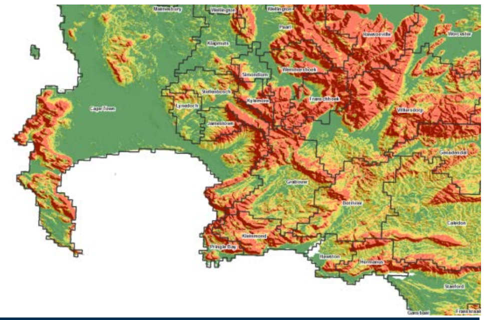
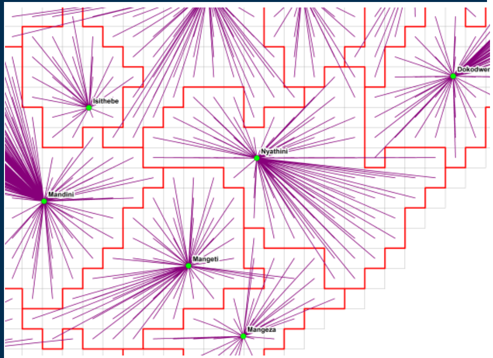
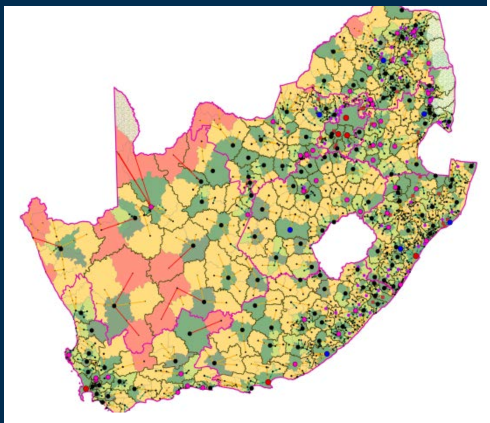
DEVELOPMENT AND PRIORITISATION OF CATCHMENTS

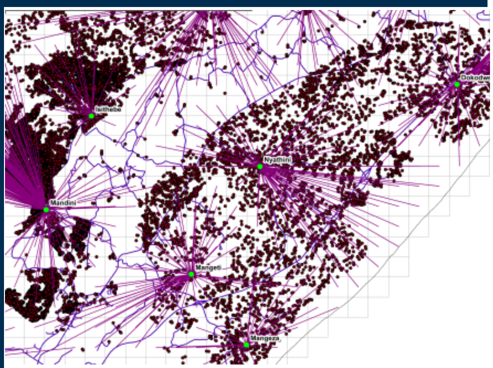
Technical Report

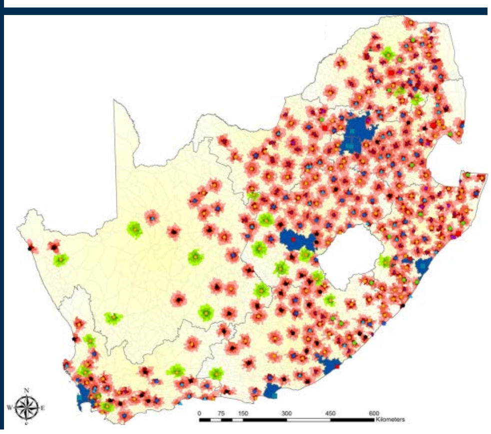
June 2016











rural development
& land reform

Department:
Rural Development and Land Reform
REPUBLIC OF SOUTH AFRICA

CSIR
our future through science

Authors:

Gerbrand Mans
Cheri Green
Mawande Ngidi
Zukisa Sogoni
Dave Mc Kelly

Acknowledgements:

Tansy Argue
Amy Pieterse

Project team members:

Cheri Green
Tansy Argue
Amy Pieterse
Mawande Ngidi
Dave McKelly
Zukisa Sogoni
Gerbrand Mans
Johan Maritz
Hunadi Mokgalaka
Athi Gxumisa
Dumisani Ndaba
Ethel Baloyi
Keamogetswe Maditse
Simangele Mahlalela

Reference to any material in this document should be cited as follows:

Mans, G., Green, C., Ngidi, M., Sogoni, Z & McKelly, D. 2016. *Development and Prioritisation of Catchments.* Technical report commissioned by the Department of Rural Development and Land Reform

TABLE OF CONTENTS

INTRODUCTION

This document forms part of a compendium of outputs developed for this project. The other documents /tools include:

- Guidelines for the Differentiated Provision of Social Services in Rural Areas which provide detail on the standards, and
- Application Guide for Social Facility Provision Toolkit which provides guidelines and support to planners in applying the standards using
- Social Facility Provision Toolkit (http://www.socialfacilityprovisiontoolkit.co.za/)

PROJECT DEFINED

This document addresses the project background and purpose as well as how and why the catchments were created.

The project itself was made up of several parts and the following is a summary of the entire project. The project was to

1. Review and update of social facility provision 'standards' compiled by the DRDLR, with a specific focus on creating a range of service levels for Government Social and Emergency Services that includes access criteria and settlement type.
2. Develop a set of functional service catchment regions that are:
    a. Based on the development of a hierarchy of service points (nodes) to guide the delivery of social services (for the country as a whole); and
    b. Profiled according to a range of indicators including aspects such as density, settlement/town type, topography and access to levels of nodes in order to guide a more differentiated and context specific delivery of government services.
3. Apply, test, and adjustment of standards and develop application guidelines within a selection of *functional service regions and municipalities*;
4. Develop a service facility calculator; and
5. Spatial viewer for the differentiated *functional service regions*. to support investment decision-making

BACKGROUND

The provision of social facilities and services in many areas of rural South Africa is generally viewed as being deficient. This is as a result of many factors including past legislation, neglect, lack of funds, poor management and planning as well as a lack of clear direction and guidance on what is to be provided, where, for whom, and in what quantities. Government has recognized the importance of access to services and that the access criteria differ depending on the developmental context and service type. The Department of Rural Development and Land Reform (DRDLR) was tasked with setting up access norms and standards to guide the development of facilities in rural South Africa.

Although the terms norms and standards are often used interchangeably, the norm can be defined as the usual or average while the standard is a desired and achievable level of performance (CRDP Norms & Standards Concept Document Version 9, 2012). In the light of this, the current project (termed the CSIR project) tried to establish desirable, appropriate and achievable geographic access and threshold standards for social service provision in rural areas. These can then be used to evaluate the norm/average and to benchmark performance and determine backlogs. The title of the project can be referred to as the "**Development of differentiated standards for the provision of rural services"**. These standards form the basis for evaluating if current services (norms) are in line with the standards.

USE OF STANDARDS IN RURAL AREAS

Currently there is a need to ensure that services are provided equitably, therefore there is a need for a set of consolidated standards for service provision especially in rural areas. The varied reality in service provision levels across rural spaces in the country makes it difficult to measure and benchmark rural service provision across these differentiated spaces. In order to ensure equitable service delivery there is a need for consolidated and context specific provision standards which are realistic and within the available budgets.

Standards for rural areas are fragmented among a wide range of stakeholders both in the public and private sector. In some cases, there are no approved norms and standards whilst certain of the relevant authorities are in the process of finalising their associated standards. The DRDLR investigation in 2010 found that of the 14 government departments interviewed, only six had approved infrastructure norms and standards. The information is also not readily available in a usable form to guide development and investment nor was there any guideline on how to differentiate provision with respect to:

a. differing geo-spatial conditions in rural communities;
b. community perceptions of service delivery and access to such facilities;
c. the estimated cost of providing the required services and infrastructure; and,
d. community investment requirements, in terms of social, economic, information communication technology and cultural/recreational infrastructure.

The approach taken by this project was to develop differentiated standards for numerous, diverse rural contexts. In the provision of services, a key consideration was the diversity of rural contexts that need to be addressed. Where provision standards did exist they were not sufficient to deal with the complexity of the rural contexts. Thus, a key component of the work was the classification and profiling of an extensive range of settlement and development contexts outside of metro areas**.**

To ensure the sustainability of services and their effective provision, the location of services at key points of accessibility and centrality is critical. Thus, the project defines and classifies a hierarchy of settlement types from which access to several levels of higher order facilities can be provided to the surrounding communities or from which mobile services can be dispatched. This provided the basis for consultation with departments on a range of standards for different settlement contexts.

While national standards may have been used for planning purposes such as in the preparation of Integrated Development Plans (IDPs) and Spatial Development Frameworks (SDFs), implementation has been significantly uneven across the country. The core reason for this is the substantial variation in types of areas which has impacted on the costs and the practicality of applying the standard in different locations.

STANDARDS ARE NECESSARY BUT NOT SUFFICIENT

Developing standards for rural provision is an essential element to redressing the inequalities in rural service provision within a structured framework of provision; however, in all cases it is necessary to be mindful of the fact the planning and constructing facilities in the right locations and to the right level/quantity is a NECESSARY BUT FAR FROM SUFFICIENT FIRST STEP.

To provide meaningful access to facilities the following amongst others are required: recruiting and retaining staff in rural areas which may even include payment of specific rural allowances; a secured stream of funding for the maintenance and operational costs associated with providing the facility and associated services; the ability to employ adequately trained staff and provide the necessary supplies when required (may include IT equipment and internet access); adequate road access to get to and from the facility to the major supply centre or ease of movement of mobile services /obtaining appropriate vehicles for the road condition; and, logistical support including deliveries, post, courier services.

The main issues impacting on service provision outside the scope of current project and requiring further attention include:

- Quality of service
- Recruitment/ retention of staff to rural areas
- Availability / training of staff
- Staff accommodation
- Maintenance
- Robustness of vehicles for mobile services
- Safety & security of equipment & buildings
- Availability & affordability of transport (public)

Thus, providing the building and the service is only the first step to achieving the desired standard of provision.

A review and update of the selected current 'standards' / provision norms was undertaken. The specific focus of this work stream was the creation of a range of service levels for government provided social and emergency services. [See Guidelines for the Differentiated Provision of Social Services to Rural Areas.]

Alignment of the facility thresholds (the number of people or the size of a community to be provided with a facility) and the appropriate access distance to reach a facility was undertaken to accord with the proposed hierarchy of settlement types and catchment sizes. A key issue here is that the threshold values and access distances for each service type are related to the different levels of provision in terms of the typology of functional catchments and distance. The provision standard packages have been linked to the settlement catchment categories and are applied in the calculator component of the Social Facility Provision Toolkit.

PROJECT FOCUS AND VALUE

The key focus of the project was to consolidate the provision standards for government provided or funded social facilities in rural areas to readily provide information to guide development and investment in these areas. See Guidelines for the Differentiated Provision of Social Services to Rural Areas which forms one of the main outputs of this multi-facet project.

These provision standards of government service points and social facilities have been customised and their location at key focal points in the country have been identified (priority places). This will promote facility location at places where it is possible to achieve the highest level of service equity to the largest number of people from the least number central places (of different levels) in order to make service provision more sustainable within the largely rural areas of South Africa.

The standards are intended to facilitate the:

- Planning;
- Budgeting;
- Provision; and,
- The equitable distribution of government service points and social facilities in rural areas to improve geographical access, adhering to the Batho Phele Principle 3.

This project has also developed a spatial framework to strategically and equitably allocate specified services within a spatial service hierarchy **without the use of detailed accessibility analysis.** Local planning for specific site allocation will still be required in each case.

The project focused on government provided / funded Social and Emergency Services and specifically addresses the aspects of geographic access (distance to a service) and demand thresholds (amount of people who can be served) in relation to a range of functional service areas. There is specific emphasis on differentiated levels of services and access to these services for those functional regions which are more remote and / or rural in nature and function.

THEORETICAL BACKGROUND AND APPROACH

As it is not possible to rely on the free market to successfully regulate the distribution and provision of social facilities in a developing country and, furthermore, it is recognised that there are insufficient funds to provide all the required facilities in every settlement in the country, therefore choices need to be made as to which locations to service. It can also be rationally argued that within the context of budget constraints, services should be provided where they can have an impact on the largest number of people at the same or lower cost (Green *et al.*, 2008).

The identification of those places of greatest need or of greatest accessibility to residents should be direct social investment. Furthermore the identification of a prioritised hierarchy of places that can be used as a means of spatially targeting the largest number of people from the least number of service points is important.

ANALYSIS APPROACH

In this project two levels of analysis were followed. The first was to demarcate and then profile and rank all catchments based on their demand threshold and centrality. This was then linked to a defined minimum basket of services for each level of catchment for a full spectrum of services under the assumption that all needs can be met. To support the differentiated and appropriate provision of facilities for different contexts, the service catchment approach (Green *et al.* 2012a) was used to allocate and define the entire country into appropriate service catchments. After which the hierarchical concept was used as the building block for allocation of facility provision packages at different levels and linked to different levels of catchment.

The second approach was to target investment requirements on the optimal provision of service access to a basket of middle-order services (which have an access reach of approximately 30km) and identify where they would best be located and preferably linked to a hierarchy. The goal was to seek the lowest number of optimal locations to service at least 80% of the population with respect to a middle-order package of critical services. The latter approach is intended to support the development of sustainable service delivery networks in an environment full of pressures relating to insufficient resources to deal with the extent of the development challenges and competing political and administrative priorities.

THE ROLE OF CENTRAL PLACES IN RURAL DEVELOPMENT

Walter Christaller introduced the concept of central place Theory in 1933 to try and explain the spatial arrangement of the number and size of settlements. Although Christaller's assumptions regarding an isotropic surface and evenly distributed population are invalid for South African rural development, his concept of a central settlement providing services to those living around it remain universally valid. The theory consists of two basic principles: that of threshold (minimum population required to provide goods or services at a place); and, the range or maximum distance people will travel for services (Christaller, 1933). The latter is often referred to as the sphere of influence.

Accessibility analysis for facility location planning has incorporated and is dependent on these two economic mechanisms, namely range or access distance and threshold both being part of the Central Place Theory. The first of these two major components refers to the ability to reach a facility using available and affordable transportation and, the second, to the ability to be able to utilise a service which has adequate capacity. The ability to reach a service is generally governed by a willingness on behalf of the potential user to pay for the trip in terms of time and/or money. In reality, this mainly translates into a maximum distance people are prepared to travel, after which the cost of travel exceeds the usefulness of the service to be received and the trip is foregone. The introduction of the concept of range/ distance to the provision of social facilities introduces a spatial dimension in planning the location, distribution and spatial organisation of services and this spatial perspective supported by GIS analysis has proved a robust approach for locating and planning social facilities.

Threshold is the minimum market (population or income) needed to bring about the selling or provision of a particular good or service. In the provision of communal free services, the minimal value will not be measured in respect of income or profit but will relate more to the efficiency of providing the service to at least a minimum (viable) number of clients;

Range (access distance) is the maximum distance consumers are prepared or able to travel to acquire goods/ services since at some point the cost or inconvenience will outweigh the need for the good/service.

PRINCIPLES OF HIERARCHIES IN SERVICE DELIVERY

As indicated, different services have different operational requirements and population thresholds that make a service viable from a service provider perspective, while users will be prepared to travel different distances to address different service needs. The latter is mostly impacted on by the frequency at which the service is required as well as the value of the service to the users. To enable such analysis a clear understanding of the typical access and threshold values for different services are required. These principles form the basis of facility provision standards which need to be incorporated as input parameters into models designed to support accessible planning of facilities. For some of these, legislated guidelines are provided; some have evolved though practise or trial and error.

When one considers facility planning thresholds and access distances, it is clear that different facility types can also be grouped based on their having similar threshold and/or access distances and that these can be broadly divided into three categories of services: low-order basic services; high-order services; and, those in between, that form the 'middle-order' facilities. Lower-order facilities that are individually used by a fairly small number of people and are accessed frequently, such as schools, should generally be universally provided and be located as close as possible to communities even at fairly low densities or small populations, while middle-order facilities, such as 24-hour clinics and Home Affairs offices, that serve a higher threshold of people but on a much more infrequent basis are located at further spaced intervals in more established places. Higher order facilities, such as universities and large hospitals can be spaced even further apart and require many more people and higher population densities to be sustainable.

This hierarchical nature of social service delivery can ideally be linked to a hierarchy of centres for clustering social facility provision to serve a wider area of different reach depending on the service level. The establishment of a hierarchy was thus considered a logical spatial structure for equitably allocating facilities of various types to different levels of a hierarchy.

PLANNING FOR THE LOCATION OF COMMUNAL SERVICES AND ECONOMIC GEOGRAPHY

In undertaking facility location planning the key concept is to plan “who gets what, where and how” and this approach provides the fundamentals of facility planning for most services irrespective of income. The “what” refers to the service provided and the “where” to the concept of spatial variation, whilst the “how” refers to the broader social and political functioning. A fundamental issue in respect to facility location is the population that it is to serve as well as a good understanding of “where” this population lives, how they are distributed and what their profile is. To this end, a key component of the project was to develop a clear understanding/description of the different service catchments including their settlement morphology.

Demand targeting and estimation in the provision of social facilities is critical for correctly calculating the size of the service while cultural, economic and social factors in facility use are also important considerations. A key output of the research undertaken was to demarcate and profile ‘wall to wall’ service catchments and to calculate the demand within each service catchment or within a specific distance of the central node of each catchment to gain a better understanding of “where” services are needed and can best be located.

In understanding the “where” of facility location, both suppliers and users will tend to minimise their costs / time to accessing or providing a service and the service/ outlet will locate “where” the provision of goods and services, including transport, is optimised. Thus travel or access distance or related cost/ time variable is critical in facility location planning.
People live at different densities and at different distances from facilities and their reasons for selecting a facility may include a range of factors. However, by introducing the concept of facility thresholds and applying similar threshold (or population ratios) relative to facility size and similar distance limits within similar contexts it is possible to work towards broader equity across a region for the “what” – i.e. the service being provided. This is true even if some citizens choose to make alternative choices based on various social, economic and cultural factors or perceptions as well as available public transport options. Modelling or planning facility location based on the assumption of the informed and rational citizens making a rational choice to visit the closest facility may not always be universally realistic; however, when applied at a strategic level such an approach can provide informed decision making with potentially greater equity in meeting service delivery backlogs.

By looking at the “who”, planning for a specific target group based on the threshold, and by examining “where” demand is located relative to facility location, and by setting a maximum access distance, time or cost limit, a certain level of equity and balance in service provision can be achieved.

SPATIAL EQUALITY AND SOCIAL WELL-BEING/ QUALITY OF LIFE

In the provision of services citizens should, as far as is possible, not be discriminated against because of where they live. Irrespective of where people choose to live (within reason), the right to access certain basic services needs to be recognised and some effort made to provide access (even if infrequently/periodically) within the restrictions of the available funding. The issue remains that the more sparsely populated an area is, the more difficult and costly it proves to provide communal services and in some cases mobile, periodic or electronic based services are the only options, while in others it may even be necessary to withhold services and allow residents to provide as best they can for themselves. Discrimination based on colour, creed or race is not acceptable and neither should discrimination be practiced on the basis of place of residence (Amer, 2007).

ACCESSING SOCIAL SERVICES: CONSIDERING USERS AND SERVICE PROVIDERS

In considering the provision of services the needs of all the competing demands need to be taken into consideration. In this the service provider and the customers are the two key groups where the balance of needs to be achieved. To ensure viability and minimise costs the service providers need to achieve minimum volume of customers and achieve a spatial match between supply and demand. Users on the other hand want improved access and availability of services and sufficient service of suitable quality. Neighbouring communities also aspire to have at least the same if not better services than their neighbours. The third important group that provides input to this provision is government policy or political pressure from ward councillors, etc. who may try to influence the provision and who may in some cases create imbalance in the provision or advance the needs of one community above another which may not be equitable or sustainable.

There are two typical access problems that need to be addressed in deciding on minimum facility provision levels, namely the accessibility and minimum threshold problem. Facilities should not be beyond an acceptable access range (time or distance) for the user, *or the* potential trip destinations too scattered for a multi-purpose trip. The facility cannot be viable if there is insufficient demand within the catchment area in relation to viable threshold.

Thus the basic principle is to balance the needs of the users and the supplies while minimising issues of access and availability for the users on the one hand and achieving minimum threshold for service provider (government department) on the other. This should all be done within the principles of equity, government policy and fairness (see figure 2).

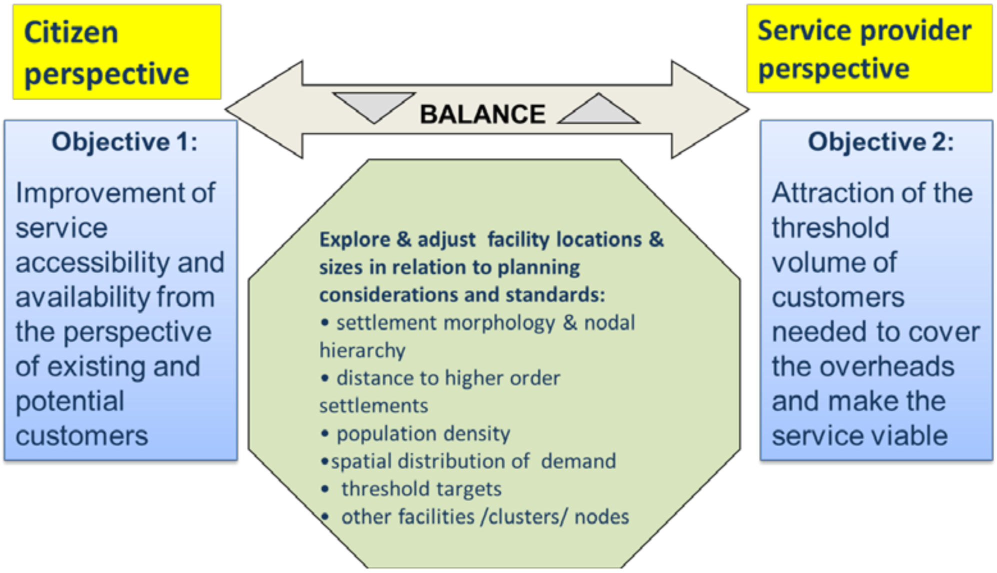


Figure 2: Basic principles of facility planning: Who gets what, where and how much

If one applies the concept of accessibility, centrality and nodal hierarchy to develop service catchments for the entire country and these are linked to well defined service provision packages that are balanced with respect to both user access demands and facility thresholds this will go a long way to achieving equity in distribution of basic minimum services to where the most people can be served from the least number of service points or towns.

CREATING THE SERVICE CATCHMENTS

FRAMEWORK FOR ANALYSING THE SOUTH AFRICAN LANDSCAPE

The starting point for the development of the service catchments was to use key natural agglomeration nodes (towns and settlements) identified throughout the country. This formed part of prior research. This was done by identifying nodes where there are a range of functions and services available, as well as a critical concentration of population. This means places where there is: a formal economy in at least the retail sector (a shop) and the services sector (a bank); basic government services (schools and clinics); and lastly a critical concentration of people for the type of area.

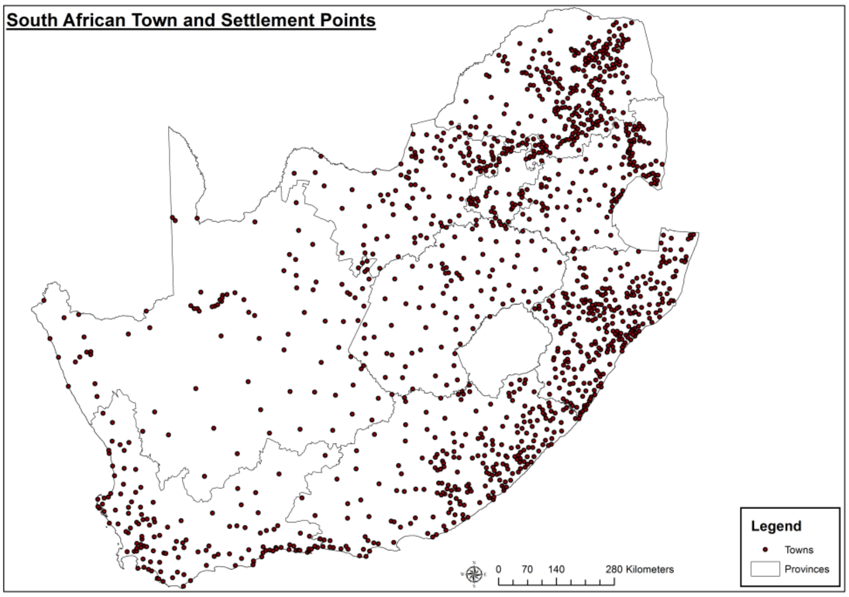


Figure 1: South African Town and Settlement Points (nodal points)

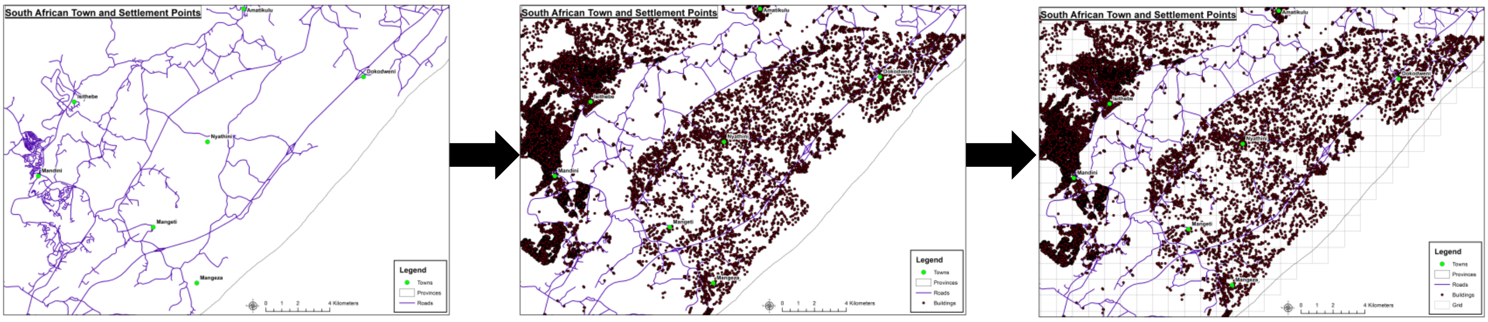
PROCESS OF CATCHMENT CREATION

For the purpose of developing the catchments and attributing population to them, the entire population, represented by GIS-based points of all dwellings (formal and informal) in the country (a dwelling frame), was allocated to their closest nodal point based on a road network. Once this was complete it was possible to determine how many people were within the catchment area of each of these nodes. The number of people within each catchment can then inform the maximum level of services each node could viably provide subject to a range to criteria including density and distance.

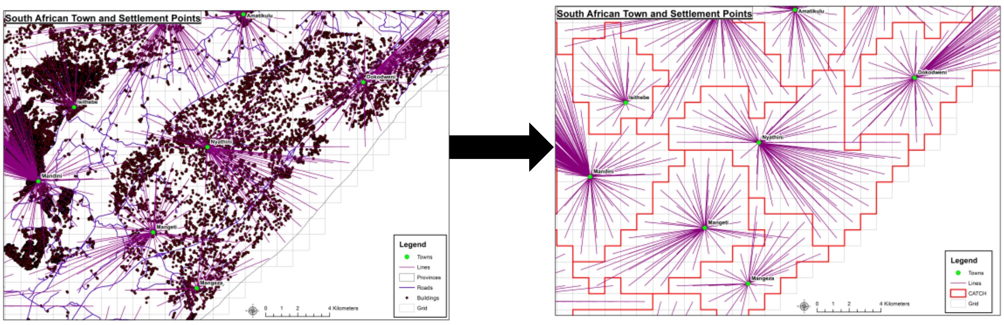
The identified nodes where services are available, were used as key input to creating the catchments. The other inputs used to conduct the analysis and in creating the catchments were:

a) A detailed national road network from AfriGIS; and,
b) A 1x1 km national fishnet grid.

1. The 1x1 fishnet grid was created to overcome issues identified when attempting to use data which had a course resolution or that was too large (Mesozone 7km x 7km polygons leading to too much generalisation) or too fine resolution (SPOT Building count for ±12 Million points which leads to cumbersome processing times when doing analysis). Therefore the grid was used as a proxy for settlements in the place of the building points and the mesozones. The below graphic depicts this process.



2. The data was segmented into its respective province, using province boundaries as hard boundaries. This was done for two reasons. Firstly computational limitations and secondly the nature of most social facility planning is done at a provincial or lower scale. Thus there are no cross border/province influences on the defined catchments
3. The data was inputted into a routing solving operation to create an Origin-Destination (OD) cost matrix. The OD cost matrix finds and measures the least-cost / distance paths along the road network from multiple origins to a single destinations, using
    a. the centroid of grid cell as origins
    b. the town and settlement points as destinations.
4. The grid cells are attributed to their nearest town or settlement point based on the road network and receive an ID to the town point it is attributed to (IDs based on the ID of the town / settlement point).
5. The grid was then dissolved based on the ID creating the first level catchments (depicted in the graphic below); the data was evaluated for spatial consistency and cleaned.



After cleaning and refining the data, a national set of service provision catchments were created. This provided the basis for subsequent processes.

PROCESS FOR CALCULATING AND ATTRIBUTING POPULATION TO CATCHMENTS

The catchment population was calculated through a process that employed methods of dissymmetric mapping and areal interpolation (Mans 2012a, 2012b). This consisted of using a combination of:

a. ESKOM's SPOT building count (SBC);
b. The StatsSA Census data for 1996, 2001 and 2011 (from EA, SP and Ward level data);
c. Weighted SBC points ;
d. The creation of relational databases that could be queried;
e. Disaggregation of the population data into the weighted points data set (therefore having population value per point);
f. The points were spatially matched to the catchment they fall within and then summed per catchment therefore producing a population total for each catchment.

This process made the attribution of the population more accurate as it uses points as a container for the data instead of polygons which may straddle more than one polygon thereby enabling a more spatially accurate attribution of population totals to the correct catchment. This enabled population data for all 3 census periods used to be allocated to the same unit.

Based on the attribution of population to catchments and in order to differentiate these catchments further in terms of their character, they were profiled based on:

- population size of catchment;
- density of development;
- morphological structure i.e. Mono-centric, Scattered, or Poly-Centric ;
- and level of centrality of the development, i.e. distribution of population intensity from central node;
- as well as the distance to a range of specific higher order places.

In addition, other elements such as components of (size of economic output (GVA), age structure and topography were also assigned and or calculated at the catchment level to provide further context and support facility location and allocation decision making.

A further process was to calculate the weighted population centroid for each catchment to identify the most central point in each catchment from a population distribution perspective. The latter was used for calculating average travel distances to other catchment areas. Lastly, the catchments were classified according to the administrative role it plays, in terms of attributing whether the main node in the catchment is a Local Municipal or District Municipal seat.

Please refer to Annexure 1 for a detailed discussion on the methodologies employed to profile the catchments.

RANK ORDER CLASSIFICATION OF THE CATCHMENTS

Using the data attributed to the catchments (as discussed in the preceding section and also see Annexure 1 for more detail on the analysis procedures), the settlements were classified into 10 distinct orders / levels. The discussion below outlines the procedure of classification and the reasoning that was followed to construct this classification.

Orders 1 to 4 were based on the SACN/ CSIR Functional Settlement Typology. In the context of this project, the nodes of catchments that aligned to the first three settlement types were classified using the framework of the SACN/ CSIR Settlement typology (refer to http://stepsa.org/settlement_typology.html). These were:

- Order 1 – City regions (e.g. Cape Town, eThekwini, Ekhuruleni, Johannesburg, etc.)
- Order 2 – Cities (e.g. Pietermaritzburg, Richards Bay, East London, Nelspruit)
- Order 3 - Regional Centres (George, New Castle, Kimberly, Upington, uMtata).

To classify / select order 4 settlements, further information was considered. This included the regional significance of small settlements in sparse hinterland regions without any significant large towns in the proximity as well the administrative ranking of places as appropriate. Thus,

- Order 4 - Service town / sizable or remote LM or DM Seat or contextually significant in that area, e.g. Springbok, Calvinia, Caledon, Sasolburg, Madibogo, Orkney, Tafelkop, , Manguzi.

The first 4 levels / orders are considered places of higher order or developed settlements that should at least provide a minimum level of all key services to their hinterland specifically 24 hour health care and citizen registration services.

The remainder of the catchments were classified based on the size of their 2011 population. It must be noted that some of the Order 5 catchments have sizable populations (more than 300 000 people) but are located in areas where another settlement (Catchment 4 or above) in the immediate region is considered to be more established and has better developed infrastructure to provide higher order services more efficiently and equitably than itself and which plays a larger administrative or economic role in the region. Simply, some Order 3 and 4 catchments may have smaller populations than certain Order 5 catchments which have large population but limited economic or infrastructure development or play a less significant regional role. The population thresholds for catchments ranked order 5 to 10 are:

- Order 5 – >60 000 population with no significant role in its regional context
- Order 6 – > 40 000 BUT < 60 000 Catchment population
- Order 7 – > 20 000 BUT < 40 000 Catchment population
- Order 8 - > 10 000 BUT < 20 000 Catchment population
- Order 9 - >5 000 BUT < 10 000 Catchment population
- Order 10 - < 5 000 Catchment populations.

CREATING THE LINKS TO HIGHER ORDER SOCIAL FACILITY SERVICE CATCHMENTS

In providing social services equitably, vital factors to consider that play a role are access distance, population threshold and density.

The product of the “calculation of distance to other catchments” is a dataset with distance from the “central location” of each catchment to the “central location” of all its neighbouring catchments. The rationale behind this thinking is that people in the catchments may need to travel to neighbouring catchments for services not provided in their own catchment.

The assumption is that services not provided in a catchment will be provided in a higher order catchment and that people in a catchment will go to the nearest higher order catchment to itself for services. The primary links between catchments is based on the nearest (or shortest distance) neighbouring catchment which has a higher order than itself.

CALCULATING DISTANCES TO OTHER CATCHMENTS

As stated earlier not all services can be provided at all places as some services have higher population thresholds than others and are provided at different levels of service, e.g. regional versus local services. Therefore services of different levels need to be distributed in different ways and/or services need to be provided at certain accessible locations for them to be feasible, equitably distributed and optimally utilised.

Knowing the distances between places provides input for the planner to assess where it is suitable to locate services in a region in a manner that will best suits user needs and meets the access distance limit for a specific facility. Thus it is important to be able to evaluate the distances between catchment nodes and the distances people may need to travel from one catchment to another to access higher order services in other catchments if that specific catchment does not warrant a particular service. Thus the calculation of distance from each catchment to other catchments is imperative and was undertaken.

Since many facilities are generally planned and budgeted on a provincial basis, the distances measurement was limited to movement within provinces. The process for calculating this is as follows:

a) A population weighted point was generated per catchment indicating the most central location in each catchment with respect to population distribution.
b) The weighted points were inputted into routing solving operation.
c) All weighted points were used as both origins and destinations as distances were calculated from all catchments to every other catchment.
d) Using the road network, the distances were calculated using the shortest road path from each weighted point all other weighted points.
e) A distance table was generated per province and joined back to weighted points so that the origin ID can be link to the destination ID, allowing for the identification of which catchment, is what distance to which other catchments.
f) The data was then inputted to the database and linked to other catchment data; and
g) Queries built to extract data.

The process of calculating distance to other catchments used the 1 329 weighted points. This process allowed the team to query the database for information for distances such as catchment distance of each catchment to linked close catchments of different orders.

LINKING CATCHMENTS OF DIFFERENT ORDERS

To efficiently distribute services, since it is inefficient to provide the same level of service at all catchments, it is important to create a hierarchy or other grouping of areas where differentiated service packages can be provided. To create a rational system with a more efficient distribution of services catchments of a lower order that do not have the sufficient thresholds to make a service viable are attributed to those catchments (catchment nodes) of higher order that are accessible within reasonable distances and that have the sufficient thresholds to provide key services and are centrally located.

Calculating the distances and linking catchments was undertaken as follows:

- An origin destination calculation based on network analysis was used to create a distance matrix for each level.
- Each level category became a destination for any lower order catchments for which it was the closest higher order within the province a sequenced manner. Therefore:
    - **Order 1** became the **destination** for catchments of **orders 2-10**
    - **Order 2** became the **destination** for catchments of orders **3-10**
    - **Order 3** became the **destination** for catchments of orders **4-10**
    - **Order 4** became the **destination** for catchments of orders **5-10**
- And so forth. All catchments of an higher order had settlements of lower orders attributed to them
- The data was then joined in a table where all the origins were linked to their destinations for all orders.

This results of this process indicate **WHICH CATCHMENT**, is **HOW FAR**, from a **SPECIFIC** catchment of a **HIGHER ORDER, with the linked higher order being the closest of its class to the catchments linked to it,** thus indicating which and how many lower order catchments are linked to each higher order catchment.

Where the distance between the immediate higher order catchments and the distance to that catchment's highest order is less than 20 kilometres, the link was made directly to the catchment with the highest order *(e.g. if [distance between 8 and 4] < [distance between 8 and 3 + 20km], the link was made between 8 and 3)*. The link between each lower order and its nearest (closest) higher order catchment was established. No links were created between a higher order catchment (Order 1, 2, 3 and 4) and another of same order

PRIORITISING THE CATCHMENT NODES

An analysis of the number of people in each catchment level confirmed the concentration of people in the higher order catchments, with over 50% living within the influence sphere of a metro, city or regional service centre. There was also a clear predominance of non-metro catchments with one or two concentrated settlements displaying a clear nodal structure. Based on this the decision to identify a selection of node centroids that could best service the maximum number of people was taken.

A travel distance analysis tested the centrality of each of the catchment nodes as well as the level of settlement concentration within each catchment. In the final analysis it was decided to focus the analysis on the 30km distance range. The reason for this was that, based on the most commonly provided middle order services, it is clear there is a convergence of acceptable access distances between several services as indicated below:

- 15 to 24km – police stations, FET colleges and community halls in a rural context;
- 25 to 30km – Home Affairs offices, Department of Labour offices, multi-purpose centres/Thusongs, SASSA offices, hospitals or community health centres depending on density.

Many of the above social facilities are crucial middle-order services that are considered to be critical for all citizens. If clustered together in close proximity or even under one roof in a Thusong centre, a multi-purpose centre (see CSIR Guidelines, 2012 for a definition of these types of centres) or even a more recent trend of so called 'service malls" they could create an essential service hub. No maximum limit of people to be served by such a facility was applied since in most cases the service offering of these services can be incrementally increased based on the elasticity of demand.

The 30km distance was selected as an appropriate structuring mechanism for most parts of the country for distribution of middle-order service malls. However, In sparse areas in the western part of the country (areas that have less than 10 person/km^2), it was noted that this distance should be extended to 50km to support the viability and cost efficiency requirements in low density contexts.

The analysis statistics show that at the 30/50km distance, 91% of people could have access to these services if placed in all catchment nodes of Levels 1 to 7 (these all having 20 000 or more people per catchment) at 535 places. To achieve the 95% coverage requires extending middle-order service to places with between 10 000 and 20 000 people (level 8), and requires having up to 805 services points. This highlights the issue that providing the same package of services to all catchments of the same levels can be costly. It will also require significant management and logistics input to support such a large network of services.

Examination of the catchment and travel distance analysis results revealed the likelihood of service redundancy due to the overlapping and competing nature of catchments and the resulting low population thresholds of some places. Both factors can lead to limiting the positive effects through excessive competition within the travel range of the services in question. In other areas, the lack of places of sufficient prominence to support certain key services was also noted.

Thus a spatial optimisation analysis approach was used to select points with non-overlapping service catchments with a specific range and with minimum threshold levels. The purpose was to potentially achieve more cost efficiency in service distribution but still maintain equity in the location of typical middle-order services. Based on the goal of service efficiency in conjunction with facility accessibility, an optimisation analysis of all node centroids in South Africa was done to identify optimum locations to potentially locate social facility 'service malls'. This approach identified the least number of service points from which to service the maximum number of citizens.

As indicated earlier, the access range of the social services in question is generally between 20 and 30km for most areas with a 50km range being acceptable for the very sparse western parts. Thus the analysis input distance parameter was set to a maximum of 30km/50km (this distance is based on the road network rather than simply a straight line distance).

The optimisation was applied to all areas of South Africa outside the boundaries of the nine metros and proposed metros. The latter were all Level 1 and selected Level 2 catchments. A key assumption was that based on the regional importance or size of the Level 1 to 4s, the analysis should by default include(prioritise and identify) all these nodes. The starting point of the analysis was thus to select these town points and demarcate a 30km catchment around each of these nodal towns based on the network distance.

Following this, the optimisation analysis algorithm was applied to all areas outside the 30km catchment from the Level 1 to 4's. In this way it was possible to identify the remaining most optimal locations to act as middle-order service provision centres from the nodes of the Level 5 to 10 catchments. Due to computational limitations the analysis was done using the mesoframe of a 50km^2 spatial unit of South Africa. The fine grain of 1x1km units used for the original catchment delineation was too large to process for optimisation purposes.

Thus the catchment optimisation model was sequentially and iteratively run and used to identify those mesozones which were the most optimal and densely populated within the distance parameter. Once all suitable mesozones were identified, a process was undertaken to align the optimised mesozones to the nearest towns serving as catchment centroids. This process had to be completed though a manual check where a final selection was made of the significant town closest to the selected mesozone. The manual check also resolved any inconsistencies and verified the final selection of points. In most cases where there was more than one town close to the optimal mesozone it was sufficient to select the node of the highest order as a default. On completion, a final catchment analysis was done to test the selected points and generate the service coverage statistics form all node points with that had more than 5 000 people within 30/50km distance.

The outcome of the analysis was very good and a service coverage of 91.03% of the total population achievable within the 30/50km range from only 380 central points. When only considering the non-metro population, 84.9% of people can be accessed / served from only 371 points. This is a major reduction from the 805 places required to reach 95.9% of the population if using the non-prioritised catchment approach as opposed to applying a spatial targeted approach. The prioritised town locations and the respective travel distance catchments are shown in the following figure.

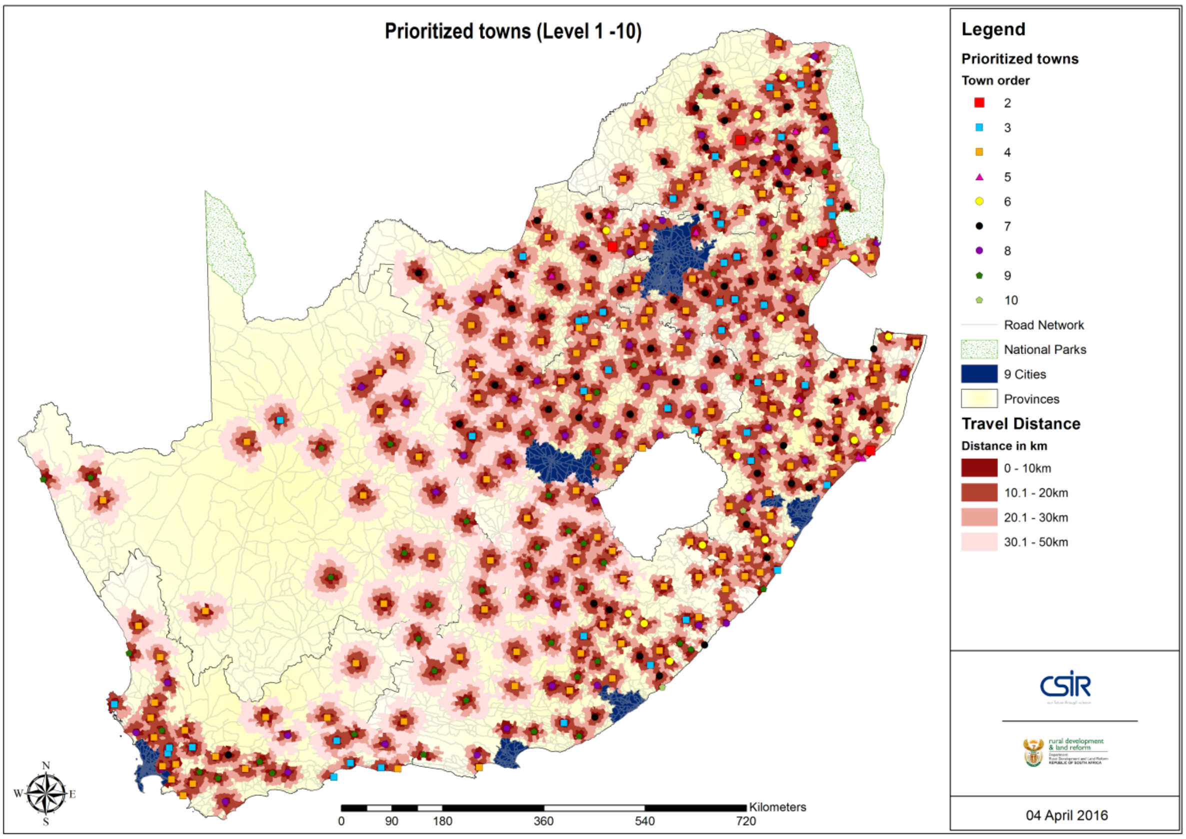


Figure 5: Prioritised towns

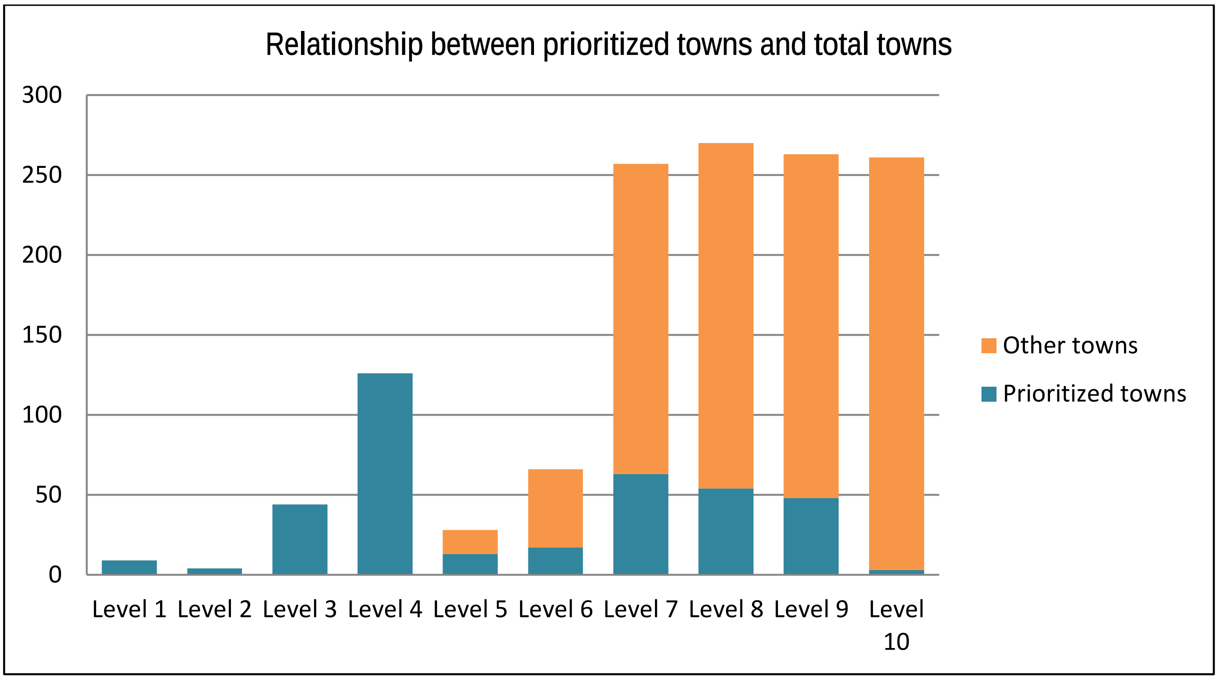


Figure 6: Service coverage relationship between prioritised and non-prioritised towns for 90% coverage

The implication of this is highlighted by the table below which shows that, by spatially targeting prioritised towns that optimally reach areas of approximately 30km travel catchment areas with no overlap, it is possible to achieve high service coverage whilst minimising the number of service points.

Town Category	Towns by Orders (Accumulative Values)										Total
	9 Cities	Order 2	Order 3	Order 4	Order 5	Order 6	Order 7	Order 8	Order 9	Order 10	
All towns (No prioritisation)											
Number of towns	9	13	57	184	212	278	535	805	1067	1328	*1328*
% population reached in 30/50km	40.39%	42.25%	55.42%	74.13	80.60%	83.60%	91.30%	95.90%	98.30%	99.20%	*99.20%*
Prioritized towns – including the 9 cities											
Number of towns	9	13	57	184	197	214	276	330	377	380	*380*
% population reached in 30/50km	40.39%	42.25%	55.42%	74.13%	77.53%	80.24%	86.15%	89.34%	90.90%	91.03%	*91.03%*
Prioritized towns – excluding the 9 cities											
Number of towns	-	4	48	175	188	205	267	321	368	371	*371*
% population reached in 30/50km	0%	3.12%	25.21%	56.60%	62.29%	66.86%	76.76%	82.12%	84.74%	84.95%	*84.95%*

It is stressed that as far as possible facilities should be clustered and that the selection of nodes where there is already existing development or infrastructure should be a key consideration in locating facilities. Resource restraints, particularly around budgets and staffing, mean that particularly in the case of the more specialised and larger facilities, that a phased roll-out of service provision may be required such that the most needy and largest populations are served first and choices are made between two similar locations. In this regard, the use of the prioritised town hierarchy which has been developed will be critical.

The lack of well-maintained datasets on current facilities also requires that additional local planning is required to avoid the duplication of services. The analysis also did not consider the availability of public transport and routes as this information is not readily available and in a usable format.

A multi-pronged approach has been taken. Firstly, to demarcate the country into services catchment regions and to profile these with parameters relevant to social service delivery and to define a social facility service package for reach catchment. Secondly, a non-overlapping hierarchy of central places/nodes where middle to higher order services can be sustainably provided at central and accessible places was developed. This structure can then provide the basis for incrementally extending services to as many people as possible over the longer term.

Most places will require all local facilities such as schools, pension pay points and small health facilities while middle-order services that are essential for citizens to transact fully in society should firstly be directed to the prioritised nodes before they are provided to any other places with sufficient demand. It is in the provision of clustered middle-order services that the opportunity exists to direct investment optimally outside the metros. This targeted approach can best serve non-metro citizens by using the prioritised town points in order to serve the maximum number of citizens in the surrounding communities from the least number of points.

The analysis has implications on service provision throughout the country. The prioritized locations specifically identified for middle order service location means that service providers can achieve high service reach levels using fewer locations rather than trying to roll out services in every corner of the country. These prioritized towns can potential service 94% of the country’s population with respect to middle order services within 30/50km from 377 selected towns. With this information, service providers will have a clear understanding of which locations can yield the optimal service reach levels in the most efficient manner. This data can also be used to support a range of other investment decisions, both public and private, in a more cohesive manner.

If the spatially targeted investment strategy is used to locate middle-order services as described above it can reduce the number of potential points to be serviced by over 50% while still being within acceptable travel distance of over 90% of citizens including those in rural areas. This could have a major impact on the rationalisation of services and more efficient allocation of resources to areas of greatest impact, potentially allowing for a greater emphasis on quality and operational efficiency. This is especially relevant given the expected increased demand and reduction in the South African fiscus within the medium term.

REFERENCES

Amer, S. 2007. *Towards spatial justice in urban health services planning*. University of Utrecht: Enschede, The Netherlands.

Christaller, W. 1933. Static Relations. In Christaller, W. Central Places of Southern Germany, pp.27-81.Baskin C.W. (trl) Englewood Cliffs, N.J.: Prentice-Hall.

Department of Rural Development and Land Reform. 2012. *Comprehensive Rural Development Plan Norms & Standards,* Concept Document, Version 9.

Green, C.A., Breetzke, K. & Argue, T. 2008. *Standards for improved governance and performance measurement in the eradication of backlogs and delivery of public facilities.* Winelands 11th International Conference on Public & Development Management. April 17-18 2008. Stellenbosch.

Green, C,A,, Mc Kelly, D., & Mans, G.G. 2010a. *eThekwini accessibility mapping and optimisation of community social services 2010. Section 18 (Vol. 3) – Node Hierarchy Catchment Analysis. Phase 3 optimising.* Report No. CSIR/BE/PSS/ER/2010/0046/B. Pretoria: CSIR.

Green, C.A., Mans, G.G. & Spocter, M. 2010b. *Evaluation of community social facilities and recreational space in City of Cape Town: current and future provision for 2016 and optimal location of new facilities*. Report No. CSIR/BE/PSS/ER/2010/0041/B. Pretoria: CSIR.

Green, C., Mans, G., Le Roux, A., Zietsman, L. and Ngidi, M. 2012a. *Providing government services in an equitable and uncontested manner through geographic accessibility processes*. Paper at Planning Africa 2012 eThekwini, September17-19 2012.

Green, C.A., Mans, G., Le Roux, A., Schmitz, P., Mokgalaka, M., McKelly, D., Ngidi, M., Badenhorst, W., Zietsman, H.L. 2012b. *Geographic accessibility study of social facility and government service points for the metropolitan cities of Johannesburg and eThekwini 2011/12.* Report No. CSIR/BE/SPS/ER/2012/0061/B. ISBN 978-0-7988-5608-9. Pretoria: CSIR.

Green, C.A. and Argue, T.C. 2012c. *CSIR Guidelines for the Provisions of Social Facilities in South African Settlements*. August 2012: ISBN 978-0-7988-5603-4. Pretoria: CSIR.

Smith, D.M. 1995. Geography, social justice and the new South Africa. *South African Geographical Journal* 77(1):1-5.

Sogoni, Z. and Ngidi, M. 2016. *The Morphological / Settlement Pattern Classification of South African Settlements, Based on a Settlement Catchment Approach, to Inform Facility Allocation or Service Delivery.* Unpublished conference paper to be presented at Planning Africa 2016, 3-6 July 2016, Johannesburg.

stepSA. 2016. *Functional City, Town and Settlement Typology* [online]. Available from: http://stepsa.org/settlement_typology.html [Accessed 14 April 2016].

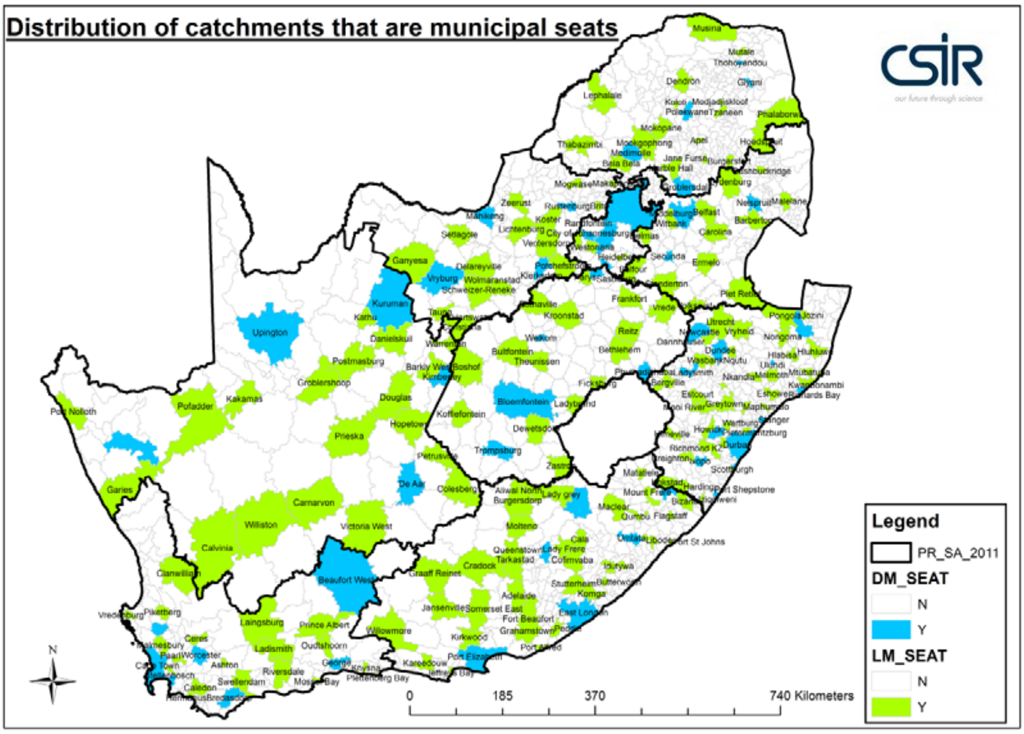
ANNEXURE A: PROFILING OF CATCHMENTS

ADMINISTRATIVE PROFILES

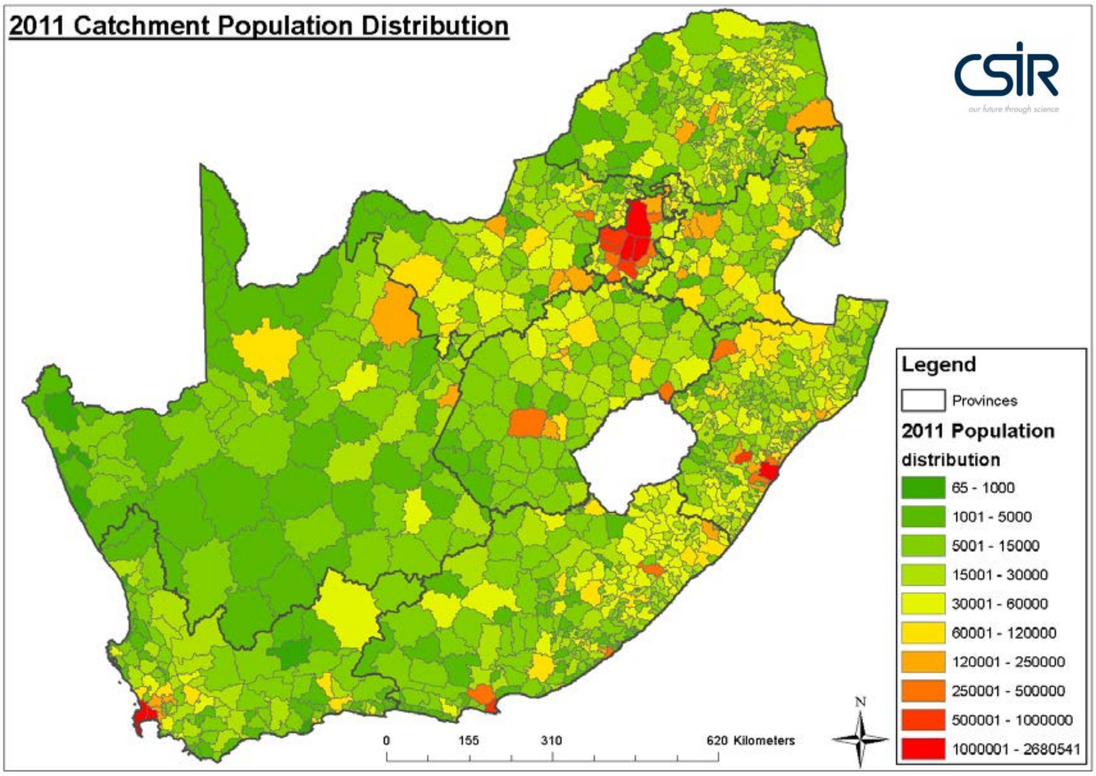
The administrative role is an important variable used for potentially ranking catchments as some services / functions could be more optimally located in areas where there is already infrastructure and administrative capacity within a region.

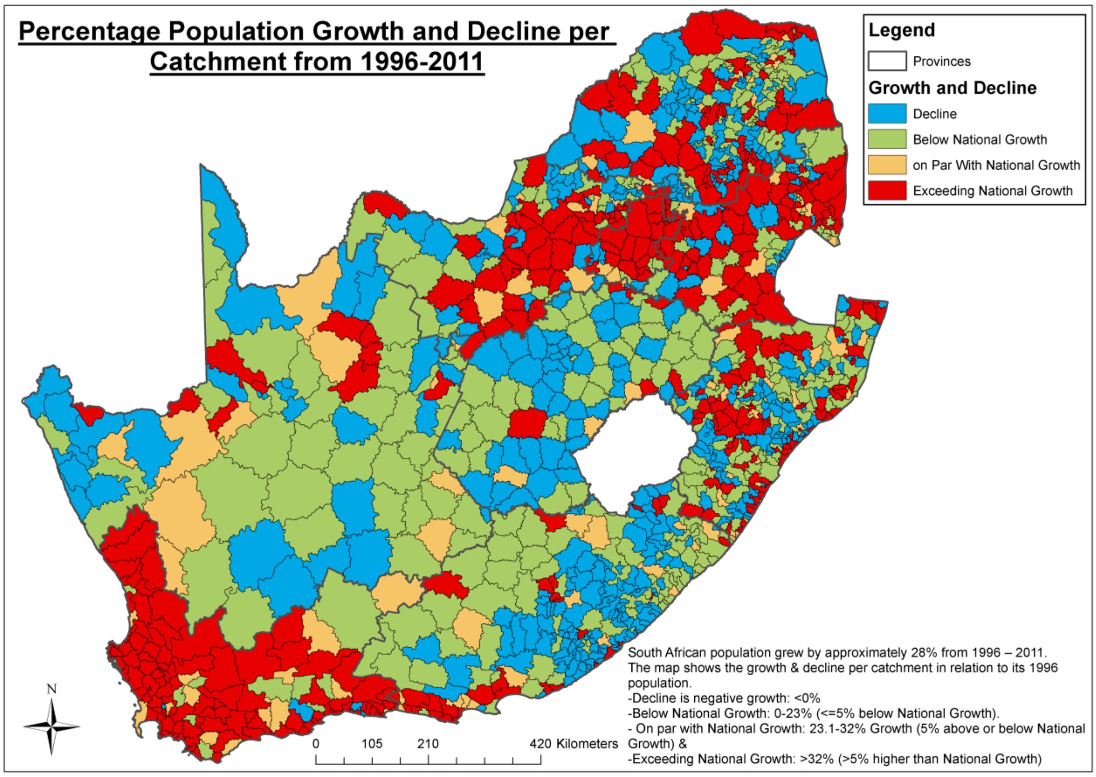
The first variables that were attributed to the catchments were the selected administrative attribute data that consisted of data that was inherited from the SACN / functional settlement typology town / settlement name; town / settlement type.

The catchments were also tagged with regard to their being local or district municipal seats, or both to indicate whether the catchment's main town / settlement has this administrative role.

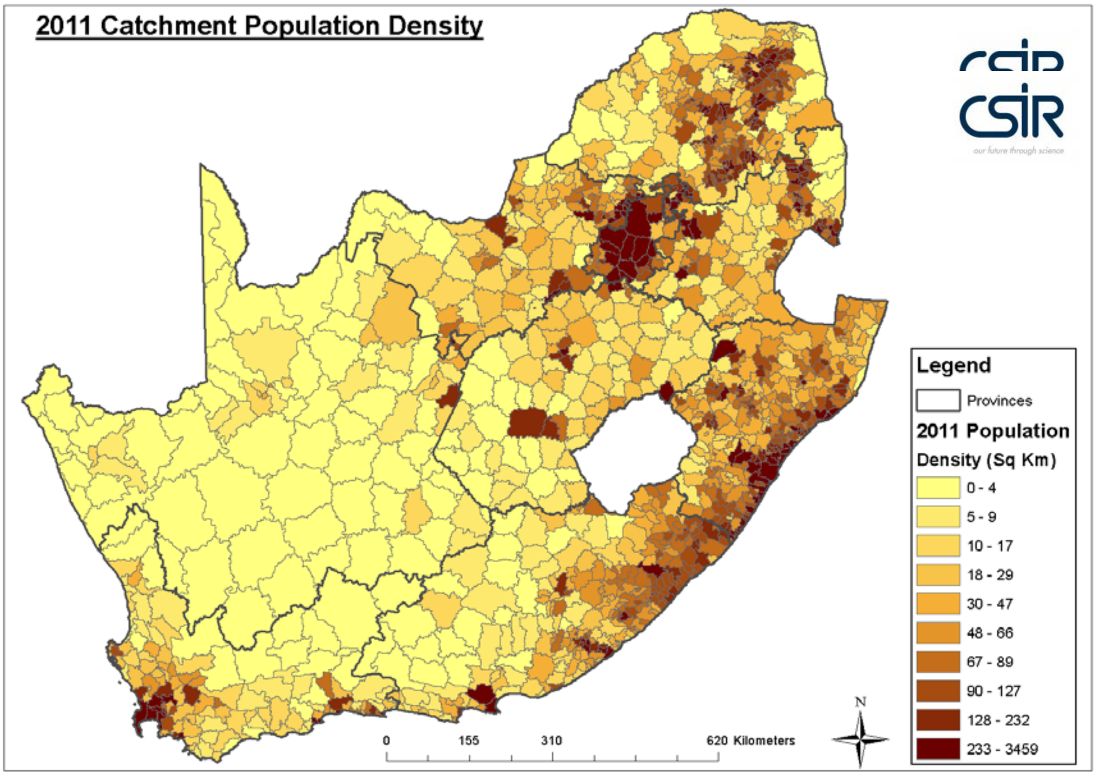


Population density and distribution was calculated for each catchment for 2011. In addition having the population figures for all 3 census years in a common spatial unit (catchment) thsu allowed for the comparison of population growth / decline over these periods adding further insight to the dynamics of each catchment. In planning for new facility development and or expansion and rationalisation a clear understanding of population trends can help to inform facility size and rate of provision. It may also impact on the type of facility provided.





The catchment density was calculated by calculating the catchment area (per square kilometre) and dividing it by the total population of the catchment (area / total population).



The economic activity of each catchment indicated by the total Gross Value Added (GVA) was calculated using the same principals of the population disaggregation and aggregation.

"GVA is a measure in economics of the value of goods and services produced in an area, industry or sector of an economy. In national accounts GVA is output minus intermediate consumption. As the total aggregates of taxes on products and subsidies on products are only available at whole economy level Gross value added is used for measuring gross regional domestic product and other measures of the output of entities smaller than a whole economy. Restated,

GVA = GDP + subsidies - (direct, sales) taxes

Simply put, GVA is the grand total of all revenues, from final sales and (net) subsidies, which are incomes into businesses. Those incomes are then used to cover expenses (wages & salaries, dividends), savings (profits, depreciation), and (indirect) taxes" (Wikipedia 2015).

GVA was used to indicate the dominant economic activity in each catchment

The GVA data was sourced from Quantec's Easy Data Standardised Regional, Income and Production on basic values database for each economic sector, annually from 1995 to 2013 at local municipal level. Data for the following classes of GVA was considered.

a. SIC 1 - Agriculture, forestry and fishing
b. SIC 2 - Mining and quarrying
c. SIC 3 - Manufacturing
d. SIC 4 - Electricity, gas and water
e. SIC 6 - Wholesale and retail trade, catering and accommodation
f. SIC 7 - Transport, storage and communication
g. SIC 8 - Finance, insurance, real estate and business services
h. SIC 9 & 10 - Community, social and personal services; and General government.

Note that SIC 5- Construction was not included since ancillary data required to disaggregate this is not available; SICs 9 & 10 combined to form Community, social and personal services, and General government.

The catchment GVA was calculated through a dissymmetric mapping and areal interpolation process in the same way used for the population data but using economic proxy data (Mans 2012a, 2012b). This consisted of using a combination of:

a. The sector relevant points from STATS SA Dwelling Frame;
b. The Quantec data from 1995 – 2013 (LM level data);
c. Per sector economic output / production Point weight (constant weight used);
d. The creation of relational access databases that could be queried; and
e. Disaggregation of the data into the weighted point's data set (thus having GVA value per point).

The points were then spatially matched to the catchment they fall within and then summed per catchment thereby producing a GVA total for each catchment per economic sector.

The above result was used to create a workable indicator for GVA. A composite calculation showing the three dominant economic sectors between 2008 and 2013 from SICs 1 to 10 excluding 5, was calculated. The three dominant sectors were derived by calculating a five year GVA mean (from 2008 - 2013) per sector, and extracting the highest three GVA contributors as a percentage of the total mean. The remaining 6 sectors were grouped as 'other'. This then indicates that, for any catchment, the 3 sector that has been dominant on average. For example) is SIC 1 (Agriculture) contributing an average of A% of the mean, followed by SIC 2 (Mining) contributing B% of the five year mean and the third highest GVA contributor is SIC 3 (Manufacturing) contributing C% of the five year mean, and the rest of the GVA total consists of the other sectors equating to the remaining percentage to make up 100% (Total).

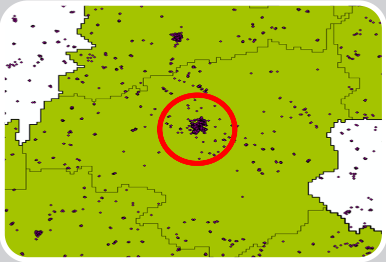
CATCHMENT MORPHOLOGY / STRUCTURE

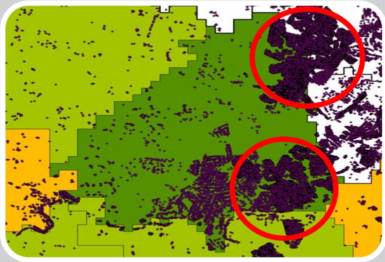
Since the key focus of the project was on differentiated services to support the application of standards in rural areas, service packages linked to the typical threshold values (and service reach) were developed for each level with allowance for extra services in more remote areas. The creation of a hierarchy of catchments thus forms an important regulating system for the equitable and efficient distribution of services.

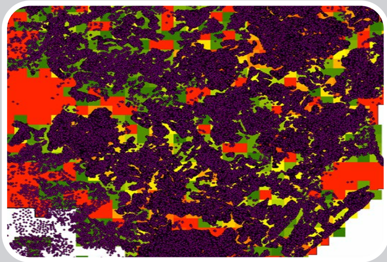
For effective application of the standards packages, an understanding of the internal settlement morphology of the catchment is also vital.

The catchment morphology / structure is used to indicate the spatial patterns that are visible within each catchment and to add detail to the broader analysis in supporting the identification of the internal structure of each catchment. This will be a key informant to where and how services should be distributed within the catchments. The morphology and its implication on service distribution networks, is addressed in more detail in a paper by Sogoni and Ngidi (2016) as well as in the application guideline document [See Application Guide for Social Facility Toolkit].

The catchments were classified into 9 classes. The main process followed to undertake this was based on a visual inspection and interpretation of settlement distribution based on the SPOT Building count, the ESCOM dwelling frame data as well as inspection of satellite imagery. Morphology was classified as follows:







Mono centric

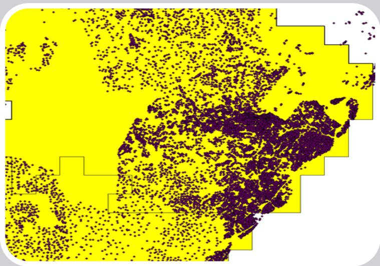
Catchments with a mono centric morphological profile have only one distinct concentrated settlement in the catchment

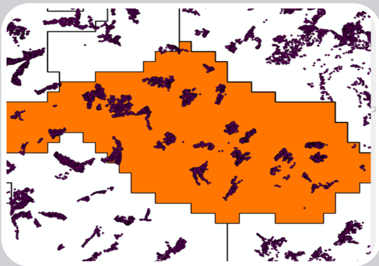
Bi Centric

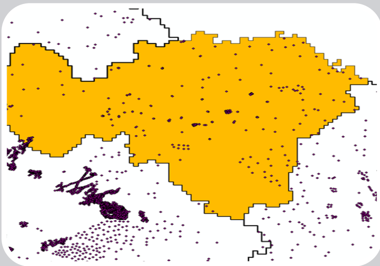
Catchments with a bi centric morphological profile have two distinct concentrated settlements in the catchment

Poly Centric

Catchments with a poly centric morphological profile have more than two distinct settlements in the catchment. This type of profile is mostly found in City Regions and Cities







Scattered Dense

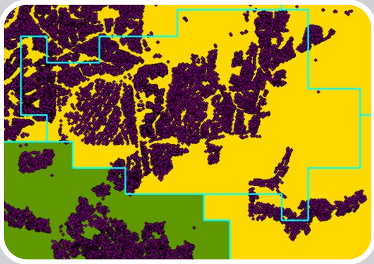
Catchments with a scattered dense morphological profile have a continuous dense point settlement coverage structure. These catchments are not as dense as metroplitan areas but are also not sparsely populated – in many instances having more than 100 people per km^2.

Scattered Clusters

Catchments with a scattered clusters morphological profile have clusters of non-uniform and non-continuous dense settlements across the catchment.

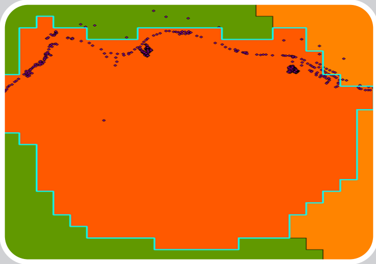
Scattered Sparse

Catchments with a scattered sparse morphological profile have sparsely scattered settlement points irregularly distributed across the catchment



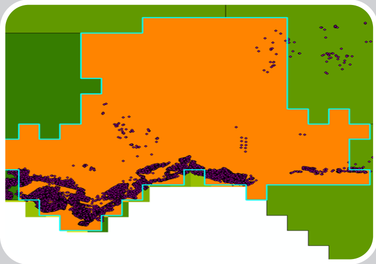
Dense

Catchments with a dense morphological profile are largely composed of continuously dense settlement with no distinguishable settlement points



Sparse Linear

Catchments with a sparse linear morphological profile have a linear pattern of sparsely populated settlement; this may mean it has developed alongside a river, the coast or a road.

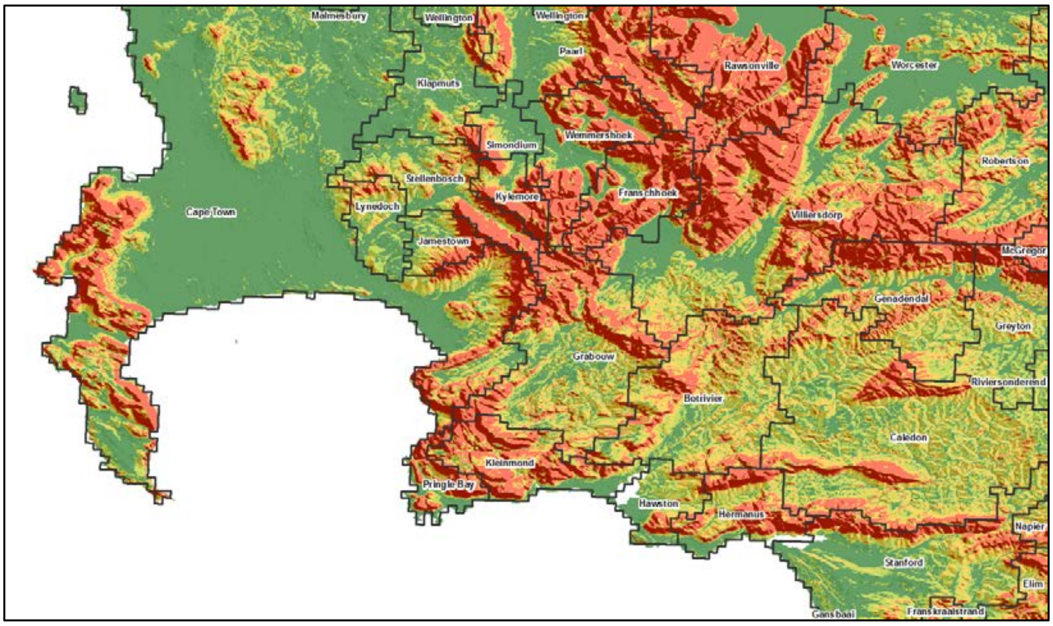


Dense Linear

Catchments with a dense linear morphological profile have a linear pattern of densely populated settlement; this may mean it has developed alongside a river, road or the coast.

TOPOGRAPHICAL PROFILE

To inform the ease / costs of development in each catchment, a Digital Elevation Model (DEM) of South Africa was used to calculate and classify the relative "ruggedness" of each catchment. Overlaying the catchments on the DEM (see below) gives the ability to examine the terrain of each of the catchments to make a preliminary assessment on the ease of local building and/or development of infrastructure (e.g. access roads) and reticulated services such as water and electricity.

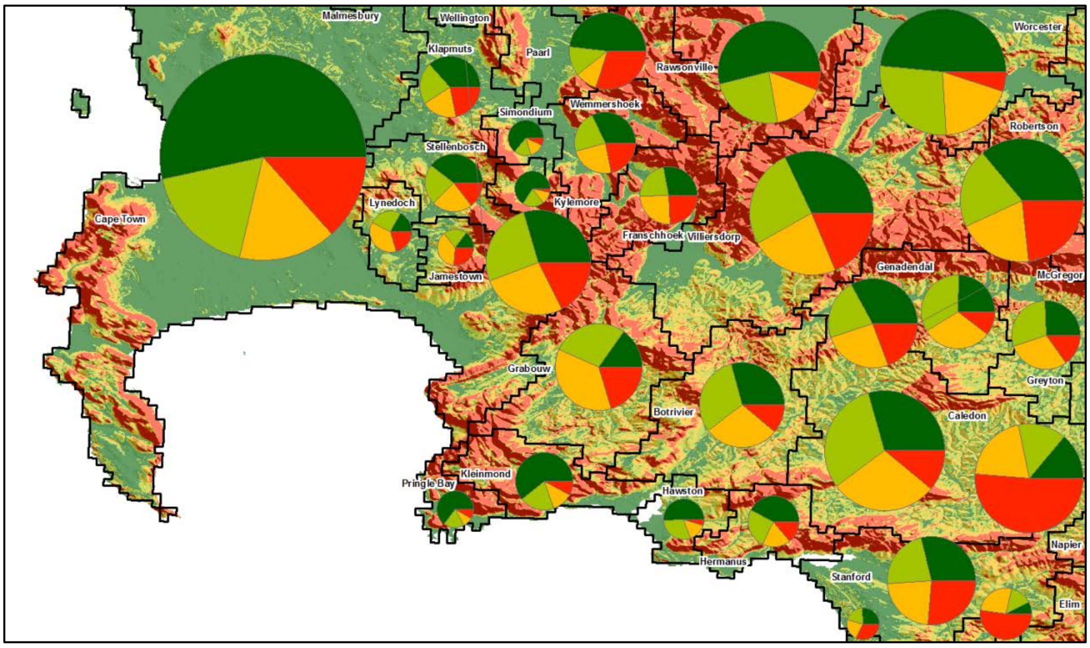


Using the DEM a slope analysis (measure of steepness or the degree of inclination) classification process was undertaken. The process measured the rise (vertical change / change in height) over run (horizontal change / distance).

From this the gradients were then classified into four classes:

- less than 5% gradient (<1:20) – Flat
- 5%-10% gradient (1:20 - 1:10) – Average (this category is approximately the limit for the feasible construction of most higher order roads; while 8% is the SANRAL maximum gradient for the construction of mountainous roads)
- 10%-20% gradient (1:10 - 1:5) – Steep
- More than 20% gradient (>1:5) – Very steep.

Facilities can generally be constructed without major cost increases on land with up to a maximum gradient of 18%. The amount of land in each of the classes was quantified and the proportions of each class for each catchment were calculated (as depicted in the example below).



ANNEXURE B: CONSULTATION WITH KEY DEPARTMENTS ON STANDARDS & APPROACH

The following were identified as potential stakeholders and have been consulted:

- Department of Home Affairs
- National Department of Arts and Culture
- National Department of Basic Education
- National Department of Communications
- National Department of Health
- National Department of Justice
- National Department of Public Service and Administration
- National Department of Social Development
- National Department of Sports and Recreation
- National Department of Traditional Affairs
- National Disaster Management Centre – Branch of the Department of Cooperative Governance and Traditional Affairs
- South African Police Services