Supporting Information for

Guidelines for the use of Unmanned Aerial Systems in flood emergency response

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1. Questionnaire

No	Questions
1	Can you describe briefly the overall role of your institution and in particular its activities in relation to flood risk management and emergency response?
	Can you outline what your particular roles is in relation to flood risk management and emergency response
2	Can you describe a flood event you were involved in? Or if you have not yet been involved how will you be involved if there is a future event
	What other organisations did (will) you work with when responding to this (a future) event?
	How was (will) the joint work (be) coordinated and what were (will be) the main means of communication?
3	At what stage of the flooding event did (will) you become involved and how were (will) you (be) informed?
	Were (will) any of the actions of others in responding to the flooding event (be) dependent upon information or decisions your organisation made (will make)? What actions or decisions?
	What were the main lessons you identified in relation to improving future responses to flood events?
4	What specific inputs are sought from your institution/department and who provides them?
	- Prior to a flooding event
	- During a flooding event
	- After a flooding event
5	What specific products are provided by your institution/department and to whom?
	- Prior to a flooding event
	- During a flooding event
	- After a flooding event
6	Which other organisations, departments, ministries, consultants, NGOs, civil armed forces, research institutions do you work with in connection to flood management and emergency response?

7	What are the challenges of working with these other departments, institutions, organizations?
8	What is the role of the states in flood emergency response and how are you involved with them? Are information exchanges and communications effective?
9	What is the role of the districts in flood emergency response and how are you involved them? Are information exchanges and communications effective?
10	Have you participated in a planned flood response exercise? If yes can you describe the nature and the sale of the exercise
11	Do you have access to all of the data and information you need to be able to make an effective contribution – if not what additional information would be useful and who do you think should provide it?
12	Does your organisation use technology for flood extent mapping and route evacuation identification? Which technology?
13	Do you use any models for flood emergency response (e.g., to detect best evacuation routes)? What models?
14	Would you find it useful to have a model that is able to predict evacuation routes in real time? Why?
15	What is your view on the use of small drones to assist in flood emergency response?
16	What information do you think could be gathered from small drones before, during and after flood events and how do you think this information could be used to improve flood emergency response activities?
17	How would you integrate drones in the emergency response tasks?
18	Would you be looking at using third party drone service providers or at developing in-house expertise in the field? Why?
19	Which other organizations / department / or people do you suggest I should approach to gain more insights into these questions?
20	Is there anything that was not included in this questionnaire but you would like to add?

2. Online survey

Q1. Type of organisation you are working

	Goverment (1)	Private sector (2)	Insurance sector (8)	University (3)	NGO (4)	Other (7)
Please select (1)	○	○	○	○	○	○

Q2. Your remote sensing background

	Low experience (20)	Medium experience (21)	High experience (22)
Please select (1)	○	○	○

Q3. Your familiarity with UAVs

	Low experience (27)	Medium experience (28)	High experience (29)
Please select (1)	○	○	○

Your familiarity with flood emergency response

	Low experience (21)	Medium experience (22)	High experience (23)
Please select (1)	○	○	○

Q4. During a flood event, how fast are you able to have access to flood extent? And what is the accuracy of that flood extent?

○ Time (hour) _____

○ Accuracy (metre) _____

Q5. During a flood event, how fast are you able to have access to flood depth? And what is the accuracy of that flood depth?

○ Time (hour) _____

○ Accuracy (cm) _____

Q6. During a flood event, how fast are you able to have access to flow velocity? And what is the accuracy of that flood velocity?

○ Time (hour) _____

○ Accuracy (m/s) _____

Q7. How fast would you like to have access to the flood extent? Choose one most preferred and one least preferred.

Most preferred		Least preferred
	>24 h	
	12-24 h	
	6-12 h	
	1-6 h	
	0.5 - 1	
	<0.5 h	

Q8. In combination with time, what level of accuracy you would like in the flood extent? Choose one most preferred and one least preferred.

Most preferred		Least preferred
	30 metre	
	10 metre	
	1 metre	
	0.5 metre	

Q9. For your most preferred time-accuracy combination for flood extent, is time or accuracy more important?

○ Time is more important

○ Accuracy is more important

Q10. How fast would you like to have access to the flood depth?

Most preferred		Least preferred
	>24 h	
	12-24 h	
	6-12 h	
	1-6 h	
	0.5 - 1	
	<0.5 h	

Q11. In combination with time, what level of accuracy you would like in the flood depth?

Most preferred		Least preferred
	50 cm	
	30 cm	
	20 cm	
	1 cm	

Q12. For your most preferred time-accuracy combination for flood depth, is time or accuracy more important?

○ Time is more important

○ Accuracy is more important

Q13. How fast would you like to have access to the flood velocity?

Most preferred		Least preferred
	>24 h	
	12-24 h	
	6-12 h	
	1-6 h	
	0.5 - 1	
	<0.5 h	

Q14. In combination with time, what level of accuracy you would like in the flood velocity?

Most preferred		Least preferred
	0.7 m/s	
	0.5 m/s	
	0.3 m/s	
	0.1 m/s	

Q15. For your proposed time-accuracy combination for flood velocity, is time or accuracy more important?

◯ Time is more important

◯ Accuracy is more important

3. Organisations involved in flood emergency response: England and India

England

Following the 2004 Civil Contingency Act, there are two categories of responding organizations (Category 1 and Category 2), and at the local level there are three levels of emergency response: Operational (Bronze), Tactical (Silver) and Strategic (Gold) [1]. Category 1 comprises the organizations that are at the core of the response to most emergencies and includes the emergency services, Local Authorities, National Health Service (NHS) bodies and the Environment Agency. Category 2 responders are co-operating bodies involved in incidents that affect their sector and include organizations such as the transport and utility companies.

The Local Resilience Forum is led by the local authority and brings together all the Category 1 and 2 responders within a police force area to facilitate co-operation (Table S1). Lead Local Flood Authorities (LFA) (i.e., County Councils, Metropolitan, Unitary Councils) are responsible for the management of local flood risk [2] including mapping, planning and assessment [3]. They fulfil this responsibility through working with others including other local councils, the Environment Agency, water companies and internal drainage boards. At the local level, a Tactical Coordinating Group (TCG) is convened when multiple agencies need to be co-ordinated [1]. The TCG comprises the most senior officers of each agency working within the affected area of operations. At the strategic level, the Strategic Coordination Group (SCG) coordinates the local multi-agency response and is chaired by an appropriate person such as a senior police officer or the Local Authority Chief Executive. When an incident affects more than one area a strategic level Response Coordinating Group is established. The Response Coordinating Group ensures consistent information, joint risk assessment and worst case scenario planning reaches all relevant partners; it can bring together key representatives of the SCG or other organizations but does not interfere in local command and control arrangements [4].

India

The national government develops policies and also provides advice and assistance when there are major events, whilst the States are the responsible for carrying out risk assessments and planning and implementing mitigation measures [5]. The State disaster management plans, initiated and coordinated by the State Disaster Management Authority, are implemented at District level by the District Disaster Management Authority (DDMA). In the event of a flood, multi-organization incident response teams (IRTs) are established at a local level. The IRTs manage the incident response, with the District Magistrate as incident commander [6]. Each State and District have a State and District Disaster Response Force. The incident commander can call on the services of the Response Force who are people from the local police department, civil defense, and fire and rescue service.

Table S1. Organisations involved in the flood emergency response in England and India and their associated role.

	Type of organisation	Organisation	Role
England	Government department	Department for Environment, Food and Rural Affairs (Defra)	Lead Government Department in England for response
		Ministry of Housing, Communities and Local Government - Resilience and Emergency Division (MHCLG RED)	Attend the local Strategic Coordinating Group and are a conduit for information between central government departments and the local area [8]
		Cabinet Office Briefing Room (COBR)	Crisis management arrangements activated in the event of an emergency which requires co-ordination at the national strategic level
	Government bodies and agencies	Meteorological Office	Source of meteorological information for the government, agencies, local responders and civil society

		Flood Forecasting Centre	Provide forecasts of river, surface water, coastal and groundwater flood risk to Category 1 and 2 responders
		Environment Agency (EA)	Involved in the design, construction, maintenance and operation of flood risk management assets, flood related monitoring, modelling, mapping, and warning. The EA has a strategic overview role for all sources of flooding, specific responsibilities for flooding from main rivers and the sea and provide advice to government, local authorities, emergency services and the public. A first responder to flood events and a member COBR arrangements.
		NHS England	To ensure that local NHS responders have the capacity and resources to deal with people related flood impacts [8]
		Highways Agency	Responsible for providing and managing highway drainage and roadside ditches, and must ensure that road projects do not increase flood risk [2].
	Local arrangements	Lead Local Flood Authorities (LFA)	Lead Local Flood Authorities (unitary authorities or county councils) are responsible for developing, maintaining and applying a strategy for local flood risk management in their areas and for maintaining a register of flood risk assets. They also have lead responsibility for managing the risk of flooding from surface water, groundwater and ordinary watercourses.
		District councils	Key partners in planning local flood risk management and can carry out flood risk management works on minor watercourses, working with Lead Local Flood Authorities and others, including through taking decisions on development in their area which ensure that risks are effectively managed.
		Local Resilience Forum (LRF)	Forum of all Category 1 and 2 responders within a police force area for the purpose of facilitating co-operation [1]
		Tactical Co-ordinating Group	A multi-agency group that co-ordinates and delivers the tactical response, also known as the Silver Group [1]
		Strategic Coordinating Group (SCG)	A multi-agency body responsible for co-ordinating the joint response at the local strategic level, also known as the Gold Group [8]
		Science and Technical Advice Cell	Specialist scientific and technical advice to local responders [1]
		Flood event responders	Police, Fire and Rescue
	Private sector	Utility companies	Water and sewerage companies are responsible for managing the risks of flooding from water and foul or combined sewer systems.
	Civil society	Volunteers	Volunteer flood wardens and provision of shelter and food and drink.
India	National agency	Ministry of Home Affairs	Coordinate flood response functions
		Ministry of Water Resources	Lead ministry for river flooding
		Ministry of Urban Development	Lead ministry for urban floods
		National Disaster Management Authority (NDMA)	Develop and implement flood related policies, guidance and plans
		Indian Meteorological Department	Weather forecasting and issuing alerts
		Central Water Commission	Forecasting river floods and issuing alerts
		National Executive Committee	Coordination of flood response functions
		National Crisis Management Committee	Review and monitoring of flooding events
		National Emergency Operation Centre	Warning, communicating and evaluating flood events
	State/District/Local agency	State Disaster Management Authority (SDMA)	Implementing flood related policies, guidance and plans

	District Disaster Management Authority (DDMA)	Coordinating and implementing flood related plans based on NDMA and SDMA guidance [6]
	DDMA advisory Committee	To advise the DDMA [6]
	State Emergency Operation Centre	Warning, communicating and evaluating flood events
	Flood event responders	Police, Fire and Rescue, including the National/State/District Disaster Response Forces.
Civil society	Interagency group (IAG)	Coordination and collaborative actions at the district level among NGOs, CSOs, district administration, stakeholders groups and international agencies [6]
	Social and Emergency Response Volunteers	Volunteer flood wardens and provision of shelter and food and drink.

References

1. HM Government Emergency Response and Recovery: Non statutory guidance accompanying the Civil Contingencies Act 2004 2013, 233.

2. Defra Flood and Water Management Act 2010. Department for Environment Food and Rural Affairs 2010, 84.

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5. NDMA National Disaster Management Plan (NDMP) 2016, 192.

6. District Disaster Management Authority Madhubani *District Distaster Management Plan - Madhubani*; District Distaster Management Authority Madhubani, Bihar, 2013;

7. Tripathi, P. Flood Disaster in India: An Analysis of trend and Preparedness. *Interdiscip. J. Contemp. Res.* **2015**, *2*.

8. Defra The National Flood Emergency Framework for England. December 2014. Department for Environment, Food and Rural Affairs 2014, 102.