Assessing Flood Risk for Small Water Systems with GIS

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Image Courtesy of ready.gov/floods.

For those of us living in the Western U.S., the news is dominated by stories that describe the effects of water scarcity and how climate change is making the future of many water sources uncertain. Yet, drought is not the only potential hazard that climate change is contributing to. For instance, on Oct. 24, 2021, Sacramento had 5.44 inches of rain in a 24-hour period, causing some local flooding and exceeding the previous record set in 1880. This massive rain event shows that even in a drought, flooding is still a real concern.

Across North America, rainstorms are growing more intense. More rain falls faster, flooding streets and gutters, and causing streams and rivers to overflow. Drinking water systems may be particularly vulnerable to flooding. Many are located in low lying areas that provide easy access to the lakes or rivers that serve as the drinking water source, but those locations are also vulnerable when the source water is impacted by flooding. During a flooding emergency, residents trapped in homes or shelters, possibly without power, may have no way to get bottled water and limited options to boil water if the drinking water supply becomes contaminated. How can a small water system assess its risk and start thinking about mitigation?

Inventory Assets in Flood Plains

Mitigating disasters starts with effective planning. For flood planning, the Federal Emergency Management Authority (FEMA) develops and publishes Flood Insurance Rate Maps (FIRM) for most of the country. The maps are used to designate flood insurance rates through federally-backed programs and are widely recognized as the standard official flood risk maps. These maps can be accessed via FEMA's National Flood Hazard Layer Viewer and the area of interest exported either as a PDF of the map or as a GIS layer.

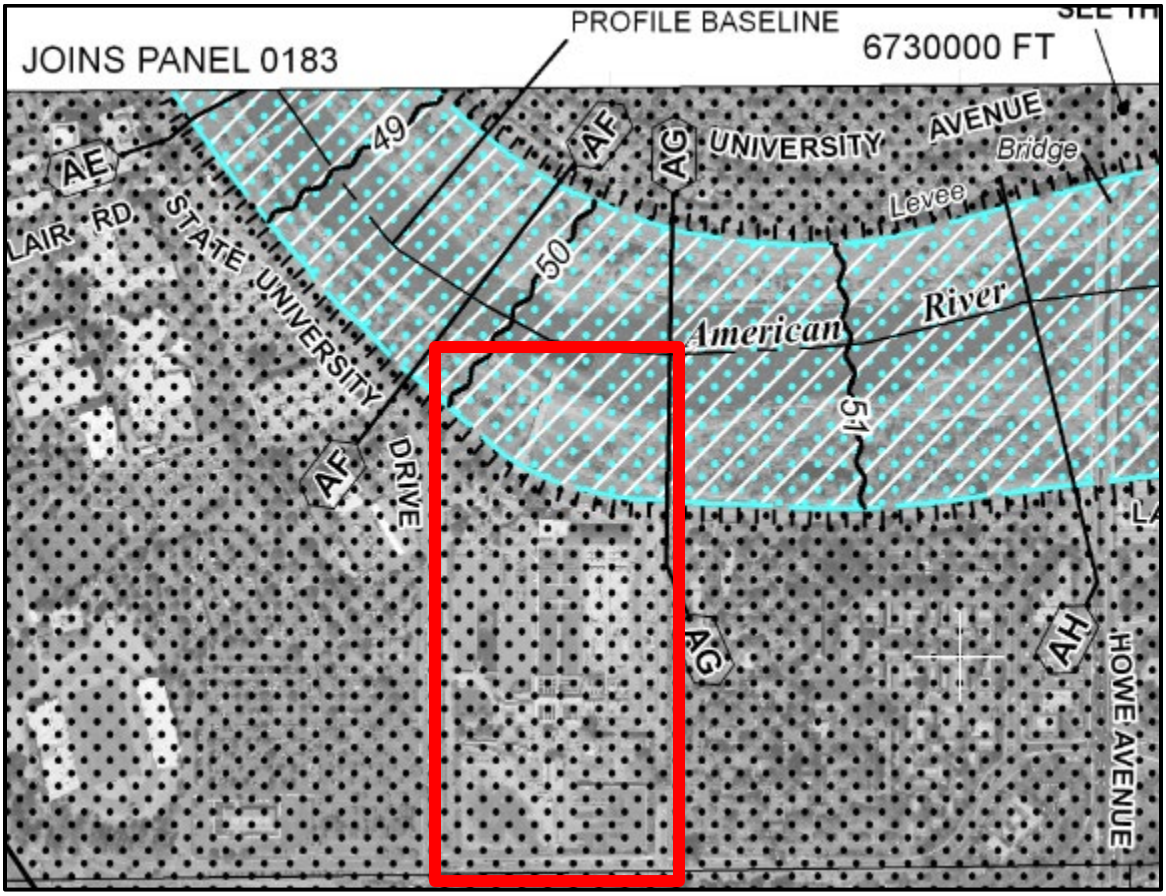

Figure 1. A Portion of a FEMA Flood Insurance Rate Map (FIRM) Depicting the E.A. Fairbairn Water Treatment Plant Adjacent to the American River in Sacramento, CA.

While a PDF of the FIRM will show if a facility falls within a 100- or 500-year floodplain, the resolution is lacking (Figure 1). Using a GIS layer of the floodplain maps can make analysis much more powerful. As discussed in a previous blog entry, using GIS as part of asset management is particularly helpful when viewing assets spatially. Overlaying assets with a FIRM, as shown in Figure 2, is a good example of this. Using tools built into GIS programs like ArcGIS, it is possible to update the attribute tables for all assets that fall within a floodplain layer with that information. This can save quite a bit of time when compared to manually updating hundreds or possibly thousands of asset attribute tables.

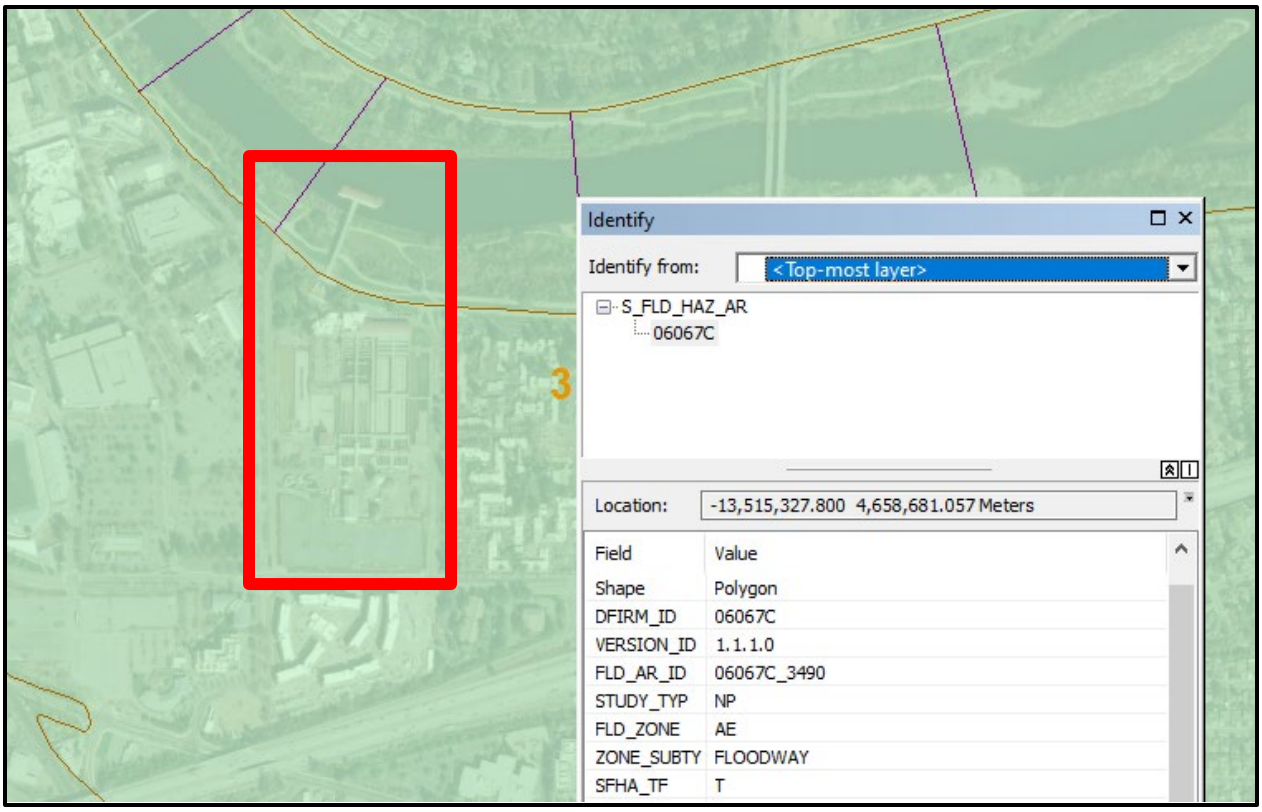

Figure 2. A Portion of a FEMA Flood Insurance Rate Map (FIRM) in ArcGIS with Associated Layer Data Depicting the E.A. Fairbairn Water Treatment Plant Adjacent to the American River in Sacramento, CA.

Determine an Acceptable Risk Using Asset Management Techniques

If assets are located in a flood plain, risk can be evaluated through a multi-step process to identify assets at risk, evaluate the level of risk, and identify ways to ensure essential drinking water systems can function during extreme events. An asset management approach provides a framework for this.

The EPA publishes Flood Resilience: A Basic Guide for Water and Wastewater Utilities containing worksheets and advice that water and wastewater utilities can use to walk through the risk assessment process as well as mitigation strategies. Figure 3 shows a sample table from the guide.

Vulnerability					Consequences		Priority for Mitigation[5]		
1	2	3	4	5	6	7	8		
Asset/ Operation	Height of Asset Above Floor (ft)[1]	Elevation of Asset (ft)[2]	Elevation of Flood Threat (ft)[3]	Vulnerable to Flooding? (Yes/No)[4]	Replacement Costs ($) for Asset	Impact to Facility Operations from Asset Failure	Low (✓)	Moderate (✓)	High (✓)
Raw Water Pump	0.5	238.5	240	Yes	20,000	Inability to feed raw water to the process tanks will render the facility **inoperable.**			✓
Air Compressor	0.75	238.75	240	Yes	15,000	Inability to provide high air pressure will limit the operation of pneumatic valves on the treatment process systems. This will render facility **inoperable.**			✓
Automatic Transfer Switch	2.5	240.5	240	No	5,000	If water damaged the Automatic Transfer Switch, the facility would be **inoperable.**	✓		
Electrical Outlets	2.5	240.5	240	No	5,000	The outlets for general use are **not critical** to facility operations and they are located above the 500-year flood elevation.	✓		

Figure 3. Asset Criticality Sample Worksheet from the EPA Guide*: Flood Resilience: A Basic Guide for Water and Wastewater Utilities*.

For each asset, risk is determined by its vulnerability to a flood event. As shown in the vulnerability section of the worksheet in Figure 3, risk is largely associated with whether or not flood water will reach the asset, making the elevation of each asset a critical attribute for risk determination. The consequence of failure should evaluate the impact to regular facility operations as well as emergency operations. This is an important distinction as regular drinking water plant operations may not be feasible during a flood event; however, it may be possible to continue to deliver already treated water from a storage tank and maintain distribution system pressure with some flood mitigation actions.

A key difference between traditional asset management and flood risk evaluation are the mitigation actions that can be taken to ensure a minimum level of service. While traditional asset management may focus on preparing for the end of an asset's predicted service life and then replacing the asset, flood mitigation actions can include waterproofing an enclosure or electrical connections or elevating the asset a few feet to place it above the predicted flood water elevation. In these cases, the flood mitigation actions can be inexpensive, performed by drinking water system maintenance staff, and focus more on protecting critical assets than replacing them.

In a time of increasingly extreme weather events, being aware of the risk that flooding poses to critical facilities is important for managers of small water systems. While the process may seem daunting, following the step-by-step guidance provided in the EPA flood resilience guide and leveraging resources like the FIRM GIS layers and an existing asset management database can greatly simplify the process.