

4. ASSESSING FLOOD RISK: DATA, METHODS AND ANALYSIS

4.1 SECTION CONTENT

This chapter covers elements involved in assessing the risk posed by flooding. For the purposes of the Flood Green Guide, flood risk involves knowing (1) who can be affected, (2) how they can be affected, and (3) where they can be affected. It is critical for the guide user to understand these issues in selecting and planning for the range of flood management methods in chapter 5. The chapter provides a review of flood risk management information needs, tells the guide user where to find the information, and offers a simple process to understand the nature of a watershed. Since a wide range of risk assessment techniques and tools are currently available to the guide user, this chapter focuses on the results that should be produced by any risk assessment and on how these results can be used to select and manage flood management methods. This chapter closes with a method to define institutional capacities to manage flood risk, a key consideration in deciding which flood management approaches are most appropriate for the local context.

4.2 FLOOD RISK ASSESSMENT

4.2.1 DEFINING FLOOD RISK

For the purpose of the Flood Green Guide, **flood risk** represents the threat of flood damage to individuals, households, communities and society. There are several sources for accepted definitions of flood risk; most definitions are understood as a function of hazards, exposure, vulnerability and **capacity**.

The guide user should understand flooding in terms of "the type, source and **probability** of flooding,"¹ the vulnerability to damage, and the capacities that exist to resist this damage.² These elements can be simply presented as

Flood Risk = Flood Hazard, Exposure, Vulnerability modified by the Capacities to resist this damage.³

- Hazard is a function of frequency, magnitude and extent.
- **Exposure** is the potential area covered by a flood.

¹ Jha, Bloch and Lamond, Cities and Flooding.

² Ibid; Zhiyu et al., Guidelines on Urban Flood Risk.

³ Zhiyu et al., Guidelines on Urban Flood Risk; IPCC, "A Special Report," 65-108.

- Vulnerability is the potential for harm.
- Capacities are attributes that can reduce negative impacts.

Procedures to assess flood risk are discussed in section 4.2.3. Selecting the most appropriate procedure depends on the data available for each of the four risk elements.

4.2.2 WHY ASSESS FLOOD RISK?

Although the process of assessing flood risk can seem complicated and time consuming, a good **flood risk assessment** will identify:

- How frequently floods of specific magnitudes and extents are likely to occur.⁴
- Where damage will occur the location of people and physical and natural resources that will be affected by flooding.
- Who is vulnerable people affected by floods for each frequency, indicating the gender and age of those vulnerable where damage is likely to occur.
- Why they are vulnerable the physical, social, environmental and economic impacts expected from a flood of a given frequency and magnitude; how these differ by gender and age.
- What the capacities are to avoid or reduce the impacts of flooding before it occurs, or to alleviate the impacts after flooding.

Flooding can affect people in the same location differently, and flood impacts can vary significantly over relatively small distances. A risk assessment helps identify these differences so flood management efforts can be tailored to the specific locations and populations at risk.

Flood risk assessments help communities understand the extent and nature of their flood risk, an essential requirement for getting people to support risk management actions. A risk assessment should incorporate specific community concerns about flooding, increasing the credibility of the assessment results. Engaging communities in flood risk assessments creates a more participatory approach, which is essential when flood management methods depend on collective actions.

Finally, flood risk management involves time and financial resources. Many flood risk management methods involve changing the way society understands and addresses flooding; in other words, some methods require a change in human behavior. Choosing flood management options and convincing people to finance and support them, therefore, depend on the guide user's developing a clear understanding of flood risks and how they can be managed and reduced to an acceptable level. A clear and well-understood flood risk assessment can help build political and community support and engagement in the chosen flood management methods.

4.2.3 ASSESSMENT PROCEDURES

Flood risk assessment procedures include recording local knowledge of damages and who was affected in past flood events, and highly technical modeling. The latter may use remotely sensed data to assess possible levels of future flooding and calculate expected damage based on detailed spatial analysis of

⁴ Flood frequency is usually calculated by professionals using time series data and is often expressed as the probability a flood of a specific magnitude will occur sometime during a specific time period (also called the recurrence interval, the term preferred by hydrologists). For example, a flood of a specific magnitude occurring during a 100-year period will have a probability of occurrence in any given year as 1 in 100, or a 1% chance in any given year. This does not mean one flood in 100 years, but that there is a probability that a flood of a specific magnitude will occur at least once in any given 100-year period.

flood location, duration and assets at risk. In addition, risk assessments can consider the level of resilience of those who are affected by a flood, thus incorporating their capacities to recover from flood damage.

The Flood Green Guide anticipates that most users will have conducted, or will have access to, some type of flood risk assessment. Where this is not the case, users can refer to the following resources for information on risk assessment methods and identify a relevant approach:⁵

- PrepareCenter.org
- Disaster Assessment Portal
- PreventionWeb

The risk assessment methods available through these sources focus on low-cost and highly participatory approaches manageable at the community level. Depending on the local context, these methods can be fully adequate for community flood risk management planning purposes. However, it is essential to regularly update risk assessments to capture changes to the local context, including a changing climate, which may affect flood risk and thus require an adjustment to management approaches.

Guide users also should be aware that there are both commonalities and differences in concepts, conceptual frameworks, and methodologies for flood risk assessments and climate change adaptation (CCA) assessments, although all may be useful to understanding flood risk. The primary disaster risk reduction assessment tools are vulnerability and capacity assessments (VCA). The most common CCA assessment methodology is vulnerability (impact) assessments (VA or VIA).⁶

Finally, guide users should consider developing the Watershed Characterization Report (see section 4.5). The characterization report collects a range of information on a watershed that can be used in the risk assessment process as well as the selection of the optimal flood management options.

4.2.4 REPORTING FLOOD RISK ASSESSMENT RESULTS

For the purpose of the Flood Green Guide, a flood risk assessment report should ideally cover the six areas of information described in this section and be accompanied by several annotated maps with as much supporting information as possible. The guide uses the Flood Risk Data Summary table (see Framework Worksheet) to organize assessment results into a format that can be used in the Flood Green Guide Framework (framework) (see chapter 2) to help select the optimal flood management methods.

If the guide user is using a **geographic information system** (GIS), the information sets collected as part of the risk assessment process and the watershed characterization (described in section 4.5) can be established as layers (files) and used to generate maps indicating the results of the assessment. If GIS is not available, the results can be presented in narrative and tabular form supported by hand-annotated maps. (Read more about GIS in section 4.4 of this chapter. The information that should be collected for a GIS or presented as tables and in narratives is described in sections 4.2.4.1–4.2.4.6).

⁵ For flood risk assessment resources, see the PrepareCenter.org website, managed by the International Federation of Red Cross and Red Crescent Global Disaster Preparedness Center, http://preparecenter.org/topics/community-risk-assessment; the Disaster Assessment Portal, http://www.disasterassessment.org/; and PreventionWeb, http://www.preventionweb.net/ english/professional/trainings-events/edu-materials/?tid=44 (search for risk identification and assessment).

⁶ More information on VCA, DRA and hazard assessments can be found at the websites in the previous footnote. Information on climate change adaptation assessments can be found at the Climate Adaptation Knowledge Exchange (search vulnerability assessments in the virtual library), cakex.org. Other resources include the CARE Climate Vulnerability and Capacity Analysis handbook, http://careclimatechange.org/tool-kits/cvca/, and Flowing Forward, http://www.flowingforward.org/.



An annotated map showing the extent of flooded areas and direction of flood water.

4.2.4.1 Spatial and Temporal Extent of Flooding

To make flood mapping easier, a separate map for each flood frequency can be developed. (If flood modeling is used, historical and projected flooding should be noted separately and marked differently on the maps.) Copies of the map developed in the Watershed Characterization Report (see section 4.5) can be used in recording flood information to compare the features of the watershed along with the impacts and causes of flooding.

Typically, five flood frequencies are identified:7

- 1. 1:1 (100% probability of flooding in any one year)
- 2. 1:5 (20% probability in any one year)
- 3. 1:10 (10% probability in any one year)
- 4. 1:20 (5% probability in any one year)
- 5. 1:50 (2% probability in any one year)

If data on all of these frequencies is not available, then the known flooding frequencies should be indicated.

⁷ See footnote 4. These frequencies/recurrence intervals may also be expressed as 100%, 20%, 10%, 5% and 2% chance of flooding in any one year.

4.2.4.2 Factors Contributing to Flooding

The factors identified as contributing to floods for each of the five probabilities should be identified. These factors can be classified as anthropogenic (the result of human action) and natural (the result of natural conditions). For instance, annual flooding may be caused by heavy rainfall at the beginning of the summer, while flooding once in five years is associated with several weeks of heavy rainfall and water backing up behind a bridge. The levee is an anthropogenic (engineered) factor, while several weeks of rainfall are a natural factor.

To the extent possible, contributing factors of flooding should be based on well-defined parameters (e.g., observed precipitation) and observations. These factors can be listed in a table, indicating their return period, the scope of flooding experienced, and other natural and anthropogenic factors related to the cause of floods. The same information can be added to an annotated map.

4.2.4.3 Damage Incurred or Expected

The locations affected at each flood frequency should be described and damage listed with as much detail as possible for each flood return period. Valuing damage in monetary terms is preferred. If this is not possible, then the listing should be a detailed catalogue of all damage that has occurred or is expected to occur for the five flooding frequencies. This inventory should be based on historical damage or on projected damage when a flood risk assessment has used modeling to anticipate future flood areas and damage.

Where a catalog of damage is developed, a monetary value should be determined for each type of loss based on replacement costs; these values should then be multiplied by the number of items and totaled for all losses. This process generates an indicative monetary loss estimate. The same process and values should be applied to all flood damage so that results are comparable.⁸

Damage information should be added to the annotated maps in summary form.

4.2.4.4 Vulnerable Groups

A list of the groups that have been most affected by flooding in the past and/or could be affected by future flooding should be developed.⁹ This list should indicate the level of damage experienced for each group to the extent this information can be identified. It can include people who live in a specific flooded area; populations can be defined by social or economic conditions (e.g., elderly, less wealthy). An explanation for why specific groupings are considered vulnerable to flooding should be provided.

In most risk assessments, assumptions are made about who is most vulnerable, such as single-headed (as opposed to couple-headed) households, those households with limited assets, the elderly, people with disabilities and similar marginalized groups most vulnerable to hazards; these groups can be included in the list. It is necessary, however, to ask whether other groups are also vulnerable to flooding and to add these groups to the list.

To the extent possible, these groups' locations should be marked on the maps that indicated the spatial extent of the five flood frequencies.

4.2.4.5 Capacities - Vulnerable Groups

The listing of vulnerable groups should include an indication of the capacities that each vulnerable group has that will enable them to resist or respond to damage caused by flooding. **Capacities** can be described

⁸ While a comprehensive monetary loss number of each flood event is preferred, an indicative number for each event, using the same procedure for estimating losses for all floods, is an acceptable alternative.

⁹ Not all residents of a flooded area are assumed to be vulnerable, and the level of vulnerability will vary based on socioeconomic factors and location as well as the effectiveness of warnings, preparedness and evacuation capacities, all of which can be considered in assessing adaptive capacity.

as "the combination of strengths, attributes and resources available" to a vulnerable group to reduce the negative impacts of flooding¹⁰ and often include coping strategies (what is done in the case of flooding) and adaptations (the changes that are made, or can be made, to reduce the impact of flooding).

4.2.4.6 Capacities – Institutions

Understanding the abilities of communities and organizations to implement flood management actions is critical to help select and manage the optimal flood management methods. To assess and capture information on capacities for use in selecting management methods and for use in the Flood Green Guide Framework process, the Institutional Flood Management Capacity Assessment table should be completed (see Framework Worksheet Robert 2) as part of documenting the risk assessment results.¹¹ (Refer to chapter 3 for more information on institutions and policy-making.)

4.3 PRIORITIZING ASSESSMENT RESULTS

Risk assessments usually include a process for prioritizing results to identify which risks should be addressed first. Prioritization provided through the risk assessment process should be indicated in column 9 of the Flood Risk Assessment Data Summary table (Framework Worksheet), chapter 2). If the risk assessment does not produce a clear risk prioritization, an initial prioritization can be done—for example, by financial loss parameters:

- Add a 10th column to the table that divides the level of loss by the number of persons affected and then by the expected frequency of flooding, providing the expected per capita loss per year.¹²
- Rank the level of per capita loss per year from high to low.

The flood hazard events with the highest per capita losses per year are initially considered the highest priority, with the order of priority decreasing as the per capita loss decreases.

Those involved in the flood risk assessment, along with a wider group of relevant participants where possible, should confirm the initial ranking. In some cases, the per capita damage ranking can conceal other social factors important in the ranking process. To address this, the initial per capita damage ranking should be compared to the flood impact on specific vulnerable groups (column 6 in the Framework Worksheet Flood Risk Assessment Data Summary table). Taking into account adaptive capacities (column 7), identify whether priorities need to be adjusted to better reflect the expected impact of flooding on humans and livelihoods, or on another identified priority such as maintenance of ecosystem services. Any such changes should be made on an updated column 9 of the table. The prioritization process should involve careful consideration of the ranking factors and not be rushed in order to minimize the chance of discounting areas of social, cultural or environmental importance.

¹⁰ Marilise Turnbull and Edward Turvill, Participatory Capacity and Vulnerability Analysis: A Practitioner's Guide, Oxfam Policy and Practice: Climate Change and Resilience 8, no. 1, February 2012, 71-113.

¹¹ For more information about institutional mapping methods, see SPICOSA Project Report, http://www.coastal-saf.eu/design-step/ support/introducing_institutional_mapping.pdf, and the World Bank's *Institutional Perception Mapping*, http://web.worldbank.org/WBSITE/ EXTERNAL/TOPICS/EXTSOCIALDEVELOPMENT/EXTTOPPSISOU/0,,contentMDK:20591794~menuPK:1572522~pagePK:64168445~piPK:6416 8309~theSitePK:1424003~isCURL:Y,00.html.

¹² For example, 20,000 people affected with losses of \$400,000 from a flood that is expected to take place once in 20 years; or \$20 of losses per person, then divided by 20, the number of years expected between floods, or an average loss of \$1 per person per year over the period of when the flood is expected to take place.

4.4 FLOOD RISK ASSESSMENT AND MANAGEMENT-RELATED INFORMATION NEEDS AND SOURCES



mages courtesy of NASA

Satellite imagery from NASA shows the Brahmaputra River running through India and Bangladesh. The first photo shows the Brahmaputra River during a year of average rainfall, and the second shows the river swollen in 2014 after a year of severe flooding from above-average rainfall and meltwater from the Himalayas.

This section summarizes types of information helpful for both assessing and selecting flood management techniques. In addition, this section provides information on how to collect and use information on weather conditions and flood monitoring (useful in assessments and in flood management). It includes a discussion of the roles of GIS, remote sensing and watershed modeling in generating information for flood management.

4.4.1 TYPES OF INFORMATION

The information needed to understand risk and manage floods covers a range of topics, and can be organized into the following categories:

Hydrologic data: including water level or depth; flow rates (usually in cubic meters per second); precipitation (snow and rain, in millimeters); quantity totals and per period of time (per minutes or hours); runoff rates and (soil) retention; and flow rates for springs (cubic meters per second).

Geophysical data: including the nature of the geology, soil, watershed slope, aspect (direction the slope faces) and hazards present (e.g., landslide zones, volcanic activity, earthquake probability, frequency and type).

Natural and built environment data: including the locations of rivers, streams, lakes and other water bodies and natural resources as well as built infrastructure – including roads, buildings, irrigation systems, flood management structures and other engineered structures that can impact flooding. Built environment data should also include sites of cultural, religious or social importance.

Landscape and land use data: including the types of land cover (e.g., vegetation, hard surface); how the land as a natural resource is used (e.g., farming, pasture, housing); how land use has changed over time; and land use plans, if they exist.

Social data: including data on population numbers, composition and location; livelihoods and access to livelihood assets (financial, natural, fiscal, social and physical); education; perception and attitudes toward

the use of the environment and natural resources; potential, past or actual conflicts related to the use of natural resources; and existence of organizations or social networks with roles in managing natural and other resources in a watershed (e.g., community forest committees, irrigation water users' associations).

Governance data: including information about flood management or related water management authorities (if they exist); the local disaster, land use and natural resource management administration authorities; and planning and procedures for dealing with flooding, including preparedness, warning, response, recovery and risk reduction plans and practice.

Flood impact and management data: including data on past losses from flooding, where these losses have taken place, and the economic and social impacts of these losses. This category also includes investment in reducing flood impacts with structural and non-structural interventions.

4.4.2 SOURCES OF INFORMATION

4.4.2.1 Human Sources (Informants)

Human sources – including longtime local residents and community groups, local government officials, and specialists working for the government, NGOs, the private sector or academia (together generally referred to as **informants**) – can provide detailed, locally relevant information on flood causes and consequences, as well as identify management options and lessons from past efforts to manage floods. Informants are an excellent source for understanding the social aspects of flooding.

Information provided by informants is often qualitative – for example, an elderly woman speaking about her experiences with flooding when she was young. This qualitative information, however, can be organized quantitatively through the use of questionnaires and/or guided interviews or group discussions.¹³ Human sources of data can provide a deeper background to flooding issues from their experiences in a watershed over time.

Quantitative data and analysis of flood factors are often available from those working in local government or NGO offices and local or regional academic institutions. This data can be incorporated into more formal analysis, including a GIS (see section 4.4.4).

Finally, while many organizations document lessons learned, informants are often a source of specific and experience-based lessons about the causes and consequences of flooding, as well as what has or has not worked in flood management in the past. Interviewing local informants is an essential part of any flood risk assessment or management effort.

4.4.2.2 Reports and Documents

Listed below are resources that can help with a flood risk assessment. Many of these are available online.

- water level and flow records (e.g., stream gauges), often compiled into tables and reported on a monthly or annual basis by water resource managers
- official flood and flood damage reports—useful for the details of the process and timing when flooding occurred; comprehensive damage and recovery data; potential risk reduction measures and lessons

¹³ The guided process uses a formal set of questions to guide discussions, with responses appropriate for each question noted. However, the discussion should be allowed to move forward without posing and answering each question in order. This technique is more suited for the open discussions that take place in a group setting.

- flood management plans, project documents, and final reports detailing the scope of the flood hazard (often including flood maps) and the costs and benefits of flood management options
- academic research articles, reports and other publications that document flood risk and impacts and may include risk management options
- drawings, paintings and pictures depicting flooding, often useful in understanding the scale of a flood and communicating flood impact to target audiences
- newspaper articles and books on floods, often useful for providing a broader perspective on flood impacts by emphasizing human impacts and losses

4.4.2.3 Physical Evidence

While historical evidence of flooding impact is often included in reports and documents, and provided by informants, it is also available from physical evidence like on-site inspections of flooded areas after flood levels have dropped; markers recording historic flood levels; and other visual evidence of past flood events, including flood level marks on buildings. Such physical evidence will help the guide user understand how flooding affected a location in the past, and educate stakeholders about flood impacts and management options. While collecting physical evidence is best done immediately after a flood, hydrologic or flood specialists can often collect useful information well after a flood event. For instance, a hydrologist may be able to assess flood depth and flow rates by measuring stream channels and flooded areas, and a soil scientist specializing in flood impacts can identify the extent and impact of flood sediment.



Post-disaster housing reconstruction project built in floodplain in Aceh, Indonesia.

4.4.2.4 Flood and Other Maps

Maps of actual or potential flood areas are often included in government, academic, or NGO reports and documents. Flood maps can be used to

- verify actual flood damage in discussion with informants and when verifying physical evidence;
- indicate changes in flood impact areas based on changes in watershed conditions, including the worsening of flooding or reduced flood impacts due to management efforts. These can include maps produced using flood modeling and GIS to generalize different flood scenarios.

Also useful in flood risk assessment and flood management are maps covering the following:

- topographic information
- watershed composition and boundaries
- hydrologic, geological and topographic features
- floodplain composition and boundaries
- historic extent of flooding
- land cover and land use
- built infrastructure: roads, buildings, bridges, etc.
- land formations and water storage areas (e.g., wetlands)
- areas of potential or actual conflict
- protected areas and areas of unusual natural, cultural or social value

In using maps, the guide user should consider

- Whether a map is up to date. Floods, the development of the built environment and land use changes can quickly make maps dated. Where possible, maps should be updated before use, or the differences between information on the map and what is actually on the ground clearly noted. (In some cases, these differences can be used to assess flood impacts.)
- The scale of a map. When combined, information from maps of different scales is only as accurate as the least accurate map. If maps of 1:50,000 and 1:5,000 scales are combined, the resulting accuracy is 1:50,000 much less than the 1:5,000 map.

If appropriate maps do not exist or are not up to date, participatory or crowd-sourced mapping can be used.¹⁴ This is normally done by having one or more informants either mark up an existing map with changes or draw a new map covering the information required (e.g., extent of most recent flooding). This data can be used to update old maps or create new maps, usually by transferring the data into a GIS. Additional information on participatory mapping can be found in *Good Practices in Participatory Mapping*.¹⁵

Many maps useful for flood management are available online through a keyword search using technical terms (e.g., "flood mapping") or geographic terms (e.g., "flood map Jakarta").

4.4.2.5 Remote Sensing

Remote sensing is the science and art of obtaining information about an object, area or phenomenon by analyzing data acquired by a device that is not in contact with the object, area or phenomenon under

¹⁴ Participatory and crowd-sourced mapping examples include openstreetmap.org and Ushahidi.com.

¹⁵ Jon Corbett, Good Practices in Participatory Mapping: A Review Prepared for the International Fund for Agricultural Development (IFAD) (International Fund for Agricultural Development (IFAD), 2009), http://www.ifad.org/pub/map/pm_web.pdf.

investigation.¹⁶ In recent years, remote sensing and GIS (digital, remote sensing data can be incorporated into a GIS) have become critical tools for flood prevention, flood risk reduction and flood monitoring.

Remotely sensed data is typically collected using a sensor that detects (passive) or emits and detects (active) electromagnetic waves on a satellite, airplane, helicopter, unmanned aerial vehicle (UAV), or balloon. The most common sources of remotely sensed imagery for flood management are

- aerial photos, often dating to the 1950s or earlier. Common challenges with aerial photos include expense and need to digitize hard copies for GIS. The use of UAVs means getting aerial photos is quick and low cost¹⁷ but can involve legal restrictions and other issues.¹⁸ A low-cost and generally less legally challenging method of aerial mapping is to use a balloon or kite to collect aerial photos.¹⁹
- satellite imagery, available from commercial (e.g., Google Earth, Digital Globe) and nonprofit sources. This imagery, which can date back more than 20 years, is useful for assessing changes to watersheds, land use, urban areas, coasts and river courses over time. Note that accessing the UN-based system at no cost normally requires a threatened or actual disaster.

Quite often, national agencies involved in remote sensing – or university-based programs in geography, remote sensing, cartography, land use, environmental management or disaster management – have access to satellite imagery and GIS and capacities to do at least basic analysis. These services can be free or low cost and can involve students doing a practicum, particularly at the graduate level.²⁰ In some cases, these organizations can access imagery through International Charter: Space and Major Disasters and perform detailed analysis locally.²¹

4.4.3 LOCAL DATA COLLECTION

It is critical for the Flood Green Guide user to understand the local context of flooding, including information on local precipitation, temperature,

i ADDITIONAL INFORMATION

Selected Sources of Satellite Imagery and Analysis

International Charter: Space and Major Disasters is a unified system of space data acquisition and delivery to those affected by disasters (https:// www.disasterscharter.org).

UN-SPIDER connects disaster risk management and space communities, and facilitates capacity-building and institutional strengthening (http://www.un-spider.org/linksand-resources/data-sources).

UNOSAT (via UNITAR) supports international humanitarian assistance operations to respond to crises (http:// www.unitar.org/unosat/maps).

Hazards Data Distribution System (HDDS) provides access to beforeand-after imagery of flooding and other disaster events (http:// hddsexplorer.usgs.gov/).

¹⁶ Thomas M. Lillesand, Ralph W. Kiefer, and Jonathan W. Chipman, *Remote Sensing and Image Interpretation*, 7th ed. (Hoboken, NJ: John Wiley and Sons, Inc., 2015).

¹⁷ See blogs: DroneFlyersCraig I., "Quadcopter Aerial Photography and Video on a Shoestring Budget - Drone Flyers," *Drone Flyers*, May 4, 2014, http://www.droneflyers.com/2014/05/quadcopter-aerial-photography-video-shoestring-budget/;SUAS News, "Drone Imagery Helps Map Flood Risk," June 2015, http://www.suasnews.com/2015/06/drone-imagery-helps-map-flood-risk/.

¹⁸ See Daniel Gilman, Unmanned Aerial Vehicles in Humanitarian Response, OCHA Policy and Study Series 10, June 2014.

¹⁹ See Stewart Long, "An Illustrated Guide to Grassroots Mapping," last accessed March 12, 2016, http://archive.publiclaboratory.org/ download/Grassroots_Mapping_English_2_0.pdf.

²⁰ For an example of free or low-cost mapping, see openaerialmap.org.

²¹ See United Nations Office of Outer Space Affairs (UNOOSA), "International Charter Space and Major Disasters," UN-SPIDER Knowledge Portal, accessed February 2016, http://www.un-spider.org/space-application/emergency-mechanisms/international-charter-space-and-major-disasters.

and wind and water levels. Managers need this information for real-time monitoring and warning for potential floods, to understand how flood risk may change over time, and to assess the effectiveness of flood management efforts. A community can easily begin to collect climate data and conduct simple flood hazard analysis using easily available resources. In addition, a community-based system of monitoring weather conditions can contribute to community participation in, and ownership of, flood risk management. (For more information on how community participation benefits flood management, see chapter 3.)

4.4.3.1 Local Weather Station

Data on precipitation, temperature and wind are needed to define the conditions that could lead to flooding. This data is usually available from NMHSs, agricultural stations, or river basin authorities, among other locations.

To complement these sources (and to collect data close to flood risk areas), a simple station to collect precipitation, temperature and wind data can be constructed at minimal costs. A basic station consists of the following:

- A rain or snow gauge that is monitored once every 24 hours at the same time each day (preferably after the normal period of heaviest precipitation), with the total precipitation in millimeters (mm) recorded, and the gauge emptied once daily. Rain gauges can be purchased, or they can be constructed by cutting a 1.5-liter plastic bottle just below the top and inverting the top into the lower part of the bottle as a collector. The side of the bottle can be marked in millimeters, or a ruler can be used to measure water depth.²²
- A thermometer that is recorded twice a day for instance, at dawn and 1500 hours. (The thermometer should be protected from direct sunlight.)
- A windsock that is recorded at the same time as the temperature. The direction of the wind using directions of a compass (e.g., north, southwest, etc.) and the strength of the wind should be indicated (see appendix C, Beaufort Wind Scale). The windsock can be made of a meter-long piece of cloth and should be at least three meters above the ground, unobstructed by buildings or trees.

The data on precipitation, temperature and wind are recorded in a daily report (and can be posted on a public board) for later analysis.

Contact the local weather services office for more information on how to set up a weather station.²³

4.4.3.2 Water-Level Gauge

A water-level gauge in the nearest stream or river can complement the weather station. This gauge, which can be a strong pole placed in a stream, or markings on the abutment of a bridge, should clearly indicate water depths in tens of centimeters (for instance, in alternative white and black bars, each marking 10 cm of height so that the water level can safely be seen from the shore). The water gauge should be monitored at the same time as the precipitation gauge is read, and the data should be recorded together with the weather data.

Advice from local weather station staff or the national hydrologic service can be used to set up the stream water gauge station.

²² For locations where snow is collected in the gauge, remove the collector (cut-off top of the bottle) before it snows. Melt the snow to measure the amount of water collected in the snow. Because of different types of snow, the amount of water resulting once the snow is melted is more important than the actual depth of snowfall.

²³ Note that the same station can be used to monitor for drought.

4.4.3.3 Data Collection and Organization

Community groups (e.g., a water users' association, a women's gardening group) can organize climate data collection. Data collection can also be integrated into school activities via youth groups, such as a weather watcher's club, or as part of the normal curriculum.

4.4.4 DATA ANALYSIS TOOLS

4.4.4.1 Geographic Information System

A GIS is software that enables the manipulation of digitally stored spatial information. A GIS provides a framework to turn raw data into clear results and can be used to analyze, model, evaluate, plan, inform and make decisions (see figure 4.1). GIS software allows for mapping and analysis of information that can guide evaluation of risk and planning decisions.

In the context of flood risk management, GIS software can be used to

- evaluate the impact of historic flooding
- identify flood hazard zones and potential losses from floods of different levels
- plan evacuation routes, designating open areas that can be used in the event of a flood and plan flood impact reduction interventions
- monitor flood conditions in real time
- illustrate a local spatial plan and location in the watershed
- analyze social, economic and other data about populations at risk from flooding
- visualize and quantify damage to gray and green infrastructure

A GIS allows manipulation of different sets of stored data to assess variations in potential flood impact. For example, a GIS can be used to show how the addition of a flood retention basin might reduce the depth and area of a flood, thereby indicating the efficacy of different levels of flood management interventions. While modeling using a GIS can be complicated, making simple changes to specific data in the GIS (e.g., adding a retention basin) can show the effects of interventions (e.g., a reduction in flow), thereby contributing to decisions on flood management options.

A variety of GIS software packages are available, ranging from free to costly (>\$1,000/year) and offering a range of capabilities. Commercial packages such as ESRI ArcGIS[™] are most common and provide users with a broad set of extensions and tools, including a flood planning application template and hydrologic modeling. Open-source (free) GIS packages also exist, including GRASS, QGIS and SAGA GIS.²⁴



FIGURE 4.1 A SCHEMATIC OF GIS LAYERS USED IN ANALYSIS

24 Sources for open-source operating system software include, for Linux, http://www.linuxmint.com/ and http://www.ubuntu.com/; for Windows, Mac, and Linux, http://www.osgeo.org/.

4.4.4.2 Flood Modeling

Modeling floods involves collecting data on precipitation, **stream flows**, land use and land cover, and other factors; accessing topographic information; and using formulas to project the height and extent of floodwaters under the specific conditions set in the model. An overview of flood modeling can be found in the book *Flood Mapping*, which is available online for free use.²⁵

The **rational method** is a simple process to model runoff in urban areas and small watersheds.²⁶ The model uses data on rainfall intensity, watershed slope, area of the drainage and the nature of the land cover to project peak water discharge at the lower end of the watershed.

While the rational method is not as precise as other, more complex modeling, it provides results that are useful in defining the peak volume (cubic meters per second) of water expected from a watershed for a given level of precipitation. By changing the volume of expected precipitation, different discharge rates can be estimated. While peak discharge alone does not indicate the area that will become flooded, it can be used to determine the maximum capacity requirements for flood channels, drains, and gutters, and the impact of flood retention or diversion.

Instructions on using the rational method are available on the web, particularly from academic courses and in drainage system guidance. "A Study Guide on the Empirical Version of the Rational Method to Estimate Peak Discharge Runoff" provides an overview of the rational method and how it can be applied.²⁷ More complex flood modeling is appropriate for medium to large watersheds and should be undertaken if there are sufficient resources to hire a hydrologist or through work with a university.

4.4.4.3 Local Weather and Stream-Level Analysis

Local weather and stream level data can be analyzed in a number of ways. A simple but useful approach is to use data collected over the course of a year or more to answer the questions in table 4.1. The answers to these questions provide a basis for identifying possible weather and water level conditions that could lead to flooding. Answers should be updated annually as new data becomes available. To better engage a community in the management of flooding and other climate risks, a monthly report (using charts of the data collected) can be posted near the weather station or in another frequently visited location.

²⁵ Associated Programme on Flood Management (APFM), ed., *Flood Mapping*, Integrated Flood Management Tools, no. 20 (Geneva, Switzerland: World Meteorological Organization: Associated Programme on Flood Management, 2013), http://www.apfm.info/publications/tools/ APFM_Tool_20.pdf.

²⁶ Gordon Keller and James Sherar, Low-Volume Roads Engineering: Best Management Practices Field Guide (Washington, DC: USAID, 2003), http://pdf.usaid.gov/pdf_docs/Pnadb595.pdf.

²⁷ Bruce Carey, "A Study Guide on the Empirical Version of the Rational Method to Estimate Peak Discharge Runoff," July 2014, http://landcare.org.au/wp-content/uploads/2013/01/Empirical-version-of-the-Rational-method-to-estimate-peak-discharge-Runoff.pdf.

QUESTION	IMPLICATION
When (which months, days) during the year does the most precipitation fall?	Knowing peak precipitation times helps identify times of year when flooding is possible.
When (which months, days) during the year are river/stream levels the highest?	Knowing when river/stream levels are the highest helps identify when flooding is possible.
Do periods of high precipitation and high river/stream levels occur at the same time, or close to the same time, during the day?	Knowing whether precipitation and high river/ stream levels occur near the same time helps identify when flooding may occur due to precipitation.
Do periods of high temperature and high river/stream levels occur at the same time, or close to the same time?	Knowing whether high temperature and high river/ stream levels and flooding occur near the same time helps identify when flooding may occur due to high temperatures (e.g., from the melting of snow or ice).
Do periods of high wind speeds and high river/stream levels occur at the same time, or close to the same time?	High winds are often associated with storms that can trigger heavy precipitation. Knowing whether high wind speeds and high river/stream levels occur near the same time helps identify when flooding may occur due to storms that may not occur where the data is being collected.

TABLE 4.1 QUESTIONS TO GUIDE A SIMPLE WEATHER AND STREAM-LEVEL DATA ANALYSIS

4.5 CHARACTERIZING THE WATERSHED

The guide recommends that managers understand the basic features of a watershed (see chapter 3). Knowing these features, and being able to compare the features to those in other watersheds, helps build understanding of what causes floods and the measures required to manage them.

Very large watersheds may require breaking down the characterization by sub-watershed (e.g., upper elevation, lower elevation), especially if there are significant differences in the characteristics throughout the watershed.

A manager can use a range of informational sources to characterize a watershed. (Section 4.4 of this chapter provides an overview of sources.) Mapping (also described in this chapter) is one of the most effective ways to record and present information. In addition, possible sources of information for watershed characterization are identified in the Watershed Characterization table (see Framework Worksheet).

The watershed characterization process involves two steps:

- 1. Completing the Watershed Characterization table
- 2. Completing the Watershed Characterization Report

Both steps involve using a map of the watershed to document the information collected.

4.5.1 WATERSHED MAPS

A map of the watershed is needed for both characterization steps (see section 4). The map should be detailed enough to identify key physical aspects of the watershed—including infrastructure and occupied areas, streams, rivers, and other physical features—and have space for making notations. In general, a minimum of two copies of the map are needed: one for completing the Watershed Characterization table and one for the Watershed Characterization Report. (The first map can be considered a working document, and the second should be a more formal presentation of the information collected.)

4.5.2 WATERSHED CHARACTERIZATION TABLE

The Watershed Characterization table (Framework Worksheet S, chapter 2) should be completed by those living in the watershed, based on their knowledge and observations, including the key information detailed in chapter 3. While one person familiar with the watershed can complete the table, it is recommended that groups of community members be involved in the process. Specialist input – for instance, from water managers, agricultural stakeholders, natural resource managers and/or forest agents – can also be used to complete the form or add technical details.

The manager completes the table by circling the appropriate answers to the 13 questions in the first column and by adding text. The answers should also be noted where appropriate on the watershed map.

At a minimum, a working map should be attached to the characterization report (see section 4.5.1). The following information should be noted on the map:

- areas of different slope
- soils
- vegetation
- wetlands
- lakes and marshes
- dominant land use
- key infrastructure
- built-up urban areas

The map used for the Watershed Characterization table can provide a focal point for discussions, and users should feel free to revise and change markings and notations over the course of the characterization process.

The table also provides summary information on the implication of different answers or input in terms of flooding and flood management options. (See chapter 5 to learn how these implications can be used in selecting appropriate approaches to managing flooding.)

4.6 ADDITIONAL RESOURCES

- Associated Programme on Flood Management (APFM). Flood Mapping. Integrated Flood Management Tools Series, no. 20, (Geneva: WMO, 2013), http://www.apfm. info/publications/tools/APFM_Tool_20.pdf.
- 2. Disaster Assessment Portal, http://www.disasterassessment.org/default.asp.
- 3. International Charter: Space and Major Disasters, https://www.disasterscharter.org.
- International Fund for Agriculture (IFAD). Good Practices in Participatory Mapping: A review prepared for the International Fund for Agriculture, 2009, http://www.ifad. org/pub/map/pm_web.pdf.
- 5. International Federation of Red Cross and Red Crescent Global Disaster Preparedness Center, PrepareCenter.org, http://preparecenter.org/topics/ community-risk-assessment.
- UNISDR, PreventionWeb, http://www.preventionweb.net/english/professional/ trainings-events/edu-materials/?tid=44.
- 7. UNOSAT (via UNITAR), http://www.unitar.org/unosat/maps.
- 8. UN-SPIDER, http://www.un-spider.org/links-and-resources/data-sources.
- 9. USAID, NOAA, SERVIR, https://www.servirglobal.net/default.aspx.
- 10. USGS, Hazards Data Distribution System (HDDS), http://hddsexplorer.usgs.gov/.