ONE PERCENT ANNUAL CHANCE FLOOD RISK-SOLUTIONS TO COMMUNICATION AND TECHNICAL CHALLENGES INVOLVING LEVEES AND DAMS

DOUG BELLOMO
AECOM Arlington, Virginia, United States of America

1. INTRODUCTION

There are a multitude of complex technical issues and risk communication challenges when it comes to estimating how dams and levees might perform during a 1% annual chance flood. As a Production and Technical Service contractor for the US Federal Emergency Management Agency (FEMA), we have been helping identify flood hazards nationwide. The final products developed include digital flood boundaries, estimated 1% annual chance flood elevations, and floodway boundaries. This information is used by FEMA to price federally backed flood insurance and by states and local governments to mitigate flood risks through floodplain management practices. The impact of water infrastructure such as levees and dams must be considered in this work, thus coordinating and collaborating with owners and operators of these facilities is critical.

This paper describes how, the US Army Corps of Engineers (USACE), the Federal Emergency Management Agency (FEMA), the private sector and others help ensure that the flood hazard data developed for the National Flood Insurance Program (NFIP) considers dam and levee structures in a technically credible way. It will also provide insights into how US governmental organizations are communicating complex technical issues and flood risk information to the public.

2. BACKGROUND

Data available online through the National Oceanic and Atmospheric Administration (NOAA) suggests disasters in which flooding has contributed to damages are on the rise in the United States (NOAA,2019). A very notable event, hurricane Katrina in August 2005, is estimated to have caused over $165b in damage and killed over 1,800 people. Other events, however like hurricanes Ike and Gustav in September 2008, combined caused over $43b in damage and killed approximately 165 people. Superstorm Sandy which slammed into the New York/New Jersey coastline in October 2012 killed approximate 159 people and caused over $72b in damage. More recently three consecutive hurricanes in August and September of 2017 caused combined damages of over $270b and killed over 3,100 people (. In fact, as noted in Table 1, total disaster damages from events in which flooding contributed to the losses is approaching 1 trillion US dollars since 1980 (NOAA, 2019).

Table 1 : US Flood Related Disaster Damages By Decade

Decade	# of Flood Related Events	CPI-Adjusted Damage (US Dollars Billions)
1980's	8	$37.5
1990's	16	$88.9
2000's	18	$376.8
2010's	28	$469.2
TOTAL	70	$972.3

With this increase in damage and human suffering has come increased US investments focused on improving the way in which flood hazards and risks are analyzed, communicated, and managed. Two federal agencies playing a role in helping to advance these areas are the US Army Corps of Engineers (USACE) and the Federal Emergency Management Agency (FEMA).

Both agencies have deep experience in identifying flood hazards, quantifying flood risk, communicating this information to the public, and helping people manage flood risk. They are working closely together to help inform public policy debates regarding new ways to reduce flood risk and increase resiliency against flooding.

3. US FLOOD HAZARD MAPS, FLOODPLAIN MANGEMENT, AND FLOOD INSURANCE

Though the US National Flood Insurance Program (NFIP) has evolved since its inception in 1968, the underlying structure of the program has remained consistent: federally backed flood insurance is made available in local communities that agree to adopt and implement a set of minimum floodplain management standards. These standards largely involve ensuring new construction (and substantial improvements to existing homes and businesses) is built to minimize flood damage from storms with a 1% or greater annual chance of being equaled or exceeded in any given year (commonly referred to as the "100-year" or "base flood").

To facilitate both the floodplain management and flood insurance aspects of the program FEMA has worked with state and local governments to develop and maintain maps depicting floodplain boundaries and in some areas has estimated base flood elevations (1% annual chance exceeded flood stages). These maps form the basis for pricing federal flood insurance policies and for implementing local floodplain management regulations.

In 2015 there were approximately 22,000 local governments participating in the NFIP, about 5.1 million flood insurance policies in force, and over 1.13 million miles of 1% annual chance flood hazard analysis (rivers, lakes, streams, and coastlines) (TMAC, 2015).

Along detailed studied rivers and streams, the flood hazard data shown on the NFIP maps include: floodplain boundaries (estimated extent of 1% annual chance flood), flood elevations, floodway boundaries, and in some cases 0.2% annual chance floodplain boundaries. Figure 1 is a typical section of NFIP map depicting this data.

The NFIP, including the resulting flood maps and floodplain management elements, has been helping people in the US avoid and reduce flood damages since the inception of the program. The program has also played a key role in ensuring the burden of flood losses and managing flood risk is shared. Nonetheless, in 2009, at the direction of Congress, FEMA published a multi-year plan which represented the beginning of a shift from identifying a single flood hazard (the 1% annual chance flood) and implementing minimum federal floodplain management standards to assessing flood risks and managing them more directly (FEMA, 2009).

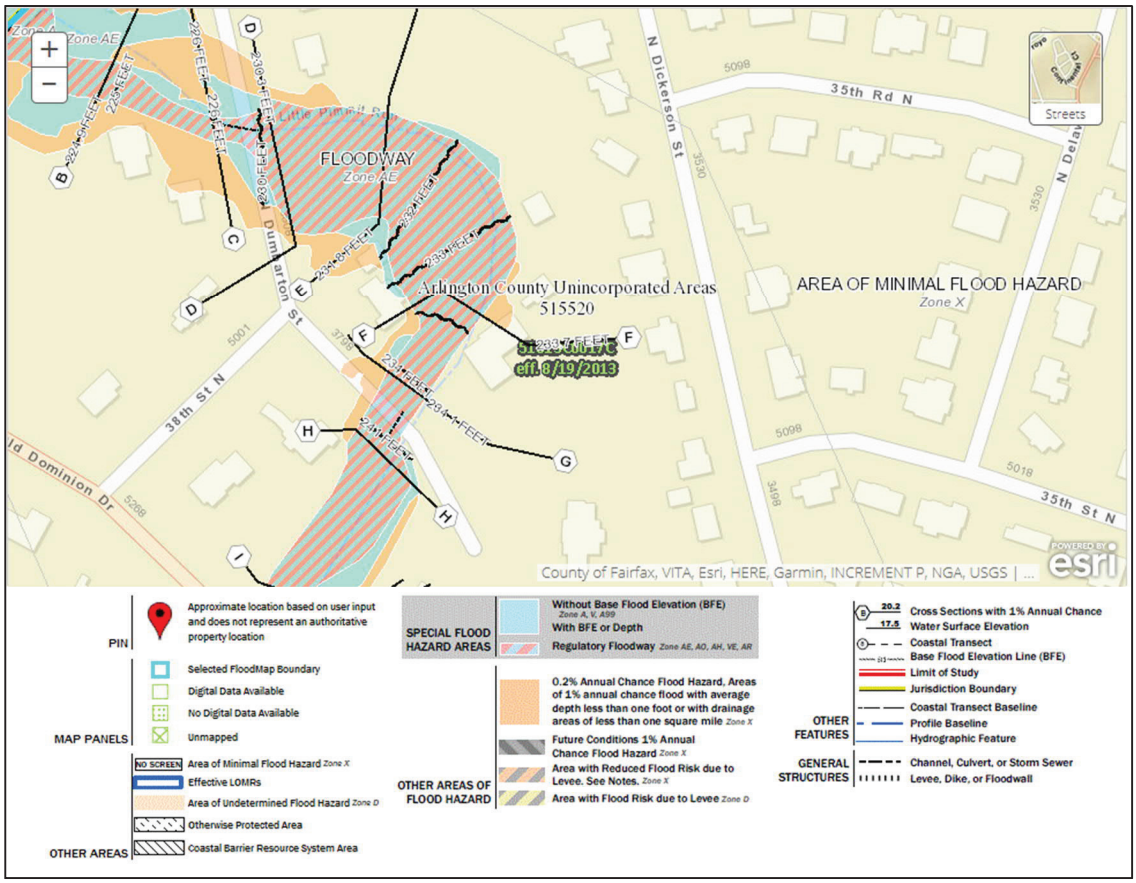

Figure 1 : Typical NFIP Flood Hazard Information

4. FLOOD MAP DEVELOPMENT PROCESS

While FEMA has procedures in place for small map updates or amendments by request, they also perform more wholistic updates on a routine basis. These updates are planned out based on need (indications that the hazard has changed, or improved methods might lead to different results) and other factors in coordination with states and once funded involve

engaging local communities and the public in the process. Most updates will take anywhere from 3 to 5 years before going into effect for flood insurance pricing or floodplain management purposes. The steps in Figure 2 below outline at a high level the steps FEMA takes to updates NFIP maps (FEMA, 2014).

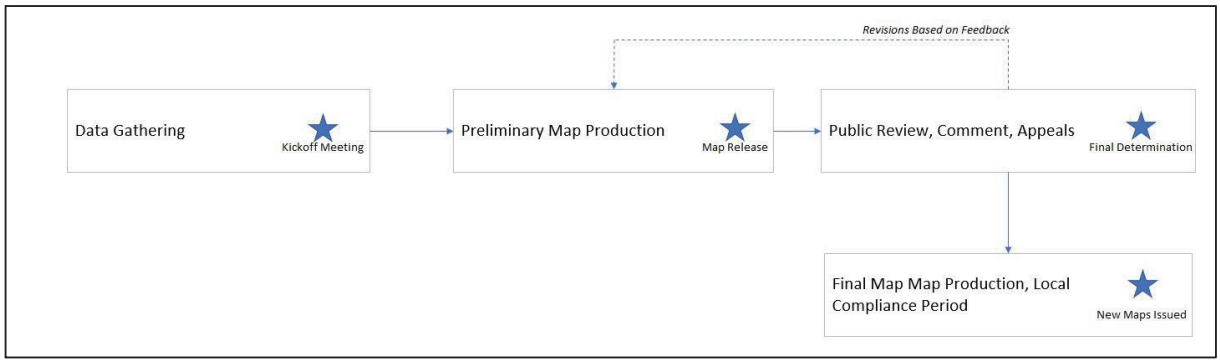

Figure 2 : Generalized FEMA NFIP Map Update Process

Step 1: Gather Information

Once a watershed has been identified as in need of an update, key information such as current land cover data, topography, existing hydraulic models, historical flood records, hydraulic structure measurements (e.g. bridge and road crossings, levees, dams, culverts) and other information necessary to ensure the most accurate and current information is collected. That information is then reviewed more closely to either confirm an update is likely warranted or to document that the existing flood map is sufficient.

Step 2: Kickoff Meeting

Should an update be warranted, FEMA, state, local, and tribal governments convene to kick off the project and begin the development of a project plan. This plan ultimate results in the development of a document that outlines the schedule and scope of the map update. Areas to be updated or studied are identified, the method and models to be used are decided, what data is or will soon be available for inclusion in the analysis is outlined, and who will be performing which elements of the study are determined. Those performing technical aspects of the study are generally either capable state and local government agencies or FEMA hired contractors who specialize in flood hazard analysis, risks assessments, and mapping.

Step 3: Preliminary Map Production and Release

Once the scope and schedule have been established, those conducting the work begin the development of a preliminary map. The map updates are conducted using a robust set of guidelines and standards developed, maintained, and published online by FEMA including guidelines and standards for assessing flood hazards and risks impacted by levees and dams, which are explained in a bit more detail later in this paper.

Once completed the preliminary map and its companion flood insurance study are presented to local officials and ultimately the general public. Publication of the preliminary map and study kicks off a comment and appeals period where review of the data, methods, and analysis are encouraged and anyone with better information is invited to propose changes to the products.

Step 4 : Public Review, Comment, Appeals, and Final Determination

Because the maps underpin local floodplain management rules and insurance pricing, they can have impacts on land use and construction requirements as well as the cost of federal flood insurance. For this reason, they undergo both formal and informal comment and appeals periods. By law, anyone who believes his/her property rights have been adversely affected has 90 days to file an appeal. The appeal must clearly indicate which of the proposed flood elevations are scientifically or technically incorrect and why or demonstrate that alternative methods would result in more correct estimates of base flood elevations (Code of Federal Regulations, 1984).

Beyond review of the flood hazard data presented, FEMA also seeks information to improve the utility of the maps such as improvements to base map features such as the location roads, corporate limits, or more current aerial images. FEMA reviews all comments and appeals, incorporates them as appropriate, and ultimately issues a letter to communities impacted by the changes noting that comments/appeals have been resolved and the updates have been completed.

Step 5: Final Map Production, Compliance Period, New Maps Released

A six-month period kicks off with the issuance of the letter indicating all appeals and comments have been resolved and the updates have been completed. During this period, FEMA finalizes the maps and study for publication and communities participating in the program adopt the maps into local floodplain management ordinances. Upon conclusion of this period, the new maps are published and made available on the FEMA mapping website. It is important to remember

however that the maps can be revised or amended by request anytime anyone has information that would improve them so in some respects they are never "final".

5. DAMS AND LEVEES

As noted previously, dams and levees present unique challenges when it comes to mapping flood hazards and estimating flood risks. Both FEMA and the USACE have worked together to ensure the impact these structures may have on flood conditions are understood and considered as part of the NFIP map update process. To this end, the USACE in coordination with FEMA administers two critical national scale datasets: The National Inventory of Dams (USACE, 2020), and the National Levee Database (USACE, 2020). Further, both agencies have worked together to develop flood hazard identification guidance and standards for flood map updates.

5.1 Datasets: National Inventory of Dams (NID) and National Levee Database (NLD)

As of Jan 2020, there were a total of 91,468 dams in the NID. The average age of those dams was 57 years, about three quarters of the high hazard dams have an Emergency Action Plan (about 25% do not), about 69% are regulated by state agencies with an additional 5% regulated by Federal Agencies. For any given dam within the NID, you can find the owner type (Private, Local Government…), the impoundment area and height, the dams primary purpose, whether it's regulated, and if it has an Emergency Action Plan.

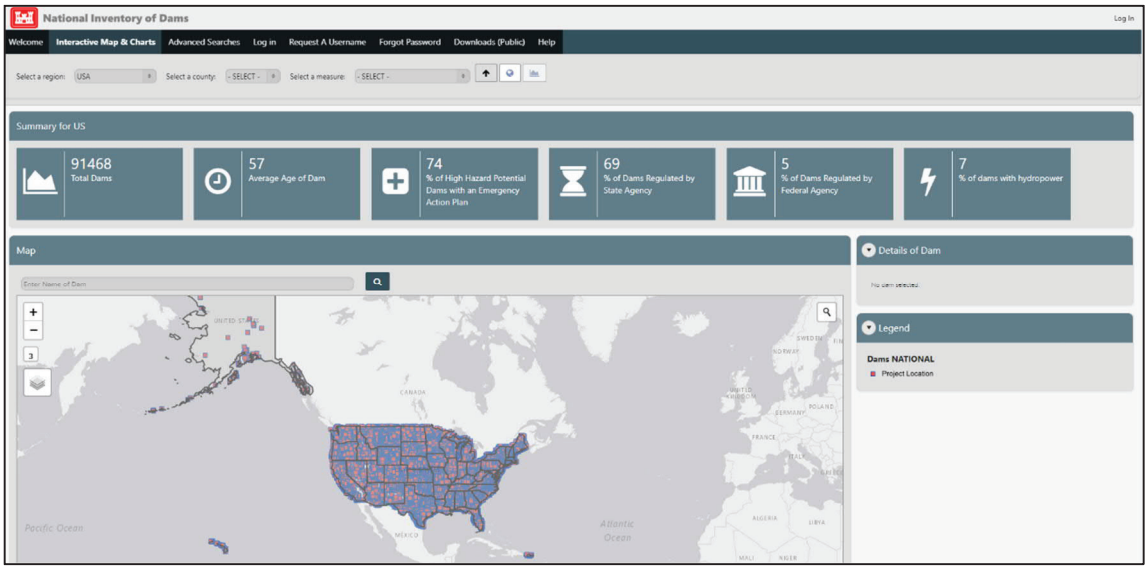

Figure 3 : Screenshot of USACE National Inventory of Dams

The NLD, also administered by the USACE, is the most comprehensive resource of levee information in the United States. As of Jan 2020, it was comprised of 8,624 levee systems with linear features whose combined length is approximately 27,881 miles. Those systems also contain some 45,703 different components (pumps, gates, closure devices…) and, like dams, have an average age of 56 years. For any given system in the NLD, users will find information about the area serviced by the system including its size and total property value, number of structures, and population within the service area. For some systems the USACE has performed a risk screening which includes a general characterization of the risk (very low thru very high) and a summary of key findings including risk drivers.

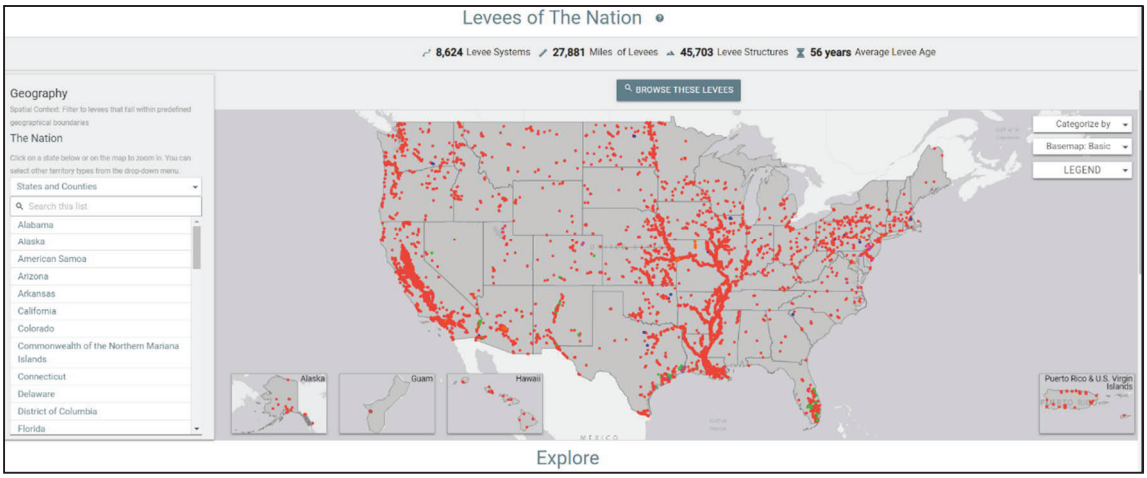

Figure 4 : Screenshot of USACE National Levee Database

Both datasets are a great resource in the data gathering phase of an NFIP flood study update. Beyond that however, given they are national in scale, they are also an excellent way to gain insights into the overall health of this critical infrastructure. For example, in March of 2018, the USACE released "A Summary of Risks and Benefits Associated With the USACE Levee Portfolio" (USACE, 2018). While the assessment was done on only a subset of the NLD, it provides interesting insights into what is driving the risk of failure across their portfolio, the number of people and assets being serviced by the systems analyzed, and what entities are primarily responsible for operation and maintenance.

5.2 Levees and FEMA Flood Map Updates

Though both levees and dams are similar in that they are man-made and can have impacts on 1% annual chance flood hazards, they are treated differently during the FEMA flood map update process.

For example, when it comes to levees, there are federal regulatory requirements that must be met before a levee system can be shown on an NFIP map as affording protection from the 1% annual chance flood. A levee meeting these requirements is said to be "accredited", however, FEMA is careful to note that because there are great uncertainties in how a system might perform during any given flood event, the accreditation of a levee system does not constitute a warranty or guarantee of performance. Rather it demonstrates the levee system has been "designed in accordance with sound engineering practices to provide protection from the base flood." (Code of Federal Regulations, 2001).

Among other items, the levee accreditation regulations require (Code of Federal Regulations, 1986):

- The crest of the levee be set 3 feet or more above the computed based flood stage, though exceptions to 2 feet may be approved (e.g. freeboard);
- All openings must be provided with closure devices that are structural parts of the system during operation and design according to sound engineering practice;
- Embankments and levee foundation must be analyzed for stability;
- The magnitude of settlement must be analyzed in the context of potential loss of freeboard;
- Interior drainage analyses must be performed to determine the extent of flood hazards resulting from rainfall and other sources;
- Operation plans must address procedures for system closure during an event, warning systems, interior drainage elements (pump stations and gravity drains), and they must include specific actions and assignments or responsibility by name or title including annual operational testing;
- Maintenance plans must be officially adopted, and a copy provided to FEMA noting all maintenance activities are under the jurisdiction of a Federal or State agency, an agency created by Federal or State law, or an agency of a community participating in the NFIP

Once a levee system is found to meet the necessary requirements, the flood risk reduction service area is shown on the NFIP map as outside the 1% annual chance floodplain associated with the flooding source or sources it was designed against (though interior drainage floodplains remain in many cases). FEMA works hard to ensure people living behind accredited levees understand that uncertainties in the analysis exist and floods larger than the 1% are possible particularly when looking over longer periods of time. Through their outreach efforts, FEMA strongly encourages home and business owners to purchase flood insurance both inside and outside mapped floodplain. Further, FEMA and the USACE work hard to convince communities to take action to lower their risks by adopting floodplain management standards that exceed minimum program participation requirements or by recommending specific interim risk reduction measures.

FEMA and the USACE worked together in 2013 to develop new standards for mapping areas behind levees that do not meet the accreditation requirements (FEMA, 2013). The new procedures were designed to be compliant with all applicable federal regulations, leverage local knowledge and input through enhanced engagement, align limited risk assessment resources commensurate with flood risk, while also considering unique characteristics of the levee system being studied. These procedures were a significant improvement to the previous methods which largely assumed any levee that did not meet the accreditation requirements would have little impact on 1% annual chance flood hazards – a fair assumption for small levees, but less appropriate for larger systems that, for example, fell short of the documentation requirements outlined in the federal regulations.

In short, the flood hazard mapping procedures developed are more refined than the prior approach and better meet the needs of the public by looking at how the systems components may perform both individually and as a whole. The National Academy of Sciences (NAS) reviewed the procedures developed and determined "they were founded on sound algorithms with sound science and engineering behind them." (NAS, 2013).

FEMA and the USACE continue to work together to improve the science associated with estimating flood hazards in and around levee systems and to ensure the people serviced by them understand the risks they face and are taking action to improve their safety.

5.3 Dams and FEMA Flood Map Updates

Dams pose a unique challenge when it comes to mapping flood hazards. While the probability of failure for any given dam can be low compared to the frequency of a flood that has a 1% annual chance of being equaled or exceeded in any given year, the rate of dam failures is on the rise in the US (NAS, 2012). Regardless of failure probability, how the dam was designed, and how it is operated can impact 1% annual chance flood hazards both upstream and downstream of the facility. For those dams specifically designed to mitigate flood hazards, it is critical to obtain detailed information about its capability, past performance, and current operational status when conducting any assessment of flood risks where the dam may have impacts.

FEMA works closely with State Dam Safety Officers as part of the mapping process – particularly if dams are found in the study area using the NID. However, not all dams are regulated by the state and there may be gaps in the NID, so engaging local officials to determine if they are aware of or have data and information about dams that could impact flood hazards is an important step in the data gathering phase.

Once the dams have been identified, there is a concerted effort to ensure the most current information available is used to assess their potential impact on flood hazards. Importantly, should a dam be determined to impact flood hazards, contact with the owner to discuss those potential impacts is critical. The owner of the dam and the flood mapping specialists need to be in agreement on how the dam is being treated in the analysis before presenting results to the public. Any disconnect between the two could lead to miscommunication regarding the risk which in turn could lead to property damage or life loss.

Beyond ensuring the dams are properly considered in the NFIP map update process, FEMA strongly encourages dam owners and local officials to publicize additional data to increase the public's awareness of the dam and its impact (or not) on flooding. Additional information such as the area inundated under maximum pool conditions behind dam, easement areas (upstream and downstream), dam failure inundation zones, and flood wave arrival time information, can be helpful in informing emergency action plans, land use decisions, building codes and much more (FEMA, 2016).

6. CONCLUSION

As challenging as it is to estimate flood hazards for large flood events involving levees and dams, it can be equally challenging to ensure the information developed is well communicated to those making important choices like where to live, how to build their home or business, or where to go when flood warnings are issued. In its 2012 report, the NAS painted a future vision for dam and levee safety where professionals and the public work collaboratively to enhance safety and community resilience by moving beyond a regulatory compliance model and toward more collaborative incentive-based frameworks (NAS, 2012). FEMA, the USACE, the private sector, and others continue to work in this same spirit: to improve the science of flood hazard and risk assessment analysis while also seeking new ways to ensure it is available and relevant to those looking to reduce human suffering and more effectively manage flood risk.

REFERENCES

1. NOAA Billion Dollar Disasters (accessed April 2019):https://www.ncdc.noaa.gov/billions/events/US/1980-2019
2. Technical Mapping Advisory Council, 2015, "TMAC 2015 Annual Report"
3. FEMA, 2009, "Risk Mapping Assessment and Planning (Risk MAP), Multi-Year Plan: Fiscal Years 2010-2014"
4. FEMA, 2014 , "What is a Flood Map?", version 031814.
5. United States, 1984, 44 Code of Federal Regulations (CFR), Part 67.5, "Right of appeal"
6. USACE, 2020, National Inventory of Dams (NID), https://nid.sec.usace.army.mil/ords/f?p=105:22:5180976672416::NO:::
7. USACE, 2020, National Levee Database (NLD), https://levees.sec.usace.army.mil/#/
8. USACE, 2018, "A Summary of Risks and Benefits Associated With the USACE Levee Portfolio"
9. United States, 2001, 44 Code of Federal Regulations (CFR), Part 65.2 b, "Definitions"
10. United States, 1986, 44 Code of Federal Regulations (CFR), Part 65.10, "Mapping of areas protected by levee systems"
11. FEMA, 2013, "Analysis and Mapping Procedures for Non-Accredited Levee Systems"
12. NAS, 2013, "Levees and the National Flood Insurance Program"
13. NAS, 2012, "Dam and Levee Safety and Community Resilience"
14. FEMA, 2016, Guidance for Flood Risk Analysis and Mapping. Dam-Specific Non-Regulatory Flood Risk Datasets"