

**COASTAL INUNDATION FORECASTING
DEMONSTRATION PROJECT**

- IMPLEMENTATION PLAN -

JCOMM Technical Report No. 64

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DEMONSTRATION PROJECT**

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NOTES

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COASTAL INUNDATION FORECASTING DEMONSTRATION PROJECT (CIFDP) IMPLEMENTATION PLAN

1 Background

1.1 Introduction

Coastal disasters are a major threat to the people whose lives and livelihoods depend on safety and socio-economic development in low-lying, highly-populated coastal areas. They include storm surges and wind-induced waves associated with severe cyclones, and their combined effect with river flooding, leading to coastal inundation. Risk management for such coastal disasters represents a great challenge to scientists and policy makers in Meteorology, Hydrology, Oceanography, Emergency Management and Coastal Planning. In particular, recognizing this extreme vulnerability of coastal areas to storm surges and coastal inundation/flooding due to Tropical Cyclones (TCs), there is a strong need for the development and implementation of comprehensive forecasting and warning systems, which allow dedicated disaster prevention agencies to safeguard lives and mitigate damages to infrastructure in coastal areas.

The goal of the Coastal Inundation Forecasting Demonstration Project (CIFDP) is to show how coastal inundation forecasting products can be improved and effectively coordinated with warning services provided by the National Meteorological and Hydrological Services (NMHSs). This process will be facilitated primarily by the WMO Technical Commissions, in particular the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) and the WMO Commission for Hydrology (CHy), in cooperation with a consortium of experts and related institutions of excellence in the field of storm surge, wave and hydrological flooding in order to deal with the coastal inundation matter from the viewpoint of the Total Water Level Envelope (TWLE)¹.

The CIFDP is to contribute to the improvement of the interaction of the national operational forecasting agencies (e.g. National Meteorological and Hydrological Services: NMHSs) with Disaster Management Agencies (DMAs), through an integrated coastal management strategy, including the development of preparedness, response and management strategies of storm surges and waves associated with coastal inundation. These strategies will be built on the basis of hazard and vulnerability maps and related information by developing scenarios, for the use of DMA. These scenarios will be the basis for disaster preparedness, and will provide valuable assistance to national partners involved in recovery and reconstruction activities.

The key to successfully develop a comprehensive coastal inundation forecasting and warning system is the cooperation of different scientific disciplines and user communities. An integrated approach to river flow, storm surge, wave and flood forecasting will be the strategy for building improved operational forecasts and warnings capability for coastal inundation.

Key players for development and operation of such a system should be the operational national forecasting agencies including NMHSs and other responsible national agencies of affected states. At present, the number of national agencies globally that run storm surge, wave and hydrological models, and coupled coastal forecasting systems is fairly limited and almost non-existent in developing countries. Hence, the CIFDP will work with responsible national agencies to support them in utilizing forecast products operationally and linking them to coastal flood

1 This 1st JCOMM Symposium on Storm Surges (2-6 October 2007, Seoul, Korea), taking into account the emerging awareness of the need to promote the storm surge activity, strongly recommended to improve prediction for total water levels that is the real source of risk in coastal areas comprising tide, wave, surge and other factors.

management programmes and related activities. This requires substantive training in the use of these products, under different hydro-meteorological and risk situations.

As many sectors are involved, this requires an integrated approach that is embedded in an overall framework of coastal risk management. Other key players include national and local institutions responsible for disaster prevention, international organizations and centres of excellence in research and application of storm surge and coastal inundation mapping, modelling and forecasting. Moreover, early and full engagement of intermediary and end users of coastal inundation information, through the entire process of the development, verification, and application, is key to ensure sustainability and usability of such systems.

Introduction to and summary of progress in National Sub-Projects, as well as other up-to-date information on the CIFDP can be found at the Project web site: <http://www.jcomm.info/CIFDP>.

1.2 Project Initiation and Organization

WMO Fifteenth Congress (May 2007) requested the Secretary-General to “coordinate the collection and dissemination of information on meteorological, hydrological and climate-related hazards and their impacts, when possible and available”. Furthermore, in response to a request of the WMO Executive Council, at its 60th session (June 2008), WMO has initiated, through the joint efforts of Tropical Cyclone Programme (TCP) and JCOMM, the development of Storm Surge Watch Schemes (SSWS) in regions subject to tropical cyclones. Finally, WMO, through its Hydrology and Water Resources Programme (HWRP), is contributing through the improvement of tools and methodologies for flood hazard and risk analysis.

In this context, the JCOMM and CHy have initiated the CIFDP. The WMO Secretariat, through its Marine Meteorology and Oceanography Programme (MMOP), has coordinated and supported regular CIFDP meetings from June 2009, where the Project Steering Group (PSG) was established to review various existing storm surge, wave and hydrological models and integrated systems for coastal inundation forecasting as well as to identify the technical gaps and societal needs. The PSG has also developed the CIFDP Concept and Implementation Plan (this document), which is continuously reviewed and revised through its regular Steering Group Meetings taking into account the latest development and progress of the Project. The PSG is also tasked to provide general guidance to the implementation of the Project (see section 2.4).

The Project is to be implemented under each national Sub-Project launched for a country that meets the essential requirements. The overall project concept for each of these Sub-Projects should not be limited to the country itself but approached regionally. The procedures/best practices developed through a sub-project should be applicable to other (neighbouring) countries with common issues and interests (see section 2.5).

2 Description of the CIFDP

2.1 Goals and Objectives

The goal of the CIFDP is to demonstrate how coastal inundation forecasting products can be improved and effectively coordinated with warning services. This process will be facilitated primarily by WMO technical commissions, in particular JCOMM and CHy, in cooperation with national and international programmes and activities in the field of storm surge, wave and coastal flooding.

The CIFDP is to contribute to the improvement of the interaction of forecast producing agencies with DMAs, through an integrated coastal management strategy, including the

development of preparedness, response and management strategies of storm surges and waves associated with coastal inundation. These strategies will be built on the basis of hazard and vulnerability maps and related information by developing scenarios, for the use of DMA. These scenarios will be the basis for disaster preparedness, and will provide valuable assistance to national partners involved in recovery and reconstruction activities.

The CIFDP aims to provide an example of cooperative work as a strategy for building improved operational forecasts and warnings capability for **coastal inundation, combining extreme waves, surges and river flooding events** that can be sustained by the responsible national agencies through:

- Identifying the national and regional requirements;
- Implementation of open-source coastal inundation end-to-end operational forecasting and warning systems;
- Developing cross-cutting cooperation among different scientific disciplines and user communities;
- Building communication platforms between researchers, forecasters and disaster managers involved in coastal inundation management;
- Specialized training for operators, forecasters and disaster managers.

2.2 Scope

The main focus of the CIFDP will be to **facilitate the development of efficient forecasting and warning systems for coastal inundation** based on robust science and observations. The CIFDP should:

- Identify and support end-user needs. In this context, full engagement of the stakeholders and partners in the CIFDP from early stages is critical for the successful development and implementation of this project;
- Support informed decision-making on warning issuance and dissemination (that includes information on land-use and planning) in coastal zones;
- Transfer and translate science and technology to communities (technology development and transfer);
- Facilitate the development of a comprehensive Storm Surge Watch Scheme (SSWS) in basins subject to tropical cyclones and storm surges, jointly with (fluvial) flood events;
- Facilitate the development and implementation of warning services;
- Support coastal risk assessment, hazard and risk mapping.

In doing so, the CIFDP will make efforts to integrate cross-cutting scientific models into an open forecasting environment for the purpose of improving/ expanding/ developing the forecasting and warning systems for storm surges, hydrological response to heavy rainfall and Tropical Cyclone landfall on delta/estuary areas, and other phenomena causing coastal inundation.

The project will focus on integrating the forecasting models already in operational use as modular components which can be easily replaced or updated as enhanced versions become available. The modelling components will be developed and adapted to fit in an open, flexible and easily extendable forecasting system: the future coastal inundation forecasting system. The new system is expected to underpin a significant improvement of flood disaster management in coastal areas.

2.3 Expected Outcomes and Deliverables

The major expected outcomes of the CIFDP are as follows:

- Technology development and transfer, including training, which would enhance the capabilities of responsible national agencies to produce and provide integrated coastal inundation forecasting and warning services;
- Established procedures, best practices and outcomes of CIFDP will serve as guidelines to other countries to develop and improve their related service capabilities, and furthermore, contribute to building specific criteria for designated WMO Regional Specialized Meteorological Centres (RSMC) to provide NMHSs with advice on coastal inundation forecasting and warnings;
- CIFDP implementation would create synergies with the ongoing regional and global programmes and activities; for example, enhancing effective use of improved Numerical Weather Prediction (NWP) products by building a “cascading forecasting process” for coastal processes with the WMO Severe Weather Forecasting Demonstration Project (SWFDP) process, and providing technical requirements to develop the regional SSWS;
- Communication platform, which would improve interactions of responsible national agencies and partners (e.g. governmental forecasting agencies, agencies responsible for disaster management, Civil Protection Agencies, media), will provide a mechanism for continuous improvement in identifying user requirements, technical needs, and user feedback.

2.4 Strategic Approach for Project Implementation

JCOMM at its 4th session (May 2012, Yeosu, Republic of Korea) adopted a general strategy for a Coastal Inundation Forecast Demonstration Project (CIFDP) as follows:

- The Project would be implemented under each regional/national sub-project, launched for a country that meets the essential requirement for initiating a national agreement between national institutions with relevant responsibilities, and the provisional establishment of a NCT that includes operator(s) of the NMHS;
- The Project would be designed based on users’ perspectives and requirements, considering only existing and available open-source techniques. Final products of the Demonstration Project should be operated and maintained by a national operational agency which has the responsibility/authority for storm surge warning and flood warning;
- The procedures/best practices developed through a sub-project should be applicable to other (neighbouring) countries with common issues and interests, and should be closely linked to and cooperating with related projects and activities.

The project will be implemented in a **phased approach**, which provides opportunity to adjust the scope of the next phases to fit the prevailing requirements. As well as the final results of the Project, the accomplishment of each phase will serve as a useful exercise for the target country to raise the issue of coastal inundation management within its governments and among a wide range of multidisciplinary communities, and to take steps toward integrated forecasting and warning services.

At the end of each phase the status of the project will be reviewed by PSG before starting the next phase. A detailed description of the phases is discussed in section 4.

2.5 Overall Project Setup – Regional Sub-Projects

Considering that the Project will address both institutional and technical aspects relating to the operational coastal inundation forecasting and warning, which will be an essential part of the disaster management in the country, the Project will be implemented under each national sub-project launched for a country that meets the essential requirements (see section 3).

Countries that intend to develop a sub-project are invited to prepare and deliver to WMO an Initial National Agreement between participating national agencies responsible for coastal inundation forecasting and warning, to be the basis of a Definitive National Agreement (DNA).

The overall project concept for each of these Sub-Projects should not be limited to the country itself but approached regionally. The procedures/best practices developed through a sub-project should be applicable to other (neighbouring) countries with common issues and interests.

The implementation of specific sub-projects is described in detail at the Project web site: <http://www.jcomm.info/CIFDP>.

3 Project Organization

3.1. Overview

Implementation of CIFDP is governed by a Project Steering Group (PSG) with appropriate expertise for the development and implementation of the project, comprising met-ocean, hydrological and social experts. The Terms of Reference and membership of the PSG are defined in Appendix A. The PSG will be supported by the WMO Secretariat that coordinates the overall Project activities.

A demonstration of integrated operational forecast system will be conducted with the lead at the national agency that has the mandate for operational forecasting in a country; this will be done in coordination with other technical agencies which are involved in various aspects of coastal inundation forecasting, and through seamless interaction with user community (c.f. immediate users of the forecasting/warning services, including disaster management authorities). The lead agency will be the owner of the system, with a responsibility to maintain its daily operation.

3.2. National Commitment

CIFDP will be implemented for each sub-project initiated by a country, with leadership and participation from operational forecast agency(ies), with the following requirements:

- Given mandates/responsibilities for coastal inundation forecasting and warning services;
- Availability of qualified staff to run the system in 24/7 mode, with appropriate computer and communication infrastructure;
- Commitment to sharing all data and information relevant to the inundation forecast process.

In the framework of JCOMM and CHy, the NMHS in cooperation with other national stakeholders, should play a key role in developing, implementing and applying the results of this Project. The NMHS and other national stakeholders including responsible national agencies will establish a Sub-Project National Coordination Team (NCT) to lead the Sub-Project implementation,

with guidance by the PSG for each phase (see section 3.4). Close cooperation with the national authorities for coastal disasters risk and emergency management as well as other stakeholders will ensure that user requirements are fully taken into account in the technical development.

It is strongly recommended that members of a NCT, particularly those of the NMHSs and other responsible forecasting agencies, are selected with a view of their continuing involvement in all phases of the Sub-Project implementation, in order to ensure the efficient and effective implementation of the Project.

User commitment is key; to ensure usability and sustainability of the outcome/results of the project, the end users will be involved from the early phases of project planning. The national and regional implementers should play the main role in identifying users and user requirements.

3.3. Links to Other WMO / Global, Regional Activities and National Initiatives

Modalities for interactions with and input from associated projects will be developed by the PSG. Activities which may be relevant to one or more regional sub-projects may include, but are not limited to the following:

- Pilot projects and activities of the JCOMM Expert Team on Waves and Coastal Hazard Forecast Systems (ETWCH), including the coordination of storm surge climatology;
- Precedent activities will provide the basis in planning CIFDP, such as the UNESCO project on “Enhancing regional capabilities for coastal hazards forecasting in North Indian Ocean” (<http://www.jcomm.info/SSIndia2>);
- The *eSurge* project of the European Space Agency (<http://www.storm-surge.info/>) will be implemented in close cooperation with the CIFDP, in view of improving storm surge forecasting systems and applications through the innovative use of ocean, land and atmospheric satellite observations. Common goals from these coordinated activities will include a comprehensive definition of data requirements - both in-situ and remotely sensed – and establishing an integrated information system to support the operation;
- Completed and ongoing regional initiatives, both in research and in operational development, will be taken into account to identify optimal technical solutions and procedures for the region/country of interest;
- UNOSAT is a critical organization in identifying past events and in providing the associated data required for evaluation and calibration of models;
- Multi-hazard Early Warning System (MH-EWS) projects organized by WMO in different Regions;
- Integrated Coastal Area Management (ICAM);
- PSG will also consider possibilities to engage with risk assessment activities, e.g. UNESCO Coastal Cities at Risk program.

3.4. Project Organization

The PSG, supported by the WMO Secretariat, has the task to review and approve the CIFDP Implementation Plan, and its Sub-Project components.

The Sub-Project National Coordination Team (NCT) will be comprised of the responsible national operational meteorological and hydrological agencies for the implementation of a forecasting and warning system developed through the CIFDP, and stakeholders and disaster

managers from the national and international institutions involved in disaster risk reduction and disaster response. The membership of the NCT will be determined during the initial stakeholders workshops, with a clear description of the roles and responsibilities of each participating agency. Specific names should be provided by each agency following the workshop as an essential part of the detailed sub-project plan. NCT will report to the PSG for approval of the Sub-Project Implementation Plan at each phase of the implementation.

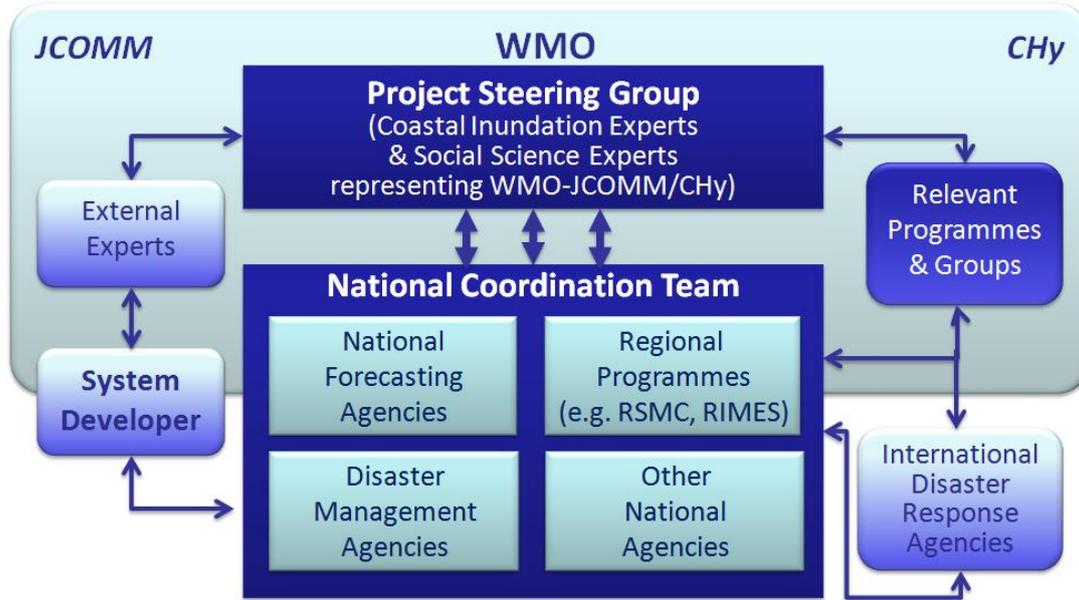


Figure 1. CIFDP Organigram

4 Approach to Project Implementation

The project for each region/country will be implemented for 3 years, in a **phased approach that leaves scope for adjustment in the next phases** to fit the prevailing requirements:

- Phase 0: Preparation
- Phase 1: Information Gathering – Project Adaptation
- Phase 2: System Implementation
- Phase 3: Pre-Operation Testing and Capacity Development
- Phase 4: Live Running and Evaluation

The project phases are described in more detail in the following sections. Description of the phases and activities will become more detailed as the project progresses.

4.1. Preparation (Phase 0)

Before the actual start of the CIFDP, **Initial National Agreements** at the political level should be prepared:

- based on a high level definition of the operational scope for the national sub-projects;

- to ensure commitment and coordination of the national agencies
- to ensure free and open exchange of data and information required for implementing a coastal inundation forecast project.

Task responsibility: WMO, responsible national agencies

4.2. Information Gathering – Project Adaptation (Phase 1)

In the implementation of CIFDP at the national level, Phase 1 is critical to confirm the national commitment toward the following phases, and to design a tailored coastal inundation forecasting and warning system addressing the national requirements. The PSG, in coordination with the WMO Secretariat must decide by the end of Phase 1 on the continuation of each National Sub-Project based on the review results.

4.2.1. Initial Assessments

The national capabilities in the fields of coastal flood risk, inundation forecasting and related emergency management structures will be assessed and described. A high level inventory of the institutional end-users' information and communication needs for emergency management during extreme coastal flood events will be made. Combining assessments of both technical capacities and end-users requirements (gap analysis) will demonstrate where the CIFDP could provide added value.

Task responsibility: NCT

4.2.2. Stakeholder Workshop

The stakeholder workshops will be organised for each National CIFDP Sub-Project, with objectives of: 1) wider introduction of the CIFDP; 2) information collection on stakeholder needs and requirements, and; 3) obtaining agreement and commitment on the project objectives.

Participants in this workshop will include:

- Organisations/agencies playing key roles in emergency management related to coastal flooding, for consideration of user needs;
- Forecasting agencies related to coastal flood risk forecasting systems, to discuss feasible technical options addressing user requirements.

The national stakeholder workshop will be a key activity in this phase of the project. The workshop will last not longer than one week, and if required, preparatory discussions can be held among the WMO Secretariat, PSG, and key national stakeholders prior to workshops to ensure tangible results.

In planning and conducting the workshop, interaction with and input from the Operational Satellite Applications Programme (UNOSAT) of the UN Institute for Training and Research (UNITAR), RSMC and other relevant data producing agencies will be actively sought and encouraged. The workshops will be concluded with following outcomes:

- recommendations for the Sub-Project implementation, both on technical development and users aspects;
- detailed work plan and time line for the first year.

These results will be the basis to establish and update a Sub-Project Plan, which will also serve as a proposal for funding that is required for the Sub-Project Implementation.

Task responsibility: WMO, NCT in consultation with PSG

4.2.3. *Definitive National Agreement (DNA)*

Based on the initial/updated Sub-Project Plan arising from the stakeholder workshop, a definitive commitment is to be obtained from the national government including the responsible national forecasting/warning agencies, to carry out the subsequent phases of the CIFDP Sub-Project, to ensure a long-term coordination between the national agencies within NCT.

Task responsibility: NCT

4.2.4. *Establishment of National Sub-Project Coordination Team (NCT)*

Based on the initial/updated Sub-Project Plan at the stakeholder workshop, a National Sub-Project Coordination Team (NCT) will be established, which will be responsible for the timely project implementation at the national level under the guidance and advice of the PSG. Its membership and a Terms of Reference (ToR) should be agreed along with the DNA. Within the NCT the national agency responsible for the operational forecasts, as agreed in the DNA, will take the leading role for project implementation at the national level.

Task responsibility: NCT in consultation with PSG

4.2.5. *Information Collection and Implementation Specification*

Following the stakeholder workshop, a full information collection should be undertaken by the NCT. In addition, documentation of the national approach to the CIFDP implementation (that is, establishment of a Sub-Project Plan) including the specification of technical systems, existing and required information products, and both intermediate and end user requirements should be undertaken. This Sub-Project Plan should identify:

- Specification of forecasting model components, forecasting system and hardware requirements;
- Definition of organisational setting - assessment of responsibilities structure & personnel capacity (training requirements, technical implementation approach);
- Inventory of vulnerability mapping data and products and practices in Coastal Flood Management.

Special attention will be given to the information collection for the following subjects:

- Assessment of existing marine meteorology, hydrology and tropical cyclones forecasting capacities, with the focus on compatibility with open-source modelling software packages;
- Assessment of the availability of met-ocean, atmosphere and hydrology data, including access to real-time observations, bathymetry, Digital Elevation Model (DEM), Geographic Information System (GIS) and data related to coastal inundations past events;
- Data collection and establishment of a storm surges/coastal floods events database, in coordination with storm surge climatology initiatives.

Task responsibility: NCT.

4.2.6. *Development of Sub-Project Plan*

Based on the workshop outcomes and follow-up, the NCT will compile a National Sub-Project Plan (see sections 4.2.1 to 4.2.5). At minimum, the Plan should describe

- Current status: technical and institutional capabilities with regard to the coastal inundation forecasting and associated services (e.g. capabilities of participating agencies in the NCT, and national structure for coastal inundation management);
- Gaps and needs: identified at the stakeholders workshop(s), to be the basis of the technical and organisational aspects of the Sub-Project;
- detailed working arrangements;
- selection of the forecast components for coastal inundation forecasting system, upon the advice of PSG;
- plans to identify financial resources and human resources required for Sub-Project implementation (e.g. a draft funding proposal).

If it is deemed appropriate, a set of recommendations may be delivered to the PSG addressing required advice and assistance from the PSG and WMO.

Task responsibility: NCT in consultation with PSG

4.2.7. *Project Phase Review and approval from PSG*

The compiled National Sub-Project Plan will be presented to the PSG for review, discussion and approval to start the next phase of the project. At this stage a definitive commitment from the national government and national agencies must already be in place.

This approval involves the technical and organisational aspects of the Sub-Project and the selection of the forecast components for coastal inundation forecasting system that allows integration of different modelling software packages in a modular mode, manages input and output data and provides standardized options for data analysis and presentation.

Task responsibility: WMO, PSG

4.3. **System Implementation (Phase 2)**

It should be recognized that the CIFDP is primarily a technical implementation of an integrated forecasting system and the main focus from this point on will concentrate on those aspects. In the meantime, the needs of the end users must always be kept in mind from the initial stage of the Sub-Project planning.

System implementation in Phase 2 will be the responsibility of the NCT comprising national agencies and the system developers. Experts designated by the PSG and by JCOMM/CHy will be involved at relevant moments in the implementation process while the PSG will be regularly updated on the progress of the work.

4.3.1. *Implementation Kick-off*

Prior to implementation, a kick-off meeting will be held to confirm the system implementation approach and the forecasting system setup as defined in the updated

Implementation Plan. The specifications will be updated and detailed (i.e. describing concretely the links to data, software, models, hardware, communication platforms) if required.

All key stakeholders at the national level should participate in the meeting and agree on the Sub-Project working arrangements, including a review of the membership and terms of reference of the NCT, the meetings timeline and the reporting structure. The end point of the Kick-off Meeting will be the generally accepted Sub-Project Plan.

Task responsibility: NCT

4.3.2. *Model & System Development*

4.3.2.1. *Forecasting Models*

Forecasting models needed for coastal inundation simulation (e.g. meteorological input including hurricane/tropical cyclone and rainfall, ocean modelling including storm surges, hydrological and hydraulic modelling) will be selected for the focus area(s) of the Sub-Project, based on available open-source modelling software. Serious attention must be given to the model interconnectivity and inter-changeability, and flexibility for later integration of advanced/upgraded modules into the forecasting system.

Task responsibility: NCT upon advice by PSG

4.3.2.2. *(Pre-)Operational Forecasting System*

The prototype forecasting system will be built for operational use integrating the various forecasting models. The national forecasting system will be built through configuration of an existing open forecasting system framework (e.g. Delft FEWS). In addition some development may be required to develop interfaces between models to work as an integrated forecasting system.

As part of the system implementation, the set-up of formalized communication platforms for data management and project coordination will be worked out.

Technology transfer and on-the-job training will be an important element throughout the system implementation phase (see section 4.2.4), to ensure that the developed system will be autonomously operated and maintained by the responsible national forecasting agency(ies). The system implementation will be carried out by the system developers, either identified within the NCT or external expert(s), with support from the technical experts of the NCT and other identified national agencies to build local experience and capacity.

Task responsibility: NCT and/including system developers

4.3.2.3. *Hardware setup*

Following the hardware specifications developed from Phase 1 of a National Sub-Project, a hardware platform will be set up or upgraded to run the forecasting system including the forecasting models. Where possible co-hosting may take place with existing systems.

The hardware platform should be available at an early stage of Phase 2 to allow operation and testing of initial versions of the forecasting system. If required, on-the-job and some formal training of system managers will be part of this task.

Task responsibility: Responsible national agencies with support from system developers.

4.3.2.4. *System Testing*

System testing will include functional, performance and operational tests of prototype versions of the forecasting system from an early stage in the implementation phase. Based on simulation and hindcast of several characteristic historical events (e.g. tropical cyclones, storm surges, floods) the performance of the forecasting system including the forecasting models will be tested and demonstrated.

As part of this task, an acceptance testing plan will be prepared for testing in Phase 3 of the CIFDP. Further validation and improvement of the forecasting system will be carried out in the operational testing phase during the tropical cyclone season in coordination with forecasters from the responsible national agencies.

Task responsibility: system developers with support from NCT / responsible national agencies

4.3.3. *End User Products*

An iterative approach will be followed for (web based) forecasting product development and related communication procedures to ensure a good and practical connection to end-user needs. Feedback from end-users and forecasters will be obtained on regular basis.

Development of coastal inundation scenarios (based on flood risk mapping) will be carried out in collaboration with Disaster Management and Civil Protection Agencies (DMCPAs), disaster response and risk reduction institutional partners following existing guidelines such as the WMO/HWRP Integrated Flood Management approach, and ICAM guidelines. User feedback should be duly documented as part of the Sub-Project implementation results.

Task responsibility: NCT

4.3.4. *Capacity Development and Training*

Throughout the system implementation phase, the system developers should conduct appropriate training for system operators / professionals in order to ensure that the responsible national agency(ies) would be able to operate and maintain the developed forecasting systems at the completion of the project.

Training in this phase should also be the basis of more extensive formal training in Phase 3 of the CIFDP, as well as the development of system user guidelines (see section 4.5).

Task responsibility: Identified system developers for sub-projects, with support from appropriate experts.

4.3.5. *Sub-Project Implementation Progress and Plan Update*

The NCT will advise the PSG of any issues which may arise during the implementation of the project phase, or any delays in the project timeline as soon as they may arise.

Based on the results from the implementation of the prototype of the forecasting system, the Sub-Project Plan will be updated and detailed for the remaining phases of the CIFDP. The update is expected to include:

- Acceptance testing plan;
- Plan for the operational system set-up;
- CIFDP communication plan (dissemination of project results to wider audience);

- Human resource development and training plan.

Task responsibility: NCT with advice from PSG.

4.3.6. *Project Phase Review and approval from PSG*

The deliverables of a National Sub-Project will be presented to the PSG, for their review, discussion and approval for the start of the next phase of the Sub-Project. Discussion among NCT members, PSG and other identified experts will follow, to decide on the specific plans and requirements.

Task responsibility: WMO, PSG (and NCT upon the approval for next step)

4.4. **Pre-Operational Testing and Capacity Development (Phase 3)**

The objective of Phase 3 of the CIFDP is to transfer the new technology and methods developed in the previous phase to an operational Forecasting and Warning System. This phase will include development of operational procedures, development of Coastal Flood Management tools, acceptance testing and capacity development. A major event in this phase of the project is the simulation of an extreme flood event using the CIFDP technology **involving all key stakeholders from the forecasters to the end users at local level**. CIFDP Phase 3 will be concluded with the CIFDP Forecasting System going live at the national level.

4.4.1. *System User Guidelines*

This task will focus on developing procedures and best practices to use the new CIFDP technology and allow the effective use of coastal inundation forecasts for issuing warnings and disaster management. The developed procedures will take into account forecasts – and the uncertainties in these forecasts - of risks resulting from combinations of various events causing coastal inundation, such as storm surges, heavy rainfall and river flooding.

The main outcome of this task will be completed user and support documentation. These should provide a basis for embedding the CIFDP technology in the national and local flood disaster management procedures.

Task responsibility: System developer(s) and NCT with support from identified experts

4.4.2. *Further Training and Capacity Development*

An important part of the capacity development for the National Agencies and key stakeholders has taken place in the system implementation phase (Phase 2) through on-the-job training and implementation workshops. In this Phase, the task will focus on formal training of national agency professionals and other key stakeholders at national and local level, on the operation, maintenance and further development of the CIFDP technology and the use of the forecasting products in flood disaster management procedures.

The training will pay attention to the set-up, strengthening and adaptation of marine meteorology and hydrological forecasting modelling skills, forecasting system handling, maintenance and related operational capacity. User and support documents developed under the previous task (section 4.4.2) will be used for, and updated through the training.

Task responsibility: NCT

4.4.3. *Acceptance Testing*

A formal acceptance procedure will be followed to test whether the developed system is ready to be used operationally ('go live'). Defects identified during acceptance testing will be resolved and may require some retesting. The acceptance test procedure will have been specified in task 4.3.4.3.2.4.

At the end of this task the developed coastal inundation forecasting system should be ready to be used in the next task: an end-to-end forecasting simulation event.

Task responsibility: NCT

4.4.4. *End-to-End Forecasting Simulation Event*

A full **end-to-end** forecasting simulation event should demonstrate that the developed coastal inundation forecasting system is ready to be used operationally in national and local disaster/hazard warning and flood management procedures. This major event includes a multi-agency test that includes the simulation of an extreme flood event using the CIFDP technology. The test will involve all key stakeholders from the forecasters to the end users at national and local level.

Task responsibility: NCT with advice from PSG

4.4.5. *Handover and going live*

The final step in this Phase will be the formal hand-over of the CIFDP system to the national agencies responsible for its operational use. This event may be used for promoting the CIFDP achievements nationally and internationally. The current idea is to organise a one day festive handover and media event.

Task responsibility: NCT/responsible national agencies with support from WMO

4.4.6. *Project Phase Review by PSG*

The PSG will review the end-to-end operational system and provide advice to the NCT prior to Phase 4.

Task responsibility: WMO, PSG and NCT

4.5. **Live Running & Evaluation (Phase 4)**

The CIFDP system is operational at this Phase of the project. Realistically, some additional user requirements and change requests will become apparent when operating the system in real time. By giving room for some fine tuning, these requirements can be accommodated and will thereby contribute to the acceptance and appreciation of the new CIFDP technology. Further training will also contribute to this.

4.5.1. *System Updates, Support & Maintenance*

The procedure for system support and maintenance will be fine tuned at this stage of the project. This task will be implemented in close coordination with the training and technology transfer, by providing up-to-date technology and information for the related training activities at national/regional/global levels such as the annual JCOMM-TCP training workshops on wind waves and storm surges forecasting. The required training associated with this task can also be co-organized with these ongoing training programmes and activities.

Based on practical experience with live operation of the forecasting and warning system, end-users' needs will be identified for (early) warning systems, disaster management and support to decision-making. System updates will be implemented where required.

Task responsibility: NCT

4.5.2. *Follow-up Training*

Further capacity development will be done involving technical training in collaboration with RMSC partners. Also disaster management training is expected to be initiated, to improve understanding and use of the new service products through the developed coastal inundation forecasting system – this part of the task may be co-organized with or planned back-to-back with the Sub-Project evaluation workshop (described in section 4.5.3).

Task responsibility: responsible national agencies, WMO

4.5.3. *Sub-Project Evaluation Workshop & international Conference*

Approximately one year following the new coastal inundation forecasting system going live, a project evaluation workshop will be organised. The workshop will be combined with an international conference on coastal inundation forecasting and flood disaster management in coastal areas.

This major international event should provide an outlook to future benefits and enhancements of the implemented CIFDP technology and strategy. It is expected to contribute to the WMO vision on future capacity development over different domains such as operational marine and hydrologic forecasting, and flood management strategies.

The project evaluation will focus on the benefits of the CIFDP approach to coastal inundation early warning, risk analysis and coastal flood management. It is expected give direction for the integration of the CIFDP approach into national MH-EWS in collaboration with national/regional disaster risk management agencies.

Task responsibility: NCT and WMO

4.5.4. *Project Wrap-Up*

The project will be wrapped up by finalising a dedicated website for coordination and centralization of the project information, such as documentation of best practices and time schedule of capacity development events; and for linking to an extreme coastal events database, distribution of open-source (model or system/framework) software, archiving and models inter-comparison studies.

A direction will be formulated for transition from the project demonstration phase to a global implementation phase coordinating ocean-related hazards systems with WMO Regional Associations, UN bodies and other partners involved in particular in the development of a comprehensive SSWS.

Task responsibility: NCT, WMO and PSG

5 **Planning**

Based on the Project Concept, Strategy and Implementation Plan, the PSG will review the established implementation of ongoing sub-projects and advise the respective National Coordination Team (NCT) on required establishment and updates of the National Sub-Project Plan

with detailed workplans and milestones. The PSG, in particular, will advise on the following points to be included in the initial workplans:

- Clear direction of the technical plan;
- Clear identification of participating national agencies and partners (e.g. regional bodies such as RSMC) and their respective roles and responsibilities;
- Timelines and milestones for sub-project implementation.

The PSG will review progress of the sub-project on a continuing basis, the specific nature of the review depending on the tasks in each Phase.

5.1. Effort Estimates

Each sub-project, until phase 3, is expected to last 18-21 months depending on the timing and relationship to local constraints such as tropical storm season. The estimated duration for each of the phases is as follows:

Phase 0: 2 -3 months;

Phase 1: 4-6 months;

Phase 2: 8 months;

Phase 3: 4 months;

Phase 4: (operational and evaluation) will start after phase 3 is completed and is anticipated to last for a year.

5.2. Timeline

The time line for each country is drawn with the aim to deliver the pre-operational and operational system before the start of the tropical cyclone seasons. Meetings, workshops and conferences that are important and relevant to the CIFDP project are shown in the time lines as well as an overview of the milestones.

5.3. Milestones

Timelines will be developed separately for each sub-project, but will incorporate the specific milestones described below for each phase of the project, and in line with the overall guidelines described in the section 5.2 above.

Phase 0

- Delivery of an initial national agreement to WMO, which expresses national agencies approval on the CIFDP initiative and willingness to co-operate and contribute in the preparation phase.

Phase 1

- Stakeholder Workshop;
- User requirements and system specification;
- Definitive National Agreement between relevant national agencies on the scope of the sub-project, by appointing the agency to operate it, and willingness to co-operate and

contribute (by appointing members of the NCT) in the development and operational phase;

- Development of sub-project implementation plan and year-1 work plan;
- Communications Plan developed;
- Approval of the updated plan by PSG before commencing phase 2.

Phase 2

- Sub-Project Plan for CIFDP;
- Testing of past cyclones completed;
- Testing of individual modules of forecast system;
- CIFDP-framework / system in place;
- Approval of the updated plan by PSG before commencing phase 3.

Phase 3

- CIFDP pre-operational version completed;
- End-to-end forecasting simulation event;
- System Manual and Guides;
- Completion of training / capacity development;

Phase 4

- CIFDP operational version completed and implemented;
- Review / evaluation completed;
- Contribution to international conference and/or scientific journals as appropriate;
- Recommendations for way forward.

6 Cost Estimate and Financing

WMO will provide financial support for the initiation of the Project and general coordination, mainly through the PSG. The financing structure of each subsequent National Sub-Project will be developed in detail and agreed on the basis of the decisions taken during technical and stakeholders workshops at the national level. Details on cost estimates and financing will be provided in the Project Plan for each National Sub-Project.

The PSG will be requested to provide input on the potential donors and partners to CIFDP (global and regional), and make suggestions for possible actions:

- Potential and identified national resources (both human and financial), primarily within the responsible national agencies, for each sub-project implementation;
- Potential and identified funding sources for implementation of each sub-project;
- Identified funding within WMO for CIFDP support.

The NCT will work with the PSG to develop proposals for donor support for CIFDP activities.

TERMS OF REFERENCE AND MEMBERS OF THE CIFDP STEERING GROUP

(as revised at the 3rd meeting of the Project Steering Group, 2-4 April 2012, Jacksonville, USA)

The CIFDP will be under the oversight of the Project Steering Group (PSG) for overall project planning, implementation, review progress and reporting. The **PSG** will work closely with the WMO Secretariat and with the Sub-project National Coordination Teams (NCTs) to ensure that each sub-project will be implemented in line with the overall Project Framework that was endorsed by the WMO Congress and its technical commissions including the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) and Commission for Hydrology (CHy).

The **PSG** will work with the **WMO Secretariat** in:

- regular review and update of the Project Concept and Implementation Plan;
- initiation of national sub-projects, by reviewing the initial requirements and providing advice to WMO Technical Commissions (JCOMM and CHy);
- reviewing progress of national sub-projects in each phase, and provide recommendations to relevant WMO Technical Commissions (JCOMM and CHy) regarding the following steps of the project implementation;

The **PSG** will work closely with each **Sub-project National Coordination Team (NCT)**, in:

- selecting technical solutions for the storm surge, wave and hydrological forecasting and operation, which meet the national and regional capabilities and requirements;
- providing guidance to the development and implementation of Sub-project Plan, including technical development as well as stakeholder interactions and consultations;
- developing modalities for interactions with, and input from, associated projects;
- issuing the final review report on the national Sub-project and preparing recommendations to be transmitted to the relevant bodies.

The **PSG** is comprised of experts on coastal inundation (e.g. storm surge, wave and hydrological modelling and forecasting) and associated areas (e.g. service delivery and social science), including:

- Dr Donald Resio (co-chair) – Meteorological Modelling and Forecasting expert
- Mr Val Swail (co-chair) – Meteorological Modelling and Forecasting expert
- Mr Fidel Perez - Hydrological Modelling Expert
- Dr Linda Anderson-Berry - Social Science Expert
- Dr. S.H. Fakhruddin - Hydrological Modelling and Forecasting Expert
- Prof Shishir Dube - Metocean Modelling and Forecasting Expert
- Dr Monika Donner Hydrological Modelling and Forecasting Expert
- Mr Deepak Vatvani – Hydrological and Metocean Modelling Expert
- Mr. Jamie Rhome – Meteorological Modelling and Forecasting expert
- Dr. Paula Etala - Meteorological Modelling and Forecasting expert

The ToR as well as the membership of the PSG will be regularly reviewed and updated through the PSG meetings.

DEFINITIONS

The words “**model**” or “**system**” are often used in different context with different meanings. To avoid misunderstanding the following definition will be applied in this document.

Modelling software: Software code used to solve certain hydrodynamic equations (equation solver). It is sometimes also referred to as Modelling Tools. Examples: *HEC-RAS, ADCIRC, Delft3D, MIKE21, SWAN, MIKE11, SOBE, etc.*

Model (application): Application for a specific area built using one of the modelling software examples mentioned earlier. Model application is defined by its input / output. *Example: Bay of Bengal storm surge model (application), Gulf of Mexico storm surge and wave model (application).*

Open-source technique, or open-source modelling: the CIFDP aims to demonstrate “open-source” coastal inundation end-to-end operational forecasting and warning systems, which is characterized by free and non-restrictive access to source code. In the implementation of each National Sub-project, it is possible to apply non-proprietary techniques/modelling, upon the agreement of the Project Steering Group (PSG) and National Coordination Team (NCT), as long as the source code is available for review by the PSG and NCT.

Forecasting system: Software for coupling various model applications, with some intelligence and built in standard interfacing. Examples of such standard interfaces are: „plug and play” feature for various modelling software, telemetry data import archiving and client-server approach etc.). In case it is applied for specific purpose or for specific area, then the system requires (re-) configuration of the front- and back-end. *Example: NWS River Forecast System, CHPS forecast system, NFFS, FEWS Spain etc.*

System developer: in the context of this Implementation Plan a system developer can be an individual, company, or agency, either internal or external, which may be engaged to carry out specific components of the work plan to develop, modify, integrate or implement various modules of the forecast system, or to contribute essential data resources such as bathymetry. Different system developers may be engaged in different phases of the project, or to carry out different tasks in the same phase.

ABBREVIATIONS

CHy	WMO Commission for Hydrology
CIFDP	Coastal Inundation Forecast Demonstration Project (WMO)
DEM	Digital Elevation Model
DMA	Disaster Management Agency
DNA	Definitive National Agreement (CIFDP)
DMCPA	Disaster Management and Civil Protection Agency
ETWCH	Expert Team on Waves and Coastal Hazard Forecast Systems (JCOMM)
FEWS	Flood Early Warning System (product of Deltares)
GIS	Geographic Information System
HWRP	Hydrology and Water Resources Programme
ICAM	(UNESCO/IOC) Integrated Coastal Area Management
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
JCOMM	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
MH-EWS	Multi-hazard Early Warning System
MMOP	Marine Meteorology and Oceanography Programme (WMO)
NCT	National Coordination Team (CIFDP)
NMHS	National Meteorological and Hydrological Services
NWP	Numerical Weather Prediction
PSG	Project Steering Group (CIFDP)
RSMC	Regional Specialized Meteorological Centre (WMO)
SSWS	Storm Surge Watch Scheme (WMO)
SWFDP	Severe Weather Forecasting Demonstration Project (WMO)
TC	Tropical Cyclone
TCP	Tropical Cyclone Programme (WMO)
ToR	Terms of Reference
TWLE	Total Water Level Envelope
UNESCO	United Nations Educational, Scientific and Cultural Organization
WMO	World Meteorological Organization
