Epidemic cholera in KwaZulu-Natal: The role of the natural and social environment

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DECLARATION

I declare that the thesis, which I hereby submit for the degree Philosophiae Doctor at the University of Pretoria has not been previously submitted by me for a degree at another university.

M D Said **Date**

SUMMARY

Title:	**Epidemic cholera in KwaZulu-Natal:** **The role of the natural and social environment**

By

Maryam Darwesh Said

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Degree:	**PhD - Water Resource Management**

Cholera made an unforeseen appearance on the eastern coast of South Africa in the province of KwaZulu-Natal (KZN) in August 2000. Having started from the more urban centres of the coastal region of the province, cholera proceeded unabated to the interior of the province where no community was spared from the scourge. Despite prompt medical intervention, health education and media awareness campaigns, cholera continued to spread throughout KZN. By March 2004, the official statistics of cholera cases in KZN as per the Cholera Database records, stood at 158 895 cases (Dept-KZN Health, 2000). The death toll as reported in the Cholera Database was 575 persons that translated to a percentage case fatality rate of 0.36%; the lowest when compared to the previous epidemics recorded in South African (Kustner *et al.*, 1981; Küstner and du Plessis, G. 1991). An interesting feature of the epidemic was that 99% of the cases recorded by the central and provincial Departments of Health during the height of the epidemic were all from KZN.

The question then was, what factors played a role in the cholera epidemic of KZN? This study sought to understand the outbreak and the factors that possibly contributed to the spread of the 2000-2004 cholera epidemic in KZN. The drivers of disease associated with the communities affected by cholera were also explored by analysing the complex and

dynamic interaction of their biological, socio economic, and environmental nature over time and space. The nature of the study was such that it called for a multi faceted design to involve not just understanding the societal aspect of the disease but its demographic, ecological and spatial characteristics as well. Thus GIS was used as a research tool to facilitate the comparison of the disease trends and risk factors on a spatial level in order to determine the possible role(s) played by the different environmental and socio-economic drivers.

The objective of the study was to investigate the possible role of the natural environment i.e. temperature, rainfall and humidity as the primary factors that influence cholera outbreaks in KZN; on the basis of its uniqueness in climatic conditions as compared to other areas of the Republic of South Africa (RSA). The other socio-economical and demographic factors were considered as factors that enhance the spread of the disease. As such, the exploration of the Cholera Database by use of spreadsheet, statistical correlations and spatial mapping using GIS technology mutually investigated the relationships between the different variables that came up as important factors in the spread of cholera.

Results indicated that 52% of the total cholera cases in KZN were reported from DC28 (Uthungulu), making it the focal point of the epidemic. In general, all the age groups were represented in the cholera database though the age groups 15-19 years and 0-4 years featured more prominently in the overall epidemic picture. On average the male to female case ratio was 1:1.5 respectively. The major cholera peak was experienced in 2001 and a minor peak in 2002. Both the peaks appeared during the summer months, which are also characterised by heavy rains.

The issues that were statistically proven to be associated with the spread of the disease were related to issues highlighting the inefficiencies in the provision of water and sanitation, which go hand in hand with poverty. Thus poverty was indirectly reflected in the data as an issue that compounded the cholera epidemic. There was no statistical correlation between the incidence of cholera and the climatic variables of rainfall, humidity and temperature. Notwithstanding, there was an overall seasonality revealed by the data, as seen with the cases peaking and waning between the summers and the winters respectively. Furthermore, GIS mapping revealed a concurrence between the incidence of cholera and the climatic variables of rainfall, humidity and maximum temperature.

At the spatial level, the characteristics of the epidemic as revealed by the GIS maps and spatial modelling highlighted possible relationships between the incidence of cholera and the various socio-economic and climatic variables (Chapter 6: 6.2.3; 6.2.3). The spatial disease picture displayed a link between climatic seasons and the incidence of cholera. Spatial modelling offered more insight that the statistically supported climatic and socio-economic aspects were indeed important factors in guiding cholera outbreak predictions in the future. The cholera model illustrated this as it selected for areas considered to be at high risk for cholera (Map 34).

The results give an altogether holistic portrayal of the cholera epidemic from all perspectives and also supported to the hypothesis that cholera is a function of social and environmental factors. The results from this study further confirm the negative health effects of inadequacies in basic services delivery. The study made use of data resources to understand the relationships between the incidence of cholera and the different demographic, socio-economic and climatic variables implicated in the spread of cholera epidemics (Chapter 3: 3.3.3). It also emphasizes the importance of using reliable data as a management tool to model various scenarios in order to obtain information that could be used in the prediction and management of diseases like cholera at the community level in the future.

Keywords: Epidemic Cholera
Disease trend
Socio-economic variables
Climate
Poverty
GIS mapping
Risk models

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LIST OF ABBREVIATIONS

AIDS	Acquired Immuno Deficiency Syndrome
CFR	Case Fatality Rate
CIR	Cumulative Infection Rate
DC	District Council
DOH	Department of Health
E	East
EA	Enumerator Area
GEAR	Growth Employment and Redistribution
GIS	Geographical Information System
HIV	Human Immunodeficiency Virus
km	kilometre
KZN	KwaZulu-Natal
MD	Magisterial District
n	Number
N	North
^{o}C	Degree Celsius
ORS	Oral Rehydration Salts
ORT	Oral Rehydration Therapy
p	probability
PHC	Primary Health Care
r	Correlation coefficient
R	Rand
RSA	Republic of South Africa
S	South
sq	Square
STATSSA	Statistics South Africa
UN	United Nations
WHO	World Health Organisation
WRC	Water Research Commission

The degree PhD

Maryam Darwesh Said

Maryam Darwesh Said obtained her BSc(Hons) in Zoology and Botany from the University of Nairobi in 1985. In 1994, she completed her MSc(Med) in Molecular Biology at the University of the Witwatersrand. Thereafter she joined the National University of Lesotho as a Lecturer in the Department of Biology. She commenced with her PhD studies at the University of Pretoria in 2002 in Water Resource Management.

In her thesis, **Epidemic cholera in KwaZulu-Natal: The role of the natural and social environment**, the promovendus investigated the possible role of the natural environment i.e. climatic factors that influence cholera outbreaks in KwaZulu-Natal; on the basis of its uniqueness in climatic conditions as compared to other area in South Africa. In addition, the socio-economic and demographic factors were also considered. The issues that were proven to be associated with the disease were related to issues highlighting inefficiencies in the provision of water and sanitation, which go hand in hand with poverty. GIS technology and spatial mapping and risk modelling was used to select areas considered to be at high risk for cholera due to the inadequacies in basic service delivery. The study illustrated how health, demographic, climatic and socio-economic data can be used as a reliable disease management tool that could be used in the prediction and management of diseases like cholera. The research findings from this thesis have been presented at conferences both locally and internationally.

Supervisor: Prof: T.E. Cloete (University of Pretoria)
Co-supervisor: Prof: S.N.Venter (University of Pretoria)

CHAPTER 1:

Introduction

When the first cholera cases due to *Vibrio Cholerae* El Tor were reported in KZN in August 2000, few would have imagined that it would develop into one of the largest outbreaks yet recorded in South Africa. Coincidentally, the cholera epidemic struck at a time when the privatisation drive for water supply services was in progress. Several reports linked cholera to the water privatisation, and that the communities affected were mostly those who could not afford to pay for water services thus resorting to the use of natural water sources (Nhlapo-Hlope, 2001; Ka-Min, 2000). This popular thinking pointed to natural water sources as being a possible environmental reservoir for cholera organisms, implying that a direct link exists between the use of natural water sources, and the spread of cholera.

Although *Vibrio cholerae* is known to occur in diverse aquatic systems, there is limited knowledge about its ecological interaction with abiotic environmental factors. For that reason, an environmental approach is essential for evaluating the role of *Vibrio cholerae* in human disease. Cholera incidence is influenced by a changing micro-ecology of *V. cholerae*, vulnerability of people through exposure to health risks, resistance to infection through immunity and/or nutritional status, and environmental, socio-economic and behavioural changes (Collins, 2003). Thus in a given environment *Vibrio cholerae* may be establishment as an endemic or a recurrent pathogen. These two modes suggest the possible establishment of at least a transient environmental reservoir for cholera in the region affected (Shapiro *et al.*, 1999).

Cholera has long been recognised as a disease that reflects a complicated transmission pattern, in that multiple factors may play a role in the spread of the disease. Factors implicated in one area as being important in the spread of cholera may not be significant in another. Figure 3.1 outlines the relationships between the cholera pathogen, and the various factors that can act as possibly routes for transmission. A detailed discussion of these factors is given in more detail in Chapter 2: 2.3.4.

Historical records describe the disease cholera since the pre-Christian era affecting civilizations in Indo-Asia, China, the Middle East and Europe; where an array of myths surrounded the disease. The earlier interventions, proposed in an era of limited knowledge about infectious diseases, though well meaning, caused more harm than good. Modern medicine has taken great strides in the treatment and prevention of infectious diseases, yet even in this age of advanced technical medical interventions, cholera still instils a sense of fear in the communities it affects. Despite the abundance of scientific information on the disease and how to control it with the simple intervention of Oral Re-hydration Therapy (ORT), cholera still evades prevention.

Since 1970, when the seventh cholera pandemic first crossed over to the African continent, South Africa had experienced few imported cholera cases from neighbouring countries of Mozambique, Malawi, Angola and Zambia to name a few (Barua, 1992; WHO, 2000). Most of these cases are thought to be a consequence of migrant labourers coming to seek employment in South African mines or plantations (Isaäcson, 1974). As such, the Department of Health (DOH) of South Africa, documented cholera cases reported from all the provinces from 1980 – 2000 (DOH-Statistical Notes, 2000). According to the aforementioned record, the annual cholera cases in Kwa-Zulu, Natal (KZN) during 1980 – 2000 were the lowest in 1980, with only one cholera case, and highest in 1982 with 12 263 cholera cases.

Cholera made an unforeseen appearance on the eastern coast of South Africa in the province of KwaZulu, Natal (KZN) in 2000. Having started in August 2000, from the more urban centres of the coastal region of the province, cholera proceeded unabated to the interior of the province where no community was spared from the scourge. Despite prompt medical intervention, health education and media awareness campaigns, cholera continued to spread throughout the province of KZN. By March 2004, the official statistics of cholera cases in KZN as per Cholera Database records, stood at 158 895 cases (Dept-KZN Health, 2000). The death toll as reported in the Cholera Database was 575 persons that translated to a percentage case fatality rate of 0.36%; the lowest compared to the previous epidemics recorded in South Africa (Kustner *et al*., 1981; Küstner and du Plessis, G. 1991). An interesting feature of the epidemic is that 99% of the cases recorded by the central and provincial Departments of Health during the peak of the epidemic were all from KZN. The remaining eight provinces reported only sporadic outbreaks or were completely spared from the disease (DOH-a, 2002).

The question then was, what were the factors that contributed to cholera reaching to epidemic proportions in KZN? This study therefore sought to understand the outbreak and the factors that possibly contributed to the spread of the cholera epidemic in KZN over the period 2000-2004. The study also called for the issues associated with the communities affected by cholera to be determined by analysing the complex and dynamic interaction of biological, socio-economic, and environmental factors over time and space. The nature of the study was such that it called for a multi faceted design to involve, not just understanding the societal aspect and trend of the disease, but also its spatial characteristics. In addition to the knowledge of the microbiology and ecology of the disease, GIS (Geographical Information System) facilitated the comparison of the disease trends and the implicated factors on a spatial level in order to determine the possible role(s) played by the different environmental and socio-economic parameters.

More specifically, the aim of the study was to investigate the possible role of the natural environment i.e. temperature, rainfall and humidity as the primary factors that influenced the spread of cholera outbreaks in KZN; on the basis of its (KZN) unique climatic conditions as compared to other areas of the Republic of South Africa (RSA). The other socio-economic and demographic factors were considered as factors that enhanced the spread of the disease. Thus a hypothesis was put forward that both the climatic conditions and socio economic variables like sanitation, clean water supply, population density, health service delivery etc., contribute to the vulnerability of communities and assist in the spread of cholera in KwaZulu-Natal. As such, the objective of the study was to contribute in the identification of factors that can be used as principles in pre-empting possible cholera outbreaks within the region. Overall, the \study demonstrated the usefulness of health data within the fraternity of water resource management in addressing issues linked to the possibilities of waterborne diseases like cholera.

CHAPTER 2:

Literature Review

"On the bed lay an expiring woman…presenting an attitude of death which…I never saw paralleled in terror…On the floor, extended on a palliasse… lay a girl of slender make and juvenile height, but with a face of a superannuated hag. She uttered no moan, gave expression of no pain, but she languidly flung herself from side to side …The colour of her countenance was that of lead- a silver blue, ghastly tint; her eyes were sunk deep into the sockets, as though they had been driven an inch behind their natural position; her mouth was squared; her features flattened; her eyelids black, her fingers shrunk, bent and inky in their hue. All pulse was gone at the wrist, and a tenacious sweat moistened her bosom. In short, Sir, that face and form I can never forget, were I to live beyond the period of man's natural age."

Dr. W.B. O'Shaughnessy's description of a cholera patient in 1831 (Cosnett, 1989).

2.1 Introduction: Cholera pandemics

Cholera is an ancient disease described by Hindus, Chinese, Arabs, Greeks and, Romans since the pre-Christian era (Russell, 1925). Documented cholera dating back to 1817, acknowledge all cholera pandemics to have originated from India, where the infection has probably been entrenched since times immemorial (Swaroop and Pollitzer, 1955; Blake, 1994). The geographical distribution harbouring the endemic foci has its centre in Bengal, in the Indian subcontinent, with a consistent and well-marked seasonal variation in individual parts of India (Swaroop and Pollitzer, 1955). The early pandemics revealed no apparent pattern of periodicity, though records show that the intervals between pandemics were no less than 5 years (Russell, 1925). Cholera, since first documented, has been around the world in seven pandemics, the latest (seventh), which is still in progress, is purported to have originated in Sulawesi, Indonesia in 1961 (Fig. 2.1). When the seventh cholera pandemic began, it was initially limited to areas in Asia and the Indian subcontinent, and later spread into the former USSR and Middle East (WHO, 2000).

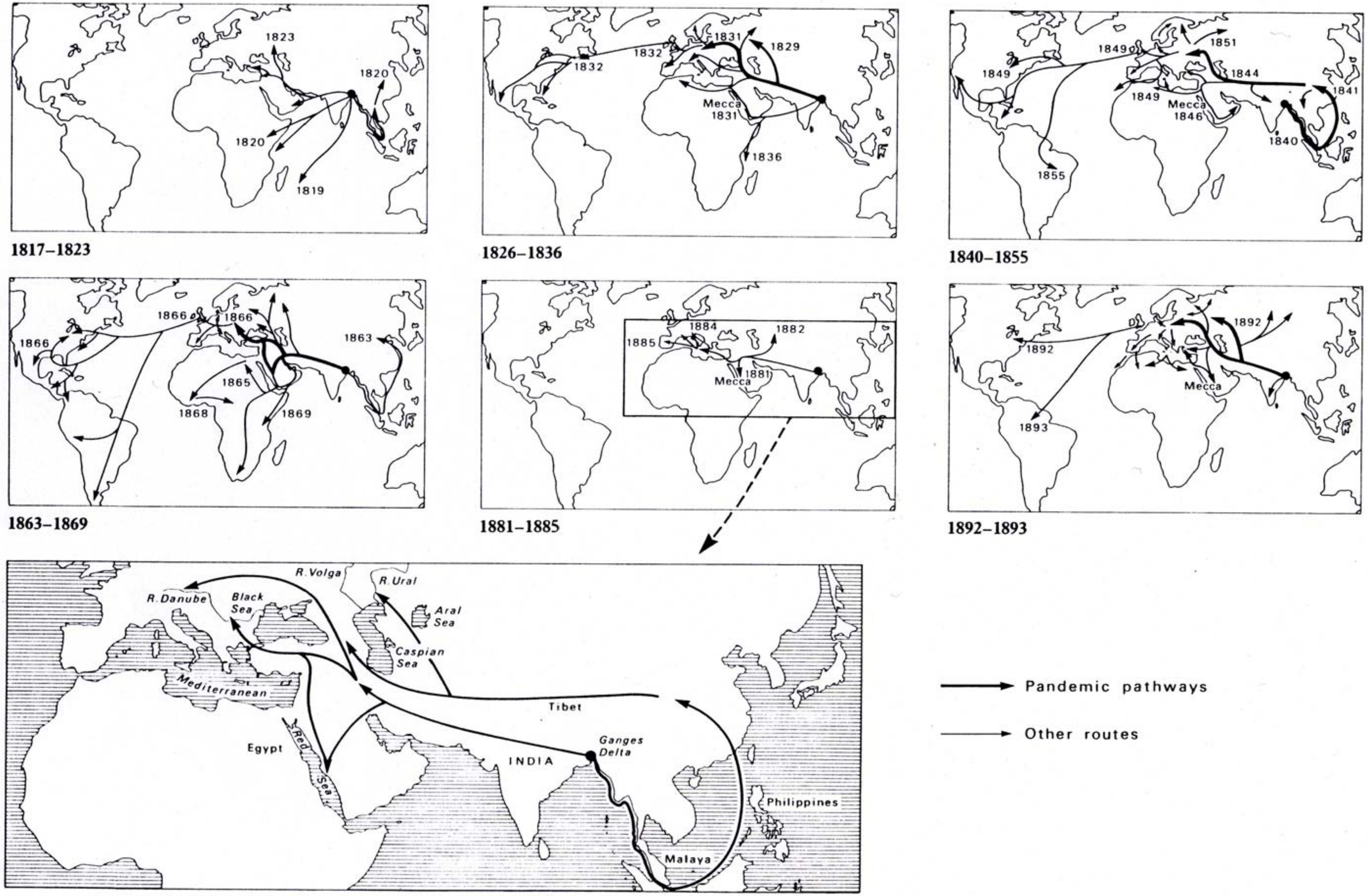

Fig 2.1. World maps of six cholera pandemics in the nineteenth century showing the main pathways followed (Adapted from: A.D. Cliff and P. Haggett. 1988. Cholera in London. In: Atlas of Disease Distributions. Analytical approaches to epidemiological data. p5-11. Blackwell Publishers. U.K.)

2.1.1 Cholera in Africa

During the 19th century five of the pandemics affected North Africa. Pilgrims returning from Mecca introduced cholera into Egypt, and the infection subsequently spread along the river Nile, into Upper Egypt and Sudan. Egypt had an outbreak of 33 000 cholera cases and 20 500 deaths in 1947 (Barua, 1992). The outbreaks of cholera in West Africa that occurred between 1868 and 1894 were thought to have followed the introduction of the disease by caravans (Swerdlow and Isaäcson, 1994). In 1970 cholera struck West Africa again, which had not experienced the disease for more than 100 years. The disease quickly spread to a number of countries and eventually became endemic in most parts of the African continent (WHO, 2000a). As the pandemic navigated its way into Africa, there were two main epidemic foci, in southern and eastern Africa (Zambia, Mozambique, Malawi and Angola) and in West Africa (Barua, 1992).

The West African epidemic, began in Guinea in August 1970 and by September of the same year, over 20 000 cases and 60 deaths were reported (Goodgame and Greenough, 1975; WHO, 1991). Initially, cases were concentrated along coastal regions and subsequently spread to the other regions by the travels of fishermen and boatmen. Between September 1970 and February 1971, epidemics occurred in Sierra Leone, Liberia, Cote d'Ivore, Ghana, Togo, Benin, Nigeria, southern Cameroon and Mali. Chad and northern Cameroon, with their desert like regions were also affected by cholera, proving that cholera could spread in drier areas (WHO, 1991). At the same time epidemics of cholera thought to have originated from the Middle East spread into Libya, Tunisia, Algeria, Djibouti, Ethiopia and Somalia. By 1971, 25 countries had reported cases of cholera to the WHO, with an overall case fatality rate of 16%. The number of deaths from cholera in Africa represented 73% of the global total for that period (Crowcroft 1994).

Since the 1970s, cholera has occurred among refugees and displaced persons in Somalia, Ethiopia, Sudan, Malawi and Mozambique. Such groups of people are particularly at risk because of overcrowding, inadequate sanitary facilities and water supplies as well as malnutrition (Moren et al., 1991; Toole and Waldman, 1990). Cholera continued to be reported by many African countries well into the 1980s with

Malawi doing so in October 1989. During the same period sub-Saharan Africa reported nearly three quarters of the global cholera cases. Countries close to South Africa, which were also affected at the time, were Angola, Mozambique and Zambia (Anonymous, 1990).

In 1991, there was a resurgence of cholera in many parts of Africa with 21 countries reporting outbreaks of cholera, the highest number since the start of the seventh pandemic on the continent in 1970. The massive outbreak of the El Tor strain of cholera among Rwandan refugees in Goma, Zaire, resulted in 70 000 cases and 12 000 deaths in July 1994 (Sánchez and Taylor, 1997). By 1996, cases of cholera notified to WHO from Africa were accounting for 93% of all reported cholera cases worldwide, with a case fatality rate of 5.7% (WHO, 1997).

Zambia experienced widespread intermittent cholera epidemics in 1991 (13 154 cases), 1992 (11 659 cases), 1999 (11 327 cases) and in 2003/2004 (2 529 cases), (CDC, 2004). In response to the 1999 cholera outbreak, there was a widespread campaign to promote in-house chlorination of drinking water supplies as well as promoting microbial safe-water storage strategies (CDC, 2004). The year 2000 saw 56 countries officially notifying the WHO of cholera, with 27 of these countries belonging to the African continent. Africa's cholera cases still accounted for the highest global total of 87%. The year 2000 witnessed major cholera outbreaks in the Comoros, Djibouti, the DRC, Mozambique, Somalia, South Africa (Kwa-Zulu-Natal) and Madagascar, which was cholera free until 1999 (Duval *et al.*, 1999). The statistics of cholera in South Africa for the year 2000 ranked third (19 667 cases) after Madagascar (29 083 cases) and the DRC (14 995 cases), though South Africa had a comparatively low case fatality rate (CFR) of 0.35% (WHO, 2001a). Overall, epidemic cholera continues to be reported every year since it was introduced in the 1970s.

2.2 The history of cholera in South Africa

Cholera outbreaks made their mark in South Africa in the 1970s, about the same time the disease was considered endemic in neighbouring Angola, Malawi, Mozambique and Zimbabwe, and was fast spreading southwards through the African continent

(Küstner *et al.*, 1981; Isaäcson, 1986). It was inevitable for cholera outbreaks to cross into South Africa considering that migrant labourers seeking employment especially in the South African mining industry came from the cholera endemic neighbouring countries (Isaäcson *et al.*, 1974). This migrant labour force was well positioned to introduce cholera into rural areas of South Africa, due to the high labour turnover rate (Isaäcson, 1986).

Endemicity in these southern neighbouring countries warranted the establishment of a surveillance system to follow up on all reported cholera cases in South Africa (Isaäcson *et al.*, 1974). The asymptomatic cholera cases identified in a Transvaal gold mine after the introduction a large-scale surveillance programme in 1974; were the earliest official records of cholera in South Africa since the onset of the seventh pandemic (Isaäcson *et al.*, 1974). These reported cases could however, hardly be considered an epidemic, at best it was an outbreak that was quickly contained. Consequently, within two months the source of the cholera outbreaks was recognized and swiftly contained by instituting a sewage surveillance system using Moore pads (Isaäcson *et al.*, 1974). The surveillance system put in place managed to isolate *V.cholerae* from sewage prior and during an outbreak of cholera. In addition to the sewage system being recognised as a source of cholera organisms, another transmission route was thought to be due to contamination of drinking water kept in open containers on the floor of acclimatization centres. This was observed during the Transvaal (Gauteng) gold mine outbreak, whereby it was hypothesized that *Vibrio cholerae* O1 might have been carried by perspiration from the perianal region of asymptomatically infected persons to the floor of the acclimatization room and subsequently infect other miners directly or possibly indirectly via the humidifying system (Isaäcson *et al.*, 1974).

Subsequent to the cholera reports from the gold mines in the 1970s, there were cholera seasonal peaks in South Africa documented between 1980 and 1985. This cholera seasonality showed a pattern, which had become familiar in other cholera endemic areas of the world, whereby cholera was expected to wane, only to be followed by a recrudescence (Isaäcson, 1986). The initial cases were all from the eastern Transvaal (Mpumalanga) close to the Mozambique border. Later on, the epidemic spread into the provinces of Natal as well as Gauteng. The overall epidemic had an upward trend starting October 1980 to reach its peak in July 1983 and thereafter started waning until July 1987. Thus, within this particular epidemic, there were seven distinct cholera epidemic periods between October 1980 and July 1987 (Küstner and Du Plessis, 1991). Starting in October 1980, there was a cholera outbreak in Kangwane in the former eastern Transvaal (now Mpumalanga). By March 1981, there were 2,748 reported cholera cases with 36 deaths. The overall case fatality rate at the time being 1.3% (Kustner *et al.,* 1981). An epidemiological investigation into the outbreak revealed that all the patients had consumed water from an irrigation canal that served the farms they resided on. By November 1981, there was another cholera outbreak in Lebowa (Mpumalanga). Just like the epidemic in Kangwane, an investigation revealed that cholera patients had consumed water from a nearby Gumpies river (Sinclair *et al.,* 1982). The study also positively associated drinking water from water vendors with an increased risk of contracting cholera. As the cholera cases started declining, between August1982 - Jul 1987, the disease was mostly confined to the Natal province (Küstner *et al.,* 1981). In support of this observation, was a study in 1983 that screened in-patients at Eshowe hospital in Natal for cholera over a two-week period and finding a high incidence of cholera positive stools among the paediatric in-patients. This was also suggestive of endemicity within the community (Chapman and Collocott 1985). It became apparent then, that socio-economically deprived black communities, living in rural areas with relatively high rainfall, as in the former tribal homelands of Natal, KwaZulu and KaNgwane were the ones most affected by cholera outbreaks (Küstner and du Plessis, 1991).

Around the same period, there was a cholera outbreak in the Transkei (Eastern Cape) between October 1982 and September 1983 (Transkeian Dept of Health, 1982; Tshibangu and Stawski, 1984). A survey of water supply and sanitation services in rural Transkei found 87.2% of the respondents made use of natural water sources i.e. rivers, wells, springs, streams, dams and stagnant pools, as the main sources of drinking water supplies (Tshibangu, 1987). These natural water sources were susceptible to pollution and were potential carriers of pathogenic bacteria. In Transkei, cholera was one of the most common notifiable water-borne infections, often linked with the use of unprotected water supplies coupled with poor personal hygiene and unsanitary practices among the rural communities (Tshibangu, 1987).

After a decline in cholera cases since 1985, the Department of Health (DOH) released a communiqué in November 1997 warning about the spread of cholera southwards in Africa and the possibility of outbreaks in South Africa if precautionary measures were not taken. As such, provincial health facilities throughout the country were placed on alert and the necessary guidelines for managing a potential cholera outbreak were widely distributed. Bacteriological surveillance was carried out in the sewers of the major cities to detect cholera bacteria and laboratory facilities were prepared for confirming clinical diagnosis of the disease. Extensive public awareness campaigns to communities most at risk were also intensified (DOH, 1997).

Mpumalanga had another outbreak recorded early in 1998 and the use of surface water for drinking was quoted as the probable route for cholera transmission (Athan *et al.*, 1998). Mpumalanga's lowveld region is predominantly rural, an environment where clean water and adequate sanitation were often unavailable making the black communities particularly vulnerable to waterborne diseases like cholera (Athan *et al.*, 1998; Keddy and Koornhof, 1998). Considering this region borders Mozambique and Swaziland, many of the migrants casual labourers who are attracted to the banana and sugar plantations often contract cholera due to lack of sanitary facilities and safe water (Athan *et al.*, 1998; Durrheim *et al*., 2001).

2.3 Cholera – the affliction

Cholera is an acute diarrhoeal disease of humans caused by the bacterium *Vibrio cholerae*. Cholera is often confirmed through cultures and diagnostic tests of stool samples and serotyping the isolate; though the diagnosis remains primarily based on clinical findings (Weir and Haider, 2004). Onset of illness is usually rapid, with incubation periods varying from 6 hours to 5 days. Disease progression can also be rapid. The symptoms in the early stages of the disease may begin with intestinal cramping and the sudden onset of profuse, watery diarrhoea often accompanied by vomiting (WHO, 2000). In the classic clinical cases of the disease, *Vibrio cholerae* produces an enterotoxin that causes a copious, painless, watery diarrhoea that can quickly lead to severe dehydration, shock and death if treatment is not promptly given (Bennish, 1994). More than 90% of patients present with episodes that are of mild or moderate severity and these cases are difficult to distinguish clinically from other types of acute diarrhoea; while less than 10% of ill persons develop typical cholera with signs of moderate or severe dehydration (WHO, 2000a). Severe cases are associated with a clinical picture of a patient becoming lethargic with sunken eyes and cheeks (Cosnett, 1989).

Epidemics of cholera arise after *Vibrio cholerae* is introduced in non-endemic areas where most of the population have no immunity (Glass and Black, 1992). Epidemics are often unpredictable but usually occur seasonally. Cholera exhibits periodicity in the heavily endemic region of the Indian subcontinent. This varies from year to year and seasonally as well, depending on the amount of rain and the degree of flooding (Finkelstein, 1999). Cholera appears to wax and wane in endemic regions on time scales of 3 to 6 years, a pattern that has long been recognized (Pascual *et al.,* 2002). Once an epidemic wanes, the transition to an endemic phase occurs, as a large proportion of the population is immune or semi-immune at the time. Previous immunity decreases illness in adults and higher attack rates are therefore seen in children and women of child bearing age, who act as caretakers of the young and are inevitably exposed to large inocula of *Vibrio cholerae,* capable of initiating an infection (Kolvin and Roberts, 1982; Bradley *et al.*, 1996).

2.3.1 The pathogen

Vibrio cholerae, the causative agent of cholera is a chemo-organotrophic, asporogenous, Gram negative curved bacillus, motile by means of a polar flagellum. It is a facultative anaerobic organism; oxidase positive and can tolerate alkaline conditions up to a pH of 10, but is inhibited at pH6 or below. All isolates grow at 20C^{o} and most can grow at 30^{o}C (Baumann *et al.*, 1984). Being a halophilic organism, it requires NaCl for optimum growth, thus typically found in estuarine and marine environments, whereby it can be free living or in association, with shellfish, oysters and plankton, mostly copepods (Colwell *et al.,* 1977; Hood *et al.,* 1981; Tamplin *et al.*, 1990).

Although, more than 200 recognized *Vibrio cholera* O serogroups exist, until recently only two groups of *Vibrio cholerae* strains were documented; the O1 and non-O1 group. The O1 group was considered to be the pathogenic strain capable of causing epidemic or pandemic cholera. This is because of the O1 strain's ability to produce the cholera toxin (CT) responsible for the typical symptoms presented as cholera. The strains of the O1 group can be further subdivided into the “classic” and the El Tor biotypes, both of which are associated with epidemic cholera. During the 7th pandemic, El Tor has become endemic to Africa. It is a hardier strain than the classic biotype and survives longer in the environment (Shapiro *et al.*, 1999). *V.cholerae* O1 survives refrigeration and freezing, thus contaminated food products including those being shipped internationally, can distribute the organism far and wide from the point of original contamination (MMWR, 1991). In an epidemic situation, the source of contamination is usually the faeces of an infected person.

The non-O1 groups were generally identified as agents of sporadic cases of mild cholera-like diarrhoea in many parts of the world, and considered incapable of initiating cholera on an epidemic or pandemic scale (Blake *et al.*, 1980). This notion held true until 1992 when the causative agent for an epidemic in Bangladesh was found to be a non-O1 strain, a previously unrecognised serogroup of *V. cholerae,* now designated O139, synonym Bengal (Cholera Working Group, 1993; Shimada *et al.*, 1993; Islam *et al*., 1994). The epidemic potential of the new strain and the lack of immunity to it lead some authorities to question whether epidemics caused by the new strain may mark the beginning of the eighth cholera pandemic (Swerdlow and Ries, 1993). The potential of such a scenario is heightened when one considers that rapid transportation, frequent international travels and large population movements may support epidemics to spread faster than what has previously been the case. Within months of its appearance, *V. cholerae* O139 overwhelmed the entire Indian subcontinent and several Asian countries in a series of cholera outbreaks (Albert, 1996). By the year 2000, WHO had documented reports citing *V.cholerae* O139 as being responsible for outbreaks in 11 countries in South-East Asia (WHO, 2000).

The *V.cholerae* O1 and O139 appear to be genetically adapted to survive the entire transmission and infection cycle, i.e. from surviving the low gastric pH levels to colonization and proliferation in the ileum and finally expulsion through diarrhoea and survival in aquatic environments (Weir and Haider, 2004). As with the O1 strains, water and food seemed to be the vehicles of infection. Many family contacts of the index cases of O139 cholera were found to be infected with *V. cholerae* O139, and in many of them, the infection was asymptomatic, which is reminiscent of O1 EI-Tor infections. Also, as with O1 EI-Tor infection, individuals of blood group O were more susceptible to O139 infection than those with other blood groups (Albert, 1996).

2.3.2 Infection and symptoms

Infection normally starts with the oral ingestion of food or water contaminated with *V. cholerae*. Subsequently, the bacteria must pass through and survive the gastric acid barrier of the stomach, then penetrate the mucus lining that coats the intestinal epithelia. The primary site of *V. cholerae* colonization is the small intestine. Inoculum size as low as 10^2 organisms may cause disease although a higher dose is probably required because of the acid sensitivity of *V. cholerae* cells, which are exposed to low pH in the gastric compartment (Cash *et al.*, 1974). The surviving bacteria adhere to and colonize the intestinal epithelial cells, eventually producing the CT and causing cholera symptoms (Reidl and Klose, 2002).

The majority of infected patients develop only mild or no illness, although the bacterium may be present in their faeces for 7-14 days. Such sub-clinical illness in most cases, resolve in 4-6 days (Sánchez and Taylor, 1997). Depending on the dose of ingested organisms, onset is usually rather sudden, with clinical manifestations ranging from asymptomatic carrier state, mild, watery diarrhoea to acute diarrhoea with characteristic rice water stools. This is a result of the toxin produced by the bacterium acting on the mucosal cells of the small intestine and stimulating production of water and electrolytes leading to profuse, watery diarrhoea, a typical feature of the disease cholera. Severe cholera cases can lead to watery stool outputs of between 500-1000ml per hour, rapidly leading to rapid dehydration and electrolyte imbalance followed by acidosis, muscular cramps, hypotension, tachycardia and vascular collapse (Keen and Bujalski, 1992).

2.3.3 Global surveillance

The International Health Regulations require governments to report all cases of the three diseases; cholera, plague and yellow fever. The aim is to provide a rapid international alert system for diseases of international public health importance (WHO, 1999). Among the acute enteric infections, cholera received the greatest attention from bodies like the World Health Organisation (WHO) because of its propensity for rapid epidemic spread. The WHO monitors countries reporting cholera in order to follow trends in the disease over time. As a result the WHO has set up "Expert Committees" on cholera since 1951 (Barua, 1978). Just after the seventh epidemic appeared in 1961, the WHO quickly intervened by establishing Inter-Regional Cholera Teams to assist in programmes dealing with training, control, and research on the treatment and prevention of cholera. Since then, the WHO has been in the forefront in assisting epidemiological investigations and information dissemination campaigns about cholera. Nonetheless, this surveillance is by no means complete since many countries with major cholera problems do not report their cases for political, economic, or other reasons including the lack of facilities for surveillance (WHO, 2001a). Even in countries with nationwide surveillance, reporting is incomplete both because of problems of reporting and difficulty in field diagnosis of a disease with a clinical spectrum that ranges from mild to severe symptoms (Glass and Black, 1992).

Undoubtedly, cholera remains an important cause of morbidity and mortality worldwide. High incidences of the disease continue to be reported from Asia, Middle East, Africa, South and Central America. Its spread may be rapid and unpredictable because of the relative ease of transportation including the public modes of travel be it by road, rail, sea or air (Blake, 1994; WHO, 1999). Migration of people due to war or political unrest of the magnitude seen in Goma, Rwanda has contributed to entrenching cholera on the African continent (Crowcroft, 1994). As such, cholera is now endemic in many parts of the African continent (Barua, 1992; Swerdlow and Isaäcson, 1994). Endemicity of cholera carries the potential of outbreaks, which can quickly attain epidemic status, especially in developing countries where a large part of the populace live in crowded conditions with inadequate clean water supply and poor sanitation options (Barua, 1992).

2.3.4 Transmission and spread of the disease

The main vehicles of cholera transmission are water and food. Contaminated water with free-living *V. cholerae* cells are probably the main origin of epidemics, followed to a lesser extent by contaminated food, especially seafood products like oysters, crabs, and shellfish (Reidl and Klose, 2002). Cholera is a highly contagious disease, and is transmitted primarily by ingestion of faecally contaminated water by susceptible persons. Waterborne transmission has been documented as being the most important route for the spread of cholera in Africa. Several studies in Africa have linked diarrhoeal diseases, including cholera, with drinking water from contaminated sources such as shallow wells, river water, and water contaminated while being stored (Sitas, 1986; Patel and Isaäcson, 1989; Bradley *et al.,* 1996; Shapiro *et al.,* 1999). Cholera has also been associated with bathing in contaminated river water (Acosta *et al.,* 2001). Consequently, rivers contaminated with the cholera bacterium tend to transmit the disease from one community to the other, contributing to the rapid spread of the disease. Sudden large outbreaks are usually caused by contaminated public water supplies. Thus, water plays an important role in the transmission and epidemiology of cholera, be it surface water, wastewater or seawater. *Vibrio cholerae* will survive up to 24 hours in sewage, and as long as 6 weeks in certain types of relatively impure water containing organic matter. This makes it difficult to eradicate cholera organisms from such waters, which are thus likely to remain a serious threat to public health for some time (Crowcroft, 1994).

Besides water, food has been recognized as an important vehicle for the transmission of cholera. If due care is not taken, foods are likely to be faecally contaminated during preparation, particularly by infected food handlers in an unhygienic environment (Rabbani and Greenough, 1999). Thus, in an epidemic, the source of contamination is usually the faeces of an infected person. The physicochemical characteristics of foods that support survival and growth of *V. cholerae* O1 and O139 include high-moisture content, neutral or an alkaline pH, low temperature, high-organic content, and absence of other competing bacteria. *Vibrio cholerae* can survive on a variety of foods that become contaminated through direct contact with the stools of a carrier; or by polluted water. The WHO fact sheet No. 107 (2000a) notifies that low temperatures limit proliferation of the organism and thus may prevent the level of contamination from reaching an infective dose necessary to initiate infection. Furthermore, the organism is sensitive to acidity and drying, thus commercially prepared acidic (pH 4.5 or less) dried foods are therefore without risk.

Contamination of food be it at home, during shared social functions, at markets, and during preparation by street vendors, is common, especially in developing countries where public health measures are poorly enforced by the relevant authorities. *Vibrio cholerae* can survive for 2-14 days in food and for many weeks in shellfish and molluscs (Kolvin and Roberts, 1982). Sharing meals with persons with watery diarrhoea, eating food at a funerals, improperly cooked food, leftover food contaminated after cooking, and lack of hygienic practices e.g. washing hands before handling food are also thought to be some of the routes through which cholera spreads among communities (St. Louis *et al.*, 1990; Shapiro *et al.,* 1999).

Certain types of foods, especially seafood, i.e. fish, shellfish, crabs, oysters and clams as well as dried fish and prawns, have all been incriminated in cholera outbreaks in several countries (Acosta *et al.*, 2001; Gangarosa and Tauxe, 1992; St. Louis *et al.*, 1990). Contaminated rice, millet gruel, and vegetables have also been implicated in several outbreaks. Other foods, including fruits (except sour fruits), poultry, meat, and dairy products, have the potential of transmitting cholera (Rabbani and Greenough 1999). An investigation led by the Centre for Disease Control (CDC, 2004) during a cholera epidemic between November 2003 and January 2004 in Zambia, implicated food borne transmission via raw vegetables.

To reduce the risk of food-borne transmission of cholera, it is recommended that foods should be prepared, served, and eaten in an hygienic environment, free from faecal contamination. Proper cooking, storing, and re-heating of foods before eating, and hand-washing with safe water before eating and after defecation are important safety measures for preventing food-borne transmission of cholera (Rabbani and Greenough, 1999; WHO, 2000a; CDC, 2004). Generally, results from studies of transmission of cholera emphasize the importance of hygiene, clean water, and sanitary food handling for cholera prevention.

Altered gastric acidity induced by buffering substances predisposes a person to *Vibrio cholerae* infection. Studies showing people who had consumed acidic foods and survived *Vibrio cholerae* infection amidst an epidemic demonstrated the importance of an alkaline environment for the survival of *Vibrio cholerae* (St. Louis *et al.,* 1990). Certain life styles, like chewing of coca leaves have also been implicated in predisposing a person to *Vibrio cholerae* infection in. The slaked lime added to the coca leaves release cocaine and free bases that buffer the gastric juices rendering the stomach alkaline for hours. Thus coca chewers will predictably be more at risk of infection from a few *Vibrio cholerae* organisms than non-coca chewers. This practice of coca chewing is common in Peru and other parts of South America where it is suggested to play a role in the transmission of *Vibrio cholerae* (Feldmeier and Krantz, 1991).

Rarely is cholera transmitted by direct person-to-person contact. Researchers from Tanzania, Malawi and Mozambique have reported nosocomial cholera infections, which they proposed spread via the person-to-person route (Cliff *et al.*, 1986; Mhalu *et al.*, 1984). Nosocomial infections were also reported from a South African hospital though as in the other African countries the exact mechanism of infection was not determined (Chapman and Collocott, 1985). However, a common feature to all these reports was that the conditions in the hospital wards were extremely overcrowded with inadequate sanitary facilities and supplies, like insufficient number of washbasins per ward and lack of hand washing soap.

2.3.5 Treatment

When cholera occurs in a susceptible community, case-fatality rates may be as high as 50% either due to lack of treatment facilities or the treatment being given too late. In contrast, a country with a well-organized diarrhoeal disease control programme could limit the case-fatality rate to less than 1% (WHO, 2000a). Clinicians should suspect cholera whilst attending to any case that involves massive, shock-producing diarrhoea, especially if the patient has travelled to a cholera-affected country or region.

By 1970, when the disease spread into Africa, there was a shift of attention to the provision of appropriate treatment such as oral re-hydration therapy, rather than ineffective vaccines (Martinez *et al.*, 1988). *Per se*, the World Health Assembly abolished the requirement of cholera vaccination for international travel as an International Health Regulation in 1973 (Martinez *et al.*, 1998). Effective treatment requires immediate replacement of the massive fluid loss by oral re-hydration salts (ORS), before conducting confirmatory diagnostic tests in the laboratory. The benefit of oral rehydration therapy (ORT) for cholera was demonstrated in 1968 (Nalin, 1968). Subsequently, this had lead to the application of the therapy to stabilise all forms of infectious diarrhoeal diseases (Pierce *et al.*, 1969). The global application of

ORT has decreased the death rates from diarrhoeal diseases by more than half in the last 30 years (Greenough III, 2004).

Therapy of acute watery diarrhoea requires replenishing water and electrolyte losses (re-hydration phase) and maintaining the water and electrolyte balance after re-hydration until the diarrhoea ceases (maintenance phase) (Nalin *et al*., 2004). The original oral re-hydration solution (ORS) formulation developed by the World Health Organization (WHO) struck a compromise between the ideal solutions for diverse disorders in cholera and non-cholera diarrhoeas, in both adults and children (Nalin *et al*., 2004). Indeed, ORS has been hailed as one of the most important medical advances of the past century, particularly because of its simplicity, low cost, and remarkable ease of use (Nalin and Cash, 1970). As such, most cases of diarrhoea caused by *V.cholerae* can be treated adequately by giving a solution of oral rehydration salts as prescribed in the WHO/UNICEF standard formulation (Duggan *et al*., 2004). During an epidemic, 80-90% of diarrhoea patients can be treated by oral rehydration alone, but patients who become severely dehydrated must be given intravenous fluids (Bennish, 1994; WHO, 2000a). In severe cases, an effective antibiotic can reduce the volume and duration of diarrhoea and the period of vibrio excretion. Tetracycline is the usual antibiotic of choice, but resistance to it is increasing, thus its administration is not recommended. Other antibiotics that are effective against *V. cholerae* include cotrimoxazole, erythromycin, doxycycline, chloramphenicol and furazolidone (Sanchez and Taylor, 1997; O'Grady *et al* 1976; WHO, 2000a).

2.4 *Vibrio cholerae* and the environment

Recent investigations strongly suggest the existence of an environmental aquatic reservoir for *Vibrio cholerae* (Speelmon *et al.,* 2000). *Vibrio cholerae* strains are inhabitants of estuarine and marine environments where they can be free living or in association with plankton, mostly copepods (Tamplin *et al.,* 1990). Cholera has been observed to have a specific relationship with particular geographical niches, seasons and ecology (Merson *et al.,* 1978). The aquatic environment is also thought to be the habitat of the quiescent pathogenic *Vibrio cholerae* strains (Shandera *et al.,* 1983; West, 1992), although other habitats have also been suggested to support the survival of *Vibrio cholerae* between epidemics. The association with the aquatic environment is further supported by the fact that, throughout history, and up to the present, cholera pandemics have spread by following world coastlines (Colwell and Huq, 2001). The extensive use of the Great Lakes in Africa for socio-economic activities (transport, bathing, drinking etc) have also been implicated to encourage widespread dissemination of *V.cholerae* when conditions for transmission are suitable, subsequently leading to cholera epidemic among the riverine communities (Birmingham *et al.,* 1997). This association with the aquatic environment (marine and riverine) also underscores the various biological, physical and chemical factors, which are important for the survival of *V.cholerae* in the aquatic environment (Colwell and Spira, 1992; Sánchez and Taylor, 1997). As *V.cholerae* prefers moderate salinity averaging between 0.5-3.0%, with transmission being most probable when water salinities fall in the range of 0.01-0.1% (Miller *et al.,* 1982; Singleton *et al*., 1982); implies that in estuarine environments, fluctuations in salinity will only be conducive for the transmission for *Vibrio cholerae* at certain times of the year. This may be one of the factors that support the seasonal pattern of cholera.

The seasonal behaviour of cholera is erratic and its driving factors poorly understood. Cholera seasonality in endemic areas suggests possible long-term survival of *V.cholerae* in the environment (Speelmon *et al.,* 2000). Several proposals have been put forward to explain this. Feachem (1976) suggested that *V.cholerae* survived unfavourable environmental conditions by colonising copepods or related species in the Ganges delta area. While Huq *et al,* (1983) observed that live copepods contribute significantly to the survival and distribution of the cholera organism in the aquatic environment. Thus, the seasonal cycle of persistence in the sediments, where bacterial numbers increase during plankton blooms, results in the appearance of *V. cholerae* in larger numbers capable of causing outbreaks and possibly accounting for the seasonality of epidemic cholera (Colwell, 1996; Patz *et al.,* 1996; Lipp *et al*., 2002).

On the other hand, the occurrence of sporadic outbreaks of cholera and cholera-like illnesses in areas free of sewage contamination or carriers of *V.cholerae* or both can be accounted for if the organism remains viable, though not necessarily recoverable, in brackish waters until salinity and nutrient conditions become favourable for growth (Colwell and Huq, 1994). The “viable but non culturable” state, in aquatic systems provides a remarkably clear explanation for the phase of dormancy, survival and persistence in the environment and may explain the disappearance of *V.cholerae* between epidemics in cholera-endemic areas of the world (Byrd *et* al., 1984; Roszak *et al.*, 1984 and Colwell *et al*., 1985).

In addition to *V.cholerae* having symbiotic relationships various aquatic organisms, other modes of survival and dispersal have also been surveyed. Venkateswaran *et al.* (1989) noted that *V. cholerae* was prevalent in the aquatic environment of the United States, and its distribution is influenced by the degree of nutrients rather than the association with zooplankton. *V.cholerae* has also been found in samples of ballast water of ships docked at Chesapeake Bay (Ruiz *et al.*, 2000), suggesting that global shipping lines can disperse human pathogens through ballast water and thus merit attention as couriers of long distance dispersal of waterborne diseases. This observation partly supports Grimes *et al.* (1986) who had earlier suggested that the wastewater discharge into the aquatic environment could well be the source of nutrients, which may stimulate growth of the autochthonous pathogens rather than it being the source of the pathogens. The sampling undertaken by Ruiz *et al.* (2000) went a step further to show that ballast water, in addition to discharging nutrients into the aquatic environment, also introduces novel microbial species. *V. cholerae* may therefore be surviving in the aquatic environment using any one, a combination, or all of the means suggested.

Terrestrial environments have also been suggested as retreats for *V. cholerae* during inter-epidemic periods, like the savannahs and deserts of Africa which would be expected to be least conducive to the survival of vibrios (Feachem, 1981). Plantation land has also been suggested as a possible reservoir of *V.cholerae.* Agarwal and Shukla (1999) noted that the distribution of cholera matches the geographical distribution of sugar cane, and sugar-cane harvesting synchronises with inter-epidemic periods of cholera epidemiology in the Indian sugar-cane belt. They suggested the hypothesis that most of the sugar-cane waste that is released into drains, streams, and rivers, or used in farming to increase farm produce is sufficient to sustain the organism to its next epidemic flare up. The distribution of cholera in the mainly sugar-cane growing areas of South America, USA, Australia, Africa, south east Asia, and Japan adds credence to their hypothesis. The connection of this aspect in KZN has yet to be established as sugar-cane plantations along the Indian Ocean coastal belt of KZN form the mainstay of the economy and agriculture.

2.4.1 Cholera epidemics and climate

The climate change at both the global and regional level fuels the debate over the effects of changes in climate on disease exacerbation in endemic areas and in their proliferation to non-endemic regions (Brown, 1996; Patz *et al.*, 1996; Rose *et al.*, 2001). Tropical regions of the world also tend to be more severely affected by infectious diseases than the temperate ones (Sattenspiel, 2000). Rainfall, runoff waters and floods have always been associated with outbreaks of waterborne diseases, considering that pathogens of faecal origins can find their way into such waters. Although the discovery of *V.cholerae* in surface waters not known to be faecally contaminated or in areas with no record of human infection have contradicted the conventional rationale of cholera being exclusively a waterborne disease (Colwell *et al.*, 1977, 1981).

Local weather conditions may have a direct or indirect effect on environmental sanitation with ensuing susceptibilities to diseases like cholera. An epidemiological feature noted in the 1980-1987 cholera epidemic in South Africa was linked to the local rainfall pattern, whereby, 99% of all cholera patients fell ill in areas with an annual rainfall of more than 600 mm (Kustner and Du Plessis, 1991). On the other extreme, water scarcity as a result of droughts or shortage of clean water will inevitably lead to unsanitary conditions that encourage transmission of pathogens like *V. cholerae* (Feachem, 1981).

Thus unravelling the mechanisms of disease dynamics will be useful in the prediction of their propagation in the different scenarios presented by climatic changes. Evidence is emerging that many ecosystems on the African continent carry risks of climate-driven threats to human health. Predisposing factors include geographic location, socio-economic status, and knowledge and attitude toward preventive measures (Anonymous, 2001). Factors, which are known to have an influence on the survival of *V.cholerae*, have been extensively studied, thus contributing to the understanding of the bacterium and the epidemiology of cholera. Notwithstanding; an aspect of cholera receiving relatively little attention until lately, is the climate, which needs to be considered in the context of other non climatic potential drivers of the disease, such as those related to population demography and socio-economic variables.

Evidence supporting the autochtonous nature of *V. cholerae* in brackish waters and estuaries has more recently highlighted the potential significance of environmental factors to the dynamics of the disease, including its' sensitivity to climatic patterns (Tamplin *et al.*, 1990; Pascual *et al.*, 2000, Singh *et al.*, 2001). Throughout the different seasons, climatic factors such as water temperature will have a direct influence on the abundance of *V. cholerae* in the aquatic environment, or alternatively, an indirect influence on other aquatic organisms such as zooplankton, phytoplankton and macrophytes, onto which the pathogen is found to be attached to (Colwell, 1996). High ambient temperatures have been implicated in the dynamics of diarrhoeal diseases and of *V.cholerae* in Peru (Salazar-Lindo *et al.*, 1997), while sea surface temperatures (SSTs) in the Bay of Bengal have also been shown to display a bimodal seasonal cycle similar to that of cholera cases in Bangladesh (Lobitz *et al*., 2000). Recent time series studies have shown an increase in cases associated with warmer temperatures (Singh *et al.*, 1998; Speelmon *et al.*, 2000). Existing evidence also favours the role of increased water temperature through its effect on the pathogen's growth and survival (Pascual *et al.*, 2002).

The climate-cholera link, which is likely to involve multiple pathways, is yet to be deciphered. The marked seasonality of cholera and the simultaneous appearance of cases at different locations thousands of kilometres apart in a short span of time have prompted researchers to investigate climatic and environmental drivers. Such almost simultaneous outbreaks of cholera in parts of India and South America have lead to the view that primary transmission from an environmental reservoir initiates the seasonal outbreaks of cholera in endemic regions. A case in point is Peru when in 1991, cholera revisited the country after it was last reported in 1895, almost a century of absence (CDC, 1991; Gangarosa and Tauxe, 1992). When the epidemic struck, there was an almost simultaneous appearance of the disease along the Peruvian coastline. This happened at the same time when Peru was experiencing the El Niño weather phenomenon in 1991-92, which brought rain and consequently an influx of nutrients from land as well as warm sea surface temperatures. These climatic conditions initiated phytoplankton blooms, (a food source for zooplankton) which in turn amplified the resident zooplankton numbers, with which vibrios including the autochtonous *V. cholerae* species have a commensal or symbiotic relationship with (Colwell, 1996; Epstein *et al.*, 1993). Cholera outbreaks have been shown to almost always follow zooplankton blooms (Huq *et al.*, 1995). As phytoplankton blooms can be measured by satellite imagery, it is suggested that conditions associated with a cholera outbreak or epidemic can be monitored by satellite as well.

It is now widely accepted that the epidemiology of cholera is indisputably reliant on a complex of environmental and social factors (Miller, 1982). The information on the local climatic factors will permit a better understanding of the existing *V. cholerae* strain and its associated disease virulence, transmission, ecology and epidemiology. The growing availability of climatic data offers opportunities for retrospective and prospective analyses through remote sensing and computer processing to integrate ecological, epidemiological, and remotely sensed spatial data for developing early warning systems for epidemic cholera (Pascual *et al.*, 2002).

2.5 Socio-economic factors associated with cholera

The disease incidence of cholera is associated with several socio-economic variables, such as population density, water quality, sewer connections and poor personal hygiene. The disease can spread rapidly in areas without adequate and proper treatment of sewage and drinking water. Epidemics of cholera claimed thousands of lives in London before the physician John Snow, in 1854, demonstrated that cholera was a waterborne disease. He traced water delivered to various private pumps in the Soho neighbourhood to a public pump known as the Broad Street Pump in Golden Square. By simply removing the handle of this polluted well, he was able to stop individuals from accessing the water. He prevented contaminated water from being pumped, and thereby effectively helped to stop the 1854 cholera outbreak (Cliff and Haggett, 1988). Since then, the study of cholera outbreaks has contributed to the development of epidemiology as a branch of medical science, and also forced attention on the problem of water treatment and purification.

2.5.1 Access to basic services

The basic services required by communities are safe drinking water; sanitation; refuse collection and electricity. World wide, one billion people lack access to safe drinking water and 2.4 billion to adequate sanitation. A looming crisis that overshadows nearly two thirds of the Earth's population is drawing closer because of continued human mismanagement of water, population growth and changing weather patterns as reported by UN organizations (WHO World Water Day Report, 2001c). The United Nations set eight goals for development in its 2000 Millennium Declaration for improving the human condition by 2015 (UNMD, 2000). Goal 7 aims to ensure environmental sustainability and target 10 of this goal is to halve, by 2015, the proportion of people without sustainable access to safe drinking water and sanitation (Millennium Indicator Database, 2005; MDG, 2005). To achieve this target, an additional 1.5 billion people will require access to some form of improved water supply by 2015, that is an additional 100 million people each year (or 274 000/day) until 2015 (UNESCO).

Poor sanitation practices in highly populated areas harbouring endemic toxigenic strains are the source of occasional outbreaks due to contamination of drinking water and/or improper food preparation. Factors associated with precarious living and environmental conditions have also been implicated in cholera epidemics. A study in Brazil showed that households without tap water or sewage disposal and with an income less than or equal to the minimum wage revealed a positive association with cholera incidence (Gerolomo and Penna, 2000). In Mexico, cholera incidence was higher in coastal states than in the interior, and four times higher in the least urbanised areas compared to the most urbanised areas. Thus suggesting that areas associated with high poverty and low urbanisation be given priority in the supply of safe water and sanitation (Borroto and Martines-Piedra, 2000). Even in relatively stable countries of the developing world, where ordinary people have inadequate sanitation, future prospects are undermined by the impact of international debt on their struggling economies (Crowcroft, 1994).

2.6 Epidemic control and prevention

When cholera appears in a community it is essential to ensure three things: hygienic disposal of human faeces, an adequate supply of safe drinking water, and good food hygiene (WHO, 2000). Effective food hygiene measures include cooking food thoroughly and eating it while still hot; preventing cooked foods from being contaminated by contact with raw foods, including water and ice, contaminated surfaces or flies; and avoiding raw fruits or vegetables unless they are first peeled. Washing hands after defecation, and particularly before contact with food or drinking water, is equally important and a well-known fact (St Louis *et al.*, 1990; Kaysner and Hill, 1994; CDC, 2004).

Routine treatment of a community with antibiotics, or "mass chemoprophylaxis", has no effect on the spread of cholera (WHO, 2000). Restricting travel and trade between countries or between different regions within a country is not recommended as it may promote the suppression of information on cholera outbreaks (WHO, 1998). Setting up a *cordon sanitaire* at frontiers uses personnel and resources that should be otherwise devoted to effective control measures; and hampers collaboration between institutions and countries that should unite their efforts to combat cholera (WHO, 2000).

Limited stocks of two oral cholera vaccines that provide high-level protection for several months against cholera caused by *V. cholerae* O1 have recently become available in a few countries (WHO, 2001b). Both are suitable for use by travellers but they have not yet been used on a large scale for public health purposes. Use of this vaccine to prevent or control cholera outbreaks is not recommended because it may give a false sense of security to vaccinated subjects and to health authorities, who may then neglect more effective measures (WHO, 2001b). In 1973 the WHO World Health Assembly deleted from the International Health Regulations the requirement for presentation of a cholera vaccination certificate (WHO, 2000). As such, today, no country requires proof of cholera vaccination as a condition for entry.

Broadly speaking the literature review gives a synopsis of the disease cholera and the different factors that play a role in its transmission. It is evident that to understand cholera whether in an endemic or epidemic form requires a multi-disciplinary approach. The following Chapter 3 outlines the rationale of the study and the overall project scope. The research approach and the methodology used are explained in detail. In effect the following chapter constitutes the foundation of the study through which outputs in the form of results were generated.

CHAPTER 3:
Research Approach and Methodology

3.1 Introduction

The growing availability of various types of information offers opportunities for retrospective analyses and computer processing to integrate health, epidemiological, demographic and socio economic data for developing early warning systems for epidemic cholera (Pascual *et al.,* 2002). GIS technology provides new opportunities to study associations between social and environmental factors and the spatial distribution of disease (Tim, 1995; Croner, 1996). The ability to evaluate geospatial information provides a unique perspective of public health issues associated with an infectious disease like cholera (Waring *et al.,* 2005). GIS also provides computer mapping and analysis capabilities of integrating large quantities of geographic (spatial) data as well as linking geographic with non-geographic (study) data e.g., demographic, climatic, socio-economic information and in this case cholera incidence (Vine *et al.,* 1997). As such, a study of this nature called for an inter-disciplinary approach in the management of data relating to cholera, demography, socio-economic status and climate to realize the full potential of GIS technology towards understanding the complex questions at hand. Indeed, a number of environmental epidemiologists have made use of GIS to find possible associations between environmental drivers, socio-economic factors and spatial distributions of cholera (Craig 1988; Emch 1999; Myaux *et al.,* 1997)

3.2 Rationale

Many investigations of cholera have been approached from a clinical standpoint, thus falling short of appreciating the role of the socio-economic and natural environments in the transmission of *V.cholerae.* The magnitude of the cholera epidemic in KZN gave credence to investigate the multiple factors that may have been responsible for the outbreak of cholera, as well as those that assist in the spread of the disease. Exactly one year after the epidemic broke out in August 2001, an assessment of the cholera situation revealed that 99% of the cholera cases were reported from KZN (Dept of Health, 2002b). This raised the question as to why almost all the cases were from KZN, while during the same period; the Northern Cape province did not have a single case on record (Dept of Health, 2002b).

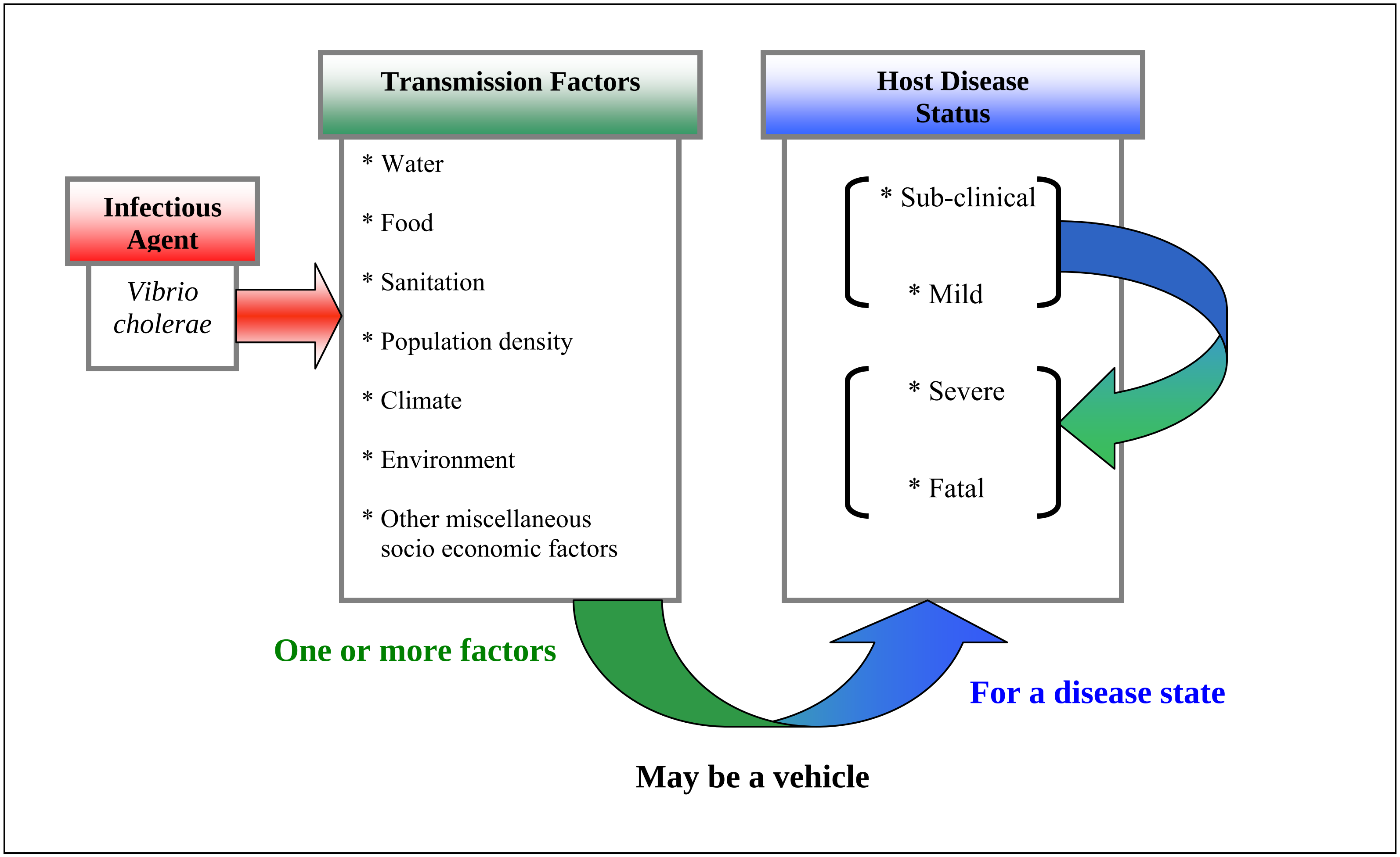

Figure 3.1: The possible relationships between the cholera pathogen, transmission factors and the human host.

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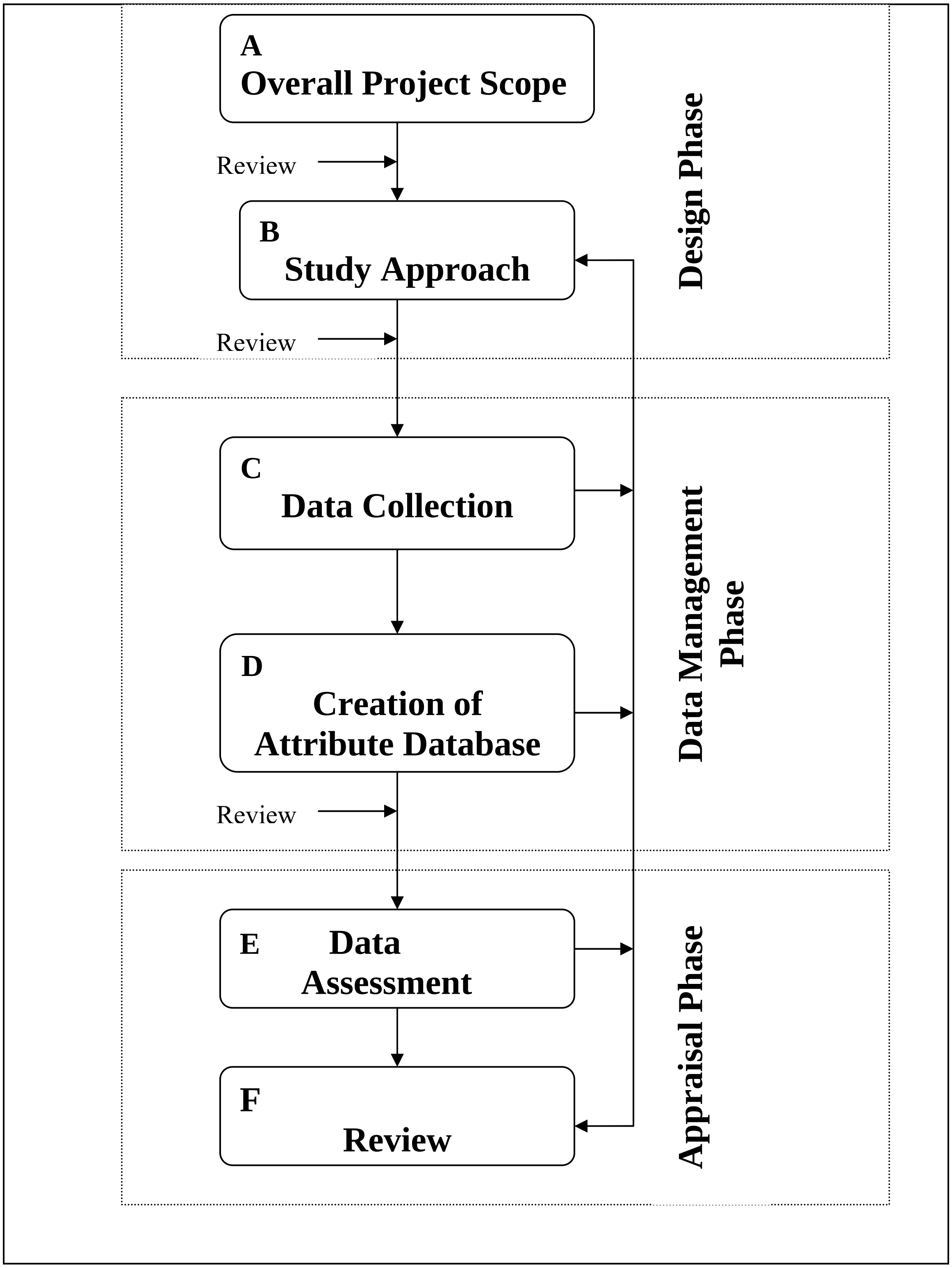

Figure 3.2: An illustration outlining the research framework.

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This state of affairs lead to the thinking that possibly the climate had a role to play in the cholera epidemic of KZN. Especially when one considers that the socio-economic status of rural areas in the other provinces was just as disadvantaged as those in KZN. The climatic aspect of the other provinces however, differs significantly to that of KZN, which is characteristically hot and humid. This observation gave impetus to the proposal to investigate the possible role of climatic conditions as the primary factors influencing the cholera outbreaks in Kwa-Zulu-Natal. Socio-economic factors were considered as enabling factors towards the spread of the disease. The anticipation was that the study findings would contribute in identifying risk factors including environmental factors that could be used as guiding principles to predict possible future cholera outbreaks within the region.

3.3 Design and development of the research framework

The research framework was drawn up to give direction to the project and in the process guide and include all the projected tasks as illustrated in Figure 3.2.

3.3.1 Design and operations framework (A)

3.3.1.1 Designate scope (A1)

The scope of the research was to assess the Cholera Database as well as compliment it with demographic, socio-economic and climatic databases. These would then be used as a disease management tool to determine the possible relationships between cholera and the demographic, socio-economic and climatic environment in KZN. The results would then be used to spatially map the cholera epidemic and attempt to interpret the disease trend. As such, the outcome of study would be used to guide the prediction of possible cholera outbreaks especially in areas that demonstrate risk factors associated with cholera. It will also assist to devise/design intervention measures capable of handling future possible cholera epidemics.

3.3.1.2 Determine information requirement (A2)

The main task was to define the types of data that were required and then locate their source and their availability thereof. As it were, all the data types required for the study already existed in

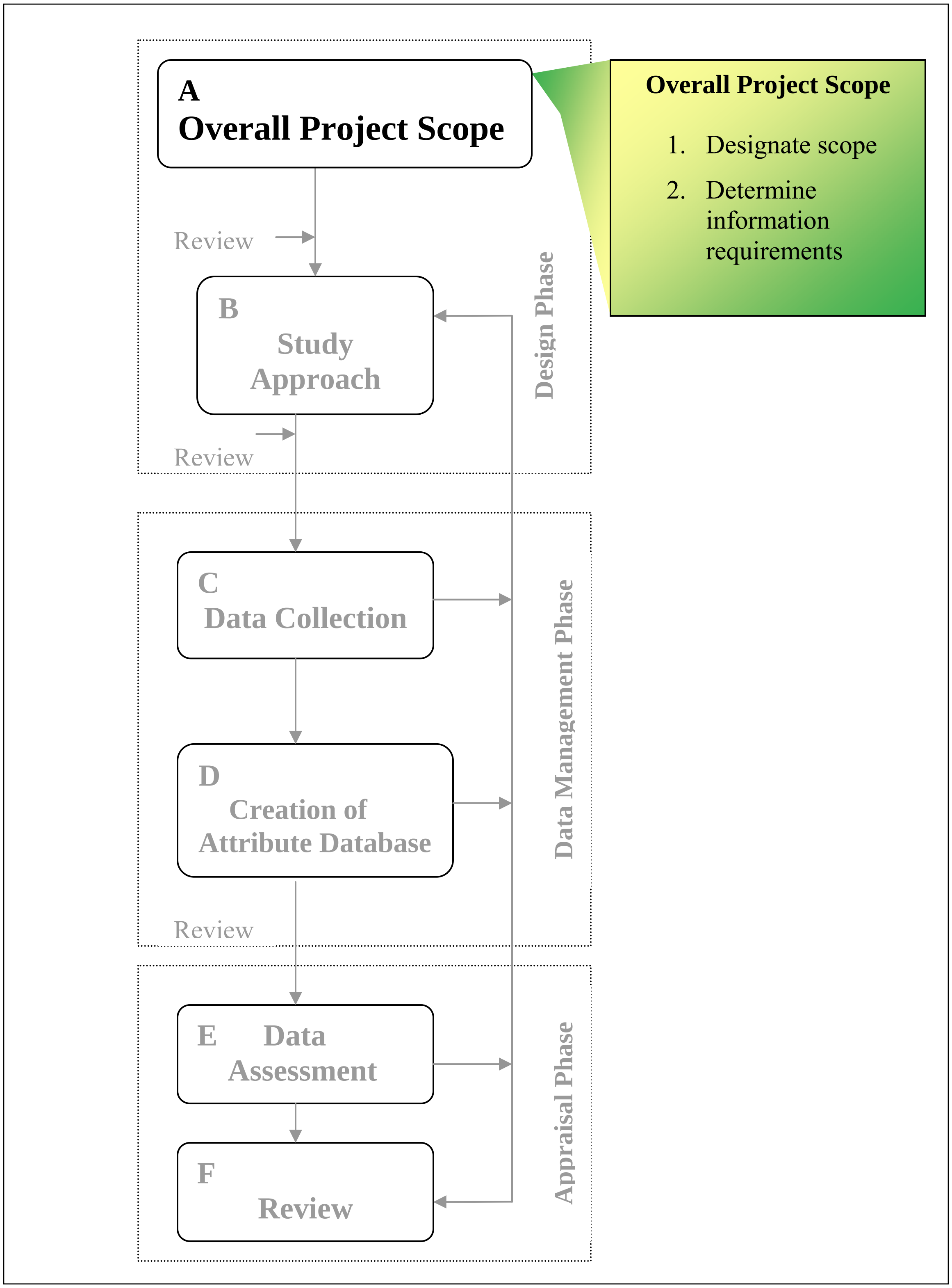

Figure 3.3: An illustration of the tasks assigned to the design and operations framework.

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one form or another within the various relevant institutions. Following is a list of the types of data required for the study:

1. Data on cholera cases for the 2000-2004 epidemic.
2. Climatic data specific to the study area for the defined epidemic period.
3. The demographic profile (gender and age profiles) of KZN population.
4. Data on the socio economic status of KZN population that included supply clean water, sanitation, housing, refuse collection and income in the study area.
5. Geographical and spatial information of KZN communities including the topography, the areas (of place-names) in sq km and the types of natural water sources of the region.

3.3.2 Study Approach (B)

The study approach defined the purpose of the study by proposing a hypothesis. Thereafter, the hypothesis guided the formulation of the research objectives, which set out the course of action in the formulation of the various tasks towards the fulfilment of the research project.

3.3.2.1 Hypothesis (B1)

The hypothesis put forward was that climatic conditions play a significant role in the outbreak of cholera in KwaZulu, Natal. In addition, socio economic variables like sanitation, clean water supply, population density and public health services, contribute to the vulnerability of communities to the risk of cholera in KwaZulu-Natal. Thus the null hypothesis was that neither the climatic conditions influence the outbreak of cholera nor the socio-economic factors contribute to the vulnerability of communities to the risk of cholera in KwaZulu-Natal.

3.3.2.2 Objectives (B2)

To evaluate the dynamics of the 2000-2004 cholera epidemic in KZN, with respect to the natural environment, i.e. temperature, rainfall and humidity and the socio economic status of the communities in that region.

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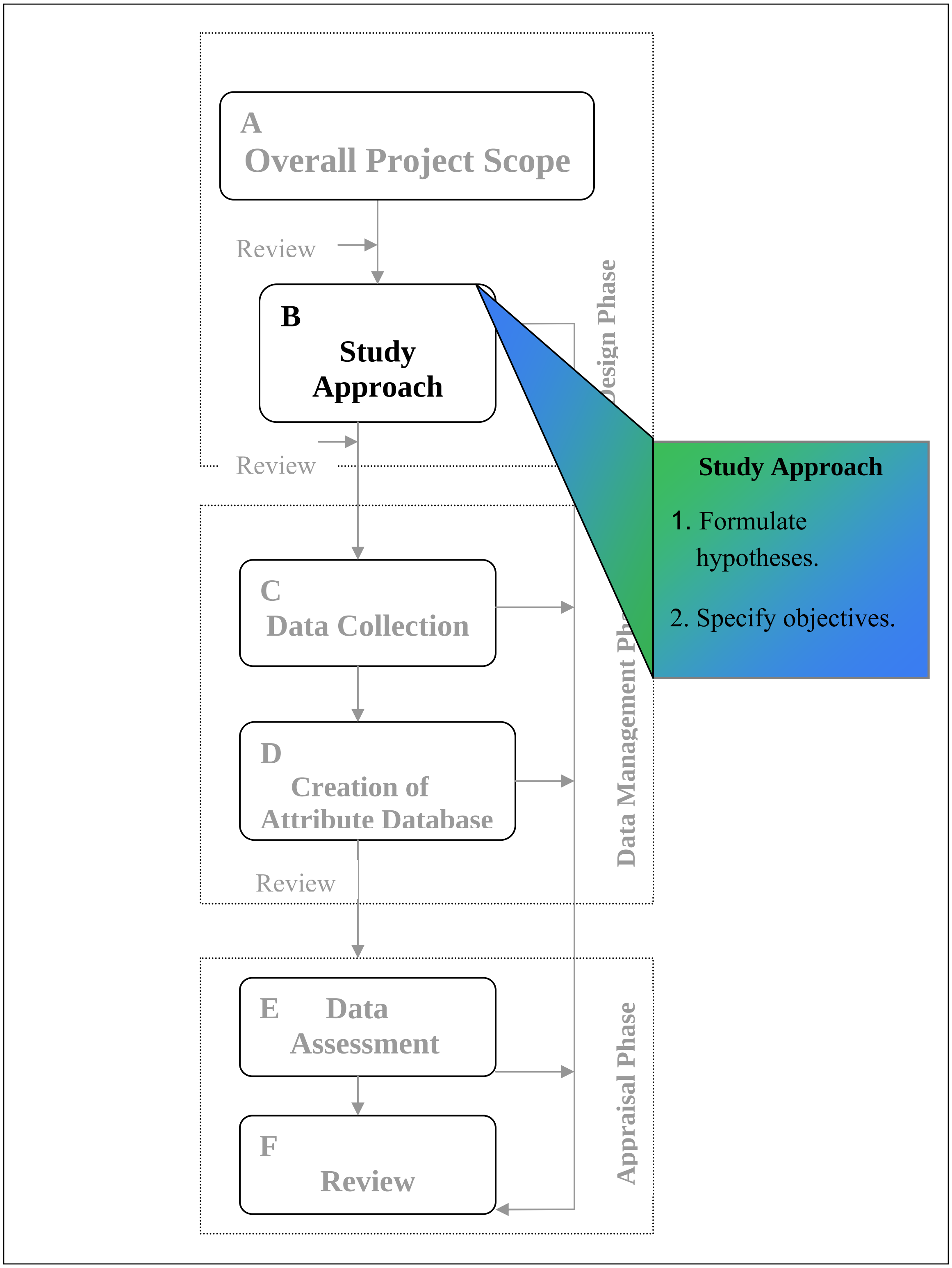

Fig 3.4: An illustration highlighting the tasks associated with the study approach.

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Specific objectives

a. Investigate how factors like sanitation, water supply, population density; and other socio economic factors expose communities to the risk of cholera, through the use of retrospective data.

b. Use the available data as a management tool to identify the enabling factors that contribute to the spread of the disease as the basis for predicting future cholera outbreaks within the region.

c. Develop GIS maps that will spatially demonstrate how the important factors relate to one another in the spread of cholera.

3.3.3 Data Collection (C)

Even though the Cholera Database was the focal point of the study, the demographic, socio-economic and climatic data were just as important in the portrayal of a holistic epidemic picture. Hence, during this phase, the main research activities involved identifying the custodians of the data types required for the study and their subsequent acquisition. Basically though, data was obtained in order to obtain information that could be used in the management of cholera.

3.3.3.1 The KZN Cholera Database (C1)

The GIS Unit of the KZN provincial DOH in Pietermaritzburg established the surveillance of morbidity and mortality statistics of the 2000 - 2004 cholera epidemic. The aim of gathering this data was to convey an understanding of the distribution and status of cholera within KwaZulu-Natal (KZN Cholera 2000). Thus, this exercise of systematically collecting information on all the cholera cases reported at health institutions in KZN led to the establishment of the Cholera Database. The Cholera Database was vital to the study in that it provided a sound scientific foundation to study the cholera epidemic. A similar study in Delhi highlighted the usefulness of surveillance data to identify age groups, geographical localities and seasons with increased risk to cholera and to allow for focussed control measures (Singh *et al.,* 1998). The database has an

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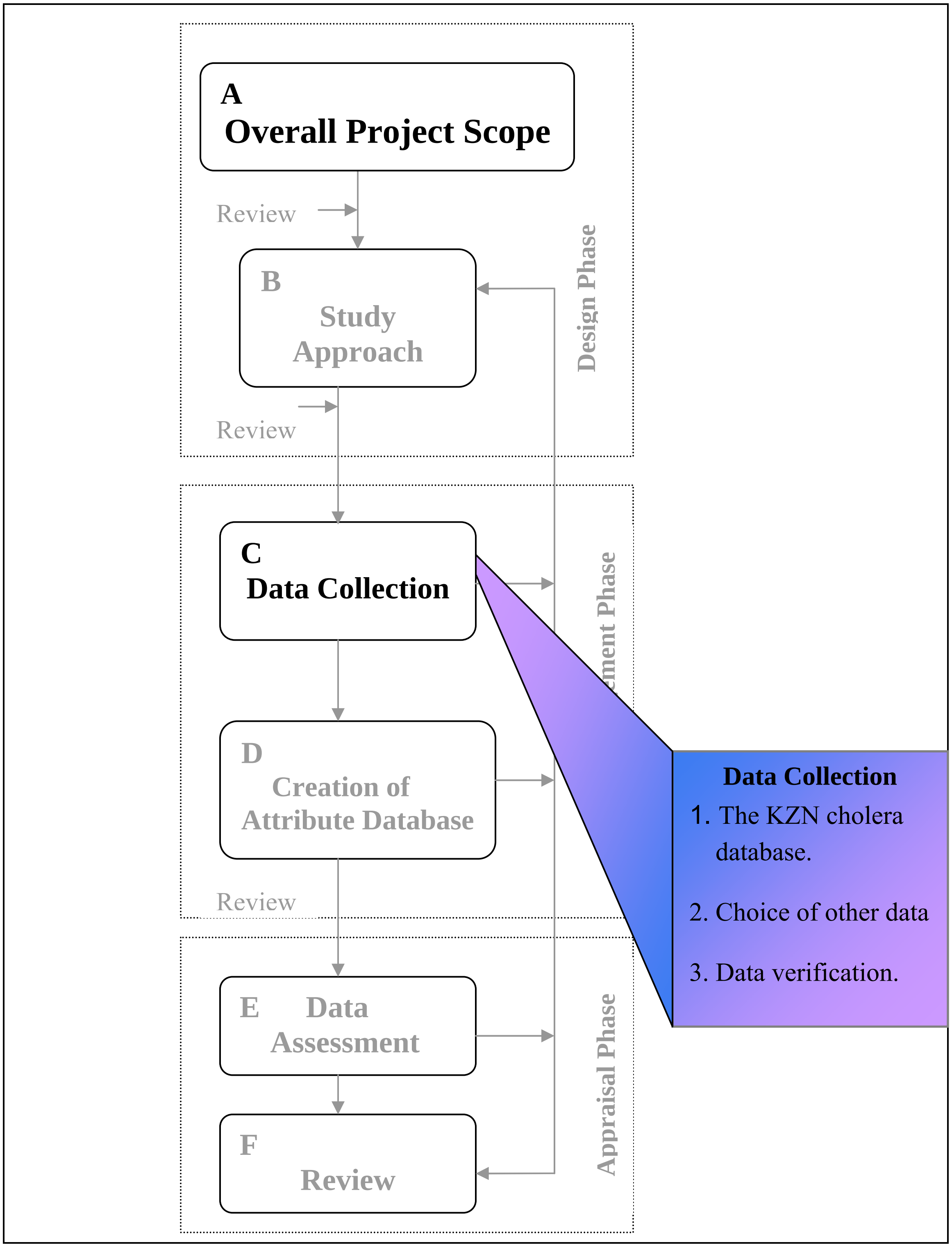

Figure 3.5: An illustration of the tasks assigned to the data collection & verification task.

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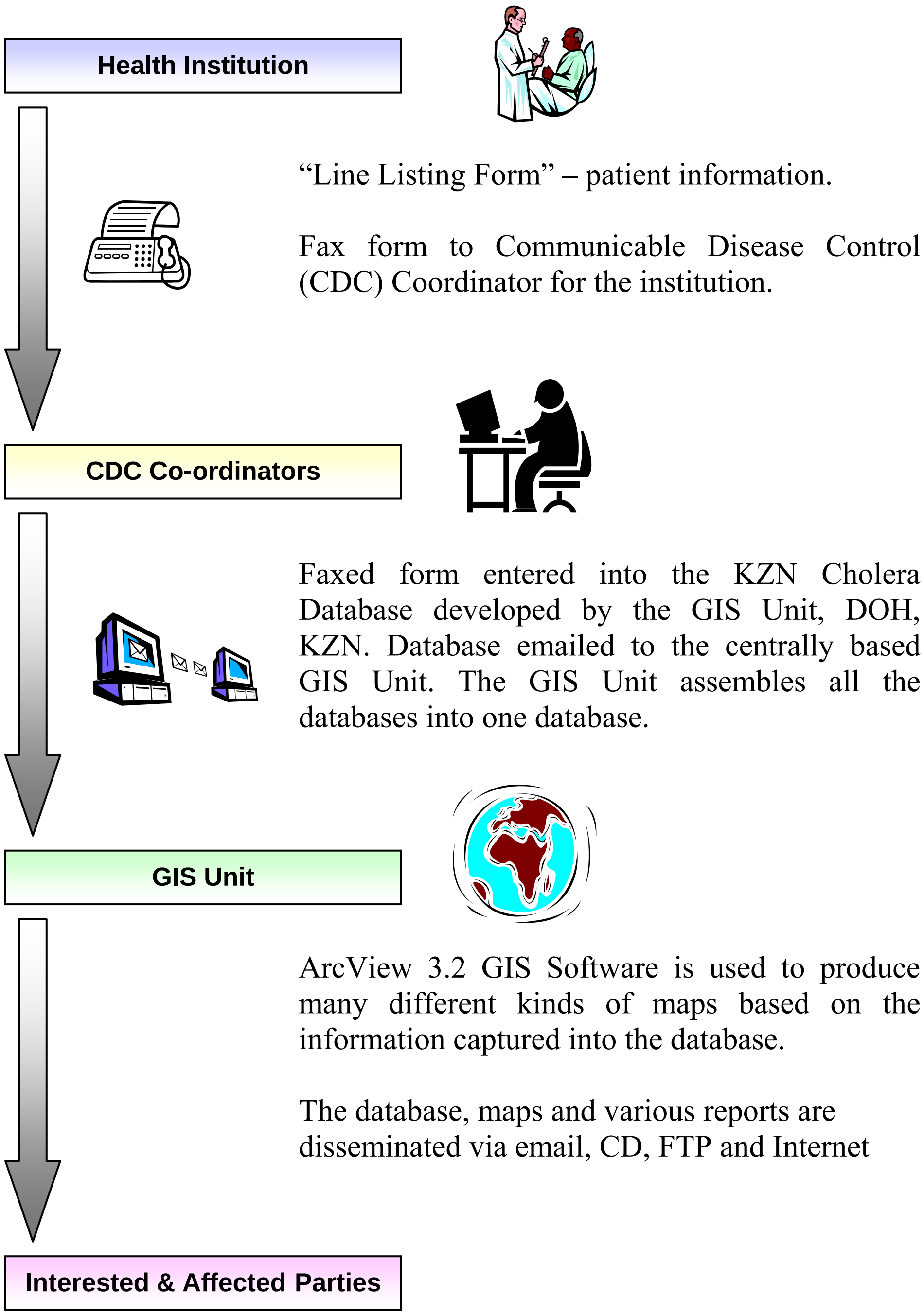

Fig 3.6: An illustrative representation of how the Cholera Database was assembled.

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inventory of all the cholera patients registered at the various health institutions that are linked to the central database collecting system in KZN. This data collection network, which is an ongoing activity, is illustrated in Figure 3.6. Each cholera patient represented a data entry, as shown in the sample of the "line listing" form (Table 3.1). Information on the patient's age; gender; place of residence; the date they fell ill; and the hospital they reported to, were also captured in the database. The patient's personal information was therefore captured when they (patients) sought treatment (both on an in-patient and on an out-patient basis) at health centres. Some data entries had additional "follow-up" information collected on the progress of the disease, such as whether cholera was diagnostically confirmed and in terminal cases, the date when death occurred. Considering that data collection on cholera reports is an ongoing exercise, it is important to note that the Cholera Database referred to in this study, is meant to reflect the period from August 2000 to February 2004. Notwithstanding, this time frame afforded the study sufficient data entries to investigate annual trends between the years 2000 - 2003.

3.3.3.2 Choice of data and selection of parameters (C2)

In addition to the cholera data that formed the foundation of the study, there were other major factors considered in this study. These included the demographic, socio economic, geographical and climatic factors. All the data types collected, including the cholera data were processed to introduce a geo-spatial link using ArcView GIS 3.3.

Demographic and socio-economic data

Demographic data of KZN was important to the study in that it reflected the profile and the proportion of the resident population affected by cholera with the respect to the overall KZN population. While the socio economic aspects of the KZN population, like availability of piped water, sanitation services, source of energy; income and housing complemented the demographic profile of this population. All data under this category were sought from Census 1996 data from Statistics South Africa (STATSSA, 1998). A point to note is that the study used the 1996 census data for all its demographic and socio economic data. Several interrelated issues led to this decision. The cholera epidemic in question started in the year 2000 before the national census of 2001 was carried out. One of the main information types that the GIS Unit of the KZN

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provincial DOH needed in the creation of the Cholera Database were all the geographical place-names. This was for the obvious reason that they will be able to identify at any time where cholera is reported from; as each patient will be required to indicate where they came from (the geographical place-name). As such the GIS Unit of the KZN provincial DOH used the census data that was available at the time as their source of place-names, which was Census 1996 (Personal communication). Thus the demarcated place-names as listed in Census 1996 are the same as those listed in the Cholera Database of August 2000 - February 2004. Albeit, during the course of this study, Census 2001 data did become available (in 2003), though there one major issue of concern. It became apparent that some of the magisterial demarcations, place-names, geographical codes etc. of KZN, had changed, and this would have provided confusion in correctly placing the cholera patients who had already been included in the Cholera Database thus far. As one newly demarcated place name may now be overlapping into more than one previously demarcated place-name(s). It can also be assumed that new cholera patients at the grass root level most probably still provided information of where they come from with the old place-names as they may have been oblivious of the newly demarcated areas. Thus to provide consistency with the Cholera Database, which had used the Census 1996 demarcations for communities, towns and village during the data collection exercise, it was decided that the Census 1996 dataset would also be used for all the other demographic and socio-economic data types.

Geographical data

The place-names, their P-codes (place codes), magisterial districts and district councils represented geographical parameters. The source of the data on these parameters was the Cholera Database itself, making their retrieval straightforward. This information was documented on the "Line listing form" that was used to record the required information on all the patients presenting with cholera at health facilities in KZN. The surface area of place-names in square kilometres was sourced from Census 1996 data (STATSSA, 1998) while their elevation above sea level was processed using ArcView GIS 3.3. The types of water resources (perennial rivers, dams, pans, wetlands and canals) were sourced from Environmental Potential Atlas (ENPAT, 2001).

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Climatic data

As previously explained, the notion behind the inclusion of climatic data is based on the climatic environment in KZN as a possible major driver of *V.cholerae* transmission. Thus, the hypothesis that, climate probably plays a pivotal role in the transmission of *V.cholerae* in KZN. Climate data collected over the same period as that of the cholera epidemic, i.e. from August 2000 to February 2004 was requested from the South African Weather Service (SAWS). The SAWS is the national organisation responsible for the provision of meteorological data, and the custodian of such data at the national level. The climatic data included minimum, maximum and average temperature, rainfall, and humidity.

The unprocessed climatic data of all climatic parameters mentioned above, was made available (from SAWS) as data collected on a daily basis. Considering the study had envisaged that the climatic variations would be assessed on a monthly basis, the daily climatic data was therefore processed to give monthly averages. Thus, the climatic data was summarized per weather station to include the average relative humidity per month, average temperature per month, average minimum and maximum temperatures per month and average rainfall per month. The calculations to process the average monthly climatic data were performed in MS Excel 2000. The spatial analysis tool in ArcView GIS 3.3 was used to interpolate the various data points and eventually geo-process them to add valid maximum, minimum and average monthly temperatures, average monthly humidity values and average monthly rainfall numbers to each place-name polygon. Thus, every weather station was assigned a set of values for the period August 2000 to February 2004 on a monthly basis. To derive seasonal weather data for the individual DCs in KZN, each place-name was allocated to a DC and thereafter summarised to display seasonal weather data for each DC in KZN.

3.3.3.3 Data verification (C3)

It was important to inspect the databases and confirm that all the relevant information was present in every data entry. In addition, information details such as geographical names and age entries had to be checked for possible spelling mistakes and/or other errors before any data

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analyses could be undertaken. Most importantly, the data verification exercise ensured that the results and conclusion drawn from the data were a true interpretation of it.

Incomplete Cholera Database entries

One of the main shortcomings of the Cholera Database was incomplete data entry. Although the Cholera Database recorded a total of 158 896 cases, only 136 262 could be included in the study. The remaining 22 634 cholera case records had one or more data entries missing, thus could not be used in the study. The incomplete entries made up 14.2% of the Cholera Database. Entries with incomplete information had one or more aspects of the patient personal information omitted. Missing information was encountered under all the variables i.e. age, gender, place name, p-code, and date of notification. An extract of the "line listing" capture form with its comprehensive list on patient information is shown in Table 3.1. Among the omitted parameters, the p-codes and the GIS place-names were the most common, followed by age and gender respectively. A total of 4 825 (3%) cholera case entries from the original 158 896 of the Cholera Database had both the place-name and p-code information missing. In the event that either the p-code or the place name was available, some of the data entries could be salvaged, as the p-code could be linked to a place name and vice versa. However, if all the geographical parameters were missing, it made placing of data entries into their respective DCs and MDs particularly difficult. Data with missing information on age, gender and/or date of notification could not be salvaged as such, as this meant tracing patients through hospital records to verify the information. An exercise, that was beyond the scope of the study.

Table 3.1: Extract of a "line listing form" used to capture information on cholera patients.

Age (Yrs)	Gender	Area Patient Sickened	GIS Place Name	Date of Notification	Admit Yes /No	Institution Admitted to	Stool Result	Died Yes /No	Death Date
23	Male	Ezitendeni	Weenen NU	2001/12/20	Yes	Estcourt Hospital	Not Taken	No	
36	Male	Mngwenya	Weenen NU	2001/12/19	Yes	Estcourt Hospital	Not Taken	No	
60	Female	Ngodini	Weenen NU	2001/12/12	Yes	Estcourt Hospital	Not Taken	No	

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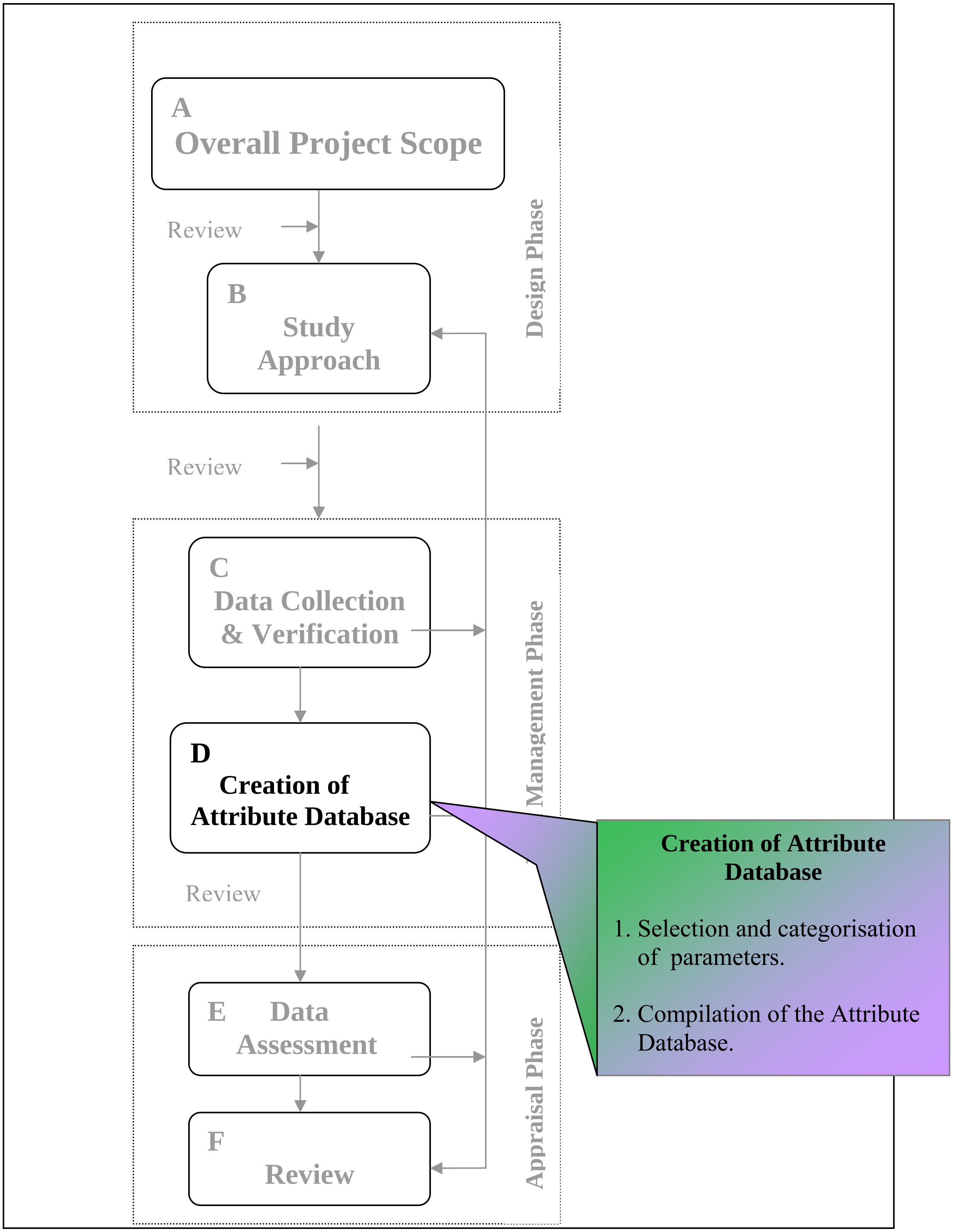

Figure 3.7: An illustration of the assigned tasks that lead to the creation of the study database.

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3.3.4 Creation of the Attribute Database (D)

The reliability and compatibility of the data sources was of fundamental importance. This was particularly important because eventually all data types collected were reconciled and merged to assemble an all-inclusive study database, hereby referred to as the Attribute database. The exercise thus culminated in the generation of a study database that was used for all the graphic and spatial representations, and as well as for statistical evaluation. The choice of the parameters from each of these groups is explained below.

3.3.4.1 Selection and categorisation of parameters (D1)

Once the type of parameters relevant for the study were identified and subsequently verified, categorisation of the data types followed. This is because the magnitude of the database dictated that some of the variables within the different groups of data be categorised for ease of assessment. The types of variables in each data group follows, and where categories were introduced, the rationale behind it is provided.

Cholera data

The creation of the Cholera Database is already explained in 3.3.3.1. The categories formed for each of the demographic, socio-economic and climatic variables were independent of each another. The categories directly related to the cholera cases are explained below:

i. Cholera per age groups

The cholera database used in this study had 158 895 entries, each representing the personal record of a cholera patient. The first exercise that was undertaken was to sort the database by age into age groups compatible and comparable with the demographic data of Census 1996, which had age presented into groups of 5-year intervals thus cholera entries by age followed the same grouping starting from 0-4, 5-9,10-14 up to and above 100 years. The basis for keeping consistency with this age grouping was to be able to subsequently perform age related comparisons. One difference worthy of note was that the Census 1996 age groups gave a count

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that was the sum of both the genders while the cholera data had an option of presenting the cholera cases by age groups of individual genders or as a sum of both.

ii Gender

The Cholera Database specified the gender of each cholera patient. Thus, for spreadsheet analysis and graphical representation of the data, the genders could be analysed separately. For statistical and spatial analyses though, correlations were based on age groups that represented both the genders. This is because the study did not have Census 1996 population data that had further divided the age groups according to gender.

iii Calculation of Percent Cumulative Infection Rate (%CIR)

The %CIR represents the infection rate per 100 individuals in a defined population. Statistically, the cumulative infection rate is the risk of individuals in the population getting the disease during a specified period (Beaglehole *et al.,* 1993). In this study, the %CIR was used as a measure of vulnerability to the incidence of cholera. The %CIR was used to standardise the infection rates for each DC and MD in that it reflected the percentage of the population in question that got the disease and not the actual number of cases. This also ensured that the comparisons and correlations based on the different MDs were standardized.

Thus the %CIR was calculated using the formula outlined below by Beaglehole *et al.* (1993):

$$CI = \frac{\text{Number of people who get a disease during a specified period}}{\text{Number of people free of the disease in the population at risk during a specified period}} \times 100$$

Demographic indicators

Demographic profiles were used to investigate their broader relationships with the cholera epidemic. In this case the demographic indicators were those from the Census 1996 database as already explained in 3.3.3.2. These included age and gender. Subsequently, the corresponding

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cholera cases were sorted likewise by similar age groups and gender. This exercise was done using Pivot tables in MS Excel (Refer to Annex A- Methodology).

i Age

There were 21 sets of age groups at five year interval starting from 0-4, 5-9, 10-14, up to +100 years. For statistical analysis, the age groups were sorted to give nine categories, to represent the different phases an individual normally goes through from birth to adult life. The basis for each of the following categories is explained below:

- Age 0-4 years

  This group represents the paediatric age, a phase during which an individual is susceptible to diseases because of their underdeveloped immune system.
- Age 5-9 years

  The pre-adolescence stage is characterised by individuals who are starting to attend formal education. They are semi independent and their susceptibility to diseases is dependent on the environment around them.
- Age 10-14 years

  This is the age of puberty where adolescence starts to set in. Individuals in this age group notice physiological changes as they progress through the puberty stage. There may also be psychological changes as individuals start perceiving themselves as semi-independent young adults.
- Age 15-19 years

  The mid to late teenage group contributes significantly to the reproductive base of expansive populations such as the one of KZN (MDG, 2004, PRB, 2005).
- Age 20-29 years

  Such individuals are considered to be adults. Unless immuno-compromised by chronic disease states, normal individuals of this age group have a healthy immune status operating at its peak. This age group contributes the most to the reproductive base of an expansive population, such as that of KZN. They are also the caregivers, especially the

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females. Such responsibilities constantly expose them to a high risk of infection as they take up the responsibility of looking after the young and the sick.

- Age 30-39 years

  Most of the productive/active work force belongs to this group. It is also quite possible that this group include the many individuals that leave their homes to become migrant workers elsewhere. The state of being migratory means that their immune systems are constantly challenged by new infections, with the possibility of being overwhelmed at one time or another (Wilson, 1995a).
- Age 40-59 years

  The middle age group would normally have an established family set up and in most cases expected to have a steady income.
- Age 60-74 years

  Retirement starts at this age group. Health also becomes an ongoing concern as the immune system of such individuals start waning.
- Age 75- over 100 years

  This age group comprises the elderly. These may be nutritionally disadvantaged in poor communities. Their immune system has weakened with age and they are thus susceptible to a wide range of illnesses.

Socio economic indicators

The indicators in this category, include types of dwellings, income and services such as clean water supply, sanitation, refuse collection and electricity. The groups and their resultant categories, if any, are explained in the following sub sections. Most of the explanations are in whole or in part as put forward by the Census 1996 report (STATSSA, 1998).

i. Water services

Issues surrounding availability and usage of water are always a point of focus when it comes to cholera epidemics. Therefore, the information on types of water services as listed in Census 1996 database were not grouped into categories. It was considered important that each water

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service/utility be assessed and correlated independently to the incidence of cholera. There were seven distinct types of water services and utilisations listed. A brief explanation of each is given below:

- Piped water in dwelling

  Listed under this group are households with piped tap water in their dwelling. The assumption here is that the water they received was treated using conventional water treatment methods before reaching them. The group also includes those who had the same service but were accommodated in hostels or other types of communal dwellings.

- Piped water on site

  Households listed under this group received water from a standpipe, which was installed within their yard. It also included individuals who had the same service, but resided in hostels or other types of communal dwellings.

- Public tap

  As the name suggests, households who had this service made use of taps shared with other households/residents in their communities. Public taps were also assumed to deliver clean treated water to the residents they served.

- Water-carrier/tanker

  Water tankers are carrier trucks that carry and distribute water in areas where there is a shortage of piped water services. The water brought in by such tankers is clean treated water. This service is more often than not, run on a commercial basis. It is thus only available to those who can afford it, unless it is a special extension of water services to communities by their local authority. Especially in emergency situations like droughts, floods and epidemics.

- Borehole/well/ rain-water tank

  Households under this group mostly use water from underground sources or that, which is collected from precipitation. These sources suggest no water treatment takes place except perhaps by natural. Borehole and well water undergo natural filtration through soil layers to considerably reduce the microbial load. Well water may however, be polluted from surface contaminants if left exposed or due to surface run-off during heavy

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rains or floods. Harvested rainwater often carries high contamination loads depending on how it was collected and the vessels used for storage. Most often rainwater does not meet drinking water standards, especially with respect to the bacteriological water quality (Gould, 1999).

- Dam/river/stream/spring

  Under this option are households that make use of surface water sources that do not undergo natural filtration or chemical treatment. Depending on the locality and the associated land use activities in the area, such as agriculture, industry and domestic use, such water sources usually carry high microbial loads.

- Other water sources

  Households listed here use water sources that are not specified. It may be that they use all or any of the above listed water services/sources whenever and wherever they become available to them.

ii. Sanitation services

Sanitation parallels water as a necessary basic service required within a community. With respect to this study, sanitation refers to the development and application of measures for the safe collection, transportation, treatment and disposal of human wastes. Sanitation is an important public health measure essential for the prevention of infectious diseases. The types of sanitation listed by STATSSA (1998) during the Census 1996 data collection are thus explained:

- Flush toilet

  This group of households had flush toilets that made use of water cisterns. This meant that the households were connected to a piped water system that supported the operation of such toilets. In addition there must have been a sewer system supported by the local authority or individual sewer pits for the safe disposal of sewage.

- Pit latrine

  Pit latrines, once built, are a low maintenance sanitation option. The system is as the name implies, a pit dug in the ground that serves as a semi permanent sewage disposal unit. The pit latrines considered here are of the VIP type (Ventilated Improved Pit), with

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a vent pipe to take odours away from the enclosure of the latrine. This vent pipe is also covered with a mesh filter to prevent flies from getting in.

- Bucket toilet

  This option offers households the use of a bucket as a disposal unit that has to be frequently emptied by the local authority. It is a high maintenance system and in the event that the local authority fails to collect and empty the bucket, the service is easily compromised.

- Other types of toilet

  Households included under this group did not have any of the sanitation options listed above but could have used other rudimentary options.

iii. Refuse disposal

In the context of this study, refuse disposal is the collection and disposal of solid wastes/rubbish (excluding sewage) of a household.

- Refuse collected once a week

  The local authorities removed refuse at least once a week.

- Refuse collection irregular

  Refuse was removed by local authority less often and on an irregular basis.

- Refuse disposal in community dump site

  Refuse was disposed at a dumpsite used by several households of a particular community.

- Refuse disposal in own dump site

  This group of households disposed of their refuse in their own dumpsites, implying the dumpsite must have been located in an area the household had authority over.

- No disposal of refuse

  Most probably this group refers to households that had no particular area assigned for rubbish disposal.

- Other types of refuse disposal

  Though unspecified, the households included here may have used other elementary type of refuse disposal such as incineration.

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iv. Income groups

Income is defined as all money received from salary, wages or own business, as well as money from additional work activities, remittances from family members living elsewhere, pensions or grants and income from investments (STATSSA, 2004). The Census 1996 socio-economic data had a total of 16 income groups, including the "None income" group. Subsequently these income groups were clustered into eight categories. The income of the different groups below is given in South African currency (Rand) per month.

- No income

  According to the definition given by Census 1996, the people under this group were considered those who were employable but did not have the opportunity to earn an income through formal employment.
- Low income

  The group of individuals earning between R 1-R 1,500.
- Medium income

  The group of individuals earning between R 1,501-R 6,000.
- High income

  The group of individuals earning between R 6,001-R 16,000.
- Highest income

  The group earning between R 16,001 to above R 30,000.
- Unknown income

  There was no information available about the net income of this group.

v. Household size and type

The type of dwelling refers to the various structures used for accommodation. Such structures include houses, traditional houses, townhouses, flats/apartments, hostels, huts, informal dwellings such as shacks, semi-detached houses, etc. These were grouped into four categories.

- Traditional houses

  A traditional dwelling is one made of clay, mud, thatch or other traditional materials. Traditional dwellings may be found as single units or in clusters.

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- Conventional house

  All the house types built of standard brick and mortar were grouped under this category. This included houses, townhouses, flats/apartments and semi-detached houses.
- Informal

  Informal dwellings included shacks, whether in backyards or in squatter settlements. These types of dwellings are made out of basic materials like poles, cardboard and plastic covers for protection against the elements.
- Temporary shelters

  Hostel, caravan/tents were considered as temporary shelters, in that the residents had a transitory occupancy of the accommodation.
- Homeless

  Homeless persons are those who had no form of shelter and no known address. Such persons are typically found spending nights on street pavements, in alleyways, or at railway stations to name a few.

vi. Energy source

The types of energy sources considered here are those used for domestic purposes such as cooking, heating and lighting. There were a total of eight sources of energy groups listed in the Census 1996 database. These sources were subsequently grouped into three categories:

- Electricity

  Electricity supplied directly by the municipality/local authority or electricity from another source, e.g. generators, solar cells.
- Petrochemicals

  The energy sources making up this group are of petrochemical nature and these include gas, paraffin and candles.
- Other energy sources

  These energy sources included coal, wood and animal dung.

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vii. Health facilities

Information on the health facilities in KZN was provided together with the Cholera Database. A total of 1 101 health facilities were listed by type and by their administrative authority.

a. Health facilities by authority

The administration of the health facilities fall under the authority of any one of the following:

- Provincial

  Provincial health facilities get their funding from the provincial government budgets.
- Local authority

  Health facilities that fall under this category are clinics funded by their municipalities.
- Private facilities

  Many of these hospitals are owned and managed by a consortium of private physicians or by large business organisations. Private hospital fees are generally higher than those of provincial hospitals.

b. Health facility type

The health facilities were classed according to the type of service they rendered to the public. The definitions of the different types of health facilities found in KZN, are in accordance with the National Department of Health (DOH, 2003-b).

- Hospital

  A public health facility, which receives referrals from and provides generalist support to clinics and community health centres with health treatment, administered by general health care practitioners or primary health care nurses (KZN-DOH, 2000).
- Clinic

  A public health facility at and from which a range of primary health care services are provided and that is normally open eight or more hours a day based on the need of the community for such services. There are no facilities to admit a patient on an in-patient basis (KZN-DOH, 2000).

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- Mobile base

  A mobile clinic is a temporary point of service providing primary health care (PHC) services. As it can be moved, it is set up for the convenience of the patients (DOH, 2003).
- Satellite clinic

  Such a health facility represents the main clinic of a particular area. It is usually placed at a distance from the main clinic to serve the communities that cannot easily access the main clinic.

Climatic data

To make the weather station data compatible with the study database, GIS interpolation and calculations was used to derive a monthly value to each place-name (P-code) as explained in 3.3.3.2. This means prior to these calculations, the climate data from the weather stations did not give specific data for each place name but the general climatic data for a specific area that represented many place-names. In addition to monthly climatic variables, seasonal extrapolations were also performed. Summer months were considered to be from December to February; autumn; from March to May; winter; from June to August and spring; from September to November. The calculation of average and seasonal climatic data was also for the purpose of introducing consistency within the Attribute database. This would then allow monthly cholera cases to be compared with monthly climatic variables and seasonal cholera cases to be compared with seasonal climatic variables. Below is a brief explanation of the individual climatic variables used in the study.

i. Temperature

Temperature is measured in degrees Celsius. The SAWS weather stations recorded minimum, maximum, and average temperatures on a daily basis.

- Minimum temperature

  The lowest temperature recorded in a 24 hour period is referred to as the minimum temperature for that day. Averages of monthly minimum temperatures were calculated

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by adding all the minimum temperatures recorded for the month, divided by the number of days the minimum temperature readings were taken for that month.

- Maximum temperature

  The highest temperature recorded in a 24 hour period is referred to as the maximum temperature for that day. Averages of monthly maximum temperatures were calculated by adding all the maximum temperatures recorded for the month, divided by the number of days the maximum temperature readings were taken for that month.

- Average temperature

  This is calculated as the mean of the maximum and the minimum temperatures. Averages of monthly average temperatures were calculated by adding all the average temperatures recorded for the month, divided by the number of days the average temperature readings were taken for that month.

Table 3.2: The definition of temperature ranges in South Africa as classified by the South African Weather Service.

Description	**Summer (Oct – Mar)**	**Winter (Apr - Sep)**
Very hot	>35 °C	>35 °C
Hot	30 - 34 °C	27 - 34 °C
Warm	26 - 29 °C	23 - 26 °C
Cool	20 - 25 °C	-
Mild	-	17 - 22 °C
Cold	15 - 19 °C	12 - 16 °C
Very Cold	<15 °C	12 °C

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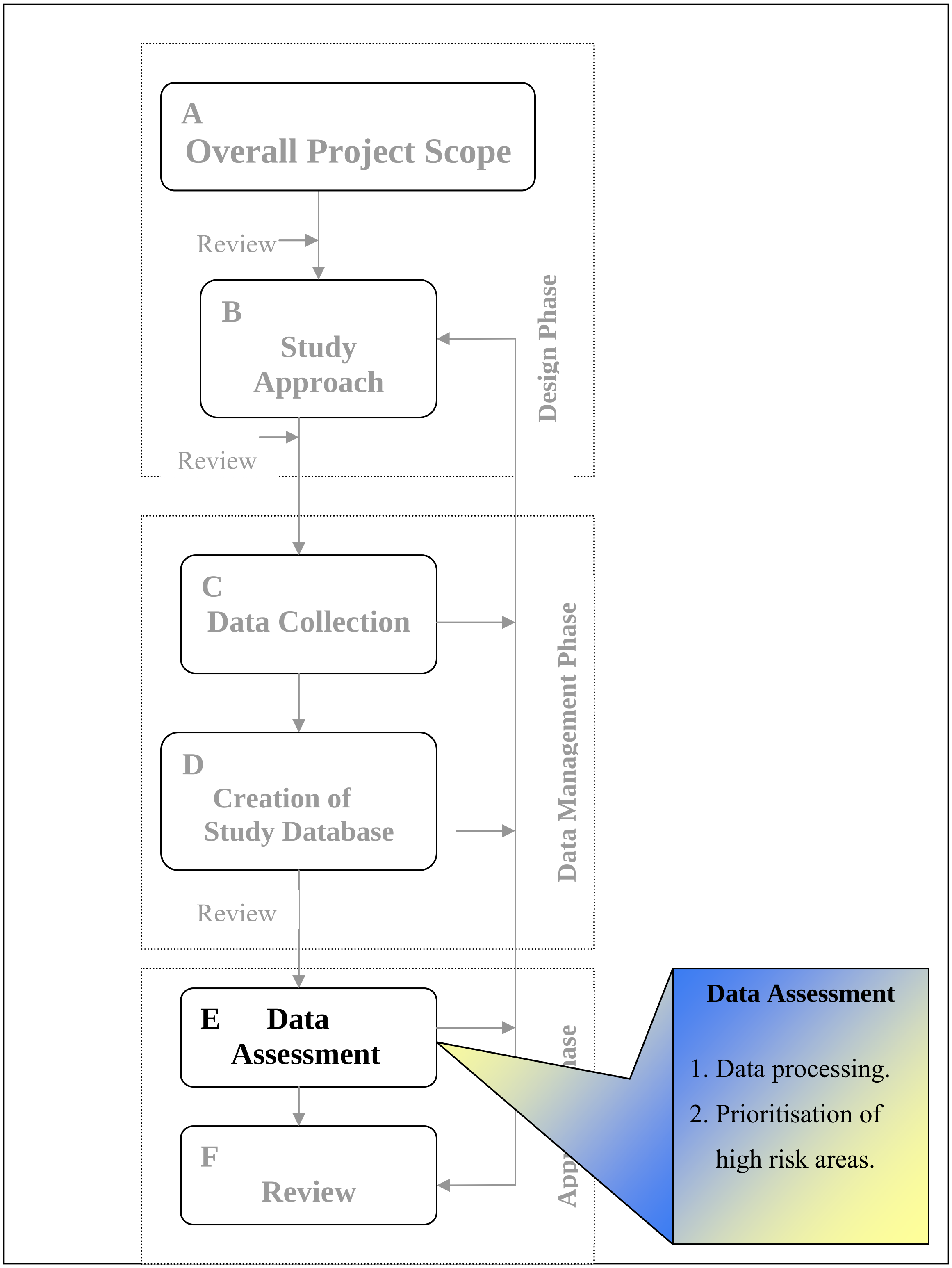

Figure 3.8 Schematic illustration of the tasks assigned to the overall assessment of the data.

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The temperature values in the Attribute database represent the average monthly minimum, maximum and average temperatures. Though the values used to determine the possible relationships between temperature and the incidence of cholera was that of maximum temperature.

ii. Rainfall

Rainfall can be defined as more or less continuous precipitation measured in millimetres. Precipitation includes all of the forms of water particles, whether liquid or solid, that falls from the atmosphere and reach the ground. Values representing average monthly rainfall were the ones incorporated in the Attribute database, thus used throughout the study while investigating the possible relationships between rainfall and the incidence of cholera. Averages of monthly rainfall were calculated by adding all the rainfall values recorded for the month, divided by the number of days the average rainfall readings were taken for that month.

iii. Humidity (Relative humidity)

This is the ratio of the amount of moisture in the air to the amount that the air could hold at the same temperature and pressure if it were saturated, usually expressed as a percent. The humidity values incorporated in the Attribute database represent average monthly humidity. Averages of monthly humidity were calculated by adding all the humidity values recorded for the month, divided by the number of days the humidity readings were taken for that month.

Geographical data

Geographical parameters were not grouped into specific categories. Their categorisation only came in during data processing and analyses, i.e. whether the data is evaluated according to DCs (District Councils), MDs (Magisterial Districts) or individual place-names.

3.3.4.2 Compilation of the Attribute database (D2)

The creation of the Attribute database was made possible once all the variables described thus far, were collected, verified and in some cases categorised. This means the three databases of

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cholera cases, climatic, demographic and socio-economic variables required to be reconciled before being merged into a single Attribute/study database. The success of the creation of the Attribute database exercise required that each place-name be linked with a full set of variables across all the three databases mentioned above. The magnitude of the study database can be describes as follows: There were 2 741 place-names listed. Each place-name was accompanied by 135 variables related to the cholera case profiles, i.e. cholera by place name, by age groups and by gender. There were 34 variables related to demographic profiling for each place name, i.e. the size of the population and the associated age groups and gender. A total of 68 types of socio-economic variables including those related to water, sanitation, refuse, income and energy options were available for each place name together with 11 types of geographic variables of topology and natural water bodies and 216 monthly climatic variables that included rainfall, humidity and temperature data. This meant that each place-name had a total of 464 variables geo-spatially linked to it. Thus in its entirety, the Attribute Database was made of a spreadsheet containing 2741 rows and 464 columns of data entries, therefore a total of 1 271 824 cells with data.

3.3.5 Data assessment (E)

The fact that the study is of a multi factorial nature, each variable was assessed on its own as well as in relation to other variables. Data analyses were performed in terms of how the epidemic correlated with different environmental factors; e.g. temperature; rainfall; humidity versus cholera incidence; and which socio-economic factors like water; sanitation; housing; refuse collection and income may have facilitated the spread of the outbreak.

3.3.5.1 Data processing (E1)

Data was processed using Microsoft Excel 2000, ArcView GIS 3.3 and SAS statistical computer software. The study made use of these research tools to analyse and interpret the Cholera Database as well as the Attribute Database. The initial set of analyses served to study the general trend of the 2000-2004 cholera epidemic. These preliminary analyses used spreadsheets to explore the Cholera Database, whereby results were presented in the form of tables and graphs.

Later on, once the creation of the Attribute Database was complete, more involved statistical analyses and spatial representations were performed. As such the available data was looked at from three different perspectives, vis-à-vis the general, the statistical and the spatial approaches.

The general approach

The following spreadsheet analyses using MS Excel (2000) were performed. The results from this exercise are presented in the form of line graphs and bar charts in Chapter 5.

1. Cholera according to DCs.
2. Cholera according to MDs.
3. Cholera trend from 2000-2004.
4. Cholera cases and gender.
5. Cholera according to gender and age group.
6. Cholera according to DCs and %CIR of cholera

Statistical approach

Once the Attribute Database was created, it was then considered as unprocessed data, from which derived values were obtained. Derived values were obtained through statistical data processing using SAS® (version 8.2). The following is a list of derived values calculated from the Attribute Database based on the DC totals of KZN.

1. Population proportions of DCs for the total population of KZN.
2. Cholera case proportions according to DCs.
3. Cholera death proportions according to DCs.
4. Age group category proportions according to DCs.
5. Cholera age group category proportions according to DCs.
6. Mean monthly humidity according to DCs.
7. Mean monthly minimum temperature according to DCs.
8. Mean monthly maximum temperature according to DCs.
9. Mean monthly rainfall according to DCs.

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10. Mean seasonal humidity by DC.
11. Mean seasonal minimum temperature by DC.
12. Mean seasonal maximum temperature by DC.
13. Mean seasonal rainfall by DC.
14. Household type category proportions by DC.
15. Household number proportions by DC.
16. Mean number of people per household per DC.
17. Water services proportions by DC.
18. Sanitation services proportions by DC.
19. Health facility number proportions by DC.
20. Mean number of people per health facility per DC.
21. Health facility category proportions by DC.
22. Natural water source category proportions by DC.
23. Natural water source category by number by DC.
24. Cholera cases per month per year proportions by DC.
25. Cholera cases per month per season proportions by DC.
26. Energy source proportions by DC.
27. Refuse services proportions by DC.
28. Income category proportions by DC.
29. Monthly mean % CIR according to DC.
30. Mean % CIR according to age group categories of DCs.

The following is a list of derived values calculated from the Attribute Database based on the MD totals of KZN:

1. Population proportions according to MD
2. Cholera case proportions according to MD.
3. Cholera death proportions according to MD.
4. Household type category proportions according to MD.
5. Household number proportions according to MD.

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6. Mean number of people according to household according to MD.
7. Water services proportions according to MD.
8. Sanitation services proportions according to MD.
9. Health facility number proportions according to MD.
10. Mean number of people according to health facility according to MD.
11. Health facility category proportions according to MD.
12. Energy source proportions according to MD.
13. Refuse source proportions according to MD.
14. Income categories proportions according to MD.
15. Mean %CIR according to MD.
16. Mean % CIR according to age group categories according to MD.

These derived values formed the basis of the statistical correlations to investigate which variables statistically correlated with the incidence of cholera as outlined in 4.3.5.2.

Spatial approach

The outputs from both spreadsheet and statistical processing supported the production of GIS maps using GIS ArcView 3.3 Software. GIS maps presented a spatial picture of the different characteristics of the cholera epidemic. As such, the following spatial analyses were performed and the associated GIS maps generated.

- The creation of basic maps to spatially depict housing, income, population density, water and sanitation services in KZN and how they correlate with the incidence of cholera.
- The creation of maps to show how the climate of KZN spatially correlated with cholera incidence during the major peak of the epidemic from November '00 to January 01.

Statistical correlations

Partial Spearman's correlation was used in the statistical analysis of the data as all the variables in the different categories were used as proportions, which implies that the data was continuous. By performing partial correlations, a variable in a particular category was assessed while keeping

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the effect of all the other variables in that category, constant. For example, in the household category, there are 5 household type variables. Thus, when performing a partial correlation of traditional houses with %CIR of cholera, the other 4 household types variables were kept constant, as a household type was a proportion of the entire category considered.

Partial Spearman's correlation analyses were performed in two parts. The first part dealt with all the variables that had a once off, data value. This refers to the data presented as a single value representing a particular collective time period e.g. number of households with piped water services during the epidemic period in question. Thus, such a value was statistically assessed versus the percent cumulative incidence rate (%CIR) of cholera in the context of the entire epidemic period. The second part statistically assessed the %CIR of cholera with variables whose data was collected in a continuum, as was the case with the climatic variables that were collected on a daily basis. As already explained in 4.3.4.1, climatic data was extrapolated to give monthly and seasonal averages. This meant that the monthly %CIR of cholera in an area (e.g. in a MD) could be correlated with the climatic variables on a monthly or seasonal basis.

The preliminary assessment of the Cholera Database did point out the fact that although the cholera case reports were collected from August'00 to March'04, the majority of the cases were experienced in the year 2001. Thus to insure that the cholera cases reported in the Cholera Database prior to and after 2001 would not introduce bias in the statistical correlations, a decision was made to propose a minimum cut off value for the monthly %CIR of cholera in an area (place-name). That meant that for a place name to be included in the monthly calculations of %CIR of cholera under its MD, it had to qualify by having the proposed minimum cut off value for the monthly %CIR of cholera for every individual month of the epidemic under study. Thus a place-name will only be included in its MDs monthly %CIR calculations for the months it individually qualifies with the minimum monthly %CIR cut off value, and left out in the calculations in the months that it did not qualify.

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Table 3.3 lists the monthly %CIR for each of the 52 MDs of KZN. The %CIR value represents the average of the monthly %CIR of cholera of that particular MD; which was calculated from the %CIR of cholera of each place-name (town, village etc) under that particular MD, divided by the total number of place-names under that MD. The value 0.082 was the lowest monthly %CIR of cholera value (Paulpietersburg) of all the MDs. Thus, the lowest %CIR of cholera value of 0.082 was proposed as a cut off value that the places that make up the MDs had to have. This meant that the monthly %CIR of cholera of each place name must be 0.08 or above to qualify for inclusion in the monthly climatic (rainfall, maximum temperature and humidity) correlations of the MDs to the %CIR of cholera. This cut off point was justified considering %CIR 0.082 of cholera translates to 0.82 person or approximately one person in a population of 1000 will get cholera, which is a high enough risk for transmission of cholera in a community. Thus as a prerequisite, there should be at least 1 case of cholera in a community (place-name) in a particular month, for the place to be included in the monthly correlation analyses of the monthly MD climatic variables against the %CIR of cholera (Figure 3.9).

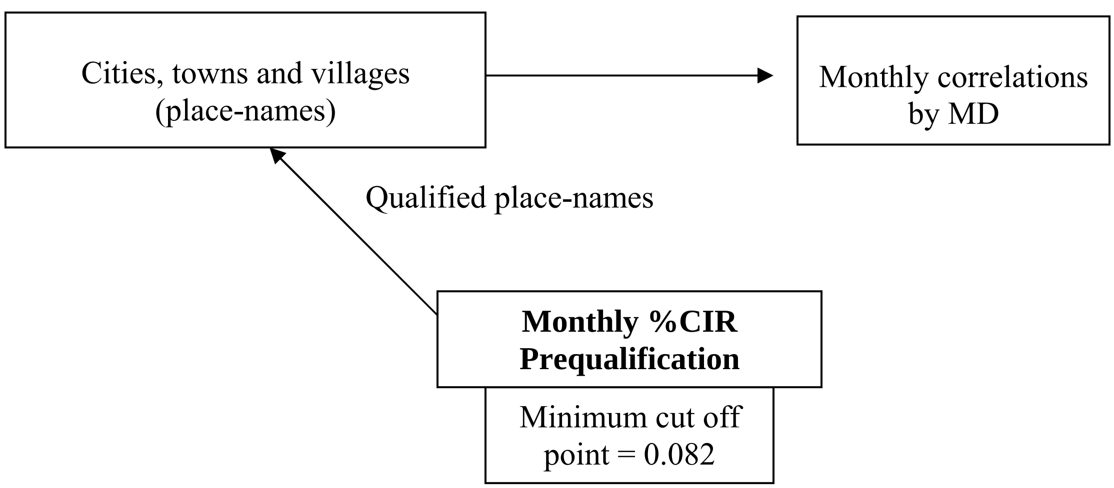

Figure 3.9: Flow diagram to show the selection criterion for place-names to qualify for the monthly climatic correlations variables-cholera correlations.

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GIS output

Parameters, which were statistically proven to have a positive correlation to the incidence of cholera were, selected to portray the possible spatial relationships. Thus the GIS maps of the selected parameters were either reconciled and merged with the cholera cases reported over the entire epidemic period or the cholera cases within a specified reporting period, as was the case with the climatic variables (Maps 5-26).

Table 3.3: The mean % CIR of cholera of the Magisterial Districts in KwaZulu-Natal.

MD	N	MPCIRN	STD	STDERR	VAR	MIN	MAX	MEDIAN
Alfred	69	0.307	0.812	0.098	0.659	0.000	4.865	0.053
Babanango	25	0.117	0.150	0.030	0.023	0.000	0.615	0.055
Bergville	37	0.442	0.733	0.121	0.537	0.000	3.494	0.163
Camperdown	31	1.086	2.752	0.494	7.572	0.000	13.333	0.114
Chatsworth	18	0.124	0.253	0.060	0.064	0.000	0.962	0.012
Dannhauser	33	0.232	0.448	0.078	0.201	0.000	2.300	0.081
Dundee	31	0.162	0.287	0.051	0.082	0.000	1.389	0.057
Durban	96	1.223	5.820	0.594	33.867	0.000	54.546	0.028
Escourt	44	0.699	2.522	0.380	6.361	0.000	14.127	0.086
Eshowe	97	0.179	0.603	0.061	0.363	0.000	5.314	0.000
Glencoe	7	0.148	0.207	0.078	0.043	0.000	0.559	0.090
Hlabisa	52	0.175	0.340	0.047	0.116	0.000	2.100	0.083
Impendle	28	0.566	1.604	0.303	2.574	0.000	7.143	0.000
Inanda	145	0.610	1.766	0.147	3.120	0.000	14.400	0.024
Ingwavuma	85	0.394	2.004	0.217	4.018	0.000	17.122	0.000
Ixopo	61	0.194	0.365	0.047	0.133	0.000	1.640	0.000
Klipriver	32	0.111	0.214	0.038	0.046	0.000	1.136	0.042
Kranskop	28	0.664	2.443	0.462	5.966	0.000	12.935	0.007
Lions River	5	0.574	0.711	0.318	0.505	0.000	1.469	0.188
Lower Tugela	26	0.674	1.619	0.317	2.621	0.000	7.607	0.037
Lower Umfolozi	86	0.299	1.173	0.126	1.376	0.000	9.203	0.000
Mahlabathini	78	0.103	0.181	0.020	0.033	0.000	0.880	0.000
Mapumulo	76	0.196	0.429	0.049	0.184	0.000	2.387	0.000
Mooi River	4	1.166	1.439	0.720	2.072	0.018	3.099	0.775
Mount Currie	9	0.171	0.310	0.103	0.096	0.000	0.927	0.000
Msinga	61	0.133	0.198	0.025	0.039	0.000	0.706	0.043
Mthonjaneni	50	0.243	0.728	0.103	0.530	0.000	4.024	0.000
Mtunzini	71	0.130	0.213	0.025	0.046	0.000	1.017	0.000
Ndwendwe	51	0.185	0.332	0.047	0.111	0.000	1.704	0.062

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Table 3.3: cont'd

MD	N	MPCIRN	STD	STDERR	VAR	MIN	MAX	MEDIAN
Newcastle	6	0.279	0.248	0.101	0.062	0.044	0.705	0.193
New Hanover	18	0.326	0.907	0.214	0.823	0.000	3.855	0.027
Ngotshe	4	0.153	0.187	0.093	0.035	0.000	0.420	0.095
Nkandla	114	0.154	0.342	0.032	0.117	0.000	1.798	0.000
Nongoma	126	0.218	0.518	0.046	0.268	0.000	3.968	0.000
Nqutu	94	0.120	0.222	0.023	0.049	0.000	1.579	0.000
Paulpietersburg	38	0.082	0.182	0.029	0.033	0.000	0.761	0.000
Pietermaritzburg	100	0.650	2.046	0.205	4.187	0.000	15.416	0.096
Pinetown	77	0.299	0.510	0.058	0.260	0.000	3.233	0.136
Polela	74	0.197	0.359	0.042	0.129	0.000	1.942	0.000
Port Shepstone	81	0.656	3.448	0.383	11.891	0.000	30.435	0.056
Qutu	1	0.000	.	.	.	0.000	0.000	0.000
Richmond	18	0.645	1.413	0.333	1.997	0.000	5.951	0.155
Simdlangentsha	24	0.259	0.672	0.137	0.452	0.000	3.274	0.089
Ubombo	64	0.224	0.585	0.073	0.343	0.000	3.644	0.000
Umbumbulu	48	0.262	0.622	0.090	0.387	0.000	3.580	0.106
Umlazi	26	0.942	0.922	0.181	0.850	0.000	3.720	0.730
Umvoti	24	0.300	0.452	0.092	0.204	0.000	1.376	0.121
Umzinto	97	0.456	2.935	0.298	8.613	0.000	28.800	0.086
Underberg	10	0.729	2.009	0.635	4.034	0.000	6.423	0.000
Utrecht	3	1.382	2.205	1.273	4.863	0.101	3.929	0.117
Vryheid	8	0.598	1.171	0.414	1.370	0.000	3.372	0.102
Weenen	9	0.095	0.155	0.052	0.024	0.000	0.459	0.000

Abbreviations:

MD = Magisterial District
MPCIR = Mean % CIR
STDERR = Standard error
N = Total place-names in the MD
STD = Standard deviation
VAR = Variance
MIN = Minimum
MEDIAN = Median
MAX = Maximum

3.3.5.2 Ranking of areas with a high risk for cholera (E2)

The purpose of this exercise was to determine why some areas were more affected than others. In light of the fact that no positive correlations could be established between any of the climatic variables and the incidence of cholera (Chapter 6: 6.1), it was decided to pick 30 of the most

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affected place-names for a comprehensive examination into their climatic variables. Therefore, 15 of the most affected places during the major peak and 15 of the most affected places during the minor peak of the epidemic were selected. The main criterion of selecting the 30 most affected places was that they showed an exponential increment of cases from November to January of each peak period in question. Thereafter, GIS ArcView 3.3 was used to calculate the monthly averages of the climatic variables i.e. monthly averages of humidity, rainfall, minimum, maximum and average temperatures of November to January of the two peaks. For the purpose of this exercise, the average monthly climatic variables, refers to the monthly climatic variables averages of the 15 chosen place-names of the respective epidemic peaks. The results generated from this evaluation were used to develop a spatial model for the creation of a vulnerability map using ArcView GIS 3.3. Thus the selected climatic and socio-economic data of the 30 selected place-names were compared to the rest of KZN during the same time period of November, December and January (NDJ) over the 4 years of the epidemic period. Patterns to compare the average climatic and socio-economic profiles of the selected place-names to the averages of the rest of the place-names in the Attribute Database can be distinguished from the graphs portrayed in Chapter 5: Figures 5.22-5.25). At the same time, a spatial model was built using spatial queries in the GIS system to depict place-names with similar environments, natural and human made, which were most susceptible to cholera outbreaks. Due to the significant humidity variations between the two datasets of the major peak and the minor peak, 2 models were proposed, depending on the height above sea level, i.e. one for the lowlands and one for the highlands.

3.4 Spatial Modelling

Spatial models are site selection or suitability models that attempt to find optimum locations, in this case, for outbreaks of cholera. The purpose is to locate the most probable place that is vulnerable to cholera. As the two models are explained below, its worth keeping in mind that the start of the cholera epidemic was in August 2000. It reached peak proportions during the spring and summer months of November and December 2000 and January and February 2001. The

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second peak in the following year of 2002 recorded a similar trend during the same afore-mentioned months.

3.4.1 Lowlands Model

According to NDJ 2000/01 major peak, a place-name has to have the following characteristics for it to fit into the lowland model. This means that if a place-name situated in the lowland areas satisfies the following criteria, the possibility of a cholera outbreak is high. Thus:

- The humidity should be ≥ 70.7%.
- The height above sea level should be below 900m.
- The minimum temperature should be ≥ 20.8 ^{0}C.
- The maximum temperature should be ≥ 28 ^{0}C.
- The monthly rainfall should be ≥ 222 mm.
- The population density should be at least 170 persons/sq km.

Additional criteria based on the statistical correlations supporting the probability that socio-economic factors also have an influence, were also included (refer to Chapter 5: 5.3.1). A flow chart portraying all the characteristics required to be fulfil the pre-requisites for inclusion in the lowlands model is given in Chapter 5: Figure 5.26.

3.4.2 Highlands Model

According to NDJ 2001/02 minor peak, a place has to have the following characteristics for it to fit into the highland model. This means that if a place-name situated in a highland area satisfies the following criteria, the possibility of a cholera outbreak is high. Thus:

- The humidity should be ≥ 58.7%
- The height above sea level should be > 900m.
- The minimum temperature should be > 15 ^{0}C.
- The maximum temperature should be > 26.3 ^{0}C.
- The monthly rainfall should be 130.4 mm.
- The population density should be at least 324 persons/sq km.

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In addition, as socio-economic factors (all related to water and sanitation) could also have an influence, selected criteria from these data types were also included. A flow chart portraying all the characteristics required to be fulfil the pre-requisites for inclusion in the highlands model is given in Chapter 5: Figure 5.27.

The results presented in the following Chapter 4 are part of the outcome of the methodology described in this chapter. In particular, chapter 4 gives an overview of the study area of KZN, highlighting the province of KZN, its geographical characteristics; demography, socio-economic status and the history of cholera going back two decades prior to the epidemic in question. The description of the study area brings forth awareness of the existence of cholera in the province of KwaZulu-Natal over the last two decades. This, together with the crisis brought about by the epidemic that started in August 2000, rationalised the interest in undertaking the study.

CHAPTER 4:

The Research Area

4.1 Introduction

4.1.1 The Province of KwaZulu-Natal

KwaZulu-Natal (KZN) owes its name to the incorporation of KwaZulu, a former Bantustan of the Zulu people into Natal province after the collapse of apartheid in 1994. Natal, meaning Christmas in Portuguese was so named because Vasco da Gama sighted the coast on Christmas day in 1497. The province lies between longitudes 28^0 27’ and 32^0 54’ E and latitudes 26^0 52’ to 31^0 25’ S, on the southeastern coast of South Africa. The most eastern point is Kosi Bay at 32^0 54’ E, most northern, Nduma at $26^0$52’ S, most western, Matatiele at $28^0$47’ E and most southern, Port Edward at $31^0$25’S. In total, KZN covers an area of 92 100 square kilometres that makes up 7.6% of the entire area of South Africa (STATSSA, 2004).

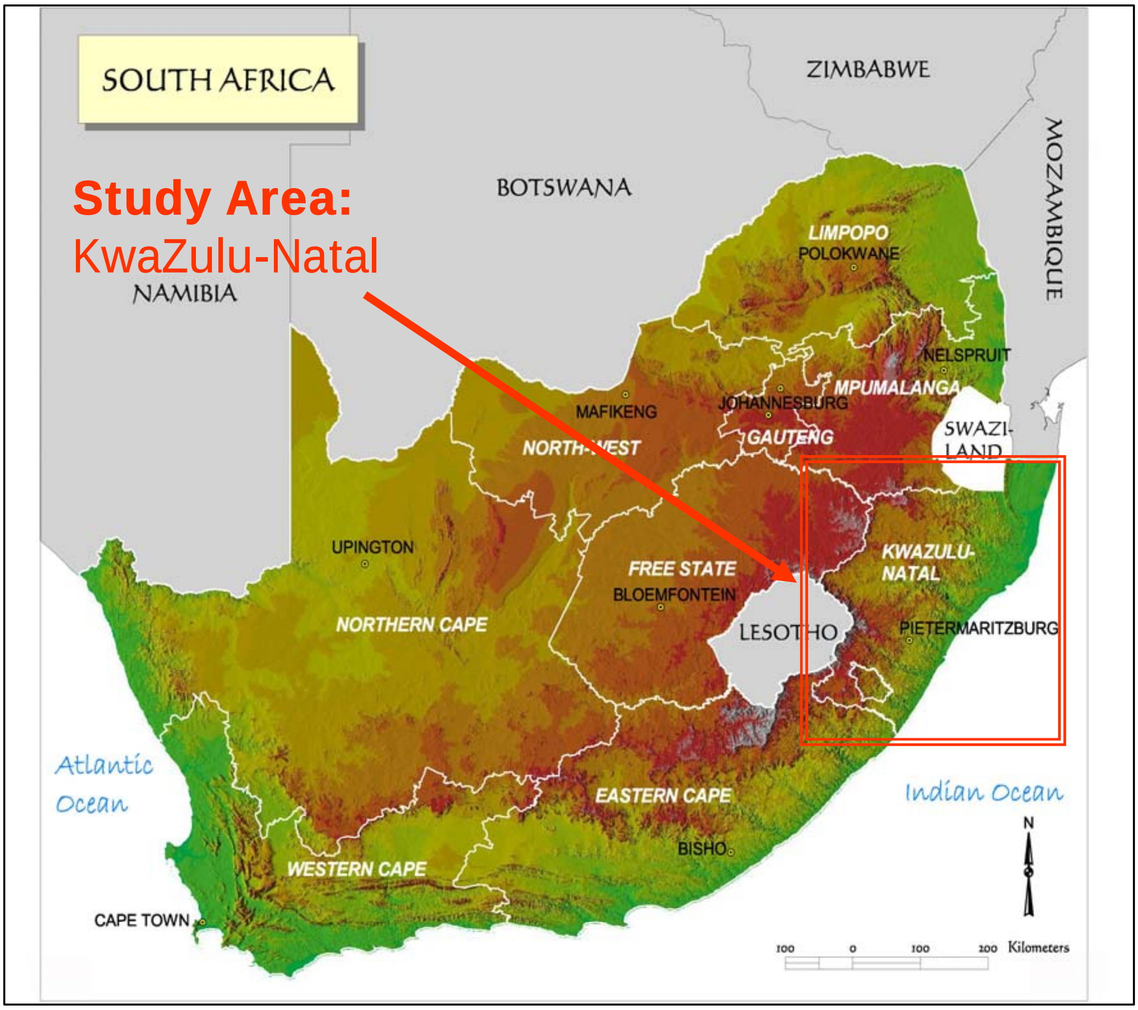


Figure 4.1: Orientation map showing the study area of KwaZulu-Natal in South Africa.

KZN extends from its borders with Swaziland and Mozambique in the north to the Eastern Cape border in the south. Westwards inland, it borders the Kingdom of Lesotho, the Free State and Mpumalanga, which is more towards the northwest. The eastern edge of the province is entirely bordered by the Indian Ocean (Figure 4.1). The province has a varied topography, with lowlands found along the Indian Ocean coast, plains in the midlands, and two mountainous ranges i.e. the Drakensberg and the Lebombo Mountains. The summer seasons of KZN are wet, hot and humid while the winters are mild. Rain falls throughout the year with a mean annual rainfall of 845 mm (Enviro-Info, 2001).

4.2 The demography of KZN

According to the census count of 2001 of South Africa, KZN has a total population of 9 426 017, with 5 016 927 females and 4 409 092 males, thus a male: female ratio of 1:1.14 (STATSSA, 2003). One of the reasons for the slight dominance of females, especially in the rural areas is the fact that a significant proportion of male adults seek employment outside their province (Mugero and Hoque, 2001). Overall, this population makes up 21% of the national populace, the largest provincial population in South Africa. The population growth in KZN over the period between the census of 2001 and the previous census of 1996 was almost 12%; when one considers that the provincial population count of census 1996 was 8 417 021 (STATSSA, 2004).

The population pyramids of KZN (Figures 4.2 and 4.3) give a description of the population's composition by number and gender in each age category (Census, 1998; Census, 2003). Although there was a population growth of 12% between 1996 and 2001, the general population profile has remained consistent to a large extent. Both population pyramids have a characteristically expansive age groups distribution pattern, in that young age groups represent a large portion of the population. The population pyramids are characteristic of populations with very large fertility rates and lower than average life expectancy (PRB, 2005). The collective age group of 15 - 34 year olds, which is by and large the reproductive age group, makes up 49% of both the 1996 and 2001 population pyramids of KwaZulu-Natal.

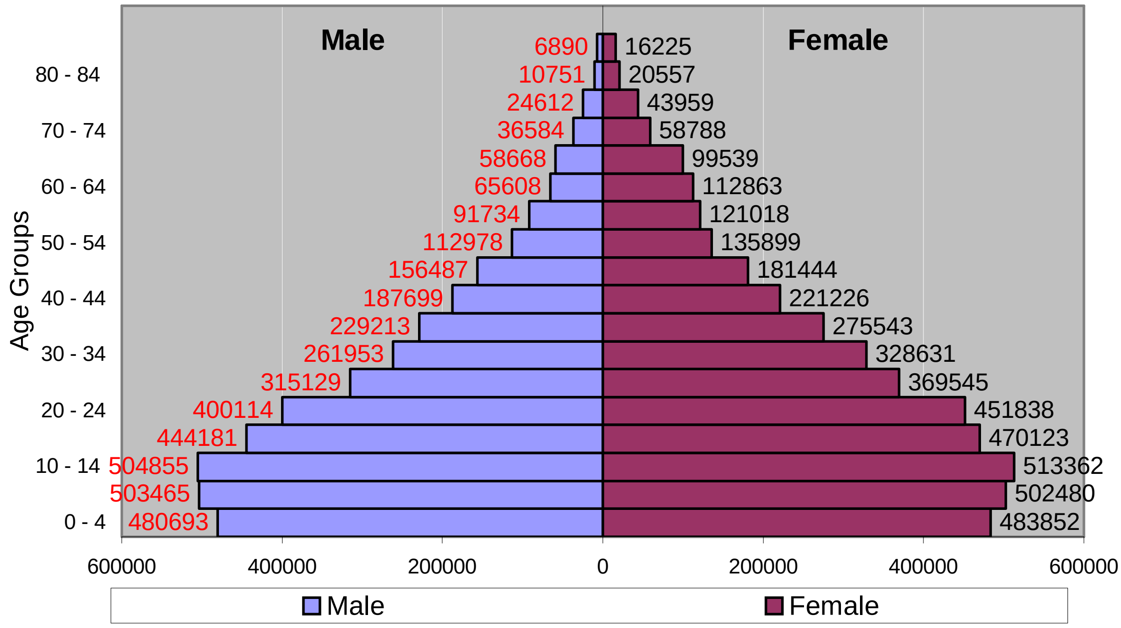


Figure 4.2: KZN population statistics as reported by Census 1996.

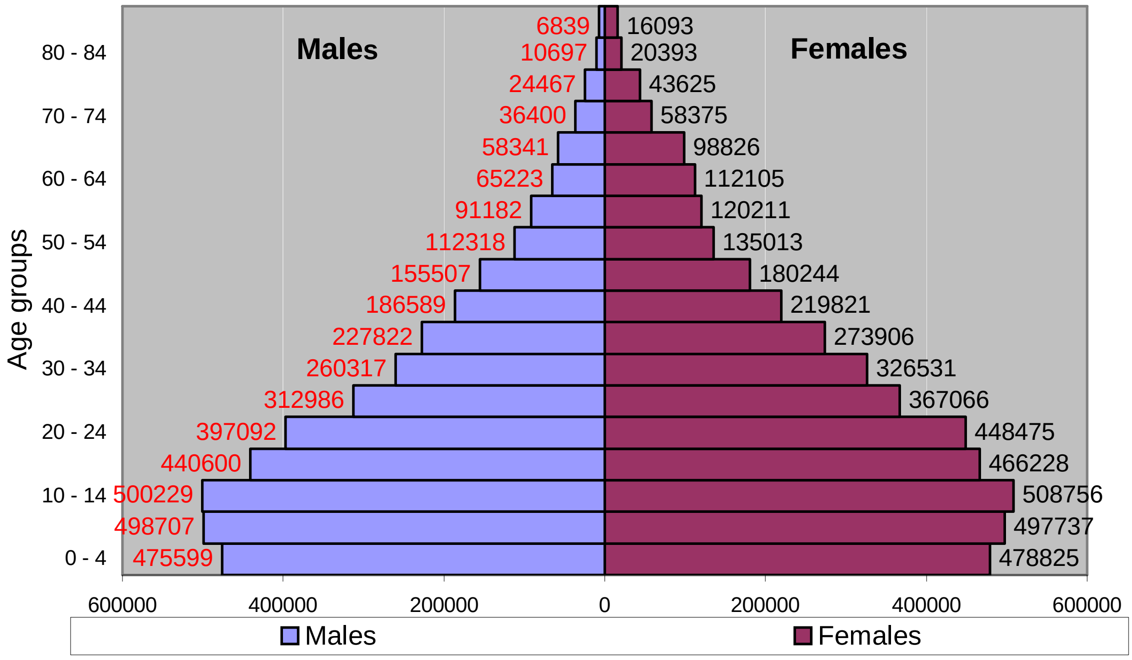


Figure 4.3: KZN population statistics as reported by Census 2001.

This accounts for the high reproductive rate in the province. The age-sex distributions of developing countries would typically display such a pattern (PRB, 2005). As it will be seen later in Chapter 5, the age groups most affected by cholera are in the majority represented by the 5 - 34 years age range of which the reproductive age group is well representative.

4.3 The socio-economic profile of KwaZulu-Natal

The socio-economic variables used in this study together and the creation of the cholera database was based on information sourced from the South African census 1996 database, as explained in 3.3.3.2. Thus the socio-economic profile presented here reviews the situation in KZN as presented by both the 1996 and 2001 censuses. In 1996 at least 43% of the province's population lived in urban areas as opposed to more than 57% who live in non-urban areas (STATSSA 1998). The census 2001 did not present a comparison between the urban and non-urban population. Notwithstanding, it is probably more or less the same.

Several reports highlighted the fact that most people do not have access to clean water either because the infrastructure is non-existent or they cannot afford to pay for access for basic services (Ka-Min, 2000; Nhlapo-Hlope, 2001). Attention had also been drawn to the fact that in KwaZulu-Natal at least one million people do not have access to adequate sanitation, while the figure is around 18 million for the whole country (Sidley, 2001). A list of the basic socio-economic indicators is presented in table 4.1 as reported by the 1996 and 2001 national censuses, highlighting the developments in the delivery of basic services by 2001. According to this information, there has generally been a significant improvement in the sectors of education and housing. In particular, there was a major improvement in the situation of the homeless category; whereby it decreased by 186.9% in KZN, and by 221.7% nationally. This major decrease can be attributed to several factors. It is possible that the homeless people found opportunities of shelter in one of the three larger housing categories i.e. formal, informal or traditional. It could also be that the low-income national housing schemes undertaken by the government are addressing the housing issue positively. Improvement in the employment sector between 1996 and 2001 was marginal, standing at only 2%. While over the same period, unemployment increased by 33.8%. In the energy sector, the proportion of households affording the use of electricity and other hydrocarbon energy sources increased between 8-24.5%. At the same time, there was an almost 50% increase in households reverting to using animal dung and other unspecified sources for their energy needs, reflecting a generally low economic status of such households. The water services sector had a decrease of 5.2% households with piped water in their dwelling, which is probably indicative of discontinuation of the service for economic reasons. The proportion of households with piped water inside their yard was the highest at 64.9%, probably because it is a cheaper option than having piped water inside a household. There was also a substantial increase of 38.5% households continuing to use public taps, which may not be surprising considering this is a free service to the public. In general there has been a decrease in houses using water from natural sources, especially the households using boreholes that had reduced by 25.8%. The reduction of households using dam/river/stream/spring water was relatively far less at 4.8% which is reflective of the corresponding improvements in the supply of piped water to the KZN communities. Despite these improvements, 49.3% of households had their water supply source(s) termed as “other” thus implying that they have no specific source of water supply. This may be an indirect reflection that the natural water bodies are still important resources to the livelihoods of some rural communities.

There was a substantial increase in the proportion of households with sanitation; even though some options were not necessarily safe like the bucket latrine. Needless to say, a major part of the 29% increase of households with flush or chemical toilets would be located in urban or peri-urban areas where people can afford such facilities. The increase in the number of pit latrines was the smallest at 7.6%. This is surprising considering that pit latrines are a cheaper sanitation option than the flush or chemical toilets and safer than the bucket latrine especially in rural settings. On the other hand, the largest increase in a sanitation option was the 34.6% of households using the bucket toilet. Even more interesting is that an increment of such a proportion was not reflected at the national level. The alarming thing is that the bucket toilet has been identified as unhygienic and environmentally undesirable by DWAF (2002a), thus a potential health hazard especially in areas where the municipal service of emptying the buckets is not regular.

Table 4.1: Comparing the socio-economic variables of Census 1996 and Census 2001 (KZN and South Africa).

	KZN - 1996	RSA -1996	KZN - 2001	RSA - 2001	Diff '96-01 - KZN	Diff '96-01 - RSA	% Change KZN	% Change RSA
Highest Level of Education	Persons	Persons	Persons	Persons	Persons	Persons	Persons	Persons
No Schooling	957,217	4,066,187	1,100,291	4,567,497	143,074	501,310	13.0	11.0
Some Primary	747,586	3,512,415	849,144	4,083,742	101,558	571,327	12.0	14.0
Complete Primary	278,435	1,571,774	287,070	1,623,467	8,635	51,693	3.0	3.2
Some Secondary	1,328,708	7,130,121	1,447,674	7,846,125	118,966	716,004	8.2	9.1
Grade 12 / Standard 10	665,303	3,458,434	995,616	5,200,602	330,313	1,742,168	33.2	33.5
Higher/Tertiary Education	200,819	1,294,720	348,744	2,151,336	147,925	856,616	42.4	39.8
Unspecified/Other	217,428	1,112,568	N/A	N/A	N/A	N/A	N/A	N/A
Labour Market Status	Persons	Persons	Persons	Persons	Persons	Persons	Persons	Persons
Employed	1,570,573	9,113,847	1,602,270	9,583,762	31,697	469,915	2.0	4.9
Unemployed	1,008,944	4,671,647	1,523,214	6,824,075	514,270	2,152,428	33.8	31.5
Not Economically Active	N/A	N/A	2,629,796	12,019,290	N/A	N/A	N/A	N/A
Total Labour Force	N/A	N/A	3,125,484	16,407,837	N/A	N/A	N/A	N/A
Type of Dwelling	Households	Households	Households	Households	Households	Households	Households	Households
Formal	918,793	5,834,819	1,271,795	7,680,421	353,002	1,845,602	27.8	24.0
Informal (Incl. Caravan/Tents)*	188,301	1,470,141	225,825	1,836,231	37,524	366,090	16.6	19.9
Traditional	532,046	1,644,388	581,036	1,654,787	48,990	10,399	8.4	0.6
Other (Homeless & unspecified)*	21,793	110,223	7,595	34,266	14,198	75,957	-186.9	-221.7
Energy Source for Cooking	Households	Households	Households	Households	Households	Households	Households	Households
Electricity	760,611	4,265,305	1,007,737	5,761,354	247,126	1,496,049	24.5	26.0
Gas	52,691	286,657	63,917	284,295	11,226	2,362	17.6	-0.8
Paraffin	296,017	1,943,862	374,356	2,394,919	78,339	451,057	20.9	18.8
Wood	490,122	2,073,219	562,970	2,292,674	72,848	219,455	12.9	9.6
Coal	38,877	320,830	42,267	310,059	3,390	10,771	8.0	-3.5
Animal dung	10,533	106,068	20,736	110,969	10,203	4,901	49.2	4.4
Solar	N/A	N/A	6,146	24,225	N/A	N/A	N/A	N/A
Other	12,085	63,629	8,122	27,210	3,963	36,419	48.8	-133.8
Supply	Households	Households	Households	Households	Households	Households	Households	Households
Piped Water to the Dwelling	650,677	3,976,855	618,267	3,617,603	32,410	359,252	-5.2	-9.9
Piped Water inside yard	145,237	1,491,228	413,535	3,253,861	268,298	1,762,633	64.9	54.2

Table 4.1: (Cont'd).

Piped Water to Community Stand (Less or more than 200m) (public tap)*	304,502	1,765,945	494,966	2,594,904	190,464	828,959	38.5	31.9
Borehole (Well)*	110,755	441,884	88,065	270,882	22,690	171,002	-25.8	-63.1
Rain-water Tank	N/A	N/A	15,787	67,680	N/A	N/A	N/A	N/A
Dam/ river/ stream/ spring	402,822	1,116,484	384,448	1,050,055	18,374	66,429	-4.8	-6.3
Water vendor	20,059	111,204	18,126	83,634	1,933	27,570	-10.7	-33.0
Other	26,882	155,970	53,056	267,086	26,174	111,116	49.3	41.6
Toilet Facility	Households	Households	Households	Households	Households	Households	Households	Households
Flush toilet or chemical toilet	693,130	4,552,854	978,016	6,031,385	284,886	1,478,531	29.1	24.5
Pit latrine with/without ventilation	690,560	2,919,594	747,091	3,193,433	56,531	273,839	7.6	8.6
Bucket latrine	15,713	420,185	24,025	457,376	8,312	37,191	34.6	8.1
None	250,956	1,118,132	337,119	1,523,512	86,163	405,380	25.6	26.6
Unspecified/Other	10,575	48,807	N/A	N/A	N/A	N/A	N/A	N/A
Refuse Removal	Households	Households	Households	Households	Households	Households	Households	Households
Removed by municipality weekly	696,395	4,641,115	1,026,046	6,210,215	329,651	1,569,100	32.1	25.3
Removed by municipality less often	20,148	200,477	21,281	172,027	1,133	28,450	5.3	-16.5
Communal refuse dump	47,852	287,199	16,934	195,679	30,918	91,520	-182.6	-46.8
Own refuse dump	672,398	2,905,586	806,028	3,655,043	133,630	749,457	16.6	20.5
No rubbish disposal	186,567	862,726	215,962	972,741	29,395	110,015	13.6	11.3
Unspecified/Other	37,574	162,469	N/A	N/A	N/A	N/A	N/A	N/A

Source: Stats in brief. Ten years of democratic governance. 2004. Statistics South Africa. Pretoria.

By 2001, households with a regular (weekly) refuse removal service by the municipality had increased by 32.1% and those receiving a similar but irregular municipal service, increased by 5.3%. Households that depend on communal refuse dumps had decreased by 182.6%, probably because there was a decrease in the availability of such facilities within the communities of KZN. There was still an increment of 16.6% of households who used and managed their own refuse, indicating the lack of service from the municipalities involved. There was also a 13.6% increase of households that had no organised form of rubbish disposal. These households most certainly contribute significantly to the environmental pollution of their localities.

4.4 History of cholera in KwaZulu-Natal

Cholera has long been recognised as a disease of poor sanitation and poor living conditions. Previous epidemics in South Africa have shown cholera to be most prevalent in fairly densely populated rural communities of low social economic status (Isaäcson, 1986). After several years of surveillance, it was established that cholera in southern Africa affected socio-economically deprived communities in densely populated, rural, tropical and subtropical areas; with the peak incidence occurring after the onset of the main summer rains (Kustner and du Plessis 1991). In South Africa, KZN is one of the poorest provinces, with over nine million residents, the majority of whom live in crowded, rural and underdeveloped conditions that favour the spread of the disease (Laskow, 2001). In addition, many people in Kwa-Zulu-Natal still rely on river water for cooking, drinking and washing practices which have been demonstrated to be positively associated with an increased risk for transmission of cholera (Kustner *et al.*, 1981; Shapiro *et al.*, 1999).

The DOH of South Africa compiled a record of cholera cases reported in South Africa from the year 1980 to 2000 (Table 3.2). It is interesting to note that, at the beginning of the DOH monitoring and surveillance exercise, KZN recorded only one case in 1980. This state of affairs changed from 1982, when KZN was foremost in reporting cholera (DOH-Statistical Notes, 2000a). The escalation of cholera in KZN was marked during the period November 1981 to January 1982 with the outbreak of cholera in the Umvoti Mission Reserve situated 75 km north of Durban. A total of 154 cases of cholera were reported, which at the time, showed a strong association between consumption of impure water, socio-economic conditions and the incidence of cholera (Sitas, 1986). The study suggested that the typical pattern of spread implied that the disease may not have been exclusively waterborne, and that other mechanisms like person-to-person transmission may have had a role in the spread of the disease.

Table 4.2: Cholera cases reported over the past 20 years.

PROVINCE → YEAR ↓	EC	FS	GA	KZN	MP	NP	NW	WC	X X	TOTAL
1980	-	-	68	1	1238	96	15	-	-	1418
1981	-	22	205	943	1275	2458	633	-	-	5536
1982	125	1	140	12263	462	858	51	-	-	13900
1983	30	15	156	6427	142	107	2	-	-	6879
1984	7	1	12	1663	1	1	-	-	-	1685
1985	-	-	-	699	1	1	-	-	-	701
1986-1990	-	-	6	330	-	-	-	1	-	337
1991-1 995	1	-	9	89	15	-	3	-	2	119
1996-2000	1	-	3	37	21	-	4	-	4	70
SA TOTAL	**164**	**39**	**599**	**22452**	**3155**	**3521**	**708**	**1**	**6**	**30645**

EC = Eastern Cape FS = Free State GA = Gauteng KZN = KwaZulu-Natal
MP = Mpumalanga NP = Northern Province NW = North West WC = Western Cape
XX = Cases acquired outside South Africa - = No reported case(s)

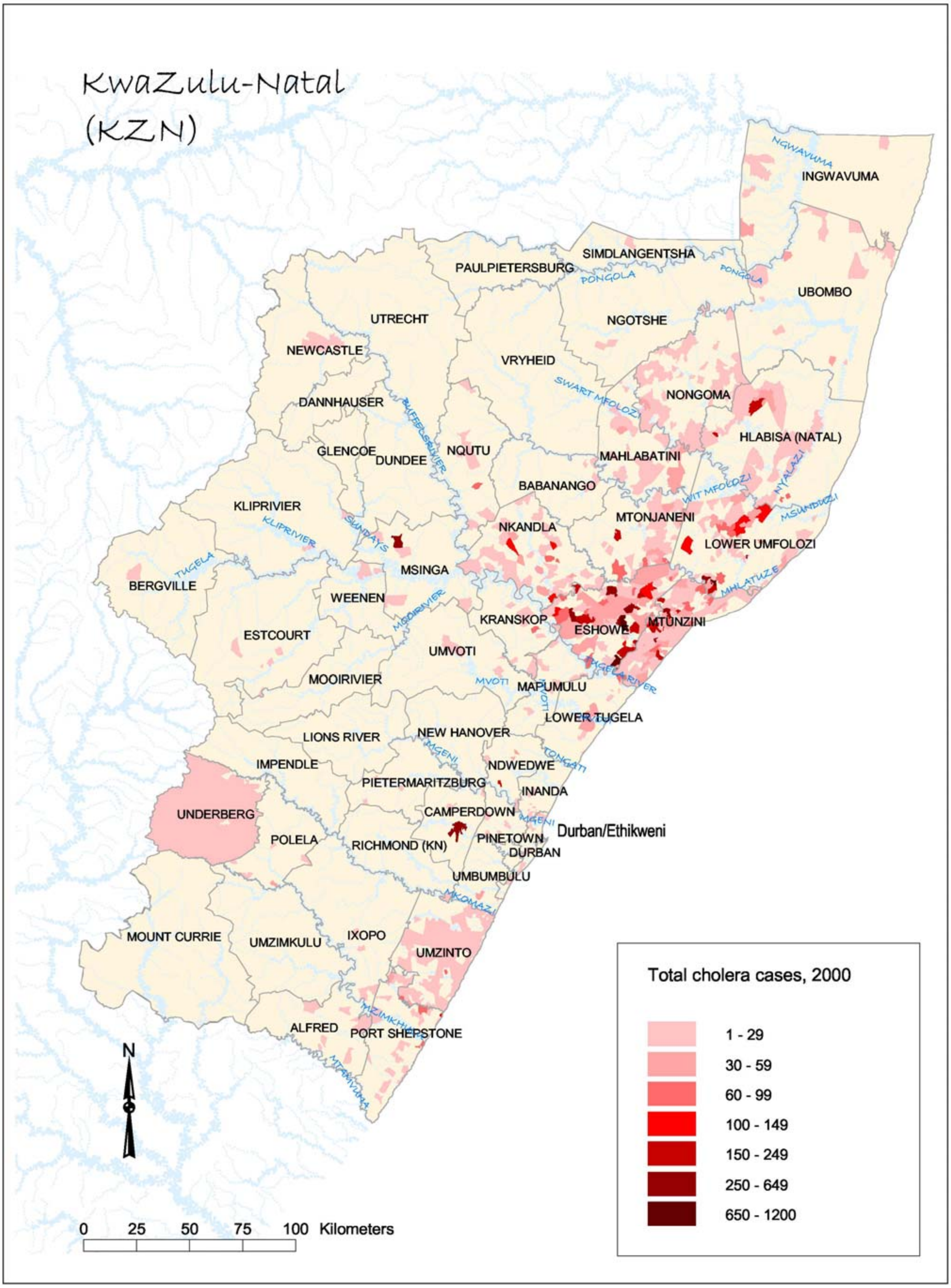
Source: Department of Health, Statistical Notes, 2(14) March 2000.

As from 1981-1985, KZN reported 21 995 (76.6%) cholera cases from a national total of 28 701 cholera cases within the same period (Table3.2). Thereafter, from 1986 up to mid 2000, there were random reports of cholera cases, with KZN reporting 456 cases, accounting for 87% of the national total of 526 (DOH-Statistical Notes, 2000a). Since then, KZN regularly reported cholera cases up to the start of the new epidemic in August 2000. The trend was probably indicative of cholera having become endemic in KZN, suggesting that *V. cholerae* strains capable of causing epidemics are resident microorganism within the environs of KZN. Just before the 2000 cholera epidemic, Simpson & Charles (2000) released the outcome of a study they had conducted covering the period between July 1998 – February 2000, where they monitored effluent discharge from rural hospitals in KZN. In 1999, two hospitals tested positive for cholera organisms in their raw sewage. This was seen to pose a grave health risk to the communities that were using water from springs in close proximity to the hospital.

4.5 The cholera epidemic of 2000-2004 in KwaZulu-Natal

South Africa experienced a new wave of cholera that swept the eastern coast of South Africa starting in mid August 2000. The causative organism was identified as *Vibrio cholerae* El Tor (Mugero and Hoque, 2001). The outbreak was predicted by Keddy & Koornhof (1998), when they foresaw that an ongoing cholera epidemic in Mozambique would possibly re-emerge in South Africa. Before then, cholera had last posed as a public health crisis between 1980-1985 (DOH-Statistical Notes, 2000a). The start of the outbreak was attributed to an incident where a local authority stopped supplying free water and introduced a charge to the very poor people living in an informal settlement near the town of Empangeni (Hemson, 2000; Sidley, 2001, Cottle and Deedat 2002). Subsequently, cholera had a firm grip on the rural parts of Kwa-Zulu Natal, as it developed into the most serious epidemic yet experienced in KZN with cases still continuing to be reported well into the year 2004.

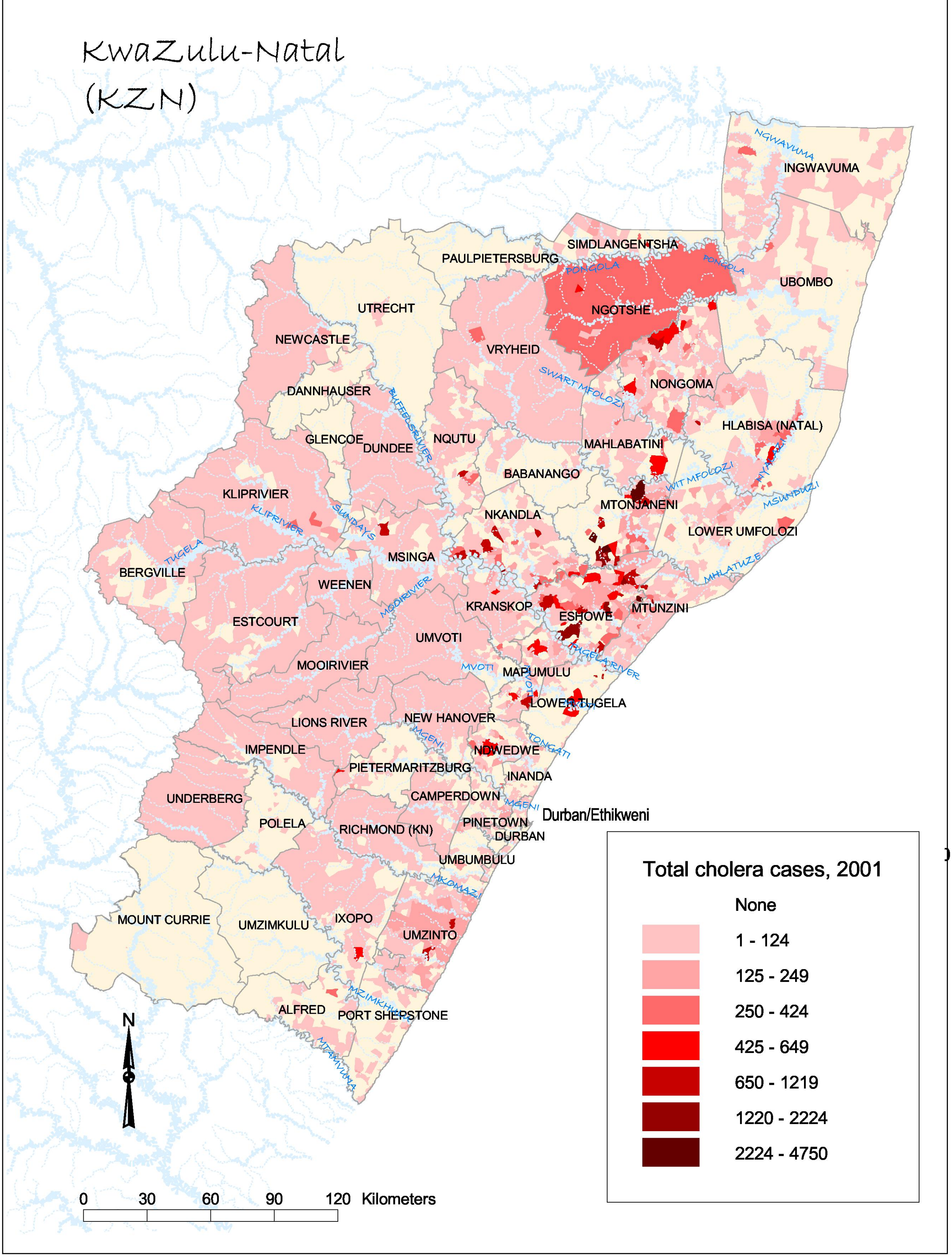
The index case was notified on 14th August, a patient from Empangeni, who had attended a funeral gathering the previous week (DOH, 2000-b). As cholera swept through KZN, it became obvious that most of those who had fallen ill lived in rural areas with little or no running water or adequate sanitation, yet again supporting previous observations that in southern Africa, cholera affects socio-economically deprived communities in densely populated rural area with tropical and subtropical climates (Kustner *et al.*, 1981; Isaäcson 1986; Sitas 1986). The multitude of new cholera cases being reported on a daily basis since the start of the epidemic in August 2000 developed into a national emergency. Cholera became the standard term used to describe any case of diarrhoea in the panic stricken province (McDonald, 2002).



Map 1: Occurence of Cholera in KZN in 2000

The annual cholera incidence trends in GIS maps 1-4 portray the distribution of cholera between August’00 and December’03 as well as the most affected areas. Map 1 highlights the spatial pattern of the spread of cholera in the year 2000. The incidence of cholera in the MDs (Magisterial Districts) of Eshowe, Mtunzini and Lower Umfolozi were the highest in the year 2000, with areas reporting up to 1 200 cases (Map 1). The zone of cholera cases within the afore-mentioned MDs appear to be confined within a region bordered by the rivers Tugela and Mhlatuze, making it the main disease foci. Notwithstanding, there were more cholera cases reported along the localities along the coastal border of the province of KZN than to the interior. The rest of the cholera cases reported from the other MDs within the same year were relatively lower in the range of 2-29 cases. Predictably, with the movement of people within the province, especially towards the end of the year 2000, which is also a holiday season, *V. cholerae* rapidly spread to other areas (Reeves and Boshielo, 2001; Mahmood, 2001).

The national and the provincial governments both allocated resources for the treatment and prevention of the disease (Mugero and Huq, 2001). Despite prompt medical intervention, health education and media campaigns, cholera spread to almost every corner of DC28, which was the epicentre of the outbreak in a matter of weeks. As in most cholera epidemics, there were several early fatalities, possibly due to the general lack of immunity within the communities against the infection, as well as because of the unprepared-ness of the health institutions to deal with the sudden overwhelming number of cholera patients. This situation prompted two important responses. Most important us that affected individuals began to seek help quickly when they developed severe diarrhoea; and the authorities reciprocated by establishing a network of field re-hydration centres within, or close to the affected communities to reduce the delay between development of symptoms and receipt of treatment (Mugero and Hoque, 2001; Reeves and Boshielo, 2001). By 2001, the spread of cholera in KZN was extensive, spreading to cover almost the entire province (Map 2). The major peak of the cholera epidemic in KZN was experienced in 2001. At this point, the health institutions of some of the worst affected areas were receiving reports of over 1 000 cholera cases per day (Nhlapo-Hlope, 2001; Kriner, 2002).

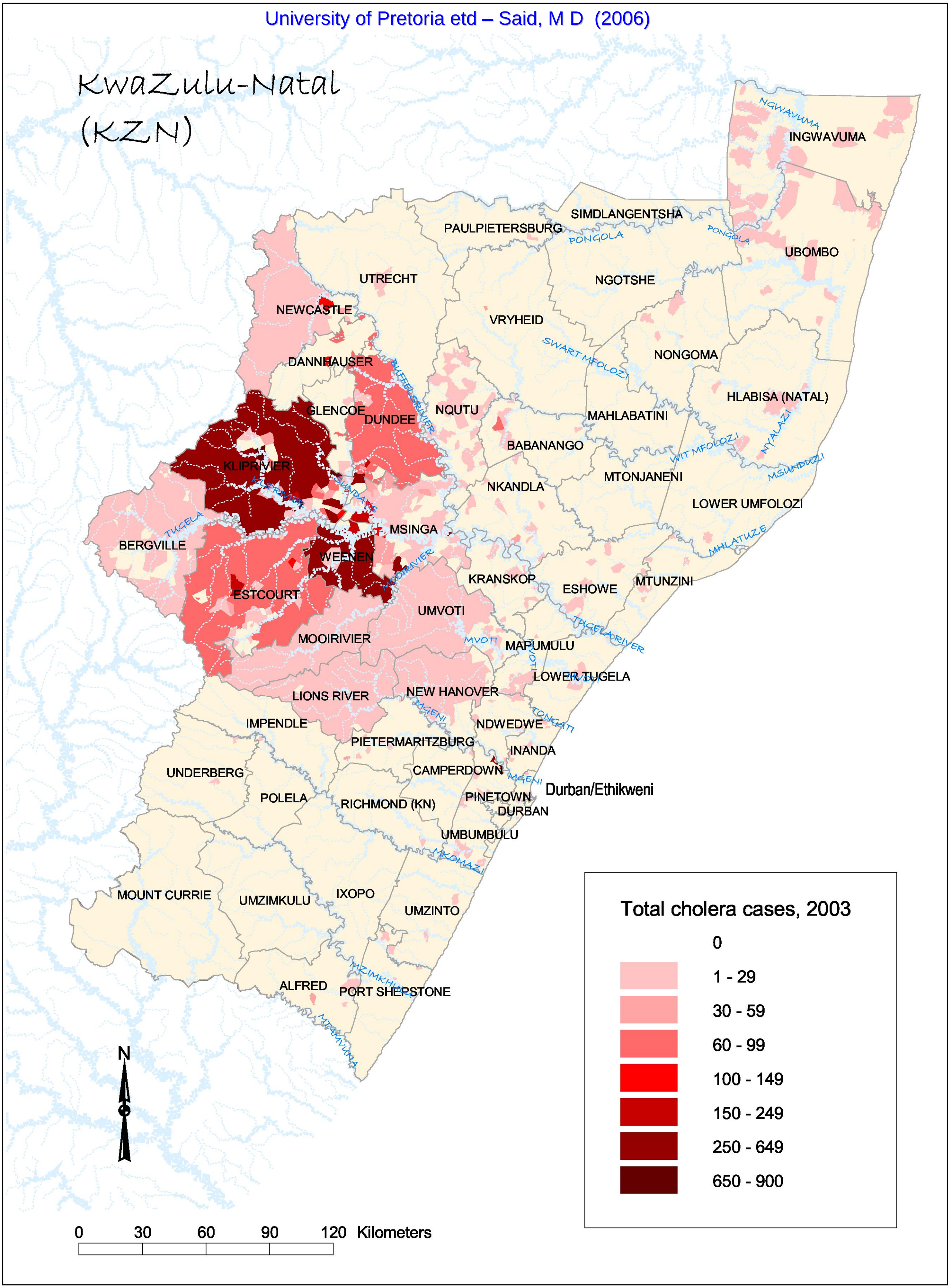


Map 2: Occurence of Cholera in KZN in 2001

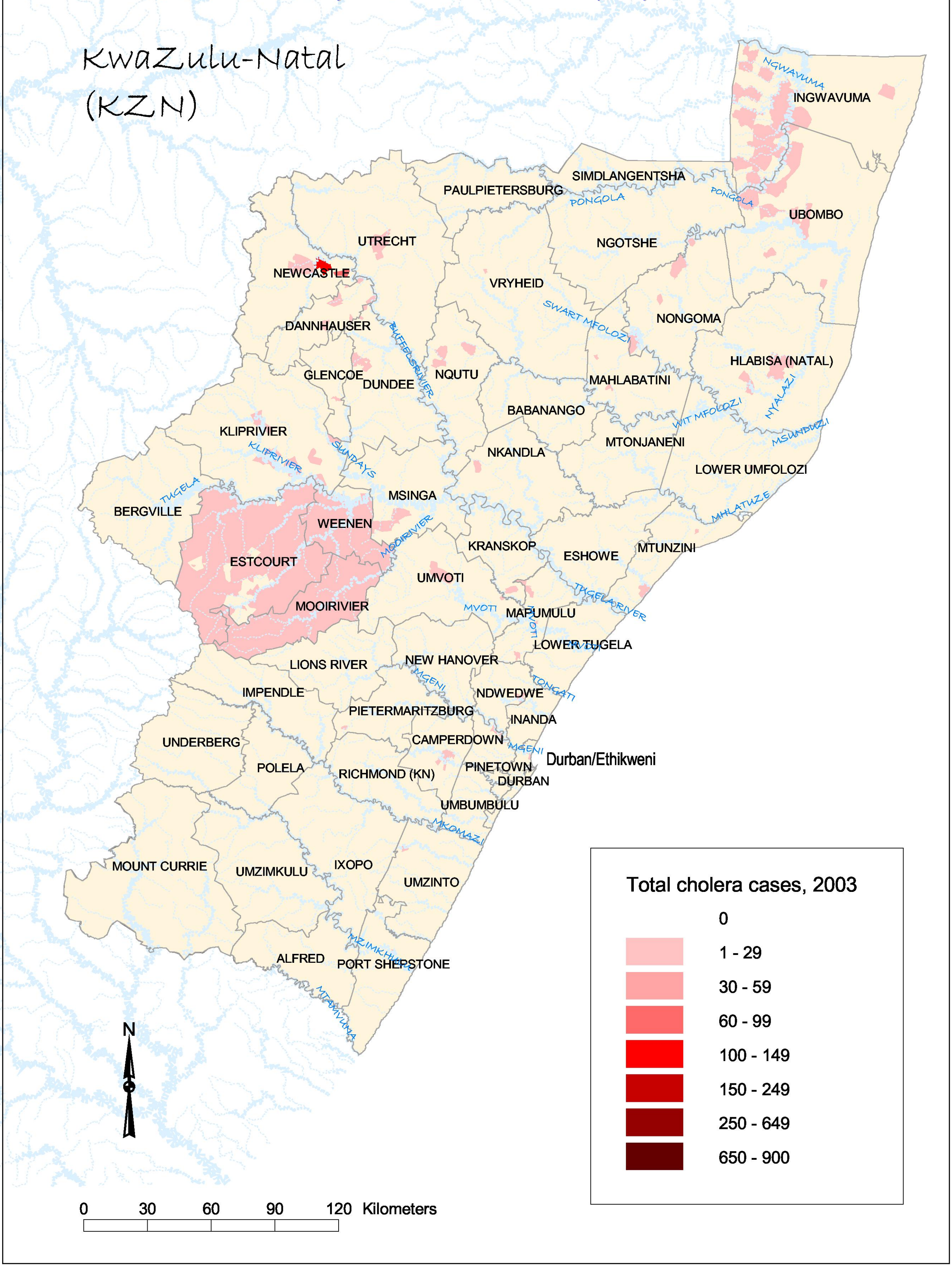
At a public level, there was media fury with local and international press speculating on the factors that brought about the epidemic. In the forefront was the consensus that introduction of water charges was one of the main reasons. Such that people who were too poor to pay their bills consequently had their water supply cut, forcing them to use polluted water from the rivers that were suspected to have harboured the pathogens responsible for the outbreak (Ka-Min, 2000; Pauw, 2003). This opinion was supported by labour unions who felt that the Growth Employment and Redistribution (GEAR) strategy of cost recovery for social services that required people to pay for previously free clean water had left the poor no choice but to opt for surface water (Laskow, 2001). The theory was strengthened with the news that the Department of Water Affairs and Forestry had acknowledged the possibility of this link (Weissman, 2000).

On a broader level, government and health officials systematically tackled the epidemic with mandatory reporting and treatment of the disease. This involved setting up of temporary health facilities, providing adequate supplies to the existing hospitals, clinics and re-hydration centres, as well the establishment of clean drinking water sources. Immediate measures especially within the most affected, ill serviced areas included provision of water tanks serviced by tanker trucks that delivered chlorinated water (Nhlapo-Hlope, 2001; Sidley, 2001). This action discouraged the use of potentially contaminated traditional water sourcing points and greatly reduced the burden of those whose job it is to fetch water for their families' daily domestic needs. Subsequently though, people became dependent on the tanker water supplies and the withdrawing of the costly service to resort to other strategies met with resistance from the community and sparked much debate amongst planners and decision makers (McDonald, 2002).

Mass education and awareness campaigns made use of radio, television, posters and pamphlets in an attempt to demystify the scourge and help curb the spread (Mugero and Hoque, 2001; Reeves and Boshielo, 2001). High on the agenda of educational campaigns was to raise the level of awareness of the communities, particularly on how to protect themselves against cholera (Reeves and Boshielo, 2001). The main focus was to urge people to either boil or add bleach to water sourced from natural water sources like rivers, streams and dams (Mugero and Hoque, 2001; Sidley, 2001). There was also inter-sectarian collaboration between the Department of Health and



Map 3: Occurence of Cholera in KZN in 2002



Map 4: Occurence of Cholera in KZN in 2003

other government departments, professional bodies, non-governmental organisations (NGOs) and members of the community to contain the spread of cholera (Mugero and Huq, 2001). The World Health Organisation (WHO) was also requested for assistance in tackling the epidemic (Laskow, 2001; Mahmood, 2001). The organisation responded by assigning an epidemiologist to the cholera stricken province on an advisory capacity to the DOH. The WHO team reported that the successful case management of cholera casualties accounted for the “exceptionally low” death rate, estimated at 0.29% (Morris, 2001; Kriner 2001).

In 2002, the disease foci shifted to the west side of the province (Map 3). In this period, high numbers of cholera cases (650-900) were reported in the Uthukela district (DC23), especially the MDs of Klipriver, Weenen, Dundee and Escourt respectively (DOH-KZN, 2002). A sharp contrast from the other neighbouring communities that reported fewer cases of between 1-29. By the year 2003, cases of between 1-29 persisted in the Uthukela district (DC23) in the MDs of Mooiriver, Weenen and Escourt (Map 4). By this time though, cholera had by and large waned throughout KZN but not completely disappeared. A case in point is the cholera foci in the community of Madadeni, which is adjacent to Newcastle. The same foci is also visible in 2002 (Map 3). Madadeni is an informal township just outside Newcastle. In the 1996 Census, the population of Newcastle was approximately 44 000, while that of Madedeni was nearly 2.5 times more at approximately 110,000 individuals. This scenario implies that low standards of living go hand in hand with high infection rates.

On a different level, though a shortage of clean water and adequate sanitation have carried the banner of blame for the epidemic, HIV has also been implicated as one of the underlying causes of the persistence of cholera in KwaZulu-Natal, when one takes into account that the province has the highest HIV infection rate in the country (UN-IRIN, 2001). This was supported by the findings that those badly affected by cholera are mostly patients with chronic ailments, elderly individuals, and those with clinical evidence of a compromised immune system. (McDonald, 2002). HIV/AIDS data for the general population of KZN was not available to the study to conclusively demonstrate a link between HIV and the cholera epidemic. Thus, the assumption made during the study was that HIV was affecting the KZN communities evenly.

By March 2004, the Cholera Database continuing the official statistics of cholera cases in Kwa-Zulu-Natal, for the period August 2000 to February 2004, stood at 158,895 cases (KZN-DOH, 2004). The fatalities associated with these cholera statistics were 575 deaths, (a case fatality rate [CFR] of 0.36%) which to date is the lowest compared to previous South African epidemics. The exploration of the Cholera database whether independently or in association with other databases related to demography, socio-economic and climatic variables in KZN are explained at length in Chapter 5. The results in Chapter 5 are essentially outputs from the spreadsheet manipulation of the Attribute Database, presented in basic formats such as tables, charts and different types of graphs. The following chapter highlights the general trend of the 2000-2004 cholera epidemic in KZN, thus giving a holistic picture of the epidemic in relation to the demographic picture of KZN and within the administrative demarcations of KZN.

CHAPTER 5:
Data Interpretation

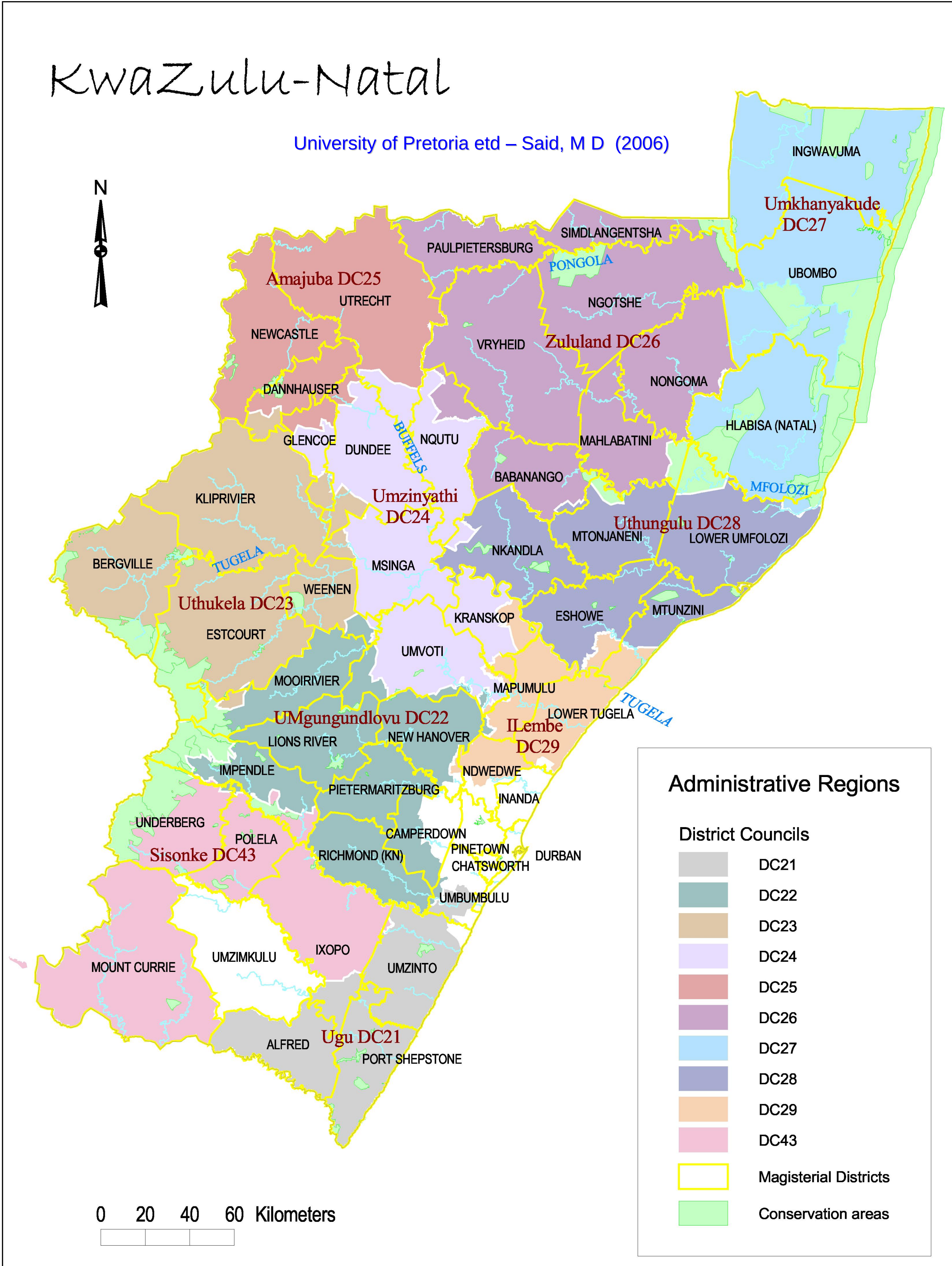
5.1 Introduction

The KZN cholera outbreak of 2000-2004 caused widespread suffering and in some cases it even led to death. The Cholera Database afforded a sound basis for the study to investigate the epidemic. The aim was to investigate the epidemic trend from a demographic, socio-economic and climatic perspective, using the methodology explained in Chapter 4. The intention behind the multitudes of analyses was to get an insight into the disease drivers of the 2000 - 2004 cholera epidemic. The preliminary assessment was done by means of spreadsheets (Microsoft Excel 2000) and thereafter followed by statistical and spatial manipulations of the database. The study yielded useful results that suggested which variables among the demographic, socio-economic and climatic parameters might have possibly contributed to the epidemic.

5.2 The general epidemic picture

5.2.1 Cholera within the demarcation of KwaZulu-Natal

KZN Province is made up of 10 District Councils (DCs) and the Metropolitan Council of eThekwini (Durban) (Map 28). Within the 10 DCs, are 52 Magisterial Districts (MDs), which together form the administrative demarcations of the province of KwaZulu, Natal. The preliminary results describe a holistic picture of the epidemic whereby the annual trend from 2000-2004 are presented as well as the cholera cases within the different DCs and MDs of KZN. In addition, the demographic profile of the cholera patients within the administrative borders (DCs and MDs) of KZN is illustrated and the possible relationship between the monthly cholera cases and the monthly climatic variables highlighted. The presentation of the results in this chapter is based on a total of 136 793 cholera cases, collectively reported from all the nine district councils. A categorization of the cholera cases in question is presented in Table 5.1. DC 28 (Uthungulu) reported more than half (52.2%) of the cases in KZN making it the focal point of the epidemic. This was further supported by a similar pattern at the MD level whereby 50% of the 10 most affected MDs belong to DC28, while three (MD26, MD27 & MD29) of the remaining five MDs are



Map 5: KwaZulu-Natal: District Councils, Magisterial Districts and Conservation Areas

neighbours to DC28 (Map 28). The percent cumulative incidence rate (%CIR) of DC28 was also the highest in relation to the other DCs (Fig 5.1). As it were, when cholera started in August 2000, all the reported cases in that month were exclusively confined to DC28 (Fig 5.1).

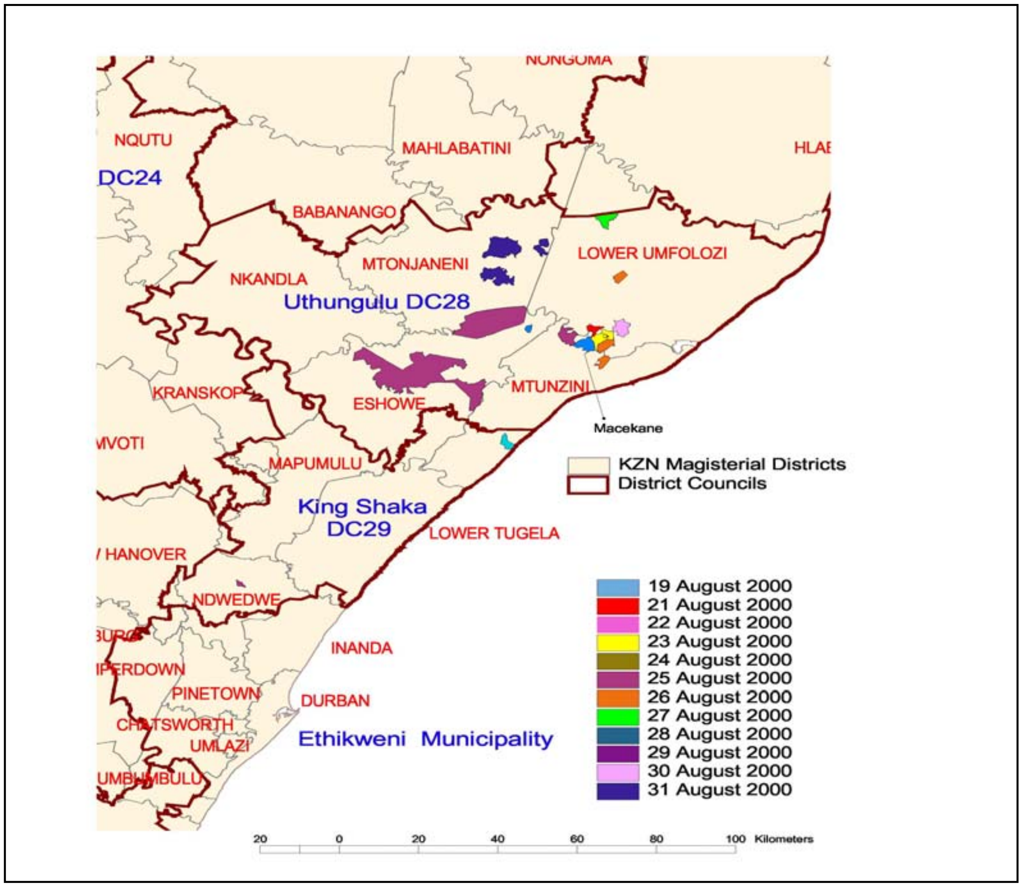


Figure 5.1: Initial cases as reported in KZN during the month of August 2000.

5.2.2 The annual trends of cholera in KwaZulu-Natal: 2000-2003

The first confirmed cholera case in KZN was reported on 14th August 2000 (Mugero and Hoque, 2001). Though the earliest cholera case report documented in the Cholera Database was on 19th August 2000. From then onwards, there was a progression of cholera case reports. All the cases that were reported and recorded in the Cholera Database between the 19th and 31st August 2000, were exclusively confined to DC28 and in particular the MDs of Lower Umfolozi, Mtunzini, Eshowe and Mtonjaneni (Figure 5.1). It is from this initial focal point illustrated in Figure 5.1 that that cholera started spreading to the other DCs, and eventually affecting the entire province of KZN.

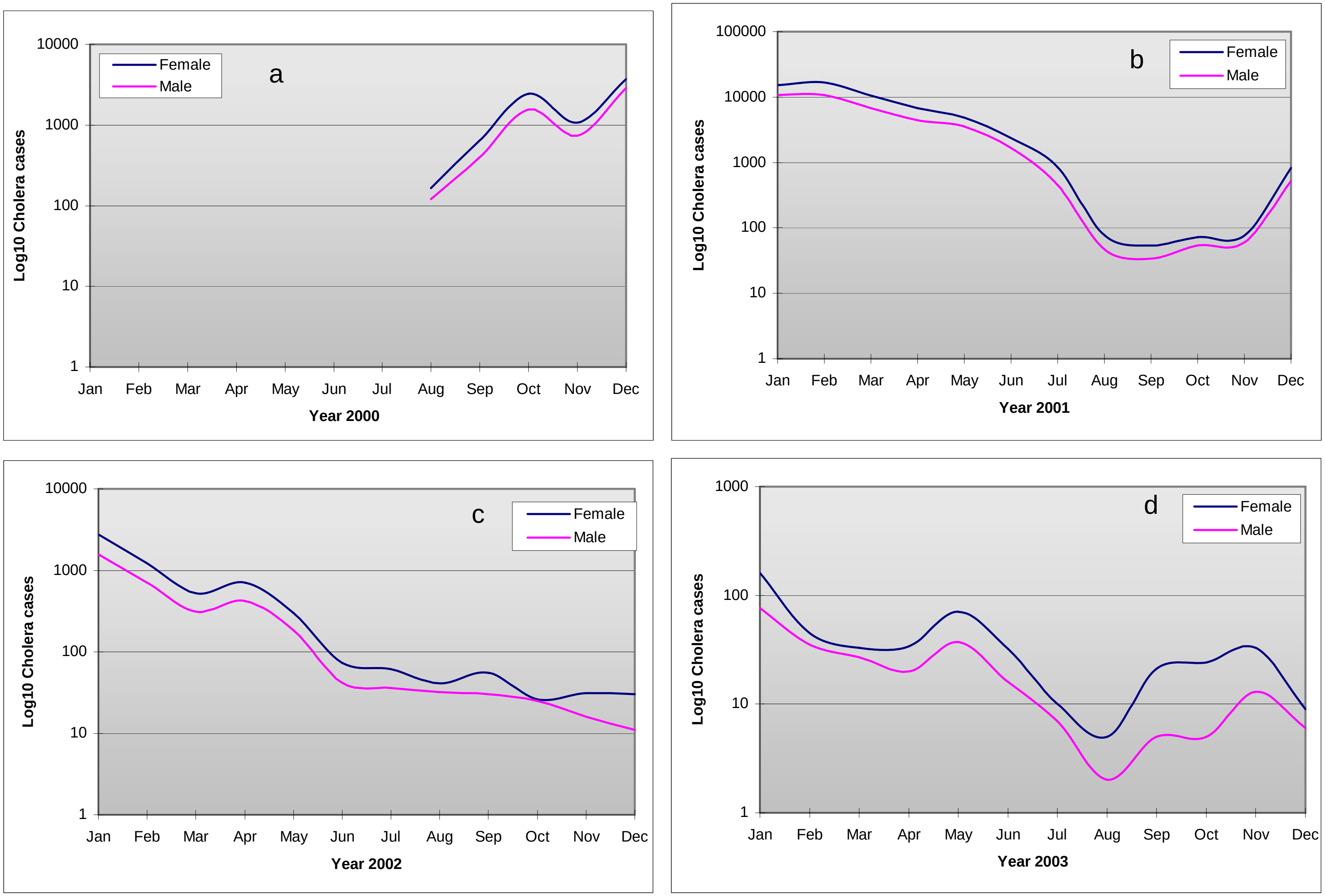


Figure 5.2 a-d: The annual cholera case trends in KZN.

From the onset of the epidemic in August 2000, there was a steady increase in cholera cases (Fig 5.2a). This was to be expected, as the majority of individuals in the KZN population had most probably not been previously exposed to the infection, considering cholera was last reported in significant numbers in the mid 1980s (DOH-Statistical Notes, 2000a). Thus as a consequence, the majority of individuals most probably had low levels of immunity if any, to the cholera pathogen. The rate of increase in cholera cases was at peak proportions from November 2000 to February 2001. This was the time the major epidemic peak was experienced (Figure 5.2b). At this point, cholera had spread beyond the original focal point of the disease in DC28 to affect every DC within KZN. Cholera cases started waning to low numbers in July 2001. Overall, the decline in case numbers reflected the effect of good case management through intervention measures (Mugero and Hoque, 2001). These included provision of treated clean water to the affected communities using water tanker-trucks; the establishment of rehydration centres within the affected communities to provide prompt medical assistance; addition of medical personnel to the province to help manage the epidemic and education and awareness campaigns through mainstream media (radio, TV), pamphlets and posters (Reeves and Boshielo, 2001). A similar upward trend in cholera cases was noted between December 2001 and February 2002 when the cholera epidemic experienced a minor peak, again waning to a minimum in July 2002. The case numbers during the previous major peak of the year 2001 were 6 times those of the minor peak, probably as a result of the positive outcome and experience of the intervention measures already described, during the major peak (Figure 5.2c). The cholera cases reported in the year 2003 were 10 times lower than those reported in 2001 (Figure 5.2d). These relatively fewer incidents may have been as a result of applying the lessons leant from the intervention measures since the beginning of this outbreak to prevent cholera transmission in vulnerable communities. Albeit, by the year 2003, most of the cases were random reports from areas were cholera still persisted, which may also have been indicative of an endemic situation setting in, rather than an epidemic situation. As aptly defined by Kamal (1963), "Endemicity of cholera is a phenomenon involving the continuous circulation of the pathogenic vibrio to and fro between patients, carriers and vehicles of infection, particularly water". Therefore, within the larger context of the epidemic period in KZN, there were inter-epidemic periods whereby case numbers would wane in between the two epidemic peaks.

From a climatic perspective, the regularity of the monthly trends in the two consecutive years of 2001 and 2002 is suggestive of a seasonal link to the incidence of cholera, whereby the peak incidences occurred after the onset of the main summer rains in KZN (Refer: Figure 4.3). During the epidemic period that encompassed the two cholera peaks, there was a decrease in cholera cases during the winter months between June and August, only to pick up again as the temperatures increased (Refer: Figure 5.3). Isaäcson (1986) and Küstner and Du Plessis (1991), observed a similar trend in previous cholera epidemics in South Africa whereby cholera was linked with the summer rain months and a lull in cholera case reports was observed during the winter months.

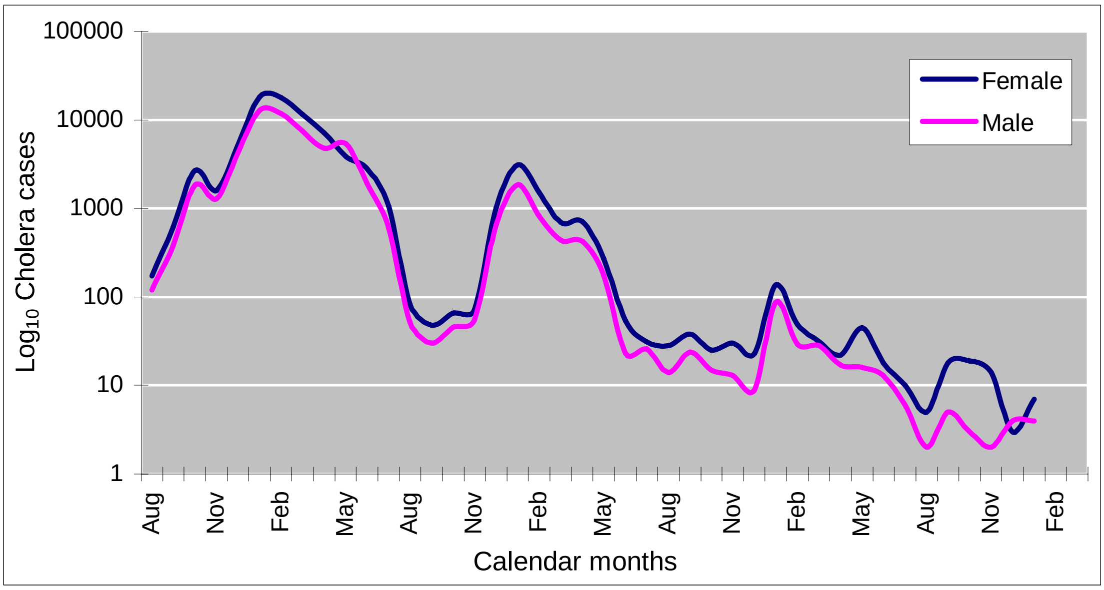


Figure 5.3: Annual epidemic trends of cholera in KZN from Aug 2000 to Feb 2004.

The general epidemic trend also displayed another distinct feature worthy of note. Throughout the epidemic period, both the two cholera peaks occurred at a time of increased mobility within the province because of end of year holidays and festivities. This is the time when individuals especially men, who are migrant workers return to their rural homes for their holidays (Koornhof and Keddy, 1998; Bateman, 2002). Looking at the trend, month wise, the timing of the occurrence of the annual cholera peaks are consistent throughout the epidemic period, irrespective of the actual number of cholera cases in a particular year. This is illustrated in Figure 5.3, whereby the peak cholera incidence for each of the peaks occurred during the month of January of the year in question. This adds credence that the transmission of cholera is favoured by holiday periods, which mostly involve community gatherings, festivities and movement of individuals from place to place. This possible link between increased mobility during holiday periods and the incidence of cholera in the precious cholera epidemics in South Africa was also likewise noted (Küstner *et al.*, 1981; Isaäcson, 1986; Sitas, 1986 and Küstner and Du Plessis, 1991). Figure 5.3 also reveals a slight increase in cholera cases in the months of April and May 2000 just after the two peaks; this incidentally also coincides with another holiday period of Easter. Unlike the previous scenario of the major peak, this rise shows the males dominating the disease picture, which may mean that there were more susceptible males than females in the population at the time. The increase in male cases may have been as a result of a new group of susceptible migrant workers returning to their rural homes (for holidays) in the cholera-affected province.

5.2.3 Cholera and climate

The monthly patterns of the climatic variables of rainfall, humidity and maximum temperature versus the spread of cholera throughout the epidemic period are highlighted in Figures 5.4 - 5.6. The average rainfall revealed an interesting trend whereby, both the major and the minor cholera peaks were experienced just after the high rainfall months. The consequence of this coincidence is reflected in the heavy rains and flooding at the time, which increased the risk of contamination to surface waters. KZN experienced heavy rains and flooding in 2000 just before and after the cholera outbreak in August 2000 (Kriner, 2001; Bateman, 2002). A similar occurrence was reported from Djibouti, whereby outbreaks occurred immediately after heavy rainfalls, which resulted in flooding and contamination of surface waters (Morillon *et al.*, 1998). The heavy rains between the Christmas and New Year of 2000/01 were also linked to increasing cholera case admission in some parts of KwaZulu-Natal (Wessels, 2001). This risk of the heavy rains was made worse because of the precarious sanitation situation that lead to human waste mixing with flood waters and consequently contaminating rivers and drinking wells, which could have been possible reservoirs for the cholera organisms (Kriner, 2001).

The monthly and seasonal variations of both the humidity and maximum temperature were not obvious as was the case with the average rainfall patterns throughout the

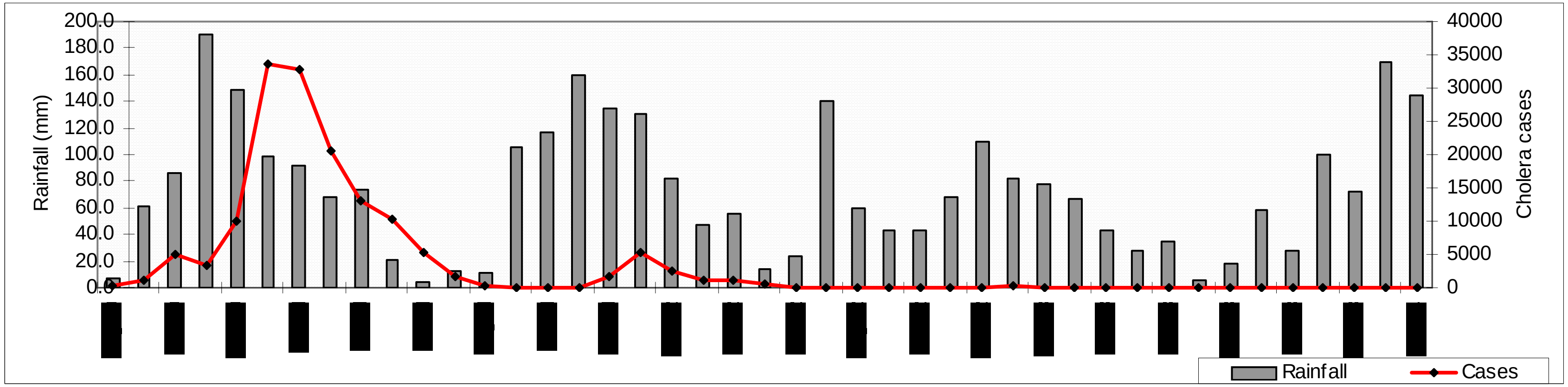


Figure 5.4: Variations in monthly rainfall (mm) patterns and the number of monthly cholera cases during the epidemic.

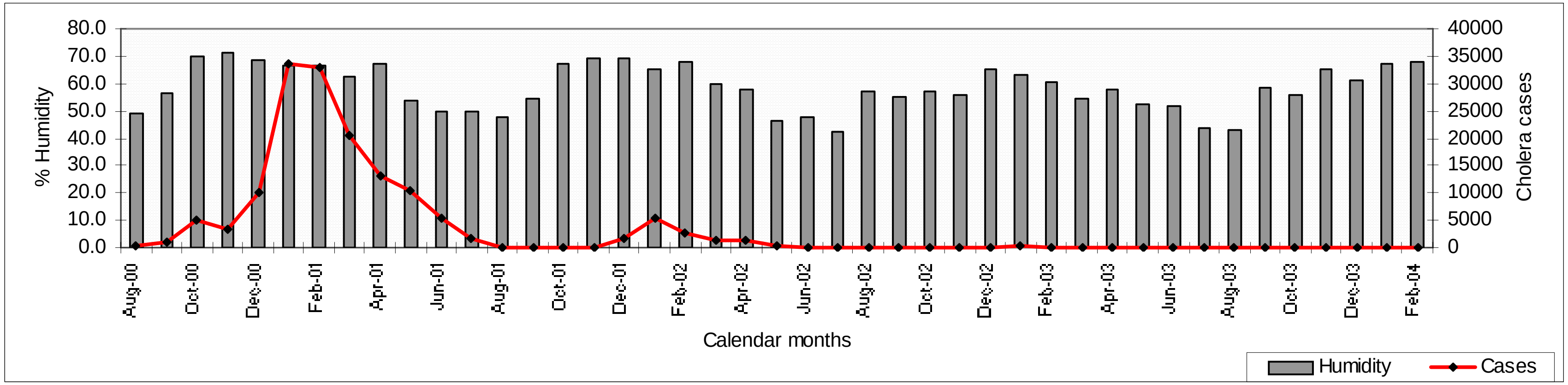


Figure 5.5: Variations in monthly humidity (%) and the number of monthly cholera cases during the epidemic.

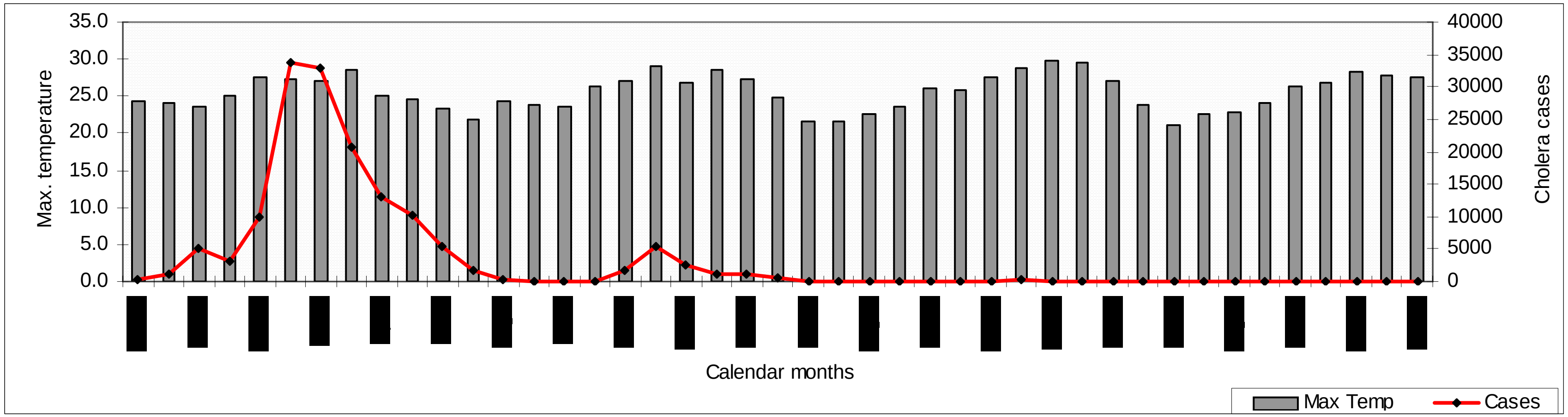


Figure 5.6: Variations in monthly max temperatures (^{0}C) and the number of monthly cholera cases during the epidemic.

epidemic period. Both humidity and maximum temperature were by and large range bound, with slight decreases in the winter months of June and July. Unlike rainfall, the measurements of the two factors, i.e. humidity and maximum temperature were not out of the ordinary to warrant any speculations from the public that they may have contributed to the spread of cholera. Humidity and high temperatures have been previously linked to high incidences of cholera in Lima and Delhi (Salazar-Lindo *et al.,* 1997; Speelmon *et al.,* 2000; Singh *et al.,* 1998). Such a relationship though was not apparent in Figs 5.5 and 5.6. Further elaboration on the possible spatial relationship between humidity and maximum temperature and cholera is presented in the following Chapter 6.

5.2.4 Cholera and gender

The demographic trend of both the major and minor peaks consistently demonstrated male cholera cases being outnumbered by those of females (Fig 5.3). On average the male to female case ratio was 1:1.5 across all the DCs (Table 5.1). The high female case numbers is most probably a consequence of the labour migration practices of male adults in the affected communities leaving females to constitute a larger proportion of the population (Mugero and Hoque, 2001). As such, the exposure rate of females to the risk of cholera risk within the affected communities will inevitably also be high resulting in more female sufferers. The high numbers of female cholera patients may also be a reflection of them being more forthcoming in seeking medical assistance if they suspected they had the infection. Thus more females being represented in the cholera case count of the Cholera Database of KZN. Previous cholera outbreaks showed a similar bias in the infection rate towards the females (Kustner *et al.,* 1981; Sitas, 1986; Kustner and Du Plessis, 1991). The proportion of the total deaths was also highest in DC28 most probably because of the high number of cholera cases that gripped the district from the beginning. The overall CFR (case fatality rate) from the count represented in Table 5.1 was 0.33%. The CFR was thus well within the WHO expectations. According to the WHO cholera prevention and control guidelines, given good preparedness and implementation of control strategies, the CFR should be below 1% (WHO, 1993a).

5.2.5 Cholera and age

All the age groups were represented in the cholera dataset i.e. from infants of less than one year to the elderly of above 100 years. The dominant age groups are equally presented in all the DCs though they were more distinct in DC28 (Figure 5.7). This is

Table 5.1: Cholera case count per KZN District Councils.

DISTRICT NAME	FEMALE	MALE	TOTAL CASES (%)	FATALITIES (%)
DC28 - Uthungulu	42,925	28,677	71,602 (52.34)	116 (25.11)
DC26 - Zululand	8,666	5,475	14,141 (10.34)	23 (4.98)
DC29 - iLembe	7,692	5,665	13,357 (9.76)	83 (17.97)
DC23 - Uthukela	6,360	3,950	10,310 (7.54)	49 (10.61)
DC27 - Umkhanyakude	4,499	3,420	7,919 (5.79)	35 (7.58)
DC21 - Ugu	4,427	3,068	7,495 (5.48)	18 (3.90)
DC24 - Umzinyathi	3,724	2,554	6,278 (4.59)	49 (10.61)
Durban - eThekwini Metropolitan	1,653	1,298	2,951 (2.16)	51 (11.04)
DC22 - Umgungundlovu	918	609	1,527 (1.12)	17 (3.68)
DC25 - Amajuba	549	300	849 (0.62)	20 (4.33)
DC43 - Sisonke	220	144	364 (0.27)	1 (0.22)
Grand Total	**81633**	**55160**	**136793**	**462**

to be expected because the cholera case numbers were the highest in DC28 when compared to other DCs, and so easier to notice the age groups that were most affected by cholera. The age groups 15-19 years and 0-4 years featured more prominently in the overall epidemic picture followed by the 10-14, 20-24, and 5-9 year age groups respectively (Figure 5.7). Figures 5.8-5.16 give a more elaborate picture of the various age groups affected by cholera in all the DCs of KZN. This age pattern distribution whereby the younger age groups are more represented in the disease picture is said to be typical of an endemic scenario, whereby adults have a substantial immunity from previous infections (Mugero and Hoque, 2001).

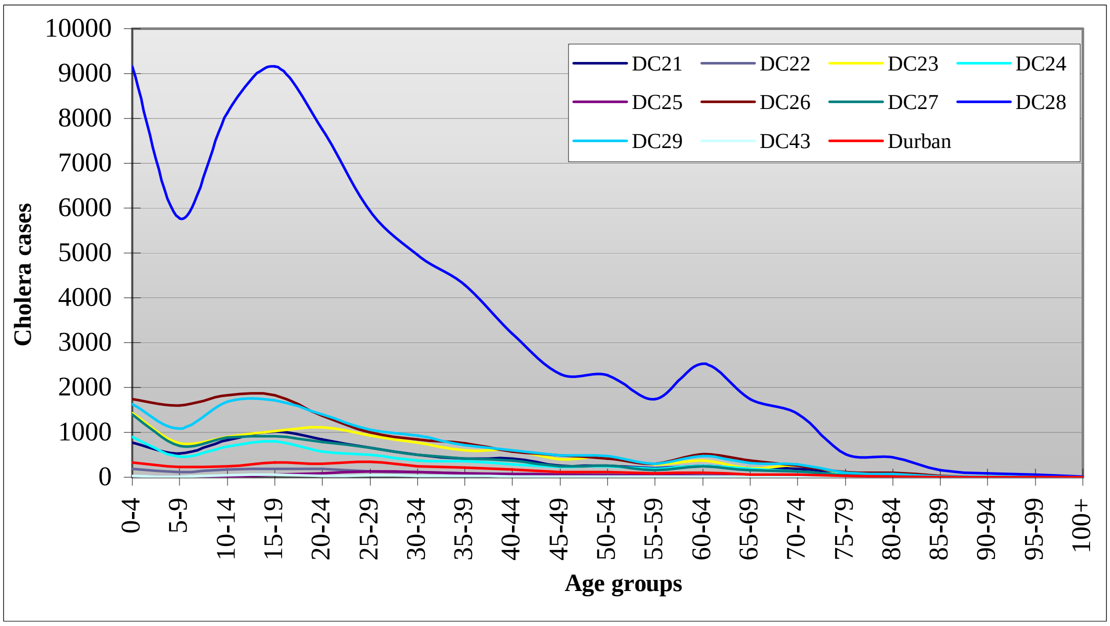
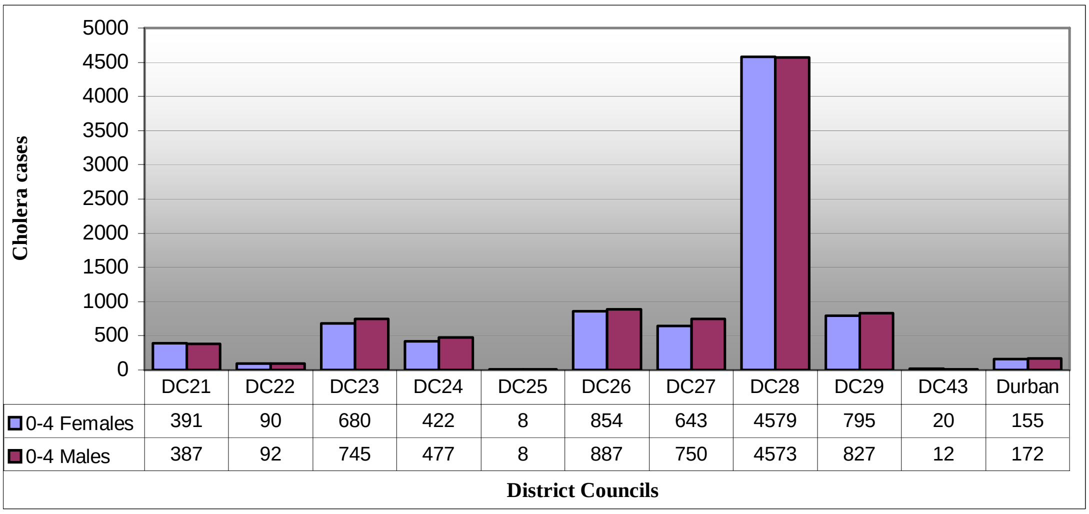


Figure 5.7: The age-group distribution of cholera cases within the DCs of KZN.

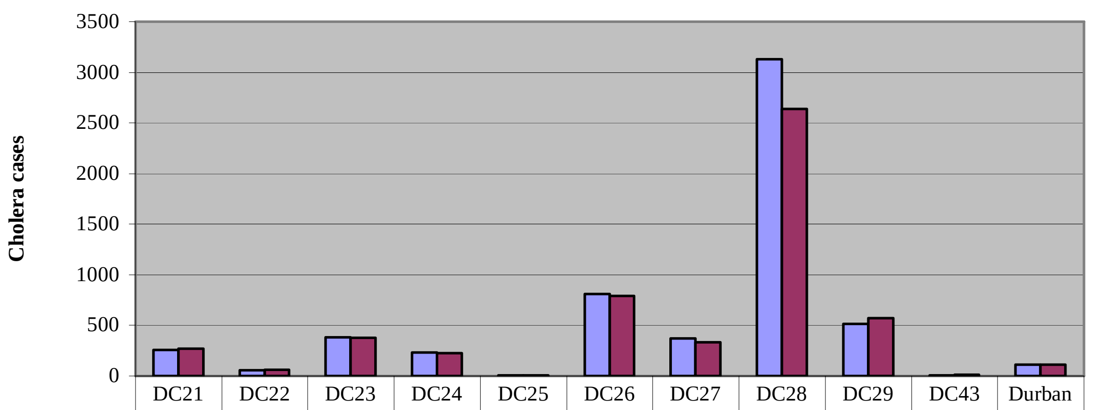


	DC21	DC22	DC23	DC24	DC25	DC26	DC27	DC28	DC29	DC43	Durban
0-4 Females	391	90	680	422	8	854	643	4579	795	20	155
0-4 Males	387	92	745	477	8	887	750	4573	827	12	172

Figure 5.8: Cholera in the 0-4 years age group: August 2000- Mar 2004.

The 0-4 years age group was the second most affected by the epidemic with a total of 17 567 cholera cases recorded during the epidemic period (Figure 5.8). Accounting for the high infection rate of this group during the cholera epidemic is most probably their under developed immune system not being unable to offer adequate protection against the infection. This is typical of any infectious diseases within the paediatric age. The difference in case numbers between the genders was very small. Indicating both genders were exposed equally vulnerable to the predisposing factors to the disease (Figure 5.8).

There was a slight decrease in case numbers in the 5-9 ages group when compared to the previous age group (Figure 5.9). The immune system of the 5-9 ages group is more advanced than that of the 0-4 age group, having already been exposed to various infections since birth. The 5-9 year olds were thus in a better position to ward off infections, in this case, cholera. This age group also showed small differences in cholera case numbers between the genders. In addition to the immune status, it is possible that there were more cases in the age groups below 10 years because the individuals of these age groups were also more represented in the overall populations; thus contributing significantly to the base of the population pyramid of KZN (refer to Chapter 4: Figures 4.2 and 4.3).

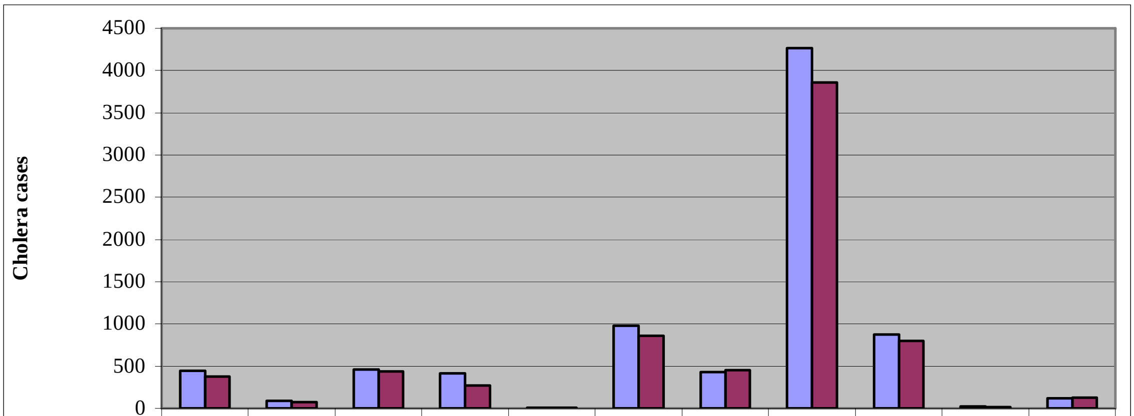


	DC21	DC22	DC23	DC24	DC25	DC26	DC27	DC28	DC29	DC43	Durban
5-9 Females	255	59	384	232	4	813	372	3128	516	9	113
5-9 Males	271	61	380	228	7	789	333	2637	573	12	111

District Councils

Figure 5.9: Cholera in the 5-9 year age group: August 2000 - March 2004.

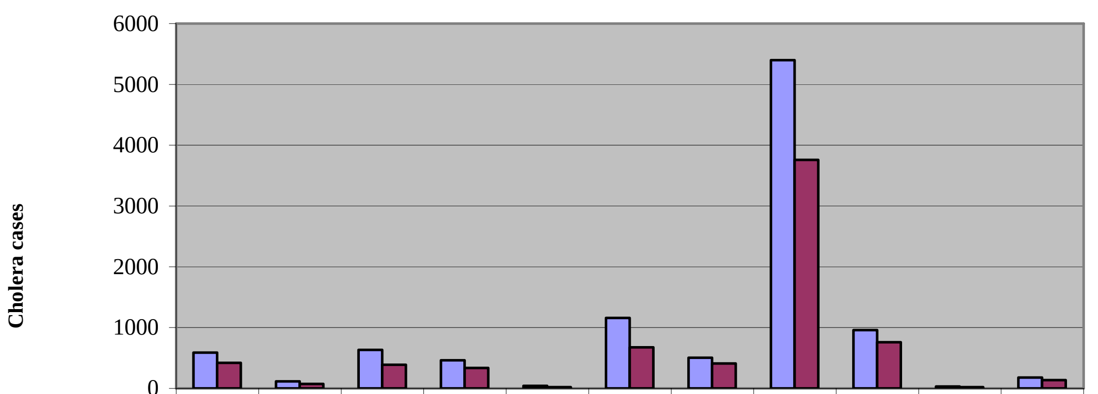
Cholera cases were high in the 10-14 year age group compared to the previous 5-9 year age group making it the third most affected age group (Figure 5.10). The cholera case numbers in this age group were consistently more in all the DCs when compared to the previous 5-9 year age group. For some reason, this pre-adolescent age group was more susceptible to cholera possibly because of other issues like age related behaviours that exposed them to situations or activities which were likely to bring them into contact with disease causing organisms like *Vibrio cholerae*. One possibility is that this age group, especially the girls are closely associated with issues associated with water provision in the house e.g. fetching water from rivers, streams and public taps. Thus if the disease causing organisms exist in any of the aforementioned environments, their risk to waterborne infections like cholera is increased.



	DC21	DC22	DC23	DC24	DC25	DC26	DC27	DC28	DC29	DC43	Durban
10-14 Females	447	89	462	417	9	978	426	4264	878	26	118
10-14 Males	378	79	436	269	10	857	454	3859	801	13	130

District Councils

Figure 5.10: Cholera in the 10-14 year age group: August 2000 - March 2004.

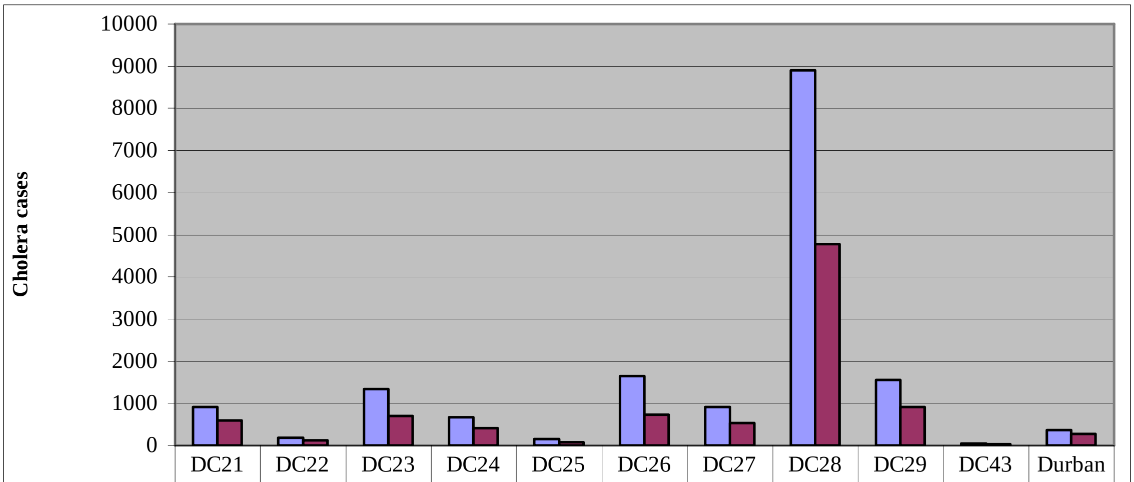


	DC21	DC22	DC23	DC24	DC25	DC26	DC27	DC28	DC29	DC43	Durban
15-19 Females	593	111	635	468	37	1156	506	5395	959	31	182
15-19 Males	420	75	390	336	18	676	412	3761	753	19	140

District Councils

Figure 5.11: Cholera in the 15-19 year age group: August 2000 - March 2004.

The group that recorded the highest number of cases was the 15-19 year age group (Figure 5.11). This age group contributes to the reproductive group of an expansive population like the one in KZN (PRB, 2005). The fact that this group was the most affected implies that the individuals had a higher risk of exposure to the factors associated with cholera transmission. The 15-19 year old individuals are semi independent in that they most probably still live with their parents though associate with their peers more freely than the younger age groups. Thus, the possibility of getting infected by their peers during various academic and social activities; is high. The females of this age group are also closely associated with the domestic affairs within a home such as the management and transport of water; as well as cooking, washing, cleaning and providing drinking water for the family (Throop, M. 2004). Therefore, those that belong to households that need to source their domestic water supply from external sources, in the event that the water resource is contaminated, females would be at a greater risk of getting exposed to the infection, than males. The difference in the cholera case numbers between the genders as seen in Figure 5.10 adds credence to this supposition, as there were more females affected than their male counterparts.



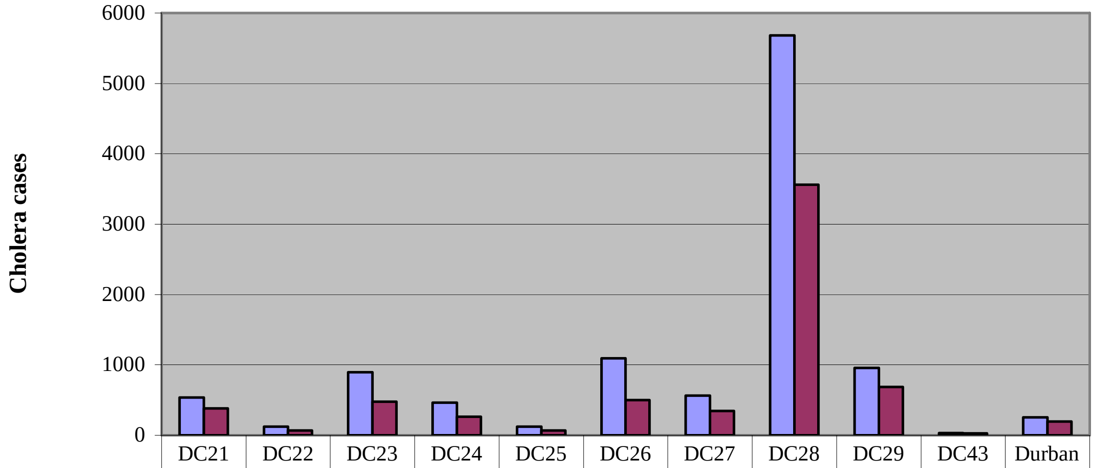
	DC21	DC22	DC23	DC24	DC25	DC26	DC27	DC28	DC29	DC43	Durban
20-29 Females	916	184	1335	665	149	1640	910	8911	1547	48	364
20-29 Males	591	121	707	411	72	736	528	4777	911	30	274

District Councils

Figure 5.12: Cholera in the 20-29 year age group: August 2000 - March 2004.

The 20-29 age groups make up the majority of the individuals in the reproductive base of the population (refer to Chapter 4: Figures 4.2 and 4.3). There is a marked difference in the cholera case numbers between the genders in this age group (Figure 5.12). This may be indicative of the migratory nature of the males in this group. It is a common assumption that most males of this age group would venture out to seek employment in areas that are far away from their parental or family homes especially in a province like KZN where the unemployment rate is high (Kustner *et al*, 1981, Mugero and Hoque, 2001). As such, the age group would mostly have a greater representation of females in all of the DCs of KZN. The same would thus also be true regarding the infection rate being more biased towards females than males (Figure 5.9). Incidentally, the females of this age group also feature prominently in the HIV/AIDS profile of KZN. A South African national survey of HIV sero-prevalence (serum samples tested for HIV antibodies) in women attending antenatal clinics in 2000, found the 25-29 year group to be the group with the highest sero-prevalence of 30.6%. Whereas those aged 20-24 yielded a sero-prevalence of 29.1% (DOH, 2001). A similar study in 2002 found a comparable trend with women aged between 25 and 29 years with an estimated 34.5% of pregnant women in this age group being HIV positive while those aged 20-24 years had a steady 29% positive test (DOH, 2003-a).

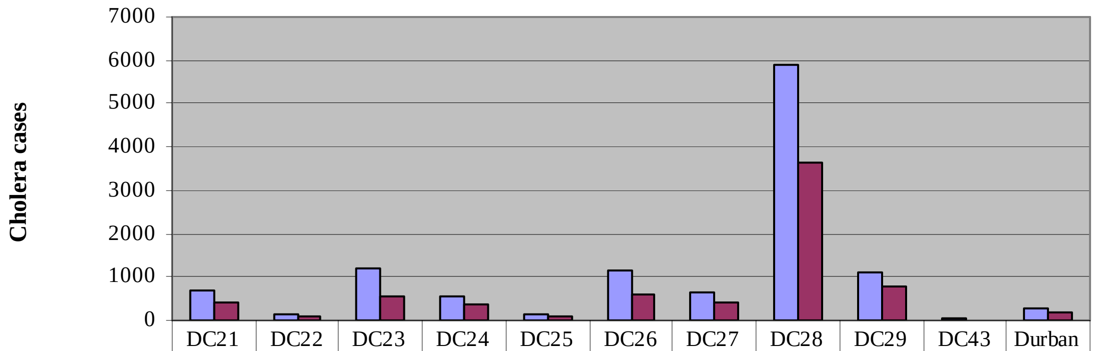
The 30-39 and 40-59 year age groups also showed a similar pattern of cholera incidence and distribution among the genders (Figures 5.13 and 5.14). The differences though, are slightly less than those seen for the 20-29 year age group. The 30-39 year age group is characterised with individuals who are in transition from the reproductive age group to a group with an established family. The 40-49 year age group would be in a similar family set up as that of the 30-39 year age group except that most would have children who are old enough to help with the day to day domestic chores of the household like fetching water, preparation of meals and taking care of the general cleanliness around the house. Thus the association of the 40-49 year age group is such that it is slightly detached from their children as most of the children would be independent or at least semi independent as young adults. That means that even the risk of cross infection between the heads of the family and the children would be to a degree minimised.



	DC21	DC22	DC23	DC24	DC25	DC26	DC27	DC28	DC29	DC43	Durban
30-39 Females	535	125	898	464	121	1093	564	5681	958	30	256
30-39 Males	383	68	477	263	68	501	347	3560	686	27	197

District Councils

Figure 5.13: Cholera in the 30-39 year age group: August 2000 - March 2004.

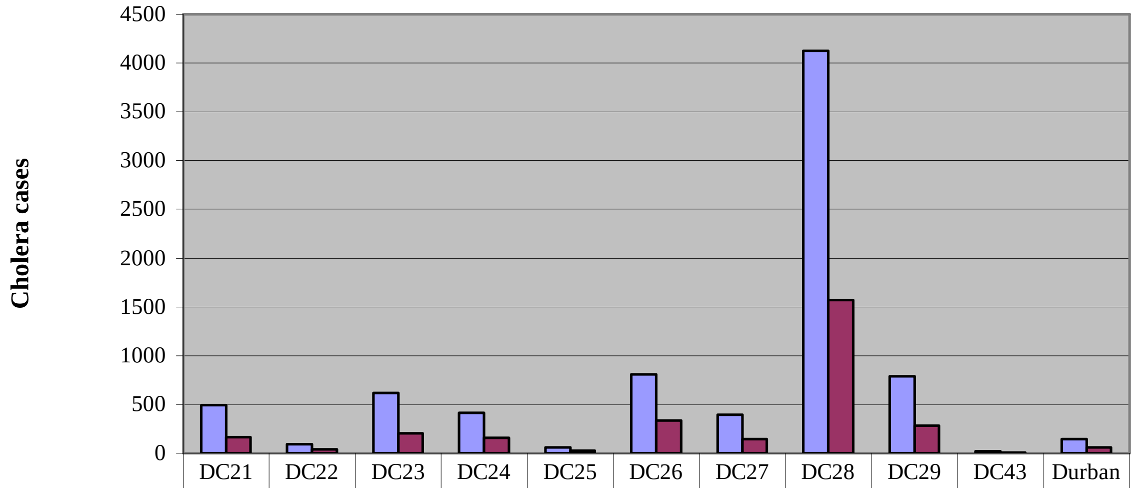


	DC21	DC22	DC23	DC24	DC25	DC26	DC27	DC28	DC29	DC43	Durban
40-59 Females	707	147	1185	558	135	1147	633	5900	1104	33	280
40-49 Males	417	71	554	376	80	620	410	3625	769	22	205

District Councils

Figure 5.14: Cholera in the middle age 40-59 year group: Aug 2000 - March 2004.

Cholera among the 60-74 year olds was quite marked especially in DC28 (Figure 5.15). On examining of the overall age group trends, the cholera cases among the 60-69 year age group were higher when compared to the other older age groups (Figure 5.7). The 60-69 year age group includes individuals who are approaching or are already at the retirement age. At this age, physiological changes including an aging immune system impacts on their susceptibility to infectious diseases, like cholera. Females suffered the brunt of the epidemic (Figure 5.15). In this era of HIV/AIDS, it



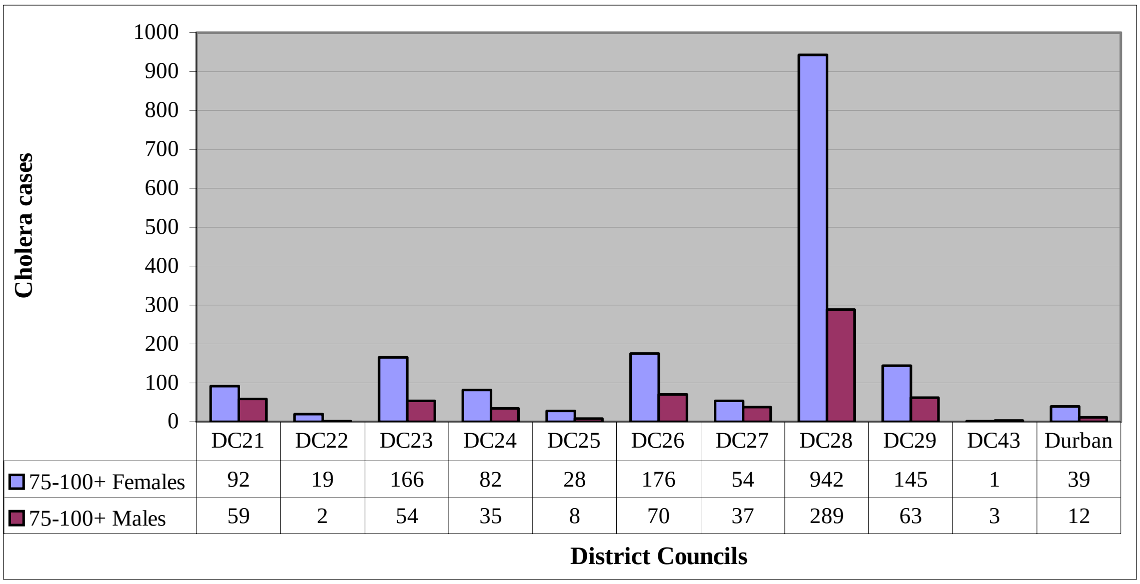
	DC21	DC22	DC23	DC24	DC25	DC26	DC27	DC28	DC29	DC43	Durban
60-74 Females	491	94	616	416	58	809	391	4125	790	22	146
60-74 Males	162	40	204	158	29	336	147	1573	282	6	56

District Councils

Figure 5.15: Cholera in the 60-74 year age group: August 2000 - March 2004.

is common to find grandmothers within 60-69 years age group tending to their grandchildren who have been orphaned as their parents succumbed to the AIDS pandemic. As such, it is quite probable that females between the ages of 60-69 are still associated with domestic chores and raising young children. Such a probable scenario would most probably expose female grandparents rather than the male ones to infectious diseases that children contract. Therefore, in the case of cholera, if there were a child under the care of a grandparent, it would be easy for a female individual in the 60-69 year age group to get infected. More so, as one considers that the immune system of the elderly has weakened in a way comparable to the underdeveloped immune state of the young.

Thus the increase in the risk for cholera among the very young and the very old is proportionally comparable. The situation is not the same with the elderly males, in that they do not share the same burden as their female counterparts. The short life expectancy of the elderly males also implies that their overall numbers in the population is less when compared to the females in the same age group (Chapter 4: Figures 4.2 and 4.3).



	DC21	DC22	DC23	DC24	DC25	DC26	DC27	DC28	DC29	DC43	Durban
75-100+ Females	92	19	166	82	28	176	54	942	145	1	39
75-100+ Males	59	2	54	35	8	70	37	289	63	3	12

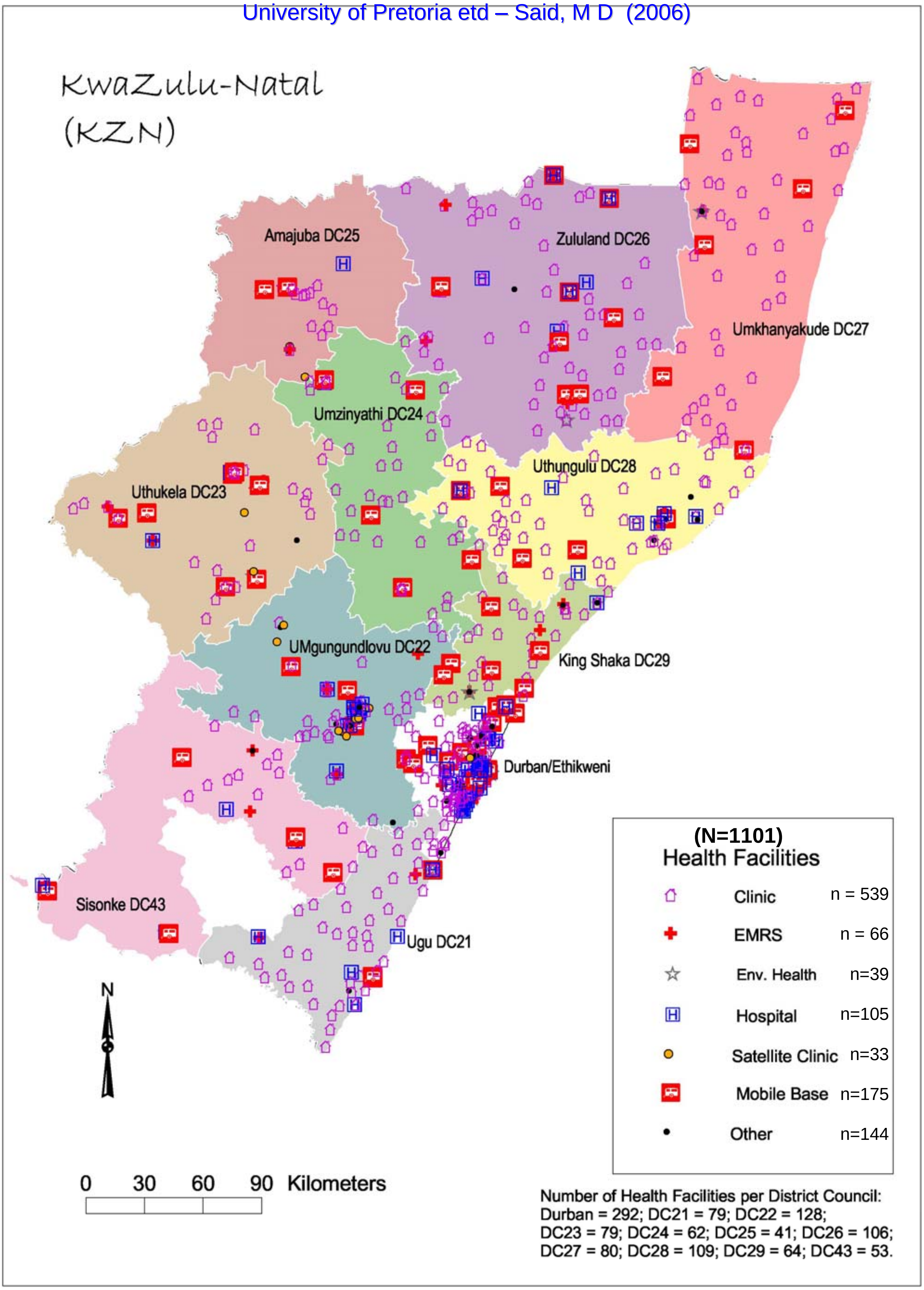
Figure 5.16: Cholera in the 75 and > 100 year age group: August 2000 - March 2004.

Cholera incidents were the lowest in the 70 to over 100-year age group. Nevertheless, more females than males were affected in this age group as well (Figure 5.16). There were very few individuals over 70 years in the population of KZN and likewise few cholera cases (Chapter 4: Figures 4.2 and 4.3). On the other hand, it could also be argued that the cholera cases reported is an underestimation of this group as most of them may have been too frail to access medical services when they contracted cholera. Hence only those who had assistance to get to a medical facility were included in the Cholera database, while many more could have been possibly left out.

5.2.6 Cholera among the DCs of KwaZulu-Natal

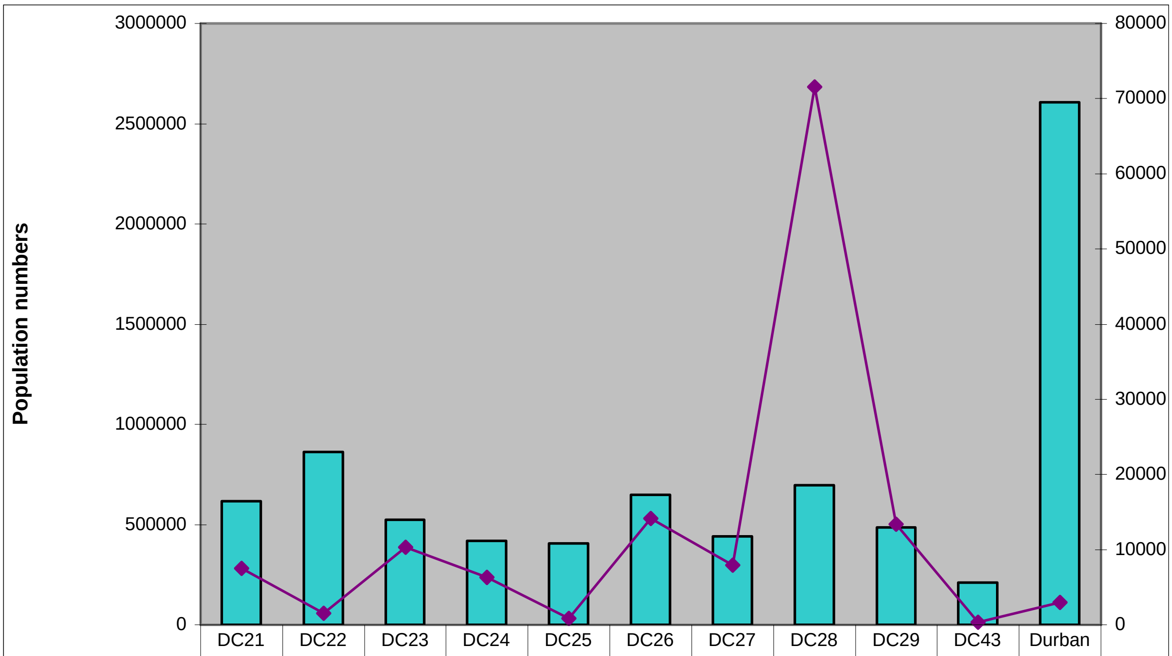
The proportion of cholera cases in the individual DC populations is given in Figure 5.17. Durban, being the provincial capital has the highest population, though it reported only 2 951 (2.16%) of the total cholera cases. This was attributed to the high level of service delivery in the sectors of health, water supply, sanitation and refuse collection. DC28 had the third highest population in KZN but the highest number of cholera incidents.

The %CIR standardised the actual infection rate in that it expressed the number of individuals that got infected per every 100 within a particular population (Figure 5.18).



Map 28: Distribution of Health Facilities in KZN

The percentage of cholera related deaths in this case refers to the percentage of individuals who died from the cholera incidents reported for a particular DC (Figure 5.18). DC25 had the highest percentage of deaths from cholera followed by Durban. It was argued that DC25 experienced such a high proportion of deaths because the numbers of health facilities (hospitals, clinics etc.) were fewer compared to the other DC's, thus a disadvantage in terms of health service delivery (Map 28). Death may have been as a result of various factors including patients seeking medical attention too late, the medical facilities not being easily accessible or the individuals not affording the transport and/or medical costs. Map 28 adds credence to this as it shows the health facilities being mostly situated at the centre of the district boundaries; implying that



	DC21	DC22	DC23	DC24	DC25	DC26	DC27	DC28	DC29	DC43	Durban
Population	618047	863095	523976	419238	406173	648555	441172	697269	486736	210297	2605482
Total # cholera	7495	1527	10310	6278	849	14141	7919	71602	13357	364	2951

Figure 5.17: Cholera case distribution among the DCs in KZN: August 2000 - December 2004.

those who live in areas near the periphery of the district boundaries; may have to travel long distances to access a public health facility. On the other hand, the Durban Metropolis had the highest number of health facilities nonetheless it had the second highest proportion of cholera associated deaths at 1.73 % (51 cases). This high proportion of cholera-associated deaths in the Durban Metropolis may not be a true reflection of the actual situation in Durban *per se*. The following scenario is probable in explaining the high proportion of deaths in Durban. The Durban Metropolis, being the provincial capital has the highest number of health facilities in KZN. Among which are those that operate as referral hospitals for the province. It is thus to be expected that serious cases related to cholera were referred to some of these referral health facilities, where some of the fatalities subsequently occurred, especially if the patient initially sought medical attention in a facility that was scarcely equipped to assist in the matter. In the event that a death had occurred, it would have been registered as having taken place in the referral hospital, thus the apparent high number of deaths associated with cholera in the Durban Metropolis.

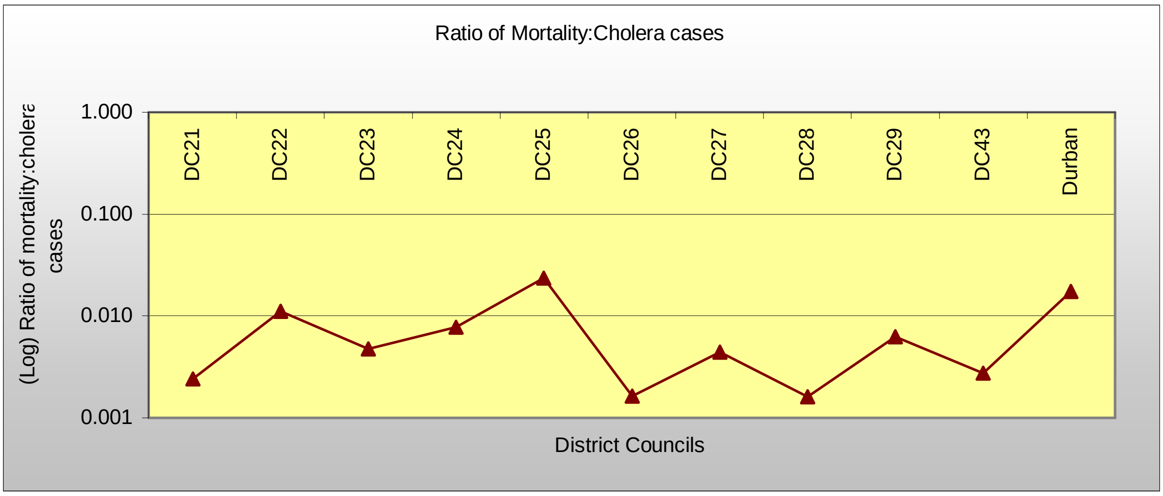


Figure 5.18: The ratio of mortality rate to total cholera cases among the DCs of KZN during the 2000 - 2004 epidemic.

Although DC28 reported most of the cholera incidents, it had the least proportion of cholera - associated fatalities at 0.16 % (116 cases), as was the case with DC26 at 0.16% (23 cases), when compared to the other DCs (Figure 5.18; Table 5.1). DC28 had a relatively even distribution of health facilities across the district (Map 28). This even distribution of health facilities may have positively contributed to keeping the percentage of fatal cases to a minimum. In addition, the fact that DC28 was the first to experience the cholera outbreak, the earlier health intervention measures complemented the health facilities in managing the epidemic. One of the immediate short-term interventions was to augmenting the health facilities with additional medical personnel to support in disease management and case surveillance. Parallel to this was the establishment of rehydration centres, extensive use of mainstream media for awareness campaigns, distribution of bleach to purify water and the service of water tankers to supply water to rural communities. These intervention measures collectively made DC28 better prepared to handle the casualties of the epidemic as cholera continued to spread to the other DCs of KZN.

The most affected MDs as well as the DCs each belongs to, as shown in Figure 5.19, whereby DC28 is highlighted as being the most affected. Among the 10 most affected MDs, half of them belong to DC28. A feature previously noted in other studies is that cholera reveals a strong association with the sea and those that depend on the sea for their livelihoods, e.g. fishermen (Colwell, 1986; Goodgame and Greenough III, 1975; Borroto and Martines_Piedra, 2000; Lipp *et al.*, 2002). As it were, eight of the most affected 10 MDs have a coastal border with the Indian Ocean. In the case of KZN though, no scientific documentation was found that linked seafood or fishermen of the rural coastal communities of KZN being an possible link to the introduction of cholera in those areas as compared to other coastal or lake communities in East Africa, West Africa, the Indian subcontinent, and South America, (Goodgame and Greenough, 1975; Glass *et al*., 1991; Wilson; 1995a; Colwell; 1996; Birmingham *et al*., 1997; Shapiro *et al*., 1999 and Acosta *et al*., 2001).

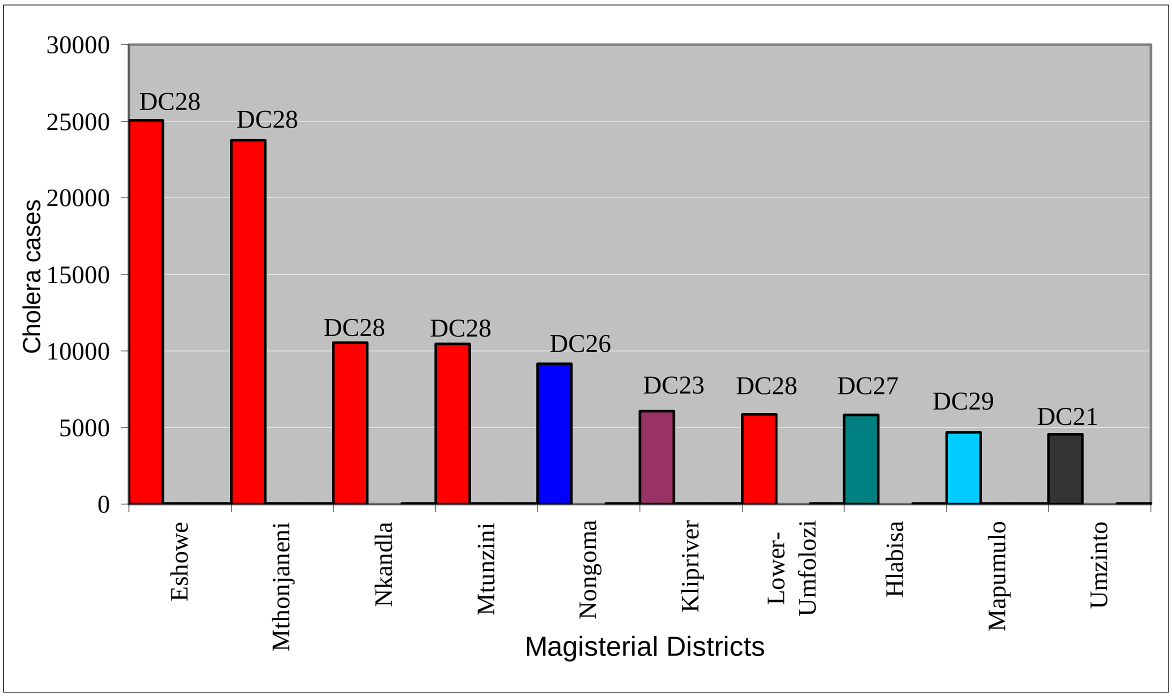


Figure 5.19: Magisterial Districts that reported the highest cholera cases during the epidemic period between August 2000 and February 2004.

This chapter sums up the database results within the administrative confines of KZN. In general cholera affected mostly the very young, young adults and the aged individuals of the communities affected. This age distribution pattern reflects an endemic scenario whereby it implies that majority of the adults may have had immunity from previous infections. That is to say, for the KZN population, the pool of susceptible individuals was mostly from the younger age groups and the older age groups for obvious reasons of being physiologically more susceptible to diseases. This possibility is supported by Codeço (2001); who through cholera modelling studies noted that endemism, especially in poor communities requires just transient reservoirs and sufficiently high number of susceptibles.

The centre of the epidemic was Uthungulu District (DC 28) where the initial outbreak of cholera was recorded. Judging from the total number cholera cases reported (71 602); the intervention measures introduced in the district must have matched the intensity of the outbreak. This also implies that as cholera spread to the other DCs, the interventions measures were well established in DC28. According to the KZN Cholera Database used in this study, the overall CFR for the epidemic was 0.34%. The most affected DC 28 had a CFR of 0.16%, indicating that the intervention measures put in place were effective in the overall management of the epidemic. The major peak of the cholera epidemic occurred in January 2001, and thereafter, there was an exponential decrease in case numbers (Figure 5.3). This reflects the period when all the relevant government sectors, NGOs and private organisations directly involved in curbing the epidemic were fully mobilised. The first (major) epidemic peak was a learning curve to evaluate how effective intervention measures were, especially those dealing with case management, hygiene practices and water handling practices. The lessons learned from the epidemic experiences of the major peak may also have significantly contributed to the reduction of the annual peak (minor) of December-February 2001/02; though this may also be attributed to the reduction of susceptible individuals in the affected communities.

The logistic and behavioural implication of the intervention measures were limiting in some aspects. This included availability and accessibility of water and sanitation services especially to the rural areas; shortage of health staff in some areas; and slow behavioural change and low community participation (Mugero and Hoque, 2001). Nonetheless, the intervention measures managed to reduce the burden of disease and the fatalities associated with cholera in the affected communities.

CHAPTER 6:

Statistical and Spatial Analyses

6.1 Variables statistically associated with cholera

The results presented in this chapter can be broadly grouped into two levels. On one level, statistics offered indications that some of the selected study variables have positive correlations to the incidence of cholera at a community level. At another level the results revealed certain spatial relationships between certain variables and the incidence of cholera. The justifications offered by statistical correlations were not always in accord with the spatial portrayal of the study database. This does not imply that the results from one type of analysis contradicted the other. Rather, when considered holistically, each set of results complimented the understanding of the complex disease picture presented by the cholera epidemic of 2000-2004.

Derived values that were calculated from the variables included in the study database using SAS (version 8.2) are presented in Tables 6.1 and 6.2. These derived values formed the basis of all the statistical correlations performed on the study database. All the variables that were included in the study database were assessed statistically. The relationships between the study variables and the incidence of cholera were performed through Partial Spearman's Correlations using SAS (version 8.2). It was decided to perform all the correlations at the Magisterial District (MD) level and not at the place-name level or the District Council (DC) level. This is because at the place-name level, the points generated along the regression line will be overwhelming (2 741 place-names) to decipher a correlation. Also a bias may be introduced considering the fact that some place-names existed where not a single cholera case was reported. At the DC level, the points along the regression line will be too few (11) as there are only 10 DC and the Metropolis of Ethikweni (Durban). Thus, the decision to use MDs struck a compromise with 52 points (52 MDs in KZN) presented along the regression line while evaluating the correlations.

Table 6.1: Derived values of the cholera situation in the DCs of KZN.

Abbreviations										
DC	**DC - Name**	**PopTotperDC**	**PopTotKZN**	**Popprop**	**CholTotperDC**	**CholTotKZN**	**Cholprop**	**CholDTotperDC**	**CholDTotKZN**	**CholDprop**
Durban	eThekweni Metropolitan	2605482	7923346	32.8836	2951	136337	2.1645	51	460	11.087
DC21	Ugu	618047	7923346	7.8003	7491	136337	5.4945	18	460	3.913
DC22	UMgungundlovu	863095	7923346	10.8931	1527	136337	1.12	17	460	3.6957
DC23	Uthukela	523976	7923346	6.6131	10303	136337	7.557	49	460	10.6522
DC24	Umzinyathi	419238	7923346	5.2912	6239	136337	4.5762	48	460	10.4348
DC25	Amajuba	406672	7923346	5.1326	849	136337	0.6227	20	460	4.3478
DC26	Zululand	648555	7923346	8.1854	14062	136337	10.3141	23	460	5
DC27	Umkhanyakude	441172	7923346	5.568	7919	136337	5.8084	35	460	7.6087
DC28	Uthungulu	698851	7923346	8.8201	71275	136337	52.2785	115	460	25
DC29	iLembe	486736	7923346	6.1431	13357	136337	9.797	83	460	18.0435
DC43	Sisonke	211522	7923346	2.6696	364	136337	0.267	1	460	0.2174

DC = District Council
PopTotperDC = Population Total per DC
PopTotKZN = Population Total in KZN
Popprop = Population by proportion
CholTotperDC = Cholera Total per DC
CholTotKZN = Cholera Total in KZN
Cholprop = Cholera by Proportion
CholDTotperDC = Cholera Deaths Total per DC
CholDTotKZN = Cholera Deaths Total in KZN
CholDprop = Cholera Deaths by proportion

Table 6.2: Derived values of the cholera situation in the MDs of KZN.

MD	PopTotperMD	PopTotKZN	Popprop	CholTotperMD	CholTotKZN	Cholprop	CholDTotperMD	CholDTotKZN	CholDprop
Alfred	106632	7681847	1.38810	735	136262	0.5394	2	460	0.4348
Babanango	35690	7681847	0.46460	348	136262	0.2554	2	460	0.4348
Bergville	106154	7681847	1.38188	184	136262	0.1350	2	460	0.4348
Camperdown	187559	7681847	2.44159	123	136262	0.0903	4	460	0.8696
Chatsworth	189884	7681847	2.47185	47	136262	0.0345	1	460	0.2174
Dannhauser	57678	7681847	0.75084	150	136262	0.1101	6	460	1.3043
Dundee	85332	7681847	1.11083	1514	136262	1.1111	5	460	1.0870
Durban	546124	7681847	7.10928	311	136262	0.2282	10	460	2.1739
Estcourt	144439	7681847	1.88026	1313	136262	0.9636	19	460	4.1304
Eshowe	178015	7681847	2.31735	25047	136262	18.3815	48	460	10.4348
Glencoe	24123	7681847	0.31403	681	136262	0.4998	4	460	0.8696
Hlabisa	169288	7681847	2.20374	5817	136262	4.2690	5	460	1.0870
Impendle	37052	7681847	0.48233	9	136262	0.0066	0	460	.
Inanda	722470	7681847	9.40490	659	136262	0.4836	10	460	2.1739
Ingwavuma	154230	7681847	2.00772	1177	136262	0.8638	26	460	5.6522
Ixopo	104763	7681847	1.36377	791	136262	0.5805	0	460	.
Klipriver	188478	7681847	2.45355	6050	136262	4.4400	22	460	4.7826
Kranskop	45319	7681847	0.58995	1957	136262	1.4362	7	460	1.5217
Lions-River	35627	7681847	0.46378	5	136262	0.0037	0	460	.
Lower-Tugela	167916	7681847	2.18588	1729	136262	1.2689	13	460	2.8261
Lower-Umfolozi	215633	7681847	2.80705	5872	136262	4.3093	10	460	2.1739
Mahlabathini	121861	7681847	1.58635	2711	136262	1.9895	6	460	1.3043
Mapumulo	132312	7681847	1.72240	4680	136262	3.4346	32	460	6.9565
Mooi-River	22569	7681847	0.29380	27	136262	0.0198	0	460	.
Mount-Currie	41980	7681847	0.54648	6	136262	0.0044	0	460	.
Msinga	142798	7681847	1.85890	3309	136262	2.4284	24	460	5.2174
Mthonjaneni	72669	7681847	0.94598	23773	136262	17.4465	33	460	7.1739
Mtunzini	179265	7681847	2.33362	10456	136262	7.6735	25	460	5.4348

Table 6.2(cont)

MD	PopTotperMD	PopTotKZN	Popprop	CholTotperMD	CholTotKZN	Cholprop	CholDTotperMD	CholDTotKZN	CholDprop
Ndwendwe	123721	7681847	1.61056	2768	136262	2.0314	27	460	5.8696
New-Hanover	69410	7681847	0.90356	152	136262	0.1115	3	460	0.6522
Newcastle	237220	7681847	3.08806	692	136262	0.5078	14	460	3.0435
Ngotshe	35223	7681847	0.45852	881	136262	0.6465	4	460	0.8696
Nkandla	123852	7681847	1.61227	10559	136262	7.7490	15	460	3.2609
Nongoma	170808	7681847	2.22353	9148	136262	6.7135	6	460	1.3043
Nqutu	179432	7681847	2.33579	965	136262	0.7082	16	460	3.4783
Paulpietersburg	57930	7681847	0.75412	8	136262	0.0059	0	460	.
Pietermaritzburg	549825	7681847	7.15746	879	136262	0.6451	11	460	2.3913
Pinetown	435745	7681847	5.67240	301	136262	0.2209	12	460	2.6087
Polela	71880	7681847	0.93571	241	136262	0.1769	0	460	.
Port-Shepstone	205605	7681847	2.67650	1369	136262	1.0047	11	460	2.3913
Qutu	1069	7681847	0.01392	0	136262	0	0	460	.
Richmond	60724	7681847	0.79049	34	136262	0.0250	1	460	0.2174
Simdlangentsha	86367	7681847	1.12430	876	136262	0.6429	1	460	0.2174
Ubombo	119749	7681847	1.55886	1010	136262	0.7412	6	460	1.3043
Umbumbulu	162583	7681847	2.11646	379	136262	0.2781	1	460	0.2174
Umlazi	339305	7681847	4.41697	0	136262	0	0	460	.
Umvoti	80612	7681847	1.04938	576	136262	0.4227	5	460	1.0870
Umzinto	219392	7681847	2.85598	4556	136262	3.3436	5	460	1.0870
Underberg	16177	7681847	0.21059	5	136262	0.0037	1	460	0.2174
Utrecht	22916	7681847	0.29831	3	136262	0.0022	0	460	.
Vryheid	74811	7681847	0.97387	352	136262	0.2583	1	460	0.2174
Weenen	21631	7681847	0.28159	1027	136262	0.7537	4	460	0.8696

Abbreviations:

MD = Magisterial District
PopTotperMD = Population Total per MD
PopTotKZN = Population Total in KZN
Popprop = Population by proportion

CholTotperMD = Cholera Total per MD
CholTotKZN = Cholera Total in KZN
Cholprop = Cholera by proportion
CholDTotperMD = Cholera Deaths Total per MD
CholDTotKZN = Cholera Death Total in KZN

A comprehensive list of all the correlation results from the derived values of the variables represented in the study database is presented in Table 6.3 a-k.

Table 6.3 a-k: Partial Spearman's Correlations of the socio-economic, demographic and climatic variables used in the study.

a. Household categories

		Traditional	Conventional	Informal	Temporary	Homeless
%CIR	Correlation	0.27255*	0.20283	0.24916	0.17161	0.38525*
	P-value	0.0978	0.22200	0.13140	0.3029	0.0169
%Mortality	Correlation	-0.2344	-0.18859	-0.25270	-0.24099	-0.18469
	P-value	0.1566	0.25680	0.12580	0.145	0.267

In the household categories, the homeless had the highest positive correlation to the incidence of cholera, followed by those that reside in traditional houses. Being homeless is synonymous to being poor (Table 6.3a). Homeless individuals would obviously not afford the basic services of water and sanitation thus making them vulnerable to diseases associated with the lack of such services. Individuals residing in traditional households are also associated with a low standard of living. And as far as the availability of basic services is concerned, their most probable water supply would be the natural water sources, which may carry high contamination loads, and their sanitation options would be rudimentary at best, further suggesting that households in these categories have a high risk to infectious diseases that are associated with the lack of clean water and adequate sanitation. The association of low standards of households, be it in the rural or urban/peri-urban squatter/slum dwellings have been previously linked to the incidence of cholera in countries like Philippines (Velimirovic *et al.*, 1975); Mozambique (Aragon *et al.*, 1994); Peru (Franco *et al.*, 1997); Brazil (Gerolomo and Penna, 2000); Tanzania (Acosta *et al;* 2001) and Bangladesh (Ali *et al.*, 2002).

b. Water services/options

		Piped water (In house)	Piped water (Within yard)	Public tap	Water tank	Borehole	River/Stream
%CIR	Correlation	0.3691*	-0.0760	0.13152	0.06354	0.33617*	0.50754*
	P-value	0.0267	0.6594	0.4445	0.7128	0.045	0.0016
%Mortality	Correlation	-0.56253	0.1571	0.43711*	0.09951	-0.40562	-0.63153
	P-value	0.0004	0.3602	0.0077	0.5636	0.0141	<0.0001

Within the water service categories, river water, piped water (in house) and borehole water had positive correlations to the %CIR of cholera (Table 6.3b). In comparison, river water had the strongest positive correlation to the incidence of cholera (r = 0.507, p = 0.0016), stressing the risk polluted natural water sources pose to communities' dependant on them. The risks associated with using polluted water from rivers, stream and springs has been long recognised and widely documented (Tshibangu, 1987; Sitas, 1986; Bradley *et al.,* 1996; Shapiro *et al.,* 1999; Patel and Isaäcson, 1989).

There was a positive correlation between having piped water (in house) and the incidence of cholera (r = 0.369, p = 0.026). The use of tap water inside a house was also documented as a potential risk factor in a prospective hospital-based, case-control study in Southern Tanzania, (Acosta *et al;* 2001). The risk of contracting an infectious disease like cholera in households with piped water (in house) may highlight an indirect association with the lack of education in matters of basic hygiene especially when handling water. More so in rural areas where even when a piped water supply within the house or mostly within a close proximity to the house is available, water would still be stored and used from containers such as buckets and drums (Tshibangu, 1987; Patel and Isaäcson, 1989). As such, the disinfection and cleanliness of the containers where the water is stored is important to reduce the risk of contracting infectious diseases like diarrhoea and cholera (Sánchez and Taylor, 1997; Quick *et al*., 1999; Sobsey *et al.,* 2003). Another aspect to consider with the piped water (in house) service is that, although the database records the presence of piped water in a dwelling, it may just be reflecting the fact that the infrastructure for piped water exists. In reality, the data does not guarantee that there is a supply of water nor does it guarantee that the quality of water is of the standard acceptable for human consumption. The various reports at the start of the cholera epidemic claiming that households had their water supplies terminated because of non-payment also adds credence to the notion that having piped water inside a dwelling does not necessarily guarantee a supply of clean water (Hemson, 2000; Morris, 2001; Cottle *et al.*, 2002 Pauw, 2003).

Water sourced from borehole also had a strong positive correlation to the incidence of cholera (r = 0.336, p = 0.045), implying that the water sourced from the boreholes might have been of questionable quality, possibly contaminated with cholera causing microorganisms. A possible explanation for this could be the heavy rains that were recorded in the KZN region just before the start of the cholera epidemic (Kriner, 2001; Sidley, 2001). The surface run off that resulted from the heavy rains may have eventually contaminated the water table, which is usually the source of the water from boreholes A similar situation was also being experienced in neighbouring Mozambique in 2001when heavy rains had flooded rural areas together with their pit latrines and sewage systems (Bateman, 2002). Likewise, the risk of cholera was expected to increase after the heavy rains contaminated water sources.

c. Sanitation services

		Flush toilet	Pit latrine	Bucket system	Other	None
%CIR	Correlation	0.01655	0.01785	0.30015	NOT	0.41089
	P-value	0.9204	0.9141	0.0634	CONSIDERED	0.0094
%Mortality	Correlation	-0.0717	-0.07219	-0.27802		-0.28575
	P-value	0.6645	0.6623	0.0866		0.0778

There was no positive correlation between the use of flush toilets and pit latrines and the %CIR of cholera (Table 6.3c). The sanitation options that were positively correlated to the %CIR of cholera were the bucket toilet system (r = 0.300, p = 0.063) and no sanitation (r = 0.410, p = 0.009). Among all the sanitation options, the most positive statistical correlation was that of no sanitation. Individuals or households without basic sanitation most often have no option but to use their surrounding environments, be it terrestrial and/or aquatic, indiscriminately for this purpose. Therefore, communities with a high proportion of households lacking in sanitation facilities face higher risks to infectious diseases that may be transmitted as a result of improperly disposed untreated sewage. Individuals that defecate indiscriminately on land or in aquatic environments contribute significantly to environmental pollution. Environmental pollution in communities already lacking in adequate sanitation further exacerbates the public health of disadvantaged communities.

d. Refuse collecting services

		Serviced	Self serviced	No service
%CIR	Correlation	0.01643	0.01095	0.39147*
	P-value	0.9198	0.9466	0.0125
%Mortality	Correlation	-0.20846	-0.19878	-0.41631
	P-value	0.1968	0.2188	0.0075

The positive correlation between no refuse removal service and %CIR of cholera (r = 0.39 p = 0.013) is in support of shortfalls in environmental sanitation (Table 6.3d). The difference in the correlation between those who have some sort of refuse service and those that do not emphasise the importance of environmental sanitation in improving the basic hygiene of a community and thereby reducing the risk of infectious diseases like cholera.

The different types of health services and energy options considered in the study did not show any significant correlations to the %CIR of cholera nor the % mortality due to cholera (Table 6.3e). The same can be said with the energy options (Table 6.3f). All the income groups were negatively correlated to %CIR of cholera except for the high-income group (Table 6.3g). The positive correlation (r = 0.293 p = 0.078) of the high-income

e. Health services

		Hospital	Clinic	Mobile Base	Satellite Clinic
%CIR	Correlation	-0.15905	0.10646	0.00602	-0.09437
	P-value	0.3767	0.5554	0.9735	0.6014
%Mortality	Correlation	0.07113	-0.12927	-0.02359	0.07175
	P-value	0.6941	0.4734	0.8963	0.6915

f. Energy options

		Electricity	Petrochemicals	Other
%CIR	Correlation	0.11558	0.13245	0.25672
	P-value	0.4776	0.4152	0.1098
%Mortality	Correlation	0.12011	0.11322	-0.25612
	P-value	0.4604	0.4867	0.1107

g. Income categories

		None	Low	Medium	High	Very high	Unknown
%CIR	Correlation	-0.06033	-0.1637	-0.21763	0.29336	-0.27931	-0.15607
	P-value	0.7228	0.333	0.1957	0.078	0.0941	0.3563
%Mortality	Correlation	-0.0342	0.13706	0.02116	-0.15118	0.0756	0.09921
	P-value	0.8407	0.4186	0.9011	0.3718	0.6565	0.5591

h. Age group categories and cholera age group categories

	0-4 yrs	5-9 yrs	10-14 yrs	15-19 yrs	20-29 yrs	30-39 yrs	40-59 yrs	60-74 yrs	75-95 yrs
CAC1T									
Correlation	0.01593								
P-value	0.6348								
CAC2T									
Correlation		-0.00398							
P-value		0.9129							
CAC3T									
Correlation			-0.00978						
P-value			0.7795						
CAC4T									
Correlation				-0.00314					
P-value				0.9268					
CAC5T									
Correlation					0.01786				
P-value					0.5662				
CAC6T									
Correlation						-0.00816			
P-value						0.8002			
CAC7T									
Correlation							-0.0063		
P-value							0.8409		
CAC8T									
Correlation								-0.02815	
P-value								0.4202	
CAC9T									
Correlation									0.01805
P-value									0.687

group (R6 000-16 000) may be an indication on a particular aspect of the life style of this income group, such as the ability to afford to travel from one area to another. As such, individuals of this income group can afford to travel around, thus run the risk of being exposed to infections *en route*, especially during the holiday seasons when visiting communities that may be vulnerable to diseases like cholera.

No statistical significant correlation could be established between the age groups and the %CIR of cholera (Table 6.3h) even though the individual age group graphs (Figures 5.4-5.13) revealed patterns that indicated some age groups were more affected than others. This means that there was no statistical proof to support the belief that the most affected age groups (i.e. 0-4 years, 10-14 years and 15-19 years) were particularly at risk to cholera infection, thus implying that all the age groups carried the same degree of risk to contracting cholera. The fact that some age groups appeared to be more affected than others may just be an indication of their representative proportion to the overall provincial population. That is, there will be more young people affected because they are more young people making up the population of KZN (Chapter 4: Figures 4.2-4.3).

i. Population density

%CIR	Correlation	-0.36029
	P-value	0.0102

There was a negative correlation between population density and %CIR of cholera (Table 6.3i). The assessment of the correlation coefficients of the population density of individual MD to %CIR also showed a negative or no correlation, save for the three positive correlations of the MDs of Babanango (r = 0.62355 p = 0.013), Newcastle (r = 0.88571 p = 0.0188) and Pinetown (r = 0.43238 p = 0.0135) (Table 6.3j). From the general results of the study database, a correlation may have been expected between population density and %CIR of cholera. Such a correlation may well exist, if one MD was to be assessed in isolation from the other MDs. A collective analysis of all the MDs does not however support a significant correlation between population density and %CIR of cholera (Table 6.3j).

j. Correlation of the Population density for the individual MDs

MD (Total cholera)	Correlation	P-value
Alfred	-0.27896	0.1355
Babanango	0.62355*	0.013
Bergville	-0.54165	0.0063
Camperdown	-0.6314	0.0372
Chatsworth	-1	<.0001
Dannhauser	-1	-
Dundee	0.0382	0.8804
Durban	0.26158	0.0943
Escourt	-0.2833	0.8756
Eshowe	0.21565	0.0614
Glencoe	-0.4	0.6
Hlabisa	0.11751	0.4367
Impendle	-0.94868	0.0513
Inanda	-0.06221	0.655
Ingwavuma	0.16036	0.2871
Ixopo	-0.07741	0.7255
Klipriver	0.16368	0.4053
Kranskop	0.16724	0.4243
Lions River	-0.86603	0.3333
Lower Tugela	0.15634	0.5631
Lower Umfolozi	0.1713	0.1831
Mahlabathini	0.24148	0.0566
Mapumulo	-0.01961	0.8881
Mooi River	-0.31623	0.6838
Mount Currie	-	-

… continues

j. (continued)

Msinga	-0.08781	0.5318
Mthonjaneni	0.0759	0.6461
Mtunzini	0.02912	0.8207
Ndwendwe	-0.08163	0.6796
New Hanover	-0.09303	0.7518
Newcastle	0.88571*	0.0188
Ngotshe	0.5	0.6667
Nkandla	-0.00431	0.972
Nongoma	0.017472	0.087
Nqutu	-0.02963	0.8332
Paulpietersburg	-0.5	0.6667
Pietermaritzburg	-0.07598	0.6693
Pinetown	0.43238*	0.0135
Polela	-0.31022	0.3264
Port Shepstone	0.15111	0.3053
Qutu	-	-
Richmond	-0.55907	0.2488
Simdlangentsha	0.74003	0.0038
Ubombo	0.3371	0.0385
Umbumbulu	-0.12403	0.6239
Umlazi	-	-
Umvoti	-0.51138	0.0893
Umzinto	-0.16175	0.1778
Underberg	-1	-
Utrecht	-	-
Vryheid	1	<0.0001
Weenen	-0.77143	0.0724

- No *r* or *p* values available.

k. Climatic variables

		Min. temperature	Max. temperature	Ave. temperature	Rainfall	Humidity
%CIR	Correlation	0.03889	0.034411	0.0393	0.04042	0.0371
	P-value	-	-	-	-	-

- No *p* values available.

From the data interpretation of Chapter 5, among the climatic variables, only the annual rainfall pattern showed a probable relationship to cholera when plotted against the cholera cases of the entire epidemic period. However, statistically, the Partial Spearman's correlation did not establish a good correlation between the %CIR of cholera and the climatic variables of rainfall, temperature (minimum, maximum and average) or humidity (Table 6.3k). There may have been a correlation with the climatic variables within specific months when cholera was at its peak but not when the entire database was statistically assessed. There may also have been a correlation with the climatic variables if only certain places that reported high cholera case were considered. Both these possibilities have limitations of the sample size being too small for statistical assessment. In general, statistical verification that clearly link climatic variables to the incidence of cholera has been ambiguous in several studies in the past (Kamal, 1963; Singh *et al.,* 1998, Pascual *et al.,* 2002). Recently Koelle *et al.,* (2005) put forward a mathematical model that demonstrate an interplay of environmental forcing, i.e. climate variability, and temporary immunity to explain the inter-annual disease cycles present in a four-decade cholera time series from Matlab, Bangladesh. Thus, if to have such long term data (four decades) is a pre-requisite for seeing a relationship between climatic variables and cholera, this would be a limitation to most researchers in the field, especially so in developing countries where retrieval of long-term data may not always be feasible.

It should be noted that a regression analysis was not pursued because statistically insubstantial r^2 values (< 0.25) were returned for all variables investigated. There was no r^2 value greater than 0.0017 in the regression model that included all the socio-economic variables that had a correlation to the %CIR of cholera (refer Table 6.4). Notwithstanding though the p-values were positive, they were not strong.

Table 6.4: An extract of the Partial Spearman's correlations of the variables that were positively associated with the %CIR of cholera.

% CIR → Variable↓	Correlation	P-value (p<0.05)
Traditional house	0.27255	0.0978
Homeless	0.38525	0.0169
Piped water	0.36910	0.0267
Borehole	0.33617	0.0450
River water	0.50754	0.0016
Bucket toilet	0.30015	0.0634
Unspecified sanitation	0.41089	0.0094
No refuse service	0.39147	0.0125
Income: R6,000–R16,000/month	0.29336	0.0780

6.2 The spatial approach

The variables that were statistically established to have a positive correlation to the incidence of cholera presented guidance as to the types of GIS maps to be generated (Table 6.4). Thus, a GIS map was created for all the variables that were found to have a correlation with the incidence of cholera. By and large, the purpose of these maps was to portray the spatial characteristics of the epidemic. The GIS maps presented here were generated from a combination of outputs from the spreadsheet analyses, as well as the statistically derived data. Maps 5 to 26 are a result of a combination of two features. As a basis, they illustrate the socio-economic or climatic conditions of the study area at the time. In addition there was also superimposition of the cholera cases onto the socio-economic or climatic variables in question. This exercise formed the basis for examining how the different variables spatially correlated to the incidence of cholera. The statistical outcome of the previous section may or may not be in agreement with all the spatial relationships revealed by the GIS maps. Nonetheless, the challenge was to highlight the possible relationships between the incidence of cholera and the various socio-economic and climatic from a spatial perspective.

6.2.1 Spatial GIS mapping

With regards to this study, all the census socio-economic variables surveyed, include the various categories represented by water and sanitation services, refuse collection, source of energy, income, types of dwelling and health facilities. The spatial perspective of the possible relationships of the statistically correlated variables to the incidence of cholera also gives a general depiction of the socio-economic status of the study area of KZN (Maps 6 to 17). In addition, these maps were also superimposed with all the reported cholera cases such that each map served a double purpose; i.e. to illustrate a particular variable and how it spatially related to the incidence of cholera. This was done for ease of comparing between the various MDs at a glance. The choice of GIS maps presented here are those where the particular socio-economic variable had a positive correlation with %CIR of cholera or those that revealed an interesting spatial connection with the distribution of cholera cases in the affected areas, as was the case with the climatic variables.

6.2.2 Demographic variables and cholera

6.2.2.1 Population

Urban areas like the Durban Metropolis and the MD of Pietermaritzburg were the most populated for obvious reasons of being central business districts (CBDs), accommodating 5.7-9.4% of the provincial population (Map 6). The most populated non-urban MD situated closest to the foci of the epidemic was that of Lower Umfolozi, accommodating 2.3-3.1% of the provincial population, while the rest of the neighbouring MDs accommodated between 1.1-2.3% (Map 6). The areas that reported high cholera incidence were also relatively densely populated, accommodating 1.7–3.1% of the total KZN population when compared to other MDs (Map 6).

The spatial trend demonstrated the cholera spread to be more among densely populated communities than in the sparsely populated ones. Cholera being an infectious disease will understandably require a direct or indirect contact between a patient/carrier of the disease and the susceptible person. The chance of contracting the disease is thus higher if a patient/carrier of the disease is placed among a large pool of susceptible individuals within a community. With the exception of the urban areas, the population density was highest in the MD of Lower Umfolozi, with 38-57 persons residing per km^2 as compared to the other MDs where relatively high cholera cases were also reported (Map 6). Most of the affected MDs had population densities of between 4-57 persons per sq km, indicating that even if an MD may accommodate between 1.7-2.3% of the provincial population, it does not necessarily mean that the population density will be high, as this factor also depends on the habitable land area of the particular MD in question. Therefore on average, larger areas tend to portray lower population densities and *vice versa* (Map 7). To add credence to this observation is the fact that areas that reported high cholera cases were in the majority rural in nature.

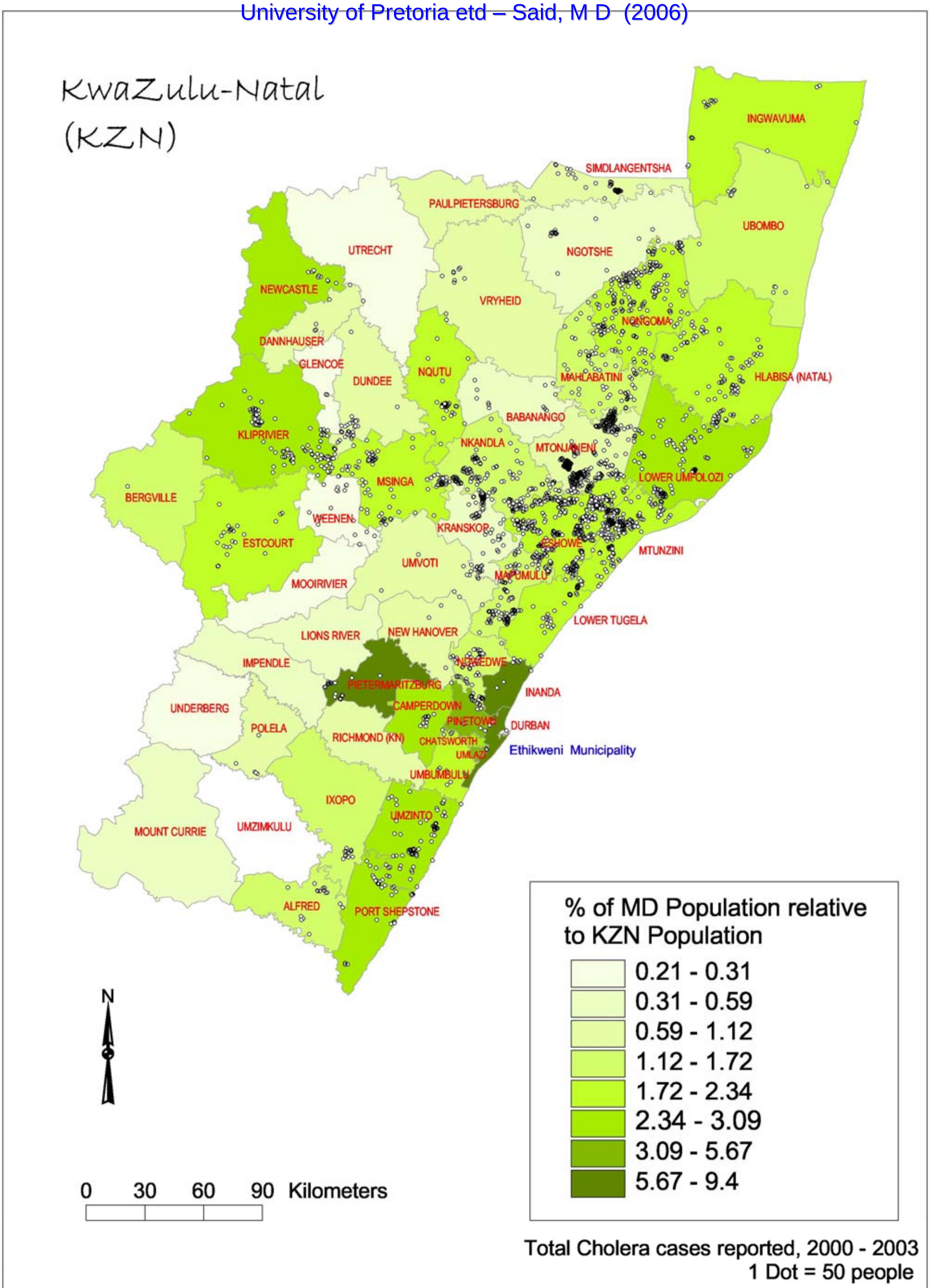
6.2.2.2 Housing

The housing situation was such that most areas (excluding the Durban Metropolis and other urban centres) had at least 12% of the dwellings being of the traditional type, whereas in some areas the proportion is up to 95% (Map 8). The areas with the cholera case clusters had 42-95% of the dwellings being of the traditional type; indicative of a predominantly rural setting.

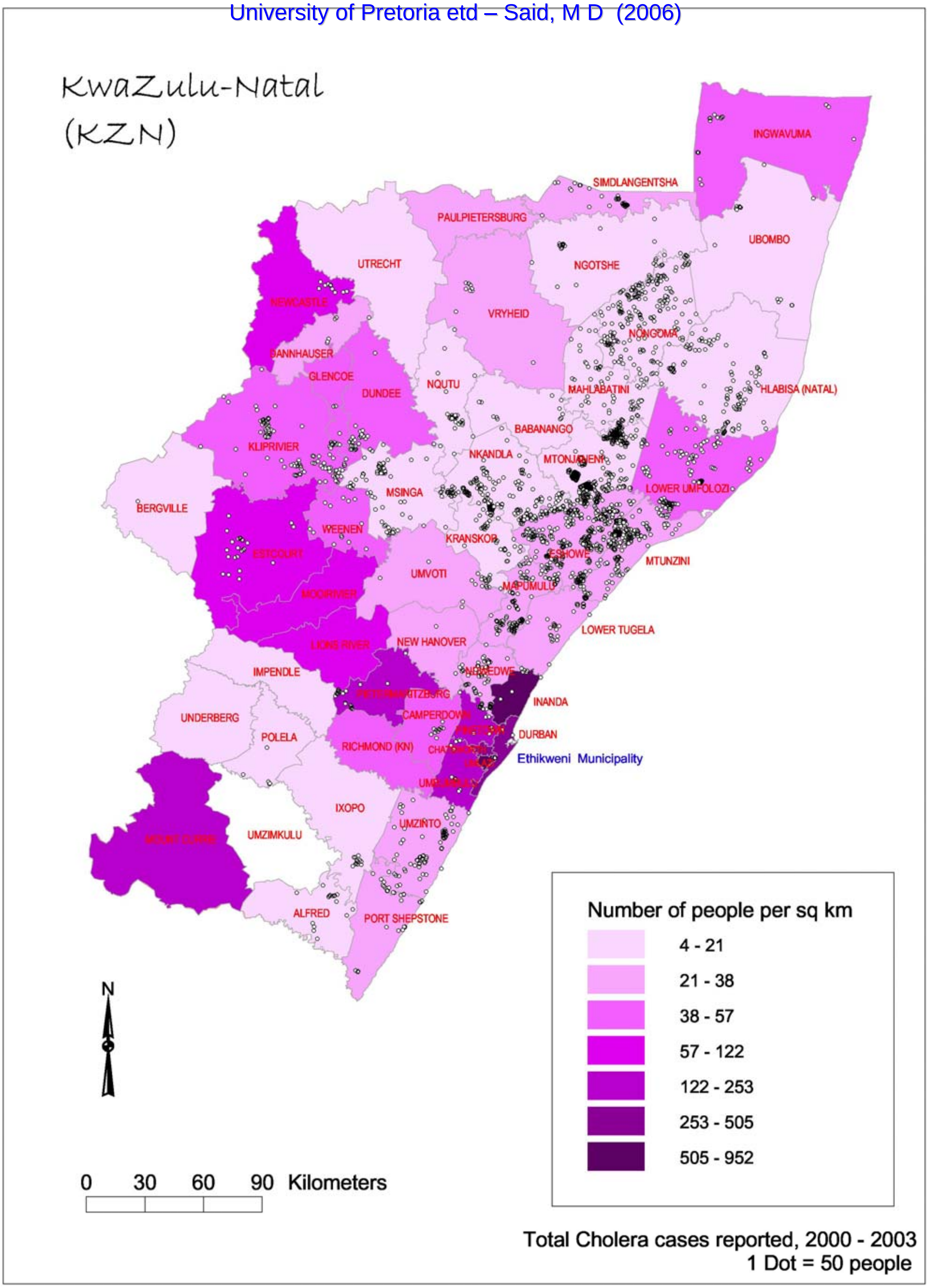
The statistical results positively correlated living in a traditional house type to the %CIR of cholera ($r= 0.272$ $p= 0.09$). Acosta *et al*, (2001) also observed similar correlation in a study in Tanzania, whereby living in a mud house was significantly associated with cholera. The same areas also had relatively high population densities of 17 - 99 persons/sq km with 0.01-0.12% of their population classified as homeless (Maps 7 and 9). This was exacerbated by the fact that between 30-87% of people within individual MDs of KZN had no form of income implying a general state of poverty in the areas where such individuals lived (Map 10). The housing situation depicted here together with the high level of unemployment is consistent to a state of affairs that implies that most households would probably not afford basic services like water, sanitation and refuse collection.

6.2.3 Socio-economic variables and cholera

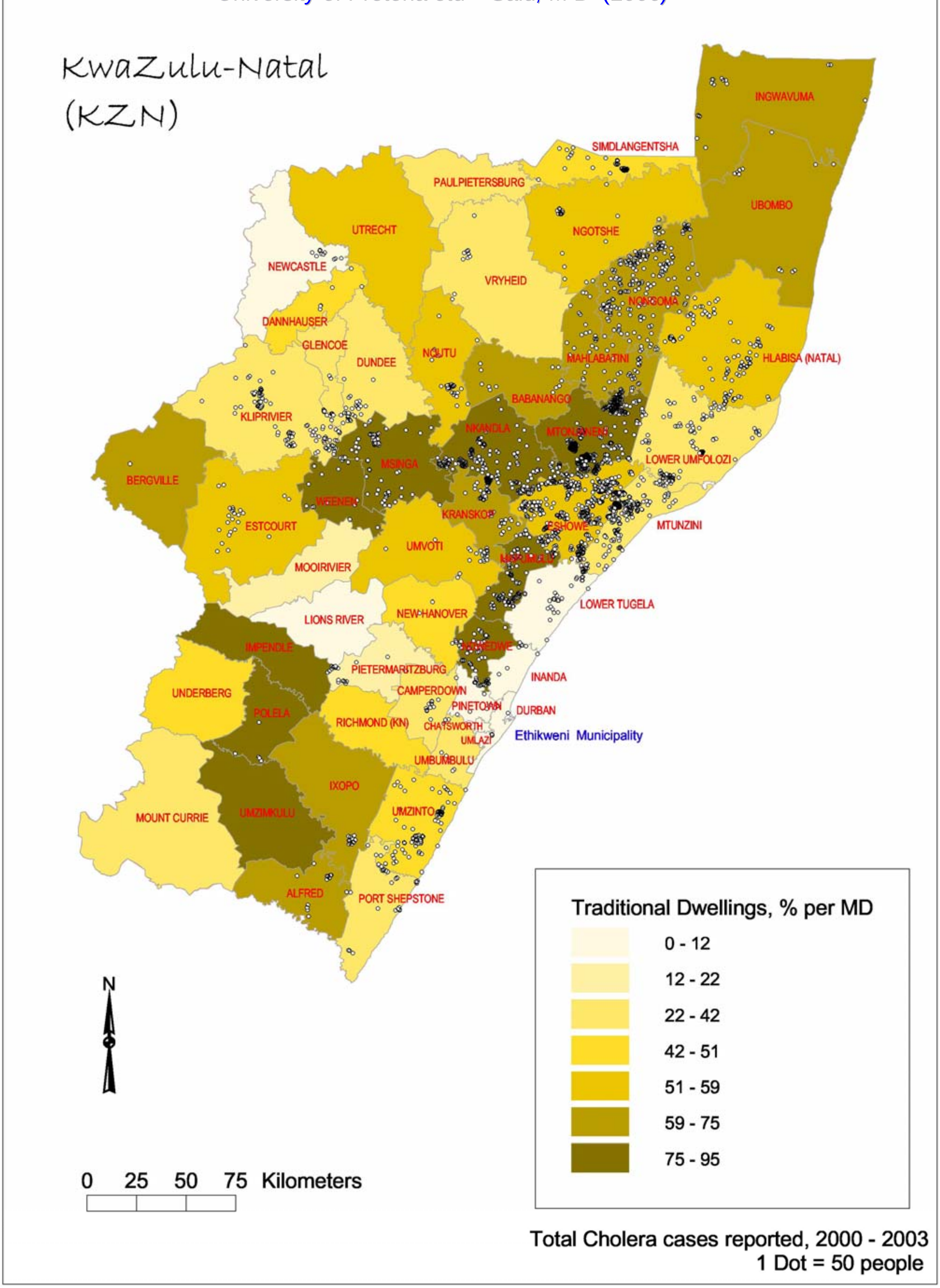
The socio-economic variables of water, sanitation and refuse service categories were the basic types of services considered in the study (refer Table 5.4). *Per se*, all the GIS maps presented here spatially demonstrate the type of basic services that were positively correlated to the incidence of cholera. The names of the 52 MDs are also



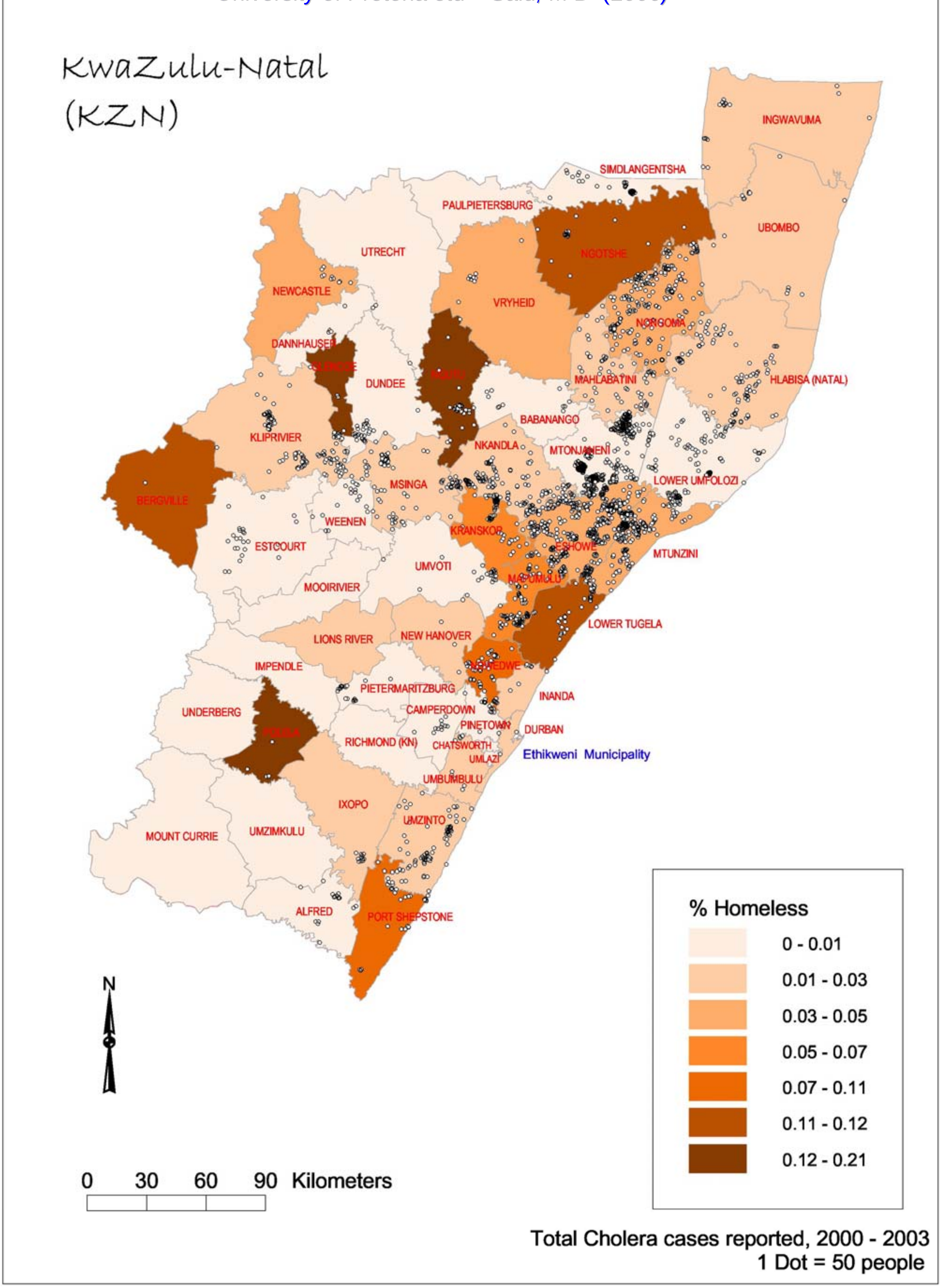
Map 6: The proportion of people per MD (as percentage) in relation to total KZN population



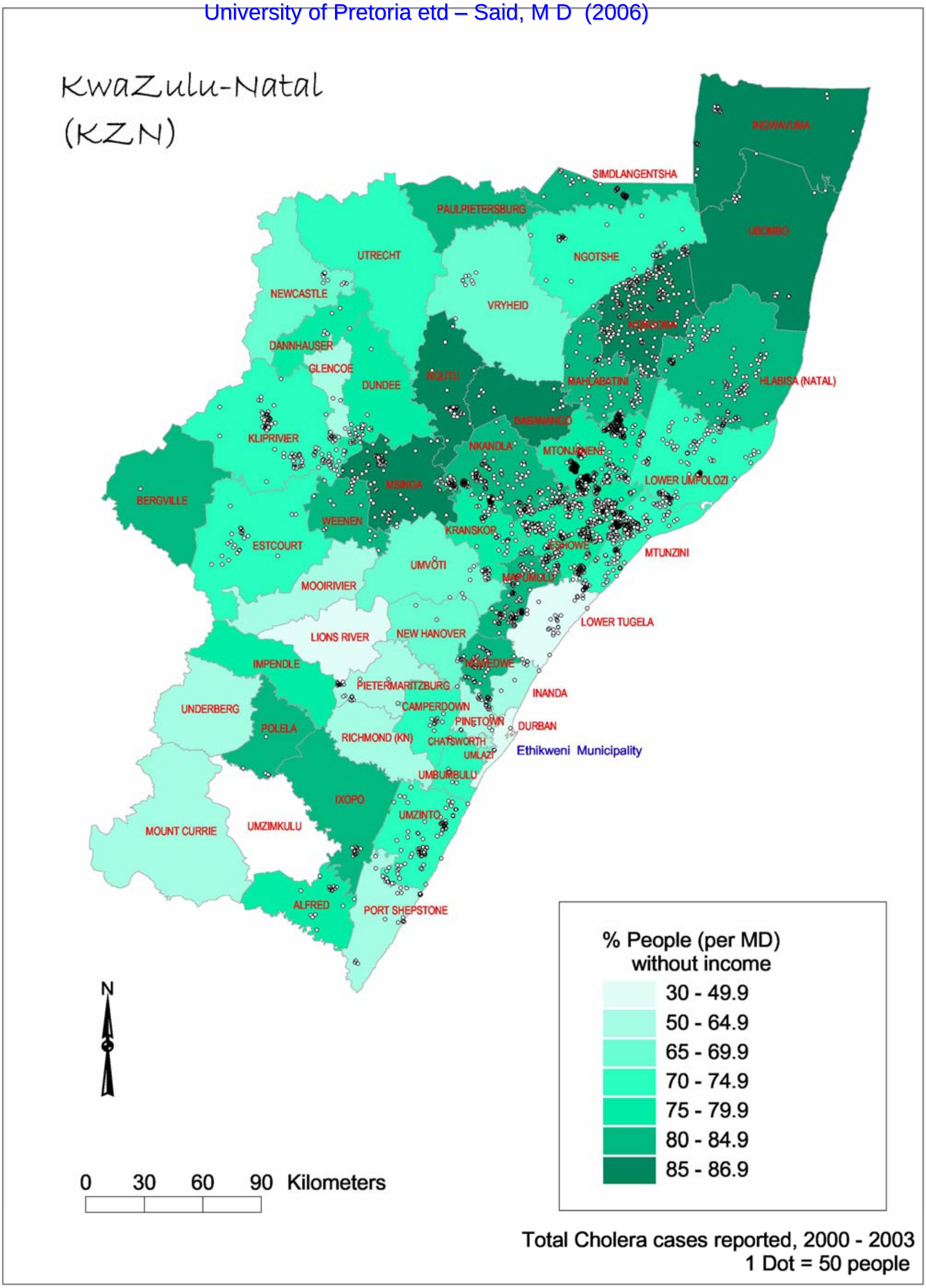
Map 7: Population density (people per square kilometer) per MD in KZN



Map 8: Distribution of traditional dwellings (as percentage of MD) in KZN



Map 9: Distribution of homeless persons (as percentage of MD) in KZN



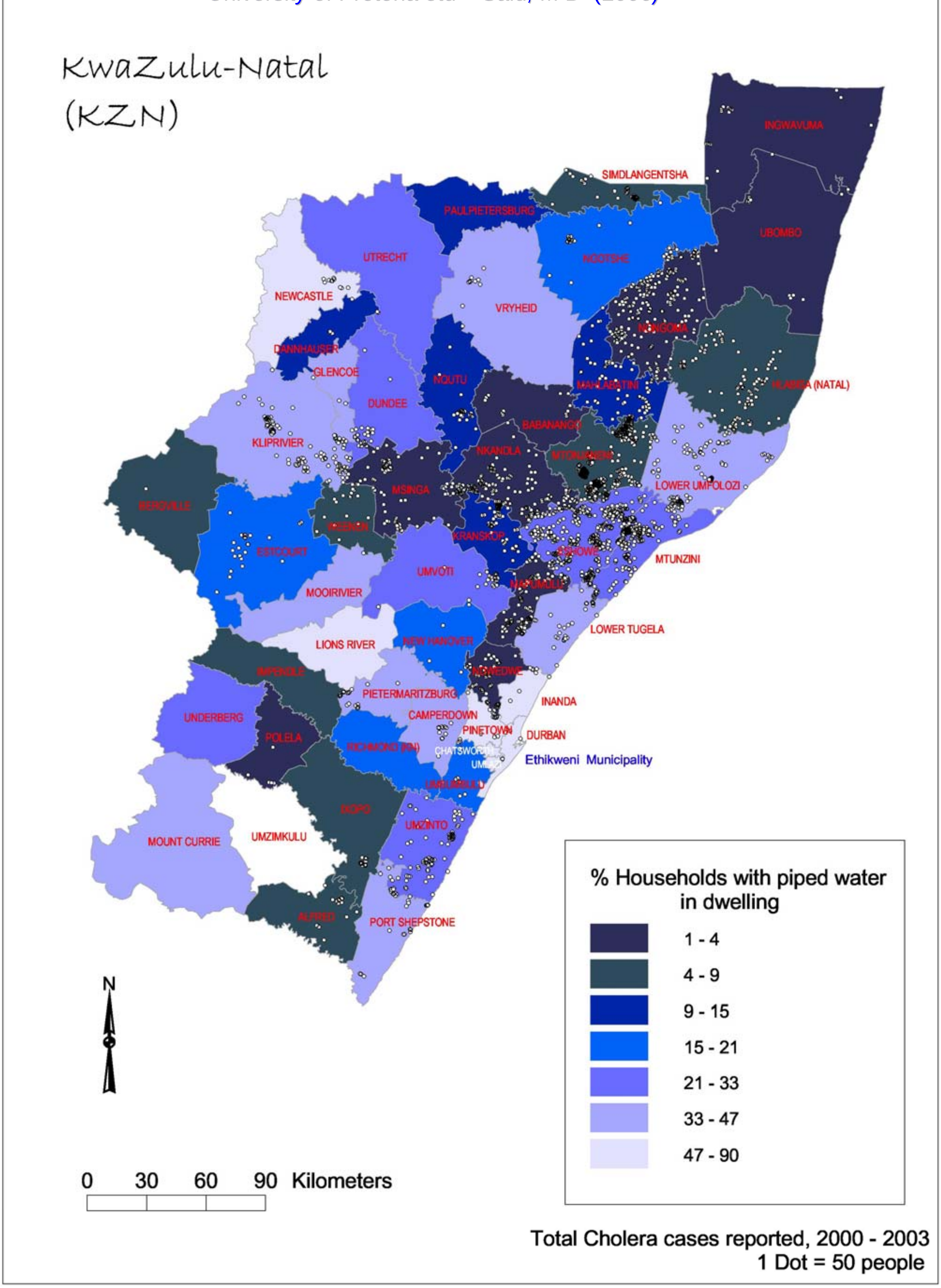
Map10:Percentage of people with no income (as percentage of MD) in KZN

included in these maps to make comparison between the different MDs straightforward. The maps also include a colour-coded legend to show the different levels of basic services available in the different MDs.included in these maps to make comparison between the different MDs straightforward. The maps also include a colour-coded legend to show the different levels of basic services available in the different MDs.

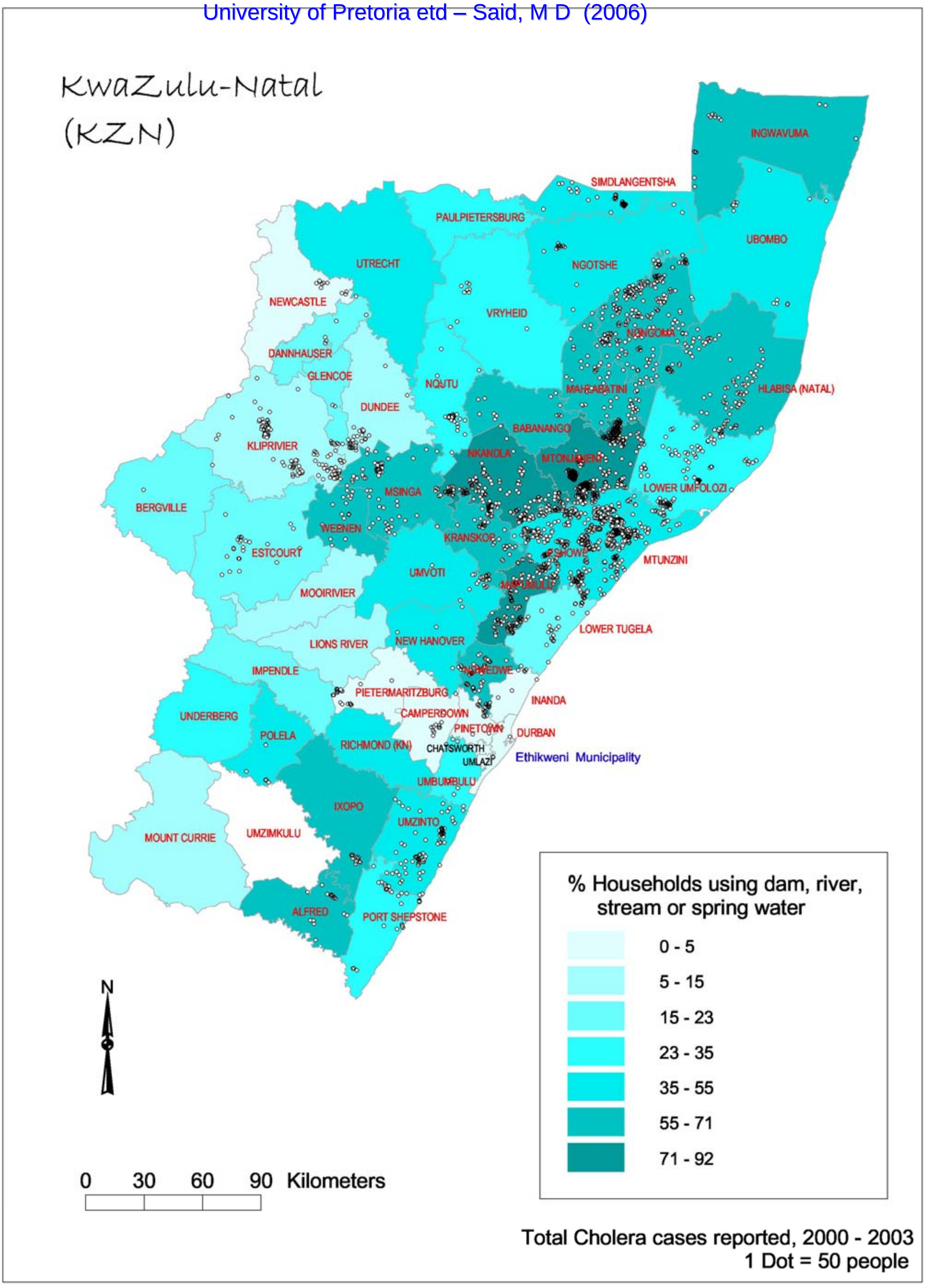
6.2.3.1 Water

There was a total of seven water services/options considered in the study, of which three were positively associated with the incidence of cholera, i.e. having piped water inside the dwelling, using boreholes and using water from rivers, dams, streams and springs. The distribution of water services in KZN was such that only 15-47% had piped water in their dwellings, 6-14% depended on boreholes while the majority at 23-55% sourced their water from rivers, streams and springs (Maps 11 to 13). The most affected areas had between 1 - 33% of households with piped water in their dwelling. In the MDs of Eshowe and Mtunzini where most of the cholera cases were reported, there were 21-33% of household with piped water in their dwelling which means two thirds of the population in that area sourced their water from sources external to their households (Map 11).

As cholera spread out of its original foci in the MDs of Eshowe and Mtunzini (Figure 5.1) to the north, south and west, the next most affected MDs of Nongoma, Hlabisa, Nkandla, Mtonjaneni, Msinga, Mapumulu and Ndwendwe had a mere 1-9% of households with piped water in their dwelling (Map 11). Although Lower Umfolozi was better off with 33-47% coverage of households with piped water in their dwellings, it was not spared, considering the high number of cholera cases that were reported. Thus, if the areas where cholera was first reported had relatively better off households as far as piped water was concerned, it is then safe to assume that the areas where cholera spread to were even more vulnerable to the infection, as is clearly seen in the MDs neighbouring Eshowe, Mtunzini and beyond (Map 11). The MDs named above as having the least percentage of households with piped water in their dwelling were the ones with the high proportion of households (55-92%) using water from natural sources like rivers, dams, streams or springs (Map 12). Among the water service categories, the natural water option had the strongest statistical correlation ($r = 0.507$ $p = 0.0016$) to



Map 11: Percentage households in KZN with piped water in their dwellings



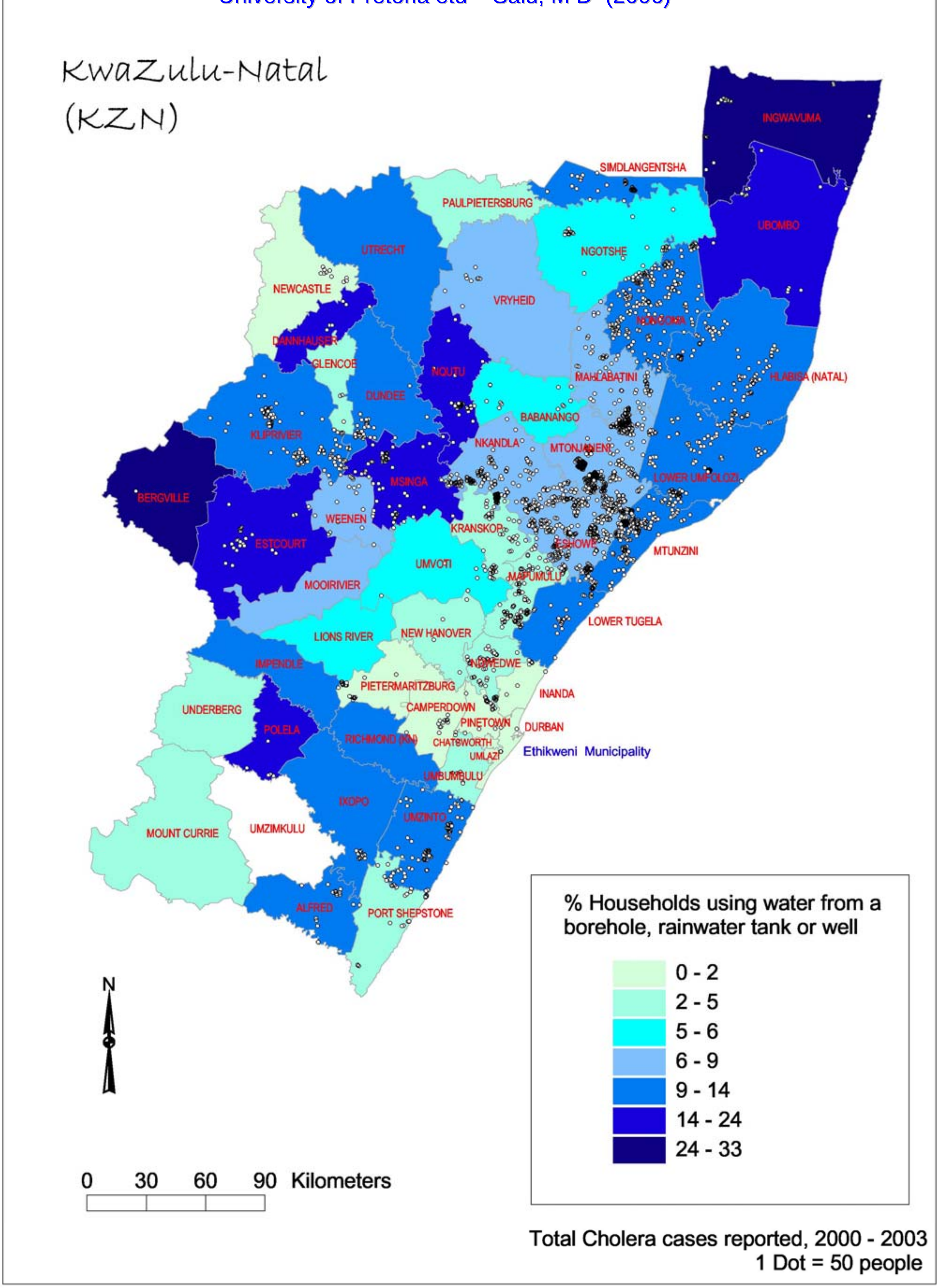
Map 12: Percentage households in KZN using dam, river, stream or spring water

to the %CIR of cholera. This spatial scenario is in agreement with the reports of people getting cholera because they could not afford to pay for water and had thus to resort to natural water sources which were most probably polluted with pathogens including the cholera organisms (Ka-Min, 2000; Nhlapo-Hlope, 2001; Sidley, 2001; Cottle and Deedat 2002).

The spatial distribution of cholera cases in KZN corresponded well with areas that have households using boreholes (Map 13), concurring with the positive correlation between the use of boreholes and %CIR of cholera (0.336 p = 0.045). The MDs of Hlabisa, Lower Umfolozi, Mtunzini, Lower Tugela, Nongoma, Msinga and Klipriver had 9-14% of households using boreholes. While the MDs of Eshowe, Nkandla, Mtonjaneni and Mahlabatini had 6-9% of households using boreholes. It is quite probable then that if the natural water sources around the areas where cholera was rampant were polluted, this could have affected the quality of water sourced from boreholes as explained in 6.1. Especially in the event that the borehole water was for domestic purposes without first being treated either by boiling or adding bleach after it was sourced. There was also the possibility of wells and boreholes being polluted because of the heavy rains and the subsequent surface run off that occurred around the same time period as the cholera epidemic (Kriner, 2001; Bateman, 2002). Environmental pollution could also have exacerbated the contamination of groundwater that recharges wells and boreholes. Inevitably then, people using untreated water from these sources were at risk of contracting waterborne diseases such as cholera.

6.2.3.2 Sanitation

Five types of sanitation services/options were considered and correlated with the %CIR of cholera. It was reasonable to assume that sanitation options like the flush or chemical toilets were mostly available in the urban areas because of the high maintenance costs associated with them. Also, a flush toilet would require that a household have access to piped water and be connected to a sewage disposal system; such as a septic tank or to a municipal sewer, as a necessity for the operation of the system. The proportion of households with pit latrines ranged from 8.8 - 97% within the individual MDs, thus probably the most widely distributed sanitation option (Map 14). As it were, initial expenses of setting up a pit latrine are reasonable and within

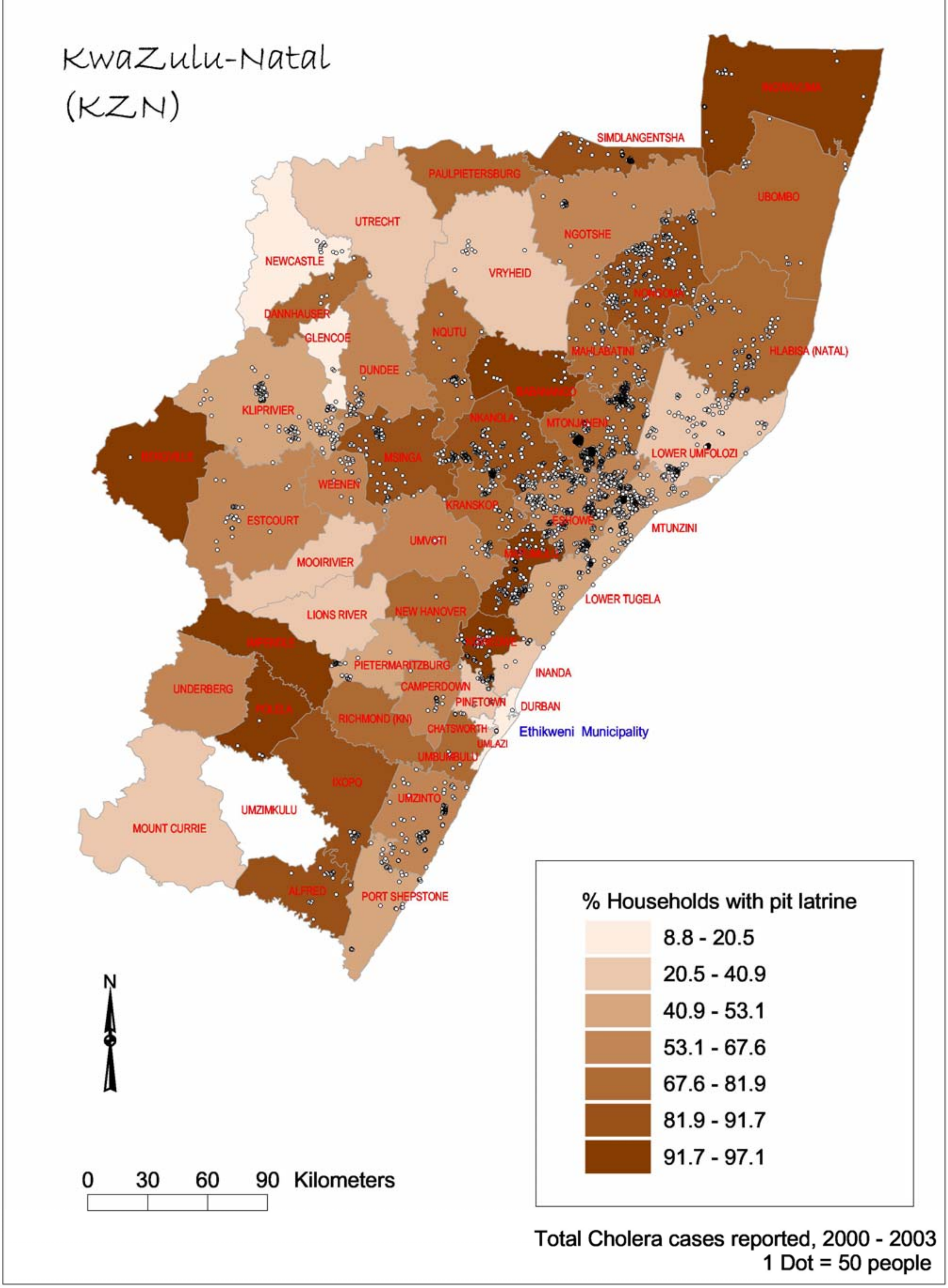


Map 13: Percentage households in KZN using water from boreholes, rainwater tanks or well

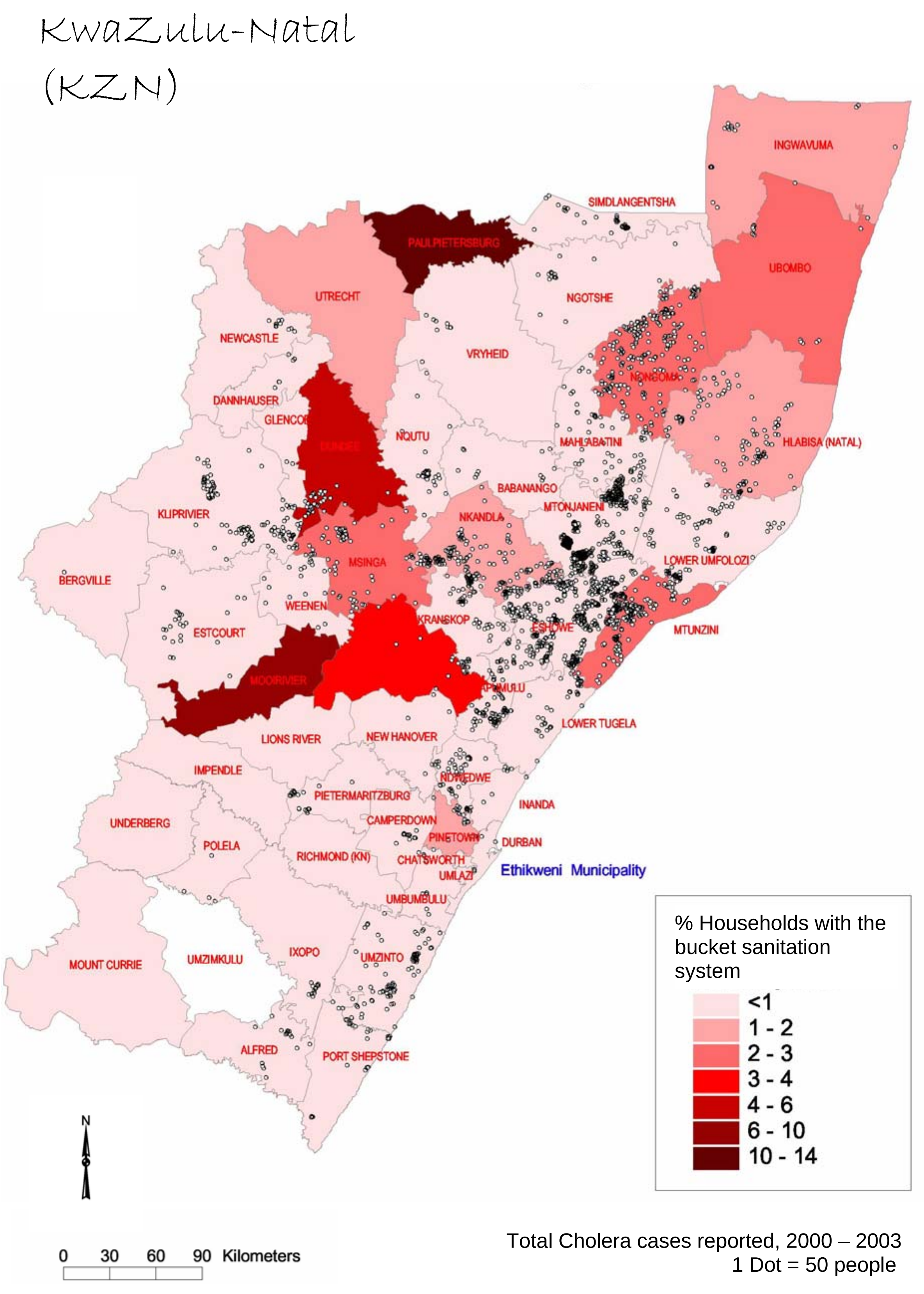
reach of most community sanitation programs or government funded housing schemes. Also, once set up, the system provides for adequate sanitation over a lengthy period of time with minimum maintenance requirements. Incidentally, this wide range in the proportion of availability of pit latrines, with the lowest being 8.8% and the highest being 97% is also a direct indication of the availability of piped water in the individual MDs of KZN. This relationship can be seen when comparing the services illustrated on Map 11 (% households with piped water) and those on Map 14 (% households with pit latrines); that, MDs with a low coverage of piped water in households generally have a high provision of pit latrines. For obvious reasons that such households would most probably not be able to maintain nor afford a sanitation option like a flush toilet that is dependent on the availability of piped water.

MDs that reported high cholera case clusters had 1-3% of households using the bucket toilet (Map 15). The MDs of Mtunzini, Nongoma, Nkandla and Hlabisa, which reported high number of cholera cases, had 3-4% of households using bucket toilets as a sanitation option. Similarly, all the other MDs of KZN had a proportion of households using the bucket toilet even if it was at less than 1%. This is a point of concern considering that the bucket toilet has been documented to have a high potential to expose households to unsanitary conditions particularly in areas where the bucket maintenance (emptying) service is not regularly provided by the local authorities concerned (DWAF; 2002a).

On the negative extreme spectrum of the sanitation options is the 1- 6.3% of households in the most affected MDs having had no specified form of sanitation (Map 16). Thus, the environmental pollution pressure in the affected areas is high as households turn to rudimentary means, like using the open areas/bushes in their environs for sanitation purposes. An important aspect to consider especially in an epidemic environment, is that people with no specified sanitation options will probably also include disease carriers who may continuously seed the aquatic and terrestrial environmental with pathogens like *V. cholerae*. Therefore, in support of the type and distribution of sanitation options or lack thereof and the associated risks, the use of bucket toilets was positively correlated to %CIR of cholera ($r = 0.30$ $p = 0.063$). Similarly, on the other extreme, households with unspecified sanitation were also positively correlated to



Map 14: Percentage households in KZN with pit latrines



Map15: Percentage households in KZN with bucket sanitation system

%CIR of cholera (r = 0.411 p = 0.0094). The spatial demonstration provided by Maps 14 - 16 clearly highlight that the worst affected cholera areas were also the ones with a high proportion of households that require serious attention as far as their sanitation needs are concerned.

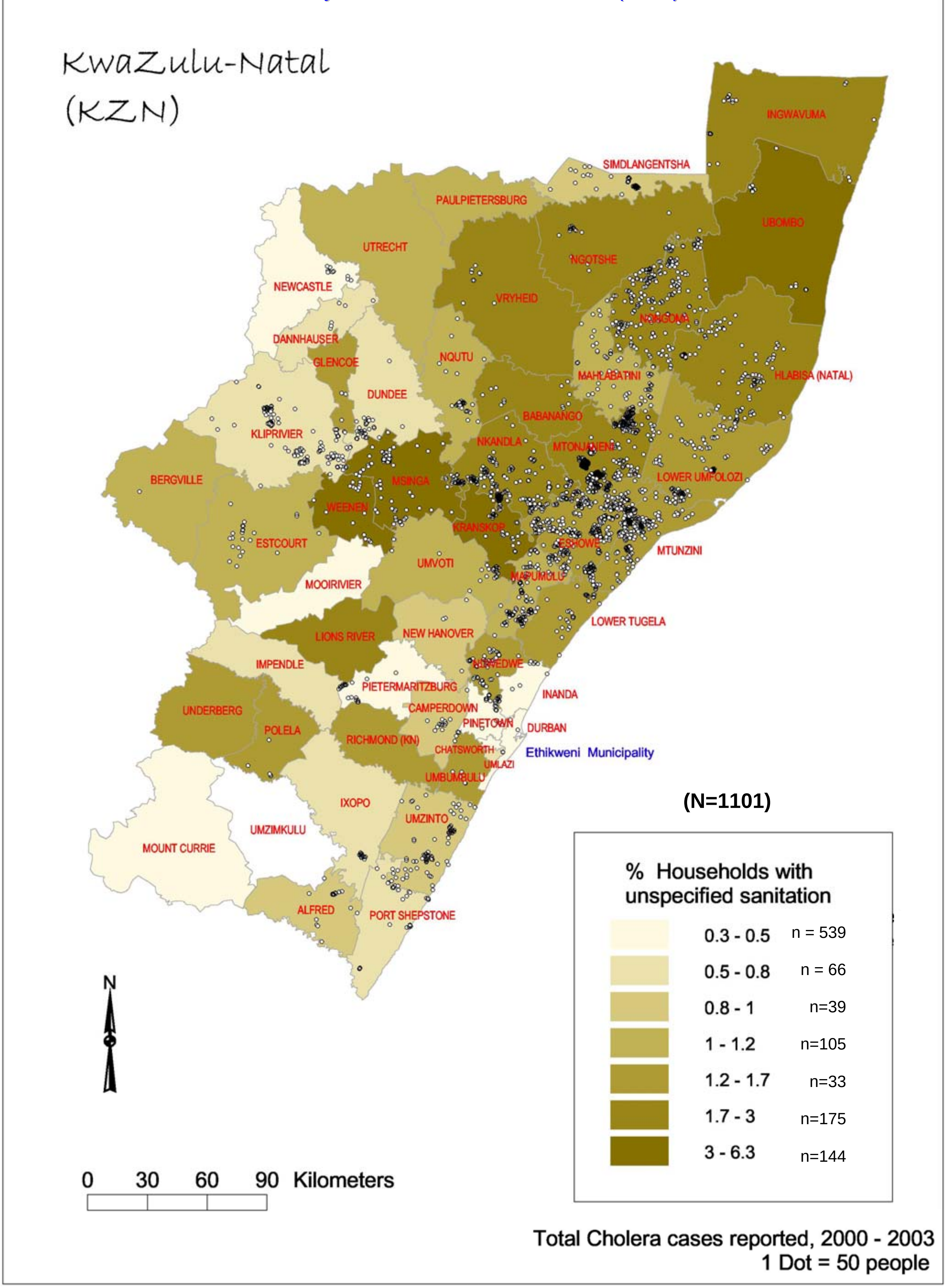
6.2.3.3 Refuse

Lack of water and sanitation are always implicated first as the primary driving factors during epidemics of cholera. Environmental pollution that can come about as a result of the lack of refuse services is not usually directly connected to epidemics of cholera as such. The general picture in KZN as far as the refuse situation is concerned is that almost 80%of the MDs (excluding Durban) in KZN (i.e. 42 of the 52 MDs) have 8-55% of their households with no refuse removal services (Map 17). The MDs where the bulk of the cholera cases were reported from have at best 12-17% of households with no refuse removal service. While the rest of the MDs have between 42-55% of households with no refuse removal services.

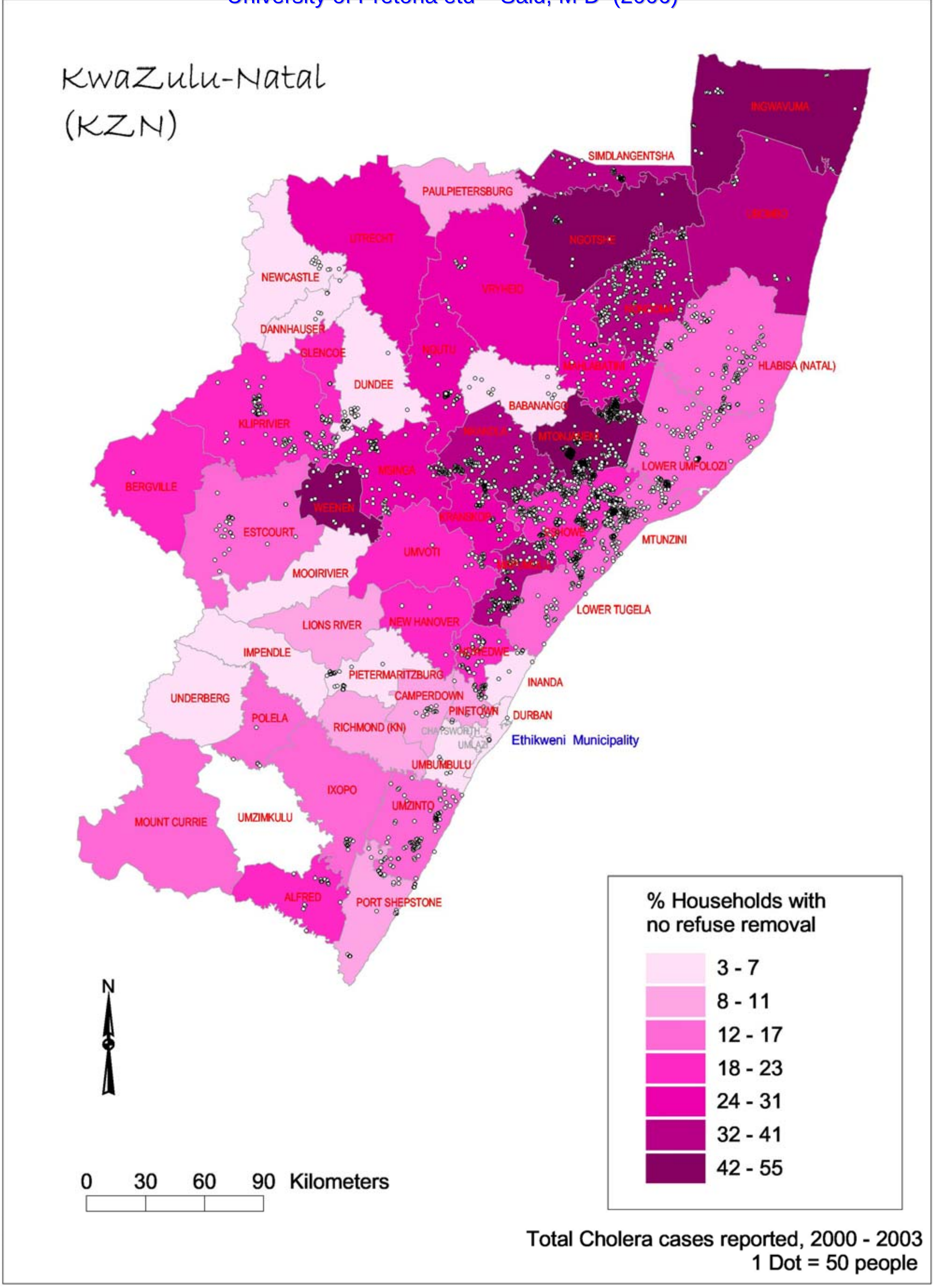
The spatial illustration of the areas with cholera cases clusters in relation to the refuse removal situation is presented in Map 17. Most of cholera cases clusters concur with the least serviced areas within the various MDs (Map 17). This observation is supported by the positive correlation (r=0.39 p 0.01) between %CIR of cholera and lack of refuse services. Thus the question; what type of refuse disposal do most of these households opt for? This state of affairs implies a significant level of indiscriminate refuse disposal, which may inevitably lead to environmental pollution. Thus in light of the cholera epidemic in question, indiscriminate environmental pollution may as well have acted as a significant environmental factor in the transmission of cholera.

6.2.4 Climatic variables and cholera

The spatial representation of the climatic variables of rainfall, relative humidity and maximum temperature during the major peak of the cholera epidemic follows. Maps 18-26 demonstrated a significant concurrence at the spatial level. The climatic maps were slightly different in that each of the three climatic variables was followed over a three-month period of November, December and January (NDJ). In addition, only the



Map 16: Percentage households in KZN with unspecified sanitation



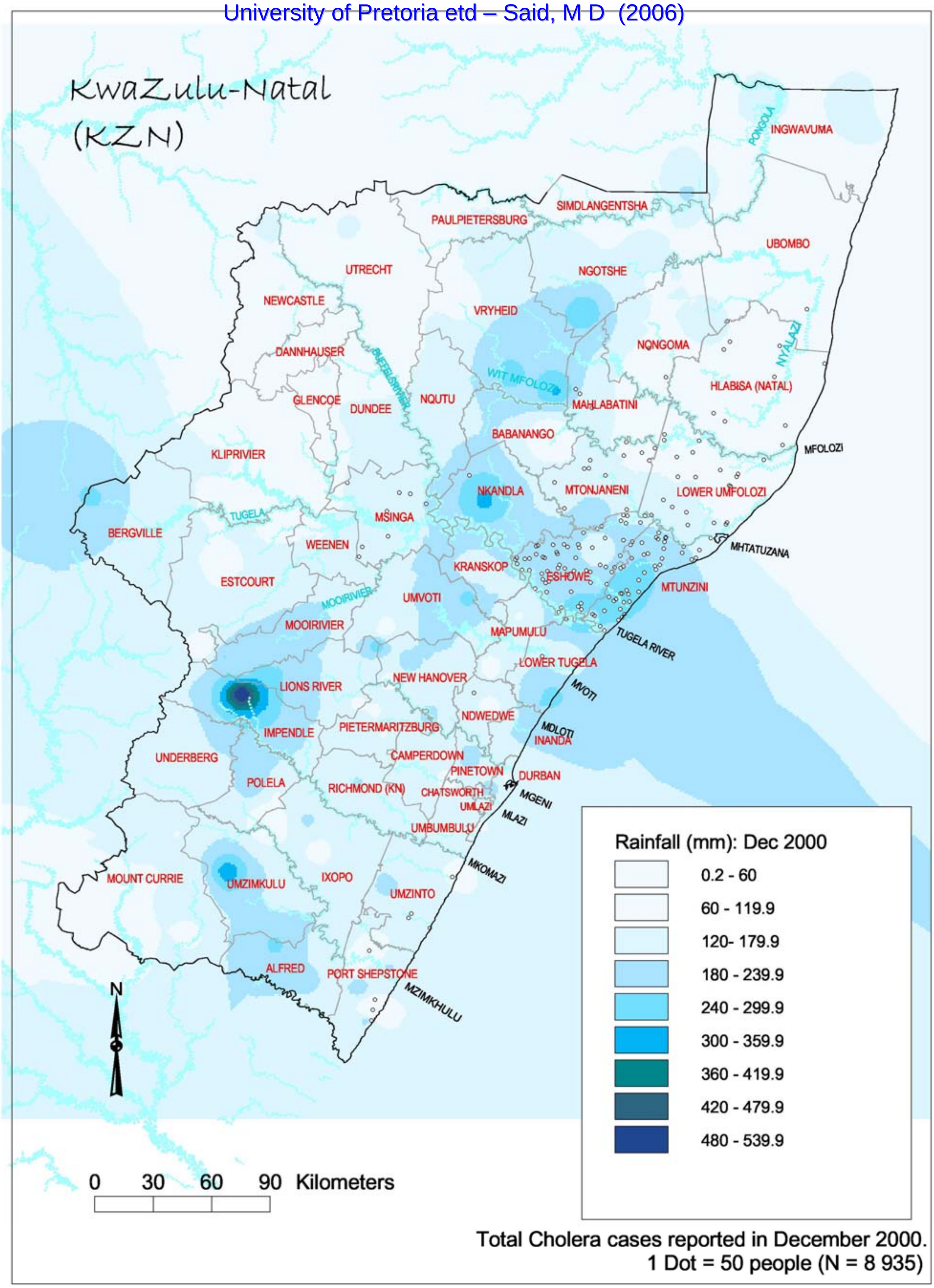
Map 17: Percentage households in KZN with no refuse removal services

cholera cases that were reported during the individual month in question were superimposed on the specific climatic conditions of the time.

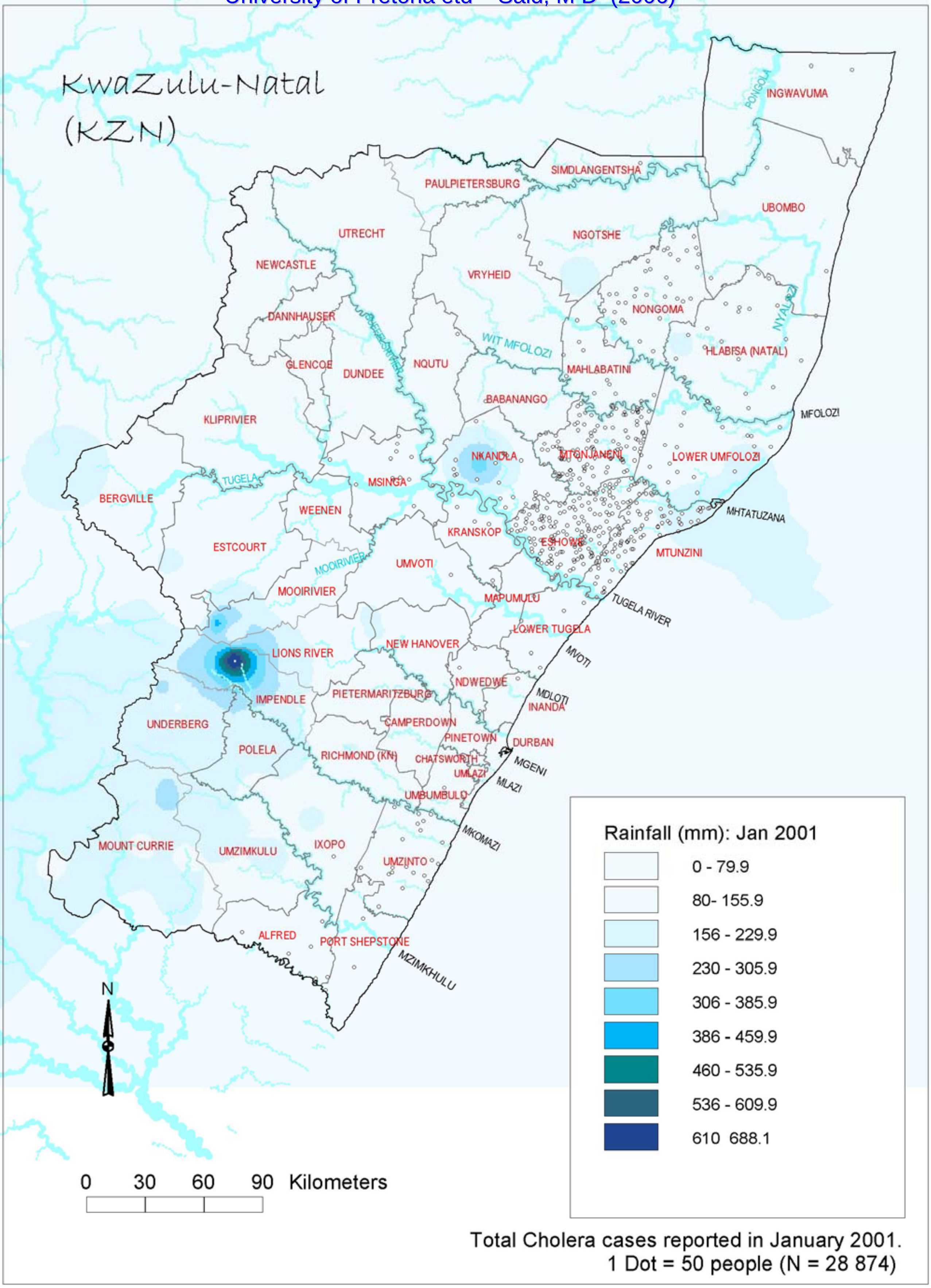
6.2.4.1 Rainfall

In December 2000, the bulk of the cholera case clusters were in the Mtunzini and Eshowe areas, where rainfall of up to 299.9 mm was recorded. A few cases were reported to the north and even less to the south where the rainfall was less (up to 119.9 mm). The spatial picture of the rainfall pattern in December 2000 concurred with the disease foci as seen in Map 18. The fact that statistical correlations linked inadequate sanitation or lack of it to the cholera outbreak makes probable that the heavy rains of December 2000 may have also contributed to the initial spread of the disease. In that the effluent resulted from environmental pollution was carried off into rivers and streams that people depend on for their livelihood. With the presence of cholera in the communities, such conditions inevitably supported further transmission of the disease.

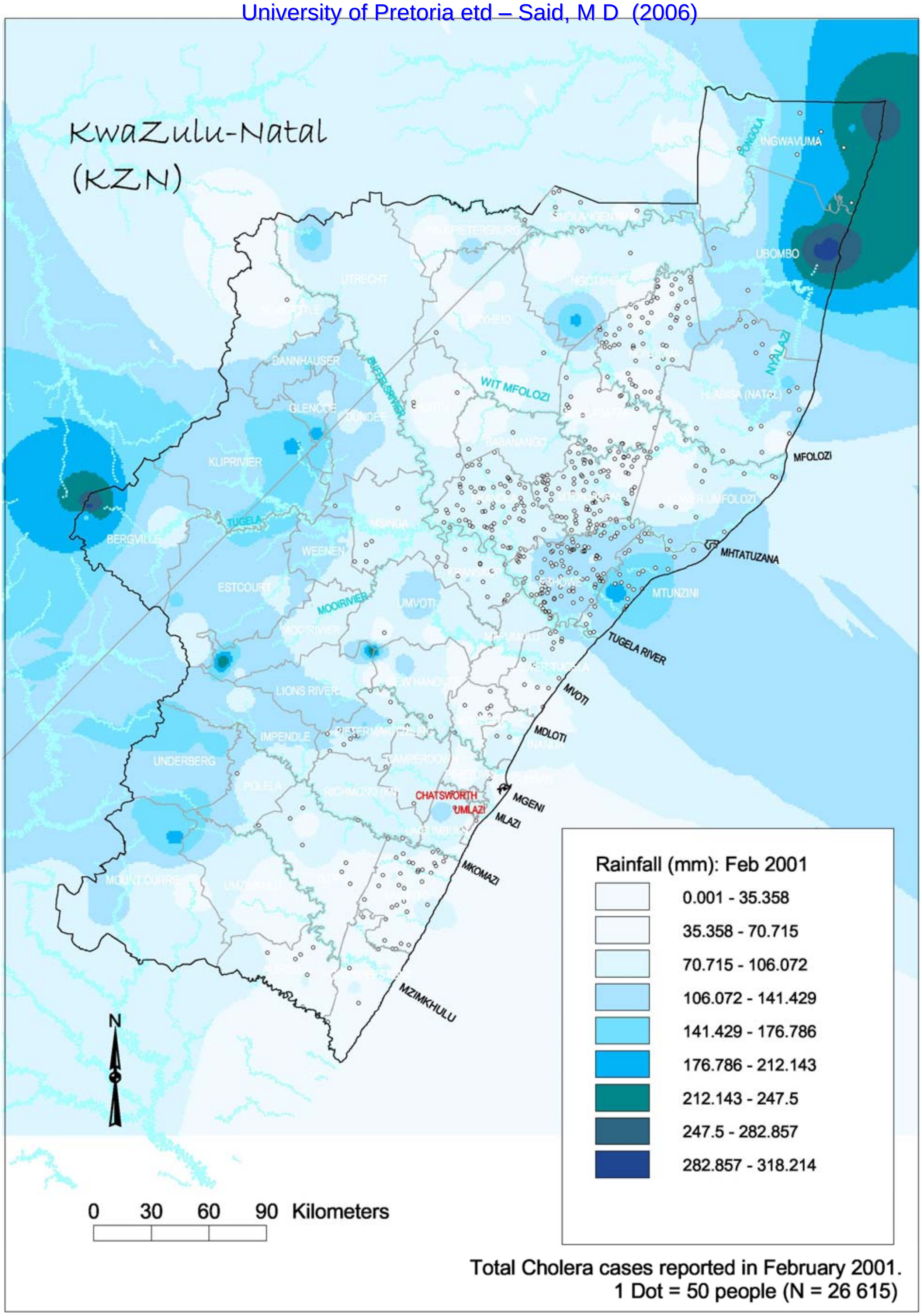
The rains had subsided but not the spread of cholera, possibly because; the rains of the previous month had provided an adequate trigger for cholera to reach epidemic proportions. January 2001 saw an unpredictable situation with an increase of new cases radiating more to the north than to the south of the disease foci along the coastline of KZN (Map 19); affecting the communities of Mtunzini, Eshowe and Mtonjaneni. By February 2001, the heavy case clustering seen around Mtunzini, Eshowe and Mtonjaneni eased slightly, even though the rains did return in the same month, measuring up to 212 mm (Map 20). The effect of the February 2001 rains did not appear to contribute to the disease picture as those of reported in December 2000. This could be attributed to the intervention measures of augmenting health facilities with additional medical personnel to support in the surveillance. Additional intervention measures of establishment of rehydration centres, stock piling medical supplies (ORS, Intravenous fluids, gloves, soap and other essential medical supplies), use of awareness campaigns, distribution of bleach to purify water and water tankers to supply water to rural communities also contributed to reducing the case numbers.



Map 18: Distribution of Cholera cases and monthly rainfall during December 2000 in KZN



Map 19: Distribution of Cholera cases and monthly rainfall during January 2001 in KZN

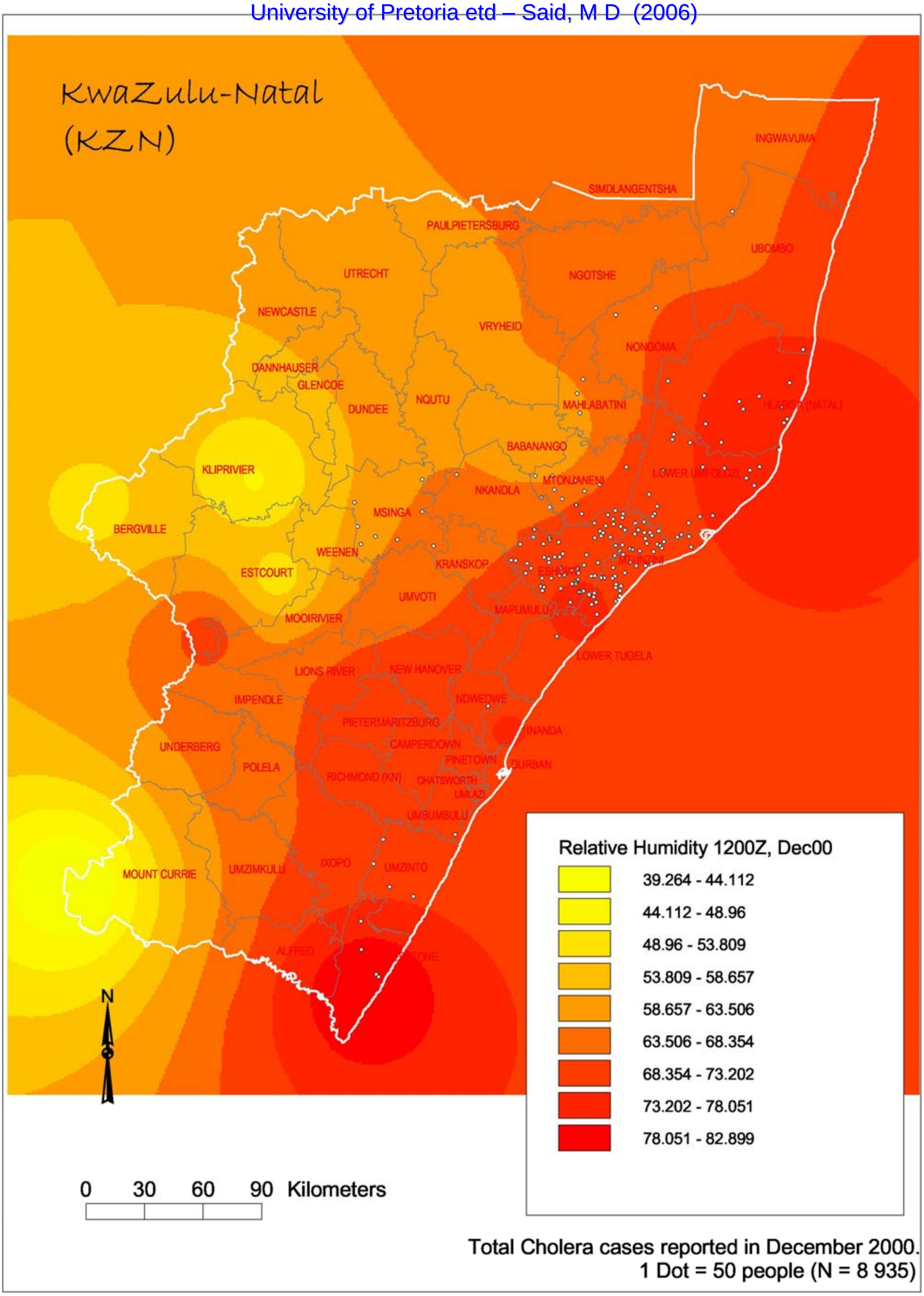


Map20: Distribution of Cholera cases and monthly rainfall during February 2001 in KZN

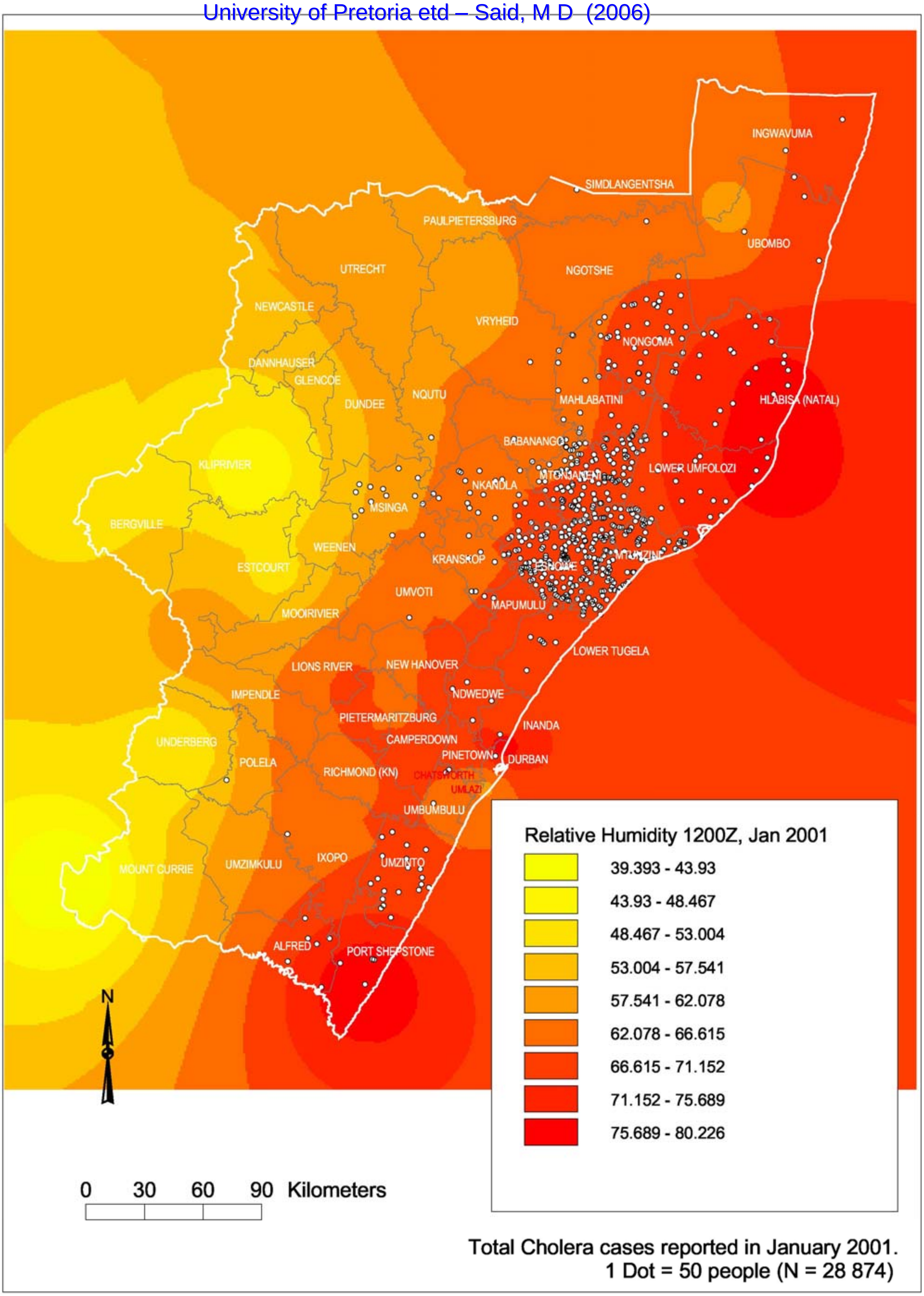
6.2.4.2 Relative Humidity

High humidity levels were reported in the months of December, January and February 2000/01 in KZN (Maps 21-23). The disease focus was amidst a longitudinal belt of humidity of between 73–83% during December 2000. The heavy rains reported during the same month (Map 18) along the coastal border of KZN probably also contributed to these high humidity conditions. Very few cases were reported beyond the longitudinal belt of 63-68% humidity. In the following month of January, the increase in cholera cases coincided with humidity levels of 62-76% along the eastern coastal border of KZN. The areas around Eshowe, Mtunzini and Mtonjaneni experienced higher humidity of between 71-76%.

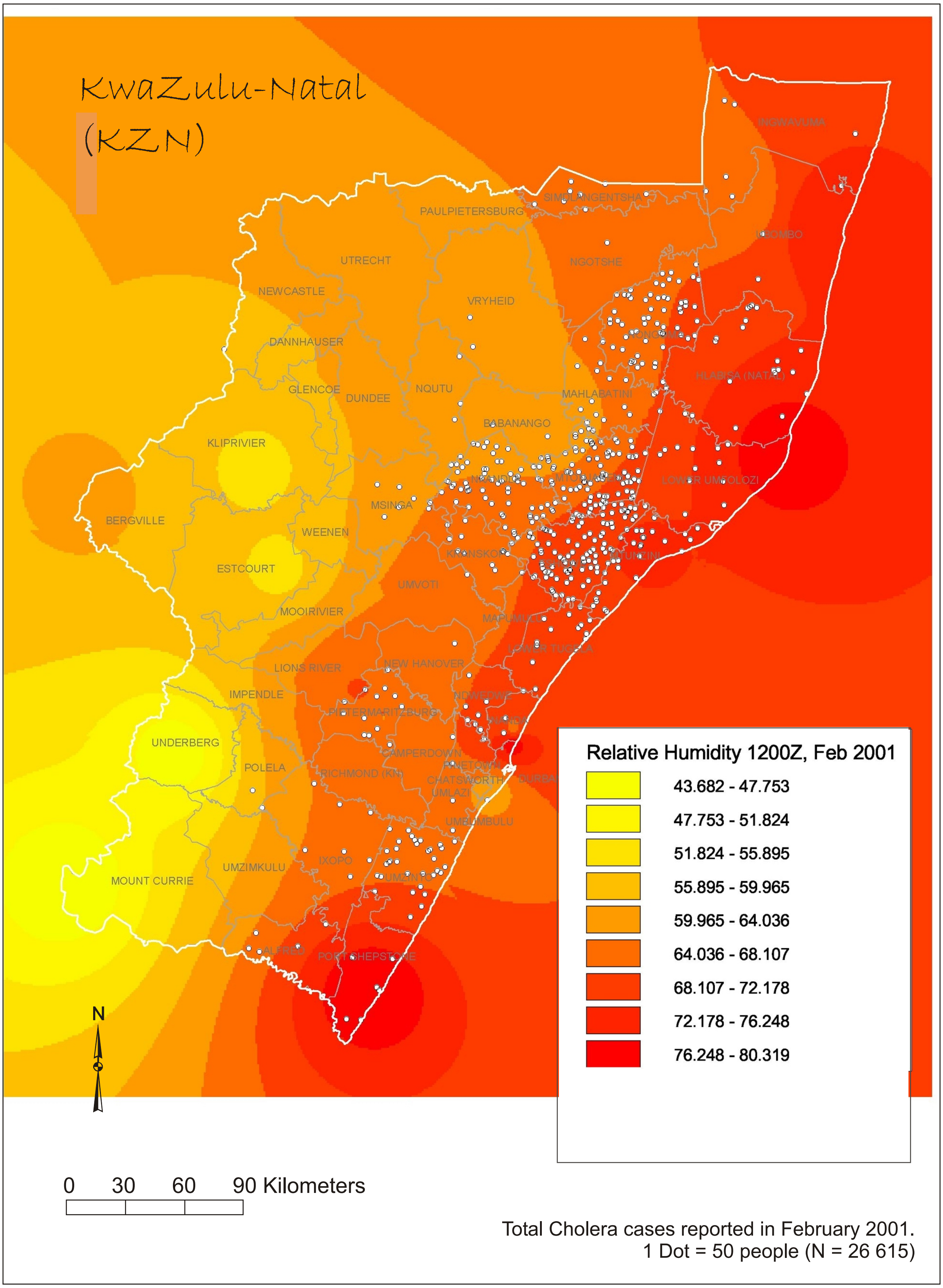
Most of the case clusters that were reported to the north, south and west of the disease foci were confined to areas with humidity levels of at least 62%. The humidity levels in February 2001 were more or less similar to those of January 2001, with most of the case clusters confined to areas with humidity levels of 64% or above. There was not a single case cluster that was reported in areas with humidity below 50%, even with the cases reported to the interior of the province. The initial cholera cases seem to correspond with high humidity (>60%) probably as a result of the heavy rains and from evaporation due to the high temperatures of the time (Maps 24-26). These conditions are known to play an important role in the occurrence of many infectious diseases (Epstein, 2001; Lipp *et al*., 2002). In the case of *V. cholerae,* warm and humid regions have been known to encourage the proliferation of the organisms rapidly to the level of an infective dose (Huq and Colwell, 1996; Pascual *et al*., 2002).



Map21: Distribution of Cholera cases and humidity during December 2000 in KZN



Map22: Distribution of Cholera cases and humidity during January 2001 in KZN

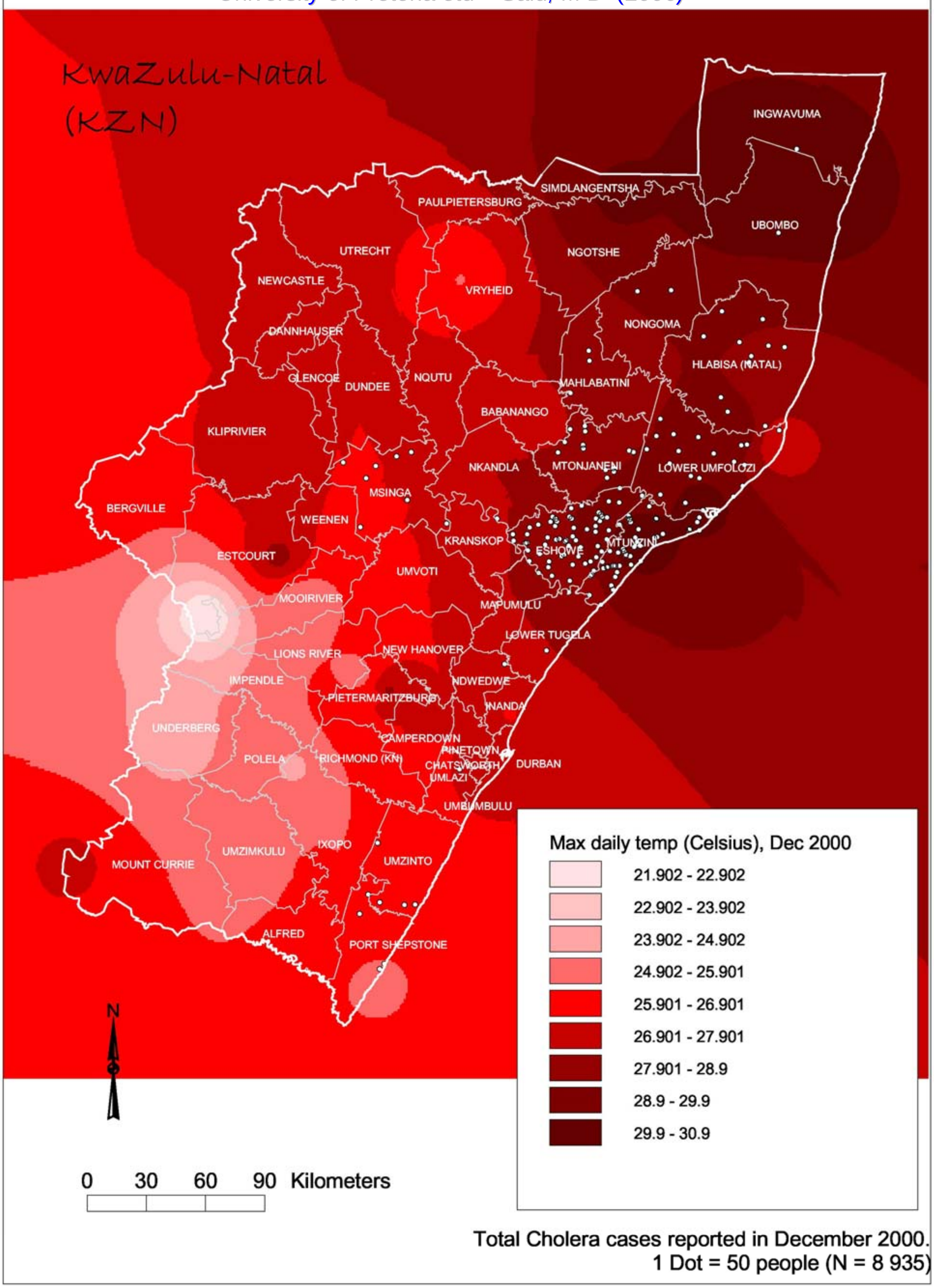


Map 23: Distribution of Cholera cases and humidity during February 2001 in KZN

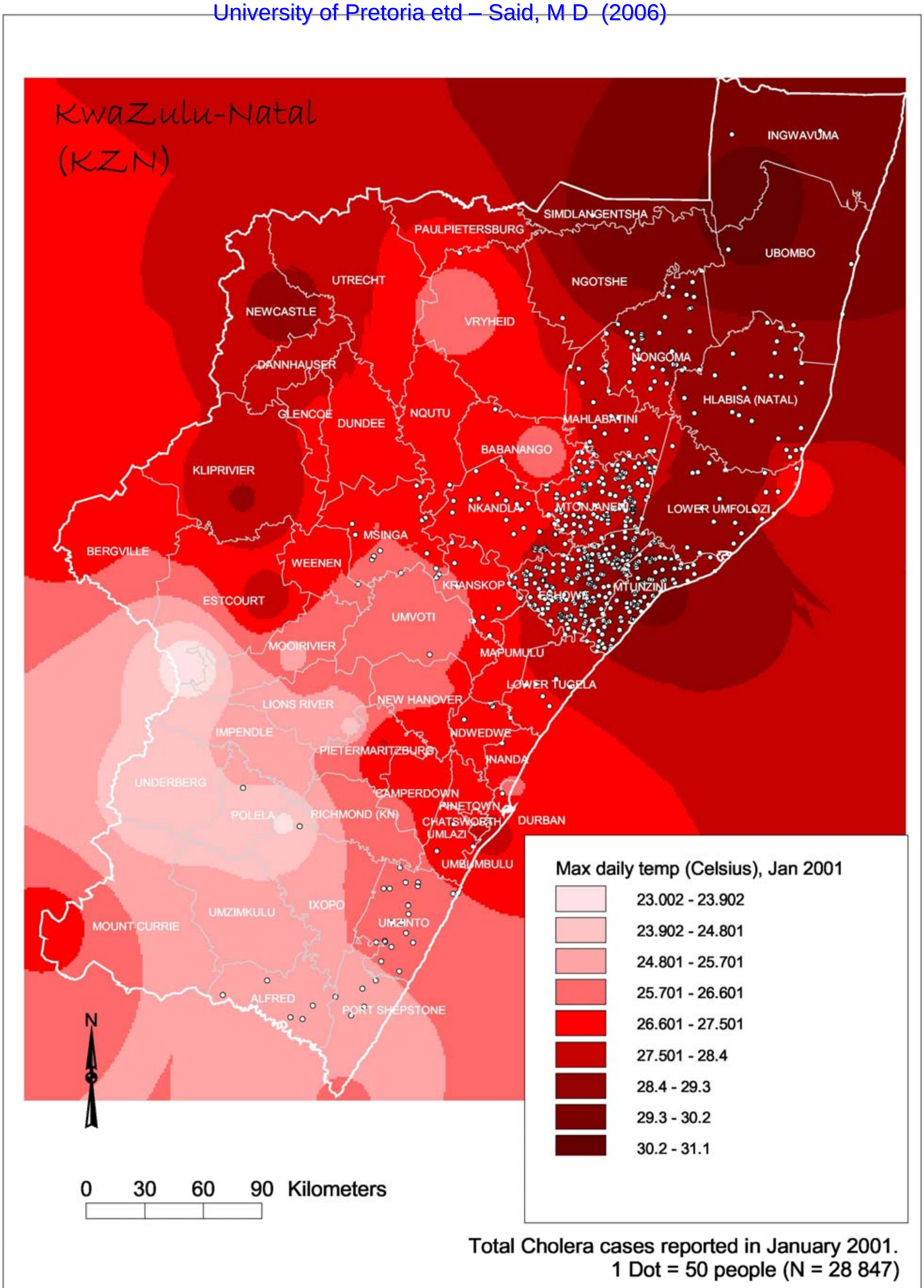
6.2.4.3 Maximum temperature

In the months of December – February 2000/2001, the maximum temperature in KZN ranged between 25-32^{o}C (Maps 24-26). In the Mtunzini and Eshowe areas where most of the cases of December 2000 were reported from, the maximum temperatures ranged between 27-30^{o}C (Map 24). It was much warmer though towards the north-eastern coastal border of the province. The maximum temperatures in Eshowe, Mtunzini and Mtonjaneni were the same in the following month of January 2001; with warmer conditions still persisting in the northeast while the southeast depicted slightly milder maximum temperatures between 23-27 ^{o}C (Map 25). By February 2001, the disease foci in the above-mentioned areas had maximum temperatures of between 27-29^{o}C (Map 26). Overall, the maximum temperature fluctuations between December-February 2000/2001 were minimal with a more or less 1^{o}C change.

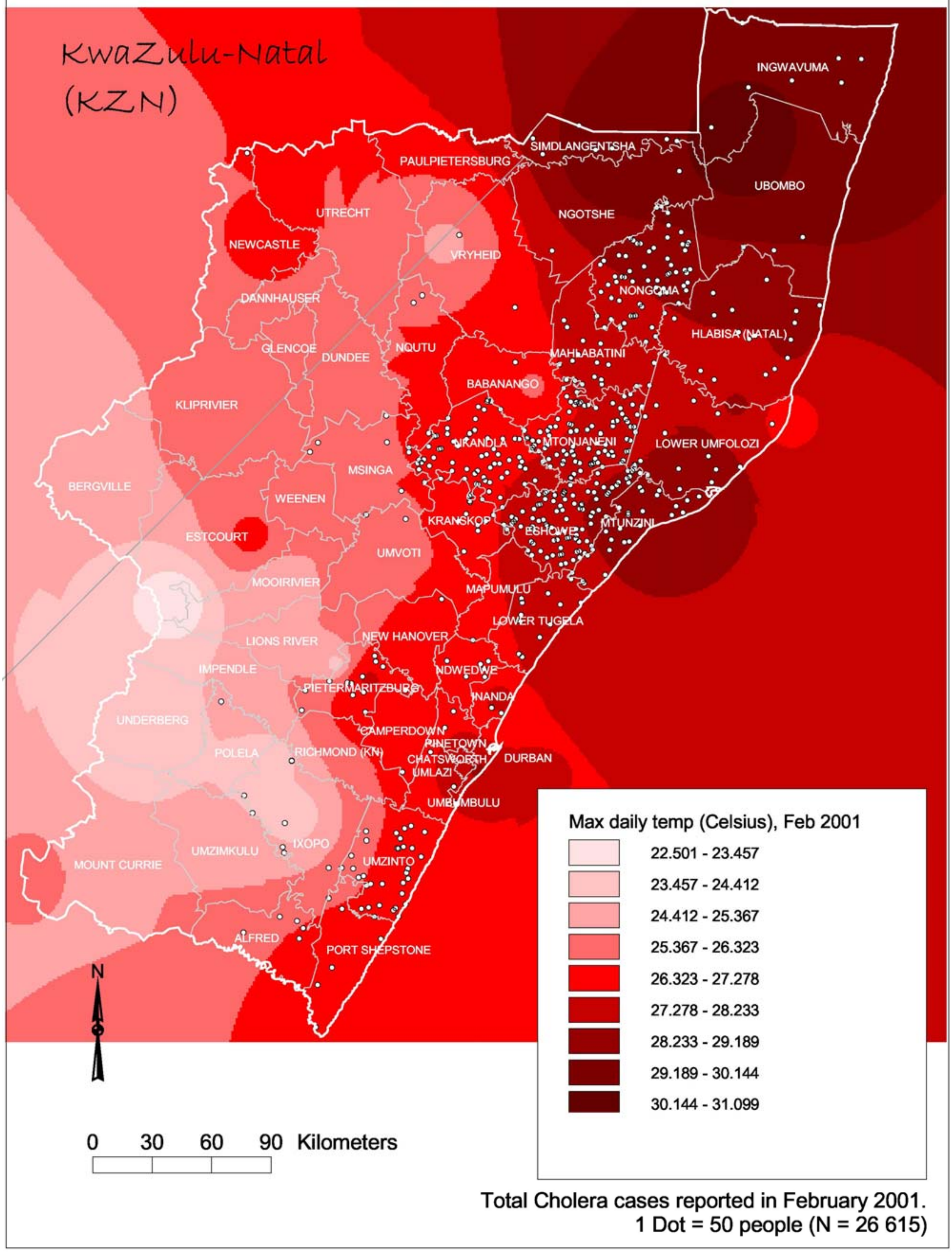
The climatic maps (Maps 18-26) depict that cholera started in the coastal MDs that experienced high rainfall, humidity and maximum temperatures. The disease then spread to the interior, where less rain, low humidity and milder maximum temperatures were recorded. The climatic conditions of the coastal MDs were ideal for cholera in that high temperatures, high humidity and the estuarine environments, were optimum for the growth of *V. cholerae*. Such condition*s were* supported by Lipp *et al*., (2002) when they reviewed cholera as a model for climate related infectious disease. Huq and Colwell (1996) also reported that warm and humid regions supported the rapid proliferation of *V. cholerae* to the level of an infective dose. During a cholera outbreak in Lima, Peru, Speelmon *et al.,* (2000) demonstrated that high ambient temperature was positively correlated with the number of cholera cases. Louis *et al*., (2003) supported the role that marine ecology and estuarine environments play in the survival of *V. cholerae*. Results from their sampling experiments in the northern Chesapeake Bay frequently detected *V. cholerae* during the warmer months and where the salinity is lower (Baumann *et al.,* 1984, Colwell *et al.,* 1977; Hood *et al.,* 1981; Tamplin *et al.,* 1990).



Map24: Distribution of Cholera cases and maximum temperature during December 2000 in KZN



Map25: Distribution of Cholera cases and maximum temperature during January 2001 in KZN

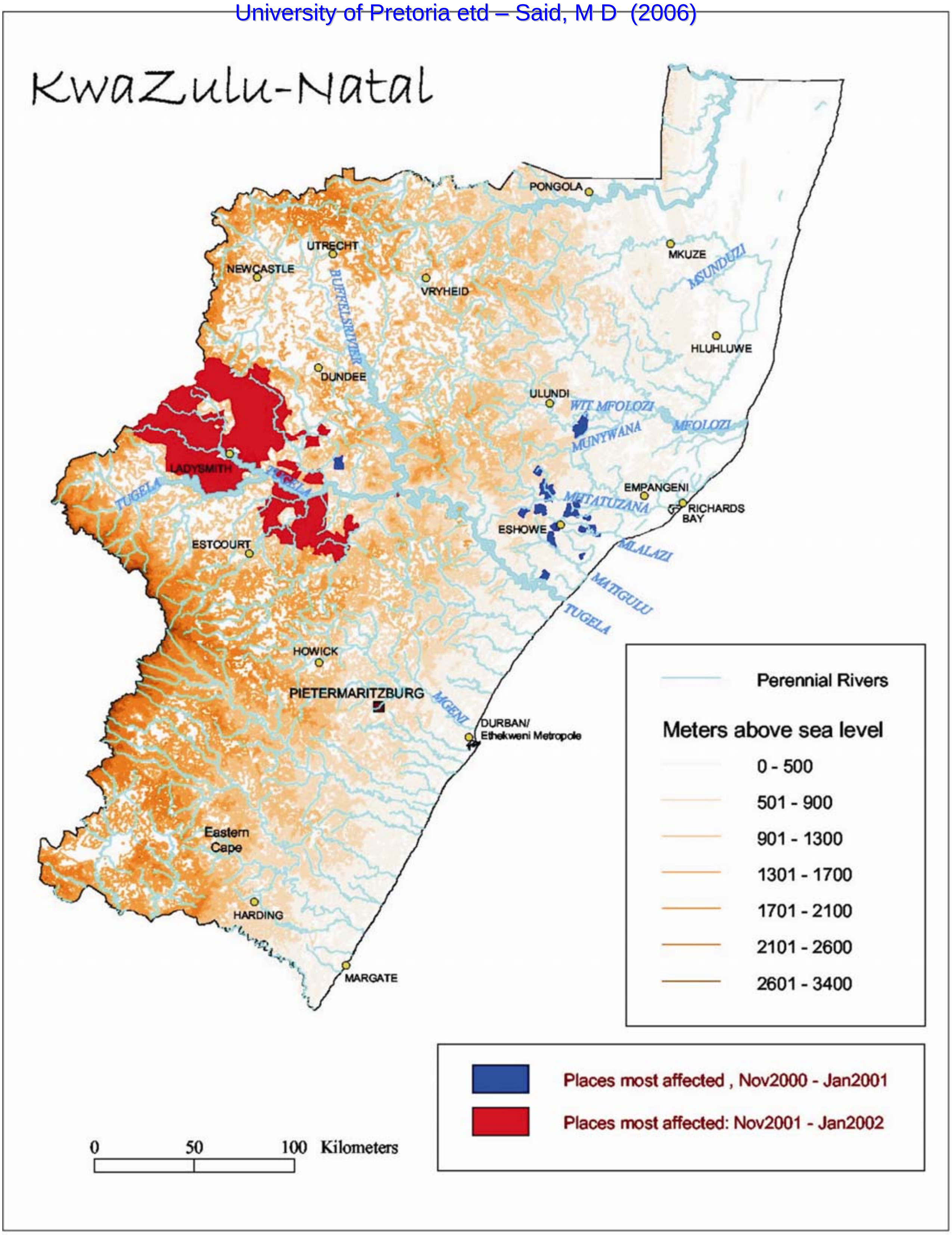


Map26: Distribution of Cholera cases and maximum temperature during February 2001 in KZN

6.3 Spatial modelling for ranking high-risk cholera areas

There were a total of 2 741 place-names (communities) listed in the attribute database. Among these, 1 316 (48%) place-names did not report cholera; 176 place-names reported only 1 case (6.4%). At the higher scale of reporting, only 47 (4.7%) place-names reported between 251 to over 4000 cases, which the rest of the case ranges being represented within the remainder, 1202 place-names (40.8%). This shows that less than 5% of the listed communities of KwaZulu-Natal had reported cholera in numbers above 250 cases. Thus, for the purpose of spatial modelling of high risk cholera areas, a total of 30 place names were selected; with 15 place names that ranked highest during the major peak and the rest during the minor peak. All of the 15 top places of the major peak belonged to DC28, save for one that belonged to DC23 (Map 27). During the minor peak, 10 places belonged to DC23 and the remainder 5 to DC24. Thus indicating that even during the major peak, cholera already had a foothold in DC23. Tables 6.5 and 6.6 give a case profile of the places over the December-February 2000/01 period. Almost all the 30 top places, except for Mtunzini, had a progressive increase in cholera case reports from November to January of 2000-2002. This cholera case progression compared with the upward trend of the peaks of 2000/01 and 2001/02 respectively. The spatial positioning of the 30 top places also revealed an additional aspect of their locality, i.e. being close to the main rivers of KZN or their tributaries (Map 27). An association that was statistically supported, i.e. river water as a risk factor for the incidence of cholera.

A break down of the water and sanitation services between the top 15 places of the major and the top 15 places of the minor peak is detailed in Figures 6.1 and 6.2 respectively. These water and sanitation aspects were also incorporated in the spatial modelling process. DC28 was worst off than DC23 in the basic services sector. 44.3% of the households in DC28 used rivers water as compared to 19.1% in DC23 while 48% of households in DC 23 had piped water compared to 26.5% in DC28. The availability of the piped water facility is also indirectly reflected in the sanitation sector where more households in DC23 (34.9%) had flush toilets compared to those in DC28 (27.9%). There were more households in DC28 (69.8%) with pit latrines than in DC23 (60.2%).



Map 27: **Location of perennial rivers in relation to the places most affected by cholera in KZN**

WATER SUPPLY for top 15 places (First Peak) in mostly DC28

MAJOR PEAK

Piped water in house
Sum: 1451
Count: 15
Mean: 97
Maximum: 1277
Minimum: 0
Range: 1277
Variance: 107785
Standard Deviation: 328

Public Tap
Sum: 1400
Count: 15
Mean: 93
Maximum: 1316
Minimum: 0
Range: 1316
Variance: 114596
Standard Deviation: 339

Water Tank
Sum: 58
Count: 15
Mean: 4
Maximum: 29
Minimum: 0
Range: 29
Variance: 83
Standard Deviation: 9

Borehole or tank
Sum: 337
Count: 15
Mean: 22
Maximum: 121
Minimum: 0
Range: 121
Variance: 1096
Standard Deviation: 33

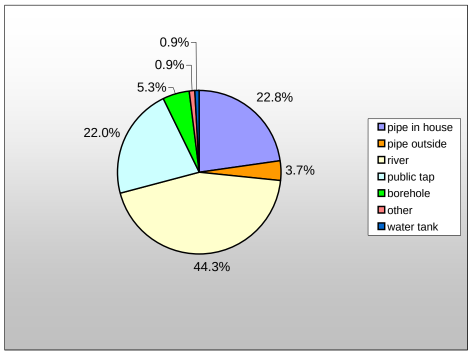
Water from river
Sum: 2818
Count: 15
Mean: 188
Maximum: 741
Minimum: 0
Range: 741
Variance: 40013
Standard Deviation: 200

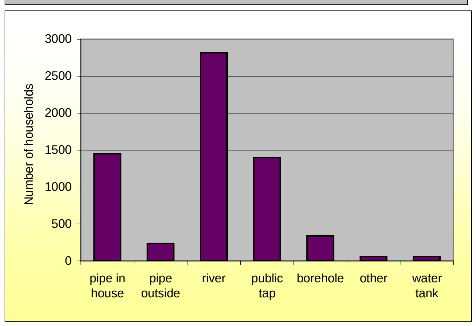
Water - other sources
Sum: 59
Count: 15
Mean: 4
Maximum: 17
Minimum: 0
Range: 17
Variance: 29
Standard Deviation: 5

Piped water on stand
Sum: 236
Count: 14
Mean: 17
Maximum: 191
Minimum: 0
Range: 191
Variance: 2649
Standard Deviation: 51

Summary	
pipe in house	1451
pipe outside	236
river	2818
public tap	1400
borehole	337
other	59
water tank	58

6359 =Total





WATER SUPPLY for top 15 places (Second Peak) in mostly DC23

SECOND PEAK

MINOR PEAK

Piped water in house
Sum: 6110
Count: 15
Mean: 407
Maximum: 5425
Minimum: 0
Range: 5425
Variance: 1937900
Standard Deviation: 1392

Public Tap
Sum: 3809
Count: 15
Mean: 254
Maximum: 1639
Minimum: 0
Range: 1639
Variance: 176995
Standard Deviation: 421

Water Tank
Sum: 199
Count: 15
Mean: 13
Maximum: 99
Minimum: 0
Range: 99
Variance: 662
Standard Deviation: 26

Borehole or tank
Sum: 3328
Count: 15
Mean: 222
Maximum: 990
Minimum: 0
Range: 990
Variance: 91998
Standard Deviation: 303

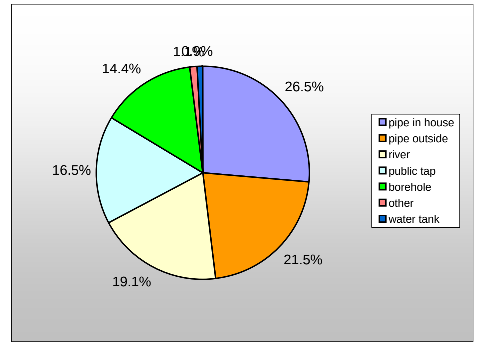
Water from river
Sum: 4416
Count: 15
Mean: 294
Maximum: 1696
Minimum: 0
Range: 1696
Variance: 220451
Standard Deviation: 470

Water - other sources
Sum: 247
Count: 15
Mean: 16
Maximum: 95
Minimum: 0
Range: 95
Variance: 881
Standard Deviation: 30

Piped water on stand
Sum: 4955
Count: 15
Mean: 330
Maximum: 3639
Minimum: 0
Range: 3639
Variance: 855924
Standard Deviation: 925

Summary	
pipe in house	6110
pipe outside	4955
river	4416
public tap	3809
borehole	3328
other	247
water tank	199

23064 = Total



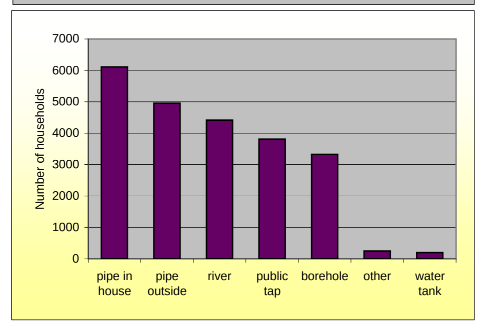


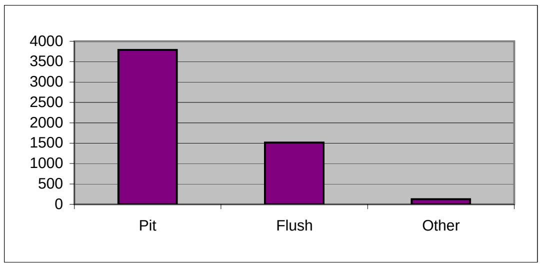
Figure 6.1: The status of the water services/options for the top 15 places of the major and minor peaks respectively .

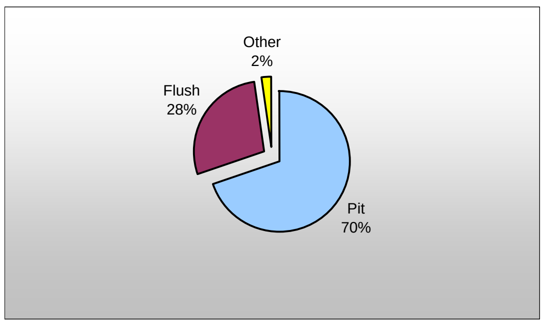
SANITATION for top 15 places (First Peak) in mostly DC28

MAJOR PEAK

Pit toilet
Sum: 3789
Count: 15
Mean: 253
Maximum: 2782
Minimum: 0
Range: 2782
Variance: 502120
Standard Deviation: 709
Flush Toilet
Sum: 1514
Count: 15
Mean: 101
Maximum: 1320
Minimum: 0
Range: 1320
Variance: 114928
Standard Deviation: 339
Bucket
Sum: 20
Count: 15
Mean: 1
Maximum: 5
Minimum: 0
Range: 5
Variance: 3
Standard Deviation: 2
Toilet Other & unspecified
Sum: 107
Count: 15
Mean: 7
Maximum: 61
Minimum: 0
Range: 61
Variance: 238
Standard Deviation: 15

Pit	3789
Flush	1514
Other	127



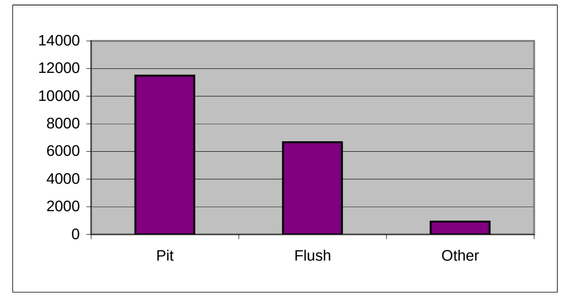


SANITATION for top 15 places (Second Peak) in mostly DC23

MINOR PEAK

Pit toilet
Sum: 11491
Count: 15
Mean: 766
Maximum: 3849
Minimum: 15
Range: 3834
Variance: 1288784
Standard Deviation: 1135
Flush Toilet
Sum: 6665
Count: 15
Mean: 444
Maximum: 6278
Minimum: 0
Range: 6278
Variance: 2610156
Standard Deviation: 1616
Bucket
Sum: 811
Count: 15
Mean: 54
Maximum: 396
Minimum: 0
Range: 396
Variance: 15672
Standard Deviation: 125
Toilet Other & unspecified
Sum: 113
Count: 15
Mean: 8
Maximum: 41
Minimum: 0
Range: 41
Variance: 178
Standard Deviation: 13

Pit	11491
Flush	6665
Other	924



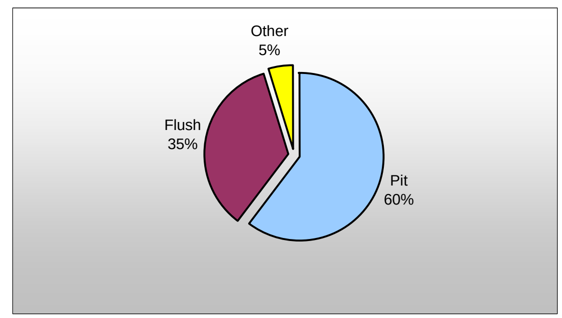


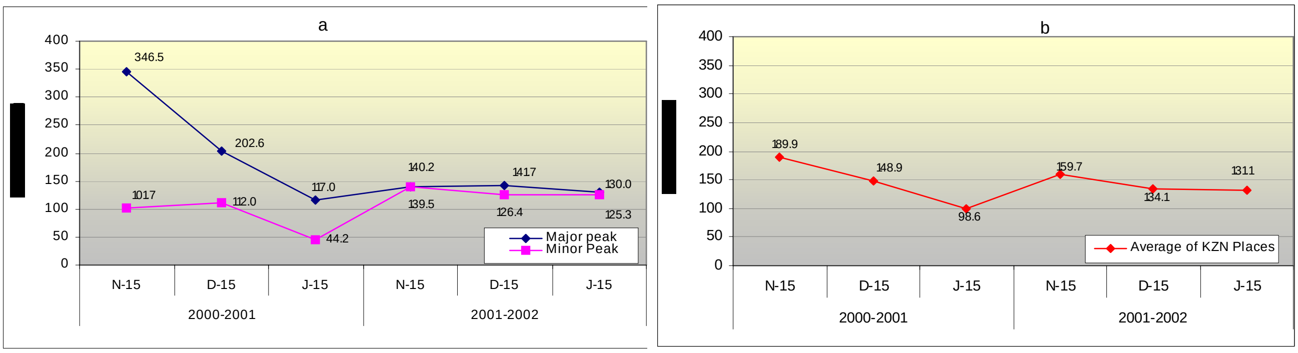
Figure 6.2: The status of the sanitation options for the top 15 places of the major and minor peaks respectively.

Table 6.5: Top 15 places that reported high cholera case numbers during the major peak.

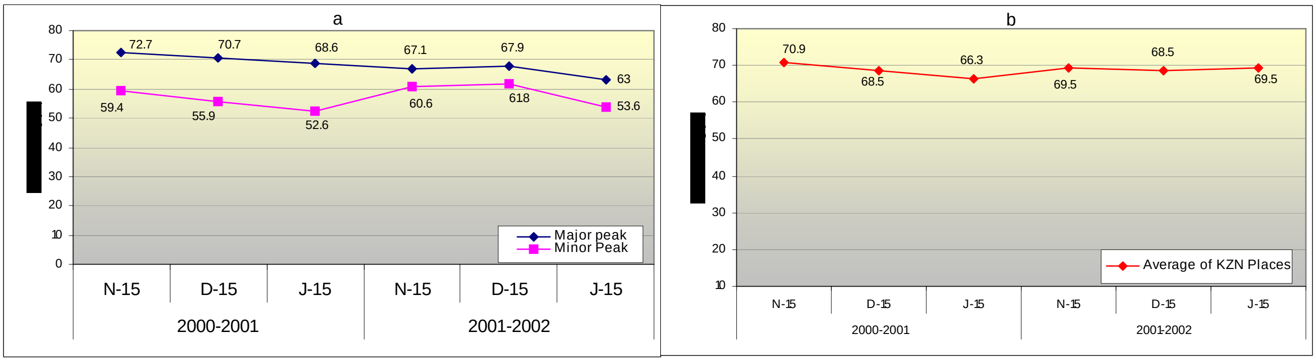
Place-name	Magisterial District	District Council No.	Total cases 00-04	Nov_00 cases	Dec_00cases	Jan_01 cases	Sub Total
Mfanefile	Mthonjaneni	28	4777	0	18	990	1008
Lumbi	Mthonjaneni	28	4168	0	6	1012	1018
Mpumaze	Eshowe	28	2857	0	498	1611	2109
Mabhudle	Eshowe	28	2476	201	379	690	1270
Endlondlweni	Eshowe	28	2201	402	595	699	1696
Izimpongo Eziphansi	Eshowe	28	1959	6	189	645	840
Emtembeni	Mthonjaneni	28	1953	0	66	801	867
Vongotho	Mtunzini	28	1848	21	513	990	1524
Emaqeleni	Eshowe	28	1701	3	111	465	579
Obanjeni	Msinga	23	1455	33	394	627	1054
Habeni	Eshowe	28	905	6	112	424	542
Mhlathuzana	Mtunzini	28	1166	6	121	515	642
Izikoshi	Mtunzini	28	832	102	306	355	763
Ngunundu	Eshowe	28	819	21	210	318	549
Gingindlovu	Mtunzini	28	783	117	271	210	598

Table 6.6: Top 15 places that reported high cholera case numbers during the minor peak.

Place-name	Magisterial District	District Council No.	Total cases 00-04	Nov_01 cases	Dec_01 cases	Jan_02 cases	Sub Total
Watersmeet	Klipriver	23	1081	6	178	589	773
Ezakheni	Klipriver	23	1052	1	173	447	621
Wittekleinfontein	Klipriver	23	716	6	211	292	509
Peace Town	Klipriver	23	688	2	84	458	544
Modderspruit	Klipriver	23	566	0	32	120	152
Ekuvukeni	Glencoe	24	557	0	30	109	139
Weenen NU	Weenen	23	516	0	4	189	193
Klipriver NU	Klipriver	23	464	4	67	116	187
Rockcliff	Dundee	24	371	0	6	261	267
Mjinti	Klipriver	23	199	6	45	76	127
Imbangi-Somshoek	Dundee	24	316	0	10	256	266
Oqungweni	Msinga	23	265	0	50	92	142
Limehill	Dundee	24	244	0	65	106	171
Uitvaal	Dundee	24	120	2	26	58	86
Mziyonke	Klipriver	23	111	0	34	56	90

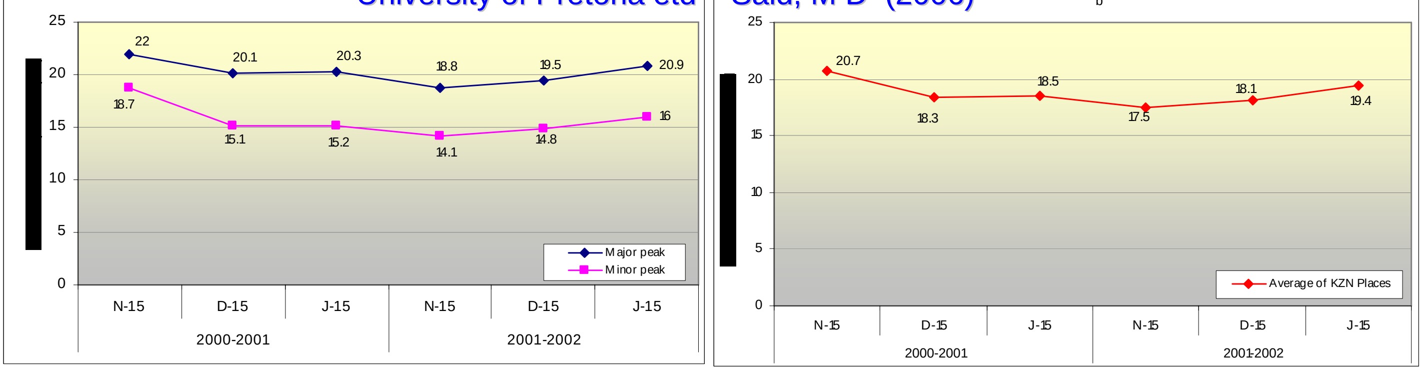


Figures 6.3a-b: A comparison of the average rainfall of the 30 most affected places in relation to that of the entire KZN province.

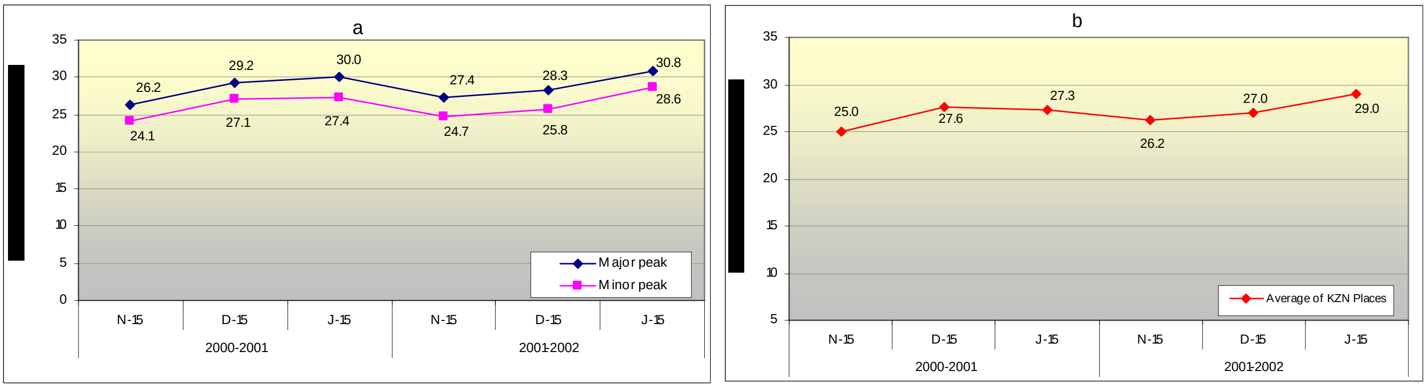


Figures 6.4a-b: A comparison of the average relative humidity of the 30 most affected places in relation to that of the entire KZN province.

At the climatic level, patterns to compare the average climatic profiles of the selected place-names to the averages of the rest of the place-names in the attribute database are illustrated in the graphs depicted by Figures 6.3-6.6. From November-January 2000/2001, the top 15 places had comparatively higher rainfall than that for the whole of KZN, though their rainfall averages were comparable during the minor peak months (6.3a-b). The heavy rains experienced in the top 15 places of the major peak could have stimulated the *V.cholerae* strains in the environmental reservoirs to multiply to infective proportions. Rainfall averages of the top 15 places of the minor peak were consistently lower than the provincial average during both the peaks. This indicated that the interior of the province experienced less rain than the provincial average.



Figures 6.5a-b: A comparison of the average minimum temperatures of the 30 most affected places in relation to that of the entire KZN province.



Figures 6.6a-b: A comparison of the average maximum temperatures of the 30 most affected places in relation to that of the entire KZN province.

During the major peak, the relative humidity was higher in the top 15 places of the major peak when compared to the provincial average (Figure 6.4a-b). This trend was reversed during the minor peak season whereby the top 15 areas that featured in the minor peak had generally lower humidity levels than the provincial average. This is to be expected considering these areas are more to the interior of the province where the topology is generally mountainous and the air more dry. Minimum and maximum temperatures of the top 15 places of the major peak were consistently higher than the provincial averages (Figures 6.5a-b and 6.6a-b). Thus indicating that these areas had warmer conditions during the epidemic peaks. A contrasting situation persisted with the top 15 places of the minor peak, whereby both the minimum and maximum temperatures were generally lower than the provincial averages (Figures 6.5a-b and 6.6a-b).

6.3.1 The spatial model

These consistent variations in the rainfall, humidity and temperature between the top 15 places of the major peak and the top 15 places of the minor peak suggested that two spatial models be developed depending on the height above sea level. This is because the two peaks occurred in two different geographical niches i.e. one near the coast and the other to the interior. The two peaks were also associated with contrasting climatic conditions as well as different socio-economic conditions (Figures 6.1 and 6.2). The two spatial models suggested were thus referred to as the Lowland and the Highland models respectively. The variables related to the lowlands model and the highlands models are illustrated in Figures 6.7 and 6.8 respectively. Table 6.7 gives additional information on the environmental and socio-economic factors used in the two models and subsequently in the creation of the risk maps.

From the original dataset, the average NDJs rainfall, humidity, minimum and maximum temperatures of 2000-2004 were calculated using filed calculations within ArcView GIS 3.3. Thus the averages used in the creation of risk maps are given in Table 6.7. Cholera cases were not included in the criteria, as they were not considered to be the disease drivers *per se*. In the context of the spatial model, cholera cases were rather a consequence of the environmental and socio-economic factors. Climatic and the socio-economically related factors of water and sanitation were considered as potential drivers of cholera outbreaks. Four different criteria were put forward in the creation of the risk maps. Table 5.8 gives a guide of what type of environmental and socio-economic factors made up of the 4 criteria, which are explained below:

- Criterion 1: Used all the highlighted factors of the 1^{st} peak NDJ of 2000/01.
- Criterion 2: Used all the highlighted factors of the 2^{nd} peak NDJ of 2001/02.
- Criterion 3a: Used the highlighted factors of the average NDJs of 2000/04 and the highlighted socio-economic factors of the 1^{st} peak NDJ of 2000/01.
- Criterion 3b: Used the highlighted factors of the average NDJs of 2000/04 and the highlighted socio-economic factors of the 2^{nd} peak NDJ of 2001/02.

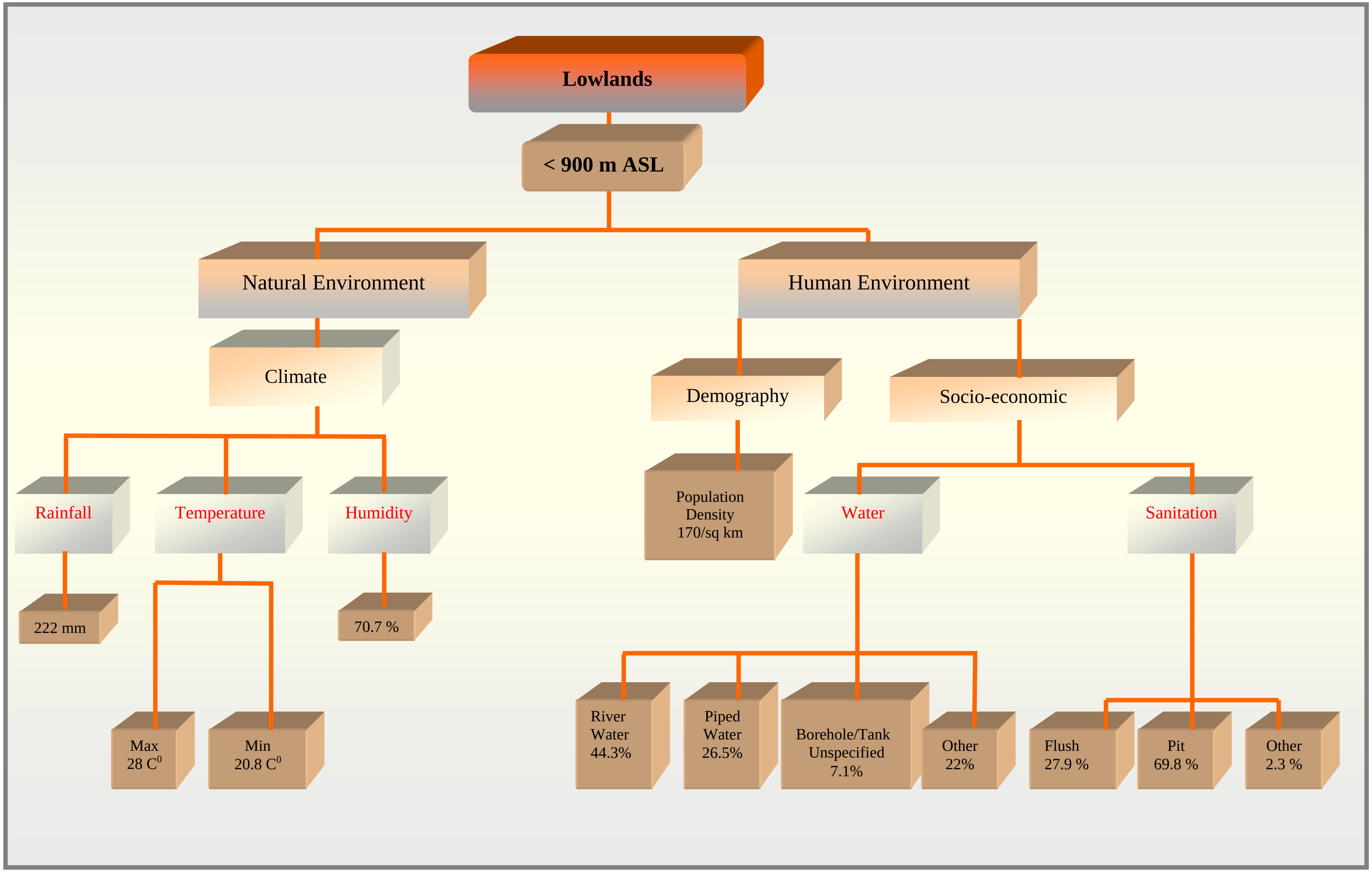


Figure 6.7: Flow diagram showing the climatic, demographic and socio-economic variables related to the Lowland Model.

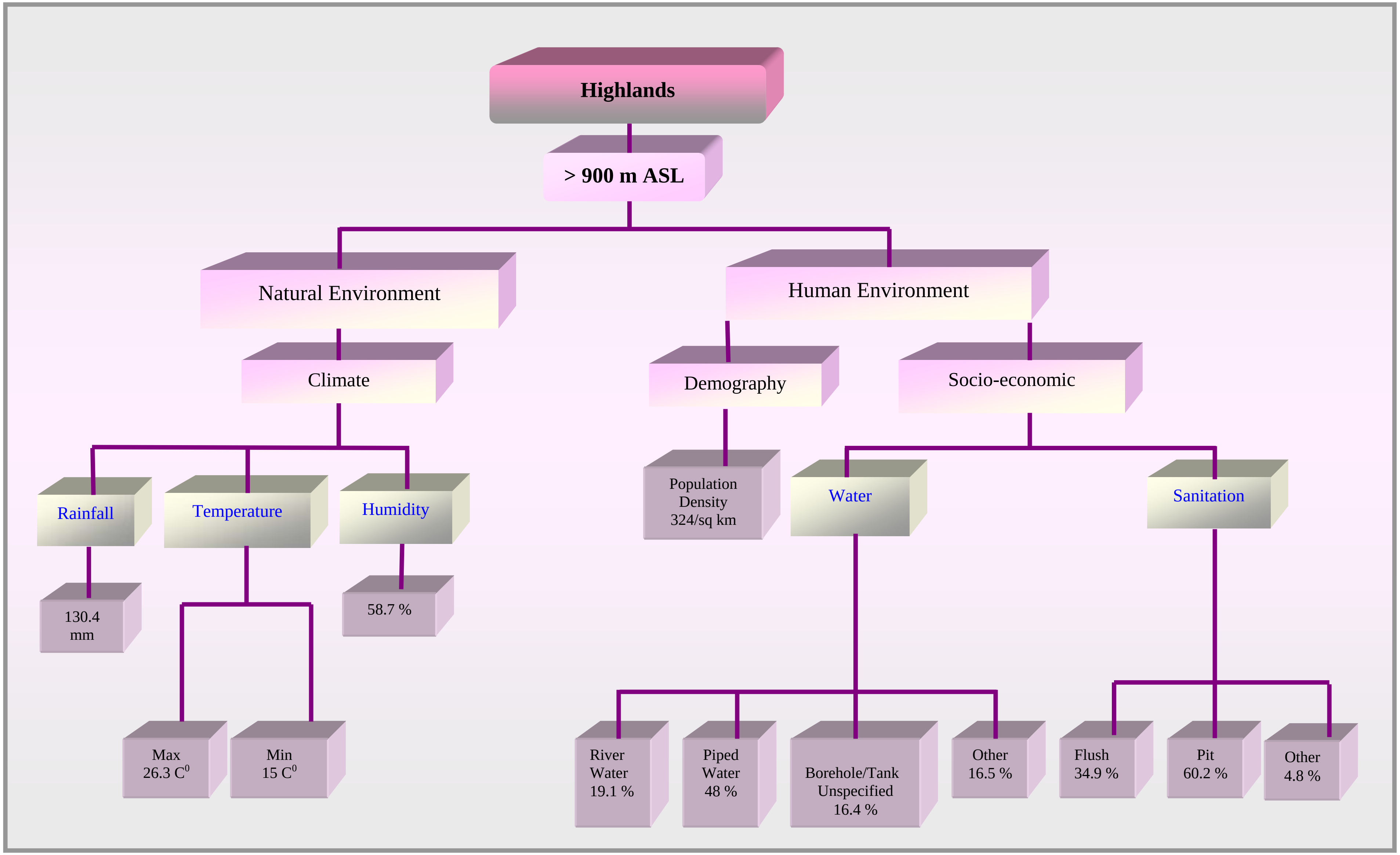


Figure 6.8: Flow diagram showing the climatic, demographic and socio-economic variables related to the Highland Model.

Table 6.7: Factors used in the creation of the spatial model to create risk maps

	Top 15 places	Top 15 places	All places	All places	All places	All places	Average (All places)
	1st Peak NDJ 2000/01	2nd Peak NDJ 2001/02	NDJ 2000/01	NDJ 2001/02	NDJ 2002/03	NDJ 2003/04	NDJ 2000/04
ENVIRONMENTAL FACTORS							
Height - ASL	<900 m	>900 m	Varies from sea level to 3 400 m				
Humidity	70.7 %	58.7%	68.6%	69.2%	65.8%	64.3%	67.0%
Rainfall	222 mm	130.4 mm	145.8 mm	141.6 mm	86.5 mm	114 mm	122 mm
Temperature							
- Maximum	28.0°C	26.2°C	26.6°C	27.4°C	27.3 °C2	27.6°C	27.2°C
- Minimum	20.8°C	15.0°C	19.2°C	18.4°C	17.4°C	17.6°C	18.15°C
- Variation	7.2°C	11.2°C	7.4°C	9.0°C	9.9°C	10.0°C	9.0°C
SOCIO-ECONOMIC FACTORS							
Population Density / m^2	171	324					
Population: Max density / m^2	701	1610					
Water Supply							
-Piped water in house	22.8%	26.5%					
-Piped water in yard	3.7%	21.5%					
-River	44.3% [a]	19.1% [b]					
-Public Tap	22.0%	16.5%					
-Borehole	5.3%	14.4%					
-Other	1.8%	2.0%					
Sanitation							
-Flush	27.9%	60.2%					
-Pit	69.8% [a]	34.9% [b]					
-Other	2.3%	4.8%					
Cholera cases (NDJ)	15 059	4267					

* NDJ = Nov-Dec-Jan
*ASL = Above Sea Level

Criterion 1 **Criterion 2** **Criterion 3 a** **Criterion 3 b**

Source: Values computed from primary and secondary data in GIS

Boolean Operators were used in ArcView GIS 3.3 to make spatial queries on the 4 criteria put forward. This means that selecting the climatic and socio-economic factors making up each criterion tested each of the 4 criteria. Thus, depending on the criterion, the specific factors were selected using Boolean Operators in GIS Arcview. This process then sought for places (communities) that portrayed the specific factors selected for. Table 6.8 lists the outcome of the spatial queries according to the individual criteria and the NDJ data values of the four-year epidemic span, which is the selection of the number of places that showed high risk to cholera. Criterion 1 did not fit any other NDJ period other than that of the major peak i.e. NDJ 2000/01, indicating it was specific in seeking out only the place names that closely experienced the factors that fit it (Criterion 1). This implied that the factors making up Criterion 1 were probably due to the unusual climatic conditions of heavy rainfall; high humidity and high temperatures of the year 2000 create chance events. This led to Criterion 1 picking up the least number of places as compared to the other criteria (Map 29). Criterion 2, though relatively better than Criterion 1, was still not the ideal situation, considering that it did not select any places to be at risk of cholera in 2000/01, which was the year; the epidemic produced its major peak (Map 30).

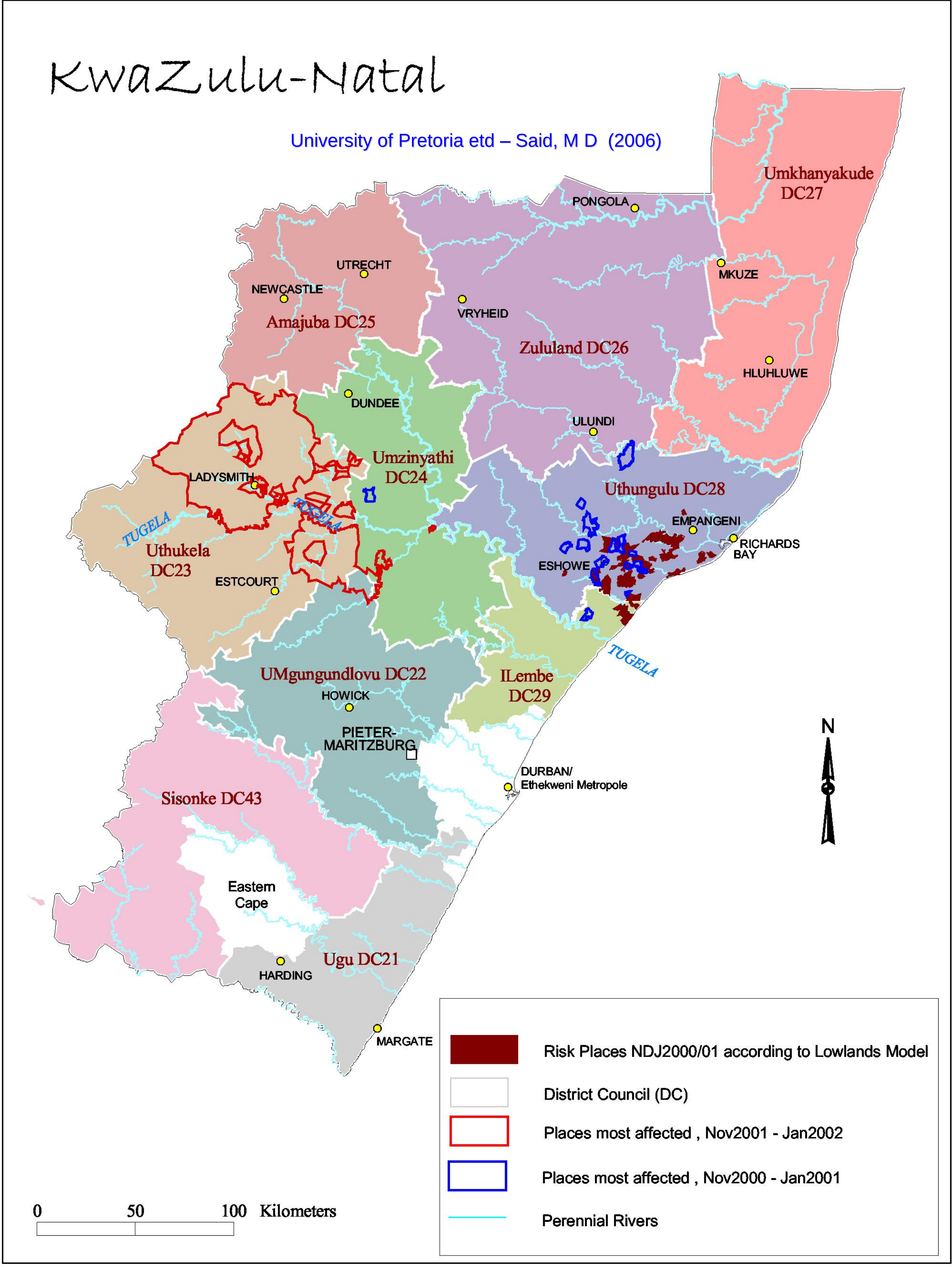
Table 6.8: The different selection criteria used in the risk assessment model versus the datasets of the Nov-Dec-Jan (NDJ) months of the 4 years.

	Data of NDJ 2000/01	Data of NDJ 2001/02	Data of NDJ 2002/03	Data of NDJ 2003/4
Criterion 1	√ (50 places) Refer Map 29	x	x	x
Criterion 2	x	√ (495 places) Refer Map 30	x	√ (183 places) Refer Map 31
Criterion 3 a	√ (368 places) Refer Map 32	x	x	x
Criterion 3 b	√ (450 places) Refer Map 33	x	x	x

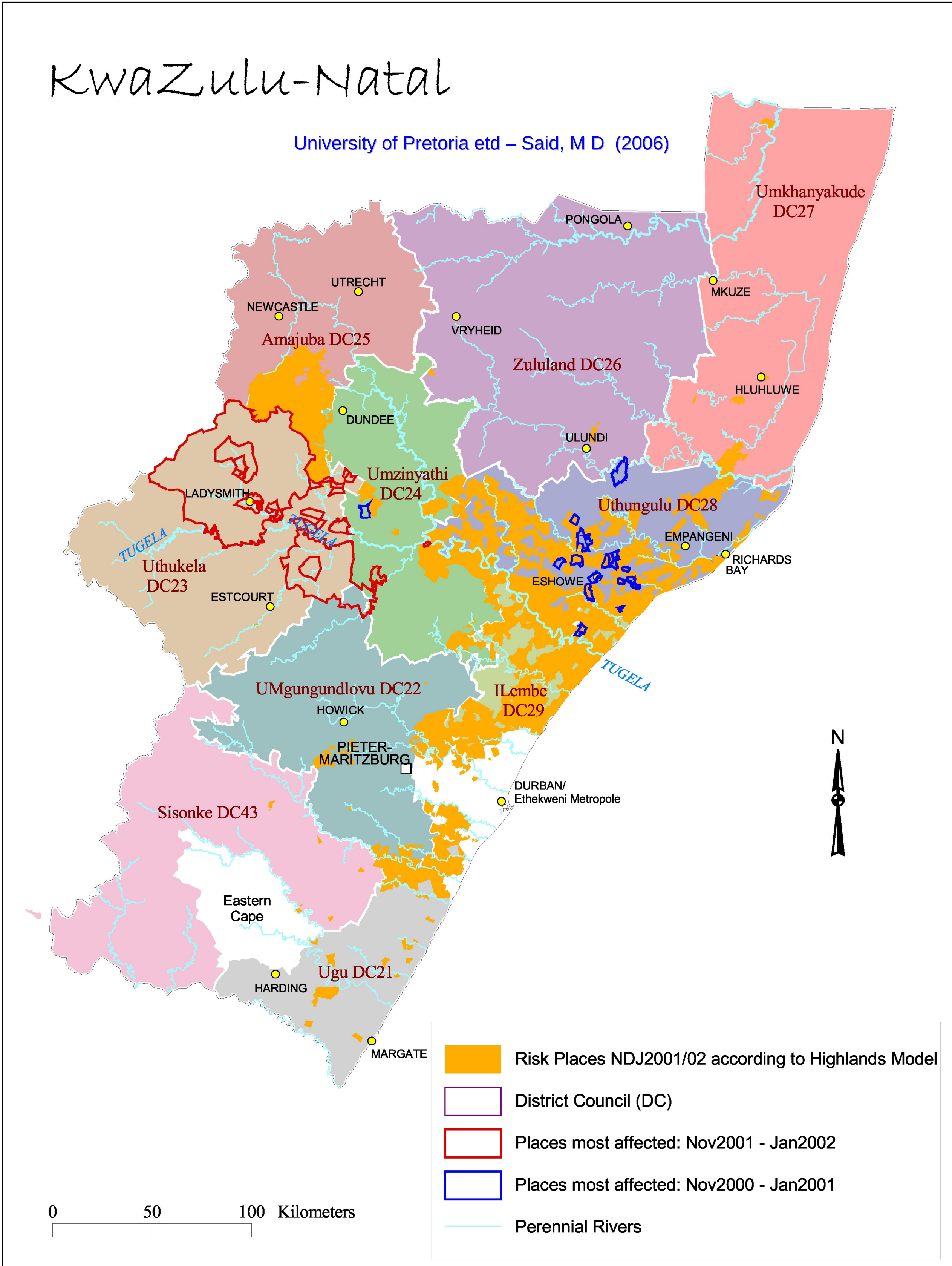
( ) = Number of places that showed high risk to cholera using the specific selection criterion.

The scenario depicted by Criterion 1 implied that the Lowlands Model was a chance event as all the factors differed from the other NDJ datasets throughout the 4 years (2000-04). For this reason, the Lowlands and the Highlands model were combined to one complete set (Criterion 3a/b) (Map 34). This was found to be more realistic as it compares well with the averages of the NDJs of the 4 epidemic years. This combined model was used in conjunction with either the water and sanitation factors of lowlands (Criterion 1); or those of the highlands (Criterion 2). Table 6.8 highlights the number of place names selected as high-risk areas using the 4 criteria suggested. The table also refers to the maps that spatially portray the selected high-risk areas using each of the criteria.

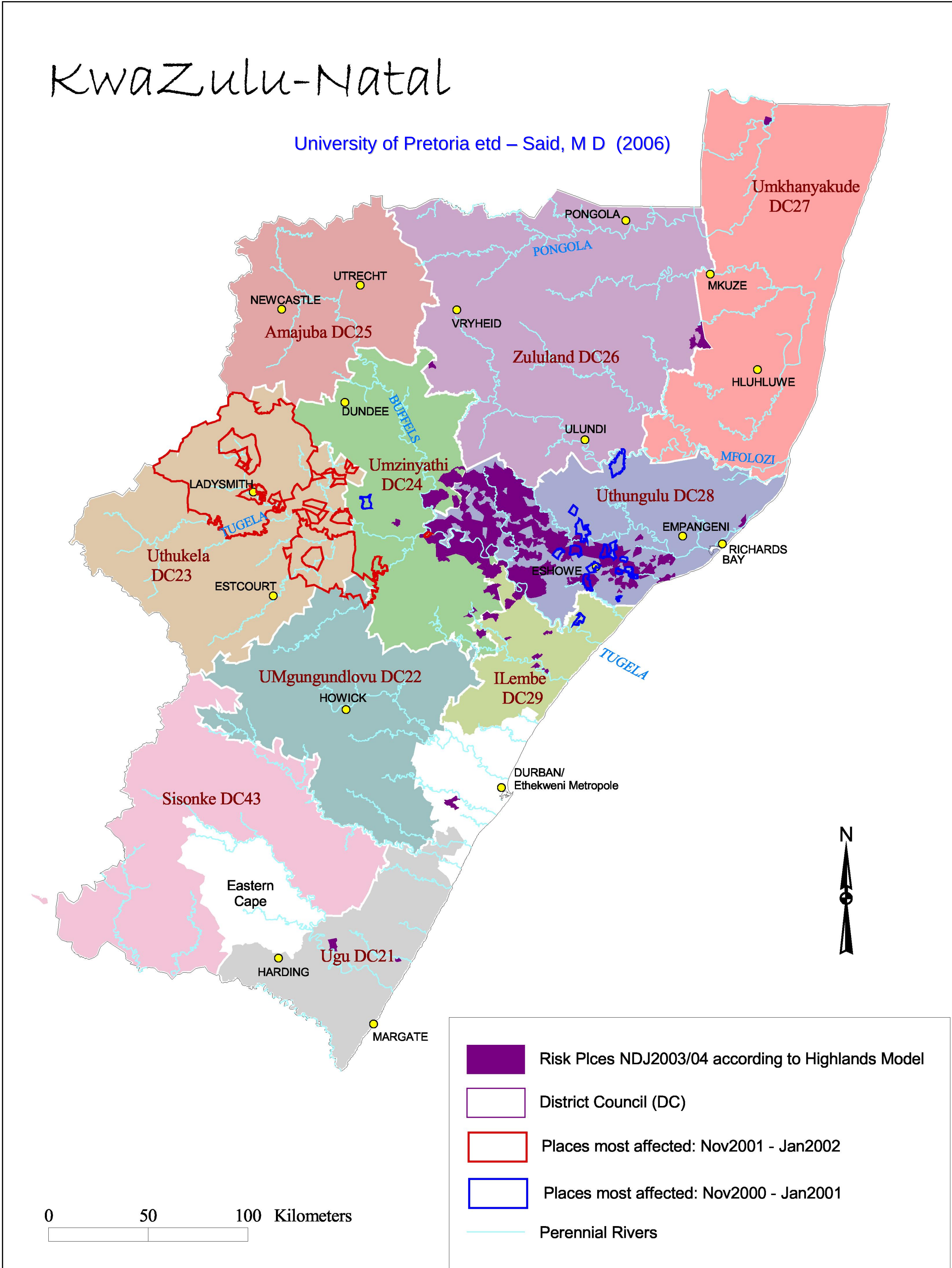
Maps 29-33 draw attention to the places that are at risk to cholera. Criterion 1 (Lowlands Model) versus the NDJ data of 2000/01 picked up the least number of places (50) as being at risk to cholera (Map 29). Most of the places highlighted to be at risk were positioned close to the places that were most affected during the major peak. This is to be expected, considering the closer a place is to a high disease incidence area, the higher the chances of cross transmission. In such instances, the transmission route may involve common travel routes, sharing of a common water resource e.g. rivers, dams and streams and environmental reservoirs of the pathogen that may be common to neighbouring communities. A total of 495 places were selected using Criterion 2 (Highlands Model) versus the NDJ data of 2001/02, which included places situated both in the lowland and those in the highland areas (Map 30). While the same Criterion 2 (Highlands Model) versus data of 2003/04, selected only 183 places, of which the bulk were confined to DC 28 (Map 31). Cholera risk areas selected by Criteria 3a and 3b were to a large extent consistent in that they both selected areas confined to DC 26, DC 27 and DC 28, though Criterion 3a selected for fewer places (368) than Criterion 3b which selected for more places (450) (Maps 32-33). A combination of the Criterion 3a and 3b selected for cholera risk areas both in the lowlands and in the highlands of KZN (Map 34). This meant the combined model was all-inclusive in its selection of cholera risk areas.



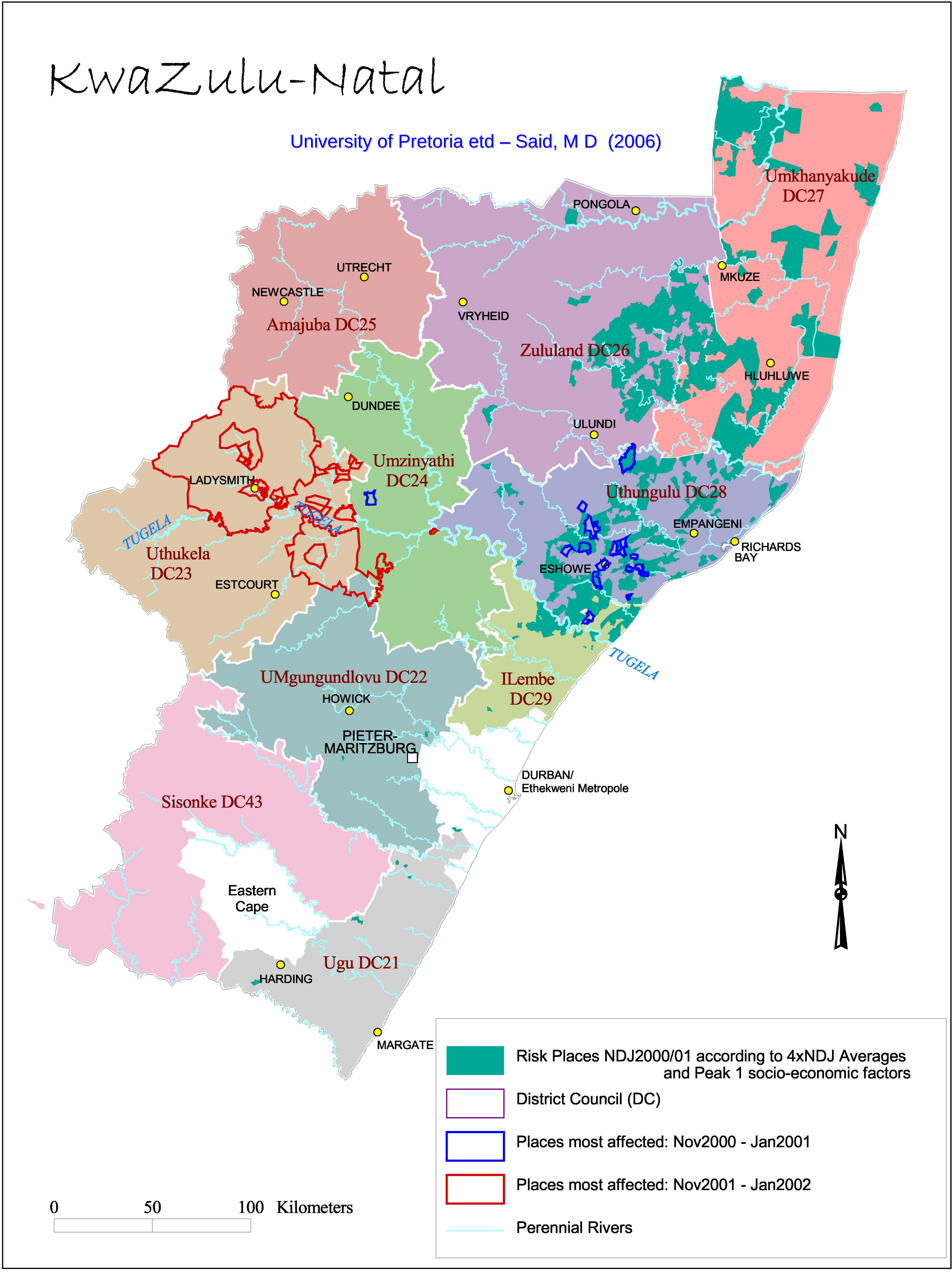
Map 29: Showing Cholera Risk Areas by applying the Lowlands Model during Peak 1 (NDJ2000/01)



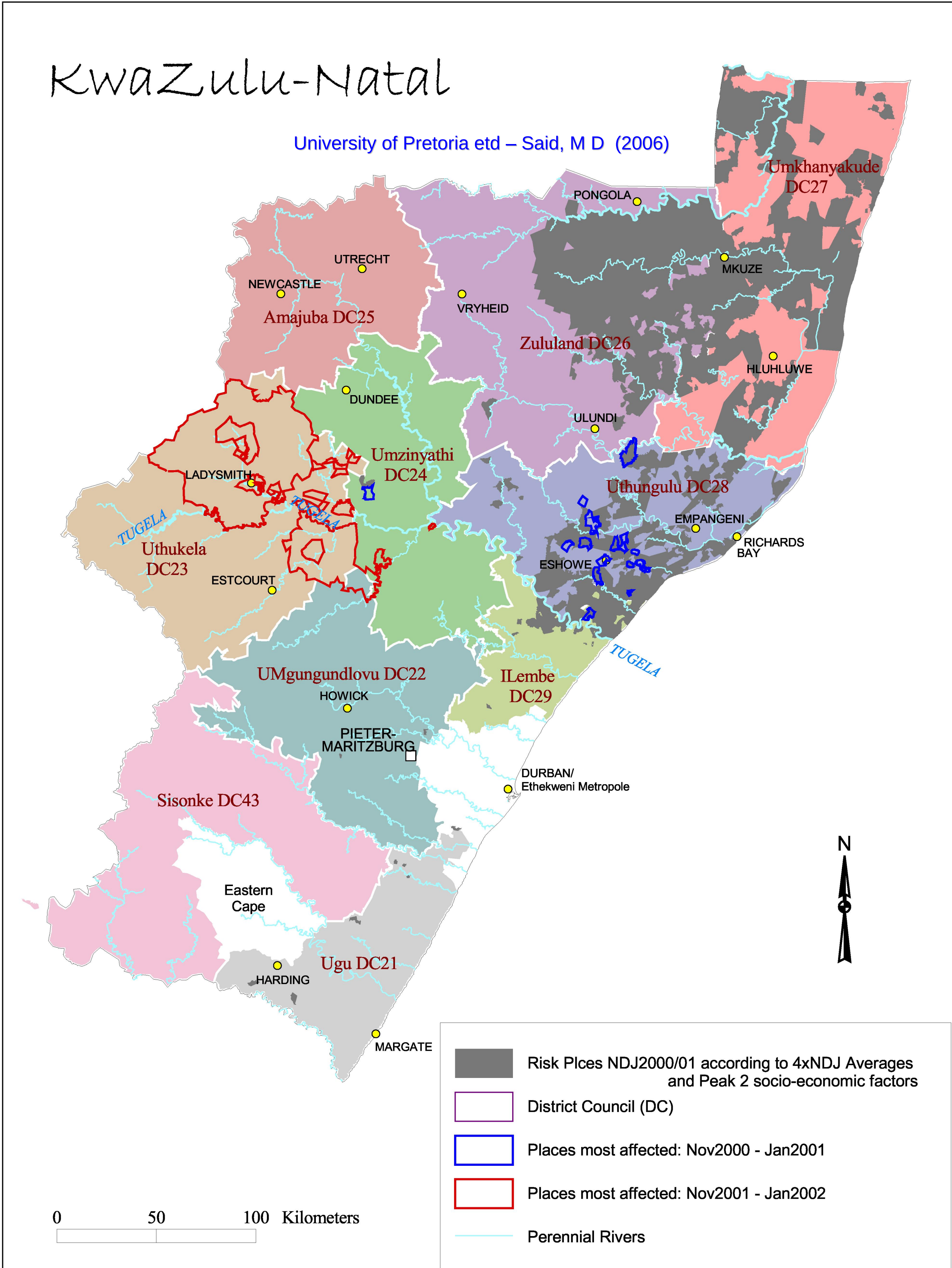
Map 30: Showing Cholera Risk Areas by applying the Highlands Model during NDJ2001/02



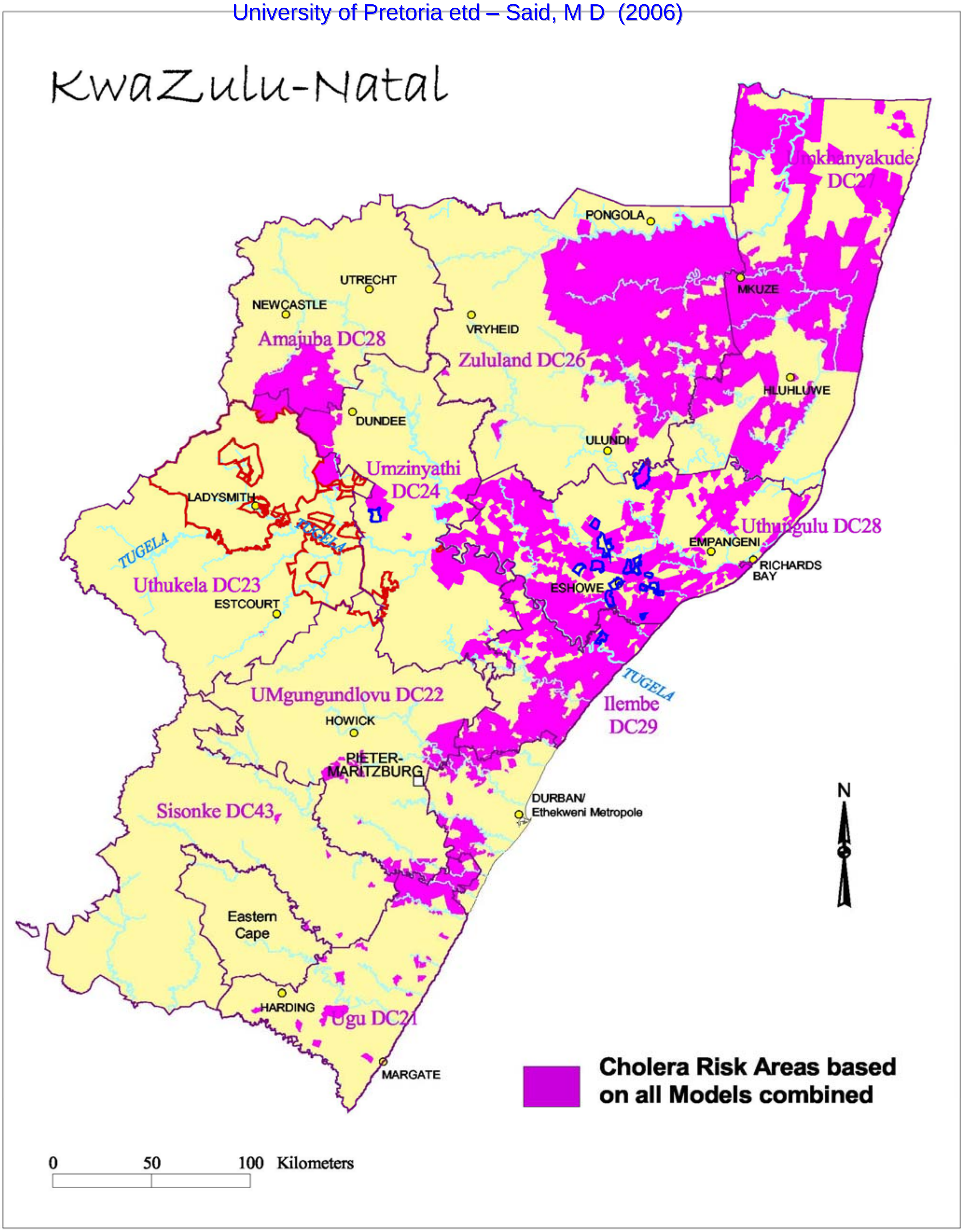
Map 31: Showing Cholera Risk Areas by applying the Highlands Model during NDJ2003/04



Map 32: Showing Cholera Risk Areas by applying the 4xNDJ Averages and Peak 1's socio-economic factors



Map 33: Showing Cholera Risk Areas by applying the 4xNDJ Averages and Peak 2's socio-economic factors



Map 34: Showing Cholera Risk Areas by applying the models on all NDJ's over the 4 year period 2000-2004

The results presented in this chapter were a continuation of the results from Chapter 5, which generally assessed the disease trend to portray the basic epidemic picture. Thus the analytical results and representations produced through statistical evaluations and spatial scenarios, give an altogether holistic portrayal of the cholera epidemic from all perspectives. In effect, these results put to test the validity of the hypothesis put forward that climatic conditions played a significant role in the spread of cholera in KwaZulu, Natal. And in addition, socio economic factors like sanitation, clean water supply, population density and public health services, contributed to the vulnerability of communities to the risk of cholera.

The spatial disease picture displayed a link between climatic seasons and the incidence of cholera. This seasonality link was also expressed in Chapter 5, Figure 5.3. The statistical challenge of the data did not support a direct link between climate and cholera for the province of KZN. Thus, the hypothesis was partially supported at the seasonal level at least. The second aspect of the hypothesis that factors like sanitation, clean water supply, population density and public health services, contributed to the vulnerability of communities to the risk of cholera was statistically supported in its entirety. Spatial modelling offered more insight that the statistically supported climatic and socio-economic aspects were indeed important factors in guiding cholera outbreak predictions in the future. The cholera model illustrated this as it selected for areas considered to be at high risk for cholera. Incidentally, this is in agreement with a previous study where most of these areas were implicated as high health risk areas due to faecal pollution (DWAF, 2002b). Chapter 7 discusses the significance of these results and interprets them further in order to understand the cholera epidemic of the magnitude that faced KZN.

CHAPTER 7:

Conclusion

7.1 Concluding Remarks

All microbial infections consist of interplay between the infectious agent (a pathogen), the affected host(s) and the environment in which the infection occurs. Climate can influence pathogens, vectors, host defences and habitat (Epstein, 2001). Climate is a key determinant of health as it constrains the range of infectious diseases, while weather affects the timing and intensity of outbreaks (Dobson and Carper, 1993). On the other hand, human activities are the most potent factors driving disease emergence (Wilson, 1995b). The worsening of social conditions and inadequate public health programmes underlie the rebound of an individual's vulnerability to diseases (IPCC, 2001). An understanding and a quick response to disease emergence require a global perspective, conceptually and geographically (Wilson, 1995a). This concluding discussion focuses on various factors that contributed to the outbreak of cholera and its subsequent spread to epidemic proportions at the community level. The issues put forth is as a result of using available data on the disease together with the demographic, socio-economic and climatic data of KwaZulu-Natal (KZN) to model different scenarios in order to obtain information that could be used in the management of cholera.

The occurrence of outbreaks of cholera in Africa in the 1970s (Goodgame and Greenough, 1975; WHO, 1991; WHO, 2000) and mainly in coastal communities of Peru in 1991 (CDC, 1991; Tauxe *et al.*, 1994; Seas *et al.*, 2000), in India (Blake, 1994; Finkelstein, 1999) and in Bangladesh (Shimada *et al.*, 1993; Lobitz *et al.*, 2000) have stimulated efforts to understand environmental factors influencing the geographic distribution of epidemic *V. cholerae*. Included in these efforts was this study, whose primary objective was to evaluate the dynamics of the 2000-2004 cholera epidemic in KZN, with respect to the natural environment, i.e. temperature, rainfall and humidity and the socio economic status of the communities in that region. In particular investigate how issues associated with sanitation, water supply, population density; income and housing expose communities to the risk of cholera.

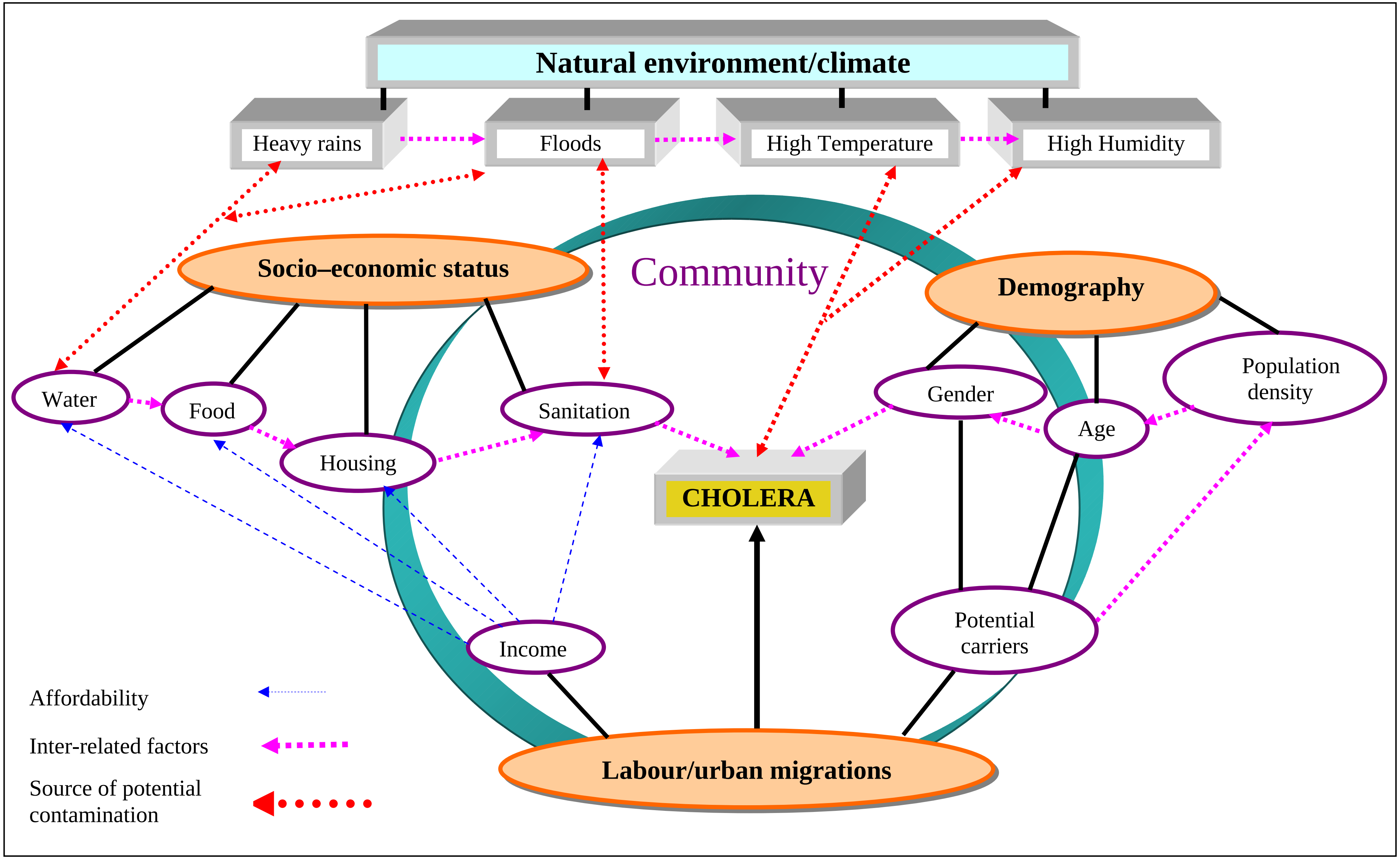


Figure 7.1: The role of the natural and social environment in the cholera epidemic of KZN

The study was therefore, an integration of knowledge about cholera and how it relates to the natural environmental, especially the local climate, the socio-economic status and demography (Figure 7.1). This holistic approach brought to the fore factors implicated in previous cholera outbreaks and more (Isaäcson *et al.,* 1974; Kustner *et al.*, 1981; Tshibangu, 1987; Küstner and du Plessis, 1991; Athan *et al.,* 1998; Keddy and Koornhof, 1998).

There was no link to the local climatic conditions to the incidence of cholera in KZN, though an overall seasonality to the incidence of cholera in KZN was demonstrated (Chapter 5: 5.2.2). Spatial analyses using GIS technology demonstrated that the incidence of cholera in KZN concurred with the seasonal variations in rainfall, humidity and temperature. Cholera case numbers increased in the summer months when high rainfall and elevated ranges of temperature and humidity exist in KZN. While the opposite was true in the winter months whereby case numbers would wane to a minimum when rainfall, temperature and humidity are at their lowest annual levels. Similar seasonal patterns have also been observed in previous epidemics in South Africa (Isaäcson, 1976; Sitas, 1986; Küstner and du Plessis, 1991). The decrease in case numbers in winter is indicative of such climatic conditions as not being supportive of the optimal growth conditions of *V.cholerae.*

The secondary aspect of the study set to investigate the hypothesis involving socio-economic variables and their contribution to the spread of cholera. This relationship was proved to be positive (Chapter 6: 6.1). Furthermore, it was realised during the study that the dynamics of cholera is however a complex issue involving interrelationships between the natural environments and factors associated with the socio-economic status of the affected communities, especially with the supply of basic services (Figure 7.1). It is reasonable to understand that water and sanitation plays a significant role in the transmission of cholera considering the pathogen is waterborne and its entry and exit from the human host is through the oral-faecal route.

During the height of the epidemic period, the following conditions/situation prevailed:

- Heavy rains were recorded in KZN at the time (Nov-Jan 2000/01).

- It was during the end of annual festive season (Nov-Jan 2000/01).
- The population was highly migratory as is usually is the case during such festive periods when migrant labourers return to their homes.

Cholera was more severe in the rural areas and townships of KZN. More so around the peri-urban areas near the town of Empangeni in District Council (DC) 28 (Map 27). The cholera epidemic revealed a possible interdependence of facilitating factors such as water, sanitation, housing and climate and social behaviour, which made the epidemic picture complex (Chapter 6: Table 6.4). It was easy for cholera to spread from DC28 to the adjacent DCs and subsequently spread further because the status of the basic service delivery (water, sanitation, housing) was either at the same level as that of DC28 or most of the time even worse off as spatially demonstrated spatially by Maps 6-17.

The environmental reservoir of cholera has been established to be the aquatic environment and it is linked to biological sources including cyanobacteria, zooplankton and copepods (Colwell, 1996; Colwell *et al.*, 1981; Hood *et al*, 1981; Huq *et al.*, 1983; Colwell and Huq, 2001). An epidemiological and ecological surveillance lasting 4 years by Huq *et al.*, (2005) has revealed significant correlations of water temperature, water depth, rainfall, conductivity, and copepod counts with the occurrence of cholera toxin-producing bacteria. Marine studies of *Vibrio cholerae* and its link to outbreaks of cholera in South Africa have yet to be established. To date, there is no conclusive evidence as to the exact source, be it aquatic or terrestrial, of the 2000-2004 cholera epidemic. The source may have well been a traveller from one of the neighbouring countries such as Mozambique where cholera is known to be endemic. Alternatively, cholera may have already been endemic in KZN communities, and the timing of the extreme weather condition of the last quarter of the year 2000 offered optimum conditions that supported the proliferation of *V. cholerae* to infective doses; leading to an epidemic.

The social-economic factors supporting the outbreaks clearly point to the low level of delivery of water and sanitation services in the affected communities. In addition, the development of man-environment transmission cycle that stems from unsatisfactory disposal of sewage or uncontrolled defecation, contributes to contamination of the environment with vibrio-bearing faeces. Establishment of a transmission cycle through pollution of water sources appears to have been the most common form, though soil and food may also have been contaminated. The scourge of HIV/AIDS within the last two decades also inevitably further complicates the disease picture of cholera epidemics. Albeit, although unsafe drinking water, inadequate sanitation and environmental pollution have previously been associated cholera pandemics, the main issue underlying all these shortfalls is poverty.

7.1.1 Priorities in meeting basic needs

Access to safe and sufficient water and sanitation are basic human needs and essential to the health and well being of an individual. Domestic water is recognised as the first priority in national water policies in many countries including South Africa. The provision of improved sanitation and hygiene is often linked to this. Improved sanitation and hygiene are proven to be most effective in reducing diarrhoea morbidity (even more so than the water quantity and quality). Thus the provision of basic sanitation should be considered just as important as that of water services in the most affected areas. Linked to this but secondary, are issues that involve women such as fetching water from rivers for domestic uses and as caregivers to cholera victims. These are the target groups of choice in addressing social habits, which require cultural/educational programmes (WHO, 2002). The above-mentioned factors/issues supported the spatial model (Chapter 6: 6.3.1) in selecting for areas with a high potential to cholera outbreaks. The model can thus also be used to prioritise management efforts in other provinces to improve the implementation and roll out of basic services.

7.1.1.1 Managing risks

Provision of security from floods, pollution and other water related hazards, is a basic human right as it directly impacts on the basic human requirements of safe water, food and shelter.

- Recognise the link between population growth, climatic and environmental change, global migration, human health and security (Wilson, 1995a). Understanding how climate affects the transmission of these diseases will led to enhanced preparedness for early and effective interventions as well to control the resurgence of infectious disease.
- Develop databases that combine information about climate, demography, population movements, and communicable diseases that will improve surveillance and response capability. This was aptly demonstrated where clusters of cholera cases were shown to be confined to certain climatic ranges (Chapter 6: 6.2.4). Such initiatives will also ensure that long-term disease monitoring programmes become an integral part of health surveillance systems.
- Identify markers for regions or populations at high risk of epidemic disease as illustrated by the creation of Map 33 (Chapter 6: 6.3.1); so that interventions to reduce the impact of disease can be put in place. Timeous warning systems based on the health monitoring programme will lead the way to environmentally sound public health policies and interventions (Epstein, 2001).

7.1.2 Issues at hand

Whether cholera originated from an undiscovered endemic site or from a fresh importation is unknown. The cholera epidemic persisted for four years, so permanent endemicity in KZN must be considered a definite possibility. The continued survival of *V. cholerae* makes new epidemic outbursts probable in the future. Especially as one considers that with time, antibody levels in the population will decline and the numbers of individuals like young children, old people and new community members with no previous exposure to cholera will increase (Stock, 1976). As the level of susceptibility of the population rises, so does the risk to new epidemics.

This state of affairs immediately put forward certain issues that either had a direct or indirect impact on the cholera outbreak and its subsequent spread to epidemic proportions. These include the influence of the local climate on disease transmission, the economic and social factors of poverty, HIV/AIDS, the gender biased disease picture and the role of travel in the dissemination of the disease.

7.1.2.1 Poverty

The issues that were proven to be significant in this study related to issues highlighting the inefficiencies in the provision of water and sanitation, which go hand in hand with poverty. Thus the issue of poverty was indirectly reflected in the data and statistically supported as an issue that compounded the cholera epidemic. The poor are most vulnerable to water related hazards; extreme floods, pollution etc. and often suffer from multiple vulnerabilities, the effects of which compound each other (Soussan, 2003). Health hazards where water is a vector are endemic in many regions. Poor people also suffer disproportionally from malnutrition and other health problems, which are exacerbated by a lack of water and sanitation (WHO, 2002). In South Africa, the lack of a social security and high levels of unemployment mean that poor households and communities slip further and further into poverty and deprivation. Invariably, with the burden of coping falling on women, particularly girls and grandmothers (AFSA, 2005).

7.1.2.2 HIV/AIDS

The national average of the proportion of HIV positive women attending antenatal clinics in 2003 was 27.9%. The province of KwaZulu-Natal continued to have the highest prevalence, at 37.5% (AFSA, 2005). Waterborne diseases like cholera are a threat to people living with HIV/AIDS. The risk of cholera to immuno-compromised individuals will thus always be an issue, considering their increased susceptibility to infections including cholera. The link between HIV/AIDS and water reflect some of the often-unanticipated long-term implications in the provision of clean water to communities (Ashton and Ramasar, 2002). Exposing people infected with HIV/AIDS to poor quality water heightens the risk to waterborne diseases like cholera. In the meantime, individuals with healthy immune systems will continue to be challenged as they get in contact with *V. cholerae* from neighbouring aquatic environments to become asymptomatic carriers and serve as transient reservoirs for *V. cholerae,* until conditions are suitable for the organism to start another epidemic cycle. Consequently, the pool of carriers may in turn help to seed the aquatic and terrestrial environments even further with *V. cholerae* if among them are those that cannot afford basic water and sanitation services.

7.1.2.3 Women

Gender issues continuously come to the spotlight and it was no exception with the resultant picture of this cholera epidemic. Acknowledging the fact that females operate in a defined social structure especially in rural settings goes hand in hand with the associated social and environmental responsibilities. To suggest to rural women to boil or chlorinate water increases the already heavy labour burden, in terms of collecting firewood and water; the labours of cooking, cleaning and child-care (Mbali, 2002). The multiple demands on women in the rural world are intensified in the case of households headed by women; moreover, these women do not have equal access to resources, wages, credits or decision-making. The cost recovery initiatives especially in the water sector that were implicated in fuelling the cholera epidemic in question, also increases the amount of time women had to spend caring for sick family members and in child care (Mbali, 2002). As such, these issues can only start to be addressed once the availability of safe drinking water and the availability of safe excreta disposal become basic services available to all individuals.

7.1.2.4 Travel and labour migrations

Travel is a potent factor in the emergence of diseases. Migration of humans has been the pathway for disseminating infectious diseases through various mechanisms. In addition, social, economic, political, climatic, technologic and environmental factors shape disease patterns and influence emergence (Wilson, 1995a). To assess the impact of travel on diseases emergence, it is necessary to consider the receptivity of a geographic area and its population to microbial introduction. The likelihood of transmission involves many biological, social and environmental variables (Wilson, 1995a). Another type of travel relevant to disease emergence is the shift of populations to urban areas. It is estimated that by 2025, 56.9% of the world population will be living in urban areas (Harpham and Stephens, 1991). This may even further take away focus on rural areas to try and cope with the urban slums as far as water and sanitation are concerned.

The large volume of travellers supported the transmission of the infection in the urban centres located in the vicinity of cholera-affected areas. Specific rural functions such as funerals were frequently found to be responsible for the introduction and dissemination of cholera into other villages. As the pool of susceptible individuals had increased in the different areas during the festive season, some were bound to have sourced their water from contaminated water bodies. At the same time, visitors who could afford to travel to areas with high potential for cholera outbreaks may have also become carriers in the process and spread it further to other areas.

7.1.3 Predicting cholera

There was no proof that a direct link exists between the local climatic variables of KZN and the transmission of cholera. Notwithstanding, there was an overall seasonality revealed by the data, as seen with the cases peaking and waning between the summers and the winters respectively (Chapter 5: Figure 5.3). Furthermore, GIS mapping revealed a concurrence between the incidence of cholera and the climatic variables of rainfall, humidity and maximum temperature (Chapter 6: 6.2.4). There may have well been a statistically supported correlation between %CIR cholera and climatic variables within localised areas though for the purpose of this study, the focus was to seek correlations for the entire province. Therefore, chance events whereby heavy rains are experienced in cholera prone areas should still be considered as an alarm that, given certain conditions are fulfilled, a chain of events can be set off that could trigger an outbreak of cholera. This was aptly demonstrated with the spatial model (Chapter 6: 6.3).

Being able to predict the diffusion of cholera would clearly be of considerable value. Control measures could then be focused on preventing the establishment of the infection in highly susceptible communities or minimising its impact. Results from this study revealed that cholera diffusion did not occur uniformly within the areas affected by the epidemic, but diffused and persisted in particular ecological niches and conducive to environmental settings. Thus the scarcity of human resources, and time, to combat cholera necessitates the selection of particular high-risk target populations as the primary concern of control programmes. The census data used in the study was helpful in pointing out the level of basic service delivery at the MD level (Chapter 6: Table 6.2), which can be useful in selecting high-risk target populations. Notwithstanding, prediction is more likely to be feasible on the local scale, while low population density areas may be ideal locations for intensive campaigns to inhibit further diffusion.

7.2 Towards the future

The epidemic did eventually come to pass, as with the previous epidemics. Nonetheless, future cholera outbreaks are almost certain unless the delivery of basic services is guaranteed for all. Controlling the environment which *V. cholerae* depend on for its survival would be difficult because of the fact that it is primarily an aquatic organism. Thus ideally, the definitive control programme should involve the elimination of the transmission routes, suitable for *V. cholerae* survival through improved sanitation and housing and the provision of protected water supplies. This ideal is not far fetched though it involves huge financial implications and a longer time frame. Meanwhile, as the socio economic picture improves, albeit at a slow pace, areas with low delivery of basic services may still have to opt for natural water sources and alternative sanitation measures irrespective of the consequences.

The findings of the study through the use of data as a disease management tool emphasized the implication that interactions exist between people, their socio-economic issues and the environment. Subsequently, it is these interactions that become the deciding factors as to whether a community resists or succumbs to cholera. One helpful avenue is by using awareness campaigns instituted by educational policies, to address problematic issues like hygiene through behavioural change.

7.2.1 Campaigns to eradicate poverty

- Central to the cholera epidemic are issues of poverty. Alleviating poverty is vital in improving the standard of living of underprivileged communities. For an individual to be out of the state of poverty implies that one has a reasonable income that affords basic services of clean water, adequate sanitation, housing and education.
- Most often than not, the poor communities of the urban slums and rural areas pose the highest health risks. Thus such communities should be given priority

in issues of water supply and sanitation. Cholera affects the poor living in crowded unsanitary conditions.

- Creation of income generating opportunities in a province like KZN will contribute significantly to the well being of its people including population stabilization and income distribution.
- Women should be encouraged to take a greater role in self reliance activities considering that there is a tendency of the men moving out to urban areas of KZN or other provinces altogether in search for work..

7.2.2 Public awareness campaigns

- The success of public awareness on the benefits of a healthy environment and the associated risks of neglected environments is dependent on the availability of basic services of water and sanitation to all. In particular, environmental sanitation, pollution and protection of water sources.
- While initiatives to provide the basic services are underway, educational programmes on hygiene, improved household water storage and safe sanitation should be introduced in parallel as an ongoing concern to all the communities. Programmes such as clean up campaigns; chlorination may be used to reduce the favourability for survival of cholera organisms.
- Children in schools should be one of the major targets of health education. Children are more impressionable and this attitude should be exploited to introduce them to healthy habits like boiling water, washing their hand after using the toilet and before eating to name a few.

7.2.3 Women as partners in progress

- Women ought to be accommodated and recognised as important members of communities. Above all, women should be encouraged to take active in matters pertaining to community public health and environmental issues.
- Empower women, through a participatory process in issues of water management and sanitation.

- In the political environment, decision-making processes and policies should be gender sensitive, particularly those appertaining to public health and the socio-economy of communities.
- Women should be the focus of public health education especially because they have a close relationship with issues of water, sanitation and housing. Simple messages targeting women to promote within their households hand washing with soap before preparation of food and after dealing with faeces.
- Through women, encourage their children to be ambassadors of change. For example, women should be educated on the dangers of children bathing in infected rivers, as children's exposure to microbiological contamination in water is greater than that of adults. Children need to be taught healthy behaviours such as hand washing and encouraged to use sanitation facilities.

7.2.4 Introduction of simple and effective technologies

The global shortage of clean water and inadequate sanitation to the world's poor, has witnessed a myriad of simple and effective technologies towards the supply of water and sanitation. Each community is unique in its environment and its needs. Such factors have to be considered in the choice of technologies to be introduced.

- The ideal technologies would be those that are affordable, easy to install and operate and simple to put back into working order in instances of breakdowns.
- Women (both urban and rural) should be encouraged to participate in understanding matters pertaining to the management of water supply and sanitation technologies.

7.2.5 Management of natural resources

Community resources can be better managed with appropriate interventions directed at issues that place the community most at risk. Natural resources like water bodies (dams, rivers, streams etc) and forests have a direct influence on the lives of people especially those in rural areas. Communities should be educated on the general effects of the use and misuse of these resources. For example, the consequence of river pollution should be addressed and the community encouraged to make concerted efforts to ensure their water resources are protected. Above all, communities should be made to feel that they have a collective ownership to these resources such that individuals will take a keen interest in protecting them.

7.3 Final Conclusion

Reliable data, in addition to being used for monitoring and evaluation purposes can also be used in disease management issues. This study made efficient use of available data resources as a disease management tool to understand the relationships between the incidence of cholera and the different factors previously implicated in its spread to epidemic proportions. The scope of this ecological analysis was to test the application of retrospective data to shed new light on our understanding of occurrence of cholera as well as how to use this knowledge in controlling the disease. In general, there was a search for spatial patterns that might suggest an environmental etiology. The study showed that an ecological analysis could be used to establish a link between a risk factor and the disease (Morgenstern, 1982). Furthermore, the exercise demonstrated the important role of routine environmental surveillance using health, climatic and socio-economic data. The ability to evaluate geo-spatial information associated with health and socio-economic data provides a unique perspective of public health issues to water resource managers such as endemic and emerging infectious diseases and environmental health (Waring *et al*., 2005). As such, methodological development of such studies can give important contribution to the public policy of the sector. Thus, the development of integrated information systems to handle information and provide authorities with successful solutions is explicitly encouraged.

All the emergent issues are pertinent at the community level. And although there has been significant progress in improving the supply of safe water in South Africa, the backlog in basic sanitation services still calls for attention, as an estimated 16 million still lack basic sanitation and an estimated 6 million do not have access to safe drinking water (DWAF, 2002b). The results from this study further confirm the negative health effects of inadequacies in water and sanitation services. It is hoped that the findings of this study will contribute in the prediction and management of diseases like cholera at the community level in the future.

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ANNEXURE I: METHODOLOGY

CREATING PIVOT TABLES USING MICROSOFT® EXCEL

Due to the big size of the Cholera Dataset, the cholera cases of Aug’00-Feb’04 had to be divided into years and others into months to be able to sort the data effectively. Microsoft Excel could not accommodate all the data entries in one spread-sheet, it is limited to process up to a maximum of 65,535 data entries. Thus, the entries were divided into files based on cholera cases of particular years, months or a combination of months (Table 1).

Table 1: Annual/monthly cholera case counts between Aug 2000 – February 2004.

Spread-sheet #	File Name	Number of data entries (cases)
1	Non Dated cases	226
2	Cases 2000	20,415
3	Cases January 2001	34,837
4	Cases February 2001	32,123
5	Cases March-May 2001	46,491
6	Cases June-December 2001	9,571
7	Cases 2002	12,352
8	Cases 2003	864
9	Cases 2004	16
		158,895 (Total Cases)

N.B.

This part of the data sorting exercise was conducted for the entire Cholera Dataset as it was provided for the study. At this stage all the cholera cases were considered irrespective of whether the individual data entries were complete or not. That means it was at the end of this sorting exercise that the complete data entries were considered for inclusion in the attribute dataset. Nonetheless, the steps outlined here were also used for sorting the attribute dataset at one point or another.

The entire Cholera Dataset was divided to create individual Excel spread-sheets as listed in Table 1. This exercise was done by sorting the Cholera Dataset which was created in Microsoft Access as follows:

1. Data was copied from Cholera Dataset (Access Spreadsheet) into Excel
   From Excel the data entries were sorted by date. Thus:
    a. Highlight all the data entries
    b. Click > Data >Sort > Choose "Date of notification"
    c. The data entries are now sorted orderly.
2. Transferred the sorted data into the assigned files (Table 1).

PIVOT TABLES

Information from each spread-sheet was used to generate the following information:

a. Total monthly cases

A compilation of all the monthly cases that can also be separated by gender.

b. Age groups by GIS place names

Lists the age groups affected in all the GIS place names reporting cholera. The age groups can also be separated by gender.

c. Age groups by gender

Sorts all the cholera cases by age groups and by gender.

d. Cholera cases by DC

Number of cholera cases in each DC. These could also be sorted by gender.

e. Cholera cases by MD

Number of cholera cases in each MD. These could also be sorted by gender.

CREATING PIVOT TABLES WITH MICROSOFT EXCEL

Before creating pivot tables, the column “Date of notification” (Table 2) was split into Day, Month and Year (Table 3).

Procedure:

1. Insert 3 columns after the column of “Date of notification” And them as Day, Month and Year respectively.
2. In the Day cell > type: =Day (E2)>Enter

   In the Month cell > type: =Month (E2)>Enter

   In the Year cell > type: =Year (E2)>Enter

   (N.B: (E2) is the designation of the cell - “Date of Notification”.
3. Each of the above commands can be copied from the first cell to the rest of the individual column to enter the day, month and year figures respectively.

The Dataset format will now appear as the example given in Table 3.

CREATING PIVOTS.

- Open the relevant spread-sheet.
- Go to Data > Pivot table & Pivot chart report.

Pivot Table and PivotChart Wizard - Steps 1 of 3

Where is the data that you want to analyse?

Choose: ◘ Microsoft Excel list or database.

What kind of report do you want to create?

Choose: ◘ Pivot Table

Click > Next

Pivot Table and PivotChart Wizard - Steps 2 of 3

Where is the data that you want to use?

The range is automatically chosen.

Click > Next

Table 2: Example of the line listing of Cholera cases from the Cholera Database.

Age (Years)	Gender	GIS Place Name	PCODE	Date of Notification	Died?	Death Date
49	Female	Mtubatuba	53510105	2000/11/09	No	
37	Male	Mtubatuba	53510105	2000/12/07	No	
32	Female	Mtubatuba	53510105	2001/02/08	Yes	2001/02/10
	Male	Mtubatuba	53510105	2001/04/04	No	

Table 3: Example of the line listing of Cholera cases after 'Date of notification' was separated into Day/Month/Year.

Age (Years)	Gender	GIS Place Name	PCODE	Date of Notification	Day	Month	Year	Died?	Death Date
0	Male	Mfanefile	53720034	31-Jul-01	31	7	2001	No	
17	Male			01-Aug-01	1	8	2001	No	
68	Male	Ingwavuma	55010101	01-Aug-01	1	8	2001	No	
34	Female	Greytown	52010101	01-Aug-01	1	8	2001	Yes	06-Aug-01

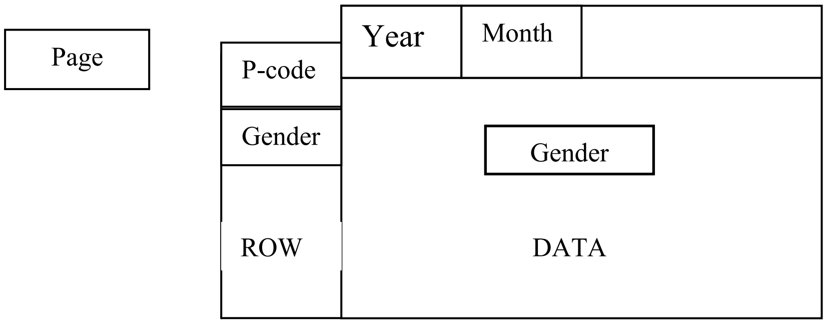
Pivot Table and PivotChart Wizard - Steps 3 of 3

Click > Layout: A Pivot Table layout is given. Drag the fields listed on the right and arrange them according to the output required as shown in Figs 1-4.

N.B: Fonts in italics refer to the text as it appears in Microsoft Excel 2000.

a. Total monthly cases

Drag the specified fields from the right and arrange them accordingly as shoen below.



Click > OK

The Pivot table from the above layout will be as shown below.

Click to select gender(s).

Click to select year(s) of interest.

Click to select month(s) of interest.

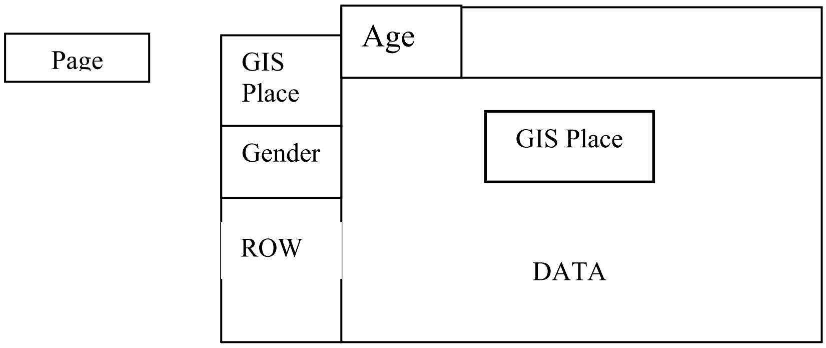
Count of Gender		Year ▼	Month ▼	
		2001		
PCODE ▼	Gender ▼	6	7	8
	Female	206	47	8
	Male	127	29	10
50110008	Female	2		
50110014	Male		1	
50110023	Male	2	1	
50110027	Female	1		

b. Age groups by GIS place names

Do the same for steps 1 and 2.

Step 3 of 3

Click Layout and arrange the fields as follows:



Click > OK.

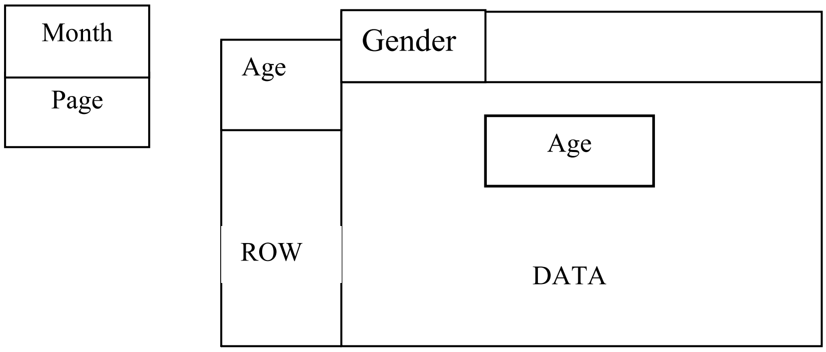
From the resultant Pivot Table, the different gender(s) and age(s) and GIS Place-names can be selected as shown in Fig 1.

c. Age groups by gender

Do the same for steps 1 and 2.

Step 3 of 3

Click Layout and arrange the fields as follows:



Click > OK.

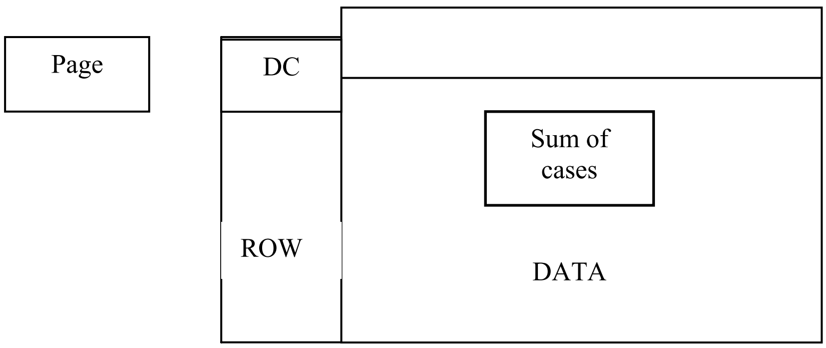
From the resultant Pivot Table, the different age(s) and gender(s) and months can be selected can be selected as shown in Fig 1.

From the Pivot Table, individual ages can also be arranged into age groups e.g. to add ages 0-4 to become one group, as follows:

- Highlight the ages to be grouped (include female cases, male cases and totals)
- Go to > Data > Enter
- > Group & outline > Enter
- > Group > Enter
- > OK
- Each group can be labeled appropriately.

d. Cholera cases by DC

For this Pivot Table, a column with DC information had to be added, to identify with the appropriate place name and another column for the sum of female and male cases.



e. Cholera cases by MD

For this Pivot Table, a column with MD information had to be added, to identify with the appropriate place name and another column for the sum of female and male cases.