SOIL TYPES
AND WHY YOU SHOULD HAVE A SOIL TEST
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SOIL TYPES AND WHY YOU SHOULD HAVE A SOIL TEST DONE

Building foundations needs to be on stable and strong soils. Soils range in strength. Some soils are able to support a skyscraper, while other soils are not even able to support the weight of a human. If the soil under a building is not stable, the foundation of the building could crack, sink, or worse - the building could collapse. The purpose of a foundation (substructure) is to transmit the loads imposed by the building above ground (superstructure) safely and without causing excessive movement or distress to the elements of the structure it supports. Foundations must therefore be so designed to resist differential movement and also to prevent the passage of moisture to the interior of the building.

The strength and stability of the soil depends on its physical properties. Soils with good structure are more stable. Clay textures are often more stable than sand textures because they have better structure. However, a mix of particle sizes (and pore sizes) is best for engineering (just as it is best for growing crops). It is also important that soil is stable through wetting and drying cycles, so that expanding soil does not crack foundations. Some clay minerals, from a family called smectite, are more likely to shrink and expand during wetting and drying cycles than minerals from other families, such as kaolinite.

In order for a foundation to serve its intended purpose, it is essential that suspect soil conditions are referred to an Engineer or Geotechnologist, and that the foundation system be appropriately designed to suit such conditions. The objectives of the geotechnical investigation and soil testing are to determine what construction methods need to be used. It is very common that soil tests are done for large projects and developments, but not as common in small residential housing projects. The consequences of not providing sufficient, accurate and reliable geotechnical information can have a huge effect on a project; possibly leading to delays and extra costs being incurred during construction. In addition, in some cases it’s a NHBRC requirement and the structure could fail because of incorrect or insufficiently designed foundations.

Field identification
Experienced geotechnical technicians and engineers can identify a soil by just looking at the physical characteristics of a soil. The most obvious is that of colour. Apart from colour, soil is identified in the field using the following characteristics.

- Shaking test – take a handful of wet soil and form a ball of about 25mm in diameter. The ball is placed in the open palm and shaken horizontally so it hits against the palm of the other hand. The appearance of a glossy surface caused by water constitutes a positive reaction. As the sample is further shaken, the ball stiffens as the water gloss disappears. The ball will finally crack or crumble. Very fine sands give the quickest reaction; inorganic silts give a moderately quick reaction; and clays give no reaction.
- Compressibility – take a handful of wet soil and shake it around in the palm of your hand. If there is water on your skin, the soil is defined as showing characteristics of compressibility. With the soil still in your palm, close your hand and squeeze the soil. When you open your hand, you will find that the soil remains in a lump but now appears stiff and crumbly. Very fine sands will crumble soon thereafter, while clays will remain stiff.
- Toughness test - Plastic characteristics - A toughness test ascertains the consistency of a soil sample near the plastic limit. The test is to demonstrate the cohesive (ability to stick together) properties of clay. Take a soft lump of clay (roughly a 12mm cube) and roll it in your hand to form a long thread about 3mm in diameter. As you continue rolling, the thread becomes stiffer as the water evaporates – this is the plastic phase of soil. When the soil crumbles it has reached its plasticity and crumbles. Now shape the clay into a lump again and start to roll a new thread (note how difficult it has become since the first time); the tougher the thread is near the plastic limit and the stiffer the lump when it crumbles, the more colloidal clay there is in the soil. Weakness in the thread at the plastic limit and easy crumbling of the lump indicates the presence of either inorganic clay with low plasticity or organic clay.
- Dry strength - The dry strength test begins by wetting a soil sample until its consistency approaches that of stiff putty and moulding it into a ball of approximately 25mm in your hand. Then place it in the sun and allow it to dry out for a few hours. Once dry hold the sample between your thumb and forefinger and apply pressure and note the pressure necessary for it to crumble. Repeat the process if necessary for different types of soils, taking careful note of the different pressures needed for each soil sample to crumble. This characteristic is known as the dry strength of the soil. If it does not break or crumble, the soil is highly plastic and characteristic of clays. If the sample breaks but is difficult to rub the crumbled sections to a powder when rubbed between the fingers, it has a medium plasticity. If the sample breaks easily into a powder it has low plasticity.
• Colour - Soils usually have a distinguishing colour; dark or black soil indicates the presence of organic matter in the soil, while lighter coloured soils indicate they are inorganic. Clay is whiteish to a light grey. Soils with iron-oxide particles give soil its reddish colour. While beach sand and sand dunes are clear or white.

• Smell - Certain soils smell when disturbed and is usually distinctive when freshly disturbed, especially in organic soils, for example a compost layer, the more distinctive the smell the greater the presence of organic matter in the soil.

• Feel/coarseness - The feel or touch of a soil can distinguish silts from clays and from sand. Take a handful of sand and rub it between your fingers – feel how coarse it is. By using other soil samples, you can distinguish between the roughness and coarseness of each. Grab a lump of clay and you can immediately tell the difference. Sand is coarse; clay is smooth and greasy and can even be sticky.

• Soil moisture content - The moisture content of soil plays an important part in determining the physical properties of the soil and is an important factor during soil compaction; the density will vary depending on the moisture content. Simply put - one can say that water acts as a lubricant in the soil and allows particles to move better over each other when compacted. A moisture content in optimal amounts enables soil to be compacted to its maximum density. This is called the optimum moisture content and is determined by laboratory testing of soil samples.

Another factor to consider when examining soil on site is its permeability. Permeability measures the ability of water to penetrate through the soil. Sand has a high permeability rating, while clays have a low permeability.

Soil Classification
Soils are classified by the sizes of their particles and their physical properties. Most soils are a mixture of the following five types of soils:

1. Gravel – a hard rock material with particle sizes larger than 6.4mm in diameter but smaller than 76mm.
2. Sand – consists of fine rock particles smaller than 6.4mm in diameter to 0.05mm.
3. Silt – consists of fine sand particles smaller than 0.05mm and larger than 0.002mm.
4. Clay – is a very cohesive material with microscopic particles less than 0.002mm.
5. Organic matter – is partly decomposed animal and vegetable matter.

The process of classification is to place a soil sample in a group or class that can be internationally accepted and understood. Soil classification systems are based on particle sizes found in the soil mass and where the system recognises three main types of soil:

1. Coarse grained\(^1\)/cohesionless soil, e.g. sand
2. Fine grained/cohesive soil, e.g. clay
3. Organic soil, e.g. peat

\(^1\) Grained refers to the individual mineral properties in the soil.

1. Coarse grained soils – the sieve analysis test is usually carried out on these soils. This is because the size of the particles and the proportions of the different sizes have an important effect on the behaviour of the soil. Coarse grained material does not necessarily mean large particles, Umgeni sand or beach sand can also be considered as coarse-grained material.
2. Fine grained soil – the properties of fine-grained soil are affected by the water content. The criteria for testing are that of consistency and plasticity. Consistency is the tendency of the particles to stick together, while plasticity is the ability of the soil to deform without rupture or breaking (see toughness test above)
3. Organic soil – The properties of peat and other organic matter are insufficient in bearing strength they are extremely compressible, and structures built over peat may settle by very large amounts over long periods of time.

Two of the most commonly used soil classification systems in South Africa are:
- Casagrande classification system
- Unified Soil Classification System (USCS)

The Unified Soil Classification System classifies soils according to the percentage of grain-size particles in each of the established soil grain sizes in the soil distribution index, the liquid limit, and the organic matter content. Soils are grouped in fifteen classes – eight of which are coarse grained soils; six are fine grained; and one class of highly organic soil. Soils on the borderline between two classes are given a dual classification, for example GP-GM. Descriptive details are provided in Table 1 on the following page.
Table 1 – Classification of soils using the Unified Soil Classification System

<table>
<thead>
<tr>
<th>Type</th>
<th>Letter Symbol</th>
<th>Description</th>
<th>As Subgrade material</th>
<th>As Surfacing material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse grained soils</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel and gravelly soils</td>
<td>GW</td>
<td>Well-graded gravel; gravel-sand mixture; little or no fines</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>Poorly graded gravel; gravel-sand mixture; little or no fines</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>GM</td>
<td>Gravel with silt; gravel-sand-silt mixtures</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>Clayey gravels; gravelly sands; little or no fines</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Sand and sandy soils</td>
<td>SW</td>
<td>Well graded sands; gravelly sands; little or no fines</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>Poorly graded sands; gravelly sands; little or no fines</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>SM</td>
<td>Silty sands; sand-silt mixtures</td>
<td>Fair</td>
<td>Fair</td>
</tr>
<tr>
<td></td>
<td>SC</td>
<td>Clayey sands; sand-clay mixtures</td>
<td>Fair</td>
<td>Excellent</td>
</tr>
<tr>
<td>Fine-grained soils</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silts and clays with</td>
<td>CL</td>
<td>Inorganic clays of low to medium plasticity; gravelly clays; silty clays; lean clays</td>
<td>Fair</td>
<td>Fair</td>
</tr>
<tr>
<td>liquid limit greater than 50°</td>
<td>OL</td>
<td>Organic silts of low plasticity</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Silts and clays with</td>
<td>MH</td>
<td>Inorganic silts; micaceous or diatomaceous fine sandy or silty soils; elastic silts</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>liquid limit less than 50°</td>
<td>CH</td>
<td>Inorganic clays with high plasticity</td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>OH</td>
<td>Organic clays of medium to high plasticity; organic silts</td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Highly organic soils</td>
<td>Pt</td>
<td>Peat and other highly organic soils</td>
<td>Unsuitable</td>
<td>Unsuitable</td>
</tr>
</tbody>
</table>

*The liquid limit is the water content, expressed as a percentage of the weight of the oven-dried soil, at the boundary between the liquid and plastic states of the soil.*

**Note:** If a problem soil is identified, further investigation will be needed to be carried out by using an Engineer or Geotechnologist and a suitable foundation design would need to be undertaken.

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There is a basic difference in behaviour between coarse granular soils and fine cohesive soils. The percentage of silt and clay size particles (or fines smaller than 0.06 mm) in a soil is important since, when this percentage is high, the soil will cease to behave as a granular soil. The critical magnitude of the fines content is expected to be in the range of 10–25%, and typically about 15%.

**Soil Types**

**Potentially collapsible soils**
Collapsible soils are usually made up of sandy and residual materials of low density that are subject to collapse under loading or moisture ingress. The degree of collapsibility varies from area to area, and in some instances is of such low movement that conventional foundations may be established on these soils.

Where the soils exhibit high risk potential, they are typically removed and replaced with a more suitable founding material or require the employment of more sophisticated foundation solutions.

**Expansive soils**
Expansive soils behave in the opposite way that collapsible soils do. The expansion or heaving characteristics of these soils is usually due to their clay content which expands when it absorbs water.

The heaving of these soils has the consequence of causing distress to the foundations which could result in failure. Again, the degree of expansiveness varies from area to area. In instances where the heave potential is low, use of conventional foundations may be made, but in others such material should be removed and replaced with a more suitable founding material.

In instances of severe expansion, a more sophisticated type of foundation system is required.

**Highly expansive soils**
These types of soils often described as active clay, are found in large parts of South Africa. They exhibit far greater expansive characteristics making the use of conventional foundations impossible.

In areas where such material is encountered, it is common for the foundation system to employ the use of raft or piled foundations.

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**Distribution of expansive and collapsible soils in South Africa**

Areas where some movement due to heaving clay has been recorded

Areas where severe movement due to heaving clay is common
It should be understood that a Soils Map of a large area such as South Africa can only be viewed as a rough guide in identifying areas where soils are problematical and cannot on its own be regarded as an adequate assessment for any development. Area or site specific geo-technical investigations will always be required in order to determine the most appropriate type of foundation solution.

Soil Bearing Capacities
A field test can be conducted in determining the bearing capacity of an open foundation trench by taking a deformed reinforcing bar/rod of around 1m in length with a diameter of 16mm (minimum) and then try pushing this bar into the ground by hand (don’t use a hammer). If the bar can be pushed in easily for more than 300mm to 1000mm then the bearing capacity is inadequate. One can excavate further until a suitable stratum is found and the bar can no longer be pushed into the ground.

For buildings not exceeding two storeys the local authority or building contractor would usually be able to assist with determining whether the soil in the area is capable of carrying these types of loads – However it is always recommended that an engineer be consulted to make this determination.

If the soil in the area of the building is uniform in composition and the foundation design is adequate, the building will remain stable. While some settlement may occur over time, it will remain uniform. If the soil composition varies and is not compensated for in foundation design, the building could experience differential settlement.
Extraordinary Development Conditions for Residential Homes

Extraordinary development conditions refer to site characteristics which require measures over and above the “norm” to be employed to ensure satisfactory outcomes.

Extraordinary conditions result from climatic, topographic (natural ground slope of the site) and geo-technical (inherent geology) conditions and also typically relate to:
1. Seepage / groundwater (high water tables).
2. Erodibility of the soil.
3. Hard excavation.
4. Site soil class designations (movement in near surface soil horizons).
5. Dolomite area designations (subsidence or settlement) associated with sinkhole formation in areas underlain by dolomite land.

Certain geographic areas are subjected to mining induced or natural seismic activity or fall within the Southern Cape Coastal Condensation Areas where condensation can occur on the underside of metal roofing sheets, at ceiling level, or interstitially (e.g., in spaces and gaps between components).

The Need for Geo-technical Investigations

In order to prevent the failure of foundations, the National Home Builders Registration Council (NHBRC) requires that site specific geo-technical investigations be undertaken by a listed competent person or a certification body to enable decisions to be made as to whether or not the design and construction of homes may be in accordance with the “norm” and if not, to identify what additional measures need to be taken to compensate for the site-specific conditions.

The determination of whether or not the intended build site should be regarded as extraordinary and appropriate measures to be taken to cater for extraordinary conditions is not the responsibility of the Home Builder.

Listed competent persons like engineers or certification bodies are responsible for the design of the precautionary measures that are required.

Geo-technical Investigations to Determine Appropriate Foundation Design

The Owner, or the Home Builder shall appoint a certification body or a listed competent person in the relevant category to conduct suitable geo-technical investigations on prescribed forms to:

Classify the site in accordance with the site class designations contained in Table 2 where homes are located in buildings which are not higher than two storeys including a basement and advise on the necessity of installing subsurface drains on sites that are located in marshy areas, have shallow water tables including seasonal shallow water or ground water levels and are to be terraced to the extent that the depth of cut below original ground level exceeds 0.75m; and Formulate an opinion regarding the parameters upon which the design of the foundations is to be based where homes are located in buildings which are:
1. Not higher than two storeys including a basement and either have walls not of masonry construction or have walls of masonry construction which are supported by steel, concrete or reinforced masonry columns.
2. Not higher than two storeys including a basement and are located on a site having a P site class designation.
3. Higher than two storeys including a basement.

Site Class Designation

Site class designations shall be derived from an estimation of the expected range of total soil movements experienced by single-storey and double-storey homes having masonry walls that are not supported by steel, concrete or reinforced masonry columns under the following assumptions:

a) The foundation has a width that does not exceed 0.6 m and 0.8 m in respect of single-storey and double storey buildings, respectively.
b) The soil bearing pressure is not to exceed 50 KPa.
c) The total soil movements are such that the resultant differential movement implied by Table 2 is equal to that which is to be expected in the field.

Multiple Descriptions

Where it is not possible to provide a single site designation and a composite description is inappropriate, sites may be given multiple descriptions to indicate the range of possible conditions.

Class P Sites

The reasons for classifying sites as class P shall be provided in brackets after the suffix for the site class designation using the typical founding material or site descriptor provided in Table 2 or any other suitable descriptor. In the case of dolomite land, the dolomite area designation determined in Table 3 shall be provided after the descriptor.

Geo-technical investigations shall in addition to satisfying the requirements of multiple descriptions, satisfy specific requirements established by the NHBRC.
Certification bodies and listed competent persons may elect to make use of existing investigation reports in order to reduce the number of additional investigations required provided that they satisfy themselves of the adequacy and validity of such information.

If during the course of development, it emerges that a site class designation requires revision in the light of new geotechnical information: a) the certification body or a listed competent person shall immediately notify the NHBRC Council on a prescribed form; and b) the Home Builder shall ensure that the design of foundations for a home constructed on such a site is amended to conform to the revised site class designation.

A certification body or listed competent person may be called upon to justify in writing their classifications or opinions to consumers, Home Builders and NHBRC Council inspectors when called upon to do so. Failure to provide such a justification when called upon to do so shall be interpreted that the service does not satisfy requirements and the certification was made fraudulently.

### Table 2 - Residential Site Class Designations

<table>
<thead>
<tr>
<th>Typical founding material / site descriptor</th>
<th>Nature of founding material</th>
<th>Expected range of total soil movements (mm)</th>
<th>Assumed differential movement (%) of total</th>
<th>Site class designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock (excluding mud rocks which may exhibit swelling to some depth)</td>
<td>Stable</td>
<td>Negligible</td>
<td>-</td>
<td>R</td>
</tr>
<tr>
<td>Fine grained soils with moderate to very high plasticity (clays, silty clays, clayey silts, and sandy clays)</td>
<td>Expansive soils</td>
<td>&lt; 7.5</td>
<td>50%</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.5 – 15</td>
<td>50%</td>
<td>H1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 – 30</td>
<td>50%</td>
<td>H2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;30</td>
<td>50%</td>
<td>H3</td>
</tr>
<tr>
<td>Silty sands, sands, sandy and gravely soils</td>
<td>Compressible and potentially collapsible soils</td>
<td>&lt; 5</td>
<td>75%</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5-10</td>
<td>75%</td>
<td>C1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;10</td>
<td>75%</td>
<td>C2</td>
</tr>
<tr>
<td>Fine grained soils (clayey silts and clayey sands of low plasticity), sands, sandy and gravely soils</td>
<td>Compressible soils</td>
<td>&lt; 10</td>
<td>50%</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-20</td>
<td>50%</td>
<td>S1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;20</td>
<td>50%</td>
<td>S2</td>
</tr>
<tr>
<td>Contaminated soils, controlled fill, dolomitic areas, landslip, landfill, marshy areas mine waste fill, mining subsidence reclaimed areas, uncontrolled fill and very soft silts / silty clays</td>
<td>Variable</td>
<td>Variable</td>
<td>-</td>
<td>P</td>
</tr>
</tbody>
</table>
Dolomite Investigation
The Owner, or a Home Builder shall appoint a certification body or a listed competent person in the relevant category on prescribed forms to:

a. Conduct suitable geo-technical investigations to determine and certify on a prescribed form the inherent hazard class of a site on dolomite land in accordance with the relevant provisions of SANS 1936-2: Development of dolomite land – Part 2: Geotechnical investigations and determinations, and any modification or additional requirements as may be prescribed by the NHBRC Council.

b. Establish in the case of land underlain by Black Reef Formation whether or not such land presents a susceptibility of sinkhole formation in accordance with the relevant provisions of SANS 1936-2 and any modification or additional requirements as may be prescribed by the NHBRC Council and, if not, classify such sites as having a D1 dolomitic area designation.

c. Where required, undertake footprint investigations in accordance with the relevant provisions of SANS 1936-2 and any modification or additional requirements as may be prescribed by the NHBRC Council.

d. The NHBRC Council may accept a home for enrolment if underlain by dolomite land provided that the Home Builder furnishes the Council with:
   • A letter from the relevant municipality and, in the case of an interconnected complex, the body corporate established in terms of the Sectional Titles Schemes Management Act of 2011 (Act No. 8 of 2011) or, if not established, the owner of such complex, confirming that such person undertakes to establish, implement and maintain a dolomite risk management strategy in accordance with the relevant provisions of SANS 1936-4, Development of dolomite land – Part 4: Risk management, and any modification or additional requirements as may be prescribed by the NHBRC Council;
   • A certification by a certification body or a listed competent person on a prescribed form that homes on sites and surrounding infrastructure including wet and dry engineering services having a dolomite area designation of D2 or D3 in terms of Tables 11 or 10 have been or are to be designed and constructed in accordance with the relevant provisions of SANS 1936-3, Development of dolomite land – Part 3: Design and construction of building structures and infrastructure, and any modification or additional requirements as may be prescribed by the Council
   • And any additional documents that the NHBRC Council may prescribe.

Certification in-lieu of Dolomite Investigation
The NHBRC may accept a home for enrolment if underlain by dolomite land on sites having a dolomite area designation of D4 provided that the Home Builder furnishes the NHBRC with:

a. A certification by a certification body or a listed competent person in the relevant category on a prescribed form that the precautionary measures that are to be adopted in addition to the relevant provisions of SANS 1936-3 and any modification or additional requirements as may be prescribed by the NHBRC Council to enable the performance requirements of 2.6 to be satisfied; Part 5: Development of dolomite land.

b. A favourable independent review of the proposed approach to mitigate the hazards associated with the development of the site to satisfy the performance requirements of 2.6 by two certification bodies or listed competent persons in the relevant category who are free of conflicts of interest appointed on a prescribed form.

Table 3 - (Table 11 SANS 1936)- Dolomite area designations

<table>
<thead>
<tr>
<th>Dolomite area designation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>No precautionary measures are required to support development</td>
</tr>
<tr>
<td>D2</td>
<td>General precautionary measures that are intended to prevent the concentrated ingress of water into the ground are required to support the development</td>
</tr>
<tr>
<td>D3</td>
<td>Precautionary measures in addition to those pertaining to the concentrated ingress of water into the ground are required.</td>
</tr>
<tr>
<td>D4</td>
<td>Precautionary measures:</td>
</tr>
<tr>
<td></td>
<td>• In addition to that described for dolomite area designation D3 are required to reduce the hazard rating to tolerable levels so as to support development; or</td>
</tr>
<tr>
<td></td>
<td>• are considered to be uneconomic or impractical to reduce the hazard rating to tolerable levels so as to support development</td>
</tr>
</tbody>
</table>

Acknowledgments - National Home Builders Registration Council (NHBRC) - Simplified Home Building Manual - ISBN: 978-0-620-79583-8 – August 2018

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Creating Concrete Possibilities
Table 3 - Dolomite area designations

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</tr>
<tr>
<td>D4</td>
<td>Precautionary measures: • In addition to that described for dolomite area designation D3 are required to reduce the hazard rating to tolerable levels so as to support development; or • are considered to be uneconomic or impractical to reduce the hazard rating to tolerable levels so as to support development</td>
</tr>
</tbody>
</table>

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- Postal Address: P O Box 82223, Southdale 2133
- Telephone number: (011) 835-3117
- SANAS accredited testing laboratory, No T0062

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**North West**

Rustenburg

- Physical Address: 112 Zendeling Street, Rustenburg 0299
- Postal Address: P O Box 128, Tlhabane 0309
- Telephone number: (014) 594-5031

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