CONTRACT FOR CONSULTANT'S SERVICES

Lump-Sum

Selection of Consultant Services for Development of Dynamic Web Based Composite Risk Atlas and Decision Support Tool for Cyclone and associated impacts including Storm Surge and Inland Flooding under National Cyclone Risk Mitigation Project-II (NCRMP-II)

Credit No.IDA-5693-IN

Contract No.IN-NDMA-8677-CS-QCBS

Between

The Project Director,
National Cyclone Risk Mitigation Project (NCRMP)
National Disaster Management Authority (NDMA),
(Ministry of Home Affairs, Govt. of India),
NDMA Bhawan, A-1, Safdarjung Enclave,
New Delhi-110029

&

M/s RMSI Pvt. Ltd.
A-8, Sector-16, Noida-201301 (UP)

Dated /8/04/2018

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1. Form of Contract-LUMP-SUM

This CONTRACT (hereinafter called the "Contract") is made the 13th day of the month of March 2018, between, on the one hand, The Project Director, National Cyclone Risk Mitigation Project (NCRMP),National Disaster Management Authority (NDMA), New Delhi(hereinafter called the 'Client') and, on the other hand, M/s RMSI Private Limited, Noida (hereinafter called the 'Consultant').

WHEREAS

(a) the Client has requested the Consultant to provide certain consulting services as defined in this Contract (hereinafter called the "Services");

(b) the Consultant, having represented to the Client that it has the required professional skills, expertise and technical resources, has agreed to provide the Services on the terms and conditions set forth in this Contract;

(c) the Client has received credit from the International Development Association (IDA) toward the cost of the Services and intends to apply a portion of the proceeds of this credit to eligible payments under this Contract, it being understood that (i) payments by the Bank will be made only at the request of the Client and upon approval by the Bank; (ii) such payments will be subject, in all respects, to the terms and conditions of the financing agreement, including prohibitions of withdrawal from the credit account for the purpose of any payment to persons or entities, or for any import of goods, if such payment or import, to the knowledge of the Bank, is prohibited by the decision of the United Nations Security council taken under Chapter VII of the Charter of the United Nations; and (iii) no party other than the Client shall derive any rights from the financing agreement or have any claim to the credit proceeds;

NOW THEREFORE the parties hereto hereby agree as follows:

1. The following documents attached hereto shall be deemed to form an integral part of this Contract:

(a) The General Conditions of Contract (including Attachment 1 'Bank Policy – Corrupt and Fraudulent Practices);

(b) The Special Conditions of Contract;

Section I. General Conditions of Contract

1. Definitions

A. GENERAL PROVISIONS

1.1. Unless the context otherwise requires, the following terms whenever used in this Contract have the following meanings:

(a) "Applicable Guidelines" means Guidelines for Selection and Employment of Consultants under IBRD Loans and IDA Credits & Grants by World Bank Borrowers, dated January 2011.

(b) "Applicable Law" means the laws and any other instruments having the force of law in the Client's country, or in such other country as may be specified in the **Special Conditions of Contract (SCC)**, as they may be issued and in force from time to time.

(c) "Bank" means the International Bank for Reconstruction and Development (IBRD) or the International Development Association (IDA).

(d) "Borrower" means the Government, Government agency or other entity that signs the financing agreement with the Bank.

(e) "Client" means the implementing agency that signs the Contract for the Services with the Selected Consultant.

(f) "Consultant" means a legally-established professional consulting firm or entity selected by the Client to provide the Services under the signed Contract.

(g) "Contract" means the legally binding written agreement signed between the Client and the Consultant and which includes all the attached documents listed in its paragraph 1 of the Form of Contract (the General Conditions (GCC), the Special Conditions (SCC), and the Appendices).

(h) "Day" means a working day unless indicated otherwise.

(i) "Effective Date" means the date on which this Contract comes into force and effect pursuant to Clause GCC 11.

(j) "Experts" means, collectively, Key Experts, Non-Key Experts, or any other personnel of the Consultant, Sub-consultant or JV member(s) assigned by the Consultant to perform the Services or any part thereof under the Contract.

(k) "Foreign Currency" means any currency other than the currency of the Client's country.

(l) "GCC" means these General Conditions of Contract.

(m) "Government" means the government of the Client's country.

(n) "Joint Venture (JV)" means an association with or without a legal personality distinct from that of its members, of more than one entity where one member has the authority to conduct all businesses for and on behalf of any and all the members of the JV, and where the members of the JV are jointly and severally liable to the Client for the

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(c) Appendices:

Appendix A: Terms of Reference & Description of Services   with
Annexure regarding Pre bid Clarifications
Appendix B: Key Experts
Appendix C: Breakdown of Contract Price
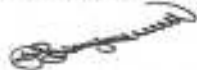Appendix D: Negotiation Meeting Minutes

In the event of any inconsistency between the documents, the following order of precedence shall prevail: the Special Conditions of Contract; the General Conditions of Contract, including Attachment 1; Appendix A (with Annexure I); Appendix B; Appendix C; Any reference to this Contract shall include, where the context permits, a reference to its Appendices.

2.   The mutual rights and obligations of the Client and the Consultant shall be as set forth in the Contract, in particular:

(a)   the Consultant shall carry out the Services in accordance with the provisions of the Contract; and

(b)   the Client shall make payments to the Consultant in accordance with the provisions of the Contract.

IN WITNESS WHEREOF, the Parties hereto have caused this Contract to be signed in their respective names as of the day and year first above written.

For and on behalf of The Project Director, National Cyclone Risk Mitigation Project (NCRMP),National Disaster Management Authority (NDMA), New Delhi
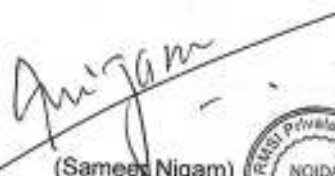
For PMU, NCRMP, NDMA

(Narayanan P.E.)
Project Manager
Narayanan P. E.
Project Manager
Government of India
Ministry of Home Affairs
NCRMP, NDMA, New Delhi

For M/s RMSI

(Sameer Nigam)
Head – Bidding Division

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performance of the Contract.

(o) "Key Expert(s)" means an individual professional whose skills, qualifications, knowledge and experience are critical to the performance of the Services under the Contract and whose Curricula Vitae (CV) was taken into account in the technical evaluation of the Consultant's proposal.

(p) "Local Currency" means the currency of the Client's country.

(q) "Non-Key Expert(s)" means an individual professional provided by the Consultant or its Sub-consultant to perform the Services or any part thereof under the Contract.

(r) "Party" means the Client or the Consultant, as the case may be, and "Parties" means both of them.

(s) "SCC" means the Special Conditions of Contract by which the GCC may be amended or supplemented but not over-written.

(t) "Services" means the work to be performed by the Consultant pursuant to this Contract, as described in Appendix A hereto.

(u) "Sub-consultants" means an entity to whom/which the Consultant subcontracts any part of the Services while remaining solely liable for the execution of the Contract.

(v) "Third Party" means any person or entity other than the Government, the Client, the Consultant or a Sub-consultant.

2. Relationship between the Parties

2.1. Nothing contained herein shall be construed as establishing a relationship of master and servant or of principal and agent as between the Client and the Consultant. The Consultant, subject to this Contract, has complete charge of the Experts and Sub-consultants, if any, performing the Services and shall be fully responsible for the Services performed by them or on their behalf hereunder.

3. Law Governing Contract

3.1. This Contract, its meaning and interpretation, and the relation between the Parties shall be governed by the Applicable Law.

4. Language

4.1. This Contract has been executed in the language specified in the **SCC**, which shall be the binding and controlling language for all matters relating to the meaning or interpretation of this Contract.

5. Headings

5.1. The headings shall not limit, alter or affect the meaning of this Contract.

6. Communications

6.1. Any communication required or permitted to be given or made pursuant to this Contract shall be in writing in the language specified in Clause GCC 4. Any such notice, request or consent shall be deemed to have been given or made when delivered in person to an authorized representative of the Party to whom the communication is addressed, or when sent to such Party at the address specified in the **SCC**.

6.2. A Party may change its address for notice hereunder by giving the other Party any communication of such change to the address specified in the **SCC**.

7. Location

7.1. The Services shall be performed at such locations as are specified in **Appendix A** hereto and, where the location of a particular task is not so specified, at such locations, whether in the Government's country or elsewhere, as the Client may approve.

8. Authority of Member in Charge

8.1. In case the Consultant is a Joint Venture, the members hereby authorize the member specified in the **SCC** to act on their behalf in exercising all the Consultant's rights and obligations towards the Client under this Contract, including without limitation the receiving of instructions and payments from the Client.

9. Authorized Representatives

9.1. Any action required or permitted to be taken, and any document required or permitted to be executed under this Contract by the Client or the Consultant may be taken or executed by the officials specified in the **SCC**.

10. Corrupt and Fraudulent Practices

10.1. The Bank requires compliance with its policy in regard to corrupt and fraudulent practices as set forth in **Attachment 1** to the GCC.

a. Commissions and Fees

10.2. The Client requires the Consultant to disclose any commissions, gratuities or fees that may have been paid or are to be paid to agents or any other party with respect to the selection process or execution of the Contract. The information disclosed must include at least the name and address of the agent or other party, the amount and currency, and the purpose of the commission, gratuity or fee. Failure to disclose such commissions, gratuities or fees may result in termination of the Contract and/or sanctions by the Bank.

B. COMMENCEMENT, COMPLETION, MODIFICATION AND TERMINATION OF CONTRACT

11. Effectiveness of Contract

11.1. This Contract shall come into force and effect on the date (the "Effective Date") of the Client's notice to the Consultant instructing the Consultant to begin carrying out the Services. This notice shall confirm that the effectiveness conditions, if any, listed in the **SCC** have been met.

12. Termination of Contract for Failure to Become Effective

12.1. If this Contract has not become effective within such time period after the date of Contract signature as specified in the **SCC**, either Party may, by not less than twenty two (22) days written notice to the other Party, declare this Contract to be null and void, and in the event of such a declaration by either Party, neither Party shall have any claim against the other Party with respect hereto.

13. Commencement of Services

13.1. The Consultant shall confirm availability of Key Experts and begin carrying out the Services not later than the number of days after the Effective Date specified in the **SCC**.

14. Expiration of Contract

14.1. Unless terminated earlier pursuant to Clause GCC 19 hereof, this Contract shall expire at the end of such time

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15. Entire Agreement

period after the Effective Date as specified in the **SCC**.

15.1. This Contract contains all covenants, stipulations and provisions agreed by the Parties. No agent or representative of either Party has authority to make, and the Parties shall not be bound by or be liable for, any statement, representation, promise or agreement not set forth herein.

16. Modifications or Variations

16.1. Any modification or variation of the terms and conditions of this Contract, including any modification or variation of the scope of the Services, may only be made by written agreement between the Parties. However, each Party shall give due consideration to any proposals for modification or variation made by the other Party.

16.2. In cases of substantial modifications or variations, the prior written consent of the Bank is required.

17. Force Majeure

a. Definition

17.1. For the purposes of this Contract, "Force Majeure" means an event which is beyond the reasonable control of a Party, is not foreseeable, is unavoidable, and makes a Party's performance of its obligations hereunder impossible or so impractical as reasonably to be considered impossible under the circumstances, and subject to those requirements, includes, but is not limited to, war, riots, civil disorder, earthquake, fire, explosion, storm, flood or other adverse weather conditions, strikes, lockouts or other industrial action confiscation or any other action by Government agencies.

17.2. Force Majeure shall not include (i) any event which is caused by the negligence or intentional action of a Party or such Party's Experts, Sub-consultants or agents or employees, nor (ii) any event which a diligent Party could reasonably have been expected to both take into account at the time of the conclusion of this Contract, and avoid or overcome in the carrying out of its obligations hereunder.

17.3. Force Majeure shall not include insufficiency of funds or failure to make any payment required hereunder.

b. No Breach of Contract

17.4. The failure of a Party to fulfill any of its obligations hereunder shall not be considered to be a breach of, or default under, this Contract insofar as such inability arises from an event of Force Majeure, provided that the Party affected by such an event has taken all reasonable precautions, due care and reasonable alternative measures, all with the objective of carrying out the terms and conditions of this Contract.

c. Measures to

17.5. A Party affected by an event of Force Majeure shall

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be Taken continue to perform its obligations under the Contract as far as is reasonably practical, and shall take all reasonable measures to minimize the consequences of any event of Force Majeure.

17.6. A Party affected by an event of Force Majeure shall notify the other Party of such event as soon as possible, and in any case not later than fourteen (14) calendar days following the occurrence of such event, providing evidence of the nature and cause of such event, and shall similarly give written notice of the restoration of normal conditions as soon as possible.

17.7. Any period within which a Party shall, pursuant to this Contract, complete any action or task, shall be extended for a period equal to the time during which such Party was unable to perform such action as a result of Force Majeure.

17.8. During the period of their inability to perform the Services as a result of an event of Force Majeure, the Consultant, upon instructions by the Client, shall either:

(a) demobilize, in which case the Consultant shall be reimbursed for additional costs they reasonably and necessarily incurred, and, if required by the Client, in reactivating the Services; or

(b) continue with the Services to the extent reasonably possible, in which case the Consultant shall continue to be paid under the terms of this Contract and be reimbursed for additional costs reasonably and necessarily incurred.

17.9. In the case of disagreement between the Parties as to the existence or extent of Force Majeure, the matter shall be settled according to Clauses GCC 44 & 45.

18. Suspension

18.1. The Client may, by written notice of suspension to the Consultant, suspend all payments to the Consultant hereunder if the Consultant fails to perform any of its obligations under this Contract, including the carrying out of the Services, provided that such notice of suspension (i) shall specify the nature of the failure, and (ii) shall request the Consultant to remedy such failure within a period not exceeding thirty (30) calendar days after receipt by the Consultant of such notice of suspension.

19. Termination

19.1. This Contract may be terminated by either Party as per provisions set up below:

a. By the Client

19.1.1. The Client may terminate this Contract in case of the occurrence of any of the events specified in

paragraphs (a) through (f) of this Clause. In such an occurrence the Client shall give at least thirty (30) calendar days' written notice of termination to the Consultant in case of the events referred to in (a) through (d); at least sixty (60) calendar days' written notice in case of the event referred to in (e); and at least five (5) calendar days' written notice in case of the event referred to in (f):

(a) If the Consultant fails to remedy a failure in the performance of its obligations hereunder, as specified in a notice of suspension pursuant to Clause GCC 18;

(b) If the Consultant becomes (or, if the Consultant consists of more than one entity, if any of its members becomes) insolvent or bankrupt or enter into any agreements with their creditors for relief of debt or take advantage of any law for the benefit of debtors or go into liquidation or receivership whether compulsory or voluntary;

(c) If the Consultant fails to comply with any final decision reached as a result of arbitration proceedings pursuant to Clause GCC 45.1;

(d) If, as the result of Force Majeure, the Consultant is unable to perform a material portion of the Services for a period of not less than sixty (60) calendar days;

(e) If the Client, in its sole discretion and for any reason whatsoever, decides to terminate this Contract;

(f) If the Consultant fails to confirm availability of Key Experts as required in Clause GCC 13.

19.1.2. Furthermore, if the Client determines that the Consultant has engaged in corrupt, fraudulent, collusive, coercive or obstructive practices, in competing for or in executing the Contract, then the Client may, after giving fourteen (14) calendar days written notice to the Consultant, terminate the Consultant's employment under the Contract.

b. By the Consultant

19.1.3. The Consultant may terminate this Contract, by not less than thirty (30) calendar days' written notice to the Client, in case of the occurrence of any of the events specified in paragraphs (a) through (d) of this Clause.

(a) If the Client fails to pay any money due to the Consultant pursuant to this Contract and not subject to dispute pursuant to Clause GCC 45.1 within forty-

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five (45) calendar days after receiving written notice from the Consultant that such payment is overdue.

(b) If, as the result of Force Majeure, the Consultant is unable to perform a material portion of the Services for a period of not less than sixty (60) calendar days.

(c) If the Client fails to comply with any final decision reached as a result of arbitration pursuant to Clause GCC 45.1.

(d) If the Client is in material breach of its obligations pursuant to this Contract and has not remedied the same within forty-five (45) days (or such longer period as the Consultant may have subsequently approved in writing) following the receipt by the Client of the Consultant's notice specifying such breach.

c. Cessation of Rights and Obligations

19.1.4. Upon termination of this Contract pursuant to Clauses GCC 12 or GCC 19 hereof, or upon expiration of this Contract pursuant to Clause GCC 14, all rights and obligations of the Parties hereunder shall cease, except (i) such rights and obligations as may have accrued on the date of termination or expiration, (ii) the obligation of confidentiality set forth in Clause GCC 22, (iii) the Consultant's obligation to permit inspection, copying and auditing of their accounts and records set forth in Clause GCC 25, and (iv) any right which a Party may have under the Applicable Law.

d. Cessation of Services

19.1.5. Upon termination of this Contract by notice of either Party to the other pursuant to Clauses GCC 19a or GCC 19b, the Consultant shall, immediately upon dispatch or receipt of such notice, take all necessary steps to bring the Services to a close in a prompt and orderly manner and shall make every reasonable effort to keep expenditures for this purpose to a minimum. With respect to documents prepared by the Consultant and equipment and materials furnished by the Client, the Consultant shall proceed as provided, respectively, by Clauses GCC 27 or GCC 28.

e. Payment upon Termination

19.1.6. Upon termination of this Contract, the Client shall make the following payments to the Consultant:

(a) payment for Services satisfactorily performed prior to the effective date of termination; and

(b) in the case of termination pursuant to paragraphs (d) and (e) of Clause GCC 19.1.1, reimbursement of any

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reasonable cost incidental to the prompt and orderly termination of this Contract, including the cost of the return travel of the Experts.

C. OBLIGATIONS OF THE CONSULTANT

20. General

a. Standard of Performance

20.1 The Consultant shall perform the Services and carry out the Services with all due diligence, efficiency and economy, in accordance with generally accepted professional standards and practices, and shall observe sound management practices, and employ appropriate technology and safe and effective equipment, machinery, materials and methods. The Consultant shall always act, in respect of any matter relating to this Contract or to the Services, as a faithful adviser to the Client, and shall at all times support and safeguard the Client's legitimate interests in any dealings with the third parties.

20.2. The Consultant shall employ and provide such qualified and experienced Experts and Sub-consultants as are required to carry out the Services.

20.3. The Consultant may subcontract part of the Services to an extent and with such Key Experts and Sub-consultants as may be approved in advance by the Client. Notwithstanding such approval, the Consultant shall retain full responsibility for the Services.

b. Law Applicable to Services

20.4. The Consultant shall perform the Services in accordance with the Contract and the Applicable Law and shall take all practicable steps to ensure that any of its Experts and Sub-consultants, comply with the Applicable Law.

20.5. Throughout the execution of the Contract, the Consultant shall comply with the import of goods and services prohibitions in the Client's country when

(a) as a matter of law or official regulations, the Borrower's country prohibits commercial relations with that country; or

(b) by an act of compliance with a decision of the United Nations Security Council taken under Chapter VII of the Charter of the United Nations, the Borrower's Country prohibits any import of goods from that country or any payments to any country, person, or entity in that country.

20.6. The Client shall notify the Consultant in writing of relevant local customs, and the Consultant shall, after such notification, respect such customs.

21. Conflict of

21.1. The Consultant shall hold the Client's interests

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Interests

paramount, without any consideration for future work, and strictly avoid conflict with other assignments or their own corporate interests.

a. Consultant Not to Benefit from Commissions, Discounts, etc.

21.1.1 The payment of the Consultant pursuant to GCC F (Clauses GCC 38 through 42) shall constitute the Consultant's only payment in connection with this Contract and, subject to Clause GCC 21.1.3, the Consultant shall not accept for its own benefit any trade commission, discount or similar payment in connection with activities pursuant to this Contract or in the discharge of its obligations hereunder, and the Consultant shall use its best efforts to ensure that any Sub-consultants, as well as the Experts and agents of either of them, similarly shall not receive any such additional payment.

21.1.2 Furthermore, if the Consultant, as part of the Services, has the responsibility of advising the Client on the procurement of goods, works or services, the Consultant shall comply with the Bank's Applicable Guidelines, and shall at all times exercise such responsibility in the best interest of the Client. Any discounts or commissions obtained by the Consultant in the exercise of such procurement responsibility shall be for the account of the Client.

b. Consultant and Affiliates Not to Engage in Certain Activities

21.1.3 The Consultant agrees that, during the term of this Contract and after its termination, the Consultant and any entity affiliated with the Consultant, as well as any Sub-consultants and any entity affiliated with such Sub-consultants, shall be disqualified from providing goods, works or non-consulting services resulting from or directly related to the Consultant's Services for the preparation or implementation of the project, unless otherwise indicated in the SCC.

c. Prohibition of Conflicting Activities

21.1.4 The Consultant shall not engage, and shall cause its Experts as well as its Sub-consultants not to engage, either directly or indirectly, in any business or professional activities that would conflict with the activities assigned to them under this Contract.

d. Strict Duty to Disclose Conflicting Activities

21.1.5 The Consultant has an obligation and shall ensure that its Experts and Sub-consultants shall have an obligation to disclose any situation of actual or potential conflict that impacts their capacity to serve the best interest of their Client, or that may reasonably be perceived as having this effect. Failure to disclose said situations may lead to the disqualification of the Consultant or the termination of its Contract.

22. Confidentiality

22.1 Except with the prior written consent of the Client, the Consultant and the Experts shall not at any time communicate to any person or entity any confidential information acquired in the course of the Services, nor shall the Consultant and the Experts make public the recommendations formulated in the course of, or as a result of, the Services.

23. Liability of the Consultant

23.1 Subject to additional provisions, if any, set forth in the SCC, the Consultant's liability under this Contract shall be provided by the Applicable Law.

24. Insurance to be Taken out by the Consultant

24.1 The Consultant (i) shall take out and maintain, and shall cause any Sub-consultants to take out and maintain, at its (or the Sub-consultants', as the case may be) own cost but on terms and conditions approved by the Client, insurance against the risks, and for the coverage specified in the SCC, and (ii) at the Client's request, shall provide evidence to the Client showing that such insurance has been taken out and maintained and that the current premiums therefore have been paid. The Consultant shall ensure that such insurance is in place prior to commencing the Services as stated in Clause GCC 13.

25. Accounting, Inspection and Auditing

25.1 The Consultant shall keep, and shall make all reasonable efforts to cause its Sub-consultants to keep, accurate and systematic accounts and records in respect of the Services and in such form and detail as will clearly identify relevant time changes and costs.

25.2 The Consultant shall permit and shall cause its Sub-consultants to permit, the Bank and/or persons appointed by the Bank to inspect the Site and/or all accounts and records relating to the performance of the Contract and the submission of the Proposal to provide the Services, and to have such accounts and records audited by auditors appointed by the Bank if requested by the Bank. The Consultant's attention is drawn to Clause GCC 10 which provides, inter alia, that acts intended to materially impede the exercise of the Bank's inspection and audit rights provided for under this Clause GCC25.2 constitute a prohibited practice subject to contract termination (as well as to a determination of ineligibility under the Bank's prevailing sanctions procedures.)

26. Reporting Obligations

26.1 The Consultant shall submit to the Client the reports and documents specified in **Appendix A**, in the form, in the numbers and within the time periods set forth in the said Appendix.

27. Proprietary Rights of the Client in Reports

27.1 Unless otherwise indicated in the SCC, all reports and relevant data and information such as maps, diagrams, plans,

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and Records	databases, other documents and software, supporting records or material compiled or prepared by the Consultant for the Client in the course of the Services shall be confidential and become and remain the absolute property of the Client. The Consultant shall, not later than upon termination or expiration of this Contract, deliver all such documents to the Client, together with a detailed inventory thereof. The Consultant may retain a copy of such documents, data and/or software but shall not use the same for purposes unrelated to this Contract without prior written approval of the Client.

27.2 If license agreements are necessary or appropriate between the Consultant and third parties for purposes of development of the plans, drawings, specifications, designs, databases, other documents and software, the Consultant shall obtain the Client's prior written approval to such agreements, and the Client shall be entitled at its discretion to require recovering the expenses related to the development of the program(s) concerned. Other restrictions about the future use of these documents and software, if any, shall be specified in the **SCC**.

28. Equipment, Vehicles and Materials

28.1 Equipment, vehicles and materials made available to the Consultant by the Client, or purchased by the Consultant wholly or partly with funds provided by the Client, shall be the property of the Client and shall be marked accordingly. Upon termination or expiration of this Contract, the Consultant shall make available to the Client an inventory of such equipment, vehicles and materials and shall dispose of such equipment, vehicles and materials in accordance with the Client's instructions. While in possession of such equipment, vehicles and materials, the Consultant, unless otherwise instructed by the Client in writing, shall insure them at the expense of the Client in an amount equal to their full replacement value.

28.2 Any equipment or materials brought by the Consultant or its Experts into the Client's country for the use either for the project or personal use shall remain the property of the Consultant or the Experts concerned, as applicable.

D. CONSULTANT'S EXPERTS AND SUB-CONSULTANTS

29. Description of Key Experts

29.1 The title, agreed job description, minimum qualification and estimated period of engagement to carry out the Services of each of the Consultant's Key Experts are described in **Appendix B.**

30. Replacement of Key Experts

30.1 Except as the Client may otherwise agree in writing, no changes shall be made in the Key Experts.

30.2 Notwithstanding the above, the substitution of Key Experts during Contract execution may be considered only based on the Consultant's written request and due to circumstances outside the reasonable control of the Consultant, including but not limited to death or medical incapacity. In such case, the Consultant shall forthwith provide as a replacement, a person of equivalent or better qualifications and experience, and at the same rate of remuneration.

31. Removal of Experts or Sub-consultants

31.1 If the Client finds that any of the Experts or Sub-consultant has committed serious misconduct or has been charged with having committed a criminal action, or shall the Client determine that Consultant's Expert of Sub-consultant have engaged in corrupt, fraudulent, collusive, coercive or obstructive practice while performing the Services, the Consultant shall, at the Client's written request, provide a replacement.

31.2 In the event that any of Key Experts, Non-Key Experts or Sub-consultants is found by the Client to be incompetent or incapable in discharging assigned duties, the Client, specifying the grounds therefore, may request the Consultant to provide a replacement.

31.3 Any replacement of the removed Experts or Sub-consultants shall possess better qualifications and experience and shall be acceptable to the Client.

31.4 The Consultant shall bear all costs arising out of or incidental to any removal and/or replacement of such Experts.

E. OBLIGATIONS OF THE CLIENT

32. Assistance and Exemptions

32.1 Unless otherwise specified in the SCC, the Client shall use its best efforts to:

(a) Assist the Consultant with obtaining work permits and such other documents as shall be necessary to enable the Consultant to perform the Services.

(b) Assist the Consultant with promptly obtaining, for the Experts and, if appropriate, their eligible dependents, all necessary entry and exit visas, residence permits, exchange permits and any other documents required for their stay in the Client's country while carrying out the Services under the Contract.

(c) Facilitate prompt clearance through customs of any property required for the Services and of the personal effects of the Experts and their eligible dependents.

(c) Issue to officials, agents and representatives of the

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Government all such instructions and information as may be necessary or appropriate for the prompt and effective implementation of the Services.

(d) Assist the Consultant and the Experts and any Sub-consultants employed by the Consultant for the Services with obtaining exemption from any requirement to register or obtain any permit to practice their profession or to establish themselves either individually or as a corporate entity in the Client's country according to the applicable law in the Client's country.

(e) Assist the Consultant, any Sub-consultants and the Experts of either of them with obtaining the privilege, pursuant to the applicable law in the Client's country, of bringing into the Client's country reasonable amounts of foreign currency for the purposes of the Services or for the personal use of the Experts and of withdrawing any such amounts as may be earned therein by the Experts in the execution of the Services.

(f) Provide to the Consultant any such other assistance as may be specified in the SCC.

33. Access to Project Site

33.1 The Client warrants that the Consultant shall have, free of charge, unimpeded access to the project site in respect of which access is required for the performance of the Services. The Client will be responsible for any damage to the project site or any property thereon resulting from such access and will indemnify the Consultant and each of the experts in respect of liability for any such damage, unless such damage is caused by the willful default or negligence of the Consultant or any Sub-consultants or the Experts of either of them.

34. Change in the Applicable Law Related to Taxes and Duties

34.1 If, after the date of this Contract, there is any change in the applicable law in the Client's country with respect to taxes and duties which increases or decreases the cost incurred by the Consultant in performing the Services, then the remuneration and reimbursable expenses otherwise payable to the Consultant under this Contract shall be increased or decreased accordingly by agreement between the Parties hereto, and corresponding adjustments shall be made to the Contract price amount specified in Clause GCC 38.1

35. Services, Facilities and Property of the Client

35.1 The Client shall make available to the Consultant and the Experts, for the purposes of the Services and free of any charge, the services, facilities and property described in the Terms of Reference (**Appendix A**) at the times and in the manner specified in said **Appendix A**.

36. Counterpart Personnel

36.1 The Client shall make available to the Consultant free of charge such professional and support counterpart personnel, to be nominated by the Client with the Consultant's advice, if specified in **Appendix A**.

36.2 Professional and support counterpart personnel, excluding Client's liaison personnel, shall work under the exclusive direction of the Consultant. If any member of the counterpart personnel fails to perform adequately any work assigned to such member by the Consultant that is consistent with the position occupied by such member, the Consultant may request the replacement of such member, and the Client shall not unreasonably refuse to act upon such request.

37. Payment Obligation

37.1 In consideration of the Services performed by the Consultant under this Contract, the Client shall make such payments to the Consultant for the deliverables specified in **Appendix A** and in such manner as is provided by GCC F below.

38. Contract Price

F. PAYMENTS TO THE CONSULTANT

38.1 The Contract price is fixed and is set forth in the **SCC**. The Contract price breakdown is provided in **Appendix C**.

38.2 Any change to the Contract price specified in Clause 38.1 can be made only if the Parties have agreed to the revised scope of Services pursuant to Clause GCC 16 and have amended in writing the Terms of Reference in **Appendix A**.

39. Taxes and Duties

39.1 The Consultant, Sub-consultants and Experts are responsible for meeting any and all tax liabilities arising out of the Contract unless it is stated otherwise in the **SCC**.

39.2 As an exception to the above and as stated in the **SCC**, all local identifiable indirect taxes (itemized and finalized at Contract negotiations) are reimbursed to the Consultant or are paid by the Client on behalf of the Consultant.

40. Currency of Payment

40.1 Any payment under this Contract shall be made in the currency (ies) of the Contract.

41. Mode of Billing and Payment

41.1 The total payments under this Contract shall not exceed the Contract price set forth in Clause GCC 38.1.

41.2 The payments under this Contract shall be made in lump-sum instalments against deliverables specified in **Appendix A**. The payments will be made according to the payment schedule stated in the **SCC**.

41.2.1 *Advance payment:* Unless otherwise indicated in the

SCC, an advance payment shall be made against an advance payment bank guarantee acceptable to the Client in an amount (or amounts) and in a currency (or currencies) specified in the SCC. Such guarantee (i) is to remain effective until the advance payment has been fully set off, and (ii) is to be in the form set forth in **Appendix D**, or in such other form as the Client shall have approved in writing. The advance payments will be set off by the Client in equal portions against the lump-sum instalments specified in the SCC until said advance payments have been fully set off.

41.2.2 _The Lump-Sum Instalment Payments._ The Client shall pay the Consultant within sixty (60) days after the receipt by the Client of the deliverable(s) and the cover invoice for the related lump-sum instalment payment. The payment can be withheld if the Client does not approve the submitted deliverable(s) as satisfactory in which case the Client shall provide comments to the Consultant within the same sixty (60) days period. The Consultant shall thereupon promptly make any necessary corrections, and thereafter the foregoing process shall be repeated.

41.2.3 _The Final Payment_ .The final payment under this Clause shall be made only after the final report I have been submitted by the Consultant and approved as satisfactory by the Client. The Services shall then be deemed completed and finally accepted by the Client. The last lump-sum instalment shall be deemed approved for payment by the Client within ninety (90) calendar days after receipt of the final report by the Client unless the Client, within such ninety (90) calendar day period, gives written notice to the Consultant specifying in detail deficiencies in the Services, the final report. The Consultant shall thereupon promptly make any necessary corrections, and thereafter the foregoing process shall be repeated. 41.2.4 All payments under this Contract shall be made to the accounts of the Consultant specified in the SCC.

41.2.4 With the exception of the final payment under 41.2.3 above, payments do not constitute acceptance of the whole Services nor relieve the Consultant of any obligations hereunder.

42. Interest on Delayed Payments

42.1 If the Client had delayed payments beyond fifteen (15) days after the due date stated in Clause GCC 41.2.2 , interest shall be paid to the Consultant on any amount due by, not paid on, such due date for each day of delay at the annual rate stated in the SCC.

43. Good Faith

G. FAIRNESS AND GOOD FAITH

43.1 The Parties undertake to act in good faith with respect to each other's rights under this Contract and to adopt all reasonable measures to ensure the realization of the objectives of this Contract.
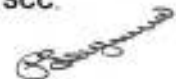
44. Amicable Settlement

H. SETTLEMENT OF DISPUTES

44.1 The Parties shall seek to resolve any dispute amicably by mutual consultation.

44.2 If either Party objects to any action or inaction of the other Party, the objecting Party may file a written Notice of Dispute to the other Party providing in detail the basis of the dispute. The Party receiving the Notice of Dispute will consider it and respond in writing within fourteen (14) days after receipt. If that Party fails to respond within fourteen (14) days, or the dispute cannot be amicably settled within fourteen (14) days following the response of that Party, Clause GCC 45.1 shall apply.

45. Dispute Resolution

45.1 Any dispute between the Parties arising under or related to this Contract that cannot be settled amicably may be referred to by either Party to the adjudication/arbitration in accordance with the provisions specified in the **SCC**.

General Conditions

Bank's Policy – Corrupt and Fraudulent Practices

Guidelines for Selection and Employment of Consultants under IBRD Loans and IDA Credits & Grants by World Bank Borrowers, dated January 2011:

"Fraud and Corruption

1.23 It is the Bank's policy to require that Borrowers (including beneficiaries of Bank loans), consultants, and their agents (whether declared or not), sub-contractors, sub-consultants, service providers, or suppliers, and any personnel thereof, observe the highest standard of ethics during the selection and execution of Bank-financed contracts [footnote: In this context, any action taken by a consultant or any of its personnel, or its agents, or its sub-consultants, sub-contractors, services providers, suppliers, and/or their employees, to influence the selection process or contract execution for undue advantage is improper.]. In pursuance of this policy, the Bank:

(a)   defines, for the purposes of this provision, the terms set forth below as follows:

   (i) "corrupt practice" is the offering, giving, receiving, or soliciting, directly or indirectly, of anything of value to influence improperly the actions of another party[1];

   (ii) "fraudulent practice" is any act or omission, including misrepresentation, that knowingly or recklessly misleads, or attempts to mislead, a party to obtain financial or other benefit or to avoid an obligation[2];

   (iii) "collusive practices" is an arrangement between two or more parties designed to achieve an improper purpose, including to influence improperly the actions of another party[3];

   (iv) "coercive practices" is impairing or harming, or threatening to impair or harm, directly or indirectly, any party or the property of the party to influence improperly the actions of a party[4];

   (v) "obstructive practice" is

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[1] For the purpose of this sub-paragraph, "another party" refers to a public official acting in relation to the selection process or contract execution. In this context "public official" includes World Bank staff and employees of other organizations taking or reviewing selection decisions.

18 For the purpose of this sub-paragraph, "party" refers to a public official; the terms "benefit" and "obligation" relate to the selection process or contract execution; and the "act or omission" is intended to influence the selection process or contract execution.

[19] For the purpose of this sub-paragraph, "parties" refers to participants in the procurement or selection process (including public officials) attempting either themselves, or through another person or entity not participating in the procurement or selection process, to simulate competition or to establish prices at artificial, non-competitive levels, or are privy to each other's bid prices or other conditions.

[20] For the purpose of this sub-paragraph, "party" refers to a participant in the selection process or contract execution.

(aa) deliberately destroying, falsifying, altering, or concealing of evidence material to the investigation or making false statements to investigators in order to materially impede a Bank investigation into allegations of a corrupt, fraudulent, coercive, or collusive practice; and/or threatening, harassing, or intimidating any party to prevent it from disclosing its knowledge of matters relevant to the investigation or from pursuing the investigation, or

(bb) acts intended to materially impede the exercise of the Bank's inspection and audit rights;

(b) will reject a proposal for award if it determines that the consultant recommended for award or any of its personnel, or its agents, or its sub-consultants, sub-contractors, services providers, suppliers, and/or their employees, has, directly or indirectly, engaged in corrupt, fraudulent, collusive, coercive, or obstructive practices in competing for the contract in question;

(c) will declare mis-procurement and cancel the portion of the Loan allocated to a contract if it determines at any time that representatives of the Borrower or of a recipient of any part of the proceeds of the Loan were engaged in corrupt, fraudulent, collusive, coercive, or obstructive practices during the selection process or the implementation of the contract in question, without the Borrower having taken timely and appropriate action satisfactory to the Bank to address such practices when they occur, including by failing to inform the Bank in a timely manner they knew of the practices;

(d) will sanction a firm or an individual at any time, in accordance with prevailing Bank's sanctions procedures[5], including by publicly declaring such firm or an ineligible, either indefinitely or for a stated period of time: (i) to be awarded a Bank-financed contract, and (ii) to be a nominated[6] sub-consultant, supplier, or service provider of an otherwise eligible firm being awarded a Bank-financed contract.

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21 A firm or an individual may be declared ineligible to be awarded a Bank-financed contract upon (i) completion of the Bank's sanctions proceedings as per its sanctions procedures, including inter alia: cross-debarment as agreed with other International Financial Institutions, including Multilateral Development Banks, and through the application of the World Bank Group corporate administrative procurement sanctions procedures for fraud and corruption; and (ii) as a result of temporary suspension or early temporary suspension in connection with an ongoing sanctions proceedings. See footnote 12 and paragraph 8 of Appendix 1 of these Guidelines.

22 A nominated sub-consultant, supplier, or service provider is one which has been either (i) included by the consultant in its proposal because it brings specific and critical experience and know-how that are accounted for in the technical evaluation of the consultant's proposal for the particular services; or (ii) appointed by the Borrower.

Section II. Special Conditions of Contract

Number of GC Clause	Amendments of, and Supplements to, Clauses in the General Conditions of Contract
1.1(b) and 3.1	The words "in the client's country" are amended to be read "in India".
4.1	The language is: English
6.1 and 6.2	The addresses are: Client : **The Project Manager** **National Cyclone Risk Mitigation Project (NCRMP)** Attention : National Disaster Management Authority NDMA Bhawan, A-1, Safdarjung Enclave, New Delhi-110029 Facsimile : 011- 26714321 E-mail (where permitted): pd.ncrmp@gov.in Consultant : M/s RMSI Private Limited, Noida Attention : Sameer Nigam Facsimile : 0120 - 2511109 E-mail (where permitted) : bids@rmsi.com
8.1	N/A
9.1	**The Authorized Representative** **For the Client:** **The Project Manager** **National Cyclone Risk Mitigation Project (NCRMP)** **National Disaster Management Authority** **NDMA Bhawan, A-1, Safdarjung Enclave,** **New Delhi-110029** **For the Consultant: M/s RMSI Private Limited, Noida** **Name: Sameer Nigam** **Title: Head – Bidding Division**

12.1	Termination of Contract for Failure to Become Effective: The time period shall be One Month.
13.1	Commencement of Services: The number of days shall be 15 days from the date of awarding the contract.
14.1	Expiration of Contract: The time period shall be 20 Months including training.
21 b.	The Client reserves the right to determine on a case-by-case basis whether the Consultant should be disqualified from providing goods, works or non-consulting services due to a conflict of a nature described in Clause GCC 21.1. N/A

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24.1	The Insurance coverage against the risks shall be as follows (a) Professional liability insurance, with a minimum coverage of 1.5 times of the value of the contract. (b) Third Party liability insurance, with a minimum coverage of Rs. 7 Lakh. (c) Employer's liability and workers' compensation insurance in respect of the experts and Sub-consultants in accordance with the relevant provisions of the applicable law in the Client's country, as well as, with respect to such Personnel, any such life, health, accident, travel or other insurance as may be appropriate; and (d) Insurance against loss of or damage to (i) equipment purchased in whole or in part with funds provided under this Contract, (ii) the Consultant's property used in the performance of the Services, and (iii) any documents prepared by the Consultant in the performance of the Services.
27.1	The Consultant shall not use these documents and software for purposes unrelated to this Contract without the prior written approval of the Client.
38.1	The Contract price is: INR (Indian Rupees) 1,42,23,450/- (Rupees one crore forty-two lakhs twenty-three thousand four-hundred fifty only) excluding local indirect taxes. Any indirect local taxes chargeable in respect of this Contract for the Services provided by the Consultant shall be paid by the Client to the Consultant. The client shall pay GST payable in India as per applicable law. The consultant shall register itself for GST with appropriate authorities in India and provide registration number to the Client.
41.2	The payment schedule shall be as follows: (a) 10% of the lump-sum amount shall be paid upon successful submission & acceptance of Deliverable 1 (b) 15% of the lump-sum amount shall be paid upon successful submission & acceptance of Deliverable 2 (c) 15% of the lump-sum amount shall be paid upon successful submission & acceptance of Deliverable 3

	(d) 15% of the lump-sum amount shall be paid upon successful submission & acceptance of Deliverable 4 (e) 15% of the lump-sum amount shall be paid upon successful submission & acceptance of Deliverable 5 (f) 20% of the lump-sum amount shall be paid upon successful submission & acceptance of Deliverable 6 (g) 10% of the lump-sum amount shall be paid upon successful submission & acceptance of Deliverable 7 and handing over of data and software.
41.2.4	**The accounts are:** for local currency: [insert Bank Account Number]. M/s. RMSI PRIVATE LIMITED Kotak Mahindra Bank Ltd., Kasturba Gandhi Marg, New Delhi, G-F,Amba Deep,14 New Delhi, Bank Account number: 9011128789 IFSC Code: KKBK0000172 MICR: 110485002
42.1	**The interest rate is:** 10% for INR.
45.1	**Disputes shall be settled by arbitration in accordance with the following provisions:** 1. Selection of Arbitrators. Each dispute submitted by a Party to arbitration shall be heard by a sole arbitrator or an arbitration panel composed of three (3) arbitrators, in accordance with the following provisions: (a) Where the Parties agree that the dispute concerns a technical matter, they may agree to appoint a sole arbitrator or, failing agreement on the identity of such sole arbitrator within thirty (30) days after receipt by the other Party of the proposal of a name for such an appointment by the Party who initiated the proceedings, either Party may apply to President, Institute of Engineers, India for a list of not fewer than five (5) nominees and, on receipt of such list, the Parties shall alternately strike names therefrom, and the last remaining nominee on the list shall be the sole arbitrator for the matter in dispute. If the last remaining nominee has not been determined in this manner within sixty (60) days of the date of the list, Institute of Engineers, India shall appoint, upon the

request of either Party and from such list or otherwise, a sole arbitrator for the matter in dispute.

(b) Where the Parties do not agree that the dispute concerns a technical matter, the Client and the Consultant shall each appoint one (1) arbitrator, and these two arbitrators shall jointly appoint a third arbitrator, who shall chair the arbitration panel. If the arbitrators named by the Parties do not succeed in appointing a third arbitrator within thirty (30) days after the latter of the two (2) arbitrators named by the Parties has been appointed, the third arbitrator shall, at the request of either Party, be appointed by President, Institute of Engineers, India .

(c) If, in a dispute subject to paragraph (b) above, one Party fails to appoint its arbitrator within thirty (30) days after the other Party has appointed its arbitrator, the Party which has named an arbitrator may apply to the President, Institute of Engineers, India to appoint a sole arbitrator for the matter in dispute, and the arbitrator appointed pursuant to such application shall be the sole arbitrator for that dispute.

2. Rules of Procedure. Except as otherwise stated herein, arbitration proceedings shall be conducted in accordance with the rules of procedure for arbitration of the United Nations Commission on International Trade Law (UNCITRAL) as in force on the date of this Contract.

3. Substitute Arbitrators. If for any reason an arbitrator is unable to perform his/her function, a substitute shall be appointed in the same manner as the original arbitrator.

4. Nationality and Qualifications of Arbitrators. The sole arbitrator or the third arbitrator appointed pursuant to paragraphs 1(a) through 1(c) above shall be an internationally recognized legal or technical expert with extensive experience in relation to the matter in dispute and shall not be a national of the Consultant's home country [If the Consultant consists of more than one entity, add: or of the home country of any of their members or Parties] or of the Government's country. For the purposes of this Clause, "home country" means any of:

	(a) the country of incorporation of the Consultant [If the Consultant consists of more than one entity, add: or of any of their members or Parties]; or (b) the country in which the Consultant's [or any of their members' or Parties'] principal place of business is located; or (c) the country of nationality of a majority of the Consultant's [or of any members' or Parties'] shareholders; or (d) the country of nationality of the Sub-consultants concerned, where the dispute involves a subcontract.
	5. Miscellaneous. In any arbitration proceeding hereunder: (a) proceedings shall, unless otherwise agreed by the Parties, be held in [select a country which is neither the Client's country nor the Consultant's country]; (b) the [type of language] language shall be the official language for all purposes; and (c) the decision of the sole arbitrator or of a majority of the arbitrators (or of the third arbitrator if there is no such majority) shall be final and binding and shall be enforceable in any court of competent jurisdiction, and the Parties hereby waive any objections to or claims of immunity in respect of such enforcement.

TERMS OF REFERENCE & DESCRIPTION OF SERVICES

Selection of Consultant for Development of Dynamic Web Based Composite Risk Atlas and Decision Support Tool for Cyclone and Associated Impacts including Storm Surge and Inland Flooding under National Cyclone Risk Mitigation Project Phase-II (NCRMP-II)

1. Introduction

India is one of the most densely populated countries in the world with over one billion people and is exposed to a wide range of geological, hydro-meteorological hazards such as cyclones, floods, earthquakes, landslides etc. Approximately 5,700 km of total 7,500 km of coastline is exposed to severe cyclones, and an estimated 40% of total population lives within 100 km of the coast. On an average, one third to one half of the tropical cyclones affecting this region hit the Indian coastline, which is particularly susceptible to storm surge due to effects including shallow coastal bathymetry and tidal characteristics. Low-lying terrain, high population density and limited community capacity makes the population in these coastal States/Union Territories (UTs) extremely vulnerable to the cyclone and storm surge events. In Orissa super cyclone of 1999 killed over 10,000 people and further millions suffered severe physical and financial losses. In subsequent cyclones, Phailin in 2013 and Hudhud in 2014, the death toll reduced significantly because of timely evacuation of a large number of population from risk prone areas. However, the state had to bear significant physical and financial losses.

Along the coastline, storm surge is often the greatest threat to life and property from a cyclone. In the past events, large deaths have resulted from the rise of the ocean associated with many of the major cyclones that have made landfall. 1999 Orissa super cyclone is a prime example of the damage and devastation that was caused by surge. Close to 10,000 persons lost their lives during the 1999 super cyclone and many of those deaths occurred directly, or indirectly, as a result of storm surge.

Risk assessment and vulnerability studies are underway in several coastal states and it is envisaged to further develop comprehensive decision support system for emergency response and disaster risk mitigation.

2. Background and Context

National Cyclone Risk Mitigation Project (NCRMP) initiated by Government of India takes a view to have comprehensive address of cyclone risks across the coast. The overall objective of the project is to reduce the vulnerability of coastal communities to cyclone and other hydro meteorological hazards. National Disaster Management Authority (NDMA) under the aegis of Ministry of Home Affairs (MHA) with World Bank assistance is implementing the Project in coordination with participating State Governments.

As part of NCRMP Phase-I, Hazard, Vulnerability and Risk Assessment (HVRA) study has been conducted and a Web-based Composite Risk Atlas (Web-CRA) has been developed having deterministic hazard scenarios that would be used by these States/UTs for mitigation planning. This web-based risk assessment system provides the concerned stakeholders with a comprehensive risk assessment framework that offers cross-cutting decision support for mitigation planning at all levels of

Government-Central, State, District, Taluka/Tehsil/Mandal (Taluka), City/Town and Village.

The various components of this study are:

- **Hazard:** The deterministic scenarios cyclone hazard model development consisted of modeling historic cyclonic winds and storm surge using ADCIRC (ADvanced CIRculation) and flooding due to cyclone induced rainfall using HEC tools (HEC HMS, RAS and 2D). These deterministic hazard scenarios are available in Web-CRA as static layers.

- **Exposure:** The exposure data development consisted of inventory of the coastal assets at village and city levels. These are population, buildings (residential, commercial, industrial); cyclone shelters, schools, hospitals, fire stations, police stations, administration headquarters, religious places, heritage buildings; infrastructure elements, such as roads, railway line, airports, ports etc., utilities networks such as communication towers, water and sewerage, electrical lines etc.; ecological assets such as coastal plantation and mangroves. The exposure data of all these exposure elements are available in Web-CRA as dynamic data layers that could be further updated.

- **Vulnerability:** As part of physical vulnerability, a set of physical vulnerability functions are developed for various exposure elements and are available in the web-CRA as dynamic curves that could be further updated.

- **Risk Assessment:** For mitigation planning, the Web-CRA has provisions to estimate risk and generating various exposure and risk assessment reports (detailed and summary) at different administrative levels for decisions making including Hot Spot analysis.

- **The Web**-CRA is based on the GeoNode platform with extension built using python.

Operationally, a risk assessment system is required that caters for both mitigation planning *(static pre-event planning)* and response *(responding to a real-time cyclone- dynamic response)* needs of cyclone prone States/UTs. A range of products are envisaged as part of this second phase of assessment.

- This initiative will aim to develop national level storm surge inundation maps which in turn will make it clear that the risk extends from the immediate coastline into several kms inland. A coastal line depiction of the cyclone and the storm surge risk / inland flooding risk will help communities and infrastructure operators to evaluate their vulnerability and associated risk. The district administration can make use of these maps to undertake advance planning of evacuation and identification of inland evacuation destinations. It is expected that this study will use a representative sample of hypothetical cyclones to estimate the near-worst case scenario of flooding for each cyclone category *(Cyclonic Storm, Severe Cyclonic Storm, Very Severe Cyclonic Storm, Extremely Cyclonic Severe Storm, Super Cyclone)*. The product generated will be used for development planning and emergency preparedness plans.

- Using the past climatology information and exposure database created in the Phase I of the risk assessment, total exposure and event based exposure of the assets can be tracked across the coastline (it shall not suggest or predict future impacts or exposure).

- The coastline contain a large tract of coastal/marine infrastrucure and several ports are in the dircet path of the cyclones. There is also a strong potential for future investment in the coastal areas. It is important to guide the infrastructure planners to benefit knowing the historical exposure to cyclones and plan for reducing existing infrastrcuure vulnerabiity ad protection of new assets planned in the near future.
- The real-time product will take into account the dynamic information from a real-time cyclone *(issued by IMD and other global products)* and estimate the potential flooding scenarios and the products generated shall be used for purpose of evacuation planning and protection of assets.

3. Study Area

The study area is coastal Talukas of the States/UT's falling within 10 m elevation from mean-sea level (States: Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa, West Bengal; Union Territory: Andaman & Nicobar Dadra and Nagar Haveli, Daman and Diu, Puducherry).

4. Objectives

With the overarching goal of providing a robust scientific and practical basis for assessing qualitative and quantitative risk information for the Coastal States/UTs, the key objective of the study is to:

- Develop probabilistic products for depiction of cyclone risk and storm surge flooding / coastal flooding vulnerability maps for the coastal line of India (not a real-time product)
- Enhance Web-CRA with capability for dynamic risk assessment of an impending cyclone (Web-DCRA)
- Provide specific and quantitative information of the exposure to a real-time cyclone event and generation of information products to support decision making at the State/District and Local level (real-time product, including development of Decision Support Tool)
- Add capability in Web-CRA to work in offline (*desktop*) mode for updating of exposure database
- Develop impact graphics and standardize the products in consultation with IMD, NDMA, MHA and other key Government and Scientific Institutions
- Develop communication protocol on the products developed and enhance the analytics and prediction capability over a period of 18months after development (experimental phase)
- Provide training and capacity building support on the Decision Support Tool to the designated officers of the National and State/UT administration and the Coastal District Administration (during the experimental phase)
- To develop a **DCRA App.** This App. will enable users to access features of DCRA and geological events specific to study area through location based technology. For example, in the event of a hazard it helps people to prepare their family and home, find help, facilities/ evacuation routes and let others know they are safe in the hazard event. Perhaps one of the most comforting features on the App is the "We're safe" button. At the press of a button this message is sent to anyone entered on your preloaded list of contacts.

Note: *The firm engaged for undertaking this initiative will not issue advisories and warnings during the development or the experimental phase. The engagement is meant for developing impact forecast products, decision support tool, establish required protocols for decision making under the guidance of the national weather agencies and disaster management institutions and support the designated national agency (during experimental phase) to formulate the mechanism to issue explicit warnings that could be implemented in the next couple of years.*

5. Scope of Services

The scope encompasses development of probabilistic products (not a real-time product) and a real time product for decision making.

Probabilistic Risk Assessment Maps / Products

The scope will include analyzing and improving the probabilistic products for depiction of cyclone risk and storm surge flooding / coastal flooding vulnerability maps for the coastal line of India (not a real-time product). Based on the climatology analysis the service provider will use a representative sample of hypothetical cyclones to estimate the near-worst case scenario of wind-speed information, storm surge and inland flooding for each cyclone category *(Cyclonic Storm, Severe Cyclonic Storm, Very Severe Cyclonic Storm, Extremely Cyclonic Severe Storm, Super Cyclone)*. The product generated / outputs will be in the form of maps which shall be used for development planning and emergency preparedness plans.

The potential storm surge and coastal flooding map will map target areas along the east coast and the west coast of India at risk from storm surge during a cyclone event.

The map shall show:
- Cyclone track and related information of key events
- Measure and quantify location exposure to cyclone tracks and wind events
- Geographical areas where inundation from storm surge and coastal flooding could occur
- The potential heights of water above ground could reach in those areas for a given storm intensity and inundation represented by different colors on the map based on the water depth
- Exposure database (population at risk, critical/emergency infrastructure, utilities, marine infrastructure, environmental infrastructure)
- The map generated will be displayed on the website in an interactive map viewer

The preparation of the maps shall take into account:
- Flooding due to storm surge form the ocean and adjoining features of the coast to determine the surge
- Normal astronomical tides
- Topography Data (DEM) / Land elevation
- Historical cyclone track and related characteristics of the events

The preparation of the maps will not take into consideration:
- Wave action
- Freshwater flooding from rainfall
- Riverine discharge
- Overtopping from existing coastal embankments or other structures

Purpose and key audience:

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The purpose of this map/decision support tool is to provide information which enables users to make decisions related to demarcation of risk prone areas and protection of life and property from storm surge flooding. The tool can be used to tackle specific ocean challenges, marine infrastructure planning, economic development and undertaking conservation measures. The key audience for use of these maps/products are Government officials at State/District/Local level, State Disaster Response Force (SDRF), Development agencies and communities/general public.

Real-time Decision Support Tool (Web based Dynamic Composite Risk Atlas)

The scope is to determine exposure to a particular category of real-time cyclone event and generate impact forecasting on the coastline and the landfall region (including associated storm surge, rainfall, inland flooding). Modelling will use deterministic approach using single simulation based on accurate meteorological forecast provided by IMD. The model will run based on the information release cycle by IMD and for surge forecast the location and the timing of the cyclone landfall will feed to determine which areas will be inundated by the storm surge. The model will keep a track of the changes in the cyclone path, intensity, size, forward speed and the determined landfall location to generate impact forecasting. The impact forecasting will aim to provide an accurate depiction of the cyclone event and the storm surge / coastal flooding vulnerability. This data will be used by the disaster manager sand emergency responders to make evacuation decisions.

The impact forecasting is an event based exercise and will be operational initially in an experimental phase for 18months for cyclone events occurring in Arabian Sea and Bay of Bengal with a potential for landfall along the Indian coastline. The emergency evacuation phase is a short window and for planning purpose the administration would be on a standby or state of readiness prior to T-48 to T-72 hours of landfall. As the event is dynamic, average track errors prior to 72hours is considerable. For decision making purpose the time period of T-24hour and T-48hour window is crucial. A worst case storm surge estimation summarized with local impacts shall be generated for the coastline and the inland areas. The decision-makers will make informed decisions taking into consideration the current forecast limitations.

The map products shall provide a reasonable flooding information at particular landfall location for storm surge. This information products shall be conveyed to the respective institutions for decision making and evacuation.

The decision support system will develop a feedback method to obtain real-time information from the field (ground truth) and compare with the forecast information. This will provide information for technical assessment of the model results and improve the forecast results.

The map shall show:
- Real-time Cyclone track and related information from IMD and other global datasets
- Show exposure database (population at risk, critical/emergency infrastructure, utilities, marine infrastructure, environmental infrastructure)

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- Identify geographical areas where inundation from storm surge and coastal flooding could occur
- Map potential heights of water above ground could reach and represent inundation by different colors on the map based on the water depth
- Activate the interactive map viewer platform and display information based on the event onset information release by IMD
- Generate impact / risk map on the interactive map viewer / decision support tools. During the experimental phase, the map shall be made available approximately 120mins following the advisory release by IMD for a potential landfall

The preparation of the maps shall take into account:
- Flooding due to storm surge form the ocean and adjoining features of the coast to determine the surge
- Normal astronomical tides
- Topography Data (DEM) / Land Elevation
- Real-time cyclone track and related characteristics of the event

The preparation of the maps will not take into consideration:
- Local factors that play a crucial role in determining actual surge or flooding impacts (for example, topping of flooding water from embankments or any other structure).

Purpose and key audience:

The purpose of this tool is to provide information which enables users to make decisions related to demarcation of risk prone areas and protection of life and property from storm surge flooding. The key audience for use of these maps/products are trained officers of the Government at various levels, State and District/city Emergency Operations Centre, Disaster Management Authority (State/District/Local), and emergency responders.

In order to undertake the Probabilistic Risk Assessment Maps / Products and development of the Real-time Decision Support Tool (Web based Dynamic Composite Risk Atlas), the following indicative list of activities are envisaged:

1. **Understanding existing Web-CRA and Models:** The consultant should understand that existing models and risk assessment developed as part of NCRMP Phase-I

2. **Methodology development:** The consultant should explain the methodology for enhancing the Web-CRA for dynamic computation of cyclone hazard, exposure, vulnerability and risk. The consultant should also explain the working of the enhanced Web-CRA in offline mode for updating the exposure database. The methodology should consider risk assessment needs at a hierarchy of spatial scales from macro to micro, spanning State/District/Tehsil/Taluka/Mandal/Village levels.

3. **Hazard and Risk Model Automation and Impact Forecasting:** The Web-CRA should bring in capability for dynamic hazard assessment and referred as a decision making tool. It should take into consideration:
   - Existing model for cyclonic wind, storm surge and rainfall induced flood hazards should be extended for dynamic use

- Ability to model real time cyclone and associated impacts
- Process cyclone data and estimate risk and generate information products that is used for deployment of first responders and essential stocks/supplies, staging response and timely evacuation of people

4. **Desktop Version of Web-CRA:** The desktop version of Web-CRA should have capability to work in offline (*desktop*) mode for exposure updating at State/UT local server with provision of auto upload of exposure data once connectivity to the Web-CRA host server is available.
   - Create off-line version of Web-CRA for exposure data updating
   - The offline version should be capable of running on a desktop, if required. Also, the offline version should run in a client server mode with users updating different datasets
   - Ability to sync and upload the updated exposure data to Web-CRA
   - The look and feel of desk-top version should be same as that Web-CRA

   Experimental Phase: The development phase is envisaged for a time frame of six-eight months followed by 18months of experimental phase which will take into consideration real-time cyclone risk assessment and related product development, finalizing the interactive map viewer platform, protocol development for warning etc.

5. **Quality Assurance:** An appropriate QA process should be implemented throughout the development process. The enhanced Web-CRA shall undergo a proper testing plan and activities such as system, functional and non-functional testing. The Consultant is required to devise performance test criteria to ensure that the system functions as required in the production environment. The User Acceptance Test (UAT) will be done at the NIC Server at the time of the handing over of fully operational Geonode based enhanced Web-CRA.

6. **Documentation and guidelines:** Produce an updated *Technical User Guide* for the Web-DCRA. The User guide should be simple, practical and easy to understand for system users.

7. **Training and Capacity Building:** In addition the consultant shall also provide technical support to the National, State and District Level agencies through training and capacity building programme.

6. Deliverables & Schedule for Completion of Tasks and Services

The consultancy must be completed within 20 months from the date of signing the contract. The schedule for completion of tasks and deliverables is as follows:

No	Deliverables	Timeline w.r.t signing of contract
1	Inception Report	15days
2	Development of probabilistic risk assessment maps/products and display through interactive map viewer	3 months
3	Development of Alpha version of Web-DCRA/Decision Support Tool, DCRA App, Demonstration and Presentation to key stakeholders, draft Technical User Guide	5 months

No	Deliverables	Timeline w.r.t signing of contract
4	Demonstration of Beta version of Web-DCRA & DCRA App. for User Acceptance Test	7 months
5	Closure Report and fully operational Web-DCRA and offline Desktop version of Web-CRA	7 months
6	Experimental Phase	20 months
7	Training Workshops and capacity building activities (This is an ongoing activity and will get initiated after the development and approval of the Decision Support Tool/Web-DCRA) including successful hosting of Web CRA, duly security audited by Cert In empanelled, on NIC Server. Cost of audit shall be borne by the bidder.	20 months

Note: The duration of Development phase & Experimental phase may suitably be modified by the Consultant so as to suit the overall governing Table of Deliverables as mentioned above.

7. Staffing Requirements

The assignment is expected to be implemented by a highly experienced and professionally qualified team. The key experts should have the relevant qualification and experience requirements. The consultant team will consist of the following key experts. In addition, the consultant can include the required support team for software development requirements in order to meet the objectives and scope of services.

List of Key Personnel

S.No	Title and Description	Indicative effort in months
1	**Team Leader** Post Graduate with minimum 20 yrs experience in a hazard risk assessment field. S/he should have led at least 3 multi-hazard HVRA assignments. S/he should have expertise in hazard models, exposure database, risk assessment, software for disaster risk management along with developing risk atlas. The Team Leader must have proven experience in leading consultancy teams for projects funded by the Multilateral/Bi-lateral agencies, UN agencies, or the Private Sector. S/he must have experience of working on national and international assignments	6
2	**Deputy Team Leader** Post Graduate with minimum 15 yrs experience in a hazard risk assessment field. S/he should have led at least 3 multi-hazard HVRA assignments. S/he should have expertise in disaster risk management. The Deputy Team Leader must have proven experience in leading consultancy teams for projects funded by the	2

	Multilateral/Bi-lateral agencies, UN agencies, or the Private Sector. S/he must have experience of working on national and international assignments	
3	**Hydrologist/Flood Risk Modeler** Advanced/ Post Graduate degree in Hydrology related subject, and at least 15 years experience in flood hazard assessment/ modeling and customizing flood models for automation. S/he must have experience of carrying out similar assignments.	3
4	**Modelling Expert (specialization in Cyclonic Wind and Storm Surge Risk Modelling)** Advanced/ Post Graduate degree in oceanography / geophysics related subject, and at least 15 years' experience in cyclone hazard assessment studies. S/he must have experience of carrying out similar assignments	3
5	**GIS Expert** Post Graduate in Geology or GIS or related field and atleast minimum 10 years' experience in all aspects of Remote Sensing and GIS related database development for hazard and exposure data. S/he must have experience of carrying out similar assignments.	6
6	**IT Expert (software development) - 2 persons** Graduate in Computer Science/IT with at least 5 yrs exp in design and development of web-based software with specific experience of developing risk atlas with Geonode. S/he must have experience of carrying out similar assignments.	6 x 2 = 12
7	**QA Engineer** Graduate in Computer Science/IT with at least 5 yrs exp in QA of web-based software applications. S/he must have experience of carrying out similar assignments.	4
	Total	36

8. Project Management and Reporting Requirements

The consultant will be reporting to the PMU of the NCRMP at NDMA. This is an ongoing task, in which the status of the project shall be communicated to project management, other key stakeholders through monthly/quarterly brief progress reports (10-15 pages) by the consultant and specific meetings as needed with the consultant This task also includes ongoing project management, including preparation of a project work plan following project initiation, quarterly written project management reports etc.

9. Payments

Payment to the consultant will be delivery based and in instalments as per the Schedule of Payment mentioned in para 41.2 of the Special Conditions of contract.

10. Data & Services Provided to the Client

Deliverables provided by the consultant to the client will be exclusive property of the client which the consultant should not share with any third party without the express consent of the NCRMP, NDMA. Data obtained by the consultant from the government agencies during the course of study should be treated as confidential by the consultant and not to be shared with any third party.

11. Returning of Data
At the end of assignment, the Consultant shall submit the raw data collected during the execution of the assignment and the processed database to the client.

12. Submission and Acceptance of Deliverables
The Consultant shall be submitting deliverables to the client (PMU, NCRMP) for acceptance. Invoice for payment shall be raised by the Consultant only after confirmation of acceptance of the deliverables.

13. Services and Facilities to be Provided by the Client

The client shall facilitate the Consultant in obtaining the data from the other Ministries/ Departments/ States, if so required. However, the format for obtaining data is to be decided by the Consultant who will also be liaisoning with the concerned Ministry/Department/State.

Description of Services

14. Technical Approach and Methodology

The project has been divided into phases – the first phase focused into developing a Risk Atlas that is capable of identifying hotspots of high vulnerability coastal areas for communities at-risk. This was expected to enable support for land use planning, shelter planning, evacuation routing, emergency and contingency planning. In accordance with the planning, Hazard, Vulnerability and Risk Assessment (HVRA) study was conducted as part of NCRMP –I, and a Web-based Composite Risk Atlas (Web-CRA) was developed. This study was successfully completed by RMSI in 2016. This web-based risk assessment system provides the concerned stakeholders with a comprehensive risk assessment framework that offers cross-cutting decision support for mitigation planning at all levels of Government - Central, State, District, Taluka/Tehsil/Mandal (Taluka), City/Town and Village.

It was realized that in addition to the above, mitigation planning (static pre-event planning) and response (responding to a real-time cyclone- dynamic response) planning for cyclone prone States/UTs needs to be conducted. Thus, this second phase was conceptualized with very specific objectives including:

- Developing probabilistic products for depiction of cyclone risk and storm surge flooding / coastal flooding vulnerability maps for the coastal line of India (not a real-time product)

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- Enhancing Web-CRA with capability for dynamic risk assessment of an impending cyclone (Web-DCRA)
- Providing specific and quantitative information of the exposure to a real-time cyclone event and generation of information products to support decision making at the State/District and Local level (real-time product, including development of Decision Support Tool)
- Adding capability in Web-CRA to work in offline (desktop) mode for updating of exposure database
- Developing impact graphics and standardizing the products in consultation with IMD, NDMA, MHA and other key Government and Scientific Institutions
- Developing communication protocol on the products developed and enhancing the analytics and prediction capability over a period of 18 months after development (experimental phase)
- Providing training and capacity building support on the Decision Support Tool to the designated officers of the National and State/UT administration and the Coastal District Administration (during the experimental phase)
- Developing a DCRA app that will enable users to access features of DCRA and geological events specific to study area through location based technology. For example, in the event of a hazard it helps people to prepare their family and home, find help, facilities/ evacuation routes and let others know they are safe in the hazard event. Perhaps one of the most comforting features on the App is the "We're safe" button. At the press of a button this message is sent to anyone entered on your preloaded list of contacts

A key objective that our team considers extremely important is availability of appropriate detailed documentation on the web-CRA as well as the DCRA app. These documents are expected to explain the operation and administration of the tools in a user-friendly manner. CONSULTANT team would ensure that all the knowledge is transmitted to the concerned officials for smooth functioning of the system even after the project is over.

15. Overall Approach
Consultant with the advantage of being involved in the first phase and having developed the Web-based Composite Risk Atlas (Web-CRA), is confident of a smooth start and finish to this assignment. Being a key part of the first phase helped the team understand the gap and need for a further study to develop a dynamic risk assessment tool for real-time analysis of impending cyclonic events. Consultant has devised a robust approach to ensure that the objectives of this phase are achieved in a timely manner with best possible quality.

16. Leveraging Experience of Phase 1
Our overall approach will be to build upon the work completed in the first phase including the data collected, discussions held with key agencies involved in cyclone and related hazards' analysis, software developed, and training imparted to key stakeholders in the Government.

17. Flowchart showing approach and involvement of stake holders

Fig.1
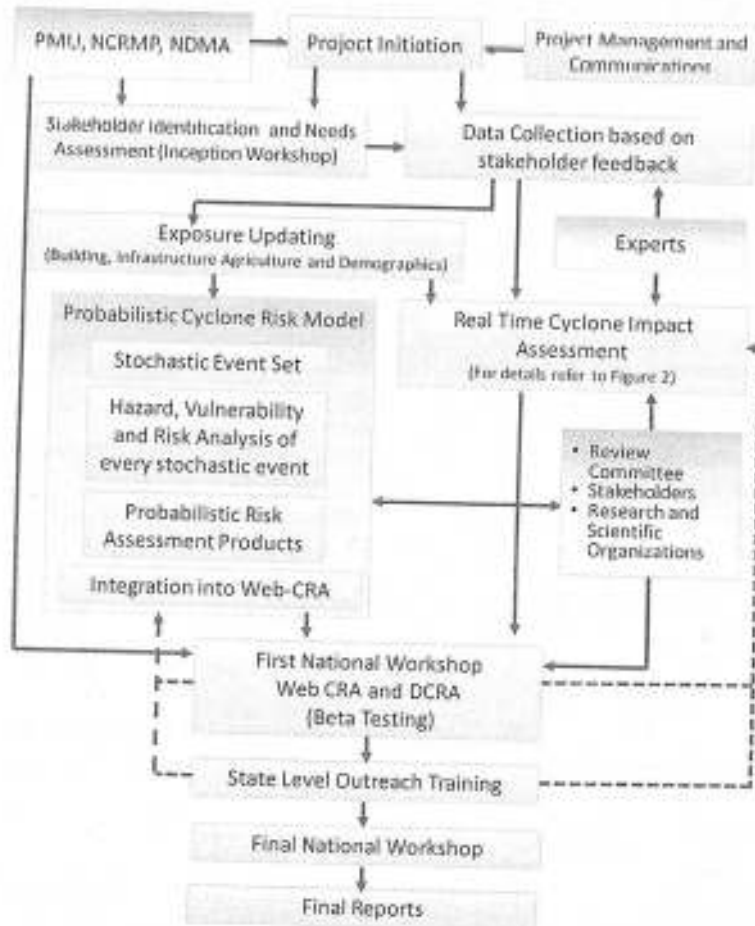
The impact of all the stochastic events will be estimated using the above models. These scenarios (including worst case ones) will demonstrate how various hazards associated with cyclones are impacting the population, buildings, infrastructure, agriculture, etc. of the high-risk areas of the country. These scenarios will be communicated through Probabilistic Risk Assessment Products that include return period hazard and risk maps, Average Annual Loss (AAL), Loss Exceedance Curves (LEC), Maps by hazard intensity like 1-meter surge risk map, 2-meter surge risk map, etc. This will help communities understand their vulnerability and associated risk, and allow the administration to undertake advance mitigation planning, planning of evacuation routes and destinations and prepare appropriate emergency preparedness plans. These probabilistic risk assessment products, in the form of

pre-compiled worst-case scenarios for each State/UT, would be made available in the Web - CRA.

Fig.1 shows the process of real time cyclone event impact assessment and communication of results as part of the Web- DCRA. For Hazard and Risk Model Automation and Impact Forecasting ADCIRC and HEC-RTS models will be automated to run through a Web based Dynamic Risk Atlas (Web-DCRA). The web-DCRA will take as input real time input data like cyclone track details and rainfall from sources like IMD, JAXA, etc. to generate real-time analysis of an impending cyclone.
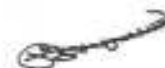
The Web-DCRA will provide the following key outputs:

- Cyclone hazard map
- Cyclone impact map in terms of population impacted, potential losses to various types of exposure
- A situation report that provides the details of the impact
- Send event situation report to pre-defined individuals via email
- Web service to extract event related risk details to connect the Web-WEB-DCRA to any other government web-sites
- The system will send SMS and pre-recorded voice alerts to all mobiles in the coastal areas, near airports, train stations, etc.
- The system will send SMS and pre-recorded voice alerts to homes that have potential for impact on what they can do to reduce losses
- Register missing people information
- SMS alert to mobiles in the area regarding missing people
- Reporting of missing identified

The Offline version of Web-CRA for exposure management will be created using a Smart Client framework that uses a thick client for desktop user interface and is capable of connecting to a database that could be on the desktop or on any computer on the LAN. Capability to auto-synchronize with the Web-CRA server will be implemented in the Smart Client.

The Web-WEB-DCRA will be supplemented by an Android based Mobile App that will server following key features:

1. "I AM SAFE" feature: By clicking 'I AM SAFE' button the system will send SMS alert to predefined numbers.
2. Crowd Sourcing feature to get feedback from people, who want to submit information related to event such as:
   o Status of flooding
   o Approximate wind speed, surge height
   o Damage description
   o Need to be evacuated
   o Need Emergency Medical help" etc.

18. Storm Surge Warning System

Fig.2
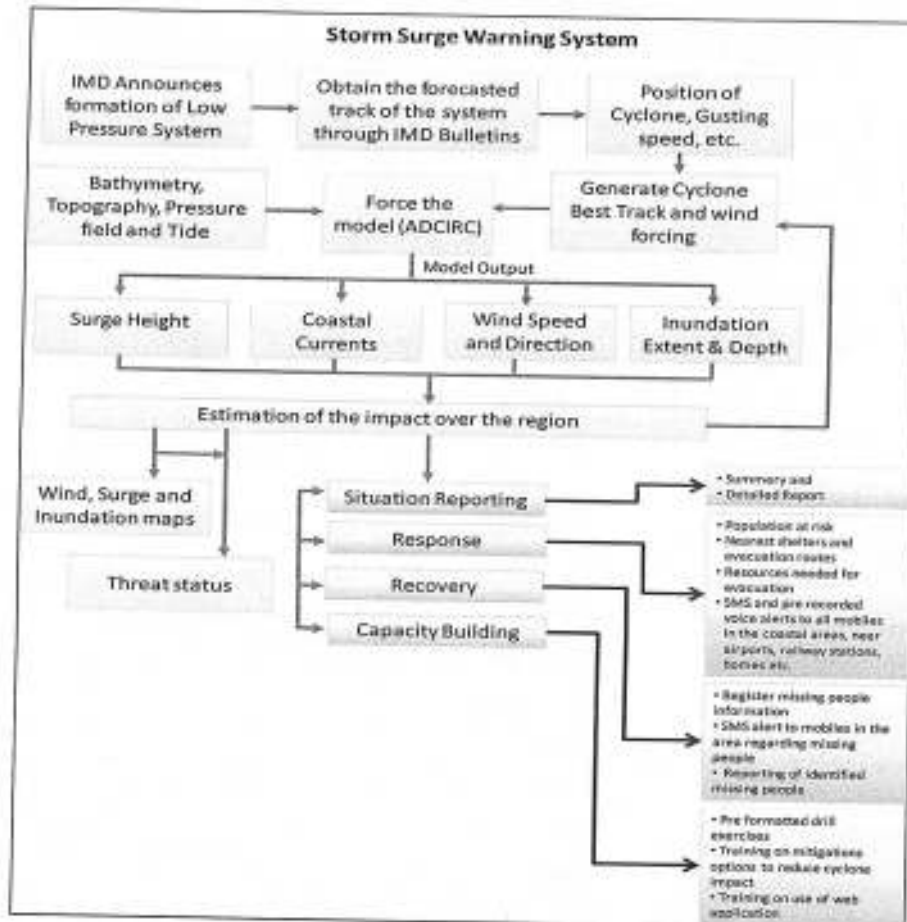
19. Data Type and Sources Utilized in Creating Hazard, Risk &Vulnerability Composite Risk Atlas under NCRMP Phase-I

S.No.	Data Description	Data Source
1	Bathymetry data having high resolution for shallow sea levels	National Hydro- graphic Office (NHO), Dehradun
2	Discharge data of rivers on daily/weekly/monthly basis	Central Water Commission (CWC)

S.No.	Data Description	Data Source
3	Village & City Level admin boundary data	Survey of India (SOI)
4	Cyclone track and intensity data since 1877 AD	India Meteorological Department (IMD)
5	Village & City level housing (in percentage terms depending upon house type) and demographic data	The Registrar General and Census Commissioner, India (RGI)

20. Details of aggregated and site-specific exposures

S. No.	Exposure Elements	Categories	Sub Categories
1	Buildings	Residential	
		Commercial	
		Industrial	
		Religious	
2	Infrastructure	Public Buildings	Government Buildings, Police and Fire station and Safe shelters
		Essential Facilities	Schools, Health
		Transportation	Airports, Bridges, Ports, Roads and Railway lines and stations
		Utilities	Potable water, Waste water, Oil and gas, Electric power, Communication
			systems
		Other critical infrastructure	Power plant, hazardous storage etc.
3	Demographics		
4	Agriculture & Livestock		Major agriculture crops and natural ecosystems (plantation, mangroves)

The buildings were derived mainly using satellite images as building clusters for residential, commercial, and industrial buildings. The structural details derived from Census 2011 at village/city levels were grouped into 25 combinations and distributed over the building clusters. Out of these 25 combinations, mainly six building

structural classes dominate the study area. These classes were further validated through sample-field verification surveys conducted. Wherever data was not available, accepted proxy data were used. Replacement values of various exposure elements were collected from various organizations and field surveys.

As part of this assignment, the Consultant will update all the above listed parameters with the latest data available. Consultant has a significant head start in this area since it is well-versed with the sources (of where to find the relevant data) and the organizations, structure and officials in these organizations (contact persons), which is likely to reduce the ramp-up time significantly.

21. Data Cleansing and Gap Analysis

Data cleaning has already been performed by a series of quality control (QC) checks to identify missing values and to flag suspected values on data used during Phase 1 and the same will be applied to all new data that will be gathered during this assignment. It is noteworthy that Consultant will have a significant head start in both the areas – data collection and cleansing and gap analysis – saving time and money for NDMA.

To recap on the processes followed, two types of data validations were carried out, namely, replacement of erroneous values and supplementing missing values using standard and internationally accepted processes.

Future updates will be applied on above datasets that Consultant team will receive from 13 Coastal States/ UTs' nodal agencies during the execution of this project. For example, there will be better cyclone shelter database than the one that went into the Phase 1 Web-CRA, simply because of relevancy of the information and construction of additional cyclone shelters since the Phase 1 version of Web-CRA was launched. In addition, aggregated exposure data on various exposure elements would be updated with site-specific data as per its availability.

Consultant team will do a gap analysis and in case of non-availability of data related to any exposure elements, including marine infrastructure, secondary data will be used to fill the gaps. Consultant will also seek information about potential future infrastructure elements planned and would try to incorporate those if information is made available by relevant state or central agencies.

22. Data Inputs for Storm Surge Modelling for Real Time Extreme Events

The principal requirement for the operational use of numerical storm surge model is the availability of accurate data of surface wind field together with a reliable forecast of track of the tropical cyclone. India Meteorological Department (IMD) is the nodal agency of Government of India that issues cyclone warning bulletins indicating tidal wave / gales / heavy rainfall / cyclone track at every three hours during cyclone genesis to dissipation stage in the North Indian Ocean. This information is publicly available at http://www.rsmcnewdelhi.imd.gov.in. IMD is also responsible for

checking the data quality and completeness before delivering the information on public domain.

23. Understanding of existing Web-CRA and Models

RMSI team has developed the Web-CRA as part of National Cyclone Risk Mitigation Project (NCRMP) Phase 1 and thus have a detailed understanding of the same. The Web-CRA provides software tools to help decision makers in risk mitigation planning and preparedness for the coastal states/UTs to protect the people and assets of the country.

24. Software Architecture

Web-CRA was developed using open source web development technologies. It uses World Bank's GeoNode as the base platform. Key technologies that drive the platform are:

- PostGreSQL/PostGIS for spatial relational database
- Geoserver for map publishing
- Python scripting for UI and application framework

RMSI team enhanced the GeoNode platform further into Web-CRA using python coding to provide all the functionalities.

25. Hazard and Risk Data

The development of Web-CRA was done using the hazard data and risk information generated as part of tropical cyclone Hazard, Vulnerability, and Risk Assessment (HVRA) for areas of 13 coastal States and UTs, which lie up to 10 m elevation (with reference to mean-sea level along the coastline). Web-CRA provides risk estimates from cyclone induced strong winds, flooding due to storm surge, and flooding due to cyclone induced rainfall.

HVRA was done by applying scientific methods that simulate the impact of a cyclone in a computer based model. Following models were developed as part of HVRA

- ADCIRC based Cyclone wind and surge estimation model – This was developed for entire coastline of India so that all cyclones could be modeled whether they generate in Bay of Bengal, Indian Ocean or Arabian sea. The model was calibrated against all major historical cyclones including Phailin and Hudhud cyclones.
- HEC RAS based cyclonic rainfall induced flood model – This model was developed for all the basins along the entire coastline. The model was calibrated against all major historical floods that happened due to cyclonic rains including the 2015 Chennai floods.

The models were run for all historical events and the estimated wind, surge height and flood heights at village level were incorporated into the Web-CRA.

Exposure was developed for all the exposure elements. Vulnerability functions were developed for types of exposure. Both the exposure dataset and the vulnerability functions are incorporated in the Web-CRA.

Risk model was developed to estimate the impact of all historical cyclones on today's exposure by applying the hazard and associated vulnerability to all exposure elements. This risk information was generated for all historical cyclones and integrated into Web-CRA.

26. Key Features of the Web-CRA

Dashboard: The Dashboard provides a quick overview of the risk to a senior level administrator for his/her state/UT. It summarizes the overall risk of the state using a Risk Meter and then provides an idea of total exposure and exposure at risk to cyclones including population. By clicking on any of the above summaries the user could view the details under the summary.

27. Key Components

The three key components of Risk Atlas are:
1. Precompiled digital risk atlas
2. Risk Analyzer
3. Hotspot Analysis
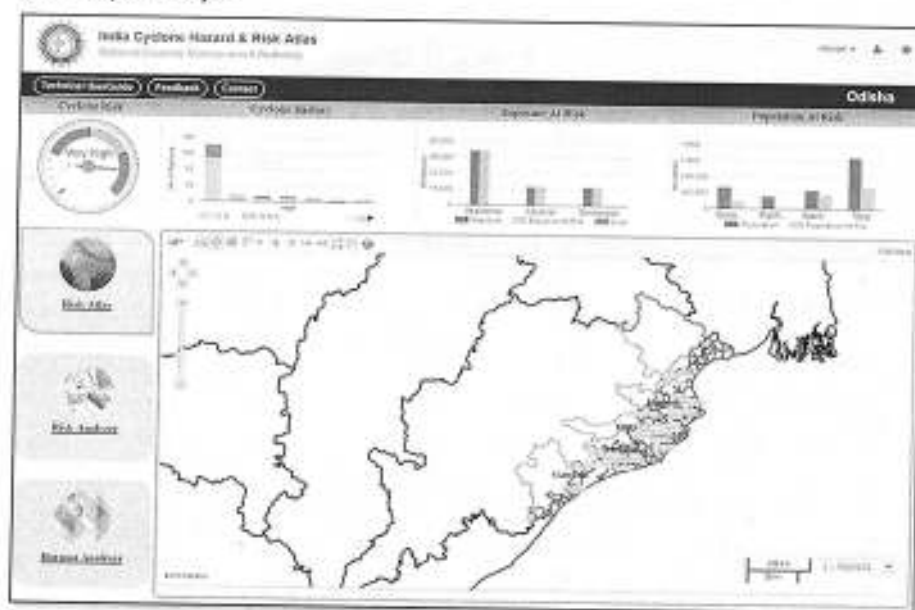
Figure 3: Dashboard screen of Phase 1 Web-CRA

The precompiled digital Risk Atlas is a ready reckoner to understand the cyclone risk in any part of the study area of all the 13 coastal States/UTs. It provides cyclone risk

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in terms of population at risk, buildings and infrastructure assets at risk and estimated damage and loss from various possible cyclone scenarios.

The Risk Analyzer provides capability to decision makers to update the risk atlas and analyze regional district and taluka level mitigation options. Within the Risk Analyzer the functionality has been implemented to update the exposure dataset and estimation of loss to all exposure elements using the hazard and vulnerability functions. It also helps decision makers to generate Exposure Report and Risk Analysis Report at State/UTs, District, Taluka, City and or Village level.

The Hotspot Analyser provides the decision makers tools to conduct a micro-level risk analysis of Communities at high risk' at village/ward level and provide option to generate "Hotspot Risk Analysis Report" that helps in risk mitigation and preparedness.

28. Methodology Development

This study has two main components for which methodology has been described in this section:

1. Probabilistic Risk Assessment Maps / Products
2. Real-time Decision Support Tool (Web-based Dynamic Composite Risk Atlas)

As specified in the previous section, RMSI conducted the Hazard, Vulnerability, and Risk Assessment (HVRA) for areas of 13 coastal States and UTs as part of the Phase 1 of the NCRMP project. As part of the HVRA RMSI team developed the cyclone wind and surge models using ADCIRC for the entire coastline of India and cyclone induced flood model using HEC RAS for all the basins along the Indian coastline. Consultant team plans to reuse nearly all the models that were developed as part of the Phase 1 either as is or extend it to implement the capabilities needed for the implementation of the current ToR.

For the HVRA, RMSI team also developed a very detailed Exposure dataset covering Buildings, Essential Facilities, Infrastructure (including coastal and marine infrastructure) and Demographics for all the coastal districts up to 10-meter elevation. Consultant team plans to enhance the same exposure dataset wherever more recent updates could be provided by the state of national agencies.

For all the exposure elements a detailed vulnerability analysis was also conducted as part of Phase 1 using which Vulnerability functions were developed for all classes of exposure. Consultant team plans to reuse the same Vulnerability functions for assessment of impact of probabilistic as well as live events. Wherever we could get some more information that requires updating the Vulnerability functions the same will be attempted.

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29. Methodology for Probabilistic Risk Assessment Maps and Products

RMSI understands that the aim of conducting a probabilistic risk assessment is to develop risk assessment scenarios for different probabilities of exceedance (also known as return period scenarios). Generation of these scenarios is important from a cyclone risk mitigation planning perspective, since observations suggest that coastal locations and states that only experienced low intensity cyclones earlier are now being impacted by higher intensity cyclones.

The 2014 Cyclone Hudhud is a classic example in this direction. It made landfall near Vishakhapatnam at a wind speed of about 185 km/h unknown hitherto to the city, and caused colossal socio-economic losses. The analysis of cyclone history since 1877 shows that Vishakhapatnam city had experienced maximum wind speeds of only about 93 km/h (in 1983 and 1985) in this long period.

This also implies that there is no guarantee that if a place has not experienced a damaging cyclone in the past, it cannot experience one such devastating cyclone in the future. Thus, there is always a probability of experiencing a higher intensity cyclone than that experienced in cyclonic history. Such events are generally called low-probability-high-impact events.

This task is well taken care of through stochastic modelling and our methodology addresses this need significantly, thereby reducing future surprises to an extent. The methodology is described forthwith in detail.

Fig. 4 shows the Modelling Framework that will be followed for the development of probabilistic cyclone risk model. The model takes into account near-worst case scenarios of wind speed, storm surge, and inland flooding for each cyclone category Viz. (Cyclonic Storm, Severe Cyclonic Storm, Very Severe Cyclonic Storm, Extremely Cyclonic Severe Storm, Super Cyclone). In general, this modelling framework holds good for generating the probabilistic risk maps of worst case scenarios of each cyclone category.
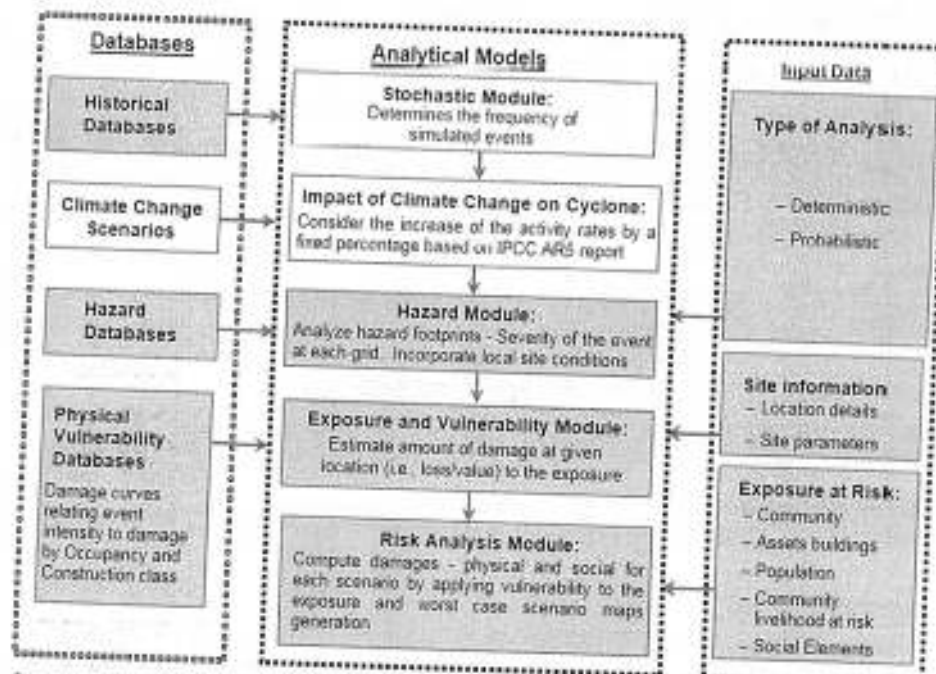
Components shaded in green colour are those already developed by RMSI as part of NCRMP Phase I

Fig.4 Probabilistic Risk Modelling Framework

All activities shaded in green in Fig. 5 (9 out of 12 components in the above shown framework) have already been completed as part of Phase 1 of the NCRMP project. The team proposes to reuse data/components from all these activities, with updates where required, for the development of the probabilistic model in Phase 2. The Consultant has a significant head start in these areas thus reducing ramp-up time that would result in major savings as well as improving upon many of these already developed datasets/components.

The subsequent sections provide a more detailed explanation of the activities that will be performed as part of Phase 2 of this project and how Phase 1 activities will be reused in Phase 2. Two key activities that need to be performed before Phase 1 components could be reused are:

- Generation of stochastic event set using historical cyclone and rainfall data
- Analysis of climate change scenarios to derive the extent of change in frequency and severity of cyclonic events and incorporate these changes in the stochastic event set

The digital framework for probabilistic map generation for all the hazard components (Wind, Surge and Cyclonic rainfall induced floods) has been shown in Fig. 5 below.

The desired methodology for each of the components has been elaborated in subsequent sections that follow.
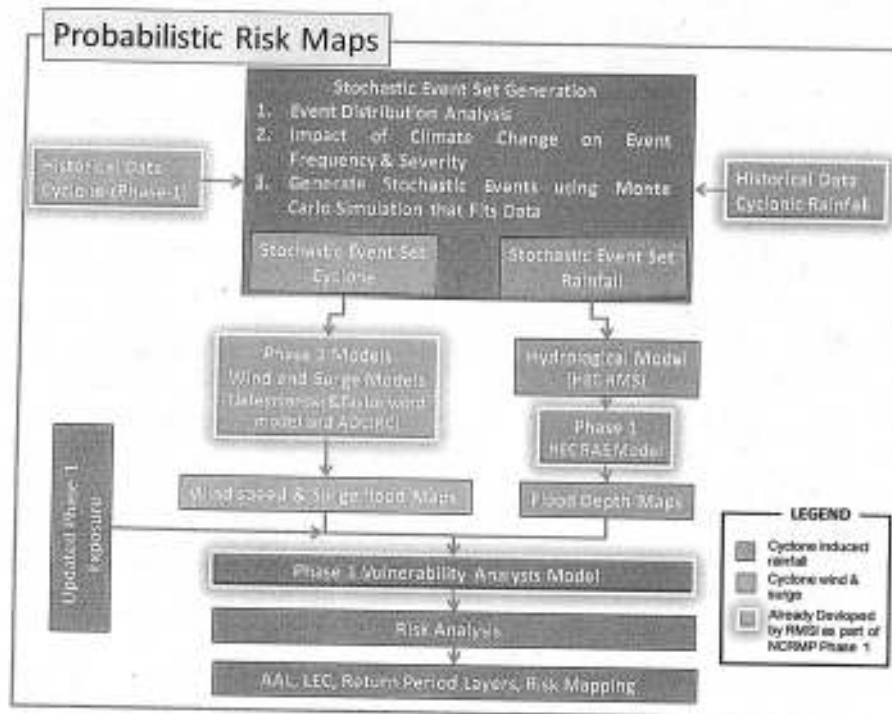
Fig. 5 Probabilistic risk maps generation

30. Stochastic Event Module

Thousands of possible event scenarios will be simulated using Monte Carlo simulations based on realistic parameters and historical data. Each cyclone event will be defined by a specific strength, genesis location and path, and probability of occurrence or event rate. Each cyclonic rainfall event will be defined by duration of the event in days (1- day, 2-day, 3-day rainfall events...) and associated daily rainfall.

The detailed model will be based on historical cyclone track data from the North Indian Ocean. This data is already up and running for the team since it was used in phase 1 and other activities. The data consists of the location and the maximum wind speeds of every known tropical cyclone in that area from the period 1877–2017, recorded at intervals of 6 hours. The data set is a composite of best track data in the North Indian Ocean of India Meteorological Department (IMD) and International Best Track Archive for Climate Stewardship (IBTrACS). Fig.7 shows the tracks of all the cyclonic disturbances to be considered for stochastic modelling of cyclone tracks.

Fig.6 Storm tracks in the North Indian Ocean from 1877–2016

For stochastic rainfall modelling the rainfall associated to all these cyclones will be used as a basis.

The main steps of this module can be elaborated as follows:

- Analyse historical cyclone tracks to extract important characteristics. Therefore, before creating a simulation from observed data, all the historical cyclones will be separated into more homogeneous classes and observation windows will be segmented into 3-4 zones. On the same lines, rainfall events of various durations will be identified using the historical data to ascertain the frequency of various duration rainfall events. This gives various rainfall duration events into which the entire history could be categorised.
- Next, the historical cyclones will be assigned to different classes according to the combinations of zones they started or ended in or across which they moved during their life span.
- The model will include the following characteristics:
  - Point of genesis of storm within the observation window, they will be modelled as random point processes, therefore, an inhomogeneous Poisson point process will be used to model the distribution of genesis points
  - Rainfall Event for every duration will also be modelled as random point processes, therefore, an inhomogeneous Poisson point process will be used to model the distribution of rainfall events
  - Direction of storm movement and Translation speed: to model storm movement from the points of genesis, a travelling direction and a translation speed are needed. A density for the initial direction of a storm

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will be estimated from the data using kernel techniques. The same will be done for the change in the cyclone's direction. An analogue procedure will be employed for modelling translation speed and maximum wind speed.

- A probability of exceedance of any particular peak gust will be calculated using a Poisson Point Process
- The termination (or death) of a storm will also be modelled as a random variable. Depending on its location and maximum wind speed, the storm will be assigned a certain termination probability according to the storm's current position
- With the Monte Carlo technique, the adequacy of the model for the simulation of the tracks can be tested by comparing the point patterns of the second points, third points, etc. of synthetic cyclones with the corresponding historical data.

It is important to note that for generating the actual event sets of cyclone tracks, an acceptance-rejection method will be used. After generating a storm track originating from one of the initial points, the obtained track will be classified to determine whether a track has been produced that matches the class of its initial point. If this is not the case, the track will be rejected and a new track will be generated, until a track with the correct classification is obtained.

The simulation parameters in the case of cyclones are location of genesis, central pressure, forward velocity, and location of landfall. In the case of floods, rainfall is the primary parameter. A sample stochastic event set of location of cyclone genesis is presented in following figure.
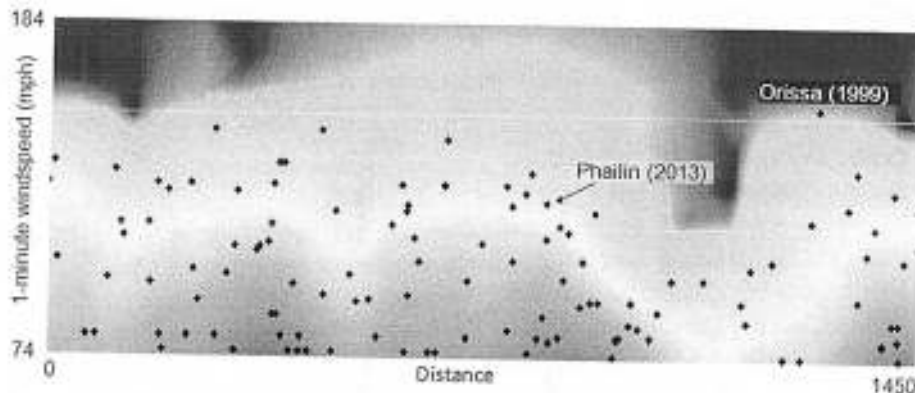
Fig.7 Sample output of stochastic event set of location of genesis. Shading indicates annual exceedance frequency where red is highest and dark blue is lowest

31. Climate Change Impact on Cyclone Hazard

Till date, very few models have simulated tropical cyclones in context with climate change other than those simulating temperature and precipitation changes and sea level rise. This is because the time scale and resolutions required - not only to capture and understand the characteristics of tropical cyclones by itself are not easily available/ identifiable. In the present assignment, analysis will be based on published research results to assess the implications of climate change on cyclone severity.

The future projections based on theory and high-resolution dynamical models consistently indicate that greenhouse warming will cause the globally averaged intensity of tropical cyclones to shift towards stronger storms, with intensity increases of 2-11% by 2100 (Knutson et al. 2010). In order to study the effects of climate change, the pressure drop will be increased by 7% (an average value) and by 11% (extreme value) over the stochastic events. RMSI has already used these processes in several recent projects across the Indian sub-continent to factor in climate change projections for mid and late 21st Century.

32. Hazard module: Cyclonic Wind, Storm Surge and Flood Hazard Modelling

It is noteworthy that three out of four models to be used in the Hazard module have already been developed, calibrated and validated as part of NCRMP Phase 1 by RMSI team. These are the Wind model, Surge model, and the HEC RAS model for flood inundation as shown by the highlighted boxes above. The only model that needs to be developed in this project is the HEC HMH for modelling the flows. This is because the stochastic events for flood will be based on rainfall. Therefore, significant time and money savings are expected in reusing these with minor efforts as required.

Continuing from our discussion in the previous section, once the parameters of each event in the stochastic set are defined, this module will analyse the intensity at a location given that an event in the stochastic set has occurred. In the case of cyclones, the hazard is quantified in terms of wind speed expressed as Peak Gust. This module will model the attenuation/degradation of the event from its location to the site under consideration and evaluate the effects of local site conditions to amplify or de-amplify the impact. In the case of flood, the hazard module will quantify the hazard in terms of flood flows/ extreme precipitation for flood risk modelling.

All the stochastic cyclonic event sets will be grouped according to their frequency and severity, i.e., Depressions, Deep depressions, Cyclone Storms, Severe Cyclonic Storms, Very Severe Cyclonic Storms, Extreme Severe Cyclonic Storms and Super Cyclonic Storms. The probabilistic worst-case scenarios of cyclonic wind speed, associated inland inundation due to surge, and cyclonic rainfall induced flooding will be prepared using three different models (developed during NCRMP Phase-1 as shown by the highlighted boxes above) and the HEC HMS model. Details of these model are appended in Annexes.

33. Cyclonic Wind Hazard Modelling

Since this model was already developed as part of NCRMP Phase 1, the methodology used there is highlighted here in brief.

Surface winds associated with a tropical cyclone were derived using a dynamic storm model (Jelesnianski and Taylor, 1973). Meteorological inputs used for this model include positions of the cyclone, pressure drop, and radii of maximum winds at any fixed interval of times. The model was used for the computation of maximum wind at each grid point of the analysis area and retained these wind speeds for input to the surge model. The wind model was then calibrated and validated using available observed data related to important historical cyclones.

Further, the validated wind hazard model was used for the computation of wind speeds associated with historical cyclonic events that made landfall in and around the coast during 1877-2014. The Gumbel's[7] extreme value probability distribution was applied to the modelled wind speeds at each grid point of the model domain and wind speeds for key return periods (2, 5, 10, 25, 50, and 100 years) were estimated. The key output of the wind model is a wind speed that provides peak gust at every grid point covering the area of impact. This output of the cyclone hazard analysis has been used to develop wind hazard maps at village level.

34. Storm Surge Hazard Modelling

This model is also up for significant reuse and was already developed as part of NCRMP Phase 1. The methodology used there is highlighted here in brief.

Storm surge hazard modelling was performed using the ADCIRC-2DDI hydrodynamic finite-element model[8]. A finite-element mesh for the study area was constructed using the software package Surface Modelling System (SMS) (Westerink et al. 1994)[9]. The maximum surge height computed with the model was calibrated and validated against observed surge heights. The validated storm surge model was then applied for historical cyclone events that made landfall and the associated surge amplitude, velocity, and surge flood depths were computed accordingly.

The Gumbel's extreme value probability distribution was applied to the modelled surge flood depths at each grid point and flood depths for key return periods (2, 5, 10, 25, 50, and 100 years) were calculated. Finally, scenarios of storm surge flooding were prepared for all the return period events. These scenarios were then used to delineate the flood-prone extent along the coast. The framework shows a complete step-wise methodology followed for storm surge hazard assessment during NCRMP Phase 1 project.

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[7] Gumbel, EJ (1954) Statistics of extremes. Nat. Bureau of Stand. App. Math. Series. 33, Washington D.C.
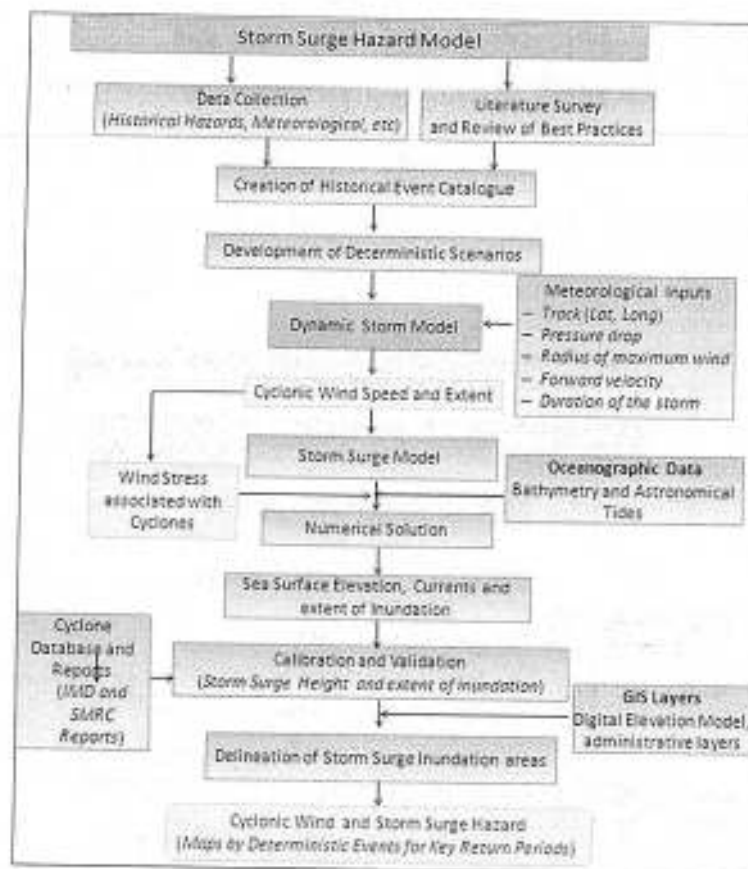
Fig.8 Framework of storm surge modelling (NCRMP Phase-1)
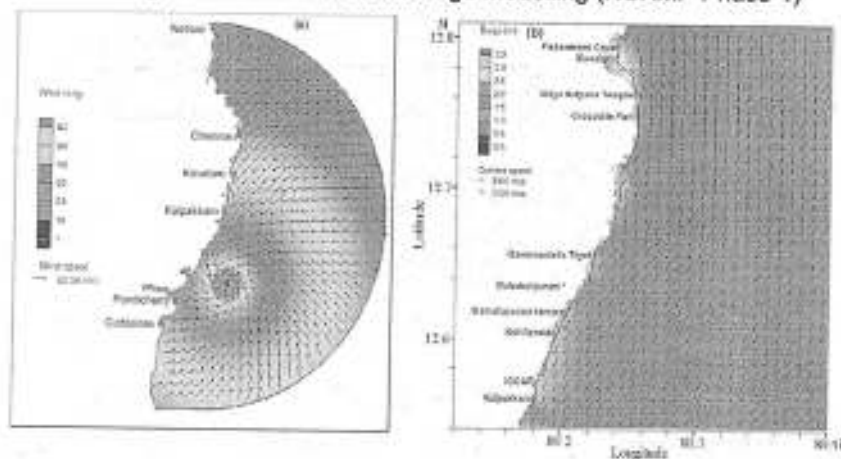
Fig.9 Sample of computed wind field

35. Cyclone Induced Rainfall Flood Modelling

The flood module, based on the historical datasets has been already generated by RMSI during NCRMP- Phase 1, and will be reused to the benefit of Phase 2 implementation. For the flood inundation and flood depths at coastal cities and areas, the methodological framework based on the integration of hydrological and hydrodynamic models, namely HEC-RAS and HEC-HMS, is used. Out of these HEC-RAS has been already formulated by RMSI during NCRMP- Phase 1.

For Phase 2 implementation, only the HEC-HMS model will have to be created for all the basins. The stochastic cyclonic rainfall events will be used to generate probabilistic flood depth maps. The stochastic rainfall event will be input to the HEC-HMS model that will generate the flows associated to that rainfall event. These flows will be input to the HEC-RAS model to generate the inundation and depth maps. The updated stochastic flood inundation and flood depth maps generated based on the stochastic events will be the part of updated Web-CRA.

The details on the HEC-HMS model development has been explained in the digital flood forecasting module in the following sections.

36. Calibration and Validation of Cyclone, Storm Surge and Flood Models

In NCRMP Phase-II project, stochastic event sets of cyclones and rainfall events will be generated as a part of storm surge and flood modelling. However, for stochastic events set, the models will require further calibration and validation for preparing the worst case cyclone wind speed and storm surge flooding vulnerability maps. The criterion that will be used for calibration and validation of hazard models is described below:

The calibration and validation process is intended to ensure that the model parameters are well set to reflect the physical nature of each cyclone. A good fit indicates a robust simulation, which can be used with reasonable confidence. A poor fit, on the other hand, indicates low confidence. Model calibration consists of changing values of model input parameters in an attempt to match field conditions within some acceptable criteria.

Validation runs will be made with the selected "best fit" parameters without further parameter changes. The validation process uses events that were not included in the calibration to evaluate the reliability of the model for other historical events. Therefore, an independent sample of events will be used to validate the cyclone model in terms of pressure drop, which plays a fundamental role over the wind speed for the episode, and surge height and associated extent of inundation in the coastal areas, an important factor owing to the high flow velocities. The performance of the model parameters (wind speed, surge height, and flood depth) simulations will be checked by means of relative error against observed values, expressed as percentage (%ERR):

$$\%ERR = \frac{(Vs - Vo)}{Vo} * 100$$

Where Vo and Vs are the observed and simulated parameters (e.g. surge height, wind speed and flood depth). Therefore, %ERR > 0 and %ERR < 0 indicates an over- and underestimation by the model, respectively.

37. Exposure Module

Exposure describes the absolute amount of assets (building, infrastructure, agriculture and population) and economic activity that may experience harm due to the effects of natural events. The Exposure module computes inventory of assets at model resolution.

As suggested in above, this module is also up for significant reuse as this data has already been developed as part of NCRMP Phase 1 and will only require updating rather than building from scratch and going through all the earlier steps once again. The process of exposure data updating has already been discussed in Section 0 above.

38. Vulnerability Module

Based on our interactions with key stakeholders during the Inception meeting we will reach out to them for enhancing vulnerability datasets. Based on the exposure data enhancements made and incorporated in Phase 2, the Consultant team will review the vulnerability model implemented as part of Phase 1. Following para provides a summary of the approach used for development of vulnerability functions in Phase 1.

Development of physical and social vulnerability functions for all the 13 States/UTs were mainly, but not solely, based on damage data from historical events. An analytical approach complemented by engineering analyses along with expert judgment based on national/international experience helped in developing vulnerability functions with sound reasoning and these two approaches also filled the gaps in the available damage data for various historical events. This methodology for developing the vulnerability functions uses the three different approaches i.e., damage statistics of the past events, analytical/synthetic and or engineering studies and the international experience. The following tasks constitute the methodology:
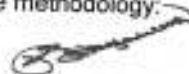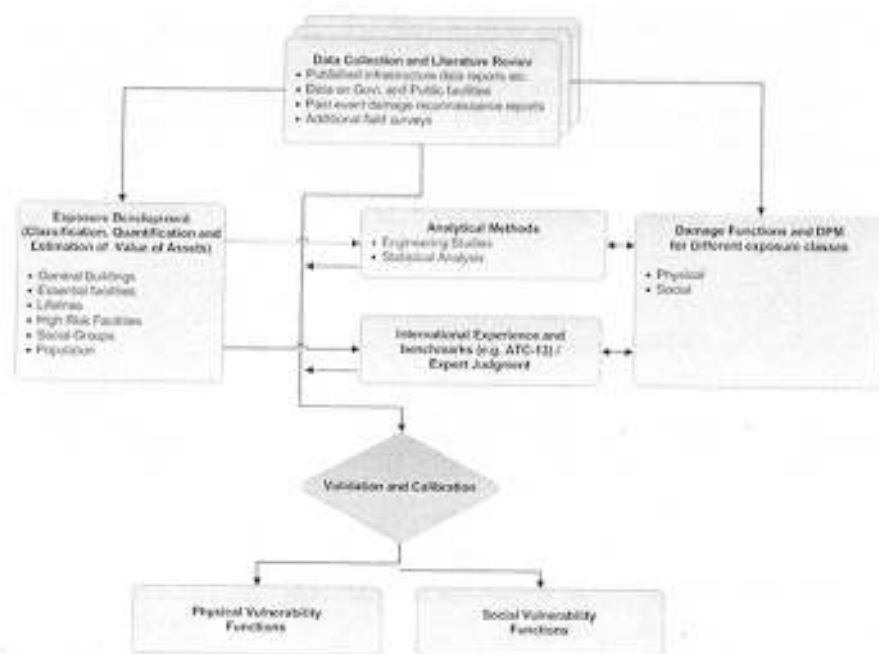
Fig.10 Vulnerability Functions Development Methodology

39. Probabilistic Risk Assessment Products

Probabilistic Risk Assessment products will be derived from the outputs of the hazard and vulnerability assessment models. While hazard model provides the intensity of the hazard at various locations for all the events in the Stochastic event set, the vulnerability analysis provides an understanding of the impact of the hazard intensity at a location on the exposure elements present there. The exposure elements could be population, buildings, essential facilities, and coastal & marine infrastructure. *As part of post-processing, return periods associated to all the events in the stochastic set will be aligned with the hazard intensity value by location. This will help specify a return period of hazard intensity at a location, e.g., at a particular coastal village a 2-meter surge has a once in 100-year chance of occurrence.*

Following probabilistic risk assessment products will be provided:

* Probabilistic wind, surge and cyclone induced flood maps by return period
* Probabilistic wind, surge and cyclone induced flood maps by hazard value. For example, hazard map of 2-meter surge with a once in 100-year chance of occurrence.
* Wind, surge and cyclone induced flood maps of worst-case scenarios for each State/UT

- **Loss Exceedance Curve (LEC):** LEC shows the probability that a loss will exceed a certain amount in a year. It is displayed as a curve, to illustrate the probability of exceeding a range of losses, with the losses (often in millions) running along the X-axis, and the exceedance probability running along the Y-axis shows a sample EP curve.
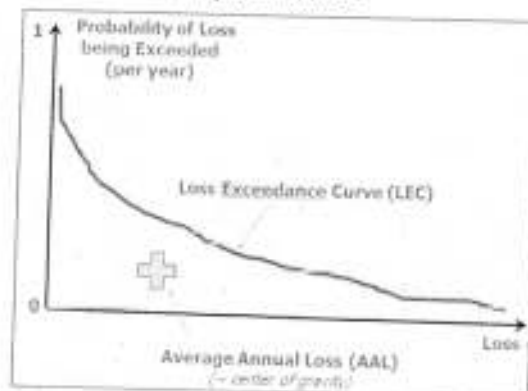
Loss Exceedance Curve and Average Annual Loss

- LEC curves will be provided by:
    - Exposure Type (Residential, Commercial, Industrial, Essential Facilities, Coastal Infrastructure, Marine Infrastructure, etc.)
    - State/District
    - Combination of the above, i.e. By State by Exposure Type
- **Return Period Loss:** Return periods provide another way to express exceedance probability. Rather than describing the probability of exceeding a given amount in a single year, return periods describe how many years might pass between times when such an amount might be exceeded. For example, a .4% probability of exceeding a loss amount in a year corresponds to a probability of exceeding that loss once every 250 years, or "a 250-year return period loss."
- **Loss by Hazard Intensity:** As mentioned in case of return period hazard maps, we will also provide the view of the loss in relation to hazard intensity. *For example, loss due to a 1 or 2 or 3-meter surge in a coastal area.*
- **Annual Average Loss (AAL):** AAL is the average loss of all modelled events, weighted by their probability of annual occurrence. In an LEC curve, AAL corresponds to the area underneath the curve (**Error! Reference source not found.**), or the average expected losses that do not exceed the norm. *It provides a useful, normalized metric for comparing the risks due to Wind, Surge and Cyclone Induced Flood.* AAL will be provided as Maps as well as Tables by
    - Exposure Type (Residential, Commercial, Industrial, Essential Facilities, Coastal Infrastructure, Marine Infrastructure, etc.)
    - State/District
    - Combination of the above, i.e. By State by Exposure Type
- **Coefficient of Variation (CV):** The CV measures the size, or degree of variation, of each set of damage outcomes estimated in the vulnerability module. This is

important because damage estimates with high variation, and therefore a high CV, will be more volatile than an estimate with a low CV. Mathematically, the CV is the ratio of the standard deviation of the losses (or the "breadth" of variation in a set of possible damage outcomes) over the mean (or average) of the possible losses.

All the above products will be provided as maps and tables by:
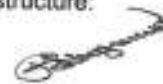
- Exposure Type (Residential, Commercial, Industrial, Essential Facilities, Coastal Infrastructure, Marine Infrastructure, Population, Agriculture, etc.)
- State/District
- Combination of the above, i.e. By State by Exposure Type
- These key probabilistic risk assessment products will be made accessible through the Web-CRA as:

  - **Reports** – Summary reports by country, state or district. Summary reports by exposure type as country/state/district level. These reports will include charts, maps and tables of LEC, AAL, Return Period Losses and Losses by hazard intensity.
  - **Pre-complied maps** – The Risk Atlas within the Web-CRA will be extended to show pre-compiled probabilistic hazard and loss maps.
  - **Query** – A query capability to be added to Web-CRA where a user can specify the exposure, location of interest and type of result to generate a dynamic tabular view of the risk.
  - **Probabilistic Risk Analyser** – The Web-CRA Risk Analyser will be enhanced to run probabilistic analysis. This will provide mitigation planners with options to estimate the benefits of mitigation options being planned. *Through this approach, the users will be able to compare the benefits from multiple mitigation options and then implement the ones that give the best cost benefit ratio.*

The various probabilistic risk assessment products discussed above will help States/UTs disaster managers not only in mitigation planning, but also in preparedness phases through the years. These products would also help disaster managers in identifying the various exposure elements at risk and prioritizing various risk mitigation options based on the principle of benefit-cost analysis (BCA).

40. Real time cyclone impact forecasting

Consultant proposes to use the ADCIRC model for the real time forecasting of cyclone events as its robustness in storm surge modelling has already been proven in the NCRMP Phase -1 project. This is another area where reuse is likely to play an important role in executing NCRMP Phase 2 since the team proposes using the ADCIRC model for forecasting of surge inundation during the execution of this phase also.

Following are the ADCIRC capabilities, which are vital in forecasting of wind, storm surge, and coastal flooding is vital to protecting lives and coastal infrastructure:

ADCIRC model applications include modelling tides, storm surges and their associated inland inundation. It has additional capability of wetting and drying algorithm to study inland penetration of water from storm surge. FEMA (Federal Emergency Management Agency) in 2002 accepted the robustness of ADCIRC. A real time storm surge warning system should have following potentialities:

- A high-resolution, physics based circulation model with flooding and drying capabilities.
- A high resolution water depth (bathymetry) and land (topography) elevation data cot
- Accurate (time and space) wind and pressure fields to drive the model.
- High resolution (variable grid resolution) mesh
- Advanced Decision Support System

The next section describes the operating procedures of the model coupled to the Web-DCRA, which will provide responders an end-to-end solution to take appropriate mitigation measures to minimize the severe consequences of extreme cyclone events.

41. Cyclonic Wind and Storm Forecasting for Real Time Extreme Event

Storm surge model (ADCIRC) coupled with a dynamic storm model, will be imbedded within the web-DCRA and will be run on a Server in an automated mode for the computation of wind, and surge flood extents and depths along the coast. The Phase 1 Vulnerability and Risk models will help identify the exposure and quantify the losses associated with extreme cyclone events. The model set-up steps are as follows:

Initially, surface winds associated with real time tropical cyclone will be derived using a dynamic storm model (Jelesnianski and Taylor) along with setting up Web-DCRA for executing the appropriate window (forecast domain) based on initial and likely final positions of cyclone tracks using a buffer of 100 km around it.

The Web-DCRA will next automatically take model input parameters from IMD bulletins (characteristics of tropical cyclone) for computing the wind distribution. These inputs will include:

1. Cyclone positions (latitude and longitude),
2. Pressure drop (HPA) and
3. Radius of maximum winds (meters) at any time interval (preferably six hourly observations), probable landfall location

These input data are provided by IMD from INSAT imageries, cyclone detecting radars, and surface synoptic analysis. The duration of the forecast will be performed for 48-72 hours as per IMD bulletins.

The final step will be to run the storm model and the surge model. Storm model will compute the required surface wind stress associated with the tropical cyclone in the model domain for each time step. This goes as input to the Surge model. The output of the surge model will be sea-surface elevations, depth averaged current fields and peak surge envelope. A proposed framework of a real-time forecasting system for storm surge hazard and risk assessment is provided in the figure below.

The cyclone features described above will then be displayed through an appropriate user interface where the user may select any part of the coastal region to get more detailed expected results/features, if needed.

The web-WEB-DCRA will be designed in such a way that the whole process of running the model for a 48-hour forecast will take less than 120 minutes.

One of the significant features of this web-DCRA will be its ability to investigate multiple forecast scenarios to be made in real time. For example, as the cyclonic storm moves nearer to the coast and India Meteorological Department's forecast of landfall become more accurate, the track of the cyclone will be updated at regular time intervals.

Following will be the model outputs displayed on the screen:
- Surge wave height and direction
- Probable maximum surge envelope
- Current speed and direction
- Wind speed and direction
- Surge inundation extent and water depth
- Assets/exposure at risk
- Suggested action/advice
- Detailed event report with maps

The overlay analysis will identify the exposure elements at risk. The vulnerability and risk mapping modules imbedded in the Web-DCRA will identify and quantify the losses in monetary terms due to all the three hazards.

Validation of Web-DCRA: In order to validate the models during real-time events, data from the field or other national/global sources will be collected and the model will be run again with updated information to redisplay the hazard maps and associated exposed assets and loss estimates. An attempt will also be made to compare the simulated sea surface elevations with observations from local tide gauges where ever possible or with post storm survey.

Web-DCRA will estimate, in this sequence of order, the losses due to cyclonic wind, storm surge flood, and cyclonic rainfall induced flooding from the event. These individual losses will then be combined to obtain the composite loss from cyclonic wind, storm surge flood, and cyclonic rainfall induced flood. Losses aggregated at administration level (village/city/tehsil/ district/ state) will also be displayed.

Storm Surge Warning System

```
IMD Announces                Obtain the forecasted                Position of
formation of Low      →      track of the system       →       Cyclone, Gusting
Pressure System              through IMD Bulletins                  speed, etc.
                                                                          ↓
Bathymetry,                                                     Generate Cyclone
Topography, Pressure   →     Force the          ←             Best Track and wind
field and Tide               model (ADCIRC)                        forcing
```

Model Output

```
Surge Height       Coastal          Wind Speed         Inundation
                   Currents        and Direction      Extent & Depth
```

Estimation of the impact over the region

```
Wind, Surge and                    Impact on Population
Inundation maps
                                   Impact on buildings

                                   Impact on essential facilities

Threat status                      Impact on transportation systems

                                   Impact on utilities

                                   Impact on agriculture and livestock
```

Proposed framework of real-time forecasting system

42. Real-time Flood Forecasting

There are many ways in which recently observed storm flood flows and extreme rainfall data can be used for updating forecasts and various updating procedures are available. They differ in detail or in their mode of operation, but essentially, they provide the hydrological simulation model with feedback information from the most recently observed flows to estimate errors and thereby improve the accuracy of forecasts. The updating procedures can either be continuous, that is, they can be applied at each time step, or periodic, which will involve periodic recalibration of the model. A dynamic web-enabled flood forecasting module is proposed that is

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calibrated validated against historical events and tested on the stochastic events sets for the preparation of probabilistic risk maps.
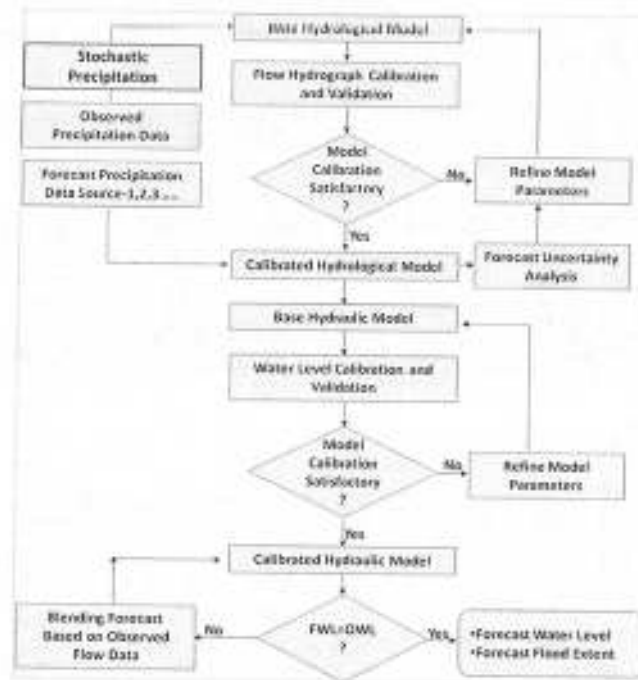
Flood forecasting model/components of HEC-RTS

43. HEC-RTS Framework

While the HEC RTS model is a new addition in NCRMP Phase 2, Consultant is already using it across river basins in India and therefore has sufficient prior expertise in setting it up for Phase 2 requirements.

HEC-RTS is an all-inclusive system that picks up precipitation data, simulates a rainfall-runoff model, runs a hydraulic model and makes available inundation maps, stage and plots. Once the models have been calibrated and validated to reflect current hydro-meteorological conditions, they can be executed to produce forecasts of flood characteristics. That will assist the concerned agencies to evaluate the effects of their operating decisions in the near future. Reservoirs, bridges and other data from the field will be incorporated in the model to make it robust. The ability of HEC-RTS is to forecast floods with a sufficient lead-time for early flood warning dissemination and to take timely protection measures. This will also help in effectively undertaking flood mitigation measures and minimizing damage during floods in coastal cities. It will specifically address flood risk management and loss-of-life concerns in the coastal cities.

The integrated hydrological-hydrodynamic modelling framework HEC-RTS will be capable of providing probabilistic flood details using stochastically generated cyclonic rainfall as well as flood forecasting.

The flowchart of the flood forecasting model has been shown above. The flood forecasting model can be viewed as having following major components:

1. The HEC-RTS framework incorporates hydrological modelling using HEC-HMS and hydrodynamic flood modelling using HEC-RAS. The HEC-RTS model for this project will use the same HEC-RAS based basin models that were developed as part of NCRMP Phase 1. The HEC-HMS models will be created for all the basins involved in the study.
2. Both the key components of HEC-RTS framework, HEC-HMS and HEC-RAS, can run independently. However, in HEC-RTS they are combined to provide a comprehensive watershed forecast that includes river stages and flooding extents.
3. Probabilistic Flood Modelling

    • The above HEC-RTS framework will be used for the generation of stochastic flood flows using stochastic rainfall events, integration of pluvial floods, and generation of probabilistic flood depth maps and inundation maps.
    • The stochastic flows generated from HEC-HMS will be taken as input into the HEC-RAS module to generate the various probabilistic scenarios of floods.
    • Various components of HEC-RTS contain, to some extent, some uncertainty in their outputs. Therefore, an uncertainty analysis of stochastic rainfall will be done prior to probabilistic analysis of flood.
    • For model calibration and validation flood flows, extents and depths of historical floods would be used. Global mapping agencies, such as the Dartmouth Flood Observatory (DFO), and government agencies record the behaviour of historical flood events and provide footprints of recent floods. IMD has historical storm event datasets. All these will be utilized for the validation of the flood inundation maps.

4. The same framework will also be used real time flood forecasting from the cyclonic rainfall from a live cyclone. For this analysis, the rainfall forecasts associated to the live cyclone from various sources will be used as input.

Pluvial/Flash flooding, as a result of extreme rainfall event due to their storm characteristics, accumulate large amounts of water over the ground before it enters a natural or man-made drainage system. Pluvial flooding is associated with short duration with high intensity rainfall. It includes different dynamic processes such as flow paths and ponding, steepness, barriers to flow, wetness, permeability and antecedent soil conditions. For Pluvial flooding the road network and canal network will be used as water channels. *Pluvial/Flash flooding will be incorporated in the present framework and will be used for both probabilistic flood modelling as well as flood forecasting in cities.*

44. Data inputs for Flood Forecasting

For the real time flood forecasting, the forecasted precipitation data, available from different sources (IMD WRF, IMD GFS, Global GFS), will be used, and the real time observed rainfall data from IMD, JAXA, and TRMM will be used.

The forecasted and real time observed data availability is specified in the tables below:

Table 1: Real time rainfall data

REALTIME RAINFALL			
Source	Resolution	File type	Interval
TRMM	0.25deg X 0.25 deg.	.tif	3hr
JAXA	0.1deg X 0.1deg.	.tif	1hr
JAXA	0.1deg X 0.1deg.	.tif	24hr
IMD	Station Data (Point Rainfall)	Excel	24hr

Table 2: Forecasted rainfall data

FORECASTED RAINFALL				
Source	Resolution	File type	Interval	Forecast period
IMD-WRF	9km X 9km	.dat	6hr/24hr	3-days
IMD-GFS	0.25deg X 0.25 deg.	.dat	24hr	7-days
Global-GFS	0.25deg X 0.25 deg.	.tif	3hr	7-days

The user would be able to forecast floods in every 3-5 hours for every rainfall forecast input to the model. The model would take about an hour to forecast the extents and depth.

45. HEC-RTS Modelling Framework for Real Time Flood Maps Generation

The dynamic maps generation and flood inundation will be created at smaller scale (e.g. focus will be on exposure area) for all coastal cities. The flood discharge will be generated in HEC-HMS module utilizing real time physical and meteorological data inputs. The main dynamic real time/forecasted meteorological variable, namely rainfall, will be input to the model to generate real time/forecasted flood flows. The real time/forecasted flood flows will be the main input to the HEC-RAS module to generate flood depths and inundation maps, which will be able to illustrate the effect of cyclonic extreme rainfall events. Pluvial flooding will be incorporated in the present framework by incorporating extreme rainfall events that occur with real time and forecasted precipitation data. The inundation from the pluvial impact will be assessed and then incorporated with the riverine floods. The HEC-HMS module of HEC-RTS will be updated based on pluvial and riverine floods.

Calibration and validation of a flood forecasting model requires flood extent and/or depth measurements (spatial distribution) for particular events based on the real time observed and real time flood forecasting. The real time high flood marks will be used to calibrate and validate the hydraulic model for the flood event. The real time and forecasted scenarios of flash floods and flood depth maps would be a great asset for the user prior to estimating the severity of future cyclonic events. The RAS Mapper tool in HEC-RAS enables the modeller to visualize the flood inundation areas. Computed model results can be displayed dynamically on the fly. A sample of RAS output flood map for Rapti river has been shown below:
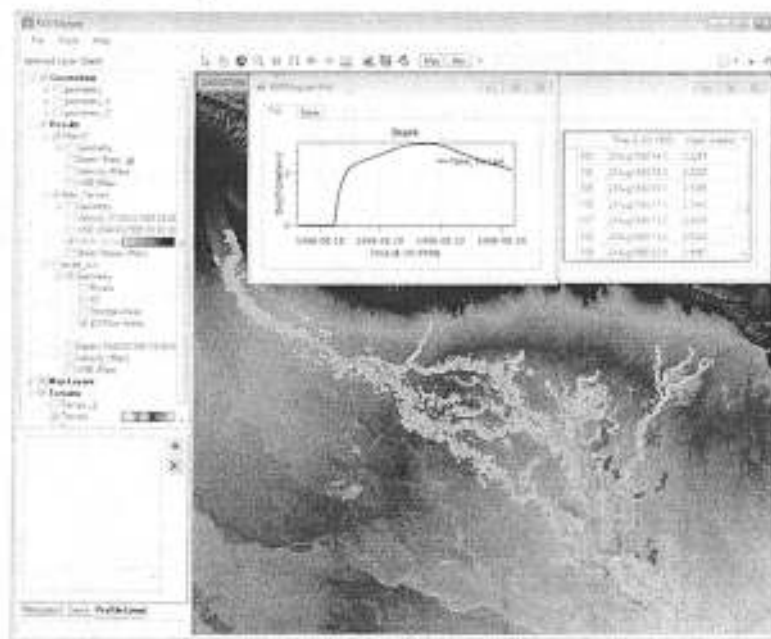
A sample of RAS output flood map.

46. Real Time Cyclone Hazard and Risk Model Automation and Impact Forecasting

As per our understanding of the requirements, the proposed WEB-CRA will be an enhanced version of the present WEB-CRA, which was developed as part of NCRMP phase – I project. The proposed enhanced WEB-CRA functionalities can be divided under three main heads:

1. Enhance Web-CRA
2. Offline Web-CRA (Desktop version)
3. WEB-DCRA App - Android based mobile phone application

47. Enhanced Web-CRA

The below mentioned enhancements will be done in the existing WEB-CRA:

- The proposed enhanced Web-CRA should be able to perform probabilistic risk analysis for cyclone risk and storm surge flooding / coastal flooding and should be able to generate vulnerability maps for the coastal line of India. This will not be a real time product. but ex (not a real-time product)
- Integrate a Dynamic Cyclone Risk Assessment capability (WEB-DCRA) to Web-CRA.
- The Web-CRA should be enhanced further into an open source web GIS based decision support system (DSS) for Natural Disaster Management for coastal states of India. The key features of the DSS are as given below.
  - Providing vital information of exposure at risk on real time basis for an impounding cyclone at the State/District and Local-level Support response and recovery operations.
  - A decision support system for planning and to catalyse the process of preparedness, response and mitigation.
  - Early warning dissemination through e-mail and SMS (mobile based application)
  - Emergency communication for timely relief and response measures.
  - Building Knowledge base to facilitate planning and policy making.

48. WEB-CRA- Probabilistic Risk Assessment

The existing WEB-CRA can perform deterministic risk assessment. This functionality will be enhanced to perform probabilistic risk assessment. The system will utilize the stochastic events sets generated as part of modelling enhancement done in this phase to perform probabilistic risk assessment.

Enhancement on Risk Analyser Module to Perform Probabilistic Risk Assessment

This option will allow user to perform probabilistic risk analysis on base and the user defined data. Users can also view the status of the various analysis job submitted. The three hazards listed for Risk Analysis are:

- Cyclone
- Flood
- Surge

To perform the Probabilistic Risk Analysis user has to select Probabilistic Risk Analysis option from the drop down of Model Type on the Risk Analysis Dialog Box. The dialog box below shows the sample user interface for risk analysis menu and risk analysis options:

Risk Analysis ▾	Risk Report ▾
Risk Analysis	
Analysis Status	

Risk Analysis Menu

Risk Analysis window

The sample report generated by the WEB-CRA for probabilistic risk analysis is shown below:

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India Cyclone Hazard & Risk Atlas
National Disaster Management Authority

Risk Assessment Summary Report

Scenario

Analysis Name	TestAnalysis
State	Andhra Pradesh
District	Srikakulam
Tehsil	Kaviti
Village	Kaviti
Analysis Level	Village
Analysis Date	2016-07-11 19:10:00
Structure Type	All (For details see Annexure 1)
Hazard Type	Cyclone
Scenario	Cyclone 100 Year Return Period

Exposure	5.165	100 Year RP Loss	72

Exposure	5.165	100 Year RP Loss	72

Total Exposure and Loss in INR Lakhs

Exposure	5.165	100 Year RP Loss	72

Exposure Map

NOTE
1. Exposure and Loss in INR Lakhs
2. Structure Type: The Building Type in India is divided into different classes based on their material type used in there walls, foundation and there Structural types

Risk Assessment Summary Report - Page No. 1 of 5

Risk Assessment Summary report

49. Dynamic Cyclone Risk Assessment (Web-DCRA) - Decision Support System for Disaster Management

The disaster management activities initiate immediately at the onset of a disaster event such a cyclone and flood in terms of immediate response, slowly transitions into recovery activities which lead to identification of mitigation measures for better preparedness. The emergency response activities can only be successful only through multi-departmental coordination.

This demands for the availability of spatial and non-spatial data of various departments in single platform. Effective emergency information management requires concerted planning, organizing, controlling, and influencing of human, material, and information resources to endure that information is disseminated to the

right decision-makers at the right time to satisfy those needs. The high level design of the proposed WEB-CRA DSS is given the Figure below.
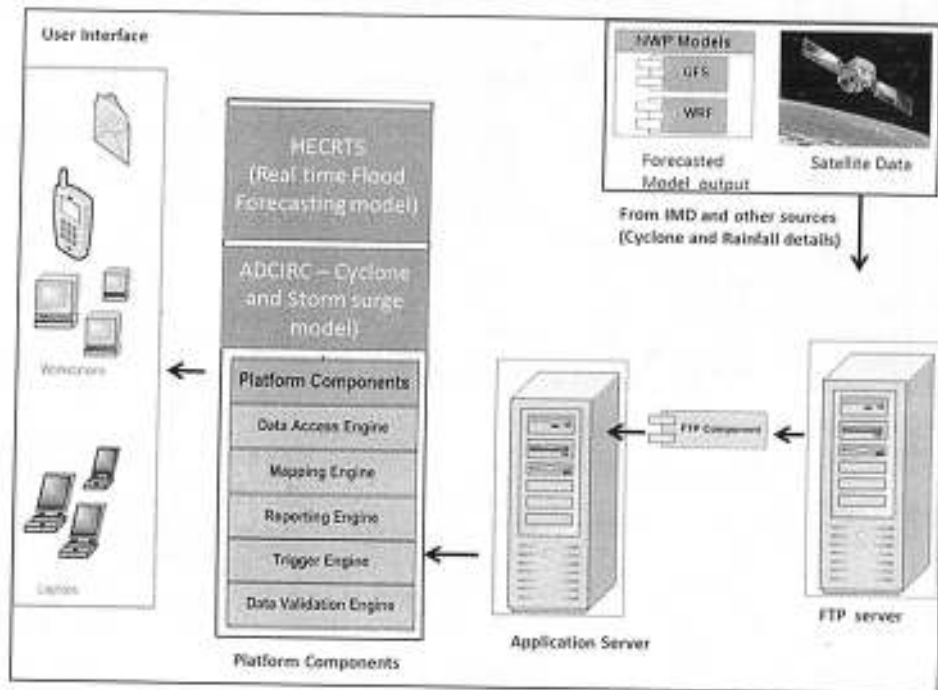
High level design of DSS

The proposed WEB-DCRA will be open source web GIS application that will be based on existing WEB-CRA platform. It will provide information about exposure, hazards and vulnerability from an impending cyclone, to support for planning, coordination, response, guidance and decision making for emergency management personnel.

To perform this analysis on real-time basis, existing WEB-CRA analysis engine will be enhanced so that below mentioned tasks will run on automatic mode:

- Fetching cyclone information from IMD in automatic mode
- Running hazard models viz. – Flood, Cyclone and Storm
- Running vulnerability module
- Running loss module
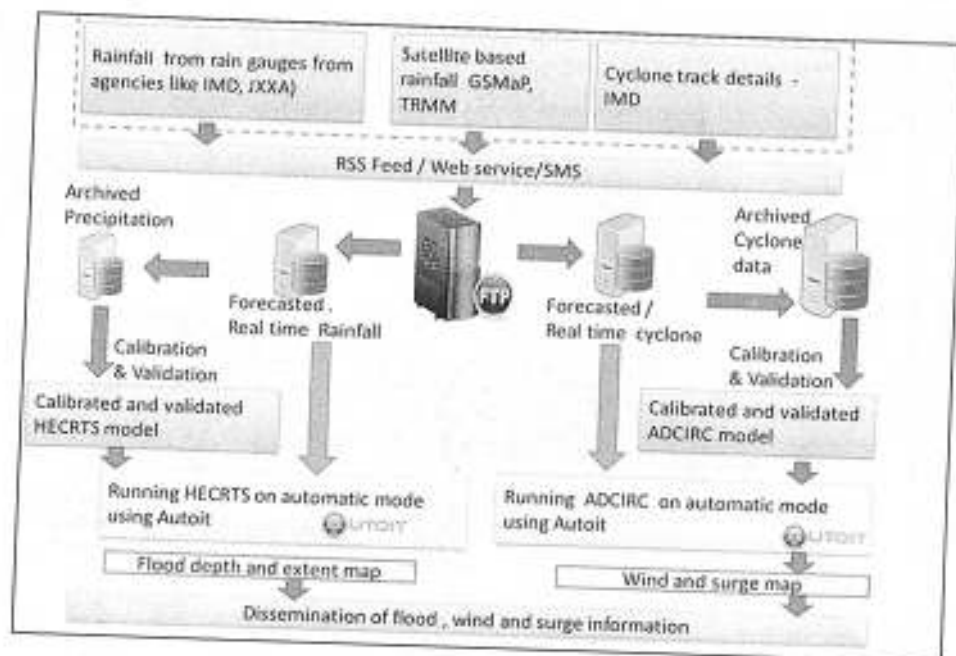
Process flow of WEB-CRA dynamic analysis engine

The following five are the major components will be added in the existing WEB-CRA analysis engine:

1. Real time input data collection: This module will fetch the input data such as cyclone track details and rainfall from the various sources (IMD, JXXA, OpenWeatherMap, Weather Underground etc.) finalized for the model on real time basis through RSS feed, web services and SMS and store that in FTP server located at data centre.

2. Wind and Surge Module – This module will use ADCIRC model to generate wind and storm surge hazard maps using IMD's cyclone track details on real time basis. The AUTOIT software will be customized to run calibrated and validated ADCIRC model to perform cyclone wind and storm surge estimation tasks on real time basis.

3. Flood forecasting module – Flood forecasting module will use HECRTS Model to forecast flood (Convert rainfall to run off and generated flood inundation map) real time basis. The AUTOIT software will be customized to run calibrated and validated HECRTS model to perform flood-forecasting tasks on real time basis.

4. Vulnerability and loss module – This module will generate damage and loss based on hazard information generated by previous two modules and exposure information and vulnerability functions available within the Web-CRA.

5. Dissemination module – This will be developed to perform dissemination of cyclone warning to decision makers and general public through websites, media and mobile SMS.

- Send event situation report to pre-defined individuals via email

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- Web service to extract event related risk details to connect the WEB-DCRA to any other government web-sites
- The system will send SMS and pre-recorded voice alerts to all mobiles in the coastal areas, near airports, train stations, etc.
- The system will send SMS and pre-recorded voice alerts to homes that have potential for impact on what they can do to reduce losses
- Register missing people information
- SMS alert to mobiles in the area regarding missing people
- Reporting of missing identified

The sample user interface of WEB-DCRA Dashboard is shown below. The user can view results on maps, graphs or tables. The system will display the following layers by default as the application is loaded:

- Cyclone track
- River network with basin boundary
- District, state and country boundary map
- Basic GIS tools like zoom, pan, Zoom to selection, zoom to entire layer, location attribute information and calculate distance.
- Observed and forecasted flow levels from various hydrological/hydrodynamic model as table and chart in map
- Wind hazard map
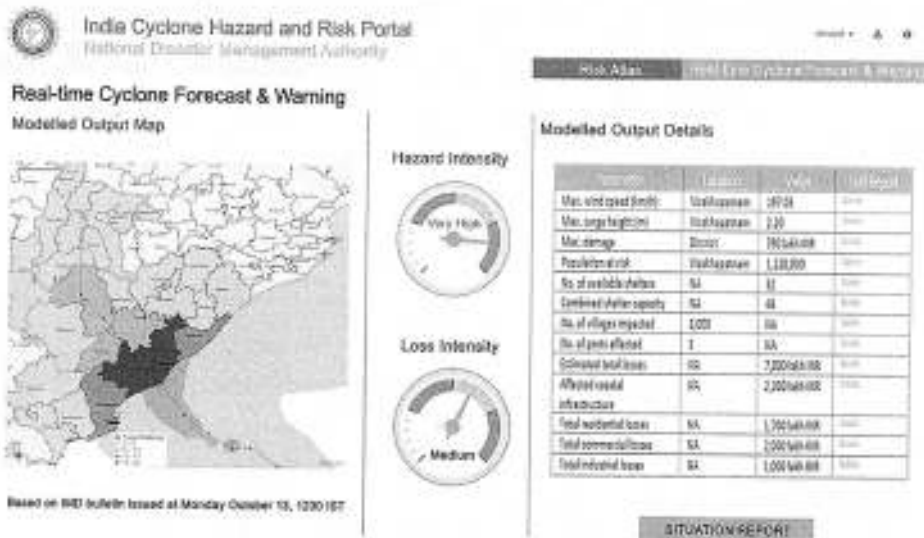
Sample user interface - WEB-CRA DSS

Clicking the Detail hyperlink in the table (to the right in above figure) will allow users to navigate to detailed modelled results at a more granular level of the selected parameter. A sample screen shot is shown in below:

Risk Atlas | Real time Cyclone Forecast & Warning

Real time Cyclone Forecast & Warning

Max. wind speed details summary

District	State	Wind speed (km/h)	Surge height (m)	village-level data
Visakhapatnam	Andhra Pradesh	197.05	2.20	Details
Yanam	Puducherry	81.33	0.15	Details
Gadchiroli	Maharashtra	57.84	0	Details
Bastar	Chattisgarh	87.71	0	Details
Koraput	Odisha	119.06	0	Details

Wind speed village-level details: Visakhapatnam

Village (Census Code)	District	State	WindSpd	Max Spd	Max km/h
541311	Visakhapatnam	Andhra Pradesh	79.60	149.68	149.68
531029	Visakhapatnam	Andhra Pradesh	101.76	161.76	161.76
530040	Visakhapatnam	Andhra Pradesh	103.87	113.95	113.95
531151	Visakhapatnam	Andhra Pradesh	109.99	178.06	178.06
531077	Visakhapatnam	Andhra Pradesh	114.79	158.28	158.28
535145	Visakhapatnam	Andhra Pradesh	118.69	173.42	173.42
531149	Visakhapatnam	Andhra Pradesh	128.22	136.68	136.68
531024	Visakhapatnam	Andhra Pradesh	130.48	173.31	173.31
531086	Visakhapatnam	Andhra Pradesh	131.97	146.73	146.73
531177	Visakhapatnam	Andhra Pradesh	132.44	151.28	151.28
531111	Visakhapatnam	Andhra Pradesh	134.38	173.51	173.51

Details screen of Max wind speed

The application will generate a situation report based on model output. A sample report is given below:

Cyclone Situation Analysis

Summary

District name:	Puducherry
Analysis name:	Analysis_2
Event name:	Cyclone Test
Hazard:	Cyclone
Scenario level:	Village
Demographic source:	Census
Analysis date:	

Cyclone Event Description

Maximum wind speed(kmph): 197.88
Minimum wind speed(kmph): 165.50

Exposure Name	Total	Damaged/Loss/Affected
Paddy(Mts)	374087980	117569190.8
Buildings	189065	112395
Residential Kachsha buildings	63610	48429
Residential Masonary buildings	30690	20283
Residential Concrete buildings	83932	33271
Commercial Masonary buildings	7745	3810
Commercial Concrete buildings	20477	6080
Industrial Masonary buildings	636	384
Industrial Concrete buildings	2218	519

Sample situation analysis report

The information provided by this report will be updated on real time based on information received in the server through WEB-DCRA App (mobile application).

50. Offline Web-CRA (Desktop version)

We propose to develop a smart client based application to update exposure database. The Smart Client Application has a desktop based client that can connect to a database that is on the desktop of somewhere on the LAN. Following are the key capabilities that will be made available through the Smart Client based Offline Web-CRA.

- A user interface that has all the exposure editing capabilities as are available on WebCRA
- A Map based user interface to insert new point type exposure elements (like hospitals, Fire stations bridges, airports, communication facilities, etc.) and polyline type exposure elements (like roads, pipelines, etc.). A tool will be provided in the toolbar for respective editing types. The user can select the tool

and then specify the location on the map using the mouse pointer. Once the location is provided, the application will show a table to insert the attributes.

- A separate interface to insert details of ports as a group of buildings and structures.
- Person with data update privilege to the system will be able to update/modify/delete the exposure database.
- A data approval cycle where the exposure data created or updated by operators is reviewed by predefined reviewers, and approved for update to central server. **Reviewer privilege** will be provided to support this functionality.
- Auto synchronize capability in the database to updated all the approved exposure data changes to the central server whenever internet connectivity becomes available.
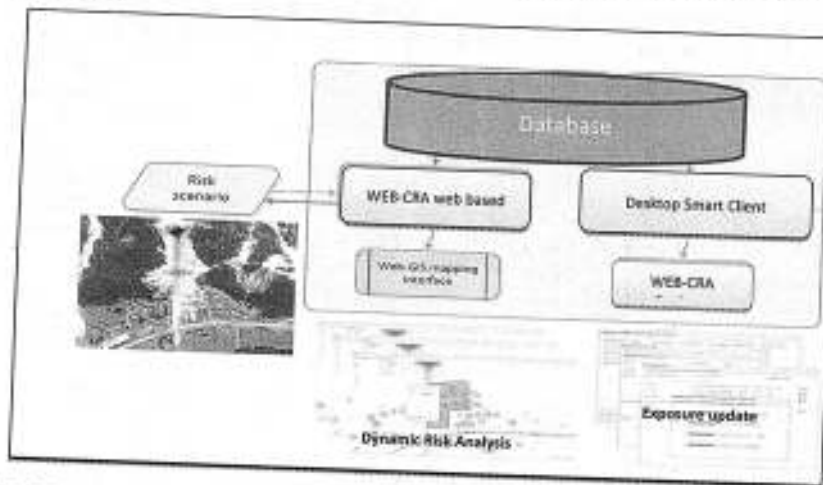
WEB-CRA – Layout of web and desktop application of WEB-CRA
This desktop application will be connected to centralized database server of WEB-CRA over internet. Figure below shows the layout of the proposed solution.
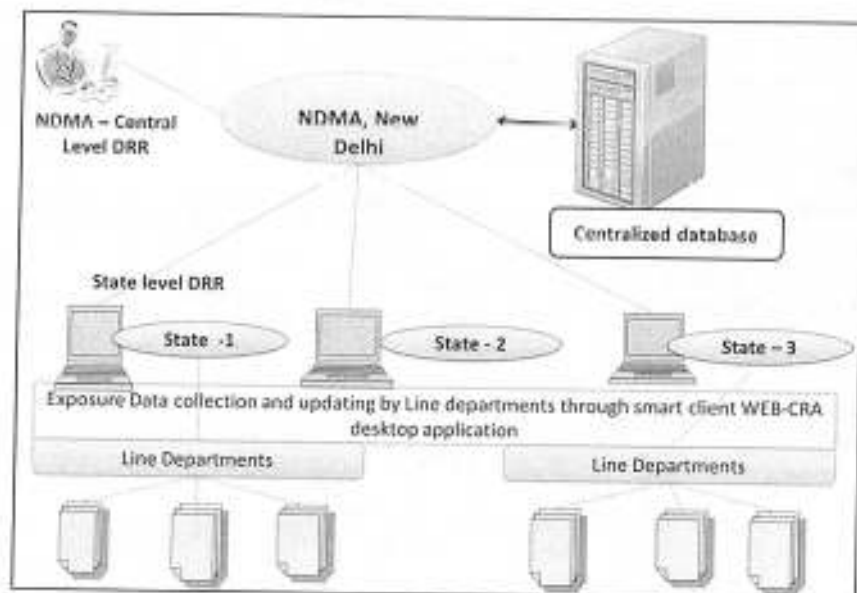
Layout of the proposed WEB-CRA desktop smart client application

51. WEB-DCRA App - Android Based Mobile Phone Application

Consultant proposes a mobile-based WEB-DCRA App application that will provide below mentioned functionalities on smart-phones:

6. Simple registration process to receive alerts in case of an impending disaster event like SMS and pre-recorded voice alerts regarding potential for impact, what they can do to reduce losses, etc.

Figure 1: Sample user interface (Mobile application) for WEB-DCRA App

7. "I AM SAFE" feature: By clicking 'I AM SAFE' button the system will send SMS alert to predefined numbers. This will help the user relatives that the user is safe and a considerable effort will be reduced to search these people.
8. Crowd Sourcing feature to get feedback from people, who wants to submit information related to event such as:

- Status of flooding
- Approximate wind speed, surge height
- Damage description
- Need to be evacuated
- Need Emergency Medical help" etc.

WEB-DCRA APP will also be developed using Open Source Technologies for mobile development. Android SDK will be used as the development platform, and PostGre/PostGIS will be used to store data on mobile device. The Android SDK provides the tools and APIs necessary to begin developing applications on the Android platform using the Java programming language.

Figure belowError! Reference source not found. depicts technical architecture of the Android platform-based mobile application.
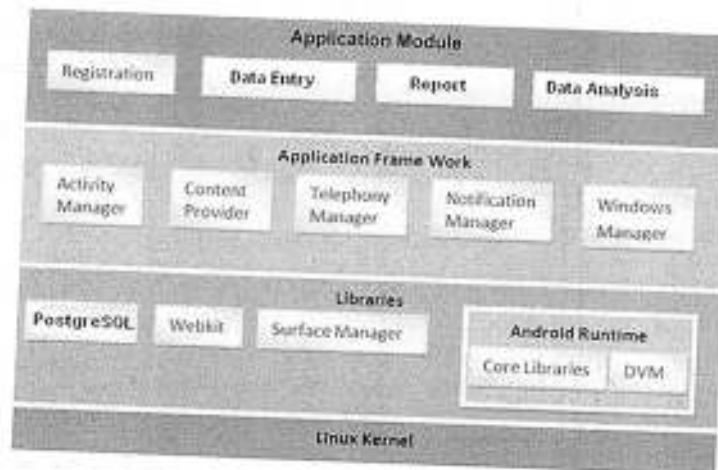
Android Architecture

The Android OS can be referred to as a software stack of different layers, where each layer is a group of several program components. Together it includes operating system, middleware and important applications. Each layer in the architecture provides different services to the layer just above it. Android is a Linux-based operating system for mobile devices such as smart-phones and tablet computers. The Android NDK (Native Development Kit) is a toolset that embeds components which make use of native code in the Android applications. Android applications run in the Dalvik virtual machine. The NDK allows implementing parts of the applications using native-code languages. Hence, Consultant proposes to develop modules (described below) on the top application frame work.

52. Proposed Physical Architecture WEB-CRA
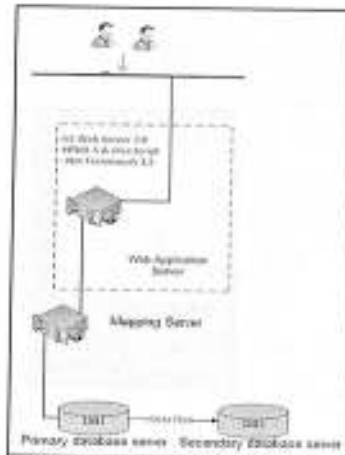
Schema showing physical architecture

Security

53. Integrated Authentication and Authorization

The authentication strategy will be implemented for the security and reliability of the web applications. Since the presentation and business layers are deployed on the same machine, resources will be accessed based on the original caller's Access Control List (ACL) permissions. The services will be secured by authenticating users, taking advantage of the features of the underlying development platform. Secure protocols such as Secure Sockets Layer (SSL) will be used during Basic authentication or when credentials are passed as plain text. Message-level security mechanisms supported by the WS* standards (Web Services Security, Web Services Trust, and Web Services Secure Conversation) will be implemented with SOAP messages.

The authorization strategy will provide the security and reliability to the web applications. Resources will be protected by applying authorization to callers based on their identity, account groups, roles, or other contextual information. For roles, the granularity of roles will be minimized as far as possible to reduce the number of permission combinations required. Role-based authorization will be implemented for business decisions, resource-based authorization for system auditing.

The authentication, authorization, and profile provider web service will provide security services to the web applications with central web based management application to manage users, roles and users in roles.

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54. Audit Trail

The audit trail mechanism will track all changes to the systems underlying data so that an auditor can examine these at any later point in time.

For each database table that requires an audit trail, another table will be created that will have the exact same schema as the parent table with four additional fields:

1. AuditID - a primary key, IDENTITY field
2. Deleted - a bit field that defaults to 0 that indicates if the record has been deleted.
3. Created On - a date time field that defaults to the current date and time.
4. Created By - a field that records who changed the data.

A trigger will be created on the parent table for UPDATE and INSERT that inserts the contents from the inserted table into Audit table.

Similarly, a trigger on parent table will be created for DELETE that inserts the contents from the deleted table into Audit table, putting in a value of 1 into the audit table's Deleted field.

55. Passwords Encryption

For Password Encryption, development framework's inbuilt support for encryption will be utilized. The following encryptions are part of the development framework such as Hashing, and Symmetric and Asymmetric Encryption.

The Hash based encryption will be implemented by adding a salt (unique string) to every password before hashing it. Hash based encryption is optimized for speed.

Database Mirroring: The proposed deployment will consist of database mirroring. Database mirroring maintains two copies of the single application database and will reside on different server instances of PostGRES/PostGIS Server Database Engine.

Out of the two databases, one database server instance will serve the database to clients (the primary server). The other secondary instance will act as a hot or warm standby server (the mirror server), depending on how it is configured as well as the state of the mirroring session. The database mirroring provides a hot standby server that supports quick failover without any loss of data from committed transactions when a database mirroring session is synchronized. When the session is not synchronized, the mirror server is typically available as a warm standby server (with possible data loss). The technology, which will be used to develop the proposed application, is given in Table 3.

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Table 3: Technological details - Open Source Technology

Technology	Description
PostGreSQL (Database Server)	PostgreSQL is a powerful, open source object-relational database system. It has more than 15 years of active development and a proven architecture that has earned it a strong reputation for reliability, data integrity, and correctness. It runs on all major operating systems, including Linux, UNIX (AIX, BSD, HP-UX, SGI IRIX, Mac OS X, Solaris, Tru64), and Windows. It is fully ACID compliant, has full support for foreign keys, joins, views, triggers, and stored procedures (in multiple languages). It includes most of SQL:2008 data types, including INTEGER, NUMERIC, BOOLEAN, CHAR, VARCHAR, DATE, INTERVAL, and TIMESTAMP. It also supports storage of binary large objects, including pictures, sounds, or video. It has native programming interfaces for C/C++, Java, .Net, Perl, Python, Ruby, Tcl, ODBC, among others, and exceptional documentation.
Geoserver	GeoServer is an open source software server written in Java that allows users to share and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards. GeoServer is the reference implementation of the Open Geospatial Consortium (OGC) Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as a high performance certified compliant Web Map Service (WMS). GeoServer forms a core component of the Geospatial Web.
Geowebcache	GeoWebCache is a Java web application used to cache map tiles coming from a variety of sources such as OGC Web Map Service (WMS). It implements various service interfaces (such as WMS-C, WMTS, TMS, Google Maps KML, Virtual Earth) in order to accelerate and optimize map image delivery. It can also recombine tiles to work with regular WMS clients.
Apache Tomcat (Web Server)	Apache Tomcat is an open source software implementation of the Java Servlet and JavaServer Pages technologies. The Java Servlet and JavaServer Pages specifications are developed under the Java Community Process. Apache Tomcat powers numerous large-scale, mission-critical web applications across a diverse range of industries and organizations.

56. Experimental Phase

Before exposing WEB-CRA to target users, a team of key experts nominated by client and Consultant experts will work together to analyse the outcome of the WEB-CRA for about 18 months by considering real cyclone risk assessment and related product development, finalizing the interactive map viewer platform, protocol development for warning etc.

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57. Quality Assurance

System Testing - The objective of system testing exercise is to validate that the software built conforms to functional and non-functional requirements specified Software Requirement Specifications so that it works as expected. Thus software testing ensures the quality of product built.

To ensure that adequate effort is made towards producing quality software, a separate team for system testing comprising of full-time test engineers will be formed. Iterative builds will be released to testing team.

Consultant will carry out the following activities in this step:

Test Case Preparation: The purpose of preparing test cases is to have a documented way of validating specified functionality in a structured and exhaustive manner. Test case preparation will involve the following activities:

- Study of Software Requirement Specifications document
- Documenting test cases detailing the steps to carry out to validate specified functionalities
- Review of test cases to ensure adequate coverage

Test Environment Preparation: The output of this step will be a well-isolated environment suitable for system testing.

Test Case Execution and Defect Tracking: This step involves performing the actual testing of the system and includes performing the following activities: Test site links, execute test cases to test Business logic and functional requirements, Test overall site, Test template with target browsers, and Logging of defects found in a defect tracking tool and assignment of defects to appropriate developer for rectification. The output of this step will be a test report giving details on defects validated and new defects found with their severity and priority.

Non-functional testing: The purpose of this step is to test whether the portal meets the non-functional requirements including response time, throughput and load. It may involve one or more of the following activities: Recording of test scripts, simulating load on system using the test scripts, and Taking measurements of response time. The output of this step will be test report detailing the measurements recorded and identification of potential areas of bottlenecks.

User Acceptance Testing: The purpose of User Acceptance Testing is to establish whether the system developed meets the expectations of the system users or not. This will involve carrying out of following activities: Deployment of system at the operation environment for testing by its users, Execution of user acceptance test cases by the users, and Reporting of defects/issues by users and fixing of the same

by Consultant. The output of this step will be issuance of acceptance certificate by the client.

58. Training and Capacity Building Support

Consultant team understands the importance of training and capacity building support at all levels and hence devise an inclusive training program to ensure knowledge transfer, capacity building and project sustainability. As mentioned, with the help of NDMA, we will be involving disaster managers from all the 13 coastal states/UTs from the inception phase of this assignment. Accordingly, Consultant team will map the key stakeholders, understand their requirements, capacity and accordingly will develop a detailed training and capacity building plan. The training and capacity building plan include content, schedule and plan of actions for implementation and this will be finalized in consultation with NDMA.
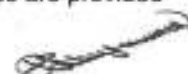
Our proposition for training and capacity building is to involve identified stakeholders from all the 13 States/UTs:

- In key project activities including exposure data updation of Web-CRA and its usage till Beta version of Platform (WEB-DCRA, Updated Web-CRA, Offline Exposure Management and Mobile APP).
- In testing once Beta version of the Platform is ready
- In national and state level trainings and capacity buildings activities.

The training and capacity building activities will be carried out to phased manner and at different levels. This included 2 national level workshops and trainings and 14 State/UT level outreach training and workshop (twice in 7 identified and agreed locations in different States/UTs with the help of NDMA). The stakeholders for these activities will be carefully identified at two levels.

- Senior Officers from each State and UTs who will attend two high level workshops at NDMA in addition to project Inception meeting.
- Middle level officers (who have a basic background on DRR and who will be carrying out the operational activities in the various State/UTs), who will attend two trainings of two days each at NDMA (in the developmental phase of the project in consultation with NDMA) and two trainings during experimental phase through 14 State Outreach Training and capacity Plan. This would provide opportunity to middle level officers to attend at least 4 trainings (2 at NDMA and 2 at State/UT levels as TOT (Training for Trainers), a total of 8 days training and hands on sessions) and participation in the modal outputs verifications through comparison of modelling outputs of live cyclone(s) to field outputs during the experimental phase of project. This approach will also ensure ownership among stakeholders in addition to capacity building and knowledge transfer.

The details of the training and capacity buildings and outreach activities are provided below.

59. National Level Workshops

The objectives of the national level workshops are to familiarize the key stakeholders are NDMA, National Agencies and Senior Level State Officials and key Middle Level State Officials WEB-DCRA, Updated Web-CRA, Offline Exposure Management, and Mobile APP. The idea is to start with these selected audience, make any suggested changes and subsequently take platform to the wider audience.

Consultant propose 2 national workshops of 3 days each for this. While the first day workshop would cater to Senior Level Officials, the next two days training would be focused on ToTs.

Testing beta version of Platform: Once the beta version of the Platform (WEB-DCRA, Updated Web-CRA, Offline Exposure Management and Mobile APP) and their respective Technical User Guides are ready, Consultant in coordination with NDMA will conduct first 3 days National Level Workshop-cum-Training Program to present the functionalities and capabilities of the Platform to Senior Level Officers and Training and hands on sessions to ToTs. The attendees of the 1-day workshop mostly will be policy makers and selected representatives from 13 States/UTs, NDMA, the World Bank, IMD, and any other stakeholders that NDMA would like invite. The team will demonstrate the functionalities and the base data available in the system and its application.

To the attendees of the 2 days TOTs, development of cyclonic disaster scenarios and assessment of vulnerability and risk assessment specific user cases based on some of the low-probability-high-impact events will be demonstrated. As the stakeholders will have on-ground experience dealing with these past events, the specific use case scenarios of these events may be used for bench marking and verifying the capability and authenticity of the system. The team beforehand explains the data layers involved in the analysis and its limitations if any for building the scenarios. The opinion and suggestion of the stakeholder will be documented and will be considered for finalization of the WEB-DCRA (Web and desktop versions) and App.

Demonstration of Platform: The second national workshop will be conducted in coordination with NDMA after we address the suggestions and recommendations of the stakeholders. Now the application will be ready to open to wider audience accommodating the requirement and expectations of client and users. The same stakeholder invited for the first national workshop will be invited for this workshop and present the risk atlas again to ensure that all the comments and suggestions were addressed satisfactorily before opening to wider audience.

Second national level workshop: This national level workshop will be conducted as part of the closure session and demonstrating the fully operational Platform

(WEB-DCRA, Updated Web-CRA, Offline Exposure Management and Mobile APP). A larger audience including senior and middle level officers (participants of first national workshops), policy makers both at state and national level from all 13 States/UTs, other stakeholders like IMD, INCOIS, NRSC, NDMA, the World Bank will be invited. The team will explain the study in details and further present the WEB-DCRA (Web and desktop versions) and App. capabilities. The second and third day of the workshop would focus on hands on to ToTs. For this, we would form smaller groups in which the ToTs will have hands on training sessions including demonstration of the software developed. Consultant team will actively support the groups in exploring and understanding the WEB-DCRA (Web and desktop versions) and App. capabilities.

The agenda for these two training and workshops will be designed carefully in consultation with NDMA. *Key principle for developing the agenda would be to ensure active involvement of stakeholders and provide opportunities to stakeholders to contribute in finalizing the beta version and understand the capabilities in full potential.*

Consultant will take the support of NDMA to identify and invite the stakeholders, required logistics for the participants, venue location and facilities required for the workshop and trainings. Consultant will prepare presentation materials, hand-outs, workbooks, reference sheets etc. that will be provided to the participants during these trainings and workshops. These will not only facilitate the dissemination of the findings of the study but will also keep all the stakeholders informed and be at the same level of understanding regarding the process/methodology as a result of which it would pave the way to develop a road map for Disaster Risk Reduction in all the 13 coastal State/UTs.

60. State Level Training

The objective of state level outreach is to provide comprehensive hands on training to as many the state level stakeholders as possible on use of *WEB-DCRA, Updated Web-CRA, Offline Exposure Management and Mobile APP.*

The state outreach trainings will be carried out twice in experimental phase *(a total of 14 State Outreach trainings covering all the 13 States/UTs)* starting from the demonstration of fully operational *WEB-DCRA, Updated Web-CRA, Offline Exposure Management and Mobile APP.* The dates and schedules of these trainings will be decided in consultation with NDMA and concerned state stakeholders.

The broad outline of the training activities at the state level will follow the same agenda that will be followed in National Level trainings; however, the data discussion and analysis will be more focused to the participating States/UTs. The use case scenarios demonstrated in Technical User Guides will also considered with

reference to that particular state. We propose a 2 day focused interactive Training Program with a total of 14 such Training Programs in different States/UTs. All the states will have separate sessions according to the category they are grouped into. The UTs will be invited to the nearest state for the sessions. However, this tentative plan will be further discussed with NDMA to see the modalities and feasibility of grouping 2 states together for outreach activities. It is logical to consider adjoining states together as it is essential to have coordination between states for any mitigation and adaptation activities particularly for hazard like cyclone which will often have regional impact.

61. Deliverables & Schedule for Completion of Tasks and Services

As per requirement of ToR, Consultant would adhere to the requirements of timelines for various deliverables as shown in the table below.

Table 4: Deliverables and Schedule

S.No.	Deliverables	Duration (from date of signing the contract)
1	Project Inception Report	2 weeks
2	Development of probabilistic risk assessment Maps/products for Cyclonic wind, storm surge and rainfall induced flooding and demonstrate them through interactive map viewer	3 months
3	1. Alpha version of • WEB-DCRA, • Updated Web-CRA, • Offline Exposure Management and • Mobile APP 2. Demonstration and Presentation to key stakeholders, 3. Draft Technical User Guide	5 months
4	Demonstration of Beta version of • WEB-DCRA, • Updated Web-CRA, • Offline Exposure Management and • Mobile APP	7 months
5	1. Fully Operational • WEB-DCRA, • Updated Web-CRA, • Offline Exposure Management and • Mobile APP 2. Closure Report	7 months
6	Experimental Phase	8 – 20 months
7	Training Workshops and Capacity Building activities	8 – 20 months

62. Work Plan

S.No.	Project Tasks	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8 & Month 9
04	Development of Beta version of Web-DCRA, DCRA App, And Offline								
04.1	Update Web DCRA based on Alpha design demo feedback								
04.2	Update DCRA App based on Alpha design demo feedback								
04.3	Demonstration of the Beta Version								
05	Create Report and fully operational Web-DCRA and offline								
05.1	Update the Web DCRA based on User Acceptance Testing								
05.2	updated DCRA App based on User Acceptance Testing								
05.3	Update Offline Desktop value based on User Acceptance Testing								
05.4	Deploy Report and fully operational Web-DCRA and offline Desktop version								
06	Experimental Phase								
07	Training and Workshops								
07.1	Creation of training modules								
07.2	Internal Workshops								
07.3	State Workshops								

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63. Project Planning and Management
Key Features

For the successful implementation of a project, it is important to follow standard project management practices. As a first step, during the project initiation meeting, we will define the project communication protocol between Consultant and PMU-NCRMP by defining single point of contact on both the sides. The key activities under project management are further elaborated below:-

1. **Project Initiation** - The Project Manager will undertake a detailed discussion during the project initiation meeting and finalize core team, and roles and responsibilities, and discuss the project plan with the PMU representatives.
2. **Development of Project Plan** - Consultant Project Manager will develop a project plan defining roles and responsibilities, communication protocol, key milestones, assumptions, constraints, task dependencies & budget; listing the anticipated risks and Consultant risk mitigation plan; project monitoring protocol including the monitoring team; project status reporting; quality objectives and management plan.
3. **Project Monitoring and Control** - The project monitoring procedure will be defined, in close consultation with the PMU-NCRMP, to regularly measure project progress and refurbish the execution plan, if required. The project monitoring team will consist of Consulant Senior Management, Project Manager, and key client representatives. This will aid in identification of problems and taking corrective action in a timely manner.
4. **Project Status Reporting** - Consultant team will undertake regular monthly project status discussions and subsequent reporting. Along with status reporting, the team will also maintain regular communication between Consultant and PMU-NCRMP, and within the project implementation team. The reports and other outputs generated as part of the project will be shared with the key stakeholders for review. While regular correspondence will be through e-mail, other modes of communication like teleconference, video-conference, and site visits will also be undertaken.
5. **Communication Plan**- The project team will follow a defined communication protocol to ensure regular communication with PMU-NCRMP. This will help us ensure prompt issue resolution, feedback attraction, monitoring and evaluation of the project against set targets, and refurbishment of workplan/ methodologies for effective implementation.
6. **Risk Management** - Consultant Project Manager will develop a project-specific strategy for identifying, analyzing and mitigating risks, and also set up an escalation mechanism with the client during project initiation meeting. This will consist of preparation of a list of anticipated risks and their sources; Prioritization and categorization; and Risk Mitigation Plan for major anticipated risks including contingency plans. A spreadsheet will be shared every month with the client highlighting all the risks faced and mitigation measures adopted.

64. Project Meetings

We propose the following meetings as part of our effective project implementation plan.

Name	Purpose	Location / Method
Project Initiation Meeting	• To identify the points of contact; and finalize the project approach, deliverables, work schedule, communication protocol, project team and roles and responsibilities.	• PMU, NCRMP
State training workshops	• To demonstrate the web-DCRA and the app to state stakeholders • To share results of state-level assessment	• States as discussed with PMU, NCRMP
National training workshops	• To share the assessment and result information and discuss the recommendations • To demonstrate the web-DCRA and the app	• 2 locations as discussed with PMU, NCRMP

Sub: Consolidated Clarifications to Queries Raised during Pre-proposal Conference held on 30.11.2017 against RFP No. PMU/RFP/2017/1dated 07.11.2017 for Hiring of Consulting Services for Dynamic Web-based Composite Risk Atlas for Cyclones & Associated Impacts

Sl. No.	Clause No.	Queries of Bidders	Clarification by NDMA
1.	Page 19-20, Section 2. Instructions to Consultants and Data Sheet, 15. Technical Proposal Format and Content, Sub Point 15.1.1	Can a brief summary of format, if any, (requirements for fonts, margins, etc.?) and page limits be provided?	Refer R=P document (Section 3 & 4) as the standard format to be followed. Font 'Arial', size "12" is preferable.
2.	Page 65, Section 7: Terms Of Reference,	We understand that "Understanding existing Web-CRA and modules' is part of indicative activities list as part of Phase-II execution. But, in order to propose optimal solution for the problem statement, is it possible to access documents, technical details & URL related to Web-CRA application developed during NCRMP Phase-I,	Necessary Demo of Web CRA (developed during Phase-I of NCRMP) provided during pre-bid meeting.
3.	Page 65, Section 7: Terms Of Reference,	Kindly confirm that it is required to use the existing platform implemented for Phase-I for development of Phase-II application or The consultant is free to choose any other platform to address the requirements of Phase-II. Request you to kindly provide the high level design or architecture used for Phase-I.	Yes, It is required to use the existing platform of Phase-I. Necessary Demo of Web CRA (developed during Phase-I of NCRMP) provided during pre-bid meeting.
4.	Page 65, Section 7: Terms Of Reference,	Is the deployment environment (Hardware & Software) provisioned by NDMA or to be procured by the bidder? In case it is to be procured by bidder, what are the requirements for deployment environment? (viz., Cloud based / physical deployment & licensing).	To be developed at own server by the Consultant initially. Final hosting and security auditing to be done by Consultant with necessary

#	Reference	Query	Response
5	Page 66 / Para 2, Section 7: Terms Of Reference,	Please clarify that whether an ADCIRC grid that was developed and used for the deterministic hazard scenarios during Phase-I be provided to the consultant for use in Phase-II?	migration to NIC cloud server as per the terms mentioned for 7th deliverable in RFP (section 7, para 6). The Consultant have to use own ADCIRC grid (licensed version) at their own cost.
6	Page 66, Section 7: Terms Of Reference,	Please clarify that whether ADCIRC is configured to accept river discharges? We are particularly interested in the horizontal resolution, how the thalweg was defined in the river, the bank elevations, and the nodal distribution across the channel sections?	ADCIRC is used for Wind and Storm Surge. For river discharges and flood modelling, HEC tools are used.
7	Page 66, Section 7: Terms Of Reference,	Request to you for providing the details of the deterministic cyclone hazard simulations done in Phase-I? a. What was the grid size (number of nodes, elements)? b. What was the source of bathymetry data? c. What was the source of tidal boundary conditions? d. What was the source for initial condition? e. How long were the simulations? f. What was the source of hurricane track? g. What was the source of rainfall data? Were those hind cast simulations for historic storms of the past? If so, which storms?	a- Location specific model was customised for each State using ADCIRC model, grid size varies between 80-100 m near the cost and about 30-40 km offshore. As the model was location specific so number of nodes and elements were different for each State depending upon the area. b- NHC. c- Global tidal information. d- Surge simulation resulted from the application of wind (IMD tracks), pressure gradient, and tidal constituents. e- Simulation was performed depending upon the length of the cyclone track. f- IMD. g- CWC & IMD.
8	Page 66, Section 7: Terms Of Reference	What is the status of the hydrology model developed as part of Phase 1? 2. Whether the hydrology model developed in	Yes

Phase 1 is validated and calibrated for each of the rivers?

#	Reference	Question	Answer
9.	Page 66, Section 7: Terms Of Reference	If a hydrology model is not currently available through Phase 1, will we have access to the parameter information needed to set up a hydrology model: • high-resolution DEMs, • river depth information, • soil moisture maps • soil texture maps, • potential evaporation data, • high-resolution land use/land cover maps; and • Stream flow measurements to validate and calibrate the model?	Yes, necessary/relevant data will be shared with successful bidder.
10.	Page 66-67, Section 7: Terms Of Reference	How many of the rivers within India have been included in the hydrology model or need to be included in the model?	All rivers in study area are to be included in the hydrology model/other model.
11.	Page 66, Section 7: Terms Of Reference	Request you to kindly provide the details of the existing coastal ocean bathymetry and coastline boundary data from Phase-I?	Broadly Bathymetry data with high resolution available for Shallow sea levels. This will be shared with successful bidder
12.	Page 66, Section 7: Terms Of Reference	Please provide the no. of deterministic hazard scenarios developed in Phase-I using ADCIRC and HEC-tools?	Necessary Demo of Web CRA (developed during Phase-I of NCRMP) provided during pre-bid meeting.
13.	Page 66, Section 7: Terms Of Reference	Request you to confirm whether the exposure data developed in Phase-I would be provided to the consultant / Bidder?	This will be shared with successful bidder.
14.	Page 66, Section 7: Terms Of Reference	Kindly provide detail about the no. of vulnerability functions which are developed in Phase-I?	Vulnerability functions are developed for various exposure elements. Any improvement/ modification may please be suggested. Necessary Demo of Web CRA (developed during Phase-I of NCRMP) provided during pre-bid meeting.
15.	Page 66, Section 7: Terms Of Reference	The Web-CRA is based on the GeoNode platform with extension built using python.	Yes
16.	Page 66, Section 7:	Please clarify whether the ADCIRC model developed during	Yes, to the extent possible.

	Terms Of Reference	Phase 1 is validated and calibrated for all the areas along the coast of India?	
17.	Page 66, Section 7: Terms Of Reference	Request to NDMA to share the basics of the Web-CRA based on GeoNode platform with extension build in using phython to the consultant?	Necessary Demo of Web CRA (developed during Phase-I of NCRMP) provided during pre-bid meeting. Further details will be shared with successful bidder
18.	Page 66-67, Section 7: Terms Of Reference	Is there any statistical data of storms in the area collected as part of Phase-I, and Would it be provided to the consultant for the development of the suite of hypothetical storms to generate the worst-case scenario flood risk maps?	Yes, the necessary/relevant data will be provided to the successful bidder.
19.	Page 68, Section 7: Terms Of Reference,	Is the authority (NDMA) looking for native mobile app or is it okay to provide mobile friendly web-app. If native mobile app is required, please let us know mobile app development requirements. (viz. mobile app platform).	Requirement is of android app. on mobile not native.
20.	Page 68, Section 7: Terms Of Reference	RFP asks to "Add capability in Web-CRA to work in offline mode for updating exposure database". However, exposure database is developed in phase-I with information in the database such as population, buildings, roads, utility lines, etc. No exposure data is expected to be produced as part of Phase-II's probabilistic and real time development. In this case, Can you clarify what capability in relation to exposure database needs to be added?	Exposure updation shall be required. Any new layer may be suggested by the Consultant who shall provide necessary technical assistance and do follow up/ coordination with concerned organisation/State government to get it. Project Management Unit (PMU), NCRMP will facilitate the process. Cost of data (if any) to be borne by NCRMP.
21.	Pages 68-69, Section 7, Clause 5. Scope of Services	In the Probabilistic Risk Assessment Maps/Products section on pages 68 and 69, the first paragraph indicates that "the service provider will use a representative sample of hypothetical cyclones to estimate the near-worst case scenario of wind-speed information, storm surge and inland flooding for each cyclone category", however, in the list of	Monsoon rainfall is beyond scope of study. Cyclone induced rainfall /flooding & inland flooding caused by storm surge have to be modelled.

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		Query	Response
		items not to be taken into consideration in developing the maps is freshwater flooding from rainfall and riverine discharges. Thus, is the inland flooding in this instance only looking at that caused from the storm surge only?	
22.	Page 69 / Section 7 : Terms Of Reference / Para 1, Scope of Services, Probabilistic Risk Assessment Maps / Product	As the RFP mentions the development of probabilistic products, it later mentions a representative sample of hypothetical cyclones to estimate the near-worst case scenarios. Is there expectancy on the minimum/maximum number of simulations to be done? Can this regenerated map concept requirement be further clarified.	Through Stochastic modelling, Consultant needs to develop various scenarios for different probability of exceedance. This means all probable scenarios need to be developed including worst-case scenarios.
23.	Page 70 / Section 7 : Terms Of Reference / Para 1, Scope of Services	Please clarify that how frequently IMD will provide new information to be used during real-time applications? What meteorological information will be provided?	In case of depression and deep depression, IMD issues bulletins five times a day [based on 00, 03, 06, 12 & 18 Coordinated Universal Time (UTC) observations] and in case of cyclone storm and above bulletins are issued every three hourly (based on 00, 03, 06, 09, 12, 15 & 18 UTC observations). A typical bulletin is attached.
24.	Page 70, Section 7: Terms Of Reference,	Could you provide mode of data exchange between IMD and proposed application viz., data exchange formats , periodicity etc.	Currently data is provided by email as a word file and pdf file. Graphics are given in png format. For creation of track and intensity graphics data can be provided in digital form.
25.	Page 70 / Scope of Services, Para 2, Real-time Decision Support Tool Web based Dynamic Composite Risk	RFP says "a worst case storm surge estimation shall be generated for coastline and inland areas" What does "worst case" here means considering that impact forecasting will not be a probabilistic effort?	Worst case scenario is a low probability high impact event. Consultant has to simulate such an event with different variables in various scenarios. For e.g. a super cyclone may be simulated.

	Atlas		
26.	Page 70 / Scope of Services, Para 3	What does particular landfall location means? Is there a list of particular locations of interest or does that imply the potential landfall location of the forecasted storm?	It is a dynamic situation. It may vary depending upon forecast accuracy, time etc.
27.	Page 70 / Scope of Services, Para 4	Request to confirm that who will provide the ground truth field data to compare with the forecast within the decision support system? How quickly that information may be provided? Is there a list of data that will be provided for such comparison?	Any new layer may be suggested by the Consultant who shall provide necessary technical assistance and do follow up/ coordination with concerned organisation/State government. Data to be collected by consultant. Necessary facilitation with State Govt. / organisation will be done by PMU, NCRMP. Cost of data (if any) to be borne by NCRMP.
28.	Page 70/ Scope of Services, RealTime Decision Support Tool	Request to detail about the information release cycle (i.e. every 6 hours) by the IMD?	Refer Q. 23
29.	Page 70-71/ Scope of Services, Real Time Decision Support Tool	However, in the preparation of the maps section on page 71, it does not indicate that freshwater flooding from rainfall and the riverine discharge should be taken into consideration. Thus, are the maps to take into consideration the freshwater flooding from rainfall and the riverine discharge?	Refer Q. 21
30.	Page 71, Section 7: Terms Of Reference	Request you to provide following details - 1) Approximate number of concurrent users for: i) Web-DCRA ii) DCRA App iii) Desktop version of Web-CRA 2) High availability & Disaster Recovery requirements for the solution 3) Security requirements and envisaged audit compliance (CERT-IN, GIGW etc.)	1. i, ii & iii there will be maximum 100 users. 2. To be suggested by the Consultant. 3. Refer to Q.4
31.	Page 71, Section 7: Terms Of Reference	Request you to provide information for the riverine areas in India such as river boundaries, cross-sections, bathymetry,	River discharge & bathymetry data will be provided to successful bidder.

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		etc. provided to the consultant?	
32.	Page 71/ Section 7, Clause 5. Scope of Services	How often and how quick would the emergency responders require information from impact forecasting to make evacuation decisions? 120 minutes following the advisory?	36-48 hours will be required for emergency responders. Impact forecast to be monitored during the entire lifecycle of event.
33.	Page 71 / Understanding existing WebCRA.	Please share the details of the Web-CRA developed in Phase-I and examine its contents to see what is available from Phase-I work?	Necessary Demo of Web CRA (developed during Phase-I of NCRMP) provided during pre-bid meeting.
34.	Pages 68 and 72 / Clause 5. Scope of Services	Please share the details of computational resources available to run the Real-Time Decision Support Tool and the modelling effort to provide the information to the Web-CRA?	Present server configuration is 1TB storage, 64 GB RAM – Web CRA hosted on NIC cloud server. Necessary demo provided. The modelling effort will depend on number of simulations required to complete the dynamic model.
35.	Page 72, 4. Desktop Version of Web-CRA	How will the offline version of Web-CRA acquire results from the real-time decision support tool if/when it is offline?	It will be automatic from offline desktop to Web CRA.
36.	Page 72 / Real Time Decision Support Tool, Clause 7	May the training and capacity building activities be online rather than in-person?	Training has to be in person. Consultant has to design interactive training strategy.
37.	Page 72, 6. Deliverables & schedule for completion of tasks and services	Please confirm whether the duration of the project is 24 months inclusive of the training and capacity building or it is additional.	Refer to Amendment No. 1. Duration of the project is 20 months including training.
38.	Page 72-73	Please confirm about the no. of computational resources (number of nodes, processors, system details, etc.) does the authority (NDMA) plan to use after receiving the final real-time decision support tool at the end of the project?	Refer to Q. 34. PMU, NCRMP & States shall use the decision support tool.
39.	Page 73, 6. Deliverables &	Please share the existing computational resources (high end systems) to execute simulations with the real-time decision	Refer to Q. 4 & 34.

#	Reference	Query	Response
	schedule for completion of tasks and services	support tool developed in Phase-II, OR the bidder is expected to supply them as part of the project?	
40.	Page 73, 6. Deliverables & schedule for completion of tasks and services	6 months commitment from the team leader is more than any other team member contributions. Is there specific kind of work expected from the team leader during the 6 months of time? For example, are there going to be certain travel requirements from the team leader for periodic meetings in India?	RfP condition prevails locking to technical nature of job involved There will be travel requirement from Team Leader/experts etc. for periodic meetings etc. as and when required for which cost will be borne by consultant.
41.	Page 73-74, 7. Staffing Requirements	Are there any travel requirements from and one of the key-experts for any project meetings in India? Will there be any travel funds provided?	There will be travel requirement from Team Leader/ other experts for periodic meetings etc. as and when required for which cost will be borne by consultant. As & when required consultant has to depute experts to States at its own cost. This is a lump sum contract.
42.	Page 73-74, 7. Staffing Requirements	Is there a limit on the number of non-key expert, technical, administrative support staff besides the key-experts?	No. Based upon requirement of consultant. Cost is to be borne by the Consultant.
43.	Page 73-74, 7. Staffing Requirements	Are the indicative efforts in months for key-experts indicating annual efforts of their total effort over 24 months?	It is estimated /tentative man month requirement for the effort to be put by expert within a period of 20 months.
44.	Page 73-74, 7. Staffing Requirements	Can the key-experts go over the indicative effort in months if needed for the successful completion of the project?	Yes, as these are tentative /estimated requirements. This may vary as per requirement of consultant to complete the job.
45.	Page 73-74, 7. Staffing Requirements	Can the consortium members tie up with educational / research institutes willing to share key domain expertise, in the better interests of the project?	No, Refer to RFP clause (Section 2, Data Sheet Clause 14.1.1).
46.	Page 73-74, 7. Staffing	Can additional modelling staff be hired in addition to the hydrology/flood risk modeller and the modelling expert? (	Consultant can hire at their cost based on requirement.

	Requirements	
47.	Section 7 : Terms of Reference page No 69	We request you to please specify the Number of concurrent users of Web GIS application.	Maximum 100.
48.	Section 7 : Terms of Reference page no 66	It is assumed that the developed Web- CRA and all data gathered during the NCRMP Phase-I study will be available for implementation in phase-II. Please confirm.	Yes, to be shared with successful bidder.
49.	Section 7 : Terms of Reference page no 66	It is assumed that the only platform used for development of Web-CRA is GeoNode platform and the only technology used for extension is Python. Please confirm.	Yes, however consultant may propose better technology.
50.	Section 7 : Terms of Reference page no 66	We request you to please share the sample reports (designed during the phase I) and an example of enhancement required in the repo4 in phase-II Please confirm.	Necessary Demo of Web CRA (developed during Phase-I of NCRMP) provided during pre-bid meeting.
51.	Section 7 : Terms of Reference page no 66	It is assumed that physical Vulnerability functions are finalized during the phase I and addition of such vulnerability functions is out of scope of current project. Please confirm. Please confirm.	Consultant may add and update the vulnerability functions.
52.	Section 7 : Terms of Reference page no 66	The exposure output will be based on exposure data of exposure elements available in Web—CRA and any addition in that data is not part of scope of this project. Please Confirm.	Consultant will update exposure data. Any new layer may be suggested by the Consultant who shall provide necessary technical assistance and do follow up/ coordination with concerned organization.State government to get the same. FMU, NCRMP will facilitate the process. Cost of data, if any, will be borne by NCRMP.
53.	5. Scope of Service page No. 68	We request you specify the source of DEM. We also assume that NDMA will provide the high resolution DEM? Please Confirm.	DEM by NRSC. Best possible/available resolution shall be provided to successful bidder.
54.	Section 7 :	it is assumed that the probability (statistical) models for	Deterministic model based on historical

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	Terms of Reference page no 67	depiction of cyclone risk and storm surge flooding/coastal flooding are already developed and the scope of this project is limited to implementation of the probabilistic models. Please specify in case development of such models is part of scope of this project.	events and statistics has already been prepared under Phase-I, Dynamic/probabilistic model for real time application is to be prepared.
55.	Section 7 : Terms of Reference page no 68	We request you to please mention the number of users for offline (desktop) mode.	It will be a single user.
56.	Section 7 : Terms of Reference page no 68	Is enhancing in prediction capability to be based on improvement in statistical models of implementation improvements? Please specify if the improvement of Statistical models part of bidders scope?	All possible measures to be utilised/suggested by the Consultant.
57.	Section 7 Terms of Reference page no 68	We request you to please share an indicative scope of training and capacity building in terms of number of officials to be trained and training duration.	Training strategy to be designed by Consultant covering all 13 Coastal States/UTs to train relevant government officials/ States. This is also a technical parameter for evaluation.
58.	Section 7 : Terms of Reference page no 68	Is development of a mobile app a part of scope of this project? If yes, please mention the detailed scope for such activity.	Yes Refer to Q. 19.
59.	Section 7 : Terms of Reference page no 68	It is assume that data like Topography data/ Land elevation, normal astronomical tides and historical cyclone track is available with the department. Please confirm.	Yes, it will be shared with successful bidder.
60.	insurance to be taken out by the consultant I. Special conditions of contract Page No. 92	We assume that insurance coverage against the risk shall be for the project execution phase, excluding the Operations and Maintenance phase.	Refer to RFP, Special conditions of contract (Clause 24.1). Necessary up to project completion period including extended period if any.
61.	No. reference given	Whether the data generated from recently concluded ICZM project under MoEF, India for all the Coastal states will be available to be consultant or The Vendor has to collect the required data from different sources? Please confirm.	Subject to utility of data established by the selected Consultant, PMU, NCRMP will facilitate sharing of necessary data generated from

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			ICZMP(MoEF).Technical assistance from Consultant will be required and cost of data, if any, will be borne by NCRMP.
62.	39. Taxes and Duties page no. 97	We request to please specify the details of Taxes and Duties as applicable and exemptions, if any.	GST will have to be paid as applicable. It will be paid by NDMA along with the bill amount. No exemption.
63.	GCC	We request PMU, NDMA to keep provision of contractual clauses discussion (GCC) and change in any clause with mutual consent during negotiation and contract signing stages. Please confirm.	No change. GCC prevails.
64.	No. reference given	We request PMU, NDMA to keep provision of SLA and change in any clause with mutual consent during negotiation and contract signing stages. Please confirm.	RFP condition prevails. There will be no change.
65.	Under the section 3 (Study area) on page 67	Under the section 3 (Study area) on page 67 of the RFP, Lakshadweep and Andaman & Nicobar Islands are not mentioned which implies that these Islands will not be a part of this study. However, we understand these were considered during phase-I. Please clarify.	Lakshadweep and Andaman & Nicobar are part of this study.
66.	Page 68	On page 68, it is mentioned "To develop a DCRA App. This App. will enable users to access features of DCRA and geological events specific to study area through location based technology." As we are considering climate-related natural hazards only (Cyclone, surge and rainfall), what is the significance of geological events for this assignment.	Geological events are outside the scope of this study.
67.	Data Sheet on page 34	Though the time and venue for proposal opening is mentioned in the Data Sheet on page 34, the date is not mentioned. Please indicate the opening date.	The bids will be opened on 20/12/2017 at 5 pm.
68.	Section 7, Terms of Reference, Page #73, Staffing Requirement	There are Seven experts listed into the table given at page #74 as key expert whereas the total marks (50) stated at page 35 for five positions only. Please clarify: If there any marks for expert S. No. 6 & 7. If these are non-key positions, will bidder include the CVs in	RFP prevails. Only 5 key professionals will be evaluated.

		their proposal? (Section 7, Terms of Reference, Page #73, Staffing Requirement.)	
69.	Section 7, Terms of Reference, Page #72, "Training and Capacity Building".	**Please clarify:** (a) Total number of Trainings and Workshop to be organized at National, State and District Level. (b) The cost of organizing the trainings and workshops is **NOT** included into the proposal. (c) The travel and lodging cost of the trainers is to be included in Financial Proposal or will be reimbursed later on submission of actual bills. Since, trainings and workshops is mainly for DSS tools, are the key experts such as Modelling Experts required in the workshops at state, districts level trainings.	No. of workshop, trainings, place and identification of officials to be trained will be done in consultation with PMU, NCRMP... Logistic and travel arrangements for Central/State Government officials for the National Workshops are going to be arranged by PMU, NCRMP. However consultant has to bear cost of travel/lodging etc. of their own experts/staff required for this purpose. Venue for National / State workshop/training inclusive of equipment shall be provided by PMU, NCRMP/State.
70.	Section 7, Terms of Reference, Page #72, "Desktop version of Web-CRA".	It is understood that no hardware/software is to be supplied by the consultant. **Please clarify.**	Refer Q. 4.
71.	No. reference given	Understanding existing Web-CRA and Models: The consultant should understand that existing models and risk assessment developed as part of NCRMP Phase-I. To understand the existing risk assessment developed as a part of NCRMP Phase 1, TARU would like to know whether the data or the assessment report done in the NCRMP will be shared with the consultants during the pre-bid meeting.	To be shared with successful bidders. Necessary Demo of Web CRA (developed during Phase-I of NCRMP) provided during pre-bid meeting.
72.	No. reference given	What kind of datasets on Hazard, Vulnerability, Exposure and Risk are already developed as a part of the NCRMP	Necessary Demo of Web CRA (developed during Phase-I of NCRMP)

#	Clause Reference	Query	Reply
73.	No. reference given	phase1? Is this data will be made available to the consulting company once the project is awarded? In which format?	provided during pre-bid meeting. Yes to successful bidder.
		It is mentioned in the RFP document that "As part of NCRMP Phase-I, Hazard, Vulnerability and Risk Assessment (HVRA) study has been conducted and a Web-based Composite Risk Atlas (Web-CRA) has been developed having deterministic hazard scenarios that would be used by these States/UTs for mitigation planning". Is this India Cyclone hazard and Risk Atlas developed by RMSI for 13 states is available online? Is it hosted in NIC Server? Or any dedicated server of NCRMP? "These deterministic hazard scenarios are available in Web-CRA as static layers as mentioned in R=P document". Whether NCRMP project team can share details in the pre-bid phase? If yes, this will help in developing plan for the augmentation of the Web CRA.	Necessary Demo of Web CRA (developed during Phase-I of NCRMP) provided during pre-bid meeting. Present CRA is hosted on NIC cloud server of PMU,NCRMP. Details will be provided to successful bidder. Also Refer to Q 34.
74.	No. reference given	For dynamic Web CRA, which Govt departments will be involved? Is it the responsibility of the consulting company to work at the end of these agencies to assure compatibility of the systems and application for dynamic updating of data and live decision support systems?	Relevant government departments of 13 Coastal States/UTs like DM/Revenue/SDMA/NIC/IMD/DDMA shall be involved. Updating will be Consultants responsibility till successful completion of project.
75.	No. reference given	How many users are expected? Central, State, District, Taluka/Tehsil/Mandal (Taluka), City/Town and Village. Desktop version is for view or data updating? Please clarify.	Maximum 100. Desktop version is for view as well as for updating.
76.	No. reference given	The timeline to complete probabilistic risk assessment and the web-based tools and App is too ambitious. Within the project duration of 24 months, we would like to propose that	RFP prevails. Amendment NO.1 may also be referred as duration of Project is 20 months now.

#	Ref.	Query	Response
	No. reference given	the delivery of the tools and App be extended to 14 months, overlapping with the capacity building effort	
	No. reference given	The functionality of the real-time decision support tool relies heavily on the data provided by IMD and other agencies. Does the client have agreements with those agencies to provide data on a real-time automatic basis?	Data can be provided on real time. Required automation for exchange of data between IMD and the proposed system in NDMA has to be developed by the Consultant. The conversion of existing data in IMD into the desired format for use into the system has to be carried out by Consultant. Refer Q 23 also.
78.	No. reference given	Probabilistic risk assessment of the coastal states requires a large number of data that may exist at the national level, but more likely, at the state and even lower administrative levels. Will the client facilitate data collection?	Any new layer may be suggested by the Consultant who shall provide necessary technical assistance and do follow up/ coordination with concerned organisation/State government for obtaining reqd. Data. Necessary facilitation shall be done by PMU, NCRMP. Cost of data to be borne by NCRMP.
79	No. reference given	Please could you confirm the indicative budget range for this project?	Consultant has to quote based upon their experience, quantum of work/scope involved, tentative man month of experts indicated in RFP and keeping into account other admin expenses etc.
80	No. reference given	Do you have any technical document available, what database is used and what tables are available in that?	Necessary/relevant data bank will be shared with successful bidder.
81	Pg. 69	The preparation of maps will NOT take into consideration: wave, flood from rainfall, riverine discharge	Preparation of map will not take into consideration wave and flood from rainfall, however, cyclone incuced flood

#	Reference	Response
82	Pg 71 3rd para	"The preparation of the maps will not take into consideration: - Local factors that play a crucial role in determining actual surge or flooding impacts (for example, topping of flooding water from embankments or any other structure). Why? Please comment?	and riverine discharge will be taken into consideration in the area of study. RFP prevails.
83	No. reference given	We request to extend the last date of submission up to two weeks for preparation of quality proposal.	RFP condition prevails. No change.
84	No. reference given	Current Web based system is looking a very old technology so I think development time should be increased to recreate the old system into new technology. Please consider it.	RFP condition prevails. No change regarding development time. Bidder may suggest better technology.
85	No. reference given	Please advise the estimated value of these consultancy services for preparation of competitive offer.	Please refer Q. 79
86	No. reference given	If the funding agency wants a high resolution, coupled model system (based on ADCIRC) for more accurate results. Could you ask if the timeline is negotiable? Whether the duration may exceed 24-months or also more time may be provided for the deliverables.	As per Amendment No.1 to RFP, the duration of the project has been changed from 24 months to 20 months.
87	No. reference given	Could you ask if they want a coupled model system based on ADCIRC (used in Phase-I) or if they are open to the use of other coarser resolution models?	The bidder may suggest most appropriate model.
88	No. reference given	Please consider minimum 12 months time for development phase as compared to 8 months noted in RFP.	RFP condition prevails. No change.

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Key Experts

S.No.	Name	Designation	Qualification	Experience
1.	Sh. Pushpendra Johari	Team Leader	• B.Sc. (Computer Science) • M.Sc. (Computer Applications)	More than 20 yrs in Risk Hazard, Vulnerabilities Assessment & Risk Insurance
2.	Dr. Sushil Gupta	Dy. Team Leader	• Ph.D (Civil Engg.) • M.Tech. (Applied Geophysics) • MBA (Insurance Mgmt.)	More than 25 years in multi-hazard Hazard, Vulnerability and Risk Assessment and Risk insurance, and DRR related Assignments
3.	Sh. Pratul Srivastava	Hydrologist/Flood Risk Modeller	• ME (Civil Engg.)	More than 10 yrs. In modelling & Climate Resilience, HR&VA
4.	Dr. Indu Jain	Cyclone & Storm Surge Risk Modelling	• Ph.D (Oceanography) • IIT, Delhi • MA (Maths.)	More than 20 yrs in Hydro Risk Modelling & HR &VA
5.	Ms. Niva Srivastava	GIS Expert	• MSc. (Geology)	More than 15 yrs experience in mapping GIS, HR&VA
6.	Sh. Lokendra Dixit	IT Expert	• MCA	More than 8 yrs. in software Development in DM, HR&VA
7.	Sh. Ashutosh Singh	IT Expert	• M.Sc. (IT)	More than 18 yrs in software Development Arc GIC, and Web based Applications.
8.	Sh. Rishi Chugh	QA Engineer Software Project	• MCA	More than 13 yrs Lead Quality Assurance , Testing of Apps, Review of test Data and Defect Tracking

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BREAKDOWN OF CONTRACT PRICE

Item	Cost
	INR
Cost of the Financial Proposal	
Including:	
(1) Remuneration	1,11,46,750
(2) Reimbursable	30,76,700
Total Cost of the Financial Proposal:	1,42,23,450 + GST (as applicable)

Appendix-D

Minutes of Meeting Between PMU, NCRMP, NDMA and M/s RMSI Pvt. Ltd., Noida for Negotiations on Draft Contract on Consulting Services for Developing Web-based Dynamic Composite Risk Atlas for Cyclone & Associated Impacts Held on 09.03.2018

As M/s RMSI Pvt. Ltd., Noida was selected on the basis of QCBS for the above-mentioned consultancy services; the firm was invited for negotiations on draft contract by PMU, NCRMP, NDMA.

2. The negotiation meeting took place on 09/03/2018 at 1500 hrs NDMA BHAWAN. The Meeting was attended by the following:-

PMU, NCRMP

i. Sh. S. S. Jain Dy.PD, NCRMP- Member, CEC
ii. Sh. Narayanan P.E., Project Manager- Member
iii. Gp Capt(R) Chandra Shekhar, Proc. Spl.- Member
iv. Sh. Gireesh Kumar, Fin. Spl.- Member
v. Ms. Minati Sinha, Member
vi. Sh. Sanjay Sharma-Env. Spl.

M/s RMSI Pvt. Ltd.

i. Sh. Pushpendra Johari, Team Leader
ii. Dr. Sushil Gupta, Dy. Team Leader
iii. Sh. Sameer Nigam, Head Bidding Division

3. During the negotiation meeting, following decisions/confirmations were made:-

(a) M/s RMSI confirmed the availability of all key experts as stated in their Technical Bid.

(b) M/s RMSI also confirmed conducting 14 State Outreach Training Sessions in two phases and 02 National Workshops.

(c) M/s RMSI informed that development of probabilistic tools will be done at one stroke for the complete area of study ,giving priority to highly vulnerable region initially is not possible.

(d) PMU, NCRMP confirmed that if any new data set is required/ suggested by RMSI for updation etc., same will be facilitated from relevant data sourcing organization based upon review of necessity of the same. PMU, NCRMP will bear the cost. The Consultant will have to do necessary liaison providing technical assistance. RMSI also confirmed that such received data may be incorporated into the system during developmental/ experimental phase to avoid delay in development of tool.

(e) It was also agreed that clarifications issued prior to submission of bids will form an Annexure to Appendix-A (Terms of Reference & Description of Services) to the Contract.

(f) M/s RMSI also informed that after required testing /validation, the Dynamic Web-based Composite Risk Atlas (CRA) may be made available for public viewing. M/s RMSI also confirmed to provide the limited viewing rights of CRA developed under NCRMP-1 to the public by 15th April 2018.

(g) PMU, NCRMP asked M/s RMSI to enhance the access speed of CRA developed under NCRMP Ph I. M/s RMSI informed that they will again put the CRA on cloud to check the performance, as Web-CRA performance is also dependent on the NIC server configuration, available memory (RAM and hard disk space) and its' maintenance at regular intervals. M/s RMSI promised to look into this within a short timeframe.

(h) Based upon specific request of RMSI, it was agreed that deliverables after submission, will be reviewed by the PMU within a month's time instead of the present 02 months. Acceptance of deliverables will be done at an appropriate level as decided by the Competent Authority.

(i) M/s RMSI also confirmed that Dynamic Web CRA will include all parameters related to Tracking, Intensity, Balloon/ Cone forecast pertaining to Wind, Surge etc. for impending cyclone.

4.   The meeting came to an end at 1630 hrs with thanks to the participants.

(Gp Capt (R)Chandra Shekhar)
Procurement Specialist
12/03/2018