# 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 → <br> **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.

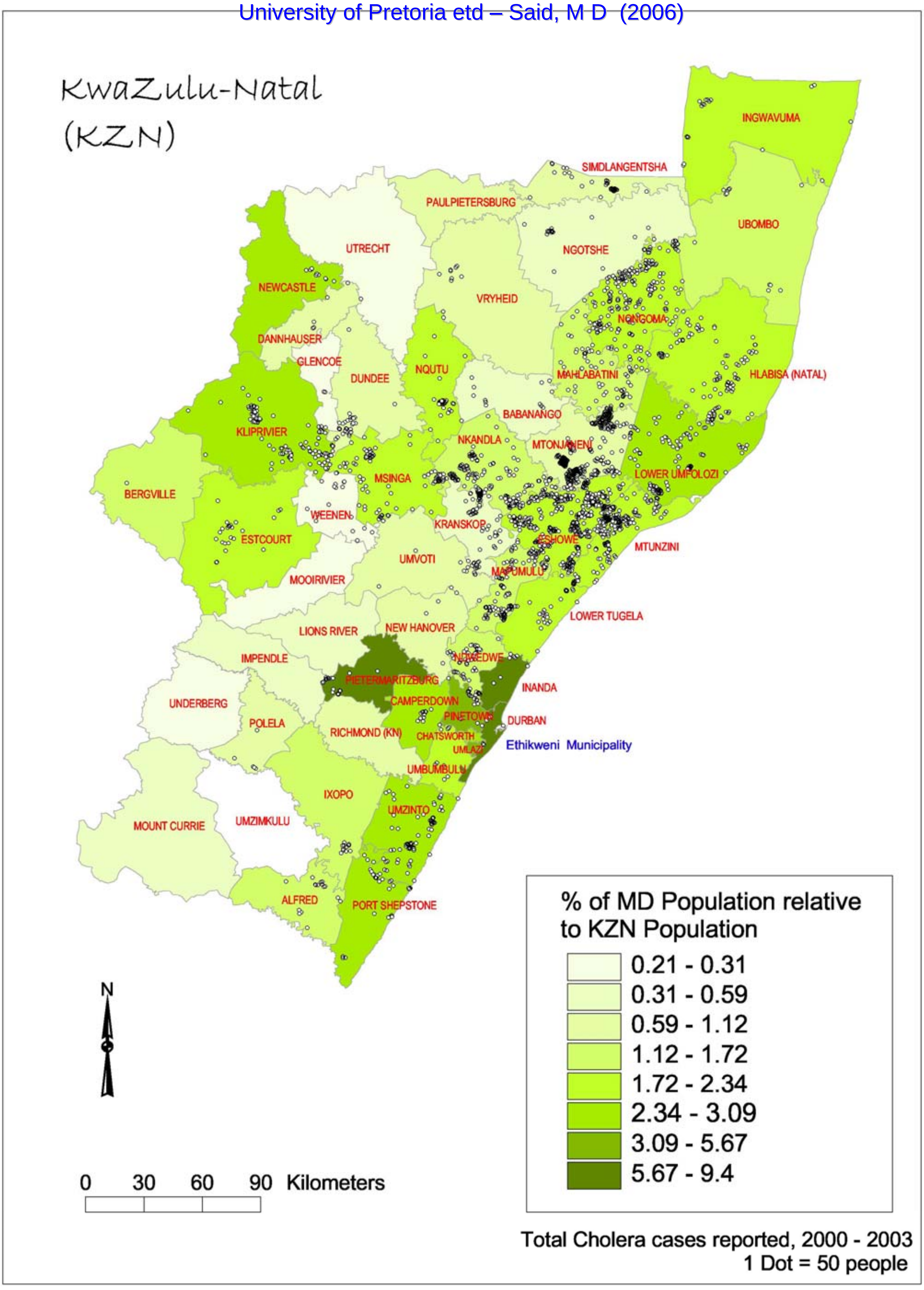
#### *6.2.2.2 Housing*

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.

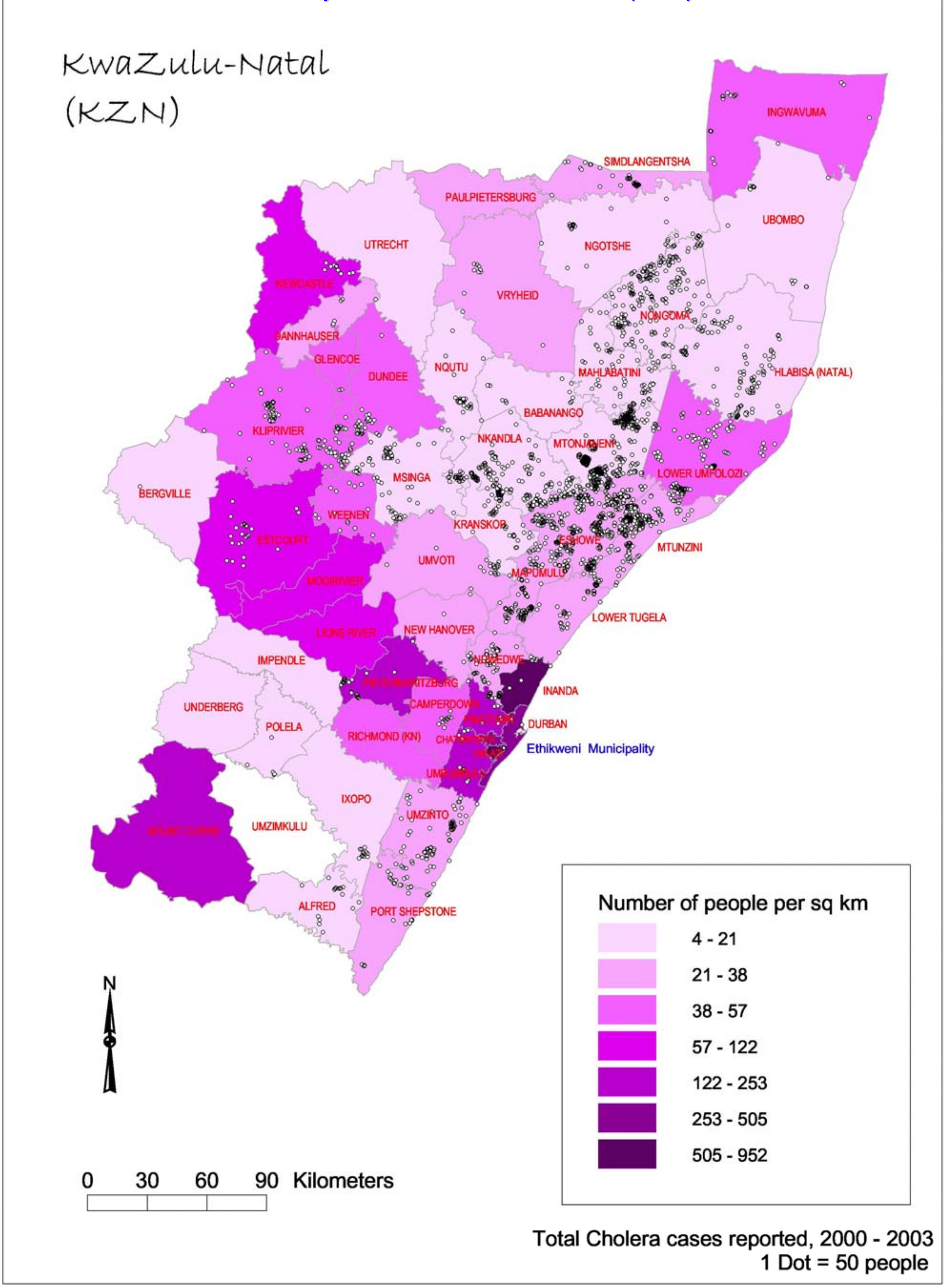
The statistical results positively correlated living in a traditional house type to the %CIR of cholera ($r= 0.272$ $p= 0.09$). Acosta *et al*, (2001) also observed similar correlation in a study in Tanzania, whereby living in a mud house was significantly associated with cholera. The same areas also 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

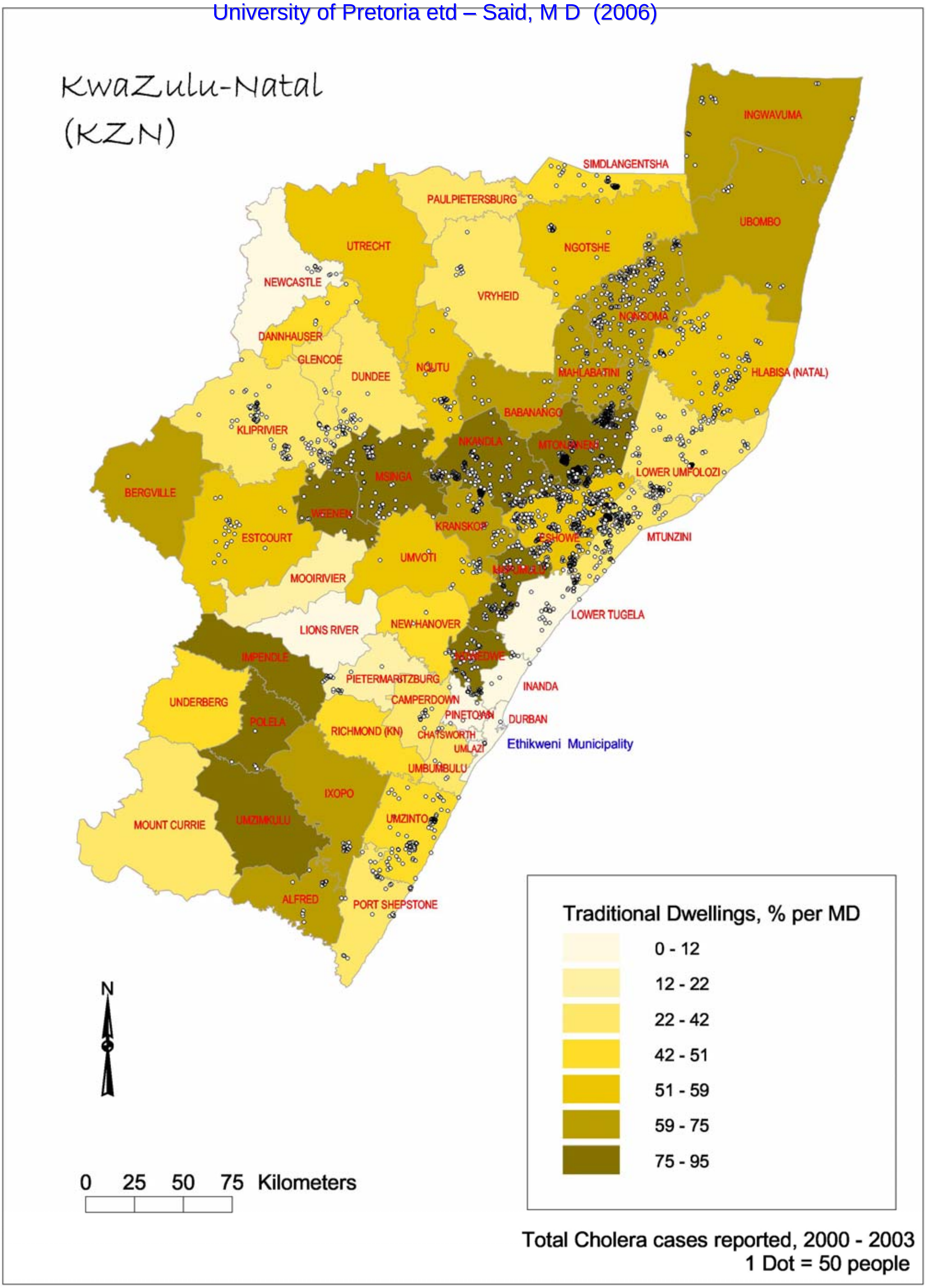
The socio-economic variables of water, sanitation and refuse service categories were the basic types of services considered in the study (refer Table 5.4). *Per se*, all the GIS maps presented here spatially demonstrate the type of basic services that were positively correlated to the incidence of cholera.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



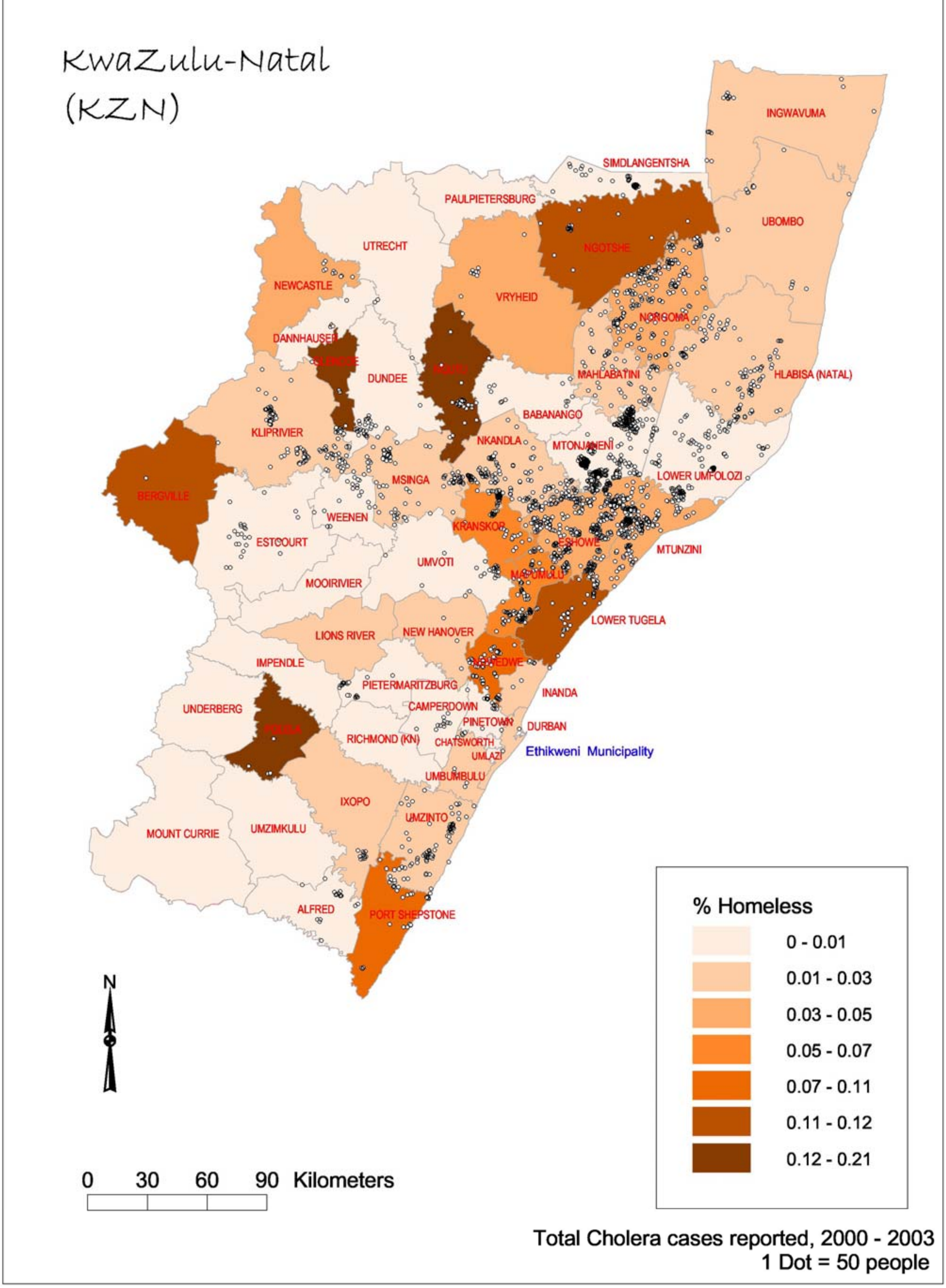

**Map 6: The proportion of people per MD (as percentage) in relation to total KZN population**



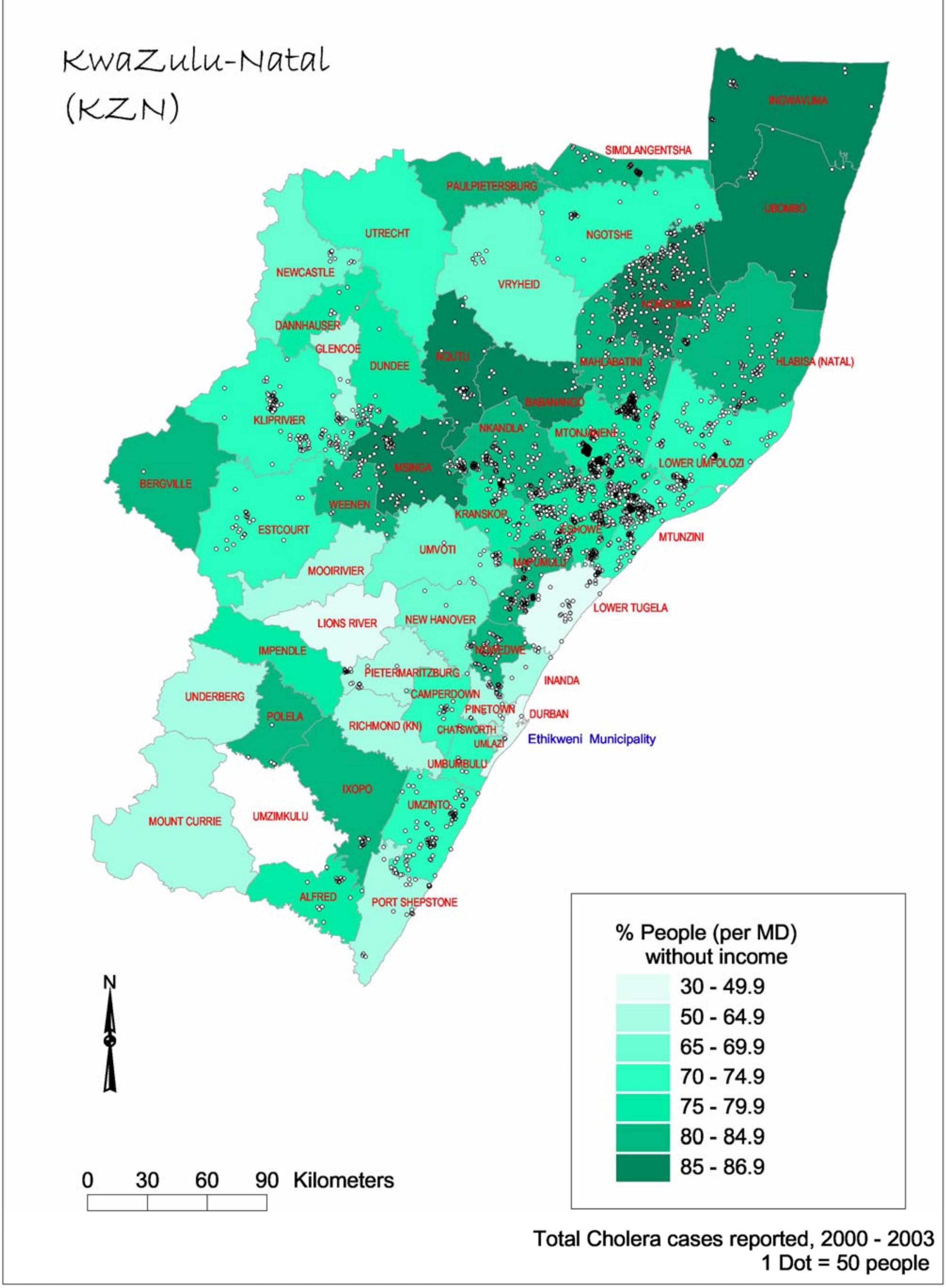

**Map 7: Population density (people per square kilometer) per MD in KZN**




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




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



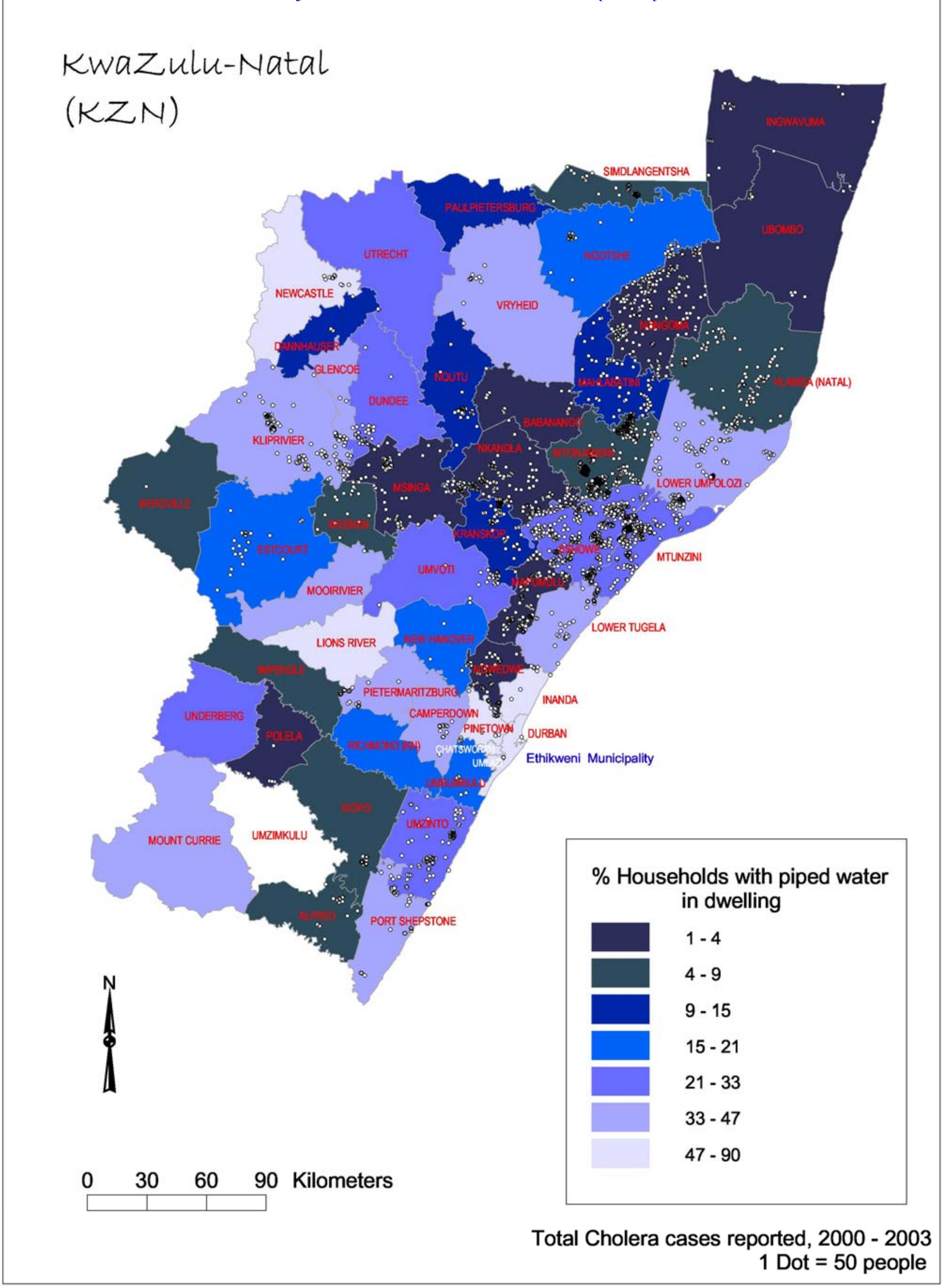

**Map 10: Percentage of people with no income (as percentage of MD) in KZN**

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.

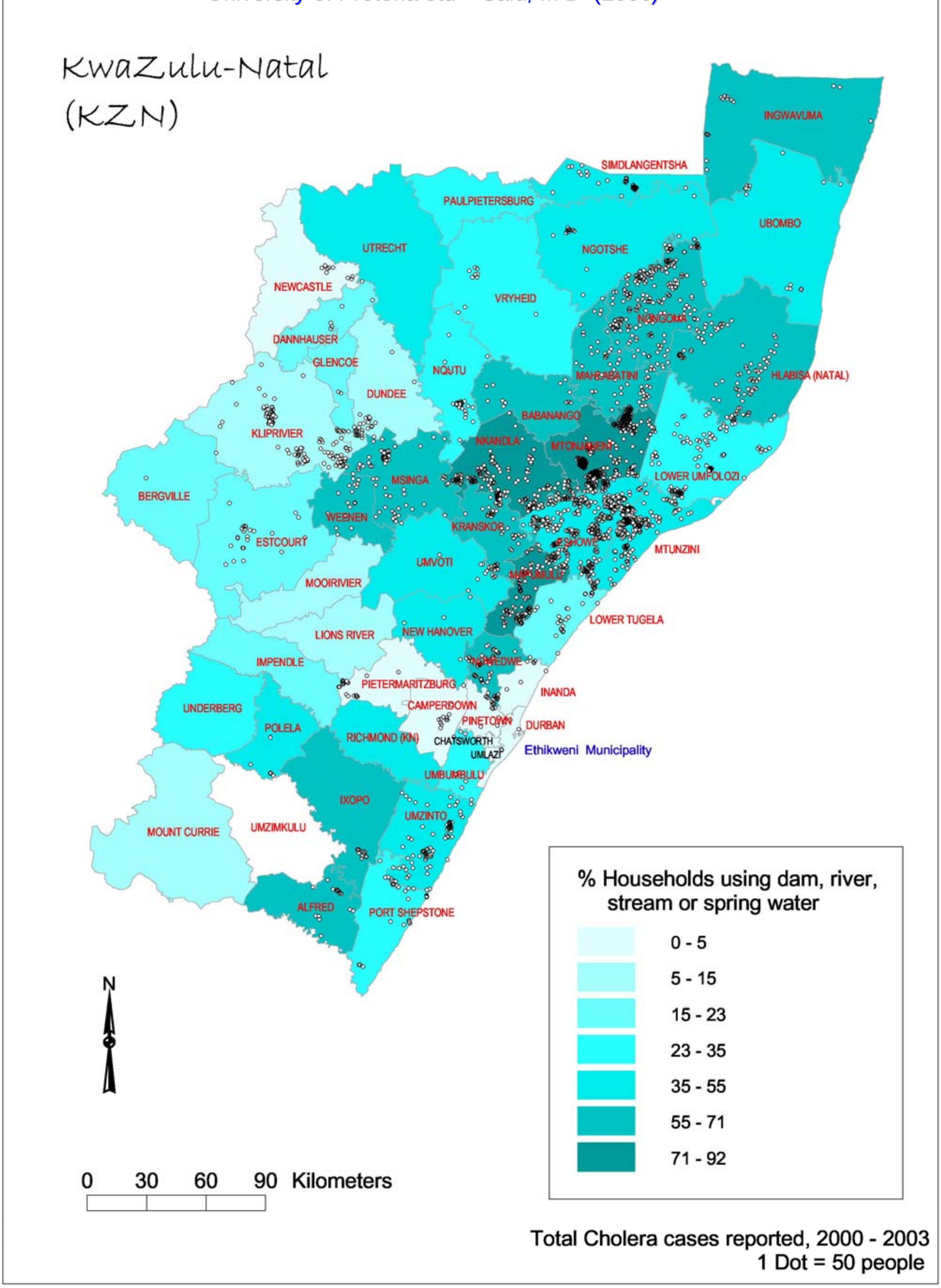
### *6.2.3.1 Water*

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**



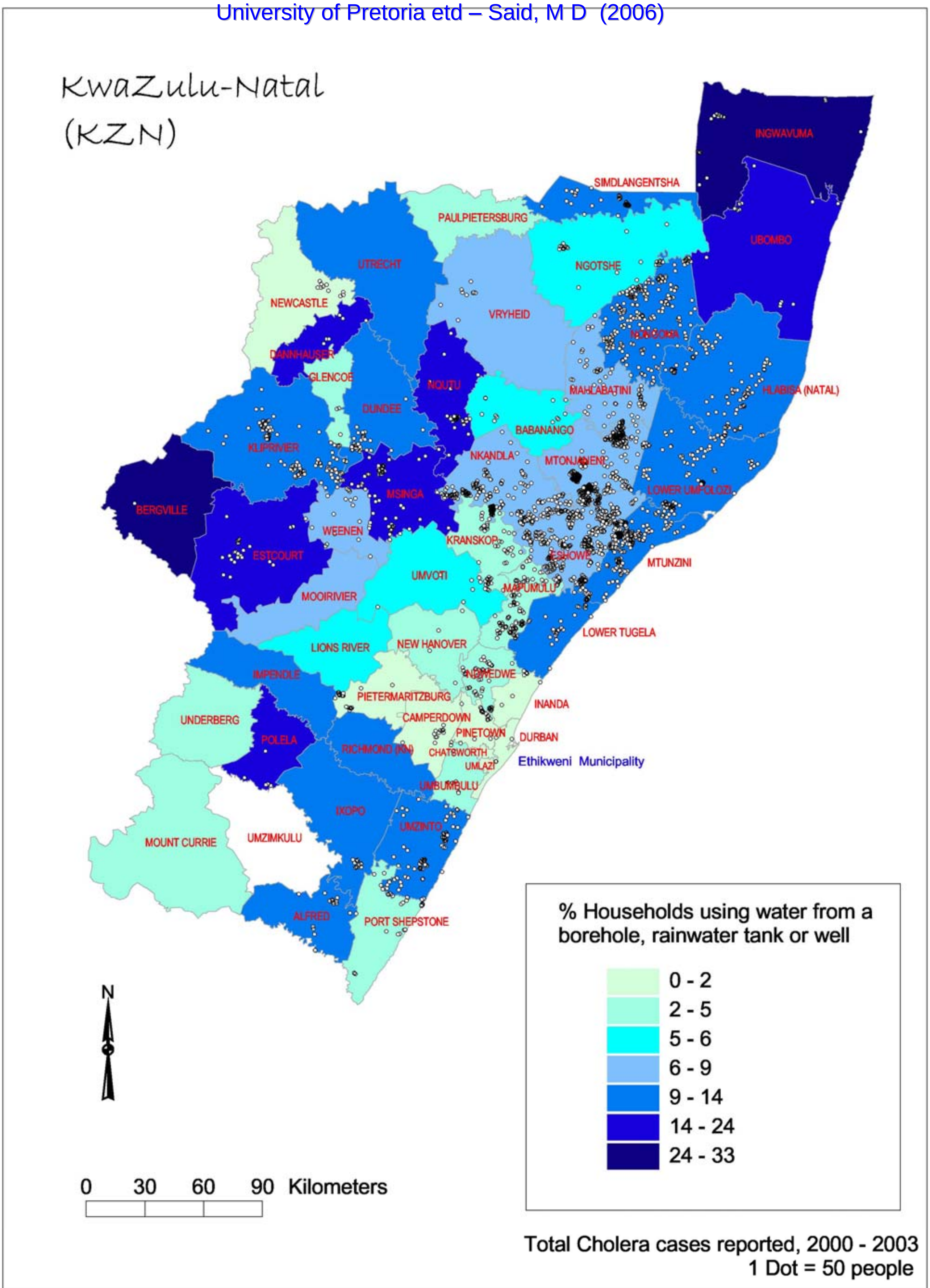

**Map 12: Percentage households in KZN using dam, river, stream or spring water**

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

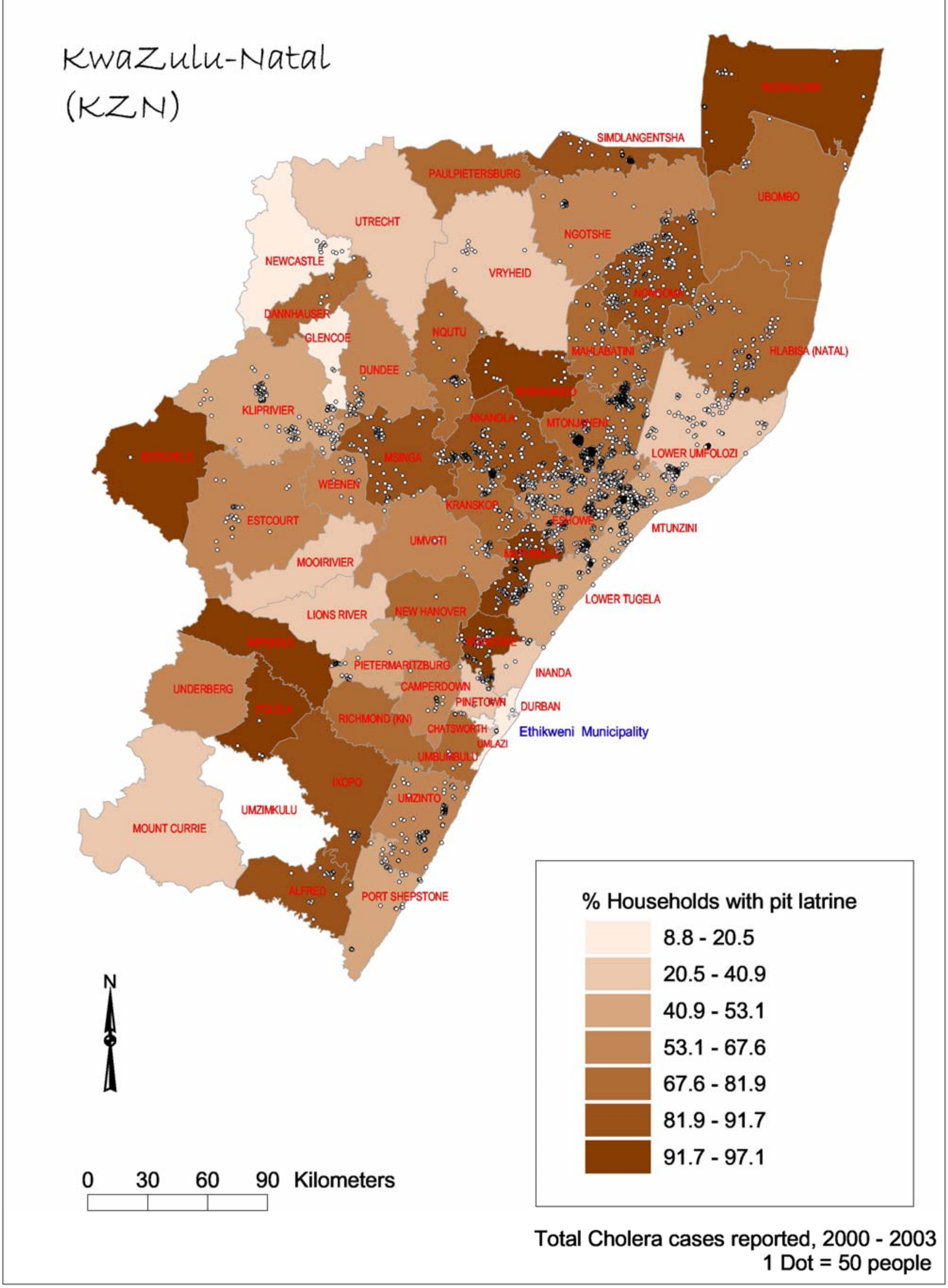



**Map 13: Percentage households in KZN using water from boreholes, rainwater tanks or well**

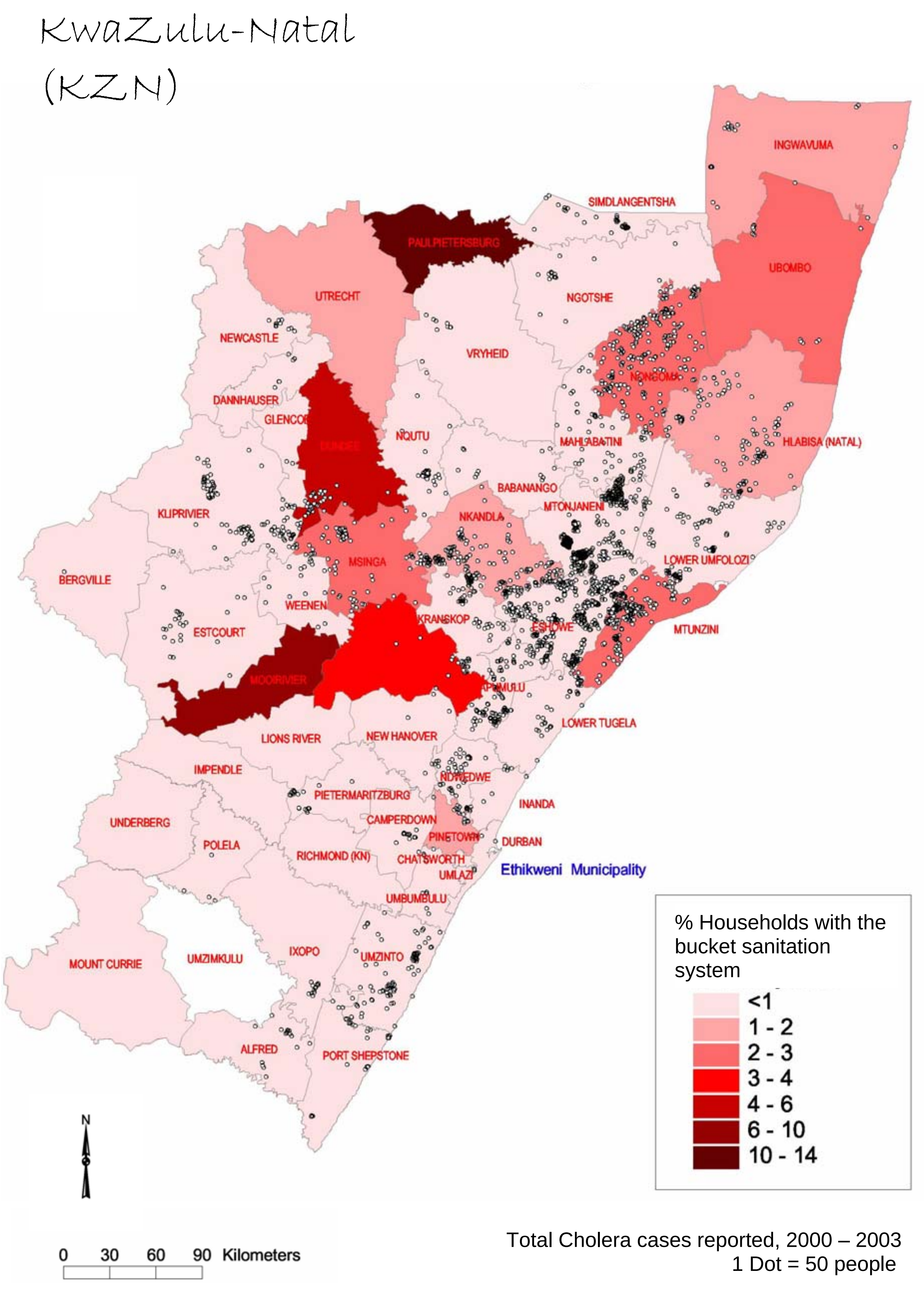
reach of most community sanitation programs or government funded housing schemes. Also, once set up, the system provides for adequate sanitation over a lengthy period of time with minimum maintenance requirements. Incidentally, this wide range in the proportion of availability of pit latrines, with the 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.

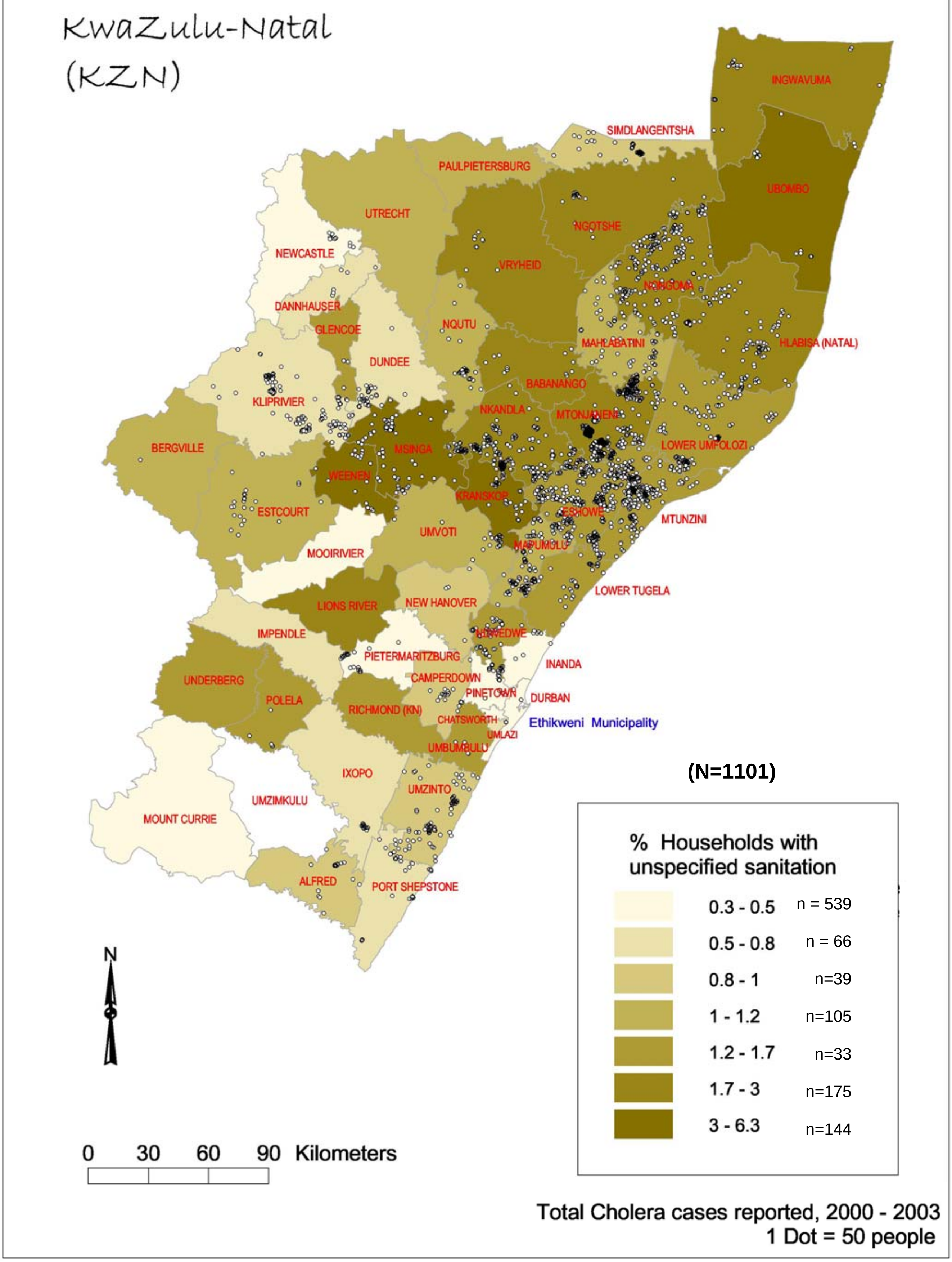
#### *6.2.3.3 Refuse*

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.

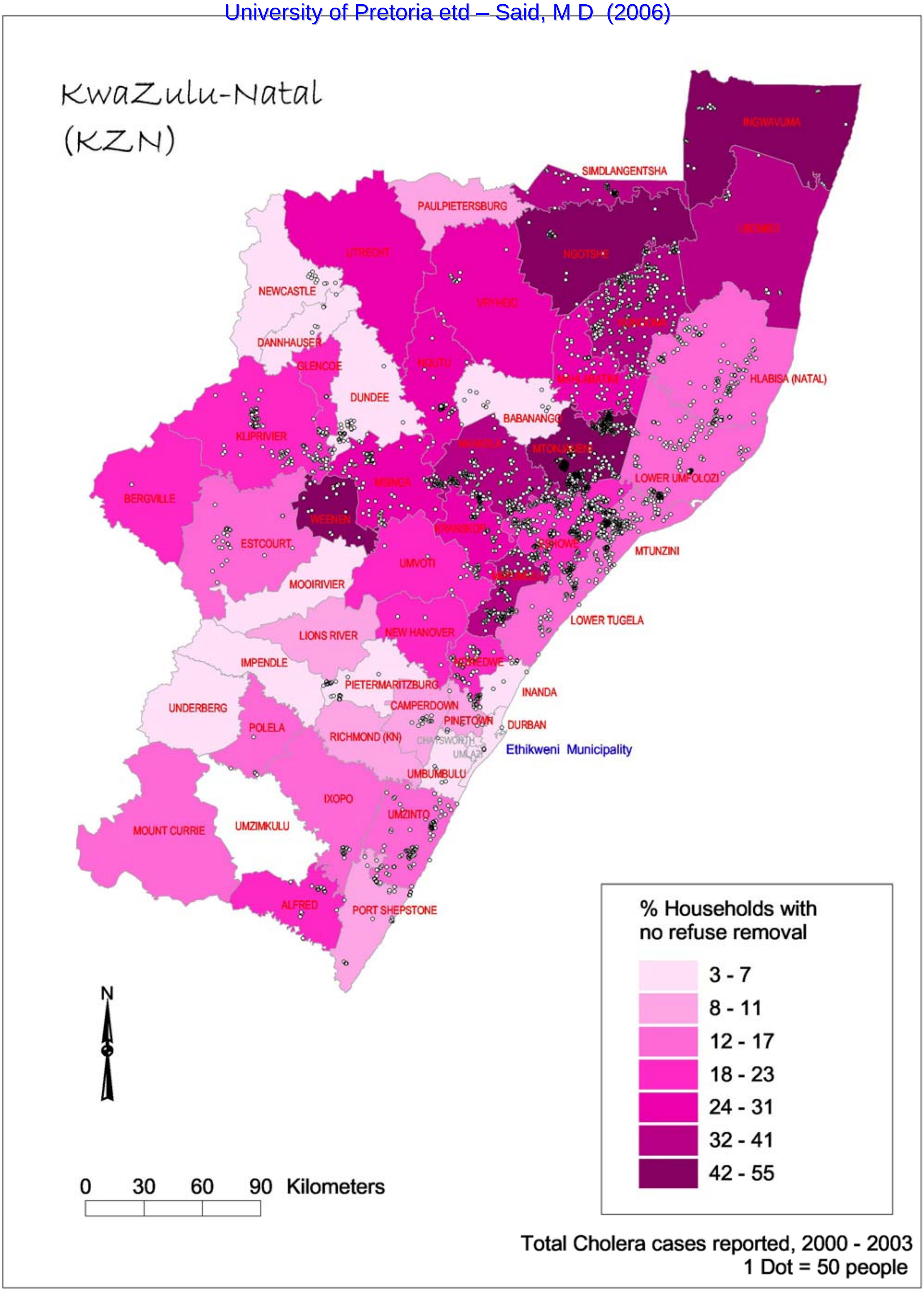
The spatial illustration of the areas with cholera cases clusters in relation to the refuse removal situation is presented in Map 17. Most of cholera cases clusters concur with the least serviced areas within the various MDs (Map 17). This observation is supported by the positive correlation (r=0.39 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**



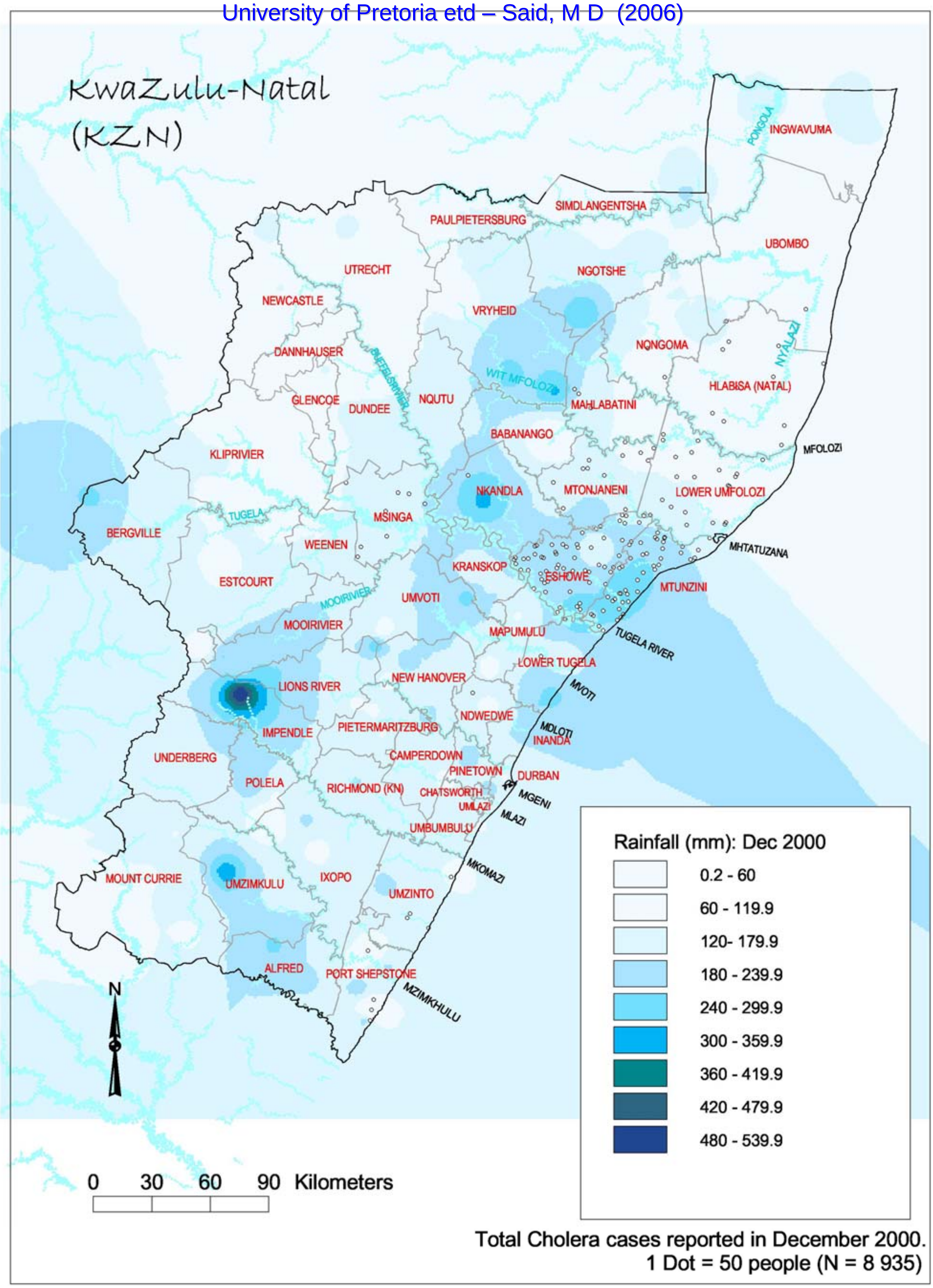

**Map 17: Percentage households in KZN with no refuse removal services**

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

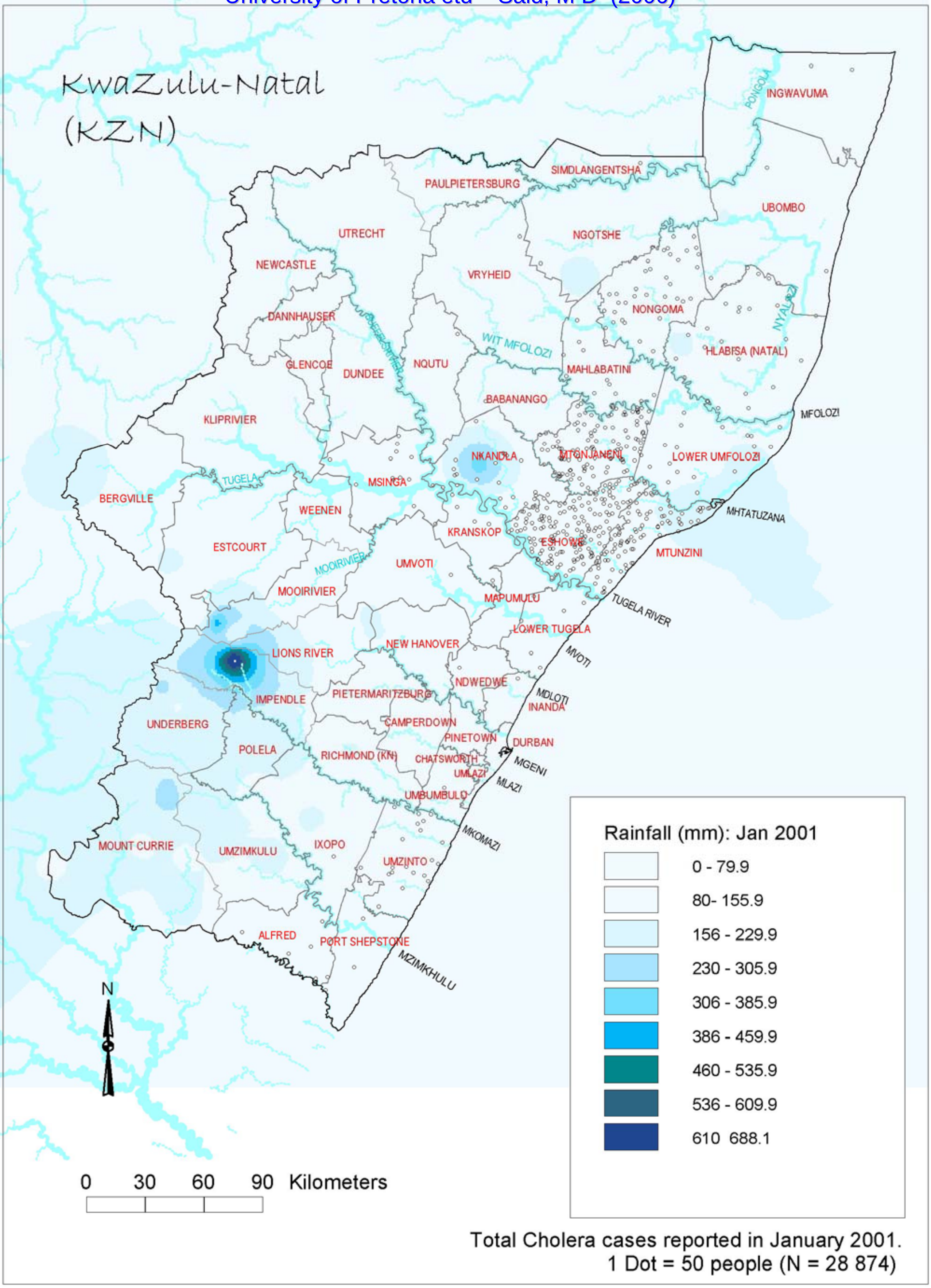
#### *6.2.4.1 Rainfall*

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.

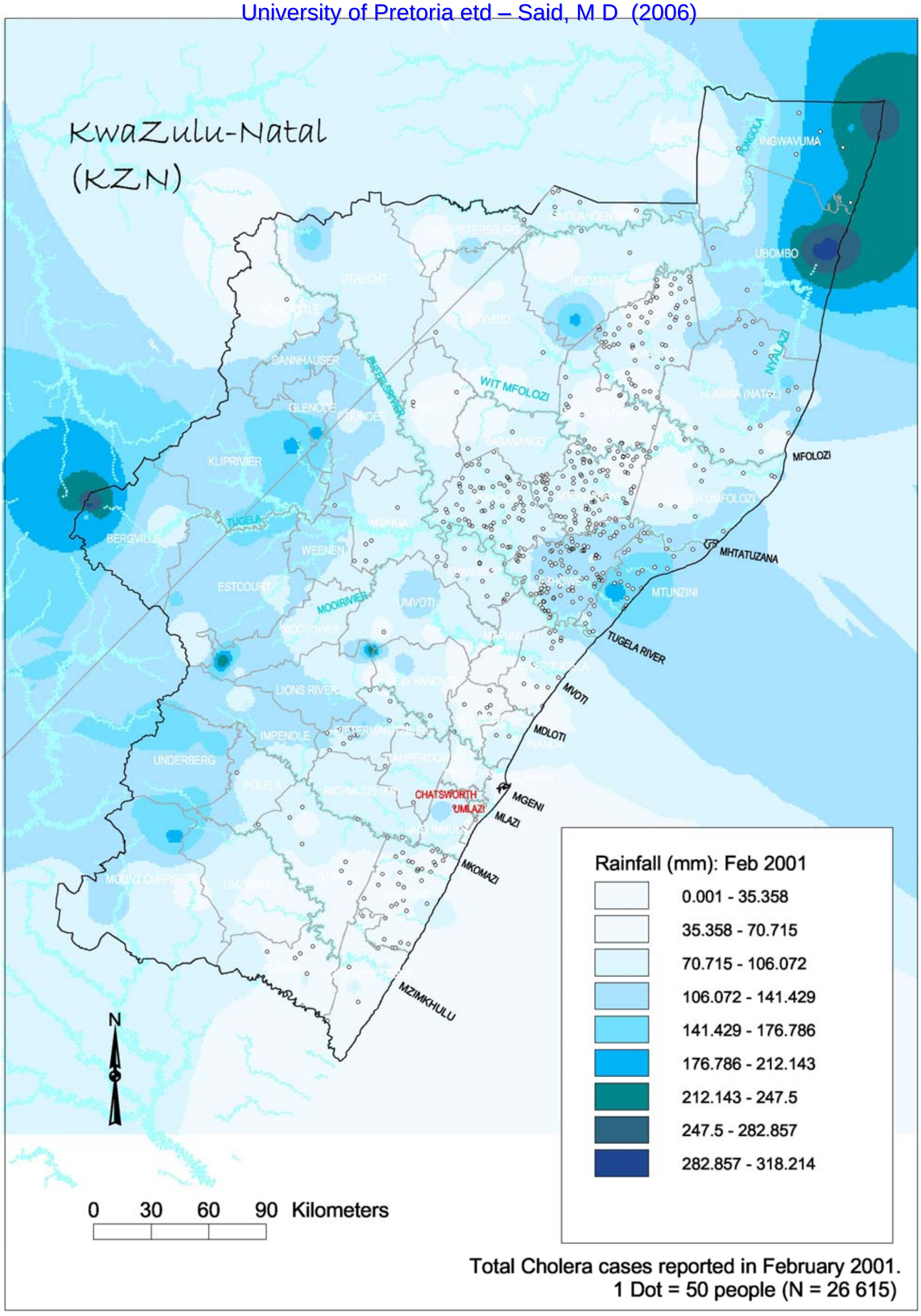
The rains had subsided but not the spread of cholera, possibly because; the rains of the previous month had provided an adequate trigger for cholera to reach epidemic proportions. January 2001 saw an unpredictable situation with an increase of new cases radiating more to the north than to the south of 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**

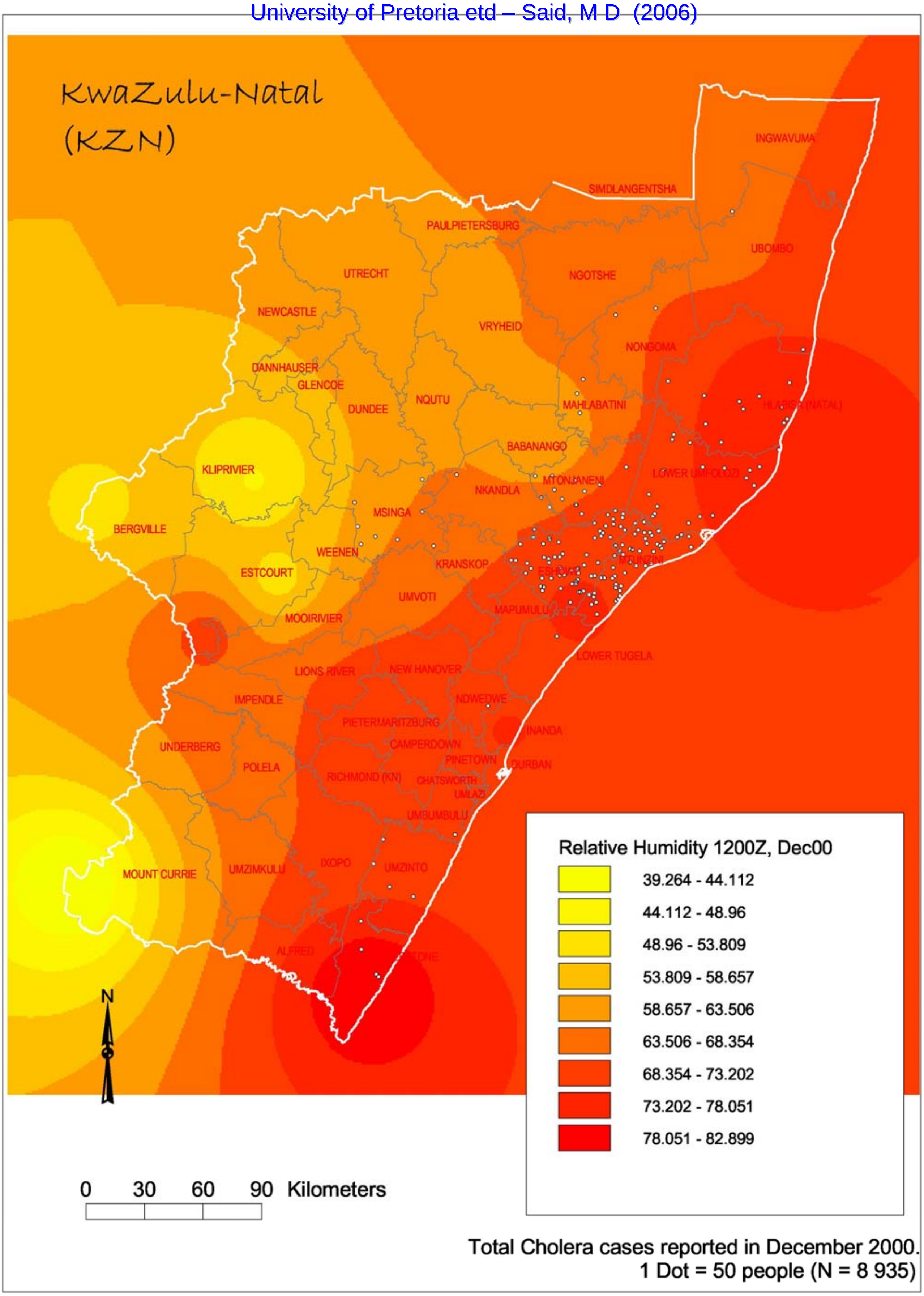



**Map20: Distribution of Cholera cases and monthly rainfall during February 2001 in KZN**

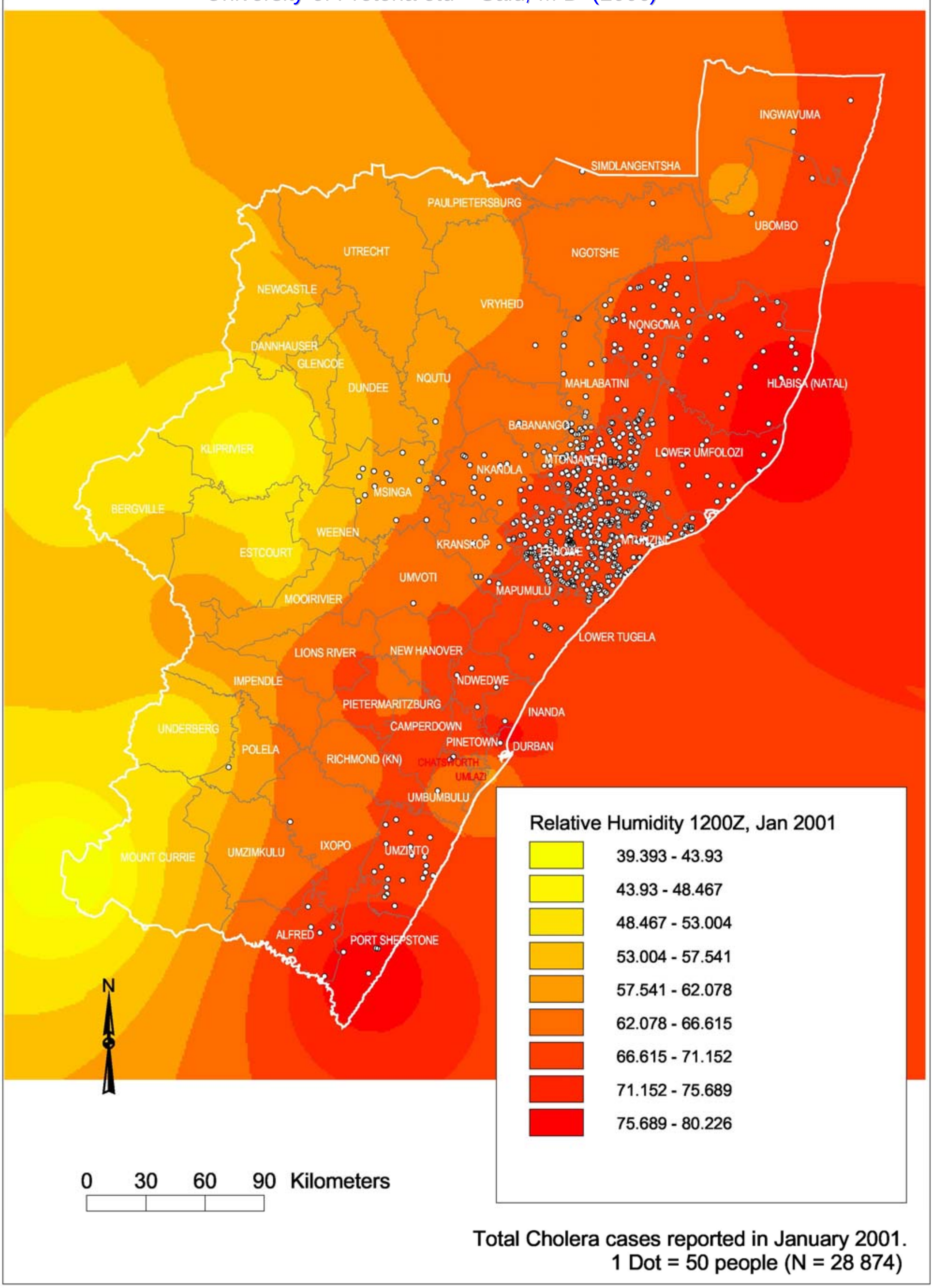
*6.2.4.2 Relative Humidity*

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%.

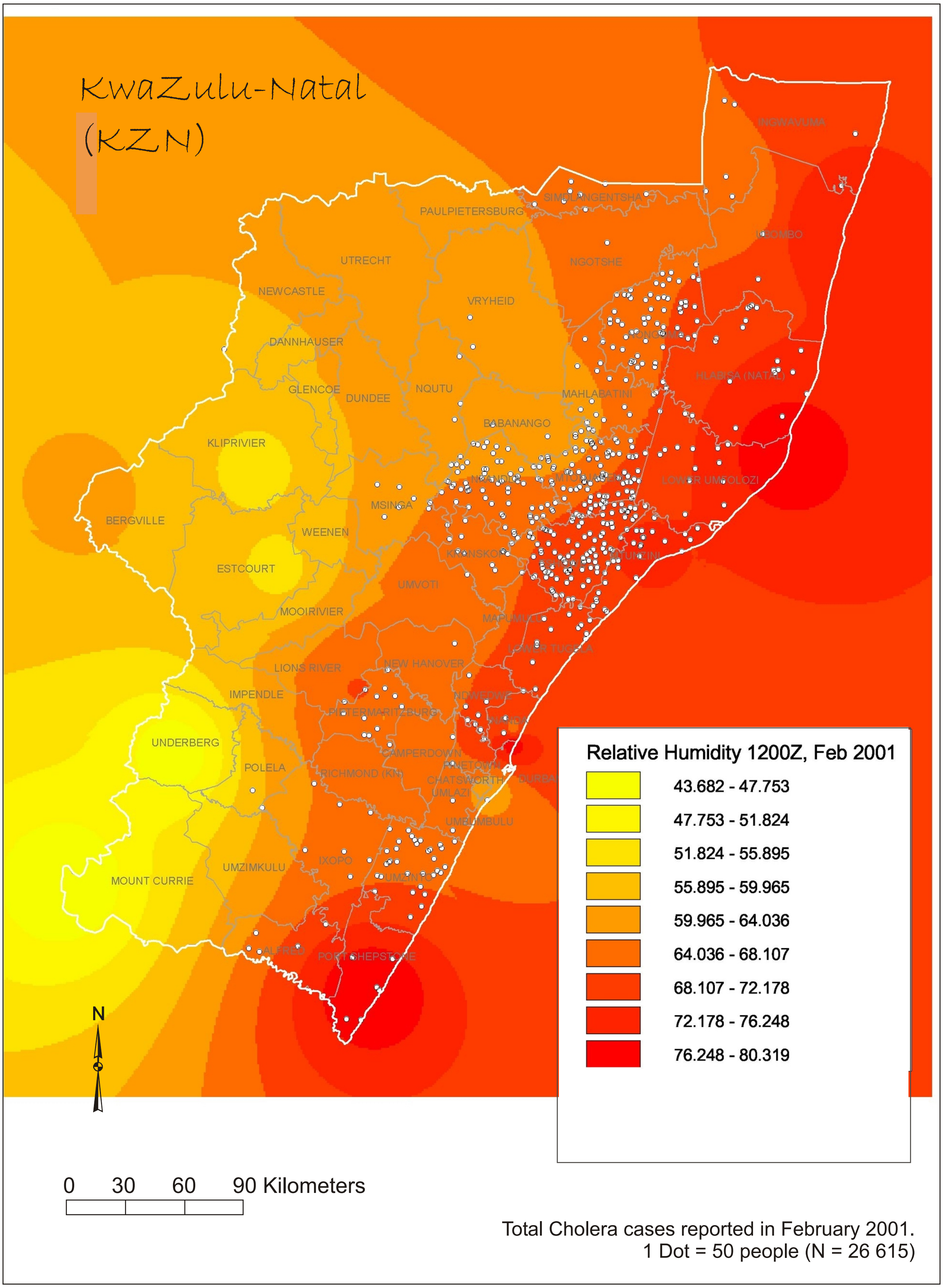
Most of the case clusters that were reported to the north, south and west of the disease foci were confined to areas with humidity levels of at least 62%. The humidity levels in February 2001 were more or less similar to those of January 2001, with most of the case clusters confined to areas with humidity 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**

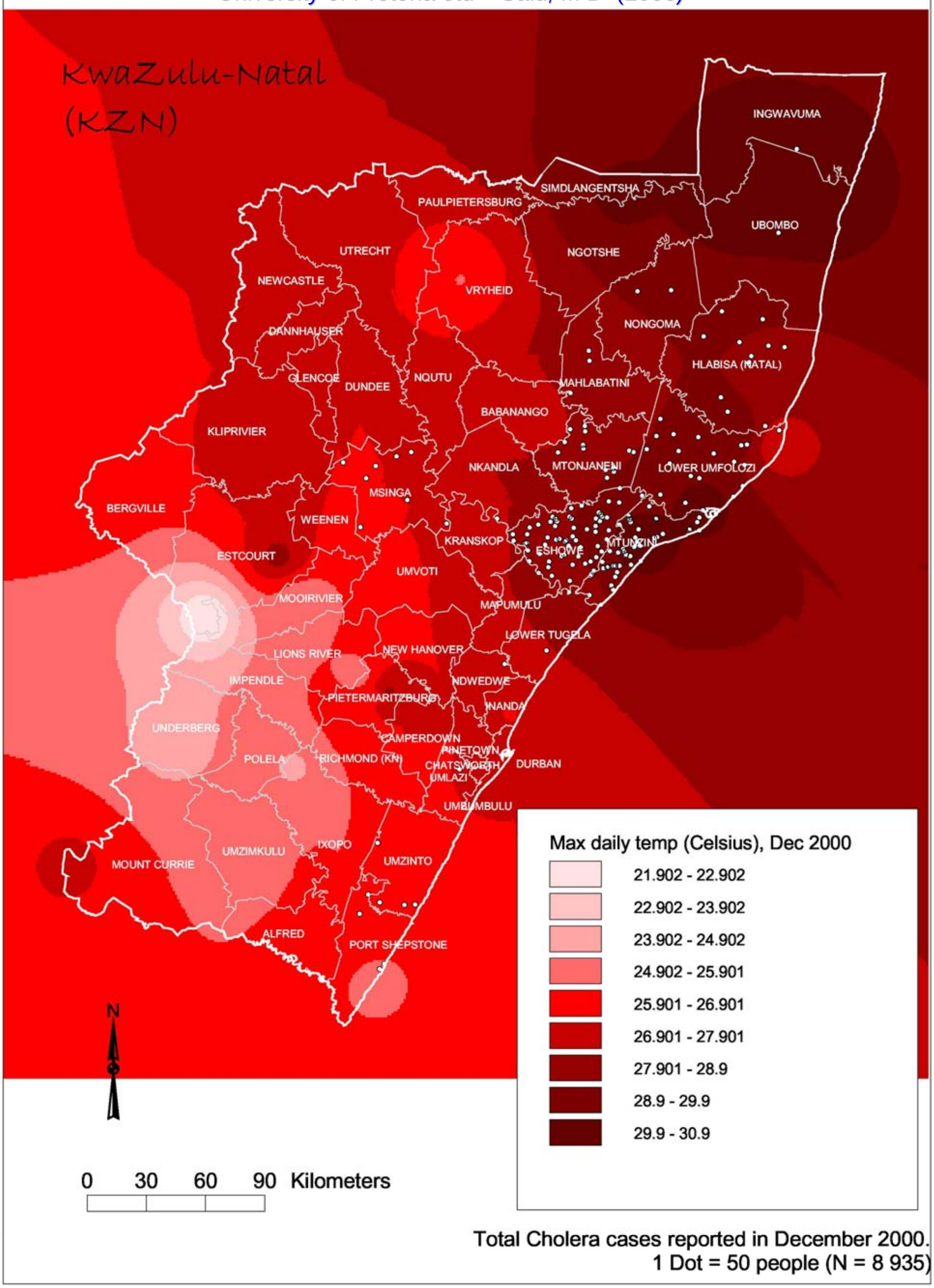



**Map 23: Distribution of Cholera cases and humidity during February 2001 in KZN**

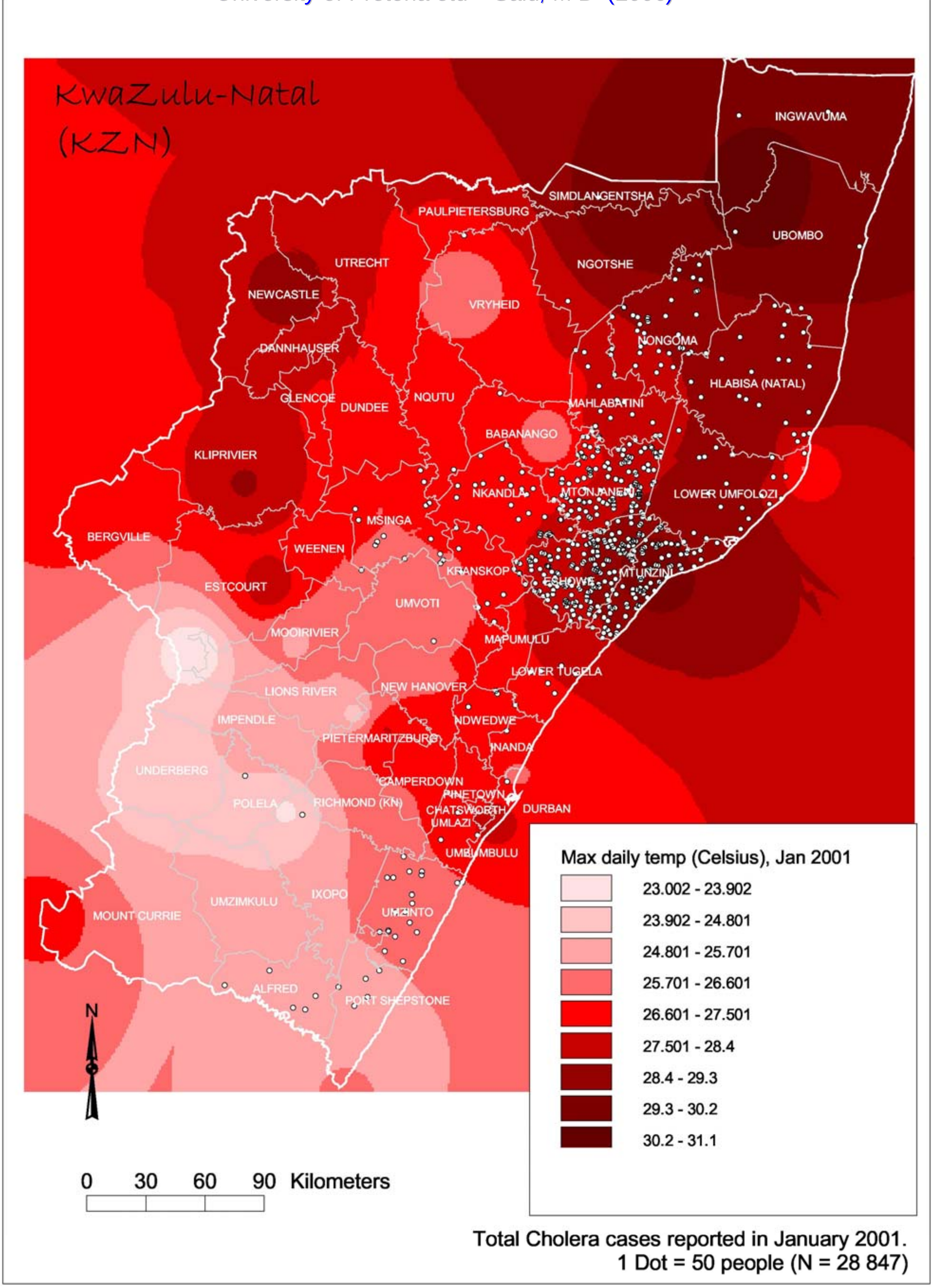
***6.2.4.3 Maximum temperature***

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.

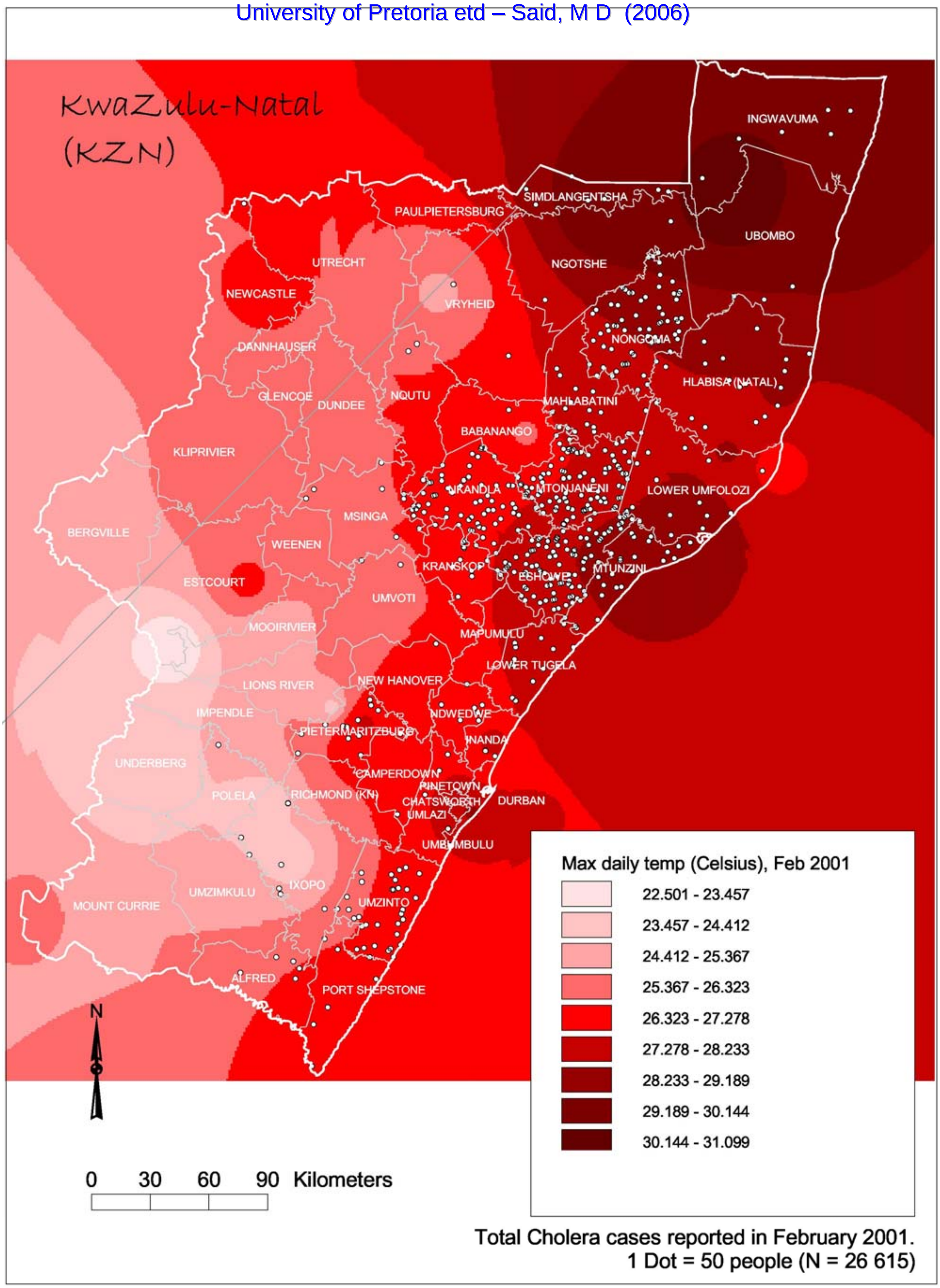
The climatic maps (Maps 18-26) depict that cholera started in the coastal MDs that experienced high rainfall, humidity and maximum temperatures. The disease then spread to the interior, where less rain, low humidity and milder maximum temperatures were recorded. The climatic conditions of the coastal 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**

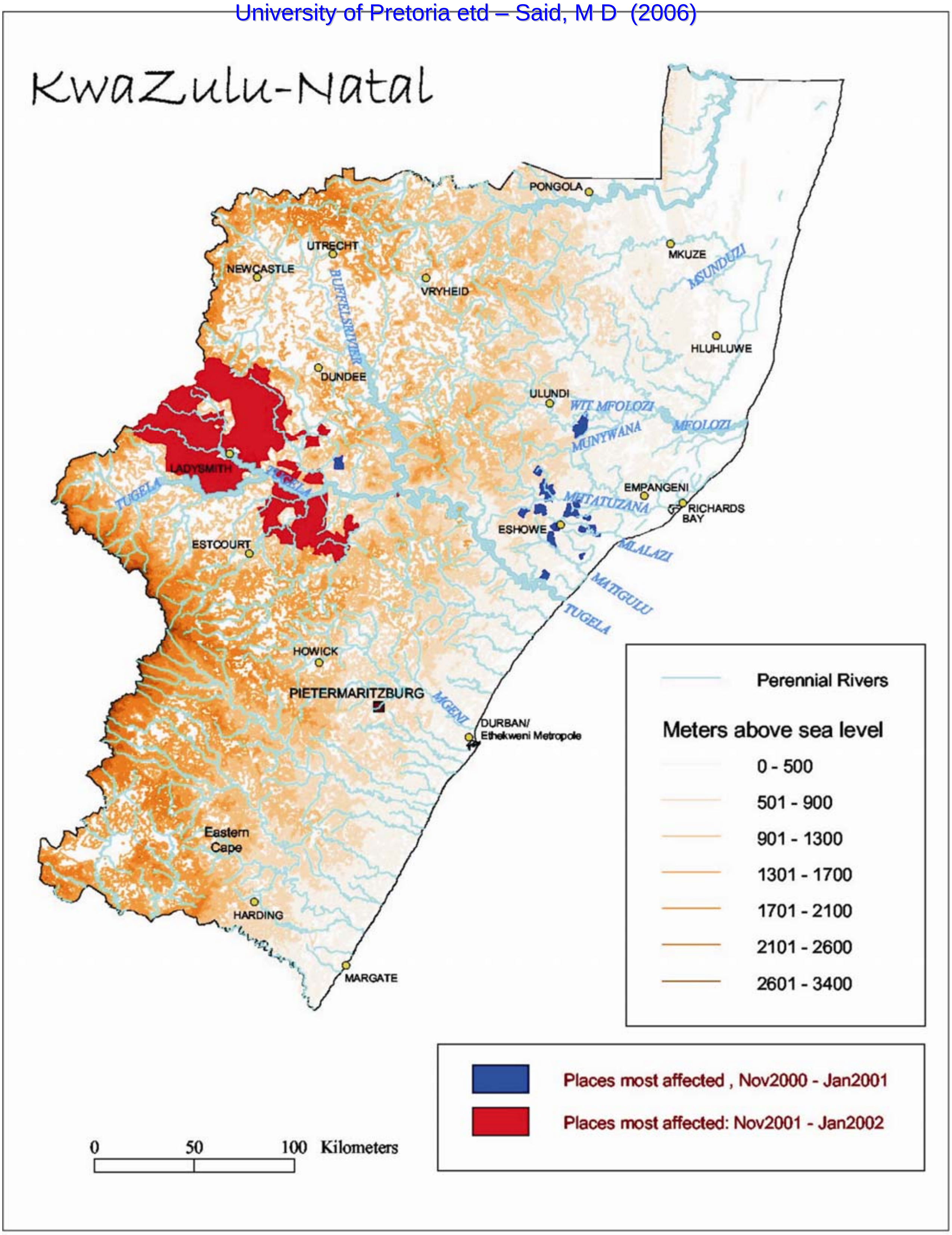



**Map26: Distribution of Cholera cases and maximum temperature during February 2001 in KZN**

## 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%).



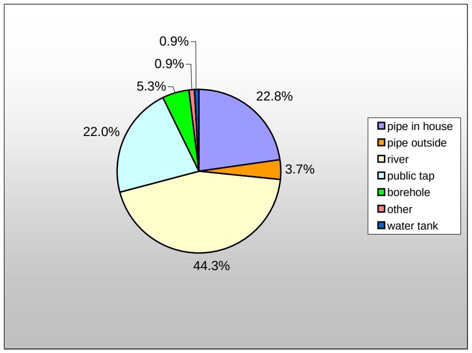

**Map 27:** **Location of perennial rivers in relation to the places most affected by cholera in KZN**

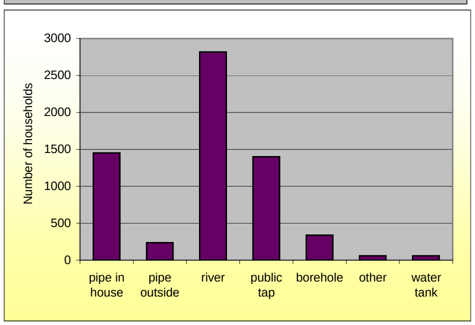
**WATER SUPPLY for top 15 places (First Peak) in mostly DC28**

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** |



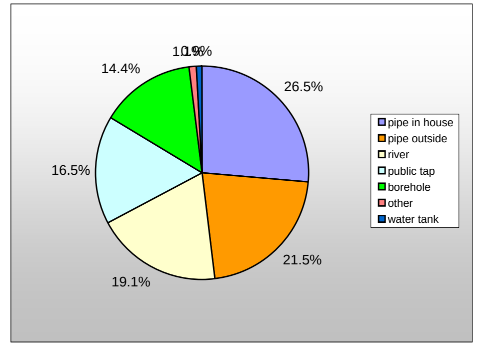

**WATER SUPPLY for top 15 places (Second Peak) in mostly DC23**

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** |



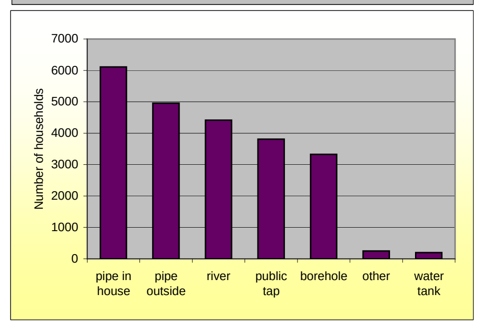



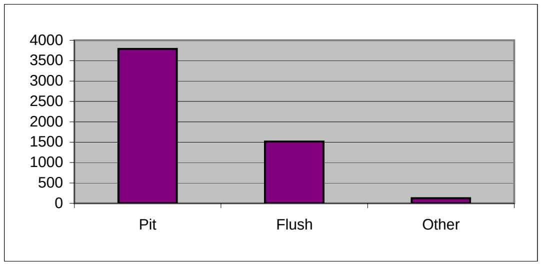

**Figure 6.1: The status of the water services/options for the top 15 places of the major and minor peaks respectively .**

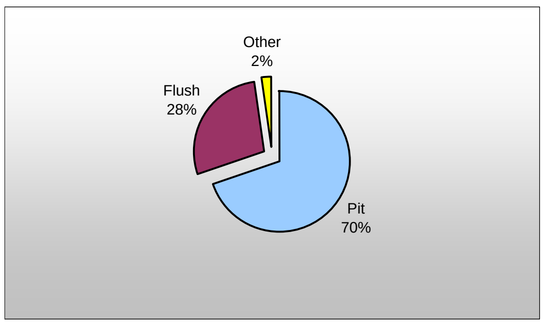
**SANITATION for top 15 places (First Peak) in mostly DC28**

**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 |



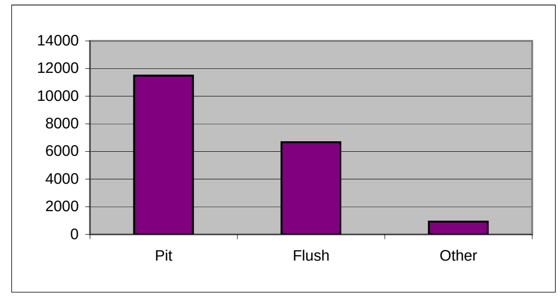




**SANITATION for top 15 places (Second Peak) in mostly DC23**

**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 |



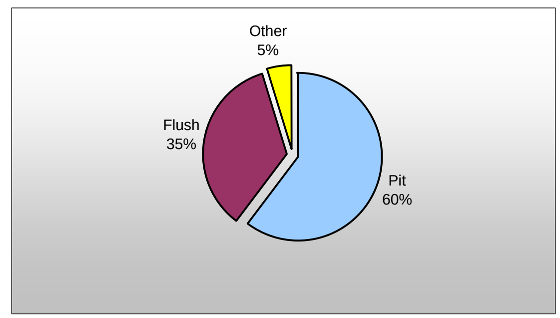



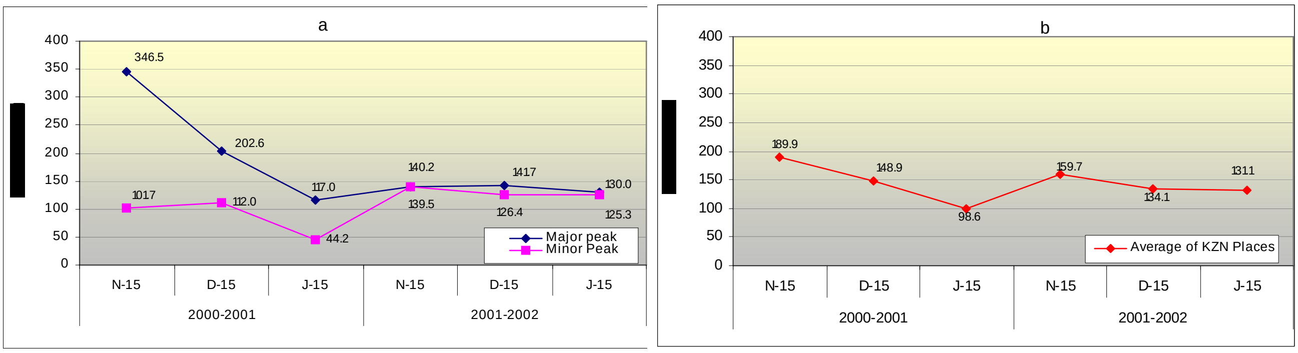

**Figure 6.2: The status of the sanitation options for the top 15 places of the major and minor peaks respectively.**

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

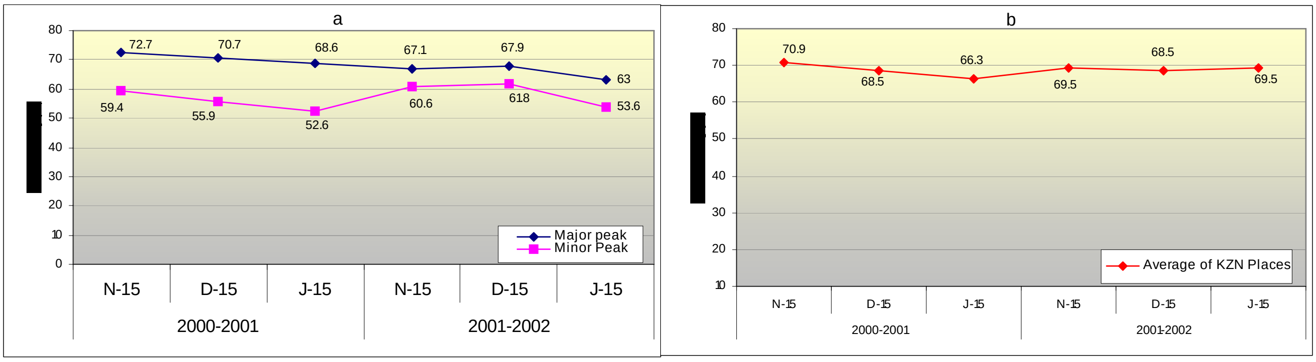
| Place-name | Magisterial District | District Council No. | Total cases 00-04 | Nov_00 cases | Dec_00cases | Jan_01 cases | Sub Total |
|---|---|---|---|---|---|---|---|
| Mfanefile | Mthonjaneni | 28 | 4777 | 0 | 18 | 990 | 1008 |
| Lumbi | Mthonjaneni | 28 | 4168 | 0 | 6 | 1012 | 1018 |
| Mpumaze | 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 |

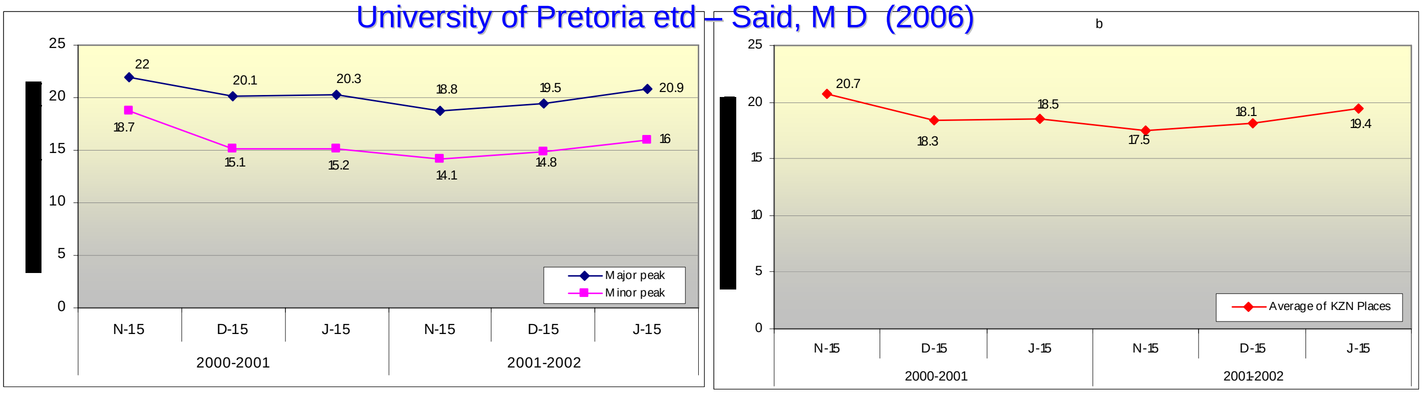



Figures 6.3a-b: A comparison of the average rainfall of the 30 most affected places in relation to that of the entire KZN province.

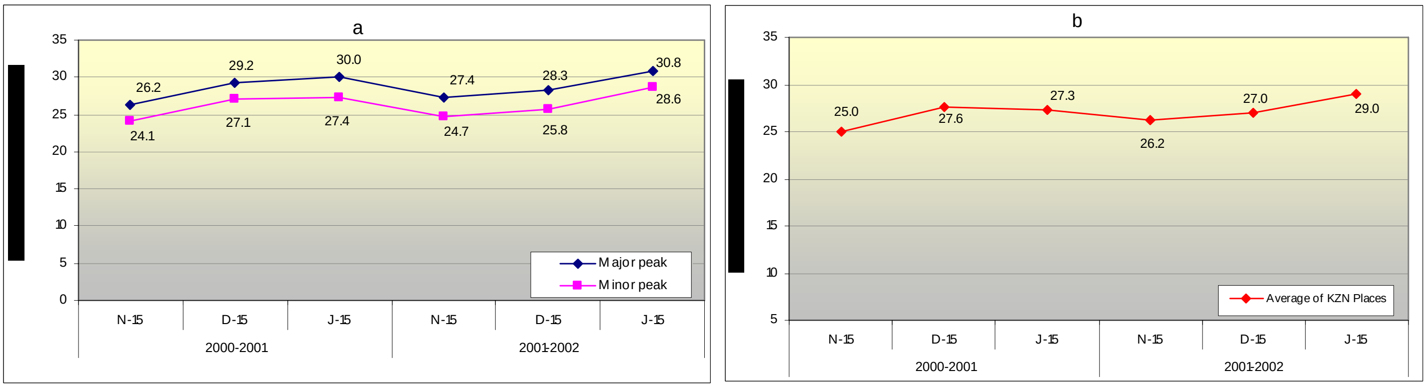



Figures 6.4a-b: A comparison of the average relative humidity of the 30 most affected places in relation to that of the entire KZN province.

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.

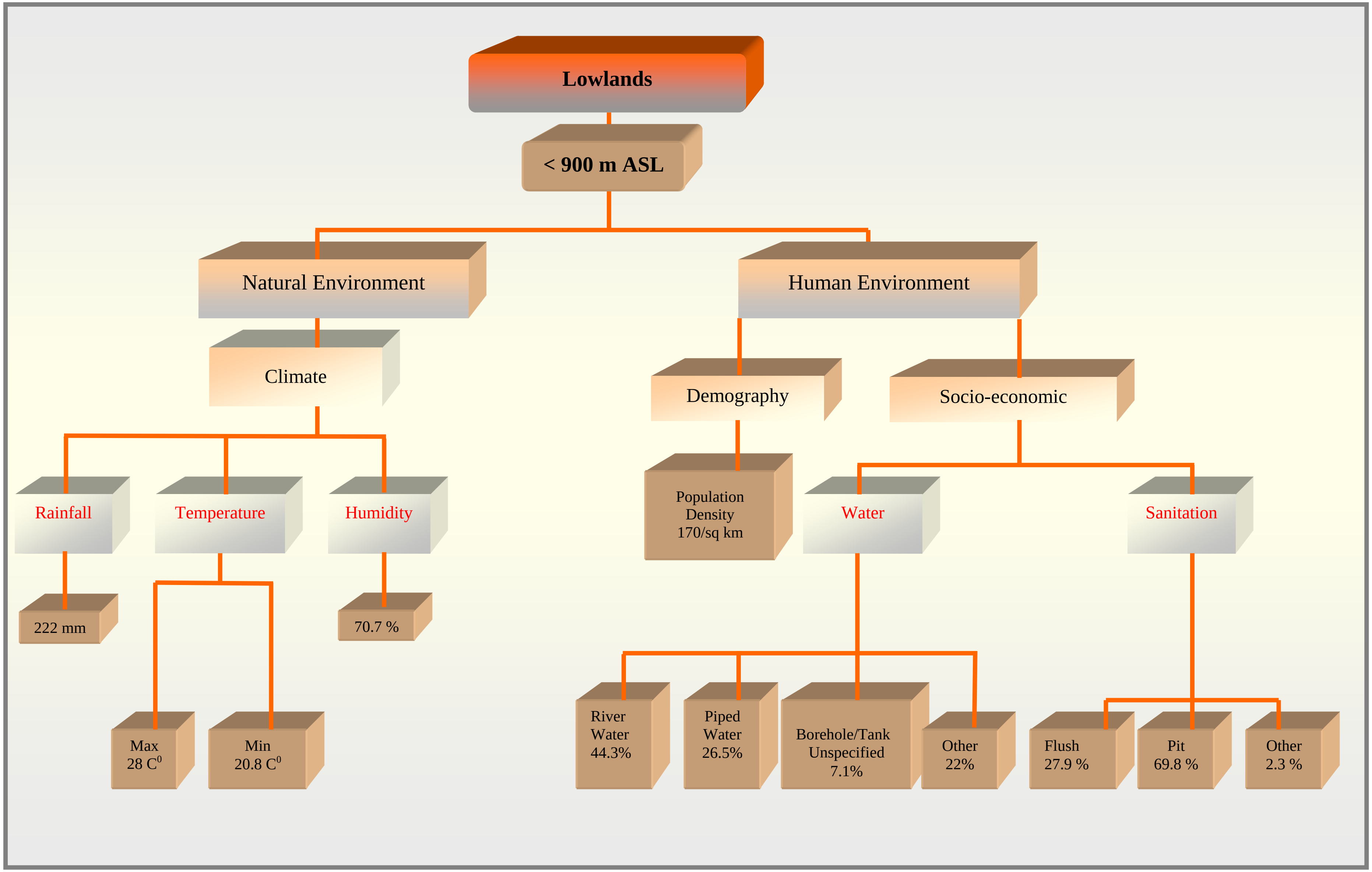



Figure 6.7: Flow diagram showing the climatic, demographic and socio-economic variables related to the Lowland Model.

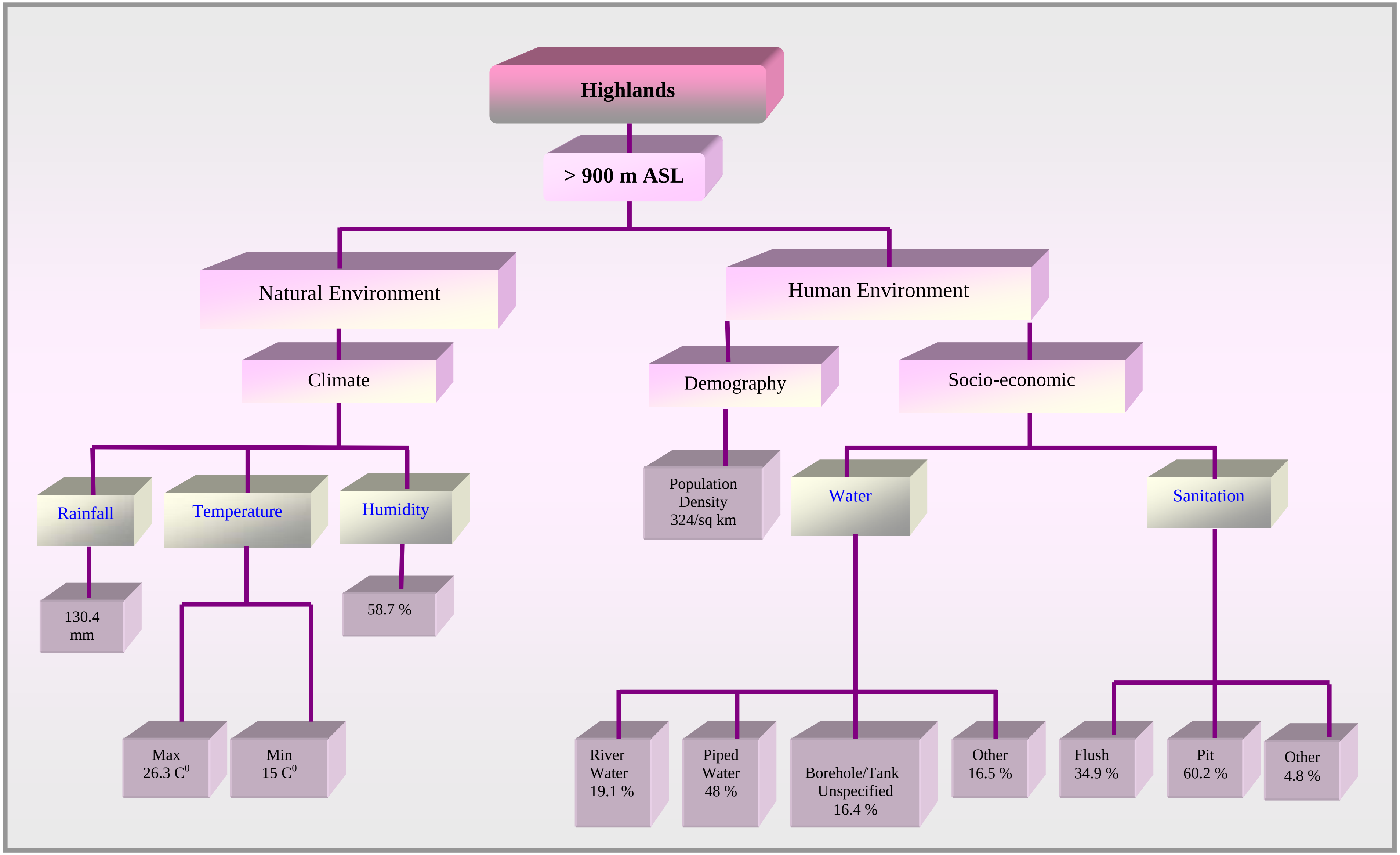



Figure 6.8: Flow diagram showing the climatic, demographic and socio-economic variables related to the Highland Model.

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).

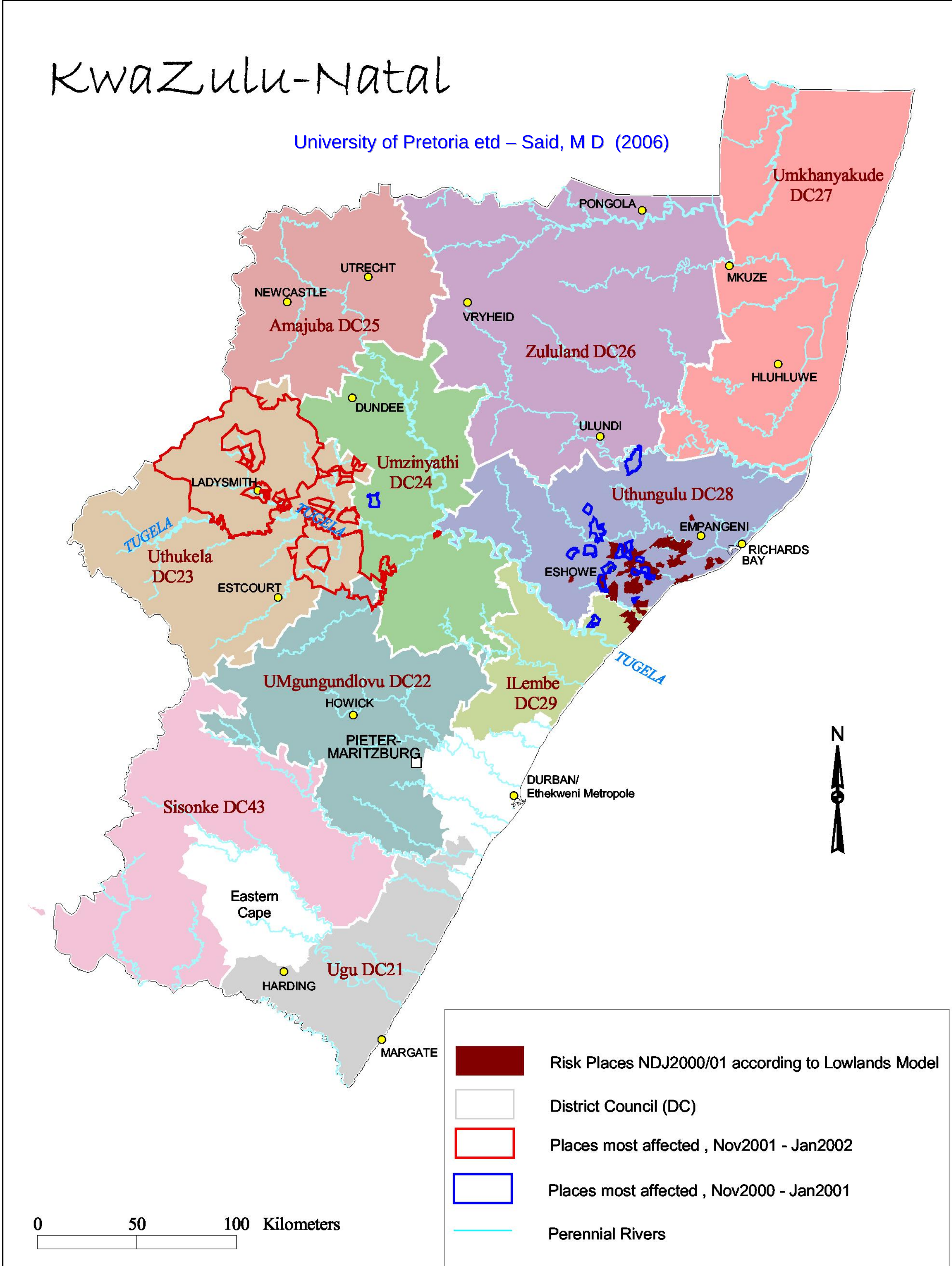
Table 6.8: The different selection criteria used in the risk assessment model versus the datasets of the Nov-Dec-Jan (NDJ) months of the 4 years.

| | 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 |

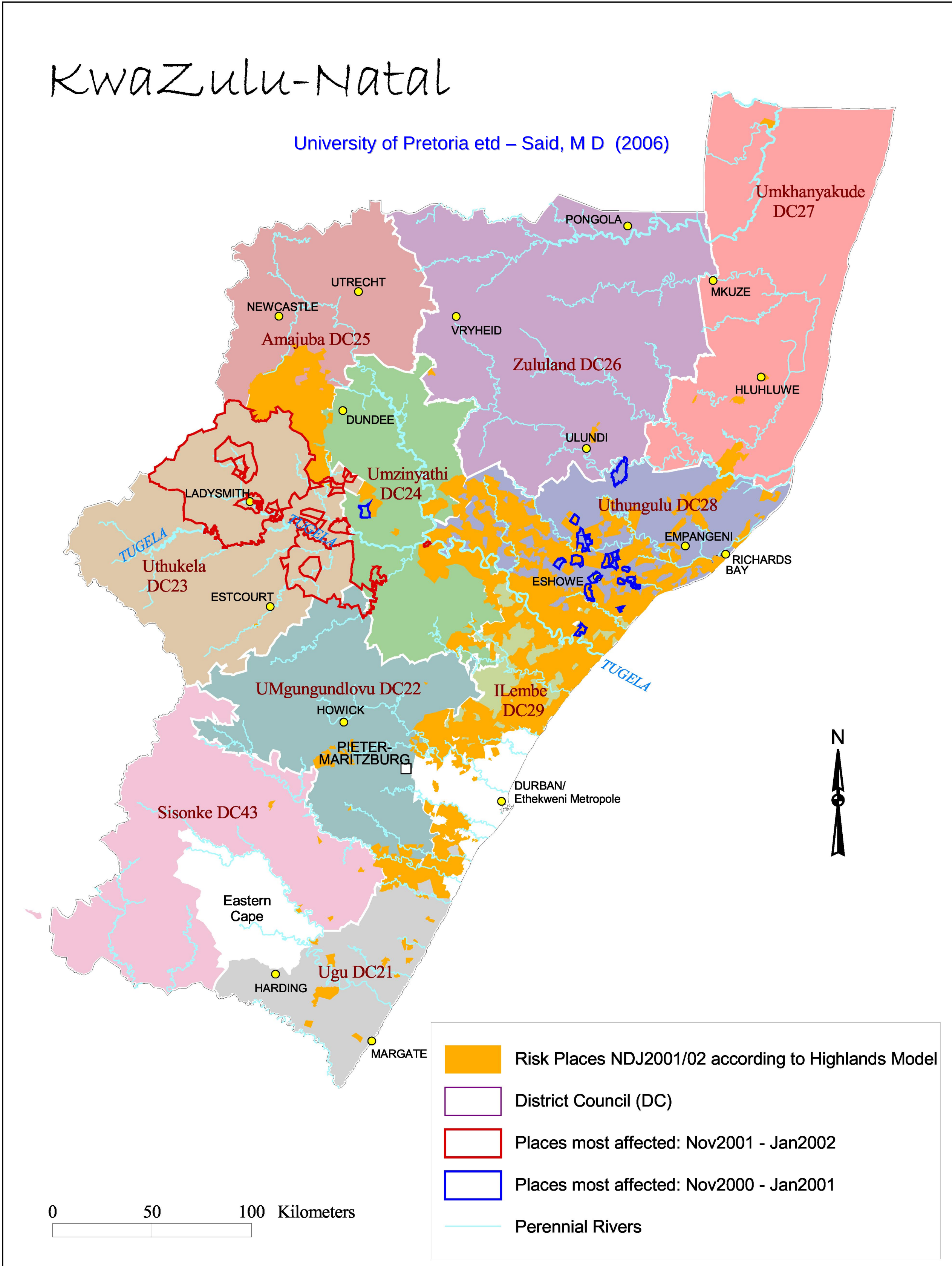
( ) = Number of places that showed high risk to cholera using the specific selection criterion.

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.

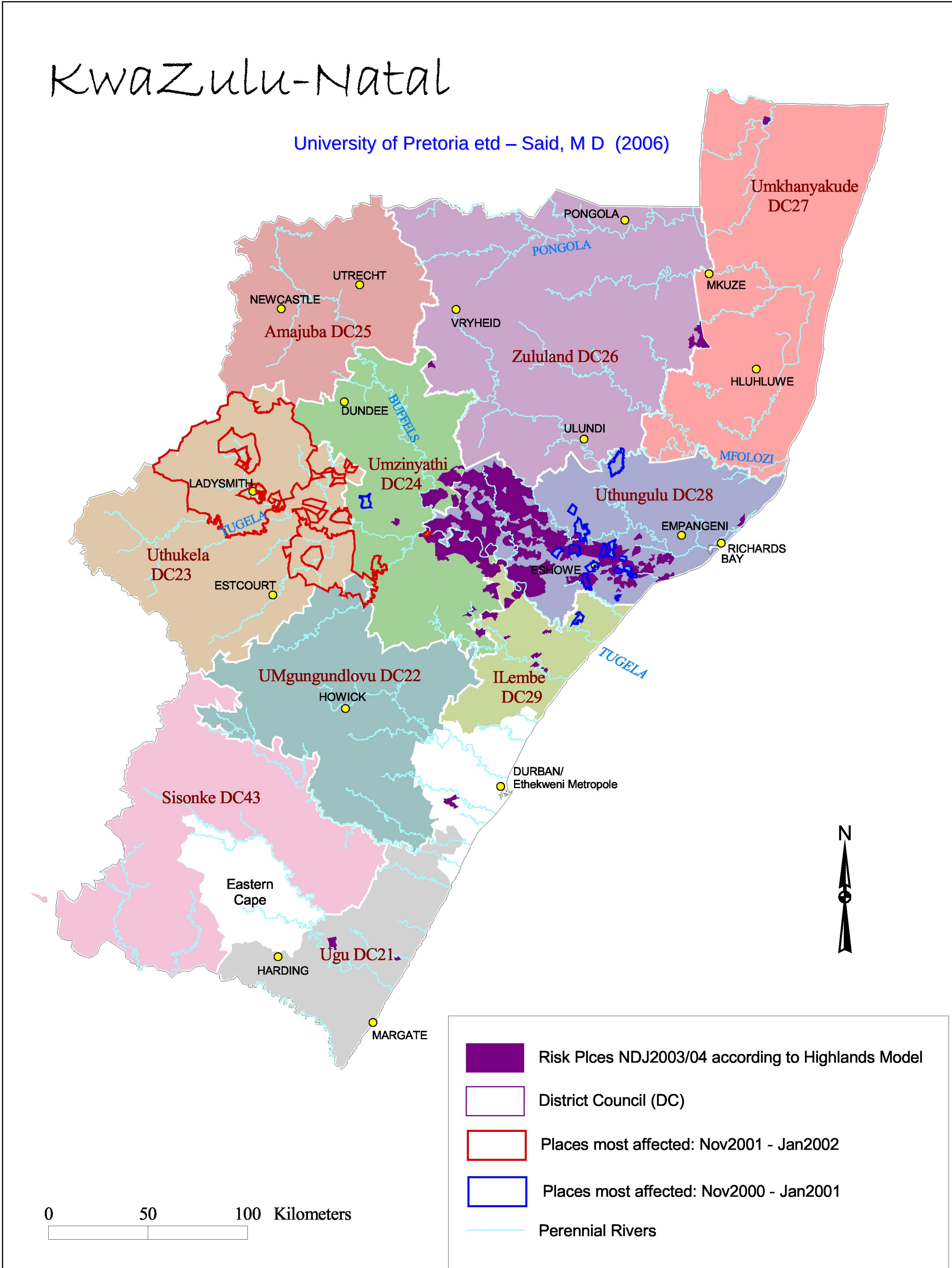
Maps 29-33 draw attention to the places that are at risk to cholera. Criterion 1 (Lowlands Model) versus the NDJ data of 2000/01 picked up the least number of places (50) as being at risk to cholera (Map 29). Most of the places highlighted to be at risk were positioned close to the places that were most 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.



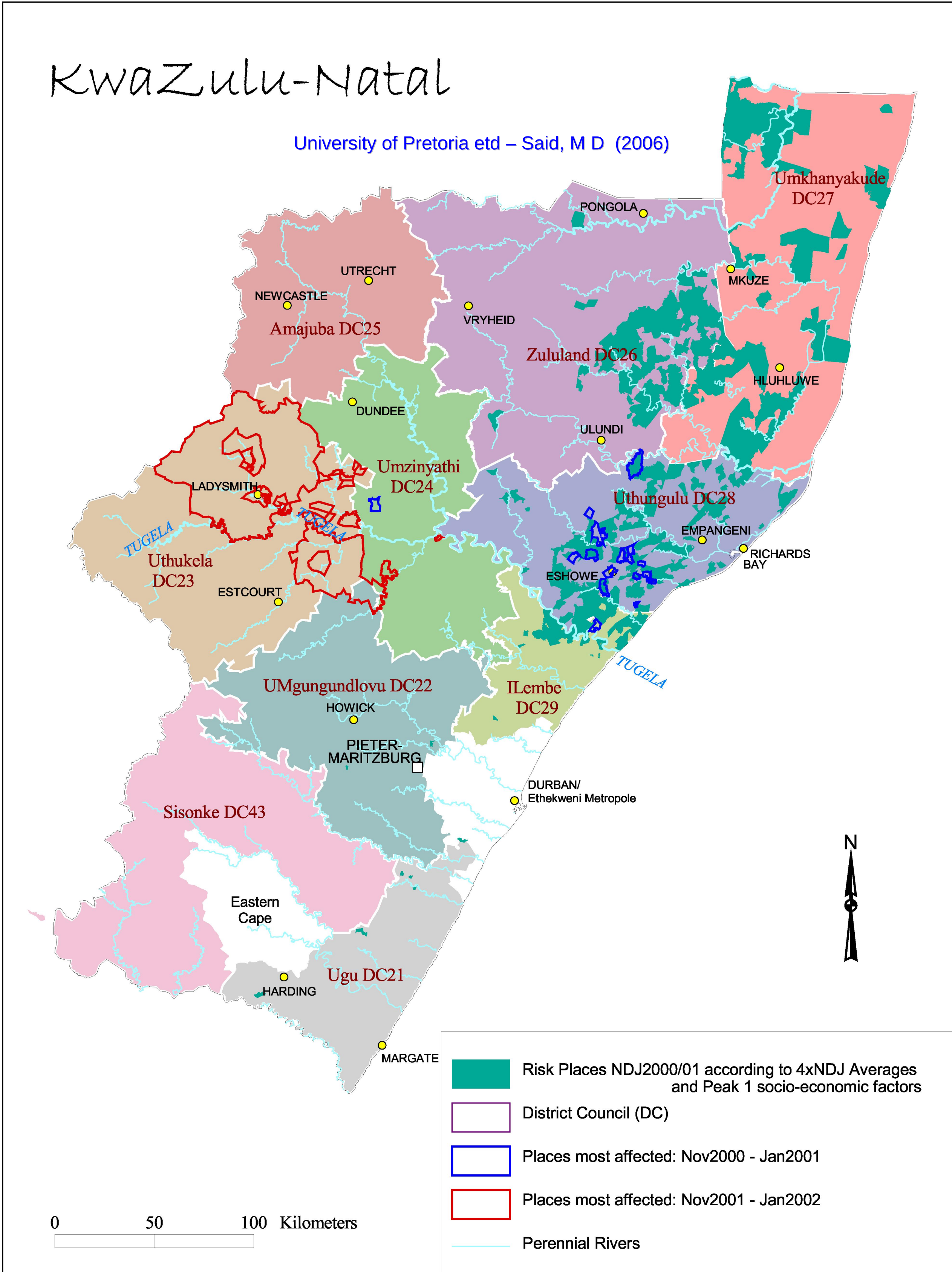

**Map 29: Showing Cholera Risk Areas by applying the Lowlands Model during Peak 1 (NDJ2000/01)**



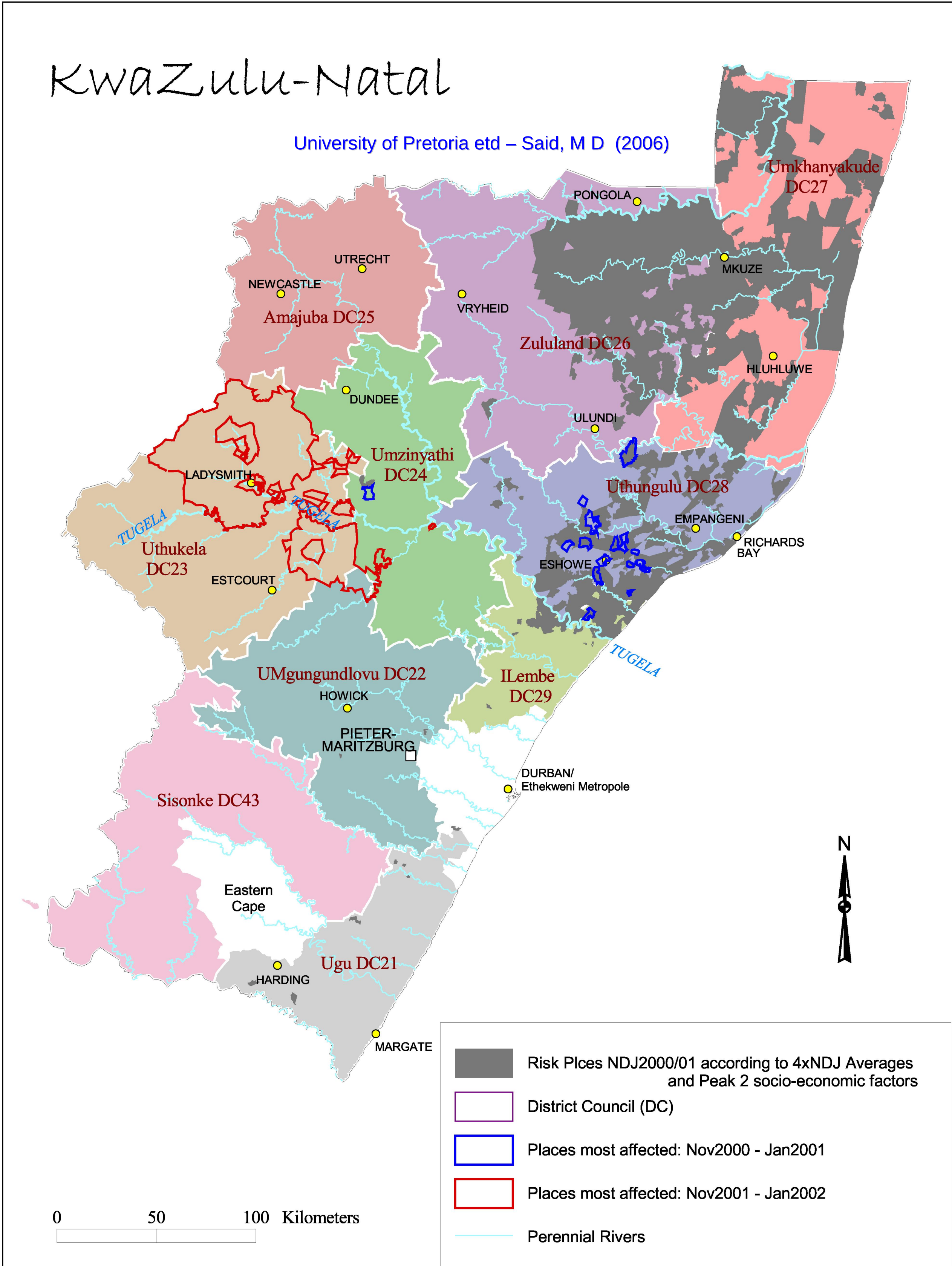

**Map 30: Showing Cholera Risk Areas by applying the Highlands Model during NDJ2001/02**



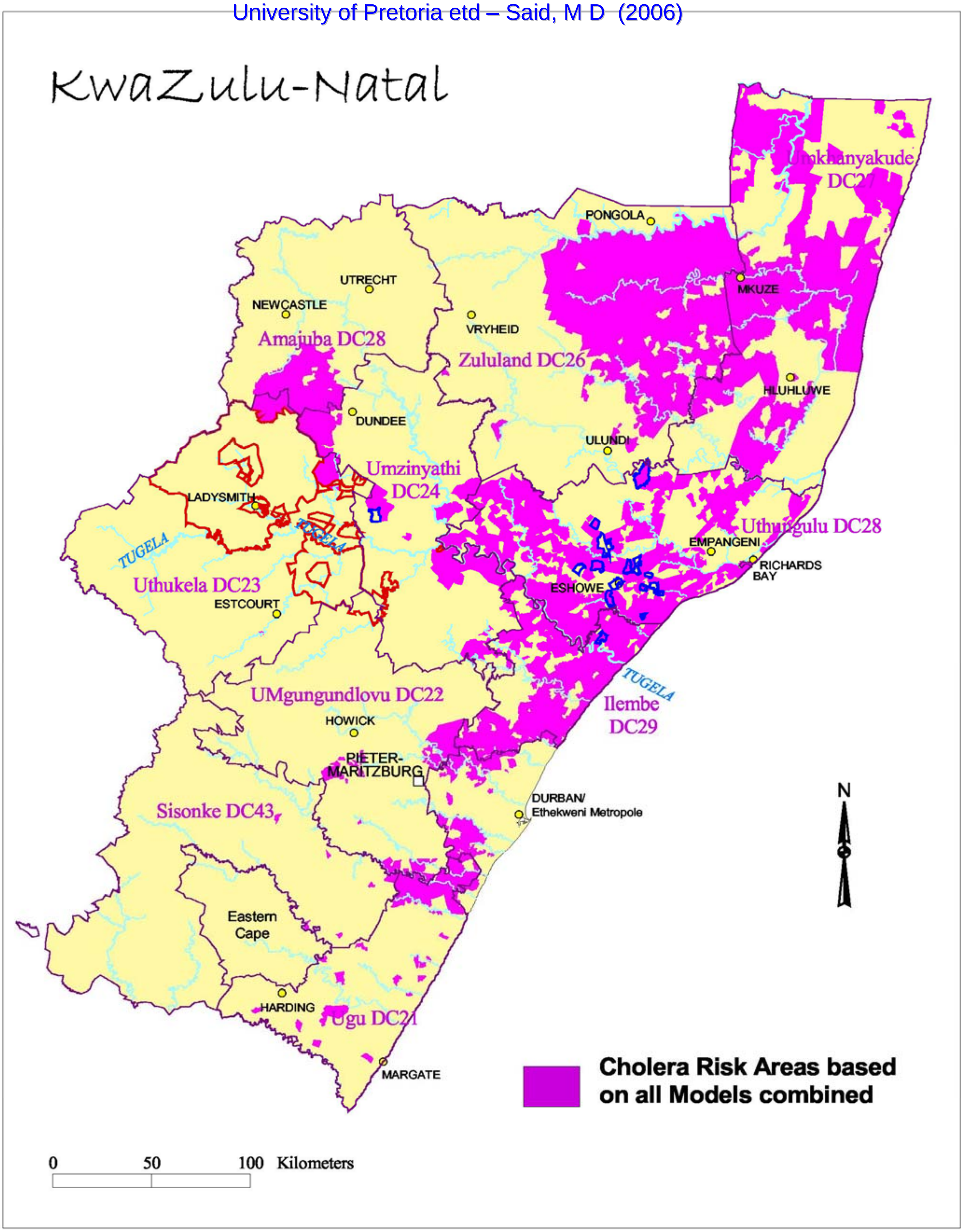

**Map 31: Showing Cholera Risk Areas by applying the Highlands Model during NDJ2003/04**




**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.