

The dam safety regulations and reinforced concrete water retaining structures: A mystery or nightmare or?

Alan Chemaly - 29 February 2024

Outline



Why dam safety or safety of dams?

Which WRS are subject to regulation?

Where are we in the world?

Basic 'toolbox' of Dam Safety in South Africa

The "framework" and the "toolbox"

Definitions

Dam safety requirements & steps

Structures and projects

Lessons from dam safety evaluations

The "way forward"

► Why dam safety or safety of dams?

Preamble from Chapter 12: Safety of dams: National Water Act, 1998

- Improve the safety of new and existing dams with a safety risk so as to reduce the potential for harm to the public, damage to property or to resource quality.
- To reduce the risk of a dam failure, control measures require an owner to comply with certain directives and regulations, such as to submit a report on the safety of a dam, to repair or alter a dam, or to appoint an approved professional person to undertake these tasks.
- These measures are in addition to the owners' common law responsibility to ensure the safety of their dams.
- An approved professional person (APP) has a statutory duty of care towards the State and the general public and must fulfil, amongst other things, defined responsibilities when acting under this Chapter.

Why dam safety or safety of dams (continued)?

Preamble from Chapter 12: Safety of dams: National Water Act, 1998 (continued)

- Not all dams are subject to regulation, and the Minister may exempt certain persons from its requirements.
- **Only** dams of a defined size ($V > 50\,000$ cubic metres and $H > \text{five (5) metres}$), **or** dams which have been **declared** to be dams with a safety risk, **or** dams falling into a **prescribed category** are affected.
- All dams with a safety risk must be **registered**.
- Compliance with any directive or regulation under this Chapter does not exempt an owner from complying with any other provision of this Act, such as the requirement for a licence or other authorisation for water use in respect of the dam.

Which water retaining structures are subject to regulation?

More than one would normally imagine!

- Dams (all types)
- Raw water reservoirs (all types – including r.c. water retaining structures)
- Potable water reservoirs (all types – including r.c. water retaining structures)
- Conservation dams & impoundments
- Pollution control dams (PCDs) (including r.c. water retaining elements or components of PCDs)
- Tailings storage facilities (TSFs)

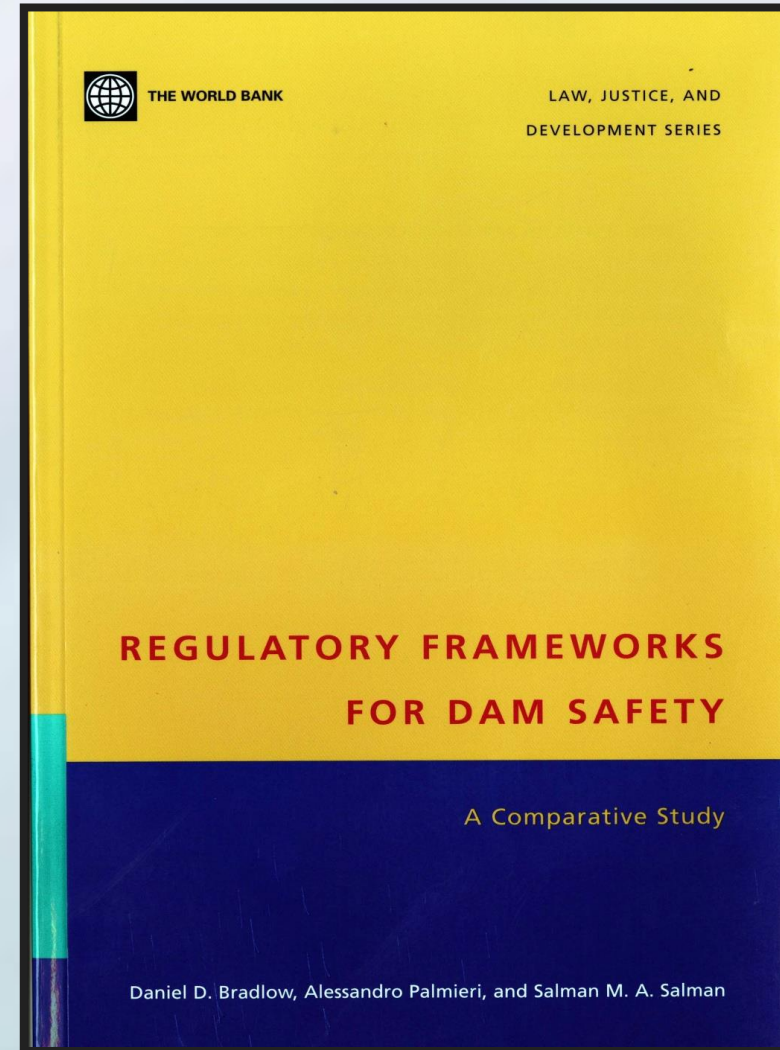
► How many dams in South Africa?

Preamble from Chapter 12: Safety of dams: National Water Act, 1998

- 60000 (for aquaculture i.e. fish, according to FAO – 200 000 RSA estimates for other uses)?
- \pm 5800 of these are regulated by dam safety legislation.
- Necessary to manage all dams?
- Yes / No?

Where are we in the world?

- "A comparative study" by The World Bank (2002) shows that South Africa can "hold its own" in all aspects of dam safety engineering and dam (or reservoir) engineering (incl. "forums") anywhere in the World!
- Cutting edge, very advanced and "way ahead"



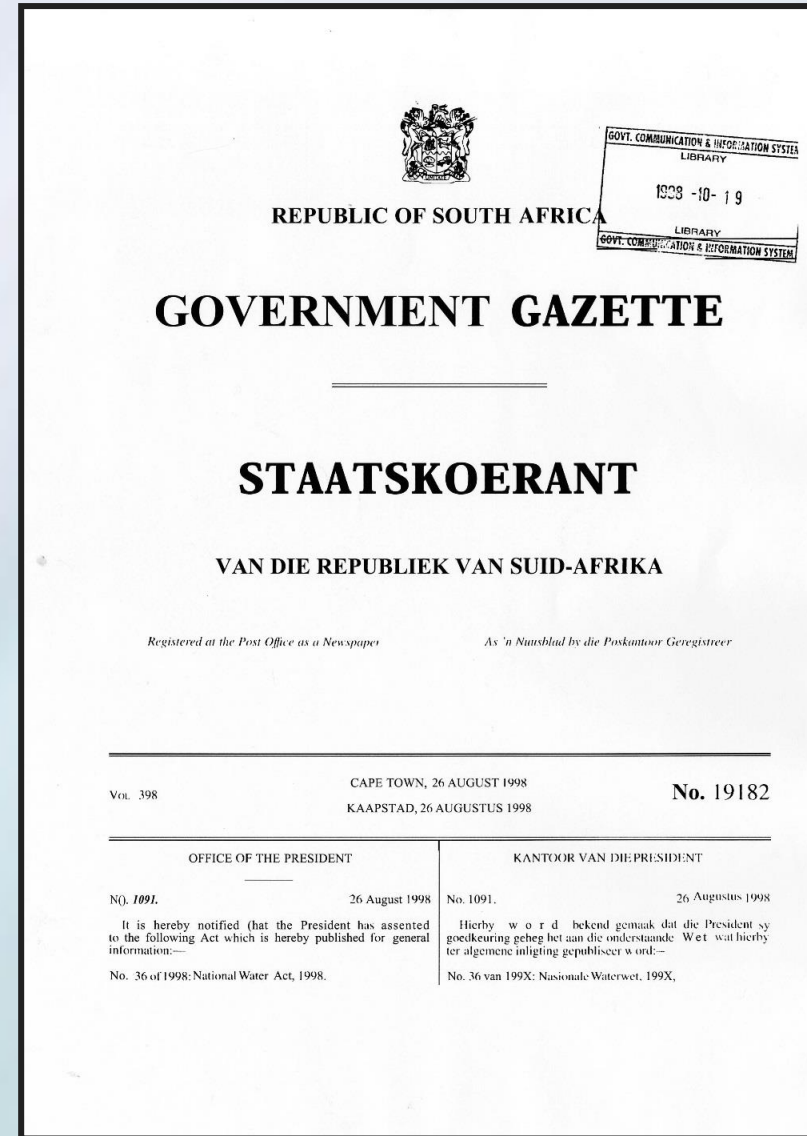
► The 'overarching elements' of Dam Safety in South Africa

A few essentials to "set the scene"

- Chapter 12 of the National Water Act, 1998 (Act No. 36, 1998) (section 117 to section 123 i.e. four and a half (4½) pages).
- Government Notice R. 139 of 24 February 2012 i.e. Regulations: Safety of Dams (56 pages).
- ECSA Policy Statement No. R2/1. "The Professional Engineer on Dams. Guidelines for Evaluation of Applications (1995/08/04)" (6 pages)
- ECSA Policy Statement No. R2/1 superceded by "Policy on Evaluation of the Competencies of Approved Professional Persons (APPs): The Professional Persons on Dams_POL-ECOSA-APP-001 (Revision.1: 25 July 2019) (12 pages)"

▶ The NWA is the "framework"

National Water Act, 1998
Act No. 36 of 1998



The NWA is the "framework" (contd)

National Water Act
1998
Act No. 36 of 1998

Chapter 12: Safety of Dams
Section 117 to Section 123
(4½ pages)

No. 19182 GOVERNMENT GAZETTE, 26 AUGUST 1998
Act No. 36, 1998 NATIONAL WATER ACT, 1998

ACT

10 provide for fundamental reform of the law relating to water resources; to repeal certain laws; and to provide for matters connected therewith.

PREAMBLE

Recognizing that water is a scarce and unevenly distributed national resource which occurs in many different forms which are all part of a unitary, inter-dependent cycle;
Recognizing that while water is a natural resource that belongs to all people, the discriminatory laws and practices of the past have prevented equal access to water, and use of water resources;
Acknowledging the National Government's overall responsibility for and authority over the nation's water resources and their use, including the equitable allocation of water for beneficial use, the redistribution of water, and international water matters;
Recognizing that the ultimate aim of water resource management is to achieve the sustainable use of water for the benefit of all users;
Recognizing that the protection of the quality of water resources is necessary to ensure sustainability of the nation's water resources in the interests of all water users; and
Recognizing the need for the integrated management of all aspects of water resources and, where appropriate, the delegation of management functions to a regional or catchment level so as to enable everyone to participate;

(English text signed by the President.)
(Assented to 20 August 1998.)

BE IT ENACTED by the Parliament of the Republic of South Africa, as follows:—

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Part 2: Catchment management strategies

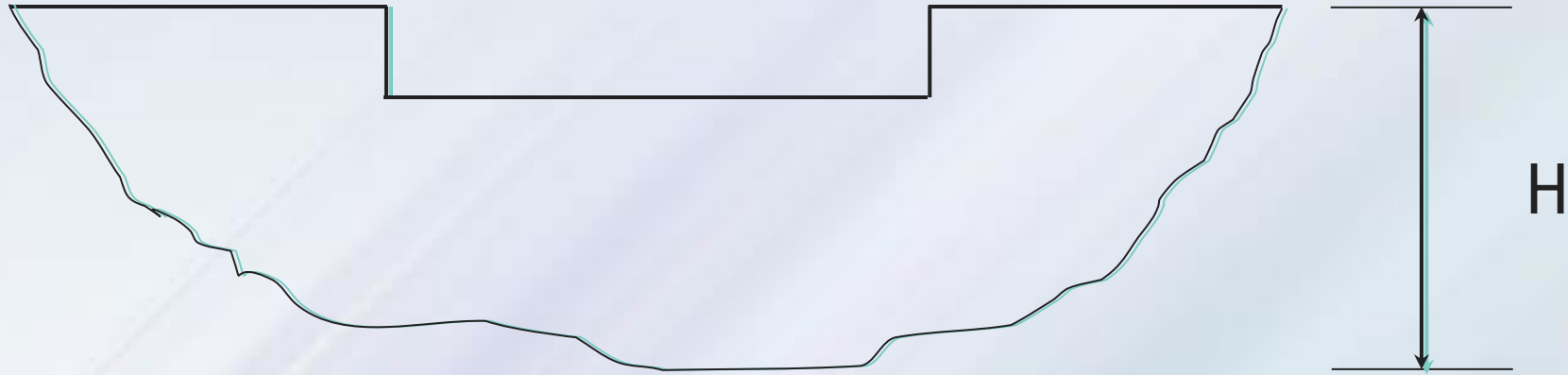
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Definitions from Section 117 of the National Water Act, 1998

Chapter 12 of the NWA is the only chapter that has its "own definitions" (quite something!)

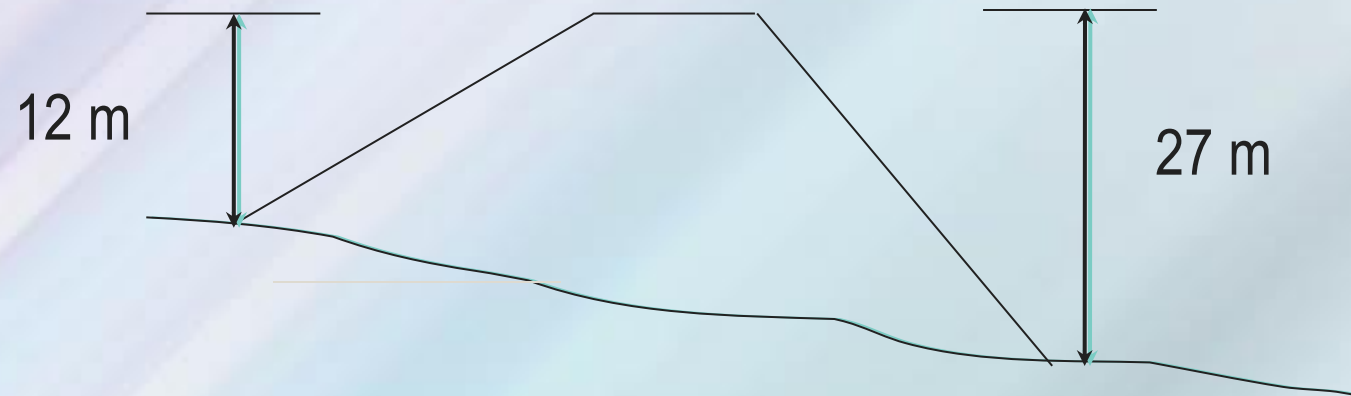
- 117. (a) "**approved professional person**" means a person registered with ECSA, and approved (for what?) by the Minister (of DWS), after consultation with ECSA i.e. ECSA (Dams) e.g. Pr Eng, Pr Tech Eng or Pr Techni Eng;
- 117. (b) "**dam**" includes any existing or proposed structure which is capable of containing, storing or impounding water (including temporary impoundment or storage), whether that contains any substance or not;
- 117. (c) "**dam with a safety risk**" means any dam –
- 117. (c) (i) which can contain, store or dam **more than 50 000 cubic metres** of water and has **wall of a vertical height of more than five (5) metres** etc. etc. etc. etc.

Height of a Dam



Upstream

Downstream



Definitions from Section 117 of the National Water Act, 1998 (contd)

Chapter 12 of the NWA is the only chapter that has its **"own definitions"** (emphasise!)

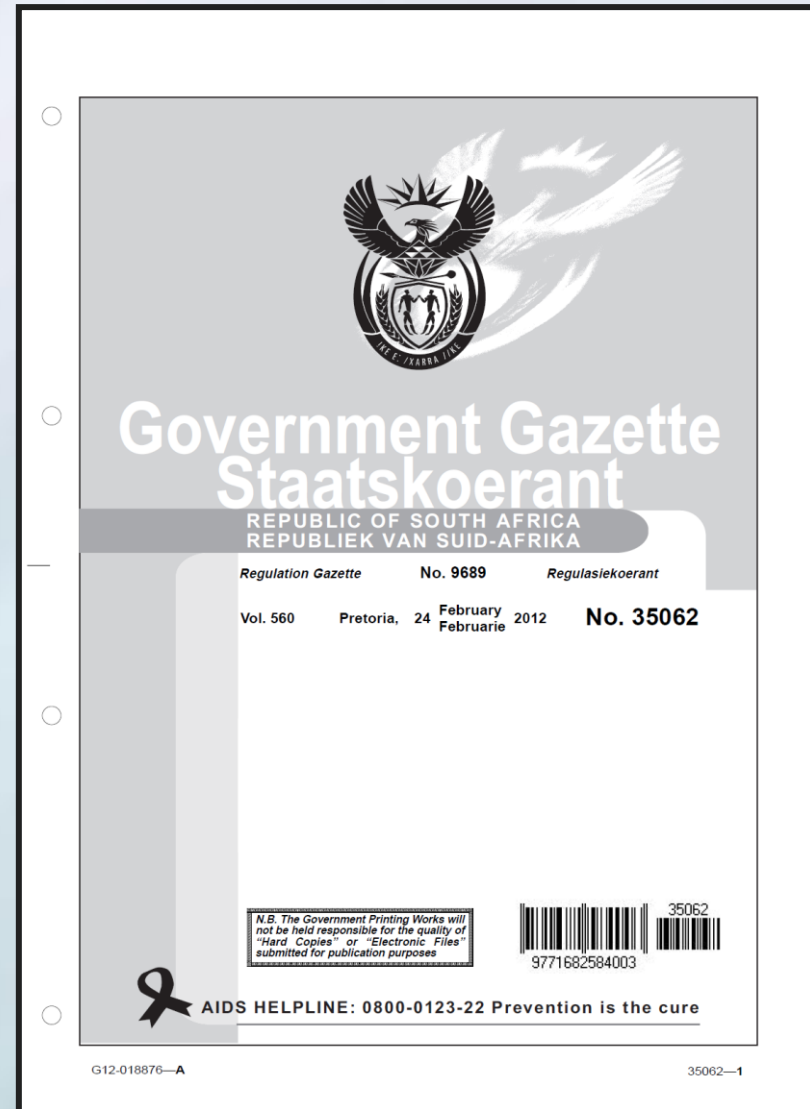
- 117. (d) **"owner of a dam"** or **"owner of a dam with a safety risk"** includes the **"person in control"** of that dam;
- 117. (e) **"task"** means any task relating to designing, constructing, altering, repairing, impounding water in, operating, evaluating the safety of (DSE), maintaining, monitoring or abandoning (decommissioning) a dam with a safety risk.

▶ The Dam Safety Regulations - "the toolbox"

Please remember (or to note) that the dam safety regulations are very practical dam (or reservoir) engineering guidelines. There are no formulae.

In contrast to the (or any) building regulations the standards to be adhered to are not prescribed.

- The steps that should be followed for dam engineering (and water retaining structures of all types) are listed
- What?
- Who?
- When?



► Classification of dams with a safety risk

The tables are in the Annexure of the Dam Safety Regulations (page 50)

- Size classification (Table 1)
- Hazard potential classification (Table 2)
- Category classification of dams with a safety risk (Table 3)

Classification of dams with a safety risk (1)

Table 1: Size classification

Size class	Maximum wall height in metres (m)
Small.....	Less than 12 m.
Medium	Equal to or more than 12 m but less than 30 m.
Large	Equal to or more than 30 m.

Table 1 must be read together with subregulation 2(2).

► Classification of dams with a safety risk (2)

Table 2: Hazard potential classification

Hazard potential rating	Potential loss of life	Potential economic loss	Potential adverse impact on resource quality
Low	None	Minimal.....	Low
Significant	Not more than ten ...	Significant.....	Significant
High	More than ten.....	Great.....	Severe

Table 2 must be read together with subregulation 2(3).

Classification of dams with a safety risk (3)

Table 3: Category classification of dams with a safety risk

Hazard potential rating	Potential loss of life	Potential economic loss	Potential adverse impact on resource quality
Low	None	Minimal.....	Low
Significant	Not more than ten ...	Significant.....	Significant
High	More than ten.....	Great.....	Severe

Table 2 must be read together with subregulation 2(3).

Registration and Classification (there is a form for each)

First step: The dam owner must apply to the Directorate: Dam Safety Regulation of DWS

- **Existing dams** - registration or register the dam (full particulars on the applicable form)
- Regional Offices should check & recommend classification to DSO (not always necessary).
- **New dams** classification required because this determines further procedures (or steps).
- Classification or re-classification **also** required for raising, enlargement and rehabilitation (always check)
- In all cases **water must be authorised** i.e. a WUL.

▶ Roleplayers

Important to summarise and reflect before we go further

- Dam owners (including the State i.e. the Department of Water and Sanitation (DWS))
- Directorate: Dam Safety Regulation (previously known as the Dam Safety Office [DSO])
- Regional Offices of DWS ("Case Officers" for water use licences (WULs) and AN Others for classifications)
- APPs and Prof. Teams (ECSA)
- Public (passive and unsuspecting)
- **"Authorised"** water use - a role player (**actually a very important factor**)

► What does the Dam Safety Office (DSO) do?

- Registration and classification of dams
- Regulating the involvement of Approved Professional Persons (APPs) in dam safety
- Issuing of licenses to construct, enlarge, alter, repair, impound water in, or to decommission dams
- Evaluate design reports, drawings & specifications
- Evaluate operation and maintenance (O&M) manuals & emergency preparedness plans (EPPs)
- Evaluate dam safety inspection and dam safety evaluation (DSE) reports
- Communicate requirements to dam owners & APPs

► What happens with a new dam? (1)

DSO = Directorate: Dam Safety Regulation of the Department of Water and Sanitation (DWS)

- Classification – Category I, Category II or Category III
- If a Category II or Category III dam – APP appointed by the owner as designer (incl. for QA and QC)
- APP prepares the design (incl. specs and dwgs) and submits with **license application** to the DSO
- DSO evaluates the design and (might) request improvements / clarifications etc. etc. etc.

► What happens with a new dam? (2)

DSO = Directorate: Dam Safety Regulation of the Department of Water and Sanitation (DWS)

- The DSO also **checks compliance** with the requirements of Chapter 4 of the NWA on Water Use Authorisation **before issuing** any licenses in terms of the Dam Safety Regulations.
- **No** water use licence (WUL) - DSO declines a (or any) licence to **construct, enlarge** or **alter**
- (WUL and **all in order**, then) DSO issues a license to **construct, enlarge, alter, repair** or **to decommission**
- Owner appoints a contractor to **construct** (etc. etc. etc.)

► What happens with a new dam or reservoir? (3)

DSO = Directorate: Dam Safety Regulation of the Department of Water and Sanitation (DWS)

- APP submits regular reports to DSO (after each visit to site – usually just a form with photographs)
- APP submits operation and maintenance (O&M) manual & emergency preparedness plan (EPP) and **license application** to impound water to the DSO
- DSO evaluates, ask for improvements / clarifications (if necessary) and then issues license to impound
- APP submits a **completion report** and application for registration (a form) to the DSO
- DSO registers dam (on its DSO database)

► What happens in the case of an existing dam or reservoir?

DSO = Directorate: Dam Safety Regulation of the Department of Water and Sanitation (DWS)

- DSO verifies that dam (or reservoir) is / has not yet been registered
- Classification – Category I, Category II or Category III (owner can appeal and ask for reclassification)
- DSO informs owner of requirement of 5 yearly dam safety evaluations for Category II and Category III dams
- If a Category II or Category III dam Approved Professional Person (APP) appointed by owner for the DSE
- APP inspects and submits a DSE report to the owner and DSO
- DSO evaluates the DSE report and comments, requests amendments or improvements (if necessary)

► What happens in the case of an existing dam or reservoir (continued)?

DSO = Directorate: Dam Safety Regulation of the Department of Water and Sanitation (DWS)

- DSO accepts the DSE report and requests the owner to implement recommendations (made in the DSE report) and to **report on the status of** implementation of the recommendations (Form DW19 and letter)
- Owner implements recommendations and submits a report (or reports) to the DSO
- DSO **sends out reminders if report(s) on implementation** of the recommendations are not submitted
- DSO reminds the owner of the requirement for the next 5 yearly DSE for a Category II or Category III dam

Paradigm shift with respect to large (or mega) dams in RSA

Era of construction of large (mega) dams in RSA is over – not for large r.c. water retaining structures



- Few new large dams being constructed in RSA.
- Many dams constructed in the 1970's, hence several are reaching their 50th anniversary.
- (Big) Shift in dam and reservoir engineering toward maintenance and rehabilitation.
- Extending the lifespan of existing dams (and r.c. reservoirs?)
- Addressing previous:
 - Poor design
 - Poor construction
 - Poor materials
 - Poor maintenance (*exceptionally poor*)

Reinforced concrete water retaining structures (1)

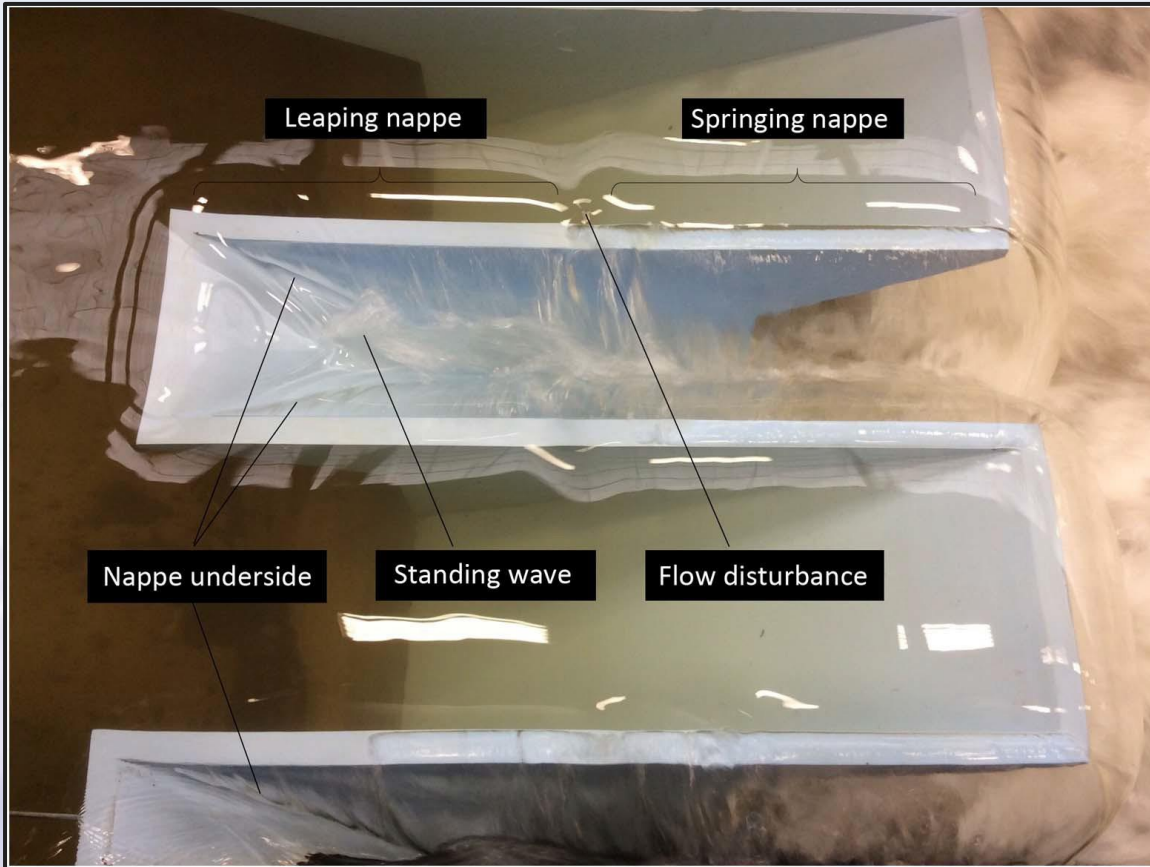
Design, construction, materials and related listed in the dot (•) points below (except last) addressed in detail in codes, literature and reports elsewhere as well as "The role of concrete in water-retaining structural design", Matteo Angelucci – Zutari (Pty) Ltd @ C&CA SA (Cape Town: 22 February 2024) and others Cape Town, Durban (28 February 2024) and Johannesburg (29 February 2024)

- Design loads (comment on earthquake and seismic – last dot (•) point below – very important)
- ULS, SLS, T1, T2, aggregate size, cement content (kg/m³) and W/C ratio
- Cover, reinforcing steel, spacing, crack width(s) "w" and limiting crack width design (C_w)
- Cements, additives, blenders and AAR, ASR and DET (collectively dealt with as "swelling concrete")
- Earthquake / seismic loading – maps – site specific and **25 km – if happened before will happen again**

(Prof Andrzej Kijko, Annual Meeting SANCOLD, November 2023)

Examples of reinforced concrete water retaining structures (1)

Piano Key Weir (PKW) of Jiji Dam under construction (HJM Burundi) – February 2024 (1)





Examples of reinforced concrete water retaining structures (2)

Vlakfontein Reservoir 210 Ml (Gauteng) – H = 11.8 m - circular post-tensioned (of largest in the world). Sliding joint between - floor slab and wall footing - to take-up thermal and dynamic movements of the reservoir as it fills and empties. Three layers blinding – high water table.



Examples of reinforced concrete water retaining structures (3)

Khutsong Reservoir 30 Ml (Carltonville) — declare as dam with a safety risk? why?

- $H > 5$ m – in the dolomites with many sinkholes
- 450 mm thick raft floor slab
- Can accommodate 5 m wide sinkhole under the floor
- To test design performance, sample beam 59.25 m long, 0.21 m wide and 0.45 m deep cast on-site.
- A single mono strand cable was used to simulate the influence of one cable on the raft floor.



Examples of reinforced concrete water retaining structures (4)

Contermanskloof Reservoir 100 Mℓ (Vissershok near Durbanville, Cape Town)

- (Although) Walls and columns 9 m high
- Defn. in Section 117. (c) (i) NWA height $H = 16 \text{ m} - 19 \text{ m}$
- Size class = Medium ($\geq 12\text{m}$ but $< 30 \text{ m}$)
- Category classification II
- Significance of H in design (stability analyses – various slip circles)



Examples of reinforced concrete water retaining structures (5)

Contermanskloof Reservoir 100 Ml (Vissershok near Durbanville, Cape Town) – inside the reservoir and facility to measure seepage from the underdrains – familiar to all?



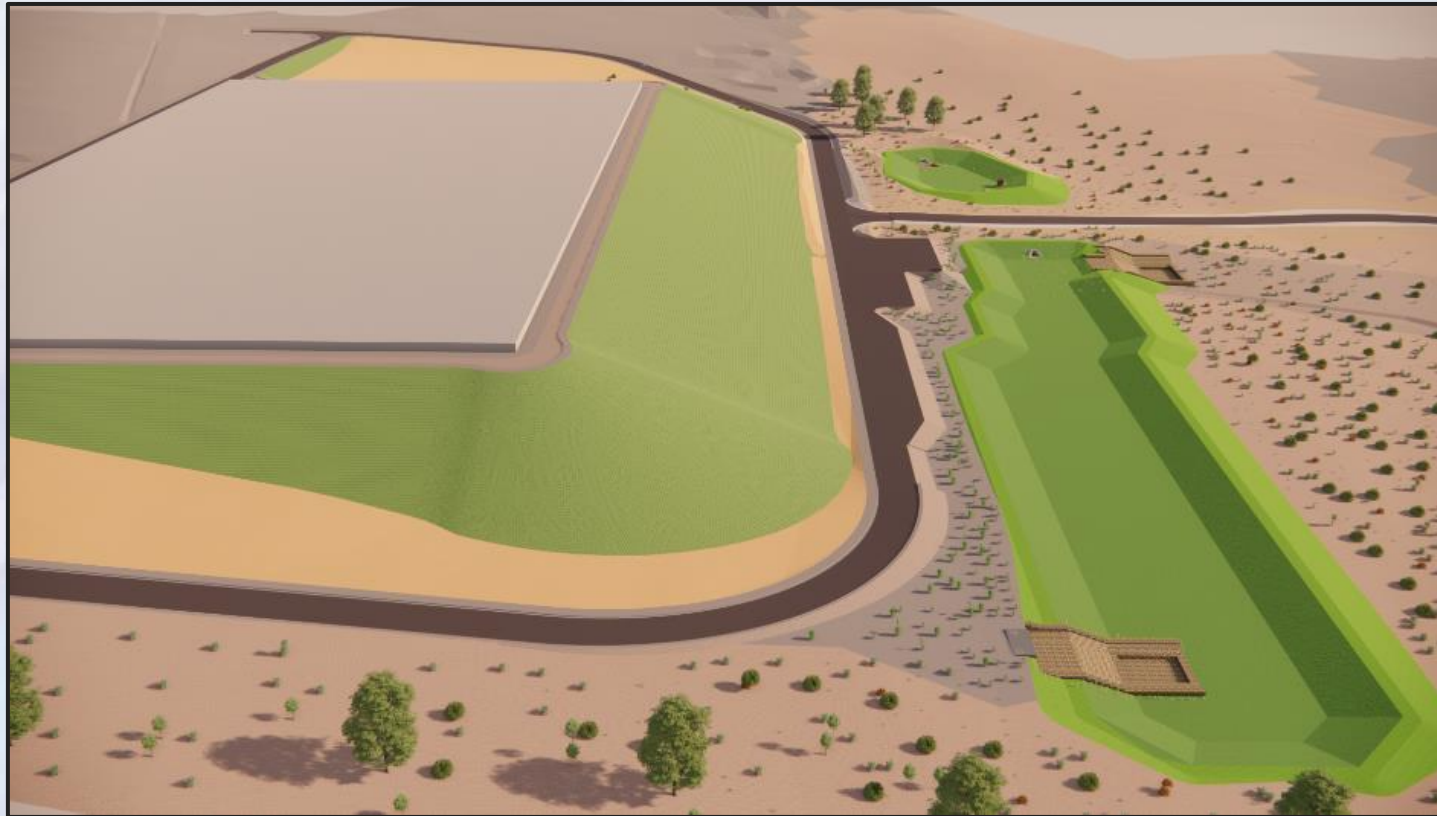
Muldersvlei Reservoir 300 Mℓ proposed (1)

Klapmuts (Cape Town)

- Rectangular footprint approximately 238 m long and 137 m wide with an estimated capacity of 300 Mℓ (300 000 m³)
- Crest length of 776 m and surface area of 3.3 ha
- Embankment consists of a U-shaped homogenous earthfill embankment of imported fill material (± 450 000 m³).
- Volume cut is approximately ± 300 000 m³ (plus) – cannot be used.
- Northern parts in cut, while the southern, eastern and western flanks to be constructed as an engineered fill.

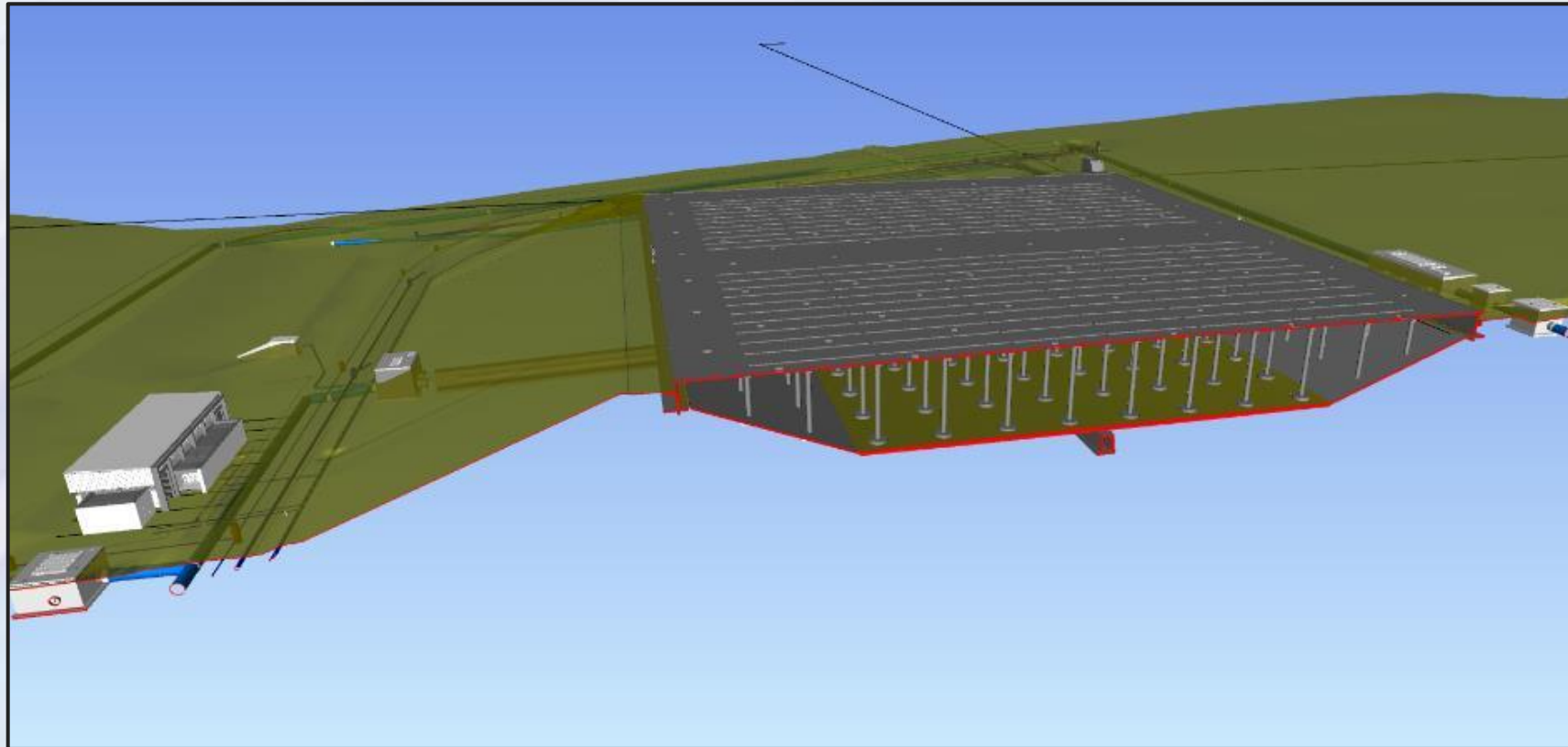
Muldersvlei Reservoir 300 Mℓ proposed (2)

Rendering of the earthworks of the roofed Muldersvlei Reservoir and roadworks



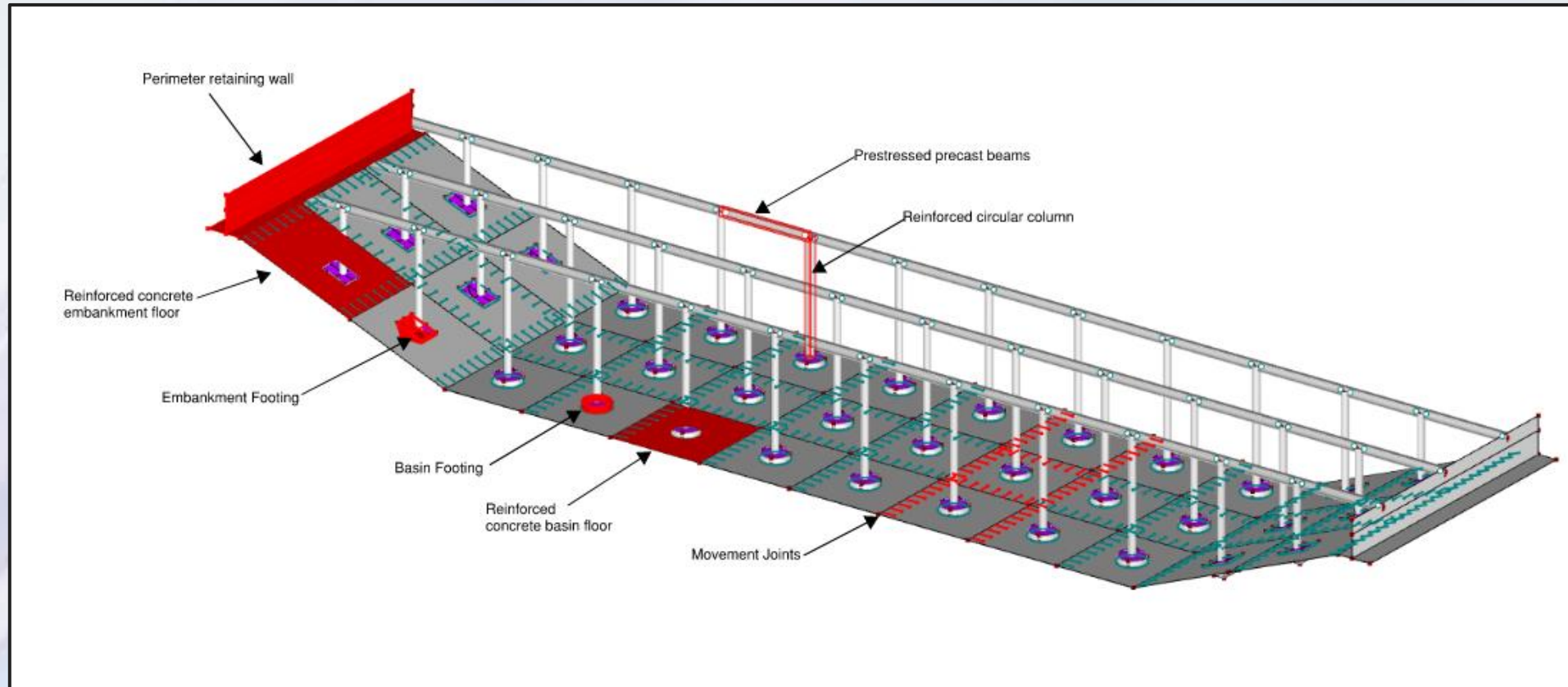
Muldersvlei Reservoir 300 Mℓ proposed (3)

Cross section through embankment and basin showing structural details



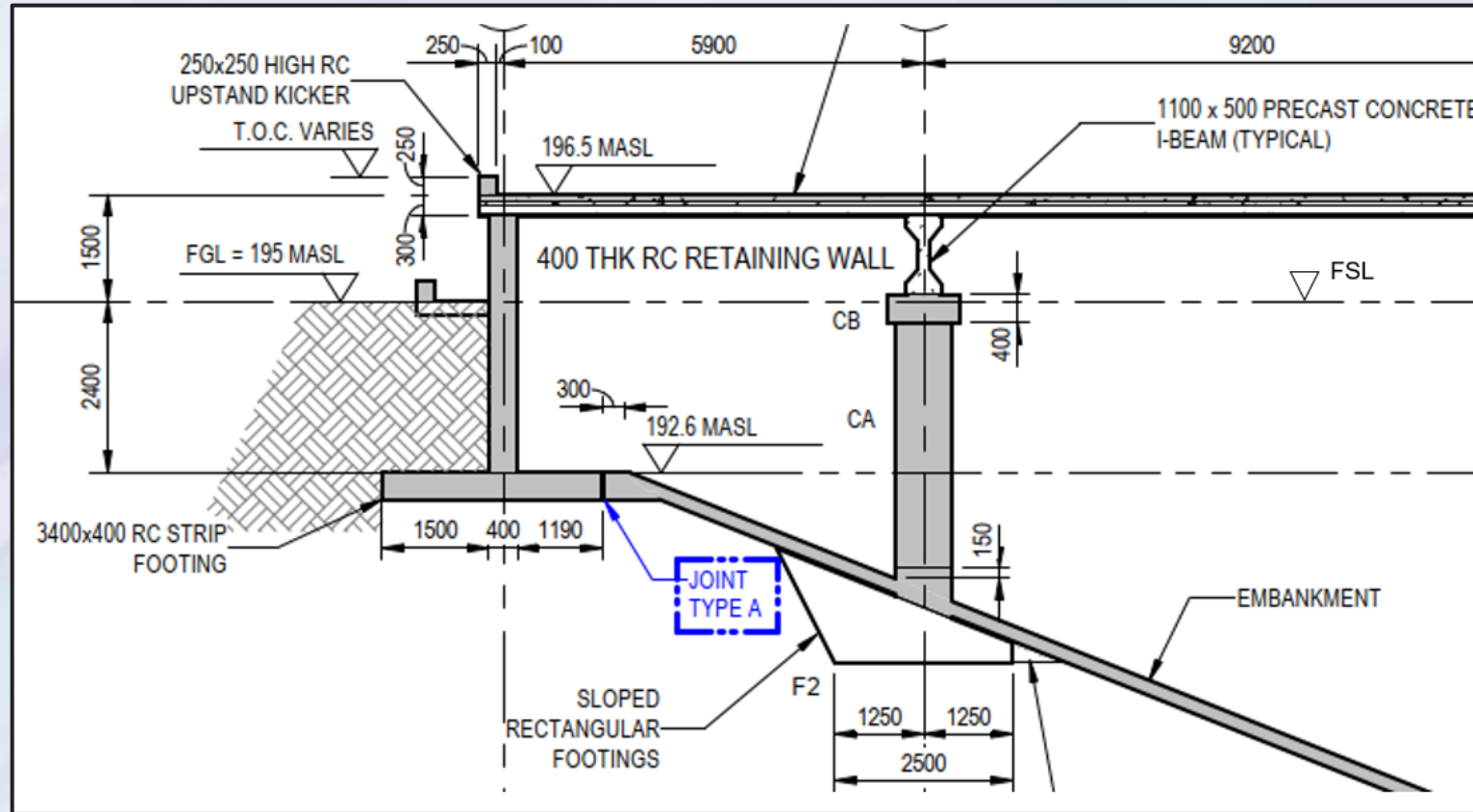
Muldersvlei Reservoir 300 Mℓ proposed (4)

Cross section (numerical analyses - structural and geotechnical – far more than usual!



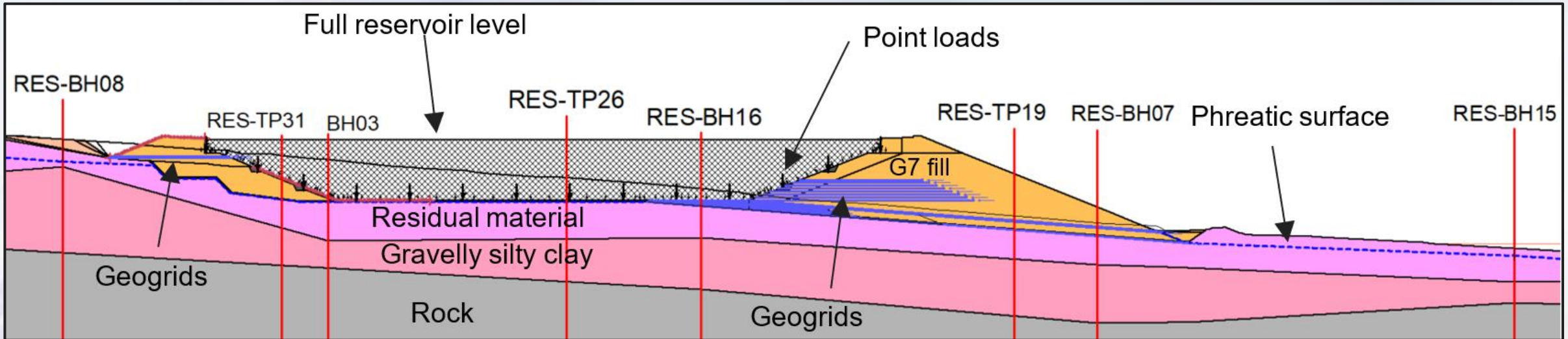
Muldersvlei Reservoir 300 Mℓ proposed (5)

Close up details of the crest wall



Muldersvlei Reservoir 300 Mℓ proposed (6)

Typical cross section of Muldersvlei Reservoir (geotechnical)



▶ AN Other Reservoir and bench marks or "survey monuments" (lost them)

Covered them whilst resealing / covering the entire roof of the reinforced concrete reservoir



► Settlement beacons, reference levels & bench marks or "survey monuments" to monitor settlement at reservoirs

- Very valuable. Important to place accurately & ensure **"permanence"**.
- Often, say (five years down the line), some cannot be located because they have been disturbed or destroyed.
- This renders **"base line"** reference pegs and settlement beacons (or monuments) **"useless"**.
- Be **"extravagant"** – rather have **"too many than too few"!**

▶ AN Other Reservoir and *"survey monuments"* – the reference beacon(s)

Have not lost the reference beacon – however of little help wrt monitoring of historical or previous settlement since completion of construction (very unfortunate)



Settlement beacons, reference levels & bench marks or "survey monuments" to monitor settlement at reservoirs (continued)

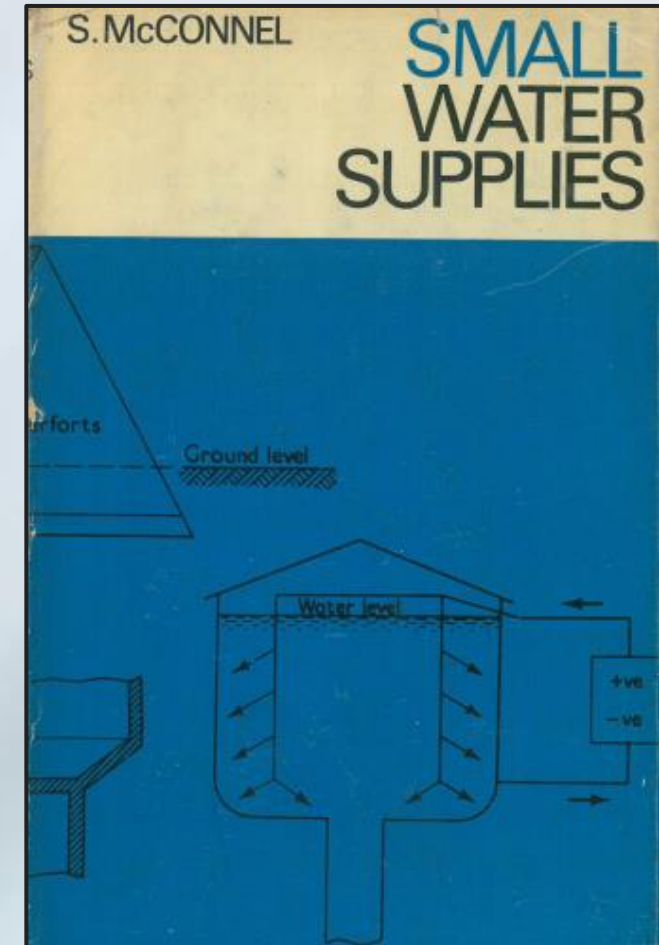


Actually a brass plug and washer. This (and variations thereof) are used all over the world



Recommended reading, literature, reports, theses etc. besides codes (1)

- Small Water Supplies – S. McConnel (1964) – old i.e. 60 years ago - interesting.
- Small Water Supplies – S. McConnel (a book by a South African Engineer – Jhb.)
- The section on reinforced concrete reservoirs (historical and quite classic)
- ***The (or a) sliding joint between floor slab and wall footing*** to take-up thermal and dynamic movements of the reservoir as it fills and empties (as per Vlakfontein Reservoir) discussed / described as far back as 1964. .



Recommended reading, literature, reports, theses etc. besides codes (2)



- AN EIs (1983)
- Operating and maintenance (O&M) manual for 400 Mℓ (400 000 m³) Brakfontein Reservoir (23 September 1999) (Rand Water)
- 2012. (Peter Gage of Jones and Wagener) Structural Cracking, Flexural, Shear and Detailing (CSA).pdf
- 2013. (McLeod Christina Helen MSc Thesis) Inv. into Cracking in Reinforced Concrete Water-retaining Structures.pdf
- 2014. (Barnardo-Viljoen C. et al) Background to the Draft SA National Standard for the design of Water Retaining Structures (138).pdf
- 2015. (David Still and Andrew Butler) FERROCEMENT RESERVOIRS - A South African Perspective (TT 499-11).pdf
- 2015. (Duvenhage P. MSc Thesis) Developing a Method for Prioritising Maintenance for Reinforced Concrete Reservoirs.pdf
- 2015. (Viljoen C.) Compilation of a National Standard for design of Liquid Retaining Structures. Vol. I - SANS 10100-3 (WRC Rep No. 2154 -1-15).pdf
- 2016. (Sollero M. and Bollerini H.) Invest. and diagnosis of a rc reservoir with intense crack formation from several sources.pdf

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We owe it to ourselves and to the next generation(s) to conserve the environment so that we can bequeath our children a sustainable world that benefits all.

WANGARI MAATHAI

ZUTARI

CONCRETE WORKING FOR WATER – FEBRUARY 2024