In order to discuss the procedures followed and the results of the wetland identification exercise it is necessary at the outset to provide some theoretical background on soil forming processes, soil wetness indicators, water movement in soils and topographical sequences of soil forms (catena). Complex geological environments are considered to be those where a narrow set of pH and redox chemistry parameters do not exist and where the expression of soil morphology and hydromorphy is a function of a wide range of chemical, physical and mineralogical determinants.

5.1 PEDOGENESIS

Pedogenesis is the process of soil formation. Soil formation is a function of five (5) factors namely (Jenny, 1941):

- Parent material;
- Climate;
- Topography;
- Living Organisms; and
- Time.

These factors interact to lead to a range of different soil forming processes that ultimately determine the specific soil formed in a specific location. Central to all soil forming processes is water and all the reactions (physical and chemical) associated with it. The physical processes include water movement onto, into, through and out of a soil unit. The movement can be vertically downwards, lateral or vertically upwards through capillary forces and evapotranspiration. The chemical processes are numerous and include dissolution, precipitation (of salts or other elements) and alteration through pH and reduction and oxidation (redox) changes. In many cases the reactions are promoted through the presence of organic material that is broken down through aerobic or anaerobic respiration by microorganisms. Both these processes alter the redox conditions of the soil and influence the oxidation state of elements such as Fe and Mn. Under reducing conditions Fe and Mn are reduced and become more mobile in the soil environment. Oxidizing conditions, in turn, lead to the precipitation of Fe and Mn and therefore lead to their immobilization. The dynamics of Fe and Mn in soil, their zones of depletion through mobilization and accumulation through precipitation, play an important role in the identification of the dominant water regime of a soil and could therefore be used to identify wetlands and wetland conditions.

5.2 WATER MOVEMENT IN THE SOIL PROFILE

In a specific soil profile, water can move upwards (through capillary movement), horizontally (owing to matric suction) and downwards under the influence of gravity.

The following needs to be highlighted in order to discuss water movement in soil:

- Capillary rise refers to the process where water rises from a deeper lying section of the soil profile to the soil surface or to a section closer to the soil surface. Soil pores can be regarded as miniature tubes. Water rises into these tubes owing to the adhesion (adsorption) of water molecules onto solid mineral surfaces and the surface tension of water.

The height of the rise is inversely proportional to the radius of the soil pore and the density of the liquid (water). It is also directly proportional to the liquid's surface tension and the degree of its adhesive attraction. In a soil-water system the following simplified equation can be used to calculate this rise:

$$\text{Height} = 0.15/\text{radius}$$

Usually the eventual height of rise is greater in fine textured soil, but the rate of flow may be slower (Brady and Weil, 1999; Hillel, 1983).

- Matric potential or suction refers to the attraction of water to solid surfaces. Matric potential is operational in unsaturated soil above the water table while pressure potential refers to water in saturated soil or below the water table. Matric potential is always expressed as a negative value and pressure potential as a positive value.

  Matric potential influences soil moisture retention and soil water movement. Differences in the matric potential of adjoining zones of a soil results in the movement of water from the moist zone (high state of energy) to the dry zone (low state of energy) or from large pores to small pores.

  The maximum amount of water that a soil profile can hold before leaching occurs is called the field capacity of the soil. At a point of water saturation, a soil exhibits an energy state of 0 $J.kg^{-1}$. Field capacity usually falls within a range of -15 to -30 $J.kg^{-1}$ with fine textured soils storing larger amounts of water (Brady and Weil, 1999; Hillel, 1983).

- Gravity acts on water in the soil profile in the same way as it acts on any other body; it attracts towards earth's centre. The gravitational potential of soil water can be expressed as:

  $$\text{Gravitational potential} = \text{Gravity} \times \text{Height}$$

  Following heavy rainfall, gravity plays an important part in the removal of excess water from the upper horizons of the soil profile and recharging groundwater sources below.

  Excess water, or water subject to leaching, is the amount of water that falls between soil saturation (0 $J.kg^{-1}$) or oversaturation (> 0 $J.kg^{-1}$), in the case of heavy rainfall resulting in a pressure potential, and field capacity (-15 to -30 $J.kg^{-1}$). This amount of water differs according to soil type, structure and texture (Brady and Weil, 1999; Hillel, 1983).

- Under some conditions, at least part of the soil profile may be saturated with water, resulting in so-called saturated flow of water. The lower portions of poorly drained soils are often saturated, as are well-drained soils above stratified (layers differing in soil texture) or impermeable layers after rainfall.

The quantity of water that flows through a saturated column of soil can be calculated using Darcy's law:

$$Q = Ksat.A.\Delta P/L$$

Where Q represents the quantity of water per unit time, Ksat is the saturated hydraulic conductivity, A is the cross sectional area of the column through which the water flows, ΔP is the hydrostatic pressure difference from the top to the bottom of the column, and L is the length of the column.

Saturated flow of water does not only occur downwards, but also horizontally and upwards. Horizontal and upward flows are not quite as rapid as downward flow. The latter is aided by gravity (Brady and Weil, 1999; Hillel, 1983).

- Mostly, water movement in soil is ascribed to the unsaturated flow of water. This is a much more complex scenario than water flow under saturated conditions. Under unsaturated conditions only the fine micropores are filled with water whereas the macropores are filled with air. The water content, and the force with which water molecules are held by soil surfaces, can also vary considerably. The latter makes it difficult to assess the rate and direction of water flow. The driving force behind unsaturated water flow is matric potential. Water movement will be from a moist to a drier zone (Brady and Weil, 1999; Hillel, 1983).

The following processes influence the amount of water to be leached from a soil profile:

- Infiltration is the process by which water enters the soil pores and becomes soil water. The rate at which water can enter the soil is termed infiltration tempo and is calculated as follows:

  $$I = Q/A.t$$

  Where I represents infiltration tempo ($m.s^{-1}$), Q is the volume quantity of infiltrating water (m^3), A is the area of the soil surface exposed to infiltration (m^2), and t is time (s).

  If the soil is quite dry when exposed to water, the macropores will be open to conduct water into the soil profile. Soils that exhibit a high 2:1 clay content (swelling-shrinking clays) will exhibit a high rate of infiltration initially. However, as infiltration proceeds, the macropores will become saturated and cracks, caused by dried out 2:1 clay, will swell and close, thus leading to a decline in infiltration (Brady and Weil, 1999; Hillel, 1983).

- Percolation is the process by which water moves downward in the soil profile. Saturated and unsaturated water flow is involved in the process of percolation, while the rate of percolation is determined by the hydraulic conductivity of the soil.

During a rain storm, especially the down pouring of heavy rain, water movement near the soil surface mainly occurs in the form of saturated flow in response to gravity. A sharp boundary, referred to as the wetting front, usually appears between the wet soil and the underlying dry soil. At the wetting front, water is moving into the underlying soil in response to both matric and gravitational potential. During light rain, water movement at the soil surface may be ascribed to unsaturated flow (Brady and Weil, 1999; Hillel, 1983).

The fact that water percolates through the soil profile by unsaturated flow has certain ramifications when an abrupt change in soil texture occurs (Brady and Weil, 1999; Hillel, 1983). A layer of course sand, underlying a fine textured soil, will impede downward movement of water. The macropores of the coarse textured sand offer less attraction to the water molecules than the macropores of the fine textured soil. When the unsaturated wetting front reaches the coarse sand, the matric potential is lower in the sand than in the overlying material. Water always moves from a higher to a lower state of energy. The water can, therefore, not move into the coarse textured sand. Eventually, the downward moving water will accumulate above the sand layer and nearly saturate the fine textured soil. Once this occurs, the water will be held so loosely that gravitational forces will be able to drag the water into the sand layer (Brady and Weil, 1999; Hillel, 1983).

A coarse layer of sand in an otherwise fine textured soil profile will also inhibit the rise of water by capillary movement (Brady and Weil, 1999; Hillel, 1983).

Field observations and laboratory based analysis can aid in assessing the soil-water relations of an area. The South African soil classification system (Soil Classification Working Group, 1991.) comments on certain field observable characteristics that shed light on water movement in soil. The more important of these are:

- Soil horizons that show clear signs of leaching such as the E-horizon – an horizon where predominantly lateral water movement has led to the mobilisation and transport of sesquioxide minerals and the removal of clay material;
- Soil horizons that show clear signs of a fluctuating water table where Fe and Mn mottles, amongst other characteristics, indicate alternating conditions of reduction and oxidation (soft plinthic B-horizon);
- Soil horizons where grey colouration (Fe reduction and redox depletion), in an otherwise yellowish or reddish matrix, indicate saturated (or close to saturated) water flow for at least three months of the year (Unconsolidated/Unspecified material with signs of wetness);
- Soil horizons that are uniform in colouration and indicative of well-drained and aerated (oxidising) conditions (e.g. yellow brown apedal B-horizon).

5.3 WATER MOVEMENT IN THE LANDSCAPE

Water movement in a landscape is a combination of the different flow paths in the soils and geological materials. The movement of water in these materials is dominantly subject to gravity and as such it will follow the path of least resistance towards the lowest point. In the landscape there are a number of factors determining the paths along which this water moves. **Figure 4** provides a simplified schematic representation of an idealised landscape (in “profile curvature”. The total precipitation (rainfall) on the landscape from the crest to the lowest part or valley bottom is taken as 100 %. Most geohydrologists agree that total recharge, the water that seeps into the underlying geological strata, is less than 4 % of total precipitation for most geological settings. Surface runoff varies considerably according to rainfall intensity and distribution, plant cover and soil characteristics but is taken as a realistic 6 % of total precipitation for our idealised landscape. The total for surface runoff and recharge is therefore calculated as 10 % of total precipitation. If evapotranspiration (from plants as well as the soil surface) is taken as a very high 30 % of total precipitation it leaves 60 % of the total that has to move through the soil and/or geological strata from higher lying to lower lying areas. In the event of an average rainfall of 750 mm per year it results in 450 mm per year having to move laterally through the soil and geological strata. In a landscape there is an accumulation of water down the slope as water from higher lying areas flow to lower lying areas.

To illustrate: If the assumption is made that the area of interest is 100 m wide it follows that the first 100 m from the crest downwards has 4 500 m^3 (or 4 500 000 litres) of water moving laterally through the soil (100 m X 100 m X 0.45 m) per rain season. The next section of 100 m down the slope has its own 4 500 m^3 of water as well as the added 4 500 m^3 from the upslope section to contend with, therefore 9 000 m^3. The next section has 13 500 m^3 to contend with and the following one 18 000 m^3. It is therefore clear that, the longer the slope, the larger the volume of water that will move laterally through the soil profile.

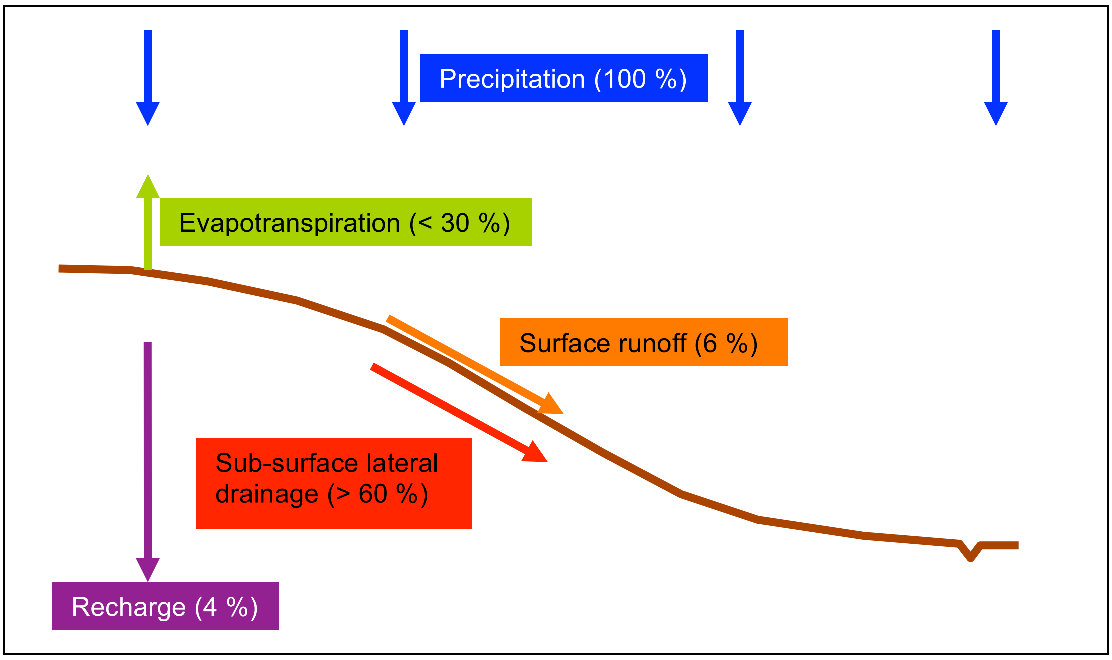


Figure 4 Idealised landscape with assumed quantities of water moving through the landscape expressed as a percentage of total precipitation (100 %).

Flow paths through soil and geological strata, referred to as "interflow" or "hillslope water", are very varied and often complex due to difficulty in measurement and identification. The difficulty in identification stems more from the challenges related to the physical determination of these in soil profile pits, soil auger samples and core drilling samples for geological strata. The identification of the morphological signs of water movement in permeable materials or along planes of weakness (cracks and seams) is a well-established science and the expression is mostly referred to as "redox morphology". In terms of the flow paths of water large variation exists but these can be grouped into a few simple categories. **Figure 5** provides a schematic representation of the different flow regimes that are usually encountered. The main types of water flow can be grouped as 1) recharge (vertically downwards) of groundwater; 2) lateral flow of water through the landscape along the hillslope (interflow or hillslope water); 3) return flow water that intercepts the soil/landscape surface; and 4) surface runoff. Significant variation exists with these flow paths and numerous combinations are often found. The main wetland types associated with the flow paths are: a) valley bottom wetlands (fed by groundwater, hillslope processes, surface runoff, and/or in-stream water); b) hillslope seepage wetlands (fed by interflow water and/or return flow water); and wetlands associated with surface runoff, ponding and surface ingress of water anywhere in the landscape.

Amongst other factors, the thickness of the soil profile at a specific point will influence the intensity of the physical and chemical reactions taking place in that soil. **Figure 6** illustrates the difference between a dominantly thick and a dominantly thin soil profile. If all factors are kept the same except for the soil profile thickness it can be assumed with confidence that the chemical and physical reactions associated with water in the landscape will be much more intense for the thin soil profile than for the thick soil profile. Stated differently: The volume of water moving through the soil per surface area of an imaginary plane perpendicular to the direction of water flow is much higher for the thin soil profile than for the thick soil profile. This aspect has a significant influence on the expression of redox morphology in different landscapes of varying soil/geology/climate composition.

5.4 THE CATENA CONCEPT

Here it is important to take note of the "catena" concept. This concept is one of a topographic sequence of soils in a homogenous geological setting where the water movement and presence in the soils determine the specific characteristics of the soils from the top to the bottom of the topography. **Figure 7** illustrates an idealised topographical sequence of soils in a catena for a quartz rich parent material. Soils at the top of the topographical sequence are typically red in colour (Hutton and Bainsvlei soil forms) and systematically grade to yellow further down the slope (Avalon soil form). As the volume of water that moves through the soil increases, typically in midslope areas, periodic saturated conditions are experienced and consequently Fe is reduced and removed in the laterally flowing water. In the event that the soils in the midslope positions are relatively sandy the resultant soil colour will be bleached or white due to the colour dominance of the sand quartz particles. The soils in these positions are typically of the Longlands and Kroonstad forms. Further down the slope there is an accumulation of clays and leaching products from higher lying soils and this leads to typical illuvial and clay rich horizons. Due to the regular presence of water the dominant conditions are anaerobic and reducing and the soils exhibit grey colours often with bright yellow and grey mottles (Katspruit soil form). In the event that there is a large depositional environment with prolonged saturation soils of the Champagne form may develop (typical peat land). Variations on this sequence (as is often found on the Mpumalanga Highveld) may include the presence of hard plinthic materials instead of soft plinthite with a consequent increase in the occurrence of bleached soil profiles. Extreme examples of such landscapes are discussed below.

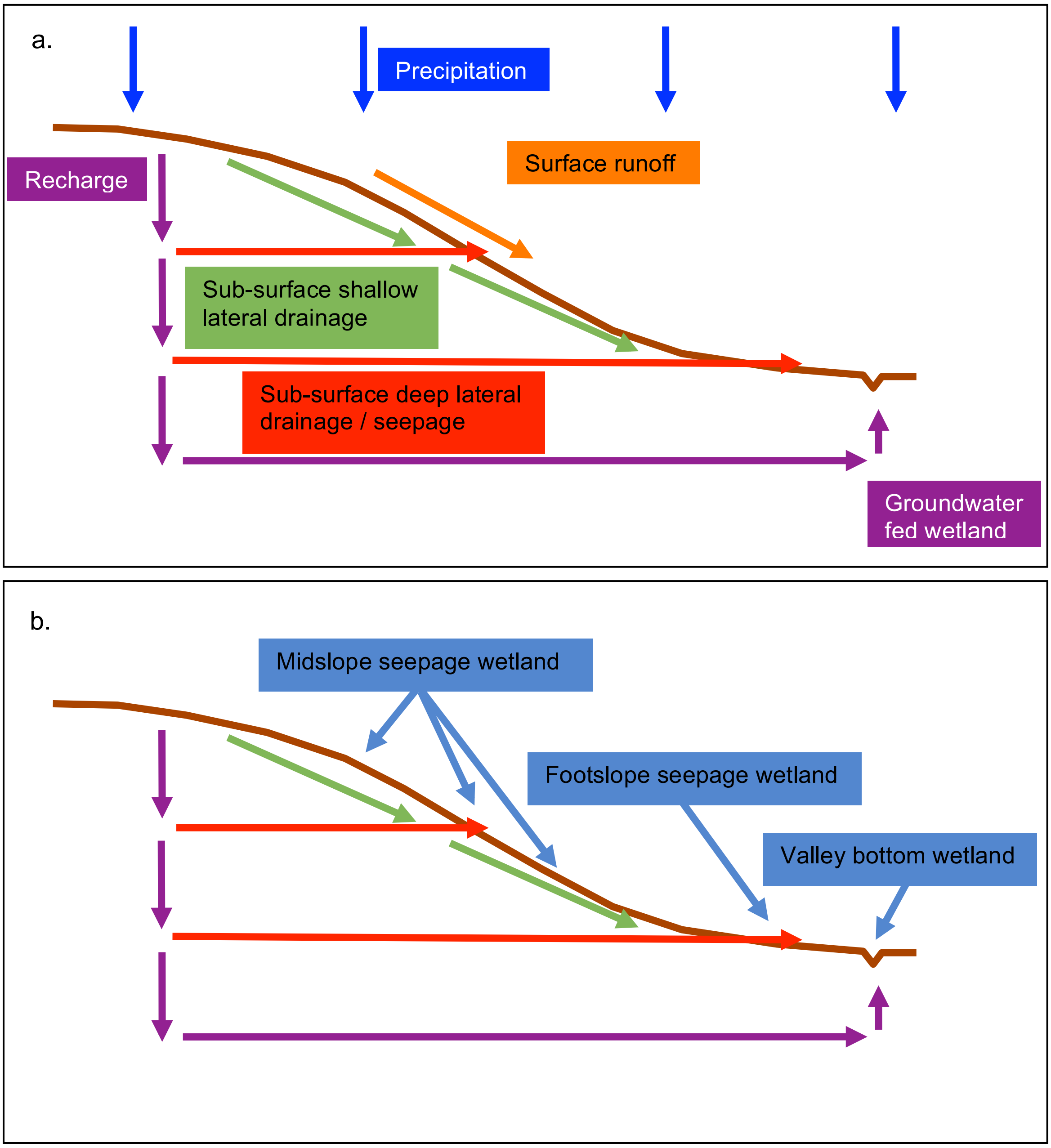


Figure 5 Different flow paths of water through a landscape (a) and typical wetland types associated with the water regime (b)

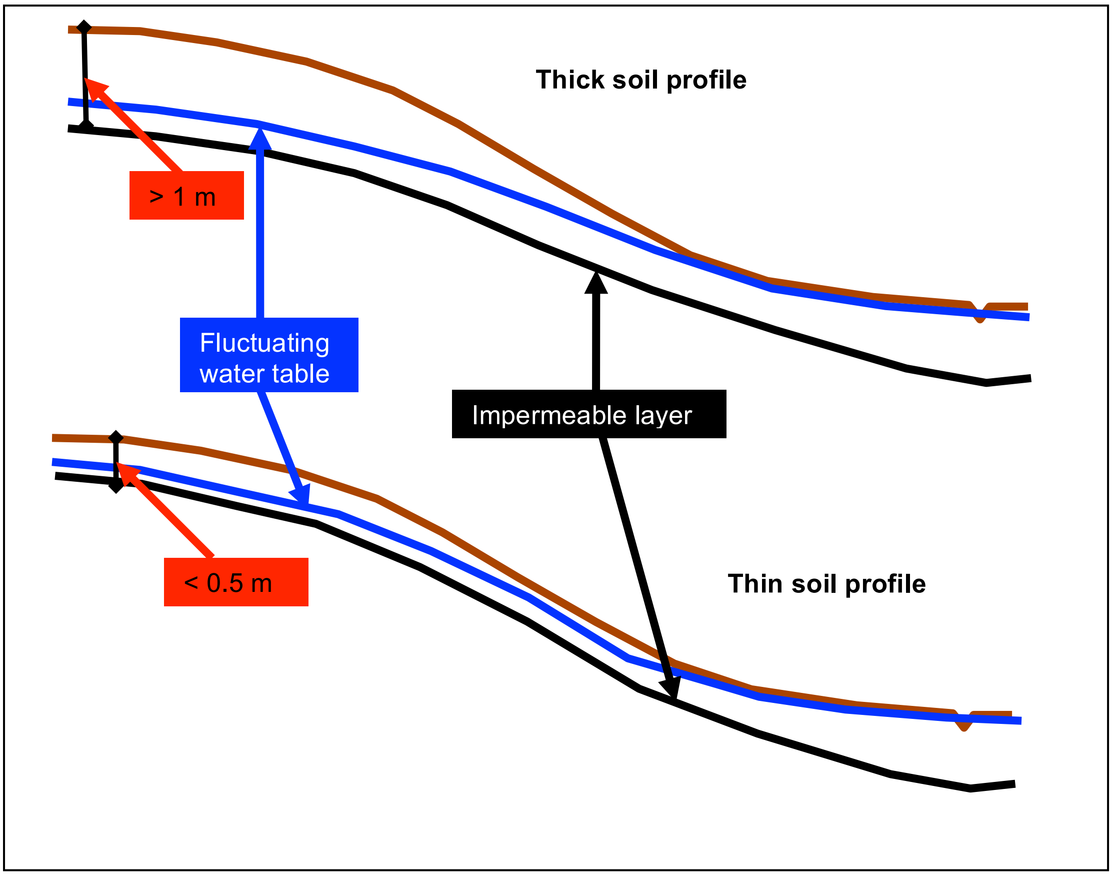


Figure 6 The difference in water flow between a dominantly thick and dominantly thin soil profile.

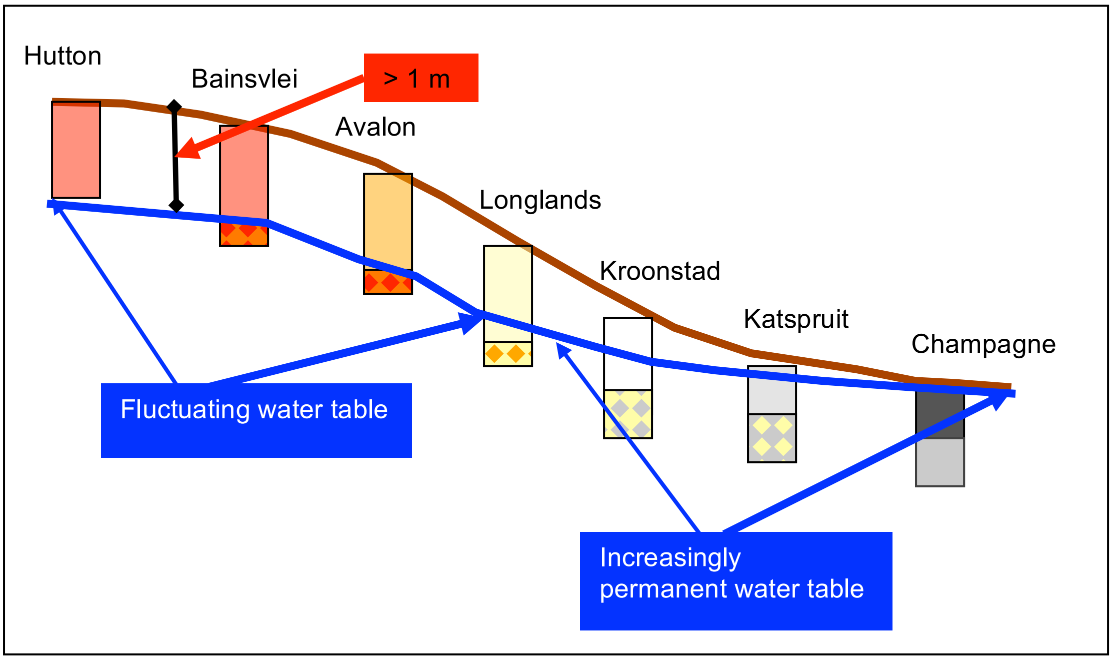


Figure 7 Idealised catena on a quartz rich parent material

5.5 CONVEX VERSUS CONCAVE LANDSCAPES IN AN IDEALISED CATENA

An additional factor of variation in all landscapes is the shape of the landscape along contours (referred to a "plan curvature"). Landscapes can be either concave or convex, or flat. The main difference between these landscapes lies in the fact that a convex landscape is essentially a watershed with water flowing in diverging directions with a subsequent occurrence of "dryer" soil conditions. In a concave landscape water flows in converging directions and soils often exhibit the wetter conditions of "signs of wetness" such as grey colours, organic matter and subsurface clay accumulation. **Figure 8** presents the difference between these landscapes in terms of typical soil forms encountered in an idealised catena. In the convex landscape the subsurface flow of water removes clays and other weathering products (including Fe) in such a way that the midslope position soils exhibit an increasing degree of bleaching and relative accumulation of quartz (E-horizons).

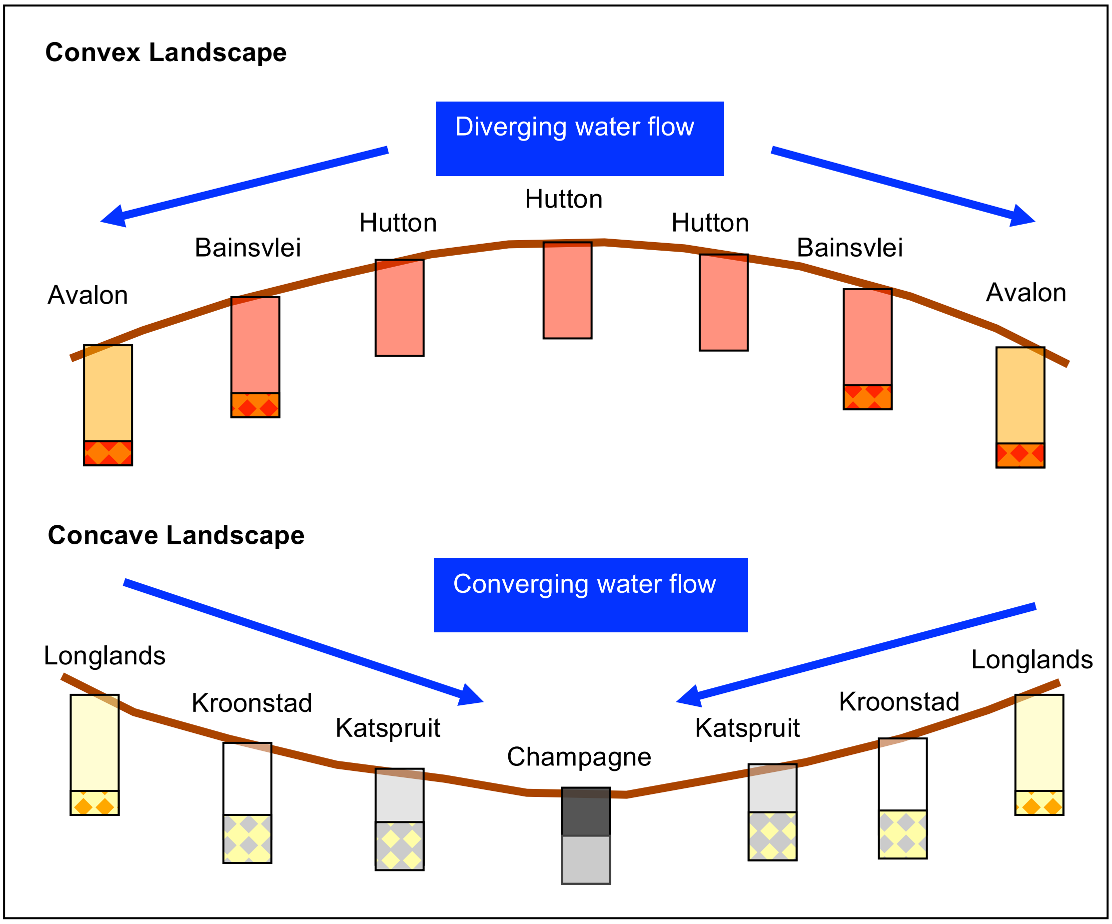


Figure 8 Schematic representation of the soils in convex and concave landscapes in an idealised catena

In the concave landscapes clays and weathering products are transported through the soils into a zone of accumulation where soils start exhibiting properties of clay and Fe accumulation. In addition, coarse sandy soils in convex environments tend to be thinner due to the removal of sand particles through erosion and soils in concave environments tend to be thicker due to colluvial accumulation of material transported from upslope positions. Similar patterns are observed for other geological areas with the variation being consistent with the soil variation in the catena.

Often these concave and convex topographical environments occur in close proximity or in one topographical sequence of soils. This is often found where a convex upslope area changes into a concave environment as a drainage depression is reached (**Figure 9**). The processes in this landscape are the same as those described for the convex and concave landscapes above.

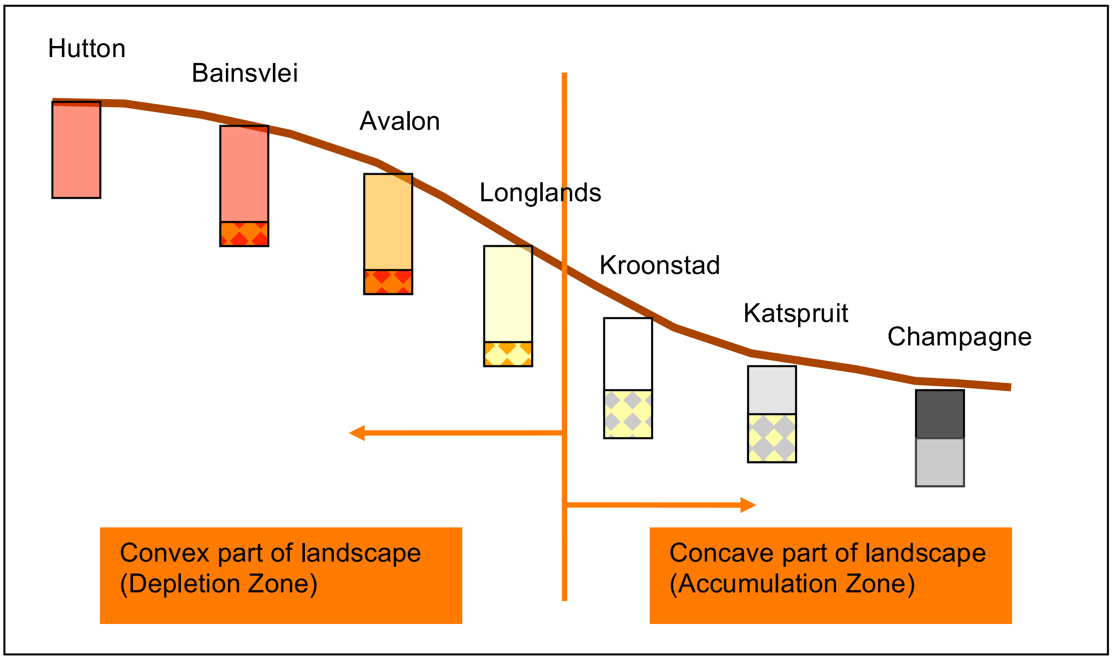


Figure 9 Schematic representation of the soils in a combined convex and concave landscape in an idealised catena.

5.6 THE BA9 LAND TYPE CATENA CHALLENGE

The Ba9 land type covers a large area of the eastern part of Pretoria and comprises a wide range of geological materials. As such it is not possible to describe a typical catena. In the north-eastern section the geology is dominated by shale and andesite or diabase. The shale leads to the formation of shallow soils in most areas and the formation of deeper silty soils in valley bottom positions. The diabase and andesite lead to the dominance of rocky soils on crests and highly structured soils in footslope and valley bottom positions. In the specific land type there are many instances of structured soil material overlying shale dominated subsoil material due to colluvial transport of the soil material. In these cases extensive areas of structured soils occur in gently sloping terrain

The typical catena that forms in the **Ab9** land type in the areas as discussed above is presented in **Figure 10**. It differs from the idealised one discussed above in the previous section in a number of respects namely that 1) the soils throughout the higher lying parts of the landscape are predominantly rocky with red structured clay soil, 2) the soils in the lower lying landscape positions predominantly exhibit high clay content, structure and swelling properties and 3) the drainage features are dominated by younger soils that range from recently eroded and deposited alluvial material to soil with signs of incipient soil formation. The soils in the drainage features exhibit higher chroma than the structured soils immediately outside of the features and this aspect complicates the understanding of the drainage channels in a strict wetland delineation guideline context. A part of the elucidation problem is that fact that the structure soils with swelling properties allow for no lateral movement (or seepage) of water within the profile due to a very low saturated hydraulic conductivity. In such cases the dominant water flow regime is one of surface runoff with this runoff entering the drainage feature directly with the clear signs of erosion and surface soil removal once the vegetative cover has been compromised. The vegetation associated with these drainage features is very rarely classified as wetland vegetation. Rather, these drainage features exhibit a clear expression of riparian character in its tree, forb and grass species composition.

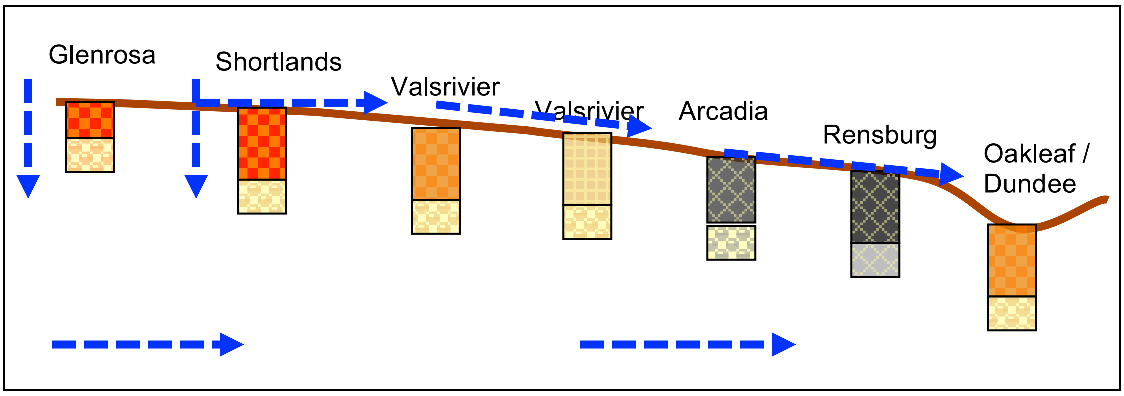


Figure 10 Idealised lower portion of the catena in the Ba9 land type in areas dominated by shale and basic igneous rock

A problematic aspect of this type of landscape in terms of wetland delineation is that the high clay content and often structured soils have a high base status with above neutral pH values. The specific clay minerals (2:1 swelling and non-swelling clays) that occur in these landscapes form under above neutral pH conditions. This aspect has very specific implications for the identification of morphological signs of wetness. Wetlands are invariably associated with the lowest points in the landscape and as such this aspect is critical (and therefore addressed in more detail later). Due to the high clay content (and often swelling nature) the soils are characterised predominantly by surface flow of water with very slow percolation rates through the profiles. Lateral flow of water on impervious layers is therefore not encountered with the exception being planes of weakness in the underlying weathered and hard rock. The drainage depressions in these landscapes often exhibit signs of high energy flow events in the form of eroded soils as well as young recently transported soil material.

Below follows a discussion on the expression of redox morphology in alkaline (swelling clay soils) environments.

5.7 REDOX MORPHOLOGY IN ALKALINE SOILS

Wetland delineation is a very challenging exercise in areas dominated by alkaline soils such as lime containing and/or vertic/melanic soils. This is mainly due to the almost complete absence of Fe-mottles in the soils that grade from the terrestrial to the wetland areas. There are a number of reasons that will be explained in more detail below.

In order to illustrate the stability and distribution of Fe minerals in soils the figure provided below (**Figure 11**) was copied from page 124 of a book entitled “Soil Chemistry” by Bohn, et al., (1990). The essence is that when reduction and oxidation reactions of Fe (in this case) are considered in soils both the electron activity (driver of reducing conditions) and pH have to be considered as they are intimately linked and dependent on each other. Suffice to say that for redox and mineral stability purposes they are indicated on the same graph. From Figure 4.6 (**Figure 11**) it is clear that as the Eh decreases (increasing reducing conditions) the dominant Fe species in solution changes from Fe^{3+} (insoluble and forming brightly coloured minerals) to Fe^{2+} (soluble and essentially colourless). Once pH is included in the observation it is clear that distinct Fe minerals come into play. Applying the decreasing Eh values to Fe minerals at high pH it is clear that the dominant Fe mineral under oxidizing conditions is FeOOH (Goethite – predominantly yellow). As the conditions become more reducing the equilibrium shifts to $FeCO_3$ (Siderite – white) and thereafter to FeS_2 (Pyrite). Whereas goethite has a distinct colour in soil, siderite and pyrite are less conspicuous in small quantities. It follows therefore that Fe minerals are much less visible in high pH reduced soils than in oxidised soils. In addition, vertic and melanic soils are dark coloured and it is therefore also clear that this dark colour will mask the presence of the above mentioned Fe minerals.

Another factor related to pH is the degree of reduction that is required to reduce Fe from its oxidised to its reduced state. From the graph it is clear that there is a steep decreasing gradient as the pH of the soil increases. This implies that much more intensive reducing conditions are required for the same degree of Fe reduction when high pH conditions (as those experienced in vertic and melanic soils) are compared to low pH conditions.

The situation becomes even more complex as other intermediate Fe minerals (blue green rusts) come into play. The essence of the presence of blue-green rusts is that they are tints that occur extensively in poorly drained and poorly aerated soils such as G-horizons under vertic and/or melanic A-horizons. These minerals are not stable and often disappear within a few minutes of exposure to the atmosphere. They in all probability form some of the most important Fe phases in vertic soils but disappear rapidly. Before they disappear it is also evident that these minerals are visible against a grey matrix but poorly visible against a black or dark background.

In essence therefore, a number of factors, including degree of reduction, soil pH and dominant Fe minerals, conspire against the use of Fe indicators in vertic, melanic and lime containing soils for the delineation of wetlands. There is no quick solution to this problem and delineators should use as many other indicators of wetland conditions in such soils as they can.

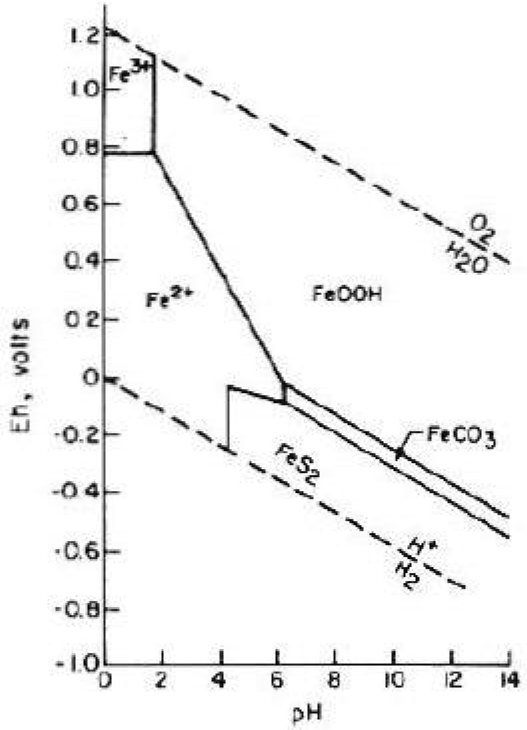


FIGURE 4.6. The *Eh*–pH diagram of various iron ions and compounds.

Figure 11 Eh pH diagram as sourced from Bohn, et al., (1990) p124

<u>**One word of caution**</u>: The wetland delineation guidelines (DWAF, 2005) indicate the Rensburg and Willowbrook soil forms as occurring in the permanent wetland zone. This is somewhat erroneous. Although these can occur in permanent wetland zones their formation is dependent on distinct cycling between wet and dry seasons. The development of 2:1 clays (found in these soils) depends on the accumulation of weathering products and clays in lower lying landscape positions. These clays are, depending on a range of factors, either swelling or non-swelling and their formation requires a distinct time (seasonally) where evaporation exceeds precipitation, with consequent drying of the soil, to lead to a concentration of bases (Ca and Mg). These clay minerals (such as smectite) often express themselves in the form of distinct cracks in Vertic soils. From this discussion it follows that the Rensburg and Willowbrook soils could only have formed in conditions that resemble a **seasonal wetland**. Drainage lines on the site can, if dominated by Rensburg or Willowbrook soils, therefore not be classified as permanent wetlands unless there are other characteristics indicating conditions of permanent saturation.

5.8 IMPLICATIONS FOR WETLAND DELINEATION AND APPLICATION OF THE GUIDELINES

The main implication for the delineation of wetlands and the application of the guidelines is the fact that highly variable conditions occur in the specific land type. The problem is compounded by the fact that the parent materials lead to the formation of high clay content soils of which the dominant ones are vertic in nature. As indicated earlier vertic soils are not necessarily and indication of wetland conditions and the determined wetland boundary in such environments is sometimes incorrect. One set of indicators of hydromorphism cannot be used as many of the clayey soils do not exhibit mottling or grey colours. A delineation exercise is therefore a complex process with a very distinct possibility of not elucidating the hydrological parameters needed for the making of informed decision regarding the impact of the development on the wetland.

5.9 IMPLICATIONS FOR WETLAND CONSERVATION IN URBAN ENVIRONMENTS

Whether an area is designated a wetland or not loses some of its relevance once drastic influences on landscape hydrology are considered. If wetlands are merely the expression of water in a landscape due to proximity to the land surface (viz. the 50 cm mottle criterion in the delineation guidelines) it follows that potentially large proportions of the water moving in the landscape could fall outside of this sphere – as discussed in detail above. **Figures 12** and **13** provide schematic representations (as contrasted with **Figure 5**) of water dynamics in urban environments with distinct excavations and surface sealing activities respectively.

Through the excavation of pits (**Figure 12**) for the construction of foundations for infrastructure or basements for buildings the shallow lateral flow paths in the landscape are severed. As discussed above these flow paths can account for up to 60 % of the volume of water entering the landscape in the form of precipitation. These severed flow paths often lead to the ponding of water upslope from the structure with a subsequent damp problem developing in buildings. Euphemistically we have coined the term “wet basement syndrome” (WBS) to describe the type of problem experienced extensively on the HHGD. A different impact is experienced once the surface of the land is sealed through paving (roads and parking areas) and the construction of buildings (in this case the roof provides the seal) (**Figure 13**). In this case the recharge of water into the soil and weathered rock experienced naturally is altered to an accumulation and concentration of water on the surface with a subsequent rapid flowing downslope. The current approach is to channel this water into storm water structures and to release it in the nearest low lying position in the landscape. These positions invariable correlate with drainage features and the result is accelerated erosion of such features due to a drastically altered peak flow regime.

The result of the above changes in landscape hydrology is the drastic alteration of flow dynamics and water volume spikes through wetlands. This leads to wetlands that become wetter and that experience vastly increased erosion pressures.

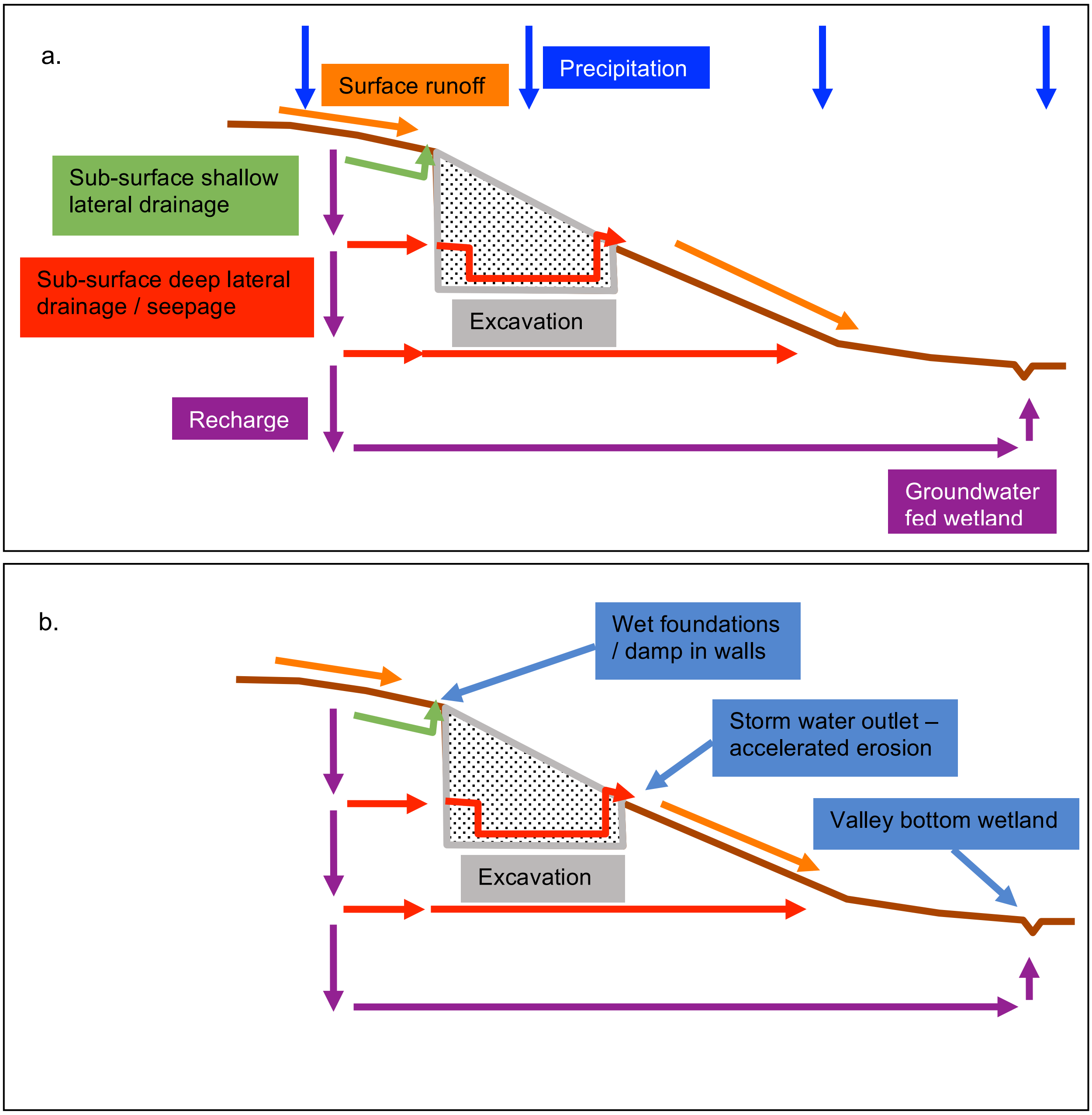


Figure 13 Different flow paths of water through a landscape with an excavated foundation (a) and typical wetland types associated with the altered water regime (b)

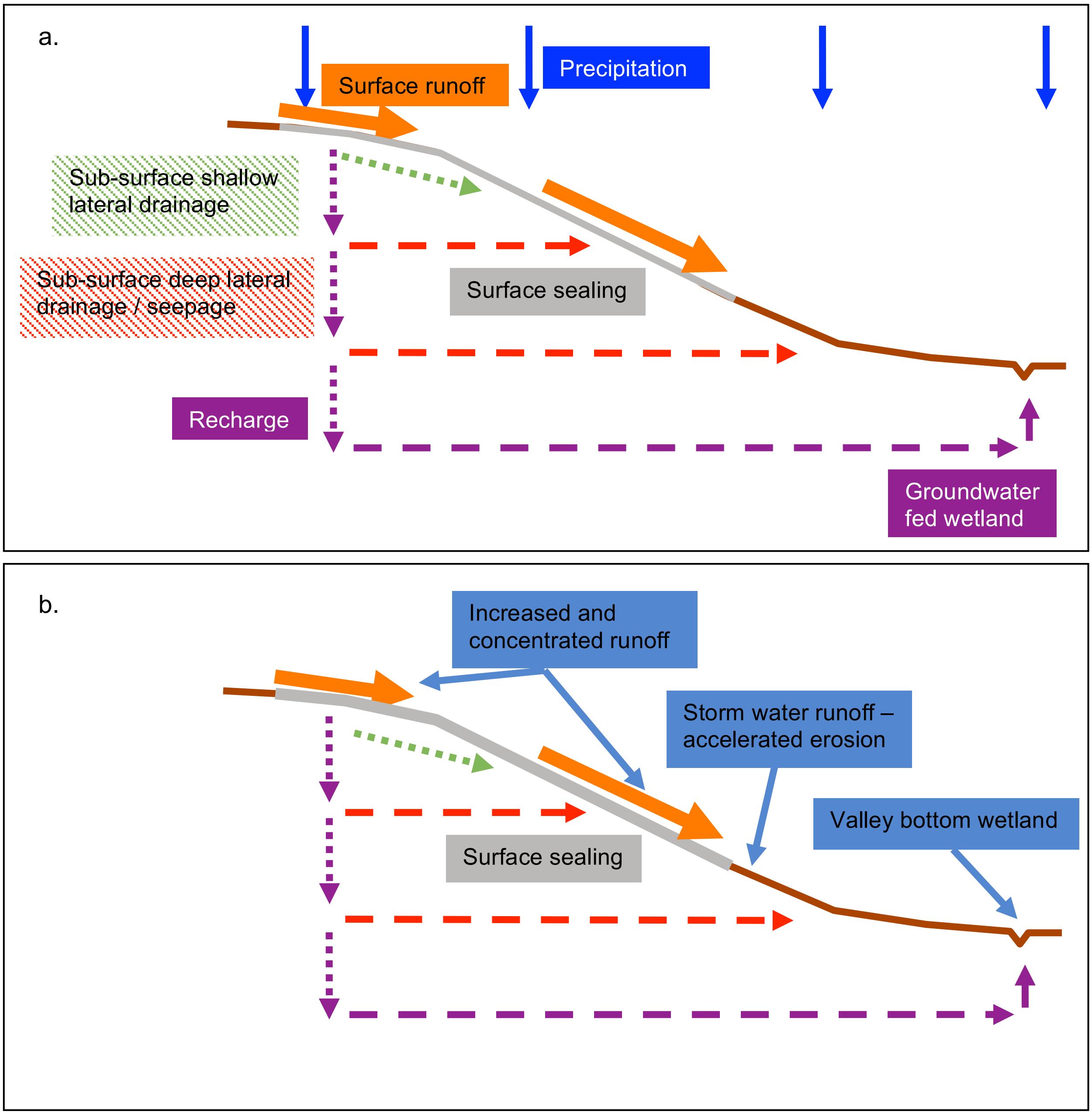


Figure 14 Different flow paths of water through a landscape with surface sealing (buildings and paving) (a) and typical wetland types associated with the altered water regime (b)

5.10 RECOMMENDED ASSESSMENT APPROACH – HYDROPEDOLOGY INVESTIGATION

5.10.1 Hydropedology Background

The identification and delineation of wetlands rest on several parameters that include topographic, vegetation and soil indicators. Apart from the inherent flaws in the wetland delineation process, as discussed earlier in this report, the concept of wetland delineation implies an emphasis on the wetlands themselves and very little consideration of the processes driving the functioning and presence of the wetlands. One discipline that encompasses a number of tools to elucidate landscape hydrological processes is "hydropedology" (Lin, 2012). The crux of the understanding of hydropedology lies in the fact that pedology is the description and classification of soil on the basis of morphology that is the result of soil and landscape hydrological, physical and chemical processes. But, the soils of which the morphology are described, also take part in and intimately influence the hydrology of the landscape. Soil is therefore both an indicator as well as a participator in the processes that require elucidation.

Wetlands are merely those areas in a landscape where the morphological indicators point to prolonged or intensive saturation near the surface to influence the distribution of wetland vegetation. Wetlands therefore form part of a larger hydrological entity that they cannot be separated from.

5.10.2 Hydropedology – Proposed Approach

In order to provide detailed pedohydrological information both detailed soil surveys and hydrological investigations are needed. In practice these intensive surveys are expensive and very seldom conducted. However, with the understanding of soil morphology, pedology and basic soil physics parameters as well as the collection and interpretation of existing soil survey information, assessments at different levels of detail and confidence can be conducted. In this sense four levels of investigation are proposed namely:

1. Level 1 Assessment: This level includes the collection and generation of all applicable remote sensing, topographic and land type parameters to provide a "desktop" product. This level of investigation rests on adequate experience in conducting such information collection and interpretation exercises and will provide a broad overview of dominant hydropedological parameters of a site. Within this context the presence, distribution and functioning of wetlands will be better understood than without such information.
2. Level 2 Assessment: This level of assessment will make use of the data generated during the Level 1 assessment and will include a reconnaissance soil and site survey to verify the information as well as elucidate many of the unknowns identified during the Level 1 assessment.
3. Level 3 Assessment: This level of assessment will build on the Level 1 and 2 assessments and will consist of a detailed soil survey with sampling and analysis of representative soils. The parameters to be analysed include soil physical, chemical and mineralogical parameters that elucidate and confirm the morphological parameters identified during the field survey.
4. Level 4 Assessment: This level of assessment will make use of the data generated during the previous three levels and will include the installation of adequate monitoring equipment and measurement of soil and landscape hydrological parameters for an adequate time period. The data generated can be used for the building of detailed hydrological models (in conjunction with groundwater and surface hydrologists) for the detailed water management on specific sites.

For most wetland delineation exercises a Level 2 or Level 3 assessment should be adequate. For this investigation a Level 2 assessment was conducted due to the extensive urban development in the area and on the site.

The process of the hydropedology assessment entails the aspects listed in the methodology description below. These items also correspond with the proposed PES assessment methodology discussed in section 4.4.4. The results of the assessment will therefore be structured under the headings as provided below.

6. METHOD OF SITE INVESTIGATION

6.1 WETLAND CONTEXT DETERMINATION

For the purposes of the wetland assessment the context of the specific wetland was determined. This was done through the thorough consideration of the geological, topographical, climatic, hydropedological and catchment context of the site. In this sense the relative contribution of water flow from the catchment upstream was compared to the contribution from the slopes on the specific site. The motivation being that the larger the contribution of the catchment upstream the smaller the impacts of the proposed developments on the site would be in terms of modification of the wetland. The elements of context are described in more detail below.

6.2. AERIAL PHOTOGRAPH INTERPRETATION

An aerial photograph interpretation exercise was conducted through the use of Google Earth images of the site. This data was used to obtain an indication of the extent of the wetlands on the site as well as to provide an indication of the artificial modifiers evident on the site and in the catchment.

6.3 TERRAIN UNIT INDICATOR

Detailed contours of the site were used to provide an indication of drainage depressions and drainage lines. From this data the terrain unit indicator was deduced.

6.4 SOIL FORM AND SOIL WETNESS INDICATORS

The soil form and wetness indicators were assessed on the site through a dedicated soil survey within the context of the description as provided in sections 5.5 to 5.7.

Historical impacts were identified as the impacts on the soils are very distinct. Soil characteristics could therefore be used to provide a good indication of the historical impacts on the grounds of a forensic approach. In areas where soil impacts are limited the standard approach in terms of identification of soil form and soil wetness indicators was used.

6.5 VEGETATION INDICATOR

Due to the extent of the historical impacts as well as the timing of the investigation a dedicated vegetation survey for the purpose of wetland delineation was not conducted. Relevant vegetation parameters were noted and these are addressed in the report where applicable.

6.6 ARTIFICIAL MODIFIERS

Artificial modifiers of the landscape and wetland area were identified during the different components of the investigation and are addressed in the context of the wetland management plan.

7. SITE SURVEY RESULTS AND DISCUSSION

7.1 WETLAND CONTEXT

The land type, topography and geological setting of the site have been elucidated in sections 2, 5.6 and 5.7 of this document. The most important aspect to keep in consideration here is the explanation of the challenges to wetland delineation in alkaline soils in section 5.7. The wetland under investigation is limited to a stream / watercourse that runs along the eastern border of the site. The catchment of the wetland / watercourse is situated to the south in a built-up area that comprises Silver Lakes and its associated developments as well as the N4 highway. The investigation into the wetland on the site indicated that there are several historical impacts and modifiers applicable. These are discussed in further detail below through the use of historical Google Earth images spanning the period 2004 to 2015.

7.2 AERIAL PHOTOGRAPH INTERPRETATION

The Google Earth images of the site were used to identify specific impacts and their timing in high resolution. **Figure 15** indicates the land use during 2005 compared to 2015. The main changes on the site are the cessation of crop production and the increase in dumping of rubble (**Figures 16** and **17**). It is evident that the entire site, excluding the watercourse and shallow soil areas to the southwest was used for the production of crops and therefore tilled. The soils of the site will be discussed later but it is important to note that the entire crop production area is characterised by structured swelling soils (often erroneously associated with wetland conditions) and that the crop stands indicate no signs of poor growth due to waterlogging. It is therefore safe to assume that no waterlogging occurred on these soils and that, given that the crops grow during the wet season, there was no permanent or even seasonal wetland zone associated with the tilled area.

Figure 15 Google Earth images from 2005/04/21 (top) and 2015/09/09 (bottom) indicating land use changes on and around the site as well as dumping of rubble (yellow arrows)

Figure 16 Dumping of rubble on the site

Figure 17 Dumping of rubble on the site

7.3 TERRAIN UNIT INDICATOR

The contour data for the site was used to generate a topographic wetness index (TWI) (**Figure 18**).

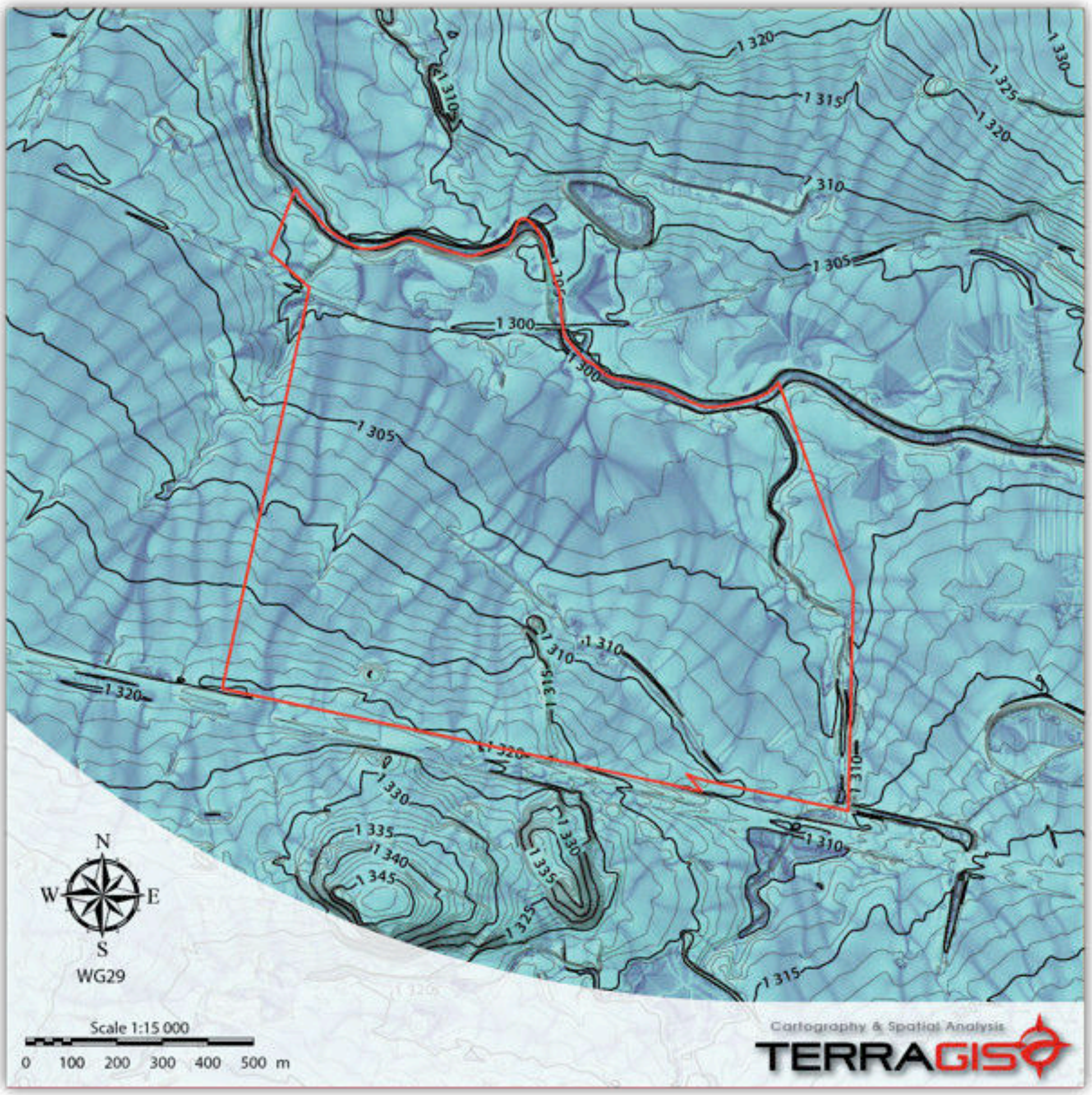


Figure 18 Topographic wetness index (TWI) of the survey site

From extensive experience on the field of hydropedology it is evident that the TWI provides a very accurate indication of water flow paths and areas of water accumulation that are often correlated with wetlands. This is a function of the topography of the site and ties in with the dominant water flow regime in the soils and the landscape (refer to previous section where the concept of these flows was elucidated). Areas in darker shades of blue indicate concentration of water in flow paths with lighter shades of blue indicating areas with very little surface water flow.

From the terrain unit indicator it is evident that the site is not characterised by any other watercourses or concentrated water flow areas that may form wetlands. The only area that qualifies as a distinct watercourse (from the site investigation) exhibits no signs of concentrated flow emanating from the specific site. This leads to the conclusion that the water flowing in the watercourse / stream emanates from upslope areas to the south of the site.

7.4 SOIL FORM AND SOIL WETNESS INDICATORS (AND VEGETATION)

A reconnaissance soil survey conducted during the wetland investigation indicated that the site consisted of four distinct soil zones (**Figure 19**). These are: 1) rocky soils and rock outcrops to the south; 2) shallow and high chroma structured soils on shale predominantly on the eastern section of the site, 3) a band of structured swelling soils from north to south along the eastern edge of the site and 4) young and alluvial soils associated with the drainage feature on the eastern edge.

Figure 19 Generalised soil map of the investigation site

The following soils were found to dominate in the four soil areas:

1. Rocky soils and rock outcrops to the south: Mispah (Ms – orthic A horizon / hard rock) and Glenrosa (Gs – orthic A horizon / lithocutanic B horizon) (**Figures 20** and **21**);
2. Shallow and high chroma structured soils on shale predominantly on the eastern section of the site: Glenrosa (Gs – orthic A horizon / lithocutanic B horizon), Valsrivier (Va – orthic A horizon / pedocutanic B horizon / unconsolidated material without signs of wetness) and Swartland (Sw – orthic A horizon / pedocutanic B horizon / lithocutanic B horizon) (**Figures 22**);
3. Structured swelling soils: Rensburg (Rg – vertic A horizon / G horizon) and Arcadia (Ar – vertic A horizon / unspecified – usually hard or weathering rock) (**Figures 23** to **25**); and
4. Young and alluvial soils associated with the drainage feature on the eastern edge: Oakleaf (Oa – orthic A horizon / neocutanic B horizon / unspecified material without signs of wetness), Dundee (Du – orthic A horizon / stratified alluvium) and Valsrivier (Va – orthic A horizon / pedocutanic B horizon / unconsolidated material without signs of wetness) (**Figures 26** to **30**).

None of the soils on the site qualify as wetland soils as described in the wetland delineation guidelines. Sections 5.6 and 5.7 provide a contextualisation of the structured soils indicated on the map as Rensburg and Arcadia. From the soil map it is evident that the distribution of the vertic soils on the site is landscape and geology related rather than wetness related. In this sense the Rensburg soils found on the site are not considered to be wetland soils but rather soils with poor internal drainage only. As discussed earlier, these soils often occur in level topography where geological drivers dominate without any wetland associated drivers.

The soils that are considered to be indicative of watercourse conditions are the Oakleaf and Dundee forms. Although these exhibit no signs of wetness or redox morphology (by definition) they are indicative of high energy erosion and deposition environments with varying degrees of soil formation. In this sense these soils fall within the category of riparian zone soils and as such form the basis for the wetland delineation outcome below.

7.5 VEGETATION INDICATORS

Although a dedicated vegetation survey was not conducted it was observed that extensive alien vegetation (especially tree species) has established within the riparian zone identified in this report (**Figures 31** to **33**).

7.6 ARTIFICIAL MODIFIERS

The historical artificial modifiers within the drainage feature / watercourse are considered to be limited to erosion and deposition of materials on an accelerated basis due to intensifying human activities upslope in the catchment. On the other parts of the site the historical modifiers include extensive soil surface alteration through tillage as well as large areas of rubble dumping.

Figure 20 Rocky soils in the southern part of the site

Figure 21 Rocky soils in the southern part of the site

Figure 22 High chroma structured soils in the western part of the site

Figure 23 Rocky soils in the southern part of the site

Figure 24 Rocky soils in the southern part of the site

Figure 25 Rocky soils in the southern part of the site

Figure 26 Eroded channel along the watercourse

Figure 27 Eroded channel along the watercourse


Figure 28 Eroded channel along the watercourse


Figure 29 Eroded channel along the watercourse

Figure 30 Exposed lime nodules in a subsoil horizon with surface horizons removed through erosion along the watercourse

Figure 31 Riparian vegetation along the watercourse

Figure 32 Eucalyptus trees along the watercourse

Figure 33 Syringa trees along the watercourse

8. WETLAND ASSESSMENT

8.1 PROPOSED DELINEATION AND BUFFER

The wetland area is limited to the watercourse and as such the riparian character dominates. The outcome of a riparian wetland delineation is provided in **Figure 34**. Due to the fact that the watercourse is not fed significantly from water emanating form the specific site but rather from water generated upslope in the catchment an extensive buffer is considered unnecessary. Rather, effort should be made to conserve the current riparian zone, stabilise the banks of the channel and remove alien vegetation.

Figure 34 Wetland area on the site

8.2 Wetland Classification / Types

Based on the information generated in this document the wetland area is classified as an erosion impacted watercourse with riparian vegetation.

8.3 Wetland Functionality

The functionality of the watercourse is dominantly the channelling of water from the upslope areas through the site to the Pienaars River. The catchment area has been altered significantly through urban infrastructure development and as such storm water pulses are expected to increase in size within the watercourse on the site.

8.4 Present Ecological Status (PES) Determination

Hydrological Criteria:

- Flow modification: Large modification due to urban infrastructure in the catchment with significant erosion in the channel and on the banks. Score 2, Confidence 4.
- Permanent inundation: Permanent inundation not possible due to the extensive modification as well as the rainfall and catchment characteristics. Permanent inundation not part of the reference state. Score 2, Confidence 4.

Water Quality Criteria

- Water quality modification: Score 2, Confidence 4
- Sediment load modification: Score 2, Confidence 4

Hydraulic / Geomorphic Criteria

- Canalisation: Score 2, Confidence 4
- Topographic Alteration: Score 3, Confidence 4

Biological Criteria

- Terrestrial encroachment: Score 2, Confidence 3
- Indigenous vegetation removal: Score 2, Confidence 4
- Invasive plant encroachment: Score 1, Confidence 3
- Alien fauna: Score 2, Confidence 3
- Overutilisation of biota: Score 1, Confidence 4

Score

PES category D-E

From the data generated as well as the extent of the identified alterations the conclusion is that the watercourse system on the site has a PES rating of a D to an E. This is mainly due to the extensive alteration of runoff characteristics in the catchment as well as the alteration of the channel and encroachment of alien plant species.

9. IMPACTS OF INFRASTRUCTURE

9.1 INFRASTRUCTURE TYPES

The proposed infrastructure developments on the site that will encroach on the wetland area are (detailed engineer drawings to be viewed on the relevant plans not included in this report):

1. Storm water infrastructure and pipelines (**Figure 35**);
2. Sewer infrastructure and pipelines (**Figure 36**);
3. Water pipeline infrastructure (**Figure 37**);
4. Bridge over the watercourse (Option 1: **Figure 38**; Option 2: **Figure 39**)

Figure 35 Extract from engineer drawings of storm water pipelines and layout

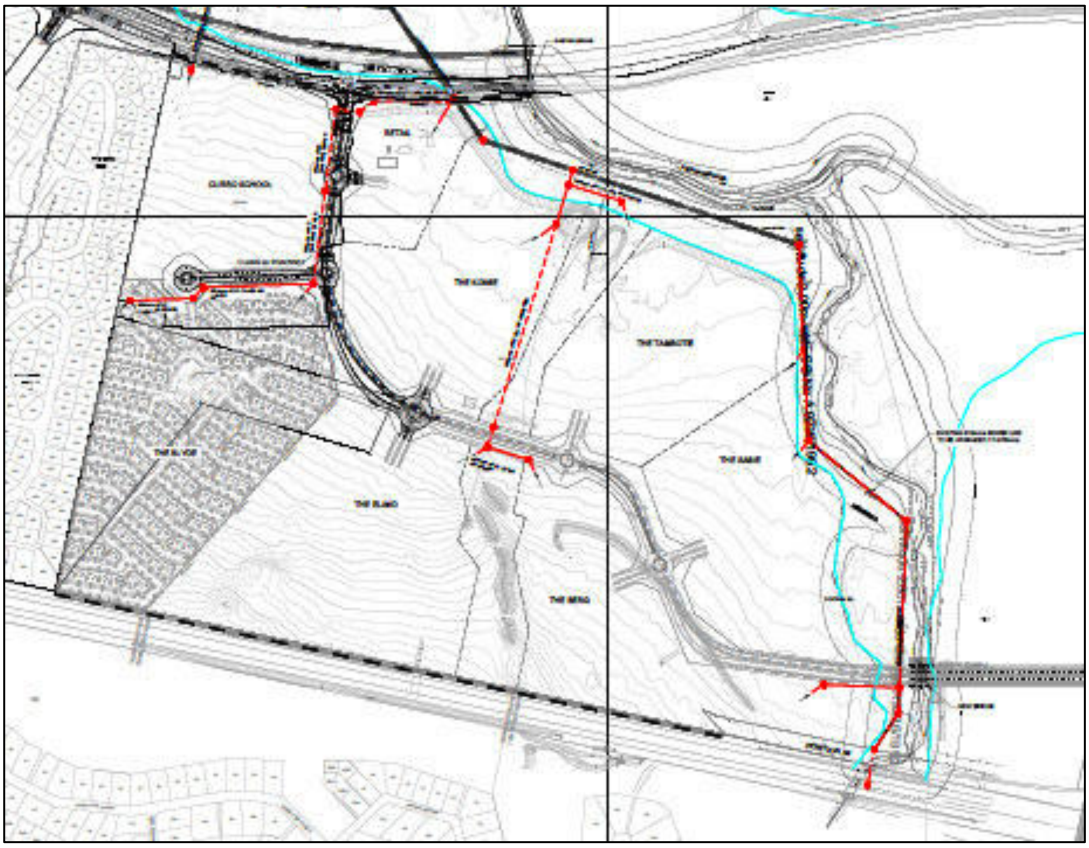


Figure 36 Extract from engineer drawings of sewer pipelines and layout

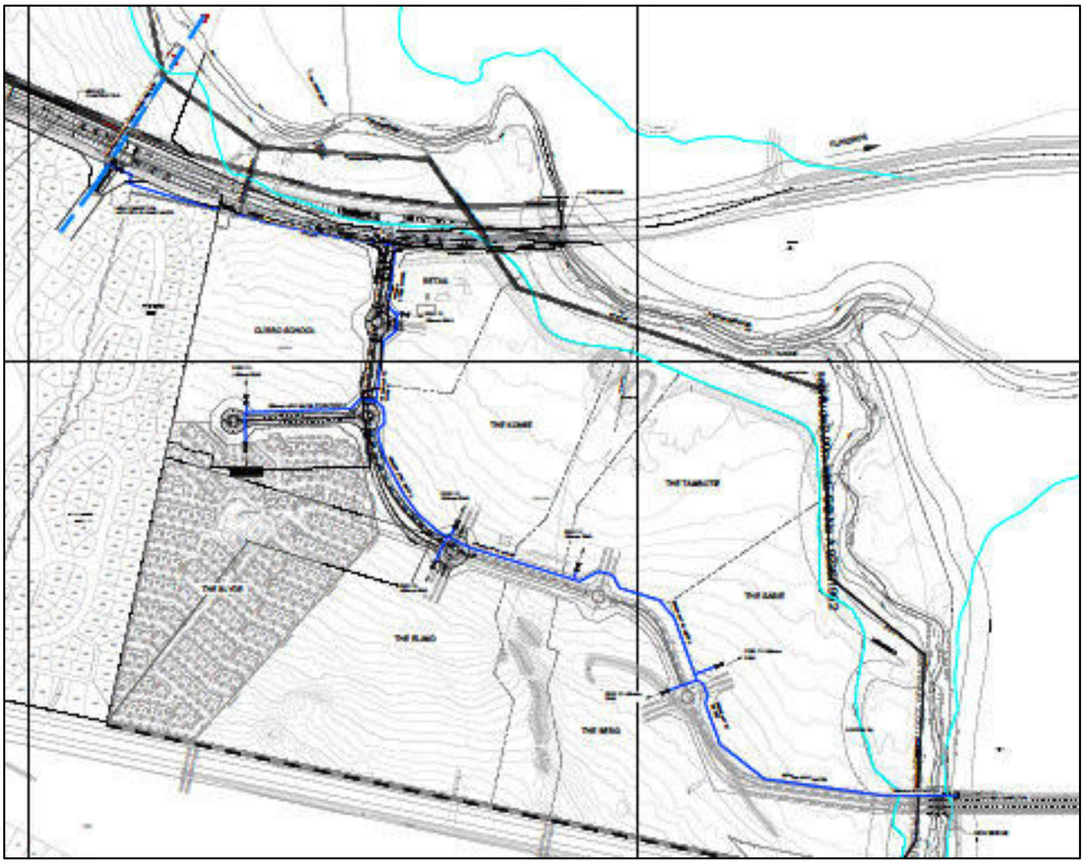


Figure 37 Extract from engineer drawings of water pipelines and layout

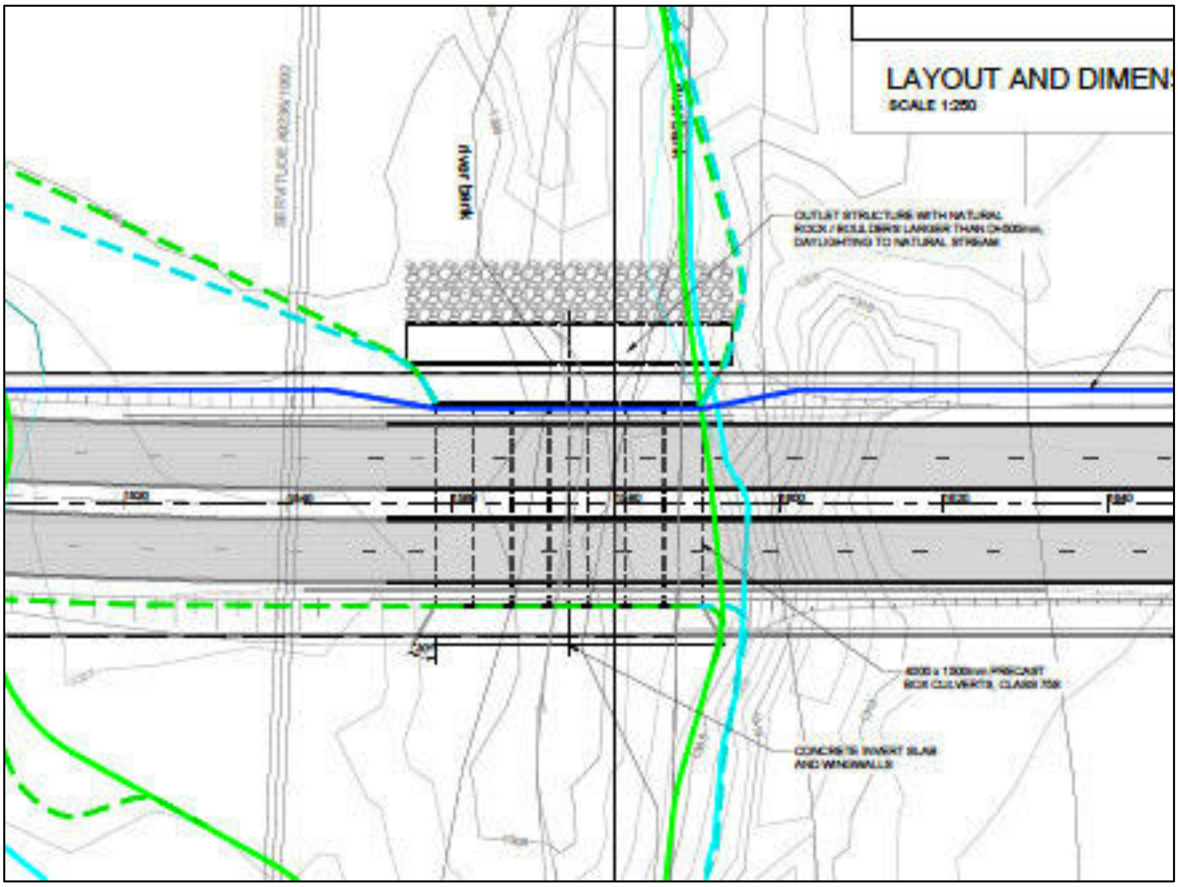


Figure 38 Extract from engineer drawings of bridge layout Option 1

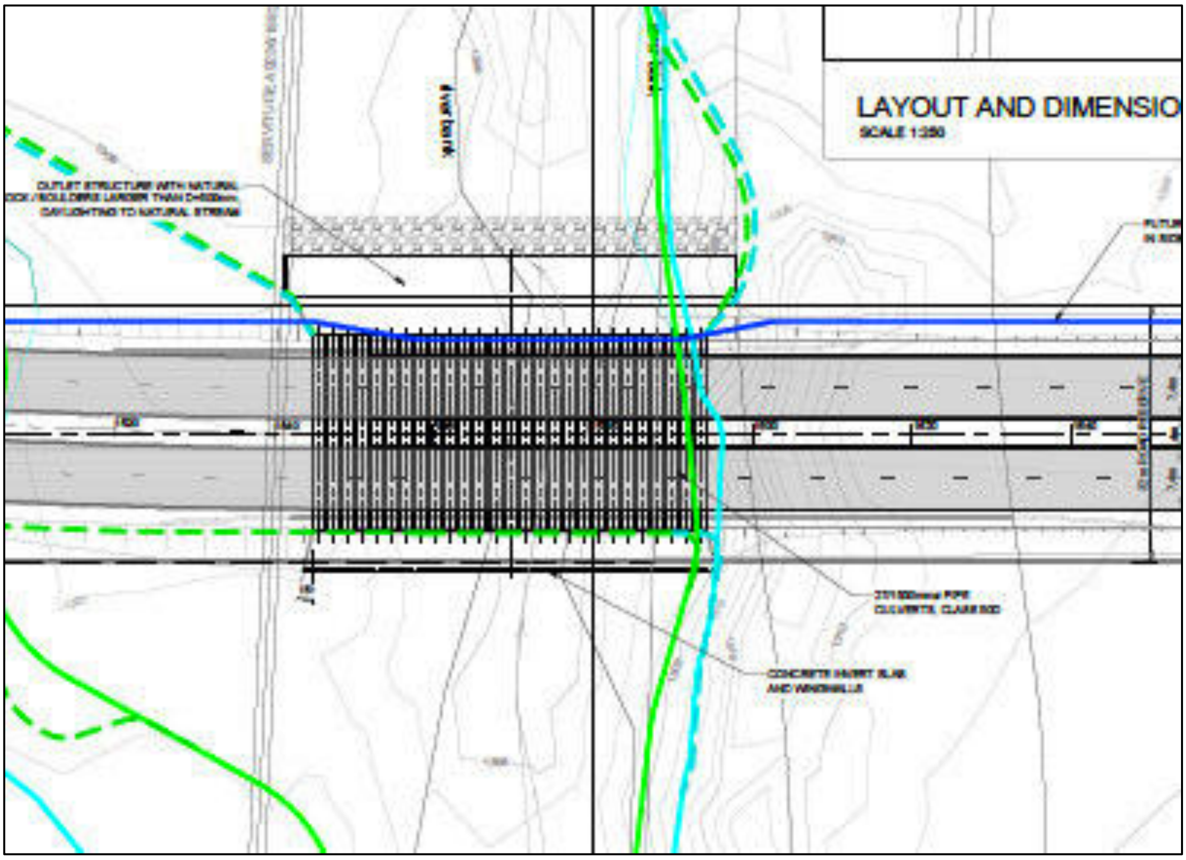


Figure 39 Extract from engineer drawings of bridge layout Option 2

9.2 MITIGATION MEASURES AND REHABILITATION STRATEGY

IMPORTANT NOTE: The mitigation and rehabilitation measures for the pipeline cannot be separated from the impacts expected for the development for which the pipeline is earmarked. The mitigation measures and rehabilitation strategy will therefore be discussed in the context of the future developments as well as the current state of the site.

The important mitigation measures for the construction and maintenance of the infrastructure include the following:

1. Sediment generation should be prevented through adequate housekeeping during construction as the swelling soils are particularly dispersive and erodible. The specific mitigation measures should be generated by the project engineer and implemented by the site manager. These measure include:
   a. The establishment of earth bunds on the downslope area to trap sediment.
   b. Timing of the excavation (if possible) to coincide with the dry season.
   c. Compaction of fill material on the surface to increase hardness and resistance to erosion. This is not possible if swelling soil material is used and it is recommended non-swelling soil material be used for the infilling.
   d. Identification of preferential flow areas of water on the surface (as a function of local topography) and the establishment of stabilised vegetated or concreted preferential flow areas into the storm water infrastructure.
2. Post development the exposed surface area of the pipeline corridor should be stabilised against erosion on slopes.
3. Lateral seepage water that accumulates upslope of the compacted fill area of the pipeline trench should be mitigated and managed to allow for flowing over the in-filled trench area without causing erosion. This can be done through the establishment of stabilised overflow areas and vegetation of the soil covering.
4. The hydrological impact of the trenching and compaction of the fill material cannot be mitigated but is negligible in the presence of a roadbed that runs along the pipeline corridor. In this regard the hydrological attenuation should be conducted along with the approved and established storm water management infrastructure associated with the roads on the site.
5. Bridge crossing of the watercourse should be stabilised on the banks and within the stream bed making use of the erosion mitigation and control procedures described above.

10. CONCLUSIONS AND RECOMMENDATIONS

A wetland investigation and soil survey yielded that:

1. A drainage feature is located on the eastern boundary of the investigation site.
2. The drainage feature is a watercourse with distinct riparian character.

3. There are no seepage wetlands on the site feeding into the wetland / watercourse. Due to the structured and swelling nature of the soils on the site the dominant water movement into the drainage feature is via surface runoff.
4. The structured and swelling soils on the site do not qualify as wetland soils as described in the wetland delineation guidelines. The main reason is the explanation provided earlier regarding the origin of swelling clay minerals as well as the geological driver for the formation of the soils outside of the watercourse area.
5. Due to the fact that the water that flows in and through the channel on the site emanates from upslope areas that have been impacted by human activities and infrastructure development a dedicated buffer on the watercourse will contribute little to its protection. Rather, it is recommended that an integrated storm water plan be generated for the entire site and immediate upslope catchment area.

REFERENCES

Brady, N.C. and Weil, R.P. 1999. *The Nature and Properties of Soils*. Twelfth edition. Upper Saddle River, New Jersey: Prentice Hall.

Department of Water Affairs and Forestry (DWAF). 2005. A practical field procedure for identification and delineation of wetland and riparian areas. DWAF, Pretoria.

Hillel, D. 1982. Introduction to soil physics. Acedemic Press, INC. Harcourt Brace Javonovich, Publishers.

Jenny, H. 1941. Factors of soil formation. New York, NY, USA: McGraw-Hill Book Company, p 281

Land Type Survey Staff. (1972 – 2006). *Land Types of South Africa: Digital map (1:250 000 scale) and soil inventory databases*. ARC-Institute for Soil, Climate and Water, Pretoria.

MacVicar, C.N. et al. 1977. *Soil Classification. A binomial system for South Africa.* Sci. Bull. 390. Dep. Agric. Tech. Serv., Repub. S. Afr., Pretoria.

Soil Classification Working Group. 1991. Soil Classification. A taxonomic system for South Africa. *Mem. Agric. Nat. Resour. S.Afr.* No.15. Pretoria.

Geotechnical Report

Appendix G3

REPORT ON THE ENGINEERING GEOLOGICAL INVESTIGATION FOR THE PROPOSED AFRICAN RENAISSANCE LIFESTYLE ESTATE SITUATED ON THE FARM ZWARTKOPPIES 374 JR

LOUIS KRUGER GEOTECHNICS CC
PO BOX 90093
Garsfontein
0042
Tel /Fax (012) 348 4819

JULY 2006

Client

CALIBER MANAGEMENT

REPORT ON THE ENGINEERING GEOLOGICAL INVESTIGATION FOR THE PROPOSED AFRICAN RENAISSANCE LIFESTYLE ESTATE SITUATED ON THE FARM ZWARTKOPPIES 364 JR FOR TOWNSHIP ESTABLISHMENT

1. INTRODUCTION

Louis Kruger Geotechnics CC was appointed by Caliber Management to do an engineering geological investigation for the proposed African Renaissance Lifestyle Estate situated on the farm Zwartkoppies 364 JR, for township establishment. The investigation was undertaken according to the normal requirements for township proclamation to assess the suitability of the site for residential development (Guidelines for Urban Engineering Geological Investigations 1997). The following aspects are addressed in this report:

- Geology and Soil profile
- Geohydrology
- Foundation conditions
- Construction material

2. TERMS OF REFERENCE

The appointment was to do an engineering geological investigation for the for the proposed new African Renaissance Lifestyle Estate situated on the farm Zwartkoppies 364 JR The proposed layout of the site is shown on Figure 2. The following aspects were to be addressed:

- The geotechnical characteristics of the site
- Geotechnical constraints
- Founding conditions
- NHBRC Zoning

The locality of the site is shown on Figure 1.

3. AVAILABLE INFORMATION

The following information was available:

- 1 : 50 000 Geological Map 2528 CB Silverton
- 1 : 50 000 Geological Map 2528 CD Rietvleidam
- 1 : 50 000 Topographical Map 2528 CB Silverton
- 1 : 50 000 Topographical Map 2528 CD Rietvleidam
- Contour and Layout Plan
- Colour aerial photographs, Tshwane Metropolitan Council
- Tshwane Internet Geographical information System
- "Report On The Reconnaissance Engineering Geological Investigation Of Various Portions Of The Farms Hatherley 331 JR, Zwartkoppies 364 JR, Donkerhoek 370 JR and Pienaarspoort 339 JR", Louis Kruger Geotechnics, February 2006.

- "Report on The Engineering Geological Investigation of The Existing Mamelodi Transnet Township IR For Township Establishment" Louis Kruger Geotechnics, February 2005.

4. LOCALITY

The proposed site covers approximately 150 hectares and is situated on the farm Zwartkoppies 364 JR. The proposed site is bounded by the Pienaars River in the north, by a tributary of the Pienaars River in the east, by the N4 highway in the south and by a new residential development and Hans Strydom Drive in the west. The old Pretoria – Bronkhorstspruit road intersects the site. The locality of the site is shown on Figure 1.

5. TOPOGRAPHY AND DRAINAGE

The topography of the site is characterized by a gentle slope towards the Pienaars River. The site slopes at an average of 2% to 3% towards the Pienaars River in the north, the closer to the river the slope becomes flatter (±1%). On the western part of the site the general slope is disturbed by low, north-south striking "ridges", there are no steep slopes associated with the "ridges".

Surface water drains by means of sheet wash towards the Pienaars River on the northern boundary of the site. The flood lines of the Pienaars River and the tributaries are present on the site. The topography of the site is shown on Figure 2.

6. METHOD OF INVESTIGATION

Forty-six test pits were dug on the site with a TLB and the soil profiles were described according to the standard method proposed by Jennings, Brink and Williams (1973). Disturbed samples of the most prominent soil horizons were taken and submitted to a soils laboratory for foundation indicator tests. Due to the composition (high clay- or gravel content) and consistency (loose) of the materials encountered on the site no undisturbed samples were taken.

7. GEOLOGY AND SOIL PROFILE

According to the 1 : 50 000 scale geological map, the site is underlain by shale of the Pretoria Group, by diabase and syenite intrusions and by transported materials. The geology was confirmed during the investigation, shale, diabase and syenite was encountered in the test pits. The test pit positions are shown on Figure 2 and the soil profiles are included as Appendix A. The following materials were encountered on the site:

7.1 Colluvium

Three types of colluvium were encountered on the site; the profiles are summarized in the following sections;

- Slightly moist, brown, soft, shattered, silty gravely sand with plant roots with an average thickness of 0,4 meters was encountered in test pits 19, 20, 21, 25, 26 and 27, on the western part of the site south of the old Bronkhortspruit Road.

- Slightly moist, dark brown, loose to medium dense, micro-shattered, silty, sandy gravel consisting of diabase pebbles and abundant shale fragments and with plant roots with an average thickness of 0,7 meters was encountered in test pits 10, 16, 24, 28, 29, 30, 31, 32, 33, 34, 42, 43, 44 and 45 on the southern part of the site.

- Slightly moist, light brown, loose, shattered, silty gravely sand with abundant shale fragments and with plant roots with an average thickness of 0,4 meters was encountered in test pits 11, 12, 13, 14, 15, 17 and 35 on the southern part of the site, north of the old Bronkhorstspruit road.

7.2 Alluvium

Four types of alluvium were encountered on the site; the profiles are summarized in the following sections;

- Slightly moist to moist, firm, shattered and fissured, slickensided, clayey sand with plant roots with an average thickness of 2,0 meters was encountered in test pits 1, 2, 3, 5, 6 and 7, on the flood plain north of the old Bronkhorstspruit road.

- Moist, black, firm to stiff, fissured, slickensided, sandy clay with plant roots with an average thickness of 0,9 meters was encountered in test pits 4, 8, 18, 36, 37, 38, 39, 40 and 41, on the flood plain on the eastern part of the site.

- Moist, grey, firm, intact, slickensided, sandy clay was encountered in test pits 38, 39, 40 and 44 from an average depth of 1,0 meters up to an average depth of 2,4 meters. This material predominantly occurs on the eastern and south-eastern parts of the site.

- Moist, orange brown mottled grey, firm to stiff, intact, slickensided, clayey sand with diabase pebbles and shale fragments and with ferricrete nodules was encountered in the flood plain in test pits 4, 5, 6, 7, 15, 18, 19, 26, 27, 35, 36, 37, 38, 39 and 44 from an average depth of 1,2 meters up to an average depth of 2,6 meters.

7.3 Shale

7.3.1 Residual shale

Slightly moist, orange brown mottled black and red, stiff, intact, slickensided, sandy clay with very soft rock shale fragments was encountered in test pits 3, 4, 20, 21, 24, 28, 32, 41, 42, 43, 46 from an average depth of 0,7 meters up to an average depth of 1,2 meters. In test pit 6 the residual shale was encountered below the alluvium at a depth of 2,4 meters.

7.3.2 Shale bedrock

Shale bedrock was encountered in 23 test pits at an average depth of 1,2 meters. Very soft rock shale was encountered in 6 of these test pits from an average depth of 1,4 meters up to an average depth of 2,3 meters. Soft rock shale was encountered in test pits 11, 12, 13, 14, 16, 42 and 43 from an average depth of 0,5 meters up to an average depth of 1,1 meters, and in test pits 15, 17, 21 and 28 from an average depth of 1,7 meters up to an average depth of 2,5 meters.

Medium hard rock shale was encountered in test pits 3, 11, 12, 13, 14, 16, 20, 25, 29, 32 and 41 from an average depth of 1,0 meters up to an average depth of 1,4 meters. In test pits 17 and 18 medium hard rock shale was encountered from an average depth of 2,4 meters up to an average depth of 2,7 meters.

7.4 Diabase

7.4.1 Residual diabase

Slightly moist, red brown, firm, fissured, slickensided, silty clay with diabase cobbles and boulders and with ferricrete nodules and plant roots was encountered in test pits 9, 10, 22 and 23 from surface up to an average depth of 0,5 meters, this material is expected to be thicker, this could not be verified since the back actor refused on diabase boulders at shallow depth. In test pit 2 the residual diabase was encountered at a depth of 2,2 meters below alluvium.

Slightly moist, khaki, stiff, intact, slickensided, silty sand with diabase corestones was encountered in test pits 8, 22, 30 and 33 from an average depth of 0,6 meters up to an average depth of 1,1 meters.

7.4.2 *Diabase bedrock*

Very soft rock diabase was encountered in test pit 22 from a depth of 1,0 meters up to a depth of 1,8 meters and medium hard rock diabase was encountered in test pits 8 and 31 at an average depth of 1,1 meters. The cuts on the N4 highway show that shallow diabase bedrock can be expected on the southern part of the site.

7.5 Syenite

7.5.1 *Residual syenite*

Slightly moist, yellowish brown, firm to stiff, intact, slickensided, clayey sand with syenite corestones was encountered in test pits 7, 34 and 45. In test pits 34 and 45 the residual syenite was encountered from an average depth of 1,0 meters up to an average depth of 2,4 meters and in test pit 7 it was encountered from a depth of 2,7 meters, below the alluvium.

7.5.2 *Syenite bedrock*

Soft rock syenite was encountered in test pit 34, below the residual syenite, from a depth of 1,7 meters up to the maximum reach of the back actor. In test pit 35 the soft rock syenite was encountered below the alluvium at a depth of 2,3 meters. The cuts on the N4 highway show that shallow diabase bedrock can be expected on the southern part of the site.

8. GEOHYDROLOGY

Ground water seepage was encountered in the alluvium and where shallow shale bedrock is present. The presence of the ferricrete in the soil profile furthermore confirms that a shallow, perched water table can be expected during periods of high rainfall.

9. LABORATORY TEST RESULTS

9.1 Indicator test results

The laboratory test results are attached as Appendix B and are summarized in the following table:

MATERIAL	TP	DEPTH ((m)	PI	% Clay	% Silt	% Sand	% Gravel
Brown colluvium	20	0-0.3	14	17	18	45	20
Brown colluvium	5	1-1.7	10	18	22	57	3
Dark brown colluvium	29	03-0.6	14	12	12	20	56
Dark brown colluvium	11	0-0.3	13	6	11	34	49
Light brown colluvium	13	0-0.2	13	13	16	47	24
Dark brown alluvium	5	0-0.1	28	21	23	57	0
Dark brown alluvium	6	0-2.1	23	30	25	45	0
Black alluvium	18	0-0.8	30	45	18	35	2
Grey alluvium	39	08-2	38	40	25	31	3
Orange brown alluvium	38	1.6-3	26	25	15	61	0
Orange brown alluvium	6	2.1-2.7	28	33	22	42	2
Orange brown alluvium	7	1.4-2.4	23	29	19	44	8
Orange brown alluvium	27	2.5-3.1	42	59	27	13	0
Orange brown alluvium	18	08-2.6	22	26	13	60	2
Orange brown alluvium	27	05-2.5	30	56	22	19	2
Orange brown alluvium	15	0.4-2.4	30	33	22	39	6
Residual shale	4	1.1-1.5	25	33	23	41	3
Residual shale	6	2.7-3.2	35	23	16	56	6
Red brown residual diabase	22	0.2-0.5	35	34	27	20	20
Red brown residual diabase	22	0-0.2	24	24	25	33	18
Yellow residual diabase	8	0.5-1.1	23	27	31	32	11
Yellow residual diabase	22	0.5-1.0	37	38	42	18	2
Residual syenite	34	1-1.7	39	34	24	24	18
Residual syenite	35	2.3-3	27	24	17	52	7

The difference between the colluvium and the alluvium is shown by the higher clay- and lower gravel content of the alluvium and the difference between the transported- and residual materials is reflected by the higher clay- and silt content of the residual materials. The laboratory test results furthermore clearly reflect the variation in the composition of the materials.

9.2 Potential expansiveness

The potential expansiveness of the materials encountered on the site was calculated according to the method proposed by Van der Merwe (1964). The following material characteristics are considered when applying this method:

- Plasticity index
- Clay fraction (< 0,002 mm)
- Thickness of expansive material
- Thickness of non - expansive material

Assuming the laboratory test results typify the material encountered on the site, the application of the method of Van der Merwe shows that the colluvium classify as "Low" and are therefore considered non-expansive. The black alluvium classifies as "High" and the grey alluvium classifies as "Very high". One sample of the dark brown alluvium, the red brown residual diabase, the residual shale and the residual syenite classifies as "High" and one sample classifies as "Medium". It is recommended that a conservative approach be adopted and a classification of "High" rather than "Medium" be assigned to these materials. Two samples of the orange alluvium classify as "High", two samples classify as "Very high" and three samples classify as "Medium". It is recommended that a conservative approach be adopted and a classification of "High to Very high" rather than "Medium" be assigned to this material. One sample of the yellow residual diabase classifies as "Very high" and one sample classifies as "Medium". It is recommended that a conservative approach be adopted and a classification of "High" rather than "Medium" be assigned to this material. With this approach the calculated heave for the test pits in which the potentially expansive materials were encountered is as follows:

- In the test pits in which shallow shale bedrock was encountered the calculated heave is between 7,5 and 15 mm

- In the test pits where deep shale bedrock, covered by residual shale and colluvium, and the test pits where residual diabase was encountered, the calculated heave is between 15 mm and 30 mm.

- In the test pits where thick alluvium is present and where residual syenite was encountered, the calculated heave exceeds 30 mm.

9.3 Undisturbed samples

Due to the composition (high clay- or gravel content) and consistency (loose) of the materials encountered on the site no undisturbed samples were taken.

10. ENGINEERING GEOLOGICAL ZONING

Based on the soil profile and the laboratory tests, the site was divided into four engineering geological zones:

- Zone A: Alluvium underlain by deep shale bedrock (Calculated heave > 30 mm)

- Zone B: Colluvium underlain by residual shale and shallow shale bedrock (Calculated heave7,5<> 15 mm)

- Zone C: Colluvium underlain by residual shale and deep shale bedrock (Calculated heave 15 <> 30 mm)

- Zone D: Colluvium or alluvium underlain by residual syenite and very soft rock syenite (Calculated heave > 30 mm)

- Zone E: Colluvium underlain by residual diabase and by very soft- and medium hard rock diabase (Calculated heave 15<> 30 mm)

- Zone F: Alluvium underlain by residual diabase (Calculated heave > 30 mm)

- Zone G: Parts of the site below the flood line

The zoning is shown on Figure 3. The boundaries between the different zones are based on field observations, aerial photographic interpretation and the interpolation of information between test pits. Therefore a conservative approach to the use of the engineering geological boundaries is recommended.

11. GEOTECHNICAL CONSIDERATIONS

The following geotechnical considerations, which could influence the proposed development, were identified:

11.1 Founding of structures

11.1.1 Zone A: Alluvium underlain by deep shale bedrock (Calculated heave > 30 mm)

- The alluvium is potentially expansive, and classifies as "High" and "Very high". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The residual shale is potentially expansive, and classifies as "High". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The calculated heave is more than 30 mm.

11.1.2 Zone B: Colluvium underlain by residual shale and shallow shale bedrock (Calculated heave7,5<> 15 mm)

- The composition and consistency of the colluvium varies, therefore it is not considered suitable founding material. If unadapted structures are founded on this material and the moisture content should change, unacceptable differential, vertical movements could occur, with resultant cracking of structures.

- The residual shale is potentially expansive, and classifies as "High". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The calculated heave is between 7,5 mm and 15 mm..

- Shale bedrock, which is considered suitable for the founding of structures, is present at depths shallower than one meter.

11.1.3 Zone C: Colluvium underlain by residual shale and deep shale bedrock (Calculated heave 15 <> 30 mm)

- The composition and consistency of the colluvium varies, therefore it is not considered suitable founding material. If unadapted structures are founded on this material and the moisture content should change, unacceptable differential, vertical movements could occur, with resultant cracking of structures.

- The residual shale is potentially expansive, and classifies as "High". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The calculated heave is between 15 mm and 30 mm.

- Shale bedrock, which is considered suitable for the founding of structures, is present at an average depth of 1,5 meters.

11.1.4 Zone D: Colluvium or alluvium underlain by residual syenite and very soft rock syenite (Calculated heave > 30 mm)

- The composition and consistency of the colluvium varies, therefore it is not considered suitable founding material. If unadapted structures are founded on this material and the moisture content should change, unacceptable differential, vertical movements could occur, with resultant cracking of structures.

- The alluvium is potentially expansive, and classifies as "High" and "Very high". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The residual syenite is potentially expansive, and classifies as "High". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The calculated heave is more than 30 mm.

11.1.5 Zone E: Colluvium underlain by residual diabase and by very soft- and medium hard rock diabase (Calculated heave 15<> 30 mm)

- The composition and consistency of the colluvium varies, therefore it is not considered suitable founding material. If unadapted structures are founded on this material and the moisture content should change, unacceptable differential, vertical movements could occur, with resultant cracking of structures.

- The red brown residual diabase is potentially expansive, and classifies as "High". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The yellow residual diabase is potentially expansive, and classifies as "High". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The variable weathering depth of the diabase over short distances and the presence of corestones are well documented; the variation in the bedrock depth on the site confirms this. Founding unadapted structures partly on boulders and partly on the residual material may result in unacceptable differential, vertical movements in structures, with resultant cracking of structures.

- The calculated heave is between 15 mm and 30 mm.

11.1.6 *Zone F: Alluvium underlain by residual diabase (Calculated heave > 30 mm)*

- The alluvium is potentially expansive, and classifies as "High" and "Very high". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The red brown residual diabase is potentially expansive, and classifies as "High". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The yellow residual diabase is potentially expansive, and classifies as "High". Therefore, it is not considered suitable founding material. If unadapted structures are founded on this material, and the moisture condition of the insitu material should vary, unacceptable differential movements, with resultant cracking may occur in structures

- The calculated heave exceeds 30 mm.

11.1.7 *Zone G: Parts of the site below the flood line*

These parts of the site may be subject to periodical flooding.

11.2 Excavatability

The average refusal depth in the different engineering geological zones is as follows:

- Zone A: No refusal
- Zone B: Refusal on shale bedrock at an average depth of 1,5 meters below surface
- Zone C: No refusal.
- Zone D: No refusal, bedrock depth variable and boulders are present
- Zone E: Refusal less than one meter below surface on boulders, bedrock depth variable
- Zone F: Refusal at 1,5 meters below surface, bedrock depth variable and boulders are present.
- Zone G: No refusal

11.3 Construction material

The colluvium classifies as A-4, A-2-6 and A-6, the alluvium, residual diabase, residual shale, and residual syenite classify as A-7-5 and A-7-6.

11.4 Groundwater

A shallow perched water table, which could cause the flooding of excavations, is expected to be present on the site during and after high rainfall. This is confirmed by the seepage, the presence of pedogenic material and the presence of shallow bedrock.

11.5 Surface water drainage

Due to the slope of the site, surface water is expected to drain effectively by means of sheet wash over most of the site. The flood lines of the Pienaars River and the tributaries are present on the site.

11.6 Stability of excavations

Instability occurred in the sidewalls of the test pits.

12. GEOTECHNICAL CLASSIFICATION

The site was classified according to the Geotechnical Classification for Urban Development (after Partridge, Wood and Brink 1993). The criteria for the classification are shown in the following table:

GEOTECHNICAL CLASSIFICATION FOR URBAN DEVELOPMENT (after Partridge, Wood and Brink 1993)

	CONSTRAINT	MOST FAVOURABLE (1)	INTERMEDIATE (2)	LEAST FAVOURABLE (3)
A	Collapsible soil	Any collapsible horizon or consecutive horizons totalling a depth of less than 750 mm in thickness	Any collapsible horizon or consecutive horizons totalling a depth of more than 750 mm in thickness	A least favourable situation for this constraint does not occur
B	Seepage	Permanent or perched water table more than 1,5 meters below surface	Permanent or perched water table less than 1,5 meters below surface	Swamps or marshes
C	Active soil	Low soil heave predicted	Moderate soil heave predicted	High soil heave predicted
D	Highly compressible soil	Low soil compressibility expected	Moderate soil compressibility expected	High soil compressibility expected
E	Erodibility of soil	Low	Intermediate	High
F	Difficulty of excavation to 1,5 m depth	Scattered or occasional boulders less than 10% of the total volume	Rock or hardpan pedocretes between 10 and 40% of the total volume	Rock or hardpan pedocretes more than 40% of total volume
G	Undermined ground	Undermining at a depth greater than 100 m below surface (except where total extraction mining has not occurred)	Old undermined areas to a depth of 100 m below surface where stope closure has ceased	Mining within less than 100 m of surface or where total extraction mining has taken place
H	Instability in areas of soluble rock	Possibly unstable	Probably unstable	Known sinkholes and dolines
I	Steep slopes	Between 2 and 6 degrees (all regions)	Slopes between 6 and 18 degrees and less 2 degrees (Natal and Western Cape) Slopes between 6 and 12 degrees and less 2 degrees (all other regions)	More than 18 degrees (Natal and western Cape) More than 12 degrees (all other regions)
J	Areas of unstable natural slopes	Low risk	Intermediate risk	High risk (especially in areas subject to seismic activity)
K	Areas subject to seismic activity	10% probability of an event less than 100 cm/s^2 within 50 years	Mining induced seismic activity more than 100 cm/s^2	Natural seismic activity more than 100 cm/s^2
L	Areas subject to flooding	A "most favourable" situation for this constraint does not occur	Areas adjacent to a known drainage channel or floodplain with slope less than 1%	Areas within a known drainage channel or floodplain

Based on the above, the site is classified as follows:

- Engineering geological zone A: 1A 2B 3C 2D 2E 2/3F 1I
- Engineering geological zone B: 1A 2B 2C 2D 2E 2/3F 1I
- Engineering geological zone C: 1A 2B 2/3C 2D 2E 2/3F 1I
- Engineering geological zone D: 1A 2B 3C 2D 2E 2/3F 1I
- Engineering geological zone E: 1A 2B 2/3C 2D 2E 2/3F 1I
- Engineering geological zone F: 1A 2B 3C 2D 2E 2/3F 1I
- Engineering geological zone G: 3L

13. NHBRC ZONING

ZONE	NHBRC ZONE	MOTIVATION
A, D and F Geotechnical classification: 1A 2B 3C 2D 2E 2/3F 1I (see table)	P(Perched water table)–C/C1–S/S1-H3	The alluvium, residual diabase and residual syenite are potentially expansive and the calculated heave is more than 30 mm, therefore this part of the site is zoned as H3. The colluvium is expected to be potentially collapsible / compressible. Due to the consistency and composition the collapse / settlement could not be quantified. The average thickness of this material is 0,7 meters, and the thickness varies between 0,4 and 1,2 meters. Therefore this part of the site is zoned as C/C1-S/S1. The presence of the shallow perched water table is accommodated by adding a zoning of P(Perched water table).
B Geotechnical classification: 1A 2B 2C 2D 2E 2/3F 1I (see table	P(Perched water table)-R-C/C1-S/S1-H1	The residual shale is potentially expansive and the calculated heave is between 7,5 mm and 15 mm, therefore this part of the site is zoned as H1. The colluvium is expected to be potentially collapsible / compressible. Due to the consistency and composition the collapse / settlement could not be quantified. The average thickness of this material is 0,7 meters, and the thickness varies between 0,2 and 0,9 meters. Therefore this part of the site is zoned as C/C1-S/S1. The presence of the shallow perched water table is accommodated by adding a zoning of P(Perched water table). The presence of the shallow bedrock is accommodated by a zoning of R
C and E Geotechnical classification: 1A 2B 2/3C 2D 2E 2/3F 1I (see table	P(Perched water table)-C/C1-S/1-H2	The residual shale and residual diabase are potentially expansive and the calculated heave is between 15 mm and 30 mm, therefore this part of the site is zoned as H2. The colluvium is expected to be potentially collapsible / compressible. Due to the consistency and composition the collapse / settlement could not be quantified. The average thickness of this material is 0,5 meters, and the thickness varies between 0,2 and 1,0 meters. Therefore this part of the site is zoned as C/C1-S/S1. The presence of the shallow perched water table is accommodated by adding a zoning of P(Perched water table).
G Geotechnical classification: 3L (see table)	P(Flood line)	This part of the site lies below the flood lines of the Pienaars River and the tributaries, therefore it is zoned as P(Flood line)

It is important to note that since the investigation was done for township establishment the zoning is based on the profiling of test pits and the interpolation of information between test pits, therefore it is possible that variations from the expected conditions can occur. The zoning is shown on Figure 4.

14. CONCLUSIONS AND RECOMMENDATIONS

It is important to note that the recommendations are based on the profiling of test pits and the interpolation of information. It is therefore possible that variations from the expected conditions can occur.

14.1 Foundations

14.1.1 P(Perched water table)–C/C1–S/S1-H3

The alluvium, residual diabase, residual shale and the residual syenite are potentially expansive and the colluvium is considered to be potentially collapsible. Therefore this material is considered unsuitable in its natural state to act as a founding medium. This even applies for light structures with a foundation pressure of less than 100kPa. From the discussion foundation improvement and imparting flexibility in the brickwork are clearly required. The following alternatives are recommended:

- *Stiffened or cellular raft:*
  Found structures on a stiffened or cellular raft. Structures should be provided with articulation joints and lightly reinforced masonry.

- *Soil raft:*
  Remove all or necessary parts of the expansive horizon to 1,0 meters beyond the perimeter of the structures. The loose material in the bottom of excavations should be compacted, and the excavations backfilled with inert material, compacted to at least 93% of Mod AASHTO density at -1% to +2% of optimum moisture content. Structures can be founded on normal, lightly reinforced strip footings on the backfill and should be provided with light reinforcement in the masonry if the residual movements are < 7,5 mm, or the construction type should be appropriate to residual movements.

- *Piled construction:*
  Piled foundations with suspended floor slabs, with or without ground beams.

It is important though that in spite of the guidelines given above, inspection of foundation excavations and the involvement of a competent engineer familiar with structural founding are necessary. ***It is furthermore recommended that the trenches for services be profiled and that a construction report be compiled for the development. The purpose of the construction report is to confirm or adapt the zoning of the site, and to provide more accurate information regarding the founding conditions.***

14.1.2 P(Perched water table)-R-C1/C2-S1/S2-H1

The residual shale is potentially expansive and the colluvium is considered to be potentially collapsible. Therefore this material is considered unsuitable in its natural state to act as a founding medium. This even applies for light structures with a foundation pressure of less than 100kPa. From the discussion foundation improvement and imparting flexibility in the brickwork are clearly required. The following alternatives are recommended:

The following alternatives are recommended:

If shallow shale bedrock is present:

- *Normal construction:* Found structures on the bedrock, below the potentially expansive and potentially collapsible material.

If the depth to suitable founding material becomes too deep to found economically, the following alternatives should be implemented.

- *Modified normal:*
  Found structures on normal, reinforced strip footings, structures should be provided with light reinforcement in the masonry and with articulation joints at all external and internal doors and openings.

- *Soil raft:*
  Remove all or necessary parts of the expansive horizon to 1,0 meters beyond the perimeter of the structures. The loose material in the bottom of excavations should be compacted, and the excavations backfilled with inert material, compacted to at least 93% of Mod AASHTO density at -1% to +2% of optimum moisture content. Structures can be founded on normal, lightly reinforced strip footings on the backfill and should be provided with light reinforcement in the masonry if the residual movements are < 7,5 mm, or the construction type should be appropriate to residual movements.

- *Stiffened or cellular raft:*
  Found structures on a stiffened or cellular raft. Structures should be provided with articulation joints and lightly reinforced masonry.

It is important though that in spite of the guidelines given above, inspection of foundation excavations and the involvement of a competent engineer familiar with structural founding are necessary. ***It is furthermore recommended that the trenches for services be profiled and that a construction report be compiled for the development. The purpose of the construction report is to confirm or adapt the zoning of the site, and to provide more accurate information regarding the founding conditions.***

14.1.3 P(Perched water table)-C/C1-H2

The residual shale and residual diabase are potentially expansive and the colluvium is considered to be potentially collapsible. Therefore this material is considered unsuitable in its natural state to act as a founding medium. This even applies for light structures with a foundation pressure of less than 100kPa. From the discussion foundation improvement and imparting flexibility in the brickwork are clearly required. The following alternatives are recommended:

- *Split construction:*
  A combination of reinforced masonry and full movement joints, with suspended floors or fabric reinforced ground slabs, acting independently from the structure.

- *Stiffened or cellular raft:*
  Found structures on a stiffened or cellular raft. Structures should be provided with articulation joints and lightly reinforced masonry.

- *Soil raft:*
  Remove all or necessary parts of the expansive horizon to 1,0 meters beyond the perimeter of the structures. The loose material in the bottom of excavations should be compacted, and the excavations backfilled with inert material, compacted to at least 93% of Mod AASHTO density at -1% to +2% of optimum moisture content. Structures can be founded on normal, lightly reinforced strip footings on the backfill and should be provided with light reinforcement in the masonry if the residual movements are < 7,5 mm, or the construction type should be appropriate to residual movements.

- *Piled construction:*
  Piled foundations with suspended floor slabs, with or without ground beams.

It is important though that in spite of the guidelines given above, inspection of foundation excavations and the involvement of a competent engineer familiar with structural founding are necessary. ***It is furthermore recommended that the trenches for services be profiled and that a construction report be compiled for the development. The purpose of the construction report is to confirm or adapt the zoning of the site, and to provide more accurate information regarding the founding conditions.***

14.1.4 P(Flood line)

Since this part of the site lies below the flood line, the founding of structures is not discussed.

14.2 Foundations for large structures

Structure specific investigations should be done for large structures.

14.3 Excavatability

The excavatability of the materials encountered on the site was evaluated according to the South African Bureau of Standards Standardized Specification for Civil Engineering Construction DB: Earthworks (Pipe Trenches). The excavatability is considered to classify as "soft to intermediate" up to the following **average** depths:

- More than 2,0 meters in NHBRC Zone P(Perched water table)–C/C1–S/S1-H3.
- Less than 1,5 meters in NHBRC Zone P(Perched water table)-R-C1/C2-S1/S2-H1
- Variable but on average less than 1,5 meters in NHBRC Zone P(Perched water table)-C/C1-S/S1-H2, boulders is present

It is important to note that the evaluation is based primarily on the profiling of test pits and the interpolation of information between test pits. It is therefore possible that variations from the expected conditions can occur.

14.4 Geohydrology

All excavations should be provided with adequate drainage. Structures should be provided with damp proofing and provision should be made to prevent the ingress of water into– and below foundations.

14.5 Construction material

The laboratory test results show that the colluvium could, depending on the clay and gravel content, be suitable as selected subgrade and fill. The alluvium, residual shale, residual diabase and residual syenite are not considered suitable as construction material. *It is recommended that the suitability of material that is to be used, be confirmed by detailed laboratory testing.*

14.6 Services

Due to the expected corrosivity, it is recommended that all services be protected.

14.7 Stability of excavations

It is recommended that all excavations be cut back or shored. Particular attention should be paid to the lateral support of excavations where the shale bedrock is exposed, since the shale is well known for instability along bedding and joint planes.

14.8 General recommendations

Water has a significant influence on the behaviour of the in-situ material. To reduce differential movements of structures it is necessary to maintain moisture equilibrium under the structures. Therefore it is recommended that the following measures regarding drainage around structures be implemented:

- No accumulation of surface water must be allowed around the perimeter of the structures and the entire development must be properly drained.
- Down pipes should discharge into a lined or precast furrow. This furrow should discharge the water 1,5 meters away from the foundation onto a paved or grassed surface sloping away from the building.
- Preferably, if no gutters or paving is to be provided around structures, a 1,5 meter wide sealed concrete apron should be cast along the perimeter of the structures the water must be channeled away from the foundation.
- Leaks in water bearing services should be attended to without undue delay.
- No large shrubs or trees should be planted closer to structures than the distances provided in the following Table:

DESCRIPTION	MATURE HEIGHT OF TREE		
	Up to 8m	8m tot 15m	Over 15m
Buildings other than single storey buildings of lightweight construction	-	0.5	1,2
Single storey buildings of lightweight construction (e.g. timber framed)	-	0.7	1,5
Free standing masonry walls	-	1,0[1] 0,5[2]	2,0[1] 1,0[2]
Drains and underground services • less than 1 meter deep • more than 1 meter deep	 0,5 -	 1,5 1,0	 3,0 2,0

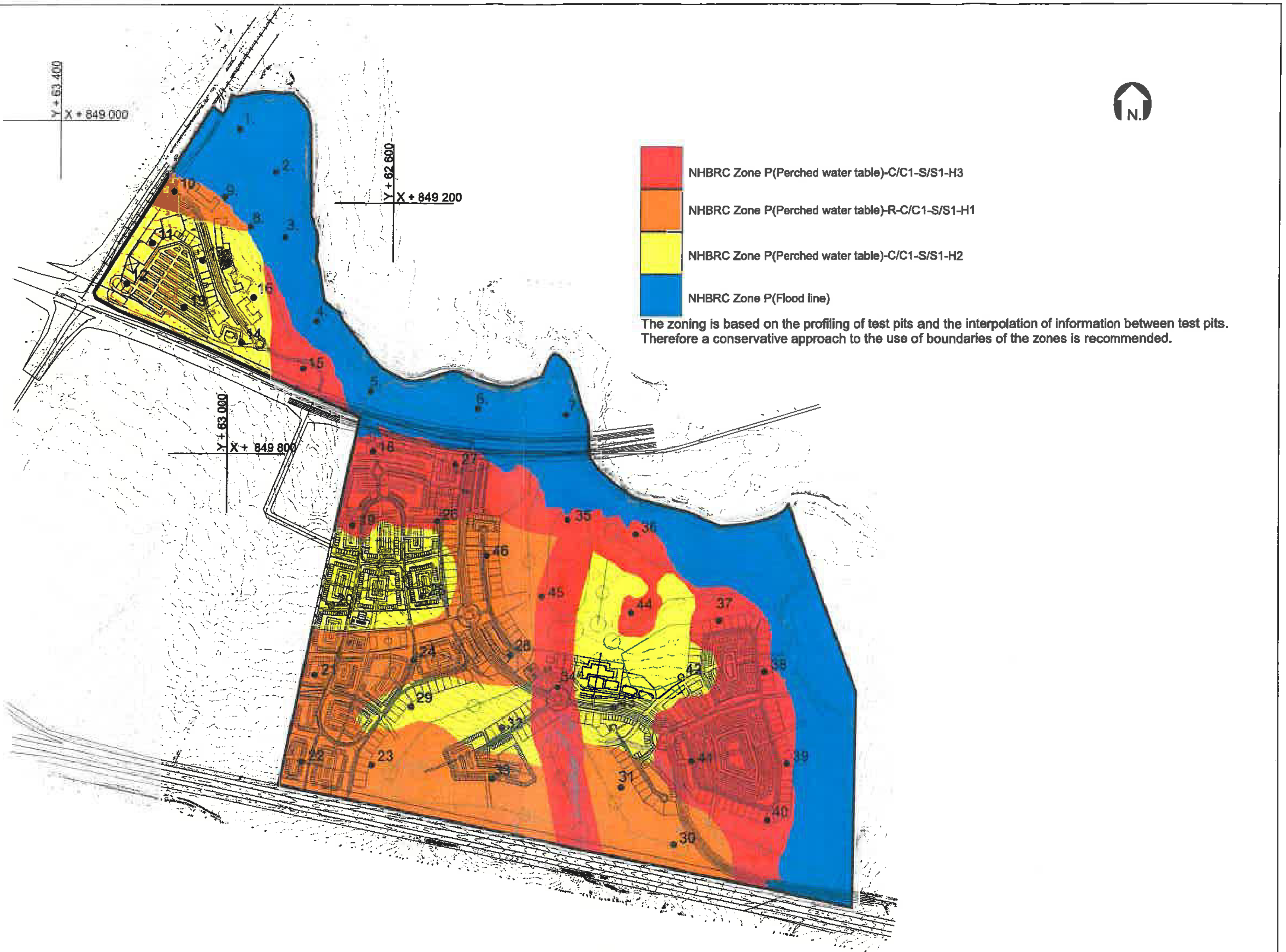
Note:
1) These distances will generally avoid all direct damage
2) These distances assume that some movement and minor damage, which may be tolerated, might occur.

This table provides guidance on the acceptable proximity of young trees or new planting to allow for future growth. This table should not be taken to imply that construction work can occur at the specified distances from existing trees; as such work might damage the tree, or render it dangerous, but refers to the potential or future growth, either of a young tree or of planting, occurring subsequent to construction.

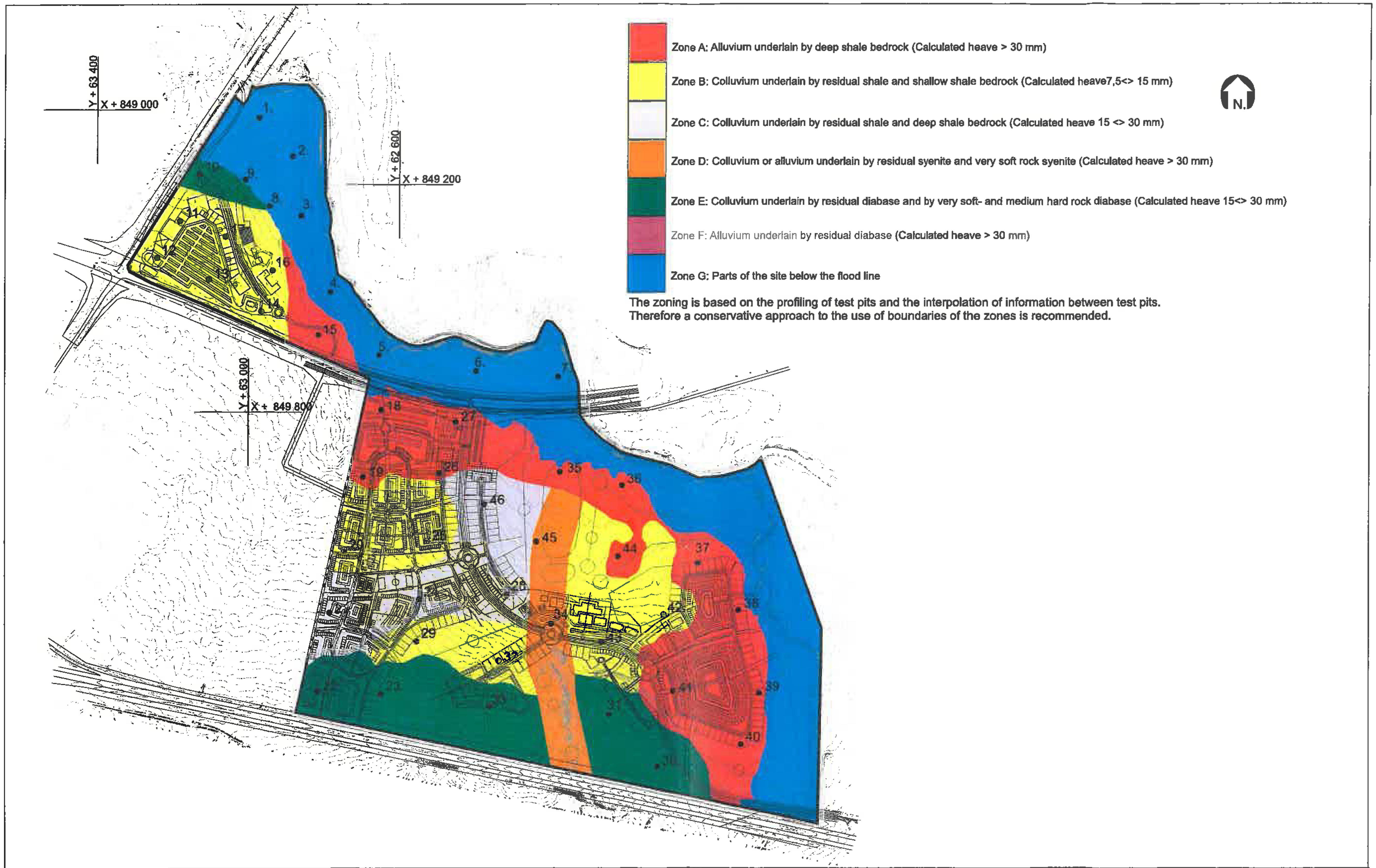
L.J Kruger Pr. Sci. Nat.

15. REFERENCES

- "Guidelines for Urban Engineering Geological Investigations", SAIEG & SAICE, 1995
- "Home Building Manual Part 1 & 2", National Home Builders Registration Council, 1999
- "Revised Guide to Soil Profiling for Civil Engineering Purposes in Southern Africa", Jennings Brink and Williams, The Civil Engineer in SA, 1973
- "The Prediction of Soil Heave from the Plasticity Index and Percentage Clay Fraction of Soils", D.H van der Merwe, The Civil Engineer in South Africa, 1964
- "A Guide to Construction on or with Materials Exhibiting Additional Settlement due to Collapse of Grain Structure", Jennings and Knight 1975
- "A Short Workshop on Suggested Interpretation Techniques of Soil Movement with Emphasis on Heave and Collapse Conditions": SAIEG, 1999
- "The Engineering Geology of Southern Africa", Volumes 1, 2 , 3 and 4, A.B.A Brink
- "Soil Survey for Engineering", Brink, Partridge & Williams
- South African Bureau of Standards Standardized Specification for Civil Engineering Construction DB: Earthworks (Pipe Trenches) SABS 1200 DB-1982
- Technical Recommendations for Highways, TRH 14 of 1985



NHBRC ZONING	SCALE 1 : 10 000	FIGURE 4



ENGINEERING GEOLOGICAL ZONING	SCALE 1 : 10 000	FIGURE 3

Services Information

Appendix G4

NOTES AND SPECIFICATIONS

NOTES:

1. RUN-OFF CALCULATION PERFORMED WITH HYDROCUBE COMPUTER PROGRAM, SUING THE FOLLOWING CONSTANTS:

a) RETURN PERIOD:
-- MAJOR SYSTEM: 20 YR
-- MINOR SYSTEM : 2 YR

b) MAP = 690mm

c) % IMPERVIOUSNESS:
-- RESIDENTIAL: 85%
-- ROADS: 85%
-- OPEN SPACES: 5%

LEGEND:

- SUB CATCHMENTS
- STORMWATER NODES
- TSHWANE RIVERS
- STORMWATER ROUTES
- FLOODLINE 1:100 WITH ROAD AND BERM
- STORMWATER CHANNEL
- 32m WETLAND BUFFER

DEVELOPER DETAIL

Balwin PROPERTIES

ARCHITECTS DETAIL

VTC Architecture
www.vtcgroup.biz

AMENDMENTS

NR.	DATE	APPROVED	DESCRIPTION	PAR.
A	MAY 2016		CONCEPT DRAWING	

DESIGNED: W.STANDER
SIGNATURE:.................... DATE:....................

DRAWN: T VAN NIEKERK

DESIGN CHECKED BY: W. STANDER
SIGNATURE:.................... DATE:....................

INFRASTRUCTURE TECHNICAL INFORMATION MANAGEMENT: D.J. CHALMERS
SIGNATURE:.................... DATE:....................

PROJECT STATUS

● CONCEPT DRAWING ○ TENDER DRAWING ○ APPROVED FOR CONSTRUCTION DRAWING ○ AS BUILT DRAWING

PROJECT ENGINEER (CONSULTANT)

INITIALS AND SURNAME .... SIGNATURE AND Pr. No. .... DATE ....

INSPECTOR OF WORKS (CITY OF TSHWANE):

INITIALS AND SURNAME .... SIGNATURE AND Pr. No. .... DATE ....

CONSULTANT DETAIL

CIVIL CONCEPTS Consulting Civil and Structural Engineers

CONSULTING CIVIL AND STRUCTURAL ENGINEERS
P.O. BOX 36148 Menlo Park 0102
Tel: (012) 460-0008
Fax: (012) 460-0005
E-Mail: mail@civilconcepts.co.za

CITY OF TSHWANE

TRANSPORT DEPARTMENT

Mr P. Letlonkane
STRATEGIC EXECUTIVE DIRECTOR
P.O. BOX 1409
PRETORIA
0001

CITY OF TSHWANE

Ms. L. V. Kegakilwe-Piki
EXECUTIVE DIRECTOR
P.O. BOX 1409
PRETORIA
0001

DRAWING APPROVED BY EXECUTIVE DIRECTOR
Ms. L. V. Kegakilwe-Piki

SIGNATURE:.................... DATE:....................

LOCATION OF PROJECT:

RIVERWALK PORTION 241 OF THE FARM ZWARTKOPPIES No. 364-JR

DESCRIPTION OF PROJECT

STORMWATER MASTER PLANNING PART 2: NETWORK MODELLING

CONTRACT No. :	PROJECT No. : C2142	
DATE : MAY_2016	SCALE : 1:2500	ORIGINAL PAPER SIZE: A1
DRAWING NO. C2142-SMP-RW	SHEET NO:	REVISION A