THE INITIATION OF A NATIONAL FLOOD STUDIES PROGRAMME FOR SOUTH AFRICA

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ABSTRACT

Estimates of design floods are required for the design of hydraulic structures (e.g. dam spillways, waterways, culverts) and to quantify the risk of failure of the structures. Most of the methods currently used for design flood estimation in South Africa were developed in the late 1960s and early 1970s and are in need of updating with more than 40 years of additional data currently available and with new approaches used internationally. The South African National Committee on Large Dams (SANCOLD) has identified the urgent need to update the data and methods used for design flood estimation in South Africa and has initiated a National Flood Studies Programme (NFSP) to update these. Working groups focussing on Rainfall, Flood Analysis Methods, Data and Products have been established to identify and prioritise research needs and this presentation will present the background to the NFSP and output from the working groups.

1. INTRODUCTION

Estimates of design floods are required for the design of both small (e.g. culverts) and large (e.g. hydraulic structures (e.g. dam spillways) in order to quantify the risk of failure of the structures (Smithers, 2012; Van Vuuren *et al.*, 2013). Most of the methods currently used for design flood estimation in South Africa were developed in the late 1960s and early 1970s and are in need of updating with more than 40 years of additional data currently available and with new approaches used internationally (Smithers, 2012; Van Vuuren *et al.*, 2013).

The need to revise existing and develop for new approaches to design flood estimation in South Africa are highlighted by Alexander (2002b), Smithers and Schulze (2003), Görgens (2007), Smithers (2012) and Van Vuuren *et al.* (2013). Alexander (1990) emphasises the need for consistency in design flood estimates, i.e. different users should obtain the same results for the same location. However, there is still no universally applicable method for design flood estimation in South Africa (Van der Spuy and Rademeyer, 2010) and a range of appropriate methods are generally applied to estimate a design flood at a given site.

The South African National Committee on Large Dams (SANCOLD), in conjunction with the Water Research Commission (WRC), has identified the urgent need to update the data and methods used for design flood estimation in South Africa and has initiated a National Flood Studies Programme (NFSP) to update these. Working groups focusing on Rainfall, Flood Analysis Methods, Data and Products have been established to identify and prioritise research needs. The objective of this paper is to provide some background to the formation of the NFSP, activities of the NFSP to date and to report on research priorities.

2. BACKGROUND

Given the need to update methods used for design flood estimation in South Africa, the WRC appointed the University of Pretoria to review the current flood estimation methods and to provide some guidance for research needed to improve, extend and update the flood estimation procedures. This resulted in the publication of a report on the "Status Review and Requirements of Overhauling Flood Determination Methods in South Africa" by Van Vuuren *et al.* (2013).

2.1 Status Review and Requirements of Overhauling Flood Determination Methods in South Africa

The deliverables of the project undertaken by Van Vuuren *et al.* (2013) were:

(i) A report reflecting the status quo of flood determination procedures and a reference list of available flood studies in South Africa.

(ii) Prioritisation of research and required updates for flood determination procedures in South Africa.

Van Vuuren *et al.* (2013) noted that most of the methods used to estimate design floods in South Africa were developed prior to 1990, for examply by HRU (1972), Hiemstra and Francis (1979), Schmidt and Schulze (1987), with more recent developments by Alexander (2002a), Görgens (2007) and Nortje (2010). A general shortcoming of most methods is the limited period of data used in their development and which did not include the severe weather incidences of the 1980s and the recent floods (Van Vuuren *et al.*, 2013). According to Van Vuuren *et al.* (2013), the use of extended record lengths may impact on: (i) the estimation of design rainfall, (ii) that antecedent moisture conditons in the catchment may need to be taken into account in some circumstances, (iii) refinement of similar hydrological response zones, and (iv) enable the estimation of higher return design events.

The three principal flood frequency estimation approaches are (Van der Spuy and Rademeyer, 2010; Smithers, 2012; Van Vuuren *et al.*, 2013):

(i) statistical analysis of observed flood data,

(ii) deterministic methods, where the statistical properties of the flood are assumed to be the same as that for the storm rainfall, which is then used in more complex conceptual rainfall-runoff models; and

(iii) empirical methods, or experience diagrams, where mathematical models are developed to fit the available data.

The approaches used to estimate design floods estimation in South Africa are summarised in Figure 1. Empirical methods are derived from observations and catchment characteristics and are more suited to check the order of magnitude of the results obtained by means of the other methods (Van Vuuren *et al.*, 2013). Deterministic methods generally assume that the exceedence probability of the runoff is the same as the exceedence of the causative rainfall which assumes that the catchment has to be in "average" conditions to produce the design flood event (Van Vuuren *et al.*, 2013).

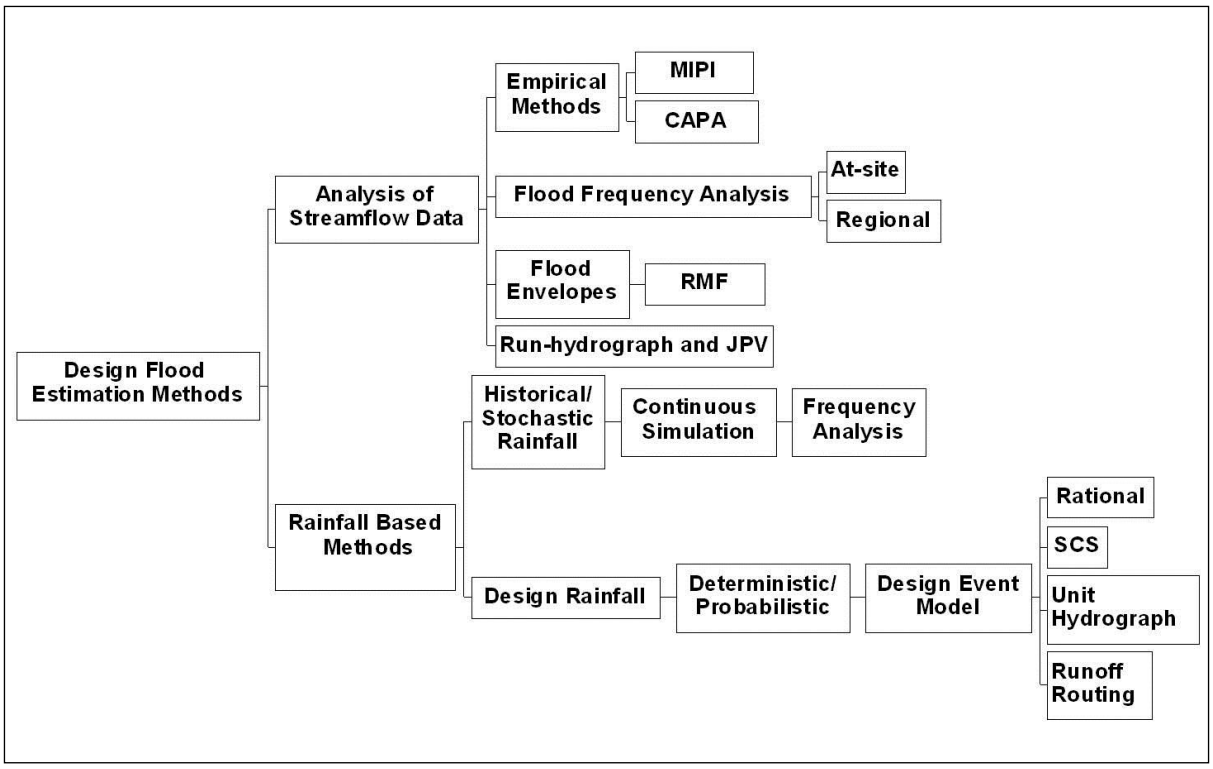

Figure 1 Approaches to design flood estimation in South Africa (after Smithers and Schulze, 2001)

Van Vuuren *et al.* (2013) estimated the percentage of currently available data which were used in the development of the design flood estimation methods, as summarised in **Table 1**. **Table 1** also includes recommendations made by van Vuuren *et al.* (2013) to improve the flood estimation procedures in South Africa.

A survey of practitioners was performed by van Vuuren *et al.* (2013). The questions were related to the years of experience, qualifications, catchment sizes, methods used to estimate design peak discharges and flood volumes, type of projects undertaken, and perceived focus for future research for flood estimation. The results from the questionaire indicated that:

(i) The majority of the respondents were inexperienced, with the majority (46%) having less than 5 years experience.

(ii) Most of the respondents (54%) had a formal qualification (BTech or BEng degree).

(iii) The majority of the catchments (55%) for which flood estimations are conducted are relatively small (<15 km^2).

(iv) Deterministic approaches were the most commonly used methods for catchment areas up to 5000 km^2.

(v) The Rational and Alternative Rational Method were the most widely used (54%) procedure for the estimation of flood peaks followed by the Unit Hydrograph Method (15%).

(vi) The Regional Maximum Flood (RMF) procedure is the most commonly used (90%) empirical procedure to estimate extreme flood events.

(vii) The Log Normal distribution was the most used probability distribution (41%).

(viii) The majority of floods were used in the design of culverts (31%), followed by the estimation of floods in conveyance systems (25%) and design of spillways (23%).

(ix) A triangular shape hydrograph was used by the majority of the respondents (55%) to estimate flood volumes.

Table 1 Currently available data not used in the derivation of the design flood estimation methods and recommendations to improve the methods (Van Vuuren *et al.*, 2013)

Method	Currently Available Data Not Used in the Derivation (%)	Recommendation
Unit Hydrograph (HRU, 1972)	67	Review regional boundaries and method using available data
Run Hydrograph (Hiemstra *et al.*, 1976; Hiemstra and Francis, 1979; Hiemstra, 1981)	67	Review veld type zones and update with longer flow records
SCS-SA (Schmidt and Schulze, 1987)	18	Based on recommendations by Smithers (2012): Improved regionalisation, method to account for antecedent moisture conditions, update use continuous simulation modelling
JPV (Görgens, 2007)	10	Procedure should be reviewed on a refined regional selection basis and further developed for use by practitioners
SDF (Alexander, 2002a)	32	Catchment boundaries to be reviewed, increase number of regions, include uncertainty and update methods using available data
RMF (Kovacs, 1988)	37	Use longer data records to refine areas with similar flood producing characteristics
Empirical procedures		Delineation of homogeneous flood regions and need to update or replace methods
REFFSA Method (Nortje, 2010)		Update data and method and evaluate in other regions
Regional Flood Frequency Analysis method (new)		Development of flood peak growth curves and methods to estimate index floods
Direct Frequency Analysis		Investigate use of L-moments for distribution fitting and develop methods to account for non-stationary data. Include palaeoflood data

Van Vuuren *et al.* (2013) made the following recommendations:

(i) All institutions responsible for the maintenance, verification and updating of hydrological data should be reinforced.

(ii) The training and building of human resource capacity.

(iii) Review the design storm relationships for different recurrence intervals and duration using longer record periods.

(iv) Review the number of homogeneous flood regions in South Africa using the longer periods of records.

(v) Assessments of catchment response to rainfall by the implementation of continuous monitoring networks.

(vi) Regions and relationships for the extreme events (RMF) be reviewed.

(vii) Palaeofloods should, where possible, be included in the estimation of design flood peaks.

(viii) The investigation of the application of the REFSSA procedure in different/other K-flood regions.

(ix) Refined regionalisation for the application of the JPV relationships.

(x) Research into the influence of antecedent conditions of catchment response.

(xi) A review of the influence of urban development on catchment response (runoff peaks and runoff volume).

(xii) A review of the regions of the SDF procedure and the re-calibration of the relationships for predicting the floods.

(xiii) Investigation into the apparent inconsistency in the volume of the design flood and volume of design rainfall over a catchment.

(xiv) Introduce bench mark catchment data sets which can be used to improve understanding and evaluate the methods.

(xv) The application of the various methods by practitioners should produce consistent results for a selected method and site.

(xvi) Given the importance of flood risk management, the shortcomings of the methods currently used by practitioners and potential impact of climate change, a NFSP should be developed to significantly improve the quality and capability of flood estimation for flood risk management in South Africa.

2.2 Establishment of the National Flood Studies Programme

Following the publication of the report on "Status Review and Requirements of Overhauling Flood Determination Methods in South Africa" by Van Vuuren *et al.* (2013), a workshop was convened jointly by the WRC and SANCOLD and held in Pretoria on 16 May 2013. Of the 30 delegates invited, the workshop was attended by 22 delegates from a range of organisations in South Africa. The workshop considered the recommendations made by Van Vuuren *et al.* (2013), revised these and recommended five Working Groups (WGs) focusing on the following aspects:

(i) rainfall analysis,

(ii) flood analysis,

(iii) hydrological data,

(iv) products used for flood estimation,

(v) institutional contribution and commitment to flood estimation.

Recommendations were made at the workshop for members to serve on WGs (i) to (iv) listed above. The membership for WG (v) was to be nominated from various institutions and has not been formed yet.

3. FUNCTION AND COMPOSITION OF WORK GROUPS

3.1 Composition

The members of the WGs are expected to be experienced professionals in the topic to be dealt with by the WG. The members nominated by SANCOLD are to be convened by the identified convenor and to

elect a chair from within their midst and to recommend other professionals to be added to the group. To date, the convenors have acted as interim chairs of the WGs.

3.2 Objectives

Following the guidelines provided by SANCOLD, a WG is expected to:

(i) Ensure the appropriate scope and timing (sequencing) of the tasks and research commissioned for the topic of the WG as part of the NFSP.

(ii) Advise the SANCOLD Management Committee on requirements of time and budget.

(iii) Advise the SANCOLD Management Committee on the adequacy of the outcomes of completed tasks and research.

3.3 Functions

To achieve the objectives the WG is expected to:

(i) Formulate the scope of various tasks and research based on the recommendations in the final Flood Studies report and the discussions at the Workshop on 16 May 2013.

(ii) Liaise with other WG's on the required timing of various tasks to ensure the correct sequencing in order to optimise the time to final completion of the NFSP.

(iii) Prepare a budget and cash flow projection to complete all tasks.

(iv) Liaise with the WRC to identify the most appropriate institutions/individual professionals to be contracted for different tasks.

(v) Liaise with the WRC to identify the most appropriate professionals to be appointed to the Steering Committee responsible for the quality of the different research contracts.

(vi) Assess the adequacy of research findings and advise the Management Committee accordingly.

(vii) Oversee drafting of reports on findings for release to professionals.

It was envisaged that once the National Flood Studies Programme Management Committee has been established, the Working Groups are to report to that body.

4. PROGRESS TO DATE

The target date for an initial feedback report from the WGs to the SANCOLD Management Committee was set for the end June 2013. However, with no management committee established or leadership appointed by SANCOLD, the NFSP initiative was largely dormant until the appointment by SANCOLD of Prof Jeff Smithers to lead and revive the NFSP in March 2014. The composition of the operational WGs, which were based on the recommendations from the workshop with some changes based on membership availability to contribute, is listed in Table 2.

Table 2 Membership of the NFSP working groups

Working Group	Member	Organisation
Rainfall	Prof Jeff Smithers (convenor)	Univ. of KZN, Jeffares & Green
	Mr Eugene Poolman	SAWS
	Dr Kobus Du Plessis	Univ. of Stellenbosch
	Dyson, Lizel	SAWS
	Dr Dennis Dlamini	DWA
	Mr Chris Kaempffer	ARC
	Prof Geoff Pegram	Pegram & Associates
Data	Mr Verno Jonker (convenor)	Aurecon
	Mr Danie Van der Spuy	DWA
	Mr Eugene Poolman	SAWS
	Mr Pieter Rademeyer	DWA
Analysis/Methods	Dr André Görgens (convenor)	Aurecon
	Prof Jeff Smithers,	Univ. of KZN, Jeffares & Green
	Mr Danie Van der Spuy	DWA
	Prof Fanie Van Vuuren	Univ. Pretoria
	Dr Kobus Du Plessis	Univ. Stellenbosch
Products	Mr Jaco Gericke (convenor)	Central Univ. of Technology
	Dr André Görgens	Aurecon
	Mr Danie Van der Spuy	DWA
	Mr Louis Hattingh	Hattingh Anderson Associates
	Mr Marco van Dijk	Univ. Pretoria
	Mr Stefan van Biljon	Retired / DWA

5. PRIORITISED AREAS OF RESEARCH

To date, the WGs have interacted electronically to:

(i) refine or add research topics to those proposed by the workshop,

(ii) prioritise the deliverables (High, Medium or Low),

(iii) estimate the project start date and duration,

(iv) estimate the category of funding (< R 100 000, R 100 000 to R 500 000, > R 500 000) required for each deliverable,

(v) provide a brief description of the deliverable, and

(vi) provide the current status of research for each deliverable.

5.1 Rainfall Analysis

The submission of the Rainfall Analysis WG is contained in Table 3.

Table 3 Submission of the Rainfall Analysis WG

Topic	Deliverable	Priority	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Requirement	Status	Ranking
A.1.1.1 Spatial and Temporal distribution of available rainfall data	Inventory and distribution of available daily and sub-daily rainfall data in South Africa	H	1	2013/4	100 - 500	Update/create database of daily and continuously recorded rainfall (location and period of available record), source and availability, i.e. update from SAWS, ARC, Smithers and Schulze (2003), Lynch (2004)	• Information of daily rainfall available from MAP map project undertaken by Pegram & Associates. • Information on availability and distribution sub-daily rainfall still needs to be updated	1
A.1.1.2 ARF's (Convert point rainfall data to catchment rainfall)	Updated ARFs for use in South Africa	H	1-5	Started	100 - 500	Develop and evaluate areal reduction factors to convert point rainfall to areal rainfall	• Postgraduate study started at CUT • Postgraduate study started at Univ. Stellenbosch	5
A.1.1.3 Extend the patched rainfall database	Updated daily rainfall database for South Africa	H	1-5	2013/4	> 500	Infill missing/ erroneous data from 2000 to present and add	MAP map project started by Pegram & Associates Output:	2

Topic	Deliverable	Priority	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Requirement	Status	Ranking
						to Lynch (2004) database	• Daily rainfall 1'x1' gridded surfaces from 1950 • MAP surfaces • Remotely sensed 3 h rainfalls from 2000 will be corrected and disaggregated Completion: March 2016.	
A.1.1.4 Assemble existing short duration rainfall data (L)	Updated sub-daily rainfall database for South Africa	M	1-5	2014	100 - 500	Collate and error check continuously recorded rainfall data		3
Extreme rainfall (T > 200 year)	Update envelope of maximum rainfall (Probable Maximum Precipitation)	H	1	2014	< 100	Current SANCOLD guidelines for estimation of PMF are dependent on PMP, hence need to update these for use until AEP related floods used for Recommended and Safety Evaluation floods for dam spillways	No update since Wits HRU 1/71 report	7

Topic	Deliverable	Priority	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Requirement	Status	Ranking
	Estimate design rainfall for T>200 years	H	1-3	2014	> 500	Cullis *et al.* (2007) recommendations to move to high return period floods for dam designs to T > 200 years, hence need to estimate design rainfall for T > 200 years	Smithers and Schulze (2003) estimate design rainfall up to T=200 years. Need to extend this to $T=10^6$ years	4
Design rainfall estimation	Update design rainfall for all durations (daily and sub-daily)	M	1-3	2014	> 500	More than 10 years of additional rainfall data available since the Smithers and Schulze (2003) study	-	4
	Account for climate change in design rainfall estimation	M	1-3	2014	100-500	Previous studies in SA have assumed a stationary climate - need to update method to account for trends in extreme rainfall events in a changing environment	-	6

5.2 Flood Analysis

The submission of the Flood Analysis WG is contained in Table 4.

Table 4 Submission of the Flood Analysis WG

Research Theme	ID No and Research Topic	Description	Priority	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Status	Proposed Ranking
Catchment data	A.1.2.3 Improve flood data-base for RSA and neighbouring countries.	Review and extend stage-discharge relationships for strategic streamflow gauging stations and re-calculate/estimate missing historically measured flood discharges, both at-site and at upstream and downstream gauges.	H	3?	2015?	>500		1
	A.1.2.1 Refine catchment response-time formulas.	Review and refine different methods for the calculation of catchment response-times (SCS Lag, T_c , T_L, etc.) in South Africa.	H	2?	2016?	100-500	Postgraduate study started at UKZN	4
Probabilistic design flood methods	A.1.2.2 Guide for annual exceedence probability distributions for floods.	Review different annual exceedance probability distributions for floods and develop a guide for the selection of the most applicable distributions and parameter estimation methods for southern Africa.	H	2?	2015?	100-500		2
	A.1.2.6 Refine regionalised / pooled Index Flood methods.	Refine and extend the application of regionalised/pooled Index Flood methods in southern Africa.	H	1-5	2015?	> 500	Postgraduate study started at UKZN	1

Research Theme	ID No and Research Topic	Description	Priority	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Status	Proposed Ranking
	Develop a fully probabilistic Joint Peak-Volume method.	Render the existing JPV method fully probabilistic by means of bivariate Copula probability theory and refine its regionalisation.	H?	2-3	2015?	> 500		1
Extreme design flood methods	Modernise and refine the existing SANCOLD Guidelines SUH-based PMF method.	Develop PMP isohyets for southern Africa as per the updated WMO method, refine and regionalise existing empirical minimum storm rainfall losses and implement new refined SUHs.	H?	2	2016?	100 - 500		2
	1.2.7.1 and 1.2.7.3 (Part 1) Update and refine the RMF method and its regionalisation.	Update the Kovacs historical maximum flood peak database with latest flood peak measurements and with a re-regionalisation of RMF K-values according to measurable bio-geo-climatic-relief rationales.	H?	2	2015?	100-500	Postgraduate study started at Univ. Stellenbosch	1
	A.1.2.7.2 Approach 1: Develop station-year-based annual exceedence probability methodology for extreme floods.	By consolidating large annual maximum flood peak samples of about 1000 station-years, according to spatially extensive homogeneous flood regions, high-RI flood peaks, or the RIs of empirically/ deterministically determined PMFs and RMFs, can be estimated by conventional regionalised/ pooled Index Flood methods.	H?	3	2015?	> 500		1

Research Theme	ID No and Research Topic	Description	Priority	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Status	Proposed Ranking
Empirical & deterministic design flood methods: <=1:200 year RI floods	A.1.2.8.1 Modernise Rational Method runoff coefficients.	Review runoff coefficients for different catchment types.	L	1-5	2018	> 500		4
	A1.2.8.2 and A.1.2.8.3 Modernise the Standard Design Flood (SDF) method.	Update and modernise the SDF methodology once the findings and deliverables of the Research Topics A.1.2.2 and A.1.2.6 become available. This could include additional catchment descriptors beyond the currently used "Area and T_c ".	H	1-5	2017?	> 500	Postgraduate pilot study started at UKZN	1
	A.1.2.8.4 Update and modernise the SCS-SA method.	Combined with Research Topic A1.4.1, review and modernise the application of the SCS-SA method for urban areas and integrate into SWMM, if feasible.	H	1-5	2016?	> 500	Postgraduate pilot study started at UKZN	3
	A.1.2.8.5 and A.1.2.4 Modernise existing Synthetic Unit Hydrographs and related “homogeneous” flood regions.	Modernise the Synthetic Unit Hydrographs of HRU 1/72, including re-working of average storm loss relationships and re-delineation of "homogeneous" flood-producing regions.	H	1-5	2015?	> 500		2
	A.1.2.8.6 Modernise existing empirical methods for small catchments.	Modernise existing empirical procedures for flood estimation and develop new methods for smaller rural and urban catchments.	H	< 1	2016	100-500		4

Research Theme	ID No and Research Topic	Description	Priority	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Status	Proposed Ranking
Combined empirical-deterministic-probabilistic methods	A.1.3.1 Refinement of existing Joint Peak-Volume method.	Refine the existing JPV method on the basis of a new delineation of "homogeneous" flood-producing regions and re-worked dimensionless observed flood hydrographs.	H	1-5	2015	> 500		2
	A.1.2.7.3 (Part 2) Update Q_T/Q_{RMF} ratios.	Re-work Q_T/RMF ratios on the basis of the outcomes of Research Topics A1.2.2, A1.2.6, A1.2.7.1 and A1.2.7.3 (Part1).	H	1-5	2016?	> 500		3
	A.1.2.7.2 Approach 2: Further develop REFSSA annual exceedance probability methodology for extreme floods.	Refine and spatially extend the REFSSA method by use of the updated RMF-related maximum flood database for southern Africa of Research Topic A.1.2.7.3.	H	2?	2015?	100-500		2
	A.1.2.5 Refine continuous hydrograph simulation methods.	Refine the application of continuous rainfall-runoff modelling (e.g. the ACRU model), including stochastic rainfall inputs, to develop Index Flood growth curves and related confidence levels for different regions of southern Africa.	H	1-5	2015?	100-500	Postgraduate pilot study started at UKZN	2
Urban stormwater methods	A.1.4.1 Research on urban development impacts pre- and post-development.	Combined with Research Topic A.1.2.8.4, do field research on storm runoff coefficient changes when undeveloped sub-catchments are urbanised.	H	1-5	2016?	100-500		3

5.3 Hydrological Data

The submission of the Hydrological Data WG is contained in **Table 5**.

Table 5 Submission of the Hydrological Data WG

Research Topic	Deliverable	Priority (H/M/L)	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Requirement	Status	Proposed Ranking
A.1.2.3: Spatial and temporal distribution of available stream flow data	Updated inventory of stream flow data in South Africa	H	0.5	2014 / 2015	100 - 500	Update/create geospatial database of stream flow gauging stations including dams. Attribute data at each gauge to include station no, type, river name, coordinates, status, catchment area, custodian, record period, number of times structural and DT limits exceeded, strategic importance i.t.o. NFSP, assessment of historically measured flood discharge data quality.	Information on DWA stations available on DWA website. Quality codes available on DWA website.	1
							Regional DWA Office staff often has good local knowledge on station performance.	
							Assessment of stations often done as part of planning studies.	
							Use stations from previous key reference studies (e.g. HRU 1/72, TR 137, JPV) as basis when identifying strategic NFSP stations.	
							DWA currently developing in-house software to extract relevant attribute data from stream flow database.	

Research Topic	Deliverable	Priority (H/M/L)	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Requirement	Status	Proposed Ranking
							Include dams where flood back routing calculations have been done as well as other key dams. Also consider municipal dams.	
A.1.2.3 & A.1.?.3: Improve flood database	Updated flood hydrograph and maximum flood peak database at strategic stream flow gauging stations	H	2 - 3	2015	> 500	Validate recorded data and re-calculate/estimate missing/erroneous historically measured flood discharges at strategic NFSP stations by extending stage-discharge relationships / by undertaking flood back routing through dams. Patch both flood peaks and flood hydrographs (volumes).	DWA currently compiling AFP info on all dams. 118 dams completed to date.	2
A.1.2.7.3: Update Kovacs historical maximum flood peak database	Updated historical maximum flood peak database	H	0.5	2015	100 - 500	Ensure that catchment sizes ranging from 10 km^2 to 20 000 km^2 are adequately represented in database. List three highest flood peaks at each site.	DWA have started with a flood catalogue of three highest recorded flood peaks at selected dams and flow gauging stations. Use output of research topic A.1.2.3	3

Research Topic	Deliverable	Priority (H/M/L)	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Requirement	Status	Proposed Ranking
A.1.2.7: Compile palaeoflood database	Estimates of flood discharges based on palaeo-stage indicators	L	1 - 5	2016	> 500	Initiate a systematic research project to obtain palaeoflood records for the larger rivers in RSA		4

5.4 Products Used For Flood Estimation

The submission of the Products WG is contained in **Table 6**.

Table 6 Submission of the Products WG

Topic	Deliverable	Priority	Expected duration of Study (Years)	Starting Time	Estimated Funding Required (Rx1000)	Requirement	Status	Ranking
C.1 SWMM-Urban Urban distribution	Temporal rainfall distributions for urban areas- To be incorporated in stormwater management models, e.g. SWMM	H	< 3	2016	> 500	Improved regionalised rainfall distributions	RLMA&SI Approach (Smithers & Schulze, 2003) is available	2
C.2 Web-based Framework of methods on SANCOLD web-site	Web-based Framework similar to the "Dam Safety Hydrology Toolbox" as developed under WRC Project K5/1420	M	2	2019	< 500	Create a web-based database which consolidates all the Rainfall and Flood WGs' outputs, along with user-friendly software containing a suite of (updated)	Design flood estimation software developed by Van Dijk (2005, UPFLOOD) and Gericke (2010, DFET) are available, but needs further refinement and needs	5

						nationally/internationally used design flood estimation methods.	to be consolidated into a single package/ form part of a web-based Framework, e.g. Dam Safety Hydrology Toolbox (WRC Project K5/1420)	
C.3 Catalogue of extreme hydrographs T=10	Catalogue/ database of extreme hydrographs similar to the information as contained in WRC Report 1420/3/07	M	> 1	2017	< 500	Extreme flood hydrographs and their associated characteristics (e.g. volume, peakflow, time to peak, baselength, etc.) needs to be extracted from the DWA primary flow data sets.	Görgens *et al.* (2007, WRC Report 1420/3/07) developed EX-HYD software to extract flood hydrographs. No separation of baseflow and direct runoff currently possible.	3
C.4 Updated catalogue of recorded maximum flood peaks	Catalogue/ database of maximum flood peaks (Based on the results from the Floods WG; "A1.2.3 Review and extension of discharge rating tables at strategic flow-gauging stations")	H	< 2	2016	< 500	Successful completion of Floods WG Item A1.2.3	-	1
C.5 “Catalogue” of large-area extreme storm isohyetal maps	Catalogue/ database of large-area extreme storms similar to information as contained in WRC Report 1420/2/07	M	< 3	2016	> 500	A collection large-area extreme storms must be published based on all available data	WRC Report 1420/2/07	4
C.6 Web-based GIS database/geodatabase	GIS database/geodatabase containing all the relevant spatial feature classes relevant to flood hydrology/ water resources management	H	< 3	2016	> 500	Create a web-based GIS database which consolidates all the spatial information on climatological variables, catchment geomorphology, channel geomorphology	Most of the datasets are available, however defragmented between different disciplines and scientific users.	6

						and catchment variables (e.g. geology, soil, land-use and vegetation, SCS hydrological soil groups, veld-type region and Kovacs flood regions)		

6. DISCUSSION, CONCLUSIONS AND THE WAY FORWARD

The urgent need to update and develop new methods for design flood estimation in South Africa is well documented in a number of studies. It is also evident that up to 67% of the currently available data was not available at the time of the development of some of the currently used methods. In addition, new approaches have been developed and are used internationally and the impact of climate change, or dealing with a non-stationary data series, should also be included in the development of new methods for design flood estimation in South Africa.

A wide range of issues have been highlighted for research by the WGs established by SANCOLD. These have been independently prioritised within each WG and some process is necessary to establish priorities across the WGs, as it is anticipated there are not adequate resources or research capacity to tackle all of the issues simultaneously.

SANCOLD and the WRC should be applauded for initiating the NFSP. It is envisaged that the NFSP could deliver coordinated and consistent research output, similar to the Hydrological Research Unit at the University of Witwatersrand output in the 1970's under the leadership of Professor Midgley. However, it is envisaged that NFSP will not be based at a single institution, but will implemented by a coordinated research plan undertaken at multiple institutions in South Africa.

The survey conducted among practitioners revealed the relative inexperience in design flood estimation by many of the practitioners and wide spread use of some of the simpler approaches. The initiation of the NFSP implemented at multiple institutions is an opportunity to grow research capacity and to train future practitioners through postgraduate research and to develop reliable and consistent methods of estimating design floods in South Africa. However, the critical aspect of funding to drive the NFSP is needed and it is hoped that institutions such as the DWA and the WRC will direct funds for research in order to operationalise the NFSP.

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