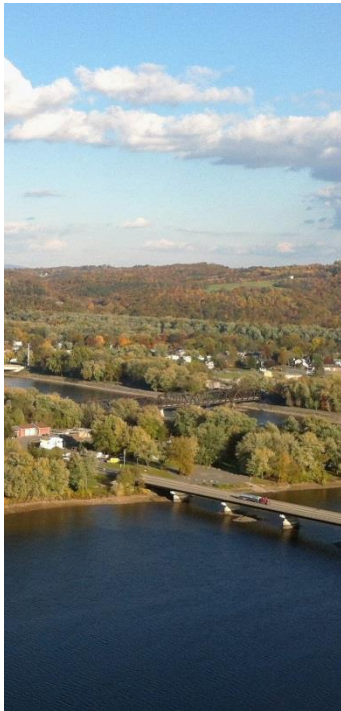




PROACTIVE FLOOD AND DROUGHT MANAGEMENT, VOL. II



April 2016

A Selection of Applied Strategies and Lessons
Learned from Around the United States

From the Policy Committee of the American Water Resources Association.

Proactive Flood and Drought Management, Volume II: A Selection of Applied Strategies and Lessons Learned From Around the United States

April 2016

L. Donald Duke
Editor

L. Donald Duke, Yung-Hsin Sun, Mark Gutshall, Lindsey Freidly
Lead authors

Wayne S. Wright, Michele Weitzel, Tiffany Castle, Harry Phillips
Contributing authors



American Water Resources Association

Policy Committee

4 West Federal Street, P.O. Box 1626

Middleburg, Virginia 20118-1626

Phone: (540) 687-8390

Facsimile: (540) 687-8395

www.awra.org

info@awra.org

© Copyright 2016

Cover photos:

Top: Susquehanna River at Northumberland, PA, one of the nation's most flood-prone basins, September 2013 (Credit: L.D. Duke)

Bottom: Folsom Reservoir, CA, at 17 percent capacity in January 2014, down from 97 percent capacity in 2011. (Credit: California Department of Water Resources)

Acknowledgements

This document was prepared under the supervision of the AWRA Policy Committee and Committee, chaired by Lisa Engelman. Thanks to Policy Committee members Brenda O. Bateman, Wayne S. Wright, Mark Dunning, and Lara Fowler for editorial support in reviewing and editing the overall report.

Thanks to Marsha Hilmes-Robinson, Robert McConnell, Ed Call, Joanne Chamberlain, Eric Jesperson, Douglas Diehl, and Chad Smith for review, comments, and local-agency perspectives for individual case studies.

Copy editing and page layout by Kathy Bowman of Joseph, Oregon. Thanks to Sharon Campbell of Bucknell University and Christy Newman of GHD Inc. for preparation of individual graphics.



Many thanks to the Florida state section of AWRA for funding to support final production.

About AWRA's Policy Committee

AWRA's Policy Committee is composed of water professionals and others with an interest in how public policy shapes our collective management of water resources. It is a diverse committee that includes scientists, educators, policy makers, and other experts at all stages of their careers. The purpose of Committee is to gather, study, and disseminate information on water resource policy issues, helping to translate scientific work into a format for action that public decision- makers can use and understand, as they go about formulating water policy. This Committee is dedicated to helping the AWRA Board take a national and international leadership role in the area of water resource policy.

Table of Contents

Introduction.....	3
Executive Summary: Highlights of Some Lessons Learned	6
Organization of This Document.....	8
Overview of Case Studies in Flood Mitigation Strategies.....	9
Fort Collins, CO Flood Mitigation Strategies.....	10
Susquehanna River, PA Small Towns Flood Mitigation Strategies	22
Lititz, PA Stream Restoration as Flood Mitigation Strategy	31
State of California Land Use Policies as Flood Mitigation Strategy	40
Overview of Case Studies in Drought Mitigation and Low Flow Strategies	48
State of California Drought Strategies	49
Hillsborough River, FL and State of Florida Minimum Flows and Levels	64
Lessons from the Case Studies in Volume II.....	75
Appendix A: A Brief History of U.S. Federal Flood Strategies	77
Acronyms Used in This Document.....	87
References	88

Introduction

This document continues the work begun in *Proactive Flood and Drought Management: A Selection of Applied Strategies and Lessons Learned from Around the United States*, published by AWRA in 2013. This current document, Volume II, adds six case studies and two overview essays to the previous volume's eight case studies. It highlights actions and programs of public agencies which are intended to mitigate the human and environmental effects of statistically extreme flows, both high and low, in natural water bodies of the U.S.

The purpose of this report is to provide, through case studies and analysis, a better understanding of problems posed by floods and droughts on society and the emerging policy responses for better addressing these critical issues with special focus on **Integrated Water Resources Management (IWRM)** as a way of better achieving more robust solutions. IWRM is increasingly being recognized as the preferred approach for addressing complex water resources issues. AWRA identifies IWRM as “the coordinated planning, development, protection, and management of water, land, and related resources in a manner that fosters sustainable economic activity, improves or sustains environmental quality, ensures public health and safety, and provides for the sustainability of communities and ecosystems” (AWRA 2011).

Through the case studies in this volume we examine the scope and impact of issues of flooding and droughts, and various policy interventions to address these impacts identifying lessons learned, successes being achieved, on-going challenges, and opportunities for further improvement. The case studies are by no means comprehensive. But they are selected to illustrate a range of circumstances, geographic conditions, and strategies from which we can draw some lessons. Our intent is to provide practitioners and interested stakeholders and citizens with a better understanding of some selected current flood and drought management strategies and to contribute to the ongoing discussion about how best to cope with floods and droughts.

The intended audiences for this document are practitioners of flood management and/or drought management strategies, and other interested stakeholders. Those interested parties include, but are not limited to:

- Federal, State, tribal, and local government officials and technical personnel
- Consultants supporting implementation of flood/drought management strategies
- Non-government organizations including broad-scale public interest groups and local groups working for improved flood/drought management strategies

Flood and drought responses in the U.S. develop within an intricate interconnecting system of regulations, delegated authority, financial opportunities and penalties, and institutional missions of multiple agencies. That system grew over time, not with regular or coordinated progress but sporadically in response to national and local problems and emergencies and decades of discussion and analysis as agencies attempted to proactively plan ways to mitigate “the next great emergency.”

In the U.S., the majority of policies and management decisions for selecting, designing and implementing the particular amalgamation of flood responses for a given region are made at the local level, with increasing involvement at the state level. Responses to mitigate low flows and drought impacts historically have relied primarily on state initiatives, along with efforts by many municipal-scale water supply utilities to ensure supply during low flows, guided predominantly by state policies. However, flood and drought mitigation in any given location in the U.S. is profoundly affected by particular federal policies or programs such as the extensive infrastructure works of U.S. Army Corps of Engineers (USACE), or the overarching insurance and disaster mitigation activities of the Federal Emergency Management Administration (FEMA).

Notwithstanding those centrally-managed programs, in most of the U.S., decisions about mitigating extreme flows are highly decentralized. Because of that, a multitude of separate agencies across the country have full or partial responsibility for mitigating effects of high and low flows. These decision makers have geographic jurisdictions that range from a few square miles to continent-draining watersheds. Their institutional settings range from single-agency programs to collaborations across political boundaries with stakeholders having complex, intersecting, and conflicting positions.

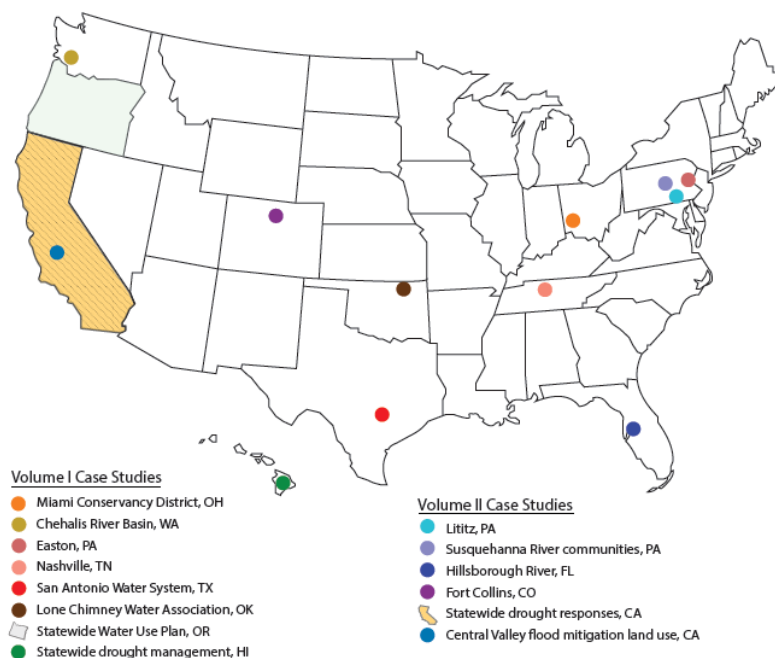
The varied institutions charged with addressing flood and drought mitigation tend to focus on their own missions, and tend to resist compromising those missions in the name of integration. Integrating means giving up authority, sometimes giving up aspects of missions that have served constituencies for decades. This leads to sometimes intractable, sometimes bitter differences among those institutions. Summaries of the kind attempted here commonly take for granted this complex, fragmented, conflicting framework of policies and authorities. Seldom do we discuss just how unusual it is to operate successfully within such a structure.

Purpose and Structure of the Proactive Flood/Drought Documents: The 2013 Volume I presented case studies provided salient examples of effective and proactive strategies by municipal and state agencies that found ways to integrate multiple water resources management objectives into programs to protect their citizens from extreme flows. Each case in Volume I described key aspects of how they accomplished their success so the reader can gain some insights, and possibly implement some aspects of the same success in other parts of the U.S.

This Volume II document serves many of the same purposes as Volume I. It broadens and deepens the total group of examples investigated. It also adds geographic diversity (Southeast U.S. and Rocky Mountain region), and extends to institutions not addressed in the first volume (very small municipalities,

statewide rules for land use planning that also address water). It also addresses a few other purposes, as follows.

Figure ES1: Geographic distribution of cases selected for these reports.



This document, as in Volume I, describes examples of proactive flood and drought mitigation programs judged to have some success at reducing impacts of flooding or low-flow conditions. The cases highlight a range of institutional barriers, a diverse set of challenges, and a variety of technical approaches. The case studies describe ways in which each program is suited to its location; document institutional settings and local choices that produced each program; identify problems or limitations those localities needed to overcome; and identify factors that may inhibit replicating their success in other locations of the U.S.

Case studies included in the document were selected by querying colleagues in the national network of AWRA for cases that illustrate a diversity of conditions with results, conditions, and lessons that may be of interest in other parts of the U.S., while providing different locations or programs than those included in Volume I of this series. Several of the cases are complex and multi-faceted, with multiple lessons to be learned, including about complex institutional interrelationships.

Case study descriptions in this document include some degree of critical analysis, including perspectives about some state, federal, and local regulations and programs that influence local decision making. We identify some external policies for each case that have enabled – and others that may have inhibited – the success of the cases. We also selected some cases that have not been fully successful or fully resolved, and make some recommendations about how those policies might be changed to better encourage similar successes.

All case study descriptions in this document were reviewed by current or former personnel of one or more agencies that were closely involved in the programs described to improve our accuracy in reporting facts, and add to our understanding of the context of each case. These reviews were immensely helpful. However, this document does not necessarily reflect any official positions of any of the agencies mentioned. All interpretations and any errors or omissions are solely the responsibility of the authors and the Editor.

Executive Summary: Highlights of Some Lessons Learned

Case studies: The cases here, along with those in Volume I, allow us to make some observations of lessons learned that may help inform the national dialogue about how to promote meaningful, effective, proactive management to mitigate the consequences of high flows and low flows on our streams, rivers, and coastal zones. There are several key take home ideas highlighted here. For more detail, see the full discussion of Lessons Learned in the concluding section of this report.

- **Disaster or need can be a significant driver of action.** We repeat this lesson learned from the Volume I document, because it remains possibly the single most visible lesson from either set of case studies. The aftermath of natural disasters often creates broad public sentiment that something must be done to prevent such occurrences in the future. As a result of public outcry political will is exercised to create task forces, develop funding strategies, and push for solutions to prevent future occurrences of the disaster. In this volume, Fort Collins Colorado responded to devastating floods in this manner and developed a sophisticated multi-faceted approach to open space preservation, flood warning systems, stream restoration, and flood mitigation funding. Many of the proactive solutions seen here arose initially as a reaction to previous damaging events, with the purpose of avoiding recurring future events. A disaster provides the opportunity for the political will needed to align the forces and funding for implementing needed changes.
- **Collaboration, communication, and education** turn potential strategies into effective strategies. The case studies demonstrate many instances where superior flood and drought management strategies were achieved through encouraging involvement of diverse stakeholders with wide-ranging points of view, and through working to achieve integrated solutions that honored that input and those diverse views. The collaboration, communication, and mutual education that took place among stakeholders resulted in more effective strategies that could not otherwise have been achieved. This level of involvement among stakeholders is one of the key elements of integrated water resources management approaches.
- **A crucial step is connecting policy makers and regulatory enforcement agencies with community stakeholders.** Identifying community priorities can lead to multifaceted solutions that both protect those priorities and attain flood or low-flow protection. Those solutions can in many instances be better accepted by communities than top-down, single-purpose decisions, and are less likely to impede other community priorities.
- **A regulatory requirement can serve as a driver, and can lead to opportunities to integrate other desirable outcomes.** In many of these case studies, the original driving force was the need to satisfy one kind of regulatory requirement. Meeting those needs in creative ways that integrate multiple beneficial outcomes can lead to more complex, innovative projects, and can meet other pressing environmental or economic needs, priorities, or pending regulations, alongside the original regulatory driver. In many instances this approach allows communities to attain cost-effective unified designs that address multiple priorities.
- **Flexibility in institutional requirements can address multiple needs.** Compliance with regulations for a wide range of purposes – protection of endangered species; management stormwater runoff hydrograph characteristics; protection of historic districts; and more – can incorporate or even drive projects that mitigate flood or low-flow impacts. This ‘lesson learned’ goes beyond effective communication – always necessary – and into a willingness to be flexible. In many cases serving multiple purposes requires innovations or modifications to routines, which can be accomplished if

responsible agencies relax existing regimented requirements to consider less-frequently-seen alternatives that can be even more effective.

Historical Development of U.S. Policies: Brief histories and overviews of U.S. flood policy concepts and programs appear as Appendix. This provides insight into the intricacies of programs, laws, decisions, obstacles and opportunities for mitigating, responding to, and recovering from floods.

- **Appendix A: Flood management in the U.S.** At present in the U.S., there is no coordinated, integrated flood or drought policy at the national level, despite extensive federal programs and activities. But many federal programs profoundly affect flood control, including U.S. Army Corps of Engineers structural and operational programs at scales ranging from local protection to basin-scale flow management; and National Flood Insurance programs affecting land-use decisions nationwide.

Organization of This Document

This document is organized as follows.

- There are two sections – one with case studies about flood mitigation, and one with case studies about drought and low-flow mitigation. Within each section are case studies describing specific locations or programs where a decision-making agency has attempted to mitigate the effects of flood or drought.
- Each case study includes: an introductory overview of the region and its problems with extreme flows; a summary of the institutional setting or enabling environment in which the mitigation strategy was developed; a summary description of the kinds of mitigating strategies applied by the case study entity; the costs of various mitigations when available – as well as a description of the financing tools and mechanisms used to cover those costs; quantifiable and/or additional benefits to society, economy, or the environment as a result of the management approach; next steps or future challenges; and lessons learned that are specific to the case study.
- The case studies each include analysis of their broader context, describing one Federal or state policy or driving force that has been instrumental in local decision-making. The Fort Collins case includes a brief discussion of FEMA’s Community Rating System nationwide; the Pennsylvania Susquehanna River Communities and Rock Lititz cases discuss the borough-township municipal system of governance found in Pennsylvania and some other northeastern states; the California Central Valley case describes state and local government approaches to land use policies in California; the California drought case study describes dimensions of the drought currently gripping the western U.S.; and the Hillsborough River low-flow case includes an overview of Florida’s statewide Minimum Flows and Levels requirements.
- The “lessons learned” sub-section at the end of each case study summarizes factors illustrated by the case, including: barriers successfully overcome; challenges that remain; and, in some cases, institutional barriers from federal or state policies that inhibit some kinds of imaginative, effective, proactive strategies that might otherwise be useful for the particular locality.
- Two case study descriptions in this report *intentionally do not* follow this outline: the Central Valley, California land-use planning case study; and the California drought management case study. Those sections describe state-level programs that are instructive and relevant to our purpose. They add important “lessons learned” to the document.
- A concluding section, following the last of the case studies and before Appendix A, is a summary collection of lessons learned in Volume II. These offer more detail about the lessons highlighted in the Executive Summary.
- Appendix A provides a brief history of federal flood control initiatives in the U.S. The appendix describes the institutional setting of flood control, mitigation, management, response, and recovery. It especially focuses on the development of federal programs and policies that have been so important in guiding local and state initiatives. The appendix also addresses integrative aspects of the policies, with an overview of both obstacles and opportunities for integration of flood management.
- References and associated resources for all sections are provided at the end of the document.

Overview of Case Studies in Flood Mitigation Strategies

Four case studies in flood mitigation and high flow strategies are included in this section.

- **Fort Collins, CO** implemented a suite of flood-mitigation strategies designed to avoid recurrence of disastrous flood damages that occurred in the past 20 years in rapidly-growing urban regions. The municipality employs a variety of approaches for varying land uses and stream morphologies, including channel stabilization, detention basins, preserving open spaces in the floodplain, effective stream gauge monitoring, community warning systems, and more.
- **Small towns on the Susquehanna River, PA** that are described here illustrate institutional and infrastructure challenges faced by communities throughout the flood-prone Susquehanna River basin. The limited resources available to a typical small community affects the range of strategies they might pursue. This case study compares two communities – Lewisburg and Milton, PA – and the ways they have found to address the repeated flooding of the past 200 years.
- **Lititz, PA** is the site of a creative, integrative stream-restoration project designed to accommodate a new land use in a long-settled, historic watershed. The *Rock Lititz* establishment will be a modern, cutting-edge facility for the music industry. Its location puts it squarely athwart one of the hundreds of small streams dammed for farm and mill uses in the 19th century. These streams hold deep legacy sediment deposits and cause water quality and flooding problems during high flows. The restoration plan implemented for the *Rock Lititz* site ameliorates problems from that flooding.
- **The State of California** has developed land-use policies that have significant implications as flood mitigation strategies. This section describes how land use modifications in the Central Valley portion of the state could limit the damages of flooding. The Central Valley is affected by multiple major rivers that drain snowmelt from the Sierra Nevada across an alluvial plain that is now home to intensive farming operations and extensive urban and suburban residential growth. Floods on those rivers have had catastrophic effects at times, and the proposed strategies could mitigate those effects.

Fort Collins, CO Flood Mitigation Strategies

Lead author:

L. Donald Duke, Florida Gulf Coast University

Contributing researchers:

Harry Phillips and Jessica Goodstein, Florida Gulf Coast University

Xueyang Zhang, Bucknell University

Introduction: Multi-Pronged Flood Mitigation in the Shadow of the Rockies

Fort Collins lies in the plains just east of the Front Range of the Rocky Mountains at the confluence of the Cache la Poudre River and Spring Creek.

With a 2014 population of 156,000, it is Colorado's fourth most populous city. The city shared the rapid growth of the western U.S. in the second half of the 20th century. Census data show 25,000 population in 1960, tripling to 88,000 in the 30 years to 1990 and nearly doubling again to 156,000 in 2014 (U.S. Bureau of the Census, 2015).

Geographic boundaries have increased over time. Since 2008 the city has encompassed just over 52 square miles (Fort Collins 2008). By the 1990s there was substantial urban and suburban land use in the floodplains, with a growing susceptibility to damage from the historically infrequent, sometimes high-magnitude, flood events.

Multiple small flood events in the 1970s prompted the city to begin serious response to flood and drainage issues, including formation of a stormwater utility in the 1980s.

In 1997, the city was struck by devastating flash flooding, affecting multiple parts of the city. Rainfall was intense both within the city and over nearby parts of multiple watersheds. The storm event generated 14.5 inches of rain in a 31-hour period—equivalent to the annual total of a typical year. The mode of flooding was a flash flood on multiple streams, with the Spring Creek area most heavily affected: discharge reached 500-year flows on Spring Creek. Flooding occurred during the evening and into the night of July 28.

In the 1997 event, five people died, and more than 50 people reported injuries. Most of the damage occurred around the Colorado State University area. More than 1,500 homes were damaged and about 200 homes were destroyed, including mobile homes in a trailer park in Fort Collins. A freight train car derailment occurred after floodwaters washed over that section of track. Upon derailment, a gas line was ruptured causing the destruction of several businesses because of the explosion. Another factor exacerbating the flash flood was the amount of debris carried by the rapidly flowing water. Cars, trailer homes, and other flood torn wreckage blocked the College Avenue Bridge downstream, impeding flow, creating more rising water in Fort Collins, and hindering rescue efforts.

The City's responses to the 1997 event drew on the stormwater utility, and applied some recovery funding and other grants to develop a multiple-approach, wide-ranging strategy. That strategy included obtaining funding from the National Hazard Mitigation Grant Program and other sources. It also included identifying—and actively implementing—a range of complementary programs including physical, data-gathering, regulatory, and public-outreach activities.

As in so many of the case studies in this document and in the preceding volume (Dennis et al., 2013), response to a disaster was a powerful driving force for the community to implement aggressive and effective efforts to mitigate future such occurrences.

In 2013, another major flood event struck Fort Collins, of an entirely different hydrologic nature. Flooding on the Cache la Poudre River originated with rainfall upstream in the mountains that was largely limited to a single large watershed.

This basin was targeted for mitigation efforts during the 1997 to 2010 period. The mitigation approach selected for this basin was open-space management. Development of “high risk” land uses are prohibited in the floodplain, and a number of flood attenuation facilities were constructed. Results were highly positive. Flooding from the 2013 event was much less damaging than from the event of just 15 years earlier.

As key parts of its strategy, Fort Collins continues to actively promote public engagement in floodplain and stream channel management, to provide ever-enhanced information to residents, and continue effective maintenance and study to identify potential future problems.

Current Strategies, Institutional Setting, and Enabling Environment

Two major institutions have been important to Fort Collins’s local municipal approaches for flood mitigation: 1) the stormwater utility and 2) the federal Community Rating System, which is cited as a driving force for the municipality’s planning, outreach, and community engagement.

The Stormwater Utility: In the 1980s, Fort Collins City Council studied potential flooding and stormwater remedies, and chose to create a stormwater utility. It was designed to provide a consistent funding stream to enable a number of responses to problems that had recently been identified. While the institutional origins were largely local, the stormwater utility was created in the context of Federal and state supporting information and policies.

Flooding problems were identified as occurring in discrete locations and on various water bodies and drainage basins across the city, including areas *not* identified on FEMA’s Flood Insurance Rate Maps (FIRMs) as subject to 100-year floods (City of Fort Collins, 2008). Crucially, the locations include stormwater runoff conveyed through the city’s drainage system to creeks, ponds and open channels on the way to the Cache La Poudre River and Fossil Creek Reservoir.

Mapping: A task the utility quickly undertook was to map the 12 drainage basins in the city. It also remapped its floodplains once again, once more extending to basins beyond those identified in the FIRMs as floodplains. The City also expended substantial funds and efforts to generate its own rainfall maps to use in place of the statewide contour maps provided by the National Oceanic and Atmospheric Administration (NOAA), which were somewhat outdated. The rainfall mapping and floodplain mapping were costly and controversial, and ratepayers questioned the value of expenditures for such detailed analysis. However, ratepayer dissent tapered off when the mapping studies proved their worth in providing invaluable predictive capacity in early warnings to the 2013 flooding.

Capital projects were facilitated by the presence of the utility. These included some flood barriers; stream channelization; drainage system upgrades; and acquisitions of some high-risk properties in the floodplains. After the 1997 flooding, the Stormwater Utility (City of Fort Collins, 2015a) was the major source of funding and the institutional driver for a wide range of preparation, data analysis, and capital programs. The City issued some relatively small bonds for the storm drainage system, intended to obtain funding quickly to allow projects to begin. These were paid off using the utility revenues. Hazard

Mitigation Grants under FEMA were used for major capital projects in the wake of the 1997 floods. The largest of these went to implement and expand a flood warning system.

The stormwater utility also undertook an expansion of capital improvements, including:

- West Vine Outfall Project;
- Dry Creek Drainage Improvement Project;
- Oak Street Project;
- Clearview Channel Rehabilitation;
- Plum Street Sanitary and Storm Drainage Improvements Project;
- Canal Importation Ponds and Outfall Project; and
- Northeast College Corridor Outfall (planned, but not yet constructed)

Funding also was applied to projects such as stream channelization at several locations; detention facilities in the Spring Creek basin; and storm sewer projects in the “old town” urban areas. In a few cases the funding was used for construction of levees, but structural barriers of this kind were limited to those locations where the Fort Collins decision-makers could identify no other good alternatives.

Essentially all of these projects had multiple purposes. For example, the City notes: “As part of the Oak Street Project, the Udall Ponds area was developed into a series of wetland-based water quality ponds and a natural habitat area. Water discharged from the storm sewer pipe slowly passes through the ponds for natural purification before being released to the river” (City of Fort Collins, 2015a).

Storm sewer refurbishment. The aging storm drain system, in place since the early development of the city, was refurbished and its capacity expanded. Capacity is now believed to satisfy the needs of the much greater density and impervious surface of the modern urban area. Open space within city limits in the Poudre River basin paid dividends, largely capturing those flows and avoiding damage during the subsequent 2013 flood event.

Community Rating System: A second institutional driving force is the Community Rating System (CRS), part of FEMA’s National Flood Insurance Program (NFIP). Stated CRS goals are to reduce and avoid flood damage to insurable property; strengthen and support the insurance aspects of the NFIP; and foster comprehensive floodplain management (FEMA, 2008).

The CRS is a national voluntary incentive program intended to recognize and encourage communities to reduce flood damage through comprehensive floodplain management beyond the minimum standards. The program is an important driving force nationwide. Some communities report the guidelines and protocols of CRS participation to be valuable information for floodplain managers, elected officials, and local residents regarding the possible kinds of measures a community could take (Duke and Zhang, 2015).

To be eligible for CRS, communities must document activities that score an aggregate of 500 points on the CRS scoring scale, and must implement a number of prerequisite activities, to enter the CRS program at Class 9 (the lowest level of participation). Policy holders in participating communities can have their flood insurance rates reduced by 5 percent to 45 percent, depending on the extent of the community’s CRS activities and their ranking by Class 9 (5 percent reduction) through Class 1 (45 percent reduction). Fort Collins has achieved a CRS Class 4 rating and is currently the highest-rated community in Colorado.

Nationwide, participation in CRS is a valued strategy to a large number of communities. Table FC1 shows that as of September 2015 there were nearly 1,400 communities nationwide participating in CRS. That number appears to be increasing: Statistics from the previous reporting period showed about 1,100 communities participating in CRS (FEMA 2013), an increase of more than 25 percent in approximately

five years. Most communities participate to a modest degree.

- As of January 2015, another 300 communities nationwide had reached CRS Class 5 or Class 6. The numbers of communities in Classes 5, 6, and 7 have increased substantially over the previous reporting period, while the number in Classes 8 and 9 have been approximately unchanged. This suggests that CRS-eligible communities across the U.S. are in general conducting more of the flood-mitigation activities outlined in the CRS program, moving up the scale to higher classes, while the total number of participants also has increased.
- However, CRS continues to reach a relatively **small proportion** of all communities in the U.S. that experience flooding problems. Nationwide in 2015 there were more than 21,600 communities participating in NFIP, which means in gross proportions that only 6 percent of them were participating in CRS.

Table FC1. Colorado and U.S. Communities Participating in Community Rating System: from highest ranking, Class 1, through lowest participation level, Class 9.

Class	Participating Communities	CO Total, 2015 ^a	US Total, 2013 ^b	US Total, 2015 ^c
1	None	0	0	1
2	None	0	0	3
3	None	0	0	3
4	Fort Collins	1	6	4
5	Arvada, Boulder	2	45	102
6	Colorado Springs, Jefferson County, Lakewood, Parker, Thornton, Westminster, Wheat Ridge	7	88	219
7	Boulder County, Delta, El Paso County, Englewood, Fountain, Golden, Green Mountain Falls, Littleton, Loveland, Manitou Springs, Monument, Palmer Lake, Vail	13	235	339
8	Arapahoe County, Aurora, Canon City, Centennial, Cherry Hills Village, Denver, Douglas County, Eagle County, Frisco, Gunnison County, Longmont, Louisville, Pitkin County, Steamboat Springs, Telluride	15	462	472
9	Alamosa, Brush, Durango, Fremont County, Gunnison, Mesa County, Morrison, Silverthorne	8	259	225
Total, all classes		46	1,095	1,368

(Sources: a. FEMA, 2015; b. FEMA, 2013; c. Martinez 2015.)

Clearly, communities participating in CRS are home to a larger number of NFIP-insured properties than other communities. The 6 percent of NFIP communities that participate in CRS contain roughly 70 percent of all NFIP insurance properties (Martinez 2015). That might suggest communities with multiple properties at risk of flood damage do participate in CRS, though it is not at present possible to document the number of properties in floodplains where the owners decline to purchase NFIP insurance. That could be a large enough number to strongly affect the statistics.

Differences among states are strong enough to suggest that many states hold a large number of flood-susceptible communities where CRS has not penetrated. For example, as of 2015 Florida lists more than 200 communities participating in CRS (including more than 80 rated at Class 6 or higher), and California has more than 90 communities participating. **Florida and California together constitute more than 20 percent** of all participating communities nationwide. Pennsylvania has 25 participating communities (of which only two are Class 6, and none are higher). Demographics in Pennsylvania suggest **the number could be much higher**, given that it is among the most flood-damaged states of the past 25 years and its municipal government structure creates a large number of autonomous communities, as noted in the Susquehanna River communities case study in this document. In brief, a large number of communities fail to take advantage of CRS or to experience it as a driving force. Certainly few take advantage of it to the extent of Fort Collins – and many do not at all.

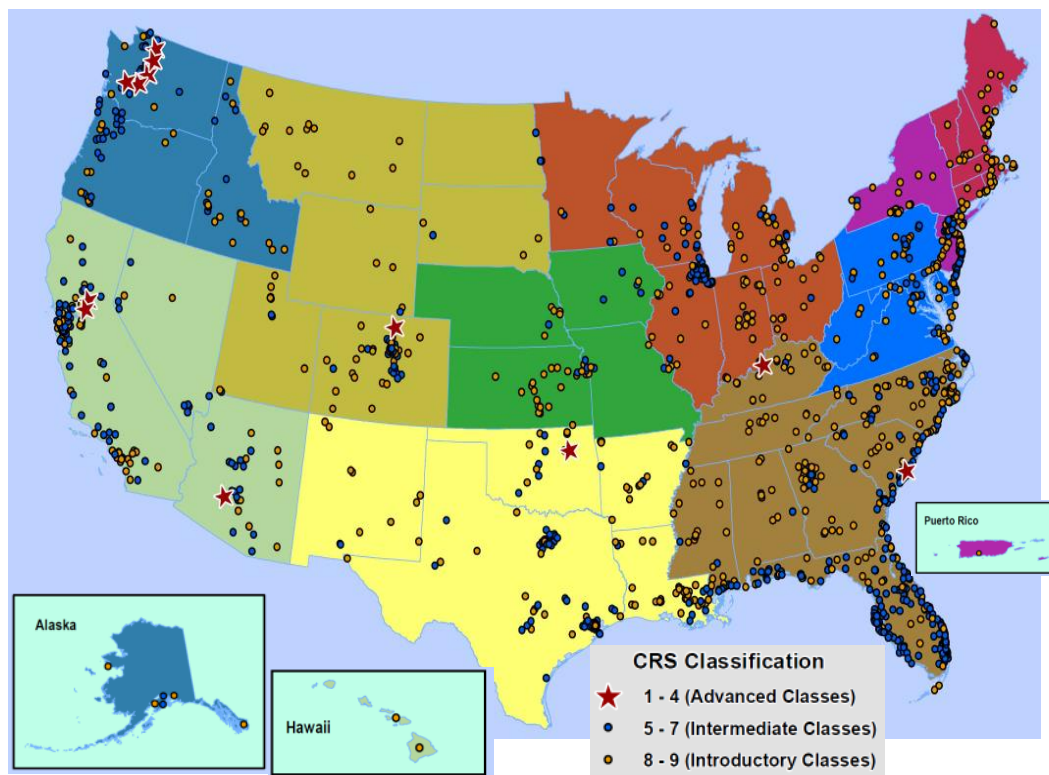


Figure FC1: Location of CRS participating communities in the U.S., by advanced, intermediate, and introductory classes. Source: FEMA, 2015c.

Colorado participation in CRS is robust. As Table FC1 shows, as of January 2015, 46 communities were participating, with half (23) in either Class 8 or Class 9. A total of nine Colorado communities participate at Class 4 or higher – which are marks of communities truly committed to flood mitigation via the CRS approaches.

Fort Collins employs CRS as a major part of its strategy. Fort Collins is the only community in Colorado to have achieved a Class 4 ranking, which makes its insurance holders eligible for a 30 percent reduction in their rates. (In the forthcoming round of ranking in 2016, Fort Collins is expected to rise to Class 2 (Hilmes-Robinson 2015)). Fort Collins’s floodplain manager identifies the city’s wide-ranging suite of activities as “nearly everything that CRS encompasses” (Hilmes-Robinson 2015). The CRS program is a major institutional driving force for the City.

The direct financial incentive of CRS, which is to reduce flood insurance premiums to policyholders in the participating communities, is not a major driving force in the case of Fort Collins. As the number of properties in local floodplains has declined, the number of policy holders has also declined. That is a direct result of the city's other flood mitigation activities. (In fact, parts of the city are no longer considered to be floodplains due to structural projects that protect specific areas from flooding.) The current count of NFIP standard flood insurance policyholders in Fort Collins is fewer than 100, along with about 300 "preferred risk" policyholders (Hilmes-Robinson 2015).

Nevertheless, the city recognizes the CRS program as an important institutional driver. Some examples are:

- CRS guidance materials that describe activities for which participating communities may earn points have been a valued guide for Fort Collins's activities. The CRS program serves as a "best practices" tool, in that preparation of the annual reports helps the City to identify activities it could implement (Hilmes-Robinson, 2015).
- In particular, the extensive community communication, engagement, and outreach activities described in the CRS Manual (FEMA, 2013), have helped Fort Collins to identify potential strategies for flood mitigation, management, and response. Some of the public-information activities now routine in Fort Collins, such as ongoing outreach meetings for stakeholders of local basins, were first identified while it undertook the CRS application process.
- Fort Collins is deeply interested in metrics to document its activities and compare their effectiveness (Hilmes-Robinson 2015), and CRS provides this. Its scoring process identifies particular activities, gives each activity a number assigned by FEMA that rates its degree of implementation in Fort Collins, and compares the city's numerical scores to those of communities elsewhere in Colorado and the nation.
- Recently, Fort Collins began implementing a Public Information Application program as outlined in the CRS Manual. The CRS process "became a valuable tool to gather stakeholders" and built cooperation toward projects (Hilmes-Robinson, 2015).

Current Strategies for Flood Mitigation, Management, and Response

Fort Collins employs a broad-based suite of strategies addressing stream flow and runoff on a number of fronts.

- | | |
|---|--|
| ○ Public outreach and communication: Awareness and preparation among the community. | ○ Capital improvements: Stream channel improvements, levee construction, drainage system improvements, and detention basins. |
| ○ A warning system: Effective modeling of stream response based on precipitation, in-stream monitoring, and the capability to alert residents and respond as necessary as a flood event develops. | ○ Maintenance: Routine funding for high level of maintenance of capital systems. |
| ○ Regulations: Enhanced zoning, building codes for flood proofing and elevation, and measures that extend beyond the minimum specified by NFIP for structures in floodplains. | ○ Open space preservation: Reducing/avoiding development in floodplains; providing detention capacity for flood peaks; and preserving the beneficial natural functions of the floodplain and its ecosystems. |

This summary describes three of the many strategies that Fort Collins has implemented: 1) the open-space strategy used on the Cache la Poudre River basin; 2) the city-wide, multi-watershed flood warning system; and 3) the use of detention and spreading areas for flood attenuation.

Open Space Preservation and Acquisition Projects: The Cache la Poudre River basin has substantial open space, and the City has taken advantage of those less-developed areas to acquire at-risk lands and ensure no sensitive future development will occur there.

- Fort Collins's Natural Areas Program has used its funds to steadily acquire land in the Poudre's floodplain since the mid-1970s. It now owns more than 920 acres of natural areas within the City's 100-year floodplain. With public support, Larimer County has levied tax dollars to fund the program since 1992. The City's Parks and Recreation Department owns several parks within the floodplain with a total of about 55 acres. The open space has multiple uses in the long periods when it is not needed as high-flow conveyance. "The Poudre River bike trail is a planned overflow area for the river during high run-off season" (Fort Collins, 2015). Enabling the river to overflow to these natural areas benefits the habitat and maintains the health and resilience of the river system.
- At the same time, Fort Collins pursues a strategy of removing vulnerable structures within the floodplain. This alleviates property damage in similar ways, but for developed rather than natural uses. The *Willing Seller–Willing Buyer* program uses City funds to purchase existing residential or commercial structures that are located in high-risk areas of the floodplain. It is another example of the City's willingness to commit local funding to improve its flood safety. Two commercial properties and two residential properties were purchased and removed from the floodplain under the *Willing Seller–Willing Buyer* program—not a large-scale change to the City, but a program that can continue to reduce future risks.

Other approaches can preserve existing structures, and their historically and economically important land uses. After the 1997 flooding, a small grant funded retrofits to existing homes in the Old Town area. This was considered a one-time upgrade of a limited number of potentially affected homes.

- The utility also manages floodplain regulations and issues permits for requiring "flood-proofing" improvements, such as water-resistant materials and elevated heating equipment for structures that undergo substantial renovations. Regulations also prevent or restrict certain kinds of sensitive development within the floodplain, so future land uses do not include at-risk structures. This is an ongoing procedure that continues to gradually improve the capability of historic structures to withstand any future floods.

Flood Warning System: Effective early warning is a strategy used by communities across the U.S. In many cases communities are served by data analysis, modeling, and stream forecasting by the National Weather Service and a variety of state-level agencies. The earliest possible indications are needed. At the same time, the system also needs to be sufficiently accurate to avoid false-positive reports and evacuations when flooding does not occur. That kind of false positive erodes confidence of the community, and can even damage the system's effectiveness if some residents choose not to act when the next emergency arrives.

In Fort Collins, the current flood warning system was not in place before the 1997 floods. The disastrous effects of those floods made clear how valuable such a system might be. The system follows the broad outlines of many such systems in the U.S. Some specifics follow.

- The warning system relies not only on technical data but on thorough advance publicity about possible responses, and effective quick communication in event of an emergency. The warning system requires all of these to be effective.
- The city supports a full-scale emergency-response network; responders are on call for potential flood damage 24/7 for the months of April through September. Larimer County, of which Fort Collins, is the seat, employs an emergency alert system that is crucial to public safety.
- The emergency alert system is provided by The Larimer Emergency Telephone Authority, called *LETA911*, provides the emergency alert system, a useful tool for warning the public about emergencies including missing children, wildfires, inclement weather (tornadoes, severe thunderstorms), and – not least – potential imminent flooding.
- This system uses multiple formats such as land lines, mobile devices, email, and text, but it can also be accessed through the *LETA911* web site for the latest alerts. City staff who monitor the Flood Warning System utilize this service and social media when notifying residents of approaching flood conditions.
- The Flood Warning System utilizes data from an assembly of stream level gauges, rain gauges and other weather data collecting instruments. The initial system included 12 gauges on various channels upstream of the city. Over time (funded by multiple small grants and the city) the network as of 2015 grew to 64 gauges. If conditions become hazardous from significant rainfall amounts or the increase in flood stage of the Cache la Poudre River, this information is combined with data from the National Weather Service to issue severe weather and flood warnings for Larimer County and Fort Collins.

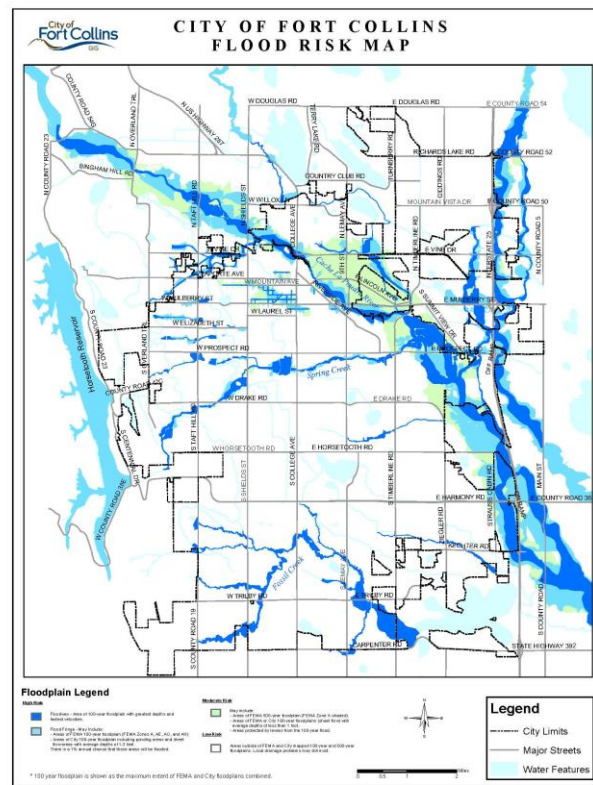


Figure FC2: Flood risk map. Source: City of Fort Collins, 2015c

When an extreme event occurs, residents are not always instructed to evacuate. On the Cache la Poudre River, advance warning (there is about a two-hour lead time for flow from the mouth of the canyon to the populated Fort Collins area) is often sufficient to act. However, advance warning can be substantially less in some of the smaller basins with headwaters near or in populated and paved areas where flash flooding is possible. Danger could be greater if people are caught trying to move during the flooding. Driving through flood waters remains a common hazard during flood events. Therefore, sometimes the warning system advises other appropriate actions, such as to remain in place but seek higher floors or higher ground.

The Fort Collins strategy also benefits from its effective public-awareness campaigns and system of communications. It is supported by monuments around Fort Collins for remembrance of previous major floods and the “*Fort Collins–Be Flood Ready*” campaign to educate residents on flooding hazards. The campaign employs an easy-to-follow web site that includes broader guidance on structural risks and improvements, as well as information on how to respond in an emergency. The information is tailored to the City’s needs, but employs an approach similar to FEMA’s “*Floodsmart*” information campaign (FEMA, 2014b).

The initial cost of this network was considerable, however the value of protection of lives and property provided by the Flood Warning System far exceeds those original funds. Moreover, the data collected has other uses, such as for historical flood stage perspectives of the Cache la Poudre River, and for hydrologic modeling for stormwater mitigation in the Fort Collins area.

Channel and Streambank Improvements and Detention Areas: Fort Collins’s structural improvements focus on stability of stream channels, detention facilities in the Spring Creek basin, and structures in service of open space in the Cache la Poudre basin. Only relatively small portions of the community have structural protection. The physical limitation of stormwater structures is seen as a possible vulnerability during major events because blockage of drainage systems can cause backups of substantial amounts of stormwater and of floodwater (Hilmes-Robinson 2015). Some examples of structural improvement in Fort Collins follow:

- A short levee known as the Oxbow Levee was constructed in 2004 on the Cache la Poudre River. The levee protects extensive pre-existing residential and commercial development in the Buckingham neighborhood. It is an example of an area where structural flood barriers may be the best solution. Even so, its design accommodates the river. The levee was set back from the river’s left bank, creating an open space that serves as valuable riparian habitat during normal flows, and provides some minimal spreading area during high flows. Perhaps most importantly, preserving the open space keeps most development out of the floodplain so high flows do not cause damage or safety risks (Hilmes-Robinson, 2015). Another structural improvement that defers to open space was creation of the Riverbend Ponds Natural Area, also off the Cache la Poudre River. This is a natural area, a series of shallow ponds formed by former gravel pits, designed as an amenity for the community.
- A 2006 structural project (a collaboration of the City’s Stormwater, Natural Areas, and Engineering Departments) stabilized the river’s banks and channel to remove a previous risk of bank collapse during potential high water. The project ensures the river will remain in its own floodplain should it overtop its banks, removing the risk that pit depressions will capture the stream channel in unwanted directions. It uses channelization and other structural improvements to create a flow path for controlled spills during high flows. The project retains the natural and beneficial uses of the floodplain, while directing any flooding where it can be accommodated.
- In the Spring Creek basin, where less open space is available and where the highest flows commonly originate as flash floods with little advance warning, a different strategy is used. The City has

constructed a number of large flow detention facilities. These are designed to hold back and attenuate peak flows in a high-rainfall event so flooding is less likely to reach high-risk land uses and to give residents time to respond and avoid safety threats.

Costs and Financing

Financing for Fort Collins's ambitious decade-long program of improvements is driven by the stormwater utility. The utility rate is based on lot size, a base rate, and a rate factor such as percent of impervious surfaces. The utility has provided the financial stability, the institutional framework, and the dedicated personnel to support a few modest bond issues and to successfully apply for FEMA National Hazard Mitigation Grants and disaster-response and pre-disaster funding. Those external sources allow the utility's budget to reach even further, and allowed some projects that might otherwise not have been completed in such a timely fashion.

Various stormwater projects throughout Fort Collins are constructed and maintained through the City's stormwater utility, but other department costs also apply. The stormwater utility was initiated in the 1980s and its last rate increase was in 2004. The average monthly stormwater fee for Fort Collins's residents is about \$14. This chart represents how the funds are allocated.

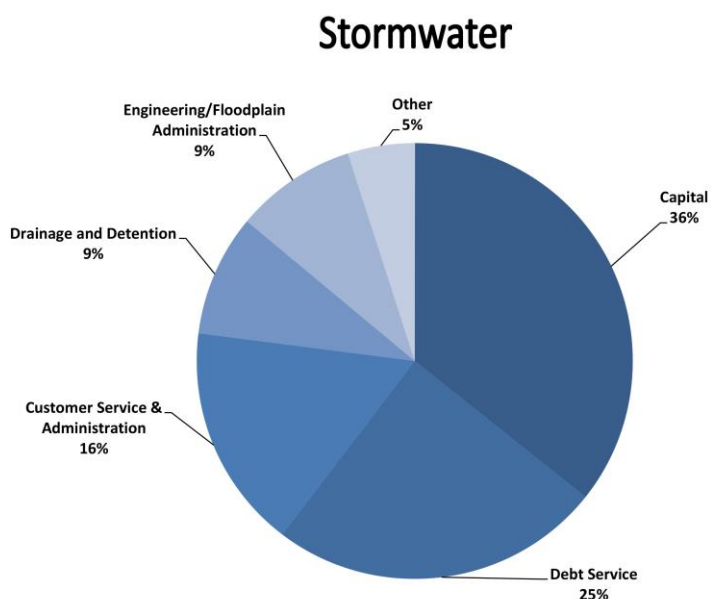


Figure FC2: Allocation of stormwater funds (City of Fort Collins, 2015b)

Improvement in flood protection along Spring Creek was one of the foremost projects completed with combined FEMA Mitigation Grant federal funds and City of Fort Collins resources. Using a \$2.7 million grant received in 2005 and an additional \$1.4 million dollars of its own funds and in-kind services, Fort Collins began flood protection projects in Spring Creek basin. Over subsequent years, these pooled funds helped to complete numerous construction activities and improvement projects.

Some solutions to flooding along Spring Creek came with construction of new detention basins and the expansion of existing detention ponds. During the 1997 flood, a railroad crossing embankment was overtopped, caused massive flooding and damage from debris. Stabilization of railroad embankments for the Burlington Northern Railroad provided a significant improvement. In addition, railroad crossing improvements at the intersection of Prospect Road and College Avenue and the confluence of Spring Creek and Poudre River provided further protection for residents downstream on Spring Creek.

Integrative Features and Benefits

The integrative nature of acquiring funding from many institutions and adapting floodplain management into the missions of those multiple institutions is a crucial aspect of successful flood mitigation planning in Fort Collins. The City's multi-pronged strategy (matching different techniques to the characteristics of different basins and watersheds) is also an integrative feature. Different approaches based on the characteristics and needs of specific areas have been integrated into a comprehensive flood management strategy. Some of the major components of this strategy include:

- Improved drainage has been crucial for older developed areas and has created the ability to accommodate and drain even sizable flash floods from precipitation within the basin.
- In the historic “old town” area, the strategy relies on flood insurance for properties and stormwater structure retrofits, because many of the buildings have historical significance and regulatory restrictions against removing them from the floodplain.
- Preserving open space – including detention in upstream regions – is a strategy that succeeds in basins where substantial amounts of the floodplain are not yet developed. The geographic extent of the City's planning made this possible, because its planning scope encompasses both undeveloped areas and long-developed areas where financial, social, and political factors would resist any major changes in land use.

The benefits of the city's approach of tailoring diverse strategies to diverse locations was demonstrated very early on, when the Cache la Poudre River experienced rainfall-driven flooding in 2013. The open-space preservation and higher regulatory standards for that basin proved highly effective, passing the test with little damage and no human casualties. That success does not prove all strategies will be equally effective for all basins, but it is certainly a strong beginning.

The ability of Fort Collins to develop a plan with appropriate approaches for different basins would not exist without a sufficiently large geographic scope to match the large conceptual scope of the efforts. Matching watersheds and basins to the appropriate strategy requires this big-picture scope, broad both in the kinds of strategies considered and the ability to capture large enough portions of the watersheds to create effective basin-scale management actions.

Challenges and Future Activities

The community's funding and support for the programs is a continuing challenge. Gaining public confidence and conviction to support stormwater capital projects is a significant challenge between storm events. The years following the 1997 flood necessitated many improvements to the policy and basin of Fort Collins' flood plan. Undeniably the flood event was still on the minds of residents. An increase in stormwater fee and an update to the rainfall standards were implemented following the 1997 flood to enhance Fort Collins' level of protection (Hilmes-Robinson, 2015).

Flood awareness education and maintaining resident's attention to the possibility of flood is crucial to facilitating stormwater fees and supporting projects. Sustaining that attention in the long term is a challenge, as human memory tends to be notoriously short when there is no imminent threat at a given moment. The *Fort Collins-Be Flood Ready* campaign aims to hold the attention of long-time and new residents, but constant vigilance will remain a challenge.

Lessons Learned

- The Fort Collins program of flood mitigation emphasizes the value of a local institution, with support from top to bottom by elected officials and community ratepayers who recognize the benefits of a city-wide program.
- The geographic extent of the Fort Collins municipality, and of its stormwater utility, allows a basin-scale multi-pronged approach that tailors its responses to those that work best for the hydrologic, economic, and cultural features of its various basins.
- The Community Rating System (CRS) has proven a valuable driving force, as an institutional feature that elected officials could point to in order to gain support from the community when making their case for flood mitigation efforts and their associated costs.
- A multiplicity of strategies, rather than reliance on a single strategy, has proven to be highly effective. Adding warning and communication strategies atop structural and land-use strategies, with approaches tailored to particular basins, has served to enhance each of the complementary strategies.
- Fort Collins has demonstrated the value of local design, funding, and operation of a regional stream gauge system, and a community warning system that uses stream data for timely warning of flood risks. Communities across the U.S. have found enormous value in an early warning system that can call for evacuations or other appropriate responses in an emergency. In many parts of the U.S., local entities' warnings rely on data and forecasts from state agencies, often in collaboration with National Weather Service. However some locations with quickly-varying microclimates, steep topography, and fast-moving stream crests, require even more precise and local information.

Growing knowledge and skill in stream modeling and forecasting is invaluable, but compensates only partly for reductions in federal gauging stations over recent decades, leaving some communities with inadequate stream information. Communities like Fort Collins that are willing to these services may be better able to gain timely and accurate warnings. Other communities that see these services as something that should be provided by state or federal agencies may find they do not receive the detailed, timely information that an intensive locally-designed and locally-funded program may provide. Willingness to pay for additional accuracy and precision with local sources make major contributions to the effectiveness of Fort Collins's warning system.

- Another clear contribution to the overall success of the flood mitigation program is the city's extensive effort to increase public awareness well before a possible event. Clear instructions at the time of an event are also important. (The best possible information is of no consequence if the responsible agency does not effectively issue warnings, and success is equally hampered if the at-risk community is not prepared to act.) The Fort Collins warning system expends substantial effort to enhance preparedness.
- Persistence and a decades-long vision are a major lesson of the Fort Collins experience. The program was not conceived, developed, funded, and implemented all at one time, but in stages over time, addressing one priority after another and adapting to changes in local preferences, funding, and land use. Support by the community, and continuing leadership from officials elected by that community, has been sustained over time, allowing a well-functioning integrated system to develop.

Susquehanna River, PA Small Towns Flood Mitigation Strategies

Authors:

L. Donald Duke, Florida Gulf Coast University

Michele Weitzel, Florida Gulf Coast University

Contributing researchers:

Seamus McLaughlin, Xueyang Zhang, Ellen M. Kalnins, and Ryan P. Murphy,

Bucknell University

Introduction: Autonomous Small Towns and the U.S. Flood Mitigation Structure

Flooding is a perennial problem along the Susquehanna River. The river is noted as the longest non-navigable river in the U.S., with one of the nation's larger watersheds (27,500 square miles), and throughout its length and breadth is a conduit for extreme flows from the high relief and multiple small valleys of the "plunging folds" geology of the central Appalachian Mountains. The Susquehanna has experienced at least 35 known extreme high-flow events since the period of European settlement began in 1730, with 13 of these between 1902 and 2011 (Hayes 2013).

The quintessential American small towns of the central Susquehanna River Valley of Pennsylvania have experienced frequent and intense flooding, along the river itself and along its multiple tributaries, since they were founded in the 18th century. Nearly all settlements of that age were established along the river as a transportation corridor (supporting canal and rail lines), and nearly all were founded around a mill district powered by a substantial tributary – a geographic basis for early industrial water power, and equally a basis for today's flood damages.

Prior to about the 1970s, most floods occurred in late winter or early spring, resulting from sudden ice-melts or seasonally warm rainfall atop pre-existing deep snowpack. Those floods primarily endangered communities along the larger waterbodies, which funneled melts from the largest watersheds.

A second flooding mode, experienced more often since about 1970, results from watershed-wide, sustained high-rainfall events, in particular hurricanes or tropical storms. Those effects have intensified as development throughout the smaller watersheds has generated increasing runoff and decreasing infiltration from individual storms, leading to ever-higher peak flows. The most severe of those events have occurred at times when rainfall was heavy prior to the major storm event saturating soils in the watershed. In many of those events, major damages have occurred along tributaries as well as the main stem, as high flows back up the tributaries and reach into communities well off the main stems, including some where flooding was rare in previous decades.

A third mode has joined these two, in the form of flooding on the smaller streams and tributaries themselves. Locally-intense rainfall episodes centered over a relatively small watershed have produced some record flooding on smaller tributaries and short segments of the main channels. This too is likely a result of increasing development in the watersheds, which are less capable of absorbing short, sharp precipitation events.

The defining event in recent history was flooding from Tropical Storm Agnes in June 1972, a watershed-

wide high-rainfall event which produced flooding along the length of both the North and West Branches. A more recent event, following Tropical Storm Lee in 2013, was of the locally-intense variety. Small portions of the basin experienced record flooding, exceeding the Agnes crests for a few locations along the North Branch just above the confluence with the West Branch.

Lewisburg and Milton: Two small towns along the river are described as a single case study for this report. Lewisburg and Milton lie about 10 river miles apart on the Susquehanna, in separate counties, and with different development patterns driving their land uses. Both municipalities, along with their neighboring townships, were severely affected by the Agnes flooding of 1972, but their paths to recovery since that time have been very different.

- Milton has a substantial industrial base that has held steady since the 1970s, with a commercial and residential district that has declined.
- Lewisburg houses a private university, has an active central business district, and a growing tax base.
- Both are surrounded by suburban-like developments where population has grown. Like most Pennsylvania boroughs, they have geographically very small town limits, so much of that development is outside the borough limits and instead occurs in the separate municipalities of the surrounding townships.
- The population of the two boroughs never reached more than 8,000 each at their peak, with the neighboring townships spreading another 10,000 to 20,000 people across less-dense acreage throughout their counties.

Table SR1 shows the population of the two boroughs, along with several other municipalities in the seven-county region, displaying changing population in recent decades. Today's small-town urban districts have a varying mix of land uses within a geographic area of a few square miles. Many contain historic districts from the mid-18th century; some have industrial facilities not far from the historic core, surrounded by infill from the 1930s through 50s; and some have outlying residential communities that grew from farmlands to leafy suburbs through the late 20th century.

Since 1970, among the boroughs, only Bloomsburg, Selinsgrove, and Lewisburg – all with universities within borough limits – have gained in population. Lycoming County, Northumberland County, and Union County show increases, most or all of which has occurred in the townships, not the boroughs.

Table SR 1: Change in population in recent decades, selected central Pennsylvania municipalities.

	1970 population	2010 population
<u>Union County excluding Lewisburg</u>	22,900	39,100
Lewisburg	5,700	5,800
<u>Northumberland County</u>		
<u>excluding Milton, Sunbury, and Shamokin</u>	66,800	70,200
Milton	7,700	7,000
Sunbury	13,000	9,900
Shamokin	11,700	7,400
<u>Lycoming County excluding Williamsport</u>	68,100	80,100

Williamsport	38,000	29,500
<u><i>Selected boroughs in other counties</i></u>		
Bloomsburg	12,000	15,100
Lock Haven	11,500	9,500
Danville	6,200	4,700
Selinsgrove	5,100	5,800

Source: US Census Bureau, 2014a. Rounded to nearest hundred. Adapted from Duke, Kalnins, and Murphy, 2013.

Institutional Setting and Enabling Environment

The Commonwealth of Pennsylvania’s system of ‘townships and boroughs’ dominate the institutional setting for much of the Commonwealth’s public policy. In Pennsylvania, all locations are incorporated as City, Borough, Township, or Village, with a few unique designations such as a single “town,” such as Bloomsburg in Columbia County. Further, the seven-county Central PA region has multiple population centers. A great number of townships contain less than 5,000 people. There are large boroughs reaching nearly 10,000 (US Census Bureau, 2014a). Lewisburg and Milton are considered small boroughs with populations between 5,000 and 15,000.

The most important feature of this system for purposes of managing water resources is the enormous autonomy exerted by the local governments. Thus, decisions by many entities have led to a great diversity of flood mitigation approaches on the Susquehanna River (Duke, Kalnins, and Murphy, 2013), though all are subject to the same Federal and State requirements, incentives, and programs.

Both Lewisburg and Milton have changed their land uses over time (Duke and McLaughlin, 2014).

- **Lewisburg Land Use:** Lewisburg’s dominant strategy has been to gradually acquire property in the floodplain, focusing on the small tributary bisecting the historic district. The borough has strategically converted downtown land uses from flood-prone commercial and residential structures to open space.
- **Milton Land Use:** The Borough of Milton has a strategy that is shaped by its decision to take advantage of massive one-time funding provided by the U.S. Congress (through the Department of Housing and Urban Development) in response to the Agnes flooding of 1972. The explicit goal of the financing was to reshape flood-damaged towns in the form promoted by HUD in the 1970s. Specifically, that means clearing out older housing stock in favor of high-density urban dwellings with surrounding open spaces, including open parking in the central business district.

The National Flood Insurance Program as Driver: For these boroughs as in thousands of municipalities throughout the U.S., the defining Federal program that drives countless local decisions is the National Flood Insurance Program (NFIP). This program is administered by the Federal Emergency Management Agency (FEMA), which since 2002 has been part of the Department of Homeland Security.

NFIP was enacted in 1968 in response to the rising cost of taxpayer funded disaster relief. It enables property owners in participating communities to purchase government-backed insurance protection. Under this law, FEMA identifies flood hazard areas throughout the United States on Flood Insurance Rate Maps (FIRMs). Funds (managed by FEMA in conjunction with the Federal Insurance Agency) are made

available to communities that agree to adopt and enforce floodplain management to reduce future flood damages (PEMA, 2012).

The insurance is **mandatory** for homeowners with federally backed mortgages who live in flood-prone areas, identified by FEMA as areas with 1% chance of flooding in a given year – the traditionally termed “100-year flood” (FEMA, 2013). Any Pennsylvania community identified by FEMA as containing a Special Flood Hazard Area is **required** to participate in the NFIP under the Pennsylvania Floodplain Management Act (§ 201, 202). Communities can also **voluntarily** participate in the Community Rating System (CRS), which provides incentives (lower insurance rates) for floodplain management activities that exceed NFIP minimum requirements. Credit points are given for each action that reduces future flood risk (PEMA, 2012). CRS ratings for the two communities are:

- Lewisburg as of 2013 had a class 8 CRS rating allowing for a 10 percent reduction in rates.
- Milton as of 2013 had a class 7 CRS rating that affords them a 15 percent reduction.

Disaster Relief and Recovery Funding: The second dominant institutional feature for the small towns of Pennsylvania, as for municipalities across the U.S. that have experienced disaster-scale flooding, has been funding for disaster relief, recovery, and redevelopment. FEMA, in addition to directing mitigation planning, also administers these continuing post-disaster funds, which in most cases are directed to State agencies. In Pennsylvania, the Pennsylvania Department of Community and Economic Development (PDCED) administers these funds.

The most familiar, and probably most visible, form of this effect is rebuilding of entire neighborhoods. Congress has directed FEMA to consider possible future flood effects when deciding how to administer funds. Since 1988, the federal Stafford Disaster Relief and Emergency Assistance Act has guided FEMA’s mitigation actions. It directs FEMA to establish hazard mitigation priorities and an appropriate hazard mitigation plan, for each community. (42 U.S.C. 5133§203)

The Act was amended in 1994, with the intent to direct some of the disaster relief funding to municipalities to “buy out” properties that have been repeatedly damaged in floods. Communities in the Susquehanna Valley, as throughout the U.S., are directed to make their own decisions about which, if any, properties they might acquire. They must apply for Stafford Act funds within a specified time frame after any flood damage (typically about two years). When funds are received, communities are permitted to choose which structures, if any, will be converted to community-managed open space.

Those decisions can profoundly affect the shape of the community for decades to come. The rules stipulate any property acquired, accepted, or from which a structure will be removed pursuant to the project will be dedicated and maintained in perpetuity for a use that is compatible with open space, recreational, or wetlands management practices (Stafford Act, 1994). That restriction has proved to be burdensome, and has resulted in the imposition of land uses that are not what a community might choose. When a property is converted to open space using Stafford Act funds, it is required to be retained indefinitely by the municipality, precluding any economic development such as residential or commercial use. The lot must be maintained, clear of large vegetation and prohibited from all but the most minimal buildings (such as benches). The long-term expense of mowing grass may be large enough to be a burden.

Current Strategies – Summary and Comparison of Two Boroughs

Lewisburg Strategies: The borough does not have an ordinance explicitly addressing flooding, but does have a single line in its county General Plan, under Policy Statements for Land Utilization. Item 5 charges the County “to use floodplains and steep lands as part of the open space of the county.” (Union County PA, 1975). To that end, Lewisburg has used various state and Federal programs to provide funding to gradually acquire land in its flood zones.

Lewisburg acquired about 30 parcels in the post-Agnes recovery period, funded by Congressional post-disaster relief. These were concentrated in a city-center neighborhood drained by a water body named Limestone Creek but colloquially known as Bull Run. Those properties were developed into a downtown park, Hufnagle Park, opened in 1983, named for a public official who lost his life while attempting to rescue residents during the June 1972 Agnes flood. The park is owned and operated by the borough, but is not subject to the floodplain restrictions of the later Stafford Act. Some modest buildings and tree plantings dot the site.

Acquisitions since the 1990s have used Stafford Act funding in the immediate vicinity of Hufnagle Park, including about 10 properties on two acres after flooding in 1999; and another 13 properties, on just over 1 acre total, in 2013 (Duke and McLaughlin 2014).

That strategy leaves substantial parts of the Central Business District and surrounding residential neighborhoods intact, with no intention to acquire those properties – including the 200-year-old historic

core of the borough. In this area, Lewisburg relies on private property owners to maintain their properties, including an assumption that NFIP policies will be held and will be sufficient to lead owners to repair properties after a flood. For the most part this appears to have held true. The borough, and especially the historic core, is noted as a prosperous downtown relative to other municipalities in the region.



***Figure SR1:** Demolition of a residence adjacent to Bull Run stream, contiguous with previously acquired properties opposite Hufnagle Park, Lewisburg, PA. Acquired using funds from FEMA, PA Dept. of Economic*

and Community Development, and Borough of Lewisburg. Lawn maintenance of acquired properties constitutes a significant obligation and expense for small towns.

Other sources of funding were applied to create public parks and open spaces in low-lying parts of nearby neighborhoods drained by Bull Run. A playground and park at St Mary’s Street, and open space immediately upstream, do not appear in any policy identified by the Borough as ‘flood mitigation’ or anything similar. Instead these appear to be individual actions over time by civic improvement groups supported to varying degrees by the Borough. Collectively they appear to form a rational response to flooding along Bull Run, but in each case they were targets of opportunity for civic improvement.

The Lewisburg approach has the advantage of focusing acquisitions within a single geographic space.

This is superior to a strategy where a municipality allows all homeowners to decide whether to seek Stafford Act funding. In those cases, the municipality has no control over spatial location of properties it acquires, and can experience a “checkerboard” pattern where a neighborhood’s remaining buildings are interspersed with open spaces. A single, contiguous region of open space is much easier for the borough to maintain. The borough can abandon electrical and other utilities for that space, and can prioritize acquisitions to the areas where hydrological models demonstrate flooding is likely to be most severe.

Milton Strategies: The current land use in the Borough of Milton is shaped by the decision to extensively rebuild its downtown using massive one-time funding from Congress after the Agnes flood of 1972. The acquisition and relocation of residents and businesses led to a decrease in local tax revenue and a patchwork of empty lots throughout town.

The acquired parcels were, for the most part, re-sold to private entities – businesses and individuals – and redeveloped in a way seen to be consistent with floodplain construction, i.e. multiple small downtown



parks; several large mid-town municipal-owned parking lots replacing structures damaged in the flood; and several medium-sized, drive-up businesses (for example, banks and fast food restaurants). The new construction is built to an elevation of 1.5 feet greater than the 30-year flood line. The town has an undulating topography, so for some commercial buildings, meeting this requirement led to building upon a berm.

Figure SR2: Redevelopment in Milton is elevated above the floodplain.

Population figures demonstrate the impact of this strategy on the borough of Milton. In 1970, two years before the Agnes flooding, the Borough population was 7,720. In 2000, after more than 25 years of recovery, the population was 6,650. It has since rebounded to about 7,000 (US Census Bureau 2014b). Because of Pennsylvania’s commonwealth system of government, the Milton borough is sharply confined to a small geographic footprint, so movement of a business or a family from within the flood zone means almost certainly that business or family will move outside the borough to an adjacent jurisdiction.



Figure SR3: Modifications to older housing stock includes structures with elevated first floor – no habitable space below the entrance.

Annexation is not an option for these boroughs because the Pennsylvania Constitution (Article IX Section 8) allows mergers and consolidations only if approved by majority vote from each municipality, precluding any municipality from directly annexing another (Pennsylvania, 2015).

Milton’s strategy for responding to and reducing damage from potential future flooding is built around local ordinances and codes that specify “smart flood-proofing”

for buildings located in the flood hazard zone. This may consist of raising the occupied portions of the structure to above the elevation specified for new buildings; raising the elevation of fuel storage tanks, furnaces, or utilities entering the building; or use of water-resistant materials rather than hardwood or plasterboard.

This strategy encourages NFIP participation and reduces property damage should a flood occur – a double advantage. It also avoids the hollowing-out effect that would occur if those buildings were instead razed and maintained as open space. However, it does not apply retroactively to existing buildings, and applies only to new buildings or those that require a new zoning permit, such as those being rebuilt, whether from damage such as fire or flood or for any other modification that requires a building permit from the Borough, so progress has been slow. Fewer than 15 buildings have been flood-hardened since the ordinance was enacted (Diehl, 2014).

The borough declines to facilitate property buy-outs should buildings experience flood damage. When Stafford Act funds are available, the borough has a policy *not* to take the required actions that would allow individuals to accept Stafford Act buy-out funds. Those actions would include providing the modest financial match – typically 3 percent of the cost paid to the private property owner – and agreeing to accept care of the property indefinitely (Diehl 2014). This policy effectively prohibits any Stafford Act acquisitions in the borough, and there have been none since at least 1999. The borough’s rationale for this is that properties that are acquired are removed indefinitely from the tax rolls, and a borough of declining population and commercial activity can ill afford such losses.

The small-town structure of Pennsylvania’s municipalities explains this effect. Boroughs’ boundaries are so small that essentially all developable land within has been developed, so any property owner who relocates will almost certainly relocate outside the borough. They can remain “local” for customer purposes if they move to the adjacent townships, whose borders are less than a mile away in any direction from downtown.

Thus Stafford Act funding for mitigation of future effects does not meet its goal in Milton. No properties are acquired, and properties are flood-hardened at a pace of less than one property per year on long-term average.



Figure SR4: Historic district, Borough of Milton, with surviving buildings at street level – not elevated. Open space behind was once densely developed.

Costs and Financing

- **Lewisburg Strategies:** Lewisburg takes advantage of funding opportunities as they become available, and thus has made progress over a period of some 40 years. The funds required to acquire properties, per acre or per building demolished, have changed substantially since the initial group of acquisitions in the 1970s. Lewisburg acquired about 30 parcels in the post-Agnes recovery period, funded by about \$400,000 from the Pennsylvania Department of Community Affairs—a fraction of the funds expended in Milton (Cairo 1975).

Subsequently, Lewisburg acquired about 10 properties on two acres using about \$700,000 (in 1999 dollars) in FEMA Hazard Mitigation Grant Program funds when funding was made available after flooding in 1999; and another 13 properties, on just over one acre total, with funds provided in response to Hurricanes Irene and Lee flooding in 2013 (Duke and McLaughlin 2014), at a cost of over \$2 million (in 2013 dollars). In both of those episodes of acquisition, FEMA funds provided about 75 percent of the funding, and State resources about 25 percent. The Borough is using Stafford Act funding in approximately the way it appears to be intended – to remove at-risk land uses from the floodplains and to modify the property into open space controlled by the municipality.

- **Milton Strategies:** The Milton approach took advantage of massive one-time funding, provided by the U.S. Congress via the Department of Housing and Urban Development in response to the Agnes flooding of 1972. Funds consisted of about \$8.2 million from HUD and a matching \$2.7 million from the Pennsylvania Department of Community Affairs, in 1972 dollars (Cairo, 1975). Milton’s subsequent programs have essentially zero direct cost to the municipality or to state and federal sources: modification of structures to be resistant to flood damages are required at the private property owner’s expense. Property owners have a variety of means to apply for PEMA and FEMA assistance directly because the municipality participates in NFIP. However, Milton does not provide any funding to homeowners or businesses, which makes it more costly for owners to repair damages, remodel and update structures, and remain in business in Milton’s central business district.

Integrative Features and Benefits

- Lewisburg’s Hufnagle Park is an example of urban development promoted by downtown open space. The park is the site of “music in the park” free concerts every Wednesday during summer months, and multiple other festivals and programs that draw large crowds into the Lewisburg central business district. An “ice festival” in sub-zero weather during January routinely draws robust crowds.
- Milton’s programs maintain the town’s history and identity with historically significant architecture. Milton’s strategy also attempts to preserve its tax base and longevity by promoting rebuilding and flood proofing rather than obtaining and promoting open space.

Challenges

- **Lewisburg Challenges:** Lewisburg’s approach of acquiring only a few properties at a time, up to perhaps 10 to 20 properties at most, is indeed a gradual strategy, but is in the long run making progress. It allows the community to apply funding from a variety of sources as they become available, providing flexibility and integration with other community priorities. However it will continue to make progress only as long as local leaders and local preferences continue to include flood mitigation as a priority.
- **Milton Challenges:** Massive redevelopment in the mode of 1970s-era urban planning has profoundly changed the character of Milton and other cities that followed a similar strategy in the 1970s, which make them highly reluctant to accept other buy-out programs. The borough prefers to rehabilitate structures, along the way, requiring them to harden so they suffer fewer damages in future floods. In this way it sustains occupancy in the urban core, and avoids urban blight. On the other hand, Milton’s

strategy enjoys none of the financial incentives that are afforded to towns pursuing buy-outs. Changes are paid entirely by private entities – an advantage to tax payers – but lead to extremely slow change.

The borough perseveres in this approach because in the long term it can strengthen the economic viability of the historic core, and is preferable to the alternative – buying out flood-damaged properties. Property buy-outs would continue to weaken the historic core that was so severely damaged in the flooding and subsequent redevelopments of the 1970s.

Lessons Learned

The federal FIDP and FEMA programs aimed gradually changing land uses within floodplains does contribute to changing those land uses in the small towns of Pennsylvania, but very gradually. The two case study towns are proceeding on different trajectories.

- **Lewisburg's successes** derived from applying property buyouts gradually, allowing urban areas time to assimilate lost housing; and from focusing those buyouts in a compact geographic area. The key lesson from the Lewisburg experience is that multiple funding sources, long-term planning, and multi-decade consistency can make flood-desirable land use changes. Another lesson is that locally prosperous regions can accommodate these practices. Lewisburg's hands-off policy for its commercial district has thrived because property values drive owners to rebuild and reinvest after damages, while less-fortunate districts – including Milton, less than 10 miles distant – have been utterly hollowed out by the same policies.
- **Milton's successes** are aimed at preserving the historic core, and have met with good local acceptance. However, a sizable proportion of the town's residents and businesses remain at risk. FEMA and PEMA have a program to help, The Flood Mitigation Assistance Program (FMA) is a pre-disaster mitigation program funded through the NFIP to reduce claims. Funding is very limited with a federal cost share of 75 percent. Individuals cannot apply directly; requests must come from their local governments. It is not known if Milton has applied for this assistance program.
- **An important lesson** from this two-town case study is to recognize that activities implemented by municipalities, including those with some of the best floodplain-management benefits, include many that are not identified as relevant to flood mitigation, and may not be related to the federal initiatives designed to promote flood mitigation. This is valuable, but raises the possibility that projects will be implemented that do not align with flood policies, because other motivations may include competing land uses, alternative priorities, and decisions that may not be well-informed about the effects on flood safety.
- **Previous Federal initiatives and programs included some negative outcomes** – as in the redevelopment of Milton's central business district, massively altered by post-flood reconstruction – because that reconstruction obliged it to use redevelopment schemes in favor in the 1970s that are now seen as counterproductive. Awareness of certain failures of the sweeping changes of the 1970s leads small-town municipal planners in some cases to be reluctant to undertake major redesign on the grounds that negative outcomes of those programs may be unforeseeable in the same way as outcomes of the 1970s redevelopment. The changes under this kind of sweeping activity may be irrevocable, or may hinder municipalities' efforts to respond to other priorities.

Lititz, PA Stream Restoration as Flood Mitigation Strategy

Lead authors:

Mark Gutshall and Lindsey Freidly, LandStudies, Inc.

Introduction: Flood Mitigating Stream Restoration in a Region with Highly Altered Floodplains

Watersheds in southeast Pennsylvania, and similar regions in nearby states, begin in steep upslope hillsides then drain through naturally low-relief alluvial valleys on their way to larger rivers and the Atlantic Ocean. The floodplains of nearly all these small streams have been drastically altered by farm practices over 300 years of settlement, most prominently by mill ponds constructed both outside and within the stream channels. These have filled over time with sediment and the original stream profiles are long buried and hidden.

In the late 1600s, Europeans first began to colonize the East Coast of the United States and established farms, towns and industries along the landscape's abundant rivers and streams. The land was heavily deforested during settlement, leading to eroding soils. Farmers and settlers quickly cleared land and often created straight channels along the edges of the valleys to redirect the water into a single stream, leaving the nutrient rich valley soils open for farming, yet contributing to excessive nutrients, such as phosphorous and nitrogen.

Dam construction also took its toll on the newly settled land. The settlers from Europe were skilled in establishing mills and employing water power to drive them. Dams created a series of ponds where formerly flowing water had formed streams, with entirely different morphology. The ponds very quickly became depositional areas for fine soils and sediments that would otherwise have been carried downstream. These became "legacy sediments" during the stream restoration projects of recent years: when dams are removed and flow is restored, the water flowing through the formerly-ponded areas quickly cut down through the legacy sediments, leaving sharply incised channels (LandStudies, 2007). The process is recognized by State policy makers, for example:

Widespread indicators of impaired watercourses and watersheds due to legacy sediment include a history of damming, high banks and degree of channel incision, rapid rates of bank erosion, high sediment loads, watercourses relocated from their natural position in a valley, low channel pattern development, infrequent flooding in the riparian zone, diminished sediment storage capabilities, riparian zones lacking groundwater at or near the surface, natural habitat degradation, and other diminished natural aquatic ecosystem functions and services (PA DEP, 2013).

Water issues in this region stem from altered land use, particularly from agriculture, and from the resulting changes to the natural and historic landscape and floodplains. An example is the Santo Domingo Creek, the site of this case study's project. A valuable resource for historical information about land use and natural systems is the 1864 Bridgen's Atlas of Lancaster County, Pennsylvania, a compendium of detailed maps. The Atlas shows a significantly different alignment of Santo Domingo Creek, shown in figure L1, as compared to today's channel, in figure L2. The channel has been straightened, likely to facilitate farming operations. Streams in this region are typically negatively impacted by buildup of legacy sediment. The sediment buildup is caused by a combination of accelerated soil erosion from post-settlement land clearing and an extensive system of mill ponds in the stream valleys collecting the upland sediment. Although the 1864 mapping does not show any mill dams immediately downstream of the site, as is typical in this region, Santo Domingo Creek's profile is typical of other streams, with an abrupt change from steep stream channels upstream in the watershed to a shallow slope at the deposition point, often historically the site of a mill dam and pond.

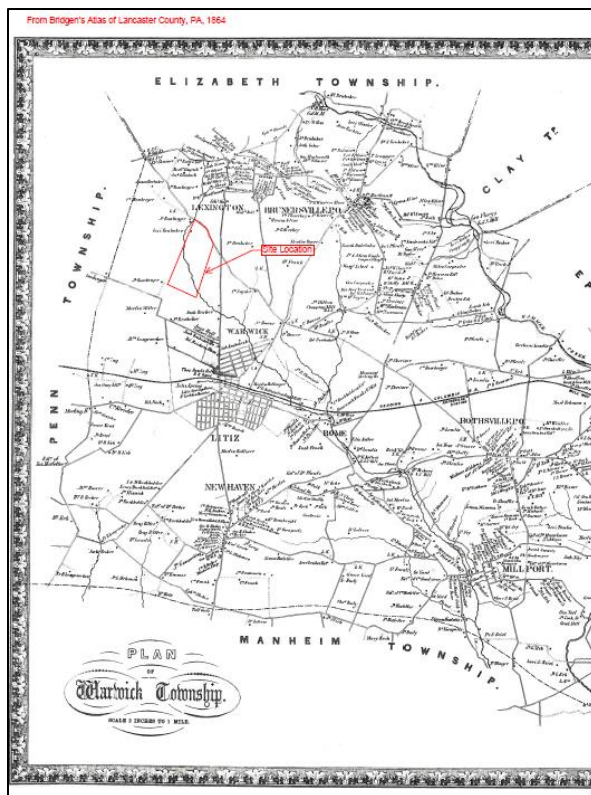


Figure L1: Land uses in Elizabeth and Warwick Townships and Lititz Borough, 1864. From Bridgen's Atlas. Creek alignment on Rock Lititz site is different from 2010 alignment.



Figure L2: Land uses, 2010. Rock Lititz site with parts of Warwick Township and Lititz Borough. Some current land uses follows patterns of 1860s, with some land in same city roads or same farming use as in 1864; other areas with modern residential/suburban development.

That is the profile associated with buildup of eroded sediment from the upstream hill slopes. Exploratory trenches excavated at several locations throughout the floodplain corridor confirmed those expectations (LandStudies, 2014; see also Merritts, Walter, & Rahn, 2010, and Walter & Merritts, 2008). Assessments indicate that as the land was cleared for farming, drainage ditches between fields were established, which then collected the surface runoff into what has become the Western Tributary of the Santo Domingo Creek.

The Rock Lititz Project Stream Restoration: Strategies and Management Instruments

Over the centuries, Lancaster County's productive economic activities have included a wide range from early industry, to farming that was intensive by 19th century standards to becoming an extensive tourism and entertainment magnet beginning some 60 years ago.

One center of activity, not well known outside its practitioners, has made the region a powerful hub over the past 40 years: the music industry. Clair Global's success in the music industry has created a hub of entertainment-technology companies in Lancaster County, Pennsylvania. Tait Towers and Atomic both moved from the United Kingdom to establish headquarters in the United States for the close proximity to Clair and for the logistics benefit of this location. That concept has continued, and there are now 13

companies located in this community supporting live entertainment production. With the growth of this base and the construction of the new industrial campus in Lititz, Pennsylvania, Rock Lititz, there will be many new entities looking to relocate to Lititz. Rock Lititz is an industrial campus for the live entertainment industry located in Lititz, Warwick Township, Pennsylvania. It is designed to house 1 million square feet of offices, design studios, warehouses, storage, and a state-of-the-art studio by 2020.

With a floodplain running through the 96.3 acre-site, an extensive land-use change of that type offers a great opportunity to maximize land area for development, reduce long-term costs, and employ best management practices that will improve the site's environmental footprint and benefit the regional watershed and its communities.

LandStudies, Inc. identified floodplain restoration as an effective strategy that will meet the principles of Economic Ecology to weigh, combine, and maximize economic and environmental gains. In conjunction with the land development activities, over 3,100 feet of Santo Domingo Creek (which runs through the site) and its associated floodplain has been restored to historical pre-settlement conditions. But the project's adoption was by no means simple, despite those advantages, because of Pennsylvania's governance.

Pennsylvania's municipal level governance of water resources has resulted in a fractured approach to addressing stormwater management, flooding and resulting infrastructure damage, total maximum daily loads (TMDLs), and other challenges. Unfortunately, this addresses symptoms of problems, rather than the root problems themselves. For example, an impacted stream reach within one municipality's jurisdiction is "restored" by planting a forest buffer, but legacy-sediment buildup in an upstream area leads to recurring sedimentation in the restored region, erasing gains in the long term. To address the root problem would require addressing the legacy sediments, which may be outside the jurisdiction where the problem occurs, and where the action is taken.



Figure L3: Rock Lititz project: Floodplain restoration and stormwater management concept plan.

For the Rock Lititz site, key elements of the restoration strategy include:

- The steep slope change moving downstream indicates eroded sediment from the upstream hillslope. To accomplish the restoration, the buildup of legacy sediment within the floodplain was

excavated to establish that it is well connected to the existing base flow.

- Woody debris was partially buried throughout the floodplain to provide increased roughness, habitat, and an additional source of carbon. A channel system consisting of several shallow flow paths was created to weave throughout the woody debris across the entire width of the floodplain.
- The active flow has remained within a temporary bypass channel for over one year to allow planted vegetation to become established prior to allowing active flow to access the newly constructed floodplain. The floodplain was designed to manage stormwater for the entire development project.

Extensive field research helped project proponents to understand the upstream sediment load that will, over the long term, need to move through the restoration site without eroding the restored channel, and without allowing sediment to drop out where it is not appropriate. The final design takes into account the length of stream that will be required to maintain the flow force needed to move the sediment when the restored channel is full and begins to spill out onto the restored floodplain. The Rock Lititz restored floodplain removes an estimated 246,000 pounds of sediment from the watershed annually.

Institutional Setting/Enabling Environment

Floodplain restoration in Pennsylvania's small streams and small political jurisdictions can be an effective response to multiple regulations and requirements from the federal, state, and local levels that are experienced by Pennsylvania's small municipalities. Floodplain restoration is shown to have great potential for improvements in stormwater management, flood mitigation, ecosystem protection and restoration, and other watershed-scale needs. The economic driver of the Rock Lititz development was a crucial factor in the decision by Warwick Township, the site of the Rock Lititz development, to undertake a floodplain restoration program in a way that integrates a response to multiple regulations and requirements.

One requirement municipalities face is stormwater management. Regional stormwater management in Pennsylvania was first addressed in 1978 when Pennsylvania passed the Stormwater Management Act (Act 167). Recognizing that "inadequate management of accelerated runoff of storm water...increases flood flows and velocities, contributes to erosion and sedimentation, overtaxes the carrying capacity of streams and storm sewers, greatly increases the cost of public facilities to carry and control storm water, undermines floodplain management and flood control efforts in downstream communities, reduces ground-water recharge, and threatens public health and safety," the Act requires counties within the commonwealth to prepare and adopt stormwater management plans in consultation with the appropriate governing municipalities.

Originally, plans were to be created on a watershed-by-watershed basis. However, the Pennsylvania Department of Environmental Protection (PA DEP) has since encouraged countywide/regional plans, dividing authority along political boundaries rather than watershed boundaries.

In response, local governments spent years developing data models to predict the impacts of storm events of varying severity. Only within the last few years have these plans been completed and approved by PA DEP. Implementation is at last on the horizon. Now municipalities must carry out the approved stormwater management plans. There is an advantage if municipalities address stormwater management simultaneously with other land use and water resources decisions. However, very many boroughs and townships decline to undertake such a broad planning effort.

Warwick Township used the stormwater management requirements to move forward with a floodplain restoration plan. Floodplain restoration was seen as a way to enhance multiple types of environmental gains throughout its watershed in a cost-effective manner, drawing from the data modeling that was completed for Act 167.

The Commonwealth views floodplain restoration as an integral part of stormwater management, even though it does not require it for each county's stormwater management plans. Another institutional driving factor is the Pennsylvania State Water Plan, enacted in 2009, which calls for strategies that floodplain restoration addresses:

"...Reestablishing natural stream corridors and floodplains through local stormwater management requirements could offer more environmentally friendly flood control options than concrete structures."

"...Innovative stormwater management should be considered and incorporated as an important component of the overall flood mitigation plan."

"Shifting from traditional stormwater management methods to designs and practices that also address channel alterations and degradation, runoff quality, dry-weather flow protection, and aquifer recharge requires an underlying change in how water resource professionals do business." (State Water Plan Principles, Pennsylvania Department of Environmental Protection).

One more institutional factor is the regional restoration efforts for the Chesapeake Bay, in particular the multi-state efforts, which further address the Chesapeake Bay Total Maximum Daily Loads (TMDL). The Pennsylvania Chesapeake Watershed Implementation Plan states that the Environmental Protection Agency expects the states to have a plan in place by 2017 to achieve 60 percent of the TMDL's nutrient and sediment reduction goals, and to have controls in place by 2025 to meet all reduction goals (EPA, 2011).

The Rock Lititz plan drew on all these institutional drivers, and succeeded in developing a collaborative effort from multiple stakeholders, which includes Warwick Township, Clair Global, TAIT Towers and Atomic Design.

Costs and Financing

The Rock Lititz campus is a concerted public-private effort due to the tremendous economic, community, and ecological benefits the project will deliver to the Lititz region.

The private partnership that comprises Rock Lititz is the primary driver of the project, committing an estimated \$755,000 for the floodplain restoration construction. Local and state entities understood the positive impacts the proposed campus would bring to the area and in turn have provided unilateral support.

Lancaster County Conservation District approved a National Pollutant Discharge Elimination System (NPDES) permit for the project on behalf of the PA DEP.

Warwick Township supported rezoning of the Rock Lititz pre-construction property from an Agricultural District to a Campus Industrial Zone. This was based on the knowledge that it would promote local business development and expansion, meet the community objectives of economic development in a planned, campus style of development and promote agricultural preservation of properties outside of the Urban Growth Boundary by purchase of transferrable development rights.

According to the Lititz Record Express, “Before plans were crafted, Rock Lititz made a commitment to preserving Warwick farmland by paying \$1.2 million to Warwick Township for transferable development rights.”

To make the project successful, key stakeholders across agency lines recognized a mutual benefit for multiple objectives, and worked together to find an approach that achieves their own missions and objectives – even if it meant deviating from the routine procedures to which they were accustomed, as their usual route to their objectives. Warwick Township manager Daniel Zimmerman commented, “This is an opportunity for us to deal with aquifer recharge, flood control, sediment load reduction, [and] improved water quality. It’s a very targeted, regional approach based on good data. The township, the borough, and LandStudies had to show the developer this is the way to go. We’ve had other projects like this, and we monitor their success, so we know it works. It’s sustainable. These whole-watershed efforts are captured in the regional strategic plan with Lititz Borough and Warwick Township. Efforts that we’ve launched like this are improving out watershed. As we continue gathering data on the status of the stream, all indications show we are moving toward meeting our TMDLs.”

Sue Barry, Lititz Borough manager added, “The Rock Lititz effort to restore the Santo Domingo Creek's floodplain will be a benefit to Warwick Township through water quality improvement, stormwater management, and farmland preservation. It also ties in beautifully with the many watershed protection projects the restoration experts have done, and continue to do, in Lititz Borough.”

Integrative Features and Benefits

A floodplain management strategy inherently attains benefits of multiple types and is an excellent approach to proactive management of waterbodies—especially well-suited for the small streams in mid-Atlantic farmlands, but highly effective in other watersheds as well. The *Pennsylvania Stormwater Best Management Practices Manual* states:

Floodplain restoration reconnects a number of key components within a stream corridor so that their interaction protects the stability of the bed and channel while the system receives, holds, infiltrates, and filters sediment and nutrients from overland flow. These components include: a floodplain that receives more routine flows, thereby reducing erosive flow forces in the channel and allowing existing sediments and nutrients to remain in storage; a floodplain that allows vegetative root systems to interact with the base flow and/or groundwater, providing frequent removal of nitrates and effective stabilization of the stream banks and floodplain; a floodplain wide and flat along the valley bottom, consisting of the proper earthen materials to absorb surface flows and increase infiltration to groundwater; a plant community adapted to frequent inundation that will provide suitable habitat for riparian wildlife and whose root systems will provide nitrate and phosphate removal from surface and/or groundwater; and increased and improved habitat for aquatic resources (PA DEP, 2006).

The Rock Lititz site plan and its restoration in Warwick Township has benefits that include:

1. **Stormwater Peak Flow Management and Regional Flood Control:** By removing legacy sediment and creating a system of low-profile riparian vegetation, flood water is stored within the floodplain rather than rapidly exported across a filled basin. Peak flood elevations and peak flow rates can be sharply reduced. The small streams of Pennsylvania exceed their banks more frequently than most other small streams nationwide. They cause property damage and threats to public safety, so this benefit is crucial in Lancaster County.
2. **Sediment Load Reduction to Downstream Waters:** Legacy sediments of the mid-Atlantic’s former

mill ponds are largely unstable, and contribute substantial erosion especially during high-flow events. A study of the effects of floodplain restoration on Big Spring Run confirms the results. After removing an estimated 21,704 cubic yards of legacy sediment, “the sediment flux out of the restoration reach is much less than prior to restoration,” and “the restored reach now traps and stores some fine sediment” (PA DEP, 2013).

3. **Nutrient Load Reduction to Downstream Waters:** Sediments typical of legacy mill-pond and farming deposits generally contain moderate to high concentrations of nitrogen and phosphorus (PA DEP, 2013). Removing the legacy sediment removes a previously substantial load of nitrogen and phosphorus that would otherwise be mobilized in high-flow events and carried by the Santo Domingo Creek and ultimately into the Chesapeake Bay, which is identified as impaired for nutrients. The restored floodplain’s healthy aquatic and riparian vegetation traps incoming sediments, further reducing downstream loads, and during normal flows, the vegetation takes up nutrients that would otherwise move downstream to receiving waters. The Chesapeake’s huge watershed contains innumerable small water bodies with uncounted deposits of legacy sediments, and reducing those loads one restored watershed at a time contributes to its recovery.
4. **Groundwater Recharge:** Slowing the movement of routine flows and high storm flows, and distributing the stream channel distributed over a wider area with shallower alluvial fill, enhances groundwater recharge in the restored floodplain. This benefit is of exceptional value on this site because it has been identified by the *Susquehanna River Basin Commission* (SRBC) as a Critical Aquifer Recharge Area (Edwards & Pody, 2005).
5. **Economic Land Use:** The use of the floodplain to manage stormwater preserves valuable land for development outside of the floodplain. This is a huge economic advantage to Rock Lititz, but it also allows for more efficient use of available land, making density targets possible and preserving other agricultural land from sprawl. Another project is already completed that utilized historic floodplain restoration, Landis Homes in Lititz, Pennsylvania, increased the available land area for development and allowed Landis Homes to seek permitting for an additional 11 cottage units.
6. **Wildlife Habitat Enhancement:** Varied habitat contributes to biodiversity of native plants and wildlife, offering food, cover, and nesting sites for a more species. For example, PA DEP found in the case of Big Spring Run that, after restoration, preferred habitat for northern red salamander had increased (PA DEP, 2013).
7. **Invasive Species Removal:** Creating a more natural floodplain and establishing a native plant community results in the elimination of invasive species and helps discourage the return of invasives. Previous experience found “the shift in vegetation characteristics between pre- and post- restoration time periods was definitive from a plant community dominated by facultative upland, non-native species to a plant community dominated by obligate/facultative wetland, primarily native wetland plants” (PA DEP, 2013).
8. **Outdoor Recreation:** The restoration includes plans for trails, encouraging the community to interact with the landscape in a way that was not possible, safe, or desired in its former state. Those changes reconnect the water body with the community along with their more tangible, water-resources aims. The natural, native landscape is and colorful, attracting butterflies, birds, and other wildlife.

Future Directions and Anticipated Challenges

The construction manager viewed the Economic Ecology approach with standard conventional goals in mind: schedule and budget, but mostly with the low-bid mindset. The client's team needed additional education on how this approach required attention from an ecological perspective more than a conventional facility would. Performance standards and comparisons of traditional contract installation needed clarification.

Figure L4: Example of the productive ecosystem that follows restoration activities of this kind: First growing season in Landis, PA, shows healthy vegetation and re-structured hydrology.



Conventional construction projects are typically managed by comparing based on pricing corresponding to the given scope of work, and the low bidder is selected to complete site work and building construction per the design. However, when the lowest bid wins, often the customer loses—because the low bid does not necessarily correspond to the highest value and lowest overall costs. Green infrastructure projects require extensive experience and certifications to properly construct so that natural ecosystems are re-created to function properly and provide the intended project benefits (Kobell, 2014). Contracting approaches specifying “best value” evaluation of bids versus lowest cost can provide some relief, as well as thoroughly-written scopes of work identifying parameters that must be included. Educating the customer to these factors is crucial to success.

For the Santo Domingo Creek floodplain restoration at Rock Lititz, contract pricing was based on work quantities derived from design documents intended to meet agency requirements **rather than** construction documents and performance metrics specific to the project needs. Green infrastructure projects are required to be monitored and maintained over a long period of time to ensure they function as designed.

Since this project provided quantitative and qualitative site and regional benefits, the performance outcomes are critical to its success. The pre-application meeting with state and federal regulators was most helpful in the education process for permitting. Additional time was needed for regulatory approval since the process of an innovative approach was not part of the standard review.

It is anticipated that the technically based outcomes will meet multiple objectives based on results of similar recent projects such as Landis Homes. The area that needs the most attention is the review and approval process itself, as the entity, organization, or individual reviewing the Economic Ecology approach is accustomed to checking a box in a standardized approval framework. An integrated approach such as this one is not standardized, and more flexibility is needed to demonstrate and quantify its value both quantitatively and qualitatively.

Lessons Learned

- The success of the Rock Lititz project relied crucially on outreach, communication, cooperation, and education of personnel from multiple agencies and decision makers, and multiple stakeholder groups from several stakeholder communities.
- The project was implemented in order to meet one private corporation's desired construction, and to acquire its required permits and authorizations. The sponsor allowed the project team to do this in an integrated, multiple-objective manner. However, this required substantial communication – and education of one another – for approval of the permit application.

The effort is viewed as a “superior project” which does not fit the traditional mold, but which does address both economic and environmental needs. This required a modified approval format, with flexibility from multiple agencies and with patience and persistence by the project sponsor. The traditional “silo” approach to regulatory management did not work for this project, which is an example of many kinds of projects around the nation that would not succeed if not for overcoming those barriers. Briefly, many outstanding projects are not implemented, or not conceived, in part owing to institutional barriers.

- This project is an example of one that found a way to work across disciplines, agencies, and organizations to meet the regulatory requirements and desired community priorities. Meeting multiple objectives for this site design, with a regional perspective rather than limited to site-specific goals, was achieved by an extensive effort in which public, private, and nonprofit stakeholders worked together and adapted the project to include one another's objectives. The costs may, or may not, have been greater than if the site met any single objective, but addressing these multiple objectives in a single design is a more cost-effective solution and makes more efficient use of Pennsylvania's environmental and economic resources.

State of California Land Use Policies as Flood Mitigation Strategy

Author:

Yung-Hsin Sun, MWH Global

Portions of this piece have been presented earlier, including at the Indo-U.S. Science and Technology Forum in February 2015; AWRA Annual Water Resources Conference, November 2014; and Association of State Floodplain Managers conference, 2014.

Introduction: Elevating Land Use Planning Discipline in California Central Valley

The Central Valley of California is a broad, gently sloping valley that drains into the largest estuary on the West Coast, the Sacramento-San Joaquin Delta. The valley is bounded on the west by the Coast Range, on the north by the Cascade Range, and on the east by the Sierra Nevada Range. Before reclamation, lower-lying lands along the valley's two major rivers, the Sacramento River and the San Joaquin River, were floodplains and marshlands that were regularly inundated for long periods during seasonal flood events.

Catastrophic floods in the Central Valley have been documented since the mid-1800s. Hydraulic mining in the Sierra Nevada Mountains in the late 1800s sent large amounts of sediment downstream, choking the channels of rivers such as the Yuba River, Feather River, and American River and increasing flooding by raising channel beds above their natural levels and surrounding lands.

In response to frequent flood events and the challenges posed by the huge and recurring sediment loads created by hydraulic mining, the current flood management system has evolved through an incremental learning and construction process. The process was originally driven by the need to defend the developing valley floor against periodic floods while maintaining navigable channels for commerce.



Figure CV1. Flooding in Sacramento, California, in 1850. Source: Casilear and Bainbridge, 1850 (Library of Congress, accessed 2014).

Over time, with development of the railroads in the late 1800s and early 1900s, and the highway system since then, river navigation has become less economically important.

The U.S. Army Corps of Engineers (USACE) has played a key role in plan formulation, design, construction, inspection, and flood fighting in the Central Valley since the late 1800s. USACE is responsible for the maintenance of navigation, management of hydraulic mining debris, and the construction and operation of many of the large multipurpose reservoirs that moderate flows into the Central Valley. USACE continues to be responsible for implementing most federally authorized flood control projects, in partnership with State and local agencies.

The current Central Valley flood management system includes more than 1,400 miles of levees along the major rivers and streams of the valley floor and around the islands of the Delta, a major bypass system for

the Sacramento River and its tributaries, several bypass segments along the San Joaquin River. The system also includes about 10 multi-purpose reservoirs on major tributaries with flood management

responsibilities, owned and operated by utilities, water districts, the USACE, the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), and the California Department of Water Resources (DWR).

This system provides protection to rural-agricultural areas and to urban areas. As Figure 2 shows, in recent decades, much of the investment has been to protect major urbanized areas such as the Sacramento metropolitan area, where per-acre property values are higher. The system protects multiple important economic benefits provided by Central Valley rivers and floodplains, including municipal, industrial, and agricultural water supply; fisheries; and wildlife habitat. Recreation, for example, has increased as a result of population growth in the state.

However, the flood management system and related investment did not change the fact that the Central Valley is highly susceptible to flooding. Four recent major floods (1983, 1986, 1995, and 1997) have caused more than \$3 billion in damage.

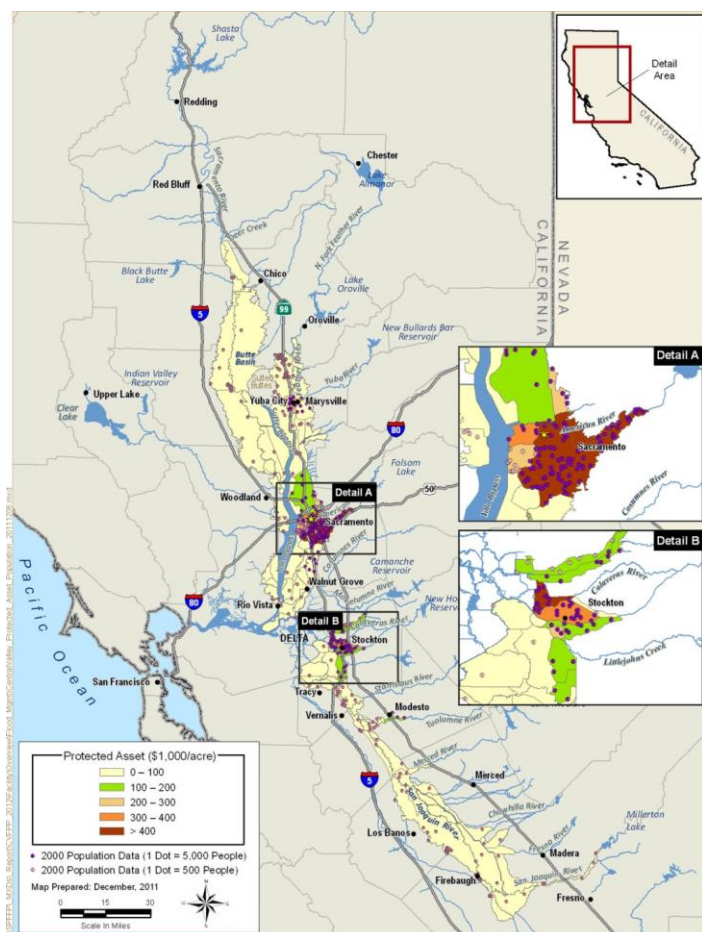


Figure CV2. Assets protected by the Central Valley Flood Management System. Source: CDWR, 2012.



FigureCV3. 1997 flooding in Mossdale, CA. Source: CDWR Photography Lab.



Figure CV4. 1997 flooding in Sacramento Valley near Sutter Butte, CA. Source: CDWR Photography Lab.

Paradox and Misalignment

California's Central Valley echoes a worldwide pattern where much of human civilization developed in floodplains, because there it can take advantage of flat and fertile lands and transportation corridors. The age-old notion of living with risk of flooding was deemed acceptable, and residents adapted to flooding by living on higher ground or elevating structures – or periodically suffered the consequences.

It seems the more we do for flood risk management, the worse it gets. Climate change is one scapegoat to help explain that effect: increasing occurrences of extreme weather have been documented, and those extremes might overwhelm risk management efforts designed for earlier weather patterns. However, the flood management paradox was evident even before we recognized effects of climate change.

Two ways to reduce flood risk are: reduce the likelihood of flooding, and reduce the consequences of flooding. Traditionally, government investment and societal attention have focused primarily on the first category, primarily by building major flood management facilities such as dams, levees, and floodwalls. Because those facilities can have very high costs, investment in the facilities has emphasized protection of financially high-value land uses, encouraging repeated investments in urban areas because they achieve a more favorable benefit-cost ratio than small communities, rural areas, agricultural land uses, and waters with important ecosystem services. That protection – or perceived protection – in turn has facilitated further development in protected urban areas, which paradoxically increases the consequences of floods if the protection should fail. The tendency to focus on financially high-value regions neglects less readily quantified values such as ecosystem services, cultural resources, and other societal considerations. This has negative outcomes from the viewpoint of social equity.

The ability to construct stronger levees and large water management infrastructure in the 20th century has contributed to altering people's mindset toward floods. In the U.S., programs under USACE, the Federal Emergency Management Agency (FEMA), and the National Flood Insurance Program (NFIP) manifested this desire to mitigate or control risks. The downside of these programs – we might say, a misalignment of priorities – has been to incentivize growth in floodplains, in some respects exacerbating the risk instead of reducing it. The programs can be said to provide a false sense of security to residents with the message that flood risks can be reduced. Those federal policies and practices provided opportunities for developers, and for local governments as the land-use authority, to create infrastructure based on short-term economic benefits without being accountable for potential long-term consequences of flooding.

By the 2000s, in the wake of devastating impacts from events such as Hurricane Katrina in 2005, USACE and FEMA began to shift their mindset. The post-Katrina mindset addresses the concept of “driving down risks,” recognizing a responsibility of decision-makers at all levels (Federal, State and local agencies; ultimately, individuals) to share in accountability for addressing risks, illustrated in Figure CV5.

That change in mindset, and increased requirement by USACE and FEMA for state and local entities to accept a share of responsibility for reducing risk, appears to have contributed to reduced building in many areas. Some regions have adopted a building moratorium pending completion of significant improvements in flood management facilities, which are delayed by requirements such as environmental permits that address a deteriorated ecosystem. These brakes on development are a result of the coalesced consequence of past management decisions, in recognition of the misalignment of priorities inherent in those decisions.

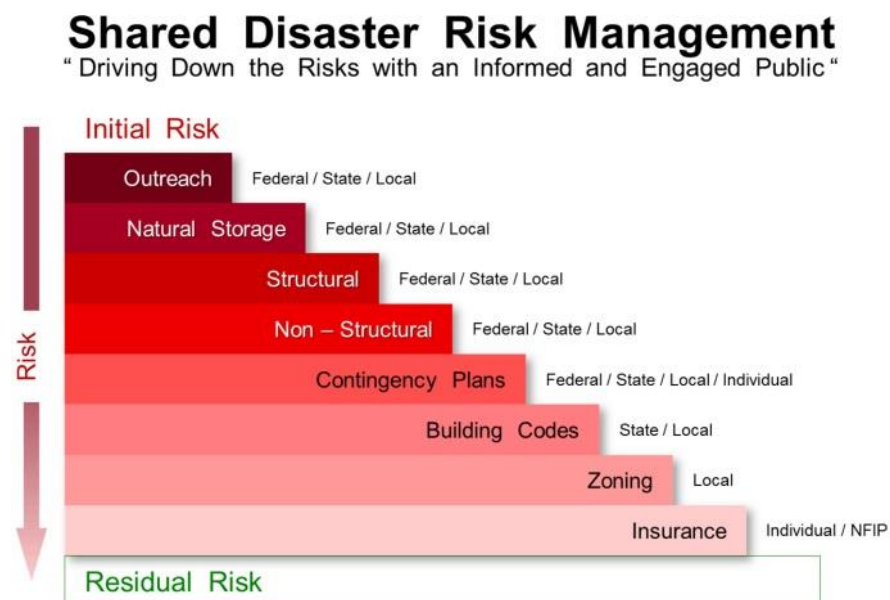
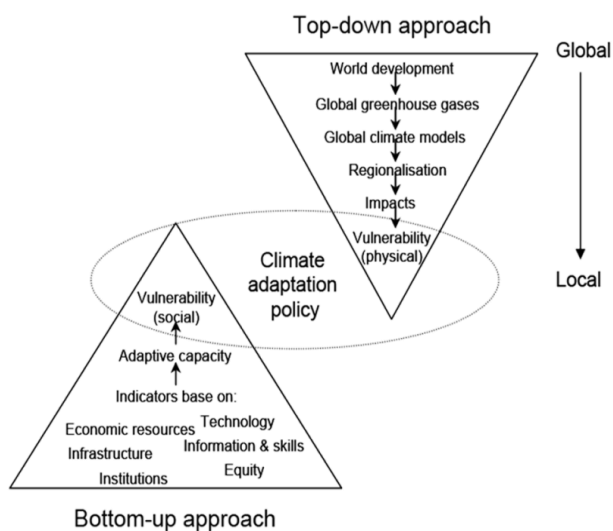


Figure CV5. From U.S. Army Corps of Engineers: Shared responsibility in flood risk management. Source: USACE, ca. 2013.

Level of Governance Matters

The concept of shared responsibility requires coordinated and complementary actions by State and local agencies to change their behavior and reduce their reliance on federal support and subsidies. This reinforces the concept of adaptation planning, which is to change our behavior for a better outcome. That is a main concept in much of the ongoing discussion of climate change, where uncertainties in future conditions are so important and effective planning may need to adapt as information continues to emerge. Traditionally, we use a top-down approach to manage our risk: we define a most likely future scenario and maximize the intended benefits under assumed conditions.

Uncertainties such as those associated with climate change interfere with the approach of planning for most-likely scenarios. The uncertainty is so high that many of the climate change scenarios identified by the Intergovernmental Panel on Climate Change are equally possible, and we have not developed any probability relationship among projections.



Proactive communities look beyond this dilemma, and adopt a bottom-up approach that emphasizes investing to address their social vulnerabilities under climate change conditions. This allows communities to evaluate the interconnection among different vulnerabilities, and devise bundled solutions for multiple vulnerabilities.

An even more powerful approach is to combine the top-down and bottom-up approaches to examine different vulnerabilities and complete climate change adaptation planning with delineated roles and responsibilities for federal, state, and local agencies.

Figure CV6. Reprinted from Dessai and Hulme, 2003: Vulnerability overlap of top-down and bottom-up approaches.

Land use is one critical component of the bottom-up approach since land use authority resides in local government and is the keystone for many associated investments such as water infrastructure. Proactive land use planning does exist, however so far, most successes are of a local or regional scale to recognize the importance of land use for an integrated solution.

In this type of application, the level of governance matters, because it is not always straightforward to coordinate land use authorities, especially when they may have competing interests in economic development and other considerations. Is this type of success scalable to an area as massive as the Central Valley in California, where land use authority is held by multiple cities and counties as land use agencies? What roles and responsibilities would State or Federal agencies have in the implementation, without compromising local land use jurisdiction?

California has made a major first step toward this future through its recent changes in legislation and implementation programs.

Integrated Flood Management in the Central Valley of California

The devastation and loss of life resulting from Hurricane Katrina in 2005 further raised public awareness of super storm events throughout the nation. In response, California voters in November 2006 passed the Disaster Preparedness and Flood Prevention Bond Act (Proposition 1E) and the Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act (Proposition 84), authorizing the sale of nearly \$5 billion in State bonds for flood management improvements throughout the State with more than \$4 billion of this amount specifically earmarked for repairs and improvements to State and federal flood projects within the Central Valley.

Recognizing the significance of flood risk in California and its negative consequences to public safety, economic development, and environmental sustainability, the California Legislature enacted six interrelated bills in 2007 – Senate Bills (SB) 5 and 17, and Assembly Bills (AB) 5, 70, 162, and 156 – to improve flood management in a sustainable way, strengthen the linkage between local land use planning decisions and flood management practices, and guide the use of Propositions 1E and 84 funds. Together, these bills added or amended over 25 sections in the California Government Code, Health and Safety Code, Public Resources Code, and Water Code.

The 2007 California flood legislation package outlined a comprehensive approach to improving flood management at the State and local levels, with elements to address both the chance of flooding (e.g., improvements to reduce the probability that floods will occur) and the consequences when flooding occurs. State and local actions related to the legislation can largely be grouped into three categories:

1. Provide updated information on flood risks statewide;
2. Require local land use planning and management to consider potential flood risks in the Sacramento-San Joaquin Valley; and
3. Develop plans to address flood management system problems in areas protected by the State Plan of Flood Control (SFPC).

DWR implements these legislative requirements through their FloodSAFE initiative, which was created in 2006 and is a long-term strategic initiative developed to reduce flood risk in California. FloodSAFE establishes a vision for a sustainable integrated water management and emergency response system throughout California that improves public safety, protects and enhances environmental and cultural resources, and supports economic growth by reducing the probability of destructive floods, promoting beneficial floodplain processes, and minimizing damage caused by flooding. Recognizing that addressing the risks of flood damage in the Central Valley and statewide will take decades, FloodSAFE as a whole is

an important component of DWR's larger integrated water management initiative to achieve a sustainable, robust, and resilient system to benefit Californians.

One major milestone toward completing the legislative requirements and intent was the adoption of the Central Valley Flood Protection Plan (CVFPP) to assert the State's interests and preference in the integrated, systemwide approach to sustainable flood management in the Central Valley. The CVFPP, prepared by DWR and adopted by the California Central Valley Flood Protection Board in June 2012, outlines a State Systemwide Investment Approach with investment of \$14-17 billion (US) in the next 20 years (CDWR, 2012). The CVFPP will be updated every five years after its first adoption to reflect the progress and new conditions.

Among the investment plan's many elements, three broad policy directives are critical to facilitate landscape-scale changes.

1. The State will not invest in growth-inducing flood management improvements, and will oppose such improvements even if local agencies are fully responsible financially.
2. The State will invest in flood management improvements that are commensurate with assets being protected, with the following targets:
 - a. A 200-year level of flood protection for existing urban and urbanizing areas, also known as the urban level of flood protection. This is the highest mandated level of flood protection in the nation.
 - b. A 100-year level of flood protection for small communities. The protection is directed to make use of both structural and non-structural, planning-oriented measures.
 - c. Varying levels of flood protection for rural-agricultural areas. Lower protection here is justified because, with lower population, there is less concern over loss of life, the dominant factor in the other areas. Protection here will accommodate potential for environmental restoration and for conservation easement.
3. The State also clarifies its investment strategy in a way that accommodates climate change adaptation, as follows:
 - a. The State will assist urban and urbanizing areas to improve levees and flood management facilities to achieve the urban level of flood protection for the current hydrology.
 - b. The State will not continue to invest in future upgrades to urban levees to accommodate hydrology changes due to climate change. Rather, the State will 1) invest in system elements, such as bypasses and easements, which would benefit more than the project vicinity, as levee improvements do; 2) provide opportunities for landscape-scale environmental restoration; and 3) provide a more affordable means of protection for nonurban areas.

These landscape policies, combined with the accompanied system approach for environmental permitting planning and implementation, are critical proclamations about the State's preference. They will likely be reflected in future state funding eligibility criteria and additional regulatory actions to promote long-term, permanent changes in behaviors. However, this would not take root unless a nexus can be established between the decision of a local land use authority and the liability of subsequent flood damages.

Accountability for Local Land Use Decisions

As part of the 2007 flood legislation, Senate Bill 5 of 2007, as amended, provide the directives for cities and counties in the Sacramento-San Joaquin Valley to amend their general plans based on the adopted CVFPP. More specifically, California Government Code §65302.9 requires that cities and counties within the Sacramento-San Joaquin Valley amend their general plans to include the locations of SPFC facilities and areas protected by the facilities, location of flood hazard zones, and goals, policies, objectives, and feasible mitigation measures based on the data and analysis contained in the CVFPP for the protection of lives and property to reduce the risk of flood damage. Additionally, in compliance with the requirements of California Government Code §65860.1, jurisdictions in the Sacramento-San Joaquin Valley will need to amend their zoning and other applicable ordinances to be consistent with the newly revised general plan content within one year of adopting general plan amendments.

Since the adoption of the 2012 CVFPP on July 2, 2013, cities and counties were allowed up to 24 months after July 2, 2013 (or no later than July 2, 2015) to amend their local general plans, incorporating the aforementioned information, and an additional 12 months thereafter (or by the 12 months after the general plan amendment adoption date or no later than July 2, 2016) to update local zoning ordinances, which can also include updates to the local floodplain management ordinance, as applicable, to be consistent with their amended general plan.

After these administrative procedures are completed, all cities and counties within the Sacramento-San Joaquin Valley will need to make findings related to an Urban Level of Flood Protection (200-year level of protection) or the national FEMA standard of flood protection (100-year level of protection) for affected land use decisions. However, the associated findings of adequate protection are under the discretion of cities and counties.

To facilitate the implementation, DWR has collaborated with cities and counties, planning professionals, and interested parties to develop the Urban Level of Flood Protection Criteria (DWR, 2013) to provide guidance and additional details to assist cities and counties to comply with the legislative requirements. With the purpose of inserting accountability, the Criteria are not regulations and the legislation provides no enforcement authority.

The seemingly apparent gap is deliberate since any citizen could enforce the law through litigation if he/she demonstrates that the city or county did not apply consistent Criteria or make a finding with insufficient evidence. This alleviates the State from potential interference with local land-use authorities or enforcement costs. DWR also developed a series of guidance documents (DWR, 2010, 2014a, 1014b) to help cities and counties understand the relationship among different flood-related land use law and regulations, and the information available for cities and counties for their general plan amendment needs.

It is important to note that SB 5 of 2007 as amended does not specify any review, approval, or enforcement authority by any State agency, but instead relies on the due diligence of cities and counties to incorporate flood risk considerations into floodplain management and planning in compliance with the general plan amendment requirements (California Government Code §65302.9).

Once the zoning consistency has been completed, other provisions in SB 5 of 2007, as amended, become effective, including provisions relating to certain land use decisions based on a finding that the land use decision satisfies an Urban Level of Flood Protection or the national Federal Emergency Management Agency (FEMA) standard for flood protection. The arrangement is deliberate so that the cities and counties would be accountable for their own decisions on land use development. With the public process for decision making, it is perceivable that the public could be the true enforcer of the law, reducing the chance of finger pointing in the future when disasters occur.

The effects of the proposed policy changes will take time to mature – perhaps a decade or more, even if the policy is consistently implemented. It is conceivable that the state may incorporate additional requirements and incentives for local entities to adopt this framework, for example as a test for eligibility for State funding for flood projects and other benefits. Codifying these strategic goals is an important step, but diligent implementation by a wide range of decision-makers will be required if we are to attain the hoped-for benefits.

Conclusions

California has made an important step to improve alignments in land use planning among different levels of government and agencies. The key element to connect land use decisions to the potential consequence of the land development is the first among all states in the United States. It may take a decade of implementation to assess the effects of this law and associated policy, and at that point we may have more information about the ways in which it can succeed and about limitations it may face. The integrated approach is designed re-align policies with societal priorities, and to address some of the unintended failings of decades or centuries of well-meaning approaches to flood risk management. This can be a model for proactive flood management in the U.S.

Overview of Case Studies in Drought Mitigation and Low Flow Strategies

Two case studies in drought mitigation and low flow strategies are included in this section.

The **State of California** along with much of the western U.S. has experienced a multi-year, extreme dry period, exceeding the capacity of its water supply system to meet its fully-allocated obligations. The state has developed an array of intensive water conservation measures, including some short-term emergency actions and some longer-term restructuring of institutions that can help the state be more resilient in the future. This piece offers a brief overview.

Hillsborough River, FL serves as one source of water supply for the Tampa Bay region and as an important ecosystem, interconnected with other riparian, groundwater, and wetland resources throughout its region. Impacts on a number of groundwater-fed resources in the 1990s, and intensive political conflicts among municipalities and stakeholders over future water supply, led the State of Florida to create a new public utility for the region and to adopt a statewide rule designating Minimum Flows and Levels for lakes, flowing waters, and aquifers. The river's interconnected strategies for flood management, drinking water supply, and ecosystem protection form a complex example of Integrated Water Resources Management, but this case study examines only the Hillsborough River's minimum flow protection as an example of low-flow mitigation strategies.

State of California Drought Strategies

Lead author:

Yung-Hsin Sun, MWH Global

Drought and its Management: A California Case Study

As of Spring 2015, California was in its fourth consecutive year of drought since 2011, a drought which appears to be the worst in more than a century.

Reservoir water levels had reached historic lows, so low that outlet structures did not function. For 2015, the water content level of the winter snowpack (a natural reservoir for the state) was a mere five percent of average after several years of drought conditions.



Figure DCA1: Folsom Lake reached a record low of 140,410 acre-feet on November 14, 2015, threatening water supply to the District and many other water agencies in the Sacramento-Placer region. Source: Yung-Hsin Sun.

Groundwater levels are in continual decline, as people resort to using groundwater in the place of surface water. Wells are running dry. Urban water use is highly restricted, farmers are fallowing their fields, and some communities resorted to emergency water supply for daily needs. The risk of wildfire is heightened with the persistent drought and the environment and fish and wildlife species are also under significant stress.

Currently, it is unclear how long or how much more severe this historical drought will be, and all levels of government and the California residents are learning their adaptive management and exploring new territories as the drought progresses.

Drought conditions have persisted in parts of the western United States throughout the past decade. Figure DCA1 shows the extent of drought conditions in May 2015, and how conditions have progressed in California over the past several years from essentially no drought in the state in 2011 to statewide intense drought conditions in 2015.

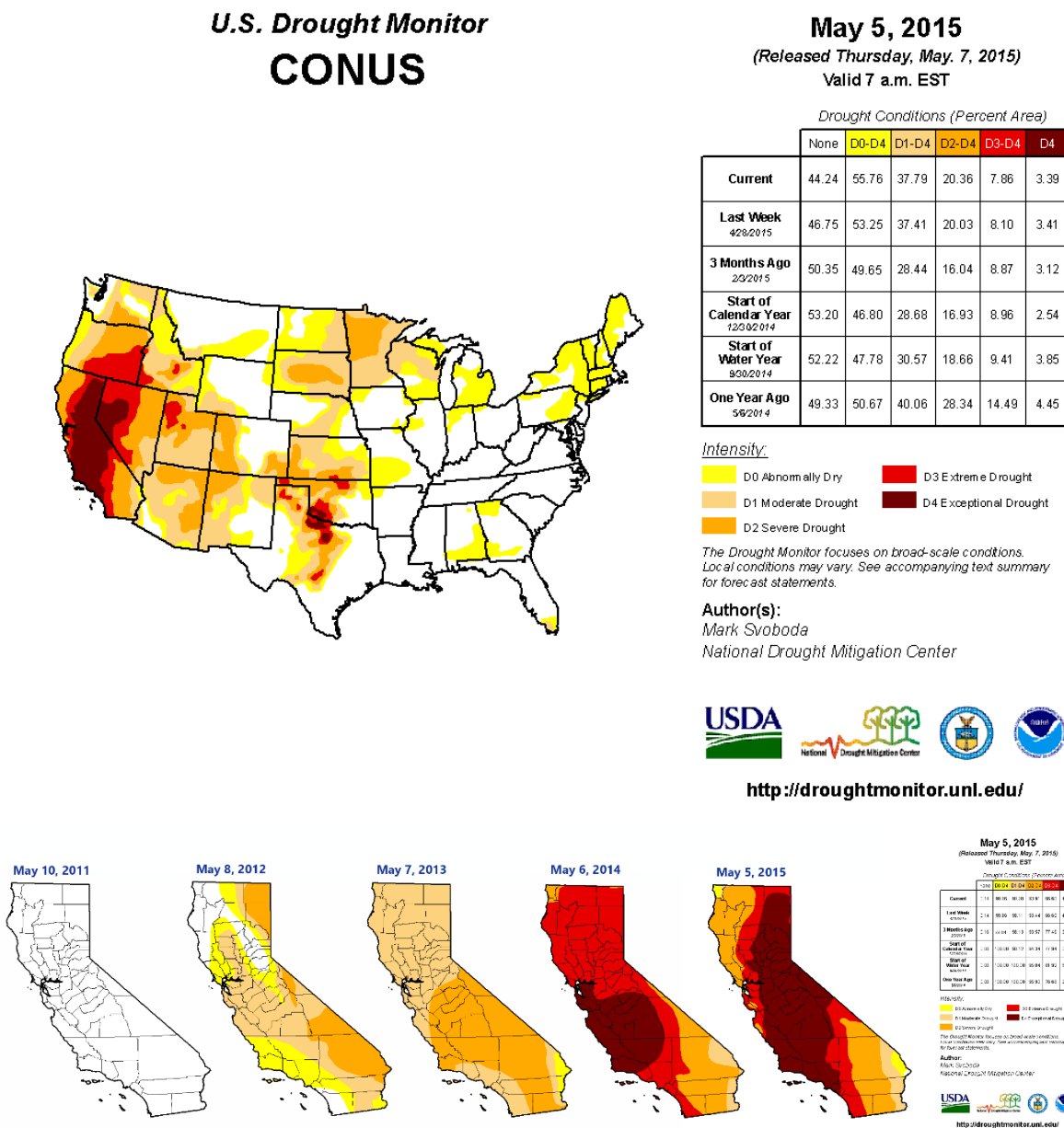


Figure DCA2. Widespread drought conditions in the United States and rapid progression since 2011: Five years to May, 2015. Compiled from U.S. Drought Monitor (USDN 2015).

Water Resources in California

As of 2015 California has 38 million residents, which is about one-eighth of the total U.S. population. The population is expected to increase continuously in the future as California attracts many with its economic prosperity and quality of life. With an estimated gross domestic product of two trillion dollars, California would be the 8th or 9th largest economy in the world if it were an independent nation. The economic drivers are varied, with major service and high-tech sectors in the large coastal cities and very large agricultural production in the inland valleys. California has deep cultural and economic roots in agriculture. It is nationally significant as well: it produces nearly half of the fruits, nuts, and vegetables in the U.S. The availability and reliability of water is crucial to social and economic success in California, and as such is crucial to the U.S. economy.

The majority of California has a Mediterranean climate, with wet winters and dry summers. California's primary source of water is from precipitation in the form of snow or rain. The Colorado River and Klamath River bring substantial amounts of water to the state from outside the state borders; the rest originates as precipitation within the state. The distribution patterns of precipitation are highly variable, both spatially and temporally.

- **Spatial Variability:** The majority, about 80 percent, of the state's annual precipitation falls in the northern part of the state, while almost 70 percent of the state's annual water demand is in the southern portion of California. It is important to point out that snowpack is the largest storage for California's water supply, melting throughout the spring to replenishing streams, reservoirs and groundwater basins. This form of precipitation is snow that accumulates mostly on the Sierra Nevada Range on the east of the State, with the highest peak in the lower 48 states.

Several major water distribution systems, among the world's largest, have been constructed over the years and continue to be operated to balance water supplies and demands on a system-wide scale. These include the Hetch Hetchy System by the City and County of San Francisco in early 1900s; the Los Angeles Aqueduct by the City of Los Angeles in 1910s the Central Valley Project by the Department of the Interior, Bureau of Reclamation (Reclamation) in the 1940s; and the State Water Project by the California Department of Water Resources (CDWR) in the 1960s. These systems include major reservoirs, conveyances, and other facilities that significantly changed the flows of water around California, with large volumes of inter-basin transfers to deliver water from its sources to the points where humans use it.

- **Temporal Variability:** Similar to most areas, California's water supply is dominated by two characteristics: seasonal and annual variability.
 - 1) Seasonal variability: California receives almost all of its precipitation in the winter months between November and April. As in much of the U.S. West, this variability prompted the construction of water management systems with massive storage reservoirs to make water available at times when natural flows are near-zero yet demand remains high.
 - 2) Annual variability: Extreme weather is the norm in California, and the state has experienced both droughts and floods in the 20th century. In the last 100 years, there have been at least four other drought periods (1976-1977, 1987-1992, 2001-2004, 2006-2010). Storage reservoirs can help meet demand in some low-water years, but for the most part are not designed to store enough to meet demands across multiple consecutive drought years. These occurrences prompted additional management actions and policies for sustainable water management, described further below.

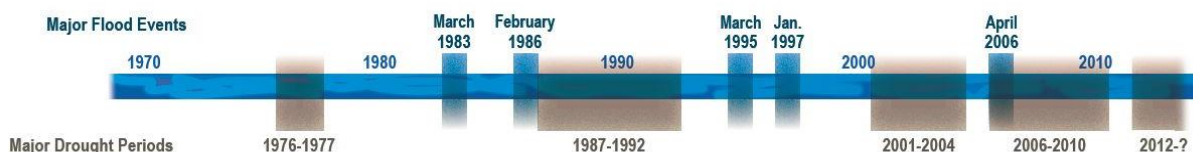


Figure DCA3. Major flood and drought events in California, 1970-present. Source: CDWR, 2014.

The Institutional Setting: In What Ways was California Prepared for This Drought?

California has many proactive drought management policies and practices in place. Many of these started as voluntary guidance and have evolved to become best management practices incentivized by funding or regulatory requirements. These were put in place because California has experienced significant droughts with intensity (e.g., 1976-1977) or duration (1987-1992) similar to those of the current drought--although not both factors at once.

An important historical context for California water management and resulting institutional setting is that the major responsibilities of water management in California's executive branch were largely **split** between California Natural Resources Agency's CDWR and the California Environmental Protection Agency's State Water Resources Control Board (State Water Board).

CDWR provides overall resources management functions and also manages one of the major water projects in California, the State Water Project (SWP) that provides supplemental water to more than 28 million people. The operations of the SWP are integrated with the operations of the Federally-operated Central Valley Project (CVP), owned and operated by the U.S. Bureau of Reclamation (USBR). The State Water Board assumed most of the regulatory functions including water rights and water quality administration.

Many other state agencies are also institutionally engaged in water management decisions, depending on geographic areas and issues. The complex governmental oversight is a challenge in California water management. That important institutional issue is not elaborated here.

Demand Management

The State population increased significantly since last major drought in late 1980s. The increases in water use efficiency and conservation in consumptive uses are necessary actions under the pressure of continued population growth and the needs for a clean and sufficient water supply for both economic development and environmental protection.

- California's Urban Water Management Planning Act of 1983 was developed due to concerns over potential water supply shortages throughout California. It requires urban water suppliers to document water supply reliability and water use efficiency measures for normal, dry and multiple dry years in a 20-year planning horizon in the Urban Water Management Plan (UWMP). This plan should be submitted to CDWR every five years (DWR, 2012). The UWMPs were later improved through litigations and subsequent legislative actions. CDWR has also incentivized plan development by making UWMPs part of the prerequisite for State grant funding eligibility.
- In 2001, Californian legislature passed Senate Bills 610 and 221, with requirements that developers provide, at the time developments are proposed, written water supply assessments and written verifications that water supply will be available to the development for the future. This enhances the

rigor of urban water management by integrating it with land use decisions.

- In 2004, the State required all urban residential water uses to be metered by 2025.
- The Water Conservation Act of 2009 created additional requirements for urban water conservation, and mandated a 20 percent reduction in per capita water usage by the year 2020. It also requires agricultural water suppliers to prepare and adopt Agricultural Water Management Plans by 2012 with updates every five years thereafter. Proper measurements of water delivery and efficient management practices (including a pricing structure for encouraging conservation) are also required for agricultural water uses. The bill also provides further restrictions in eligibility for state water grants or loans for urban or agricultural water suppliers who do not meet the conservation requirements (CDWR, 2015).

Integrated Planning and Diversified Water Supply Portfolios

For water supply planning, the state has encouraged integrated management of various water supply sources, and integrated regional water management to foster development of projects with multiple benefits for multiple stakeholders. Having diverse water supply sources and drought contingency plans are critical to account for uncertainty in water supply availability. Integration or coordination across a region can increase access to various water sources and can also improve water reliability and resilience in emergencies.

Integrated Regional Water Management. California's Integrated Regional Water Management (IRWM) encouraged regional water managers, through self-organized functions, formulate best suited and best positioned management groups and associated inter-regional water management actions for regional water supply reliability.

The program began in 2002 when the Regional Water Management Planning Act (SB 1672) was passed by the Legislature. Bond acts approved by California voters have provided \$1.5 billion to support and advance IRWM. Cities, counties, water districts, community groups, and others across the state have worked with one another to organize and establish RWMGs. These RWMGs have defined 48 IRWM regions that together cover 87 percent of the state's area and 99 percent of its population. Not only the practice promotes regional collaboration, it also enhances regional self-reliance and is critical for drought management.

Groundwater. Groundwater is not administered by the State Water Board. Groundwater has been considered a property right and unless adjudicated, the specificity of rights to volume and associated restrictions are not defined or regulated. Groundwater is a significant component of the water supply portfolio in most regions in California, especially for drought periods.

Through Assembly Bill (AB) 3030 of 1992, the State has encouraged local agencies to develop and adopt Groundwater Management Plans to describe groundwater use, conjunctive use operations, local management policies and monitoring, and other management actions. It also provides groundwater management agencies to revenue collection authority for facility development and operations. In 2002, groundwater management plans became required for agencies to receive public funding.

These voluntary actions became requirements through SB 1938 of 2002 for eligible state grants or loads for groundwater project implementation. Additional requirements were provided by subsequent legislative actions. Senate Bill x7-6 of 2009 mandates a statewide groundwater elevation monitoring program to track seasonal and long-term trends in groundwater elevations, and CDWR developed a California Statewide Groundwater Elevation Monitoring (CASGEM) program (CDWR, 2015b).

Subsequently, Assembly Bill 359 of 2011 also clarified a requirement that to identify recharge areas for the state's crucial groundwater resources. However, before 2014, California did not take an active role in groundwater management. The quality and implementation of groundwater management plans vary, and in some locations the plans, however well designed, are not sufficient to meet the intensive demands. In many areas of the State (e.g., the San Joaquin Valley), the groundwater overdraft conditions that led to the construction of the CVP continue, with continuing decline in groundwater elevation and highly-visible ground subsidence.

Water Transfers and Water Banking. Water transfers and water banking are two market-oriented practices included in drought preventive actions by many water managers in California. Temporary water transfers, which were usually negotiated and managed on an annual and as-needed basis, become very important water management tactics to manage short-term water supply and demand imbalance in the system regardless of whether the imbalance is for environmental water use or for consumptive use. This practice began in the drought of the late 1980s and gradually became popular in the late 1990s.

The actions were administrated by the State Water Board per requests from water right holders and potential beneficiary agency or agencies. While temporary water transfers cannot be used as a management action for long-term water supply reliability but it is an effective tool in water shortage conditions and droughts.

Long-term water transfers are rare because of the environmental considerations, especially for transfers of water rights. However, there have been long-term reassignments and exchange agreements among contractors of major water projects like the CVP and SWP (with limitations of water rights and other regulatory conditions) to provide additional water supply reliability during shortage conditions (CSWRCB, 2015).

Water banking is also an outcome from the drought in late 1980s. Most of the water banking practices leveraged available groundwater storage spaces for storing excess surface water through direct or in-lieu recharge and providing drought water supply when needed. This is essentially a commercial version of conjunctive use management and facilitate management actions by customers that may not be local. CDWR has led the water bank development in the early 90s. However, the services are currently mostly provided by districts and agencies, some of which were established for water banking purposes (e.g., Semitropic Water Storage District in Wasco, California).

Recycled Water. Recycled municipal wastewater is considered an option to augment water supply, and has been regulated and used in California since the 1970s. Recycled water has had its most widespread use in the Southern California due to limited local water supplies, where it has been used primarily to repel seawater intrusion by injecting recycled water into coastal groundwater basins and other industrial uses. However, it is not used for a potable water supply. In regions outside of the Southern California, groundwater recharge using recycled water was not permitted *without* the seawater intrusion concerns, but *with* concerns over additional contamination from recycled water. Potable reuses in California received little public acceptance; however, many agencies are still promoting this concept.

Under the 2009 Recycled Water Policy (CSWRCB, 2009), the state established a goal of increasing recycled water use by 2 million acre-feet by 2030. To facilitate implementation, the California State Water Resources Control Board (State Water Board, or CSWRCB) streamlined permitting for use of recycled water for landscape irrigation under a general permit in 2009.

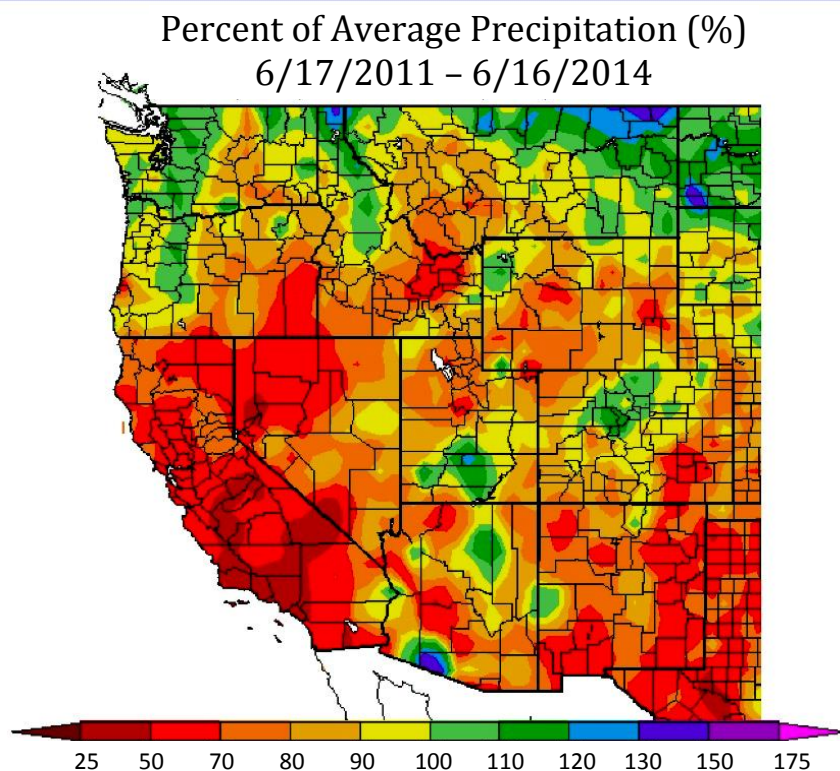
SB 918 of 2010 also directed State Department of Public Health to work with local agencies to encourage indirect potable reuse of recycled water through groundwater recharge and development consistent

implementation criteria and policy throughout the state. Under the Clean Water Act, the State Water Board's recently-established standards for Total Maximum Daily Loads of various constituents and associated discharge requirements provide additional incentives for reuse, not only for wet weather flows but also for dry weather flows.

The 2011-2015 Drought in the Western U.S.

Drought is a complex phenomenon that occurs at the point where long-term decrease in precipitation and water supply begins to impact various environmental and socioeconomic aspects of water supply. The onset of drought can be complex and difficult to identify, and the very definition of drought has multiple possible meanings, both from a conceptual standpoint and from the position of institutional decisions about when to “declare” drought (NDMC, ca. 2014).

The drought of 2011-2015 in the western U.S. is among the most extreme on record, and California has been impacted perhaps more than any other state. As of 2015, California had experienced very low precipitation for four consecutive years, increasing in intensity over time: the low snowfall of the winter of 2014-2015 was the most extreme in the sequence. In February 2014 Folsom Lake, one of the major water supply reservoirs serving the Sacramento metropolitan area, was inches above the water supply intake. If the water level had declined further, withdrawal from the lake would be impossible. That calamitous condition was averted by a minor precipitation event in March, and averted again by emergency curtailments on water diversions and by relaxing regulations for downstream environmental flow requirements – harming the environment to avoid calamity for humans in the region.



Generate 6/17/2014 at WRCC using provisional data
NOAA Regional Climate Centers

Figure DCA4. Geographic Distribution of Low Precipitation: Difference in Total Precipitation from Historical Average, June 2011 through June 2014. Source: CDWR, 2015c.

Groundwater can serve as a backup supply in areas where surface water availability is below its usual amounts; therefore, groundwater typically experiences heavy withdrawal during droughts. In general, the groundwater basin health in the San Joaquin Valley is among the worst in California. In the San Joaquin Valley, agricultural practices are prevalent and depend predominantly on imported water, and have experienced extreme and long-term groundwater overdraft.

The current drought has led land owners and water managers to a competition to drill deeper wells, many feeling the necessity of finding even the minimum water supply to remain in minimal production. The severity of the drought's impacts differs across California, depending on a region's portfolio of available water supply sources, its demand patterns, previous investment in drought planning, and strategies available for those agencies to respond to decreased water availability.

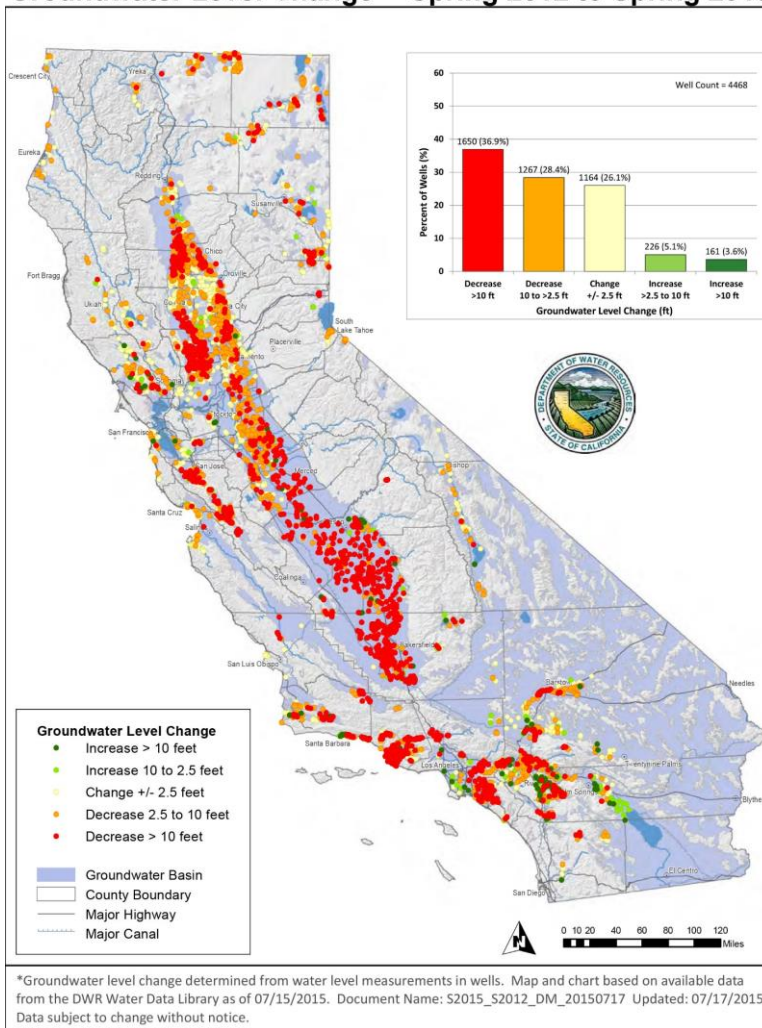
Water deficits are reflected in stream flows and reservoir levels and in the overall groundwater and soil moisture contents in all areas.

Many additional technologies have been introduced to provide a broader view of the drought conditions. For example, the use of satellite data from the Gravity Recovery and Climate Experiment (GRACE) satellites from the National Aeronautics and Space Administration (NASA) to develop the overall water deficits from the drought (JPL, 2014).

While California has experienced droughts of this duration previously, droughts have become increasingly challenging to manage with each passing year due to increases and hardening of demand.

Figure DCA5. Groundwater Level Change Spring 2012-Spring 2015.
Source: Jeanie Jones, 2015. 2015 Water Year, Current Drought Conditions and Where We Go From Here. (Presentation to California Delta Stewardship Council, CDWR, 4-23-15.)

Groundwater Level Change* - Spring 2012 to Spring 2015



The last drought with similar intensity was in 1977. Since then, California's population has grown by 73 percent. Demand for municipal and industrial water has not increased proportional to population, and may have even decreased in some areas, as higher population densities and improvements in water efficient technologies have succeeded in keeping demand low. That means that achieving additional efficiency is increasingly difficult, as many available and lower-cost strategies are already in place.

It is also difficult to reduce agricultural demand during low-supply periods, as many farmers in the state have switched to permanent, higher value tree crops, such as almonds, pistachios, fruits, and vineyards. These resulted in demand hardening, as farmers cannot easily reduce demand by land fallowing – failure to irrigate for one year means loss of the trees, rather than loss of just one year’s crop. Water becomes highly restricted because nut and fruit trees need water to survive through the drought, and it takes several years for the crops to mature and become productive.

California’s Ongoing Drought Responses and Management

On May 20, 2013, California Governor Brown issued an Executive Order to direct CDWR and the State Water Board to take immediate action to address dry conditions and water delivery limitations, by expediting the review and processing of voluntary water transfer to alleviate critical impacts to the agricultural industry. In December 2013, the Governor formed an Inter-agency Drought Task Force that includes CDWR, State Water Board, California Department of Food and Agriculture, and Office of Emergency Services to: review expected allocations and drought preparedness; recommend continued drought management actions; and coordinate with federal and local agencies.

Following recommendations from the Drought Task Force, on January 17, 2014, California Governor Brown proclaimed a State of Emergency and directed state officials to take all necessary actions to make water immediately available. On April 25, 2014, Governor Brown followed up with an Executive Order to speed up actions that would reduce harmful effects of the drought, and to request Californians to redouble efforts to conserve water.

Table DCA1: Comparison of Water Project Allocations in the Current Drought and Previous Droughts (as of Spring 2015). Source: CDWR, 20153.

Water Project	Contractors	Allocations to Demands		
		1991	2009	2014
SWP	Feather River Service Areas (Senior Water Right Holders)	50%	100%	100%
	All Contractors	M&I: 30% Agricultural: 0%	40%	5%
CVP	Sacramento River Settlement Contractors (Senior Water Right Holders)	75%	100%	75%
	San Joaquin River Exchange Contractors (Senior Water Right Holders)	75%	100%	65%
	North of Delta Agricultural Contractors	25%	40%	0%
	South of Delta Agricultural Contractors	25%	10%	0%
	Friant Division	100%	100%	0%

Many efforts are underway through federal, state and local agencies and residents to relieve the socioeconomic and ecological impacts from the ongoing drought. This section summarizes key aspects of the State’s drought proclamation, because the broad statewide measures and the State agencies’ leadership role in the overall effort are the major focus of this case study. It is important to recognize that these actions were built on many proactive management actions implemented before, as highlighted above.

Aggressive Conservation and Implementation of Local Shortage Contingency Plans

In 2014, Governor Brown initially asked all Californians to reduce water consumption by 20 percent voluntarily. The statement referred residents and water agencies to the *Save Our Water* campaign for practical advice on how to do so. *Save Our Water* is California's statewide conservation program managed through a partnership between CDWR and the Association of California Water Agencies (ACWA), leveraging information on their website (www.SaveOurWater.com) and other social media for a broad reach to Californians (ACWA, 2015). At that time, an Executive Order directed local water suppliers to immediately implement local water shortage contingency plans. In recognition of the water-energy nexus, it also directed the California Energy Commission to implement a statewide appliance rebate program for replacing inefficient household devices.

As the drought persisted, on April 1, 2015, a revised target was issued: a statewide 25 percent reduction in potable urban water use through February 28, 2016. The State also directed more aggressive actions and incentives for residential lawns and ornamental turf replacement and appliance rebate programs.

In the fourth year of drought, the State Water Board proposed additional regulations. They limited potable water use in grass irrigation for street medians, a substantial demand when aggregated across the State. Further, the regulations mandated reductions for cities' water supply on a sliding scale of up to 36 percent compared to 2013 level of use. The sliding scale, somewhat contentious among the diverse urban regions of the state, assessed required reductions considering factors such as of past conservation efforts; climate and location of the city; and community economic conditions. Those aggressive conservation targets have remained controversial and difficult to attain, but constitute an important institutional pressure on municipal entities to in turn pressure their citizens to reduce water use in the face of urgent shortfalls.

The severe drought also tested the robustness and validity of local shortage contingency plans, especially as since many of them were not structured for a drought of this severity and did not anticipate the breadth of its impacts. The contingency plans may be best when identifying available options for temporary sources of water – not itself an easy task – but in many cases were faulted further for their lack of deeper overall strategies for demand management, an even greater and more contentious challenge.

One example strategy, and an example of the kinds of institutional barriers to available strategies, is tiered pricing. Increase of water price to end users as the volume of use increases is one tool that economic studies have shown to be useful in demand management. However, California law requires water charges be closely tied to the cost of water, which can be seen to preclude tiered pricing. In one recent case where the City of San Juan Capistrano in Orange County proposed tier pricing as the drought intensified, the California Court of Appeals ruled against the proposal due to a failure to demonstrate the clear connection between the highest tier of water charge and the cost of water. This sent a shock wave across California communities as they have reevaluated practices that may be available to them (Sacramento Bee, 2015a; Sacramento Bee, 2015b).

Water Rights Actions and Curtailment

The State Water Board administers California's system of post-1914 appropriative water rights. When water availability is not sufficient to meet the demands of all users, primacy goes to the senior rights holders: those who have held water rights longest have priority over those with more recent permitted withdrawal rights. Additional protections known as Area of Origin rules give priority to in-basin uses over out-of-basin uses, even those with a senior water right.

In the face of drought conditions, a large impact can be possible through decisions about how to protect, or possibly modify, water deliveries by major water project owners – such as U.S. Bureau of Reclamation

(USBR), which owns the Central Valley Project; and California DWR, which owns the State Water Project. They are bound by the water rights permits of their end users, but have some flexibility because the contracts include specific shortage policies regarding allocating available water among contractors when supply is limited by hydrological and regulatory conditions.

USBR and DWR have in the past implemented temporary water right curtailments due to drought conditions, but they have not faced problems of the magnitude seen in the 2011-2015 drought. As the drought worsened, the State Water Board issued progressively extreme notices of potential curtailments, as well as actual curtailment orders, for several classes of users: 1) riparian water users (subject to availability of unimpaired runoff); 2) junior priority class right holders; and 3) gradually moving into the senior priority class right holders. These curtailments can cause significant financial hardship among water users – water right holders and water project contractors alike – and could reach to senior water users who have never imagined their use could be curtailed.

To respond to the State of Emergency declaration, the State Water Board adopted and implemented emergency regulations including the approval of the Temporary Urgency Change Petition (TUCP), which temporarily modifies statutory requirements for river and estuary flow and water quality in Reclamation's and CDWR's water right permits and licenses for the CVP and SWP, respectively. Under previous water right orders, these two entities are responsible for major flow and water quality requirements in the Sacramento-San Joaquin Delta and mainstems of the Sacramento and San Joaquin rivers. The TUCP allows reduced releases from major storage for flow and water quality purposes, which prolongs the limited resources for extended consumptive and instream environmental uses.

The TUCP has been modified several times since the first filing in January 2014 to accommodate the evolving drought conditions, and implemented based on recommendations from a real-time operations team consisting of operators, biologists, and federal and state regulatory agencies. Even with this emergency measure, the contract delivery to San Joaquin Valley agricultural users have been reduced to zero. That has the effect of driving water users into tapping into groundwater ever more heavily, which in some senses is a rational response to drought, using long-term stored water when surface supplies are not available. On the other hand, California has little, if any, regulatory control over groundwater use, so there is no institutional oversight that can integrate decisions about how much that resource should be depleted. Declining supplies of this depletable resource can have long-lasting and far-reaching consequences that may continue long after the 2011-2015 drought has passed.

The State Water Board also facilitates water transfers among entities to allow them to direct water from users who may have extra allocations toward those with most urgent needs. Those transfers can help reduce impacts of shortages and curtailments. But this extreme drought created an extraordinarily high imbalance between demand and supply, and has pushed the market price to several thousand dollars per acre-foot, much higher than transfers under a normal market. Some would-be users do not pay the high price and cease operations, a loss to the State economy. Other users choose to purchase water no matter the price on the ground that loss of their high-value investments would have even greater consequences: vines or orchards that die during a shortage may take many years, and very high investments, to replace. Those purchases of course have significant near-term economic consequences.

Investments in Solutions and Incentives for Changed Behaviors

A series of federal and State drought relief funding measures has made available more than \$1 billion in new or expedited funds. These have been targeted to address immediate drought needs, such as increasing emergency water supply, funding water conservation campaigns, and providing aid to people unemployed or underemployed due to drought conditions.

Subsequently, voters approved Proposition 1, the Water Quality, Supply, and Infrastructure Improvement Act of 2014, providing an additional \$7.5 billion to fund ecosystem and watershed protection and restoration, water supply infrastructure projects including surface and groundwater storage, and drinking water protection. Some portions of the funding are dedicated to food and other assistance to drought impacted communities, and some are targeted for long-term environmental restoration efforts. The remainder of these public funds are generally directed to capital projects, under the concept that structural measures can make the State systems more resilient and more robust for future droughts conditions, even though the facilities may not come on line quickly enough to have major impacts on the current situation.

Capital projects include:

- **Investing in immediate drought relief projects that can be implemented quickly and can provide additional flexibility and options for water supply locally and regionally.** These projects have in part consisted of water supply-related projects to adapt to drought conditions, such as rehabilitating intakes, pump stations, and water treatment plants to operate under lower flows; installing or reactivating old groundwater wells; and constructing new or improving interties between different agencies. These projects do not solve the drought problem but do help alleviate some of its immediate impacts.
- **Providing incentives additional expansion of alternative sources in the water supply portfolio for regional self-reliance.** Examples of alternative sources include wastewater reuse, redirected beneficial uses of stormwater, and other tactics including rainwater harvests and green infrastructures.

These options have varying degrees of success today throughout the State. The drought provides a powerful incentive to increase this kind of option, as it is shown to be valuable even in historically wetter regions like Northern California. Indirect and direct potable reuse of water is another important example. Developing a consistent regulatory framework to allow broad applications and development of reuse systems are crucial in this activity. The change in characterization of stormwater and in some cases, rainwater, from hazards to alternative water supplies is also a targeted new behavior in water supply planning. These incentives are accompanied by additional legislation to require preparation of Stormwater Capture Plans and Rainwater Capture Plans by municipalities, to drive local planning for dispersed responses to future water shortages.

- **Promoting difficult but necessary dialogue and possible implementation of more controversial options in infrastructure investment.** Much of the investments in the past decades focused on water use efficiency, environmental restoration, operational integration, and regional collaboration. Less accomplishments were on major infrastructure that can provide additional system redundancy, yields, and flexibility. The perfect example will be surface water storages, which has been a taboo due to environmental considerations. However, many also believe that with the threat of climate change, this type of infrastructure cannot be overlooked. The allocation of the fund is likely not sufficient for all needed investments. However, it begins to make progress toward the next generation of major infrastructure.

Revisiting Groundwater Management

Historically, proposals to increase regulations and requirements for groundwater management have faced steep opposition due to the fact that in California, groundwater is considered property rights and separated from the State's surface water right system. This creates a challenge in water management for sustainability since the water right system did not provide a mechanism to regulate groundwater uses by property owners, even in an overdraft basin. When the dispute among rights to groundwater becomes too much to bear, legal proceedings led to groundwater adjudication by the court. It can be expensive and

time consuming to reach a settlement. However, it provides a quantified protection of available groundwater resources for right holders. The adjudication process can be long and expensive.

The drought has intensified groundwater use, as previously discussed. That usage, and its consequences, provided an opportunity to overcome public resistance to groundwater regulation. The California Legislature passed the Sustainable Groundwater Management Act (SGMA) of 2014, a monumental step forward for groundwater management. The SGMA provides a framework for sustainable management of groundwater supplies by local authorities, with a state intervention limited to conditions where it is considered necessary to protect the resource. The Act requires the formation of local groundwater sustainability agencies (GSAs) that must assess conditions in their local water basins and adopt locally-based management plans. The act provides substantial time – 20 years – for GSAs to implement plans and achieve long-term groundwater sustainability. It protects existing surface water and groundwater rights and does not impact current drought response measures.

CDWR is charged with developing related regulations for implementation, and the State Water Board may intervene if local agencies do not form GSAs, or if they do not adopt and implement, within the given schedule of compliance, sustainable management plans considered adequate to alleviate overdraft and other undesirable conditions. Implementing the new legislation faces multiple challenges. For example, it relies on municipal entities to form effective GSAs, and not all localities agree on the desirability of those rules, or on the priority for funding them. Further, the overall water budget, the boundaries between groundwater resources, and quantification of surface water and groundwater interaction can be technically complex and uncertain, and may face disputes about fairness among municipalities that need to rely on those determinations to implement their GSAs. Not least, the municipalities and multiple State agencies will need to reconcile the complexity associated with disconnected regulatory frameworks.

The legislation and its implementation may not create positive effects in time to help ameliorate effects of the current drought. But it moves California regulations into an area that has been previously largely untouched, and could be a very important tool to further the State's ability to integrate management of groundwater resources into its water resources responsibilities.

Conclusions

California is facing uncharted territory not only in the magnitude of impacts from drought but also with identifying and implementing institutional responses intended to mitigate impacts. Mandatory restrictions and related enforcement of stringent measures meet institutional resistance of many kinds, and that resistance can increase as the measures increase – even as the drought impacts continue to increase as well. Among municipal entities across the state, some limited flexibility and opportunities for water conservation can ironically be found in those communities that previously most strongly resisted actions, because their baseline usage has remained high since the initial the voluntary conservation requirements in early 2014. The extreme nature of the impacts, and the fact that they are being experienced broadly by all segments of the population, is helping to overcome resistance to short-term mitigation efforts.

California government agencies, businesses, and residents have worked within the limitations of the existing regulatory framework and water rights system, and responded to the pressing drought conditions. They have leveraged available resources to make possible some immediate mitigation of the current emergency, and also have authorized long-term improvements that will help respond to possible future extremes. An important conceptual shift is the recognition that this kind of occurrence is not a one-time anomaly but can be expected to occur in the future, to varying degrees of severity.

The drought continues in its extreme form as of this writing, and it is too soon to tell to what extent the

suite of actions and plans will be able to mitigate impacts on California's citizens, and to what extent they may be useful in future water shortage events.

Some lessons learned from the Western U.S. drought and the California's responses to it are:

- **Conservation is a critical component for proactive drought prevention measures. If presented as a social responsibility for all, it can make inroads into reducing water use. But ingrained, consistent water use efficiency can ironically make it more difficult to respond to periods of shortage.** Available conservation measures have proven to be important for robust water resources planning – working to achieve maximum economic output and environmental protection for a given amount of water. However, those efforts may actually reduce resilience in ability to respond to short-term extreme conditions. The conservation efforts – with technological advancement and changed practices – have effectively hardened the demands, allowing less room to accommodate persistent drought conditions. This “demand hardening” means there are fewer available ways to reduce water use during supply shortages without substantial economic impacts, as the system is already accustomed to high-efficiency use.
- **Identifying solutions perceived as fair can be crucial to acceptance and effective implementation; and some readily available, extraordinary conservation efforts can have highly unequal impacts on water users if there is insufficient attention to fairness.** Effective implementation of drought measures is greatly enhanced if the business community and the public willingly and actively undertake them, and that willingness is greatly reduced if there is a real or perceived unfairness in the conception, design, or implementation of the measures. Fairness of measures needs to consider many factors, and decision-makers may not be able to identify all factors important to the various communities unless they actively seek input from as many as possible. Considerations may include: past efforts to reduce water use by particular entities; differences in regional climate conditions and in how local economies rely on water availability; differences in social and economic conditions in different communities; public ideas about the relative importance of various water uses; and others. These can take considerable time and effort to identify, and a quickly-implemented solution that is unfair (or perceived as unfair) can meet with intense community resistance. That resistance can confound or erase any efforts to reduce water usage.
- **Legacy water right systems have disconnects with the modern understanding of surface water and groundwater interactions and conjunctive use practices on a regional scale, resulting in “leakage” in management.** The failure to address groundwater and surface water as a single resource is a major barrier integrated water resources management, and a deficiency that has been apparent for many years. However, existing systems of private property rights and the overall water rights systems of the states have inhibited any measures to integrate those concerns. The Sustainable Groundwater Management Act is groundbreaking in this respect, and it was accomplished without impacting water rights, though the extent to which it succeeds in moving toward effective groundwater management remains to be seen. Regardless whether local parties prefer the adjudication route or the collaborative management practices, quantification of groundwater resources and formalizing records of groundwater use are important moves toward sustainable management of groundwater resources.
- **The existing, extensive infrastructure for storage and conveyance of water is aging. Decades of population growth, demand hardening, and the existing system of regulatory requirements limit the flexibility, redundancy, and resilience of the system, inhibiting effective response to extreme conditions.** Most of the water infrastructure that shaped the California water management landscape was built more than four decades ago. Economic activity has long been recognized to depend on the extensive water management system. It is increasingly clear that environmental

protection and restoration also rely on the intricate regulatory and physical conveyance systems. After decades of optimizing the system use beyond its original design for multiple purposes including environmental restoration, there is little flexibility, redundancy, and resilience left in the current system and its operations. New infrastructure and alignments of regulatory requirements are likely needed to meet the continually expanding social, economic, and environmental needs for water in California.

- **An integrated water management approach that can recognize the importance and connection of multitudinous water sources and uses can be achieved if regulatory and value systems evolve along with the changed conditions for future drought preparation.** It is commendable for California to capitalize the drought for advancing and funding many important water management policies and practices, with the incentive of state funding. Perhaps equally important have been the official and unofficial incentives to promote changed behavior and awareness of water use and availability in decisions about land uses and assessing the common water supply. Further gains may be made if water availability is considered in continuing decisions about stormwater management, urban development, wastewater reuse, and other practices. Many options could potentially improve regional self-reliance on water, and in that way could improve resilience for droughts in the future. Stepping outside of individual silos and recognizing the status-quo is not sustainable are important steps for a long-lasting changes.

Hillsborough River, FL and State of Florida Minimum Flows and Levels

Lead author:

L. Donald Duke, Florida Gulf Coast University

Contributing author:

Tiffany Castle, Florida Gulf Coast University

Contributing researcher:

Haisley Blankenship, Florida Gulf Coast University

Introduction: State and Regional Strategies for Low Water Conditions in a Wet Climate

Florida's population growth is one of the nation's fastest, accelerating through the second half of the 20th century. Florida's population reached 1 million in the early 1920s, 5 million in the 1960s, 10 million in the 1980s, and is estimated to have surpassed 20 million in 2015 (U.S. Census Bureau, 2015). It currently the third most populous state of the U.S. The Tampa-St Petersburg-Clearwater metropolitan area has shared in that growth, from 400,000 in 1950 to 2.4 million in 2000, an increase of greater than 400 percent during that 50 years (Demographia, 2000).

Intensive and sustained population growth has put pressure on the state's natural systems. In particular aquifers and surface waters are heavily used to supply Florida's vigorous agricultural and industrial sectors and its burgeoning public water supply needs. Even in Florida's wet-climate conditions, with long-term average rainfall in most areas in the range of 40 to 50 inches per year, water withdrawals have the potential to affect natural systems, and surprisingly can even be limited by periods of when water is not in sufficient supply for desired and permitted uses. The ecology and aquatic systems of Florida are adapted to its water-rich conditions and can experience negative impacts at stream flows and aquifer levels that would be considered plentiful in other parts of the world.

A number of institutional approaches have been innovated to avoid potential water shortfalls in Florida and its municipalities. For one, the state water allocation approach explicitly considers environmental conditions and shared usage of common waters. A second approach, significant to this case study, is creation of a regional utility with responsibility for water supply in the Tampa-Saint Petersburg-Clearwater region, known as Tampa Bay Water. A third is the statewide Minimum Flows and Levels (MFL) program, designed to identify for individual waterbodies the acceptable lower limit of water availability that will avoid unacceptable environmental impacts.

This case study describes several approaches to safeguard against low-water conditions in the Tampa Bay region, with a focus on its main freshwater system, the Hillsborough River. The case study highlights some of the complexities of the interrelated surface and sub-surface hydrologic systems and the multiple overlapping federal, state, and municipal institutions involved in the region's water supply. While it is not possible to fully isolate those features from the tightly integrated institutions, infrastructure, and operations that address water supply, flood control, and ecosystem protection, many of those aspects are not included here. Additional details of the integrated water resource management on the Hillsborough River and its environs are available elsewhere (SWFWMD, 2009; USACE, 2015; Guillory et al., ca 2012).

The region. West central Florida rivers and creeks, fed by shallow aquifers and substantial rainfall, drain west or southwest across the peninsula into the Gulf of Mexico through a watershed with large numbers

of standing water lakes and slow moving wetland streams and rivers. The region averages just over 45 inches of rain per year (National Weather Service, 2015). The northernmost of the large drainages is the Hillsborough River, flowing west to the Gulf Coast and the ecologically rich estuary of Tampa Bay, encircled by substantial urban and suburban development.

The Hillsborough River originates in the area of the Green Swamp within Polk and Pasco counties, at a relatively high point of the Florida peninsula. It flows roughly 55 miles through undeveloped land, farmland, and the suburban and urban land use of greater Tampa, emptying into the Tampa Bay estuary. The estuary is a rich ecosystem that has been under ecological pressure from urban development and is the subject of regulatory protection for nitrogen inputs. The Withlacoochee, Peace and Oklawaha Rivers all originate in the same general region. Further inland the Chain of Lakes region spawns the Peace River, flowing southwesterly. The Myakka originates southerly from there, and the Caloosahatchee River, now fed by releases from Lake Okeechobee, historically arose in the wetlands east of the Charlotte Harbor region.

The Hillsborough River can be divided into three segments hydraulically.

- The Upper Hillsborough River (UHR) originates in the Green Swamp and is fed by several aquifers and some smaller springs along with runoff and groundwater from a wide area (Leeper, 2009). That reach extends about 32 miles south to the Fletcher Avenue Bridge, now in suburban Tampa.
- The 12-mile Middle Hillsborough River (MHR) segment begins at the Fletcher Avenue Bridge and ends at the Hillsborough River Dam, so it consists almost entirely of the Hillsborough River Reservoir where water is impounded for the City of Tampa water supply (SWFWMD, 2006). Inflows in this region are diverse: runoff and stormwater drainage in its basin; groundwater from springs; and water pumped in from Harney Canal/Tampa Bypass Canal (SWFWMD, 2006).
- The Lower Hillsborough River (LHR) extends about 10 miles downstream from the dam, and thus receives inflows from two distinct watersheds: flow over the dam, and inflows within the basin, a smaller, highly-urbanized watershed; and several small springs. Most of the watershed of the LHR is urban and the shoreline has been substantially modified. Stormwater from precipitation events enters the river rapidly, as much of the watershed is paved. Groundwater inflow is not readily quantified, but one important source is outflow from Sulfur Springs. Tidal influence is important; the LHR is an estuarine system. At the location Sulfur Springs flow enters the river, the salinity averages 1.2 to 1.3 ppt (SWFWMD, 2006), increasing as it moves downstream to Tampa Bay.

The Hillsborough River has served as the water supply for the City of Tampa since the 1920s, and demands have grown as the population of the city and its environs has sharply increased since the 1970s. Operations on the Hillsborough River for water supply and water resource management are enormously complex, and are intricately interrelated with decisions about use and protection of water resources throughout the greater Tampa Bay region.

Institutional Setting

Florida's Water Resource Act of 1972 altered the state's water allocation system from its previous riparian-rights approach to a regulated-riparian form, where water is considered to be owned by the

citizens of Florida and held in trust by the state (FDEP 2015). The Act established five semi-autonomous Water Management Districts (WMDs) with jurisdictions mapped to conform to watershed boundaries, each reporting to the Florida Department of Environmental Protection (FDEP). Withdrawals require users to obtain a Consumptive Use Permit, which is issued by the Water Management District in whose jurisdiction the user is located. Those permits form the backbone of the state's regulatory framework for protecting the environment from harmful low flows, and also for allocating in a way that considers the needs of multiple users, sometimes with conflicting priorities.

The Water Resources Act gives the Water Management Districts authority in four areas: **water supply; water environment protection; water quality; and flood control**. Florida's water resources regulatory system thus is integrated, at the state level, to a degree that is unusual among the states; in most states those four responsibilities are divided among two, three, or four agencies. It integrates groundwater and surface water as well. Florida water law "makes no distinction between surface and groundwater" (Swihart, 2011). That is different from many U.S. states and is eminently sensible in Florida from a hydraulic standpoint: surface water throughout peninsular Florida is in such close connection with groundwater that withdrawal from one necessarily affects storage and flow in the other.

Three actions by the Florida legislature shape the protective strategies for low flows on the Hillsborough River, and are summarized here for purposes of this case study.

The Consumptive Use Permitting program took effect in 1983, which makes it a much newer system of allocation than in many U.S. states. The system of permitting and usage implementation has been refined over the subsequent 30 years, and clearly encompasses the concept of protection during low flows.

Two other actions of the Legislature are more major changes that are more recent still. During the 1990s, limited water supply availability to the greater Tampa Bay metropolitan area, and concern for potential impacts on the region's ecosystem, famously precipitated a political confrontation known as the Water Wars (Regan, 2003; Rand, 2003). Two outcomes of the Water Wars are crucial to this case study: the public utility Tampa Bay Water, created by the Legislature with the mission of integrating water supply planning for the region; and the statewide Minimum Flows and Levels (MFL) legislation, enacted with immediate requirements for the Tampa Bay region and planned phase-in for all of Florida.

The three institutions are discussed in separate sections that follow.

1. Consumptive Use Permitting: The Water Resources Act included language from its initial adoption in 1972 signifying the legislature's intent to address low flows and the potential harm they could do to the environment. The statutory basis for consumptive use permitting directs the Districts to consider permits under three criteria if the requested withdrawal:

- 1) Constitutes a "reasonable-beneficial use;"
- 2) "will not interfere with presently existing legal uses of the water;" and is
- 3) "consistent with the public interest" (Florida code sections 373.019-373.22, in Swihart, 2011).

The three criteria together oblige the Water Management Districts to consider low flows when writing permits for withdrawals. New withdrawals are limited such that they do not impinge on existing permitted uses, and also – with the terms "reasonable" and "public interest" – direct the permitting agencies to consider other regulatory requirements, such as available flows for endangered species and ecosystems that provide value to Florida citizens.

In this respect, the Act in essence limits total withdrawals from a given waterbody to the amounts that will not negatively impact environmental systems – a total that is to be determined by the Districts under

analyses required elsewhere in statute, in particular the MFL program described below.

2. Tampa Bay Water and regional water supply: The public utility Tampa Bay Water was formed in 1998 as a special district of the State of Florida, “created to plan, develop, and deliver a high-quality drinking water supply,” with the additional mission “to work to protect our water supply sources” (TBW, 2015). It is a non-profit, regional utility, funded by sale of water that supplies more than 2.3 million people through its six member governments: the Counties of Hillsborough, Pinellas, and Pasco; and Cities of Tampa, St Petersburg, and New Port Richey. The utility was created as an outcome of the 1990s Water Wars disputes, specifically in response to litigation referred to as “the Four Wellfields Case,” and designed as a transformation of the pre-existing West Coast Regional Water Supply Authority into “a more effective regional water management institution” (Regan, 2003). In this case the institutional setting for shared use of a finite water resource was created for that purpose out of existing agencies, and by agreement of the State and multiple collaborating institutions.

A second major utility, the City of Tampa Water Department, serves an additional approximately 0.6 million people in and around Tampa (City of Tampa, 2015a). Public supply for the city dates back to 1887, and the City department dates to 1923 when it served some 73,000 residents. By 1924 the City operated a treatment plant for surface water that withdrew an average of around 7.5 million gallons per day from the Hillsborough River, upstream of a dam constructed by a private electric utility (City of Tampa, 2015a). The dam collapsed in flooding in 1933, and the site was acquired by the City for a new dam constructed in the mid- through late-1940s. That Hillsborough River Dam, as modified several times in the years since, governs the hydraulics of the Hillsborough River today. Since the 1960s the reservoir it forms (Hillsborough River Reservoir) impounds an estimated 1.6 billion gallons (City of Tampa, 2015a).

The two agencies each are allocated withdrawals under Consumptive Use Permits issued the Southwest Florida Water Management District, as noted above. The permitting process is in turn bound by various environmental restrictions including the Minimum Flows and Levels restrictions, as noted below. The two utilities cooperate when conditions warrant: “Tampa Bay Water has a Water Shortage Mitigation Plan and supplements the City of Tampa supply during drought or emergency conditions by augmenting the Hillsborough Reservoir from the Tampa Bypass Canal through Harney Canal” (McConnell, 2015). An example of this occurred in May 2012 (TBW, 2012).

3. Minimum Flows and Levels legislation and implementation: Florida legislation adopted in 1997 (FC 337.042) directed the Water Management Districts to specify MFLs for surface waters of the state of Florida. The stated intent of the legislation was to avoid “significant harm” to the environment resulting from permitted withdrawals, and ensure that Water Management Districts consider potential effects of low water levels when writing permits. The Legislature specified immediate action for Hillsborough, Pasco, and Pinellas counties, all within the jurisdiction of the Southwest Florida Water Management District (SWFWMD), as part of the reconciliation of the “Water Wars” disputes.

Other state waters had no legislature-specified time frame, and other Water Management Districts were directed to develop procedures. The Districts have responsibility to: select waters needing MFLs; define “significant harm” in a way that is appropriate to their own ecosystems; determine uses that are to be protected (ecosystem, future supply, human uses); specify methods of analyzing impacts; and more. Beginning in 1997, each Water Management District has been required to submit a priority list and schedule for the establishment of MFLs for surface watercourses, aquifers, and surface waters within the district. In Hillsborough County, both the Upper and Lower Hillsborough Rivers are on this priority list.

The Statewide Minimum Flows and Levels Program: Progress to date and implications for the Hillsborough River case study

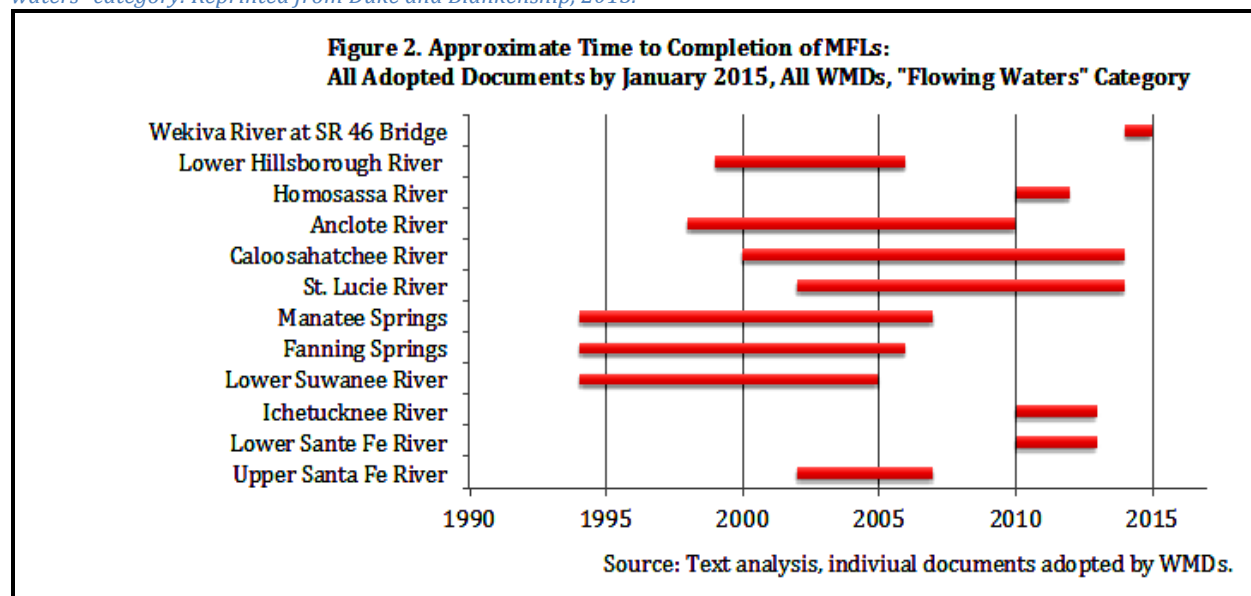
This section presents some data about how Minimum Flows and Levels analyses have been conducted and implemented in Florida by the Water Management Districts, and some ways in which the implementation has varied among Districts.

In the approximately 20 years since adoption of the MFL requirements, the five Water Management Districts have developed procedures that differ substantially, including in the ways in which they delineate waters to be addressed and the time frame over which they have developed MFL rules, especially as contrasted with other rules that protect freshwater resources in their service areas.

As one example, the term “significant harm” is intentionally left undefined in the legislation, with the intent to allow FDEP and the Water Management Districts to adopt specific definitions for separate purposes. That intentional ambiguity has conceptual advantages, allowing flexibility among the Districts to meet the needs of specific waterbodies and local users. But the ambiguity has led to some disputes and imperfect results. For this case study, the SWFWMD’s definition of significant harm applies: it “means a temporary loss of water resource functions, which result from a change in surface or ground water hydrology, that takes more than two years to recover, but which is considered less severe than serious harm” (SWFWMD, 2015).

As a result, the implementation of the MFL rules differs in different parts of Florida. Duke and Blankenship (2015) reviewed on-line information at the five WMDs and identified approximately 250 completed studies statewide that led to adopted rules. Most MFLs completed to date are for lakes. Of the 250 completed, more than 100 were for lakes in the Southwest Florida district, the focus of the initial legislation. Another 100-plus were for lakes in the St. Johns River Water Management District. Flowing waters comprised only 12 MFLs statewide, with their completion timelines shown in DFL1.

Figure DFL1: Approximate time to completion of MFLs: All adopted documents as of January 2015, all WMDs, “flowing waters” category. Reprinted from Duke and Blankenship, 2015.



The extent to which the MFL program is a component of individual Water Management Districts’ strategies, as reflected by the extent to which studies have been completed and rules adopted, appears to have an institutional component.

The Hillsborough River, which lies within the region specified by Legislature for immediate attention, is subject to an MFL adopted in 2006. Within that targeted region, Southwest Florida Water Management District (SFWMD) adopted between five and 20 MFL rules each year over the period from 2000 to 2010 (Duke and Blankenship 2015). That District reportedly created during that period a group of personnel whose main responsibilities, and accumulated expertise, were focused on the MFL process (Call, 2015).

One other district, the St. Johns River District, began a focused effort somewhat later. It developed a process for thorough review of lakes' water levels, long-term hydrological characteristics, and associated potential environmental impacts. It evaluated many water bodies during a concentrated period (Chamberlain, 2015), and adopted more than 100 MFL rules in the single year of 2014. That institutional choice to address multiple waterbodies in a single, cohesive approach had the effect of focusing personnel time and skills in a concentrated way onto one complex topic, arguably producing more thorough and more nuanced studies and solutions, and has also led to a different time frame for adoption than other Districts.

The other three Water Management Districts in aggregate have adopted only some 50 MFL rules, but institutional factors play a part in this apparent discrepancy as well. For example, the South Florida District elected to assess a single MFL for the large aquifer underlying much of the district, and another single MFL for much of the Everglades wetlands system, electing to encompass all 2,000-plus square miles and the complexly interrelated hydraulic units within a single MFL. That is not only a much more complicated task, justifying a much longer period of development; but also shows in aggregate statistics as a single item. This makes the count of completed MFLs by separate districts irrelevant. Some recent changes at the state level to MFL rules, and to the consumptive permitting procedures, are intended to increase consistency among Districts of the state.

One lesson from this is that the priority given to particular rules can vary with time and by agency. The and that the effectiveness of the MFL process needs to be considered in the context of one tool among many. In this case protecting ecosystems from significant harm from low flows is achieved using a variety of tools working together.

Current Strategies for Meeting Low Flow on the Hillsborough River

Two main institutions supply water within the region: Tampa Bay Water, the regional-scale public utility; and the City of Tampa, which supplies to a jurisdiction within the City that is separated from the Tampa Bay Water system. The City of Tampa permit issued in 2004 authorizes average withdrawals of 82 million gallons per day with a maximum withdrawal rate of 120 million gallons per day. This is an increase of 14 million gallons per day maximum over what was allowed by prior permits. Tampa Bay Water's water use permit (most recently renewed in 2007, expires 2030) allows a maximum of 258 million gallons per day withdrawal from the middle and lower pools of the Tampa Bypass Canal (TBC).

The volume allowed at any particular time is limited by canal pool stage under a procedure that accounts for flood protection and management protocols for the TBC and the Hillsborough Reservoir. The permit allows an additional maximum of 194×10^6 gal/day to be diverted from the Hillsborough Reservoir into the TBC middle pool through the Harney Canal when flows over the Hillsborough River Dam Tampa Dam exceed 65 million gallons per day.

Strategies by Type

1. Regional drinking water supply. Prior to the integrative water management strategies that included creating Tampa Bay Water as a utility, most of the region's supply was from groundwater – up to about 99 percent of supply for the region (McConnell et al., 2014). Potential impacts on natural systems in the

region from the intensive groundwater use were the driving force for the revised, integrated institutional approach. Those impacts included substantial water level declines in lakes and isolated wetland systems on or adjacent to the groundwater wellfields (McConnell, 2015). “In the 1990s, eleven regional groundwater facilities served nearly 90 percent of the members’ demand for groundwater. In 1998, the face value of these permits for these facilities totaled 192 mgd” [192 million gallons per day] (TBW, 2015).

Since the 1920s the flow to the LHR has been dominated by structural modifications and withdrawals operated by the City of Tampa. The City operates the David L. Tippin Water Treatment Facility, withdrawing its raw water from the MHR at the Hillsborough River Reservoir. The treatment facility has a capacity of 120 million gallons per day and treats between 60 million and 102 million gallons per day, depending on the raw water quality (City of Tampa, 2015b). These permitted withdrawals affect flow to the LHR, which receives most of its flow over the Hillsborough River dam. At times when the pool is being drawn down for water supply, no flow passes the dam and the LHR flow declines.

Tampa Bay Water’s supply plan, adopted in November 1998, diversified the sources with “a number of diverse, alternative water supply sources and key pipelines and interconnections.” As of January 2016, there are three main sources of water supply to the Tampa Bay Water system.

- 1) Wellfield pumping continues to be the single largest source, though at a much reduced rate: groundwater provided about 65 percent of the region’s supply as of 2013 (McConnell et al., 2014).
- 2) Surface freshwater sources now constitute about 29 percent of the total, primarily withdrawals from the Tampa Bay Bypass Canal (which feeds the LHR). Use of surface water required construction of the Tampa Bay Regional Surface Water Treatment Plant, brought online in the early 2000s and expanded in 2010 to a rated capacity of 120 million gallons per day, delivering between 90 to 99 million gallons per day.
- 3) The third component is desalinated water from the Gulf of Mexico at the Seawater Desalination Facility, the largest seawater desalination plant in North America, which came online in 2007 and delivers up to 25 million gallons per day (TBW, 2015), or about 7 percent of the region’s supply in 2013 (McConnell et al., 2014).

These diversified sources are much more flexible than the previous groundwater-dominated strategy, and reduce environmental pressures caused by groundwater extraction. Hillsborough River low flows are not affected by Tampa Bay Water withdrawals, as Tampa Bay Water’s permit from the Water Management District allows withdrawals only when flow over the Hillsborough River Dam is greater than 65 million gallons per day (or 100 cfs). That is a way to use water when conditions in the River are “excess,” relieving pressure on groundwater resources when flows in the LHR will not cause harm to the ecosystem. McConnell (2015) sums up the value of these efforts: “The diversified sources reduce environmental pressures from groundwater pumping, but also reduce over-reliance on any one single type of source, so the regional system can be managed to minimize potential impacts to surface water as well.”

2. Minimum Flows and Levels (MFL) Determination for the Hillsborough River. The Hillsborough River’s three segments can be read as three examples for the MFL process, in that they illustrate three ways in which flowing surface waters in Florida are assessed to determine the minimum acceptable flow that will not cause significant harm to the environment.

One segment, the MHR, does not have a MFL strategy. That reach of the Hillsborough River consists almost entirely of a reservoir, with its levels determined by human usage, and thus fully subject to human

control. Technical analyses were used to select MFLs for the other two segments, and because the segments violate those targets at least on some occasions, the Southwest Florida Water Management District has promulgated a strategy to restore the segments to meet their MFLs. The strategy requires integrated plans for the three, but each segment has its own requirements, as described below.

Upper Hillsborough River: The UHR is on the state’s priority list and requires MFLs be determined in conformance with statute. During most years, the UHR does not experience low flows that could produce significant harm. However, this reach is included on the priority list that requires MFLs be determined, largely because it is sensitive to precipitation patterns and can reach unacceptably low flows at times. During the water year 2000-2001 low rainfall contributed to significant declines in stream flows and reservoir levels (SWFWMD, 2007).

For its technical approach, the Southwest Florida District selected its target as a proportion of the long-term average flow. That selection relies on the assumption that the ecosystem can accommodate some decline – rather than select particular species and evaluate the system to meet their minimum flow needs. That approach requires a seasonal specification of acceptable flows. MFLs were ultimately set at 52 cubic feet per second (cfs) at all times, and other levels specified based on the pre-existing flow (Leeper, 2009), summarized in Table DFL1. The schedule prohibits changes within a 24-hour period of greater than 8 percent to 13 percent (depending on the season), and is intended to avoid rapid declines in level on a given day.

Table DFL1. Minimum Flow for Upper Hillsborough River at USGS Morris Bridge Gage

Period	Effective Dates	Where Flow (in ft ³ /sec) on Previous Day Equals:	Minimum Flow Is (in ft ³ /sec)
Annually	January 1 to December 31	≤52 >52 and <470 ≥470	52 Seasonally dependent – see Blocks below Previous day flow minus 8%
Block 1	April 20 to June 24	≤52 >52 and <470 ≥470	52 Previous day flow minus 10% Previous day flow minus 8%
Block 2	October 28 to April 19	≤52 >52 and <470 ≥470	52 Previous day flow minus 11% previous day flow minus 8%
Block 3	June 25 to October 27	≤52 >52 and <470 ≥470	52 Previous day flow minus 13% Previous day flow minus 8%

(Source: Florida Administrative Code 40D-8.041)

Middle Hillsborough River: There is no requirement for an MFL related to the Middle Hillsborough River, because that reach consists primarily of the Hillsborough Dam Reservoir, which is operated by the City of Tampa Bay as a water supply, with permitted withdrawals of up to 120 million gallons per day. Details of the operation are available elsewhere (SWFWMD, 2014; and others).

Lower Hillsborough River: The Lower Hillsborough River flows through an extensively developed urban area, has been subject to an adopted MFL since 1999 (modified several times since), but has in the past routinely failed to meet its level – requiring a Recovery Strategy in addition to a carefully-assessed MFL. Selecting the appropriate flow for protecting the environment from significant harm on the LHR has been a source of some dispute. The Florida Legislature’s 1997 action requiring the development and implementation of MFLs singled out this region, and by December of 1999, SWFWMD had implemented

an MFL. It called for a minimum of 10 cfs, with no seasonal adjustments or modifications for factors such as salinity. This was based on improvements seen at 10 ft³/sec, including increased water of the Hillsborough River Dam, which improved freshwater at the base of the dam and decreased salinity in the LHR (SWFWMD 2006).

A non-government organization known as Friends of the River moved forward with litigation which would broaden the MFL language, asking that the number be increased in order to better protect the LHR as the 10 ft³/sec was being implemented. The court denied the Friends petition, but required a five-year study which was to include recommendations.

In 2007 the Water Management District adopted a revised MFL for the Lower Hillsborough River with a much more complicated method of determining MFL. This determination was based on salinity of the river. Freshwater flows out the mouth of the river serve to keep out higher-salinity water that would otherwise be pushed upstream by tides from the brackish Tampa Bay. Low flows in the LHR would allow this saltier water to reach further up the LHR. So Section 40D-8 of Florida Administrative Code specified the MFL for the LHR on the basis that salinity would be held lower than 5 parts per thousand (ppt) through the reach of the LHR extending from the Hillsborough River Dam downstream to the connection with Sulfur Springs. This level of salinity is judged to maintain freshwater environments below the dam, while protecting the estuary-dependent species that live at the base of the dam (SWFWMD 2006).

Translating the salinity target to a flow requirement was also complex, and SFWMMD conducted analyses using a model that simulated adding water flows past the dam with inflows to the reach and changing tidal conditions. Ultimately, a schedule was selected which specified flows for separate seasons and includes limits on day-to-day changes. The specified in-stream flows are detailed in SWFWMD 2006; at most times of the year, the flow target is between 20 and 24 cfs.

Future Directions and Continuing Challenges

Strategies for Recovery for LHR: The Recovery Strategy articulates a number of specific requirements. Some of these were designed to enhance flow to the river. Others were intended to reduce input of salinity to the river, which improves the MFL because it reduces the ecological impact for a given amount of flow. Some of the requirements to enhance flow draw water from sources that would otherwise be available for human consumption, placing the environmental health of the LHR into direct competition with desired human uses for a finite water supply.

One aspect of the Recovery Strategy was structural modifications to two weirs controlling flows from the groundwater outflow known as Sulfur Springs, an important source of flow to the LHR. The main intent was to reduce salinity incursions, thereby creating a stable low salinity habitat below the dam. This is of ecological significance as it positively impacts the species which are restricted to such an environment. The lower and upper weir projects for Sulphur Springs were completed October 2011 and March 2012 respectively, with a total final cost of more than \$5 million, which was shared between the City of Tampa and the Southwest Florida Water Management District.

The Recovery Strategy also required the investigation of storage or additional supply options, and also to assess success of some of the multiple projects that have been implemented to date. This was expected to be completed by October 2015, at a cost of \$100,000.

The Recovery Strategy requires the City of Tampa and Southwest Florida Water Management District to divert up to 7.1 million gallons per day (11 cfs) from the Tampa Bypass Canal to the Hillsborough River Reservoir. Since January 1, 2008 that has been achieved using temporary pumping facilities. In conjunction with the Recovery Strategy, the City of Tampa is to take over the operation of these pumping

facilities that provide water from the middle pool of the Tampa Bypass Canal to the reservoir and from the reservoir to the LHR.

Two projects identified in the Recovery Strategy are currently in progress. A project for an inflow known as Blue Sink was originally to be implemented in 2011 with a price tag of \$7 million, with current cost estimates about \$11 million, and is expected to be completed in 2015. The sink is located within the City of Tampa, and the City will fund the modification and operate the project. The City received a permit for Blue Sink to allow a peak pumpage rate of 2 million gallons per day to assist with minimum flows.

The final project for the Recovery Strategy is pumpage from the Morris Bridge Sink. This particular sink exists on land owned by the Southwest Florida Water Management District for natural resource preservation, and it has been altered only slightly from its natural state. In 1972, a pump test was conducted to determine the possibility of utilizing this sink as a future water supply for augmentation (SWFWMD 2010). The sink was pumped for emergency potable supply on a temporary basis from May 30, 2000 through August 14, 2000 (SWFWMD 2010). This set the precedent for using a sink for public water supply. An additional pump test for the Morris Bridge Sink was conducted for 30 days in 2009 and it was determined that the sink could deliver 3.9 million gallons per day (6 cfs), though it recommended wetland impact be evaluated (SWFWMD 2010).

Other Future Challenges and Opportunities: Many of the actions required by the Recovery Strategy required substantial capital investments, and the water supply utilities are tasked with continuing vigilance in justifying rates charged to ratepayers are no higher than necessary. Retaining support of the community for this program of investments is crucial to the ability to gain acceptance for continuing and future projects.

One further source that has been considered but not pursued is redirection of treated wastewater to the flow-challenged LHR. The City of Tampa's Howard F. Curren Water Treatment Plant discharges an average of more than 60 million gallons per day of treated water. That discharge is currently directed into the Tampa Bay estuary in the Hillsborough Bay segment. That discharge could be rerouted to the upper reaches of the LHR, augmenting flow at the dam and reducing saltwater incursion with high-quality treated wastewater. This has not been pursued, because rerouting these discharges has institutional, financial, and technical implications. Costs to construct a conveyance in this urbanized area could be substantial. Further, treated wastewater has value as a source, and the City of Tampa's South Tampa Area Reclaimed (STAR) project, operational since 2004, "help[s] to maximize potable water resources by using highly-treated wastewater for irrigation" (City of Tampa, 2015a).

Lessons Learned

- **This is a case of institutions developed by the State of Florida intended to settle a confrontation among regional entities in competition for water supply.** The single-utility institutional framework provided to Tampa Bay Water contributed to clearly-formulated technical solutions. The public among multiple stake-holding agencies conversation focused on the detailed and complex technical analyses, and on applying the best available information and techniques to the technical solutions. To a great degree it succeeded in avoiding other conversations such as disputes about competing preferences or positions. The lesson here is one of encompassing the multiple positions with the mission of meeting objectives and preferences of many stakeholders, rather than continuing to pit stakeholders against one another.
- **One of the two institutions, the Tampa Bay Water public utility,** is an example of a regional agency with a broad enough geographic scope to encompass all major urban uses competing for the region's finite supply. The main lesson here is that finite supply is effectively managed by a single

agency with the mission to jointly serve all, rather than multiple agencies and municipalities competing for their own interests. The utility – with its reliable funding source, explicit mission to serve the interests of the entire region, and responsibility for environmental compliance of any water-supply actions across the entire region – has proved a highly effective means to proactively identify and address multiple kinds of water resources issues.

- **The second institution is a statewide rule for Minimum Flows and Levels (MFL).** The MFL rule was developed as a way to limit or avoid environmental harm experienced or predicted in that same region by over-use of the aquatic resources. The lesson here is how the state agencies implemented rules (in response to one region's environmental impacts) designed to avoid or reverse comparable kinds of impacts in other parts of the states.

The MFL rule has clearly had an important influence on solving problems in the Hillsborough River. The rule has been vigorously and effectively implemented throughout the Tampa Bay region under the Southwest Florida WMD. One other jurisdiction, the St Johns River WMD, adopted more than 100 MFL rules in recent years, evidence that District decision-makers chose to make the MFL mechanism an important part of their natural systems protection strategy. But it is not clear that the rule has been implemented equally effectively in other parts of the state. Other Districts have not reported sufficient data that we can judge their progress, either because their waters do not need this kind of protection or because they afford these protections under other driving forces. As a statewide response, the results are mixed.

Lessons from the Case Studies in Volume II

The cases here, along with those in Volume I, allow us to make some observations of lessons that may help inform the national dialogue about how to promote meaningful, effective, proactive management to mitigate the consequences of high flows and low flows on our waterways and communities.

Disaster or need as a driver: We repeat this lesson learned from the Volume I document, because it remains possibly the single most visible lesson. In case after case in the U.S. where we identify substantial policy modifications or infrastructure improvements that have made a real difference, those changes reached the policy agenda after some major upset, many of them sadly accompanied by damaged property and lives lost. Several of these cases show municipalities and states that have responded to disaster or near-disaster, some with strategies that appear to be highly successful; others with strategies that are responding more slowly. Three of our case studies are examples of disaster leading to change:

- The Fort Collins, CO strategy shows how thoroughly a medium-sized municipal entity can take control of its strategy, implement a suite of plans and actions well-suited the conditions of various parts of its jurisdiction, and create a system that so far has sharply ameliorated the damages of succeeding flood events.
- In the Hillsborough River basin, ecosystem damage was sufficient to prompt major regional and statewide actions. Revamping the regional water supply institution appears to have made a major difference in protecting ecosystems and water supply in that region. However, the statewide rules (an important driver for the Hillsborough River basin) have not been conclusively demonstrated as equally effective elsewhere in Florida.
- A severe drought in the western U.S. began in 2011 and continued at least through 2015, longer in some locations. Despite a long legislative and executive history of rules and requirements for water usage and conservation in California and elsewhere, the requirements proved inadequate for such a prolonged, extreme, statistically infrequent event atop the stressed infrastructure and institutional network of water supply obligations to multiple uses. California has responded with intensified policies and rules which may in future reduce impacts to the welfare of California residents, businesses, and ecosystems. The effectiveness of many of those actions will depend on the extent to which they are implemented, and continue to be implemented through future decades.

Sometimes, however, disaster does not drive the responsible agencies to take action for effective, proactive flood and drought management.

- While the small towns of Pennsylvania in our case studies bring to bear the resources they are able to muster, it is not clear those actions are sufficient to ameliorate disaster from future events. Extremes of precipitation and stream flow are well documented and are quite certain to continue in the future, and negative impacts occur not only in the most statistically unlikely extremes but also from smaller, less-infrequent, high-rainfall episodes. Mitigation activities are very different among the many small municipalities of the U.S., and examples abound of many kinds of activities that can contribute to reducing flood impacts, but in many locations are piecemeal, incompletely funded, and inadequate to prevent predictable flood impacts. Municipalities in this case study may typify too many locations in the U.S. where mitigation is not fully planned or implemented.

Collaboration, communication, education: The case studies demonstrate that many effective strategies could not have been achieved without creative, thoughtful, outside-the-box interaction of multiple stakeholders. Most crucially, many of these have relied upon communication and collaboration of multiple institutions with disparate missions. The voting, tax-paying public remains a stakeholder in these cases. Successful outcomes were reached through effective outreach, communication, and clear

explanation of expected benefits in a way that sustains broad support for continuing expenditures and community changes. “Education” is not only a matter of a project’s proponent informing others of what it thinks is best. Rather, it is not an exaggeration to say that project proponents, regulatory and approval agencies, and multiple stakeholder communities have needed to educate one another about their own priorities and regulatory requirements.

- The Rock Lititz project demonstrates how crucial it is to connect policy makers and regulatory enforcement agencies. Organizations in this case were willing to stretch their traditional mindset to approve permits for superior projects that did not fit a traditional mold but that did address both economic and environmental needs. This required a modified approval format to accommodate integrated water resource planning and implementation goals and objectives.
- The Fort Collins strategy relies on the willingness of local voters to approve expenditures on an aggressive protection system. To do so they recognized the value of defending against the infrequent hydrologic extremes that characterize the part of the world where they have chosen to live.

A single powerful regulatory requirement as driver; other desirable outcomes as opportunities: In many of our cases the driving force was the need to satisfy one kind of regulatory requirement (for example, NPDES, flood disaster planning, construction of a profit-making activity, or other). In many of these cases the simplest solution would have been to address that single driving factor, but the project proponents chose to consider other community priorities (including pressing environmental or economic needs, or pending regulatory requirements). This complicated the approval of the project, its funding, or its timing, but ultimately led to a cost-effective unified design addressing multiple priorities.

Flexibility in institutional requirements: Several projects decried the “silo” approach to regulatory management, and found their solutions by working across disciplines, agencies, and organizations. Many of our successful, proactive cases were driven by some single regulatory requirement, but adapted thoughtfully, and with long communication and interaction, to address multiple needs of the community. In nearly all of those cases, project proponents found a need to collaborate with multiple decision-making agencies, and multiple groups of community stakeholders, to achieve those multiple objectives. While solving one objective may have been quicker and required less time and less effort from so many members of the community and agencies, it would **not** have achieved the multiple benefits that are the hallmark of these case studies.

- The Rock Lititz case not only required intensive education of multiple entities, but also needed those entities to consider flexibility in permitting. Where established routines were well-tested means to enforce their requirements, a fully proactive and integrative project is only possible if agencies are willing to consider alternate approaches that might be adapted to meet their own requirements and to gain advantages outside their own mission.
- In the case of Florida’s Hillsborough River and its surrounding natural systems, the institution to solve the problem was created by thoroughly revamping the mission and the structure of pre-existing institutions in the 1990s. The agency that was created now has a jurisdiction that encompasses the problem, both geographically and institutionally. What formerly were conflicting priorities, championed by multiple responsible entities, became the overall goal of a single entity – and thus within the scope of effective planning.
- Fort Collins is an example of local areas around the nation where a multiplicity of strategies – not a single technique – can be more effective for the community. The multiple-strategy approach allows a community to for example preserve open space in undeveloped areas while avoiding the financial, cultural, and political barriers to changing land use in firmly-established residential and commercial districts; and to construct levees in only targeted, local areas rather than throughout the stream course. Adding warning and communication strategies atop structural and land-use strategies, with approaches tailored to particular basins, has served to enhance each of the complementary strategies.

Appendix A: A Brief History of U.S. Federal Flood Strategies

Lead Author:

L. D. Duke, Florida Gulf Coast University

Contributing Authors:

Michele Weitzel, Florida Gulf Coast University

Wayne S. Wright, GeoEngineers, Inc.

Historical Context: Federal Policy and Instruments for Flood Mitigation in the U.S.

At present in the U.S., it can be said that there is no coordinated, integrated flood policy at the national level. We make this assertion even in the knowledge that extensive federal programs and activities do exist that are tremendously influential in the multiple local decisions and basin-scale plans pursued throughout the nation by an enormous number of separate decision-making entities large and small.

The AWRA National Water Policy Dialogues, conducted in the years 2000 through 2007, made this point repeatedly and with multiple policies as evidence, and called for a national water vision focused on integrated water resources management. Another institution with this viewpoint has been the Association of State Floodplain Managers, whose 2007 National Flood Programs and Policies in Review comments: “The current model is a federal-level approach through which minimum standards are set that are implemented by states and localities through programs for land use, building codes, and mitigation, in exchange for federally backed flood insurance. Federal disaster assistance is then provided when significant flood losses occur” (ASFPM, 2007).

Existing Federal programs may be grouped into three categories.

1. Basin-scale hydrologic plans, structures, and operational systems. A large number of these have been designed, constructed, and/or operated by the U.S. Army Corps of Engineers (USACE) for the purpose of flood control. Others by the U.S. Bureau of Reclamation focused on water supply rather than flooding, but their basin-scale planning and operation are of the same model.
2. Emergency disaster response. The nation’s disaster-response framework was developed, and has been operated, under the Federal Emergency Management Agency (FEMA) and its precursors. These include a longstanding series of single-incident relief funds from the U.S. Congress and a decades-long history of programs under the National Flood Insurance Program to incentivize homeowners, businesses, and municipalities to plan and build in ways that might mitigate safety threats and potential damages.
3. Technical support systems. These include forecasting and hydrologic modeling under the National Oceanic and Atmospheric Administration (NOAA); scientific investigations and monitoring under the U.S. Geological Survey (USGS); the Levee Safety Act and subsequent work in levee inspections and risk reduction implemented by USACE; and others.

Centralized watershed planning and management: Basin-scale structural measures.

We sometimes think of basin-scale, multi-objective water resources planning and management as a modern innovation. But integrated planning at the watershed level has been practiced in the U.S. for some 150 years. The many basin-scale hydrologic investigations, physical structures, institutional structures, and management frameworks completed over the years have profoundly shaped the kinds of flood

mitigation that are feasible in those basins today, and set the stage for instruments that can be applied in other basins.

U.S. Army Corps of Engineers Early Responsibilities: The U.S. Army Corps of Engineers (USACE) was charged with a mission for navigation improvements at least as early as “a \$75,000 appropriation in 1824 for snagging and clearing the Mississippi and Ohio Rivers.” (U.S. Dept. of the Army, 1956).

The Corps grew in budget, responsibility, and crucial engineering experience through the Reconstruction period after the Civil War. Major ports and rivers, especially in the southern U.S., saw substantial modifications from the 1870s through 1890s (Smallwood and Izlar, 2007). USACE acquired funding for its separate engineering plans through separate acts of Congress.

Over time the USACE gained constitutional authority for these works through its responsibility for interstate commerce. However, it resisted planning for flood-control purposes on the grounds that such improvements were responsibility of the individual states. Thus the first basin-scale, spatially-integrated plans and structural systems in the U.S. were implemented at the federal level, but these explicitly excluded considerations of high and low flow events.

Extensive channelization and lock-and-dam structures to improve navigation are exemplified by the Ohio River basin, where USACE between 1885 and 1929 ultimately constructed 54 locks and dams over the 981-mile Ohio River from Pittsburgh, PA to Cairo, IL (Johnson, 2010). However, the Corps continued to decline requests for further structures designed for flood control on the Ohio: Johnson (2010) found the Corps “disapproved, not of flood control, but of using navigation improvement as the justification for federal funding of flood control.” Repeated requests by municipalities and regional interests throughout the Ohio River were declined, even when “an Ohio River flood in 1884 overtopped city-built levees at Lawrenceburg, Jeffersonville, and Shawneetown” (Johnson, 2010).

Federal Role Begins with a Few Large-Scale Programs: Congress accepted Federal responsibility for waterworks in another form in reaction to some well-publicized engineering failures. Catastrophic dam failures occurred at Johnstown Pennsylvania in 1889 (more than 2,200 fatalities) and the St. Francis Dam on San Francisquito Creek in California in 1928 (more than 600 fatalities). Federal involvement took the form of successive rounds of Congressional adoption of building codes, engineering guidelines, and inspection requirements. While these improved the structural safety of new and existing dams, they still fell short of any federal involvement in selection or design of projects (McCullough, 1968), and certainly avoided central planning on a watershed scale.

At the same time, local and regional interest groups in parts of the U.S. pressed for a Federal role in flood protection. In the early 1900s organized lobbying by local, state, and multi-state boosters and agricultural interests eventually led Congress to direct USACE to develop flood control structural approaches on the river-basin scale for the Sacramento River/Central Valley of California and the lower Mississippi River basin (O’Neill, 2006).

These were cast in principle as assistance from Congress to the individual states involved,. They were not seen as authorizing federal planning and decision-making about design or operation of facilities on the river. Sacramento River and lower Mississippi River basin continued to be separate sub-sections in the USACE’s Chief of Engineers annual reports to Congress for decades (Department of the Army, 1956). Thus the role for Federal flood-management actions in high-volume waterways predated any formal acceptance of Federal responsibility for that role, under the auspices of assistance to state and inter-state regional commercial interests.

Centralized basin-scale flood-control planning in the U.S. had its origin not with a Federal program but at the state level. The Miami Conservancy District was organized in 1913 for the tributary Miami River in Ohio (Johnson 2010). That system continues to be operated and improved, such that it was featured as an example of proactive, integrative flood management in the AWRA's 2013 white paper *Proactive Flood and Drought Management Case Studies* (Dennis et al., 2013). Thus the first basin-scale, spatially-integrated plans and structural systems in the U.S. that were designed with flood control as an integral component were implemented.

In Johnson's (2010) estimation it was drought – not flood – that led to USACE's agreeing to flow-management structures on the Ohio. In 1930, low flows on the Monongahela River interfered with barge traffic. The Corps sought funding – and Congress approved – for a flood-control and water storage dam on the Tygart River, a Monongahela tributary in West Virginia. This structure was completed in 1938 with approval and funding for this project predating by just a few years the Corps' official flood control mission of the 1936 Flood Control Act. Still USACE firmly resisted planning for flood control, taking the position that levees and other structural barriers were more appropriate and dams should not be employed for this purpose (Arnold, 1988).

Resources development was explicitly a USACE goal even earlier than a goal of flood control. In the late 1920s and 1930s, the agency conducted the so-called “308 reports,” throughout the U.S., authorized by House of Representatives Document No. 308 of the 69th U.S. Congress. The 308 reports were surveys of river basins with plans for comprehensive development, essentially inventories of potential water resources needs that Corps authorities could address. They were multi-objective in nature, addressing flood control, hydropower, recreation, and other purposes. Some observers contend these reports were the first IWRM-type approaches undertaken in the U.S. (Dunning, 2015).

Corps of Engineers and Flood Management Responsibility: In 1936 Congress passed legislation that strongly affirmed a federal concern in flood protection. Disastrous flooding on the Mississippi River in 1927 was seen as evidence that USACE efforts there were inadequate, and led to calls to more aggressively control the river through greater funding, and greater planning and analysis authority, for the USACE (Arnold, 1988).

The U.S. Omnibus Flood Control Act of 1936 built on those sentiments, along with the growing number of Depression-response Federal and state programs that invested large sums in infrastructure and make-work programs and that centralized authority for oversight of big-ticket programs of all kinds. The 1936 Act created substantial authority to the USACE to contain and minimize floods, while also authorizing the fledgling Soil Conservation Service (SCS) to address upstream measures that might reduce the magnitude of peak flows via land management activities (Black, 2012).

The Act articulated the benefit/cost analysis as the guiding principle of future decisions by Congress and USACE, specifying projects may be approved only if “the benefits to whomsoever they might accrue should exceed the costs.” That principle, of course, sidesteps the question of which entities should pay when particular businesses or municipal entities reap the benefits. This became a point of contention for many years after.

Further, the Act formalized the principle that local and state agencies participate in partnerships for flood control projects by providing “non-federal funding” for some portion of the large flood-control structures. The so-called “ABC” provisions specified what support state or local interests would do typically:

- A. Provide land for the project to the U.S. without cost (without specifying that title to the land would be held by the U.S. – usually it remains in the hands of the partner entities);

- B. Hold and save the U.S. from damages in connection with construction; and
- C. Maintain and operate the works after completion (Arnold, 1988).

This was seen in principle as codifying USACE's routine practices dating back to 1917 Congressional actions (Arnold, 1988). Thus the idea of cost-sharing was built into the practice of Corps structural flood-control projects beginning at the very start of its authority to build such projects. Ultimately, the Act embraced for the first time a Federal acceptance of constructing large dams for the purpose of flood control (Arnold, 1988).

Subsequently a large number of river basins were surveyed, and dams designed and constructed, for the purpose of holding back peak flows to prevent downstream flooding. In many cases, the same basins that had earlier received structures to promote navigation were now receiving design attention for flood management. Designing facilities for more than one purpose – occasionally, purposes that directly conflict with one another – has repeatedly added complexity to design and operation. The optimal reservoir for flood control is one that is nearly empty, maximizing capacity for unforeseen high flows; while the optimal operation for navigation maintains a predictable flow, with sufficient volume to accommodate the largest vessels for which the channel is designed, and to store water to be released to sustain sufficiently high flows.

Throughout this period the Corps enhanced its activities in providing ancillary benefits from its structures. For decades it had been actively providing electrical generation, including adapting its structures where feasible to enhance generation while serving its main purpose of navigation. With the 1936 Act it was explicitly authorized to also enhance irrigation, and to adapt its design—and add structures—to increase irrigation.

It was the 1936 legislation that clearly authorized the Corps' role in integrated water resources management – the forebear of today's integrated approaches. Notably, the multiple objectives identified at that time were firmly based on measurable economic benefits rather than non-financial benefits. Recreational benefits were among those quantified, using methods to predict vacationers' expenditures as local revenues; others that were not quantified, such as habitat protection, were largely omitted from consideration, a predilection that complicated later interest in considering that kind of benefits. These complicated conflicts, and others, remain today.

Subsequent to the 1936 Act the Corps was intensively active in identifying, designing, and constructing flood control structures. Construction was interrupted or delayed during the years when resources were devoted to World War II. In 1946, when the USACE submitted its first post-war request for funds, Congress authorized projects whose sole purpose was flood control to a total of \$610 million for approximately 110 projects. In addition, approximately 760 projects dispersed throughout the United States were identified for total authorizations of \$2.29 billion (U.S. War Department, 1946). The 1953 report updated the authorized total to \$3.76 billion for about 994 projects. Scarcely any populated corner of the nation by then was untouched by flood-control projects (U.S. Department of the Army, 1953).

Corps of Engineers Role in Environmental Protection: Multi-purpose reservoir development was generally the norm in the 1950s to 1970s with the primary purposes being flood control, navigation flow maintenance, water supply storage, recreation, and hydropower. Juggling these often conflicting objectives demands a great deal of operational expertise, as well as very close interaction among diverse stakeholders. Since the 1970s environmental quality management has also been added to the mix.

By the 1970s, USACE's mission began to explicitly include environmental protection. The 1972 Clean Water Act specified USACE as the entity permitting wetlands development and disposal of dredge and

fill material, which opened a new field of expertise and responsibility for USACE. Flood control decisions, too, needed to account for environmental factors to an increasing extent. In the 1970 reauthorization of the Flood Control Act, Congress identified four equal national development objectives for water resources project planning. These were:

1. National economic development;
2. Regional economic development;
3. Environmental quality; and
4. Social well-being (NRC, 2000).

The Water Resources Council (established in 1962 to provide integrated oversight of federal water resource projects), modified these goals by publishing “Establishment of Principles and Standards for Planning Water and Related Land Resources” in the Federal Register in 1973 (WRC 1973).

The 1973 Principles and Standards explicitly require environmental analysis and protection among the goals of USACE in its water resources projects. NRC (2000) in its *Risk Analysis and Uncertainty in Flood Damage Reduction Studies* notes that the Principles and Standards dropped social well-being as an objective, and “placed environmental concerns on an equal basis with national economic development.”

By the 1980s projects took on a more environmental focus, including multiple projects designed for ecosystem restoration, in particular in places where previous USACE projects had compromised environmental systems in favor of economic benefits (Johnson, 2014).

In 1983, USACE’s *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, known as the *Principles and Guidelines* document, codified detailed steps for calculating benefits in flood damage reduction. These offered specific guidance for fiscally evaluating water resource projects with a methodology common to all water-resources agencies (USACE, USBR, Natural Resources Conservation Service, and TVA). A key feature was requirement for non-federal cost sharing. The Principles and Guidelines specified for flood control projects that non-federal partners provide at least 35 percent and at most 50 percent for structural expenditures, and 25 percent for non-structural expenditures.

In some respects the *Principles and Guidelines* relaxed the environmental quality emphasis that was envisioned with the 1973 Principles and Standards, on the grounds that its quantitative emphasis gives precedence to financial benefits over environmental benefits. The approach of the *Principles and Guidelines*, at heart an extension of the benefit/cost methodologies of the 1950s, was subject to criticism on grounds that “there have since been significant advances in economic and other analytical techniques, advances in aquatic biology, and shifts in public values related to water and related resources” (NRC, 2000).

In 2000, the Corps adopted a regulation known as the *Planning Guidance Notebook* (USACE, 2000), which both updated the 1983 *Principles and Guidelines* and was a cornerstone of a series of circulars, pamphlets, and regulations that coordinated and publicized USACE procedures for its own staff and for the many agencies nationwide seeking partnership and collaboration with USACE. A key function of the *Guidelines* was to modify the financial methodologies to better incorporate the benefits of ecosystem restoration, thus enhancing the part played in decisions about project funding.

USACE Basin-Scale Flood Measures Decline Over Time: In all, far fewer reservoir-style and basin-scale levee flood control projects have been funded since the 1970s compared to period between the 1930s and 1960s. By the 1990s new projects of this type had become few and far between. USACE and

Congress in general chose to devote resources elsewhere, and approval of large-scale water projects was made more stringent for a variety of other reasons, as follows. Benefits attributed to structural projects required more thorough documentation and rationale than when the benefit-cost mechanism was first developed in the 1950s. At the same time costs of construction increased sharply – even more so when environmental impacts needed to be considered starting in the 1970s. Continuing reliance on benefit/cost assessment slowed approvals, and placed projects in direct competition with other federal funding. Native American groups increasingly pursued their rights and interest, in many cases resisting projects not geared to restoration, especially in large Western projects. Finally, projects faced increasing complexity of approvals in meeting the Endangered Species Act, the Environmental Impact Statement requirement of the National Environmental Policy Act, and other environmental protection requirements beginning in the 1970s, which received scant attention during the building boom of the 1950s.

Large-scale projects declined as the Federal attitude increased its emphasis on local agencies and institutions driving flood control decisions. USACE's efforts tilted toward "Local Protection Projects" (LPP), and many of these have been authorized in successive Water Resources Development Acts (WRDAs) especially from the 1980s through today. Congress's approach has been for USACE to design and construct these, with federal funding, and then turn over the structures to local interests. In this way local entities bear an increasing proportion of costs, especially for land acquisition and the operation and maintenance of projects after completion. Many locations continue to be identified for potential LPPs; for example, the Wyoming Valley on the north branch of the Susquehanna River in Pennsylvania received major new construction in the 2000s. Other examples may be found nationwide.

Rising Interest in Integrated Water Resources Management: As a direct result of the increasing barriers to dedicated flood-control structural projects, by the 1990s, it became increasingly common for projects to address multiple purposes. In many cases these included environmental priorities of multiple Federal and state regulations. Many of those extended to concerns such as water supply, water quality, and economic development of urban centers. Local interests have been led to identify funding from multiple agencies at all three levels of government for any given water resources project, which drives them to develop projects (that serve the ends of multiple institutions) for structural and non-structural solutions alike. An approach that incorporates multiple objectives in this way may fit the mold of Integrated Water Resources Management (IWRM), an approach adopted by many agencies, and a policy promoted by the American Water Resources Association (AWRA, 2011; AWRA, 2012).

IWRM solutions are developed in these instances not only because multiple goals can be integrated in a given project, but in large part because single-purpose projects are more difficult to fund as Federal and state agencies are less willing to be sole payers for water resources projects. This is a valuable result, because integrated programs and structures are less likely to be designed to conflict with one goal at the expense of another; and because cost effectiveness often is enhanced when one program or structure can meet multiple goals.

On the other hand, the difficulty in funding and the complex creative designs required for integrated projects may also suppress the number of projects undertaken for flood control or other water resources purposes, because not all local institutions have the wherewithal or the technical and management skills to develop the newer, more complex projects, and gain support from the range of agencies whose funding and approval are required.

Projects that are successfully implemented are in many cases marvelously designed and planned; but other localities do not choose to expend their financial and human resources on water resources projects because of the high costs and institutional barriers. The absence of a true national water resources management program may be resulting in fewer water resources projects than the nation needs.

Since the construction boom between 1920 and 1990, nearly all reservoirs created during that time have evolved substantial recreational value and at times, very high demand. Recreational activities include swimming, boating, fishing, diving, hiking, hunting, and more.

These activities are regulated by a variety of jurisdictions from local city/county to tribal, state, and federal agencies. Access, fees, and use regulations are also quite variable and rarely tied to the operation of the facility itself. Similarly, dikes, levees, and other structures along rivers have become hunting corridors for waterfowl, and the rivers themselves supporting boating, swimming and fishing. Lastly, some reservoirs provide hydropower production (non-federal) and community drinking water supplies requiring careful management, screening, treatment and distribution.

Disaster response and incentives for damage reduction – a growing role for floodplain management.

Early Recognition of a Federal Role: Reportedly the U.S. Congress approved funds in more than 100 instances from the 1860s through the early 1970s for post-disaster recovery and assistance to various parts of the nation (Steinberg, 2006).

The Disaster Relief Act of 1950 gave the President authority to issue disaster declarations authorizing Federal agencies to provide direct assistance to state and local governments. Calls began in the 1950s for a national flood insurance program, as a means to respond in a systematic way to what was by then clearly an ongoing problem that would continue indefinitely into the future. Langbein (1953) described the rationale and desirability for such a program in an article that remains seminal to the field today.

A Federal role in disaster response was formally recognized in 1973 by the executive branch with creation of the Federal Disaster Assistance Administration within the Department of Housing and Urban Development. This was largely in response to flooding in the Northeast U.S. from tropical storm Agnes of 1972, the most costly disaster in the U.S. up to that time. Congress authorized more than \$100 million in the form of “disaster redevelopment” grants within the Department of Housing and Urban Development in 1973. Congress adopted the Disaster Relief Act in 1974 to codify funding responses, and the Federal role has steadily expanded since then.

FEMA and National Flood Insurance: The Federal Emergency Management Agency (FEMA) was created by President Carter as a stand-alone agency, reorganizing several HUD offices, in 1979. Congress and several Presidents used reorganizations and executive orders to add to FEMA’s responsibilities in the decades since, including both response and mitigation planning for disasters including earthquakes, hurricanes and other storms, dam safety, and hazardous materials.

A profound influence on flood related policies in the U.S. is the National Flood Insurance Program (NFIP). Enacted in response to the rising cost of taxpayer funded disaster relief, the National Flood Insurance Act of 1968 is a defining piece of legislation for many of the policies that followed. Congress directed NFIP to make insurance available to property owners in participating communities to purchase government-backed insurance protection against losses from flooding (FEMA, 2013).

The Flood Disaster Protection Act of 1973 made the purchase of flood insurance mandatory for homeowners with federally backed mortgages located in special flood hazard areas (FEMA, 2013). An excellent summary of the origins, development, and conceptual role of floodplain management is found in the Association of State Floodplain Managers 2007 document, *National Flood Programs and Policies in Review* (ASFPM 2007).

The NFIP became a cornerstone of the emerging policies for floodplain management, which delegates substantial responsibility to the states, and even further responsibility to county- and municipal-level governments. The overarching strategy is a decentralized one, with the Federal role as guidance, information clearinghouse, facilitator for collaboration among agencies, and guarantor of funding for insurance compensation for financial losses.

Flood Insurance Moves to Include Acquiring Flood-Sensitive Properties: In 1988 the Robert T. Stafford Disaster Relief and Emergency Assistance Act amended the Disaster Relief Act of 1974 to make FEMA the coordinating agency for government-wide disaster relief efforts. This Act revised FEMA's role to include planning preparatory to disasters and gave states a greater degree of control over FEMA spending in their states. It also created direct connections of county and municipal disaster agencies to FEMA, providing channels for communication and guidance for local-scale mitigation programs. The Stafford Act also substantially increased FEMA's mission in regard to flood mitigation. It provided grants to states for pre-disaster preparation programs to:

- support effective public-private natural disaster hazard mitigation partnerships;
- improve the assessment of a community's vulnerability to natural hazards; or
- establish hazard mitigation priorities, and an appropriate hazard mitigation plan, for a community (CFR, 2014).

FEMA's mitigation role was increased with the Stafford Act amendments in 1994 to include funding support for a category of damages known as "repetitive loss" (RL) (filing for insurance damage recovery once every 10 years) and "severe repetitive loss" (SRL) (filing three or more times within a 10-year period).

Municipalities were provided information under NFIP to identify RL and SRL properties; and provided funding on an annual cycle to fund businesses and homeowners to repair or sell their properties. The new rules stipulated that if repetitive loss properties were repaired, they would be subject to increased requirements such as hardening structures with "smart flood-proofing" and elevating all occupied floors at least one and a half feet above the 100-year flood level.

Repetitive Loss funding also provided up to 75 percent of the cost for a municipality to acquire properties – removing the damage-susceptible land use indefinitely from the flood hazard zone. Some municipalities hailed this program as a means "to break the repetitive loss cycle from properties repaired and reconstructed replicating pre-disaster conditions."

Hazard mitigation plans were put in place so that "sounder less vulnerable conditions are produced." (Lycoming County, 2010). The acquisitions are accompanied by restrictions: "any property acquired, accepted, or from which a structure will be removed pursuant to the project will be dedicated and maintained in perpetuity for a use that is compatible with open space, recreational, or wetlands management practices" (CFR, 2014).

That has had a double-edged result. Property thus acquired is indefinitely free from potential damage; but on the other hand is not available to municipalities for economic development. Smaller municipalities find these rules highly restrictive. For example, rules prohibit even modest structures such as playground equipment or bandstands, and prohibit vegetation other than grass lawns that must be mowed. Municipalities object because the open space cannot be improved to make it an amenity (Duke, McLaughlin, and Weitzel, 2014). Lawn maintenance becomes an expense for the acquiring municipality.

FEMA's role in flood mitigation is centered on the NFIP. As part of the NFIP, FEMA identifies flood hazard areas throughout the United States on flood insurance rate maps (FIRMs). Among the flood hazards identified on these maps is the Special Flood Hazard Area (SFHA), which is defined by FEMA as land that has a 1 percent or greater chance of being inundated by a flood in a given year – formerly known as the “100-year-floodplain.” Managed by FEMA in conjunction with the Federal Insurance Agency, funds are made available to communities that agree to adopt and enforce floodplain management to reduce future flood damages (FEMA, 2013).

In 2002, FEMA was added to the newly-created Department of Homeland Security. That and subsequent reorganizations contributed to what ASFPM calls FEMA's “diminution in status, along with repeated reorganization of functions and programs, budget woes, and shifts in legislative and executive priorities,” which “resulted in lost ground for floodplain management at the federal level.” ASFPM calls for resolution of these issues to “help shape national programs and policies for the next several years.” At present the Federal strategy is unsettled, and Federal and State policies not resolved.

Federal Insurance's Role in Mitigation Planning May Continue to Grow: A National Academy of Science study promotes a community-based flood insurance (CBFI) option for NFIP. It summarizes:

“... CBFI may create new opportunities to reduce flood losses, and may enhance the likelihood of communities paying more attention to flood risk mitigation. At the same time, although CBFI may provide a solution in certain circumstances, it is unlikely that it will provide the sole solution for the nation's pressing flood insurance challenges.

Community-based flood insurance has been discussed as a possible policy option. A CBFI option could be based on aggregating the dollar sum of flood loss risks for community structures. Costs could be distributed in a variety of ways. For example, one method could be to distribute premium cost according to each individual's assessed flood risk. The community could purchase the insurance, and premiums could be collected using mechanisms such as property taxes or utility charges.”

Other Federal Programs: Data Collection, Warning Programs, and Technical Support

Federal guidance and policies include several other programs, notably the highly effective efforts by NOAA to improve information-gathering and advance-warning capabilities. We do not discuss those here because the focus of this document is on proactive structural and land use options by and within regions that will mitigate flood damages when they do occur, rather than on evacuation strategies, but we acknowledge the enormous advantages in reducing threats to public safety of the highly effective network of forecasting and evacuation that has saved many lives and continues to improve. Those programs are well documented elsewhere, and are not discussed here in the interest of space.

Summary

One vastly influential federal role in flood mitigation in the U.S. will continue indefinitely is maintenance and operation structures large small constructed for a variety of purposes, and continuing to provide economic value such as irrigation and power generation. That represents an enormous investment, implemented over hundreds of years. It includes facilities from the small, community scale to the massive basin scale, reaching to some river systems that drain large sections of North America. Programs to refine operation, fund maintenance, and improve the structures will continue to powerfully influence the local-scale decisions upon which so much flood mitigation in the U.S depends.

A second program, perhaps equal in its influence though completely different in its design, is the U.S. flood insurance program. That program shapes decisions of tens of thousands of municipalities, and hundreds of millions of individuals, about how they will design and implement their own flood-mitigation planning and strategies. Aspects of the flood insurance program that incentivize or inhibit particular options or strategies are reflected across the nation in the decisions by municipal agencies and programs. The NFIP flood insurance program and its mitigation-planning component, the CRS, could be a powerful tool to guide these decisions. At present the flood insurance program has not adopted an overarching strategy regarding land uses in the wake of a disaster; and the CRS program has not penetrated to large portions of the U.S where it might be a tool for promoting effective mitigation.

At present in the U.S., there is no coordinated, integrated flood or drought policy at the national level, despite extensive federal programs and activities that profoundly affect flood control.

Acronyms Used in This Document

ACWA	Association of California Water Agencies
ASFPM	Association of State Floodplain Managers
AWRA	American Water Resources Association
CDWR	California [state] Department of Water Resources
CVFPP	Central Valley Flood Protection Plan
CVP	Central Valley Project, by U.S. Bureau of Reclamation
FEMA	[U.S.] Federal Emergency Management Agency
FIRMs	Flood Insurance Rate Maps
FDEP	Florida Department of Environmental Protection
HUD	[U.S. Department of] Housing and Urban Development
IWRM	Integrated Water Resources Management
LPPs	Local Protection Projects [of USACE]
MFL	Minimum Flows and Levels, a Florida state program
NPDES	National Pollutant Discharge Elimination System, a part of the Clean Water Act
NRC	[U.S.] National Research Council
NFIP	National Flood Insurance Program
PA DEP	Pennsylvania Department of Environmental Protection
PEMA	Pennsylvania [state] Emergency Management Agency
RL / SRL	Repetitive Loss / Severe Repetitive Loss, FEMA programs
SWP	[California] State Water Project
SWFWMD	Southwest Florida Water Management District
TMDL	Total Maximum Daily Load program, a part of the Clean Water Act
TUCP	Temporary Urgency Change Petition [to CDWR]
UHR, MHR, LHR	Upper Hillsborough River, Middle Hillsborough River, Lower Hillsborough River
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation, part of the U.S. Department of the Interior.
USCB	U.S. Census Bureau
USEPA	U.S. Environmental Protection Agency
UWMP	Urban Water Management Plan
WRDA	Water Resources Development Acts [by U.S. Congress]
WMDs	[Florida state] Water Management Districts

References

Introduction

American Water Resources Association (AWRA), 2011. “AWRA Policy Statement: Integrated Water Resources Management in the US. Approved by the Board of Directors of the American Water Resources Association at their January 21-22, 2011 meeting, as proposed by the Policy Technical Committee of AWRA. www.awra.org/policy/policy-statements-IWRM.html

Section 1. Fort Collins, CO

City of Fort Collins, 2015a. Utilities: Stormwater: History. <http://www.fcgov.com/utilities/what-we-do/stormwater/history>. Accessed July 2015.

City of Fort Collins, 2015b. Stormwater Department: map created with data layers collected by Stormwater Department.

City of Fort Collins, 2014. *CDPS MS4 Phase II Stormwater Management Program Descriptions for Cities and Counties, March 2008 - March 2013*. Submitted to Colorado Dept. Of Public Health & Environment, Water Quality Control Division, Denver, Colorado, June 10, 2008. Accessed at http://www.fcgov.com/utilities/img/site_specific/uploads/final-2008.pdf, July 2015.

City of Fort Collins, 2014. *2013 Stormwater Annual Report, Municipal Separate Storm Sewer Systems (MS4s) Permit, COR-080000 and 090000 - Renewal Permittees*. Submitted to Colorado Dept. of Public Health & Environment, Water Quality Control Division, Denver, Colorado February 2014. Accessed at http://www.fcgov.com/utilities/img/site_specific/uploads/2013_MS4_Annual_Report_For_web.pdf, July 2015.

Dennis, Lauren; Bateman, Brenda O.; Wright, Wayne; and Duke, L. Donald, 2013. *Proactive Flood and Drought Management: A Selection of Applied Strategies and Lessons Learned from Around the United States*. Middleburg VA: American Water Resources Association. http://www.awra.org/webinars/AWRA_report_proactive_flood_drought_final.pdf.

Federal Emergency Management Agency (FEMA), 2008. *A Strategic Plan for the Community Rating System: Fiscal Years 2008-2013*. Accessed at http://www.water.ca.gov/floodmgmt/lrafmo/fmb/fas/nfip/crs/Links/doc/CRS_Strategic_Plan_2008_2013.pdf

FEMA, 2013. *National Flood Insurance Program Flood Insurance Manual, effective October 1 2013*. <http://www.fema.gov/media-library/assets/documents/34745>. Last updated September 23, 2013.

FEMA, 2014a. http://www.fema.gov/media-library-data/1398878892102-5cbcaa727a635327277d834491210fec/CRS_Communities_May_1_2014.pdf. “Community Rating System Communities and their Classes.” Updated July 14, 2014.

FEMA, 2014b. *Floodsmart.gov*, www.floodsmart.gov. Accessed August 25, 2015.

FEMA, 2015a. “CRS Resources: List of CRS Communities as of April 2015.” Accessed at <http://crsresources.org/100-2>. http://www.fema.gov/media-library-data/1424450651900-d381a14283db10e28ae624543a9526ad/20_crs_508_apr2015.pdf. Accessed August 3, 2015

FEMA, 2015b. “National Flood Insurance Program Community Rating System.” Accessed at <http://www.fema.gov/national-flood-insurance-program-community-rating-system>. Accessed at various times July-August, 2015.

- FEMA, 2015c. Map of locations of CRS participating communities in the U.S. by class: advanced, intermediate, introductory. Figure provided by Bill Lesser, CRS Coordinator, Federal Insurance and Mitigation Administration, Arlington VA.
- Grigg, Neil S.; Doesken, Nolan J.; Frick, David M.; Grimm, Mike; Hilmes, Marsha; McKee, Thomas B.; and Oltjenbruns, Kevin A. 1999. "Fort Collins Flood 1997: Comprehensive View of an Extreme Event." *Journal of Water Resources Planning and Management, American Society of Civil Engineers*, vol. 125 no. 5, September-October 1999, 255-262.
- Hilmes-Robinson, Marsha, 2014. "Fort Collins Floodplain Management Program: Success Stories from the September 2013 Flood." *Colorado Water*, March/April 2014.
- Hilmes-Robinson, Marsha, 2015. City of Fort Collins Utilities. Personal communication, July 24, 2015; and August 12, 2015.
- Martinez, Cristina, 2015. Insurance Services Office, CRS Coordinator for State of Colorado. Personal communication, data from ISO databases.
- U.S. Bureau of the Census, 2015. "Quick Facts: Fort Collins, Colorado." <http://quickfacts.census.gov/qfd/states/08/0827425.html>. Accessed August 10, 2015.

Section 2. Susquehanna River, PA Small Towns Flood Mitigation Strategies

- Baca, Anna Marie, 2008. *History of Disaster Legislation*. Office of Chief Counsel. FEMA ON CALL Disaster Reserve Workforce News. Retrieved from <http://www.fema.gov/pdf/dae/200809.pdf>.
- Cairo, Richard A., 1975. *Disaster Urban Renewal Projects in the Susquehanna River Basin*. Mechanicsburg PA: Susquehanna River Basin Commission.
- Commonwealth of Pennsylvania, 2015. *Constitution of the Commonwealth of Pennsylvania*, Article IX Section 8, 1968, accessed 2015.
- Diehl, Douglas, 2014. Code Enforcement Officer, Borough of Milton. Personal communication, July 2014; and July 2015.
- Duke, L. Donald; McLaughlin, Seamus; and Weitzel, Michele, 2014. *Floods on the Susquehanna: Small River Towns' Flood Mitigation and Response Strategies Reshape their Land Uses and Urban Centers*. Poster presented at 9th Annual Susquehanna River Symposium, Bucknell University, Lewisburg PA, November 21, 2014.
- Duke, L. Donald; Kalnins, Ellen; and Murphy, Ryan, 2013. *Floods on the Susquehanna: A Comparative Analysis of Flood Mitigation Policies in Ten River Towns of the Susquehanna River Heartland*. Poster presented at 8th Annual Susquehanna River Symposium, Bucknell University, Lewisburg PA, October 31, 2013.
- Federal Emergency Management Agency, accessed 2014. "Flood Proofing Regulations." Floodsmart.gov
- Hayes, Benjamin, 2013. "Major Floods in the Susquehanna Watershed." *Bucknell River Reporter*, v 1 n 1, Winter 2013.
- Smith, Chad, 2014. Borough Manager, Borough of Lewisburg. Personal communication, June, 2014; August 2014; and July 2015.

- Lycoming County PA, 2010. *Lycoming County Hazard Mitigation Plan*. Williamsport, PA: Lycoming County Planning and Community Development. http://www.lyco.org/Portals/1/PlanningCommunityDevelopment/Documents/haz_mit_plan/lycoming_co_hmp_26may2011_smaller.pdf. Accessed August 10, 2014.
- Pennsylvania Emergency Management Administration (PEMA), 2012. “National Flood Insurance Program and Community Rating System, Flood Mitigation Assistance Program (FMA).” Retrieved from <http://www.portal.state.pa.us>.
- Union County, PA, ca. 2014. “Union County Demographic Digest.” Accessed at unioncountypa.org, July 2014.
- Union County, PA, 1975. *Comprehensive Plan: A Plan for Development, 1975*. Lewisburg, PA: Union County.
- U.S. Census Bureau, ca. 2014a. “State & County Quick Facts.” Accessed at quickfacts.census.gov, July 2014.
- U.S. Census Bureau, ca. 2014b. “Populations of Interest – Municipalities and Townships.” Accessed at http://www.census.gov/govs/go/municipal_township_govs.html, July 2014.
- U.S. Code of Federal Regulations, 2015. Floodplain Management Regulations: Adopted Pursuant to the PA Floodplain Management Act (Act 166) of 1978 §201 &202.
- U.S. Code of Federal Regulations, 2015. Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 93-288, as amended, 42 U.S.C. 5121 et seq.

Section 3. Lititz, PA Stream Restoration as Flood Mitigation

- Burns, Patrick. "For those about to rock." *Lititz Record Express*, April 23, 2014.
- Commonwealth of Pennsylvania. Pennsylvania Office of the Budget. 2015. http://www.portal.state.pa.us/portal/server.pt/community/redevelopment_assistance_capital_program/4602/what_is_racp_/1162260.
- Commonwealth of Pennsylvania. Pennsylvania Office of the Budget. 2015. http://www.portal.state.pa.us/portal/server.pt/community/redevelopment_assistance_capital_program/4602/what_is_racp_/1162260.
- Edwards, R. E., & Pody, R. D. *Northern Lancaster County Groundwater Study: A Resource Evaluation of the Manheim-Lititz and Ephrata Area Groundwater Basins (Susquehanna River Basin Commission, 2005)*.
- Kobell, R. “Green Infrastructure Jobs Outpacing Pool of Skilled Workers.” *Bay Journal* (May 28, 2014): http://www.bayjournal.com/article/green_infrastructure_jobs_outpacing_pool_of_skilled_workers.
- LandStudies. "Floodplain Restoration." Lititz, 2007.
- LandStudies, *Santo Domingo Creek Floodplain Restoration Design Report: Rock Lititz Site* (Lititz, PA: LandStudies, 2013).
- LandStudies, *Post Construction Stormwater Management Plan for the Santo Domingo Creek Floodplain Restoration at Rock Lititz* (Lititz, PA: LandStudies, 2014).
- Merritts, D., Walter, R., & Rahnis, M. A. *Sediment and Nutrient Loads From Stream Corridor Erosion Along Breached Millponds*. (Lancaster, PA: Franklin & Marshall College, 2010).

- PA DEP. "BMP 6.7.4: Floodplain Restoration." *Pennsylvania Stormwater Best Management Practices Manual* (2006).
- PA DEP. *PA DEP Final Report. Big Spring Run Natural Floodplain, Stream, and Riparian Wetland — Aquatic Resource Restoration Project Monitoring* (PA DEP, 2013).
- PA DEP. *Applying Principles for the Ecological Restoration of Aquatic Resources to Legacy Sediment Problems in Pennsylvania*. 2013. http://www.chesapeakebay.net/channel_files/20853/legacy_sediment_pa_july_16_2013.pdf.
- PA DEP. *State Water Plan* (Harrisburg: PA DEP, 2009).
- "Pennsylvania Chesapeake Watershed Implementation Plan." 2011. *PA DEP*.
- Walter, R. C., & Merriitts, D. J. "Natural Streams and the Legacy of Water-Powered Mills." *Science* 319 (January 18, 2008): 299–304.

Section 4. California Land Use as Flood Mitigation

- World Metrological Organization / Global Water Partnership, 2008. *The Role of Land-Use Planning in Flood Management – A Tool for Integrated Flood Management*. Associated Programme on Flood Management Technical Document No. 12, Flood Management Tools Series. http://www.apfm.info/publications/tools/Tool_07_The_Role_of_Land_Use_Planning_in_FM.pdf
- California Department of Water Resources (CDWR), 2014a. *Guidance on General Plan Amendments for Addressing Flood Risk*.
- CDWR, 2014b. *Addendum to Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities*. http://www.water.ca.gov/cvfm/docs/DWR-2014-Guidance-on-GP-Amendments-for-Flood-Risk_SEPT2014.pdf
- CDWR, 2013. *Urban Level of Flood Protection Criteria*.
- CDWR, 2012. *Central Valley Flood Protection Plan*, 2012.
- CDWR, 2010. *Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities*. http://www.water.ca.gov/floodmgmt/lrafmo/fmb/docs/Oct2010_DWR_Handbook_web.pdf.
- CDWR, 2011. *Draft Central Valley Flood Protection Plan. December 2011*.
- Casilear, Geo. W. and Henry Bainbridge, 1850. "View of Sacramento City as it appeared during the great inundation in January 1850." Library of Congress, <https://www.loc.gov/item/96505338/#about-this-item> Accessed December 2015.
- Central Valley Flood Protection Board, 2012. "Adopted Resolution 2012-25 Providing the Board's Vision for and Adoption of the 2012 Central Valley Flood Protection Plan and Providing a Framework for Interpretation and Implementation of the Plan." June 2012.
- Dessai, S. and M. Hulme, 2003. "Does Climate Policy Need Probabilities?" School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK, and Tyndall Centre for Climate Change Research, UK, Tyndall Centre Working Paper No. 34, August 2003.
- U.S. Army Corps of Engineers (USACE) Institute for Water Resources, ca. 2013. "Partners in Shared Responsibility." <http://www.iwr.usace.army.mil/Missions/FloodRiskManagement/FloodRiskManagementProgram/PartnersinSharedResponsibility.aspx> Accessed January 2015.

Section 5. California statewide drought mitigation

- Association of California Water Agencies, 2015. Save Our Water Campaign Launches Revamped Website. <http://www.acwa.com/news/conservation/save-our-water-campaign-launches-revamped-website>. Last accessed on August 23, 2015.
- California Department of Water Resources (CDWR), 2015. The Water Conservation Act of 2009. <http://www.water.ca.gov/wateruseefficiency/sb7/>. Last accessed on August 23, 2015.
- CDWR, 2015b. California Statewide Groundwater Elevation Monitoring (CASGEM). <http://www.water.ca.gov/groundwater/casgem/>. Last accessed on August 23, 2015.
- CDWR, 2015c. *2015 Water Year - Current Drought Conditions and Where We Go from Here*. A presentation before Delta Stewardship Council. <http://mavensnotebook.com/2015/05/06/delta-stewardship-council-drought-update-water-management-actions-and-the-status-of-delta-fisheries/>
- CDWR, 2015d. *Groundwater Level Change from Spring 2012 to Spring 2015. July*. http://water.ca.gov/groundwater/maps_and_reports/MAPS_CHANGE/DOTMAP_S2015-S2012.pdf. Last accessed December 2015.
- CDWR, 2015e. *2015 Water Year – Current Drought Conditions and Where We Go from Here*. Presentation by Jeanie Jones before California Delta Stewardship Council, April 23, 2015.
- CDWR, 2014. California Water Plan Update 2013. October. <http://www.waterplan.water.ca.gov/cwpu2013/final/index.cfm>. Last accessed December 2015.
- CDWR, 2013. *California Water Plan*. <http://www.waterplan.water.ca.gov/>. Last accessed on August 23, 2015.
- CDWR, 2012. *2010 Urban Water Management Plans*. A report to the Legislature pursuant to Section 10644(b) of the California Water Code.
- California State Water Resources Control Board (CSWRCB), 2009. *Recycled Water Policy*. http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/recycledwaterpolicy_approved.pdf. Last accessed on August 23, 2015.
- CSWRCB, 2015. “Temporary Water Transfers Information and Guidance.” http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/infosheets/infosheet_ttransfer.pdf. Last accessed on August 23, 2015.
- Jet Propulsion Laboratory, 2014. “NASA Data Underscore Severity of California Drought.” *News: December 16, 2014*. California Institute of Technology. <http://www.jpl.nasa.gov/news/news.php?feature=4412>. Last accessed on August 23, 2015.
- National Drought Mitigation Center (NDMC), 2016. “Welcome to the National Drought Mitigation Center,” <http://drought.unl.edu/>
- The Sacramento Bee, 2015a. California cities fret over tiered water rates after court decision. <http://www.sacbee.com/news/state/california/water-and-drought/article19194072.html>, April 21. Last accessed on August 23, 2015.
- The Sacramento Bee, 2015b. California Supreme Court won’t budge on water rates. <http://www.sacbee.com/news/state/california/water-and-drought/article28414762.html>, July 23. Last accessed on August 23, 2015.
- Svoboda, Mark. National Drought Mitigation Center, 2015. “Drought Monitor: CONUS, May 15, 2015.” <http://droughtmonitor.unl.edu/>

United States Drought Monitor, 2015. Drought Maps of California and Continent United States for 5/10/2011, 5/8/2012, 5/7/2013, 5/6/2014, 5/5/2015. <http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx>. Last accessed December 2015.

Section 6. Hillsborough River, FL low flow mitigation

Call, Ed, 2015. Southwest Florida Water Management District. Personal communication, March 2015.

Chamberlain, Joanne, 2015. St. Johns River Water Management District. Personal communication, February 2015.

Christaldi, Ronald, 1996. *Sharing the Cup: A Proposal for the Allocation of Florida's Water Resources*. Florida State University Law Review.

City of Tampa, 2015a. "Fact Sheet: History of the City of Tampa Water Department." http://www.tampagov.net/sites/default/files/water/files/fact_sheet_twd_history.pdf. Accessed August 2015.

City of Tampa, 2015b. "City of Tampa Water Department Fast Facts." <http://www.tampagov.net/sites/default/files/water/files/Forms-Publications/Fact-Sheets-Brochures/Fact-Sheet-Fast-Facts.pdf>. Accessed August 2015.

Dellapenna, Joseph, 2004. "Riparianism at the Dawn of the New Millennium." *Proceedings, ASCE World Water Congress 2001*.

Dellapenna, Joseph, 2004. "Adapting Riparian Rights to the Twenty-first Century." *West Virginia Law Review*, 106:539-594.

Demographia, ca. 2000. "Top 50 Metropolitan Areas in 1996: Population Increase from 1950." <http://www.demographia.com/dm-usmet-fr50.htm>. Accessed August 2015.

Duke, L. Donald and Blankenship, Haisley, 2015. *How Low can it Flow? Effectiveness of Implementation of Florida's Minimum Flows and Levels Regulations*. Poster presented at Florida Gulf Coast University Research Day, April 17 2015.

Flannery, S., 2014. Southwest Florida Water Management District. Personal Communication, August 2014.

Florida Code, Chapter 373.042, 2015. http://leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&Search_String=373.042&URL=0300-0399/0373/Sections/0373.042.html. Accessed March 20, 2015.

Florida Department of Environmental Protection (FDEP), ca. 2014. "The Water Management Districts." www.dep.state.fl.us/secretary/watman/default.htm. Accessed July 2014.

FDEP, 2014. "Local Sources First," fact sheet posted at <https://www.dep.state.fl.us/water/waterpolicy/docs/factsheets/wrfss-local-sources-first.pdf>.

FDEP, 2015. "Minimum Flows and Levels." (www.dep.state.fl.us/water/waterpolicy/mfl.htm). Accessed August 2015.

Guillory, Marjorie F.; McNeal, Mark B.; Ellison, Donald L.; and Wachter, Paul C., III, ca. 2012. "Tampa's Integrated ASR Program: Optimization of Supply to Meet Demand." Southwest Florida Water Management District. http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/tampasintegratedasr-program-optimizationsupplymeetdemand.pdf. Accessed August 2015.

- Leeper, Douglas A., 2009. *Middle Hillsborough River: Water Levels, Water Quality and Water Management*. SWFWMD.
- McConnell, Robert; Pribble, Ray; and Janicki, Anthony, 2014. "Linking MFLs and TMDLs – Recent Case Studies in Southwest Florida." Oral presentation, Fourth University of Florida Water Institute Symposium, February 2014.
- McConnell, Robert. Manager, Drinking Water and Environmental Permitting, Tampa Bay Water. Personal communication, August 28, 2015; and September 3, 2015.
- Munson, Adam, Marty Kelly, Jonathan Morales and Doug Leeper, 2007. *Proposed Minimum Flows and Levels for the Upper Segment of the Hillsborough River, from Crystal Springs to Morris Bridge, and Crystal Springs*. SWFWMD.
- National Weather Service (NWS) Forecast Office, 2015. "Tampa Bay, Florida." <http://www.srh.noaa.gov/images/tbw/climate/tpaannnorm.pdf>. Accessed August 2015.
- Rand, Honey, 2003. *Water Wars: A Story of People, Politics, and Power*. Xlibris.
- Regan, Kevin E., 2003. *Balancing Florida Water Supply and Adverse Environmental Impacts under Florida Water Law: From Water Wars toward Adaptive Management*. Florida State University Law Review. 19:123-185.
- St. Johns River Water Management District (SJRWMD), 2008. *Minimum Flows and Levels*. http://floridaswater.com/minimumflowsandlevels/pdfs/SJRWMD_MFLs_Method_Paper_2008.pdf. Accessed April 2015.
- SJRWMD, ca. 2015. *Minimum Flows and Levels*. <http://floridaswater.com/rules/pdfs/40C-8.pdf>; <http://floridaswater.com/minimumflowsandlevels/>. Accessed April 2015.
- Southwest Florida Water Management District (SWFWMD), 1999. *An Analysis of Hydrologic and Ecological Factors Related to the Establishment of Minimum Flows for the LHR*. Peer Review Final Draft.
- SWFWMD, 2005. *Minimum Flows for the Tampa Bypass Canal, Tampa, Fl.*
- SWFWMD, 2006. *Lower Hillsborough River Low Flow Study Results and Minimum Flow Recommendation*. Draft.
- SWFWMD, 2007. "Joint Funding Agreement between the Southwest Florida Water Management District and the City of Tampa for Implementation of Recovery Projects to Meet the Minimum Flow of the Lower Hillsborough River." http://www.swfwmd.state.fl.us/files/database/site_file_sets/1960/40D-080.0738a_Joint_Funding_Agmt_Between_SWFWMD__City_of_Tampa-L_Hillsborough_River.pdf. Accessed August 2015.
- SWFWMD, 2009. *Results of Blue Sink Pumping Test No. 2, Hillsborough County Florida*.
- SWFWMD, 2009. *Middle Hillsborough River: Water Levels, Water Quality and Water Management*. www.swfwmd.state.fl.us/projects/mfl/reports/draft_middle_hills_river_report_2009-02-13.pdf.
- SWFWMD, 2010. *Results of Morris Bridge Sink Pumping Test, Hillsborough County Florida*. Final Report.
- SFWMD Resource Projects Department, 2012. "Minimum and Guidance Levels for Lake Wimauma in Hillsborough County, Florida." https://www.swfwmd.state.fl.us/projects/mfl/reports/lakes/WimaumaMFL_Final_March202012.pdf. Accessed April 2015.

- SWFWMD, 2014. *Support Document: Water Supply Plan Update, 2011-14*. http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/2011-2013_water_supply_plan_support_doc.pdf. Accessed August 2015.
- SWFWMD, ca 2015. "Projects & Programs, Minimum Flows and Levels (Environmental Flows)." <https://www.sfwmd.state.fl.us/projects/mfl/>. Accessed April 2015.
- Swihart, Tom, 2011. *Florida's Water: A Fragile Resource in a Vulnerable State*. Washington, D.C.: RFF Press.
- Tampa Bay Water, 2015. "About Tampa Bay Water." <http://tampabaywater.org/>. Accessed August 10, 2015.
- Tampa Bay Water, 2012. "Tampa Bay Water Moving Into a Phase 3 Regional Water Shortage." Clearwater, Florida: Tampa Bay Water. <http://www.tampabaywater.org/newsroom/agency-news/ArtMID/3314/ArticleID/180/Tampa-Bay-Water-Moving-Into-a-Phase-3-Regional-Water-Shortage.aspx>. Accessed August 2012.
- United States Army Corps of Engineers, 2015. *Approval of the Review Plan for the Lower Hillsborough Food Detention Area and Tampa Bypass Canal Master Water Control Manual, Four River Basins Project*. <http://www.saj.usace.army.mil/Portals/44/docs/Planning/ReviewPlans/LowerHillsbAndTampaBypassCanalMasterWCMapproval.pdf>.
- United States Census Bureau, 2015. "Quick Facts: Florida." <http://www.census.gov/quickfacts/table/PST045215/00,12>. Accessed August 2015.
- United States Geological Survey (USGS), 2008. "Water use in Florida, 2005 and trends 1950-2005." <http://pubs.usgs.gov/fs/2008/3080>. Accessed July 2014.

Appendix A

- Arnold, Joseph L., 1988. *The Evolution of the 1936 Flood Control Act*. Fort Belvoir, VA: Office of History, United States Army Corps of Engineers.
- American Water Resources Association (AWRA), 2012. *Case Studies in Integrated Water Resources Management: From Local Stewardship to National Vision*. Middleburg, VA: American Water Resources Association Policy Committee, 2013. Brenda Bateman and Racquel Rancier, editors.
- American Water Resources Association, 2011. "AWRA Policy Statement: Integrated Water Resources Management in the US. Approved by the Board of Directors of the American Water Resources Association at their January 21-22, 2011 meeting, as proposed by the Policy Technical Committee of AWRA." www.awra.org/policy/policy-statements-IWRM.html
- ASFPM ASFPM (ASFPM), 2007. *National Flood Programs and Policies in Review – 2007*. http://www.floods.org/PDF/ASFPM_NFPPR_2007.pdf. Madison, WI: Association of State Floodplain Managers. Accessed August 31, 2014.
- Black, Peter E., 2012. "The U.S. Flood Control Program at 75: Environmental Issues." *Journal of the American Water Resources Association (JAWRA)*, v. 48 n. 2, p. 244-255.
- Dennis, Lauren; Bateman, Brenda O.; Wright, Wayne; and Duke, L. Donald, 2013. *Proactive Flood and Drought Management: A Selection of Applied Strategies and Lessons Learned from Around the United States*. Middleburg VA: American Water Resources Association. http://www.awra.org/webinars/AWRA_report_proactive_flood_drought_final.pdf.
- Duke, L. Donald; McLaughlin, Seamus; and Weitzel, Michele, 2014. *Floods on the Susquehanna: Small River Towns' Flood Mitigation and Response Strategies Reshape their Land Uses and Urban*

- Centers*. Presented at 9th Annual Susquehanna River Symposium, Bucknell University, Lewisburg PA, November 21 2014.
- Dunning, Mark, 2015. Former Chief, Program Analysis Division, U.S. Army Corps of Engineers; and former President, 2014, American Water Resources Association. Personal communication, December 30, 2015.
- Johnson, Leland R, 2010. "Engineering the Ohio," pp 180-209 in Reid, Robert L., *Always a River: The Ohio River and the American Experience*. Bloomington IN: Quarry Press/University of Indiana Press.
- Johnson, James, 2014. Former Chief, Planning and Policy Division, Office of the Deputy Commissioner for Civil Works, U.S. Army Corps of Engineers. Personal communication, June 11 2014.
- Langbein, W.B., 1953. "Flood Insurance." *Land Economics* v. 29 n. 4, p. 232-230.
- Lycoming County PA. 2010. *Lycoming County Hazard Mitigation Plan*. Williamsport, PA: Lycoming County Planning and Community Development. http://www.lyco.org/Portals/1/PlanningCommunityDevelopment/Documents/haz_mit_plan/lycoming_co_hmp_26may2011_smaller.pdf. Accessed August 10, 2014.
- McCullough, David, 1968. *The Johnstown Flood*. New York: Simon and Shuster.
- National Research Council [NRC], 2000. *Risk Analysis and Uncertainty in Flood Damage Reduction Studies*.
- O'Neill, Karen (2006). *Rivers by Design: State Power and the Origins of U.S. Flood Control*. Durham, NC: Duke University Press.
- Smallwood, J.B.; and Izlar, Robert L., 2007. "Water Use," in *The New Encyclopedia of Southern Culture, Volume 8: Environment*, Martin Melosi ed. Chapel Hill NC: The University of North Carolina Press.
- Steinberg, Ted, 2006. *Acts of God: The Unnatural History of Natural Disaster in America*. Second edition. Oxford: Oxford University Press.
- U.S. War Department, 1946. *Annual Report of the Chief of Engineers, U.S. Army, 1946 in two parts, Part 1 Vol. 1*. 80th Congress, 1st Session, House Document No. 5. Washington D.C.: U.S. Government Printing Office. Accessed July 2011 at Hathi Trust Digital Library, <http://babel.hathitrust.org/cgi/pt?id=uiug.30112106730275;view=1up;seq=1>.
- U.S. Army Corps of Engineers (USACE), 1983. *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*. Accessed June 2011 at http://planning.usace.army.mil/toolbox/library/Guidance/Principles_Guidelines.pdf.
- USACE, 2000. *Planning Guidance Notebook, Engineer Regulation 1105-2-100*, Washington D.C.: U.S. Army Corps of Engineers. Accessed June 2011 at <http://planning.usace.army.mil/toolbox/library/ERs/entire.pdf>.
- USACE, 1950. *Report to the Federal Inter-Agency River Basin Committee: Proposed Practices for Economic Analysis of River Basin Projects*. Accessed July 2014 at <http://planning.usace.army.mil/toolbox/guidance.cfm?Id=269&Option=Principles%20and%20Guidelines>.
- U.S. Code of Federal Regulations [CFR], 2014. "Stafford Act," title 42 §203 5133.
- U.S. Department of the Army, 1953. *Annual Report of the Chief of Engineers, U.S. Army on Civil Works, 1953 in two parts, Part 1 Vol. 1*. Washington D.C.: U.S. Government Printing Office. Accessed July 2014 at Hathi Trust Digital Library, <http://babel.hathitrust.org/cgi/pt?id=uiug.30112042521101;view=1up;seq=3>.

- U.S. Department of the Army, 1956. *Annual Report of the Chief of Engineers, U.S. Army on Civil Works, 1956 in two volumes, Vol. 1*. Washington D.C.: U.S. Government Printing Office. Hathi Trust Digital Library, <http://babel.hathitrust.org/cgi/pt?id=uiug.30112042521150;view=1up;seq=3>.
- United States Federal Emergency Management Agency, 2013. National Flood Insurance Program Flood Insurance Manual, effective October 1 2013. <http://www.fema.gov/media-library/assets/documents/34745>. Last updated September 23, 2013.
- U.S. War Department, 1946. *Annual Report of the Chief of Engineers, U.S. Army, 1946 in two parts, Part 1 Vol. 1*. 80th Congress, 1st Session, House Document No. 5. Washington D.C.: U.S. Government Printing Office. Accessed July 2014 at Hathi Trust Digital Library, <http://babel.hathitrust.org/cgi/pt?id=uiug.30112106730275;view=1up;seq=1>.
- Water Resources Council [WRC], 1973. "Establishment of Principles and Standards for Planning, Part III." *Federal Register*, Volume 38, Number 74 on September 10, 1973.