets in other areas, or go as far as the Main Beach in order to use the public toilets. However, the municipal representative stated that informal ablution was seen as a problem. DWAF (2001b) stated that where sewage disposal was insufficient, it was likely to have a negative impact on human health, including "…diarrhoea, dysentery, typhoid, bilharzias, malaria, cholera, worms, eye infections, skin diseases, increased risk from bacteria, infections and disease for people with reduced immune systems due to HIV/Aids". DWAF (2001b) went on to say that improving the sanitary conditions of a community would greatly reduce the public health risks.

Apart from the negative impacts on human health, inadequate sewage disposal can result in the pollution of receiving waters (Austin & van Vuuren, 2001). Koné and Strauss (2004) stated that there is a welcoming shift from centralized to decentralized sewage disposal management within the cities of the developing world. They go on to say that on-site treatment of sewage can aid in overcoming the many problems regarding the disposal and treatment of sewage. Based on information received from the various stakeholders, the current state of sewage disposal in Jeffreys Bay is far from the desired status as described by the 'Strategic framework for water services' (DWAF, 2003) (Table 4.1), and therefore poses a potential pollution threat to the local terrestrial and marine environment and to the health of the local community.

4.4 CONCLUSIONS

The RA indicated that sanitation (grey water and sewage disposal) within the Jeffreys Bay storm water catchment posed a threat to human and environmental health. Further investigation provided some original insight regarding sources and causes of pollution within the catchment. The key findings of this chapter may be summarized as follows:

Table 4.1: A comparison of the state of sanitation services in the study area with the sanitation goals of the 'Strategic framework for water services' (DWAF, 2003).

Justification	**Status in Jeffreys Bay**	**Cause**	**Requirements**	**Stake holders in Jeffreys Bay**
"All people living in South Africa have access to an appropriate, acceptable, safe and affordable basic water supply and sewage disposal service."	Not met	A lack of ablution facilities. It is estimated that there are 40 toilets for 1134 residents living in informal homes.	Finance, Infrastructure	Local government, Business, Community
"All people living in South Africa are educated in healthy living practices (specifically with respect to the use of water and sewage disposal services) and the wise use of water."	Not met	The problem of abuse and over-use of communal toilets resulting in broken and blocked ablution facilities points towards a lack of education within the community.	Finance, Education	Local government, Business, Community
"Water and sewage disposal services are provided; equitably (adequate services are provided fairly to all people), affordably (no one is excluded from access to basic services because of their cost); effectively (the job is done well); efficiently (resources are not wasted); sustainably (services are financially, environmentally, institutionally and socially sustainable); and gender sensitively (taking into account the different needs and responsibilities of women and men with regard to water services and sewage disposal)".	Not met	Even though sewage disposal is provided free of charge in Jeffreys Bay there are associated problems for example dirty, broken and blocked toilets that do not allow for an efficient service. Inadequate sewage disposal poses an environmental threat with no cost to the user placing the sustainability of the service under question. Women in particular feel unsafe to use the toilets (especially at night), which does not allow for gender sensitivity of the provided facilities.	Finance, Education, Infrastructure	Local government, Business, Community

Table 4.1 continued.

Justification	Status in Jeffreys Bay	Cause	Requirements	Stake holders in Jeffreys Bay
"The prices of water and sewage disposal services reflect the fact that they are both social and economic goods (that is, pricing promotes access to a basic safe service, encourages the wise and sustainable use of resources and ensures financial sustainability)."	Not met	Currently there is no cost involved for residents to use ablution facilities, which does not encourages careful use or financial sustainability.	Finance, Education, Infrastructure	Local government, Business, Community
"Water and sewage disposal services are effectively regulated with a view to ensuring the ongoing achievement of these goals."	Not met	The status of sanitation management in Jeffreys Bay and the management plans in place in order to meet the abovementioned goals are not effectively regulated. Taking into account the rapid growth of South Africa's urban areas, an increased effort is required to assist South African municipalities to manage their water resources (Pretorius & de Villiers, 2003).	Finance, Education, Infrastructure	Local government, Business, Community

- It was estimated that a total of 24m³ of grey water was being produced within the informal residential sector of the catchment per day. Most of the grey water was being disposed of into open spaces (58%) where it posed a health and environmental threat. The local storm water system could potentially convey the grey water from the point of disposal to the marine environment and while the quality of the grey water was regarded as sufficient to have had an impact on storm water quality, the magnitude of impact on the marine environment was not known;
- The survey revealed that the sanitation situation within the informal area of the catchment was indeed inadequate. The informal sector within the catchment were provided with 40 communal toilets, which allowed for a 28:1 toilet to household ratio. The insufficient number of toilets appeared to be the primary cause of problems, although the community's awareness of the correct use of the facilities was also problematic;
- Informal ablution was considered problematic, and was thought to have been primarily the result of inadequate ablution facilities for the residents living in non-sewered informal homes;
- The lack of sewage disposal and grey water management did pose a human and environmental health threat.

The municipality's short term plans did not show much promise to meet the sewage disposal demand and effective management of grey water in order to minimize the impact on the receiving environment. Their long-term plan was to provide housing with waterborne sanitation for all. However, with a growing coastal population and municipalities in South Africa in general not being able to meet the goal of building houses for the masses, the feasibility of providing full waterborne sanitation for all must be questioned. As this appeared to be the only measure considered to address sanitation in the Jeffrey Bay storm water catchment, the negative impacts on local freshwater and marine environments are likely to persist unless alternative strategies are investigated.

The municipality's proposal of waterborne sewage systems ignores common knowledge that South Africa is a "water stressed" country, as well as additional negative environmental implications such as combined storm water and sewer overflow. Alternative sanitation options are available and will be considered as part of the integrated waste management plan for the Jeffreys Bay storm water catchment proposed in the next chapter. The challenges facing sanitation management in Jeffreys Bay, regarded as institutional, social and educational, will need to be considered.

CHAPTER 5

DEVELOPMENT OF AN INTEGRATED WASTE MANAGEMENT PLAN FOR THE STORM WATER CATCHMENT

5.1 INTRODUCTION

Previous chapters provided evidence that solid waste, grey water and informal ablution posed a threat to human and environmental health and, potentially, the marine environment in Jeffreys Bay. Storm water was considered the primary link between terrestrial pollution sources and the marine environment although based on available data, attempts to correlate storm water and marine water quality were inconclusive. Nevertheless, a precautionary approach was adopted and it was decided to apply the tools and principles of integrated environmental management (IEM) to address the potential sources of land-based marine pollution within the Jeffreys Bay storm water catchment. It was decided to formulate an Integrated Waste Management Plan (IWMP) considering the limitations and root causes of inadequate waste management in the study area as opposed to a broader Environmental Management Plan (EMP) as described within the IEM process (Fuggle & Rabie, 1992). The IWMP was based on immediate short-term and longer-term mitigations that were needed. It was envisaged that short-term mitigations would be aimed at improved management of waste to reduce entry to the storm water system and that the longer-term initiatives would concentrate on the prevention, reduction or recycling of waste at its source.

Mitigation measures, defined by DEAT (1998) as "measures designed to avoid, reduce or remedy adverse impacts", could include both technical and behavioural aspects that required willing participation and support of communities if they were to be successful (Dunmade, 2000). Community-based approaches are often more desirable than engineering mitigations as they can be seen as "…solutions (or projects) that could be implemented by local people, managerially and technically, which implies empowerment, participation and resource mobilization from various sources" (Mongkolnchaiarunya, 2003). While the primary goal of the current project was to reduce land-based marine pollution at Jeffreys Bay, the most effective and sustainable way to achieve this would potentially be to address the immediate concerns of the affected community regarding waste management. Mitigation measures need to be chosen carefully to ensure no secondary impacts are created during the implementation phase (Morris & Therivel, 2001) and that buy-in from all interested and affected parties (I&APs) is achieved. Therefore a very important part in the process of choosing appropriate mitigation measures is the participation of those concerned, in particular those whose lives will be directly affected by the decisions made (Berry, 2000; UNEP - IETC, 2004). This is a modern tendency in development decision-making, and a more self-governing system that could result in more 'buy-in' from the community (De Beer, 2002).

The use of public participation in establishing waste reduction initiatives can exist at different levels. The first is to gain insight into proposed mitigation measures by evaluating opinions and suggestions made by the I&APs (UNEP - IETC, 2004). The second level is the importance of choosing initiatives with maximum participation of the community. A study in Turkey showed that more than 80% of the sample population was willing to take part in community-based waste management projects (Metin *et al.*, 2003). This willingness of people to be part of managing their environment can be channelled into initiatives that improve the basic services and the process of environmental management. In India a study showed that in areas where the local community where not involved in waste management, it resulted in negative environmental impacts (Dahiya, 2003). The same results were obtained after studying the environmental impact assessment (EIA) experience for 15 years in the Philippines, where many problems were rooted in inadequate public participation (Lohani *et al*, 1997). South African legislation makes provision for the public participation process within the environmental management guideline documents (DEAT, 1998). In these guidelines it is suggested that insight from the public needs to be gained during the mitigation of impacts. It is furthermore stated that public participation is the cornerstone for developing and implementing the White Paper for Integrated Pollution and Waste Management in South Africa (DEAT, 2000).

Chapter 1 described barriers to waste management which need to be considered when preparing a mitigation strategy (Dunmade, 2002). The objective of this part of the study was to develop a local IWMP in order to address the pollution within the Jeffreys Bay storm water catchment based on the principals of public participation. This IWMP was specifically aimed at the reduction of storm water pollution by solid waste, sewage and grey water disposal within the catchment. In order to create an effective IWMP the following research questions had to be answered:

- What opportunities existed for integrated management (prevention, reduction, re-use and recycling) and potential beneficiation of solid waste, grey water and sewage within the catchment?
- Were the potential alternatives that were identified favoured by the various community stakeholders?
- To what extent were community members able/ willing to contribute to the implementation and maintenance of identified mitigations?
- What were the potential barriers to implementation of the above mitigations?
- Could potential short and long-term incentives be identified to improve the sustainability of the mitigations?
- Was the potential loss of Blue Flag status sufficient incentive to introduce measures to improve the quality of storm water at Jeffreys Bay?

5.2 METHODOLOGY

5.2.1 Identification of mitigation measures

Several methods were combined to identify the best possible measures for integrated management (reduction, re-use and recycling) and potential beneficiation of solid waste, grey water and sewage within the catchment. From a review of the relevant literature, which is incorporated into Chapter 1, a list of potentially suitable mitigation measures were identified for each significant aspect. These mitigation measures represented a wide field of disciplines and were drawn from international as well as South African case studies. A method of comparative analyses (Mentis, 2004; Bracken *et al.*, 2005) was used to screen all potential measures and eliminate inappropriate mitigation measures. This method involved the assessment of the strengths and limitations for each alternative mitigation measure within the local context. In order to conduct this screening a custom set of criteria and indicators were used by which alternative mitigations were judged (Table 5.1). For each of the above-mentioned criteria, a score was awarded. A value of one indicated that a mitigation measure was perceived as favourable and zero perceived as poor.

5.2.2 Public participation process: Survey

The semi-structured interview method described in Chapter 3 was also used to engage with I&APs regarding potential mitigation measures. The same sample population was used to gain insight from the local community while a representative of the Kouga Municipality and a representative from the Jeffreys Bay business community provided additional input. Questions 22, 23, 28, 29, 31 to 33 (community questionnaire; Appendix A), 9 (municipal questionnaire (solid waste); Appendix B), 15 and 16 (municipal questionnaire (sanitation); Appendix C) were aimed at identifying to what extent the various community stakeholders favoured the potential alternatives.

The potential barriers to implementation of mitigations were determined by means of questions 24 (community questionnaire; Appendix A), 9 (municipal questionnaire (solid waste); Appendix B) and 16 (municipal questionnaire (sanitation); Appendix C). The extent to which community members were able/ willing to contribute to the implementation and maintenance of identified mitigations was determined by means of questions 18, 30, 34, 35 (community questionnaire; Appendix A), while questions 15 (municipal questionnaire (solid waste); Appendix B), 3 and 8 (business community questionnaire; Appendix D) were aimed at investigating if potential short and long-term incentives could be used to improve the sustainability of mitigations. Questions 36 to 40 (community questionnaire; Appendix A), 18 to 20 (municipal questionnaire (sanitation); Appendix C) and 4 to 7 (business community questionnaire; Appendix D) were aimed at investigating if the potential loss of Blue Flag status provided sufficient incentive to introduce measures to improve the quality of storm water at Jeffreys Bay.

Table 5.1: Criteria and indicators for the comparative analyses of various mitigation measures (modified from Bracken *et al.*, 2005). These criteria were used as an initial screening of potential mitigation measures.

CRITERIA	INDICATOR
Cost	
Financial costs to implement and sustain the mitigation.	Low initiation and maintenance cost = 1 High initiation and maintenance cost = 0
Difficulty	
Skills required to implement and sustain the mitigation.	No/ limited skills = 1 Tertiary qualification/ specialised skills = 0
Socio-economic	
The potential of the mitigation to provide return such as income, employment or fresh produce to the previously disadvantaged community.	Generate return = 1 Generate no return = 0
Environment	
The potential of the mitigation to protect the environment at large.	Protection at source = 1 Protection end-off pipe = 0
Acceptability	
The probability of the mitigation measure being excepted by I&APs due to financial, institutional, legal, cultural or convenience reasons.	High probability = 1 Low probability = 0
Institutional requirements	
The potential for the mitigation to function without local government involvement.	No involvement = 1 Involved = 0

5.3 RESULTS AND DISCUSSION

5.3.1 Descriptive model

The information from the previous chapters was used to form a descriptive model (Figure 5.1) to illustrate the impacts of aspects on storm water quality and, potentially, the marine environment. The value of this model was that it provided a simplified overview of the waste streams and impacts and facilitated the identification of points where mitigation measures could be implemented within a relatively complex system. The model illustrated the findings that both sanitation (grey water disposal and informal ablutions) and solid waste posed a direct threat to human health and the quality of storm water, and an indirect threat to the marine environment.

Furthermore, these threats were primarily linked to domestic houses rather than the light industry within the catchment. Certain direct and indirect impacts on the socio-economic status of the town were also indicated on the model and highlighted the complexity of the waste management problem even on this relatively small scale. Potential mitigation measures included education (Ed), engineering (Eng) and community-based (Comm) interventions and could be applied at many different points of the waste distribution pathway. By considering the various pathways and impacts of the waste streams, it was possible to identify points of mitigation, usually closer to the source, that were likely to have most significant positive impact within the study site. Those points of mitigation with limited positive impact could also be identified, thus assisting in the screening of potential mitigation options.

5.3.2 Identification of mitigation measures

The descriptive model (Figure 5.1) indicated the potential points and broad categories (education, engineering and community-based initiatives) of mitigation that may have assisted in the prevention or reduction of pollution sources from having an impact within the catchment area and the adjacent marine environment. Based on a literature review, more specific potential mitigation measures were assigned to each significant aspect. Where possible the measures chosen incorporated, or could be linked to, some form of non-legislative incentive to facilitate empowerment and increase buy-in from the

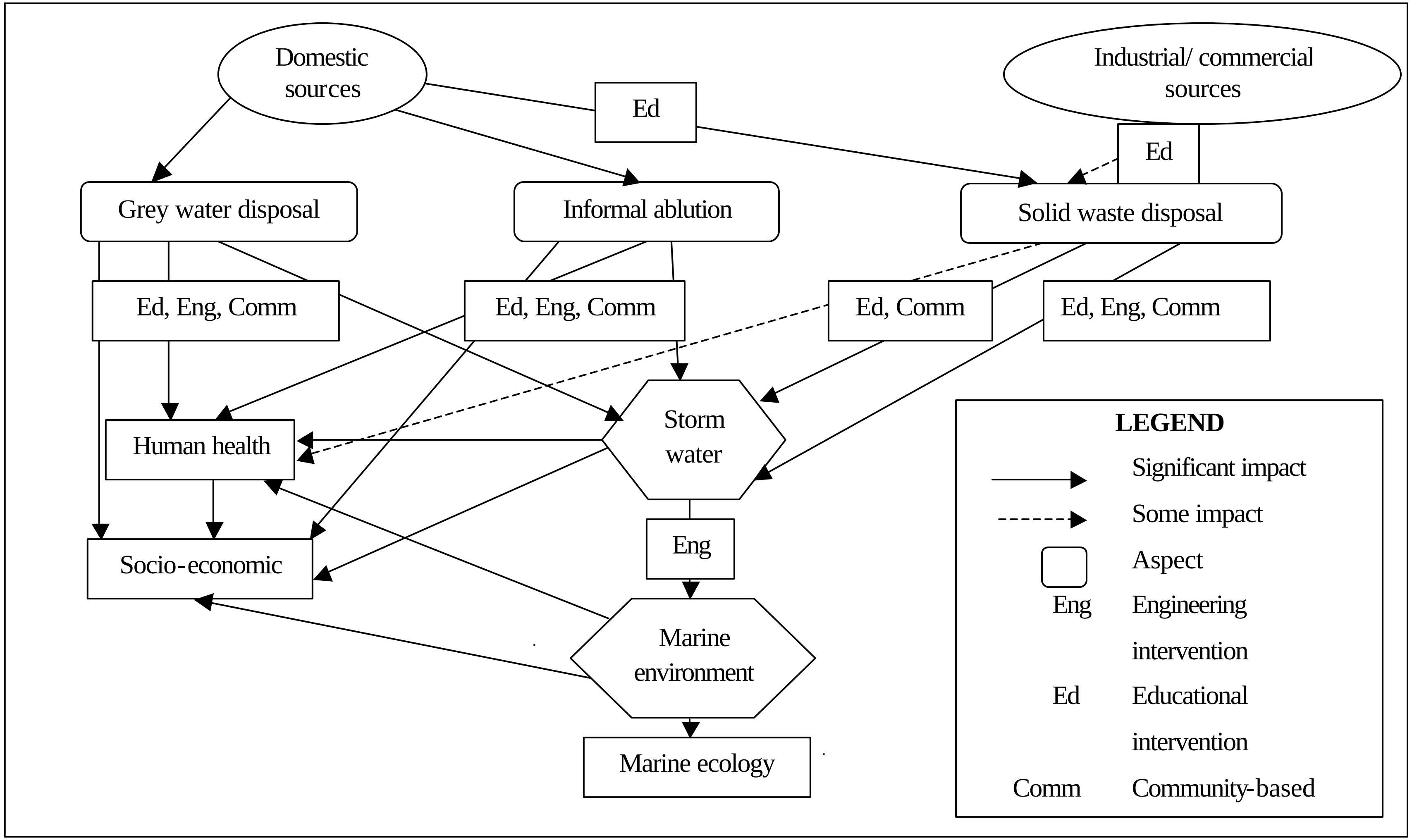


Figure 5.1: Descriptive model of the potential risks posed by various waste-related activities within the storm water catchment in Jeffreys Bay and potential points and types of mitigation.

community. Both were considered essential to the long-term sustainability of the waste management plan. Where community-based approaches were not possible, engineering interventions were considered. However, these end-of-pipe type mitigations were not regarded as ideal since symptoms, and not the root causes of the problem, were being addressed. The initial literature-based survey lead to the identification of 13 interventions that could be used to address waste management issues in the Jeffreys Bay catchment. The various mitigation measures are summarized below.

5.3.2.1 Solid waste disposal

(a) *Community-based composting (Comm, Ed)*. Community contributes organic waste, which is then composted. Funds obtained could then be used to support solid waste removal services (Palmer Development Group, 1996; Zurbrügg *et al.*, 2002; Dahiya, 2003).

(b) *Community-based recycling (Comm, Ed)*. Community separates their waste for recycling purposes. Funds obtained from the sale of recycled items are then used for solid waste removal services (UNEP, 2000a).

(c) *Gross Pollution Traps (Eng)*. Grids used to prevent solid waste from entering storm water pipes (Mackay, 1994; Marais & Armitage, 2004).

(d) *One-man-contract (Comm)*. A contract that employs a member or members from a previously disadvantaged community to collect refuse from each dwelling to a central collecting point (Palmer Development Group, 1996; Earthyear, 2001; Wood *et al.*, 2001; Dahiya, 2003; Kaseva & Mbuligwe, 2005).

(e) *Waste exchange program (Comm)*. Community exchange waste for food or money (Palmer Development Group, 1996; Mongkolnchaiarunya, 2003).

5.3.2.2 Grey water disposal

(a) *Mulch bed (Comm, Eng)*. Grey water can be diverted into a shallow pit filled with gravel at the bottom and leaves on top. The microbes aid in the decomposition of organic material contained in the grey water and the gravel aids in the evaporation of the grey water. Trees can be planted to aid in removal of excessive grey water (Källerfelt & Nordberg, 2004).

(b) *Soak-away (Eng)*. Specifically designed drains that allow for grey water from informal settlements to flow into the sewerage (Wood *et al.*, 2001).

(c) *Tower garden (Comm, Ed).* A bag filled with soil, allowing for the growth of vegetables along the sides, which is irrigated with grey water deposited down a soak-away center (Crosby, 2004).

5.3.2.3 Informal ablution

(a) *Pay-and-use latrine (Comm).* A public water-borne latrine facility that is maintained by a member from the community. Users of the facility pay the community member who is appointed (Wood *et al.*, 2001).

(b) *Urine diversion toilets (Comm, Eng, Ed)*. Environmentally-responsible (if used correctly) latrines that separate liquids from solids (Austin & van Vuuren, 2001).

5.3.2.4 General mitigations

General mitigations were considered to be measures that may have assisted in the prevention or reduction of pollution from all the significant pollution sources.

(a) *Education (Comm, Ed)*. Creative methods can be used to educate the community on pollution reduction. These can include youth programs, community clean-up days, cleanliness competitions, distribution of pamphlets and slide- or video shows (Palmer Development Group, 1996; Zurbrügg & Ahmed, 1999; Derraik, 2002; Pretorius & de Villiers, 2003; World Summit Publication, 2002).

(b) *Wetlands (Comm, Ed)*. These are natural buffer zones, consisting of vegetation and ponds specifically designed to intercept pollutants (Berry, 2000; Wood *et al.*, 2001; Koné & Strauss, 2004; Schuyt, 2005). Plants such as cocoyams and sugarcane can be cultivated in restored wetlands as a means of income generation (Grobicki, 2002; Schuyt, 2005).

(c) *First-flush bypass sump (Eng)*. An engineering mitigation that is designed to divert the base flow after a rainstorm to a sewage treatment facility (Mackay, 1994).

All 15 mitigations were subject to an initial screening process (Table 5.2) in order to rule out those that would be unlikely to be sustainable or achievable in the local context. The criteria against which the mitigations were assessed are described in detail in 5.2.1. and were all based on a desktop study. The highest scoring mitigation measure for each aspect was thought to be potentially appropriate to include in a IWMP to address the issue of storm water quality and land-based marine pollution in Jeffreys Bay. The results of the preliminary screening process are discussed below.

5.3.3. Preliminary screening of mitigation measures

5.3.3.1 Solid waste disposal

Community-based composting, community-based recycling, gross pollution traps, one-man-contract and a waste exchange program were identified as potential mitigations measures to address the issue of solid waste pollution within the storm water catchment. Community-based composting and recycling where separation is done at household level requires acceptability of the community and a high level of supervision (Ojeda-Benitez, 2003). These measures do not require a high level of skill but as suitable (economically viable) markets for the products (compost and recyclable materials such as glass and paper) do not always exist, long-term external funding may be required to support the initiatives (Palmer development group, 1996; Horan pers. comm., 2005). Therefore the acceptability rating for this intervention was low.

Establishment of a community-based composting operation can be as costly as R500 000 for a medium size town (Horan pers. comm., 2005), while alternative recycling ventures that require less capital equipment are often less expensive. Community-based composting and recycling would however successfully reduce the quantity of waste that would otherwise be discarded into the environment (Mohee, 2002) and could have socio-economic advantages for those who sell recyclable material (Kaseva & Gupta, 1996). It can furthermore be argued that composting or recycling would not necessarily reduce pollution unless sufficient solid waste collection and disposal measures were in place, and that the associated facilities adhered to environmental best practice. Waste exchange programs have the potential for effective waste

Table 5.2: Comparative analyses of the identified mitigation measures. 0 = Poor: 1= Favourable.

Mitigation	Cost	Difficulty	Socio-economic	Environment	Supervision	Acceptability	Total
Solid waste disposal							
Community-based composting	0	1	1	1	0	0	**3**
Community-based recycling	1	1	1	1	0	0	**4**
Gross pollution traps	0	0	0	0	0	0	**0**
One-man-contract	1	1	1	1	1	1	**6**
Waste exchange program	0	1	1	1	0	0	**3**
Grey water disposal							
Soak-away	0	0	0	1	1	0	**2**
Tower garden	1	1	1	1	1	1	**6**
Mulch bed	1	1	1	1	1	0	**5**
Informal ablution							
Pay-and-use latrine	0	1	1	0	0	0	**2**
Urine diversion toilets	1	1	1	1	1	0	**5**
General mitigations							
Education	0	1	1	1	1	1	**5**
First-flush bypass sump	0	0	0	0	0	0	**0**
Wetland rehabilitation	1	1	1	0	0	1	**4**

disposal and socio-economic empowerment, but these initiatives demand a high level of supervision and acceptability by the community, which have not always been the case in pilot studies (Palmer development group, 1996; Mongkolnchaiarunya, 2003). These initiatives have involved problems, for example corruption (Palmer development group, 1996), but only limited skill is required to conduct such a venture. The cost of running such a project was thought to be high with continual finances needed from either local government or external funding.

An end-of-pipe engineering mitigation such as gross pollution traps could be successful in reducing litter entering the storm water system and the marine environment (Mackay, 1994; Marais & Armitage, 2004). Such engineering mitigations are however expensive and require skilled labour to construct which may not make them acceptable to financially constrained South African municipalities. These measures also require regular supervision to prevent breakdown (Mackey, 1994; Källerfelt & Nordberg, 2004). Except for a few job opportunities being created during the building phase and improvement in community health, these initiatives were not considered to have any long-term socio-economic benefits. One-man-contracts on the other hand has proven acceptable in developing countries for example India (community funded) (Dahiya, 2003) and South Africa (local government funded) (Earthyear, 2001) as it is a more effective, convenient and financially viable method than traditional municipal cleansing. The method furthermore allows for socio-economic empowerment by means of job creation (Earthyear, 2001) and a definite improvement in the environment opposed to the waste skip method (Nel pers. comm., 2005). Case studies have shown these initiatives to be self-sustaining by means of communities paying a small fee for the removal of solid waste from their homes and community committees being responsible for the management of the scheme (Dahiya, 2003).

5.3.3.2 Grey water disposal

For the problem of informal grey water disposal various mitigation measures were suggested, for example treatment (Al-Jayyousi, 2004) and reuse (Eriksson *et al.*, 2002) as well as constructed wetlands (Dallas *et al.*, 2004). These were however large scale engineering interventions and not considered suitable for informal settlements that mainly exist illegally. The soak away was also regarded as an engineering intervention of a smaller scale that was suggested in literature as a means of addressing informal grey water disposal in informal settlements (Wood *et al.*, 2001). This mitigation received low ratings in the screening process due to skilled labour and high costs required for implementation. Except for the creation of a few job opportunities during construction, this intervention would create no work in the future. This intervention could also prove to be unfavourable with local government due to high costs and, since the informal settlements in Jeffreys Bay exist illegally and there are plans to relocate the people in the future, local government would not be willing to construct any permanent facilities. This intervention did however receive a favourable environmental rating since a soak-away would address the problem of informal grey water disposal at source and the supervision of this intervention would also be minimal.

Mitigations that received a favourable evaluation to address the issue of grey water at source were the tower garden and mulch bed. Both the tower garden and the mulch bed are relatively easy to build, can be built at a very low cost with readily available material and do not require supervision from local authorities since the intervention is maintained at household level. The tower garden and mulch bed could also result in less grey water being discarded into the open environment at source. In the case of the tower garden, grey water can be used to grow vegetables, and fruit trees can be planted next to the mulch bed which will take up excessive grey water with consequent socio-economic benefit. The benefit of using the tower garden over simply irrigating vegetables (root vegetables not suitable) with grey water, is that the soak-away center of the tower garden allows for grey water to be applied to the roots of the vegetables (Crosby, 2004), whereas basic application of grey water would allow it to come into contact with the vegetables and thereby pose a greater health risk. Health risks associated with tower gardens have not been fully established and until is has, training and supervision on the correct use of tower gardens to minimize health risk will be essential. The results of the survey, which was discussed in Chapter 4, showed that 57% of the people in Jeffreys Bay would not consider using grey water to irrigate a garden. Crosby (2004) showed however that after people were educated and shown that vegetables could be grown from grey water, their scepticism subsided. Therefore, this measure was given an acceptable rating not only due to the fact that these non-permanent low-cost structures would be more acceptable to local government, but also by the local community once they had received appropriate education. The mulch bed received a less favourable rating in the acceptability category than the tower garden due to the fact that the mulch bed occupies a relatively large surface area which is often not available in dense informal settlements, whereas to the tower garden, that is build in a vertical fashion, requires little horizontal space (Crosby, 2004).

5.3.3.3 Informal ablution

To mitigate informal ablution, the existing communal sanitation facilities could be upgraded to a 'pay-and-use' latrine system. This system does have the potential for socio-economic upliftment by the work created for un-skilled people that will be managing and cleaning the ablution facilities (Wood *et al.*, 2001). Maintenance of the toilets would be community funded, but local government would still be required to maintain the sewer. Cleaner public toilets could result in less people forced to defecate in the open environment although the results of the survey (Chapter 3) showed that communal ablution facilities were insufficient in number to meet the needs of the local community and even if they were clean, the impact on the level of informal ablution would probably have been limited.

Motivating people to build inexpensive urine diversion toilets at their homes could prove to be a solution to the informal ablution that was taking place in within the catchment. These toilets can be built at low cost (R200-R600) with unskilled labour and it has been proven that micro-entrepreneurs have benefited economically by building urine diversion toilets within communities (Holden, 2003). Urine diversion toilets allow for environmental protection due to the fact that there is no harmful sewage sludge that needs to be treated in a centralized facility (Austin & van Vuuren, 2001). The urine diversion toilets could be maintained without local government involvement, but it has been shown that these toilets are not always accepted by every community (Jackson & Knapp, 2005). Furthermore, the success and safe use of these systems is critically dependent on user education.

5.3.3.4 General mitigations

General methods to reduce storm water pollution that stood out as favourable during the evaluation, were the rehabilitation of the wetland and community environmental education. Wetlands are recognized as having the potential to increase water quality (Berry, 2000; Wood *et al.*, 2001; Koné & Strauss, 2004; Schuyt, 2005) and social and economic benefits (Schuyt, 2005) have been realised through the growth of cash crops (Grobicki, 2002) and use of the systems for aquaculture (UNEP, 2004). However, the wetland within the study site was located too high in the Jeffreys Bay storm water catchment to make a large impact on water quality. Nevertheless, the potential existed for schools to become involved in the general cleanup of the wetland, which would have significantly reduced costs and would have had exceptional environmental educational value. Due to a wetland's self sustaining capabilities, once restored the level of supervision would be low and, due to the high aesthetic value, it was likely to have been acceptable within the community.

Community education can take on various forms and needs to be incorporated into all community-based mitigations. Environmental education programs have proven to be very successful in protecting the environment (Derraik, 2002) and acceptable amongst communities as a means of socio-economic empowerment (Hill *et al.*, 2001 cited in Pretorius & de Villiers, 2003). For Jeffreys Bay, education appeared particularly appropriate since the survey (Chapter 3) revealed that the local community was not aware of the potential health and environmental impacts of poor waste management. The disadvantage to educational programs is that they tend to be costly (Fanshawe & Everard, 2002) and require skilled people to conduct, but if volunteers or funding were available no local government involvement would be required. The third general intervention, the first-flush bypass sump, was ruled out as unfavourable for the same reasons discussed for the gross pollution traps.

According to the comparative analyses, the potential mitigation measures that are appropriate to address the significant aspects Jeffreys Bay's storm water catchment were tower gardens to address grey water, urine diversion toilets to address informal ablution and one-man-contract waste removal to address solid waste pollution. Methods that would address all of the significant aspects to some extent were the rehabilitation of the wetland within the catchment and the initiation of an environmental education program. The problem with the comparative analyses thus far was that the positive and the negative aspects of the possible interventions were based on trials and case studies at other sites, and there was no specific information available for Jeffreys Bay. As discussed previously, implementation of any waste management strategy without community approval is likely to be unsuccessful. Therefore it was necessary to determine the acceptability of the proposed mitigation measures among the different I&APs within the greater Jeffreys Bay community. Of particular significance was the willingness of I&APs to contribute towards these initiatives. The results of the survey are discussed below.

5.3.4 Public participation process

Based on the above, the favourable interventions (tower gardens, urine diversion toilets, one-man-contract waste removal and the rehabilitation of the wetland) were evaluated through a questionnaire-based survey and were subjected to further investigation to assess the likelihood of success within the Jeffreys Bay storm water catchment. A more detailed description of the various technologies and the results of the survey are provided below.

5.3.4.1 Tower gardens

The building of tower gardens (Figure 5.2) as a disposal route for household wastewater was considered an appropriate measure for the mitigation of grey water and the provision of social and economic upliftment through food production. The building of the tower garden is described in Crosby (2004). According to this author it is important to build the tower garden as upright as possible, to prevent the water from running down the middle too fast and to flush the system with fresh water once a week. Education in the safe handling and application of grey water in this type of food production is very important. These systems are favourable for

Figure 5.2: Grey water soak-away of the tower garden type (Crosby, 2004).

the planting of aboveground leafy crop vegetables, which are not eaten raw (Crosby, 2004). Education must include the washing of hands after coming into contact with grey water and allowing sufficient time between irrigation and harvesting as well as cooking of all vegetables irrigated with grey water (Salukazana *et al.*, 2005).

The survey revealed that 73% of the sample population was interested in the tower gardens and that they were willing to construct such a system at their home. Those who were not interested foresaw problems such as vandalism, odour, animal damage, a lack of space, bad plant growth and the landlord's disapproval as potential barriers to implementation. Carden *et al.* (2005) also found that people were concerned that grey water would inhibit plant growth, although Salukazana *et al.* (2005) found a significant increase in plant growth when irrigated with grey water instead of tap water.

5.3.4.2 Urine diversion toilets

Urine diversion toilets were identified as a means to meet the sewage disposal backlog and thus decrease informal ablution that could lead to storm water contamination in Jeffreys Bay. Many different urine diversion systems have been developed over the years (Winblad & Simpson-Hébert, 2004). Holden (2003) describes in detail the building of a low-cost urine diversion system (Figure 5.3) that is easy to construct either indoors or outside and is popular with self-help initiatives (Austin & van Vuuren, 2001). In brief, this system allows for nutrient-rich urine to be diverted into a shallow soakaway where trees are planted to take up the excess nutrients (Holden *et al.*, 2003).

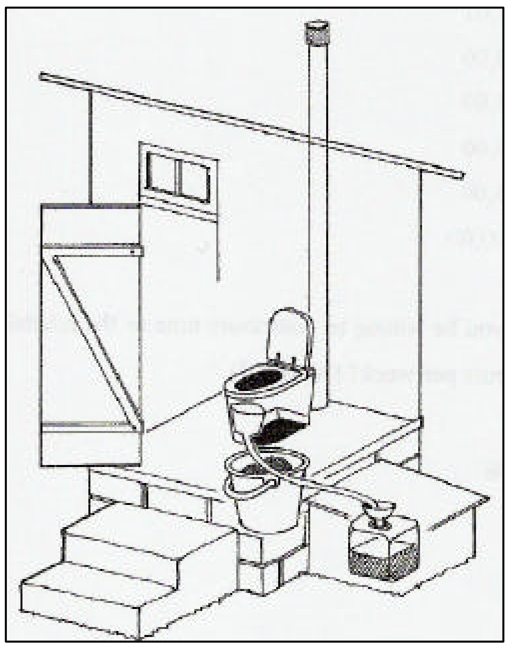


Figure 5.3: Urine diversion toilet (Winblad & Simpson-Hébert, 2004).

The faeces is collected in a bucket where wood ash and dry soil is added in order to aid in the drying of the material and the destruction of pathogens (Winblad & Simpson-Hébert, 2004). When the bucket is full the faeces is left to desiccate *in-situ* and once dry, can be burned or composted in a shallow pit (Holden *et al.*, 2003). After a period of six to 12 months the compost can be used as a soil enricher. The urine can also be collected and used as a fertiliser if carefully applied, instead of allowing the urine to drain down a soakaway (Austin & van Vuuren, 2001; Winblad & Simpson-Hébert, 2004). The survey also revealed that 76% of the sample population would consider using urine diversion toilets, even though only 63% would consider building such a facility at their home. This was mainly due to a lack of space and the fact that the land did not belong to them. The Kouga Municipality representative had never heard of urine diversion toilets but after a brief introduction to the concept, agreed that it was a possible solution to the sewage disposal backlog in the Kouga region.

The minimum cost of building a urine diversion toilet inside a home was estimated to be between R200 and R600, depending on the material being used. If it was decided to build the toilet outside, the superstructure could cost between R300 and R1800, once again depending on the material being used (Holden pers. comm., 2005a). 83% of those who were willing to build urine diversion toilets at their homes were not willing or able to contribute the minimum amount required to build such a facility. This figure was derived by means of adding the percentages (Figure 5.4) of those who would not or were not able to contribute more than the minimum amount of R200 (Holden pers. comm., 2005a) that was required to build a toilet. This echoed Holden pers. comm. (2005b) who stated that government's promise of free sewage disposal undermines any self-help self-pay sewage disposal option. Interestingly, one individual was willing to pay between R900 and R1000 for a urine diversion toilet (Figure 5.4) while 50% of respondents were not willing to contribute anything.

5.3.4.3 One-man-contract

It was thought that a more effective solid waste disposal system coupled with environmental education would result in less illegal dumping and littering. The one-man-contract solid waste removal system was thought to be appropriate and would contribute towards social and economic upliftment. The survey revealed that the one-man-contract solid waste removal system was favoured amongst the I&APs. 60% of the sample population was willing to contribute financially to such a one-man-contract solid waste removal service (Figure 5.5). The most people were willing to pay was between R75 and R80 per month and the least

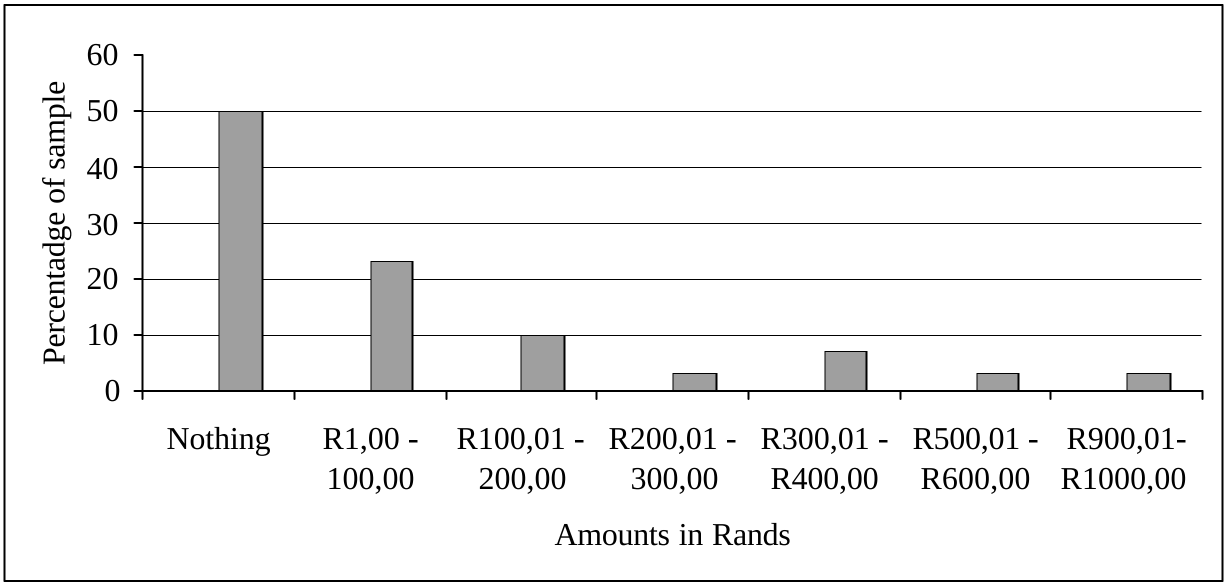


Figure 5.4: The financial contribution towards construction of urine diversion toilets by residents within the Jeffreys Bay storm water catchment (n=30).

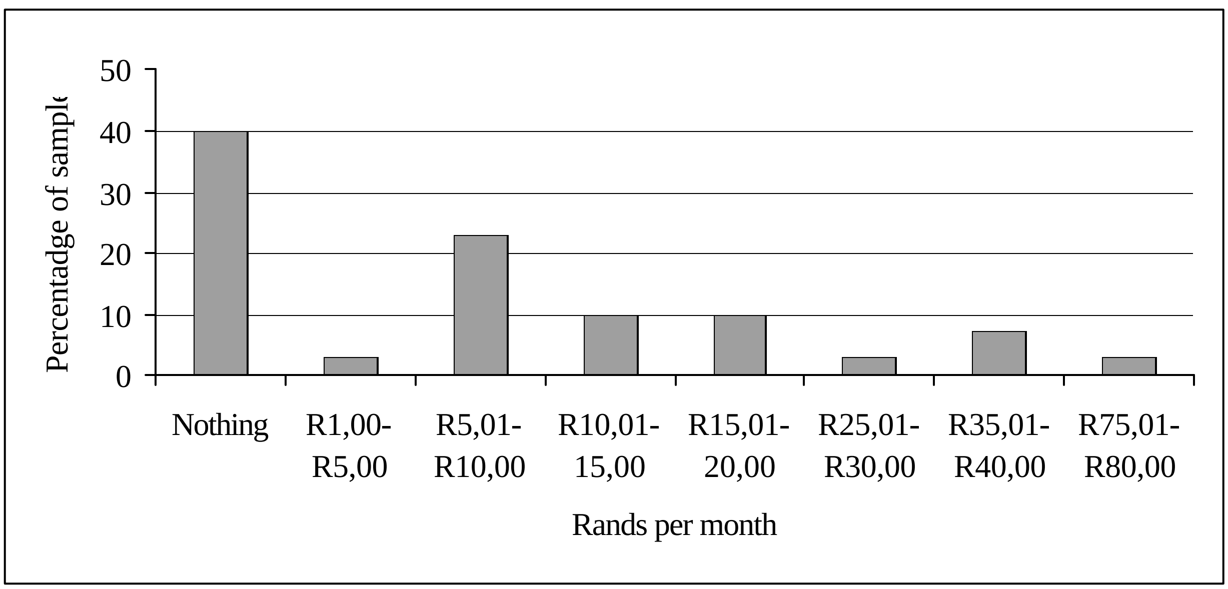


Figure 5.5: Monthly contributions for a one-man-contract solid waste removal system (n=30).

between R1 and R5. This was consistent with Pretorius and de Villiers's (2003) findings that people in South African developing communities would be willing to contribute towards a efficient solid waste removal system in order to have a cleaner living environment. The Kouga Municipality representative also agreed that a one-man-contract solid waste removal system would work. One person could service up to 400 households in a single day (Zurbrügg & Ahmed, 1999) meaning that three people would need to be employed to service the informal areas of Jeffreys Bay. Studies in the developed world showed that private contractors could be 15% less costly than municipal waste collection for the same standard of service (Palmer Development Group, 1996). In the developing world the finding was the same. In Rio de Janeiro municipal waste collection was twice as costly as in São Paulo, which made use of private contractors. Solid waste management was also of a higher standard in São Paulo (Palmer Development Group, 1996).

5.3.4.4 Wetland

As discussed previously, the location of the wetland towards the edge of the storm water catchment above the residential area meant that its value in terms of the remediation of contaminated storm water was limited. However, its cleanup was expected to have a positive impact on the aesthetics of the area and could be used as a means of enhancing environmental awareness amongst learners. 77% of the sampled population was aware of the wetland and that it was very polluted. They believed the pollution came from grey water, residential solid waste, animals, and transport and storm water. Of this group, only 6% agreed that clean up of the wetland would benefit the environment, while the rest wanted the wetland to be cleaned for personal (health and welfare) reasons.

Literature showed that people in the developing world do express significant concern for the conservation of wetlands, especially if their livelihoods depended upon it (Wattage & Mardle, 2005). Interestingly, in the current case, none of the residents relied on the small wetland for their livelihood and the value was primarily that of aesthetics. As such, environmental stewardship needed to be linked to health and quality of life by means of educating the community regarding this link. To use education plans to concentrate solely on environmental issues is unlikely to have a long-term impact. The respondents were willing to contribute finances (mostly between R5,01 and R10,00) (Figure 5.6) and time (mostly one to two hours per week) (Figure 5.7) to the rehabilitation of the wetland. The value in these figures lies in illustrating the willingness of communities to participate in activities that will increase their quality of life.

5.3.4.5 Support generation

Even though the mitigation measures discussed above were partly ranked favourable due to their potential to be self-funding, some seed funding and incentives would be required to initiate many of the proposed mitigation measures. In Jeffreys Bay the Kouga Municipality had incentives in place in order to reduce waste from industry. The businesses were placed into categories according to the volume of solid waste requiring removal and businesses in a particular category were then charged the same specific service price. The price charged increased with the quantity of waste produced. This was thought to be an acceptable incentive to reduce solid waste from industry. The Jeffreys Bay business community representative stated that a lack of solid waste management and sewage disposal impacted on the commercial sector of the town due to a perceived loss of tourism. The representative's concern was confirmed in literature where it was stated that litter (Silva-Iñiguez & Fischer, 2003) and sewage (Dorfman, 2004) on beaches and in marine waters could result in a loss of tourism and income for coastal communities. Therefore, an incentive existed for local businesses to support environmental management initiatives in the previously disadvantaged areas. According to the same source, additional indirect benefits to local business resulting from the proposed waste management initiatives would include black economic empowerment, job creation and building a better future for South Africa.

Another potential incentive to reduce marine pollution was the Blue Flag project. Only two people within the sample population knew of the Blue Flag project. This was surprising since 67% of the people within the sample population visited the beach between once a day and

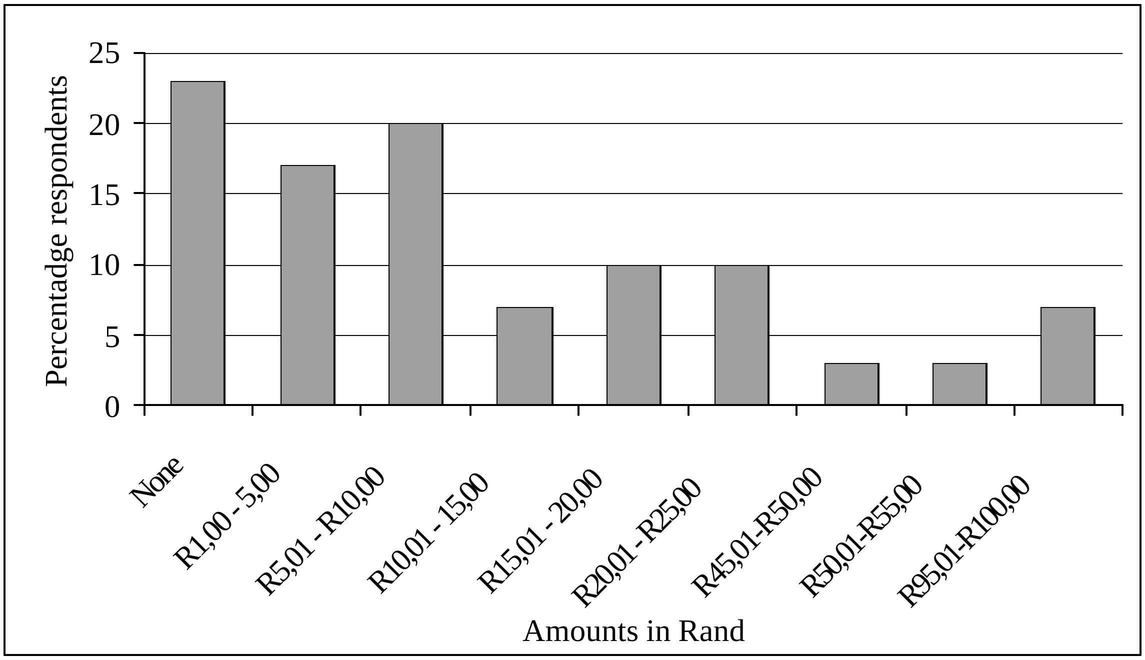


Figure 5.6: Rand amounts the sample population was willing to contribute towards wetland rehabilitation (n=30).

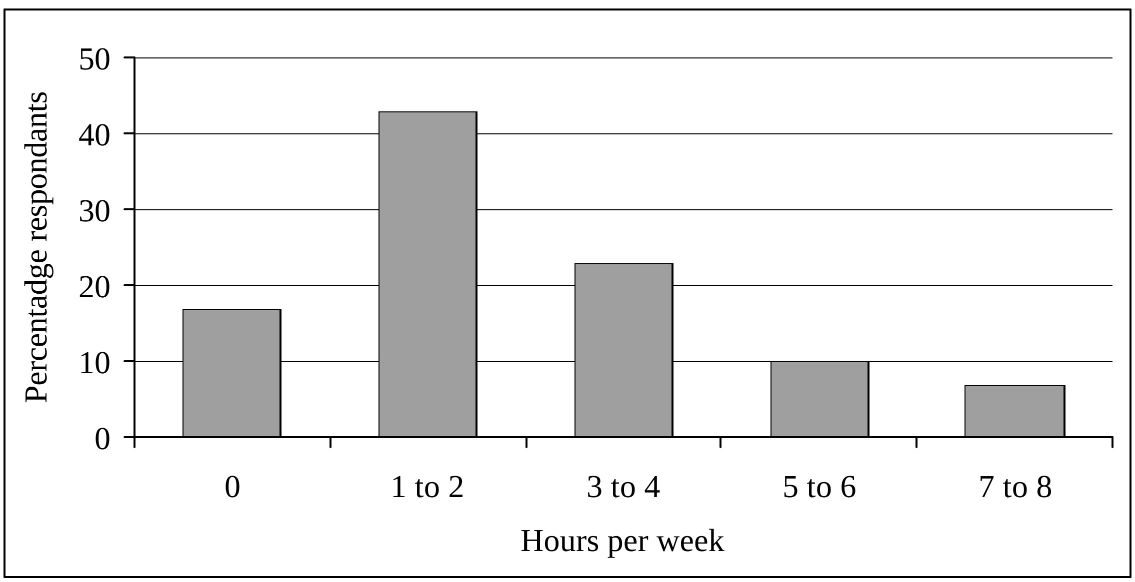


Figure 5.7: Contribution in-kind (time) by the community towards wetland rehabilitation (n=30).

once a month (Figure 5.8). The activities people most often engaged in when visiting the beach are illustrated in Figure 5.9. The data showed that 40% of the sample population indicated that they swam when at the beach and could therefore be exposed to polluted marine water. 25% of the sample population stated that they had experienced problems with waste or the water quality at the beach, and 33% said that they were aware that grey water, solid waste and sewage had an impact on the marine environment. This finding could prove to be valuable as an entry point for environmental education since the survey showed that protection of the beach environment was relevant to the sample population.

The Jeffreys Bay business community representative agreed that there were visible signs of the impact of pollution on the Main Beach. The representative also stated that the local press regularly reported on the public outcry regarding waste and water quality on the beach (Arnolds, 2004; Our Times, 2004a; Williams, 2004), which showed that it was a concern of not only business but also the residents of Jeffreys Bay. He regarded the main link between the state of the beach and seawater quality as the storm water canal that drained the study area. The representative stated that the Jeffreys Bay business community would not only be willing to contribute financially to projects that would reduce the risk of contamination of the beach and marine environment but would also contribute time and skill. In Mexico the finding was the same where up to 93% of I&APs were willing to pay to keep the beach clean (Silva-Iñiguez & Fischer, 2003), and in South Africa there have been many examples of environmental management partnership initiatives between business and communities (World Summit Publication, 2002).

The Kouga Municipality representative however felt differently. The representative stated that there have been no problems with waste or water quality on the beach. The representative did not know the financial value of the Blue Flag status for Jeffreys Bay and did not think that the state of informal ablution and waste management in the informal housing area had a negative impact on the Blue Flag status of the beach. Finkl and Krupa (2003) and Dorfman (2004) all called for an improved attitude and recognition by government to solve land-based marine

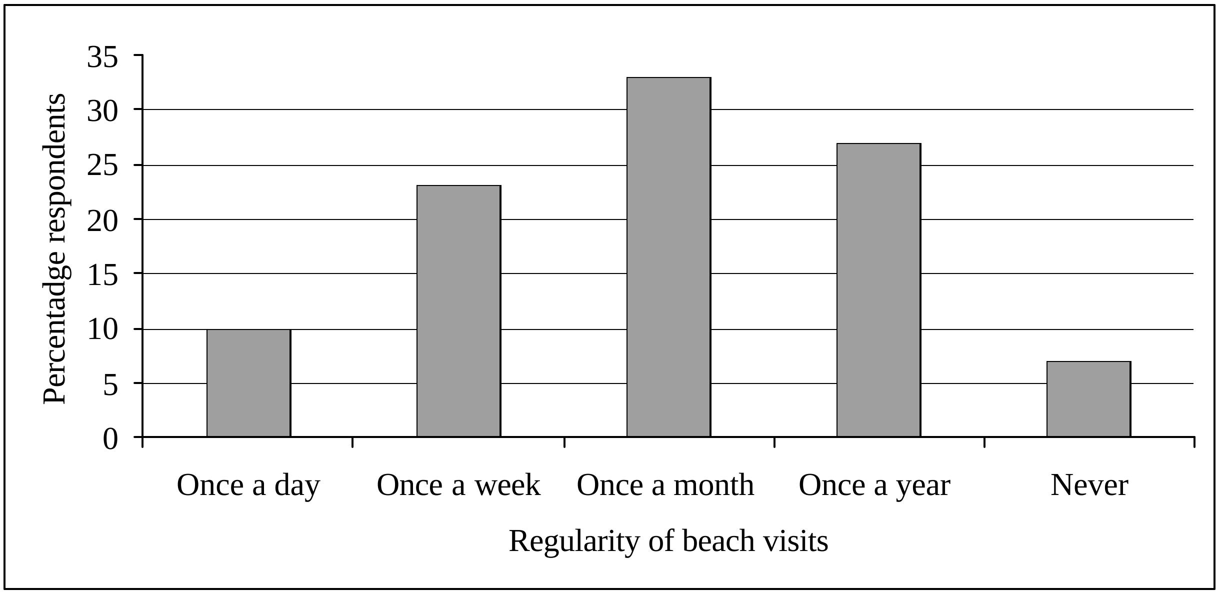


Figure 5.8: The frequency of beach visits by the sample population (n=30).

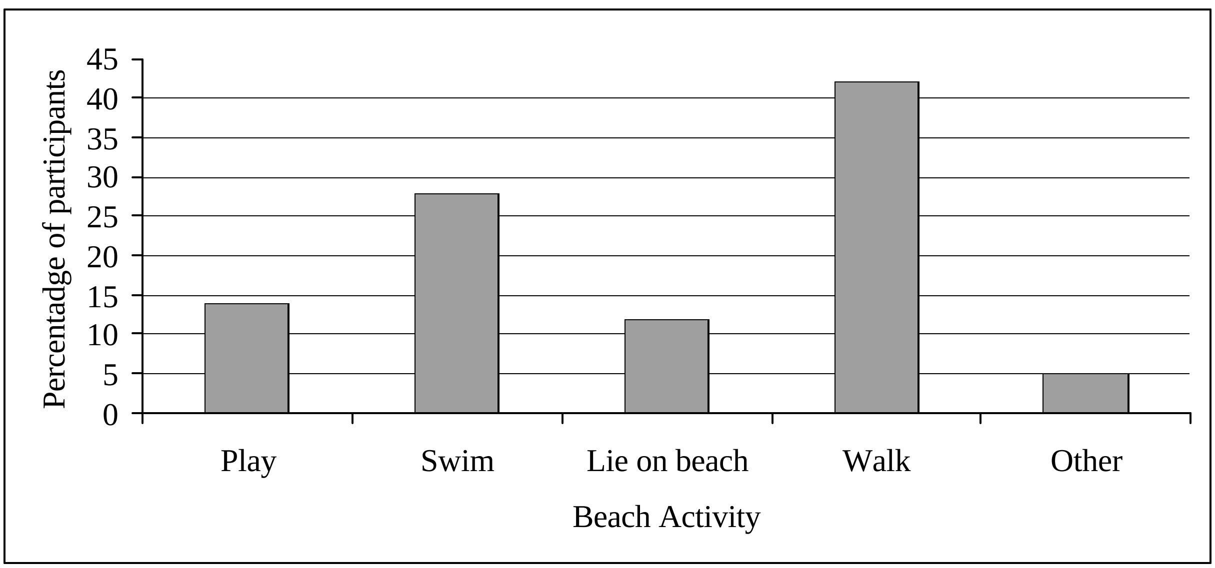


Figure 5.9: Activities the sample population most often participates in they visited the beach (n=30).

pollution problems. It is thus suggested that education of the local community as well as government play an important role in addressing the issues of land-based marine pollution. The information generated by the study this far was used to formulate a IWMP, which is described in the section below.

5.3.5 Integrated Waste Management Plan

By refining the initial descriptive model (Figure 5.1) based on the information gathered during the assessment of the various potential mitigation measures, it was possible to prepare a final descriptive model (Figure 5.10) for integrated waste management within the Jeffreys Bay storm water catchment. The plan itself has its foundation in the concept of an "Eco-industrial park" as described by Todd *et al.* (2003). The Eco-industrial park concept allows for the management of waste as a resource with the benefit of commercially viable byproducts being produced. For Jeffreys Bay such a concept could mean improved waste management with a subsequent reduction in storm water and marine pollution with the added benefit of the impoverished community profiting by means of a gain in fresh produce and/ or income.

The cornerstone of the descriptive model was considered to be education which, as suggested in literature, is essential and has formed the foundation of many other initiatives (Pretorius & de Villiers, 2003; Derraik, 2002). Education needs to stretch across the complete spectrum of I&APs which include the community, local government and the business sector of Jeffreys Bay. For each of the three significant aspects (informal ablutions, grey water and solid waste disposal) a mitigation measure was assigned in order to minimize the aspect's potential for contamination of storm water. The measures aimed at addressing informal ablution and grey water within the catchment incorporated the philosophy of ecological sanitation (EcoSan), whereby nutrients from wastes were recycled. As can be seen from Figure 5.10, the suggested technologies were urine diversion toilets and tower gardens, while the one-man-contract combined with composting was considered appropriate for the improvement of solid waste management.

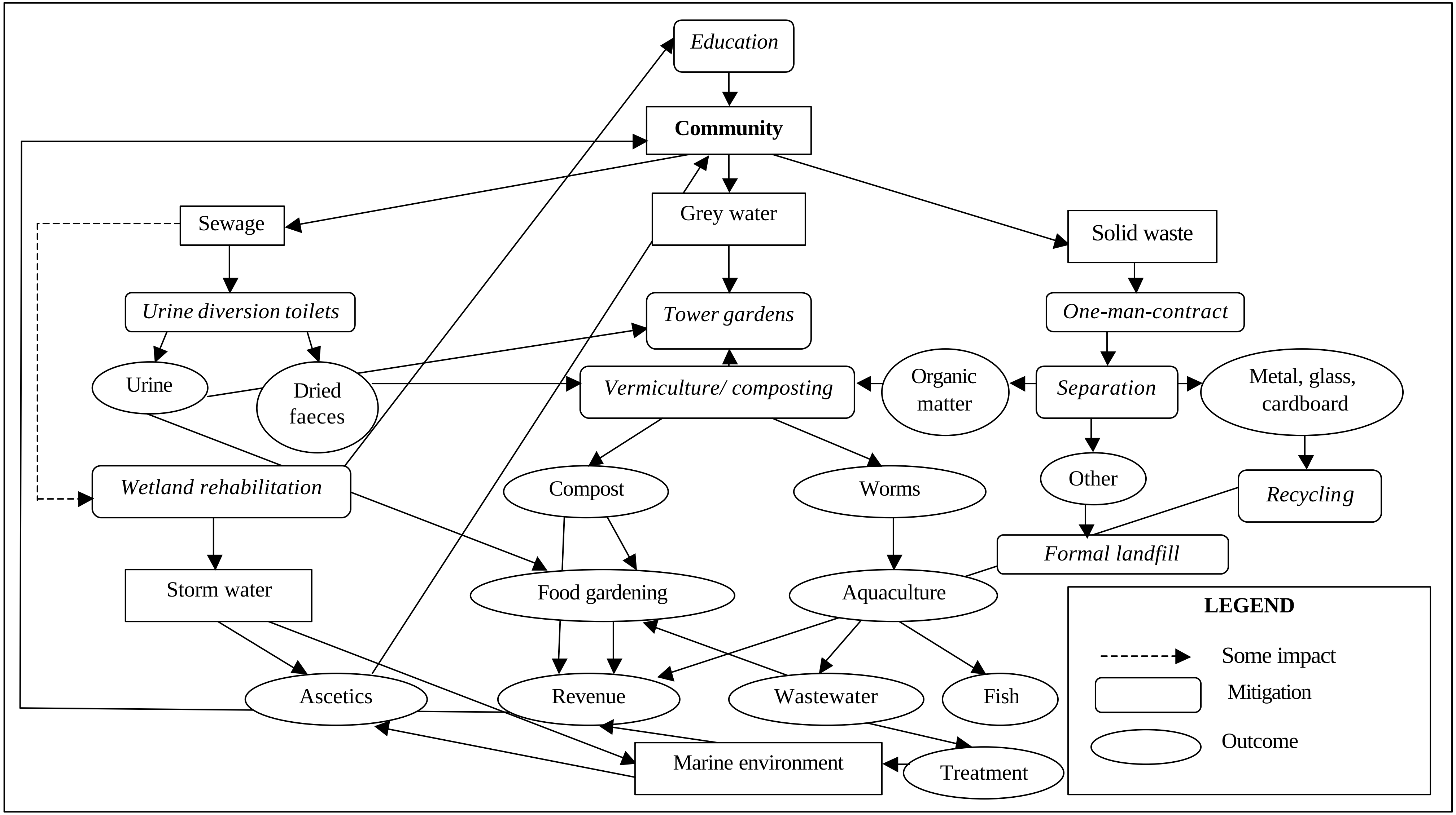


Figure 5.10: A final descriptive model of a proposed IWMP to reduce land-based marine pollution for the Jeffreys Bay storm water catchment.

Despite the apparent complexity of the proposed integrated waste management system, it was thought to be appropriate to the existing level of skill and financial resources within the study area and maximized opportunities for community participation and local economic development. The system is also highly modular and flexible, and can thus be developed according to changes in the needs of the community, waste volumes and fluctuations in markets for the end products. While the core system elements such as the urine diversion toilets, tower gardens and one-man-contract were thought to require immediate implementation to avoid further contamination of storm water and the marine environment, certain of the optional value-addition units e.g. aquaculture could be implemented at a later stage. The various elements of the system and their linkages are described in more detail below.

The urine diversion system has the potential to be introduced by means of a micro-enterprise, and could thereby lead to job creation opportunities (Holden, 2003; Pretorius & de Villiers, 2003). It has been suggested that the method of implementation should be the construction of one or more demonstration units at a strategic place within the non-sewered area of the catchment (Morel & Forster, 2002). This approach could result in people taking this initiative further by themselves with the benefit of people gaining in self-reliance and lower costs as opposed to simply building hundreds of units at the outset. A church congregation could be seen as a viable action group for such a community development effort (Swanepoel, 1993). An interested and unemployed community member with building experience could be empowered to start the micro-enterprise but would require suitable training regarding the building of the urine diversion toilets as well as basic bookkeeping and marketing of the product (Holden, 2003).

It is suggested that if this type of ecological sewage disposal systems are introduced on a large-scale in an urban context, the waste material should be collected and taken to a centralised composting facility by the municipality or a private organisation (Winblad & Simpson-Hébert, 2004). This stage of the operation could be funded through the sale of the composted material for use by domestic, community or commercial vegetable initiatives, although initial start-up capital would be required. Education will provide the cornerstone for the safe use of this system, specifically management of the faecal material and urine.

Therefore, an educational program focused on behaviour change in the areas of health, hygiene and the correct use of the urine diversion toilets would be essential. Just as important is the monitoring and evaluation of the project after implementation (Winblad & Simpson-Hébert, 2004) in order to detect any misuse and associated threats to the health of users, the community or the environment. As discussed above, it is proposed that partially-stabilised faecal material be sanitised and converted to a safe, useable product via a composting process (Pretorius & de Villiers, 2003; Winblad & Simpson-Hébert, 2004) while the urine could be used as a fertilizer for the growing of vegetables.

The tower garden can also be integrated with the urine diversion toilets. Well-composted waste material, probably a combination of faecal matter and other suitable organic material, can be used in building the tower garden, which could then be irrigated with household grey water (Crosby, 2004). The growing of food from waste (solids and liquid) and the job creation potential of EcoSan would add to social and economic upliftment. As with urine-diversion toilets, it has been suggested that examples of tower gardens should also be built in strategic places within the non-sewered storm water catchment areas to create community awareness and serve as examples for further duplication (Morel & Forster, 2002).

By employing people in a labour intensive one-man-contract solid waste removal system jobs can be created which could aid in social and economic upliftment (Palmer Development Group, 1996; Earthyear, 2001; Wood *et al.*, 2001; Dahiya, 2003; Kaseva & Mbuligwe, 2005). Through an appropriate tendering process a contract could be granted to a private person within the community. This person could then divide the informal housing areas within the catchment into sections and employ people from those areas to collect solid waste on a weekly basis. The bags of solid waste should then be taken to a central point where the municipality would be responsible for disposal in a landfill. These community contractors would be responsible for the education of the public on issues related to solid waste pollution (Wood *et al.*, 2001). Alternatively, the one-man-contract could be linked to a waste separation and recycling initiative.

Even though large-scale community-based composting and recycling initiatives were excluded based on the results of the comparative analyses, it is suggested that household or private commercial composting should be considered as a means to facilitate sustainable development. Should a commercial operation be considered economically viable, the one-man-contractors could encourage separation of waste in the solid waste stream at source i.e. at the household level. The organic fraction could then be used for composting and recyclable material including glass, metal and cardboard sold for recycling (Kaseva & Gupta, 1996). Only that fraction of the waste not suitable for either composting or recycling would be taken to a formal landfill for disposal.

Conventional compost is a relatively low-value product and therefore economies of scale apply to composting operations. However, vermicomposting, where un- or partially-stabilised organic material is composted by suitable earthworm species results in a higher value compost-like vermicast (Dahiya, 2003) and worms. As with conventional compost, vermicast can be sold to the public or used in the construction of tower gardens or food garden projects. The additional worms produced could be sold either as bait or used as feed in an aquaculture operation. As is the case with other such integrated systems, the nutrient-rich wastewater from the aquaculture operation could be incorporated into large food gardening initiatives (Todd *et al.*, 2003). As Jeffreys Bay already attracts a significant number of tourists annually, these visitors could both directly and indirectly support many of the above initiatives through purchase of products such as vegetables, fruit and fish.

As discussed previously, the value of the rehabilitation of the wetland would lie in the contribution "…to mental health by providing scientific, aesthetic and spiritual information" to the local community (de Groot, 1992 cited in Schuyt, 2005). The rehabilitation of a wetland by means of volunteer community involvement is described by Collins (2000). In brief, this process would include the assessment of the wetland, setting of aims, drawing up of a management plan, executing the management plan and monitoring. Marais & Armitage (2004) stated that schools could be encouraged to be involved in wetland rehabilitation which would allow for the added benefit of education. In Jeffreys Bay the rehabilitation of the wetland could involve the local primary school situated directly adjacent to the wetland. Such an initiative could be started with a clean-up competition, followed by the planting of indigenous trees and plants. The sustainability of such a project could be enhanced by forming an 'eco-club' at the school and encouraging the members of such a club to take ownership and care of the wetland.

The willingness of local business to contribute towards community-based initiatives financially and through the provision of skills will allow for initiative such as the urine diversion toilets to be implemented, since the community stated that they were either not willing or able to contribute financially. The support of the Municipality would also be essential for the success of such an initiative, specifically in the maintenance of existing toilets and landfill sites.

5.4 CONCLUSIONS

A final descriptive model illustrated conceptually how the implementation of community-based, private and municipal mitigation initiatives could not only reduce land-based marine pollution, but also add to local social and economic upliftment. The cornerstone for such a model was the education of I&APs in not only efficient operation and maintenance of the proposed initiatives, but increased knowledge regarding protection of the environment. The key findings of this chapter may be summarized as follows:

- The comparative analyses identified the one-man-contract, the tower garden and urine diversion toilets to mitigate solid waste pollution, grey water disposal and informal ablution, respectively, as appropriate based on local conditions;
- Education would be essential to the success of the proposed initiative and the rehabilitation of the wetland was regarded as an effective means of educating younger members of the community through school-based clean-ups;
- The proposed mitigations were furthermore evaluated by means of a public participation process which indicated that various community stakeholders favoured the proposed measures;
- The public participation process furthermore showed that community members were not willing to contribute to the implementation and maintenance of the urine

diversion toilets, but were willing to contribute towards the one-man-contract and the rehabilitation of the wetland;

- Potential barriers to the implementation of the mitigations according to the various I&APs were vandalism, smell, animal damage, a lack of space, bad plant growth, the landlord's disapproval, a lack of space and the fact that the land did not belong to them;
- Short-term incentives were currently only aimed at waste reduction by local commerce and industry even though the business community showed enthusiasm towards long-term incentives such as black economic empowerment, job creation and building a better future for South Africa through improved solid waste and sewage disposal service delivery;
- Local government and the local community did not see a lack of sewage disposal and solid waste management as a threat to the Blue Flag status of Jeffreys Bay's Main Beach. However, the threat to the Blue Flag status was regarded as a significant incentive for the local business community to support waste management initiatives within the storm water catchment.
- Education of not only the community but all stakeholders was essential regarding pollution control and potential alternatives in order to reduce the risk small coastal communities pose to marine resources;
- It was strongly recommended that some sort of contribution or participation by the local community be incorporated into the project, whether in finance or labour, in order to break the stronghold of dependency experienced in South African developing communities.

The following chapter will draw conclusions from the study in order to highlight recommendations for pollution and waste management at of other small coastal towns that rely on tourism for a significant proportion of their income. Areas of further research are also discussed.

CHAPTER 6

GENERAL CONCLUSIONS AND RECOMMENDATIONS

For small coastal communities that rely to a large extent on tourism, the protection of the marine environment as a social and economic resource becomes an important matter. As the population in the World's coastal zones increases, so too will the negative impacts of development, including those associated with inadequate waste management. The impact of liquid and solid wastes generated in lower-income formal and informal housing developments in the coastal zone is of particular concern and further study is required worldwide to identify the true state of waste management, the root causes of waste management problems and possible incentives to improve the situation. The purpose of the current study was to examine storm water quality management at Jeffreys Bay (South Africa), with emphasis on the link between storm water and marine pollution, and the use of a participatory approach to develop a plan for the improvement of local pollution and waste management. It was hoped that the findings of this study would have broader application, not only for improved planning and waste management in similar small coastal towns, but also in in-land areas where waste management is problematic.

Many tools exist to manage environmental risk, but a tool with an emphasis on sustainable community-based development was thought to be essential to address the contaminant sources with 'buy-in' from all interested and affected parties (I&APs). Integrated environmental management (IEM) is one such a tool that provides an analytical framework for issues of environmental concern and emphasizes public participation in setting mitigation targets and was therefore thought to be appropriate for Jeffreys Bay. As part of the integrated process to address the contamination of storm water in Jeffreys Bay, a risk assessment identified grey water disposal, domestic solid waste disposal and informal ablution as the main contributors to storm water and therefore, potentially also, marine pollution. Even though this risk assessment was thought to be sufficient to identify the significant aspects, it was recommended that additional methods such as site assessments by means of geographical information systems be incorporated into the risk assessment in order to allow for a more thorough assessment. This could allow for a better understanding of the interactions between water quality variables and land-use practice in order to identify significant contaminant risks.

Water quality studies were undertaken in order to verify the theoretical risk within the catchment. Although it was evident that storm water quality was a risk to human and environmental health, the effect on the marine environment was thought to be periodic and short-lived following rainfall events. The study showed that the proposed international Blue Flag criteria of water quality sampling every fortnight was insufficient since these sampling times may not always coincide with which can lead to flushing of pollutants from storm water systems into the marine environment. While the guidelines may be appropriate for certain areas, it is unlikely to be frequent enough to detect short-term temporal changes in water quality in those areas close to storm water outlets. More frequent sampling is recommended in order to provide accurate and reliable data regarding marine water quality and associated health risks to the recreational users. It is further suggested that researchers should develop a model, which could be used by local councils to determine the prolonged effect of contamination of marine waters by storm water following a rainfall event and the duration and extent of contamination events. This could also prove valuable in the protection of the health of recreational users.

Even though the water quality studies did not provide sufficient evidence to prove that storm water posed a significant risk to the marine environment, the remainder of this study followed a precautionary approach and further investigated potential pollution sources such as a lack of solid waste and sanitation management. An assessment of the status of solid waste management within the catchment revealed that the local residential community was mainly responsible for pollution through illegal dumping and littering. Even though institutional and technical aspects such as a lack of staff and equipment contributed largely to the problem, the social aspect, including the community's desensitisation towards solid waste management, was considered the most significant contributing factor. It is strongly recommended that education of residents form an integral part of any municipal solid waste management plan as legal action against polluters was regarded as logistically difficult, particularly in informal communities. New educational campaigns that are combined with a series of well-aimed incentives need to be developed and could include competitions for the cleanest street or block within the informal housing developments.

Where the solid waste assessment pointed towards social aspects as the main contributor of pollution, the in-depth study of sanitation (grey water and ablutions) revealed that institutional and technical aspects outweighed the social aspects. The root cause of informal ablution was regarded as a lack of sufficient formal toilet facilities within the catchment community. Apart from the insufficient number of units, residents also indicated that toilets were in a poor state of repair and often did not function. Social aspects such as the vandalism and inappropriate use of existing communal sanitation facilities were however recognised as contributing to the problem. Once again the importance of education in the use of sanitation facilities was recognised as important, although a greater incentive would be low-cost privately owned ablution facilities which have proven successful in other regions.

This said, it has been recognised that the absence of self-help sewage disposal initiatives within the South African context is of grave concern and, according to experts, is mainly due to Government's promise of free services. It is therefore recommended that government policy be reviewed and adapted towards a focus on short-term initiatives that will allow communities to take lead in improving their own living conditions. Government policies should be geared towards abstract gains such as self-reliance and empowerment at household level, while at the same time achieving concrete gains such as improved sanitation. Pilot projects that will allow communities to become actively involved in overcoming poverty-related issues such as a lack of sanitation, including the establishment of an ecological sanitation pilot project in the area, were regarded as usefull.

Based on the study of the key sources of storm water and, potentially, the marine pollution at Jeffreys Bay, it was decided that the development of an Integrated Waste Management Plan (IWMP) involving community input was the most appropriate approach. The IWMP was not only aimed at addressing the aspects of land-based marine pollution, but were geared towards social and economic upliftment of impoverished communities. An integration of various technologies was suggested, but the importance of education of not only the local community but also all the stakeholders, was thought to be of paramount importance. It is therefore recommended that I&APs regularly workshop together in order to work towards a common goal. Interestingly, the business community did not only pledge financial support for community-based projects, but also their time and skill. This volunteer human resource is invaluable and it is recommended that local governments aim to have a closer partnership with the volunteer sector in order to benefit from this resource. It is further suggested that research is needed in the setting of sustainability indicators for the implementation and maintenance of community-based pollution reduction projects in coastal communities. Apart from education, the other key ingredient to this type of approach, which requires participation from a number of different stakeholders, is the identification and promotion of appropriate incentives for the different stakeholders. Without these incentives the various I&APs may not participate in a proposed waste management strategy. Incentives could include improved living conditions and some kind of return such as income or fresh produce for the local community. Local business can gain by means of increased tourism due to clean and pollution-free beaches of an international standard. Lastly, the incentive of the implementation of an IWMP for local government could be a significant financial saving.

While the current project focused on the issue of environmental pollution and waste management within a small storm water catchment in Jeffreys Bay, insights gained could be applied to the reduction of land-based marine pollution at other coastal resort towns. The key to any such initiative is firstly to accurately determine the most significant sources of pollution, and then to investigate the root causes and impacts, both direct and indirect, of the pollution not only on the immediate community but on a broader stakeholder group. The reason for the latter is that the participation of a range of stakeholders with different strengths, resources and skills is likely to be required to implement a successful integrated waste management initiative. As discussed above, education and incentives are vital to the success of the initiative and therefore need to be investigated fully. The project furthermore challenged conventional pollution and community upliftment strategies by placing a strong emphasis on 'self-help' participative approaches by means of a partnership between volunteer, community and local government factions. Not only could this become the only viable option for developing coastal communities due to the envisioned population growth in coastal areas with consequent financial constraint on local authorities, but potentially a means of breaking the poverty frame of mind of the people. The end result for small coastal communities could be that their valuable marine resource, the ocean, would continue unaffected by man as always and the local people can remark with dignity that with the help of God we have done it ourselves.

REFERENCES

Albaiges, J. (1989). *Marine pollution.* United States of America: Hemisphere Publishing Corporation.

Al-Jayyousi, O.R. (2004). Grey water reuse: knowledge management for sustainability. *Desalination, I67,* 27-37.

Antunes, P., & Santos, R. (1999). Integrated environmental management of the oceans. *Ecological Economics, 31,* 215-226.

American Public Health Association (APHA), American Water Work Association, Water Environmental Federation. (1998). (20th ed.). *Standard methods for the examination of water and wastewater.* Washington, DC: American Public Health Association.

Arnolds, R. (2004, October, 29). Let's stop fooling ourselves. *Our Times.* p.4.

Attwood, C.L, Moloney, C.L., Stenton-Dozey, J., Jackson, L.F., Heydorn, A.E.F, & Probyn, T.A. (2000). *Conservation of marine biodiversity in South Africa.* Retrieved October 3, 2004, from http://www.nrf.ac.za/publications/marinerep/conserve.htm

Austin, L.M., & van Vuuren, S.J. (2001). Sanitation, public health and the environment: Looking beyond current technologies. *Journal of the South African Institution of Civil Engineering, 43(1),* 29-33.

Bay, S., Jones, B.H., Schiff, K., & Washburn, L. (2003). Water quality impacts of storm water discharges to Santa Monica Bay. *Marine Environmental Research, 56,* 205-223.

Berry, M.G. (2000). *The development of informal settlements and their impact on the vegetation and rivers in the coastal zone of the South-Eastern Cape.* Port Elizabeth: University of Port Elizabeth, Philosophia Doctor Thesis.

Biopite Engineering Geologists CC. (2004). *An environmental study for the proposed new low-income housing project at Jeffreys Bay: Scoping Report.* Report No. BEG/04351.

Botha, W. (2004). (Kouga Manager of technical services) (personal communication. October 14, 2004).

Bowen, R.E., & Riley, C. (2003). Socio-economic indicators and integrated coastal management. *Ocean & Coastal Management, 46,* 299-312.

Bracken, P., Kvarnström, E., Ysunza, A., Kärrman, E., Finnson, A., & Saywell, D. (2005). Making sustainable choices - the development and use of sustainably oriented criteria in sanitary decision making. *EcoSan - closing the loop: Proceedings of the 2nd international symposium on ecological sanitation, incorporating the 1st IWA specialist group conference on sustainable sanitation, 7th - 11th April 2003, Lübeck, Germany,* 486-494.

Buenrostro, O., Bocco, G., & Cram, S. (2001). Classification of sources of municipal solid wastes in developing countries. *Resources, Conservation and Recycling, 32,* 29-41.

Carden, K.J., Armitage, N.P., Sichone, O., Rivette, U.K., & Winter, K. (2005). Developing strategies for the disposal and use of grey water in the non-sewed areas of South Africa. *Ecological sanitation: a sustainable, integration solution. Conference documentation. 3rd International Ecological Sanitation Conference 23 - 26 May 2005 Durban, South Africa,* 362-369.

Clark, R. B. (1992). *Marine pollution.* New York: Oxford University Press.

Collins, C. (2000). *Wetland rehabilitation: Getting started. A step-by-step guide for people who want to make a difference.* Ballina: Wetland Care Australia.

Cronje, A. (2000). *Fourth level: Biomedical Science Research Methodology in Medical and Health Science year 2000.* Port Elizabeth: Port Elizabeth Technicon.

Crosby, C. (2004). Food from used water: Making the previous impossible happen. *The Water Wheel, 3*(4-5), 26-30.

Dahiya, B. (2003). Peri-urban environments and community driven development Chennai, India. *Cities, 20*(5), 341-352.

Dallas, S., Scheffec, B., & Hob, G. (2004). Reedbeds for grey water treatment - case study in Santa Elena-Monteverde, Costa Rica, Central America. *Ecological Engineering, 23,* 55-61.

De Beer, H. (2002). *The measure of sustainable development in "Die Berg" a rural community in the Eastern Cape*. Port Elizabeth: University of Port Elizabeth, Magister Artium Thesis.

DEAT. (1998). *Guideline document: EIA Regulations Implementation of Section 21, 22 and 26 of the Environmental Conservation Act.* Department of Environmental Affairs and Tourism.

DEAT. *(1999).* National waste management strategy: National waste management strategy and action plans for South Africa, strategy formulation phase (Version D). *Retrieved July 4, 2005, from*
http://www.environment.gov.za/ProjProg/WasteMgmt/waste.html

DEAT. (2000). *White paper on integrated pollution waste management for South Africa: A policy on pollution prevention, waste minimization, impact management and remediation.* Department of Environmental Affairs and Tourism.

DEAT. (2001). *Coast care fact sheet series, 2D.* Department of Environmental Affairs and Tourism.

DWAF. (1995). *South African water quality guidelines for coastal marine waters: Recreational use.* (Vol. 2, 1st ed.). Department of Water Affairs and Forestry.

DWAF. (1996a). *South African Water Quality Guidelines: Aquatic Ecosystems.* (Vol. 7, 1st ed.). Department of Water Affairs and Forestry.

DWAF. (1996b). *South African Water Quality Guidelines: Recreational use.* (Vol. 2, 2nd ed.). Department of Water Affairs and Forestry.

DWAF. (2001a). *Generic public participation guidelines.* Department of Water Affairs and Forestry.

DWAF. (2001b). *White paper on basic household sanitation.* Department of Water Affairs and Forestry.

DWAF. (2003). Strategic framework for water services. Department of Water Affairs and Forestry.

Derraik, J.G.B. (2002). The pollution of the marine environment by plastic debris: A review. *Marine Pollution Bulletin, 44*, 842-852.

DiGiacomo, P.M., Washburn, L., Holt B., Burton H., & Jones, B.H. (2004). Coastal pollution hazards in Southern California observed by SAR imagery: Storm water plumes, wastewater plumes, and natural hydrocarbon seeps. *Marine Pollution Bulletin.* Retrieved October 1, 2004, from ScienceDirect online database.

Dittke, M. (2000). Land Based Marine Pollution. *Earthyear, 21*, 86-87.

Dorfman, M. (2004). *Swimming in Sewage: The growing problem of sewage and how the Bush administration is putting our health and environment at risk*. Natural Resources Defence Council and the Environmental Integrity Project.

Dunmade, I. (2002). Indicators of sustainability: assessing the suitability of a foreign technology for a developing economy. *Technology in Society, 24*, 461-471.

Earthyear. (2001). Turning South Africa clean and green. *Earthyear, 23*, 56-57.

Eriksson, E., Auffarth, K., Henze, M., & Ledin, A. (2002). Characteristics of grey wastewater. *Urban Water, 4,* 85-104.

Fanshawe, T., & Everard, M. (2002). *The impacts of marine litter.* (Report No. MaLITT). Marine Pollution Monitoring Management Group.

Farmer, T., & Garcia, S. (2002, October 9). *UN Atlas of the Oceans: Human Health and the Ocean.* Retrieved October 21, 2004, from http://www.oceansatlas.org/

Fatoki, O.S., & Mathabatha, S. (2001). An assessment of heavy metal pollution in the East London and Port Elizabeth harbours. *Water SA, 27*(20), 233-240.

Finkl, C.W., & Krupa S.L. (2003). Environmental impacts of coastal-plain activities on sandy beach systems: Hazards, perception and mitigation. *Journal of Coastal Research, 35,* 132-150.

Fuggle, R.F., & Rabie, M.A. (1992). *Environmental Management in South Africa.* Ndabeni, Cape: The Rustica Press.

Global Environmental Facility. (2000, March 1). *Land-based sources of marine pollution and biodiversity treats.* Retrieved September 2, 2004, from http://www.gefweb.org/meetings/WaterForum/landbased.pdf

Grobicki, A. (2002). *Cultivation of plants in restored urban wetlands for income generation in local communities.* WRC Report No. 1054/1/02.

Guild, R., Erlich, R.I., Johnston, J.R. & Ross, M.H. (eds). (2001). *Handbook of occupational health practice in the South African mining industry*. Johannesburg: SIMRAC.

Hill, J., & Wilkinson. C. (2004). *Methods for ecological monitoring of corral reefs. A resource for managers.* Townsville: Australian institute for marine science.

Hift, R. (1998). *Legends of Jeffreys Bay*. Jeffreys Bay.

Holden, R. (2003). *Self help guidelines for improving household sanitation, without subsidies*. Braamfontein: Mvula Trust.

Holden, R., Terreblanche, R., & Nawasam, M.M. (2003). Factors which have influenced the acceptance of ecosan in South Africa and development of a marketing strategy. *EcoSan - closing the loop: Proceedings of the 2nd international symposium on ecological sanitation, incorporating the 1st IWA specialist group conference on sustainable sanitation, 7th - 11th April 2003, Lübeck, Germany,* 169-174.

Holden, R. (2005a). (Manager social impact: Department of Science and Technology) (personal communication. April 12, 2005).

Holden, R. (2005b). (Manager social impact: Department of Science and Technology) (personal communication. June 7, 2005).

Horan, M.P. (2005). (Consultant: Sustainable Environmental Technologies) (personal communication. September 22, 2005).

Islam, M. S., & Tanaka, M. (2004). Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: A review and synthesis. *Marine Pollution Bulletin, 48*(7-8), 624-649.

Jackson, B., & Knapp, A. (2005). Lessons from a multi-country review of EcoSan experience in East and Southern Africa. *Ecological sanitation: a sustainable, integration solution. Conference documentation. 3rd International Ecological Sanitation Conference 23 - 26 May 2005 Durban, South Africa*, 95-101.

Jooste, S., MacKey, H.M., Scherman, P.A., & Muller, W.J. (2000). *Feasibility of using a risk-based approach to set integrated environmental objectives for the protection of water resources*. WRC Report No. 914/1/00.

Källerfelt, C., & Nordberg, A. (2004). *Evaluation of Local Grey water Treatment in South Africa: Grey water Characteristics, Water Use and User Acceptance*. Göteborg: Chalmers University of Technology, Diploma Thesis.

Kanistanon, K. (1997). *Correlation of Environmental Temperature, Precipitation, and Humidity with Salmonella Culture Results from Cattle in Virginia*. Thesis submitted to the Faculty of the of Veterinary. Blacksburg: Virginia-Maryland Regional College, Master of Science Thesis.

Kaseva, M.E., & Gupta, S.K. (1996). Recycling - an environmentally friendly and income generating activity towards sustainable solid waste management. Case study - Dar es Salaam City, Tanzania. *Resources, Conservation and Recycling, 17,* 299-309.

Kaseva, M.E., & Mbuligwe, S.E. (2005). Appraisal of solid waste collection following private sector involvement in Dar es Salaam city, Tanzania. *Habitat International, 29*, 353-366.

Koné, D., & Strauss, M. (2004). *Low-cost options for treating Faecal Sludge (FS) in developing countries - Challenges and performance.* Duebendorf: SANDEC/ EAWAG.

Lee, J. H., & Bang, K.W. (2000). Characterization of Urban Storm Water. *Water Research, 34*(6), 1773-1780.

Lohani, B., Evans, J.W., Ludwig, H., Everitt, R.R., Carpenter, R. A., & Tu, S.L. (1997). *Environmental Impact Assessment for Developing Countries in Asia: Volume 1 - Overview*. Asian Development Bank.

MacKay, H.M. (1994). *Management of water quality in an urban estuary.* Port Elizabeth: University of Port Elizabeth, Philosophia Doctor Thesis.

Macyk, T.M., & Richens, T.C. (2004). *Volume III: 2004 Technical Rationale Document - Draf.* Retrieved June 12, 2004, from http://www.axys.net/news/fullstories/AENV%202004%20Technical%20Rationale%20Document%20DRAFT.doc

Mardon, D., & Stretch, D. (2004). Comparative assessment of water quality at Durban beaches according to local and international guidelines. *Water SA*, *30*(3), 317-323.

Margerum, R.D. (1999). Integrated Environmental Management: Lessons from the Trinity Inlet Management Program. *Land Use Policy*, *16*, 179-190.

Marais, M., Armitage, N., & Wise, C. (2004). The measurement and reduction of urban litter entering storm water drainage systems: Paper 1 - Quantifying the problem using the City of Cape Town as a case study. *Water SA*, *30*(4), 469-482.

Marais, M., & Armitage, N. (2004). The measurement and reduction of urban litter entering storm water drainage systems: Paper 2 - Strategies for reducing the litter in the storm water drainage systems. *Water SA*, *30*(4), 483-492.

Mbande, C. (2003). Appropriate approach in measuring waste generation, composition and density in developing areas. *Journal of the South African Institution of Civil Engineering*, *45*(3). 2-10.

Mentis, M. (2004). *Environmental Project Management: Certificate Course 21 - 26 June 2004.* Grahamstown: Rhodes University.

Metin, E., Eröztürk, A., & Neyim, C. (2003). Solid waste management practices and review of recovery and recycling operations in Turkey. *Waste Management, 23*, 425-432.

Midmore, D.J., & Jansen, H.G.P. (2003). Supplying vegetables to Asian cities: Is there a case for peri-urban production. *Food Policy, 28*, 13-27.

Mohee, R. (2002). Assessing the recovery potential of solid waste in Mauritius. *Resources, Conservation and Recycling, 36*, 33-43.

Mongkolnchaiarunya, J. (2003). Promoting a community-based solid-waste management initiative in local government: Yala municipality, Thailand. *Habitat International, 29*, 27-40.

Morel, A., & Forster, D. (2002). *Survey on environmental sanitation*. Sideng Environmental Sanitation Survey 2002.

Morris, P., & Therivel, R. (2001). (2nd ed.). *Methods of environmental impact assessment.* London: Spon Press.

Nel, S. (2005). (Munitech: Maintenance & operations specialist) (personal communication. June 23, 2005).

NSW EPA. (2003). *Consultation Paper, NSW Litter Survey Program: Proposed method for surveying litter in New South Wales.* Sydney: New South Wales Environmental Protection Authority

O'Donoghue, S., & Marshall, D.J. (2003). Marine pollution research in South Africa: A status report. *South Africa Journal of Science, 99*, 349-355.

Ojeda-Benitez, S., de Vega C.A., & Rami´rez-Barreto, M.E. (2003). Characterization and quantification of household solid wastes in a Mexican city. *Resources, Conservation and Recycling, 39*, 211-222.

Oldman, L. (2004, October 8). Coveted Blue Flag status awarded to Jeffreys Bay. *Our Times*. p.1.

Ottoson, J., Stenström, T.A. (2003). Faecal contamination of grey water and associated microbial risks**.** *Water Research, 37*, 645-655.

Our Times. (2004a, September 24). Mainbeach have a long way to go. p.4.

Our Times. (2004b, August 6). Stank was onuithoudbaar. p.4.

Palmer Development Group. (1996). *Evaluation of solid waste practice in developing urban areas of South Africa.* WRC Report No 629/1/96.

Pretorius, L., & de Villiers, G. (2003). The impact of a developing community on the water quality of an urban river. *Acta Academica Supplementum , 1*, 173-191.

Pumsa, K. (2005). (Field officer: DWAF) (personal communication. July 26, 2005).

Rahardyan, B., Matsuto, T., Kakuta, Y., & Tanaka, N. (2004). Resident's concerns and attitudes towards solid waste management facilities. *Waste Management , 24*, 437-451.

Randall, L. (2004, July 23). Rioolwater loop in Pellsrus se strate. *Our Times*. p.10.

Salukazana, L., *et al.* (2005). Plant growth and microbiological safety of plants irrigated with grey water. *Ecological sanitation: a sustainable, integration solution. Conference documentation. 3rd International Ecological Sanitation Conference 23 - 26 May 2005 Durban, South Africa*, 273-280.

Sawman, M., & Lirqhart, P. (1998). *A place called home: Environmental issues and low cost housing.* Cape Town: University of Cape Town Press.

Schoeman, G. (1997). *The development of programs to combat diffuse sources of water pollution in residential areas of developing communities*. WRC Report No. 519/1/97.

Schuyt, K.D. (2005). Economic consequences of wetland degradation for local populations in Africa. *Ecological Economics 53.* 177-190.

Silva-Iñiguez, L., & Fischer, D.W. (2003). Quantification and classification of marine litter on the municipal beach of Ensenada, Baja California, Mexico. *Marine Pollution Bulletin, 46*, 132-138.

Singer, S.F. (1970). *Global effects of environmental pollution: A symposium organized by the American Association for the Advancement of Science held in Dallas, Texas, December 1968.* Dordrecht, Holland: D. Reidel Publishing Company.

South African Weather Service. (electronic communication. 26 July, 2005).

Statistics SA. (2001). *Census 2001 by province, refuse or rubbish disposal and population group of head of household (derived).* Retrieved March 23, 2006 from http://www.statssa.gov.za/census01/Census/Dialog/SaveShow.asp

Statistics SA. (2003). *Statistics South Africa Census 2001: Ward profile 2003*. Retrieved March 4, 2005 from http://www.statssa.gov.za/census2001/atlas_ward2/index.html

Swanepoel, H. (1993). *Community Development: Putting plans into action.* Eppindust: Creda Press.

Taebi, A., & Droste R.L. (2004). Pollution loads in urban runoff and sanitary wastewater. *Science of the Total Environment, 327,* 175-184.

Talerko, N. (2004). Mesoscale modelling of radioactive contamination formation in Ukraine caused by the Chernobyl accident. *Journal of Environmental Radioactivity, 78,* 311-329.

Tudor, D.T., Williams, A.T., Randerson, P., Ergin, A., & Earll, R.E. (2002). The use of multivariate statistical techniques to establish beach debris pollution sources. *Journal of Coastal Research, 36*, 716-725.

Todd, J., Erica J.G., Brown, E.J.G., & Wells, E. (2003). Ecological design applied. *Ecological Engineering, 20,* 421-440.

United Nations Department of Economic and Social Affairs, & United Nations Department of Public Information. (2004, October 27). *Millennium development goals: Progress report*. Retrieved June 9, 2005 from
http://www.un.org/millenniumgoals/mdg2004chart.pdf

UNEP. (1995, December 5). *Global program of action for the protection of the marine environment from land-based activities*. Washington, DC: UNEP (OCL)/LBA/IG.2/7.

UNEP. (2000a). *International Source Book on Environmentally Sound Technologies for Wastewater and Storm water Management*. Retrieved November 12, 2004 from
http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-15/preface.asp

UNEP. (2000b, June 27). *Pollution from land: The treat to our seas*. Retrieved August 20, 2004, from
www.gpa.unep.org/documents/other/brochure/GPA_english.pdf

UNEP. (2001, August 21). *An overview of land-based sources of marine pollution.* Retrieved August 8, 2004 from
http://www.cep.unep.org/issues/lbsp.html

UNEP. (2004). *Improving municipal wastewater management in coastal cities: Training manual 1*. The Hague: Train-sea-coast GPA.

UNEP - IETC. (2004). *Environmental Management and Community Participation: Enhancing Local Programs.* United Nations Environmental Program - International Environmental Technology Centre.

Velander, K., & Mocogni, M. (1999). Beach Litter Sampling Strategies: is there a best method? *Marine Pollution Bulletin, 38*, (12), 1134-1140.

Walsh, D. (2004). Death in the Oceans. Proceedings of the United States Naval Institute, 130(9), 1. Retrieved October 17, 2004 from EBSCO online database.

Water Research Commission (WRC), Department of Water Affairs and Forestry (DWAF), Department of Agriculture, Department of Health and Sludge Consult (2002). *Permissible utilization and disposal of sewerage sludge.* (1st ed., add 1). Report No. TT154/01.

Wattage, P., & Mardle, S. (2005). Stakeholder preferences towards conservation versus development for a wetland in Sri Lanka. *Journal of Environmental Management*, 1-11.

Weistra, K. (2005). (Principal: Pam Golding Properties Jeffreys Bay) (personal communication. February 8, 2005).

Wildlife and Environmental Society of South Africa. (2004). *Blue Flag campaign: South Africa flies the Blue Flag!* Retrieved September 26, 2004, from http://www.wcape.school.za/wessa/Blue%20Flag.htm

Williams, B. (2004, October). Controversy over Blue Flag Beach. *What's up in Jeffreys Bay*. p.1.

Williams, A.T., Pond, K., & Phillip, R. (2000). Aesthetic aspects, Ch. 12: Monitoring bathing waters. Retrieved November 4, 2004, from http://www.who.int/docstore/water_sanitation_health/bathwater/ch15.htm

Winblad, U., & Simpson-Hébert, M. (2004). *Ecological sanitation: revised and enlarged edition*. Stockholm: SEI.

Wood, A., Urchronska, W., & Valashiya, G. (2001). *Grey water management in dense, informal settlements in South Africa*. WRC Report No 767/1/01.

World Summit Publication. (2002). *The long walk to sustainability: A southern African Perspective*. Johannesburg: HIS South Africa.

Wright, A., Kloppers, W., & Fricke, A. (1993). *A Hydrological investigation of the storm water runoff from the Khayelitsha urban catchment in the False Bay area, South Western Cape*. WRC Report No 323/1/93.

Zurbrügg, C., & Ahmed, R. (1999). Enhancing Community Motivation and Participation in Solid Waste Management. *SANDEC News, 4*, ISSN 1420-5572.

Zurbrügg, C., Drescher, S., Rytz, I., Sinha, M., & Enayetullah, I. (2002). *Decentralized composting in Dhaka, Bangladesh production of compost and its marketing*. Istanbul: ISWA 2002 Annual Congress.

APPENDICES

APPENDIX A

COMMUNITY QUESTIONNAIRE

Interviewer's Name:____ Number:______

SECTION A: RESPONDENT'S DETAILS

1. Age of respondent.

____

2. Male or female.

____

3. Composition of the household. (State number of persons within specific age group)

0 - 5	_____
6 - 15	_____
16 - 35	_____
36 - 60	_____
61 - 75	_____
75+	_____

4. Level of education. (Mark off)

None	_____
Primary school	_____
Secondary school	_____
Tertiary education	_____

5. Household income annually. (Mark off)

R1 - 2 400 ______
R2 401 - 6 000 ______
R6 001 - 12 000 ______
R12 001 - 18 000 ______
R18 001 - 42 000 ______
R42 001 - 54 000 ______
R54 001 - R72 000 ______
R72 001 - R 96 000 ______
R96 001 - R132 000 ______
R132 001 - R192 000 ______
R 192 001 - R360 000 ______
Over R360 000 ______
Unspecified ______

6. Employment type.

____

7. Dwelling type. (State: formal or informal)

____

SECTION B: SOLID WASTE

8. How many bags of solid waste do you produce per week?

____

____

9. What do you do with your solid waste?

____

____

____

10. What are the most common objects you dispose off? (Classify in order of merit by means of numbering)

a. Organic matter (i.e. vegetable, animal)? ______
b. Paper/ Cardboard? ______
c. Glass? ______
d. Garden waste? ______
e. Wood? ______
f. Metal (tins etc.)? ______
g. Plastic/ Rubber? ______
h. Other? ______

11. If you use the local skip do you place the waste into the tip or next to it? Why?

____

____

____

12. Are you happy with the way solid waste is managed in your area?

____

____

13. Are there problems with the operation of the waste skip? If yes, please provide details.

____

____

____

14. How would you like to see the system change?

____

____

____

15. How do you think the solid waste impacts on the environment?

____

____

____

16. Do you recycle or reuse any objects? If so, please give details?

____

____

____

17. Do you have a compost facility at your home that is used regularly? If so, what type of material do you compost and what do you do with the compost?

____

____

____

18. Would you be willing to contribute money to a one-man-contract solid waste removal service? If yes, how much per month? (Mark off)

None	_____
R1 - R5,00	_____
R5,01 - R10,00	_____
R10,01 - 15,00	_____
R15,01 - 20,00	_____
R20,01 - R25,00	_____
R25,01 - R30,00	_____
R30,01 - R35,00	_____
R35,01 - R40,00	_____
R40,01 - R45,00	_____
R45,01 - R50,00	_____
R50,01 - R55,00	_____
R55,01 - R60,00	_____

R60,01 - R65,00 ______

R65,01 - R70,00 ______

R70,01 - R75,01 ______

R75,01 - R80,00 ______

R80,01 - R85,00 ______

R85,01 - R90,00 ______

R90,01 - R95,00 ______

R95,01 - R100,00 ______

SECTION C: WASTEWATER (GREY WATER) & SEWAGE DISPOSAL

19. How many buckets of water do you use each day? (Standard 5 litter bucket)

____

____

20. What do you do with your wastewater from washing and cooking?

____

____

____

21. Would you consider using this water on a garden?

____

____

____

22. Would you use a soak away? (Explain design and show illustration)

____

____

____

23. Would you be willing to construct such a system on your premises?

____

24. Can you for see any problem with this design?

____

____

____

25. Where is the toilet that you and your family make use of?

____

____

____

26. Do you experience any problems with these facilities?

____

____

____

27. Do you always use these facilities? Explain answer?

____

____

____

28. Would you consider using an urine diversion toilets? (Show picture and explain design)

____

____

____

29. Would you be willing to building such a facility at your home?

____

____

____

30. Would you be wiling to contribute money to the building of such a facility at your home? If yes how much? (Mark off)

Not anything	_____
R1,00 - 100,00	_____
R100,01 - 200,00	_____
R200,01 - 300,00	_____
R300,01 - R400,00	_____
R400,01 - R500,00	_____
R500,01 - R600,00	_____
R600,01 - R700,00	_____
R700,01 - R800,00	_____
R800,01 - R900,00	_____
R900,01 - R1000,00	_____

SECTION D: THE WETLAND

31. Are you aware of the wetland that runs through this area?

____

____

32. Do you think that this wetland is very polluted? If yes where does the pollution come from?

____

____

____

33. How would clean up of the wetland benefit the community?

____

____

____

34. Would you be willing to contribute money to the rehabilitation of the wetland? If yes how much? (Mark off)

R1,00 - 5,00	_____
R5,01 - R10,00	_____
R10,01 - 15,00	_____
R15,01 - 20,00	_____
R20,01 - R25,00	_____
R25,01 - R30,00	_____
R30,01 - R35,00	_____
R35,01 - R40,00	_____
R40,01 - R45,00	_____
R45,01 - R50,00	_____
R50,01 - R55,00	_____
R55,01 - R60,00	_____
R60,01 - R65,00	_____
R65,01 - R70,00	_____
R70,01 - R75,01	_____
R75,01 - R80,00	_____
R80,01 - R85,00	_____
R85,01 - R90,00	_____
R90,01 - R95,00	_____
R95,01 - R100,00	_____

35. Would you be willing to contribute time to the rehabilitation of the wetland? If yes how many hours per week? (Mark off)

1 - 2	_____
3 - 4	_____
5 - 6	_____
7 - 8	_____

SECTION E: MARINE POLLUTION

36. How often do you or your family visit the local beach? (Mark off)

More than once a day	______
Once a day	______
Once a week	______
Once a month	______
Once a year	______
Never	______

37. When you are there, what do you do most often? (Mark off)

Fish	______
Play	______
Surf	______
Swim	______
Lie on beach	______
Walk	______
Other	______

38. Have you experienced any problems with waste or the water quality on the beach? If yes, provide details.

____

____

____

39. Are you aware of the Blue Flag project? If yes, what is it?

____

____

40. Are you aware of the impact of solid waste, grey water and sewage on the beach or sea?

____

____

____

APPENDIX B

MUNICIPALITY (SOLID WASTE MANAGEMENT) QUESTIONNAIRE

1. What are the different systems used for solid waste removal in Jeffreys Bay?

___

___

___

2. How is it decided whether to use a waste skip or curbside solid waste removal system?

___

___

___

3. How do you feel the solid waste management system is working in terms of environmental protection and providing a socially acceptable service?

___

___

___

4. What are your greatest frustrations regarding the Kouga solid waste management system?

___

___

___

5. What are the main complaints that you receive about the solid waste management system?

6. What do you see as possible solutions to the current state?

7. Do you provide black bags for the people to put their waste in? If not why not?

8. Why is a curbside collection not an option for the whole of the township instead using the waste skip method?

9. Do you think a one-man-contract system will work? If not why not?

10. Would you be willing to move waste skips to increase community accessibility?

11. Whose responsibility is it to issue fines for illegal waste dumping? Have any fines been issued over the last year?

____

____

____

12. What do you think of the possibility of recycling and composting?

____

____

____

13. In your opinion, is the management of waste from industry problematic?

____

____

____

14. If yes, can you provide any examples? Which industries pose the biggest problem?

____

____

____

15. Are incentives in place to encourage industry to reduce the volumes of waste produced?

____

____

____

16. To the best of your knowledge, do any of the industries in the vicinity of the study area produce toxic or hazardous waste?

____

____

____

APPENDIX C

MUNICIPALITY (SEWAGE DISPOSAL AND GREY WATER MANAGEMENT) QUESTIONNAIRE

1. Do you consider grey water as an environmental and health problem?

____

____

____

2. What management actions are planned to mitigate grey water pollution?

____

____

____

3. How many toilets are currently available for informal settlement residence in Jeffreys Bay?

____

____

____

4. What type of sewage disposal technologies are being used?

____

____

____

5. Do you think the sewage disposal services for Pellsrus and Tokyo Sexwale are sufficient?

____

____

____

6. What is the current ratio of residents to toilets?

____

____

____

7. What are the primary problems, if any, regarding Kouga sewage disposal delivery?

____

____

____

8. What are the main complaints that you receive regarding sewage disposal service delivery?

____

____

____

9. What do you see as possible improvements?

____

____

____

10. What percentage of the toilets are not working at any one time?

____

____

____

11. What are the most common causes of toilets not functioning?

____

____

____

12. How often does the municipality check public toilets?

____

____

____

13. Is informal ablution perceived as a problem and are there plans in place to address this issue?

____

____

____

14. Is Jeffreys Bay likely to comply with the millennium development goals in terms of provision of sewage disposal?

____

____

____

15. Have you heard of urine diversion toilets (ecological sewage disposal)? Explain if necessary.

____

____

____

16. Do you think urine diversion toilets is a possible solution for the Kouga sewage disposal backlog? If not, why not?

____

17. How do you think solid waste and a lack of sewage disposal impacts on the environment?

18. Have you experienced any problems with waste or the water quality on the beach? If yes, provide details?

19. What is the financial value of the Blue Flag status to Jbay?

20. Do you think that the state of sewage disposal and waste management in the informal housing area can have a negative impact on the Blue Flag status of Jbay? If yes, how?

APPENDIX D

BUSINESS COMMUNITY QUESTIONNAIRE

1. Are you satisfied with Kouga service delivery regarding solid waste management and sewage disposal?

____

____

____

2. How would you like to see the system change?

____

____

____

3. Do you think the current state of solid waste management and a lack of sewage disposal impacts on the commercial sector of the town?

____

____

____

4. Do you see a link between poor waste management and sewage disposal in the informal community and the state of the beach / seawater quality? If so, what is the link?

____

____

____

5. Have you experienced any problems with waste or the water quality on the beach? If yes, provide details.

____

6. Are you aware of the impact of solid waste, grey water and sewage on the beach or sea?

7. Do you think that businesses in the town would be willing to contribute financially to projects that reduced the risk of contamination of the beach and marine environment?

8. Would the business community see any other benefits in supporting waste management initiatives in the town?