AmericanLifelinesAlliance

A public-private partnership to reduce risk to utility and transportation systems from natural hazards and manmade threats

Flood-Resistant Local Road Systems: A Report Based on Case Studies

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Executive Summary

By their very nature, road systems are subject to flooding. Roads sometimes follow along waterways and sometimes cross the landscape without regard to hills, valleys and streams. Flooded roadways can be extremely dangerous to the traveling public. The National Weather Service reports that more than half of all U.S. flood-related fatalities in recent years occurred on roads[1].

The primary mission of a local road department is to provide safe and functional local roads for the traveling public. This mission is unchanged when flooding affects the system, but the efficiency and thoroughness with which recovery is accomplished can be challenging.

In 2004, the American Lifelines Alliance (ALA) contracted with the Association of State Floodplain Managers, Inc. (ASFPM), in partnership with the American Public Works Association (APWA), to prepare case studies of five counties to document decision-making factors and processes used to address flood risk in managing local road systems, to identify effective practices for mitigating flood impacts, and to evaluate the need for guidance for local road system managers to reduce future flood risks and losses.

The counties selected for the case studies are Allegany County, Maryland; Allegany County, New York; Calhoun County, Illinois; Uvalde County, Texas; and Wasco County, Oregon. On-site visits and interviews were conducted to characterize how some local officials factor flood hazards and flood resistance into their short-term and long-term decisions. The case studies also capture effective practices that contribute to flood resistance. Note these five case studies do not represent the full range of road departments, but only those that are rural in character. Nevertheless, these case studies suggest a significant opportunity for all road departments to reduce future losses, in part because the road departments in non-urban areas generally have less in-house technical capacity and fewer financial resources. Thus, findings and recommendations based on more rural systems should have at least some applicability to more urban systems. Furthermore, rural roadway systems represent over 77 percent of the Nation's nearly 4 million miles of roadways.

Reducing the potential for future flood damage experienced by a largely existing infrastructure of local roads and bridges is an integral part of the work of local road departments, although performance improvements come about gradually and site-specific decisions are influenced by many factors. The following broad statements summarize some of the findings based on the five case studies:

- Road departments in rural counties are constrained by limited resources, expertise and staff. Furthermore, costs for materials, supplies, equipment, and labor rise faster than revenues. For the most part, the only response available to rural road departments is to scale back their efforts to maintain roads and bridges, thereby increasing the likelihood of greater flood damages in the future.

- Consistency in post-disaster assistance is needed. The case study road departments reported that whether their proposals to incorporate measures to improve flood resistance

1 NWS, 2005. "Flood Fatalities." National Weather Service, Hydrologic Information Center, Silver Spring, MD. Online at www.weather.gov/oh/hic/flood_stats/recent_individual_deaths.shtml (accessed January 21, 2005).

were received positively by state and federal inspectors for post-disaster public assistance varied from disaster to disaster and often from inspector to inspector.

- Experience-based or on-the-job learning is the norm in rural road departments. While effective to some degree in small organizations, relying on direct experience-based learning limits exposure to successful solutions and alternatives that are implemented by other road departments, whether they are urban or rural.

- There is a wide range of state requirements that are specific to flood resistance and road construction and reconstruction. Some states require that bridges and culverts be evaluated to determine how they would perform during the 1%-annual chance flood (100-year), while others have no such requirements.

- Road departments are committed to maintaining and improving their road systems and are open and willing to learn about new and effective approaches. While some of the case study road department directors expressed concern that required standards would impose costs that outstrip their ability to pay or would limit their flexibility, they were generally receptive to learning from others. Readily accessible guidance and model practices that have proved successful in other communities would be well received.

Of the nine recommendations made to improve current practices and to reduce the impacts of flood damage on local road systems, three are framed to be pursued quickly to complement existing, on-going initiatives:

- **Recommendation 2** calls for development of a Data Collection Guideline to augment the periodic inspections of waterway crossings that are conducted by local road departments. The guideline would explain how augmenting current inspection practices to collect additional information, specifically about hydraulic capacity, would provide information useful in future local decision-making. That information could be used to support improvement of flood hazard maps and to evaluate mitigation options during repair and replacement of roads and bridges.

- **Recommendation 7** suggests that local road departments formalize their practices related to flood resistance to maximize identification of applicable mitigation measures and to justify inclusion of such measures as part of post-flood recovery work.

- **Recommendation 8** builds on APWA's periodic review and evaluation of its "Public Works Management Practices Manual" and selected other publications by incorporating practices that are specific to flood resistance.

Another recommendation has a longer term timeframe and a need for more substantial collaboration and financial support:

- **Recommendation 1** calls for development of a Model Manual of Flood Mitigation Guidance for Local Road Systems. The manual should be designed to serve as a base document that can be tailored and enhanced for individual states. It should provide, among other things, sample forms to document decisions when rebuilding, methods for evaluating the hydraulic capacity of structures, and examples of successful projects and practices to improve flood resistance. A recommended adjunct to the manual is an online resource to allow ready access by a wider audience.

The primary audience for this report is road departments, particularly those in rural areas, and related appointed and elected public officials responsible for local transportation. This can include officials in town, county or state departments of public works, transportation, planning, environment, economic development, emergency management, and/or homeland security. It includes federal agencies that have policies and programs that affect local transportation planning and disaster recovery and mitigation. In the private sector, the study can help business interests in chambers of commerce or boards of trade better understand flood-related issues to support more reliable transportation initiatives in their areas. This study also may serve as a resource for industry groups, professional organizations, research organizations, academia, and consulting engineers. To make local roads more flood resistant, cooperation and support is needed from this diverse audience. This report documents opportunities for and interest in improving local road systems in this regard.

1.0 Introduction

The U.S. Department of Homeland Security's Emergency Preparedness and Response Directorate (EP&R) was created in 2003 when the Federal Emergency Management Agency (FEMA) was transferred to the Department. FEMA, as part of the EP&R Directorate, is charged to "Lead America to prepare for, prevent, respond to, and recover from disasters, both natural and man-made."

In 1998, FEMA formed the American Lifelines Alliance (ALA) as a public-private partnership with the goal of reducing the vulnerability of lifelines (utility and transportation systems) exposed to hazards. In 2002, FEMA contracted with National Institute for Building Sciences (NIBS), through its Multihazard Mitigation Council (MMC) to, among other things, assist FEMA in continuing ALA's multihazard guideline development efforts.

In early 2004, ALA contracted with the Association of State Floodplain Managers, Inc., in partnership with the American Public Works Association, to prepare case studies of selected counties to document decision-making factors and processes used to address flood risk in managing local road systems, to identify effective practices for mitigating flood impacts, and to evaluate the need for development of non-mandatory, decision-making guidelines for local road systems. The project is supported by FEMA funds.

Flooding has significant impacts on local road systems. Flood damage to the physical road and drainage infrastructure is costly to restore, interrupts the flow of traffic, affects local businesses, and limits access by fire and emergency vehicles. Flood risks to the traveling public are significant. The National Weather Service reports that over half of all flood-related fatalities in the U.S. are vehicle-related (NWS, 2005). Roads themselves can contribute to increased flooding that adversely affects adjacent lands.

1.1 Acceptable Risk Concepts

A local road system consists of a network of components (e.g., roadways, bridges, culverts, etc.) that is owned and maintained by a city, county or other municipal transportation agency with little or no federal funding. Local road systems invariably are part of a larger network and decisions by one entity may affect regional transportation capacity if a local road is affected by any natural or man-made hazard.

By their very nature, local road systems are exposed to flooding and rainfall-runoff. Roads traverse the landscape, sometimes following along waterways and sometimes striking out across country without regard to hills, valleys and streams. Road systems, composed primarily of paved and unpaved roads and various types of structures that cross waterways, experience a range of damage. Damage results from rising creeks and rivers, and damage results from local drainage due to locally intense rainfall.

Flooding affects both the short- and long-term performance of local road systems and can affect communities in many ways, including increasing the potential for life loss and injuries, creating shortfalls in community budgets, delaying planned maintenance work because manpower and funds are diverted to recovery, disrupting normal traffic patterns, and stranding residents. Local governments, whether counties, towns or cities, typically are organized to include agencies that are charged to manage the local road system.

Various engineering, system-enhancement, and emergency-response strategies can be implemented to reduce the impacts of flooding. Each risk-reduction strategy – referred to as mitigation – has implementation costs and some residual risk of unacceptable performance will always be associated with floods that are larger than the design flood. A minimal approach (e.g., the "do-nothing" strategy) will have relatively low implementation costs but the residual risk of unacceptable system performance may be relatively high (perhaps unacceptably high). At the opposite end of the spectrum, aggressively pursuing mitigation will have high (perhaps unacceptably high) implementation costs but the residual risk of unacceptable performance will be small.

Mitigation is defined as actions taken to reduce or eliminate the long-term risk to life and property from hazards. Actions may be taken before a disaster or implemented during recovery.

Just what constitutes unacceptably high implementation costs and unacceptably high residual risk depends on the particular constraints (economic, political, and legal) under which the responsible agency operates. It is generally understood that acceptable risk is owner and stakeholder acceptance of that level at which additional costs to implement mitigation measures to further reduce losses and risks are no longer acceptable. There is no standardized method by which individual communities perceive and address risk associated with local road systems.

In a pure sense, quantitative estimates of how much it costs to provide any given degree of flood-resistance, and the direct and indirect benefits of doing so, can be developed for any risk-reduction strategy. However, as a practical matter, just how costs and benefits are taken into consideration by local road departments when determining risk and selecting risk-reduction strategies differs from one community to another. This is because of variations in geographic, economic, capability, capacity, and regulatory influences.

1.2 Project Objective

Although flooding affects local road systems throughout the Nation, there does not appear to be any widely available guidance that outlines specific factors that local transportation agencies might consider when selecting either pre-event flood hazard mitigation measures or post-event repair and recovery measures to improve flood-resistance. For the most part, the extent to which damage reduction measures are identified and incorporated is generally thought to be based on local knowledge and experience.

The objectives of the project described in this report are to begin to provide this guidance by: (a) identifying factors that influence decisions for reducing flooding risks to local road systems; (b) characterizing how such decisions have been made in five case study counties from different regions of the United States; and (c) providing findings and recommendations, including the possible need for development of non-mandatory decision-making guidelines for local road systems. These objectives do not include evaluation of the quality of decisions – that is, quantitative answers were not developed to determine, for example, whether a new structure that was "improved" actually performed better under subsequent flooding.

Using these case studies, this project characterizes how some local officials factor flood hazards and flood resistance into their short-term and long-term decisions. Such decisions may be made in both the pre-flood and post-flood periods. The case studies also capture effective practices that contribute to flood resistance.

Finally, regarding evaluation of the possible need for future development of non-mandatory decision-making guidelines or standards, it is noted that non-mandatory standards are rules which are followed voluntarily – they can be followed by choice or inclination, but they are not explicitly required by laws or regulations. In many organizations that manage accreditation programs, compliance with both mandatory and non-mandatory standards is used to determine accreditation status.

1.3 Project Approach

The American Lifelines Alliance selected the Association of State Floodplain Managers (ASFPM), teamed with the American Public Works Association (APWA), to undertake this project. ASFPM's mission is to reduce overall flood losses, including flood damage to local transportation systems. APWA is a public policy advocate for public infrastructure, and its members also have a strong interest in how states and communities deal with natural disasters.

ASFPM and APWA formed an oversight committee for the project. Committee members included experienced state floodplain managers, a state public assistance officer, and four local public works officials with experience dealing with road systems and flooding. Two researchers conducted on-site visits and prepared the case studies (Appendices B through F). Contributions were made by technical advisors with expertise in emergency management, water resources, transportation planning, and risk assessment.

The case studies were prepared based on on-site visits and interviews with local officials including the director of the local roads agency, the director of the local emergency management agency, and, where applicable, a representative of the local planning agency. Although agencies responsible for local roads are variously titled, for ease this report refers to them as departments of public works or DPW.

To prepare for the on-site visits and to provide a reasonably consistent basis for the written case studies, the project team prepared a series of questions to guide discussions with local officials. A formal survey or structured interview was not conducted. The discussion was structured to obtain information on:

- The DPW's mission, organization, budget and responsibilities.
- The physical characteristics of the local road system (lengths of road, number and types of waterway crossings).
- The impacts of flooding on the local road system and a general assessment of performance and how flooded roads affect the public.
- Procedures for routine inspection, maintenance and post-flood inspections.
- Impacts of road system flooding on emergency response.
- Regulations and other imposed requirements.
- State and federal influences in the post-flood recovery phase.

- The DPW's interpretation of risk, flood-resistance, and perceived costs and benefits of building flood-resistant roads.
- Specific factors used in making decisions and how those decisions were made.

To round out the description of each case study county and its DPW, two site-specific examples where mitigation strategies and decisions were implemented were examined in detail. These examples were selected because of repetitive damage or because they illustrated how flood damage prompted decisions that, in the opinion of the DPW, would mitigate future damage.

1.4 Case Study Counties

The project scope called for preparation of five case studies. It is recognized that this is only a small sample of the tens of thousands of local government entities likely to be responsible for local road systems, which include counties, parishes, boroughs, cities, towns, townships and villages. Nevertheless, even this small number of case studies yields beneficial information on flood risk reduction practices and decision making under a variety of different operating conditions (e.g., economic, regulatory, etc.) among the different communities studied.

Selection of the case study communities involved several steps. First, of the several types of local governments, it was determined that the county is an appropriate unit because, in general, county road systems have more miles of road and more waterway crossings. Thus, county DPWs are more likely to be faced with more decisions that involve flood hazards.

The counties were purposively, not statistically, selected, in large part because of their willingness to participate. As the next step, because state regulations specific to flooding were anticipated to be a factor that influences flood-resistance, an informal inquiry to numerous states helped to identify those states that do and do not have such regulations.

The next step involved inquiries to selected federal and state officials who are familiar with flooding and community responses to flood disasters. A number of officials in FEMA's regional offices who coordinate the Public Assistance Program were contacted to discuss recommendations for counties. Those inquiries led to contacting several staff officials. Each state has an office designated to coordinate the National Flood Insurance Program, serving as a link between the federal program administered by FEMA and communities that adopt and enforce floodplain management regulations. States also have a management function related to hazard mitigation, assigned to State Hazard Mitigation Officers.

The results of the contacts yielded a number of states with and without applicable regulations. In those states, one or more possible case study counties were identified and contacted with an invitation to participate. It is notable that a number of officials in urban jurisdictions were contacted, but while interested in reducing flood damage, they declined to participate due to competing demands for their time.

One county, Allegany County, Maryland, was selected because of the DPW director's observation made in 1996 (sidebar), after significant flooding occurred in numerous watersheds in the county. The choice also satisfies one of the selection criteria because of the State of

"In the 1996 floods, we didn't lose any bridges or culverts built to the Maryland flood standards, which require designs to minimize damage," summarized Steve Young, public works director for Allegany County, MD.

Maryland's regulatory framework. The State regulates the construction of roads, bridges, culverts and other changes to the course, current and cross-section of the waters of the state, which are defined to include the 1%-annual chance floodplain based on projected watershed development.

In addition to Allegany County, MD, four other counties agreed to participate: Allegany County, NY; Calhoun County, IL; Uvalde County, TX; and Wasco County, OR. As shown on Figure 1-1, they are in geographically diverse areas.

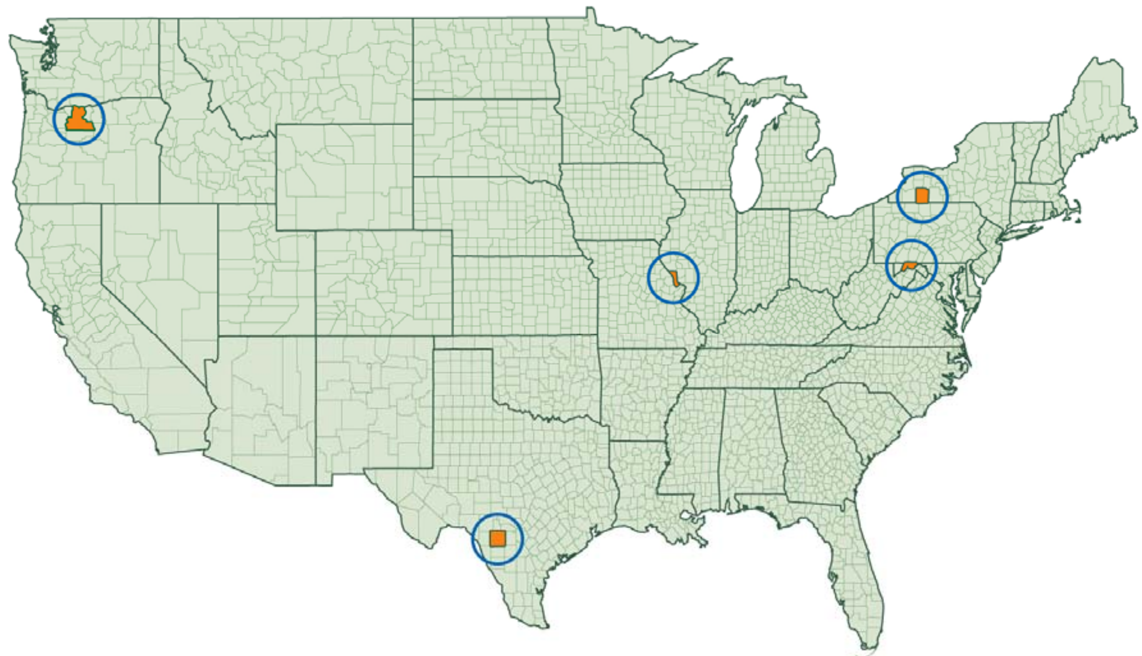

Figure 1-1. Locations of Case Study Counties.

All five counties are rural in nature (Table 1-1). Therefore, the findings and recommendations from these counties may or may not be appropriate to extrapolate to urban and urbanizing counties where new roads are planned and existing roads are upgraded. However, the findings are important because, as reported in the October 2001 issue of *Better Roads*, 77 percent of the 3.9 million miles of roadways in the United States are classified rural (a comparable estimate of the number of waterway crossings was not provided). The distinction between urban (see Key Terms), suburban, urbanizing, and rural areas is variously defined by agencies and entities. Regardless of the definition, communities with a population density of less than 500 residents per square mile are considered rural.

Table 1-1. Case Study County Population, Land Area, Density

	Allegany County, MD	Allegany County, NY	Calhoun County, IL	Uvalde County, TX	Wasco County, OR
Population (unincorporated areas; estimates provided by the counties)	74,900	50,000	4,070	25,900	10,700
Total land area (sq. mi.)	426	1,030	281	1,588	2,396
Average population density (persons/sq. mi.)	175.8	48.5	14.5	16.3	4.5

The incidence of flooding in the case study counties is varied (Table 1-2). For example, Calhoun County, IL, reported numerous high water events, including 15 major disaster declarations made by the federal government since the late 1960s. At the other extreme, Uvalde County, TX, had only 3 declared disasters, but experienced damage every year. In a 12-month period in the early 1990s, one major river rose high enough to damage six waterway crossings on thirteen separate occasions.

Table 1-2. History of Flooding in the Case Study Counties

	Allegany County, MD	Allegany County, NY	Calhoun County, IL	Uvalde County, TX	Wasco County, OR
Federal declarations for major disasters since 1965	5	10	15	3	4
Other "significant" damaging flood events	4 (in 20 yrs)	Numerous small	Not reported	Numerous every year	Isolated
Most recent flood that caused road/crossing damage	May 2002	May 2004	June 2004	July 2004	February 1997

1.5 FEMA's Public Assistance Program

FEMA's interest in decisions made by local DPWs that lead to improved flood resistance of local road systems is based on one of its primary responsibilities – administration of the Public Assistance Program. Under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act[2], the Public Assistance Program provides supplemental aid to States and communities to help them recover from major disasters. Specifically, the program provides assistance for different categories of damage, including Category C which is permanent restoration of damage to local road systems. The program also encourages protection from future damage by providing assistance for mitigation measures during the recovery process. Additional information about Public Assistance Program is presented in Appendix A.

For one 4-year period (1999-2003), $820 million (10 percent) of FEMA's total expenditures in response to flooding were in Category C, Roads and Bridges[3]. It is important to realize that this yields a far from complete measure of the impacts. It does not account for expenditures by other state and federal agencies nor include indirect costs. More important, FEMA's disaster assistance is available only after floods that prompt declaration of major disasters while many floods are local in nature and do not rise to that level; thus, in the latter situation the full costs of recovery are borne by affected communities.

2 Public Law 93-288, as amended, and Title 44 of the Code of Federal Regulations.
3 Data provided by FEMA from the National Emergency Management Information System (May, 2004).

2.0 Local Road Systems and Flood Damage

2.1 Overview

The term ”local road system” is used broadly to refer to the local transportation infrastructure, the system consists of a network of components (e.g., roadways, bridges, culverts, etc.) that is owned and maintained by a city, county or other municipal transportation agency with little or no federal funding.   It includes such components as paved and unpaved roads, road shoulders, side drainage ditches, underdrains, storm drains, storm water management facilities, rights-of-way, guide rails, and signage (see Section 2.1). The local road system also includes structures, such as overpasses over other roads and railroads and structures that span waterways (see Section 2.2).

Table 2-1 summarizes some elements of the physical inventory of the road systems in the case study counties. While there is significant difference in land areas (Wasco County is about 8.5 times the size of Calhoun County), the difference in number of road miles is less significant (Wasco County has about 2.5 times as many as Calhoun County). A more significant difference is in the number of waterway crossings, reflecting the diversity of the landscape and density of the drainage network. Allegany County, NY, has nearly 10 times as many as waterway crossings as Uvalde County, TX.

Table 2-1. Summary of Road Mileage and Waterway Crossings

	Allegany County, MD	Allegany County, NY	Calhoun County, IL	Uvalde County, TX	Wasco County, OR
Road mileage (paved)	350	344	218	112	300
Road mileage (unpaved)	200	0	43	204	397
Total road mileage	550	344	261	316	697
Bridges/boxes (> 20’)	67	122	50	4	67
Bridges/culverts (< 20’)	42	286	14	3	57
Low-water/slab crossings	1	0	20	27	0
Total number of crossings	110	308	84	34	124
Crossings/mile	0.20	0.90	0.33	0.16	0.18

The focus of this report is flood-related damage to paved and unpaved roads, road shoulders, ditches and structures over riverine waterways (as opposed to coastal flooding). Based on how the case study counties characterize the effects, flood-related damage is caused by two general types of flooding:

- **River and Stream Flooding** occurs when rainfall generates runoff such that the volume of water conveyed in waterway channels exceeds the capacity of those channels and flows into flood hazard areas, commonly called floodplains. The standard typically used for flood hazard area identification and land management is the 1%-annual chance flood, commonly called the 100-year flood.

- **Heavy Runoff** occurs when intense rainfall generates concentrated runoff that either exceeds the capacity of drainage roadside ditches and underdrains or that flows where ditches and drains are not provided.

2.2 Roads and Drainage

Every case study county reported experiencing damage to roads and drainage elements from the two general types of flooding described in Section 2.3. The term “damage” is used broadly by the DPWs and ranges from localized ditch scour to complete collapse of a length of road bed or embankment. The nature of damage to roads and drainage elements includes but is not limited to the following (examples illustrated in Figure 2-1, page 12):

- Saturation and collapse of inundated road beds;
- Loss of paved surfaces through flotation or delamination;
- Washout of unpaved roadbeds;
- Erosion and scour of drainage ditches, sometimes to the extent of undermining shoulders and roadbeds;
- Damage to or loss of underdrain and cross-drainage pipes;
- Blockage of drainage ditches and underdrains by debris, exacerbating erosion and scour;
- Undermining of shoulders when ditch capacity is exceeded;
- Washout of approaches to waterway crossings; and
- Deposition of sediments on roadbeds.

It is the opinion of the case study DPW directors that the total cost for repair of damage to side ditches, underdrain and cross-drainage pipes, shoulders, unpaved roads and paved surfaces and road beds exceeds the total cost of damage to bridges and culverts that cross waterways. Further, they observed that a large part of the damage does not occur in what are generally considered floodplains along rivers and streams, but is a result of locally intense rainfall-runoff. The estimates ranged from 60 to 70 percent for roads and 30 to 40 percent for waterway crossings. FEMA’s data on Category C expenditures for roads and bridges are not maintained in a manner that allows verification of this assertion.

2.3 Waterway Crossings

Roads over waterways are supported by bridges, culverts, and low-water crossings as illustrated in Figure 2-2 and Figure 2-3 (page 13 and page 14), and described below:

- **Bridges**. Generally speaking, a bridge is composed of abutments on both waterway banks that are designed to support the bridge deck, driving surface, traffic loads, and other loading conditions (e.g., wind, seismic, snow load, etc.) A bridge may have intermediate supporting piers.

- **Culverts**. Culverts generally are rectangular box structures that are site-built, or prefabricated units that range in shape from circular, to oval, to arched (sometimes bottomless).
- **Low-Water Crossings**. Low-water crossings allow vehicle passage and are intended to be under water all or some of the time. There are two general types: permanent concrete slabs (with or without small diameter pipes) and gravel embankments (with small diameter pipes) which form the driving surface.

A federal Public Assistance Officer observed that although waterway crossings built in the last 10 years sustain considerably less damage, Category C expenditures continue to rise because "there are a lot of old bridges out there"

For the purposes of inspections required by the U.S. Federal Highway Administration, specific definitions that vary from the common usage are used. The federal definition of a "bridge" is a structure having an opening that is more than 20 feet wide and may include multiple pipe or box culverts. A "culvert" is a structure having an opening that is 20 feet or less in width. Because the definition is based on the width of the waterway opening, a structure that is built like a bridge (abutments and superstructure) may be called a culvert.

Flood damage is rarely so severe that complete replacement of a bridge or culvert is required. However, when such damage occurs, the structure is usually older and with a previously unidentified structural inadequacy (such as an abutment or pier without solid foundation). Scour behind wingwalls also can lead to undermining of the approach road and structural damage to the abutment. Scour can also cause damage to intermediate piers and their foundations that support the bridge structure.

The case study DPWs reported that the nature of damage at waterway crossings includes, but is not limited to the following (some examples are illustrated in Figure 2-4, page 15):

- Local scour at piers and abutments with and without permanent structural damage;
- Downcutting of streambeds, which may affect bridge abutments/piers and undercut culvert inlets and outlets;
- Washout of gravel low-water crossings;
- Deposition of bed load that restricts the hydraulic capacity of crossings;
- Debris accumulation that may contribute to backup of water and damage to adjacent properties;
- Shifting of bridge decks due to pressure of rising floodwaters; and
- Shifting or migration of waterway channel alignment.

Figure 2-1. Examples of Road and Drainage Damage

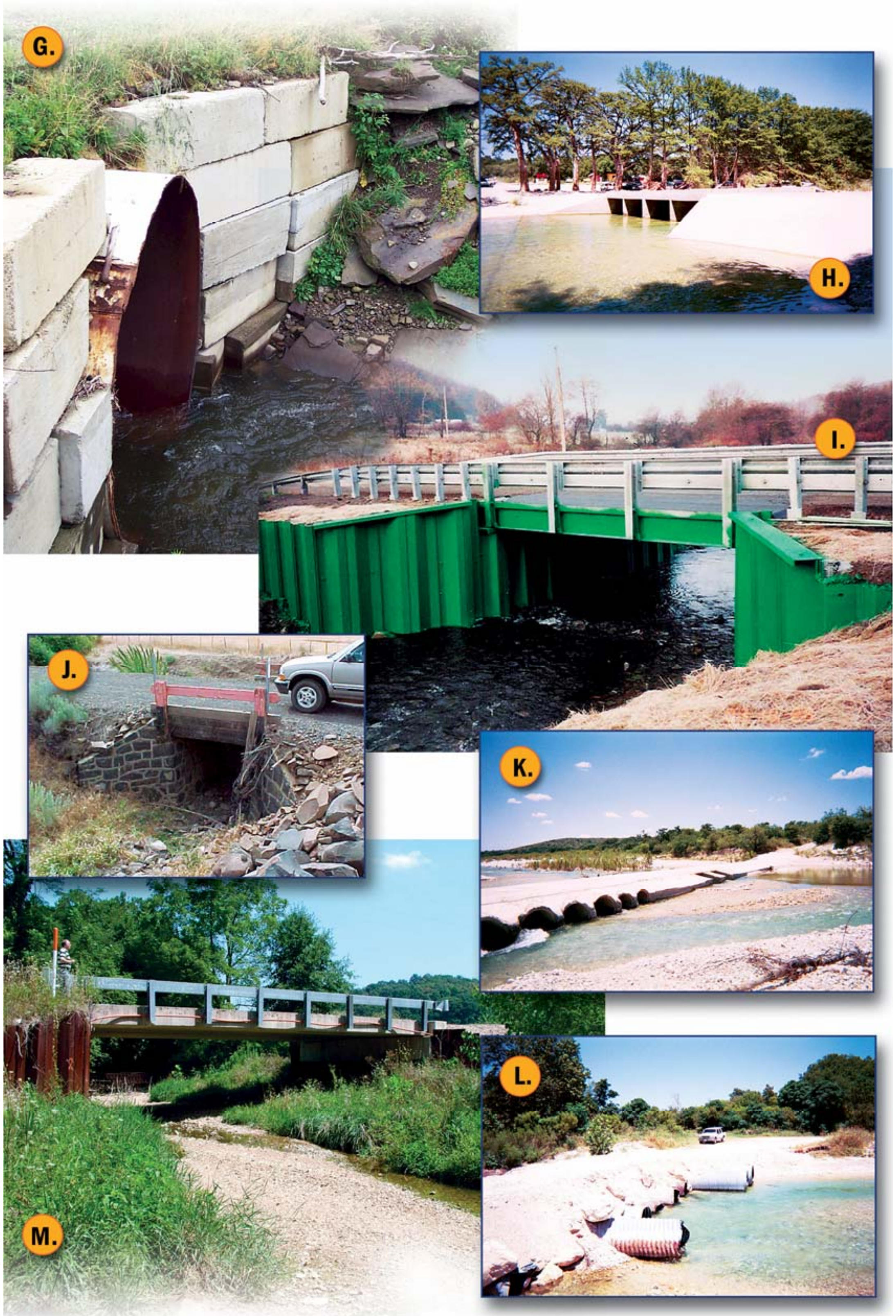

Figure 2-2. Typical Bridges, Culverts and Low-water Crossings

Figure 2-3. Typical Bridges, Culverts and Low-water Crossings

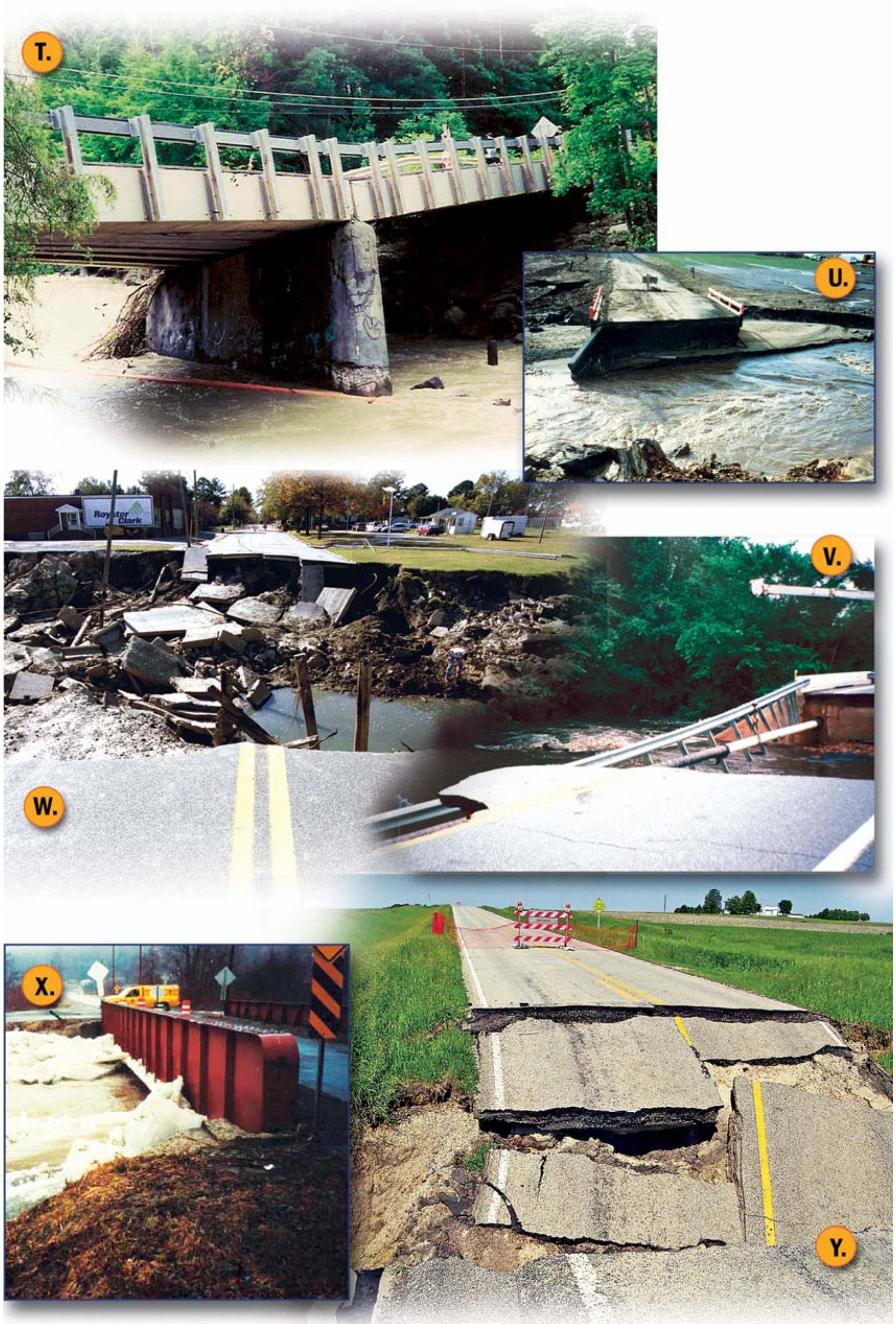

Figure 2-4. Examples of Waterway Crossing Damage

Credits for photographs in Figures 2-1 through 2-4:

A. Cleaning Mud from Road (West Virginia). Photo by FEMA.

B. Base Failure at Local Drainage Pipe (Iowa). Photo by FEMA.

C. Roadbed and Shoulder Undermined by Ditch Scour. Photo by FEMA.

D. Failure of Subbase due to Sheetflow. Photo by U.S. Army Corps of Engineers.

E. Stream Erosion of Roadbed (West Virginia). Photo by FEMA.

F. Scour Under Approach to Low Water Concrete Slab Crossing (Uvalde County, TX). Photo by Rebecca Quinn.

G. Railroad Tank Car Culvert; Block Inlet (Allegany County, NY). Photo by Rebecca Quinn.

H. Multiple Box Culvert; 5'x45' (Uvalde County, TX). Photo by Rebecca Quinn.

I. Typical Short Span Bridge (Allegany County, NY. Photo by Rebecca Quinn.

J. Typical Small Timber Bridge (Wasco County, OR). Photo by Elliott Mittler.

K. Concrete Slab Low Water Crossing (Uvalde County, TX). Photo by Rebecca Quinn.

L. Caliche Crossing; +200' Wide Channel (Uvalde County, TX). Photo by Rebecca Quinn.

M. Long Span Bridge (Calhoun County, IL). Photo by Elliott Mittler.

N. Small Box Culvert (Allegany County, MD). Photo by Rebecca Quinn.

O. Typical Long Span Bridge (Allegany County, NY). Photo by Rebecca Quinn.

P. Long, Single-Span Bridge (Allegany County, MD). Photo by Rebecca Quinn.

Q. Typical Short Span Bridge (Allegany County, MD). Photo by Rebecca Quinn.

R. Railroad Tank Car Culvert; Grouted Inlet (Calhoun County, IL). Photo by Elliott Mittler.

S. Bottomless Arch Culvert (Allegany County, MD). Photo by Rebecca Quinn.

T. Undermined Center Pier. Photo by Guy James, Allegany County Department of Public Works.

U. Caption: Complete Washout. Photo by Dan Boldt, Wasco County Department of Public Works.

V. Utilities Exposed by Washed Out Bridge. Photo by Delaware Department of Natural Resources and Environmental Control.

W. Washed out Bridge and Road. Photo by FEMA.

X. Ice Jamming Threatens Bridge. Photo by Guy James, Allegany County Department of Public Works.

Y. Road Undermined by Scour behind Bridge Abutment (Iowa). Photo by FEMA.

3.0 Case Study Departments of Public Works

This section offers summary descriptions of the organizational/functional, budgetary, and regulatory frameworks for the five case study DPWs, with some characterizations to show similarities and differences. This is important because, as discussed in Section 4.0, these frameworks can impact decision processes for reducing flooding risks to local roadways within the jurisdictions of these DPWs.

3.1 Mission, Organization, and Functions

With respect to the local road system, the missions of the case study DPWs are uniformly described as serving the public by maintaining and improving the local road system. Improving the flood resistance of the system is an integral part of the mission, especially – and more explicitly – in communities where flooding occurs frequently.

The DPWs have similar organizational structures: a director, an assistant manager, and staff responsible for maintenance, inspection, and construction. Three of the five case study counties have some degree of in-house engineering capability. DPWs with larger staffs have separate sections organized by function while those with smaller staffs do not. Table 3-1 compares the staffs of the case study counties.

Table 3-1. Summary of Staffing

	Allegany County, MD	Allegany County, NY	Calhoun County, IL	Uvalde County, TX	Wasco County, OR
DPW Director:					
Has is registered Professional Engineer PE?	Yes	No	Yes	No	No
Tenure*	28/9	30/4	11/11	13/13	28/12
DPW Assistant Director (or engineering manager):					
has PE?	Yes	No	No	No	No
Tenure*	26/9	16/4	25/15	9/9	11/11
Employees, by primary function:					
Engineering/inspection	14	3	11	13	3
Maintenance/construction	71	65			29
Non-supervisory staff/mile	0.15	0.20	0.04	0.04	0.05
Non-supervisory staff/crossing	0.77	0.22	0.13	0.05	0.26
* Total number of years with County/number of years in current position.					

The DPWs have similar functions: management, inspection, maintenance, paving, and construction. The emphasis that each DPW places on some functions varies based on such factors as climate, budget and nature of the road system. For example, maintaining road pavement in communities with severe winter weather is a major function, or departments with very small budgets rely less on site-specific engineering.

Management. The DPW directors in the case study counties each have from 20 to 30 years of experience (Table 3-1). Three have risen through the ranks of their departments, while the other two had no public works experience when hired but had considerable practical experience in the construction or power industries.

Inspection. All components of local road systems are inspected periodically, although the specific scopes and frequencies of the inspections vary widely (Table 3-2, rows A, B and C). Four of the five case study DPWs have staff that are trained to perform inspections of roads and waterway crossings; in the other community (Uvalde County, TX), only the director performs some level of inspection. Bridges (federal definition) are inspected every two years (by the state, contractors, or the DPW). Culverts (including bridges that do not meet the federal definition) are inspected periodically, but the frequency and rigor of the inspections vary. All DPWs inspect roads and waterway crossings that have been flooded before reopening the road to traffic.

Road, Drainage, and Waterway Crossing Maintenance. The workload of the DPWs is dominated by routine maintenance of the roadbeds (paving, repaving, resurfacing, and pothole repair), shoulders, ditches and drainage pipes, along with routine maintenance of waterway crossings which includes washing, painting, removal of debris, and the like. Work needs may be identified through formal inspections, by reports from crew foremen and crew members who regularly drive the roads, and by citizens. As shown in Table 3-1, three of the DPWs (Allegany County, MD, Allegany County, NY, and Wasco County, OR) have separate maintenance/construction and engineering divisions, and one of these (Allegany County, NY) has a dedicated bridge construction crew. The crews of the other DPWs are “utility players” who participate in all aspects of the DPW’s work (Table 3-2, row D).

Waterway Crossing Construction. Each case study DPW has in-house capability to build waterway crossings, although each has also contracted for construction of larger structures (Table 3-2, row C). The most cited reason for maintaining the staff and equipment needed for construction is cost; it costs significantly less for in-house construction of bridges and culverts.

Engineering. Three of the case study counties (Allegany County, MD, Allegany County, NY, and Wasco County, OR) have some level of in-house engineering capability, although the level of performance and the tools used by the engineering staffs vary significantly (Table 3-2, row G). The Allegany County, MD, County Engineer, a registered professional engineer, performs hydrologic and hydraulic analyses and scour assessments and also prepares structural designs and specifications for individual structures. This DPW contracts for some design work, which may include both hydraulic investigations and structural design.

In Allegany County, NY, the County Engineer is a registered professional engineer who performs rudimentary hydraulic evaluations and makes appropriate site-specific modifications to generic structural designs and specifications for bridges and culverts that are constructed with in-house crews. For bridge projects undertaken with FHWA funding, the DPW is required to hire consultants to perform more rigorous hydrologic and hydraulic analyses and to prepare structural designs and specifications. Wasco County, OR, has an engineering division, but all bridge design work is performed by outside consultants.

When Calhoun County, IL, and Uvalde County, TX, propose to replace a waterway crossing, outside consultants are hired to evaluate hydraulics. The evaluations are performed to select the dimensions (height and width) that will convey certain discharges. In Calhoun County, IL, the selection of waterway opening dimensions is constrained or driven by the conditions of a state general permit.   In Uvalde County, TX, the dimensions are selected in order to optimize vehicle access during frequent and prolonged low level flood flows (referred to as "normal" high water).

Table 3-2. Overview of Case Study DPW Functions and Capacities

	Allegany County, MD	Allegany County, NY	Calhoun County, IL	Uvalde County, TX	Wasco County, OR
A. Inspection of federal bridges and culverts (greater than 20 feet)	By State transportation agency every 2 years	By State transportation agency every 2 years	By trained DPW staff every 2 years, using State transportation agency procedures	By State transportation agency every 2 years	By State transportation agency every 2 years
B. Inspection of non-federal bridges and culverts (less than 20 feet)	Performed by State qualified contractors, using FHWA bridge inspection procedures, every 5 years	Performed by staff following FHWA "Culvert Inspection Manual. Structures 10-20 feet every 3 years; structures 2-10 feet every 5 years	No formal structural inspection; examined in the course of business or when reported by citizens	No formal structural inspection; biannual visual check by director; examined by crews in the course of business or when reported by citizens	Performed by trained staff member using FHWA bridge inspection procedures; every 2 years
C. Inspection and maintenance of roadbed and drainage	Crew foremen identify routine road work	Drainage components inspected by trained technician; roads driven weekly, crew foremen identify routine road work	No formal schedule; crew foremen identify and prioritize routine needs	No formal schedule; crews identify and report observed needs	Inspection using Pavement Management System every spring to identify needs and set schedule
D. Waterway crossing maintenance	Designated specialized crew	Designated specialized crew	All crew members participate	All crew members participate	All crew members participate
E. Waterway crossing construction	Major bridge construction contracted and in-house crew; 4-5 rehabilitation projects/year	Designated specialized crew; annual workload includes rehab or replacement of 5 +20-foot structures, 5 10-20-foot structures, 60-90 smaller culverts	All crew members participate	All crew members participate; some new construction is contracted	Bridge construction (+20-foot structure) by outside contractors; less than 20-foot by in-house crew (all members)

Table 3-2. Overview of Case Study DPW Functions and Capacities (continued)

	Allegany County, MD	Allegany County, NY	Calhoun County, IL	Uvalde County, TX	Wasco County, OR
F. Paving, repaving, resurfacing	Paving is contracted and In-house. Ongoing paving and overlay program for 20-30 miles/year	Contractors repave average 25 miles each year	In-house crews pave 2-3 miles of unpaved road each year, and resurface (oil & chip) 1/3 of total road mileage each year	In-house crew seal 15 paved miles/year; un-paved roads are paved only when special funds are allocated	All road crews participate in priority projects selected through the Transportation Improvement Program; less than 10 miles per year
G. Engineering for waterway crossings	Engineering Division conducts hydraulic studies and scour analyses, prepares designs, plans & specs for con-struction. Some bridge design work is contracted	Engineering Section evaluates hydraulic capacity, use State transportation agency guidelines for in-house design (generic abutment and superstructure drawings)	Bridge design contracted, including hydraulic analyses; use standard structural configurations for bridges and box culverts for ease of construction	Contractor evaluates "normal flood" conditions to size box culverts; state transportation agency generic structural design and specifications used for ease of construction	Engineering Division contracts out bridge design, including hydraulic analysis
H. Scour protection	Performs scour analyses for individual structure	Uses easy-to-install sheet piling protection at all bridges without specific analysis	Scour addressed by consultant as part of bridge design to meet regulatory requirements	Box culverts are keyed into bedrock	Scour addressed by consultant as part of bridge design to meet regulatory requirements

3.2 Operating and Capital Budgets

The operating and capital budgets of the case study counties vary significantly. Table 3-3 compares the most recent total budgets (capital and operating) and, as a basis of comparison, indicates the amounts per mile and per county resident. The amounts and availability of state funding and federal funding that are passed through the state transportation agencies varies widely. The reasons for the variations have not been explored.

Each DPW identified several funding sources, notably county general funds, state funds, federal funds (pass through the state), disaster-related funding, and special dedicated sources. Table 3-4 lists the primary sources of funding and summarizes selected notes on each county's budget. There are significant differences in the funding sources and amounts available to each county. Interestingly, federal funding is available to some, but not others. The reasons behind this were not explored, but are likely due to differences in how state transportation agencies handle various types of federal and state funding.

Table 3-3. Summary of DPW Budgets

	Allegany County, MD	Allegany County, NY	Calhoun County, IL	Uvalde County, TX	Wasco County, OR
Operating budget	$5.6 mil	$8.1 mil	$*	$*	$*
Capital budget	$0.26 mil	$0.7 mil	$*	$*	$*
Total budget	$5.86	$8.8 mil	$1.4 mil	$0.98 mil	$3.0 mil
Per mile	$10,650	$25,600	$5,400	$3,100	$4,300
Per capita	$79	$176	$276	$37	$272

* not clearly separated in department's accounting

Table 3-4. Primary Sources of Funding and Selected Notes on Budgets

	Sources of Funding	Selected Notes
Allegany County, MD	▪ State highway fund (highway user taxes) ▪ County general fund ▪ Coal Haul Roads Fund (maintenance of specific roads) ▪ Capital projects funds (state aid) ▪ Reimbursements from town projects	▪ A capital reserve fund holds leftover funds from entire DPW budget; reserves build to support capital projects when other funds are insufficient ▪ Federal (state aid) funding can be used for up to 80% of rehabilitation on +25' bridges (County's choice to exceed minimum of +20'); average has been $150,000/year ▪ Bridge rehabilitation and replacement budget averages $500,000/year (supports annual workload of 4-5 active projects); identified backlog of rehabilitation/replacements is about $10 million
Allegany County, NY	▪ Reimbursements from towns (when the county performs work on town roads and bridges) ▪ State CHIPS funds for maintenance and paving: $1.6 million (FY2004) ▪ Federal and state emergency disaster aid: $54,700 (FY2004) ▪ State aid/federal aid funds (zero in FY2004; State transportation agency allocates by region; County does not receive annual portion) ▪ County general funds (source is tax on real property; local bonds may finance larger projects)	▪ Operating budget includes some materials for bridge construction ▪ Consolidated Local Street and Highway Improvement Program (CHIPS) is apportioned based on local road mileage and use factors; two components: operations and maintenance (State general funds) and capital (sale of Thruway Authority bonds). Although capital projects are eligible, the county uses entire CHIPS allocation for paving.

Table 3-4. Primary Sources of Funding and Selected Notes on Budgets (continued)

	Sources of Funding	Selected Notes
Calhoun County, IL	▪ Local property taxes ▪ State Motor Fuel Tax (based on County vehicle) ▪ State "County Needy Program" (based on a complicated formula that includes township mileage and the county tax base) ▪ State Bridge Rehabilitation Program ▪ Reimbursements from villages ▪ Federal disaster funds (FEMA, Natural Resource Conservation Service, Farmers Home Administration; in past five years, ranged from \$62,000 in 2001 to \$778,000 in 2003) ▪ Payments from private citizens for work on private roads	▪ In recent years, total budget has varied from \$1 million to \$1.8 million, largely due to differences in federal disaster payments ▪ Amounts from State programs are adjusted annually depending on total receipts and political choices. ▪ Surplus accumulates in years when flood damage is minimal and carries over.
Uvalde County, TX	▪ Appropriated County general funds ▪ Fee and fine income ▪ State Lateral Road Fund	▪ Fee and fine income generated by a \$10.50 fee assessed on every vehicle registered in the county and a percent of fines assessed by the county on certain violations and a percent of certain special permit fees. ▪ State Lateral Road Fund determined based on intersections with state roads (\$23,000 per year; used for materials and supplies) ▪ Dedicated Flood Fund receives annual appropriation of general funds (\$55,000, determined as a percent of property tax revenue); used for materials and supplies required for repair of flood damage; this is the only County account that can accumulate from year to year, allowing unspent amounts to build reserve for years when more severe flood damage occurs.
Wasco County, OR	▪ Oregon State Motor Vehicle Fund (gas taxes, truck weight/mile taxes, vehicle registration fees) ▪ Federal Forest Receipts based on a percentage of receipts from timber sales harvests from federal lands in the Mt. Hood Forest)	▪ Material costs have increased significantly due to closure of local rock pits and rising cost of crude oil ▪ Budget has remained relatively constant over past ten years, not taking inflation into account

3.3 Regulatory Frameworks

State and federal requirements are conveyed either as permit requirements or as conditions of funding. The DPWs described requirements and guidance from the State transportation agencies (Table 3-5).

The presence of state regulations specific to flooding was anticipated to be a factor that influences flood-resistance and was taken into account when case study counties were selected. Table 3-6 summarizes floodplain and environmental regulatory requirements in each county.

The contents of Table 3-5 and Table 3-6 are based on reviews of printed materials provided by the DPWs or discussions with the DPWs; it has not been verified by state officials.

Table 3-5. State Transportation Agency Requirements/Guidance

Allegany County, MD	Work undertaken with federal funds must be designed to comply with the AASHTO “Green Book” (*A Policy on Geometric Design of Highways and Streets and The Standard Specifications for Highway Bridges*) unless the county provides documentation to justify a waiver. The State Highway Administration does not impose separately promulgated regulations or standards on local road system work that does not involve federal funds.
Allegany County, NY	Work undertaken with Pass Thru funds must be designed by external design consultants to meet specific standards, including hydraulic performance, road width, shoulder width, and drainage ditch dimensions. The expectation is that bridges will pass the 50-year discharge with 2-feet of freeboard (clearance between water surface and bottom of the superstructure). For scour analyses, the 100-year discharge must be used. County may select acceptable designs that address multiple objectives, consistent with the AASHTO “Green Book”.
Calhoun County, IL	The State Local Roads Manual requires bridges with fewer than 250 vehicles per day to pass the discharge of the 15-year flood, increasing to the 100-year flood as a function of increased traffic volume.
Uvalde County, TX	State transportation agency does not convey any design requirements, although funding is provided to county for maintenance of County roads that intersect State roads.
Wasco County, OR	State transportation agency’s hydraulics manual specifies that new bridges pass the 100-year flood discharge (recommended 1-ft freeboard to underside of superstructure). Bridges subject to debris flows to pass the 25-year flood discharge with 3-feet freeboard or the 100-year discharge with 1-foot freeboard, whichever is more restrictive.

Table 3-6. State Water Resources and/or Environmental Permits and Approvals

	State Regulation/General Permit	Waterway Crossings		
	Activities	Methods for Determining Discharges	Required Discharge for Design (new & out-of-kind)	Hydraulic (new & out-of-kind)
Allegany County, MD	State water resources permit required for all work (temporary and permanent) within waterways and floodplains Regional Letters of Authorization (general permits) issued for maintenance and in-kind replacement, pursuant to both floodplain and nontidal wetlands authorities (including Water Quality Certification)	Not required for in-kind replacements In the public domain (reviewed by State)	100-year flood that is determined by assuming ultimate development of contributing watersheds.	Hydraulic analyses to evaluate impacts on the floodplain and stability of the stream bed and banks; if not designed to pass the entire discharge, must be designed to minimize damage
Allegany County, NY	State water resources permit required for all work (temporary and permanent) within waterways and floodplains. State General Permits are issued pursuant to wetlands authorities and the State's Water Quality Certification The General Permit specifically authorizes "construction, reconstruction, maintenance, and repair of bridges and culverts and disturbance to beds and/or banks of all streams." Specific conditions are outlined for (a) in-kind bridge or culvert replacement in-kind, (b) new or other than in-kind bridge or culvert, (c) temporary detour structures for traffic management, (d) new road construction (less than 500 feet), and (e) stream bank stabilization activities	Not required for in-kind replacements Assumed to be standard engineering methods (not reviewed by State)	General permit refers to discharge of the 100-year frequency flood	In its role as the State Coordinating Office for the National Flood Insurance Program, the State includes in the General Permit several conditions related to floodplain management

Table 3-6. State Water Resources and/or Environmental Permits and Approvals (continued)

	State Regulation/General Permit	Waterway Crossings		
	Activities	Methods for Determining Discharges	Required Discharge for Design (new & out-of-kind)	Hydraulic (new & out-of-kind)
Calhoun County, IL	Statewide Permit No. 2 – Rural Bridges Over Streams Draining 10 to 25 Square Miles; fast-track approval intended to reduce delays in the approval of new and replacement structures that have little likelihood of causing significant flood damage due to changes in the floodplain, including the impacts of backwater flooding	Designs must be certified as having been prepared using standard engineering methods and in compliance with the terms and conditions of the Permit and State rules	New structures and replacements that involve raising the road must be designed to not increase water surface elevation for the 100-year flood more than certain amounts at the crossing and 1,000 feet upstream.	Designs must be certified as having been prepared using standard engineering methods Individual permits required for new and replacement structures that do not preserve waterway opening, have been the cause of demonstrable flood damage, and involve an appreciable raising of the roadway; and(b) new structures that involve channel work (straightening, enlargement or relocation)
Uvalde County, TX	U.S. Army Corps of Engineer's Nationwide Permit #3 authorizes repair, rehabilitation or replacement of serviceable structures. Authorizes work on structures that are "destroyed or damaged by storms, floods, fire or other discrete events, provided the repair, rehabilitation, or replacement is commenced, or is under contract to commence, within two years of the date of their destruction or damage."	None	None	Nationwide Permit #3 does not authorize work that would cause "more than minimal changes to the flow characteristics of the stream, or increase flooding."
Wasco County, OR	Removal-Fill Law requires a permit to remove or fill material in waters of the state (including bridge and road construction and rehabilitation); authorization also required by the U.S. Army Corps of Engineers (Clean Water Act).	None	State permit requires consistency with local plans and ordinances (which may specify discharge).	Provisions related to fish passage and water quality; no hydraulic specifications.

4.0 Decision-Making Processes for Local Road Systems

An overview of DPW decision-making processes used in the five case study DPWs, specifically describing three general aspects, is provided in Section 4.1. Most decisions are based on experience, although some decisions are constrained by state regulations or by requirements conveyed through a funding source. Most decision processes are informal, although certain types of decisions follow a more structured approach. For the most part, the case study DPWs tended to make decisions in similar fashion; where significant differences were observed, they are noted.

And finally, it is important to acknowledge that all of the case study DPW directors emphasized the difficulty they have in balancing multiple factors in virtually every decision they make, most notably limited financial resources.

The remaining subsections briefly describe five separate decision-making processes that have some bearing on the flood-resistance of the local road system. Each case study DPW approaches each process somewhat different from the others; where those differences are significant are noted. The five decision-making processes summarized are as follows:

- Subsection 4.2 describes decisions related to the annual budget, including options available when response responding to flood damage exceeds a DPW's budget.
- Subsection 4.3 briefly describes inspections of roads and drainage, and inspections of waterway crossings. While the inspections themselves are not decisions, the results form the basis of many decisions.
- Subsection 4.4 describes approaches used to decide certain design parameters for waterway crossings.
- Subsection 4.5 highlights that a number of short-term response actions must be decided in the immediate post-flood period, some of which involve repairs to roads and waterway crossings.
- Subsection 4.6 summarizes long-term decisions related to recovery from floods and factoring mitigation into recovery work.

4.1 Overview of Decision Making

From the outside, many decision-making processes applied in any field of endeavor appear deceptively simple: identify the problem, consider factors and possible solutions iteratively, balance various factors, narrow the options, and select the solution that achieves the desired outcome to the extent practical. However in practice, decision processes exercised in public works departments are not straightforward and linear and, at each interim decision point, multiple and often ill-defined variables are considered. While all of the case study DPWs focused tightly on their overall objective to provide safe roads for the traveling public, each achieved that objective by making multiple decisions about many different aspects of the DPW's work.

Although there is no standardized method by which the case study DPWs perceive and address flood risks for their entire local road systems, there are five primary steps for decisions related to waterway crossings, and each step may involve varying degrees of formality:

1. Gather data about the road and crossing to define the problem. Data about the road may include traffic count, projected growth given development in the area, criticality for emergency vehicle access and evacuation, importance for the local economy, alignment and sight distances, widths of paved surface and shoulders, and current condition. Data about the crossing may include construction plans, inspection reports, maintenance records, documentation of past flood damage and repairs, and available flood hazard maps or hydraulic studies

2. Specify target level of performance. The importance of a road and the frequency and nature of flooding are important factors that influence the level of performance that is desired at any given crossing. How the level of performance is expressed varies, but may be in terms of cost of repairs, frequency of inundation, or duration of impassible conditions.

3. Identify influence factors and viable options to achieve the target level of performance. What constitutes a viable option at any given location will vary depending on many factors, but likely will be influenced by the site constraints, whether achieving multiple objectives is desired, and whether buildings are in the floodplain upstream or downstream of the crossing.

4. Balance influence factors and evaluate consequences. For each option there are direct and indirect consequences associated with the degree to which the target level of performance is achieved. Sometimes there are no viable options to achieve the target level of performance. Some evaluations may be technical or based on experience, but all take into consideration available budget resources, construction capability, regulatory requirements, and environmental constraints.

5. Selection of the solution. Where other factors do not overwhelm achieving the target level of performance (acceptable risk), then flood-resistance becomes a significant influence on the final solution.

4.1.1 Experienced-Based Decisions

In all of the case study DPWs, most decisions are empirical – especially in the smaller and more rural agencies and those not constrained by regulations or other factors. That is, the DPW staffs know what works because they have observed that it works (e.g., acceptable performance during a subsequent flood). When the outcome is assumed to be known before the decision is made, the decision process is perfunctory. The internalization of the experience-based lessons learned appears to outsiders as a type of “shorthand” or “short cut” approach, largely because explicit consideration of other options is not part of the decision process followed by these agencies.

Although there are few if any external challenges to their decisions that would prompt changes, DPW directors who participated in the project state that they continuously seek to understand and implement improvements to their roads and bridges. Although experience with their own road system is a very strong influence, the DPWs have stated that they do not confine their lessons-learned only to what they see in their jurisdiction; rather, they are open to learning from the successes of others. However, the extent to which this can practically be done within the current operations of these DPWs is constrained by the limited availability of documentation of successes of others, and also by fiscal constraints on attending conferences and training sessions which are typical avenues to gain insight from the successes of others.

Basing decisions predominantly on past experience has both positive and negative aspects. On the positive side, experience is a result of past decisions that provide continual on-the-job training, collective learning, and ultimately organizational continuity. For example, when road crew supervisors make decisions, they communicate the decision method, considerations, and choices to their subordinates. This enables these subordinates to become imbued with DPW practices as they rise through the ranks. In successive years, work crews can review previous inspection reports and works, then either confirm or modify choices. For everyone, this is a self-reinforcing feedback system. For the agency as a whole, incremental learning accumulates and, on the whole, can be dramatic over time.

On the negative side, learning only from “close to home” experience can lead to routine decisions made within a perceived set of limited choices. More exposure to successful solutions and practices implemented by others – rather than more regulations – can minimize the negative implications. Experienced-based learning, by itself, also does not take advantage of improvements in technology; however, because the rate of change of technology with respect to public works appears to be slow, this negative aspect likely is small.

Flood events and damage that exceed what a DPW experiences during a normal year provide the opportunity for experimentation and innovation. Although most damage is similar to past damage, a specific event may present new damage situations for which the conventional experienced-based set of options is not adequate to resolve. This has prompted some case study DPWs to seek to expand their experience-based approach by searching for new options and solutions, through communication with outside consultants, professional colleagues, professional organizations, neighboring DPWs, and other peers. One expected source of information that has not always been fruitful is the team of state and federal inspectors that arrive after major disasters.

The DPW directors were uniformly clear that cost is a major constraint. As a result, they do not price out every alternative because they know when an alternative will be too costly. In terms of physical design factors, if experience shows that a structure of a certain type/size did not perform well at one location, they usually do not revisit that same type/size when making decisions for another location. Similarly, if experience shows that a certain type of wingwall is susceptible to scour, they simply do not consider it again or they augment the structure with additional scour protection. They are incremental empiricists, usually starting with what their past experience has demonstrated to be the most effective approach. They tend to explore other options and innovations only when particular flooding events and circumstances lead to situations that are not covered by past experience.

4.1.2 Formal and Informal Processes

Decisions made by the case study DPWs are made through both formal and informal processes that are described in the following subsection. These processes concern decisions related to the annual budget, inspections, road dimensions and surfaces, bridge and culvert designs, scheduling of daily work, dealing with unexpected damage, and post-flood recovery. All decisions are influenced by multiple factors and the factors often have many facets. Some factors are explicit and some are external, but many are not formally recognized, quantified, or given prescribed weight. Some factors that influence decisions regarding flood resistance in the case study DPWs are described in Section 5.

Formal processes are used to set annual budgets, to conduct inspections, and to comply with regulatory requirements. The degree of informality in other decisions varies somewhat in the case study DPWs, especially as it relates specifically to improvements for bridges and culverts. The DPWs with higher engineering capabilities tend to utilize somewhat more specific hydrologic and hydraulic tools and information; however, they do not consider themselves to be bound by rigorous application of that information. Informal decision processes are used to respond to severe flood damage or to respond to political requests on behalf of citizens.

4.1.3 Balancing Multiple Demands

The directors of DPWs and their senior managers balance the daily demands placed on them, and every day they are faced with what they describe as insufficient resources. When the weather remains benign, a DPW's annual work plans may actually be completed within the constraints of the annual budget. However, plans change for many reasons, including political and citizen complaints (often about drainage problems) and flooding that causes damage at a scale that cannot be absorbed into the originally approved annual budget and work plan. These changing conditions influence daily decisions to allocate DPW resources to maintain the local road systems and provide for the safety of the traveling public.

4.2 Decision Processes for Establishing Annual Budgets

The result of the budgetary process sets the stage for general decisions throughout the year for the allocation of resources to specific categories of work, including specific capital projects and, in some counties, funding for repair of flood-induced damage. The general budget processes for the five case study counties are summarized below.

4.2.1 Initiation of Budget Planning

It is common for the annual budget-planning cycle to be initiated by the county's executive office which provides the target budget amount. Normally, from three to six months prior to the beginning of a county's fiscal year, the DPW director and senior staff estimate both expected revenues and anticipated costs for the year's projected workload. Revenue estimates usually are based on historical data or trends, and cost estimates are based on a continuously evolving list of needs identified through periodic inspections. Table 3-3 summarizes the annual budgets of the five case study DPWs, and Table 3-4 identifies primary sources of funding and offers brief notes to explain certain aspects of each DPW's budget.

4.2.2 Revenue Sources and Estimation Practices

Typical revenues are from several external sources over which the DPW has little or no decision authority, such as state funds earmarked for specific purposes. The exception is general funds. The amount of general funds allocated by the executive branch may be influenced by the DPW's list of maintenance and improvement needs. Allegany County, MD, indicated a practice of regularly overestimating the cost of some types of capital work in the event other areas of the budget experienced shortfalls. All counties experience some degree of minor flood and runoff damage every year and, for the most part, the costs of repairs are planned for and embedded in their normal budget estimates.

In most local governments, the authority to create special funds and to accumulate unspent funds from year to year rests with the executive and legislative branches. An agency cannot make such decisions unless authorized. Of the five case study counties, only the legislative body of Uvalde County, TX, has authorized a dedicated, annually budgeted “flood fund”; however, this fund is not adequate to cover costs due to severe flooding that affects multiple watersheds or multiple floods during a single year. Calhoun County, IL, and Uvalde County, TX, are authorized to accrue unspent funds in explicit recognition of variations in their workload, especially when major flooding occurs.

Expenditure estimates are determined by assuming that: (a) there will be no floods other than the “average” experience based on recent records; and (b) there will be no other unusual demands placed on the DPW’s resources. Planned costs consist mainly of labor, materials, and equipment, and some DPWs have separate line items for paving services that cannot be done in-house. Costs associated with bridge replacement projects that are constructed with in-house forces may be included in labor and materials line items, or may be separated in a capital budget.

Budgets are very general statements of intent. Except for line items for identified capital projects or funds from outside sources earmarked for specific purposes, expenditures from most accounts are not constrained by rules that specify exactly how funds will be spent. Capital projects tend to be of two types: (a) construction (major road work or waterway crossings); and (b) purchase of new or replacement equipment. Most budget estimates for the first type of capital project are based on in-house experience with similar projects; fewer planned capital projects have cost estimates prepared by outside engineering consultants. Decisions pertaining to the second type of capital project – the purchase of new equipment – are largely driven by the desire to perform the vast majority of road, drainage, and waterway crossing maintenance and construction work with in-house crews.

All DPW directors have the ability to shift funds between line items, unless the funds are constrained by the external fund source. Some DPW directors have additional authority to move funds from one account to another or to draw down reserves, in order to deal with unexpected circumstances. This authority is explicitly granted by the executive and legislative bodies, in large measure to allow the DPW directors to exercise some independence in the decision-making process and to respond adequately to unexpected circumstances that demand immediate attention. It is a significant benefit during and after damaging floods when formal approval processes could inhibit acceptable recovery actions.

4.2.3 Additional Funding for Unforeseen Flood-Related Expenses

In the event that post-flood expenses cause budgets to be exceeded, DPWs have two options: (a) petition for additional local funds; and/or (b) seek funding from state and federal agencies. External sources are more likely to be sought for specific projects, as illustrated by the case study DPWs that developed partnerships with the Natural Resources Conservation Service (NRCS).

The fact that costs are rising faster than revenues is a significant characteristic of annual budgets that is outside the control of the DPW directors. Thus, each year it is recognized that the work they are able to accomplish either will be scaled down or they will have to become more productive. Either way, the directors are concerned that achievements made in the past decade may be undone due to lack of resources for maintenance and their ability to pursue improvements will be impaired.

4.3 Decision Processes for Road and Bridge Inspections

4.3.1 Scope of Inspections

All case study DPWs conduct road and drainage inspections, some of which are considerably more formal than others (Table 3-2, rows A, B and C). Only Wasco County, OR, uses formal inspection methods to evaluate road dimensions, pavements and shoulders, and drainage. Wasco County schedules its road inspections for the spring, while the other case study DPWs have no formal schedule. Allegany County, MD, Allegany County, NY, and Calhoun County, IL, delegate road inspections to crew foremen, while the Uvalde County, TX, director conducts visual inspections primarily during the winter months. Allegany County, NY, has an engineering technician assigned to perform inspections of drainage system on an on-going basis.

All inspections include some level of assessment of pavement condition, structural condition of crossings, drainage adequacy, and damages from winter precipitation and recent high water events. The results of the inspections are used to produce prioritized lists of road segments and waterway crossings requiring work, including routine maintenance, significant rehabilitation or upgrade, or complete replacement. The scarcity of resources (especially funding) constrain decisions about exactly which road segments and which waterway crossings will be included in the work plan. The DPW directors were able to list multiple factors that they juggle in setting actual work, but those factors and the weight given to them are not formalized.

4.3.2 Role of Inspections in Establishing Maintenance Needs

Allegany County, MD, Allegany County, NY, Calhoun County, IL, and Uvalde County, TX, rely largely on the judgments of experienced crew supervisors to make many decisions related to maintenance needs. Assistance from up the chain-of-command is requested if conditions are outside of their judgment range, but the conditions that prompt the involvement of supervisors are not rigorously defined. Wasco County, OR, after applying formal inspection methods, applies a formal methodology to determine priority maintenance needs, although final decisions are in part based on judgment of managers.

The numerical ratings produced from the required inspections of bridges with spans that are longer than 20 feet are among the only quantified factors that influence decisions. When numerical ratings fall within pre-determined levels the local DPW has little choice but to perform indicated work or to post the bridge as weight limited. Sometimes however, required work cannot be performed until funding is provided by the state transportation agency.

For bridges and culverts with spans that are less than 20 feet, the DPWs that apply the same inspection methodology use the resulting numerical ratings in a similar manner to prioritize maintenance and rehabilitation work. However, because the federal requirements do not apply, the DPWs have more flexibility in scheduling the work. The decision to use the same inspection procedures is based on a desire to minimize differences that the staff has to accommodate and to limit liability. More than one DPW director somewhat ruefully expressed frustration that when he instituted the formal inspections a much larger workload was revealed. As part of an overall scheme to replace deteriorated wooden bridges, Calhoun County, IL, postpones rehabilitation of wooden bridges until such time as structural conditions warrant replacement.

4.3.3 Inspection Frequency

Bridge inspections are performed on a fixed schedule as a function of the length of span. It is a federal requirement that bridges longer than 20 feet be inspected every two years. For the case study counties, these inspections are conducted by the state Departments of Transportation, except Calhoun County, IL, which performs the inspections for the state. Although not required, all of the case study DPWs conduct some type of inspection of bridges and culverts that are less than 20 feet in length. The frequency of inspection varies from every two years (Wasco County, OR) to every three to five years (Allegany County, MD, and Allegany County, NY); Calhoun County, IL, and Uvalde County, TX, inspect these smaller structures visually but not on a fixed schedule (Table 3-2, row B).

4.4 Decision Processes for Bridge and Culvert Structures

4.4.1 Decision Makers

It is important to restate that the five case study DPWs – each of which are rural and relatively small in terms of staff and budgets – are not building new roads and bridges. The case study DPWs regularly make decisions about rehabilitation, repair, and replacement of existing structures. Table 3-2 (row G) includes notes about how each DPW generally approaches engineering for waterway crossings. In the agencies with engineering sections (Allegany County, MD, Allegany County, NY, and Wasco County, OR), decisions involving design are delegated to the engineering manager, sometimes with support by outside engineering contractors. In Calhoun County, IL, and Uvalde County, TX, both very small agencies, the DPW directors make design decisions. Design decisions include types of structure, size of structure (hydraulic opening), abutment type, and manner of scour protection.

4.4.2 Role of Flood Risks in Overall Bridge and Culvert Decisions

Rarely if ever are decisions to replace or improve an existing structure based solely on flood-damage reduction objectives. For example, none of the case study DPWs uses hydraulic inadequacy as a dominant criterion to select projects. It is much more common that other factors that are directly related to user safety drive replacement decisions, specifically weight limitations, increasing traffic volumes, or structural deficiencies. Nevertheless, once the replacement or improvement decision has been made, then improving flood resistance becomes a significant objective – but always, the degree to which that objective and other project objectives is achieved is tempered by budget concerns.

4.4.3 Role of Regulations in Bridge and Culvert Decisions

A combination of formal and informal processes is brought to bear to arrive at decisions related to bridge and culvert configuration and flood resistance. Compliance with regulatory requirements is, in a sense, a formal process, although in practice it is not always achieved in a formal manner. State requirements set a performance standard (such as passage of a specific discharge), but rarely do those requirements constrain how that performance is achieved. For the five case study counties, Table 3-5 summarizes the requirements or guidance of the applicable state transportation agency that pertains to hydraulics. Table 3-6 is a brief summary of requirements of state water resources and environmental permits and approvals that are pertinent to bridge and culvert configuration, most notably whether use of a specific discharge is required.

4.4.4 Role of Hydraulic Assessment in Bridge and Culvert Decisions

The case study DPWs use a range of assessment tools to evaluate hydraulic performance (including outside engineering consultants) and the results have significant bearing on the final selection of the bridge or culvert configuration, including measures to protect abutments, inlets and outlets. Rarely are multiple configurations fully tested, in large measure because experienced-based interim decisions are made by the engineer or DPW director or there are physical site constraints. For example, Allegany County, NY, regularly raises bridge abutments during superstructure replacements in order to improve hydraulic capacity. However, because of the grade of approaches or concerns about floodplain fill, it was not always able to provide the preferred degree of hydraulic improvement.

4.4.5 Decisions Regarding In-Kind Replacement

Every state permit or general permit allows in-kind replacement with very few constraints. Despite this “easy” path through what some consider to be the rigors of regulatory processes, it is rare that a DPW will decide to default to a fully in-kind replacement unless there are no other objectives to be satisfied. For example, if a structure has already performed well under flood conditions, then a decision to replace in-kind is straightforward.

4.5 Immediate Post-Flood Response

Within each of the five case study counties, three or more flooding events have occurred that were declared federal disasters, and most have had numerous smaller events since 1965 (Table 1-2). The occurrence of severe flooding prompts a number of immediate decisions such as closing roads to traffic (often based on knowledge of low, floodprone areas), removal of debris accumulations at bridges, and assisting emergency responders with rescues and stranded citizens. Most of these urgent decisions are based on local knowledge and experience (DPW directors have the explicit authority to close roads), and at the direction of the chief executive officer or the designated emergency manager. Budget concerns are not part of the decision equation when faced with obvious threats to safety and the road system.

As the waters recede, the DPW staff is mobilized and involved in debris removal and inspections to identify critical needs. For a short but undefined period of time, some urgent work is performed as quickly as possible, regardless of whether the existing budget has adequate funds. The highest priority is placed on damaged road sections or waterway crossings that have isolated residents. Whether and where this urgent work occurs is a function of the nature of the work required to perform repairs and available staff, equipment and materials. However, the objective of restoring the road system for safe travel is a very strong influence.

Exceptions to this rapid repair response are when the damage is so severe that it cannot be handled by DPW staff. For example, such damage could consist of structural damage to bridges and culverts, streambank erosion, or completely washed out roads. Section 4.6 provides more detail about decisions for long-term recovery and mitigation.

The case study DPW directors asserted that the decisions they make in this immediate response period are not influenced by whether they think the event will rise to a level that will qualify for federal disaster assistance. Most presidential disaster declarations are made weeks after the event and, although inclusion in a major disaster declaration brings in funds for recovery, the urgency of the response decisions is such that they cannot be postponed.

An adverse consequence of the DPWs' need, and sometimes ability, to perform urgent work, was identified. Some case study DPWs described difficulties getting FEMA inspectors to approve reimbursements for work that was done in advance of the federal inspection, regardless of the detailed photographic documentation and records of labor and materials used at each site. However, despite the potential fiscal consequence (i.e., disapproved reimbursement requests), the urgency of those decisions was dominant.

4.6 Decision Processes Regarding Long-Term Flood Recovery and Mitigation

4.6.1 Overall Processes

At some undefined time after an event, the urgent and immediate response activities transition into the business of long-term recovery. The total picture of damage emerges as the DPW personnel report on observations and post-flood inspections of all affected road segments. In terms of timing, if an event has qualified for federal disaster assistance, the arrival of federal inspectors seems to more or less coincide with the transition period.

Decisions for long-term recovery deal with setting priorities and, for each major damage site, defining the scope of work. Although deviations in defining the scope of work for specific sites were identified within each case study community for specific sites, when defining the scope of work the DPW directors generally attempt to be consistent with their normal decision processes. This is not surprising given the empirical basis for most of their decisions that involve flood resistance and circumstances similar to those that have occurred in the past; i.e., they know what works because they have observed that it works. Of course, in some counties it was noted that each successive flood is another opportunity to learn new lessons about what works, which improves their future decision making, particularly for flood severities and circumstances that were not experienced in the past.

The occurrence of flood damage will alter and post-pone the annual list of scheduled work, in order to free up funds and staff. Determining the highest priorities among many competing priorities is difficult, especially if severe damage has closed multiple locations. DPW directors have to consider the number of people affected, the importance of the road for the local economy and school bus access, political interests, whether the work can be done with in-house resources, adequacy of the budget, and other factors.

In terms of defining the scope of work for specific damage sites, the factors that influence decisions remain the same as those that influence decisions on a daily basis, described in Section 5, although some factors may be given different weight. Actual flood experience is a very strong influence. The DPW directors routinely try to improve flood resistance rather than opt for simple in-kind replacement. When faced with actual damage, choosing in-kind replacement is contradictory to their empirical approach that is based on continual learning through experience.

4.6.2 Post-Flood FEMA Interfacing

When a county is included in a major disaster declaration, some decisions for long-term recovery are influenced by FEMA's public assistance program rules and constraints. To be eligible for reimbursement the scope of work for each site must be approved by the FEMA inspector and the state inspector. The details of the scope of work usually are prepared by the DPW following its normal decision process – often with added emphasis on improving flood resistance – and then negotiated with the FEMA inspector.

The past 5 to 10 years have been a transition for FEMA, moving away from strictly limiting reimbursements to in-kind work and toward incorporating mitigation measures to improve the flood resistance of local road systems. Based on the experiences of the case study DPWs, this transition has been neither uniform nor complete. They reported that whether their proposals to incorporate measures to improve flood resistance where received positively varied from disaster to disaster and often from inspector to inspector.

The uneven experience with FEMA inspectors and how mitigation measures are – or are not – addressed does influence some decisions. If reimbursements are inadequate to cover costs the long-term consequence is borne by the entire local road system, which may become more vulnerable to damage. This is because as the local share of recovery increases, budgeted funds are depleted which translates into less funding to undertake regular maintenance and scheduled work when the community returns to normal.

5.0 Factors that Influence Decisions

This section describes factors that the case study DPWs have identified as being influential and related to flood risk-reduction decisions. These factors are not necessarily all of the factors that come into play in any given decision. However, they were identified by all or most of the case study DPWs during discussions about factors that influence decisions related to improving flood resistance.

In Section 5.1 and 5.2, regulatory requirements and physical environments within which the case study DPWs operate are characterized as factors that influence day-to-day operations as well as individual decisions. Sections 5.3 through 5.9 then describe how the decisions within the case study DPWs are influenced by local knowledge and experience, staff and equipment capacity, inspections, immediate post-flood recovery, and cost and benefit considerations.

5.1 Requirements Imposed by Others

5.1.1 Summary of External Requirements

Requirements imposed through state regulatory programs limit some decisions as do conditions that are imposed by a funding source. Table 3-5 and Table 3-6 summarize for the case study DPWs the external requirements that may control one or more aspects of work related to waterway crossings. Those requirements are summarized below.:

- *Regulations and Individual Permits Applicable to New and Out-of-Kind Crossings.* Some states have regulatory authority and issue individual permits, usually by the water resources or environmental agency. Engineering analyses may be required to determine discharges and to evaluate the hydraulic impacts of proposed crossings in order to demonstrate acceptability of the effect on the water surface elevations of specific frequency floods.

- *General/Regional Permits Issued Jointly by the State and the U.S. Army Corps of Engineers Pursuant to Clean Water Act*. Some states simply certify Corps nationwide permits as consistent with their Water Quality Certification authority. General or regional permits are most common for in-kind replacements, although some out-of-kind replacements may be authorized if consistent with specific permit conditions. These permits are not individually issued, but are “blanket” in nature, usually with some form of self-certification and/or reporting requirement.

- *Conditions Attached to Funding from State Transportation Agency.* Funds provided by state transportation agencies may have attached conditions that must be met by the DPW in order to use these funds. For example, such conditions may be attached to funds provided to rehabilitate or replace bridges that are longer than 20 feet and are subject to biennial inspections; i.e., it may be required that such bridges convey a specific discharge.

- *Guidance/Design Manuals.* Strictly speaking, guidance and design manuals issued by state transportation agencies are not regulatory in nature. Nevertheless, they are generally treated as such.

The controlling regulatory requirements establish minimum requirements. It appears common practice for the DPWs and their engineering consultants to view the requirements as the design objective rather than as the starting point.

5.1.2 Requirements Specific to Flood Resistance

In states that have regulations specific to flood resistance, the case study DPWs (or their consultants) use sophisticated engineering tools to evaluate flood hazards (e.g., to determine discharges for different frequency events and to model hydraulics and scour of specific bridge/culvert configurations). Some DPWs rely on consultants to satisfy regulatory requirements and, thus, are not directly involved with the interim and iterative evaluations of types of structures (bridges versus culverts) and sizes of waterway openings. In those cases, the DPW's role is the selection of the alternative that best satisfies its other unwritten decision rules, which often are led by budget constraints but also may be influenced by ease of construction by in-house crews.

5.1.3 States without Specific Flood-Related Requirements

In states without explicit floodplain regulations, including those that convey flood-related objectives only as conditions of general permits, DPWs use approaches other than sophisticated engineering tools. While simplified methods may not provide the same answers as state-of-the-art hydrologic and hydraulic models, the "quick and dirty" approach was defended by the DPWs. In their opinions, even relative improvements contribute to the enhancement of the overall performance of their bridges and culverts. A relative improvement is one that produces more efficient hydraulic performance even though it would be difficult to state that it was designed for a specific discharge.

5.1.4 Influence of Environmental Regulations

Some DPWs point out that environmental regulations can also limit their ability to perform what they consider to be necessary and appropriate maintenance at waterway crossings. In particular, the restrictive limits on stream channel maintenance (removal of built-up sediment and vegetation) results in reduction of hydraulic capacity and may contribute to more scour and overtopping. The burden of having to obtain individual permits in order to undertake more extensive sediment and vegetation removal is a deterrent that, in their opinions, contributes to flood-related damage.

5.2 The Physical Environment

The nature of landscapes, underlying geology, and climatic conditions vary dramatically across the United States. The number, length, size and location of waterways, as well as the topography of an area, along with the patterns of human habitation, have influenced the historical layout of the road network. Those factors also influence the number, length and types of roads and the number and types of waterway crossings. Along with the physical constraints and consequences of weather, these factors all have substantial bearing on a DPW's potential workload.

Some differences that are due to the physical environment are obvious. Severe winter weather certainly limits when some work can be done, including routine maintenance. Pavement in northern communities must endure freeze-thaw cycles and the wear and tear of snow removal. Some regions have fairly stable, incised stream channels that exhibit little if any tendency to migrate, while others are characterized by deep unconsolidated deposits on which waterway channels tend to move with considerable regularity. Some regions receive rainfall throughout the year and side ditches and drainage components are sized to carry runoff with regularity. Yet arid regions can receive much of their average annual rainfall in just a few intense storms that quickly overwhelm the drainage system.

Geography and distribution of population also influence the shape and distribution of road networks. The routes of most local roads were likely selected by many variables that are lost in history, but certainly were related to historic development patterns. Many roads are laid out along streams and rivers, likely because those areas offered flatter land and because early settlers established communities near sources of water. Some roads follow crests, thus avoiding significant changes in grade and having to cross rivers and streams.

The connectivity of the road network is also influenced by the physical environment, especially in counties that are very large in land area with most residents concentrated in a few towns or villages. Not surprisingly, rural development in the past decades has tended to occur where the roads are already located, rather than the other way around. Dead-end local roads that extend off of state roads are common, rather than a connected “cross country” network of local roads. The presence of dead-end roads is not a deficiency in serviceability, but only a reflection of the how widely dispersed across the landscape are those who live outside of towns and villages.

Each of the case study DPWs tended to characterize as unique the physical environment in which it works and the inherent constraints. For the most part, this characterization was made when the directors expressed opinions regarding the value of a non-mandatory guideline or standard related to flood resistance. Their concern was that a standard that dictates how to make decisions could work against their flexibility to adapt to the specific constraints of their locales. However, the DPWs were more receptive to a possible future non-mandatory guideline that would document examples of successful flood-risk reduction practices/decisions that encompass a wide range of operational constraints and regional physical characteristics.

5.3 The Influence of Flood Hazards and Experience

This section discusses how flood risk-reduction decisions are affected by flood hazard data/maps and past experience with flood damage. First, there is brief background on the 1%-annual chance (100-year) flood which is the basis for flood hazard maps that are prepared by the National Flood Insurance Program (NFIP) and that are used by communities to regulate development activities. Whether shown on a map or simply known through experience, flood hazards will influence a DPW’s general operations, efforts to comply with regulations, and evaluation and selecting waterway crossing designs. Actual damage to road surfaces and drainage system components is less influential, in large part because all parts of the road system are equally likely to be exposed to intense rainfall-runoff.

5.3.1 Flood Hazards

One way that flood hazards are known is through watershed and floodplain studies and floodplain maps. Following enactment of the National Flood Insurance Act in 1968, the 1%-annual chance flood (commonly called the 100-year flood) became the basic standard for delineating floodplains. Since then, this frequency flood has served as the basis for guiding development and for design and construction of buildings. In addition, some states require that this level of flooding be used in the evaluation of bridge and culvert designs. However, as indicated in Table 3-5, other states require that waterway crossings be designed to pass other discharges. Without further investigation, the rationale for each state's position is unknown.

Many states have developed regulations and guidelines for determining whether a waterway crossing design will constrain the specific flood discharges to the point that floodwaters back up and cause increased damage on adjacent lands. The objective of these regulations/guidelines is to minimize any adverse impacts of road construction on the floodplain itself during passage of the 1%-annual chance flood. Some state regulations require that proposed designs for new bridges and culverts be evaluated to determine that they will remain stable during passage of the 1%-annual chance flood discharge (without implying that the driving surface must be above the predicted water surface elevation). Requirements for design considerations related to scour under certain discharge conditions will also have a bearing on bridge and culvert stability.

5.3.2 Flood Hazards and Experience: General DPW Operations

Section 5.1 describes how regulations influence decisions in the case study DPWs, specifically with respect to the choice of the frequency of flood discharge used for design of new and replacement bridges and culverts. Although no formal assessment of costs and benefits for using a discharge associated with a specific frequency of flood has been conducted, considerable anecdotal evidence supports this requirement (sidebar).

Local road systems are exposed to flooding and damage due to rising rivers and streams and also due to intense storms that generate rapid runoff. The nature of flooding and the potential for damage are well understood by the case study DPWs, as is the objective of flood resistance. However, these DPWs also recognize that local roads will always be exposed to some degree of flooding, and therefore, flood resistance does not mean "damage-free." This is especially likely for the many existing floodprone waterway crossings where multiple constraints often do not allow them to achieve the desired degree of flood resistance even when a crossing is replaced. These decisions may be thought of as equivalent to an "acceptable-risk" approach, although the case study DPWs do not set specific acceptable-risk levels.

> "All and all, as bad as it was, we're not in too bad of shape," he said. [County Engineer Bert] Dawson believes the reason for this is his bridges are designed to withstand 100-year storms, while many other counties only go with bridges designed to stand against 20 or 50-year storms.
>
> Morning Journal News (Lisbon, Ohio)
> August 31, 2004.

The case study DPWs strive to improve the flood resistance of their existing bridges and culverts. Work that is done with state or federal funds (primarily structures with spans longer than 20 feet) must comply with certain conditions, including flood-resistance requirements. Work that is done without those funds typically accommodates a "target" flood discharge for improved flood resistance that may be less than that specified in conditions attached to funding (this practice is described in more detail in Section 6.1). In every case, when a crossing is replaced or rehabilitated the DPWs seek to reduce the impacts of flooding, although conveying the target flood discharge is not always achieved. Sometimes the degree of success is limited by other constraints, including budget, impracticality at specific sites, measures that cannot be constructed with in-house crews, and the like.

Actual flood experience is a strong influence in decisions made by the case study DPWs – especially flooding that has occurred within the tenure of the current DPW directors. Whether flood damage has been localized or widespread, some degree of flood resistance "sells itself," and decisions to incur incremental (although undefined) costs in order to improve flood resistance are made without explicit approval from higher authorities. Although these decisions are invariably moderated to some degree by budgetary and other constraints, the decisions demonstrate the desire of the case study DPWs to achieve at least some minimum tolerable level of acceptable performance of the roadway system (corresponding to some maximum tolerable level of acceptable risk).

Because detailed flood hazard data are not yet available in the five case study DPWs, actual flood experience has a stronger influence than does FEMA flood hazard data/maps. This appears to be for two reasons. The primary reason is that DPW professionals deal with some degree of flooding nearly every year and do not depend on an external source of information to tell them where flooding is likely. They know that any drainageway can experience the effects of high water, whether it is a river, perennial stream, ephemeral stream, or simply a drainage ditch.

The other reason why FEMA flood hazard maps are not a significant influence in the case study counties is because only one county has maps that were based on detailed engineering studies. The remaining have FEMA flood maps; however, these maps show only approximate flood hazard areas without sufficient information to influence design decisions.

5.3.3 Flood Hazards and Experience: Waterway Crossings

There is considerable variation among the tools used by the case study DPWs to evaluate flood hazards during assessment of upgrade or replacement options for waterway crossings (e.g., to determine discharges for flood events with different frequencies of occurrence and to model hydraulics and scour). Sophisticated tools are used by DPWs (or their consultants) in states that have regulations and permit authority specific to flooding. In states without such regulations – including those that convey flood-related objectives only as conditions of general permits – DPWs use other approaches that, in their opinions, do contribute to the overall improved performance of their bridges/culverts.

The case study DPW directors indicate that they do not wait until bridges and culverts sustain flood damage to "do the right thing." They recognize that the capacity of their local road system to provide for safe travel is enhanced by improved flood-resistance. However, in the absence of damage, decisions about which bridges or culverts to replace or rehabilitate are driven by the results of inspections (primarily structural characteristics, see Section 5.7) and not by insufficient hydraulic capacity or a desire to achieve a specific level of flood resistance. But once a project is prioritized and selected, design decisions are always influenced by the desire to improve hydraulic performance and reduce flood damage.

The case study DPW directors also indicated that actual damage during past floods – especially major damage that prompts a replacement structure – has a strong influence on flood risk-reduction decision making. The DPW directors all expressed a significant desire to design and construct replacement structures that, as a minimum, would be capable of withstanding the most recent level of flooding. However, as noted previously, final decisions along these lines are usually tempered by such factors as budgetary constraints, environmental issues and limits on floodplain fill, and whether state and federal inspectors approve reimbursement for work other than in-kind replacement.

5.3.4 Flood Hazards and Experience: Roads and Drainage

It is standard civil engineering practice to design new installations for local drainage to handle runoff from frequent storms, such as the 2-year or 10-year runoff. Many states mandate specific frequencies for storm water and drainage design, and they may be codified in local subdivision or storm water management ordinances. Implicit in using runoff from frequent storms is that less frequent storms that produce more runoff will exceed the drainage capacity – although that, in and of itself, does not necessarily lead to damage.

The case study DPWs all make many decisions about their existing roads and drainage system components, and those decisions are always influenced to some degree by consideration of runoff (none of the case study counties is experiencing growth that would require construction of new public roads). For the most part, those decisions are not based on site-specific engineering; rather, they are based on common practice and observations about what is effective. It is important to note that many such decisions are made by crew supervisors who have the authority to exercise judgment on such matters based on field conditions.

It is difficult to delineate areas where runoff damage is likely to affect the road system drainage ditches and drainage pipes. Based on the experience of the case study DPWs, such damage may occur anywhere; it depends on where the heavy rainfall-runoff occurs, and less so on where rivers and streams rise out of their channels. For the counties examined, most drainage system components have been in place for decades and were unlikely to have been engineered for site-specific conditions.

In terms of damage to paved and unpaved roads and shoulders, much of the damage is directly related to ditch scour and the location of many vulnerable sites cannot be predicted. The exception is damage that occurs in low lying areas where roads cross rivers and streams. In these floodprone areas, inundation and fast-moving water damages surface treatments and road base. The case study DPWs did not identify this as a factor that influenced their decisions regarding how they rebuild roads in these areas. They did, however, offer some observations about characteristics of roads and shoulders that they consider to contribute to resistance to damage.

5.4 The Influence of Budgets

Sources and amounts of funding are factors that influence the ability of a DPW to maintain its local road system to the preferred level of functionality, including responding to restore safe functioning after flood damage occurs.

As summarized in Table 3-4, some of the case study DPWs have significantly more external funding than the others, and are somewhat insulated from their jurisdiction's budget processes (although those external sources are experiencing reductions over time). When local funding is provided, the executive branch usually specifies a target amount for the DPW to plan for each year's budget. However, that amount is influenced by the DPW's reports of maintenance and capital project needs. One DPW director characterized his budget this way: "We do what we can within the budget we're given, but our identified needs also influence those who make decisions about how much to give us."

While most DPWs have been able to keep operating and capital budgets at fairly consistent levels, each DPW cited inflation as a significant factor that reduces its ability to maintain a constant level of service. The occurrence of flood damage places additional demands on the budget, since funding that was allocated for routine maintenance would instead need to be diverted to recovery operations. Some DPWs establish special funds that are set aside for recovery, which moderates the adverse effect that floods have on the budget.

With respect to improving flood resistance, the DPW directors offered somewhat conflicting statements regarding the influence of budget. On the one hand, when a capital project is selected to replace or rehabilitate an undersized waterway crossing, they view as minor some incremental (but often undefined) cost of improving the capacity of the crossing to convey flood flows or improved scour protection. This opinion is based on experience, rather than a detailed comparison of costs for various alternatives. On the other hand, due to the high costs and total mileage in their systems, their opinion was different when considering flood risk reduction for roads (especially paved roads) and drainage components, rather than water crossings. This is primarily because the DPWs view it to be relatively less feasible to identify reaches of road where such improvements will actually be beneficial. They perceived that the affected areas are not due to poor maintenance; rather, they consider locations of locally intense rainfall-runoff within any given storm to simply be a function of chance.

5.5 The Influence of Local Knowledge and Experience

Section 4.1 describes the largely experienced-based decision-making process used by the case study DPWs. In this process, the experience and knowledge of individual staff (both engineering staff and field crew supervisors) are viewed as having important influence on these decisions. The past performance of individual bridges and culverts that have been exposed to flooding is another form of local experience that is very influential.

The prominence of local knowledge and experience as an influence was a consistent theme, often expressly stated by the DPW directors as “we know what works for us.” This opinion applied equally to the work performed and to all of the decisions made in the normal course of business, but very specifically to the post-flood recovery period when communities are visited by federal inspectors unfamiliar with local conditions.

Local knowledge and experience with flood-risk reduction measures that were implemented and subsequently tested during an actual flood were an important influence on subsequent decision-making by the case study DPWs. Without performing a formal analysis, DPWs with that experience believe that the investment in flood-resistance improvements beforehand will lead to substantial future benefits (in terms of avoided damage and recovery costs.). Importantly, because simply “improving what we have” was the objective for bridges and culverts, rather than designing for a specific discharge (unless required by state regulation), the case study DPWs cannot characterize the return interval of flooding for which their structures are adequate

Regarding roads, shoulders and ditches, the case study DPWs indicated that flood-resistant improvements that have been effective at a specific location may not necessarily be cost effective to apply throughout their entire road systems. For example, even though it is recognized that paved shoulders are more resistant to runoff damage, it is too costly to add paved shoulders to all local roads. The notable exception is underdrain pipes; Wasco County, OR, determined that it will no longer use 12” diameter pipe, but that all replacements will be at least 18” in diameter.

5.6 The Influence of Staff and Equipment Capacity

The case study DPWs generally determine their current staff (number and skill mix) and equipment (types and sizes) requirements based on their anticipated normal work load. Not surprisingly, budget constraints are a significant constraint on actual staff and equipment capacities. State requirements can also affect these capacities, since some states require that communities of a specific size have a registered professional engineer on the DPW staff.

The case study DPWs seem to have had considerable success in justifying staff and equipment capacity based on cost-savings. For example, the DPW with the largest in-house bridge construction capacity (Allegany County, NY) determined that the most expensive part of building a bridge is labor. Therefore, it finds that some decisions to improve a bridge are easy to make, because the incremental cost of the next larger size pipe or a somewhat longer bridge superstructure is small, while the labor costs associated with these improvements do not vary much at all. Similarly, given the high cost of contracted paving and resurfacing services, some DPWs justify maintaining their in-house paving capacity as being more efficient and cost effective.

In-house capacity for engineering structural design of bridges and culverts varies significantly among the case study DPWs (see Table 3-1). In some respects, this does not dramatically affect decisions because most of the DPWs rely heavily on one or two bridge and culvert types for which they use generic structural designs prepared by qualified entities such as the state department of transportation. Thus, with respect to flood resistance, decisions are required primarily to size the waterway opening (e.g., bridge span length and abutment height, or number and dimensions of a box culvert). Using generic structural designs also improves cost-effectiveness because construction crews hone their skills and become more efficient on subsequent projects of the same structural type.

Another related factor is the lack of engineering capability to do site-specific designs. Several of the DPW directors stated that use of generic structural designs prepared by others is viewed as a way to minimize a DPW’s liability, since the generic drawings were prepared by experienced and qualified authorities. They perceive that consistently applying the same standardized design is an effective way to minimize liability in the event of an incident that might be attributed to the physical configuration or condition of the local road system.

5.7 The Influence of Inspections

Periodic inspections of roads and crossings yield data that, in large measure, guide decisions to undertake road and drainage maintenance, as well as decisions about rehabilitation and replacement of waterway crossings. Bridges and culverts with spans longer than 20 feet are inspected every other year, in compliance with federal requirements. The resulting sufficiency and condition ratings significantly influence decisions to undertake work other than routine maintenance. However, it is notable that, although inspections will identify scour and erosion that could affect structural stability during a flood, the purpose of the inspections is not to determine the adequacy of hydraulic performance.

Four of the five case study DPWs use inspection methods for bridges with spans less than 20 feet that are generally similar to the methods used for longer bridges; however, culverts less than 20 feet tend to receive much less scrutiny (Table 3-2, rows A and B). The results of these inspections strongly influence the selection of structures for rehabilitation and replacement. With respect to flood resistance, the case study DPWs asserted that when a structure is selected for rehabilitation or replacement for any reason, measures to improving performance under flood conditions are always included.

5.8 The Influence of Immediate Post-Flood Recovery

The primary mission of local DPWs is to provide good local roads for the safety of the traveling public. This mission is unchanged when flooding affects the system, but the efficiency and thoroughness with which recovery is accomplished can be challenging.

Particularly challenging are the short- and long-term impacts on the budget. Paying for flood recovery, if not specifically planned and budgeted beforehand, results in diversion of funds from routine maintenance and planned capital projects. If this diversion of funds is not compensated by an infusion of other local funds and reimbursement from state and federal sources, previously scheduled maintenance and projects will be delayed. If multiple damaging floods occur within a short period of time or if adequate funding is not restored, then the net result is an overall reduction in the quality of the local road system.

The case study DPWs report that flood and runoff damage to local road systems occur with regularity, and most of these events do not qualify for federal disaster assistance. This experience, and the expectation that flooding will likely cause some degree of damage every year, has influenced some case study DPWs to budget for flood recovery. This usually takes the form of a special account that is allowed to accrue from year to year.

The case study DPWs also asserted that when their counties are included in a major disaster that is declared by the President and for which federal funds become available, they do not change how they make decisions and how they do business. The DPWs view the availability of federal funding as supporting their objectives – not driving their decisions. However, descriptions of their post-disaster experiences with state and federal inspectors reveal influences that are not accounted for in that view.

Quick and efficient post-flood response by a DPW can conflict with the expectations of some state and federal inspectors. Some inspectors may challenge reimbursement requests or limit approved amounts for two reasons: either the work was performed prior to inspection, or documentation of the extent of damage is inadequate. As a result, the DPWs perceive that they are penalized for having capable and responsive workforces.

Another influence revealed during discussions of post-disaster experiences relates to flood resistance. Each case study DPW described improvement of flood-resistance as part of its overall objective. Indeed, they indicate that when they are developing a project to upgrade a crossing or to replace a crossing, they always try to consider measures to improve flood resistance (within certain constraints, notably budget). However, in the post-disaster period, they described few successful negotiations with FEMA to approve measures to meet this objective; i.e., measures that are anything other than in-kind replacement. Importantly, some of the case study DPWs were aware that FEMA's policy regarding mitigation has changed, but they have not had a disaster since that change has occurred.

The case study DPWs reported a wide variety of experience with FEMA's post-disaster personnel and processes. In some instances, FEMA's inspectors made decisions or imposed limitations that appeared to conflict with FEMA's public assistance policies. It is notable that some DPW directors expressed frustration at the variations in FEMA policies from disaster-to-disaster and, within any given disaster, from inspector-to-inspector. There was no consistency in how these variations influenced decisions about specific damage sites; the more significant decisions related to how the DPWs attempted to keep records to satisfy FEMA's expectations.

5.9 The Influence of Implicit Consideration of Costs and Benefits

As noted in Section 1.2, there is no standardized method by which individual communities perceive and address risk, nor is there a standardized method for considering all costs and all benefits. However, each of the case study DPWs considers some implicit assessment of costs and benefits when making decisions about specific capital projects and routine maintenance. Due to dwindling budgets, they are keenly aware of investing wisely, although such decisions are multi-dimensional. Given the many factors that influence decisions, including political pressures, rarely is any decision based solely on measurable costs and benefits.

For any given capital project to upgrade or replace a waterway crossing, a full accounting of direct costs can be developed. Direct costs are those associated with the engineering for design and with the labor, equipment, and materials for construction. Indirect costs are other costs that are associated with a project, such as increased distance and time traveled if a detour is required. For local roads that are important to local industries, indirect costs are likely to be significant.

In other endeavors that look at the costs and benefits of mitigating the impacts of natural hazards, benefits are identified as damages avoided. Thus, a structure or road segment that experiences flooding but does not sustain damage has accrued benefits, the value of which is the avoided costs to repair flood-induced damage. A full accounting of those benefits is difficult. Unlike buildings, a damage function for bridges and culverts that is based on exposure to the forces and effects of flooding has not been developed. Therefore, it is difficult if not impossible to quantify damages avoided.[4]

The case study DPWs do not perform – and did not express interest in performing – rigorous analyses to estimate all costs and all benefits. This is partially due to the perception among the DPWs that these methods may possibly limit their ability to balance the many factors that influence all of their decisions.

Although the DPWs all develop some form of cost estimate for capital work, most of these estimates are not prepared in great detail – particularly when the work is to be performed in-house. In those cases, the estimates are simply based on the costs of similar work performed recently (which are available due to their detailed record keeping). However, cost estimates are typically prepared after decisions have been made regarding the desired level of performance (e.g., elevation of approach road, width of the road surface, waterway opening size to convey the

[4] Chapter 7 of FEMA's HAZUS®MH Technical Manual contains a brief discussion about modeling bridge damage (but only bridges in the National Bridge Inventory, i.e., those with spans longer than 20 feet). Damage to roads and drainage components is not addressed. The manual recognizes that there are at least three flood-related effects: inundation (a function of water depth); scour/erosion (a function of velocity and duration); and debris impact/hydraulic loading (a function of both depth and velocity). Despite identifying those effects, the manual develops a "damage relationship" that is based solely on the results of scour potential analyses. This is not surprising, because the inspections of these bridges do not characterize hydraulic adequacy and performance under specific flood conditions (such as the 1%-annual chance flood discharge).

target discharge, etc.). In some projects, cost estimates for different configurations are prepared. However, these will pertain to, say, comparing a bridge to a box culvert, rather than comparing incremental costs of different degrees of flood resistance. Thus, it would be difficult to separate out costs specifically associated with flood resistance.

The case study DPWs do not attempt to quantify the myriad benefits of a safe and fully functional local-road system. Nor do they make a full accounting of all direct and indirect costs associated with improving flood resistance – much less all direct and indirect benefits. The case study DPWs factor economic importance into their long-term planning for road and crossing improvements, but any balancing of costs and benefits is done is based on experience rather than detailed calculations (see Section 5.3).

As noted in Section 5.6, one DPW essentially makes a decision about cost effectiveness related to improving flood resistance when it finds that the incremental cost of the next larger size pipe or a somewhat longer bridge superstructure is small, while the labor costs do not vary significantly. However, the degree of improvement associated the next larger size or the somewhat longer bridge is not quantified.

6.0 Observed Practices Related to Flood Resistance

This section describes selected practices that are in place in one or more of the case study DPWs, and some practices that are suggested by conditions and circumstances found in one or more of the counties. The selection of these practices is not intended to imply that other practices are not effective; rather, this selection highlights practices that have some bearing on improving flood resistance. The sidebars in the following subsections are formatted in a manner similar to that used for statements of practices in the American Public Works Association's "Public Works Management Practices Manual."

6.1 Improving Flood Resistance: Hydraulics

The five case study DPWs indicate that their primary mission is to serve the public by maintaining and improving the local road system. Improving flood resistance is an integral part of that mission – and doing so is understood to save resources and time following future floods. The DPWs inherently believe that the future savings (damage avoided) due to their constant efforts at incremental improvements, no matter how small, are worth the investment. Each DPW has experiential evidence to support this conclusion.

Practice: Improvements to hydraulic performance are examined, and protection against scour is incorporated for every new crossing and for replacements of existing crossings.

Improving flood resistance is implemented to different degrees and in different ways, largely as a function of the frequency of flooding, vulnerability to damage, the nature of past damage, constraints imposed by funding sources, a DPW's resources and capabilities, and budgets. Section 2 describes, in broad terms, the nature of flood damage sustained by local road systems.

When considering a specific bridge replacement project, each DPW applies a methodology to determine a "target" flood discharge for the purpose of considering improvements and replacement structures. The methods ranged from state-of-the-art engineering tools to simplified assessments based on gross assumptions (see Table 3-2, row G). The target discharge may be established by state regulation, as a condition of a general permit, as a condition of a funding source, or by the DPW's internal objective to improve hydraulic performance. Where specified by a water resources or environmental agency, the target discharge was most commonly the discharge of the 1%-annual chance flood. Guidance documents from state transportation agencies designate different discharges as a function of road classification.

Flood flows create conditions that can lead to scour, which in turn can lead to structural failure. Scour can occur at bridge abutments and piers, at culvert inlets and outlets, and around wingwalls, headwalls and endwalls. How the DPWs explicitly or implicitly address scour in designs seems to be influenced by environmental, regulatory, and engineering capability factors (Table 3-2, row H).

In evaluating options for replacement projects, it is common for a DPW to select a bridge or culvert configuration and size that does not convey the entire target discharge. Reasons cited often revealed an unquantified balancing of costs and benefits. For example, the decision might be to replace a crossing with a wider-span bridge that improves flood conveyance. However, due to limitations of the in-house construction capacity, the span that is optimum to convey the target flood discharge may not be the selected alternative because hiring a contractor is more expensive. The end result is improved flood resistance, but the degree of flood resistance was not the final determinant.

Another example reveals the complexity of improving flood resistance. Allegany County, NY, reported on a project specifically intended to relieve frequent inundation of the approaches to a bridge, while also improving conveyance of the bridge opening which was subject to ice jamming. The flood-resistance elements of the resulting project were, in large part, driven by state concerns about fish habitat and backwater impacts on the floodplain due to raising the approach roads. The compromise resulted in improvement, but not to the degree desired by the DPW.

Based solely on experience, the DPW's asserted that every waterway crossing constructed in the past 10 years to satisfy a target discharge has performed well under flood conditions. It is notable that these statements cannot be verified because there are no measurements of the characteristics of actual floods that occurred in that period. That is, if a structure designed to convey a specific discharge was subsequently flooded, without knowing the volume of the actual event, it is not possible to quantify the improved performance and damages avoided.

6.2 Record Keeping: Labor, Equipment and Materials

All case study DPWs maintain daily records that are registered by road, waterway crossing location, or project site. How those records are compiled (e.g., as paper records or entered into computerized system) is less critical than the level of detail and categorization of information. Records include: description of work performed; labor hours by category; types and quantities of materials used; and length of time and types of equipment used.

Practice:
Documentation of work performed, including labor, equipment, and materials, is maintained by road segment and crossing location; records are filed to facilitate identification of changes in conditions over time.

Most DPWs use the records to evaluate unit costs, to estimate costs of proposed work, to identify road segments and waterway crossings that require repetitive work, and to prepare work plans based on anticipated budgets or to justify budget requests. Detailed records may be required by certain funding sources, for example to demonstrate that funds were expended as authorized.

Case study DPWs acknowledge the importance of keeping records of work performed to repair flood damage, including photographic evidence of the damage. In order to satisfy requirements for reimbursement after a major disaster, records must be maintained in sufficient detail and in a format that satisfies FEMA's requirements. Some communities that experience frequent disasters design their routine record keeping to meet FEMA's needs, in part because they perform recovery work well in advance of state and federal decisions regarding formal declaration of a major disaster or in advance of applying for public assistance.

It is reasonable to assume that detailed record keeping has a bearing on the overall effectiveness and efficiency of the DPW. With respect to flood-resistance, likely aspects related to improvement include:

- If records identify the proximate cause of damage that prompts work, then the ability to track work by waterway crossing or by road segment allows the DPW to identify parts of the system that require the most resources due to repetitive maintenance and repair and thus are the most expensive to maintain. Such records can then be used to identify areas to examine whether improvements (mitigation) are more cost-effective than continued repetitive repair.
- Detailed records improve the likelihood of reimbursements and influence the amounts of reimbursements approved under FEMA's Public Assistance program. This has bearing on overall flood resistance because, if a high percentage of extraordinary costs due to a disaster are reimbursed, then regularly budgeted funds are less likely to be diverted from planned maintenance and improvements. When all local funds are tied up in flood recovery, the overall system condition is more likely to deteriorate.

6.3 Periodic Inspections

Periodic inspections of roads, drainage, and waterway crossings are undertaken by the case study DPWs, although there are significant variations (Table 3-2, rows A, B and C). Formalized inspection procedures and standards are used by some, resulting in written reports that are used to track changes over time and to identify and prioritize maintenance needs.

The specific elements of the system that are inspected vary and the level of detail of what is inspected varies, as does the frequency of inspections. The factors most cited as contributing to these variations are budget constraints, limited staff, and capacity of staff.

Practice:
A formalized program of periodic inspection of waterways crossings to identify, document, and monitor, over time, conditions known to contribute to vulnerability to flood damage is essential.

When inspections are performed to satisfy a specific requirement (usually a funding source), the same procedures are used throughout the local system, even when not required. For example, it is common that the procedures and reporting forms used for federal-aid system bridges (longer than 20 feet) are used for non-federal-aid system bridges (shorter than 20 feet), although such inspections may not be conducted biennially (the federal-aid system requirement). The DPWs indicate that while such inspections are not required, they are undertaken for consistency and to minimize liability because it shows attention to the system.

Periodic inspections of bridges and culverts identify scour at abutments and piers, erosion at wingwalls, and scour at culvert inlets and outlets. Upstream and downstream channel conditions are evaluated, including streambank erosion, obstruction by debris, and build-up of sediment deposits and vegetation that may constrict flow. To the extent that identified maintenance needs are scheduled for action, it appears that resistance to flood damage is increased.

All DPWs perform some level of inspection of road surfaces, shoulders and drainage ditches and pipes. The complexity of the inspection varies from application of a formal system to determine how a segment compares to standards, to simply driving the roads for visual inspection (whether by crew members in their daily business or by managers who drive every road on a fixed schedule for the explicit purpose of checking conditions). Regular inspections contribute to improved resistance to flooding and runoff damage; for example, ditches that are kept open are less likely to scour and undermine road shoulders.

While all case study DPWs perform some level of inspection of their road systems, they vary in the degree to which they use the inspections to develop a time-history of performance in order to identify repetitive problem areas. Some DPWs rely on long-term employees who develop intimate knowledge of virtually every mile and every drainage structure. Paper records of inspections are common, although they may be filed by year rather than by road segment or bridge. One DPW uses formal inspection procedures with specific rating factors to monitor road conditions, and a state-mandated cost accounting system that tracks expenditures by road segment.

6.4 Functional Partnerships: Adjacent Communities

Two types of functional partnership practices were identified: general equipment sharing with incorporated municipalities and cooperative inspections teamed with a neighboring county. All of the case study DPWs undertake specific projects on a reimbursable basis for incorporated municipalities, such as construction of a bridge or paving. Partnerships may be informal or formalized by written agreements.

Sharing equipment and crews is a common practice that occurs both on a regular basis and when extraordinary circumstances warrant, such as after a damaging flood. It appears common for a county DPW to have a more extensive inventory of specialized equipment that is not used on a regular basis, including large pavers, cranes, and pile drivers.

Practice: Interjurisdictional partnerships are formed to cost-effectively co-operate to provide for the overall safe functioning of local road networks.

Wasco County, OR, described an effective partnership with a neighboring county to conduct joint inspections of roads. The cooperative venture has improved rating skills and reduced the time required to perform inspections.

Partnerships between county DPWs and incorporated municipalities also form to undertake work on specific projects, usually on a reimbursable basis. This occurs most commonly when rehabilitation or replacement of waterway crossings within a town's corporate limits is required. Most small towns have fewer staff and more limited capabilities. County DPWs may participate in one or more of the following:

- Paving and resurfacing of town roads;
- Preparation of designs and specifications for bridges and culverts (typically using well-tested generic designs that are modified for site-specific conditions);
- Bidding of supplies, materials, and services;
- Construction of bridges and culverts, using county crews and equipment; and
- Construction management and inspection, when work is performed by contractors.

Functional partnerships have multiple general benefits, especially for the smaller jurisdictions. Thus, it is reasonable to assume that the road systems in those smaller jurisdictions are better maintained and therefore more resistant to flood damage than if they operated entirely independently. County roads and town roads combine to form the public road network. Because partnerships improve the quality of the town roads and bridges, the DPWs characterized the benefits as public benefits that accrue to the traveling public by reducing the likelihood of failures on town roads.

6.5 Funds for Flood Recovery

Many people think that floods that cause damage to local road systems are infrequent events. While that characterization may have validity with respect to buildings, the same cannot be said of local road systems. Road systems are intended to function under some variations in stream flows and runoff: roads cross waterways that are subject to large variations in discharges, and drainage ditches and pipes carry runoff produced by all frequencies and intensities of rainfall.

Most DPWs consider some degree of damage to be routine and the repair work is simply part of their maintenance and operation budgets. What is considered routine varies significantly as a function of geography and frequency of flooding. It is understandable that some work required to repair water damage is considered routine, such as stabilizing limited ditch scour, removing sediment from culverts and vegetation growth from channels, or filling small scour holes at abutments.

Practice:
Provisions are made for some anticipated flood-related expenditures that exceed the normal budget so that funds are not diverted from routine maintenance and scheduled capital improvements.

When damage due to higher flood flows or more intense rainfall-runoff exceeds what a DPW considers to be routine, there are adverse budgetary implications. It may result in diversion of funds that were designated for normal operations and maintenance, or for planned rehabilitation or replacement of waterway crossings. This diversion typically results in pushing back scheduled work, which may, over time, lead to an overall lessening of the quality of the local road system.

However, when a flood event causes damage that is deemed to exceed state and local capabilities, it may be declared a major disaster. This action makes certain recovery expenditures eligible for reimbursement from FEMA's Public Assistance Program. When this occurs, the community is required to provide the non-federal share of eligible costs (typically 25 percent) and must cover all costs of work that is not eligible. Although some states provide a portion of the non-federal share to lessen the burden on community budgets, the net result is a diversion of funds which postpones scheduled work.

Two budget practices that increase a DPW's ability to address flood damage (regardless of whether federal funds become available) were identified in counties that experience significant road system damage on a frequent basis:

- A dedicated "flood fund" created by an extra surcharge on registered vehicles and a percent of certain fines assessed by the county. This approach is used in Uvalde County, TX, a very rural county that experiences significant flood damage (including total washout of low-water crossings) on one or more of its rivers almost every year. The fund is used for the non-federal share when an event is declared a major disaster. Unspent funds are allowed to accrue from year to year.

- A "reserve fund" used to bank unspent funds from other accounts and allowed to accrue from year to year. The reserve fund is the primary source of non-federal share for public assistance, or it is tapped when bridge replacement work exceeds the annual allocation. This budget practice is used by Uvalde County, TX, and Calhoun County, IL, which also invests surpluses.

6.6 Bridge Construction Crew and Equipment

Each of the case study DPWs has crew member skills and equipment that allow it to perform some level of construction work, including complete replacement of some types and sizes of waterway crossings. The specific construction capacity varies, but appears to be established to handle the majority of work encountered. For example, if the majority of bridges are less than a certain span length, then that length tends to define the capacity of the county's construction capacity.

Practice:
In-house crew capabilities and available heavy equipment are sufficient to construct the types and sizes of the most prevalent waterway crossings in the local road system.

The case study DPWs report that costs of in-house construction are on the order of about half of the cost of contracted work. Another cited justification for having significant construction capacity is the ability to undertake work as quickly as possible after a damaging flood in order to restore the local road system for safe travel.

Not surprisingly, Allegany County, NY, which has almost one waterway crossing for every mile of road, maintains the highest capacity in-house construction crew and equipment inventory. The original decision to create this capacity pre-dates the current management, and so the complete rationale is not known. It was described as beneficial not only because more work can be done with less money, but because it increases the agency's ability to work with towns and because the frequency of flood damage warrants a nimble response.

Practice:
Awareness of state and federal programs that provide technical and financial assistance is maintained; partnerships are identified and are pursued.

6.7 Partnerships: State and Federal Agencies

Leveraging resources to achieve multiple objectives through partnerships with state and federal agencies is demonstrated in Allegany County, MD, Calhoun County, IL, and Wasco County, OR. In these examples, improved flood resistance was a primary objective of the DPW and the other partners. Pursuing these partnerships may take more time to negotiate the differences and to satisfy each agency's procedural requirements, but the DPWs found them to be beneficial in more than one respect. In contrast, Uvalde County, TX, reported little success when initial inquiries for assistance did not lead to any cooperative efforts.

Agencies that were identified as partners that participated in the technical aspects of projects (and sometimes funding) included the local soil and water conservation district, the state highway/transportation agency, the state environmental/fish and wildlife agency, the USDA Natural Resource Conservation Service, and the U.S. Army Corps of Engineers. Additional funding partners were FEMA Agency and the state emergency management agency that coordinates FEMA's hazard mitigation funds. Section 6.8 includes brief descriptions of two partnerships, one that pursued watershed-based solutions and one that based a solution on stream morphology.

6.8 Watershed and Stream Morphology Approaches to Flood Problems

In recent years, Allegany County, MD, and Wasco County, OR, have incorporated multi-objective approaches to the identification of solutions. They have taken a broader view that extends outside the narrow limits of their rights-of-way in order to identify sets of factors that contribute to problems. In one instance, the broader view encompassed virtually the whole contributing watershed; in the other, the morphology downstream of a bridge was determined to contribute to unstable conditions at the bridge. These broader perspectives initially were fostered by involvement of other agencies, leading to partnerships for site-specific solutions. The benefits are expected to continue as the multi-objective approaches are applied to other problem areas.

Practice:
It is recognized that watersheds and streams are systems and that solutions to site-specific problems may involve off-site elements.

Allegany County, MD, which has experienced only two significant flood events in 10 years, has determined that improving flood resistance involves looking at field conditions as a whole, rather than focusing narrowly on one design parameter, such as discharge. For example, examining conditions downstream of a bridge may suggest the potential for higher velocities and channel downcutting or incipient bank erosion that can migrate upstream. Such conditions suggest the need for in-stream grade controls and rock vanes to divert erosive flows, as well as deeper footers or more robust scour protection at the bridge. The first such project involved partnerships with both the state transportation agency and the Natural Resources Conservation Service (NRCS).

Wasco County, OR, after yet another storm caused widespread farmland erosion and damaged roads and several crossings in a single watershed, convened an interagency planning group that included federal, state and local agencies, and landowners. The investigation looked at the watershed as a system, than rather focused narrowly at site-specific problems. For example, sediment lost from farmland reduced agricultural productivity, reduced water quality, clogged stream channels, obstructed bridges and culverts, and deposited on roads (silt removal from roads was a significant annual expenditure). Streambank erosion not only contributed to channel sedimentation but, in the vicinity of bridges and culverts, endangered infrastructure. Implementation costs were, in part, eligible for a mitigation grant from FEMA.

6.9 Staff Development

The case study DPWs engage in some form of internal staff development, primarily on-the-job training. Some DPW staffs include specialists, such as an engineering technician specifically trained to do inspections or a whole crew that specializes in bridge construction. Most staff members are cross-trained to carry out multiple jobs, especially in the smaller DPWs. As a result of cross-training, managers have greater flexibility in scheduling jobs and making assignments. The reasons this approach is effective include:

- Staff shortages due to inadequate budgets mean more people need to be capable of doing all tasks;

- The demands of both routine small jobs and less common large jobs need to be met; and
- Post-flood damage results in a wide range of conditions that need to be addressed expeditiously and cost-effectively.

Of the five case study DPWs, only the staff of Uvalde County, TX, are assigned countywide. The others assign road maintenance supervisors and crews to service regions. Employees in the supervisory positions of the service regions have the opportunity to learn managerial skills, make decisions on their own, train crew members to do a variety of tasks, and carry out some projects from beginning to end. This on-the-job training, combined with oversight by the DPW director, creates a talent pool of potential future DPW supervisors. Because local knowledge and experience are identified as strong influences in effective management and identification of improvements to flood resistance (see Section 5.5), in-house development of employees may have long term benefits for local road systems.

Practice:
Personnel are trained and cross trained, both in-house and through external opportunities, in the skills required to perform agency tasks.

In the three larger of the five case study DPWs (Allegany County, MD, Allegany County, NY, and Wasco County, OR) the director and other managers belong to professional organizations and/or actively participate in conference opportunities offered by state transportation agencies. Conferences allow them to share information concerning practices and learn how others accomplish their tasks. Results from these encounters increase professional knowledge and may lead to the adoption of new practices, hiring of new consultants, or reinforcement that current practices are adequate. Of the two DPWs that do not actively participate in conferences, one sees similar benefits because of frequent informal discussions with neighboring DPW directors.

7.0 Findings and Recommendations

This report was prompted in part by the observation that the costs of federal disaster assistance continue to rise for permanent restoration of damage to local road systems, called Category C (briefly described in Appendix A). However, despite the availability of data on that assistance, it is clear that the impacts of flood damage to the Nation's local roads and bridges cannot be measured only by the cost to the federal government.

These findings and recommendations are based on visits to and discussion with the directors of five case study DPWs and their characterization of efforts and obstacles that influence decisions. The case studies are included in Appendices B through F. For a number of reasons, including how the five counties were selected and their rural character, these five case studies do not represent the range of all DPWs. There is a sense, however, that non-urban local road systems present a significant opportunity for owners to reduce future losses, in part because the DPWs in non-urban areas generally have less in-house technical capacity and fewer financial resources.

7.1 Findings

A number of FEMA Public Assistance Officers have observed that the total inventory of local bridges and culverts that perform well under flood conditions has grown in the past decade. Although a decade is too short a period in which to confirm this observation, it is shared by the case study DPWs. If flooding has affected areas where they have deliberately incorporated flood-resistance measures, their experience is that the waterway crossings perform well. However, as noted by one FEMA Region Public Assistance Officer, total Category C expenditures continue to rise because "there are a lot of old structures out there" and material, labor and equipment costs continue to rise. Some of the case study DPWs asserted that paved roads that are located in floodprone areas are not experiencing a similar overall improvement, in large measure because of difficulties with eligibility for reimbursement in the post-disaster period.

Reducing the potential for future flood damage experienced by a largely existing infrastructure of local roads and bridges is not an easy job, but it is an integral part of the work of local DPWs. Although the directors of the five case study DPWs each described having factored flood resistance into many decisions in the past decade, performance improvements come about gradually. Given the level of spending and the amount of work to be done, it may take decades for some communities to achieve significant change. The success of any given DPW in reducing site-specific damage is influenced by many factors.

The following broad statements summarize the findings based on the five case studies:

- DPWs in rural communities are somewhat constrained by their limited resources, expertise and staff. These constraints affect their efforts to maintain and improve local road systems as well as their ability to respond effectively when major flooding causes damage that exceeds their normal capacity to respond and recover.

- The case study DPWs reported that whether their proposals to incorporate measures to improve flood resistance were received positively by state and federal inspectors for post-disaster public assistance varied from disaster to disaster and often from inspector to inspector.

- Experienced-based or on-the-job learning is effective for some jobs in a public works department, such as crew foreman who learn to make independent decisions about routine operations and maintenance, or engineering technicians who perform routine inspections. It is a less effective basis for certain engineering applications. For example, an engineer may work for many years without having certain design decisions tested by flood. While experienced-based learning is effective to some degree in small organizations, especially in nurturing the development of leaders, it limits exposure to the successful solutions implemented by those outside the organization unless specific efforts are made to seek out that knowledge.

- In general, costs for materials, supplies, equipment, and labor rise faster than revenues. For the most part, the only response available to rural DPWs is to scale back their efforts to maintain roads and bridges, thereby increasing the likelihood of greater flood damages in the future.

- Some rural DPWs are not familiar with existing state and federal programs that may provide funds for site-specific improvements, especially those that achieve multiple objectives.

- Even when measures to improve flood resistance are routinely incorporated in decisions, rural DPWs generally do not have established and documented procedures, which makes it more difficult to incorporate those same measures in post-flood recovery work that requires approval by others.

- State standards appear to be generally effective, but a wide range of requirements specific to flood resistance was noted in the regulations of five states in which the case study DPWs are located. Some states require that bridges and culverts be evaluated using the 1%-annual chance flood, while others have no requirements. The states that have standards exhibit a tendency towards leniency during post-flood recovery.

- DPWs are committed to maintaining and improving their road systems and are open and willing to learn about new and effective approaches. While some of the case study DPW directors expressed concern that a required standard would impose costs that outstrip their ability to pay or would limit their flexibility, they were generally receptive to learning from others. Readily accessible guidance and model practices that have proved successful in other communities would be well received.

7.2 Recommendations

As noted in Section 1.2, this project has three objectives:

- To identify factors that influence decisions for reducing flooding risks to local road systems;

- To identify how such decisions have been made in five case study counties from different regions of the United States; and

- To provide findings and recommendations, including the possible need for development of non-mandatory decision-making guidelines for local road systems.

The prior sections of this report address the first two objectives and the findings from this project. This final subsection provides recommendations to address the third project objective.

As noted in Section 1.2, it was anticipated that local knowledge and experience would form the primary basis on which damage reduction measures are identified and incorporated in road system work. There were many similarities between the five case study DPWs, but there also are important differences.

What is clear is that, as represented by these five specific counties, DPW directors are interested in learning more about successful projects and practices in other jurisdictions, especially if those projects are deemed to be pertinent to their circumstances. This builds on their experienced-based approach; they recognize that exposure to the experiences of others can expand their own experience.

The primary recommendation is for development of a model guidance manual of effective practices that can be tailored by states and others so that the materials are directly pertinent to different state regulatory and physical environments. A secondary recommendation calls for a guideline for data collection during a DPW's periodic inspection of bridges and culverts to support both improved mitigation and improved flood hazard mapping.

7.2.1 Recommendation 1: Develop a Flood Mitigation Guidance Manual

7.2.1.1 Description

Development of a Model Manual of Flood Mitigation Guidance for Local Road Systems is recommended. To create a viable model manual, it is important to have the participation of a cross-section of local, state, federal, professional organizations, and design and construction interests. Because much of the local transportation system is found in rural areas, it will be particularly important to have representation from small towns and urban communities.

While the guidance manual will be useful in its own right, the end product should not be a one-size-fits-all document. Rather, the manual should be designed to be tailored by each state to account for significant variation in such factors as geography, flood characteristics, construction practices, and regulatory framework. The state-specific tailoring can be undertaken by a similar cross-section of interests, with heavy emphasis on local participation. A recommended adjunct to the manual (and state-specific manuals) would be a centralized, online resource to allow rapid key word searching for applicable examples of successful projects and methods.

A complete list of the suggested contents of the manual is not presented here, but it should include management practices and field practices, including discussions of the following:

- Methods for determining the flood and runoff conditions that provide the desired level of flood resistance, allowing for differences based on local conditions and constraints. Unless already established in regulation, it is reasonable that DPWs set a target for performance to guide decisions.

- Methods for estimating the flood conditions and evaluating hydraulic impacts, especially in areas where there is insufficient existing information to define flood hazard areas and discharges.

- Capturing high water marks and other characteristics of actual flooding yields valuable information that can be used to improve post-flood recovery and mitigation decisions, even in the absence of floodplain models or computations.
- The value of building on local knowledge of problem areas and preparing plans in advance of flood damage that consider and select some components of the preferred measures to be factored into restorations. For example, an inventory of all bridges and culverts that do not perform as desired (or that do not meet a community's established and preferred practices) would be developed and preliminary evaluations could be undertaken.
- Identification of direct and indirect costs, and direct and indirect benefits, associated with improving flood resistance. The intent is not development of a formula or damage function because there are many variables that cannot readily be reduced to a formula. The intent is to provide a sound, albeit qualitative, basis on which to make mitigation decisions based on understanding the full range of future benefits (avoided damage). Because the initial cost of mitigation (direct costs) appears to be a limiting factor in many instances, decision makers should be more aware of benefits that may justify more investment.
- Examples of how taking watershed-based or stream morphology based approaches can yield multiple benefits.
- Illustrations of how DPWs justify maintaining high capacity bridge construction crews and equipment need to build the majority of bridge replacements.
- Sources of technical assistance and funding, tailored for each state-specific version of the manual.
- Examples of mitigation projects for local road system components that have qualified for funding under FEMA's Hazard Mitigation Grant Program.
- Examples of budget practices that support improving flood resistance such as creating a dedicated fund and accruing year-end balances in a special fund.
- Examples of organizations that have successfully and efficiently incorporated flood-resistant measures in their recovery decisions.
- Successful projects undertaken by interagency partnerships to address multiple objectives.

7.2.1.2 Background

Many challenges and multiple variables are involved in how DPWs make decisions about their local road systems, including how they incorporate flood resistance in those decisions. The case study DPWs expressed concern that the flexibility they have to manage their programs to respond to long-term needs, as well as post-flood demands, could be constrained, especially if the presence of a non-mandatory guideline for making decisions was construed to be the "best" way to make decisions. The authorities and constraints under which the DPWs function vary significantly and would be difficult to capture in a formal decision-making framework.

There is, however, a need for documentation and evidence of what works to improve flood resistance, and what works well in different parts of the country and under different flood conditions. While the case study DPWs asserted that their local knowledge and experiences allow them to know what works best, they also expressed interest in the successes of others and a willingness to learn from those successes. Further, an individual's corporate knowledge is ephemeral. Capturing experience and making it available in the form of a guidance manual with real-world examples will contribute to the experience of staff members who may not rise through the ranks.

The fields of bridge engineering and design and road design and construction are mature, especially with respect to designing and constructing new bridges and new roads. Over time the existing huge inventory of older roads and waterway crossings will be reduced by implementing known designs that improve the overall flood resistance of the local road systems. However, the process is slow because there appears to be a gap in knowledge of what constitutes cost-effective and feasible improvements, especially improvements that can be implemented in the post-flood recovery period.

Every state transportation agency has materials specifically addressing structural and hydraulic design of new and replacement bridges with spans longer than 20 feet. Inquiries to some State NFIP Coordinating Offices and State Hazard Mitigation Officers did not identify materials geared specifically to mitigation of road and bridge damage. Some materials are available, notably a handbook produced by FEMA Region X, "Flood Hazard Mitigation Handbook for Public Facilities." A comprehensive search for other materials that specifically address flood resistance of existing road systems was not conducted.

7.2.2 Recommendation 2: Develop a Guideline for Data Collection to Support Mitigation Decisions and Flood Map Modernization

7.2.2.1 Description

It is recommended that a guideline be developed to augment periodic inspections of waterway crossings to collect specific additional data that are needed to evaluate mitigation options. Another important and cost effective use of the additional data, especially certain elevations that can be collected using handheld Global Positioning System (GPS) units, is to support revision of flood hazard maps prepared by FEMA.

7.2.2.2 Background

All DPWs perform some level of inspection of waterway crossings, offering the opportunity to collect data efficiently. The data are valuable to develop mitigation alternatives, whether in the pre-flood or post-disaster period. Guidelines will bring uniformity to the types of data collected and method used.

FEMA's Mitigation Division, in partnership with the states and others, has embarked on a multi-year initiative to modernize the flood hazard maps for virtually every jurisdiction in the Nation (http://www.fema.gov/fhm/mm_main.shtm).   Especially in rural areas where detailed engineering methods are unlikely to be cost-effective, alternative methods have been developed to use computer-based models and digitized topography to produce flood hazard data. The lack of data on individual waterway crossings is known to be an obstacle to rapid and cost-effective development of flood hazard maps.

7.2.3 Recommendation 3: Assess Road Surface and Shoulder Durability Research

7.2.3.1 Description

Existing research on pavement and shoulder durability and existing pavement and construction standards should be examined[5] to determine if there is sufficient evidence to support applying different approaches in defined flood hazard areas.

7.2.3.2 Background

A considerable amount of damage is sustained by roads that lie in the floodplains of rivers and streams where inundation and fast-moving water can damage paved and unpaved surface treatments and road base. (While the entire road system is subject to damage due to infrequent, intense rainfall-runoff, the areas where those conditions are likely to occur cannot be identified in the same fashion that floodplains can be delineated.) Depending on the results of the examination, development of a non-mandatory standard may be appropriate to specifically address road segments that lie within mapped floodplains that are anticipated to be periodically inundated and exposed to moving floodwaters.

7.2.4 Recommendation 4: Improve Consistency of Post-Flood Inspections

7.2.4.1 Description

To identify opportunities to improve consistency and to improve implementation of mitigation in the field, it is recommended that FEMA form a partnership committee with representation from state and local agencies and professional associations to evaluate and revise guidance and training of FEMA inspectors as it specifically relates to Category C roads and bridges. Modifications should place particular emphasis on two key elements: (a) how to evaluate work performed immediately after an event that is required to restore a system to safe condition, and (b) how to identify and take into consideration local mitigation practices that are proven to increase flood resistance. Specific training should acknowledge geographic differences, differences in technical capacities, and what constitutes mitigation in different physical environments and under a wide range of hydraulic conditions.

7.2.4.2 Background

The case study DPWs related a number of concerns about inconsistencies in the post-flood public assistance inspection and reimbursement process. Inconsistencies were noted from disaster to disaster, but also from inspector to inspector. Instances also were cited where a DPW’s ability to rapidly repair its road system to safe functioning was perceived to penalize it when “unauthorized” repairs were completed prior to the arrival of FEMA inspectors, who then declined to approve reimbursements. Although some of the case study DPWs acknowledged having received approval to incorporate mitigation into project scopes, their experiences suggest it was rarely treated by FEMA inspectors as the norm.

[5] A limited Internet search did not readily identify a pavement standard that specifically addresses flood damage and flood resistance.

7.2.5 Recommendation 5: Improve Delivery of Disaster Recovery and Mitigation Information

7.2.5.1 Description

To improve regular delivery of information, it is recommended that FEMA's Recovery Division explore whether existing mechanisms used by the states to communicate to local public works departments can be used effectively to deliver information about disaster recovery requirements and mitigation. FEMA's traditional communications are conducted through state emergency management agencies, which may or may not be adequately equipped to provide regular (non-disaster) contact with local DPWs. State transportation agencies are more likely to have communication mechanisms in place, including web pages devoted to local issues. Another online resource would be a tutorial for FEMA's post-disaster requirements and paperwork that is kept current.

7.2.5.2 Background

The five case study counties have experienced multiple damaging floods in the past decade and were included in multiple declarations of major disasters. An expressed concern was the lack of timely information about FEMA post-disaster requirements – often what a community needs to know immediately after an event is conveyed weeks later. In part this is because decisions on declarations, based on information that takes time to collect, sometimes are not made immediately. However, DPWs must act as quickly as possible to restore roads to safe functioning. Having a tutorial on FEMA's post-disaster requirements available online would address a growing reliance on readily accessible information, which is not addressed if materials are available only in hardcopy.

Another benefit of improved delivery of information about FEMA's post-disaster requirements would likely be improved identification of mitigation in recovery decisions. While some of the case study DPWs had negotiated improvements as part of reimbursed project expenses, they characterized the experience as difficult. If communities were aware of mitigation measures that can be considered, they would be better prepared to explore the merits and costs when FEMA inspectors arrive onsite.

7.2.6 Recommendation 6: Improve Understanding of Distribution of FEMA's Category C Expenditures

7.2.6.1 Description

It is recommended that FEMA conduct a broader investigation (even if based only on experience of its inspector cadre) of the distribution of Category C expenditures. This could shed light on where mitigation opportunities are greatest and perhaps indicate some changes in the delivery of technical assistance during recovery. The distribution of expenditures should be considered in at least two ways: component of the road system damaged (road surface and base, ditches and drainage, bridges and culverts) and characteristics of the recipients (rural, suburban or urban, county or incorporated municipality).

7.2.6.2 Background

For the purpose of selecting case study counties, FEMA provided four years of Category C expenditures for roads and bridges for all counties. The data are too limited both in the time period covered and detail provided to draw conclusions about trends. A closer examination of the data by component of a road system that is damaged (waterway crossings, roads and shoulders, and drainage components) may be important if it confirms the reports of the case study DPWs. Some DPWs estimated that their costs associated with restoring damaged waterway crossings were about one-third of total costs of other types of damage eligible for reimbursement under Category C. If this distribution is validated, then the focus of mitigation efforts can be sharpened

The rationale for understanding the distribution of Category C expenditures by some characteristics of the recipients is related primarily to delivery of technical assistance. If urban communities are not experiencing the same damage trends, it may be because they have higher budgets and more maintenance and engineering capabilities, which contribute to a more damage-resistant local road system.

If the distribution of Category C expenditures is weighted towards small and rural communities, it may be appropriate to take that into consideration in the delivery of FEMA and state post-disaster assistance to foster more mitigation during recovery. Section 1.4 describes the case study counties as rural in nature and cites one source that indicates that 77 percent the roads in the United States are classified rural. It follows that rural towns and counties, including many that are very large in land area, also are likely to have a large percent of the Nation’s bridges and culverts.

Another recipient characteristic that may be important to understand is the distinction between counties and towns. Category C assistance is reported and aggregated at the county level by combining reimbursements made to the county and incorporated municipalities that are located in the county. Case study DPWs suggested that road and bridge damage in small towns that are responsible for their own local road systems probably exceeds the damage experienced by county roads. This is generally thought to be the case because towns have significantly fewer resources (staff, equipment, and budget) and thus have less comprehensive programs for maintenance.

7.2.7 Recommendation 7: Communities Should Formalize Local Practices Related to Flood Resistance

7.2.7.1 Description

Every DPW strives to maintain and improve its local road system on a daily basis, and it is common that this is in part accomplished by incorporating measures to improve flood resistance. However, there are reported instances where including such measures in the cost of post-disaster restoration has been met with resistance. To improve both identification of mitigation measures and justification of the cost of such measures as part of disaster assistance, it is recommended that DPWs formalize their local practices, especially those that lead to work that changes the configurations of existing roads and waterway crossings.

7.2.7.2 Background

FEMA’s fundamental disaster recovery mandate is to help States and local governments restore damaged public facilities to their pre-disaster condition. Incorporating elements that bring a facility into compliance with current “codes and standards” is part of the basic project. Therefore, if a community documents its practices and can demonstrate that those practices are uniformly applied, then negotiations to incorporate the costs of mitigation into basic project costs will be enhanced (see Appendix A for more discussion on the regulatory requirements pertaining to eligibility of mitigation as a basic project cost).

Practices that should be formalized and documented include methods to evaluate hydraulic performance, range of options considered with pros and cons (e.g., for different structure types in common usage), and methods found effective to protect abutments, inlets/outlets, and streambank erosion.

7.2.8 Recommendation 8: Review and Revise APWA Practices Manual and Other Publications

7.2.8.1 Description

The American Public Works Association (APWA) should review its "Public Works Management Practices Manual" and selected other publications and incorporate practices that are specific to flood resistance. In addition, APWA's "Emergency Management Field Manual for Public Works" should be reviewed and updated to reflect suggestions to facilitate recovery and coordination with FEMA and the Natural Resources Conservation Service (NRCS). Practical suggestions made by the five case study DPWs include:

- Post-disaster reimbursement paperwork is easier if separate task orders for materials and services are issued rather than piggybacked on existing task orders with providers.
- Field measurements that determine quantities of materials used and work performed are more defensible than map-based measurements.
- Multiple photographs taken during periodic inspections help to document pre-damage conditions.
- Documentation of in-house labor and equipment usage must conform to current FEMA requirements in order to qualify for reimbursement.
- Obtaining annual bids for materials and equipment rental rates justifies use of local rates rather than default to FEMA's regionalized cost codes.

7.2.8.2 Background

APWA's "Public Works Management Practices Manual" (Fourth Edition) is regularly updated. The Manual forms the basis of APWA's accreditation program that formally verifies and recognizes public works agencies for compliance with the recommended practices. The program is a voluntary, self-motivated approach to objectively evaluate, verify and recognize compliance with the recommended management practices (online at http://www.apwa.net/About/Accreditation). APWA views the self assessment as a valuable tool for determining how an agency's policies, procedures and practices compare to recommended practices identified by nationally recognized experts in the field of public works. Agencies can use the recommended practices contained in the manual as a model for developing or improving existing practices to enhance performance and increase productivity.

7.2.9 Recommendation 9: Capitalize on Existing Organizations Programs and Expertise

7.2.9.1 Description

It is recommended that a workshop be convened with federal, state and local agencies and professional organizations that are or may be involved with rural communities as they identify flood hazards, consider improvement options (both before and after flood damage), and implement multi-objective projects. Relevant agencies include FEMA, the U.S. Department of Transportation, NRCS, and state environmental agencies and state transportation departments. Relevant professional organizations include, but are not limited to, the Association of State Floodplain Managers, the American Public Works Association, the American Association of State Highway and Transportation Officials, the National Association of Counties, the National League of Cities, representatives of state level organizations that represent local public works agencies, and others. Content from the workshop should be captured in a new publication or online resource and made available through existing dissemination mechanisms.

7.2.9.2 Background

The primary purpose of the workshop would be to identify how to build on the relationships that the identified agencies and organizations have with DPWs in order to disseminate materials illustrating successful approaches for increasing flood resistance of local road systems. The case study DPWs each expressed receptivity to new ideas, but only three of five are active in external organizations through which they may be able to expand on their own experienced-based successes. They all have some level of communication with the state transportation agency, most have fairly regular interactions with the state water resources or environmental agency, and all interact with the state emergency management agency but predominantly in the post-disaster period. With respect to what other agencies may offer, using the Natural Resources Conservation Service as an example, there was considerable variation in the case study DPW's understanding of the types of NRCS's pre- and post-flood assistance that may be available.

7.3 Conclusions

There appear to be both opportunities for and interest in improving local road systems throughout the United States to better resist flood damage and improve road functionality during and after flooding events. Based on just five case studies of rural DPWs, it is clear that department directors and staff are keenly aware of the impacts that floods create, including physical damage, traffic flow disruption, risks to the traveling public, increased maintenance needs, and long-term diversion of scarce funds that would otherwise go for regular maintenance and planned upgrades. Similarly, they are interested in effective measures to increase resistance to flooding, particularly those that can be brought to bear in the aftermath of a damaging event.

The opportunities to reduce the effects of flooding are captured in the recommendations outlined in Section 7.2. Federal involvement, especially by FEMA, may be required to pursue some recommendations (Recommendations 1, 4, 5, 6 and 9). Recommendation 3 could be undertaken by a relevant standards development organization or a university-based highway research program.

A number of the recommendations are framed to be pursued quickly to complement existing, on-going initiatives. For example:

- **Recommendation 2.** FEMA has initiated modernization of the Nation's flood hazard maps. The Association of State Floodplain Managers, Inc., as a member of the project team, recognizes the long-term benefits of capitalizing on on-going routine inspections of waterway crossings to complement its major goal to improve flood hazard mapping. Thus, the Association believes there is a need not only to develop the guidelines, but to disseminate it to states to share with communities for which map revisions are scheduled in the coming years.

- **Recommendation 7.** An initial step towards encouraging communities to formalize their mitigation practices could be articles in journals and newsletters that reach public works departments. Both the Association of State Floodplain Managers, Inc., and the American Public Works Association produce such publications.

- **Recommendation 8.** The American Public Works Association expects to initiate its review and revision of its Public Works Management Practices Manual in 2006.

With respect to both short-term and long-term initiatives, cooperation and support from a diverse group of players at the local, state and federal levels are needed to realize the recommendations herein for more flood-resistant roads. Local DPWs should then be better prepared to fulfill their missions of providing safe and reliable transportation systems.

References

APWA, August 2001 (Fourth Edition). ""Public Works Management Practices Manual," American Public Works Association, Kansas City, MO.

APWA, 2003. "Emergency Management Field Manual for Public Works," American Public Works Association, Kansas City, MO.

FEMA, Region 10. June 2001. "Flood Hazard Mitigation Handbook for Public Facilities," Federal Emergency Management Agency, Bothell, WA. Online at www.conservationtech.com/FEMA-WEB/FEMA-subweb-flood (accessed December 7, 2004).

FEMA, October 1, 1999. "Public Assistance Program Description," Federal Emergency Management Agency, Washington, DC.

FEMA, August 13, 1998. "Standard Operating Policy 9526.1 Hazard Mitigation Funding Under Section 406 (Stafford Act)," Federal Emergency Management Agency, Washington, DC.

James Informational Media, Inc. October 2001. "*Better Roads:* Facts about the Highway and Bridge Construction Market," online at www.BetterRoads.com.

NIBS, 2003. "Multi-hazard Loss Estimation Methodology, Flood Model, HAZUS$^{®MH}$," National Institute for Building Sciences and U.S. Department of Homeland Security Emergency Preparedness and Response Directorate (FEMA), Washington, D.C.

NWS, 2005. "Flood Fatalities." National Weather Service, Hydrologic Information Center. Silver Spring, MD. Online at www.weather.gov/oh/hic/flood_stats/recent_individual_deaths.shtml (accessed January 21, 2005).

U.S. Census Bureau, 2000. "Urban and Rural Classification," online at http://www.census.gov/geo/www/ua/ua_2k.html.

Acronym List

AASHTO – American Association of State Highway and Transportation Officials

ALA – American Lifelines Alliance

APWA – American Public Works Association

ASFPM – Association of State Floodplain Managers, Inc.

DPW – used generically to refer to the local government agency charged with management of the local road system; it may be a Department of Public Works, Roads Department, Unified Road District, or other similarly named entity.

EP&R – the Emergency Preparedness and Response Directorate in the U.S. Department of Homeland Security

FEMA – a part of the Emergency Response and Preparedness Directorate, U.S. Department of Homeland Security (formerly the Federal Emergency Management Agency).

GPS – Global Positioning System

MMC – Multihazard Mitigation Council

NRCS – Natural Resources Conservation Service, U.S. Department of Agriculture

NFIP – National Flood Insurance Program

NIBS – National Institute of Building Sciences

PE – Professional Engineer

Key Terms

1%-annual chance flood, commonly called the **100-year flood**, is a flood having a one percent chance of being equaled or exceeded in any given year.

Acceptable Risk is owner and stakeholder acceptance of that level at which additional costs to implement mitigation measures to further reduce losses and risks are no longer acceptable.

Bridges generally are composed of abutments on both waterway banks that are designed to support the bridge deck and driving surface; a bridge may have intermediate supporting piers.

Category C is a term used in FEMA's Public Assistance program to refer to disaster-related damage sustained by roads, bridges and related facilities that are eligible for disaster assistance, including damage to paved, gravel and dirt roads (surfaces, bases, shoulders, ditches, drainage structures and low-water crossing) and culverts and bridges (decking and pavement, piers, girders, abutments, slope protection, and approaches).

Culverts generally are rectangular box structures that are site-built, or prefabricated units that range in shape from circular, to oval, to arched (sometimes bottomless).

Disaster means the occurrence of widespread or severe damage, injury, loss of life or property, or such severe economic or social disruption that supplemental disaster relief assistance is necessary for the affected political jurisdiction(s) to recover and to alleviate the damage, loss, hardship, or suffering caused thereby.

FEMA refers to the federal agency formerly known as the Federal Emergency Management Agency that was incorporated into the U.S. Department of Homeland Security, Emergency Preparedness & Response Directorate; FEMA coordinates the federal government's efforts to plan for, respond to, recover from, and mitigate the effects of natural and man-made hazards.

Flood Hazard Area or **Floodplain** is the area adjoining a river, stream, shoreline, or other body of water that is subject to partial or complete inundation; it is the area predicted to flood during the 1%-annual chance flood, commonly called the "100-year" flood.

Flood Insurance Rate Map is prepared by FEMA to show Special Flood Hazard Areas; this map is the basis for regulating development.

Hazard is defined as the natural or technological phenomenon, event, or physical condition that has the potential to cause property damage, infrastructure damage, other physical losses, and injuries and fatalities.

Local Road Systems consist of networks of components (e.g., roadways, bridges, culverts, etc.) that are owned and maintained by a city, county or other municipal transportation agency with little or no federal funding.

Low-Water Crossings allow vehicle passage and are intended to be under water all or some of the time. There are two general types: permanent concrete slabs (with or without small diameter pipes) and gravel embankments (with small diameter pipes) which form the driving surface.

Major Disaster, as used for federal assistance programs, means an event which, in the determination of the President, causes damage of sufficient severity and magnitude to warrant major disaster assistance under the Robert T. Stafford Disaster Relief and Emergency Assistance Act (P.L. 93-288, as amended), to supplement the efforts and available resources of

States, local governments, and disaster relief organizations in alleviating the damage, loss, hardship, or suffering caused thereby.

Mitigation is defined as actions taken to reduce or eliminate the long-term risk to life and property from hazards. Mitigation actions are intended to reduce the need for emergency response – as opposed to improving the ability to respond. Also see Section 2.5 for the State's definition.

National Flood Insurance Program (NFIP), located within FEMA, is charged with preparing maps showing flood hazard areas subject to regulations, developing regulations to guide development, and providing insurance for flood damage.

Non-Mandatory Standards are standards that are not mandated for one of two reasons: there are two or more equivalent alternatives and/or the rate of change is relatively fast so that certain practices may become obsolete and replaced by better practices. The term non-mandatory standard has come to imply best practices.

Public Assistance refers to a federal program, administered by FEMA, to provide supplemental aid to States, communities and other eligible entities, to help recover from major disasters. Specifically, the program provides assistance for removal of debris, the implementation of emergency protective measures, and the permanent restoration of public facilities and public infrastructure, including non-federal aid streets, roads or highways.

Risk is defined as the potential losses associated with a hazard. Ideally, risk is defined in terms of expected probability and frequency of the hazard occurring, people and property exposed, and potential consequences.

Rural: see Urban and Rural Classification.

Urban and Rural Classification. For Census 2000, the U.S. Census Bureau classifies as "urban" all territory, population, and housing units located within an urbanized area (UA) or an urban cluster (UC). It delineates UA and UC boundaries to encompass densely settled territory, which consists of: (a) core census block groups or blocks that have a population density of at least 1,000 people per square mile and (b) surrounding census blocks that have an overall density of at least 500 people per square mile. In addition, under certain conditions, less densely settled territory may be part of each UA or UC. The "rural" classification consists of all territory, population, and housing units located outside of UAs and UCs.

Appendix A. FEMA's Public Assistance Program

Under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 93-288, as amended, and Title 44 of the Code of Federal Regulations, the Public Assistance (PA) Program provides supplemental aid to States and communities to help them recover from major disasters and emergencies. Specifically, the program provides assistance for removal of debris, the implementation of emergency protective measures, and the permanent restoration of public infrastructure. The program also encourages protection from future damage by providing assistance for mitigation measures during the recovery process. This summary is based largely on FEMA's *Public Assistance Program Description* (FEMA, 1999).

The PA Program is based on a partnership of FEMA, State and local officials. The partnership functions through communication, training and information exchange. The roles and responsibilities of FEMA, State and local governments (and eligible private nonprofit organizations) are based on capabilities, and generally are as follows:

- FEMA's role is primarily customer service and grant assistance, with agency representatives providing information about the program before the disaster strikes and technical assistance in the development of damage descriptions and cost estimates after the disaster.
- The State is the Grantee, responsible for administering the federal grant. States have flexibility in meeting many of their responsibilities, including their involvement in inspection and preparation of damage estimates. After each declaration FEMA meets with State officials to develop a public assistance recovery strategy which includes FEMA and State staffing plans.
- The role of local governments as Subgrantees varies as a function of capability, but generally the process offers control so that local governments can meet their own needs and manage the pace of their own recovery. Many subgrantees prepare scopes of work and cost estimates for small projects (under a specified dollar limit); others request FEMA and State assistance.

FEMA's fundamental disaster recovery mandate is to help States and local governments restore damaged public facilities to their pre-disaster condition. Incorporating elements that bring a facility into compliance with current "codes and standards" is part of the basic project. For those costs to be eligible, the regulations at Sec. 206.226(d) state that the standards must:

1. Apply to the type of repair or restoration required (i.e., not limited only to new construction);
2. Be appropriate to the pre-disaster use of the facility;
3. Be found reasonable and formally adopted and implemented on or before the disaster declaration date (or be a legal federal requirement applicable to the type of restoration);
4. Apply uniformly to all similar types of facilities that are within the jurisdiction of the owner (i.e., not just privately-constructed subdivision roads, but public local roads owned by the community); and
5. Must have been enforced during the period it was in effect.

Mitigation as Part of Sec. 406 Public Assistance

Mitigation actions are those that must be specifically related to the damage, will prevent future similar damage, and exceed current codes and standards (if any are effective). All measures must be cost-effective; FEMA may approve mitigation in three circumstances:

1. If the additional cost is less than 15 percent of the total eligible cost of the eligible repair work on a particular project;
2. If the action is on the list of measures outlined in Standard Operating Policy (SOP) 9526.1 *Hazard Mitigation Funding Under Section 406 (Stafford Act)* and the cost of the measure does not exceed the eligible cost of the eligible repair work on a particular project; or
3. If the action is demonstrated to be cost-effective using an acceptable benefit/cost analysis methodology.

Related to hazard mitigation, FEMA has identified a list of some mitigation actions that are determined to be cost-effective, thus removing the requirement to prepare benefit cost analyses that could delay the processing of project. In addition, site-specific mitigation actions may be identified and included in project descriptions and cost estimates.

SOP 9526.1, effective August 13, 1998, outlines the purpose and background for hazard mitigation. Congress provided FEMA with discretionary authority to incorporate mitigation as part of permanent restorative work, recognizing that during recover there are unique opportunities to reduce similar damage from future, similar events. FEMA must balance federal, State and local interests and has an obligation for prudent stewardship when administering these discretional funds. Specific mitigation measures related to Category C that are covered by the SOP include:

Drainage/crossings and bridges

1. Drainage structures - When drainage structures are destroyed, replacing the structure with multiple structures or a larger structure. However, structures need to be considered with regard to a total drainage system and should not be replaced without a watershed hydrology study.
2. Low span bridges - Demolish/replace damaged low span bridges or other crossings that act to collect debris, increase flooding, and/or can be severely damaged.
3. Low-water crossings - Where traffic counts are low, replacing bridges with carefully placed low-water crossings.
4. Debris traps - Installing traps upstream of a culvert to prevent culverts from becoming clogged by vegetation.
5. Gabion baskets, riprap, sheetpiling, and geotextile fabric installation - Installation to control erosion.
6. Headwalls and wing walls - Installation to control erosion.
7. Restraining cables on bridges - Installation of cables to restrain a bridge from being washed off piers or abutments.

For mitigation measures not included in SOP 9526.1 and those that cost more than 100 percent of the eligible repair work, FEMA must determine whether each proposed measure is cost-effective.   The methodology for this determination (which is not the same as the methodology used under FEMA's Hazard Mitigation Grant Program authorized under Section 404 of the Stafford Act). Sometime in 2005, FEMA anticipates publishing a rule to address the repetitive damage requirement that was included in the Stafford Act by the Disaster Mitigation Act of 2000 (Sec. 205(b)).

FEMA's Public Assistance program examines replacement versus repair in some instances. If the cost to repair or restore a damaged public facility to its pre-damage condition is 50 percent or more of the cost to replace it to comply with current codes and standards, then FEMA may fund replacement rather than repair. Importantly, the codes and standards must explicitly address repairs, not just new construction.

Federal-Aid and Non-Federal-Aid Roads

Federal-Aid roads include most public roads functionally classified as arterial and collector routes (Table A-1). The Federal Highway Administration administers the Emergency Relief Program to assist State and local governments with repair of roads and bridges damaged during disaster.

Non-Federal-Aid roads are all other roads. FEMA provides disaster assistance for "non-Federal-Aid" roads that sustain damage as a result of an event that is declared a major disaster. The damage must be directly related to the disaster (as opposed to a pre-existing condition). Eligible work on paved, gravel and dirt roads includes repair or replacement of damage to road base and surfaces, bridges, culverts, drainage facilities, lighting, and the like. Only non-federal-aid roads owned by eligible subgrantees, identified by maps and records maintained by local jurisdictions (or the State Department of Transportation), are eligible for FEMA disaster assistance.

Table A-1. Road Classifications

	Classification	Type of Service
Federal-Aid Roads	Principal Arterial – Interstate	Urban and Rural
	Principal Arterial - Freeway	Urban
	Principal Arterial – Other	Urban and Rural
	Minor Arterial	Urban and Rural
	Major Collector	Rural
	Collector	Urban
Non-Federal-Aid Roads	Minor Collector	Rural
	Local	Urban and Rural

With respect to Category C, the replacement versus repair determination is readily applied to bridges and culverts. The same does not hold for consideration of other road components that are damaged by flooding, such as road base and surface treatment.

Many states and local jurisdictions do not have codes and standards that apply to roads and bridges and that relate to flood resistance. In these cases, FEMA staff may advise on measures to enhance flood-resistance, or advice may be sought from a more formal advisory group.