Eskom	Report	Technology

Title: **ESSELEN SUBSTATION SINKHOLE REHABILITATION SCOPE AND SPECIFICATION**

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1. INTRODUCTION

Esselen Transmission Substation is located in Esselen Park, Tembisa; an area which is underlain by Malmani Subgroup dolomitic rocks of the Chuniespoort Group (1: 250 000 Geological Series, 2628 East Rand. A dolomitic stability investigation (DSI) was conducted by a geo-professional and the site was classified based on the Inherent Hazard Classification (IHC) as follows:

- C3 type development in terms of SANS 1936:2012.
- IHC 3/4/6/7 with a D3 dolomite area designation.
- IHC 8 with a D4 dolomite area designation.

Sinkholes manifested in the perimeter fence of the substation in the western and southern flank. The sinkholes are formed due to poor storm water management in the periphery of the substation along the fence area in the western and southern flank of the substation. It should also be noted that there are large tension cracks in the southern flank in Region C (refer to figure 1) indicating that more sinkholes will develop.

The sinkholes at Esselen substation are formed by the ingress of the storm water into the ground. In a site visit conducted in 2017-2018 the sinkholes were identified and measured; however they have drastically increased in size.

There are four (4) regions which have developed localised sinkholes which have been identified thus far; each of the 4 regions have sinkholes which have formed near each other. The sinkholes can be classified as medium to very large sized according to table C.1 of [2].

2. SUPPORTING CLAUSES

2.1 SCOPE

The document provides the procedure to be followed for the rehabilitation of the sinkholes that have formed at the Esselen substation.

This document does not provide design cost, schedule or other project management type information.

2.1.1 Purpose

The purpose of this document is to provide the rehabilitation steps to be taken to repair the sinkholes formed at Esselen Substation in accordance with the requirements of SANS 2001-BE3.

2.1.2 Applicability

The document is applicable to the rehabilitation of the sinkholes formed at Esselen substation.

2.2 NORMATIVE / INFORMATIVE REFERENCES

2.2.1 Normative

[1] ISO 9001 Quality Management System

[2] SANS 1936-1:2012 Development of dolomite land Part 1: General principles and requirements.

[3] SANS 1936-2:2012 Development of dolomite land Part 2: Geotechnical investigations and determinations.

[4] SANS 1936-3:2012 Development of dolomite land Part 3: Design and construction of buildings, structures and infrastructure.

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[5] SANS 1936-4:2012 Development of dolomite land Part 4: Risk management.

[6] SANS 2001-BE3:2012 Construction works Part BE3: Repair of sinkholes and subsidence's in dolomite land.

[7] SAICE Code of practice for the safety of persons working in small diameter Shafts and test pits for Civil Engineering Purposes.

2.2.2 Informative

[8] Dolomite Stability Investigation report: Eskom Esselen Substation, Esselen, Tembisa, Gauteng, South Africa.

[9] Site Specific Dolomite Risk Management Strategy Report for Esselen Substation.

[10] Consultants Guide: Approach to sites on dolomite land, Council for Geoscience, Pretoria.

[11] Esselen Substation Site Visit Report – December 2021.

[12] 1:250 000 Geological Map Series 2628 EAST RAND, published by Council for GeoScience.

2.3 DEFINITIONS

Definition	Description
Bulk fill	G8 or better material in accordance with TRH14 that, once compacted, has permeability lower than that of the surrounding ground
C3	Commercial developments < 3 storeys, including 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, light (dry) industrial developments, dry manufacturing, commercial uses such as warehousing, packaging, and electrical substations, filling stations
Competent person	Person who is qualified by virtue of his experience, qualifications, training and in-depth contextual knowledge of development on dolomite. (Refer to [6] for definition in its entirety).
Contractor	A person or party who is appointed to execute the works specified herein.
D3	Precautionary measures in addition to those pertaining to the prevention of concentrated ingress of water into the ground, in accordance with the relevant requirements of SANS 1936-3, are required.
Dolomite	Rock composed of the mineral dolomite, which is a carbonate of calcium and magnesium
D4	Additional site-specific precautionary measures are required.
Excavatability	Tractor-Loader-Backhoe
Factual report	A document that is concerned with facts or contains facts
Geophysical Survey	Ground-based physical or remote sensing techniques to produce a detail image or map of an area; it is a destructive method of testing.
Interpretive report	Documents which contains interpretation of analysis of results including factual and desktop reporting, ultimately reaching objective recommendations based

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Definition	Description
	on the interpretation of results and background information of the geotechnical field.
Liquefaction	Process of or state of having been made liquid
Lithology	The general composition of a rock or rock sequence
Self-compacting concrete	self-compacting concrete shall comprise a pumpable concrete mix that requires no external vibration to achieve consolidation, with a cube strength greater than 5 MPa.
Seismic	Related to, or caused by an earthquake or other vibration of the earth
Stratigraphy	The layering of deposits, with newer remains overlaying older ones, forming a chronology of the site
Throat	An outlet for a sinkhole allowing runoff from the drainage basin of the sinkhole to flow directly into the ground.

2.3.1 Classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Abbreviation	Description
CBR	California Bearing Ratio
DSI	Dolomitic Stability Investigation
EA	Engineer Assistant
FPI	Footprint Investigation
HV	High voltage
IHC	Inherent hazard classification
MTS	Major transmission substation
MVA	Mega volt ampere
NGL	Natural ground level
OMC	Optimum moisture content
SAICE	South African Institution of Civil Engineering
SAIEG	South African Institute for Engineering and Environmental Geologists
SANS	South African National Standards
SHE	Safety, Health & Environment
TLB	Tractor-Loader-Backhoe
TMH	Technical Methods for Highways
TRH	Technical Recommendations for Highways

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3. PURPOSE OF THE PROJECT

The sinkholes formed at the Esselen Substation shall be rehabilitated by using a combination of materials as specified in [6]; i.e. dump rock, bulkfill and self-compacting concrete to cover up and fill the formed cavities. The areas that have tension cracks formation shall be induced to collapse to at least a depth of one meter (1 m) to form sinkholes that will be backfilled with the specified material. The throats of the sinkhole will be choked with dump rock, apply self-compacting concrete and bulk fill material.

The large risk identified is the instability and potential collapse of the sinkholes, and thus a competent person must assess the site before any construction works to rehabilitate the site may commence.

3.1 KEY ASSUMPTIONS AND FINDINGS

The following are the assumptions and findings that have been considered based on the site visit and the previous reports and works that have been conducted pertaining to the Esselen Substation sinkhole problem:

1. The method and material used to rehabilitate the sinkhole have been successfully previously applied.
2. There are four (4) sinkholes at Esselen which are localised sinkholes.
3. There are tension cracks which have been identified.
4. The sinkholes have been classified as medium to very large sized, i.e. sinkhole sizes diameters ranges between 2-5 m to greater than 15 m.
5. The development of the sinkholes is largely caused by the ingress of the storm water into the ground; i.e. poor storm water management.

There are four (4) regions with localised sinkholes; thus, each Region has been named A, B, C and D. The regions are depicted in the image below:

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Figure 1: Sinkholes in various regions

The sinkholes have been identified to be along the fence. The sinkholes that have developed at the substation are all located at the outer barrier fence. Typically, there is a sinkhole between the outer barrier fence and the lethal fence; and then there are more sinkholes outside the outer barrier fence adjacent to the sinkhole inside.

Additionally, there are tension cracks at Region C, indicating more imminent sinkholes to be formed.

Table 1: Sinkhole Specifications

Region	Sinkhole	Diameter (m)	Depth (m)	Volume (m^3)	Description	Total Volume (m^3)
A	1	7,5	2,5	60	This should be taken as a single sinkhole.	229
	2	8,45	2,5	169		
	3	2,5	2,5	16	Isolated sinkhole and should rehabilitated.	16
B	1	3,4	0,5	7	Isolated sinkhole and should rehabilitated.	7
	2	5	2	49	These sinkholes are actually two sinkholes in close proximity.	49
C	1	7,6	2,5	57	Isolated sinkhole and should rehabilitated.	57

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Region	Sinkhole	Diameter (m)	Depth (m)	Volume (m^3)	Description	Total Volume (m^3)
	2	16	2,5	72	Tension crack has collapsed to a depth of 1 meter.	72
	3	12	2,5	390	Isolated sinkhole and should rehabilitated.	390
	4	6,9	2,5	52	Isolated sinkhole and should rehabilitated.	52
D	1	6	4	144	Isolated sinkhole and should rehabilitated. In close proximity to ESS/JUP3 Tower	144
Total volume to be filled						**1015**

It should be noted that measurements were taken in site visit conducted on the 10 July 2022 and that the site conditions may have changed; therefore the contractor shall undertake to size the sinkholes adequately. It is also suggested that a remeasurable contract is used for the project.

3.2 SITE INFORMATION

3.2.1 Site Description

The site is located in Esselen Park, approximately 13 km north of Kempton Park and the site is adjacent R21 road. The site is accessible through Long Ave, a gravel round leading to the substation. The centre coordinates of the site are 26º 00' 17.53"S longitude and 28º 16' 06.56" E latitude. The predominant land use in the region is agricultural.

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3.2.2 Site Location

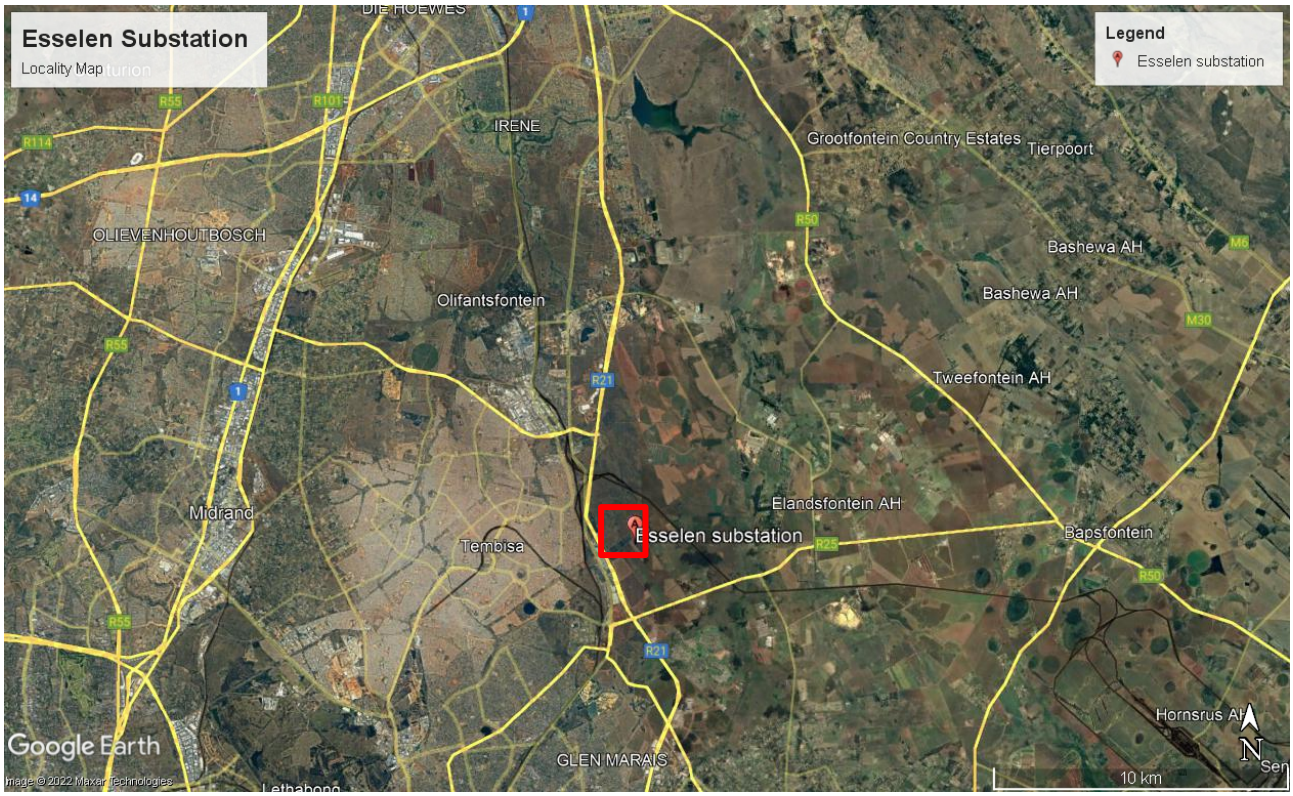

Figure 2: Satelite imagery – Esselen Substation

3.2.3 Regional Geology

The regional geology of the area is underlain by the Malmani Subgroup dolomitic rocks of the Chuniespoort Group (1: 250 000 Geological Series, 2628 East Rand). The Malmani Subgroup is comprised of the Oaktree Formation as the oldest formation followed by the Monte Christo, Lyttelton, Eccles and Frisco Formation in chronological order from oldest to youngest of age. The subdivision of the Malmani Subgroup is based on the differences in chert content, stromatolite morphology, intercalated shales and erosion surfaces (Button, 1973b).

Nature of the project will consist of the repair of sinkholes along the boundary fences at four regions as depicted on figure 1.

The scope of work for repairing the sinkholes will comprise of the following steps:

1. Collapsing of existing sinkhole
2. Removal of the rubble
3. Backfilling with Dumprock
4. Covering Dumprock with self-compacting concrete
5. Backfilling and compacting the sinkholes with G7 material or better.

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3.3 CONSTRUCTION PROCEDURE

3.3.1 Sinkhole rehabilitation

The contractor shall take measurements during the rehabilitation of the sinkhole and ensure that there are no underground services (wet services) within the vicinity where the sinkholes have been developed. The sinkhole shall be rehabilitated in accordance with [6].

1. The sidewalls of sinkholes are generally considered unstable and these should be assessed by a competent person before any work around or inside the sinkhole is permitted.
2. The contractor shall undertake to conduct site clearance within the vicinity of the sinkholes as the area is dense with shrubs. The contractors' competent person shall ensure that site clearance is done within safe procedures due to close proximity of the sinkholes.
3. The fences shall be removed and repositioned such that the area is protected from intruders.
    a. Fence includes the outer barrier fence, non-lethal fence and inner barrier fence.
    b. The contractors' competent person shall determine safe working distance and correct position to erect security fences during construction.
4. Pre-collapse all the sinkholes, including walls between them and tension cracks around them, to form one big sinkholes. This should be done in accordance to Table 1 description.
5. Pre-collapse all areas with tension cracks to a minimum depth of at least 1m to reach bedrock.
6. The sidewalls should be excavated at 45 degrees to the horizontal. Stability must be ensured prior to continuing with the works.
7. Remove rubble and loose transported wad and Chert gravel from the collapsed area. Evaluate and ensure the sidewalls are visible and stable
8. Choke the throat of the sinkhole using 500 mm diameter dump rock or larger, report to the engineer of where the throat is being identified. If the throat is not identified, fill the collapsed sinkhole with the dumprock and utilize as a subbase to layer to the sinkholes and spread out evenly. The contractors' competent person shall identify the throats of the sinkhole and apply dump rock at the identified regions.
9. Pour self-compacting concrete or soil-cement mix over the dump-rock.
10. Backfill the sinkhole with G7 or better material to the NGL in layers not more than 150 mm , using bulk fill compacted to 93% MOD-AASHTO maximum dry density at OMC.
11. The reinstated ground surface shall be elevated at least 300 mm above the level of the surrounding ground to allow for free draining and prevent the ponding of water.

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12. The finished surface shall slope at a minimum gradient of 1:60 and shall be free of hollows or depressions to prevent ponding of surface water.
13. Re-instate the security fence.

3.4 SAFETY ASSESSMENT

The stability of the sinkholes prior to the commencement of the rehabilitation works must be assessed by the contractors' competent person, i.e. an Expert Geo-Profession with level 4 as per SANS 1936-1:2012. The repair work shall be carried out under the supervision of a competent person who shall assess the safety of all the work procedures involved.

3.5 SECURITY

The security fence is compromised, and the development of the sinkholes has allowed ease of access for criminal activity. During the rehabilitation of the sinkholes, the contractor shall erect a temporary fence to keep the intruders out, additionally, a patrolling unit must be deployed to increase safety.

1. The contractor shall erect a 2,4 m high weld mesh security fence according to the drawing No. 0.54/5633.
2. The fence to be erected at regions where there are sinkholes rehabilitation working area.
3. The contractor should ensure that there is sufficient space to work during the construction activities.
4. The fence shall be erected at safe working distance from the sinkhole, to be determined by the contractors appointed geo-professional.

4. AUTHORISATION

This document has been seen and accepted by:

Name and surname	Designation
Nkosazana Leseka	Senior Geologist, Pr.Sci.Nat
Andile Maneli	Middle Manager: Substation Engineering
Bilal Hajee	Chief Engineer: Substation Engineering

5. REVISIONS

Date	Rev.	Compiler	Remarks
March 2023	0	S Mabena	First Draft

6. DEVELOPMENT TEAM

The following people were involved in the development of this document:

- Sithembiso Mabena

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7. ACKNOWLEDGEMENTS

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APPENDIX A: DESIGN OUTPUT DOCUMENTS

Document Number	Rev.	Document Title	Remarks
0.54/5633	1	Security fence with overhang	Sht 4 of 7
0.54/390-37a	2	HV yard Civil Work Standard Details – Cable Trench Ramp Cover Details	
ESS22P15-SE-E96	0	Esselen Sinkhole Rehabilitation	
ESS22P15-SE-E97	0	Esselen Sinkhole Dimensions, Plan & Cross Section View	
ESS22P15-SE-E98	0	Esselen Temporary Fence Layout for Rehabilitation	

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