

A performance based approach to the development of dolomite land

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ABSTRACT: The performance concept is driven by stated requirements which are intended to satisfy societal needs and expectations and is supported by qualitative and quantitative requirements which may be satisfied in a number of ways. A well developed performance based code or standard usually has a four level hierarchy that commences with the capturing of societal needs and expectations in a set of objectives that address the essential interests of the community at large. Functional statements at the second level state in qualitative terms the required performance to achieve the stated goal. Performance requirements at the third level state in quantitative terms the required performance to achieve a functional requirement while verification methods at the fourth level enable compliance with requirements to be verified.

The development of dolomite land can be undertaken in terms of a performance based approach. The goal of such an approach should be that:

- a) the development risk associated with the formation of sinkholes or dolines in dolomite land is within acceptable levels; and
- b) the current land usage does not compromise the future use of such land.

The functional statement is that the land usage of dolomite land shall present an acceptable level of development risk of sinkhole and doline formation over time. Performance requirements may be formulated in terms of the level of precautionary measures that are required to ensure an acceptable development risk in the context of the inherent risk, based on geotechnical investigations and dolomite risk management strategies. The means of verifying compliance may be established through the application of standard methods and procedures established in standards.

This paper presents the multidisciplinary and integrated performance based approach to land safety and land usage contained in the draft SANS 1936, *Development of dolomite land*.

1 INTRODUCTION

The geotechnical factors that influence the risk of subsidence on dolomite land include ground surface topography, drainage, the nature, thickness and origin of the transported soils and residuum, the nature and topography of the underlying strata, the depth and expected fluctuations of the groundwater level and the presence of underlying structural features such as faults, fracture zones and dykes. Sinkholes and dolines are usually induced by human activity in areas that are susceptible to such ground movement events. Primary trigger mechanisms include ingress

of water from leaking water-bearing infrastructure, structures, poorly managed surface water drainage and the lowering of the natural groundwater level.

The hazard of sinkhole formation, in the absence of risk mitigation measures and depending upon their location, can result in loss of life, severe damage or total loss of buildings and severe damage to infrastructure. The hazard of doline formation is generally confined to differential movements causing extensive damage to unprotected buildings and infrastructure.

Risk avoidance measures such as prohibiting development of any kind on areas underlain by dolomite land is neither feasible nor practical as between 3 and 4 million South Africans currently reside or work on such land. Twenty five per cent of Gauteng, the commercial, mining and manufacturing centre of South Africa is located on dolomite. At the other end of the spectrum, risk acceptance is not acceptable, given the nature of the hazard, the number of people currently residing on such land and Government's environmental obligations in terms of the Bill of Rights. Risk mitigation measures are therefore required.

Broadly, risk may be managed on dolomite land by:

- a) placing restrictions on land use;
- b) ensuring appropriate development, and
- c) establishing requirements for the:
 - i) management and monitoring of surface drainage and dewatering;
 - ii) installation of below ground infrastructure, particularly water bearing services;
 - iii) the construction of above ground water bearing structures;
 - iv) the maintenance of water bearing structures and services; and
 - v) design requirements for buildings and structures to allow the safe evacuation of occupants and users in the event of a hazard occurring.

A regulatory system is required to inform and manage the development of dolomite land in a sustainable manner.

2 THE PERFORMANCE BASED APPROACH TO THE REGULATION OF BUILDINGS

A building code or regulation is a document used by a local, state or national government body to control building practice, through a set of statements of "acceptable" minimum requirements of building performance. Building regulatory systems may be described as being:

- Prescriptive in terms of which a collection of codes and standards are used to describe how buildings should be designed, built, protected and maintained with regard to the health and safety of the public.

- Functional in which qualitative functional statements are made but no quantitative user or technical performance requirements are prescribed.
- Performance-based in which qualitative functional requirements are established, quantitative user and technical performance criteria are provided, and acceptable solutions and evaluation and design tools are offered.

In the prescriptive approach, the building parts are described, specified and procured, resulting in a building with a unique but implicit set of attributes. In the performance approach, the building attributes are described and specified, and many combinations of different building parts can be procured for which it can be demonstrated that the specified attributes will be satisfied. (Watermeyer and Milford, 2003)

The performance concept is driven by nominated requirements which are intended to satisfy a society's needs and expectations. Its key objective is to articulate societal needs and expectations, then properly capturing these requirements, translating them into required building attributes and performance criteria and providing the means by which nominated performance requirements can be verified.

A four level performance based regulatory system which aligns with the approach adopted in the third edition of SANS 10400, *The application of National Building Regulations*, is shown in Figure 1. Objectives or goals are located at level 1 i.e. at the top. The objectives presented at this level represent broad statements of intent of what the building regulations are intended to provide. Functional requirements, which set out how a building can be expected to satisfy objectives, may be found in the next level (level 2). These statements as such indicate what steps need to be taken to achieve stated objectives or community expectations. Performance requirements are located in the next level (level 3). These requirements outline a quantitative level of performance which must be met by building materials, components, design factors and construction methods in order for a building to satisfy the relevant functional requirements and in turn the relevant objectives. The means of confirming that the nominated level of performance is achieved is found in the last level (level 4).

Level 1	GOAL /OBJECTIVE	A broad statement of intent that reflects societal expectations of what the building regulations are intended to achieve.
Level 2	FUNCTIONAL REQUIREMENTS	A requirement stated in quantitative terms that sets out what is required without specifying the method of construction, techniques, dimensions or materials to be used.
Level 3	PERFORMANCE REQUIREMENTS	The qualitative performance criteria which enables the functional requirements to be satisfied for a nominated level.
Level 4	EVALUATION	Confirmation that the nominated performance is achieved.

COMPLIANCE METHOD	PERFORMANCE-BASED METHODS		
	Competent person Rational assessment	Rational design	Agreement certification
By application of deemed-to-satisfy design and construction rules	By testing and / or assessment	By application of well established engineering principles	By expert opinion and judgment

Figure 1: Four level performance based regulatory system for buildings (after Watermeyer, 2006)

3 APPLYING THE FOUR LEVEL PERFORMANCE BASED SYSTEM TO DOLOMITE LAND

3.1 Introduction

The four level regulatory system for buildings may be adapted for the development of dolomite land i.e. land underlain by dolomite or limestone rock directly or at a shallow depth typically less than:

- 60 m in areas underlain by limestone;
- 60 m in areas underlain by dolomite where no dewatering has taken place and the local authority has jurisdiction, is monitoring and has control over the groundwater levels over the areas under consideration; or
- 100 m in areas underlain by dolomite where dewatering has taken place or where the local authority has no jurisdiction or control over groundwater levels

3.2 Level 1: Objective

The system objective may be stated as the development of dolomite land in a manner that ensures that:

- people live and work in a safe environment;
- damage to and loss of assets is within limits acceptable to society; and
- the future use of such and is not compromised by current usage.

3.3 Level 2: Functional Requirements

The functional or qualitative requirement may be stated as the land usage of dolomite land shall present an acceptable development risk of sinkhole and doline formation over time.

3.4 Level 3: Performance requirements

Quantitative requirements need to quantify the functional requirements i.e. what "an acceptable development risk" is.

Buttrick *et al* (2001) suggested that an acceptable development risk is where the statistical occurrence of events in the range of 0 = 0,1 events per hectare over a twenty year period. They proposed a Method for Dolomite Land Hazard and Risk Assessment to establish the inherent risk (chance of a certain size sinkhole or doline occurring within the postulated scenario of land use and dewatering or non-dewatering) to characterise land, which together with appropriate township design, water precautionary measures and ongoing risk management systems could be used to ensure that this development risk for human settlements stays within the range of acceptable development risk. This methodology recommends the adoption of:

- a zoning system, based on the Method of Scenario Supposition (Buttrick and Van Schalkwyk, 1995), which relates the inherent risk characterisation of an area to suitable or appropriate types of development; and
- the dolomite area designations for townships, developed by the Joint Structural Division of IStructE and SAICE and adopted by the National Home Builders Registration Council, which links inherent risk classes to precautionary measures and house foundation systems so that account could be taken of the impact of

subsurface conditions of townships and stand density on development risk.

According to this methodology, the hazard and inherent risk associated with dolomite land is evaluated using a simple generalised set of factors (circumstances, facts or influences contributing to a result), based on the risk management principles and an idealised three-dimensional model by applying the Method of Scenario Supposition. Thereafter, once the stands size in residential townships is known, the permissible land usage is considered in relation to the level of precautionary measures that are required to maintain an acceptable development risk and to appropriately mitigate the loss of life should such an event occur.

Buttrick *et al's* Method for Dolomite Land Hazard and Risk Assessment provides a qualitative interpretation of what development risk is and may accordingly be used as a basis for describing proxy performance requirements which if satisfied will result in acceptable development risk.

Accordingly, the qualitative performance requirements for dolomite land may be framed around the:

- a) development of parcels of land in terms of permissible land usages based on the land usage subcategories listed in Table 1, the Inherent Risk class determined in accordance with the Method for Dolomite Land Hazard and Risk Assessment, dolomite area designations which indicate the levels of precautionary measures required to support development (see Table 2) and, where necessary, foot print investigations; and
- b) the provision of infrastructure based on infrastructure types described in Table 3, the Inherent Risk class determined in accordance with the Method for Dolomite Land Hazard and Risk Assessment and dolomite area designations (see Table 2).

These qualitative requirements, however, need to be qualified to ensure that such developments maintain an acceptable development risk throughout their lifetime. Such qualifications need to be framed around the establishment, preferably in performance terms, as to what constitutes appropriate precautionary measures in the design and construction of buildings and infrastructure, how

buildings and infrastructure are to be maintained and how surface and subsurface water is to be managed.

Owners of infrastructure located on parcels of land categorized as D2, D3 or D4 in terms of table 2, mines and developments located on parcels of land categorized as commercial and miscellaneous non-residential, low rise dwelling units, high rise dwelling units and dwelling houses need to establish and implement appropriate dolomite risk management strategies to mitigate the risks associated with the provision of infrastructure on such land. Local authorities in whose jurisdiction such developments are located also need to establish, implement and maintain a dolomite risk management strategy to mitigate the risks associated with the developments on such land.

Table 1: Categories and sub-categories of land usage

Category	Sub-category
Agricultural, recreational and private and public open spaces	Agriculture that requires intensive irrigation excluding flood irrigation.
	Agriculture that requires limited irrigation. Botanical gardens, sports fields, driving ranges, golf courses, parkland and public open space.
	Agriculture that does not require irrigation in any form or the storage of water. Parkland and public open space that are not irrigated and grazing pastures.
Commercial and miscellaneous non-residential usages	Places of detention, police stations, hospitals, hostels, hotels and institutional homes for the handicapped or aged with populations not exceeding those calculated in accordance with Regulation A21 of the National Building Regulations.
	Railway stations, shops, wholesale stores, offices.
	Places of worship, theatrical, indoor sports or public assembly venues, other institutional land uses, such as universities, schools, colleges, libraries, exhibition halls and museums.
	High rise commercial developments with populations not exceeding those calculated in accordance with Regulation A21 of the National Building Regulations.
	Light (dry) industrial developments, dry manufacturing, commercial uses such as warehousing, packaging, etc.
	Fuel depots, processing plants or any other areas for the storage of liquids.
	Outdoor storage facilities, stock yards, container depots, etc.
Low rise dwelling units	Waste sites, cemeteries.
	= 3 Storeys with 80 to 120 units per hectare with low service densities and a population not exceeding 600 people per hectare.

	= 3 Storeys with 40 to 80 units per hectare with low service densities and a population not exceeding 400 people per hectare.
	= 3 Storeys with less than 40 units per hectare with low service densities, and a population of = 200 people per hectare.
High rise dwelling units	> 3 Storeys with a population of = 1500 people per hectare.
	> 3 Storeys with a coverage ratio of = 0,4, no higher than 10 storeys, and a population of = 800 people per hectare.
	> 3 Storeys with a coverage ratio of = 0,3, no higher than 10 storeys, and a population of = 600 people per hectare.
Dwelling houses	26-60 dwelling houses per hectare with stands larger than 150 m ² , and a population of = 300 people per hectare.
	10 - 25 dwelling houses per hectare with stands no smaller than 300 m ² , and a population of = 200 people per hectare.
	2-10 stands per hectare with 1000 to 4000 m ² stands, and a population of = 60 people per hectare.
	Small holdings, <2 stands per hectare with stands >4000 m ² , and a population of = 25 people per hectare.

Table 2: Dolomite area designations

Dolomite area designation	Description
D1	No precautionary measures are required to support development.
D2	Only general precautionary measures that are intended to prevent the concentrated ingress of water into the ground in accordance with the requirements of SANS 1936-3, are required to support development.
D3	Precautionary measures in addition to those pertaining to the prevention of concentrated ingress of water into the ground are required to support development in accordance with the relevant requirements of SANS 1936-3.
D4	No precautionary measures can reduce the development risk to acceptable limits so as to support development or the required precautionary measures are impractical to implement.

Table 3: Infrastructure types

Primary and secondary roads, railway lines, power lines
Bulk pipelines including water, sewer, fuel and gas lines
Reservoirs and public swimming pools
Attenuation and retention ponds for stormwater management and artificial lakes
Dams
Runways

The qualitative performance requirement for owners who require dolomite risk management strategies may be framed around the establishment, documentation, implementation and maintenance of a systematic dolomite risk management programme based on the processes shown in Figure 2 so that;

- the development risk associated with the formation of sinkholes or dolines in dolomite land is less than or equal to 0,1 events per hectare over a 20 year period and the current land usage does not compromise the future use of such land; and
- the performance of the risk management programme is regularly reported to the organization's management for review and performance improvement.

3.5 Level 4: Compliance methods

Buttrick *et al's* Method for Dolomite Land Hazard and Risk Assessment provides a deductive framework within which professional judgement is exercised. Geotechnical investigations and the design of buildings, township services and infrastructure, including the confirmation that design intent is met during construction, are undertaken by professional persons. Appropriate dolomite risk management strategies cannot be divorced from the inherent risk characterisation of a site, the design and construction of buildings and infrastructure and the site geology and hydrology. Accordingly, compliance with the performance requirements can only be established by means of rational designs and rational assessments undertaken by competent persons i.e. persons who are qualified by virtue of his experience, qualifications, training and in depth contextual knowledge of development on dolomite land to:

- plan and conduct geotechnical site investigations for the development of dolomite land, evaluate factual data, establish interpretative data and formulate an opinion relating to the outcomes of such investigations;
- design and inspect for design intent the necessary precautionary measures required on dolomite land to enable safe developments to take place; or
- develop dolomite risk management strategies

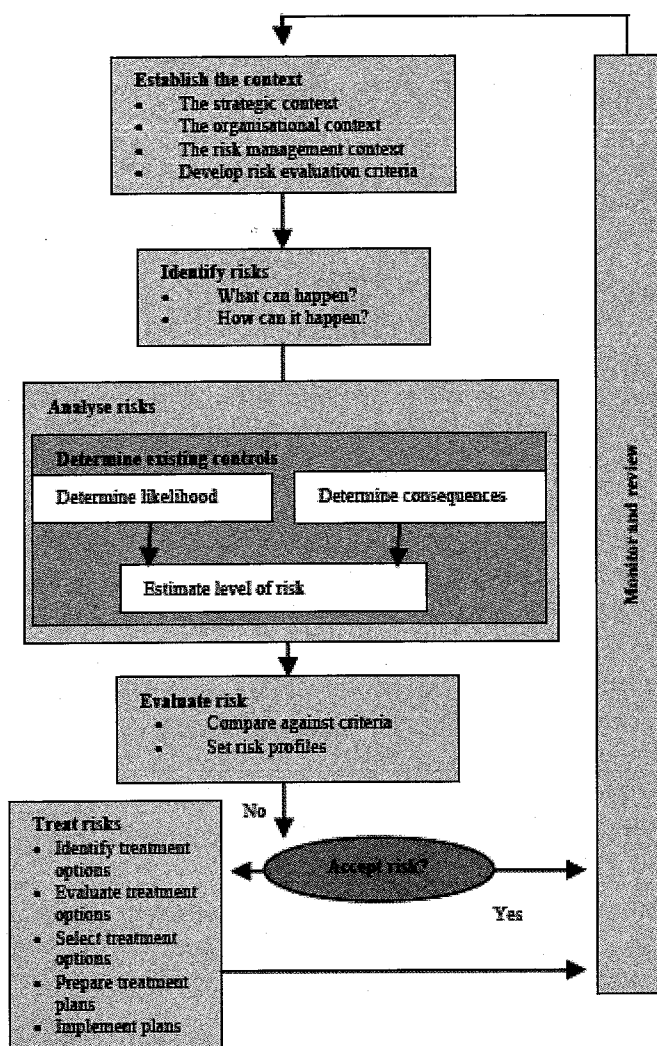


Figure 2: The process followed in the establishment and implementation of a dolomite risk management programme

4 NATIONAL STANDARDS FOR THE DEVELOPMENT OF DOLOMITE

Working drafts of a family of national standard for the development of dolomite land have been developed by a working group, based on the performance based approach outlined in this paper. This family of standards comprises four parts with scopes as described in Table 4.

SANS 1936-1, *General principles and requirements*, establishes the performance requirements for developments on dolomite land. SANS 1936-2, *Geotechnical investigations and determinations*, expands upon the GFSH-2 Specification for Geotechnical Site Investigations for Housing Developments (2003) published by the National Department of Housing and introduces detailed requirements for

footprint investigations and a methodology for determining the hazard and inherent risk. It also provides informative annexes on dolomite risk management principles, the idealised three-dimensional model for evaluating hazard and inherent risk in dolomite land, the gravity method of geophysical prospecting and the determination of geotechnical properties of the overburden

SANS 1936-3, *Design and construction of buildings, structures, and infrastructure*, establishes general requirements for the location of infrastructure, storm water drainage, sanitation systems, dewatering, landscaping and gardens, construction and the deconstruction of buildings and services. It contains specific design requirements for the design and construction of municipal township services and services in interconnected complexes, wet and dry services, infrastructure, buildings and structures and swimming pools and liquid retaining structures.

SANS 1936-4, *Risk management*, establishes generic requirements for risk management and specific requirements for a provisional dolomite risk management strategy (DRMS) (i.e. the process of utilising scientific, planning, engineering and social processes, procedures and measures to manage an environmental hazard and encompasses policies and procedures set in place to reduce the likelihood of sinkholes and dolines occurring on dolomite land) local authorities, new developments and interconnected complexes. It also provides some guidelines for monitoring.

Table 4: An overview of SANS 1936, Development of dolomite land

Part	Title	Scope
1	General principles and requirements	<p>This part of SANS 1936 establishes qualitative and quantitative performance requirements for dolomite land with respect to land safety and land usage to ensure:</p> <ul style="list-style-type: none"> a) the development risk associated with the formation of sinkholes or dolines in dolomite land is within acceptable levels; and b) the current land usage does not compromise the future use of such land. <p>This part of SANS 1936 also provides the means by which compliance with the performance requirements may be established.</p>
2	Geotechnical investigations and determinations	<p>This part of SANS 1936 establishes requirements for:</p> <ul style="list-style-type: none"> a) two phases of detailed geotechnical investigations required to determine the suitability of dolomite land for development; b) a detailed footprint stability investigation; and c) determining: <ul style="list-style-type: none"> i) the inherent risk characterisation of dolomite land; and ii) dolomite area designations.
3	Design and construction of buildings, structures, and infrastructure	<p>This part of SANS 1936 establishes requirements for the design and construction of permanent or temporary buildings, structures and infrastructure including wet and dry services on parcels of dolomite land requiring precautionary measures to support development.</p>
4	Risk management	<p>This part of SANS 1936 establishes requirements for the development of an appropriate dolomite risk management system to manage the risks associated with developments or the provision of infrastructure (or both) on dolomite land to within acceptable limits.</p>

5 CONCLUSIONS

It is possible to adapt the four-level performance based regulatory system for buildings to regulate the development of dolomite land. Objectives can be framed around safety and sustainability concerns, while functional (qualitative) requirements can be framed around acceptable development risk of sink-hole and doline formation over time. Qualitative performance requirements can quantify development risk indirectly should requirements for development be framed around land usage or infrastructure type

based on the inherent risk class determined in accordance with the Method for Dolomite Land Hazard and Risk Assessment, dolomite area designations which indicate the levels of precautionary measures required to support development, and, where necessary, detailed foot print investigations. Such requirements are, however, dependent upon appropriate precautionary measures being taken during the design and construction of buildings, structures and infrastructure and the implementation of a dolomite risk management system to ensure that acceptable development risk is maintained for the lifetime of the development.

The performance based approach outlined in this paper provides a deductive framework within which competent persons can perform rational designs and rational assessments to confirm that acceptable development risk is achieved throughout the life of a development.

The objectives and functional requirements can be readily captured in legislation and qualitative requirements and compliance methods in national standards such as those that are currently being developed under the title SANS 1936, Development of dolomite land.

6 REFERENCES

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