United Nations Expert Group Meeting on
Contemporary Practices in Census Mapping and
Use of Geographical Information Systems
29 May-1 June 2007
United Nations, New York

Census mapping and the use of geo-spatial technologies (A case of South Africa)[*]

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Census mapping and the use of geo-spatial technologies
(A case of South Africa)

This paper contains Statistics South Africa's experiences in geo-technologies and geo-information usage for census activities in the PAST, PRESENT practices, some FUTURE plans and our learning's along the way.

The PAST

Prior to 1996, Statistics South Africa's (Stats SA) mapping for censuses was purely paper-based; 1: 50 000 topo-cadastral maps were acquired from the South African mapping agency, Department of Land Affairs (DLA), and from local town councils. EA boundaries were hand-drawn on these. Photocopies were glued onto blank listing books. Newly recruited contract fieldworkers made use of the photocopied map and blank listing book to record structures on the ground, as they traversed the country during the listing phase of the census (see Appendix for examples).

After Census 1996, Stats SA was approached by the Independent Electoral Commission (IEC), the commission responsible for conducting the country's election. They required digital enumerator area (EA) boundaries so that EAs could be rolled-up into voting areas. A joint project, appropriately titled Project **EA**gle, was kick-started by four government departments (nicknamed the BIG FOUR) namely DLA (to fast track the capturing of cadastral data), Municipal Demarcation Board (MDB) who required such data for the rationalisation and re-determination of municipal and provincial boundaries, Stats SA (for census data dissemination and future census and surveys) and the IEC for electoral purposes. By 1998 South Africa, had its first digital set of EA boundaries superimposed on updated digital cadastral data.

Stats SA made use of these digital EA boundaries to package the 1996 census data using Supercross. EAs were aggregated into small areas (or city, towns, suburbs, villages and local communities) called place name areas, with census data attached to them and presented spatially. EAs were becoming the building blocks for many other spatial entities.

As a result of this, the GIS section at Stats SA started developing. Ambitiously, this time with the focus on incorporating spatial technologies for all phases of the census, with the first aim to have the country demarcated into EAs using spatial technologies and spatial data.

For Census 2001, Stats SA worked in partnership with DLA to acquire aerial photography. This photography was made available freely to all government departments. (see Appendix for coverage map) It was also during this period that Stats SA began exploring the use of satellite photography for 'change detection' by overlaying the 1996 EAs on it. About 80% of the 2001 EA demarcation was done in the office on a GIS using photography and digital topographical maps. For the other 10% field inspection was done.

Learnings from the PAST
Census demarcation and mapping are core responsibilities for a statistical agency. It is therefore imperative that in-house **capacity** and skills be built to facilitate this activity. Post Census 2001, the Geography Division was established.

A well-maintained, some what stable, **geographic frame** that enables the comparison of statistics geographically over time was required. This frame cannot be done in isolation but in collaboration with the MDB who were and continues to review and restructure the country's geography. Such a frame shows the relationships between the different spatial entities and forms the basis for data collection and dissemination for censuses and surveys. (see Appendix for diagram of geographic frame)

The difficulty in identifying the '**unaddressed**' population in South Africa had to be looked into. Owing to South Africa's historical apartheid past, almost half the country's population are not allocated official addresses. During censuses numbers were spray painted on dwellings. At the same time, other service providers allocated their own numbers, which resulted in multiple numbers. Householders felt neglected and abused, '... *yet another number*'. Stats SA is currently leading a project to identify and allocate numbers in these areas.

The PRESENT
Strategically positioning GEOGRAPHY in a statistical organisation
The convergence of GEOGRAPHY and STATISTICS was, and still is, a personal crusade of the Statistician-General, Mr. PJ Lehohla. We have come to realise that EA boundaries were no longer a unit of logistics for census enumeration, but were becoming a critical expression of development challenges as it became the basis for analysis and dissemination, thus making GEOGRAPHY a centrepiece for revolutionising statistical management from statistical production to dissemination.

The diagram in the Appendix shows Stats SA's System of Statistics. It consists of National Accounts that overarches economic and social statistics which are based on frames namely the Business and Geographic Frames, which form statistical pillars, governed by quality methods and standards. Over the past few years, Stats SA has elevated the importance of the Geographic Frame, Geographic Methods, and Geographic Standards, in essence, the inclusion of *Geographic Knowledge*, in the production and dissemination of statistics, similar to that of the Business Frame, thus formalising the strategic role geography plays in the system of statistics.

The DWELLING Frame
Started as the Address Project, then the National Address System & Register Project and now currently known as the Dwelling Frame Project. The project started with the main focus on allocating addresses to about 50% of the country's residents that have no addresses - mainly in the former homelands of South Africa. In these areas land is also not formally allocated to households, falling under Trust Land, consequently there is no formal cadastre. Formal addresses and cadastre only exist in cities and towns. In terms of spatial data for South Africa, the picture is one of incomplete data (*gaps*). Spatial data that do exist remain questionable - can it be used for statistical purposes with confidence?

The Address Project was piloted and launched in the village of Botseleni in the province of Limpopo in 2002. Dwelling points were captured on a Geographic Information System (GIS) and addresses assigned. The next major project was in the community of Thaba Nchu in the province of Free State. This was done jointly with the local municipality, DLA, South African Post Office and Stats SA.

During 2005, the project georeferenced another 15 municipalities - a total of 721 041 dwellings situated mainly in the Limpopo and Eastern Cape provinces. During 2006 another 21 municipalities - a total of 692 406 dwellings were further geo-referenced. Together with the georeferenced point for a dwelling, about 18 attributes are collected, describing the dwelling and its location. The project is gaining momentum as the target is to complete the entire country by 2009, since the Dwelling Frame will form the basis for EA demarcation and an electronic listing of dwellings for census enumeration. The project is divided into two parts, namely *formal* (areas where formal addresses exist and are linked to the cadastre); and *informal* (areas were no addresses exist).

For formal areas, address databases from local municipalities, larger cities and metropolitan councils are received, checked and compared against the 2001 census dwelling unit count and latest photography. So far there are 2 050 964 dwelling points from all 6 metropolitan areas in South Africa on our geographic database. We are in the process of setting up MoUs with local municipalities, larger cities and metropolitan councils to update gap areas. In 2005 and again in 2006, Stats SA conducted a *Municipal Spatial Data Capacity Audit*, together with the Department of Provincial and Local Government (DPLG), to determine local municipalities' current spatial data infrastructure, in terms of the four basic requirements for spatial data infrastructure namely *people*, *hardware*, *software* and *data.* The main purpose of the audit was to determine local municipalities' capacity to maintain and support spatial data and at the same time their ability to make use of such information. The results of the audits showed that there is a severe lack of capacity at the local level to keep data updated and complete. Results of the audit for 2005 showed that only 25.3% of local municipalities had capacity in all four aspects (it must be pointed out that the results looked better for 2006, see Appendix for 2005 and 2006 maps). It should be noted that the different data standards that address data are received from various sources, makes the integration extremely difficult. Stats SA initiated the creation of a national standard for address data through the national body for standards namely the South African Bureau of Standards, the standard is still under development. In the meantime, Stats SA Geography Division developed a standard address specification document which is used as a standard for the Dwelling Frame Project.

For informal areas in the country and areas with no information, aerial or satellite photography is acquired; an office exercise to put points on each dwelling takes place, then fieldworkers go into the areas to verify the point and collect the attribute data. A digital photograph of the dwelling is also taken. Stats SA conducts a 100% office quality control and a 3% field sample quality control on the data. Data are finally integrated into the geographic database.

This is certainly a massive project for Stats SA, since the capturing and its future maintenance is a tall order. Through our Minister we are in the process of seeking cabinet approval to include wider participation from other government departments so that the frame can be maintained collaboratively for the benefit of all as a common frame for infrastructure development in South Africa.

For the next census, the dwelling frame will form the foundation for EA demarcation and enumeration. Our vision is that such a frame forms the basis for all future household-based censuses and surveys and a possible substitute for the census of housing. (see data collected from the dwelling frame in the Appendix)

(See Appendix for pictures of the dwelling frame.)

National yearly coverages of AERIAL and SATELLITE photography
Stats SA made extensive use of aerial and satellite photography for the 2001 census EA demarcation. Since then we continue to make substantial investments in aerial and satellite photography collaboratively with other government departments. The maps in the Appendix show the coverage as used for the 2001 census and coverages currently available. At present, through partnerships, we have the entire country covered with Spot 2.5 metre resolution satellite imagery. This replaces old (very old!) and outdated topographical maps in some parts of the country. Our endeavour is to partner with other government departments, local municipalities, metropolitan councils and other bodies like South African Earth Observation Systems (SAEOS) (which is in effect South Africa's implementation of the Global Earth Observation System (GEOS)) to coordinate and make available annual seamless mosaic of aerial and satellite photography of the entire country.

Taking the use of aerial and remote sensing data further, through partnerships, the group of key role-players will develop and continuously maintain land cover and land use coverages as a national asset. These will be beneficial for census EA demarcation and classifications, e.g. urban and rural. Further exploration into deriving statistics such as dwelling counts, dwelling types, estimated population, population changes and movements, etc. from photography for inter-censual updates is currently being looked into by Stats SA, as this will reduce expensive fieldwork.

Going DIGITAL, surveys as the testing ground
The Dwelling Frame Project makes extensive use of GPS technologies. Points are captured for each dwelling, and attributes captured are downloaded on laptop computers and then uploaded onto geographical databases in the office.

The re-engineering of South Africa's Labour Force Survey (LFSR) afforded us the opportunity to make use of GPS and GPRS technology. A new master sample was drawn from the 2001 census EAs, fieldworkers were given GPS devices, points were captured for each structure, by means of GPSR technology point data were sent back to Stats SA Head Office directly from the field from all parts of the country. Exact locations of dwellings were required; therefore sub-meter accurate GPS technology was used.

Preparations are being made to load GPS points on the GPS devices to navigate back to the same dwelling to be interviewed for the completion of the labour force questionnaire.

The LFSR in many ways provided (and continues to provide) the testing ground for the use of new technologies that can be adapted for larger projects like a population census. In the first instance, it gave us the opportunity to revamp our map reading training materials (we have learnt that map reading is of fundamental importance to ensure that fieldworkers go to the correct EA. A joint standard map reading training course for certification is been planned by ourselves, DLA and Department of Water Affairs (DWAF)); map layouts; bulk map production applications; use of GPS and GPRS. Points collected for the sampled EAs for the LFSR will be integrated with dwelling points in the dwelling frame. GPRS technology reduced costly and time-consuming data capturing. Seeing that information was received every hour, Stats SA was able to identify problems quickly and immediately implement remedial actions. The maps in the Appendix show how we were able to ascertain that fieldworkers were in the wrong EA, and consequently notify them immediately.

The EA Demarcation Process, preparations for Census 2011
Having all of the above-mentioned in place, it is foreseen that the EA demarcation process would be less of a challenge than it was for the previous census (we certainly hope!).

The EA demarcation process depends largely on the deliverables from the Dwelling Frame Project, which depends largely on the supply of aerial and satellite photography. An important new thinking is to abandon the listing phase of the census due to having georeferenced dwelling listings from the dwelling frame. This phase will be substituted with frame maintenance of especially rapidly changing areas.

The 2001 Census EAs have been used for two master sample frames. One is currently in operation, the other only started recently. The aim is to replace the previous one, and use it until the next census can be used as the new frame. Census 2001 EAs were used for a large sample survey called the Community Survey (CS) which was conducted in February 2007. Although their listings are not digital neither georeferenced, the information is valuable as it gives an indication of EA changes since 2001. It certainly is important input data as we prepare for Census 2011.

The EA demarcation process depends on the place name area frame. For Census 1996 and 2001, EAs were aggregated into place name areas. This time the methodology is different, because place name areas will be delineated first, then EAs within these. The place name areas are important not only for data dissemination but for the proper allocation of addresses to communities.

Demarcation will follow a standard geographic frame as used by South Africa, derived by the MDB. Attributes like province, district and municipality will be linked to EAs. Any changes to the frame will be implemented to the EA frame in a well-structured manner. Linkages to boundaries not on the standard frame will be handled as special requests. Such links will be undertaken and disseminated by Stats SA, so that data can be represented correctly.

This time more research was done into the EA size. Stats SA felt strongly that the optimum EA size was required so that fieldworkers could effectively manage field operations. Indicators were developed to determine average EA sizes for different settlements, and an index was created. Such indicators include questionnaire length, literacy levels (census 2001), available daylight hours for enumeration, distance, area and terrain (photographs), number of households to enumerate (dwelling frame, Census 2001), gated communities (dwelling frame), etc.

Along with the boundary delineation, important attributes are kept which are used for classifications and later for sample design for survey master samples. Geography-types and EA-types are two such attributes attached to each EA. A Geography-type describes the area (or land). In 2001 we had four such types, namely Urban, Urban Informal, Farm, and Tribal. For 2011 this has been reduced to three types namely Urban, Farms and Tribal, because informal (squatter) areas can occur anywhere not only in urban areas. Informal (squatter) settlements are moved to an EA-type. An EA-type chiefly describes what appears on the EA, a dominant land use. Therefore, EA-types will be inline with land use activities. There are 10 EA-types of which one of the EA-types will cover collective living quarters such as school hostels, hospitals, prisons, etc. Information on geography-type and EA-type will be obtained from the dwelling frame, administrative data and photography.

Previous digital EA boundaries were polygon files. This time Stats SA is considering re-visiting the option of a line database and maintaining a database of attributes for each EA line segment. This will enable the integration of EAs with other spatial features such as roads, rivers and provincial and municipal boundaries, that belong to other spatial data custodians, especially when new datasets are acquired. It will also assist fieldworkers to identify boundaries in the field.

The classification of South Africa into urban and rural areas still remains a challenge. The urban/ rural classification used for the last two censuses in South Africa was based on the classification of EA-types into urban and rural areas, which essentially is a *land use* definition. The EA-types for both censuses were not exactly the same. For comparison purposes, the 1996 EA-types were reclassified to correspond to those of 2001 EA-types. A discussion document was produced by Stats South Africa on urban/ rural classifications of SA, which in addition, interestingly enough illustrated the classifications using population density - a first for South Africa. Stats SA is currently researching other methods like population density based on place name area, population density based on EA classifications based on type, functions, and services found in an area, using spatial data like road networks with population distribution, and even using the dwelling frame points and associated locational information in perhaps hector grid squares to calculate scarcity scores and density profiles. A rule-base needs to be determined for our country that classifies an area as urban or rural using a combined index of many contributing indicators.

Learning's from the PRESENT
Register-based information from the Business Register, Population Register and the National Address Register are the pillars of statistics. In additional the National Address Register gives the other two a sense of location and geography. A continued maintenance

programme for the dwelling frame is important. Allocation and standardising of addresses should follow. Inter-departmental support is required for the development of common infrastructural framework data that are relevant to all.

More investment in research on the optimum use of aerial and satellite photography needs to be done. Research into information (statistics) that can be derived directly from the photos, coupled with available administrative data, and consequently saving expensive fieldwork costs, needs to be undertaken. Building more reliance of other sources of data, by enforcing the Spatial Data Act to ensure high-quality data from data custodians that can be used with more confidence for statistical purposes. Programmatic classifications and recognition from photography to classify structures and features for quicker standardised classifications and pattern recognitions need to be looked into.

The FUTURE

Stats SA is the custodians of the EA and place name area frames, and now the dwelling frame. All other spatial data are obtained from other government departments and non-governmental agencies. A tighter 'enforcement' of the SDI Act to ensure that supporting spatial data from various custodians and systems are of high quality in terms of accuracy and completeness (similar to statistical data quality) as spatial data have the same relevance, even if it means a statistical agency driving this!

Geography (or spatial technologies and data) is certainly an equal partner in the production of statistics. A similar model like that of the Brazilian Institute of Geography (IBGE), where statistics and geography reside under one roof and support each other, should be explored for more statistical agencies, including South Africa.
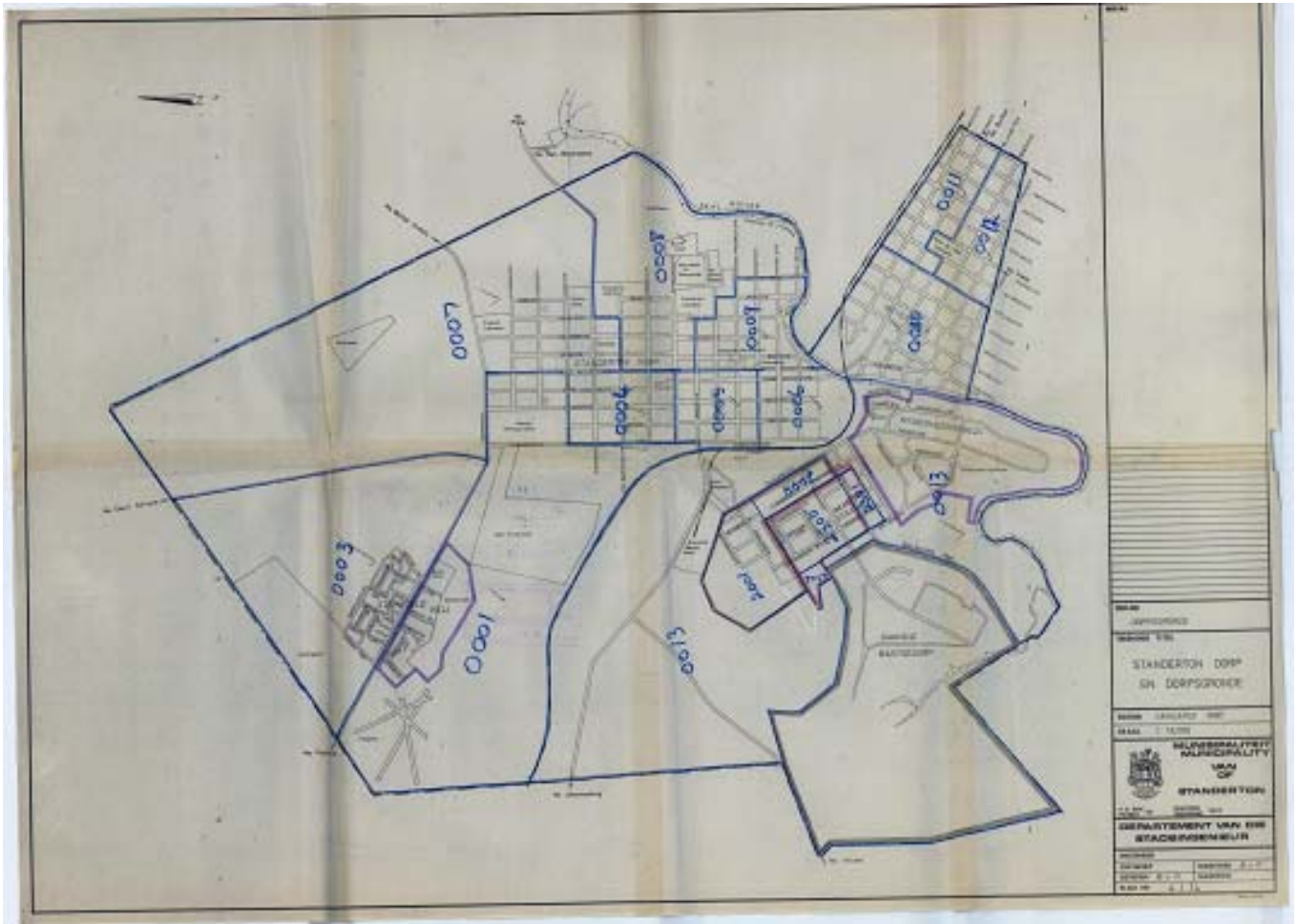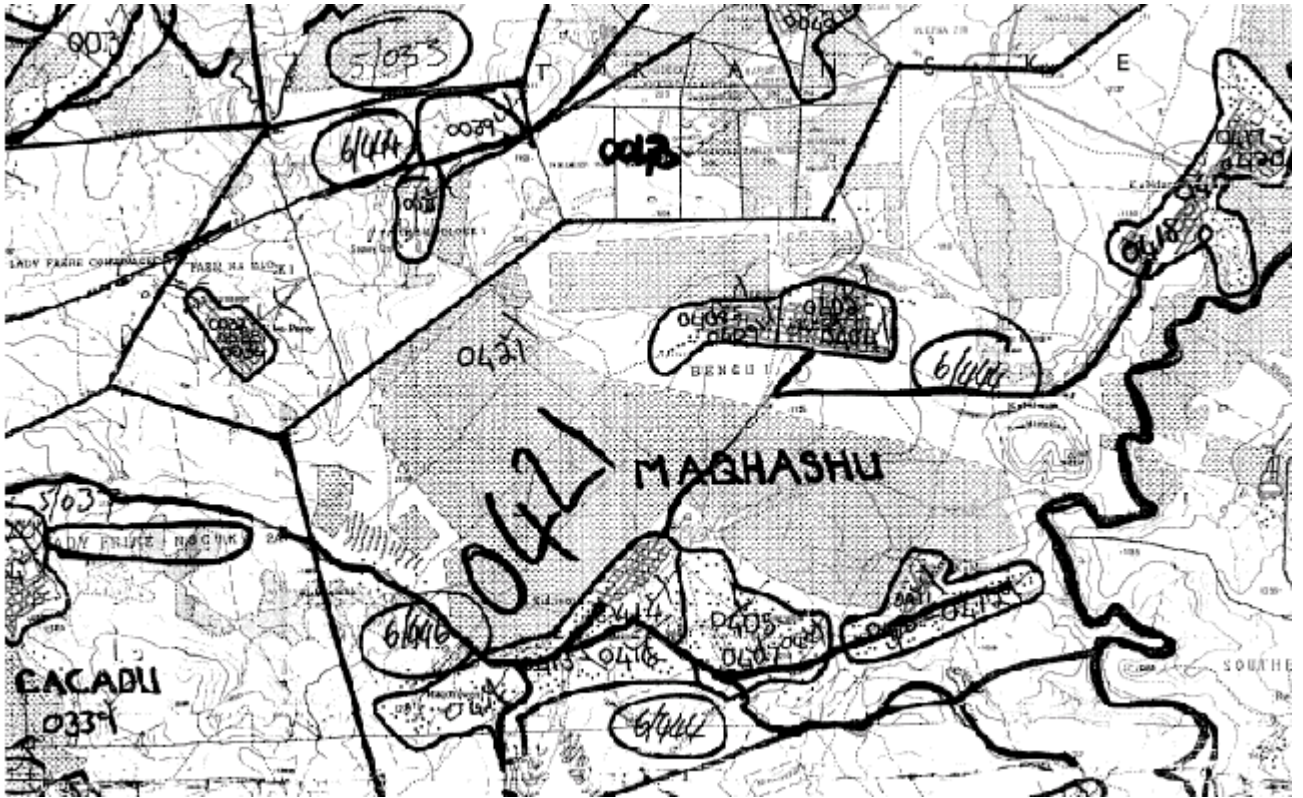
ACKNOWLEDGEMENTS

APPENDIX (PART 2)

Hand drawn EA boundaries prior to 1996 for urban settlements

Hand drawn EA boundaries prior to 1996 for tribal communities

Listing forms showing boundary descriptions

POPULATION CENSUS - 1996 - BEVOLKINGSENSUS

Form / Vorm 02

Pg. 01

District
Distrik   NELSPRUIT   N/U

To be submitted in SINGULAR form / Moet in ENKELVOUD ingedien word

SSD 24

Census officer Sensusbeampte	Initial/Paraaf	Data/Datum
	AWS	1996-06-2

EA / OG			City, suburb, town, rural Stad, voorstad, dorp, landelik	Description of boundaries of EA Omskrywing van grense van OG	Estimated population/ Beraamde bevolking	Number of visiting points/ Getal besoekpunte
1991 No	1996 No	Type/ Tipe 1)				
Portion 4209	0157	35	Ngodwana village Official residence	Start from the Police station (SAP) and go North along the street across Larkfield street to Neenah Avenue. Proceed along Neenah Avenue to the North until you reach house no 41 Windsor street. Turn East and proceed along Windsor street until you reach intersection of Shoalhaven Avenue and Windsor street. Turn South along Shoalhaven Avenue until you reach house no 3. Turn South east along Stoneywood Drive. Turn to Kaapschehoop road when you have passed house no 7 Stoneywood Drive. Turn North west along the Kaapschehoop road until you reach the entrance to Sudbrooke Ave. Turn West to the starting point when you reach the intersection of Sudbrooke Ave and Longview Drive. refer this EA to attached map please	455	123

1) See manual/Kyk handleiding

G.P.-S.

Stats SA's Geographic Frame

Municipal Demarcation Board (MDB)	Provinces	9
	District Municipalities	52
	Metropolitan Areas	6
	Local Municipalities	231
	District Management Areas	20
Statistics SA	Main Place	3 109
	Sub-Place	21 243
	Small Area	56 255
	Enumeration Area (EA)	80 787
	Geo-referenced Dwelling Frame	

MDB, 2005

Census, 2001
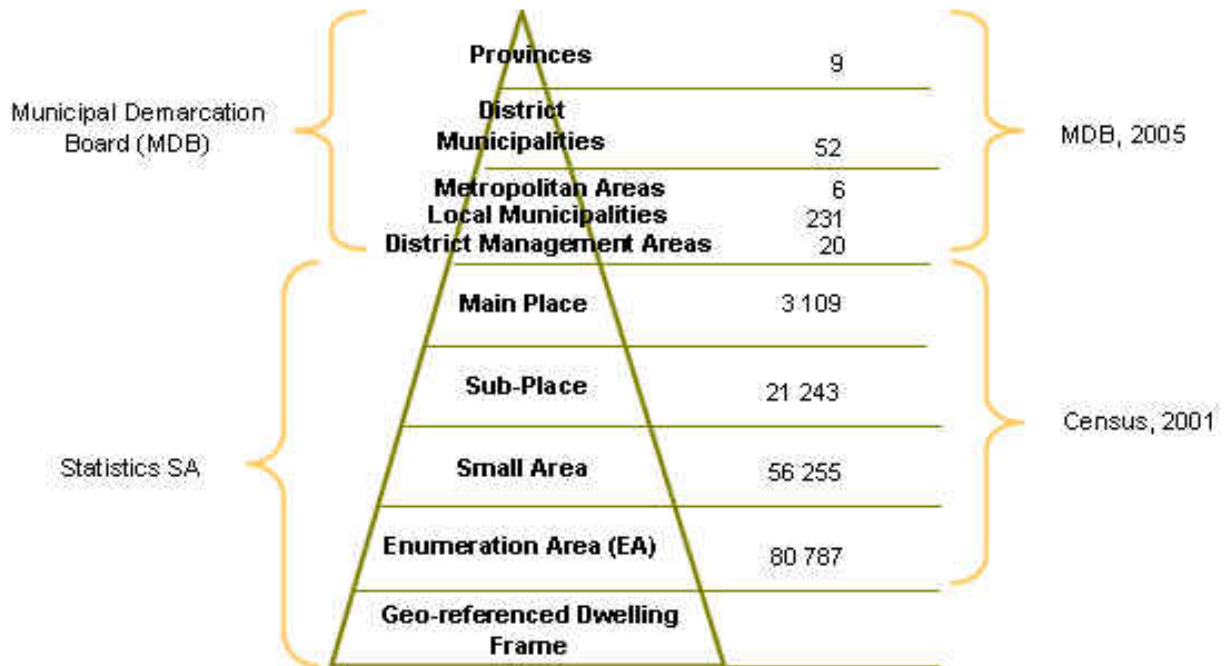
Strategically positioning GEOGRAPHY in a statistical organization

System of Statistics

National Accounts

Quarterly and annual gross domestic product estimates
Benchmarking gross domestic product estimates

Annual supply & use tables
Satellite accounts

E C O N O M I C   G R O W T H

Industry and Trade Statistics
Primary sector statistics
Agriculture statistics
Secondary sector statistics
Tertiary sector statistics
Tourism statistics
Business services statistics

Financial statistics
National Government Accounts statistics
Provincial Government Accounts statistics
Local Government Accounts statistics
Non-financial Local Government statistics
Private sector statistics

Employment Statistics
Quarterly employment survey
Labour force survey

Price Statistics
Consumer price index (CPI)
Rural consumer price index
Production price index (PPI)

Social Statistics
General household survey
Second economy information
Master sample
User paid surveys

Vital Statistics
Birth, death, health, marriage & divorce statistics
Tourism statistics
Migration statistics

Population Statistics
Population Census
Community Survey
Thematic reports on demographic processes, fertility, health, ageing and mortality

S O C I A L   D E V E L O P M E N T

Business Frame
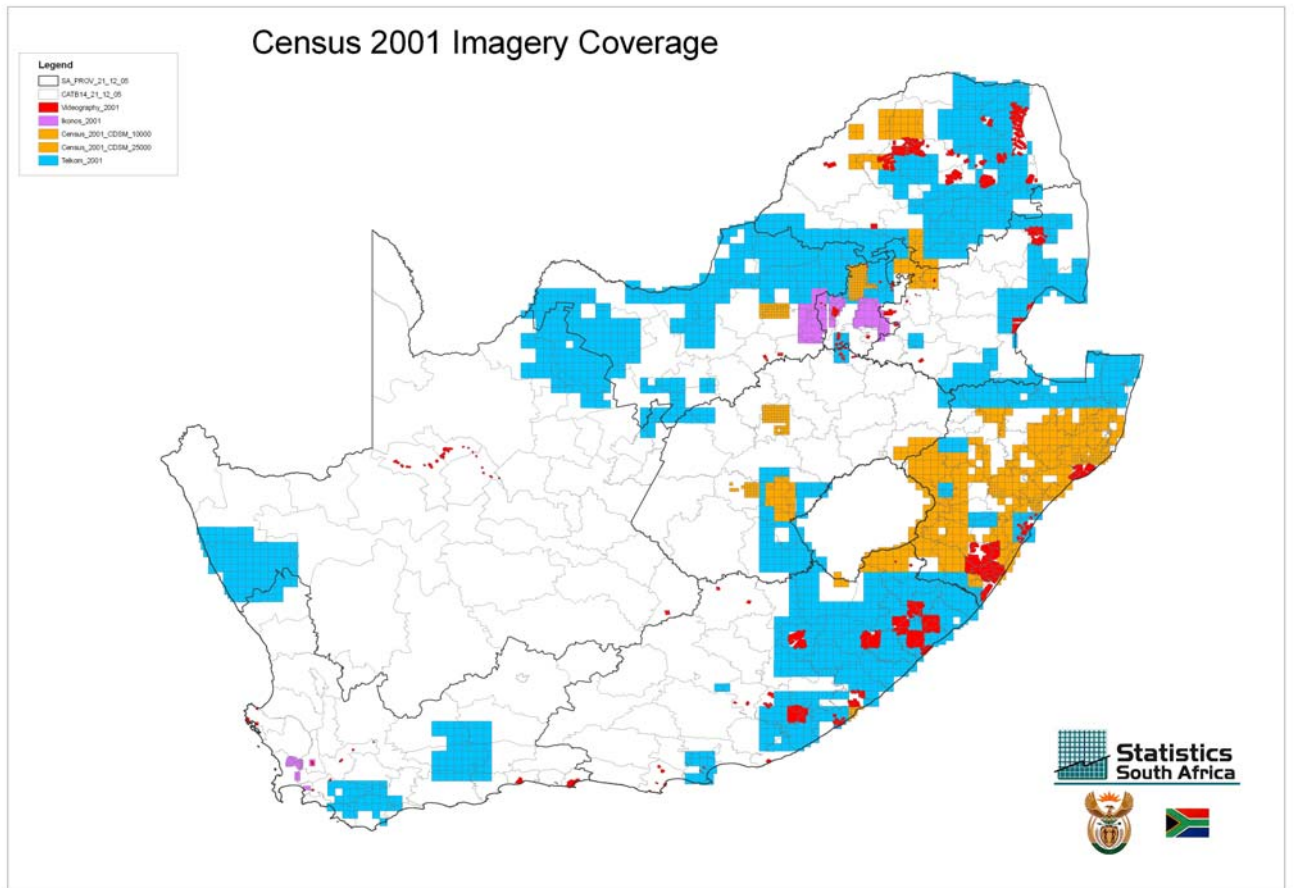
Geographic Frame

Methodology and Standards

Spatial Data Capacity Audit (2005)

Spatial Data Capacity Audit (2006)
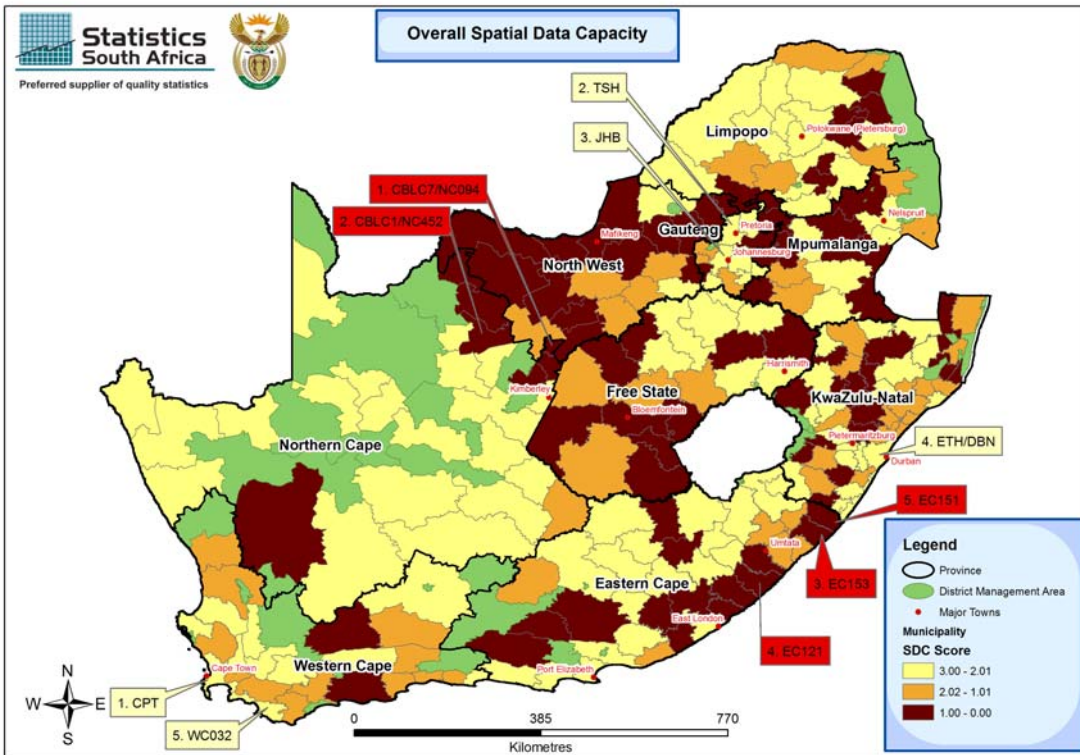
Coverages for aerial & satellite photography for 2001 & 2007

Census 2001 Imagery Coverage

Imagery Coverage: March 2007

Legend
- Municipalities
- Provinces
- 2006 - 2007
- 2004 - 2005
- 2002 - 2003
- 2000 - 2001
- Spot 5 2005-2006

Statistics South Africa
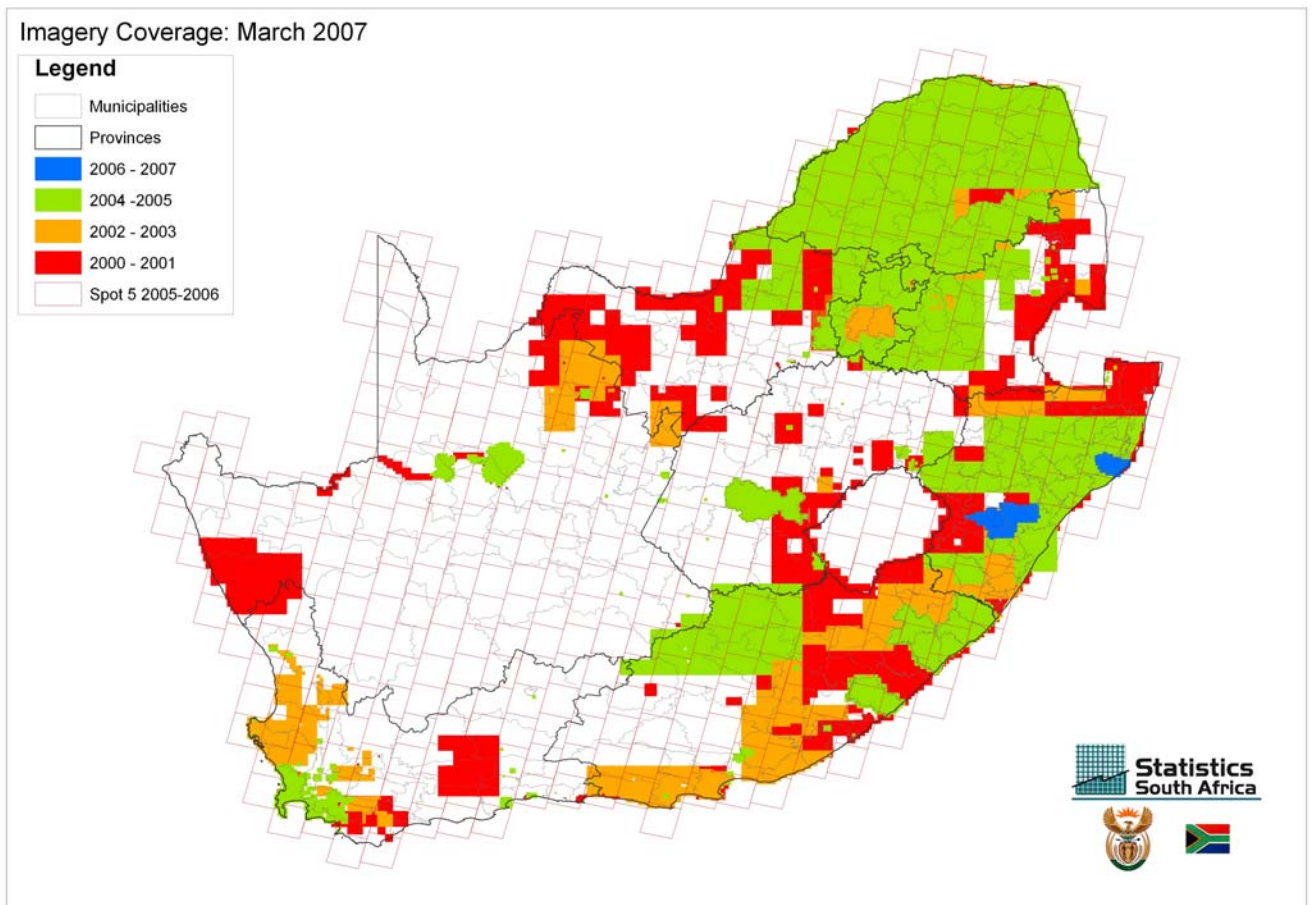
LFSR: Capturing of dwellings for listings. Fieldworkers working in the wrong EA.

The Dwelling Frame and its outputs

MNQUMA (EC122) FEATURE USE	Traditional	Urban Formal	Urban Informal	Rural Formal	TOTAL
Bank	0	4	0	0	4
Bottle Store	10	6	0	0	16
Business	62	209	10	1	282
Church / Place of Worship	386	40	15	1	442
Day Clinic	22	6	0	0	28
Demolished Structure	3,008	59	59	23	3,149
Dwelling Unit	51,548	6,520	3,400	293	61,761
Factory	0	37	1	0	38
Filling Station	3	7	0	0	10
Garage	1	3	0	0	4
Guest House / Lodge	1	6	0	0	7
Market	1	0	0	0	1
New Dwelling Under Construction	1,993	347	87	22	2,449
Offices	18	37	6	2	63
Other	152	29	7	15	203
Sports, Oval, Stadium	1	4	0	0	5
Park	0	1	0	0	1
Police Station	2	5	0	0	7
Post Office	9	5	0	0	14

	Traditional	Urban Formal	Urban Informal	Rural Formal	TOTAL
Holiday Home	58	47	0	0	105
Residential Hotel	1	9	0	0	10
School	472	52	5	5	534
Convent/ Monastery/ Religious Retreat	1	0	0	0	1
Old Age Homes	0	1	0	0	1
Hospital/ Frail Care Centre	1	2	0	0	3
Initiation School	63	0	0	0	63
Prison/ Correctional Institution/ Police Cells	0	2	0	0	2
Boarding School Hostel	1	0	0	0	1
Student's Residence	1	40	0	9	50
Workers Hostel	28	28	9	0	65
Shop	406	29	6	0	441
Storage Room	26	1	1	0	28
Vacant Dwelling	6,432	208	509	64	7,213
Vacant Stand	0	192	0	0	192
TOTAL	64,707	7,936	4,115	435	77,193

Mutale Municipality

- 98 map sheets (1:10 000 scale)
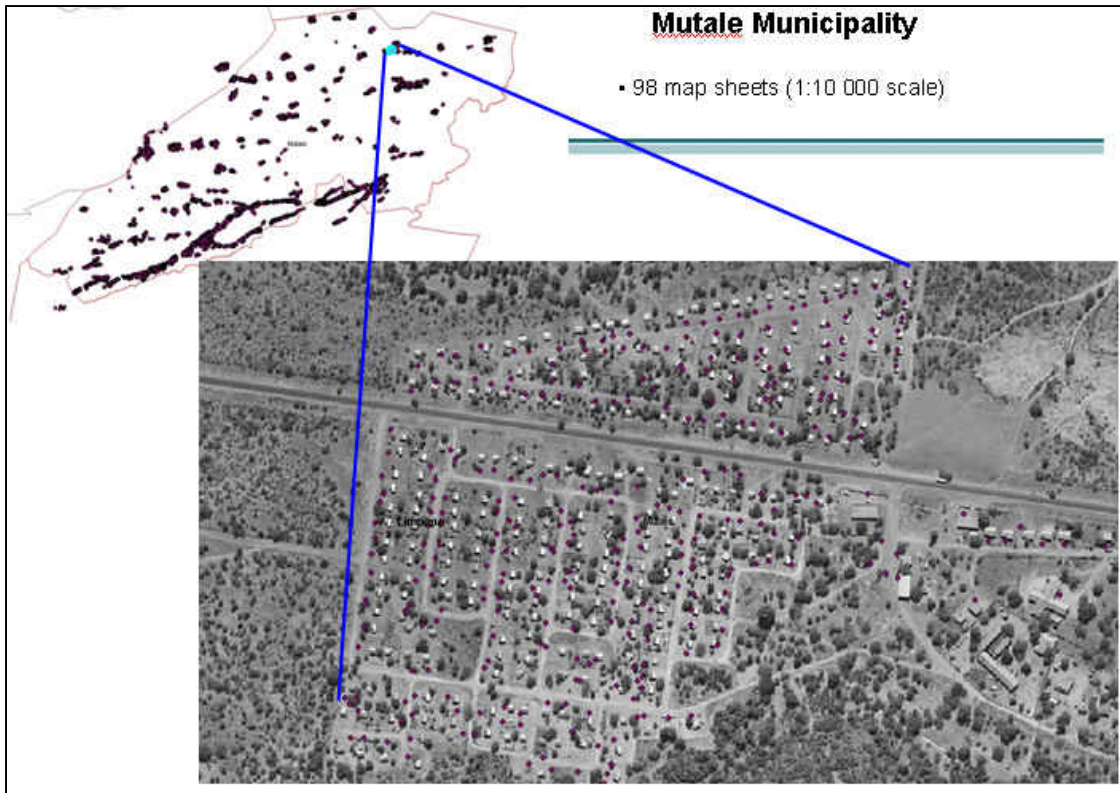
Mutale Municipality - attributes

City / Town / Traditional Authority: **Mutale**

Village name / Sub place: **Masisi**

Unique ID: **90600196_00077**

Geo-referenced Coordinates

Head of Household: **Manoli, Amosi**

Feature use: **Du (Dwelling Unit)**

Dwelling type: **Dwelling or Brick structure on a stand or yard or on a farm**