Association of State Floodplain Managers, Inc.
2809 Fish Hatchery Road, Suite 204, Madison, WI 53713
Phone: 608-274-0123 | Fax: 608-274-0696 | Email: asfpm@floods.org | Website: www.floods.org

FLOODPLAIN MAPPING OF NON-LEVEE & NON-DAM EMBANKMENTS

I. Background

Properly identifying and communicating flood risk is essential in protecting life and property. Flood Insurance Rate Maps (FIRM), as published by the Federal Emergency Management Agency (FEMA), have become the primary tool used to identify flood hazard areas. Other floodplain mapping products introduced under Risk MAP will provide enhanced flood hazard information. When these products are combined with information related to the potential consequences of flooding, they are used to communicate flood risk. Therefore, reliable floodplain mapping is vital to the resiliency and sustainability of our nation.

Levees[1], as defined by FEMA are located near/in floodplains and serve a primary function of flood protection and includes structures along canals that constrain water flows but that don't constitute a barrier across a watercourse. ***Dams***[2], are defined by thresholds (height and impounding capacity) in the Federal Guidelines for Dam Safety or by the States and can serve many capacities, including flood control. ***Embankments***[3] located in floodplains have the potential of altering the flood risk by deflecting and/or detaining storm water runoff and river flows. Levees and dams are specifically designed to retain or direct flood waters. However, embankments have been constructed primarily for reasons other than flood control or attenuation. For example embankments constructed as transportation routes (roads, railroads) are not typically designed to attenuate flow; however they can have a dramatic impact on flood conveyance and flood heights by detaining or directing flood water.

Two primary types of embankments exist. Each has a unique impact on the hydrologic and hydraulic characteristics used to predict the width and depth of flooding. 1) ***Non-levee embankments (NLE)*** are typically parallel to the direction of natural flow. These are often highways or railroads built on fill in low lying areas and thus tend to impose lateral constraints on flood flows. 2) ***Non-dam embankments (NDE)*** are generally perpendicular to the direction of natural flow and cross over the river or stream. These are typically bridges or culverts with inadequate openings that impede flow, attenuate peaks downstream, and temporarily cause storage of water upstream. But they could also include local detention facilities that are not captured under dam safety criteria.

Embankment failures during floods can create unexpected flooding on the land side of the embankment (similar to a levee failure) and/or downstream of the embankment (similar to a dam break). There is a growing awareness these transportation route embankments do not meet specifications for flood control and could pose a hazard during the 1% annual (chance) storm. Some new or updated FIRMS do not depict the potential flood hazard if embankments were to fail during a 1% annual chance (100-year) event. Other new or updated FIRMS are depicting an increased hazard behind or downstream of embankments which had not been previously mapped and communities are confronted with unexpected changes in the extent of regulatory floodplains. Accurate and credible flood hazard mapping is vital to floodplain management and sustainable growth throughout the nation.

The purpose of this discussion paper is to:

1) differentiate between the types of non-levee and non–dam embankments that may impact flood flows and heights;
2) examine the problems which have arisen due to past treatment of these embankments with respect to flood hazard identification;
3) identify existing guidance and any discrepancies in treatment of embankments as well as gaps in guidance and;
4) recommend actions that would help ensure adequate identification, analyses, and mapping of potential flood hazards around non-levee and non–dam embankments.

II. The Problem

There are numerous embankments in the floodplain that were never intended to be flood control structures, but have now been recognized to act as de facto flood control structures. Legacy hydrologic and hydraulic analyses in some Flood Insurance Studies (FIS) and Flood Insurance Rate Maps (FIRMs) have incorporated parallel embankments as hydraulic components constricting the floodplain, or perpendicular embankments attenuating peak flows behind restrictive bridge and culvert openings. While in the past these conditions were represented as existing topographic features and hydraulic structures, some structures that impact flooding are now being carefully scrutinized and considered levees or dams, and these structures should not be accredited for providing 1% annual chance (100-year) flood protection. There is a lack of explicit standards or guidelines for evaluating the floodplain impacts or the performance of non-levee/ non-dam embankments. Local jurisdictions must deal with evaluation of the new flood maps with limited technical guidance. Newly identified Special Flood Hazard Areas can affect land use planning, zoning, and flood insurance rates.

Title 44, Chapter 1, Code of Federal Regulations (CFR), Section 65.10 (hereafter referred to as 44 CFR Section 65.10) sets the criteria for levees that may be accredited with providing protection from the 1% annual chance flood or greater. Accreditation is not a statement of risk or assurance of performance during all events. In order to be accredited, an engineer must determine compliance with minimum NFIP criteria and provide reasonable assurance for containing a 1-percent annual chance flood event or locally-determined design flood events. Many of the issues related to “parallel” non-levee embankments also apply to embankments constructed as levees but not meeting the criteria set forth in 44 CFR Section 65.10. Perpendicular non-dam embankments also have some similarities to levees, but have significantly different characteristics from the criteria set for in 44 CFR Section 65.10.

The lack of clear guidelines and specifications on non-levee and non-dam embankments has lead to inconsistent mapping throughout various FEMA regions. Communities in Colorado and Arizona have expressed concerns regarding financial, economic, legal, future planning and political implications that may arise from the potentially inconsistent treatment of these embankments. Some FEMA regions are requiring levee-like compliance of some non-dam embankments before mapping them as providing attenuation, while others are not. Communities in these FEMA Regions are being required to provide professional statements of risk or map worst-case scenarios with a probability of occurrence less than 1-percent and they are concerned about lack of technical criteria, professional guidelines, and potential remedies. But in many other FEMA regions, mapping behind non-dam embankments assumes significant attenuation will occur without failure. Some communities are unaware of the potential implications that failed embankments would have because it’s not shown on their new or updated maps.

Flood Impacts of non-levee/ non-dam embankments

When embankments are constructed parallel to flow they can act as encroachments elevating flooding riverside of the embankment to higher levels than would have occurred without the embankment. When these parallel embankments fail, areas behind them will flood and peak flow rates downstream may be reduced as the flow spreads out and the conveyance area increases. Such embankments tend to eliminate natural flood storage areas and focus flood water flows within the river banks or floodway portion of the watercourse, increasing flood velocity and decreasing flow attenuation. Understanding peak flow conditions is critical for deriving worst-case flood elevations and velocity conditions contributing to failure, and therefore design of structures and accurate flood maps.

Embankments constructed perpendicular to flow, may impede flow, create storage, and reduce peak flow rates downstream. If these structures fail during a flood event, flood storage is removed and the downstream peak flow rates may significantly increase. Some perpendicular embankments do not significantly attenuate flow because the storage behind them is very small in relation to the flood hydrograph volume. However, at some threshold, the embankment acts like a dam and failure may be catastrophic if the flood volume creates a dam failure wave or the un-attenuated peak flow creates a larger inundation area than accounted for with the structure in place. In either case, there are multiple worst case scenarios depending on the performance of the structures and these must be considered to identify the extent of the true hazard and/or provide options for mediation.

Current Guidelines

In addition to 44 CFR Section 65.10 FEMA has issued Procedure Memorandums (PM) as part of Map Modernization concerning levees, de-accredited levees, and non-levee embankments (see references[4]). These PMs range from establishing an inventory of levees that appear on FIRMs to protocols for notifications related to de-accreditation of levees.

In PM 51 "non-levee embankments" are described as embankments that were not designed or constructed as flood-control structures, such as those for highways and railroads. “Because such embankments are not "levees" as defined in Section 59.1 of the NFIP regulations (44 CFR 59.1), they cannot be accredited with providing flood protection in accordance with Section 65.10 (44 CFR 65.10) of the NFIP regulations.” In the case of actual levees, PM 52 complements Appendix H of the FEMA Guidelines and Specifications as it elaborates on the series of worst cast scenarios to be considered for calculating the flood elevations for levees and de-accredited levees. Specific scenarios are described for assessment of flood elevations for the purpose of FEMA study and mapping. The basic approach is to model two scenarios; flood elevations for flow confined between the levees (parallel to the flow), and one for the unconfined flood flow elevations. When a levee is accredited, the higher elevation is shown riverward of the levee and the landward area is identified as a residual risk area defined by the area inundated in the unconfined flow scenario.

However, other than stating that non-levee embankments cannot be accredited with providing protection, no explicit guidance is provided for defining what is or is not a non-levee embankment or for modeling or mapping of parallel embankments that were not at one time identified as levees.

Embankments perpendicular to the direction of flow are partially addressed in FEMA *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix C: Guidance for Riverine Flooding Analyses and Mapping* (November 2009). The guidelines specifically allow hydrologic

analyses to include storage behind embankments but do not include any assessment of the impact of the embankment failure: Section C.2.1 “Rainfall-runoff models are applicable and necessary for studies where a flood hydrograph is required, where the regional regression equations are not applicable, or where temporary storage behind road embankments is a factor in determining the flood discharges. Storage behind bridges and culverts with high road embankments can be reflected in the hydrologic analysis.” In Section C2.4.4 on page C-20 it is stated “The impoundment of floodwaters caused by undersized culverts and high road embankments can be modeled using reservoir modeling procedures.”

Existing railroad crossings frequently result in non-dam embankment issues. Most railroads are privately owned and were constructed in the late 1800’s or early 1900’s. Some crossings have high/steep embankments and small openings. These crossings were built with unknown and/or antiquated construction methods and without the use of modern construction materials. Engineering documentation is extremely difficult to locate, and railroads do not have incentives to acknowledge problems, retrofit existing embankments, or gain access for additional data collection efforts, which makes reasonable assurance or certification against failure difficult.

Highways and railroads are continually being redesigned or replaced as part of infrastructure improvements, expansion, age, failure, etc. Typically, new crossings are designed to reduce overtopping and backwater pressures by increasing the size of the opening. This results in greater discharges downstream that are not accounted for in the floodplain models and mapping.

The Federal Highways Administration (FHWA) has clearly indicated that highway embankments are not designed to serve as flood control structures. In their memorandum dated September 10, 2008 (http://www.fhwa.dot.gov/engineering/hydraulics/policymemo/20080910.cfm) it is stated “…FHWA discourages DOTs in certifying highway embankments as levees or allowing any such certification by any entity. Additionally the FHWA discourages any type of retrofitting efforts as DOTs and FHWA are not in a position to assume such a role for statutory, financial, liability, and engineering.” The memorandum also indicates that The FHWA has regulations and design standards that relate to the interaction of highways and bridges with floodplains: 23 CFR 650 Subpart A: *Location and Hydraulic Design of Encroachments on Flood Plains*. When it is not feasible to keep embankments entirely out of floodplains, embankments are to be elevated to avoid overtopping by a flood with a 2 percent chance (50-year flood) of being exceeded in any given year.

Most state Departments of Transportation (DOTs) have specific criteria for bridge and culvert design, These vary from state to state, but typically do specify a design event and frequency for which the opening must be adequate to convey. These typically lack specifications for how the flood hazard should be evaluated and shown on FIRMs and sometimes do not acknowledge a need for participation with stakeholders and local jurisdictions through the floodplain development processes. When structures are specifically designed to detain water, then Dam Safety Program regulations apply.

III. Solution Discussion

In order to adequately address many of the issues surrounding non-levee and non-dam embankments, it is important to develop distinct definitions, guidelines, requirements for each. However, any recommended changes must not inadvertently create a loophole for actual levees or dams (built for flood control) to fall under non-levee or non-dam requirements.

Non-levee Embankments

In the case of embankments that are parallel to the flow, the guidance provided by FEMA through the series of PMs provides guidance for determining when an embankment can be accredited with providing protection as well as technical specifications for computation of flood elevations river-ward and land-ward of the embankment. It should be clearly stated that these assessments apply to all types of parallel embankments, including highways and railroads. A gap exists in the FEMA guidelines to address the numerous instances where floodplain boundaries are coincident with parallel embankments, thus implying a level of protection, without any explicit statement to that effect. These are often overlooked because the embankment is not identified as a "levee."

Non-dam Embankments

Embankments generally perpendicular to the flow, e.g. embankments associated with bridges, culverts and detention ponds are more complex and present unique challenges. There are no widely accepted guidelines to set a threshold of when a restrictive hydraulic structure is modifying flood flows to the extent that a failure would cause a significant change in the inundated area. The depth of water upstream of a restrictive crossing, the volume of water retained, the difference in flooding height downstream of the structure (with and without the attenuation of flood peaks), all need to be considered to assess the potential extent of upstream inundation. Reasonable guidelines need to be created to evaluate these thresholds when additional studies, proposed development or reconsideration of design for new or replacement structures should be considered and subsequent mapping or remapping of the SFHA. An example of such guidelines was issued by the Maryland Department of the Environment (document can be found at http://www.mde.state.md.us/programs/Water/DamSafety/GuidelinesandPolicies/Documents/www.mde.state.md.us/assets/document/damsafety/POLICY-Roadway%20Embankment%20Design%20Criteria%201996-04-03.pdf) which provides comparison thresholds when the depth of water retained behind a highway embankment is sufficiently high to warrant design as a dam.

Technical guidance on the appropriate analyses to assess and map flood risk associated with non- dam/levee embankments is needed. Additional language in the FEMA Guidelines and Specifications is needed to recommend when consideration of flooding, should an embankment fail, must be evaluated and mapped, as well as specifying the appropriate flood Zone designation. Floodway in this context needs to be explored, perhaps even broadening the function of floodway delineation to include embankment areas where development should be restricted. Furthermore, consideration must be given to the effect these structures have on the historical record at gages. Embankments and bridges/culverts modify flood flows and this effect is part of the historical gage record, which is used for future studies and model calibration.

Guidelines should provide hydrologic and hydraulic criteria to size the storms being analyzed, both from a storm frequency and storm duration perspective. Where storm volume governs, longer duration storms may need to be considered, however, such long duration storms may not trigger upstream failure. Careful consideration should be given to promote realistic scenario and risk probability analysis. There should also be guidelines on how to properly account for storage and timing, coincidence of local storm contributions, etc. These can mostly be derived from existing guidelines and reinterpreted in the context of non-levee embankments/ non-dam embankments. Failure of a roadway embankment that crosses a stream should only be considered if it will produce a higher flood downstream. The storage volume upstream of such an embankment as well as the inflow and outflow conditions can be classified to determine whether a failure analysis is necessary from a hydrologic standpoint.

While transportation departments (and other agencies/entities) are reluctant to certify such structures as flood control levees and dams, it could be in the best interests of all jurisdictions and private stakeholders that flood control efforts and the efforts of other agencies are coordinated in the future to ensure construction overlap and savings between flood control projects and other types of construction. For roads built with federal monies, FHWA and/or the State DOTs will determine if it can serve both a highway and flood control function. For local roads, if local jurisdictions wish to fix a key piece of local roadway that can also play a key role in providing a flood protection stop gap structure for their community, then they should be able to design, construct and maintain such a structure as both a flood control and transportation element, and not be forced to construct two structures. This should be contingent on the local entity providing assurances for Operations and Maintenance, warning and evacuation and liability.

If communities are to own, operate, maintain and certify such structures as levees or dams, they will need to understand their obligations and liabilities, including have the legal basis for operating and maintaining and managing these structures (retrofitting, warning, evacuation, land management, management of residual risk). Communities need to understand and communicate the hazards facing their constituents and could consider residual risk floodplain zoning in areas impacted by failure or breach.

IV. Recommendations

The issues surrounding non-levee and non-dam embankments have widespread implications. This discussion paper recommends FEMA consider the recommendations herein. The implementation of Risk Map offers an opportunity to address Non-levee and Non-Dam embankments and ASFPM recommends FEMA act quickly on implementing the recommendations contained herein. As FEMA's partners in producing flood maps and in implementing the NFIP requirements, ASFPM offers our assistance in this important effort.

Recommendation 1*: Establish a Work Group*

We suggest FEMA establish a work group that includes its federal, state and local partners to consider several of the issues in the paper and make recommendations for implementing many of the recommendations described below.

Recommendation 2: *Issue Interim Guidance on NLE's and NDE's*

FEMA should issue interim guidance for Risk MAP on NDE's and expand on the existing guidance for NLE's. The interim guidance should be issued so that Risk MAP projects can begin addressing the NLE's and NDE's issues highlighted in this paper, and so that they can be handled consistently throughout all FEMA regions.

Recommendation 3: *Distinguish between NLE's and NDE's*

There are differences in the functionality and potential risk and benefits of these embankments. Separate definitions, guidelines, and specifications should be developed for each.

Recommendation 4: *Develop Thresholds that Trigger Further Analysis*

Thresholds should be established for both non-levee and non-dam embankments that trigger FEMA attention and therefore warrant an explicit study. The thresholds should be set so that the evaluation can occur with data available as part of the standard mapping process and not require more extensive information such as geotechnical data. Specifications should include

physical thresholds such as impoundment area, embankment height, HW/D for culverts, inundation time, potential loss of life and property damage, land use measures to contain current risk, etc. We recommend a work group to develop these thresholds.

Recommendation 5: *Develop Guidelines for Analysis and Flood Risk Mapping*

FEMA should initiate collaborative efforts with state and local partners to develop guidelines and technical criteria on how the impacts of the identified non-levee or non dam embankment should be accounted for in flood studies and mapping, if additional study is warranted. Currently there are not any FEMA guidelines or technical criteria that apply to non-dam embankments that are perpendicular to natural flow and attenuate flows downstream. Consider changes to analysis, including to Appendix C, such as addressing restrictive crossings modeled using reservoir routing, and/or failed as dams. Separate technical guidance for both non-dam and non-levee embankments is needed. In the case of non-dam recommend consideration of worst case scenarios such as flood pool upstream with no failure and un-attenuated flow downstream. Further clarify existing guidance for non-levee embankments that are parallel to natural flow. When developing guidelines for mapping area impacted by NLE's and NDE's, FEMA must consider insurance, applicability of other programs (mitigation funds, 404 and 406), and land management.

Recommendation 6: *Develop Clear Options for Communities with NLE's and NDE's*

FEMA should anticipate the public reluctance to recognize the newly identified flood hazard. Therefore, FEMA should develop with state and local partners, clear options for communities with existing development within newly identified NLE and NDE areas that recognizes the variability of these structures. FEMA should consider the level of existing and future risk when developing alternatives for communities. FEMA should also consider developing variable compliance standards for NLE and NDE structures providing protection based upon the level risk.

Recommendation 7: *Develop Outreach and Implementation Schedule*

Specify how and when input from communities and states will be sought and when this information will be clearly communicated with communities, states, and stakeholders. The implementation schedule should remain aggressive so that future Risk MAP projects can account for the risk posed by non-levee and non-dam embankments.

Recommendation 8: *Strengthen Regulatory Compliance and Interagency Coordination*

Transportation projects result in a proliferation of NLEs and NDEs across the country. State DOTs, railroad regulatory agencies, and irrigation entities need to evaluate the effects of those projects on floodplains, communicate the results to local governments, mitigate adverse impacts for flooding, erosion and velocity (NAI principles) and consider their liability should these structures fail. Highway projects, irrigation conveyance systems and railroad projects consider any number of issues in project development, NEPA for example. FEMA should make a strong statement to U.S. DOT that federal transit projects (FHWA, FAA & FTA) need to carefully adhere to the NFIP, get floodplain development permits (or at a minimum comply with all floodplain requirements of the NFIP, state or local codes, whichever is more restrictive), submit CLOMRs and LOMRs the same as everyone else is required to do and coordinate/cooperate with States and locals. DOTs should design encroachments so as not to impact the floodplain, zero rise, zero alteration. FHWA and state DOTs have been historically unhelpful in LOMRs and mapping efforts, but with little effort could greatly assist in the nation's efforts to reduce flood risk and damages. Highways could be considered critical facilities (evacuation routes) and thus require greater level of reliability.

V. Resources

[1] A levee is “a man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding.” *as defined by FEMA in the National Flood Insurance Program (NFIP) in part 44 of the Code of Federal Regulations, part 65.10*.
A levee is also “an embankment, including floodwalls - the primary purpose of which is to provide hurricane, storm, and flood protection relating to seasonal high water, storm surges, precipitation, and other weather events; and that normally is subject to water loading for only a few days or weeks during a year. The term includes structures along canals that constrain water flows and are subject to more frequent water loadings but that do not constitute a barrier across a watercourse.” *as defined in the National Levee Safety Act of 2007*

[2] A dam is “Any artificial barrier, including appurtenant works, which impounds or diverts water, and which (1) is 25 feet or more in height from the natural bed of the stream or watercourse measured at the downstream toe of the barrier or from the lowest elevation of the outside limit of the barrier if it is not across a stream channel or watercourse, to the maximum water storage elevation or (2) has an impounding capacity at maximum water storage elevation of 50 acre feet or more.” *As defined by FEMA, Page 4, Federal Guidelines for Dam Safety, 2004.*

[3] “An embankment is an artificial mound of soil or broken rock that supports railroads, highways, airfields, and large industrial sites in low areas, or impounds water.” Page 588 George F. Sowers, 1979*Introductory Soil Mechanics and Foundations: Geotechnical Engineering 4th Edition*, Macmillan Publishing Co., Inc. New York.

[4] Federal Emergency Management Agency – publications

Guidelines and Specifications for Flood Hazard Mapping Partners,
Appendix H: Guidance for Mapping of Areas Protected by Levee Systems, April 2003.
Appendix C: Guidance for Riverine Flooding Analyses and Mapping, November 2009
PM 32, *Levee Review Protocol*, June 4, 2003.
PM 34, *Interim Guidance for Studies Including Levees*, August 22, 2005.
PM 43, *Revised Guidelines for Identifying Provisionally Accredited Levees*, (originally issued September 25, 2006) March 16, 2007.
PM 45, *Revisions to Accredited Levee and Provisionally Accredited Levee Notation*, effective June 1, 208 (issued May 12, 2008).
PM 51, *Guidance for Mapping of Non-Levee Embankments Previously Identified as Accredited,* February 27, 2009.
PM 52, *Guidelines for Mapping Processes associated with Levee Systems*, effective date April 24, 2009.
PM53 *Guidance for Notification and Mapping of Expiring Provisionally Accredited Levee Designations,*
Effective April 24, 2009.
EO 11988