TERMS OF REFERENCES

CONSULTANCY SERVICES FOR

DEVELOPMENT OF DECISION SUPPORT SYSTEM FOR FLOOD MANAGEMENT IN WESTERN RIVERS OF PUNJAB

Introduction:

Pakistan has suffered a loss of around $800million[1] each year due to floods in its 69-year history, primarily due to the absence of a disaster management mechanism. In 2010 alone the monsoon rains caused massive floods which killed nearly two thousand people, affected more than 20 million and made at least 7.8 million people food insecure and inflicted over US$ 16 billion in economic loss[2]. The super flood of 2010 swept away 20% of Pakistan's land. Another major flooding event in recent years, was the flood of 2014. In September 2014, severe and late monsoon spell, coupled with higher water flows in the eastern rivers, resulted in massive flood along Chenab River in Punjab. The estimated cost of the recovery effort was US$439.7 million. Out of which 94.74% damages were occurred in Punjab[3].

Disaster management itself is a stack of multi-tier yearlong activities starting from pre-flood preparedness, handling/decision making during active flooding and post flood recovery and damage assessments. Currently flood management in Punjab is being carried out with limited information/forecast along with localised knowledge and experience of previous floods. A lot of real-time information is now available due to advent of technology which can be effectively used in overall flood management and real-time decision making. Evacuation of at risk population during active flooding and breaching of an embankment at certain flood threshold requires critical decision making which can be carried out through use of accurate, reliable and timely information/data along with active participation of stakeholders.

Decision Support System (DSS) allows decision-makers to combine real-time information including hydrological data/ spatial distribution of flood from satellite imageries, personal judgment with computer output, over a user-machine interface, to produce meaningful information for decision-making process.

[1] Malevolent Floods of Pakistan – Naseer Memon. Strengthening Participatory Organization (SPO)
[2] Economic Losses Due to Floods – Leed (Pakistan) https://tinyurl.com/jb75yeu
[3] NDMA Damages & Recovery Needs Assessment Report (2014)

This system will strengthen existing flood management practices (which are currently focusing on flood management mainly during active flooding only) by integrating real-time hydrological data, spatial information, latest terrain representation, infrastructure capacities and thresholds, possible flood paths after breaching at certain location, pre-assessed damages and experience of previous flood handling. Due to integration of GIS based layers of various facilities, utilities, infrastructure, inundation layers and modeling tools, proposed DSS will also contribute in pre-flood preparedness and post flood recovery and adapting efficient flood damage reduction strategies. As the flood management is a continuous activity, Punjab Irrigation Department, being custodian of rivers and streams, intends to acquire self-reliance in field data collection, technology and use of models (through on job training and involvement of PID/FRAU professionals during project duration) for better flood management. For this purpose, the Punjab Irrigation Department has established Flood Risk Assessment Unit as a part of organizational setup. The staff comprising 31 posts, out of which 16 are officers and 15 are supporting staff. The technical staff of FRAU shall be attached with consultant team, for on job training, during the course of development of DSS.

In view of above and to handle flood situations efficiently, meaningful preparedness before each flood season and reliable flood damage assessments, there is an eminent need for development of decision support system for flood management of all rivers (Chenab, Indus, Jhelum, Ravi and Sutlej) and major Nullahs in Punjab. In the first phase, Decision Support System for Indus, Chenab and Jehlum Rivers (herein called the Western Rivers) shall be developed. To achieve this goal there is a need to hire competent consultancy services. The duration of said project has been estimated to be eighteen (18) months. The consultant will require to engage at least senior hydrologist, hydraulic modeler, GIS specialist, Survey expert and Web Developers for development of DSS.

Task wise distribution of activities being planned for development of decision support system is described as follows;

Task A: <u>Field Survey of River Hydraulic and Development of Digital Elevation Models</u>

One of the basic and most important inputs of any hydraulic model is the geometry data of the rivers or drains in order to ascertain the river morphology. In order to accurate modelling of the rivers, cross sectional elevation data and bathymetric survey is required along river centerline, upstream and downstream of all major hydraulic structures like bridges, barrages, headworks, etc. For detail investigation of flow paths & inundation extents/ depths/ velocities using models, topographic details are generally required to develop contours. These contour maps are then processed to develop digital elevation model (DEM) at required resolution.

Digital Elevation Model (DEM) represents land elevation data, which are crucial for estimating storage volume of surface flooding. The quality of the output depends on the quality of the DEM. DEM of 30m x 30m resolution are available free of cost

online from missions like ASTER and SRTM but this resolution is too rough for flood simulations and inundation analysis, especially along the embankments, cities, hydraulic and public infrastructures (roads, railways) and small settlements. While modelling breaching scenarios, the resolution of DEM becomes more vital. Procurement of new DEM with finer resolution will be crucial for accurate flood modelling. Generally, a DEM of resolution of 5m x 5m is acceptable for adequate results but this should be decided after the initial terrain analysis and review of available topographic information and required results. Final DEM will be attained by merging the river cross sectional survey data, layout and elevation data of embankments, bathymetric data and the high-resolution satellite based elevation data. Main activities for this task will include the following;

(i) Establish horizontal and vertical survey control points (of concrete), connected with Survey of Pakistan datum, along rivers and main nullahs.

(ii) Cross sectional survey along the western rivers and main nullahs. The survey shall also include recording geometry of hydraulic structures (including water crossings/culverts/bridge geometric details). The cross-sections shall be observed from left to right embankment. Where embankments on either side is not available, the cross section shall either be extended to floodplain extent or 2Km further than the bank of river (whichever gives best results for hydraulic modelling). For survey activity, eight (8) bathy meters, eight (8) DGPS and eight (8) boats shall be provided by Punjab Irrigation Department, only for the course of project. The cross sections shall be taken at an average interval of one (1) Km.

(iii) Initial terrain analysis and review of available topographic information. Propose extent and specifications of required DEM based on initial review and possible extent of water during floods.

(iv) Procurement of 5mx5m DEM (from recent archives) along western rivers and main nullahs, based on above proposals.

(v) Topographic survey of Embankments through vehicle mounted DGPS.

(vi) Transformation of cross sectional survey into raster layer and fusion with procured DEM to represent true ground surface after elimination of water.

(vii) Develop high resolution DEM (1mx1m) to be used for breach modelling using drones, around designated breaching sections along rivers.

(viii) Develop contour maps at 0.5m contour interval around the major hydraulic structures covering river reach length of 1-km upstream and 1-km downstream of the structure.

Task B: Development of Hydrological and Hydraulic models

Flood inundation models are major tools for assessing ingress of flood and mitigating the effects of flooding. They provide predictions of flood extent and depth that are used in the development of spatially accurate hazard maps. There have been significant advances in flood inundation modelling over the past decade. The centrepiece of any decision support system is the mathematical model used for flood simulation. A hydraulic model for flood wave propagation is necessary to estimate flood levels, depths and velocity of the water in the river channel and the floodplain as a function of time. Results obtained can be used to assess the impacts for the simulated scenario of flood propagation. Main activities for this task are envisaged as follows;

(i) Identify various data sources including but not limited to, trans boundary gauge data, radar data, satellite data etc. that can be used for efficient flood forecasting through hydrological models.

(ii) Calibrate rainfall data of radar estimates, satellite estimates with available observed data, in catchment and also Develop calibration relations for each catchment to be used for real time/forecasted data.

(iii) Review existing hydrological models being used in Pakistan for flood forecasting purpose, developed for upper Indus, lower Jehlum, upper Chenab and major nullahs along these rivers in view of timeliness and accuracy in prediction of flood peak.

(iv) Review existing hydraulic models/techniques (including but not limited to FEWS, IFAS, etc.) being used in Pakistan; in view of reliability and accuracy of flood modeling. In light of review and client's requirements, identify required improvement(s) in flood forecasting models/techniques focusing Punjab Rivers.

(v) Develop new distributed hydrological model to forecast river flows, by using input of forecasted and actual rainfall from various data sources. Calibrate and validate the model for flood events.

(vi) Develop new 1-D hydraulic models of rivers and nullahs, using latest geometric data, to estimate various hydraulic parameters, corresponding to various range of flood magnitudes and existing infrastructure capacities. Relevant details and data used in existing models may also be used as a reference.

(vii) Estimate flood levels and freeboard assessments along embankments on both sides of rivers and nullahs corresponding to various range of flood magnitudes with embankment geometries.

(viii) Identify vulnerable locations along embankments against overtopping/ freeboard encroachment corresponding to various range of flood magnitudes.

(ix) Estimate existing safe flood passage capacity along river reaches.

(x) Review existing floodplain maps and update them with recent topographic and infrastructure details also generate flood risk maps.

(xi) Integrate results of hydraulic modelling in web-based interface for decision makers.

Task C: Development of Models for Breaching Sections

Flood protection bunds are generally constructed either to protect irrigation infrastructure, or to safeguard certain towns, villages and adjoining agricultural lands. Due to general topography of the area in Punjab, sloping towards the south-west, pre-determined breaching sections have been provided in the right marginal bunds for safety of Headworks/ barrages in case of exceptional high flood. There are 19 breaching sections in Punjab, thirteen (13) of which are maintained by Punjab Irrigation Department, four (4) by Pakistan Railways, one (1) by C&W Punjab and one (1) by NHA. It is therefore required to reanalyse the possible damage assessment due to their operation. Main activities for this task are envisaged as follows;

(i) Procure 1 No. drones, with approved specifications and collect high resolution elevation and land use data of drone will be arranged by the consultant and later on handed over to PID for future usage.

(ii) Review and recommend software package for 1D/2D breach analysis.

(iii) Develop 1D/2D models for designated breaching sections and update existing flood Atlas with flood depths and extents. With the intentions that FRAU team will continue breach modelling after completion of project at 25 km or finer interval.

(iv) Identify vulnerable breach locations along rivers in Punjab using 1D model with latest topographic and infrastructural details.

(v) Develop 1D/2D models for vulnerable breaching sections (identified through 1D model) and update existing flood Atlas with flood depths and extents. With the intentions that FRAU team will continue breach modelling after completion of project at 25 km or finer interval.

(vi) Identify flow paths, inundation depths, velocities and drainage time at designated breaching location corresponding to various range of discharges and breaching scenarios.

(vii) Develop/update existing flood atlas, showing the drainage pattern of flood in case of breaching anywhere along the river.

(viii) Optimize/revise operational strategy of designated breaching sections at each location corresponding to range of flood scenarios and identify critical scenarios.

(ix) Develop inundation maps duly highlighting risk and vulnerable areas at each designated breaching location and update existing flood fighting plans using simulation results. Integrate simulation results with damage assessment.

(x) Propose various options for drainage of flood after breaching and practical recommendations for safe passage and re-joining the river with stake holder consultations.

(xi) Estimate depth/velocity damage functions using flood inundation simulation results (extent, depth, velocity, drainage time etc.), through modelling activity.

(xii) On job training of PID/ FRAU professionals on acquisition of data, processing, model development, interpretation of results and troubleshooting

(xiii) Integrate results of breaching section models in web-based interface for decision makers.

Task D: GIS Mapping and Web Integration

The technology of Web GIS give planners an ability to react faster with proactive response plans and the tools to execute them. It also helps to share information to the public with web maps, so local planners can visualize how their developments will affect the land, and vice versa. Keeping these aspects, a web based GIS application has been envisaged. Main activities for this task are as follows;

(i) Review and update existing GIS Layers for available data with Punjab Irrigation Department not limited to roads, populations, settlements & villages, hospitals, schools, etc.

(ii) Integrate the results of all tasks with web based interface using open source technology stack and existing server owned by client.

(iii) Using post flood free domain inundation extents, analyse and develop tools (geospatial analysis tool etc.,) for post flood damage assessments as a part of web GIS application.

(iv) Automate the procedure of extracting post flood inundation extents from free domain satellite imageries, using overlay analysis, assess infrastructure damages and integrate all spatial results with web GIS application.

(v) Development of web GIS utility to automatically extract real-time free domain satellite data and assess water extents to quantify damages.

(vi) Develop a public website for information sharing.

Reporting Requirements/ Deliverables			
Sr. No.	**Title of Report/ Presentation/ Workshop**	**Schedule of Submission**	**Details of submission**
1	Progress Report (10 hard copies along with 10 individual electronic copies on encrypted USBs). Key shall be handed over to Chief FRAU	Progress report for each calendar month shall be submitted within seven (7) calendar days of following month.	The report shall contain a list and detailed information about data collected, processed, development of models and input of man-months during reported month(s). It will also include updated work schedule and further planning of tasks.
2	Inception Report (10 hard copies along with 10 individual electronic copies on encrypted USBs). Key shall be handed over to Chief FRAU	Two (2) months after Commencement of the Services.	Sketch of methodologies and timelines to achieve all tasks of TORs
3	Organize a presentation on the Inception Report to share the road map for conducting the project.	Within one (1) week after the submission of Inception Report for client/stakeholders	Holding a combined presentation or the client and stakeholders to build understanding of the task and to enable client/stakeholders to submit observations/modifications.
4	First Interim Report Task-A: Observations of cross-sections for atleast 50% length of rivers. Task-B: covering at least TOR's item (i) to (iv) of TORs Task-D: covering at least TOR's item (i) to (iii) of TORs.	By end of six (6) months after Commencement of the Services	The submissions shall include both reports (hard format) and soft data (raw data, processed data, models, GIS tasks and soft copies of all reports)

Reporting Requirements/ Deliverables			
Sr. No.	**Title of Report/ Presentation/ Workshop**	**Schedule of Submission**	**Details of submission**
	(15 hard copies along with 15 individual electronic copies on encrypted USBs)		
5	Organize a presentation on the First Interim Report.	Within one (1) week after the submission of Interim Report for client/stakeholders to accept or suggest modifications.	Holding a combined presentation for the client and stakeholders to build understanding of the task. Also, to enable client/stakeholders to submit observations/modifications to the consultant.
6	Second Interim Report Task-A: Complete. Task-B: covering at least TOR's item (v) to (viii) Task-C: Covering atleast TOR items (i) to (v) Task-D: covering at least TOR's item (i) to (vi) (15 hard copies along with 15 electronic copies on individual encrypted USBs. Key shall be handed over to Chief FRAU)	By end of one eleven (11) months after Commencement of the Services	The submissions shall include both reports (hard format) and soft data (raw data, processed data, models, GIS tasks and soft copies of all reports)
7	Organize a presentation on the Second Interim Report.	Within one (1) week after the acceptance of Second Interim Report for client/stakeholders to accept or suggest modifications.	Holding a combined presentation for the client and stakeholders to build understanding of the task. Also, to enable client/stakeholders to submit observations/modifications to the consultant.

Reporting Requirements/ Deliverables			
Sr. No.	**Title of Report/ Presentation/ Workshop**	**Schedule of Submission**	**Details of submission**
8	Third Interim Report Task-B: covering at least TOR's item (ix) to (xi) of TORs. Task-C: covering at least TOR's item (vi) to (xiii) of TORs Task-D: covering at least TOR's item (v) to (vi) of TORs (15 hard copies along with 15 electronic copies on individual encrypted USBs. Key shall be handed over to Chief FRAU)	By end of sixteen (16) months after Commencement of the Services	The submissions shall include both reports (hard format) and soft data (raw data, processed data, models, GIS tasks and soft copies of all reports)
9	Organize a presentation on the Third Interim Report.	Within one (1) week after the acceptance of Second Interim Report for client/stakeholders to accept or suggest modifications.	Holding a combined presentation for the client and stakeholders to build understanding of the task. Also, to enable client/stakeholders to submit observations/modifications to the consultant.

Reporting Requirements/ Deliverables			
Sr. No.	**Title of Report/ Presentation/ Workshop**	**Schedule of Submission**	**Details of submission**
10	Draft Final Report (20 hard copies alongwith 20 electronic copies on individual USBs. Key shall be handed over to Chief FRAU)	By end of seventeen (17) month after Commencement of the Services.	Submission of all tasks/ procured items after completion, alongwith packages of different raw and processed data. The submissions shall include the following: i. All raw data procured/acquired during the project. (DEMs, flows, metrological, topographic data etc.) ii. All processed data. (fused DEMs with cross sections, contour maps etc) iii. All cross-sectional data in CSV format, DWG format and PDF format. iv. Contour maps of 0.5m interval. v. Embankment data in GIS format, alongwith geometry of culverts, bridges etc. vi. Integrated distributed hydrological model of all rivers. vii. Integrated hydraulic models of all rivers including breach models. viii. Flood levels, freeboard assessments, vulnerable locations, safe flood passage capacities, floodplain maps, inundation maps corresponding to various range of floods and risks at each breaching sections, both in GIS and hard format) ix. Optimized/ Revised operational strategy of designated breaching sections and upgraded flood fighting plans.

Reporting Requirements/ Deliverables			
Sr. No.	**Title of Report/ Presentation/ Workshop**	**Schedule of Submission**	**Details of submission**
			x. Upgraded flood atlas, both in GIS and hard format xi. Various options for drainage of flood after breaching and recommendations for safe passage and rejoining the river with stakeholder consultation. xii. Estimate depth/velocity damage functions using flood inundation simulation results (extent, depth, velocity, drainage time etc.), through modelling activity. xiii. Detail manual of complete system, including instructions for acquisition of data, operation of various modules, simulation, interpretation of results and troubleshooting. xiv. Details of reviews (existing hydrological models, hydraulic models, existing DEMs) xv. All GIS layers in soft format as well as printed in A_0 size. xvi. Details of Methodology adopted for completion of each task and sub-task. xvii. License keys of softwares, bought as a part of this project. xviii. All background coding, processing, calibration factors and other supporting process/data. xix. All results integrated in web based interface in the existing server of client department.

Reporting Requirements/ Deliverables			
Sr. No.	**Title of Report/ Presentation/ Workshop**	**Schedule of Submission**	**Details of submission**
			xx. Details of stakeholder consultation, stakeholder concerns and subsequent strategy. xxi. Automate the procedure of extracting post flood inundation extents from free domain satellite imageries, using overlay analysis, assess infrastructure damages and integrate all spatial results with web GIS application. xxii. Development of web GIS utility to automatically extract real-time free domain satellite data and assess water extents to quantify damages. xxiii. Develop a public website for information sharing. xxiv. Any other task defined in task A to E. xxv. Items procured as a part of this project, including drone, cars, computers, laptops, hard drives etc. All submissions should incorporate observations made by client and stakeholders

Reporting Requirements/ Deliverables			
Sr. No.	**Title of Report/ Presentation/ Workshop**	**Schedule of Submission**	**Details of submission**
11	Final Report (50 hard copies along with 50 electronic copies. 40 electronic copies on individual encrypted CDs/DVDs and 10 electronic copies on individual encrypted hard disks. 40 Key shall be handed over to Chief FRAU)	Within two weeks after acceptance of the draft final report.	The final report shall contain all items as mentioned above, after incorporation of final observations.

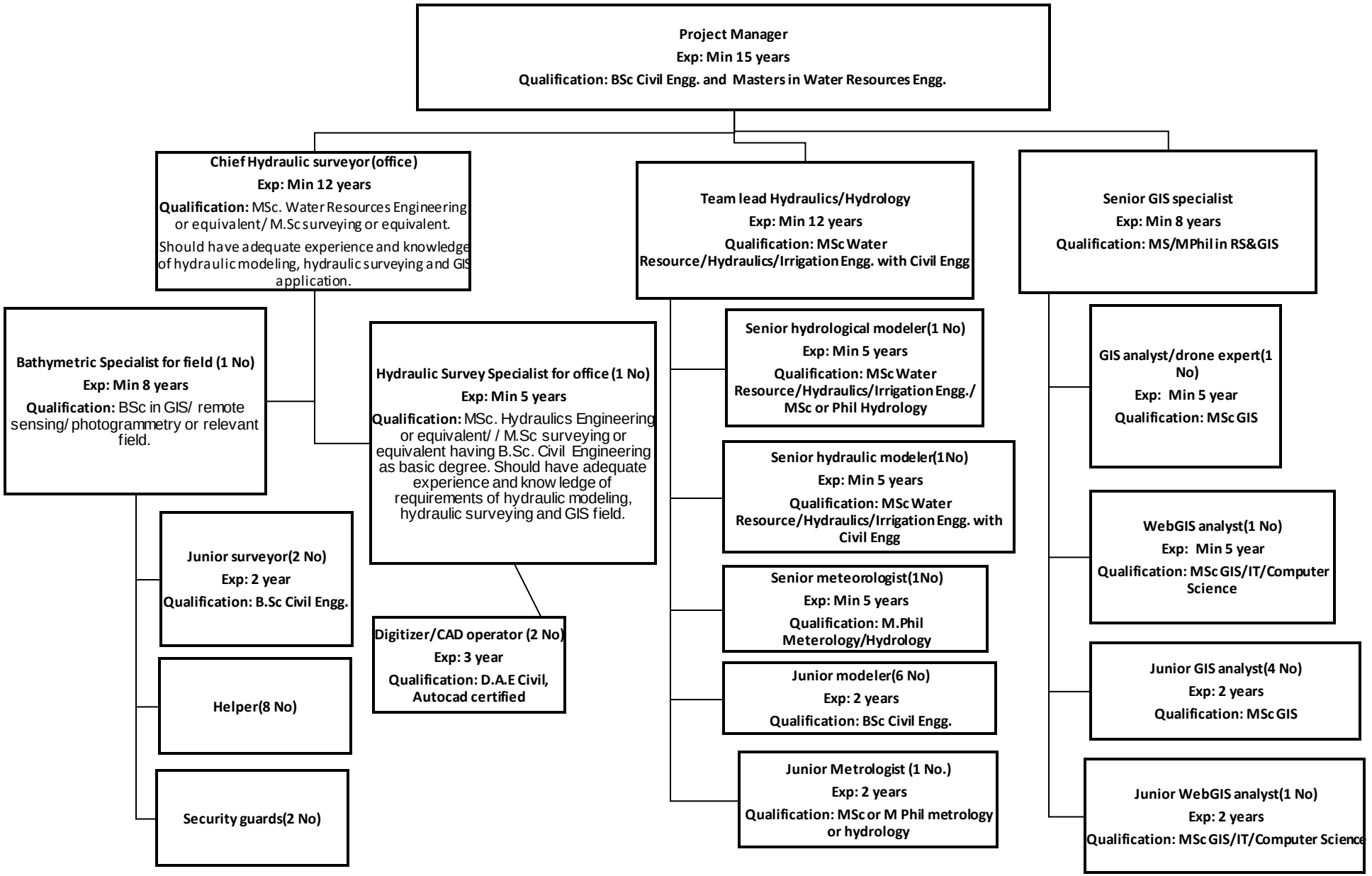
TENTATIVE WORK SCHEDULE

ACTVITIES				YEAR 1												YEAR 2					
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
TASK A	Hydraulic survey and development of digital elevation model	survey team in office		→	→	→	→	→	→	→	→	→	→	→	→						
		Survey team in field		→	→	→	→	→	→	→	→	→	→	→	→	→	→	→			
TASK B	Developemnet of Hydraulic and Hydrological model	Hydraulic modeling	Local Experts	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
			International Experts			→			→						→						
		Hydrological modeling		→	→	→	→	→	→	→	→	→	→	→	→	⇢	⇢	⇢	⇢	⇢	⇢
TASK C	Development of model for breaching section									→	→	→	→	→	→	⇢	⇢	⇢			
TASK D	GIS Maping and Web Integration			⇢	⇢	⇢	⇢	⇢	⇢	⇢	⇢	⇢	⇢	⇢	⇢	→	→	→	→	→	→

→ Continuous Activity

⇢ Intermitent activity

CONSULTANT TEAM ORGANOGRAM



REQUIRED EXPERIENCE AND QUALIFICATION OF EXPERTS				
Sr. No	**Posts**	**Minimum Experience**	**Qualification**	**Description of duties**
Project Management				
1	Project Manager	15 years post BSc Civil Engineering experience in relevant field	BSc in civil engineering and Masters in Water Resources Engineering or equivalent having BSc Civil Engineering as basic degree.	Overall supervision of project and ensure quality of modeling, quality of report and compliance of client's requirements.
Team1: Surveying and Mapping(field)				
2	Bathymetric Specialist (in field)	8 years post BSc experience in relevant field	BSc in GIS/ remote sensing/ photogrammetry or equivalent field.	Supervise survey activity in field and coordination with office. Assurance that survey is conducted along the lines provided by senior surveyor (office) using bathy meter and DGPS.
3	Junior Surveyor	8 years in relevant Field	Diploma in civil technology with certification of bathymetric survey	Conduct survey operation under supervision of senior surveyor.
4	Helper	1 Year	Matric	Assist in survey and carrying equipment.
5	Security Guard			Provision of security to all staff
Team-2: Surveying and Mapping (Office)				
6	Chief Hydraulic Surveyor	8 years post BSc experience in relevant field	MSc. Water Resources Engineering or equivalent/ M.Sc surveying or equivalent. Should have adequate experience and knowledge of hydraulic modeling, hydraulic surveying and GIS application.	Overall supervision of survey activity, ensure homogeneity in data collection, coordinate system and datum, and ensure the survey is conducted as per requirement.

7	Hydraulic Survey Specialist (in office)	5 years post BSc Civil Engineering experience in relevant field	MSc. Water Resources Engineering or equivalent/ M.Sc surveying or equivalent having B.Sc. Civil Engineering as basic degree. Should have adequate experience and knowledge of hydraulic modeling, hydraulic surveying and GIS application.	Provide coordination between modeling team and site survey team. Define geo-referred survey points and lines for field staff, keeping in consideration the requirement of modeling team. Transform and provide data to modeling team as per requirements.
8	Digitizer/CAD operator	3 years in relevant field	D.A.E Civil having AutoCAD certification with strong knowledge of AutoCAD application in engineering.	Assist in collection and transformation of survey data in required digital format.
Team3: Hydrological and Hydraulic modeling				
9	Team Lead (Hydraulics)	8 years post BSc Civil Engineering experience in relevant field	MSc. water Resources Engineering/ Hydraulics Engineering & Irrigation Engineering/ or equivalent degree	Overall supervision of modeling activity.
10	Senior Hydrological Modeler	5 years post BSc Engineering or 5 years post MSc experience in case of hydrology, in relevant field	MSc. water Resources Engineering/ Hydraulics Engineering/ Irrigation Engineering/ M. Phil Hydrology or equivalent degree	Development of all hydrological models.
11	Senior Hydraulic Modeler	5 years post BSc Civil Engineering experience in relevant field.	MSc. Water Resources Engineering/ Hydraulics Engineering/ Irrigation Engineering or equivalent degree	Development of all hydraulic models.
12	Senior Hydraulic Modeler(International)	5 years post BSc Civil Engineering experience in relevant field.	MSc. Water Resources Engineering/ Hydraulics Engineering/ Irrigation	Assist in development of hydraulic models in view of international standards.

		Experience of DSS with international exposure.	Engineering or equivalent degree	
13	Senior Meteorologist	5 years post M.Sc. experience in relevant field	M. Phil. Meteorology/ M. Phil Hydrology or equivalent	Collection, calibration and transformation of meteorological data for modeling.
14	Junior Modeler	2 years	B.Sc Civil Engineering	Assistance in hydrological/ hydraulic modeling.
15	Junior Meteorologist	2 years	MSc or M. Phil Metrology or Hydrology	Assistance in metrological/ hydrological modeling
Team4: GIS & Remote sensing				
16	GIS specialist	5 years post MSc experience in relevant field	MS/ M.Phil. in Remote Sensing & GIS or equivalent	Supervision of GIS activities.
17	GIS/RS analyst/Drone Expert	4 years	MSc. GIS or equivalent with GIS application	Extraction of modeling results in GIS format, update GIS layers, drone survey in field.
18	WebGIS Developer	3 years in relevant field	MSc .GIS /MSc.IT/MS computer sciences	Development of webGIS utility for integration of modeling results with webGIS application
19	Junior Web GIS Developer	2 years	MSc. GIS, MSc. IT or MS computer sciences	Assistance in all webGIS related tasks.
20	Junior GIS analyst	2 years	MSc. GIS	Assistance in GIS and RS related activities