A Review of the

Severe Weather Forecasting Demonstration Project (SWFDP)

prepared by

Richard Young, MSc, MBA, CMet,

Independent Consultant to WMO,

and formerly of

United Kingdom Met Office, UKMO

Addressing Resolution 1 of EC-70

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"This report is dedicated to the memory of Eugene Poolman who led the development of the first SWFDP project in Southern Africa and served for many years on the Steering Group of the SWFDP. His wise council and his willingness to share his experience were instrumental to the worldwide growth and success of the SWFDP."

Executive Summary

WMO Resolution 1 (EC-70) requested that *independent* reviews of the Severe Weather Forecasting Demonstration Project (SWFDP), the Flash Flood Guidance System (FFGS), and the Coastal Inundation Forecasting Demonstration Project (CIFDP) be carried out. The rationale for these reviews was to assess both the benefits and sustainability of these programmes; further details are contained within the Resolution, which can be found in Appendix 6. It further decided that these 3 separate reviews should subsequently be taken together in a consolidated approach, to ensure that future services related to hazardous weather, water and climate were conducted in an efficient and sustainable manner. The independent review of SWFDP ("Phase A") is the subject of this Report; the consolidated approach incorporating SWFDP, FFGS and CIFDP ("Phase B") is the subject of a subsequent Report, to be issued in early-2019.

For Phase A, the review was undertaken by utilising a number of approaches, including reviewing a wide selection of WMO documents, holding discussions with individuals who had practical experience of SWFDP, and visiting locations where SWFDP is in operation. For the latter, liaison visits were made in late-2018 to RSMC Pretoria in Regional Association (RA) I (Southern Africa), RSMC Wellington and NMHS Tonga in RA V (SW Pacific), and NMHS Philippines in RA II (SE Asia). These visits produced a wealth of information, which is detailed in Section 5.4 of this Report.

This Report on the Severe Weather Forecasting Demonstration Programme (SWFDP) reviews the perceived operation of this Programme from both strategic and operational perspectives, as analysed by an independent reviewer in late-2018, and follows the OECD DAC Principle for Evaluation of Development Assistance, focusing on relevance, efficiency, effectiveness, impact and sustainability.

SWFDP was established by WMO in the mid-2000's as a longer-term programme to improve both the quality and scope of forecasts and warnings. This was to be primarily across areas of the world where there was a recognised need to accomplish this, mainly in lesser-developed countries, and particularly in those regions especially prone to meteorological hazards and meteorologically-related environmental hazards, e.g. flooding. A key foundation of SWFDP has been the very successful usage of the Cascading Process, whereby forecast and warning information is disseminated from global centres to regional centres to national centres to national customers in a conceptually-simple, but highly-effective, manner: see Appendix 5 for a schematic representation of this.

In general terms, SWFDP has undoubtedly been a success, with forecasts, warnings and communications all gradually improving over time, albeit with inevitable detail differences both between and within regions, due to a variety of factors, including differing levels of development, funding, management, and indeed needs. One clear indicator of SWFDP's success has been the increasing number of regions of the world that have sought to be part of the global SWFDP network.

Looking at SWFDP from both regional and national perspectives, there appears to be a general consensus formed over time from early beginnings through to more-recent times, and from discussions and meetings at all levels from WMO HQ through to NMHS' customers, that the SWFDP process is an efficient and effective one, and that the Global-Regional-National Cascade Concept has been shown to generally work very well in practice as well as concept.

The current status and progress of SWFDP are well-encapsulated in the "SWFDP Status and Summary of Experience" Paper provided by the WMO Secretariat to the SWFDP RSMT in Hanoi in November 2017. The current status of SWFDP is that of a generally successful and respected component of the operational activities associated with WMO, and whose progress continues (a) in geographical expansion into new or planned Regional SWFDPs, (b) with accuracy improvements resulting from improved NWP output, and (c) in evolution with potential incorporation of new environmentally-related warnings, e.g. those associated with flooding.

This review has determined that *reliable* funding is – by far – the key to successful continuation and evolution of SWFDP; the other potentially restraining issues mentioned next could all be dealt with if a firm funding facility was available and guaranteed. The other issues that require further examination and emphasis are aspects of training, communications (both technical and interpersonal), management and publicity/promotion. These key findings are discussed in more detail in Section 9, while recommendations are provided in Section 10.

Contents listing

1) Introduction

1.1) WMO Resolution 1 (EC-70) requested that *independent* reviews of the Severe Weather Forecasting Demonstration Project (SWFDP), the Flash Flood Guidance System (FFGS), and the Coastal Inundation Forecasting Demonstration Project (CIFDP) be carried out. The rationale for these reviews was to assess both the benefits and sustainability of these programmes; further details are contained within the Resolution, which can be found in Appendix 6. It further decided that these 3 separate reviews should subsequently be taken together in a consolidated approach, to ensure that future services related to hazardous weather, water and climate were conducted in an efficient and sustainable manner. The independent review of SWFDP ("Phase A") is the subject of this Report; the consolidated approach incorporating SWFDP, FFGS and CIFDP ("Phase B") is the subject of a subsequent Report, to be issued in early-2019.

1.2) For Phase A, the SWFDP review was undertaken by utilising a number of approaches, including reviewing a wide selection of WMO documents, holding discussions with individuals who had practical experience of SWFDP, and visiting locations where SWFDP is in operation. For the latter, visits were made in late-2018 to RSMC Pretoria in Regional Association (RA) I (Southern Africa), RSMC Wellington and NMHS Tonga in RA V (SW Pacific), and NMHS Philippines in RA II (SE Asia). These visits produced a weatth of information, which is detailed in Section 5.4 of this Report.

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1.5) In general terms, SWFDP has undoubtedly been a success, with forecasts, warnings and communications all gradually improving over time, albeit with inevitable detail differences both between and within regions, due to a variety of factors, including differing levels of development, funding, management, and indeed needs. One clear indicator of SWFDP's success has been the increasing number of regions of the world that have sought to be part of the global SWFDP network.

1.6) This review has determined that *reliable* funding is – by far – the key to successful continuation and evolution of SWFDP; the other potentially restraining issues mentioned next could all be dealt with if a firm funding facility was available and guaranteed. The other issues that require further examination and emphasis are aspects of training, communications (both technical and interpersonal), management and publicity/promotion. These key findings are discussed in more detail in Section 10, while recommendations are provided in Section 11.

1.7) After this general introduction above, this review initially looks at the background to SWFDP, and how it has evolved over the past decade or so. It then looks at SWFDP from regional and national perspectives, before focusing on three Regional Associations where visits were recently made to, to assess the latest situation on the ground, at both Regional and National sites. Collating all of this information then enables a detailed analysis to be undertaken of the evolution of SWFDP through to the current time. This in turn enables key findings and conclusions to be produced, together with recommendations for the future evolution of SWFDP, including investigations into the feasibility of incorporating FFDS- and CIFDP-type forecasts and warnings into/alongside SWFDP-type products. A collection of appendices provide additional background information on items of particular interest.

2) Background to, and evolution of, SWFDP

(Reference material on the major items noted is available through the associated hyperlinks)

2.1.1) The **Vision** for SWFDP (from WMO Congresses Cg-15 in 2007 and Cg-16 in 2011) was for "NMHSs in developing countries being able to implement and maintain reliable and effective routine forecasting and severe weather warning programmes, through enhanced use of NWP products and delivery of timely and authoritative forecasts and early warnings, thereby contributing to reducing the risk of disasters from natural hazards."

2.1.2) SWFDP's **Mission** has thus been to implement and enhance SWFDP, extending into new geographical areas as necessary, evolving it into operational programmes when the process is suitably mature, and combining it with other meteorological and environmental programmes as appropriate.

2.1.3) SWFDP's **Overall Project Plan** of 2010 has been used as the broad **Guide** and **Framework** for SWFDP's gradual implementation; overall project planning is also Phase 1 of the 4 phases of SWFDP – see Appendix 12.4 of this Report for a brief description of each of the 4 Phases.

2.1.4) SWFDP's **Guidebook on Planning Regional Subprojects** (with both seminal documents updated as and when necessary) has been used to illustrate the practical ways in which SWFDP procedures underline its **Implementation Plan** in the regional networks.

2.1.5) The **global-regional-national cascade concept** has been used continually since SWFDP's inception, and has been seen to have been effective in both concept and operation. An enhanced schematic representation of this important concept is provided in Appendix 12.5.

2.2) The Severe Weather Forecasting Demonstration Project (SWFDP) was initiated subsequent to a proposal by the WMO Commission for Basic Systems (CBS) Management Group in 2003 (see Section 3 there). That proposal was to undertake a demonstration project to assess the feasibility of collectively utilising (a) a combination of forecasting methods, (b) meteorological centres at global, regional and national levels, and (c) greater involvement with disaster management agencies, in order to produce better-focused and better-resourced forecast information, especially including warning information.

2.3) A Severe and Extreme Events Forecasting workshop was held a year later in Toulouse, France, 2004. At this workshop, the Commission for Basic Systems (CBS) Management Group suggested the setting up of a demonstration project. This project would initially be a comprehensive and large-scale development, combining a selection of different types of forecasting input, a variety of likely producers (for differing geographical scales) and customers (with differing operational requirements), and a sequential processing and forwarding of forecast products. It was this project that would subsequently morph into the SWFDP, and later evolve to become the major global framework that it remains today.

2.4) By 2005, a CBS SWFDP Steering Group (SG) was set up to guide and advise on the evolution of the components of SWFDP. The SG decided that trialling a Regional Centre (with cascading raw input from global centres, and optimised output to national centres) was the best approach for trialling the efficiency of the proposed process. Pretoria, the Regional Centre for southern Africa, was selected for this trial, with further Regional Centres to be selected after a year or so, if the initial Southern Africa trial was deemed to be a success.

2.5) An initial planning meeting for the first Regional implementation of the SWFDP (for RA1, Africa) was held in the Regional Centre of Pretoria in 2006. A review meeting was held in Maputo, Mozambique the following year, which described the first experience of SWFDP in operation. It also illustrated both the highlights of operational SWFDP, as well as the inevitable issues to be overcome.

2.6) Quarterly Reports on the operational implementation of SWFDP in their own countries were produced by the National centres (Botswana, Madagascar, Mozambique, Tanzania and Zimbabwe) for the Southern African SWFDP during 2007, and a Final Project Report was produced in early-2008. This Report reflected generally very positive improvements in forecast processes and outputs, and in external customer satisfaction. However, it also noted some negatives, including insufficient fine-detail in forecasts (e.g. more-precisely where thunderstorms may occur, and associated rainfall totals and rates, and associated gust strength detail), insufficient observational data. A further issue was difficulties in verifying actual weather against forecast weather accurately, especially in areas of limited observations.

2.7) The generally-positive perception of SWFDP was recognised by WMO in its early months, and the SWFDP SG in 2008 reviewed the possibility of further enhancements to the services provided (e.g. to include warnings. It also considered extensions of forecasting services into the marine and aviation forecasting environments. Another significant consideration was to extending SWFDP to other parts of the world (e.g. Southwest Pacific), where improvements to forecasting services were perceived to be either necessary and/or beneficial. The SG also took the opportunity to update both the SWFDP Overall Project Plan, and the SWFDP Guidebook on Planning Regional Subprojects.

2.8) Two Progress Reports for Southern Africa for 2008 and 2009 were produced in 2009: ((a) and (b)), while both current developments and future plans were also extensively reviewed by the relevant groups over the same period.

2.9) Attention turned in 2009 to the second geographical area to be chosen for the implementation of the SWFDP process – the Southwest Pacific, with the provision of forecasts and warnings for the geographically small and remote island states of this region. The provision of warnings for high seas is particularly important for this region in view of many of its islands having only limited elevations above sea level. SWFDP management for this region was introduced in 2009 from the regional centre of Wellington, New Zealand, a regional implementation was subsequently actioned, and three progress reports were produced during 2010: (a), (b) and (c).

2.10) The next region chosen for the implementation of the SWFDP process was Southeast Asia, with parts of this region being particularly vulnerable to tropical cyclones hazards. Bad weather and environmental hazards induced by surges in both the southwest and northeast monsoons are additional hazards there. A workshop to enable the introduction of the SWFDP process into SE Asia was held in Hanoi (the Regional RFSC) in 2010, enabling its gradual implementation thereafter.

2.11) The third SWFDP Steering Group (SG3) was also held in 2010, and reviewed the progress of the SWFDP to date, and concluded that it was generally progressing quite satisfactorily. As part of the activities of the SG3, three major actions were taken. It was decided to (1) examine possible additional geographical areas that would benefit from the SWFDP process; (2) examine the possible incorporation of hydrological, agricultural and marine services into the SWFDP process; & (3) to update the core documentation of the SWFDP Overall Project Plan, and the SWFDP Guidebook on Developing Regional Subprojects.

2.12) A further SWFDP meeting for SE Asia was held in 2010, but this time at the global centre of Tokyo, rather than the regional centre of Hanoi. Further details of the meeting are available here.

2.13) The busy year of 2010 continued with a workshop for the new SWFDP area of Eastern Africa, which was considered by that workshop to be technically feasible.

2.14) The last SWFDP meeting of 2010 was for the SW Pacific and was held in the regional centre of Wellington. At that meeting, there was general agreement that the SWFDP process was generally progressing well, and further developments were proposed. Details of the meeting are contained in their Final Report.

2.15) During 2011, three further SWFDP meetings were held for the SWFDP areas of eastern Africa: (a), (b) and (c), all held in Nairobi, Kenya; two for southern Africa: (d) and (e), the first of these held in Mauritius; and two for southeast Asia: (f) and (g): the first of these held in Hanoi, Vietnam.

2.16) In early 2012, a meeting was held at the RSMC of New Delhi to consider the possibility of the establishment of another new SWFDP area, this time centred on the Bay of Bengal region. The meeting considered the particular need for improved warnings and associated reduction in loss of life associated with tropical storms. A comprehensive Report detailed the generally-accepted feasibility of such an establishment.

2.17) The 4th Meeting of the SWFDP SG (SG4) was held at WMO HQ in Geneva in 2012. At this meeting, the current status of the then 5 operational or planned regional SWFDPs was discussed, including relevant issues relating to each. In more-strategic discussions, the possibility of SWFDP collaborating with the Global Data-processing and Forecasting Systems programme, GDPFS (as approved by WMO Congress Cg-XVI) was reviewed. Also reviewed were the issues of insufficient finance and staffing at some smaller national centres, and the SWFDP Overall Project Plan and SWFDP Guidebook on Implementing Regional Subprojects were both recommended to have further updates. The future direction of SWDPT, including potential new geographical areas for its operation, were also reviewed.

2.18) A regional meeting of the East Africa SWFDP was held in 2012 in the regional centre of Nairobi, and reviewed – in general terms – the links between its global providers and itself, and between its national recipients and itself. Included in the meeting was a specific review of information links, including those provided via the Web.

2.19) Another regional meeting of the East Africa SWFDP was held in 2013 at Arusha in the regional country of Tanzania. This meeting reviewed the progress of SWFDP since its implementation, and noted the generally high levels of approval of both service providers and recipients. Amongst the various issues discussed was the question of speedily getting information and warnings to remote users such as fishermen on Lake Victoria, where severe storms with associated damaging winds and raised waves can develop quickly, with provision to mobile phones one of the possible solutions. Two comprehensive Reports: (a) and (b) detail the meetings' discussions.

2.20) The second regional meeting for the SW Pacific SWFDP was held in Fiji in 2013. Although this was the second SWFDP region to be established, and although there were many positive aspects of the improved services that evolved, there were nevertheless a number of issues that had arisen. Amongst the issues that had arisen from an operational perspective were funding, resources, management, communication and training issues. From a customer perspective, issues surrounding perception/belief of the forecasts and warnings were noted. This meeting took several steps to address the issues noted, and these are discussed in the Meeting's Final Report.

2.21) An extraordinary meeting of the SWFDP SG was held late in 2013. The meeting was in response to issues raised at a meeting held in Washington, USA earlier that year (between WMO, World Bank and US NWS) to discuss ways to maintain and strengthen regional and global meteorological centres. This Washington meeting had recognised the value of the regional and global centres, and were keen to maintain and enhance them, but recognised the need to ensure sustainable financial support for these centres, and also the need to have an efficient way of maintaining SWFDP-type processes, including cascade-style movement of forecast and warning products. The need to gradually evolve from a development programme (the DP of SWFDP) to an operational programme was also noted. The SG looked in particular at ways to ensure sustainable financial support for meteorological centres at all geographical levels, as well as ways to enhance SWFDP further – both in those areas where it was already in operation, and those areas where it

could potentially extend into – and also how to transition (where appropriate) from development programmes into operational ones.

2.22) No SWFDP meetings occurred during 2014, but in 2015 there were two regional SWF meetings – a delayed one for the SE Asia region, held in Hanoi, and an initial one for Central and West Africa, held in Dakar, Senegal (the Report is written in French). The Hanoi meeting reviewed the improvements that had occurred in the SWFDP process both globally and regionally, with the addition of new providers and enhanced technology.

2.23) The 6th SWWDP SG meeting was held in Geneva in 2016. The meeting reviewed the progress in the 5 operational SWFDP regions, and provided direction for 6 potential new SWFDP regions: in Central Asia, W Africa, the Caribbean, SE Europe, southern S America, and SE Asia and Oceania. In addition, SG6 reviewed the likely evolution of the SWFDP programmes into operational programmes, once suitable development had occurred. The issue of collaboration with other relevant projects was also reviewed, with around a dozen specialist areas (e.g. agricultural meteorology and disaster risk management) identified. Finally, the ongoing requirement for developments in training, plus the need to keep the core SWFDP documentation up-to-date, were fully recognised.

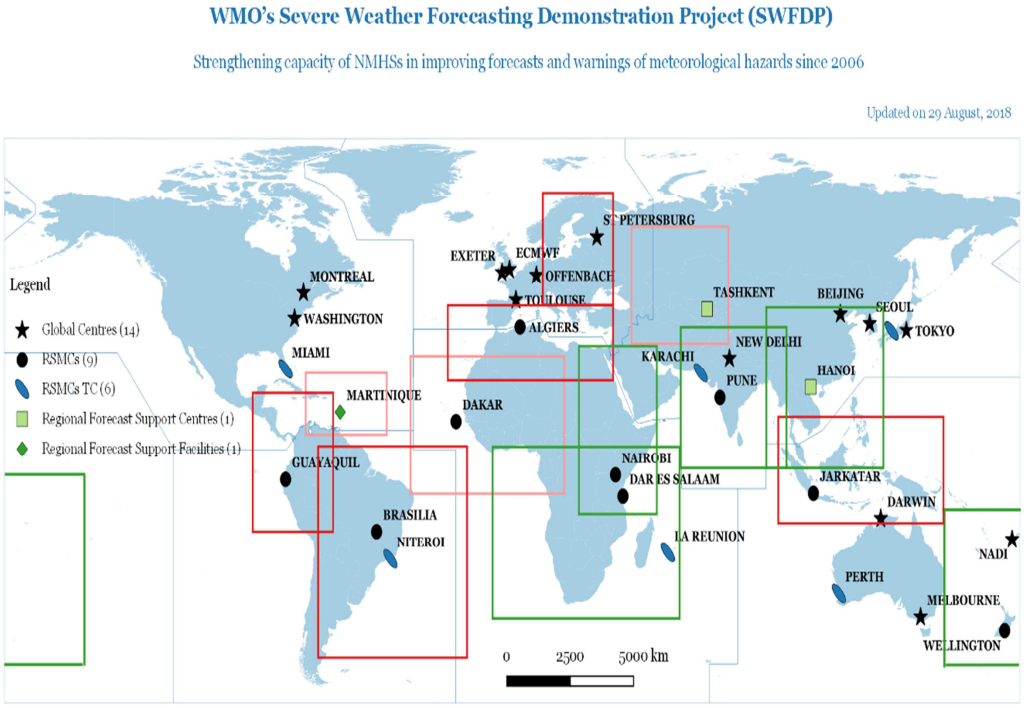
2.24) Also in 2016, the South Pacific regional SWFDP held a review meeting in Honiara, Solomon Islands. This meeting had several specific issues to address: whether or not the region should progress from phase 3 (evaluation) to phase 4 (sustainability and development); who should be responsible for the operational management aspects (rather than the meteorological aspects) of the region; and how financing and training should be enhanced. After discussion, it was decided that it would be preferable to delay transition into Phase 4 until the identified issues had been resolved. There was much positive input, including the *possible* transfer of operational management of the project to SPREP – the Secretariat of the Pacific Regional Environment Programme – responsible for environmental monitoring of the Pacific.

2.25) In 2017, a SWFDP regional meeting for West Africa was held in Abidjan, Ivory Coast, to further facilitate the introduction of SWFDP to this region. The continuing improvements in NWP and in severe weather forecasting, as well as the increasingly-noted effects of climate change, were all relevant to the West Africa region. The combining of SWFDP processes with other WMO-related activities, including agricultural meteorology, marine meteorology and public meteorology was increasing, and elements of each were certainly relevant to the West Africa region. Implementation of SWFDP to this region follows the processes and guidelines of the standard WMO SWFDP manuals. The management and accountability of the SWFDP process is also highly relevant, and follows standard WMO procedures, and future developments come within the ambit of the SWFDP Steering Group.

2.26) Finally, later in 2017, a discussion was initiated for the introduction of a new South American SWFDP. A technical planning workshop was held in Asuncion, Paraguay to discuss various requirements for launching the project in the Regional Association III (RA3). Details of this meeting (in Spanish language) are available via the weblink.

2.27) The 70th Session of the WMO Executive Council was held in Geneva in June 2018, and adopted Resolution 1 (EC-70): a consolidated approach to severe weather forecasting. This includes the conducting of a joint independent review of SWFDP, Flash Flood Guidance Systems (FFGS) and of the Coastal Inundation Forecasting Demonstration Project (CIFDP), together with DRR supporting projects, with the overall aim for the development of a consolidated approach to ensure efficient and sustainable services related to hazardous weather, water and climate.

2.28) In conclusion, current and proposed SWFDP regional areas are shown in the graphic below, current at 29th August 2018, together with global centres. Further information is contained within both the graphic itself and the key to the diagram. Note, however, that the graphic is a 'snapshot' on that date, and subsequent changes will almost certainly occur.



Green color boxes represent the domains of existing SWFDP regional subprojects. Pink and Red color boxes signify the regions for future SWFDP subprojects which will be developed within next 1-2 years and 3-5 years respectively.

Contributing Global Centres, Regional Specialized Meteorological Centres (RSMCs), RSMCs for Tropical Cyclones (RSMCs TC), Regional Forecast Support Centres (RFSCs), and Regional Forecast Support Facilities (RFSFs) are also shown for each of the SWFDP regional subprojects.

DESIGNATIONS USED
The depiction and use of boundaries, geographic names and related data shown on maps and included in lists, tables, documents, and databases on this web site are not warranted to be error free nor do they necessarily imply official endorsement or acceptance by the WMO.

3) The Aims, Objectives and Terms of Reference of this Report

3.1) The **Aims** of this Report are to address the requirements of Resolution 1 (EC-70) – in particular to assess the effectiveness, efficiency, impact, relevance and sustainability of SWFDP, and, in coordination with the reviewers of FFGS and CIFDS, to develop a consolidated approach to ensure that SWDFP, CIFDP and FFGS are all efficient, and offer sustainable services. This will be achieved by dividing this overall task into two Phases: A and B.

3.2) The **Objectives** of this Report :

3.2.1) PHASE A (by around 30.11.18): To provide findings, conclusions and recommendations to the WMO Secretariat.

3.2.2) PHASE B (by 28.2.19): By considering the independent review of FFGS and CIFDP, to provide a joint review result, with recommendations on consolidated approach to move the projects forward in a sustainable way.

3.3) The **Terms of Reference** of this Report:

The Terms of Reference of the consultant (1) for the review of SWFDP, and (2) for the joint independent review with CIFDP and FGGS, can be found in Appendix A in Section 12.1.

4) Examination, analysis and review of the SWFDP from the Regional & National perspectives

4.1) The overall *role* of SWFDP was, at its inception – and remains to the current date – to facilitate the optimum transfer of relevant NWP data, forecast products and information from global centres to NMHSs. This occurs via RSMCs, through the cascading forecasting process, allowing the latter to provide timely and accurate forecasts and warnings to their end-users.

4.2) From the perspective of RSMCs, Regional Centres are both customers and producers. It is their primary role to receive, inspect and manipulate data from global centres, in order to provide guidance on potential upcoming severe weather to the participating NMHSs. Guidelines for this process are provided via the primary documentation of the SWFDP Overall Project Plan and the SWFDP Guidebook on Implementing Regional Subprojects. Training for SWFDP-related roles at RSMCs is ideally provided on-site, while meetings relating to upgrades affecting the SWFDP system are similarly ideally provided on-site. Important components of the SWFDP process include the encouragement of (two-way) Regional-National communications (e.g. phone, text, social media, one-to-one), for each of operational, technical and managerial reasons.

4.3) NMHSs are also both customers and producers, although in a different context to RSMCs. From the customer perspective, they receive forecast data – both raw and processed – from the RSMC (and potentially also from Global Centres via their RSMC, or directly from the dedicated website maintained by the global centres). From the producer perspective, they provide forecasts and warnings to national customers: almost invariably Warnings agencies and Media, but often additional services to sectors such as aviation, marine and agricultural. In order to undertake their roles efficiently, NMHS staff (like RSMC staff) need to have appropriate training, and also to be readily able to communicate effectively with both RSMC producers and NMHS customers – particularly Civil Protection Agencies, Disaster Management Agencies and Media.

4.4) Looking at SWFDP from both regional and national perspectives, there appears to be a general consensus formed over time from early beginnings through to more-recent times, and from discussions and meetings at all levels from WMO HQ through to NMHS' customers, that the SWFDP process is an efficient and effective one. In addition, the Global-Regional-National Cascade Concept has been shown to work very well in practice as well as concept.

4.5) Part of the original SWFDP Plan was that there would be 4 implementation stages for the SWFDP programme, where the last stage (4) would be the long-term sustainability and future developments phase. As at November 2018, the SWFDP programme is currently in operation in 8 geographical areas (listed in Sections 5.4 and 6). The implementation stage generally varies between the regions, where some of the newest areal programmes are at the initial stage 1, while the southern African programme (the first to be set up) is now at stage 4, i.e. operational. Experiences – both good and bad – gained from the earlier starters can, and indeed already have been, beneficially incorporated in later-joining regions. Details of the 4 stages are given in Appendix 12.4.

4.6) A combination of evolving circumstances, such as further indications of the effects of climate change, changing customer requirements and improving ICT facilities means that SWFDP's role is also evolving over time, at both the RSMC and NMHS levels. One of the possible beneficial ways to accommodate some of these changing circumstances at both regional and national levels is to incorporate other warnings services, e.g. CIFDP and FGSS, with an evolving SWFDP – this is examined further in Section 8.

5) Contemporary evidence at the regional and national levels in the Southern African, South Pacific and Southeast Asian SWFDPs

5.1 Introduction

5.1.1) A background to the current global role and operational status of SWFDP follows this short introduction, and provides a contextual framework for recent developments in the Southern Africa, South Pacific and Southeast Asia SWFDP Regions. This is followed by short introductions to recent developments of note in each of the three Regional SWFDP Regions. The final section details the perceived situation in each of the SWFDP Regions, based on liaison visits in the last Quarter of 2018 to each SWFDP Region, with each RSMC (except for RAII), and one of their NMHSs (except for RAI) visited.

5.2 Background

5.2.1) The most-recent SWFDP Steering Group (SG6), held in WMO HQ in Geneva in 2016, noted increased confidence of an enhanced likelihood of locally frequent and/or intense weather, and associated environmental, events as a consequence of continuing gradual climate change. These effects, e.g. greater rainfall rates and accumulations, and associated greater flooding risks, could potentially occur in (parts of) any of the SWFDP Regions. Hence, the corresponding necessity for accurate and timely forecasts and warnings is likely to increase further from their current levels (and potentially associated willingness for these to be suitably funded).

5.2.2) SWFDP continues to play a significant role in this process, with further advances in NWP modelling, as well as Regional centres using multi-outputs, e.g. RFSC Vietnam using both WRF and Cosmo, to increase forecast accuracy further. Emphasis has shifted somewhat over time to issues of product delivery (e.g. timeliness of forecast and warning issues, greater lead times, etc.) and communications (e.g. how are weather and/or environmental dangers best conveyed to populace who may be unaware and/or disbelieving of the hazards posed?).

5.2.3) In addition to SWFDP's praised global-regional-national cascading forecasting process for the flow of relevant data, which in practice facilitates two-way communications between centres with differing roles and responsibilities, this process is also capable of permitting transfers of newly-developed knowledge, methods and skills, but always presuming that there are sufficient resources (both staffing and financial) to allow this to occur. At the current time, there would not be expected to be any significant changes in this cascade process, in view of both its widely-recognised ongoing effectiveness, and the lack of any evident viable replacement system.

5.2.4) One development which does have the potential to improve the services provided by SWFDP even further, is the potential future merging/incorporation of forecast and warning products from both meteorological origins (as SWFDP currently is) and specialist environmental forecasts and warnings, e.g. flooding warnings such as the Flash Flood Guidance System (FFGS) and the Coastal Inundation Forecasting Demonstration Project (CIFDP). One example of a successful synergy between SWFDP and SARFFGS (the Southern African Flash Flood Guidance System) has already occurred in S Africa. This potential merging of warning service providers is looked at in more detail in Section 8.

5.3 Recent developments

Southern Africa

5.3.1) Southern Africa was the first SWFDP subproject set up (see Sections (2.4) to (2.6) of this Report). As noted there, and reflected in SWFDP SG6, this subproject has generally been very successful, albeit with the almost-inevitable operational issues associated with a framework of complex processes.

5.3.2) Amongst the accomplishments of this RAI SWFDP in Southern Africa are:

- Expansion of the NMHSs operating with RSMC Pretoria from 5 to 15;
- Progress to, and full implementation of, Phase 4 (see Appendix 12.4 for a description of this) of the SWFDP process, i.e. full operational status;

- Successful operation of a funded regional Training Project: the South African Regional Flash Flood Guidance System (SARFFGS); &
- The transfer of overall management for SWFDP from WMO to the Meteorological Association of South Africa, MASA.

5.3.3) The major topical issues are currently considered to be necessary operational improvements to warning communications and usage, and necessary improvements to ICT infrastructure to facilitate improved and reliable transmission and receipt of weather, environmental and warning data.

South Pacific

5.3.4) The SWFDP in the South Pacific was initiated in 2009 with RSMC Wellington being the lead regional entity for the project. Four NMHSs (Fiji, Samoa, Vanuatu and the Solomon Islands) were involved through the pilot phase, progressing to the full demonstration phase in 2010 with five additional participating NMHSs (Kiribati, Tuvalu, Tonga, Niue and the Cook Islands). The Regional Subproject Management Team (RSMT) met in August 2013 and decided the project was to remain in the demonstration phase until certain criteria were met; this included identifying a regional entity to manage on-going requirements such as training needs, resources identification and MetConnect Pacific upgrades. The Secretariat of the Pacific Regional Environment Programme (SPREP) was identified as a possible entity, but this has not as yet materialised.

Southeast Asia

5.3.5) Two Meetings to establish a Southeast Asian SWFDP were held in 2010 – the first of these in Hanoi, Vietnam, and the second in Tokyo, Japan, leading to implementation of this Regional SWFDP a year later. By 2015, the SE Asian SWFDP – including its 5 NHMSs – were ready to move to the Implementation phase at the start of 2016. The main issue for this Regional SWFDP appears to have been a requirement for additional training facilities – this has subsequently been enabled by appropriate provision of these.

5.4 Contemporary situation – RSMC & NMHS liaison visits late-2018

Southern Africa (RAI): RSMC Pretoria (no RAI NMHS liaison visit)

5.4.1) The Southern African RSMC in Pretoria, South Africa, was visited on Thursday 27th and Friday 28th September 2018. It was unfortunately not possible – for a variety of reasons – to arrange a visit to a Southern African NMHS during this period.

5.4.2) In addition to a general introduction to South African Weather Service (SAWS), RSMC Pretoria, and SWFDP in operation, individual discussions were held with Ezekiel Sebego, Jan Vermeulen, Dr Winifred Jordaan and Stephanie Landman to discuss, respectively, SWFDP in general, operational RSMC forecasting and warning provision within SWFDP, training and education within SWFDP, and NWP usage, improvements and NWP-specific training within SWFDP. The role of each of the members of staff mentioned above are provided in Section 11.

5.4.3) There was general agreement that – operationally – SWFDP has been, and continues to be, a success for the Southern Africa region, but there were many concerns expressed about SWFDP's evolution, with insufficient and non-guaranteed funding frequently cited as potentially detrimental to SWFDP's future progress. (Similar concerns were also subsequently expressed in RAV.)

5.4.4) The appropriate training (and background qualifications) of staff - both at the RSMC and at the NMHSs – has been seen as a key factor in maintaining, and ideally enhancing, the quality of the services provided within SWFDP. In-post operational experience was also seen as highly beneficial. Training also needs to be repeated and updated on a regular and dependable basis, not just for current staff, but also for newer staff subsequent to staff turnover.

5.4.5) A lack of guaranteed funding has led to reduced levels of training provision, with associated negative effects including some of the poorer NMHSs being unable to afford to send their staff overseas for essential SWFDP training, resulting in a gradual reduction in forecast and warning provision quality. A potential remedy to this issue is the provision of in-house (i.e. on-site) training, which was popular with staff at locations with fewer staff, as it effectively allows more staff to participate.

5.4.6) Another issue which was noted was the heavy workload on staff undertaking SWFDP activities, especially in times of bad/severe weather, and an associated inability to realistically provide timely details of, for example, how the various models and guidance were performing at those times.

5.4.7) The possible extension of current operational SWFDP into the issue of dedicated flash flooding and coastal inundation warnings (such as, respectively, FFGS and CIFDP) was discussed, but the general consensus was that although this was fine in principle for the future, it would be more beneficial – at least in the shorter-term – for SWFDP to maintain, and ideally enhance, its core service provision.

5.4.8) The content and format of SWFDP output from RSMC Pretoria to the 16 NMHSs in the Southern African Region was also discussed. It was recognised that an ideal evolution would be for improved communication links (and associated improved ICT at NMHSs in particular) to enable a greater wealth and diversity of forecasts and warnings to be forwarded to NMHSs. However, it was similarly recognised that inadequate funding provision was currently precluding this possibility, and temporary 'work-around' solutions (e.g. provision of higher-resolution GRIB data instead of lower-resolution graphical data) were being investigated to try to facilitate this.

5.4.9) The overall management of the SWFDP processes – including the role of MASA (the Meteorological Association for South Africa) and, indirectly, SADC (the South African Development Community) is currently seen as generally satisfactory, but the underlying issue of funding: who should provide it, and who should manage it, are areas of potential concern for the future.

5.4.10) From the *management* perspective of communications, it would appear desirable for strategic-level management meetings/workshops, e.g. SWFDP SGs and other gatherings at WMO and Regional levels, to be held more frequently, to enable current and potential issues affecting successful SWFDP progress to be identified *and acted upon* at earlier lead times.

5.4.11) For meetings (including training) involving participants from countries where English is not routinely spoken, it is recommended that English language training is provided to those staff that are likely to be involved. Although there would be a cost consideration associated with this, it would be beneficial overall to both the participant country, and to the SWFDP process in general, for improved communications with NMHSs where English was not the first language.

5.4.12) Another significant issue identified was the ready availability of private-sector forecasts, e.g. by AccuWeather, and how relevant these were to SWFDP products, and to public perception of them. Within SWFDP, these products were generally held to be of inferior quality, but it was felt unlikely that (non-meteorological) recipients of SWFDP were necessarily aware of this, and thus there was a potential need identified for appropriately communicating these differences to audiences. The "Authoritative Voice" concept, whereby NMHSs have responsibility for the issue of official, national warnings is an important one, and has already been recognised, for example, by the Government of Tonga – see Section 5.4.52. As such, it is further recommended that – under the general topic of (interpersonal) communications – ways are sought to strengthen the 'single, official and authoritative voice' of all NMHSs (and RSMCs).

5.4.13) For SWFDP warnings for heavy rainfall effects, a monitoring facility (i.e. weather radar, and ideally Doppler radar) is required. While South Africa possesses weather radar facilities, it is lacking in most of the rest of the SWFDP region (a similar situation exists in RAV, with only Fiji out of 9 NMHSs having their own weather radar). This necessarily degrades accurate verification of heavy rainfall locations, rates and accumulations, both in real time, and, to a lesser extent (e.g. after appropriate analysis of suitable satellite products) in retrospective analysis. Once again, lack of funding resources is the primary cause of this SWFDP-related shortfall. The initial provision of a radar facility is unfortunately insufficient on an ongoing, operational basis – it is also necessary for there to be both the technical expertise and associated funding to maintain radars post-installation.

South Pacific (RAV): RSMC Wellington & NMHS Tonga

Part 1: RSMC Wellington

5.4.14) The South Pacific RSMC in Wellington, New Zealand was visited on Thursday 25th and Friday 26th October 2018. The roles of the staff that were liaised with are provided In Section 11 of this Report.

5.4.15) On Thursday 25th October, a general introduction to MetService (the Meteorological Service of New Zealand Ltd), and a specific introduction to SWFDDP in the South Pacific, were jointly provided by James Lunny, Chris Noble and Elke Louw. Attendance at a morning briefing in the operational Forecast Centre showed the thorough analysis given to the relevant weather patterns and their anticipated evolutions. Together, these provide the general background information on which SWFDDP forecasts and warnings are based. The briefings were very similar in nature, and standard, to those routinely undertaken in the UK Met Office Operations Centre.

5.4.16) A series of discussions – both wide-ranging and detailed – were held with various RSMC Wellington staff through both Thursday 25th and Friday 26th. These covered not just specifically SWFDDP, but also many other relevant areas which indirectly linked with SWFDDP, including policy, commercialism in meteorology, the evolving role of social media, communications (both technical and interpersonal), production, warnings policies and procedures, and operational procedures. An opportunity was taken on Friday afternoon to visit external locations in the area, where the geographical and topographical aspects of the region could be better visualised.

5.4.17) The series of discussions noted above also reviewed the activities of the Regional Subproject Management Team (RSMT), whose role is to guide the development of the RAV SWFDP through its Regional Subproject Implementation Plan (RSIP), and who have met on 5 occasions: in 2009, 2010, 2013, 2016 and 2018. Amongst the discussions therein have specifically been those relating to the criteria required to move RAV from Phase 3 to Phase 4 – these Phases are outlined in Appendix 12.4.

5.4.18) There was a general consensus that provision of SWFDDP forecasts and warnings from RSMC Wellington was as good a quality now as it was possible to get under current conditions, i.e. with current technology and staffing levels – a view that I could find no reasonable grounds to query.

5.4.19) http://swfddp.metservice.com, the (password-protected) MetConnect Pacific website, is used for the transmission of NSMC Wellington SWFDDP forecasts and warnings to the regional NMHSs, as well as a variety of other useful data, and additionally contains a wealth of other useful links. The website is much appreciated by its users, and extensive examination of its contents have readily persuaded me of its value.

5.4.20) There are, however, concerns in RSMC Wellington that there is still insufficient development at most of the South Pacific NMHSs to enable progression of SWFDDP in RAV from its current Phase 3 (evaluation) to Phase 4 (full operational implementation), as much as RSMC Wellington would like to proceed to Phase 4 if optimum conditions had been attained at both the NSMC and all of the NMHSs. Indeed, at a regional SWFDDP meeting held in the region shortly before my visit, a decision was taken for SWFDDP RAV to remain in Phase 3 – see also Section 5.4.36 – this relating primarily to issues of long-term sustainability and development.

5.4.21) As with RAI (Southern Africa), the main issue preventing desirable progression of SWFDDP is a lack of *guaranteed* funding to allow necessary progress to be made. In the case of the Pacific island states, funding is primarily necessary to (1) upgrade the training of the local staff, so that they are better able to both recognise and deal with incipient developing bad weather and/or associated adverse environmental conditions, and (2) communicate these appropriately to both meteorological and non-meteorological customers.

5.4.22) In addition to the funding need for training, there is also a need for funding to allow optimum production and communication of forecasts, especially those occurring in times of severe weather and associated adverse environmental conditions (such as flooding of low-lying areas). Additional funding is also necessary to upgrade and enhance the SWFDP Regional website (this was also subsequently noted in RAII).

5.4.23) It has been noted that operational communications between RSMC Wellington and the South Pacific NSMCs has been less than optimum at times, and that this might be related to perceptions of differences in levels of training, experience and even language between RSMCs and NMHSs. An often-perceived lack of enthusiasm and rigour with regard to completion of verification tasks is another area where communications have so far been unable to optimally resolve the issue.

5.4.24) The use of social media has increased in recent years, including within meteorology. As a means of communicating forecast and warning 'narratives' accurately, it should be encouraged, and where it can encourage 'sensible' discussion of current weather, this should also be encouraged. The negative aspects of social media in general are also well-known, and it is recommended that a review is undertaken of the use of social media within RAV (and, indeed, more-generally), to ensure that the benefits of its use are both recognised and optimally utilised.

5.4.25) In addition to the perceived need for training in (interpersonal) communication skills (and their associated funding) at NMHSs, it is also recommended that serious consideration be given to the possibility of writing a programme that would automate verification requirements – although this would have an initial cost, it would likely be cost-effective overall, as staff manual verification time could be more usefully deployed elsewhere, and staff morale in this area improved. However, even a well-written automation programme would be of minimal use if there were insufficient quality-controlled observations on which to operate, and the availability of sufficient suitable observations is another significant current issue, but outside of the remit of this Report.

5.4.26) While current staffing and work levels are reasonably correlated to current SWFDDP operational requirements, any future additional expansion of the SWFDP remit (including further project deliverables by RSMC staff) would necessitate the requirement for enhanced funding.

5.4.27) Satellite imagery in the RAV region is considered good, courtesy of the Japanese meteorological satellites Himawari 8 & (later) 9, and lightning coverage is improving thanks to the services provided by the private US company TOA Systems Inc. However, surface and upper-air observations remain inadequate across the S Pacific region. A meeting of the joint GCOS-WIGOS Workshop for the Pacific Small Island Developing States (SIDS) held in Fiji in October 2017 highlighted the importance of the upper air network in the Pacific, and noted the deficiencies there at that time.

5.4.28) RAV also covers much of the 'Ring of Fire' – the region of the South Pacific that is vulnerable to a combination of earthquakes, volcanic activity, tsunamis and flooding as a consequence of plate tectonic movements in the region. As such, specialist training is essential for staff (both management and operational) in this region to enable them to at least react optimally to any such severe environmental events that occur.

5.4.29) Another area of potential concern is the issue of long-period swell and its effects on coastal communities. Long-period swells (potentially as long as 20 seconds) are generated by (extra-tropical) storms in both the Northern and (especially) Southern Hemispheres in the associated winter seasons. Such long-period, high-energy swell has the potential to cause significant damage to coastal regions exposed to it, and it recommended that it is checked that observations of such swell are readily recognised, and that the forecasting of these is adequately addressed.

5.4.30) On the topic of SWFDP communications with warnings agencies, there has been a general degree of debate regarding whether these could be improved at NMHSs (and whether RSMCs could assist in this regard). In view of WMO's wish to review the possibility of amalgamating specialist warnings type-products such as CIFDP and FFGS output into SWFDP's cascading system, it is recommended that the overarching requirement for high-quality interpersonal communications between providers of warning information and the recipients should be enhanced by further specialist communications training for SWFDP staff and management.

5.4.31) Various aspects of the review of RSMC Wellington are relevant to the regional NMHSs, and these were reviewed again when visiting NMHS Tonga on Monday 29th and Tuesday 30th October – see Part 2 of Section 5.4, starting below.

Part 2: NMHS Tonga

5.4.32) The South Pacific NMHS of Tonga was visited on Monday 29th October 2018. Tuesday 30th October was used to document the meetings held, and also tour the main island to gain a better, visual perspective of the geographical and topographical aspects of the main island. The roles of the staff that were involved in the discussions held on Monday are provided in Section 11.

5.4.33) Discussions were held in 3 separate locations: (1) the Tonga Met Office in the Domestic Terminal of Fua'Amotu Airport, (2) the Ministry of Environment, Energy, Climate Change, Disaster Management, Information and Communications, & (3) the Geology Unit of the (governmental) Department of Land and Natural Resources.

5.4.34) As with both RSMCs Pretoria and Wellington, the general concept of Severe Weather Forecasting and DRR Demonstration Project (SWFDDP) in both concept and operation was considered good, with mostly high levels of praise for both the contents and quality of the data (which is believed to have improved over the past 5 years) cascaded from RSMC Wellington. Indeed, one comment about the routine SWFDDP operational product "South Pacific Guidance" issued by Wellington was that it was "fundamental" to Tonga Met operations.

5.4.35) Various suggestions were made about the possibility/desirability of changes to various aspects/parameters of SWFDDP output, but these are generally detail issues best dealt with using the *two-way* RSMC-NMHS cascade (of information) process.

5.4.36) It had been decided at the RAV Regional Meeting held in Tonga earlier in October (see also Section 5.4.20) that RAV would remain in Phase 3, rather than progressing to Phase 4 (see Appendix 12.4 for short descriptions of each Phase), and as such this was factored into the discussion initiated, and feedback received.

5.4.37) Discussions at Tonga Met Service were held primarily with Laitia Fifita, recently returned from his MSc in Meteorology at Reading University, U.K. The first of the common themes to SWFDP to be mentioned – unprompted – was the issue of training. It was considered essential by operational staff that relevant training needed to be provided (especially when new models, or new model configurations were introduced), whether at a Regional training event, or in-house. In-house training was favoured, so that all staff had the opportunity to participate to some extent. Training was considered to be of fundamental importance and specifically included the ability to interpret different products optimally.

5.4.38) The issue of "impacts" rather than the actual weather itself was raised next as a new and on-going requirement, for example the forecast scale of likely damage in a storm surge, rather than the height of the surge itself. The use of impacts is relatively new in Tonga, and training for this was felt to be essential, as well as refresher training about probability forecasting (with the use of this in particular when bad weather and/or severe environmental conditions were expected).

5.4.39) One issue which has become apparent during this Review has been the use by various SWFDP locations of (sometimes commercial) software and/or hardware from outside of the SWFDDP 'norm' – this has included in Tonga the use of "TOA" lightning detection hardware and software. The product is used, as is useful as far as it goes, but improvements to its output would be beneficial within RAV; however, would such (commercial) companies suddenly start to charge for their products, and is there an appropriate WMO policy for those occasions? It should be noted, however, in this particular example, that TOA is a new joint venture between (NZ) MetService and TOA Systems, and is not officially part of SWFDDP.

5.4.40) Although SWFDDP does not specifically cover tsunamis within its remit, this is an issue of high importance in Tonga, with Tonga being unofficially quoted to be the second-most vulnerable region of the world to these events, and being generally comprised of low-elevation land. In view of the fact that tsunamis can generate (wave) surges of dangerous heights, especially for low-lying islands, and that wave forecasting *is* part of SWFDDP, another question is: should there be future incorporation into SWFDDP (or, possibly more-likely, a future MHEWS) of tsunami forecasts and/or discussions, even if it as a specialist sub-forecast? Because of its local importance, Tonga is currently operationally using a workstation provided by the US Government from Honolulu, Hawaii as part of the California Integrated Seismic Network, CISN.

5.4.41) The issue of (interpersonal) communications arose next. With the growth in social media use, and both the benefits and drawbacks that this can and does entail with regard to forecasts, warnings and their perceived accuracies, Tonga has recently developed a small PR section, which can help with these issues. In particular, the issue of forecasts and warnings in 'user-friendly' language is under active review – a development that it is recommended be further encouraged.

5.4.42) A Tonga government requirement for (some degree of) commercialisation of Tonga Met forecast products has not arisen yet, but it is believed that it is likely to do so in the future, and Tonga may well be able to utilise the experiences of RSMC Wellington in this regard. The topic of the commercialisation of forecast products and warnings is a wide-ranging one, and is considered elsewhere in this Review.

5.4.43) The subject of case studies, and the often-unmet requirement for these to be produced regularly at NMHSs – as part of verification procedures, and to help confirm that RAV was ready to transition from SWFDDP Stage 3 to Stage 4 – was raised. The staff view was that more training in this area was needed to ensure that requirements were met, that sufficient staff time was allocated for these tasks, and that appropriate case study construction methods were being used. This issue has been raised at RSMCs as well, and a *possible* solution might be to transfer the task from operational staff to R&D staff, who successfully undertake this task in the Philippines – see Section 5.4.65.

5.4.44) One other external organisation and one other Program which are being worked with in Tonga are, respectively, SPREP and COSSPPac. SPREP is the regional (S Pacific) environmental organisation, which is apparently operating more efficiently than recent reports may have suggested, while COSSPPac is the Australian Program that supports S Pacific island states to ameliorate the effects of climate variability. Both organizations are outside of SWFDDP, but appear beneficial, and it is recommended that WMO policy regarding the utilisations of non-SWFDDP facilities within SWFDDP is further reviewed in the near-future.

5.4.45) ‘Ofa Fa’anunu, the Director of Meteorology at NMHS Tonga, currently has a very busy schedule in RAV, and was unfortunately working in Wellington, New Zealand during my time in Tonga. However, Moleni Tu’uholoaki, the Deputy Director and Acting Director, was fortunately able to spend time to provide a senior management perspective on SWFDDP. There was general agreement with the desirability of the SWFDDP programme continuing, although there are concerns regarding funding, and what the eventual end of the the SWFDDP project would mean for Tonga.

5.4.46) The building of resilience against adverse meteorological and environmental effects is the main issue in the S Pacific, and SWFDDP is regarded well for not impinging adversely on other co-existing programmes in these areas.

5.4.47) SWFDDP is part of WMO’s Disaster Risk Reduction (DRR) Multi-hazard Early Warning System (MHEWS), which is impact-based and in operational use in Tonga.

5.4.48) The challenge of finding the best way of communicating warnings – their content, and guidelines on how they should correctly be interpreted – is one of the issues that needs to be addressed in the near-future within SWFDDP. Visual communications are considered to be an optimum route, but further work is needed in this area.

5.4.49) Additional considerations regarding the communication of warnings to remote locations – by a variety of technical mechanisms – is another area where SWFDDP has the potential to become involved.

5.4.50) Storm surges have already been identified as a major concern for low-lying areas in particular in RAV, and the Japanese Meteorological Agency (JMA) have recently given their storm surge model to S Pacific nations, output from which looks promising. The issue of additional wave-related programmes being incorporated within SWFDDP is looked at in more detail in Section 9.

5.4.51) There is a recognised danger of multiple programmes running simultaneously alongside SWFDDP, and the associated important requirement to ensure that there is effective compatibility between all of these. Potentially, there is a role for both the Secretariat and constituent bodies of WMO, to ensure that there is effective coordination of projects and systems, e.g. with currently three separate WMO bodies currently looking after the three programmes of SWFDP, FFGS and CIFDP. As part of this issue, it is also recognised – as a relative weakness – that there is currently very limited research being undertaken in these areas, with a commensurate need for more research, as well as further training. All of these issues require consideration within RAV Regional Meetings, as well as escalation to SG level for policy considerations in these areas.

5.4.52) Mafua Maka is the Deputy Director of Tonga's National Emergency Management Office, and in the course of a meeting held with him was able to provide a perspective on SWFDP and on warnings for Tonga in general. There is a confirmed governmental wish for the public to rely on Met Office (and SWFDDP) warnings, i.e. "the Authoritative Voice", although there is also a recognition that warnings and data relating to severe environmental conditions are also available from other external sources (e.g. via the Internet).

5.4.53) Two issues follow on from Section 5.4.52 above. The first is to ensure that new warnings-related products such as CIFDP and FFGS are available on SWFDDP as soon as approval is reached for these to be (although it is recognised that there is a lot of work (and cost) involved in achieving this). The second is that social media is used to communicate *appropriately* details of expected adverse weather and/or environmental conditions.

5.4.54) As there are other environmental issues which potentially could be forecast or warned about, e.g droughts, there is an overriding question as to exactly which meteorological and environmental parameters should be forecast and warned about within SWFDDP – a decision probably taken at WMO SG level. Note, however, that MetConnect Pacific does have a weblink through to the Island Climate Update (ICU). In addition, there has been work undertaken recently to establish a Regional Climate Centre (RCC). Relevant products on that could also be linked to via MetConnect Pacific.

5.4.55) Rennie Jegsen at the Geology Unit of the Ministry of Land and Natural Resources was also met, and discussions held with, relating to earthquake monitoring and warning. For earthquakes, automatic detection is undertaken, and warnings issued by Met Office as appropriate (as the latter operate H24), after analysis by seismologists. The possible integration of SWFDDP weather-related forecasts and warnings with other environmental hazards into a future MHEWS-

style warning system is certainly worthy of future consideration (but currently outside of the remit of this SWFDP Review).

Southeast Asia (RAII): NMHS Philippines (no RAII RSMC visit)

5.4.56) The SE Asia (RAII) NMHS in Manila, Philippines – a component of PAGASA – was visited on Tuesday 27 November and Wednesday 28 November; it did not prove possible to visit RFSC Hanoi, for unknown reasons.

5.4.57) An introductory meeting was arranged by Cecilia Monteverde prior to my visit, and was hosted by Jehan Panti on Sunday 25 November in a number of locations in Manila, and at which much useful SWFDP information was exchanged.

5.4.58) A round-table introduction and discussion between myself, Cecilia Monteverde, Jehan Panti, and a number of NHMS Philippine staff (as discussed in later sections) were held in PAGASA in Manila during the morning of Tuesday 27 November.

5.4.59) After initial introductions by Cecilia and myself on our respective roles within SWFDP, a series of PowerPoint presentations were made by the attending NHMS staff, focussing on different aspects of SWFDP that they were personally involved with. All of the presentations were of high quality and informative.

5.4.60) The introduction by Cecilia Monteverde highlighted RSMC Philippines' active participation in a number of regional meetings and workshops held since their incorporation into RAII.

5.4.61) The Philippines are one of the regions most susceptible, and vulnerable, to typhoon incursions (from the West Pacific), and also located on the 'Ring of Fire' (as are RSMC Wellington and NMHS Tonga in RA V). They are thus at risk from one or more of damaging winds, earthquakes, volcanic activity, and tsunamis, as well as more-frequent hydrologically-related events such as flooding, flash flooding and coastal inundation. As such, PAGASA needs to have good understanding of these various adverse environmental events, and of the appropriate provision of warnings for these.

5.4.62) PAGASA have a good advice and warning provision for tropical storms – these were seen at first hand by myself relating to Typhoon Man-Yi prior to, and during, my visit. There are also good working relationships with the disaster agencies and the media, with active use made of both media (e.g. Press briefings) and social media. Public education is also proactively undertaken, with two groups of schoolchildren seen being hosted inside PAGASA during my visit.

5.4.63) One of the primary sources of information for NMHS Philippines should be the information provided by the Regional Forecast Support Centre (RFSC) Hanoi via their website. During my visit, and prior to it, there were many occurrences where data had not been provided. I do not know if this was for technical reasons either at Hanoi, or between Vietnam and the Philippines, or

for any other reasons, but it was having a detrimental effect on the quality of Manila's output. This issue is currently being reviewed in the WMO Secretariat. See also Section (5.4.64) below.

5.4.64) Sample Case Study presentations were made by Louis Jane Rico and Lorenzo Moron. Although the presentations were commendable, they both suffered from the quality of the input, I.e. basic charts and insufficient and/or missing data, which meant that although useful results could be, and were, obtained, they were not as accurate as they could/should have been. This issue relates directly to Section (5.4.63) above.

5.4.65) It was noteworthy that Case Studies were being undertaken much more regularly and reliably at Manila than in any of the other SWFDP locations visited. From discussions on this situation, it transpires that – generally speaking – R&D staff undertake Case Studies in NMHS Philippines, whereas operational staff (forecasters) undertake them elsewhere. Given the critical role of Case Studies in providing evidence of the quality of forecasts, the possibility of transferring Case Study work from operational staff to research staff would appear to be worthy of further consideration at other SWFDP sites.

5.4.66) Presentations on local regional forecasting (i.e. local regions within the Philippines) was provided by Jhomer Eclarino and Romeo Ganal, Jr. In addition to 'standard' forecast parameters, additional forecast requirements included heat indices, and forecasts for special events, e.g. Xmas. A combination of broadscale charts and smaller-scale parameters are utilised, to capture both advecting influences (e.g. Monsoon surges) and local effects (e.g. severe thunderstorm development). In general, forecasts issued using SWFDP input performed well.

5.4.67) Christopher Perez provided a presentation on training within NMHS Philippines, and used the example of Risk Maps (which are available from JMA, but not through SWFDP) to show how good-quality graphical representation is generally the optimum way to display forecast and warning information. As such, forecast data, e.g. risk maps, is used from other forecast providers as well as SWFDP.

5.4.68) The final presentation was provided by Jehan Panti, demonstrating the content of the RSMC Hanoi website. The website appeared (to me) rather minimalist, with f/c charts only extending to T+72 (when here is a national need to forecast out to 5 days ahead), archives covering too short a period of time, and visualisation insufficiently detailed. It is not currently known precisely what the issues are that are involved – see Section (5.4.63).

5.4.69) The daily collection of forecast presentations and discussion held in the forecast area in the early afternoon was attended, and the breadth of the forecasts and charts covered was considered to be very comprehensive, and certainly of a suitable standard for a NMHS.

5.4.70) A courtesy visit was then made to Dr Vicente Malanbo – the Permanent Representative (PR) of Philippines to WMO – during which a number of topics were discussed, and many photos taken.

5.4.71) The final visit of the day was to the Hydrometeorological Section of PAGASA, where the practicalities of measuring rainfall accumulations in river catchments were discussed, along with the provision of warnings for flooding events.

5.4.72) The future possibility of incorporating CIFDP- and FFGS-style forecasts into the SWFDP orbit was discussed, along with the likely difficulties involved, and NMHS Philippines confirmed (subsequent to earlier email correspondence on this matter) that they were very interested.

5.4.73) On Wednesday 28 November, a visit was made to the Philippines' National Disaster Risk Reduction and Management Council (NDRRMC). At a round-table meeting held there between myself, Jehan Fe Panti and Louie Jane Rico (both from PAGASA) and three senior staff from NDRRMC, discussion were held regarding the provision of warnings to NDRRMC, and NDRRMC's perceptions of them.

5.4.74) The general consensus from the NDRRMC side was of a generally high level of service provided by PAGASA. NDRRMC used the forecast outputs and warnings provided by PAGASA in the preparation and issue of warnings, and used multiple routes for the issue of their warnings and advice, including Press Briefings, their own website, and a selection of social media, particularly Facebook, as well as translating warnings from English into the multiple local languages. NDRRMC had found the level of accuracy of SWFDP forecasts and warnings to gradually improve since its inception – this helped NDRRMC regarding reliability and preparedness. They also found that graphical output was the most useful way for communicating required information, such as forecast typhoon tracks.

5.4.75) NDRRMC have independent access to other forecast information, but rely on PAGASA (and thus SWFDP as well), and never change the information received from PAGASA. The round-table meeting confirmed that communications were vital in all aspects of the warning process, but acknowledged that round-table meetings (as opposed to other forms of communication) were less-frequent than they ideally could be. NDRRMC did indicate that there was a need for a multi-hazard impacts-based warning system (MHEWS) to include volcano, earthquake and other environmental warnings, but acknowledged that this was a vision rather than an imminent expectation.

5.4.76) The visit to NDRRMC concluded with a visit to their Operations Centre, which was physically dominated by a very large (two stories high) video wall in a brand new building, where both the building and the Operations Centre had been fully funded by overseas contribution. The quality and flexibility of the display system was very impressive, as were the rest of the facilities in the building.

5.4.77) Generally, issues that have been noted in other SWFDP locations visited are equally relevant in Philippines. Funding is of primary importance – the NMHS would like to undertake much more, but are constrained by lack of funds. Their interpersonal communications are generally very good in all spheres, but the telecommunications are not: again, this is not helped by the funding issue.

5.4.78) In summary, NMHS Philippines are firm advocates of SWFDP, and can see its advantages, but are unfortunately experiencing some of its negative aspects, through no fault of their own. Once again, it would appear that the local experiences of SWFDP are generally good, but could be improved in some areas, and that the optimum route forward would be for a strategic review of how funding is obtained and guaranteed, such that NMHSs (and indeed RSMCs) are able to plan into the future with confidence.

6) Additional feedback from other current and planned SWFDPs

6.1) East Africa
6.2) Bay of Bengal
6.3) West Africa
6.4) Eastern Caribbean
6.5) South America

This Section looks at the feedback that has been received from both the 4 SWFDP Regions that have more-recently come into operation, and from 1 planned SWFDP Region. In the former category are the SWFDP Regions of East Africa, the Bay of Bengal, West Africa and the Eastern Caribbean, and in the latter category the proposed SWFDP Region of South America.

6.1) East Africa

http://www.wmo.int/pages/prog/www/swfdp/SWFDP-EA.html

An update on the status of the East Africa SWFDP was presented to the 6th SWFDP Steering Group in Geneva in March 2016, and a generally favourable account provided there of the 7 years or so that the Eastern Africa SWFDP has been operational. A list of favourable improvements in forecast and warning accuracy, usefulness and confidence were noted, while improvements in communications (both technological and interpersonal) were sought. A list of both recent meetings and planned future events are provided here.

6.2) Bay of Bengal

http://www.wmo.int/pages/prog/www/DPFS/SWFDP/RAII-BoB/BoB-RSIP.html.

An update on the status of the Bay of Bengal SWFDP was also presented to the 6th SWFDP Steering Group in Geneva in March 2016, and, as with the Eastern Africa SWFDP, a generally favourable account provided there of the 6 years that the Bay of Bengal SWFDP has been implemented. The RSMC of India has further improved its issue of forecasts and warnings with the incorporation of output from 3 specialist Indian service providers: for medium-range output (NCMRWF), for marine tide/wave/swell output (INCOIS), and for extended-range forecasts (IITM). The number of NMHSs participating has increased (to include Bhutan, Pakistan and Nepal), and progress in developments has been steady.

6.3) West Africa

http://www.wmo.int/pages/prog/www/swfdp/SWFDP-WestAfrica.html

As noted in Section 2.25 of this Report, a technical planning meeting was held in Abidjan, Ivory Coast in September 2017 to initiate this Regional SWFDP, and a comprehensive Report on this Meeting, including actions and plans agreed at it, was subsequently issued – see weblink in Section

3.25. A year later, these actions and plans are progressing on schedule – a 2018 update from RA1 (including West Africa) is provided here.

6.4) Eastern Caribbean

http://www.wmo.int/pages/prog/www/swfdp/

In the Caribbean, hurricanes are the primary source of danger, and the region is already well-served in that regard by warnings issued by the National Hurricane Centre (NHC) of Miami, USA. Most of the region's countries are also already members of the Caribbean Meteorological Organisation, CMO. In 2015, a decision was taken to discuss the potential SWFDP for this region, incorporating aspects of Miami's and CMO's output as appropriate. The performance of Miami and CMO was perceived as good, but there were gaps in inter-NMHS communications when Miami and CMO were not involved. An update on recent and planned future events in this region is provided here.

6.5) South America

http://www.wmo.int/pages/prog/www/swfdp/

In South America, there has not been any SWFDP-style method of cascading weather forecasts and warning information from global to regional to national centres, although a regional system for sending severe weather warnings from a Severe Weather Virtual Warning Centre (called ALERT-AS) was introduced at around the same time as the SWFDP system was introduced elsewhere by WMO. ALERT-S evolved since that time, but has never incorporated the cascade method of forecast and warning sharing. At a WMO RA III meeting in Asuncion in 2014, the possibility of combining ALERT-AS-style output with a SWFDP-style output was discussed. At a SWFDP Workshop in Asuncion, Paraguay in 2017, a SWFDP workshop was held – the outcomes from this workshop are in Spanish language. An update on recent and planned future events in this region is provided here (see RA-III section).

7) Detailed analysis of the performance of SWFDP from its inception until the present time

7.1 Overview

7.1.1 Overall, an analysis of both the outcomes, and the general perception of how SWFDP has performed since its inception in the early- to mid-2000's, shows that it has been a marked success, with enhanced forecasts and warnings being made available to an increasing proportion of the world's population, especially those in developing countries. Like most major projects, it has suffered, and continues to suffer, from arising and ongoing issues – with typical examples being financing, communications, and technical constraints. However, the benefits of SWFDP are widely felt to outweigh its disadvantages, and the continuation, ongoing development and geographical expansion of SWFDP, together with its potential merging with specialist warning services, all indicate both the generally positive, widespread and forward-looking perceptions of SWFDP.

7.2 SWFDP's current Vision, Mission, Guide and Implementation Plan

7.2.1) SWFDP's current ***Vision*** – from WMO's 2007 Congress Cg-XV, 2007 (item 3.1.3.11, p24) – is that *"NMHSs in developing countries are able to implement and maintain reliable and*

effective routine forecasting and severe weather warning programmes through enhanced use of NWP products, and delivery of timely and authoritative forecasts and early warnings, thereby reducing the risk of disasters from natural hazards". This Vision still appears appropriate: the Vision's desired outcomes are still the desired outcomes now – indeed, with an increased risk of the detrimental effect of increased severe weather and negative environmental impacts associated with continuing gradual climate change, the Vision is even more appropriate now than it was at its introduction. It is, however, the *methods* used to attain this Vision that benefit from adaptation, to ensure that optimum operational methods are used, e.g. the possible incorporation of specialised warning services into disseminated output, with SWFDP providing guidance to support these.

7.2.2) SWFDP's ***Mission*** is not specifically defined, but a reasonable interpretation of such a Mission would be to continue, as far as possible, to undertake those activities that would enable the SWFDP Vision to be attained. Examination of the output from SWFDP SG6 in 2016, as well as subsequent contemporary evidence (see, for example, Section 5.4) would suggest that this mission is being undertaken enthusiastically and efficiently, albeit with the inevitable drawbacks associated with issues associated with aspects of financing, management, communication and technology.

7.2.3) The SWFDP ***Guide*** (to planning Regional subprojects) has been regularly updated since its inception, and the latest (2016) version is a comprehensive and authoritative document, which remains fully fit-for-purpose, subject to on-going updates as and when appropriate.

7.2.4) The SWFDP ***Implementation Plan*** is a set of guidelines for the operational implementation of a new SWFDP regional area. There are a core set of relevant guidelines, and these can be adapted as necessary for new geographical areas, and any relevant changes of circumstances. The web-linked example from the 2010 Meeting in Hanoi is a good and usable example, but an updated standard template (but adjustable in use according to particular circumstances) would appear desirable.

7.3 The current status and progress of SWFDP

7.3.1) The current status and progress of SWFDP are well-encapsulated in the "SWFDP Status and Summary of Experience" Paper provided by the WMO Secretariat to the SWFDP RSMT in Hanoi in November 2017. The current status of SWFDP is that of a generally successful and respected component of the operational activities associated with WMO, and whose progress continues (a) in geographical expansion into new or planned Regional SWFDPs, (b) with accuracy improvements resulting from improved NWP output, and (c) in evolution with potential incorporation of new environmental-style warnings, e.g. those associated with flooding.

7.3.2) Status and Progress Reports often tend, however, to "gloss over" some of the less-positive aspects of programmes, and while this is no detraction from the positive aspects, there are nevertheless some less-than-positive aspects which are worthy of greater scrutiny. Amongst these aspects, there are primarily occasions when issues of financing, management and communications, amongst other issues, tend to lessen the otherwise positive narrative. Examples of these are noted throughout this Review, but in particularly in Section 5.4.

7.4 The fulfilment of SWFDP's Objectives, and how effectively this has been done

7.4.1) SWFDP's *Objectives* are assumed – in the absence of any evident information to the contrary – to be the same as its *Goals*. The latter are listed in the CBS's *Overall Project Plan,* updated in 2010, and reflecting the recommendations of the CBS-XIII, in 2005.

7.4.2) These Objectives/Goals are listed below:

- to improve the ability of NMCs to forecast severe weather events;
- to improve the lead time of alerting of these events;
- to improve interaction of NMCs with Disaster Management & Civil Protection Authorities (DMCPAs) before and during events;
- to identify gaps and areas for improvements;
- to improve the skill of products from GDPFS Centres through feedback from NMCs.

7.4.3) There is evidence from Regional Reports and from the SWFDG SG that the first two Objectives above have generally been met: a combination of generally-improved NWP, training and communications over the past few years have gradually led to better outcomes (improved accuracies and improved lead times).

7.4.4) Some improvements in NMC-DMCPA interactions have been noted during the period of SWFDP implementation, but there remain areas/occasions when interactions are non-optimum (possibly by being under-reported). This is considered to be a communication issue, where both sides focus on their own perspectives, and inadequately see their opposite numbers' perspectives. This is partially likely to arise from issues of heavy workloads associated with periods of bad weather, and/or environmental issues such as flooding. A combination of training (partly to see the other side's perspectives, and partly to enable more-timely warning issue) and management changes (workload and schedule changes, and review of staffing resources) may help to gradually alleviate this issue, assuming the availability of the necessary financial resources. Naturally, such training and changes are ideally undertaken in periods of (expected) quieter weather and environmental conditions, such that their effective implementation and operation can occur during periods of bad weather and/or poor environmental conditions.

7.4.5) Feedback from NMCs regarding the quality/skill of GDPFSs has been seen over time to be rather sparser than is ideal. There are a number of potential causes of this, including heavy workloads at NMCs (especially when a bad weather and/or environmental issue such as flooding, is occurring), lack of awareness of the appropriate methods/formats in producing feedback, and general communication issues. As feedback, whether quantitative or qualitative, is a good way to monitor the efficacy of the products, it is recommended that emphasis is maintained on the need for feedback, together with the necessary resourcing to facilitate this as far as possible. In this regard, the training provided in South Africa in 2016 was very positively viewed.

7.4.6) The current main gaps are currently seen to be (1) the need for a better inclusion of specialist warnings, and (2) weaknesses in areas where additional financing (e.g. for staff numbers, staff training, enhanced communications) would be of benefit. Item (1) is reviewed in more detail in Section 8, while for (2), the need to attract, and distribute, greater financing is an issue that WMO (and UN) as a whole will doubtless necessarily be keeping under on-going review.

7.4.7) How effectively have SWFDP's Objectives been fulfilled? With good leadership provided over time, and clear goals, SWFDP has been implemented as well as it reasonably could have been, given the combined drawbacks of (i) highly-technical and bureaucratic, but necessary, procedures; (ii) the need to satisfy many 'customers' who are likely have different national and operational priorities. The Goals of improving warning services and looking for ways to improve have also shown the Objectives' foresight to look ahead to, to plan for, and adapt to, future changes that will enhance the service provided by SWFDP to its customers even further.

7.5 The performance of (Regional) sub-projects

7.5.1) There are many ways to measure performance, e.g. objectively, subjectively or elements of both, which in turn relate to the definition chosen for 'performance'. The current primary role of the SWFDPs is to provide an effective forecast and warning service to customers, whether internal (i.e. other meteorologists) or, more particularly, external (e.g. NDMAs and Media), or both. As such, the performance of SWFDPs can be judged – particularly by their customers – on how (Regional) SWPDFs are perceived to have performed.

7.5.2) The current Regional sub-projects are also in different levels of development, as reflected in Sections 2, 5 and 6 of this Report.

7.5.3) Despite the intrinsic difficulties discussed in 7.5.1 above, it is still possible to form subjective opinions of the performance of Regional sub-projects, and individual ones are provided for the 5 extant SWFDPs in the following sections.

7.5.4) Southern Africa Southern Africa was the first Regional sub-project, and thus arguably initially had much attention paid to it. As noted elsewhere within this Report, the South African regional SWFDP has generally been seen as a marked success, providing well-received output to local NMHSs, with the regional SWFDP having progressed to Stage 4 (full operational implementation). In addition, strong regional management of SWFDP has been achieved through a combination of RSMC Pretoria, MASA and SADC. It is recommended, however, that a survey be undertaken in the near-future to check that RSMC guidance is indeed being used as effectively as it can be – possibly if/when on-site training is being undertaken.

7.5.5) South Pacific The South Pacific Regional SWFDP was the second Regional SWFDP to be set up. Initially, this SWFDP developed according to plan, but some years into its evolution, issues arose to slow its development: primarily those associated with its overall management. As such, SWFDP is undertaking its role reasonably well, and remains in development stage 3, i.e. not yet having full operational status, while solutions are sought for its financing and management issues.

7.5.6) Southeast Asia The SE Asia SWFDP was the third Regional SWFDP. With much of this Region particularly vulnerable to tropical storm effects, the speed of development of this SWFDP

was necessarily slower than other SWFDPs before or since. Nevertheless, the SE Asia Regional SWFDP is generally felt by its customers to be performing well.

7.5.7) Eastern Africa This 4th Regional SWFDP was selected for development shortly after SE Asia, and its development and performance have been considered very good throughout.

7.5.8) Bay of Bengal The 5th Regional SWFDP was geographically centred on the Bay of Bengal, and its geographical scope included areas particularly at risk from the adverse effects associated with tropical cyclones. This Region has developed relatively slowly, but its current performance is generally considered fully acceptable.

7.6 The costs and benefits of sub-projects

7.6.1) This Section looks initially at the general costs and benefits of the provision of forecasts and warnings, using both quantitative and qualitative methods. Costs and benefits are then reviewed from both extrinsic and intrinsic perspectives, where the latter can often tend to be overlooked in scientific environments.

7.6.2) From the particular perspective of Regional SWFDPs, all of the above generalised considerations are relevant, albeit to different extents, and in different contexts. This section thus turns to how these considerations are apposite in the Regional SWFDP context.

7.6.3) From a purely economic perspective, it is possible to calculate the financial operational costs of a Regional SWFDP, e.g. staff costs, telecoms costs, building costs, etc. With regard to the benefits, it is more difficult to provide quantifiable figures, and this proves a handicap when attempting cost-benefit analyses. Nevertheless, it is possible to obtain 'best estimates' of benefits using methods from economics – one such example is the analysis undertaken, independently, on behalf of UK Met Office, which showed large benefits relative to costs in many sectors.

7.6.4) It is also difficult to quantify how much money is saved (i.e. an economic benefit) when accurate forecasts and warnings of, for example, impacting tropical cyclone activity, enable preventative measures to be taken that result in reduced property damage and other environmental damage, and loss of life. However, once again, it is possible for calculations to be made using suitable economic methods.

7.6.5) In addition to the extrinsic costs and benefits discussed above, there are also significant *intrinsic* costs and benefits associated with the provision of forecasts and warnings. Forecasts and warnings that are *perceived* by recipients to be inaccurate, and/or misrepresent a weather event create, and can maintain, a negative image of the worth of a forecast and/or warning service. An example of this is a forecast/warning emphasising strong winds associated with a tropical storm, when in the event, heavy rainfall and associated flooding events turn out to be more significant. Such occurrences, whether on a regular basis, or on a sporadic basis, or for a specific event (e.g. the detail associated with the passage of a tropical cyclone) create, and can maintain, a negative image of the worth of a forecast and/or warning service. Conversely, forecasts and warnings that are perceived by a significant majority of their audience to be generally reasonably accurate, can generate and maintain positive impressions. Such intrinsic and generally qualitative impressions – both positive and negative – are potentially as valuable

as extrinsic (financial) cost-benefit calculations in influencing decision-makers when the latter decide whether to enhance, maintain, or reduce the funding for forecast and warning services.

7.6.6) In the SWFDP Regional context, all of the above considerations are relevant, together with the important addition of RSMCs having a number of NMHSs that are important customers. The perception of the services that NMHSs receive from RSMCs is a very important element of the perceived intrinsic value of the SWFDP Regional process. Similarly, RSMCs will have similar opinions of the value of the input that they receive from global centres, as well as feedback from NMHSs.

7.6.7) Finally, with regard to the Regional-National element of the Global-Regional-National Cascade Concept, it has already been accepted that this is a successful method of operation, and thus a clear benefit. Costs are also discernible – both the extrinsic, financial ones, and the intrinsic benefits. Once again, from a cost-benefit perspective, do the benefits sufficiently exceed the costs, and who makes that decision? In addition to the economic analysis, it is also worth investigating whether any sorts of improvements (e.g. changes in managerial methods, or service provision formats) would further favourably improve the cost-benefit analysis, and this is examined further in Section 9. A further economic consideration with cost-benefit analysis in this context is whether costs are borne more by the RSMCs, and benefits by the NMHSs, and whether this has been correctly assimilated into SWFDP's financial planning.

7.7 Is there evidence to support SWDFP being generally considered a good idea?

7.7.1) Turning now to whether there is evidence to support SWFDP being generally considered a good idea, in broad terms SWFDP could be considered to be a good idea if:

a) it meets the Aims and Objectives of the Programme;
b) it has a good cost-benefit ratio in its favour, where 'benefit' should be considered in a broad context;
c) its customers are happy with the services provided by/through it;
d) it readily adapts to meet changing circumstances;
e) it operates optimally, with competent staff and efficient management;
f) communications are good at all levels within SWFDP: within SWFDP regions; between SWFDP regions; with WMO; and especially with customers.

7.7.2) In an ideal world, SWFDP would meet all of the above criteria all of the time, but, in reality, this does not occur. However, this does *not* mean that SWFDP is not a good idea - the Southern Africa SWFDP is good evidence for this – see Section 5.3.1. With SWFDP being introduced into parts of the world where development is slower, there are inevitable issues that arise that are non-optimum, e.g. slow web speeds.

7.7.3) The Aims and Objectives of SWFDP still appear fully appropriate, and as no significant changes have subsequently been made to these since their inception, it would seem reasonable to assume that these are still fit-for-purpose. Examination of SWFDP's current Vision and Mission (see Section 7.2) provide similar sentiments.

7.7.4) The provision of sufficient funding for SWFDP has been a significant issue at times throughout SWFDP's lifetime. However, *documented* positive feedback from SWFDPs and from customers who appreciate SWFDP services, as well as positive cost-benefit analyses (intrinsic as well as financial extrinsic) all help SWFDP's case. In addition, the likely detrimental effects of continuing gradual climate change, especially on lesser-developed regions, all tend to lend support to the assertion that SWFDPs remain a fundamentally good idea.

7.7.5) Despite the complexities of the SWFDP process (e.g. differing international procedures), SWFDP generally operates efficiently, including the operational incorporation of new parameters, e.g. new NWP output, changing customer requirements, etc. A possible future evolution of SWFDP would be the introduction of forecasts and warnings that incorporate the *effects* of the weather, such as flooding and inundation, rather than just the weather itself, i.e. impact-based forecasting. An example of such an evolution that has proved very successful in operation is the incorporation of the UK Environment Agency's Flood Forecasting Centre (staffed by hydrometeorologists) alongside UK Met Office Guidance Unit meteorologists (staffed by Chief and Deputy Chief meteorologists) in the UKMO Operations Centre in Exeter, where close co-operation and agreement on precipitation forecasts and their likely effects (if any) are the norm. This potential incorporation of different forecast types will be investigated further in Section 8.

7.7.6) One of the aspects of operational SWFDP that has been highlighted in Reports that have been issued since SWFDP's inception has been the need for high-quality and appropriate (specialised) training. This is so that staff are readily capable of understanding the various pros and cons of all of the specialist data that is available to them, and advising customers based on that specialist knowledge and experience. Forecast and warning shortcomings are likely to be reduced with good-quality training, resulting in customers receiving more-accurate forecasts and warnings, and being more satisfied as a result. As such, both well-trained staff and satisfied customers add weight and evidence to the belief that SWFDP *is* a good idea.

7.7.7) A primary requirement in any complex, international, operational environment is the need for good communications – both from the physical perspective (e.g. good web speeds, reliable connections) and from the interpersonal perspective – the ability of staff to liaise effectively with everyone that they come into contact with: staff at other centres, warning agencies, media, the public, etc. Good communications enable both efficient delivery of products, and enable issues to be discussed, and hopefully resolved, in an optimum manner.

7.7.8) Finally, if SWFDPs *are indeed* generally considered by a majority of people who use their services to be a good idea, and the broad swathe of data available from various sources would tend to indicate that this is indeed the case, then the prospect that sponsors will be willing to continue, or even increase, their future funding, is likely to be increased.

7.8 What governance structures are considered optimum to maintain future benefits?

7.8.1) Governance of international entities such as SWFDP, which contain wide ranges of technical and financial attributes, and differing socio-political compositions, are always going to be complex affairs requiring careful planning and operation.

7.8.2) At national levels, countries naturally prefer to have control over at least some aspects of SWFDP provision, e.g. how, when and to whom warnings should be disseminated, and it is recommended that this should remain unchanged, with national meteorological services having governance over warnings insofar as they directly impact their nation, i.e. the "authoritative voice". In this regard, SWFDP should continue to provide the supportive guidance to help facilitate this.

7.8.3) At international levels, a global perspective is required, primarily to ensure that no areas of the world that would particularly benefit from SWFDP-style forecast and warning provision are overlooked, but also to ensure that reasonably-similar *modus operandi* are used where it is clearly beneficial to do so, e.g. the global-regional-national cascade process. Thus, it is recommended that global perspectives, i.e. governance, should persist, and there currently appears no better organisation to do so than the very-experienced WMO, especially with the latter's close association with the UN.

7.8.4) Governance at *regional* levels can be slightly more problematic. While Regional Subprograms have been effectively set-up and initiated into use, questions persist about the maintenance of such systems – effectively who maintains them (e.g. the technical facilities), and who finances them? Occasions have previously arisen where issues such as the maintaining of equipment at an NMHS have not been solved in situ (due to lack of suitably-trained staff and/or funding), with the issue cascaded upwards to the NMHSs, who themselves may not have the required skills/finance.

7.8.5) Notwithstanding the comments in the previous section, the global-regional-national cascade concept still appears to be the best way of undertaking two-way communications in a complex international framework such as SWFDP. Thus, it is recommended that this persists, at least until there is clear evidence of a better and/or alternative framework. It is further recommended that the perceived 'condition'/current status of the cascade process is examined and discussed at *each* Steering Group meeting, and also that consideration be given to shortening the time between Steering Group meetings, to enable more-frequent reviews of factors that have the potential to influence SWFDP at both operational and strategic levels.

7.8.6) Finally, the possible future incorporation of specialised warning-type services such as FFGS and CIFDP into SWFDP forecast provision is another area where governance needs to be reviewed, e.g. does SWFDP or FFGS or CIFDP have ultimate management responsibility – both strategically and operationally – for specialist-type warning issue and advice-provision? Once again, this is an area where governance decisions are required before (if?) specialist-type warnings become routinely available through the SWFDP network. This will be reviewed further in Section 8.

7.9 Should additional sub-projects be considered and potentially initiated?

7.9.1) With regard to whether additional sub-projects should be *considered,* the answer is in the affirmative. The reason for this is that there are still regions of the world where forecast and warning provision is not as good a standard as it could be. Examples of potential additional sub-projects include Central Asia and SE Europe, and occasions where such sub-projects could have been beneficial include humanitarian episodes, such as the effect of bad weather on large-scale migrations towards/into Europe seen in recent years.

7.9.2) *Consideration* does *not* automatically imply that initiation *will* occur, or even that it should. SWFDP has produced Guidelines for the establishment of new Regional SWFDPs, and the requisite conditions need to be met – or nearly so – before a Meeting to consider the potential establishment of a new Regional SWFDP is proposed.

7.9.3) Amongst the primary factors to be considered re potential new sub-projects is the provision of adequate funding – both initial capital funding, and subsequent ongoing operational costs. ***If*** suitable funding *is* available and is guaranteed, this reduces one of the major problems re the establishment of additional sub-projects, but other issues remain, such as the establishment of a suitable RSMC, and incorporating this new SWFDP sub-project into the Cascade Process. It could reasonably be argued that funding is indeed the key factor.

7.9.4) A further factor which could influence whether additional sub-projects should be considered relates to the potential availability of new forecast services, e.g. those relating to flood and inundation warnings. It may be the case that a proposed new sub-project may not be viable under current (SWFDP) criteria, but may/would be when incorporated with new services such as these.

7.10 The optimum way to operationally effectively manage future sub-projects

7.10.1) Examination of the operational management of SWFDP sub-projects to date has indicated:

(I) minimal problems at the global/WMO level, *other than* excessive workloads for Secretariat staff;
(II) sporadic issues at the national level (such as inadequate training and resources) &
(III) specific issues at the regional level, such as those associated with inadequate Phase 4 funding;

7.10.2) Focused examination of those occasions where operational management has been found to be sub-optimal has shown a variety of factors, but primarily insufficient resources (e.g. finance, time to complete tasks) and/or insufficient training (e.g. management, or specialist meteorological).

7.10.3) Based on (1) *generally*-effective operational management of current SWFDPs, (2) recognition of the likely causes of sub-optimal operational management, and (3) the possibility of new-style warnings being introduced in the near-future, it is recommended that current methods of operational management are maintained. However, there is a necessary proviso that adequate resourcing, specifically including the provision of appropriate levels of training (both specialist meteorological, and management) are elements of new contracts, and which are non-negotiable essential requirements.

7.10.4) Further to (7.10.3) above, it is further recommended that the SWFDP Guide for the establishment of regional sub-programmes is updated at the earliest opportunity to ensure that the recommendations here are both incorporated and implemented.

8) Potential operational interactions with CIFDP, FFGS and others

8.1) For Phase A of this Report (tabled on 30.11.18 version), this Review of potential operational interactions with CIFDP, FFGS and others is an initial outline draft, based on currently-available documentation and also feedback from the Regional visits; a more-comprehensive version will be available for the Phase B version (to be tabled on 28-2-19), which will include discussions with CIFDP and FFGS staff, managers and customers, as appropriate.

8.2) This Review will look in particular at ways in which CIFDP, FFGS has the potential to gradually evolve into the future in a more-joined-up manner with SWFDP that could be both more efficient in terms of production, and potentially of greater benefit to both current and potential customers. Possible interactions that are considered to have potentially significant benefits to populations in the coming years include (1) reducing disaster risk with improved warning combinations; (2) investigating regional climatic and environmental changes; and (3) facilitating better agricultural development through enhanced analysis and forecasting of weather on longer timescales. These will be included in Section 10: Recommendations for SWFDP's future evolution.

8.3) Curtis Barratt will be the Lead for the FFGS component of the potential SWFDP-FFGS-CIFDP integration, and Dr Ray Canteford (BOM, Australia) will be the lead for the CIFDP component. A lengthy teleconference has already been held between the 3 respective Leads (with myself as the SWFDP Lead), with others planned.

8.4) Initial impressions from examination of the WMO website introductions to CIFDP and FFGS websites is that there is a clear potential for a beneficial incorporation of SWFDP-originated meteorological forecast and warning output, with specialist warnings of forecast flash flooding and coastal inundations. If they were able to effectively utilise the cascading process, this would increase their suitability for potential inclusion within the SWFDP regime.

8.5) At the 'base' level, SWFDP is providing forecasts of expected weather evolution, and, where considered appropriate, issuing warnings when forecast parameters, e.g. rain accumulations, heavy rain rates, tropical storm wind speeds, are expected to exceed predefined warning criteria. At this 'base' level, the *element*, e.g. wind, rain, necessitating the issue of warnings is the "cause" of the warning.

8.6 As noted at various points in this Report, e.g. Section 5.4.38, there is a slow but gradual movement away from forecasting just weather and warning parameter *values*, and towards the adverse *effects/impacts* that significant levels of such parameters are likely to induce, i.e. impact-based forecasting.

8.7) At this "impacts" level, CIFDP- and FFGS-style warnings provide best estimates of what the malign consequences of SWFDP-forecast bad weather will be, i.e. the extent and severity of coastal inundation and/or flash flooding.

8.8) Logically, a 'joined-up approach', where CIFDP- and FFGS-style calculations and output were directly based on SWFDP-provided forecasts seems eminently sensible, but there are other factors to take into account, as discussed in the following sections.

8.9) Initial considerations regarding any potential future joint SWFDP/CIFDP/FFGS program will include deciding which NWP and other environmental forecast fields are chosen to run the programme on, as well as who has overall responsibility for the various warning elements, and the issue of the associated warnings, both from a strategic perspective, and operationally at the regional and national levels.

8.10) As noted in the CIFDP and FFGS websites, the adverse effects of flash flooding and coastal inundation are realised by significant precipitation events, but also depend to varying extents on topographical and hydrological considerations as well, e.g. how the configuration of the ground changes local flooding risks, and whether the ground is saturated or very dry – both influencing how the ground copes with heavy and/or sustained precipitation falling on it.

8.11) From an operational perspective, CIFDP- and FFGS-style services require funding – both initial capital costs, and subsequent operational funding, both of which need to be sourced and guaranteed. In addition, specialist flood forecasting requires skills above that of a 'standard' meteorologist, e.g. aspects of hydrometeorological training, and possibly specialist geological and/or geographical training.

8.12) The training requirements noted in the previous section need to be factored into consideration of a SWFDP-CIFDP/FFGS joint operational entity, as do the extra operational time requirements for the issue of 'impacts'-type forecasts and warnings, especially when severe/adverse effects are likely. A further consideration would be who has overall responsibility for the various warning elements, and the issue of the associated warnings, both from a strategic perspective, and operationally at the regional and national levels.

8.13) While this first draft of the Report has initially only considered the incorporation of CIFDP- and FFGS-type forecasts and warnings into the SWFDP process, it is likely that other specialist forecast and/or warning types will evolve during SWFDP's lifetime, and may merit consideration for incorporation into an increasingly-versatile, but also increasingly-complex, provision of environmental-style forecasts and warnings.

9) Key findings and conclusions

9.1) As SWFDP has evolved, a natural question has been how SWFDP should continue to evolve into the future, and this Report seeks to provide some guidance to answering this question. One of the key factors – indeed probably the primary one – that has underlain SWFDP's past and present evolution, and will inevitably affect its future evolution, has been the issue of *dependable* SWFDP funding: how this will be both obtained, and guaranteed – this issue has already been recognised by WMO Congress (Cg-17). With continuing and contemporary evidence of gradual worldwide climate change, with associated increased risks of locally severe weather and other negative environmental impacts, as noted both in scientific research and media perceptions, it might

reasonably be assumed that SWFDP-related funding would be easier to obtain both now and in the future. However, the current ascendency of populist governments, with their associated lower priorities on funding other countries' projects, as well as the possibility of another international financial crisis similar to 2008, may counteract the climate change effect (i.e. easier funding), to an uncertain extent. Conversely, a recent (October 2018) Special IPCC Report highlighting the very negative effects of unchecked global warning may yet provide an impetus for increased SWFDP funding, as part of an effort to better monitor, understand and mitigate against the negative impacts of global warming. A very recent (November 2018) report from the UK Government's Environment Agency, detailing the impacts of climate change and the associated adaptation processes considered necessary to prevent unchecked global warning, provide additional backing for IPCC's perspective.

9.2) As SWFDP has evolved over the years, three other factors (in addition to financing) have been seen to be of primary importance: training, communications, and management. In addition to primary meteorological training (normally university-based), specialist training is also *essential* for SWFDP staff, to enable them to understand various significant aspects of their roles, such as awareness of local environmental issues, recognising potential local severe weather scenarios, specific characteristics of local NWP output, effective liaison and communication with internal and external customers, etc. Regional training centres (with access to NWP outputs) – potentially utilising specialist global trainers on training courses – have proved highly effective in this regard, e.g. RSMC Pretoria 2016. However, funding remains problematic for training, and without sufficient guaranteed funding for this, standards – and morale – will inevitably gradually decline. Already, potential students from poorer NMHSs have at times been unable to attend essential regional training due to lack of appropriate funding.

9.3) Communications also have high levels of importance from both the technical and interpersonal perspectives. From the technical perspective, the cascade process of transmission of valuable data and products from global centres (e.g. UKMO, ECMWF, Washington) to regional centres (e.g. Pretoria, Wellington), and on to national meteorological centres (e.g. Tonga, Philippines), and from there to national customers, has proved very successful both in concept and operation. However, this success should not overlook issues such as the need to upgrade both communication link speeds and capacities, introduce a greater use of pro-active forecaster workstations (rather than reactive web terminals) as and where the need arises, to allow higher-quality output to be analysed and forwarded in timely fashion; funding restraints are already affecting link speeds in particular. For interpersonal communications, the need for forecasting staff to be able to communicate *effectively* with customers (both internal and external) is of paramount importance, especially where warnings and issues relating to severe weather are concerned. Effective training (and practice) play a key role in this.

9.4) At the operational level, but also at the strategic level, management of SWFDP-related matters also has a key role to play. At the operational level, it is assumed that staff holding (mid-level) management roles have sufficient experience in this area, but higher-level management training (up to MBA level) is recommended for staff (such as Directors of NMHSs and RSMCs) that have to deal at governmental and international levels. The transfer of powers relating to SWFDP developments (including financial powers) to non-WMO entities, e.g. South African Development Community (SADC) in South Africa, and *possibly* the Secretariat of the Pacific Regional Environmental

Programme (SPREP) in the South Pacific, also mean that the ability of (meteorological) senior managers to influence and convince non-meteorologists also assumes significant importance.

9.5) In addition to the funding, training, communication and management aspects noted above, it remains important for SWFDP to be publicised and promoted (i.e. 'marketed') appropriately. Consideration should also be given to possible 'upgrades' to the programme name, e.g. Severe Weather Forecasting and Warning Evolution Programme (SWFWEP), to reflect two items: (1) that SWFDP is not just a 'demonstration project' now, but a successful evolving programme, and (2) that part of the evolution process is an evolution into new areas, including the likely incorporation in future years of specialist forecasts such as FFGS and CIFDP. Consideration should also be given to increasing the frequency of (a) important meetings/workshops, such as the SWFDP SGs, and (b) primary documentation such as the SWFDP Overall Project Plan and the SWFDP Guidebook on Implementing Regional Subprojects, in both cases to ensure that the programme reflects the close overview that is maintained on it. A final recommendation is that consideration should be given to obtaining evidence (for potential benefactors on a global scale) of the overall positive cost-benefits of high-quality forecasts and warnings, as seen for example in an economic study on UK Met Office.

9.6) Lastly, since SWFDP's establishment over a decade ago, there have been in existence a number of WMO programmes, some new, dealing with different environmental hazards, such as aspects of flooding, tropical cyclones, etc. Many of these hazards, and, in particular, timely warnings of them and their adverse impacts, are highly relevant to SWFDP customers. In Phase 2 of this SWFDP Review (due 28.2.19), there will be a review of the feasibility of incorporating such specialist forecasts and warnings (e.g. relating to FFGS and FIFDP) into the SWFDP regime, including its cascading process (see Appendix 12.5) – Section 8 of this Report gives a contemporary overview of these considerations.

10. Recommendations for the future evolution of SWFDP

10.1) As part of the recommendations for the future evolution of SWFDP, this Section will also look at potential new areas of possible collaboration and/or interaction with new and/or proposed environmental frameworks, including CIFDP, FFGS, the Sendai Framework, WCDRR, UNFCCC and Sustainable Development. However, the Phase A Report focuses rather more on the evolution of (the current core components of) SWFDP, and less on newer projects, with the latter to be more-comprehensively processed in the Phase B final version – see also Section 8 above.

10.2) As noted at various points in this Report, SWFDP has generally been seen as successful in the fulfilling of its original objectives, and the ongoing applications for new SWFDP regions to be established reflect that the original Vision and Mission for SWFDP continue to be successfully met. However, there are also various issues related to SWFDP, such as funding, communications (including marketing/public relations aspects), training and management, which would benefit from increased consideration when reviewing the future evolution of SWFDP, and for which recommendations are made in the following sections. There are also questions about how SWFDP should optimally proceed in future years, and further recommendations are made in this regard, also in the following sections.

10.3) The issue of *dependable* and *guaranteed* funding is a *crucial* one for the successful continuation and evolution of SWFDP. As examples of this, it is noted that RAV have very recently declined to progress from Phase 3 to Phase 4 (even though they were capable of doing so), primarily because of a lack of dependable and guaranteed funding, while in RAI, regret has been privately expressed for their being in Phase 4, as funding has since that time become less reliable. As such, it is recommended that a major initiative is undertaken to ensure – as far as realistically possible – that such adequate funding becomes, and remains, both available and guaranteed. In this regard, it is recommended that serious consideration be given to the establishment of a high-level (senior/expert?) financial working group (WG), to work on optimum realistic solutions to this specific issue. Such a WG should include financial/economic experts as well as experts in the area of communications and public relations, who know best how to appeal to potential donor organisations and countries. It is further recommended that the issue of continuing global warming, together with the adverse environmental effects associated with it, continue to be heavily (but appropriately) utilised in this regard. The desired outcome is *guaranteed* funding for both capital issues (such as the establishment of new regional SWFDPs, and ongoing operational costs (such as holding *necessary* workshops and *guaranteed* training).

10.4) It is recommended that a SWFDP Steering Group meeting (SG7) be held as soon as realistically possible, and certainly before WMO Cg-18 in June 2019, such that major SWFDP-related issues, such as those identified in this Report, can be discussed at Congress, and SWFDP-related decisions taken there, and subsequently implemented in as expedient a manner as possible. At the next SG, it is also recommended that consideration be given to holding SGs slightly more frequently: possibly annually, to ensure that a *timely* oversight is maintained, and necessary actions taken, on relevant developments. Current membership of the SG appears suitable, but membership, and roles, of SG members should be reviewed by the SG itself, taking into account both current circumstances, and potential future developments.

10.5) It is also recommended that consideration be given (possibly at SG7?) to the establishment of a management workshop to review – initially in a strategic sense – how SWFDP should evolve as it enters the 2020's. Participants in the workshop should include specialists from the areas of flash flooding (e.g. FFGS) and coastal inundation (e.g. CIFDP), as well as any other areas which might beneficially be included within SWFDP over the coming decade, possibly including those associated with Disaster Risk Reduction (e.g. WCDRR) and climate change mitigation (e.g. UNFCCC).

10.6) The issue of meteorological and environmental training needs is recommended to both be reviewed as soon as possible and prioritised to higher operational and strategic levels. On the assumption that new, incoming SWFDP staff have the necessary initial university training in meteorology, consideration should then be given to the *guaranteed* teaching (i.e. not subsequently cancelled due to lack of funds) of the necessary additional SWFDP requirements, such as the specific requirements for the understanding of specialist NWP output, effective communications with varied customer types, recognition of severe weather scenarios, etc. Regional training has proven very successful (e.g. southern Africa 2016) and it is strongly recommended that this continues. Serious consideration should also be given to on-site training, for locations where staff numbers and/or resources are limited, where this would provide a better/quicker benefit in the shorter-term.

However, the problems of insufficient funding, as well as the provision of training to non-English speakers, are both issues that need to be successfully resolved to avoid deteriorations in both standards and staff morale.

10.7) The issue of (technical) communications is another one which it is recommended that it be reviewed. It is often routinely accepted that some of the poorer and/or more remote NMHSs will have poor communications because of 'limited bandwidth'. Poor communications at national levels can lead to poorer service provision, decreased staff morale, and the associated increased risk of a significant weather event being poorly forecast. The poor communications are an issue which is most likely related to lack of sufficient channelled funding, and is another reason why the overall issue of adequate and guaranteed funding is so important. Technological improvements and changes, including the widespread increase (including within meteorology and environmental areas) in the use of social media since SWFDP's introduction, further indicate the need for a comprehensive review of current communication facilities and opportunities.

10.8) Another area in which it is recommended that greater emphasis be placed is that of interpersonal communications, where this also includes aspects of both 'marketing' and management. As it is necessary, and often essential, for staff to be able to communicate effectively with a wide variety of customers, e.g. recipients of issued warnings, it is most important that they are trained how to do this in an optimum manner, and is an area in which effective training will help. 'Marketing' and 'public relations' are recognised business terms for 'selling one's services/goods effectively' and 'projecting and maintaining a positive image', respectively, and are arguably just as important in meteorology – in the context of convincing clients of the value and quality of the (forecast and warnings) services provided – as it is the retail sector, but is an aspect that is unfortunately often neglected in the scientific sector. Again, this is an area where effective training will help. With regard to management, the associated required personal capabilities to be able to effectively persuade, influence and lead assume greater importance, especially at higher management levels, and for those staff working at governmental and inter-governmental levels, it is recommended that serious consideration be given to appropriate management training, all the way to MBA level.

10.9) An area of potential concern relates to possible evolutions where financing is insufficient. If, for example, a lesser-developed NMHS decides that it urgently needs (maybe for political reasons) some particular facility and/or equipment (e.g. to better forecast coastal inundation) that is not available in a timely fashion through SWFDP, but which is offered sooner and/or with low costs from another provider (e.g. a commercial company, or a country operating at the global level), the NSMC may be tempted to accept such an offer. This raises a number of issues, including that SWFDP regional management is weakened to some extent, and different NMHSs within a particular region may have different types of equipment, with different facilities, different training needs, etc. As such, it is recommended that both regional management and WMO-level management, including the SWFDP SG, are both aware of potential developments in these areas, and have appropriate plans in place on how to optimally deal with them.

10.10) The current complexity of the SWFDP process, with its combination of components of meteorology, hydrometeorology, technology and communications, is acknowledged, as is the general operational success of this complex system. There are, however, further environmental elements that potentially could be included within a SWFDP-style process, such as forecasts and warnings and reports of earthquakes, tsunamis, volcanos, and possibly even drought and climate change, in addition to the more-familiar tropical cyclones, flash floods, coastal inundations, storm surges and significant long-period swells. The question that could reasonably be asked at this time is: "where is the boundary now between what is, and what is not, forecast under SWFDP (or SWFDDP), and should that boundary change in the future as SWFDP (or a potentially re-named evolution) evolves?" A similar question could be asked re the technology for an evolving future: "should all the technology come within the SWFDP remit, or should there be a piecemeal evolution, much as is currently occurring (e.g. non-SWFDP facilities from Japan, US, Australia)?" On a tactical level, these are questions for regional management and for the SWFDP SG, but because of the potential involvement of many other WMO Programmes, a more-strategic approach is likely to be more appropriate.

10.11) The potential incorporation of the CIFDP and FFGS f/c and warning programmes into the SWFDP process is being examined in Phase 2 of this Report (see Section 9), and it is likely that this examination will help to illustrate both the potential benefits and disadvantages of combining additional components into the SWFDP process.

10.12) It is recommended that the process of undertaking an external review of SWDFP and its evolution is maintained on a regular, but infrequent, basis, as an independent (of WMO) analysis of how efficiently SWFDP procedures are working, and for suggesting any suitable changes in its evolution. A suggested period between independent reviews is 4 years, to ideally coincide with the timescale between successive WMP Congresses.

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Romeo Ganal, Jr	Hydrometeorological Forecaster, N Luzon, PAGASA Regional Centre
Jhomer Eclarino	Hydrometeorological Forecaster, Visayas, PAGASA Regional Centre

12) Appendices

Appendix 12.1 **Terms of Reference of this Report** (concerning the review of the SWFDP)

The **Terms of Reference** of this Report (concerning the review of the SWFDP) are:

12.1.1) To review and comment on its current vision and mission, Guide and Implementation Plan as well as the current status and progress in the implementation of the SWFDP, fulfilment of its objectives and its effectiveness in so doing;

12.1.2) To examine, review and comment on the performance of sub-projects (completed or under development) based on available reports and interviews and discussions with relevant target group representatives (eg. the forecasting community, the National Disaster Management Agencies and other relevant stakeholders) including aspects of the benefits and costs of sub-projects undertaken, whilst responding to the following overall questions: is there evidence to suggest that the SWFDP is a good idea, and if so, what governance structure is recommended to ensure the projects continue to provide benefits in the long-term; and whether other sub-projects should be initiated, and if so, how would they be effectively managed?

12.1.3) Within this overall structure, this Review will also include:

12.1.3.1) Conclusions and recommendations with respect to the future directions of the SWFDP, and identify remedial actions to enhance its development and sustainability, and on the need for establishing new, modified, or complementary approaches that could be taken in advancing the concept of SWFDP;

12.1.3.2) Suggestions for means of ensuring the efficient and effective relationship of the SWFDP with other relevant initiatives including the CIFDP and FFGS especially in light of the Sendai Framework as adopted at the Third United Nations (UN) World Conference on Disaster Risk Reduction (WCDRR), the Paris Agreement (within the framework of the United Nations Framework Convention on Climate Change - UNFCCC), and the 2030 Agenda for Sustainable Development;

12.1.3.3) Suggestions to enhance the active participation and outreach of NMHS and National Disaster Management Agencies to increase benefits and use of SWFDP products for efficient decision-making;

12.1.3.4) Review and comment on the terms of reference and membership of the SWFDP Steering Group (SG), comment on their effectiveness, and make recommendations with respect to the future governance structure needed for the SWFDP efforts including its Terms of Reference and Composition, including mechanisms to improve coordination with stakeholders and donors;

12.1.3.5) A review and comment on raising of extra-budgetary resources and make recommendations on how best this should be approached; &

12.1.3.6) Methods used to gather information at visits to SWFDP locations (see also Appendix 12.2)

12.1.3.7) Any other related comments/suggestions.

Appendix 12.2 Potential questions to ask those who interact with SWFDP

In this draft of potential questions to be asked, the groups to whom the questions are going to be asked have been split into three categories, to permit more-focused feedback to be obtained. The 3 categories are: (a) both operational forecasting staff and meteorological management staff at Regional Centres (RSMCs), e.g. Pretoria; (b) both operational forecasting staff and meteorological management staff at National Centres (NMHSs), e.g. Tonga; (c) appropriate national Civil Protection Agency (CPA) staff and/or national Disaster Management Agency (DMA) staff; & national media staff, e.g. from TV and Press.

12.2.1) Questions for both operational forecasting staff and meteorological management staff at Regional Centres (RSMCs), e.g. Pretoria.

1) In your opinion, and in general terms, how well does SWFDP operate nowadays, so far as you are concerned?
   For example: very well/generally OK/adequate, but has occasional issues/has some significant flaws. What views/reasons/evidence do you have for your answer to this?

2) How do you believe – in general terms – that SWFDP has developed/evolved since its original introduction?
   Examples of possible development/evolution could include any combination of:
   generally better overall/generally worse overall/generally mixed overall (some improvements, but also some aspects worse)/significant technological and methodological changes/interpersonal communication changes (both within own centre, and between centres, e.g. need to speak/explain more/less)/too much information ('information overload')/too little information/inappropriate information (e.g. insufficient local detail and/or unsuitable forecast timescale)/conflicting information/too little time available to undertake one's tasks in a professional manner/varying levels of training.
   Can you provide opinions/reasons/evidence for your answer to this?

3) If you were suddenly switched into a different role within SWFDP, e.g. you were now a senior manager at your national DMA (rather than a meteorological forecaster/manager), and were personally responsible for the organisation of saving lives after a severe weather event, would your responses to any of the above questions be any different, and if so, why?

4) Do you receive much feedback from the national meteorological agencies (NMHSs) such as Gaborone, Windhoek, etc., e.g. formally, such as in Case Studies, and/or informally, such as in telephone conversations or via social media? How useful is any formal or informal feedback that you do receive?

5) How do you think that SWFDP could be improved (if at all)?
   For example, by ending the Programme if you didn't think it had served its purpose, or by the provision of more funds to enable better technology/equipment, or by the provision of more

training, or by more publicity being given to the various aspects of SWFDP, or by the provision of more documentation, or by further new developments/evolution in the SWFDP process?

6) Global meteorological centres (e.g. ECMWF, UKMO, Tokyo) contribute – both financially and by the provision of core guidance output – to SWFDP's implementation and operation. In practical terms, this means the operational provision of timely forecast data products to Regional Specialised Meteorological Centres (RSMCs) such as Pretoria, Wellington and Hanoi. Do you believe that the co-operation between global centres and RSMCs is generally good? Please provide reasons for your response, and suggestions for any aspects that you believe could be improved and/or enhanced.

7) Do you believe that the "cascading forecasting system" of global centre output to regional centre output to national centre output (e.g. ECMWF output to Pretoria output to Gaborone output), covering, respectively, global, regional and national geographic domains, is an optimum way to distribute and utilise forecast products, or could it be improved? Please provide reasons for your response, and suggestions for any aspects that you believe could be improved and/or enhanced.

8) In your opinion, would SWFDP be enhanced (at a later date) if it was combined with other programmes or processes, e.g. for the provision of specific flood alerts/warnings? In terms of both meteorology and other environmental factors (e.g. drought, flooding) do you believe that, generally speaking, it is more sensible to keep meteorological forecasts and warnings distinctly separate from forecasts and warnings from other environmental agencies, or would it better to try and optimally combine meteorological and other environmental forecasts and warnings together? Please provide reasons for your response.

12.2.2) uestions for both operational forecasting staff and meteorological management staff at National Centres (NMHSs), e.g. Tonga, Philippines.

1) In your opinion, and in general terms, how well does SWFDP operate nowadays, so far as you are concerned?
For example: very well/generally OK/adequate, but has occasional issues/has some significant flaws. What opinions/reasons/evidence do you have for your answer to this?

2) How do you believe – in general terms – that SWFDP has developed/evolved since its original introduction?
Examples of possible development/evolution could include any combination of:
generally better overall/generally worse overall/generally mixed overall (some improvements, but also some aspects worse)/significant technological and methodological changes/interpersonal communication changes (both within own centre, and between centres, e.g. need to speak/explain more/less)/too much information ('information overload')/too little information/inappropriate information (e.g. insufficient local detail

and/or unsuitable forecast timescale)/conflicting information/too little time available to undertake one's tasks in a professional manner/varying levels of training.
Can you provide opinions/reasons/evidence for your answer to this?

3) Do you believe that SWFDP has been helping you to achieve the overall goals of your NMHS? If so, please specify how you think that it has helped to achieve this; if not, please indicate where and how you would like to see improvements made.

4) Do you receive much feedback from your regional meteorological centre (RSMC), e.g. either formally, such as in Case Studies, and/or informally, such as in telephone conversations or via social media? How useful is any formal or informal feedback that you do receive?

5) Since the introduction of SWFDP, do you believe that your RSMC has developed closer working relationships with (a) your DMA (and/or CPA) and (b) your national media? In particular, do you believe that they are happy with the current dedicated levels of service provided by your RSMC? Please provide reasons for your answers. Please could you also describe what you believe to have been the contribution of SWFDP with regard to any changes (hopefully, improvements) in these DMA/CPA/Media working relationships.

6) How do you think that SWFDP could be improved (if at all)?
For example, by ending the Programme if you didn't think it had served its purpose, or by the provision of more funds to enable better technology/equipment, or by the provision of more training, or by more publicity being given to the various aspects of SWFDP, or by the provision of more documentation, or by further new developments/evolution in the SWFDP process?

7) Global meteorological centres (e.g. ECMWF, UKMO, Melbourne) contribute – both financially and by the provision of core guidance output – to SWFDP's implementation and operation. In practical terms, this means the operational provision of timely forecast data products to Regional Specialised Meteorological Centres (RSMCs) such as Pretoria, and from the operational provision of timely forecast data products from RSMCs to national centres (NMHSs) such as Gaborone. Do you believe that this level of co-operation between global centres and RSMCs *via NMHSs* is generally good? Would you say, or not, that it is generally suitable for your (NMHS's) needs? Please provide reasons for your responses, and suggestions for any aspects that you believe could be improved and/or enhanced.

8) Do you believe that the "cascading forecasting system" of global centre output to regional centre output to national centre output (e.g. ECMWF output to Pretoria output to Gaborone output), covering, respectively, global, regional and national geographic domains, is an optimum way to distribute and utilise forecast products, or could it be improved? Please provide reasons for your response, and suggestions for any aspects that you believe could be improved and/or enhanced.

9) In your opinion, would SWFDP be enhanced (at a later date) if it was combined with other programmes or processes, e.g. for the provision of specific flood alerts/warnings? In terms of both meteorology and other environmental factors (e.g. drought, flooding) do you believe that, generally speaking, it is more sensible to keep meteorological forecasts and warnings distinctly separate from forecasts and warnings from other environmental agencies, or would it better to try and optimally combine meteorological and other environmental forecasts and warnings together? Please provide reasons for your response.

12.2.3) Questions for appropriate staff from national CPAs and DMAs, and also from national media (particularly TV and Press).

1) What are your requirements for weather information and warnings, in both a general sense, and in detail?

2) The provision of weather information including warnings to you over the past 12 years or so has been undertaken using the SWFDP process. What is your perception of both the quality and accuracy of the forecasts and warnings that you have received over this timescale? Have you noticed any improvements in either quality and/or accuracy over this same timescale?

3) Are you aware of the various elements comprising the SWFDP process? Would you be interested in knowing more about this process, and about potential plans for its future enhancement?

4) Do you feel that there are sufficient/appropriate levels of communication between SWFDP and yourselves? What improvements do you believe that SWFDP can develop to provide an improved/enhanced service to yourselves, e.g. new products, new presentation styles, enhancements in timeliness and accuracy?

Appendix 12.3 Acronyms

CBS	Commission for Basic Systems (a WMO Technical Commission)
CIFDP	Coastal Inundation Forecasting Demonstration Project
Cg	(WMO) Congress
CMO	Caribbean Meteorological Organisation
DMCPA	Disaster Management and Civil Protection Authority
DRR	Disaster Risk Reduction
EC	Executive Council (of WMO)
FFGS	Flash Flood Guidance System
GCOS	Global Climate Observing System
GDPFS	Global Data-processing and Forecasting System
HTMIRDS	Hydrometeorology, Tropical Meteorology & Instruments Development & Research Division
ICU	Island Climate Update
IITM	Indian Institute of Tropical Meteorology
INCOIS	Indian National Centre for Ocean Information Services
JMA	Japan Meteorological Agency
MASA	Meteorological Association for South Africa
MHEWS	Multi-Hazard Early Warning System
NCMRWF	National Centre for Medium Range Weather Forecasting (India)
NDMA	National Disaster Management Agency
NDRRMC	National Disaster Risk Reduction and Management Council (Philippines)
NEMO	National Emergency Management Office
NHC	National Hurricane Centre
NMHS	National Meteorological and Hydrological Service
NWP	Numerical Weather Prediction
NWS	National Weather Service

OPAG	Open Programme Area Group (in WMO)
PAGASA	Philippines Atmospheric, Geophysical and Astronomical Services Administration
RA	Regional Association (of WMO)
RCC	Regional Climate Centre (of WMO)
RFSC	Regional Forecast Support Centre
RSIP	Regional Subproject Implementation Plan
RSMC	Regional Specialised Meteorological Centre
RSMT	Regional Subproject Management Team
SADC	South African Development Community
SARFFGS	South African Region Flash Flood Guidance System
SAWS	South African Weather Service
SG	Steering Group (of WMO's SWFDP)
SIDS	Small Island Developing States
SPREP	Secretariat of the Pacific Regional Environmental Programme
SWFDP	Severe Weather Forecasting Demonstration Project
SWFDDP	Severe Weather Forecasting & Disaster risk reduction Demonstration Project
TMS	Tonga Met Service
UKMO	United Kingdom Met Office
UNFCCC	United Nations Framework Convention on Climate Change
WCDRR	World Conference on Disaster Risk Reduction
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organisation

A fuller list of WMO acronyms associated with WMO Commissions, Programmes and other portals is also available here.

Appendix 12.4 The 4 Phases of SWFDP

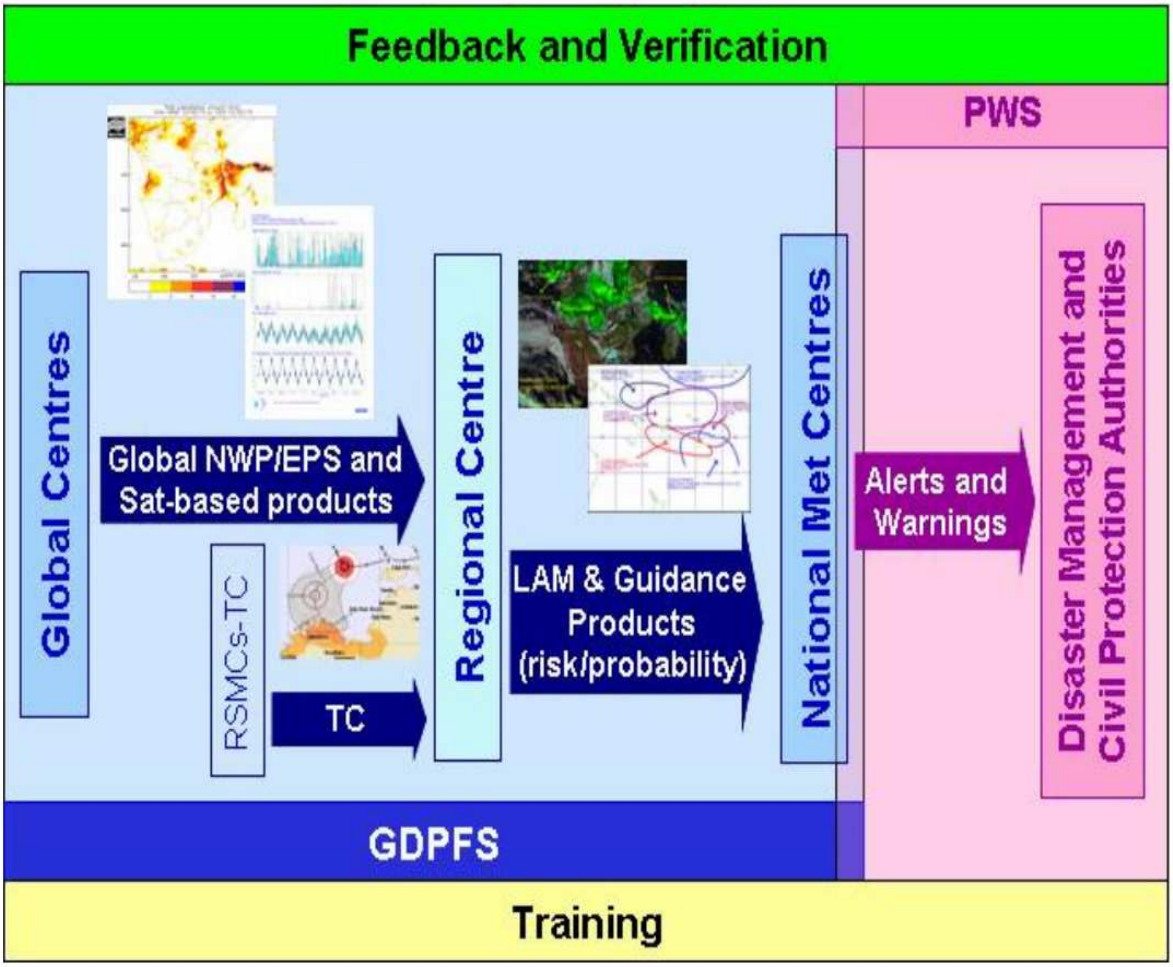
Phase I: Overall Project Planning. This phase includes the preparatory work necessary to prepare the project specifications, the list of types of products to be exchanged and the work of the Project Steering Group (PSG) to identify the possible participating centres and to select suitable regional subprojects according to the geographical area, the type of severe weather and the chosen period for the experimentation.

Phase II: Regional Subproject Implementation Planning and Execution. This phase begins with the preparation of the detailed specifications (data and products to be exchanged, performance measurements, reviewing and reporting) allowing the participants (representatives of the participating GDPFS and national centres) forming a regional subproject management or implementation team to develop the specific subproject implementation plan, including a training programme, and to manage its implementation and then to carry out the experimentation itself which is likely to last about one year.

Phase III: Regional Subproject Evaluation. This phase includes the analysis and the evaluation of the entire subproject as well as contributing to the evaluation of the overall SWFDP with respect to the goals proposed initially. This phase gives the opportunity to identify gaps and deficiencies, and areas for improvement in order to ensure a sustainability of the organization tested during the regional subproject and to provide improved specifications for other similar regional subprojects.

Phase IV: Regional Subproject Long-term Sustainability and Future Developments. This phase includes long-term sustainability of the benefits gained and a process of continual improvement. This phase gives the opportunity to continuously take advantage of future capability and technology developments, and to foster broadening of activities in synergy with other WMO programmes. In this phase, the responsibility for management, including seeking funding, lies with the Regional Association, while the PSG continues to be informed of developments and to provide advice as appropriate.

Appendix 12.5 **A schematic diagram of the Cascading Forecasting Process**



Note that while products cascade from global to regional to national level, and on to the DMCPAs (i.e. from left to right in the schematic), as does the provision of training, the process also works in the opposite direction, with the provision of feedback and verification from each level through to the next level (i.e. from right to left in the schematic).

Appendix 12.6 WMO Resolution 1 (EC-70)

WMO Resolution 1 (EC-70)

Consolidated approach to severe weather forecasting

THE EXECUTIVE COUNCIL,

Recalling:

(1) Resolution 13 (Cg-17) – Report of the extraordinary session (2014) of the Commission for Basic Systems concerning the Global Data-processing and Forecasting System and emergency response activities, which included the endorsement of Recommendation 23 (CBS-Ext.(2014)) – Proposed mechanism to strengthen operational centres, built upon the lessons learned through the Severe Weather Forecasting Demonstration Project, which proposed, inter alia, to establish the Severe Weather Forecasting Programme to emphasize the need to develop sustained operational capability,

(2) Decision 9 (EC-68) – Severe Weather Forecasting Demonstration Project, which endorsed the critical elements for consolidating the Severe Weather Forecasting Demonstration Project (SWFDP) into global sustainable operational services,

(3) That the development of SWFDP in West Africa was initiated following a technical training workshop on severe weather forecasting and public weather services held in Dakar in November 2015, and a technical planning workshop on SWFDP implementation in West Africa held in Abidjan in September 2016,

Noting that SWFDP, which was initiated in 2006 with the participation of just five countries in south-eastern Africa, has been expanded to cover eight subregions with involvement of over 75 developing countries, least developed countries (LDCs) and small island developing States (SIDS) in southern Africa, the South Pacific, eastern Africa, South-East Asia, the Bay of Bengal, Central Asia, West Africa and the Eastern Caribbean in Regional Associations (RAs) I, II, IV and V; and that this has resulted in escalating training requirements requiring increased resources,

Noting also the interest in implementing SWFDP in Oceania (RA V), South America (RA III), Central America (RA IV) and the rest of Africa (RA I),

Noting with satisfaction that SWFDP has been contributing to improving public safety and disaster risk reduction through the cascading forecasting process that facilitates improved forecasts and delivery of severe weather warnings by participating National Meteorological and Hydrological Services, and that its synergies with the Flash Flood Guidance System (FFGS) in southern Africa and other subregions is bringing more benefits to Members by allowing them to provide operational support for multi-hazard early warning services,

Acknowledging that the SWFDP regional sub-projects are mainly funded through extrabudgetary resources and that financial resource mobilization for the ongoing regional sub-projects and their synergies with other relevant projects and activities, such as FFGS, has always been challenging,

Considering:

(1) The Commission for Basic Systems (CBS) Management Group decision (March 2018) to perform the overall 12-year review of SWFDP to assess benefits to participating developing countries, LDCs and SIDS in terms of the contribution of SWFDP to forecasting and early warning services, as well as to inform the future development and strategy of SWFDP, including options to oversee the project in phase IV and to report to the Eighteenth World Meteorological Congress,

(2) That Resolution 6 (CHy-15) – The Flood Forecasting Initiative and the contribution of the Commission for Hydrology to the Disaster Risk Management Programme, and Decision 17 (JCOMM-5) – Future of the Coastal Inundation Forecasting Demonstration Project, both called for independent review of the Coastal Inundation Forecasting Demonstration Project (CIFDP) to consider developing a governance structure and procedures that would transition CIFDP to a more sustainable platform for the strengthening of national multi-hazard early warning systems to address flooding in coastal areas (see Decisions 10–12 (EC-70) and Resolution 16 (EC-70),

(3) The recommendation of the Flood Forecasting Initiative Advisory Group (FFI-AG) (December 2017) that the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) and the Commission for Hydrology (CHy) should conduct an independent review of CIFDP and FFGS; and that CBS should do the same for SWFDP; and that FFI-AG, through its Chairperson, will report on the reviews to Congress (see Resolution 16 (EC-70),

Decides:

(1) To conduct a joint independent review of SWFDP, FFGS and CIFDP, which are disaster risk reduction supporting projects, with emphasis on how these projects have made a difference to the life of communities they serve, on their training needs and sustainability, and on the importance of a national voice for the dissemination of warning information;

(2) That, following the review of these projects, a consolidated approach should be developed jointly by the presidents of CBS, CHy and JCOMM to ensure SWFDP, CIFDP and FFGS ensure efficient, sustainable services related to hazardous weather, water and climate;

(3) That the result of the review and the consolidated approach should be reported to Congress by the president of CHy, Chairperson of FFI-AG;

Requests the Secretary General to facilitate the effective implementation of the present resolution;

Invites Members to contribute to the SWFDP Trust Fund to support the severe weather programme office, enabling activities and the development of new SWFDP projects to expand the programme towards global coverage.