



Passive Flood Barrier: Survey of Practice

Requested by
Craig Tomimatsu, Office of Hydraulics and Stormwater Design

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Executive Summary

Background

Climate change has led to a rise in sea level and more frequent high-intensity storms, which increase the potential for flooding segments of California Department of Transportation (Caltrans) roadway and infrastructure in lower-lying areas, including maintenance stations; park-and-ride facilities; and underground facilities such as storage, parking, pumping or transfer stations, equipment and water quality treatment facilities.

Traditional floodgates and temporary flood barriers (such as sandbags, plywood and rubber bladders) may not be effective adaptation measures in areas where access is needed during dry periods and where floods are more frequent. To protect roads and facilities in low-lying areas, Caltrans is evaluating the use of passive flood barrier. These devices are generally used with larger permanent floodwalls or barriers and deployed to protect entryways and other openings. When not in use, these devices are usually recessed into a site so that they are not visible, allowing for normal traffic flow and uninterrupted views. Caltrans is particularly interested in self-activating systems that function without the assistance of maintenance crews. Self-activating barrier provides uninterrupted flood protection, using hydrostatic pressure or action to deploy instead of power or human intervention.

To assist Caltrans in its examination of passive flood barrier systems, CTC & Associates conducted an online survey of state departments of transportation (DOTs) to learn about their experience using these devices. A literature search of domestic and international research that included a review of specific passive flood barrier products and vendors supplemented survey findings.

Summary of Findings

Survey of Practice

An online survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Design, which included members of the Technical Committee on Hydrology and Hydraulics. The survey sought information about state transportation agency experience with passive flood barriers. Respondents could describe up to three passive flood barrier systems. Eleven state transportation agencies responded to the survey.

Nonuse of Passive Flood Barrier

Ten states—Arizona, Illinois, Missouri, Nebraska, North Carolina, Oklahoma, Rhode Island, Utah, Virginia and Wyoming—have never used and are not considering using passive flood barrier systems primarily because flooding is not a common concern in many of these areas. When flooding or overtopping is anticipated, Nebraska DOT and other agencies frequently close these roads with barricades or signage. After flooding in March 2019, Nebraska DOT considered installing some passive flood barriers but did not implement the device. Follow-up inquiries were made to determine whether Nebraska DOT had selected a barrier or barriers after this incident and why the agency did not implement the barrier(s); a response to these inquiries was not received.

Other factors limiting the use of passive flood barrier include insufficient information about barrier implementation, performance, long-term maintenance, cost and liability. Some state transportation agencies such as Illinois DOT no longer have responsibility for flood control. In the 1970s, the agency's Division of Water Resources was transferred to the Illinois Department of Natural Resources (now the Office of Water Resources). Also, the U.S. Army Corps of Engineers manages Illinois' system of levees along the Mississippi River, which is the main source of flooding in the state.

Passive Flood Barrier Use Under Consideration

Nevada DOT is considering using passive flood barrier. Currently when the agency constructs flood control facilities, it closely coordinates efforts with local flood control districts or flood plain managers. Typically these facilities are normal flood control conveyance systems.

Survey respondents from Nevada, North Carolina and Oklahoma DOTs recommended other agencies that may have experience with passive flood barriers.

Related Research and Resources

A literature search of recent publicly available resources identified publications that are organized into three topic areas:

- National guidance.
- State and local research and guidance.
- Selected products and systems.

National Guidance

A July 2013 Federal Emergency Management Agency (FEMA) publication addresses floodproofing for nonresidential buildings. Case studies in this publication and others published separately by FEMA describe the use of passive floodgates, including those installed at multiple entry points in floodwalls protecting hospitals and other buildings. The floodgates installed in a historic Texas library "were made virtually invisible, hidden below vestibule carpeting."

State and Local Research and Guidance

An October 2018 Boston Public Works Department report provides guidance for barrier systems that are deployed before and/or during a flood event and retracted after a flood event. An appendix to the report describes static (shoreline and upland) and dynamic flood barrier types.

Two documents published by A Better City, self-described as "a diverse group of business leaders united around a common goal—to enhance Boston and the region's economic health, competitiveness, vibrancy, sustainability and quality of life," examine the use of flood barrier to protect buildings and infrastructure. A September 2015 briefing document compares three self-activating passive flood barrier products available for protecting buildings and infrastructure: FloodBreak, Self Activating Flood Barrier (SAFB) and Aquafragma. A February 2015 report includes a description of permanent retractable barriers and their benefits and drawbacks; regulatory impacts and requirements; and financing options, incentives and rebates.

Two passive flood barrier systems—FloodBreak automatic floodgates in garage, vehicle and roadway applications, and the HYFLO Self Closing Flood Barrier—are highlighted in an August 2014 New Jersey Department of Environmental Protection report.

Selected Products and Systems

The products and systems provided by five domestic vendors are highlighted:

- *FloodBreak*. Provides multiple barrier types that can be used for below-grade garages, pedestrian pathways, vent openings, levees, service entrances, building perimeters and roadways.
- *Flood Control International Inc.* Offers automatic flood barriers that can operate to self-raise with rising floodwater or operate using push buttons to activate the flood barrier in advance of flooding. The vendor's flood defenses have been installed in Boston, Connecticut, Miami, Arizona and California.
- *Presray Corporation*. Serves as the North American dealer of HYFLO's Self Closing Flood Barrier, a system that automatically deploys a buoyant floodwall from below grade to protect against high water. The company also markets a product for use in parking garages and other facilities with large openings.
- *PS Industries Inc.* Provides a barrier product for use in protecting walk doors, retaining walls, driveways, storefronts or loading docks/ramps during flash flooding conditions.
- *Walz & Krenzer, Inc.* Offers the AutoSeal Watertight Roller Curtain Door, which functions as an overhead roller curtain door that becomes watertight at the touch of a button, or automatically when water levels reach a preset level. The company's AutoRising Flood Gate uses buoyancy and a spring assist to automatically deploy when water is at a predetermined level.

The products and systems of five international vendors are also described:

- *Aquafragma*. Offers a self-activating barrier that can be used "in front of building entrances, along rivers and canals, along coastal promenades and at the crest of basement ramps."
- *AWMA Water Control Solutions*. Provides demountable, portable and permanent flood barriers that can be manually operated, automated or self-regulating.
- *DENIOS*. Markets a flood "wall" for installation at doorways that provides "all the durable construction and operational characteristics of [a] doorway spill barrier but is designed specifically for floodwaters."
- *Hunton Engineering Design Ltd.* Produces a fully automated floodgate by incorporating hydraulic or mechanical means of operation. Gates can be operated locally for access to a river and operated automatically by responding to ultrasonic level detection or remote direction from a control center.
- *HYFLO B.V.* Offers the Self Closing Flood Barrier, which was developed in the Netherlands "to protect people and property from inland waterway floods caused by heavy rainfall, gales or rapid melting snow."

Gaps in Findings

The survey received a limited response, and none of the 11 agencies responding to the survey reported experience with the type of passive flood barrier of interest to Caltrans. The literature search also produced a limited amount of research and other resources that address the use of passive flood barrier. Supplemental contacts provided by survey respondents, which were not

pursued in connection with this report, could be included in a follow-up effort to gather additional information.

Next Steps

Moving forward, Caltrans could consider:

- Contacting Nevada DOT about its plans to consider using passive flood barrier.
- Consulting with the Nebraska DOT respondent to determine:
 - If the agency selected a passive flood barrier or barriers for consideration after flooding in March 2019.
 - Why the agency chose not to install the barrier(s).
- Following up with the additional contacts recommended by survey respondents:
 - Clark County Regional Flood Control District (Nevada).
 - Local agencies in Oklahoma.
 - South Carolina DOT.
- Examining vendor resources and other publications in detail to identify current users of passive flood barrier products and systems that can be contacted to learn more about the installation, use and maintenance of these systems.
- Seeking the feedback of other state DOTs not responding to the survey.
- Following up with a more comprehensive examination of flood barrier products, including deployable temporary barriers and other traditional systems.

Detailed Findings

Background

Climate change has led to a rise in sea level and more frequent high-intensity storms, which increase the potential for flooding segments of California Department of Transportation (Caltrans) roadway and infrastructure in lower-lying areas, including maintenance stations; park-and-ride facilities; and underground facilities such as storage, parking, pumping or transfer stations, equipment and water quality treatment facilities.

Traditional floodgates and temporary flood barriers (such as sandbags, plywood and rubber bladders) may not be effective adaptation measures in areas where access is needed during dry periods and where floods are more frequent. To protect roads and facilities in low-lying areas, Caltrans is evaluating the use of passive flood barrier. These devices are generally used with larger permanent floodwalls or barriers and deployed to protect entryways and other openings. When not in use, these devices are usually recessed into a site so that they are not visible, allowing for normal traffic flow and uninterrupted views. Caltrans is particularly interested in self-activating systems that function without the assistance of maintenance crews. Self-activating barrier provides uninterrupted flood protection, using hydrostatic pressure or action to deploy instead of power or human intervention.

To assist Caltrans in its examination of passive flood barrier systems, CTC & Associates conducted an online survey of state departments of transportation (DOTs) to learn about their experience using these devices. The survey inquired about the features and functionality of passive flood barrier systems in use, initial and long-term costs, as well as the benefits and limitations of these devices. In addition to the survey, a literature search of domestic and international research was conducted that included a review of specific passive flood barrier products and vendors.

This Preliminary Investigation presents the findings from these efforts in the following topic areas:

- Survey of practice.
- Related research and resources.

Survey of Practice

An online survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Design, which included members of the Technical Committee on Hydrology and Hydraulics. The survey sought information about state transportation agency experience with passive flood barriers. Respondents could describe up to three passive flood barrier systems.

Survey questions are provided in [Appendix A](#). The full text of survey responses is presented in a supplement to this report.

Summary of Survey Results

Eleven state transportation agencies responded to the survey:

- Arizona.
- Illinois.
- Missouri.
- Nebraska.
- Nevada.
- North Carolina.
- Oklahoma.
- Rhode Island.
- Utah.
- Virginia.
- Wyoming.

Ten agencies have never used and are not considering using passive flood barrier systems to protect segments of roadways and infrastructure in low-lying areas. Nevada DOT is the only agency considering using passive flood barrier for this purpose. Survey responses from the 10 agencies not using passive flood barrier and from Nevada DOT are summarized below.

Nonuse of Passive Flood Barrier

Ten states—Arizona, Illinois, Missouri, Nebraska, North Carolina, Oklahoma, Rhode Island, Utah, Virginia and Wyoming—have never used and are not considering using passive flood barrier systems primarily because flooding is not a common concern in many of these areas. When flooding or overtopping is anticipated, Nebraska DOT and other agencies frequently close these roads with barricades or signage. After flooding in March 2019, Nebraska DOT considered installing some passive flood barriers but did not implement the device. The Nebraska DOT respondent did not reply to follow-up inquiries to clarify if a barrier had been selected and if so, why the barrier was not implemented.

Other factors limiting the use of passive flood barrier include insufficient information about barrier implementation, performance, long-term maintenance, cost and liability. Some state transportation agencies such as Illinois DOT no longer have responsibility for flood control. In the 1970s, the agency’s Division of Water Resources was transferred to the Illinois Department of Natural Resources (now the Office of Water Resources). Also, the U.S. Army Corps of Engineers manages Illinois’ system of levees along the Mississippi River, which is the main source of flooding in the state (see [Related Resources](#) below). (The Illinois DOT respondent noted that the Corps of Engineers may also manage levees on the Illinois River.)

Table 1 presents survey responses by topic area.

Table 1. Factors Limiting the Use of Passive Flood Barrier

Factor	State	Description
Cost	North Carolina, Rhode Island	<i>North Carolina.</i> Issues with cost. <i>Rhode Island.</i> Lack of cost data.
Implementation	North Carolina	Difficulties with implementation.
Infrequent Flooding	Utah, Virginia	<i>Utah.</i> Flooding is uncommon; some flash floods in desert areas.

Factor	State	Description
Lack of Experience	Missouri, Nebraska	<p><i>Missouri.</i> No experience with this type of passive flood barrier.</p> <p><i>Nebraska:</i></p> <ul style="list-style-type: none"> • No need to use automatically deploying passive barriers to protect against flash flooding or highway flooding. • When highway overtopping is anticipated, maintenance personnel place barricades and signing/messaging to keep drivers from driving through low spots. • Most highways are in rural areas. The respondent is unfamiliar with municipal locations where passive barriers would be more beneficial.
Maintenance	North Carolina	Concerns with long-term maintenance.
Performance	Rhode Island	Lack of data about device effectiveness.
Other	Arizona, Illinois, North Carolina, Oklahoma, Wyoming	<p><i>Arizona.</i> The agency conveys the roadway crossing flow and provides first flood retention.</p> <p><i>Illinois.</i> Flood control management is the responsibility of Illinois Department of Natural Resources and U.S. Army Corps of Engineers (see Related Resources below).</p> <p><i>North Carolina.</i> Concerns about liability.</p> <p><i>Oklahoma.</i> When a highway is overtopped, the agency typically closes roads with barriers.</p> <p><i>Wyoming.</i> Most facilities are located on terrain where a passive flood barrier is unnecessary or impractical.</p>

Related Resources

Illinois

Office of Water Resources, Illinois Department of Natural Resources, undated.

<https://www2.illinois.gov/dnr/WaterResources/Pages/MissionAndStructure.aspx>

In the 1970s the Division of Water Resources was moved from Illinois DOT to the state Department of Natural Resources. The office's Division of Capital Programs administers the urban flooding mitigation program and serves as the technical liaison to the Illinois Emergency Management Agency.

Mississippi Valley Division, U.S. Army Corps of Engineers, undated.

<https://www.mvd.usace.army.mil/>

The U.S. Army Corps of Engineers manages the system of levees along the Mississippi River, which is the main source of flooding in Illinois. This web site provides links to the Mississippi River and Tributaries Project and the Rock Island District, which manages the Illinois Waterway.

Passive Flood Barrier Use Under Consideration

Nevada DOT is considering using passive flood barrier. Currently when the agency constructs flood control facilities, it closely coordinates efforts with local flood control districts or flood plain managers. Typically these facilities are normal flood control conveyance systems. (*Note:* See **Additional Contacts** below for a reference to Clark County Regional Flood Control District in Nevada, which may have experience using passive flood barriers.)

Additional Contacts

Survey respondents from Nevada, North Carolina and Oklahoma DOTs recommended other agencies that may have experience with passive flood barriers:

- *Nevada DOT:*

Clark County Regional Flood Control District
600 S. Grand Central Parkway, Suite 300
Las Vegas, NV 89106-4511
702-685-0000
<https://www.regionalflood.org/home>

- *North Carolina DOT:*

Tom Knight
Director, Policy and Engineering
South Carolina DOT

Note: The respondent indicated that South Carolina DOT used passive flood barrier during Hurricane Florence in 2018.

Note: At the time of publication, CTC was unable to locate contact information for Knight.

- *Oklahoma DOT:* Any city or town in the state.

Related Research and Resources

A literature search of recent publicly available resources identified publications that are organized into three topic areas:

- National guidance.
- State and local research and guidance.
- Selected products and systems.

National Guidance

Chapter 4, Other Flood Protection Measures, Floodproofing Non-Residential Buildings, Federal Emergency Management Agency, July 2013.

https://www.fema.gov/media-library-data/1541615774329-170190ea05ddb66f5f1170a018d41/P-936_11-06-18_508r.pdf

Emergency measures, including temporary flood barriers, are discussed beginning on page 4.24 of the report (page 142 of the PDF).

A case study describing use of passive floodgates begins on page 4-7 (page 125 of the PDF). *Best Practice—Floodwall System With Passive Floodgates Protects Two Hospitals* describes a FloodBreak installation of passive floodgates at 11 entry points in a floodwall protecting a New York hospital.

Note: The three Federal Emergency Management Agency (FEMA) case studies cited below highlight and expand on the use of passive flood barrier to protect buildings.

Floodwall With Passive Floodgates Signals Commitment to Patients and Community, Federal Emergency Management Agency, June 2020.

<https://www.fema.gov/node/453383>

From the web page: Columbus Regional Hospital, the only hospital serving Bartholomew County, Indiana, is now protected from future flooding thanks to hazard mitigation and a floodwall with passive floodgates.

The floodwall with passive floodgates, built with hazard mitigation funds from the Federal Emergency Management Agency (FEMA) and Columbus Regional Hospital, will protect this vital hospital from catastrophic flood damage, should the area be hit with flooding as was the case in 2008.

....

FEMA approved and provided 75-percent funding and a floodwall was designed to protect the entire hospital campus. Construction on the \$4.7 million floodwall started in June 2011 and was completed in April 2012. The 2,400 foot floodwall was built two feet higher than the 100-year flood elevation and includes 15 passive floodgates at all entry points, which allow unimpeded access by vehicles and pedestrians during dry times, and automatically deploy without reliance on power or personnel if flooding occurs.

Preserving and Protecting a Community Treasure: The Historic Rosenberg Library in Galveston, Texas, Federal Emergency Management Agency, June 2020.

<https://www.fema.gov/node/454265>

From the web page: The first floor of the historic Rosenberg Library located in Galveston, Texas, a barrier island 40 miles south of Houston, was severely damaged by Hurricane Ike storm surge. Thanks to flood mitigation funds from FEMA, flood insurance reimbursements, the state of Texas and private donations, it is now fully restored and protected from future storms.

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As part of the renovations, passive automatic flood barriers, aquarium glass and other flood control measures were installed to protect the facility from a 500-year flood event and allow it to continue its service to the Galveston community. A critical component of the renovation was preserving the historic building's architectural beauty. Floodproofing measures were selected to blend with architectural features. The flood gates were made virtually invisible, hidden below vestibule carpeting and the standard aluminum wiper walls were replaced by the polished concrete walls, stained to match the historic building interior.

Advanced Mitigation Planning Allows Hospital to Stay Dry During Tropical Storm: Full Mitigation Best Practice Story, Federal Emergency Management Agency, 2012.

https://secureservercdn.net/72.167.241.134/dgs.80b.myftpupload.com/wp-content/uploads/2012/08/FEMA_FloodMitigationBestPractice_Lourdes-Hospital_Detail-copy.pdf

From the document: Lourdes Hospital, located in the picturesque city of Binghamton (pop. 47,376) and surrounded by rolling hills and rivers, averted major storm damage thanks to hazard mitigation and a new floodwall.

The floodwall with passive floodgates, built with hazard mitigation funds from the Federal Emergency Management Agency (FEMA) and New York State, protected this vital property from floodwaters that devastated other parts of the city during Tropical Storm Lee.

State and Local Research and Guidance

Massachusetts

Section 7.0, Deployable Flood Barrier Guidance, Climate Resilient Design Standards and Guidelines for Protection of Public Rights-of-Way, Boston Public Works Department, October 2018.

https://www.boston.gov/sites/default/files/file/document_files/2018/10/section_7.0_deployable_flood_barrier_guidance.pdf

From the description and assumptions: Deployable flood barriers are being employed across the City of Boston during flood events to protect private properties. This section provides guidance for selecting appropriate deployable flood barrier solutions, which are also referred to as temporary flood barrier solutions. Deployable flood barriers are defined as a barrier system that is deployed before and/or during a flood event and retracted after a flood event. The guidance provided is modeled after the *Temporary and Demountable Flood Protection Guide*, developed by the Environment Agency of the United Kingdom (Ogunyoye, 2011). Deployable barrier systems types vary and include, but are not limited to, barriers that are:

- pre-installed or partially pre-installed at the location of deployment;
- mobile, i.e., units brought to the location of deployment, constructed, and then removed, such as sand bags;

- passive systems that deploy and retract automatically based on flood levels without human intervention or electricity;
- rigid hard structures (i.e., walls);
- soft flexible structure (i.e., membranes);
- stackable or with features to adjust height of flood protection during an event;
- tubes filled with air or water;
- containers filled with water or aggregate (soil or rock);
- standalone flood defense systems; and/or
- connected to permanent flood protection barriers (such as reinforced walls and doors).

Related Resource:

Appendix A, Overview of Flood Barrier Types, Climate Resilient Design Standards and Guidelines for Protection of Public Rights-of-Way, Boston Public Works Department, February 2018.

https://www.boston.gov/sites/default/files/embed/file/2018-10/appendix_a_-_overview_of_flood_barrier_types.pdf

This document describes static (shoreline and upland) and dynamic flood barrier types.

Passive Flood Barrier Overview and Product Comparisons: A Briefing Document, A Better City, September 2015.

<https://www.abettercity.org/docs-new/2015.09.09%20Passive%20Flood%20Barrier%20Publication.pdf>

From the purpose: This briefing supplies supplemental information on passive floodproofing and expands on the “Retractable Barriers” section of A Better City’s Building Resilience Toolkit [see page 13 for a citation for this toolkit]. It provides a high-level overview of passive barriers followed by a detailed comparative analysis of the three self-activating passive flood barrier products available for protecting buildings and infrastructure: Flood[B]reak, the Self Activating Flood Barrier (SAFB) and Aqua[f]ragma.

Note: This publication highlights a UK Flood Barriers product, Self Activating Flood Barrier. Online references indicate that UK Flood Barriers went into administration March 2018.

Enhancing Resilience in Boston: A Guide for Large Buildings and Institutions, A Better City, February 2015.

<http://abettercity.org/docs/2015.04.08%20large%20building%20%20toolkit.pdf>

From the introduction:

This report builds on a previous GRC-commissioned study *Building Resilience in Boston* and illustrates the climate-related risk potential for commercial buildings, and presents available technologies and solutions for retrofits and new construction. These tools are grouped for buildings inside and outside projected floodplains. A database of 32 technologies and products available to building owners, including their costs, suppliers and applications for addressing storm water management, flood-proofing, sea level rise and the urban heat island effect is provided in the third section of this report and will be continually added to as new technologies and products are developed.

A discussion of permanent retractable flood barriers that begins on page 69 includes a description of the barrier type (see below); benefits and drawbacks; regulatory impacts and requirements; financing options, incentives and rebates; and additional resources that include project examples. *From page 69:*

What Is It?

Temporary flood barriers are effective, but require time and labor to deploy. Depending on site conditions and frequency of flooding, it may be more cost-effective in the long-term to install a permanent, in situ flood barrier. There are many permanent flood barrier options that are passive, recessed into a site and require no deployment. In some cases, hydrostatic pressure from rising floodwaters causes flood barriers to rise from a recessed location until the barrier is fully upright and automatically sealed. Some products (e.g., Aquafragma) will issue warnings before deployment occurs. Other permanent barriers require human intervention, but often have shorter deployment times than temporary barriers. Permanent barriers will easily deploy and retract until end of service life with less setup and cleanup required than temporary barriers. Retractable permanent barriers can be combined with other permanent flood barriers (e.g., flood walls). The retractable barriers can be installed in gaps and entrances in the flood walls to allow for building access and mobility until rising floodwaters necessitate deployment of the retractable barrier.

Regular maintenance will be necessary to ensure the barrier is ready for deployment when a flood occurs, though maintenance will vary depending on the type of barrier installed. As permanent retractable barriers are often recessed into the ground until deployment, installation in existing sites will require construction and excavation. Non-passive barriers will typically require shallower foundations, lowering excavation costs. Consulting an engineer to determine optimal siting and certify structural integrity should also be considered; some suppliers (i.e., FloodBreak) include engineer certification in every purchase.

Related Resource:

Flood Barriers: Install Permanent Flood Barriers: Passive Barriers, Climate Resilience Toolkit, Sustainable Buildings Initiative, A Better City, undated.

<https://challenge.abettercity.org/toolkits/climate-resilience-toolkits/flooding-and-sea-level-rise/flood-barriers?toolkit=202>

This web site provides information similar to what appears in the report cited above and also provides links to passive flood barrier suppliers.

New Jersey

Strategies for Flood Risk Reduction for Vulnerable Coastal Populations Around Barnegat Bay, Qizhong (George) Guo, Yunjie Li, Michael J. Kennish, Norbert P. Psuty, Richard G. Lathrop Jr. and James L. Trimble, New Jersey Governor's Office of Recovery and Rebuilding and New Jersey Department of Environmental Protection, August 2014.

<https://www.nj.gov/dep/docs/flood/final-studies/rutgers-barnegat/barnegat-bay-study-area-flood-mitigation-final-report.pdf>

Beginning on page 158 of the report (page 164 of the PDF) is a summary of available flood defense measures. The summary includes discussion of two passive barrier systems:

- *Automatic floodgates*. Described as a "passive flood barrier system used to close vulnerable openings from being sites of flood penetration. During a flood event, it works automatically without human intervention and power. Automatic floodgate can be used

for commercial, residential, industrial and infrastructure flood defense.” The report includes images illustrating the use of FloodBreak automatic floodgates in garage, vehicle and roadway applications.

- *Self Closing Flood Barrier (SCFB)*. The report highlights the HYFLO SCFB automatic flood defense system and provides an illustration of its “working principle.” The authors also note that the “advantage of this system is that it works automatically without human intervention and power. The disadvantage is that this system can only be used for inland waterway floods since it is not suitable for the fluctuating water levels.”

Selected Products and Systems

Below are resources for passive flood barrier products and systems. Some resources may be used in multiple applications, such as roads and infrastructure; others apply only to facilities and other infrastructure. Resources are presented in two categories: domestic and international vendors. Some of the domestic vendors also have an international presence.

Domestic Vendors

The citations below highlight the products and systems provided by five domestic vendors:

- FloodBreak.
- Flood Control International Inc.
- Presray Corporation.
- PS Industries Inc.
- Walz & Krenzer, Inc.

FloodBreak

FloodBreak: Revolutionary Flood Control, FloodBreak, 2020.

<http://floodbreak.com/>

The company’s home page provides links to drawings, technical specifications and descriptions of FloodBreak installations.

FloodBreak FreeView Levee Topper, FloodBreak, 2020.

<http://floodbreak.com/fvlt/>

From the web site: The FloodBreak FreeView Flood Barrier System is an innovative flood control product that provides permanent passive protection along rivers, levees, lakes and coastlines without blocking views or limiting community access to the water. Designed for long linear runs without stanchions or supports, it can serve as a bike or pedestrian pathway during dry times.

....

No human intervention or power. Like all FloodBreak passive automatic flood barrier systems, FreeView flood barriers provide permanent, 24/7 flood protection while remaining hidden below ground. The FloodBreak FreeView Levee Topper (FVLT) is an innovative passive flood mitigation product that enables levees to be raised for recertification and FEMA accreditation without blocking views or increasing the levee footprint. Designed for long, continuous straight runs, there is no practical length limitation. Like all FloodBreak passive flood barriers, it is modular in nature with tension members rather than stanchions or vertical stops.

Roadway Gate, FloodBreak, 2020.

<http://floodbreak.com/products/roadway-gate/>

From the web site: The FloodBreak Roadway Gate is a fully-engineered, passive automatic flood mitigation system designed for continuous traffic service and heavy use on local roads and highways. No practical height or length limitation. FloodBreak automatic floodgates are designed to your specifications. Like all FloodBreak Automatic Floodgates, the roadway gate provides permanent flood control and is hidden underground to allow uninterrupted vehicle traffic until deployed by floodwaters.

FloodBreak Passive Flood Barriers Deploy Automatically at Customer Location, YouTube, FloodBreak, January 2013.

<https://www.youtube.com/watch?v=NuDshmb4fmAFloodBreak>

From the video description: Architects, engineers and project managers for [Hurricane] Sandy[-]related flood mitigation projects watch a demonstration of the FloodBreak passive flood barrier system as it automatically deploys during maintenance at a customer site.

Passive Automatic Flood Barriers Innovative Flood Control Solutions, FloodBreak, undated.

<http://www.kymitigation.org/wp-content/uploads/2012/02/100-Percent-Passive-No-Manpower-No-Electricity-Victor-Althoff.pdf>

This presentation describes FloodBreak's various passive automatic flood barriers. Also included are case studies describing installations and a list of worldwide customers with the year(s) of installation.

Flood Control International Inc.

Flood Barriers, Flood Control International Inc., 2019.

<http://www.floodcontrolinternational.us/PRODUCTS/FLOOD-BARRIERS/flood-barriers.php>

From the web page:

Flood Control International offers four types of flood barrier to ensure the right flood solution is provided: removable flood barriers, glass floodwalls, flip-up flood barriers and drop-down flood barriers. ... The flood barrier design varies from simple stop logs to automatic flood barriers that operate only when required. Flood protection heights up to 13 feet and unlimited lengths of flood wall systems are possible.

Automatic flood barriers can operate to self-raise with the rising flood water or be push-button operated so that the flood barrier can be operated in advance of floods with full peace of mind. They can also be manually operated as required.

The vendor's web site indicates that its flood defenses have been installed in Boston, Connecticut, Miami, Arizona and California.

Two products used for facility protection:

- **Flip-Up Flood Barrier** (<http://www.floodcontrolinternational.us/PRODUCTS/FLOOD-BARRIERS/flip-up.html>): These barriers provide unrestricted access to pedestrian and vehicle entrances and are fully recessed when not in use. Activated by a push button, automatically triggered by sensors or manually engaged, the flood barrier rises up to provide a flood control dam with a standard height of 6 feet, which can be expanded up to 40 feet.

- **Drop-Down Automatic Flood Barriers** (<http://www.floodcontrolinternational.us/PRODUCTS/FLOOD-BARRIERS/drop-down.html>): Automatic or manual operation is available for this underground garage water barrier. It is located above the head of the vehicle entrance opening when not in use.

Presray Corporation

Self Closing Flood Barrier: HYFLO SCFB, Presray Corporation, 2016.

<http://www.presray.com/flood-protection/self-closing-flood-barrier-hyflo-scfb>

Presray Corporation is the North American dealer of HYFLO's Self Closing Flood Barrier (see page 20 for information about HYFLO and its products). *From the web site:*

[The] HYFLO Self Closing Flood Barrier (SCFB) is a unique flood defense system that effectively protects property from floodwaters and requires no manpower whatsoever for effective deployment.

This award-winning system automatically deploys a buoyant floodwall from below grade to provide optimal protection against high water. The SCFB preserves a building's aesthetics and requires no valuable space. It can be built into a permanent floodwall or levee, as well as any opening in a building or facility. ... The barrier rises instantly with floodwaters and is self-closing when high waters recede. If preferred, it can also be easily raised manually before a storm. ... This system is ideal for perimeter protection again[st] riverine or tidal flooding as well as for large openings in any critical or historically important facility. It is ideal for below-grade parking garages, public transportation applications, power plants, protection of roads, or in urban environments where there is no storage and a building's aesthetics cannot be compromised.

The web page includes technical drawings, access to a product fact sheet and the following product specifications:

- **Size:** Custom-built to match protection requirements.
- **Floating Panels:** PUR foam core with a fiberglass outer layer fabricated in standard 1-meter lengths, connected to form the overall length of the wall.
- **Seals:** Long-lasting, durable gaskets.
- **Basin:** 8 standard galvanized steel models from 1 to 8 meters in length. Includes a galvanized steel lid.
- **Service Pit:** Used when the SCFB basin is lower than the stormwater outfall. Also acts as a silt trap and houses submersible pump for lowering water level post flood.

Bottom-Hinged Floodgate With Pneumatic Seals (FB55), Presray Corporation, undated.

<http://www.presray.com/flood-protection/bottom-hinged-floodgate---fb55>

From the web page:

The FB55 is perfect for parking garages and other large openings, especially where automatic deployment is desired. If your facility is prone to flash flooding, the FB55's hinged gate and pneumatic seals offers efficient and superior protection from floodwaters.

The custom-built barrier can be used at openings up 25 feet wide and 5 feet high, and is available as an automated or manual system. Access to a fact sheet, product specifications and technical drawings is provided at the web site.

PS Industries Inc.

Self-Closing Flood Barrier: SCFB-570, PS Flood Barriers, PS Industries, Inc., 2020.

<https://www.psfloodbarriers.com/product/self-closing-flood-barrier/>

From the web site:

The unique design of the Self-Closing Flood Barrier from PS Flood Barriers allows for a passive response to rising waters, protecting your facility from dangerous flooding. This barrier stores itself recessed into the ground. When flooding occurs, the barrier rises into position without human intervention, electricity or power.

This product is ideal for protecting walk doors, retaining walls, driveways, storefronts or loading docks/ramps during flash flooding conditions. Available in mild steel, stainless steel or aluminum.

A one-page marketing piece is available at <https://www.psfloodbarriers.com/wp-content/uploads/sites/4/2016/09/SelfClosing-SCFB570-Literature-112818.pdf>. Other publications available on the web site:

Test Procedures

<https://www.psfloodbarriers.com/wp-content/uploads/sites/4/2019/12/PS-FLOOD-BARRIERS-TESTING-PROCEDURE-112719.pdf>

Specification

<https://www.psfloodbarriers.com/wp-content/uploads/sites/4/2016/09/SCFB570-08390-WATERTIGHT-DOORS-111518.pdf>

Walz & Krenzer, Inc.

Automatically Deploying Flood Protection, Walz & Krenzer, Inc., 2014.

<http://www.floodbarriers.com/watertight-flood-protection/automatically-deploying-flood-protection>

From the web site: WK leads the flood protection industry with two revolutionary products which automatically deploy when flooding occurs. Once installed, no human intervention is required for these products to protect your facility.

The AutoSeal Watertight Roller Curtain Door functions as an overhead roller curtain door which becomes watertight at the touch of a button, or automatically when water levels reach a pre-set level. It is provided with a battery backup for operation when power is lost.

The AutoRising Flood Gate is installed with the panel flush to the ground surface. Using buoyancy and a spring assist, the panel automatically deploys when the water level is at a pre-determined level. The gate fully seals the opening prior to water reaching the sill. Side sealing walls found on competitor models are not required, which improves the aesthetics of the gate. These gates can be designed for any size.

Related Resources:

WK Model WT-R, Walz & Krenzer, Inc., 2014.

<https://stopfloods.com/watertight-airtight-doors/wk-model-wt-r/>

From the web site: The AutoSeal Watertight Roller Curtain Door is the latest technology in flood protection. During normal non-flooding operation, it functions as an overhead roller curtain door. Once water is sensed by the controls at a pre-determined level, it automatically

deploys and secures the opening. Alternately, a press of the button sets the door in the flood protection mode.

The door is constructed from aluminum roller curtain door slates with a stainless steel frame and a flush bottom sill. It is provided with a battery back-up for operation when power is lost. Like most standard garage doors, it has an infrared start/stop sensor to avoid closing when an object is in the way.

Applications include warehouses, entrance doors, storefronts, garage doors, parking lots, etc.

The AutoRising Flood Barrier WK Model FG-AR, Walz & Krenzer, Inc., 2014.

<https://stopfloods.com/automatically-deploying-flood-protection/the-autorising-flood-barrier-wk-model-fg-ar/>

From the web site: When flood waters begin to threaten, the barrier panel automatically begins to rise based on the principles of buoyancy—no human intervention or electrical power is required. Installed flush into the ground surface in front of your opening, it is automatically deployed by buoyancy at a pre-determined water level. Unlike other competitor[s]' models, the AutoRising barrier fully seals the opening before water reaches the sill. It can be designed to seal any size opening, and the side sealing walls found on some competitor models are not required, resulting in a more aesthetically pleasing end product with substantially lower installation costs.

The AutoRising barrier offers flood protection only when it's needed, and is out of sight when not required, making it perfect for flash floods or infrequent use.

International Vendors

The citations below highlight the products and systems provided by five international vendors:

- Aquafragma.
- AWMA Water Control Solutions.
- DENIOS.
- Hunton Engineering Design Ltd.
- HYFLO B.V.

Aquafragma

Aquafragma Self-Operated Liquid Barrier, Aquafragma Ltd., 2019.

<https://aquafragma.com/about/>

This self-activating barrier can be used “in front of building entrances, along rivers and canals, along coastal promenades and at the crest of basement ramps.” *From the web site:*

Gate normally rests flat with pavement above a buoyant body. The gate and the buoyant body are hinged so that on rotation [the] two bodies move away from each other. When hydrostatic pressure develops, the buoyant body forces the gate to rotate upwardly and the gate turns [to the] upright position automatically before flood reaches pavement level.

....

The barrier is made of modules that can be designed to any width and height to fit any type of opening through which flood water may pass. All material used is durable, such as

aluminum, plastic and stainless steel. The skeleton consists of robust structural components that can withstand loads from traffic and flood. The voids are filled with lightweight materials, which allow it [to] float and therefore lift automatically.

Illustrations and a video at the web site demonstrate barrier operation and performance. Also available are operational brochures (see *Related Resources* below) and photos of an installation in Nicosia, Cyprus.

Related Resources:

About Aquafragma, Aquafragma Ltd., undated.

<https://aquafragma.com/wp-content/uploads/2019/10/Aquafragma-791x1024.png>

In this one-page brief, applications and benefits of the barrier are highlighted.

Aquafragma: Patented Self Operating Flood Barrier, Aquafragma Ltd., undated.

<https://aquafragma.com/wp-content/uploads/2019/10/Aquafragma-Oper-410x1024.jpg>

Details and illustrations of barrier operation are presented in this one-page brief.

AWMA Water Control Solutions

Australian Flood Barriers, AWMA Water Control Solutions, undated.

<https://www.awmawatercontrol.com.au/flood-barriers/>

From the web site: AWMA offer a range of flood barriers that retrofit in and around existing infrastructure to provide instantaneous flood protection. Our water defence systems work for domestic, commercial and industrial applications and have essential features making operation and installation easy and fail safe.

With a wide range of options, you'll find demountable, portable and permanent flood barriers that can be manually-operated, automated or self-regulating. Made from the highest quality marine grade aluminium or stainless steel, all barriers can be customised to meet site specifications with optional audible and visual warning systems.

AWMA flood barriers are made to high international standards and come with full training and documentation with ongoing service and maintenance available.

....

AWMA's "FloodFree" Flood Barriers include:

- Personal Access Flood Doors.
- Concealed Flood Barriers.
- Demountable Flood Barriers.
- Retractable Flood Barriers.
- Tilting Flood Barriers.

DENIOS

Passive Flood Barriers, DENIOS, undated. (DENIOS has a production facility in Louisville, Kentucky.)

<https://www.denios-us.com/shop/flood-spill-barrier/passive-flood-barriers/>

From the web site: DENIOS US FM Approved Passive Flood Barrier System (FM Approvals Class 2510, 2012) This barrier keeps floodwaters out of your facilities by providing a flood "wall"

at your doorways. Provides all the durable construction and operational characteristics of our doorway spill barrier but is designed specifically for floodwaters.

Passive Flood Barriers are self-contained and have one-piece system design.

The Doorway Flood Barrier installs easily in existing doorways and stores horizontally in the floor, permitting normal vehicular and personnel traffic, until a flood occurs. With the first flow of water the [b]arrier automatically closes. No additional ramps or berms are needed.

....

In addition, the [f]eatures of the Automatic Doorway Flood Barrier [i]nclude:

- Solid welded stainless steel construction.
- Self-contained one piece system design.
- Fully automatic operation, no external power source or factory compressed air required.
- Easy installation in existing doorways; stores horizontally in the floor, permitting unobstructed vehicular and personnel traffic until a spill occurs.
- While [lying] flat, [b]arrier provides up to 6.5 tons axle weight capacity.
- Door heights of 12, 18 and 24 inches. Widths from 3 to 12 feet.
- Flexible design allows installation either inside or outside exterior doors.

Hunton Engineering Design Ltd.

Flood Gates, Hunton Engineering Design Ltd., undated.

<http://huntonengineering.co.uk/flood-gates/>

From the web site:

Fully Automated Flood Gates

Drawing on our knowledge of river infrastructure, Huntons are capable of fully automating flood gates and incorporating hydraulic or mechanical means of operating the gates. An example of this was the Chepstow flood gate installed in 2005. Design and constructed by Huntons and installed over a medieval slipway in South Wales, this mitred floodgate closes [and] provides an opening in the flood wall to give access to the river Wye. Each gate leaf is manufactured in 316 grade stainless steel clad with EKKI timber and operated by stainless steel hydraulic rams. [T]he gates can be operated locally for access to the river, but will [be] operated automatically responding to either ultrasonic level detection or remotely from a central control centre room. This creates complex automation risk issues which were overcome by a combination of CCTV and an array of sensors to detect potential hazards in the gate opening.

HYFLO B.V.

Self Closing Flood Barrier, HYFLO B.V., undated.

Homepage: <https://selfclosingfloodbarrier.com/>

Product page: <https://selfclosingfloodbarrier.com/scfb>

From the web page:

The Self Closing Flood Barrier SCFB [is] a unique effective flood defense system to protect people and property from inland waterway floods caused by heavy rainfall, gales or rapid melting snow. This system has been developed in the Netherlands to provide optimal protection against extreme high water levels. The barrier systems have proved to be the best flood protection and [have] already been built and installed in several countries around

the globe. In operational use globally since 1998, the SCFB is acclaimed as the world's most effective flood protection system. The success can be attributed to the simple, but ingenious concept of using the approaching floodwaters to automatically raise the barrier; effectively using the problem to create the solution. With an unblemished 100% track record the SCFB is a highly favorable preference when specifying optimal and cost-effective but passive flood defense.

....

The SCFB can be built at any required length. The basin from the SCFB can be built in concrete, steel or stainless steel.

Details about the barrier's physical properties, steel and concrete basins, and other components are provided. Key benefits include:

- No human intervention required to operate the barrier, providing 100% protection 24/7, even during a power outage.
- Reliable, economical flood barrier, with a design life of 100 years and requiring minimal maintenance. (Maintenance is recommended once or twice annually.)
- Short closing time so the area remains accessible "until the last moment."
- When not in use, the barrier is invisible and recessed in the ground.
- The barrier remained operational and watertight in "static load, dynamic load, buoyancy force, sand and gravel tests, duration tests (35 days), extreme cold temperature tests, earthquakes tests, and obstruction tests."

The web page also includes a cost comparison and performance assessment of the SCFB with mobile and demountable flood barriers.

Contacts

CTC contacted the individuals below to gather information for this investigation.

State Agencies

Arizona

Syed Alam
Manager, Roadway Drainage Section
Arizona Department of Transportation
602-712-8701, salam2@azdot.gov

Illinois

Mike Brand
Engineer, Policy and Procedures
Illinois Department of Transportation
217-782-7651, michael.brand@illinois.gov

Missouri

Natalie Roark
State Maintenance Director
Missouri Department of Transportation
573-526-4316,
natalie.roark@modot.mo.gov

Nebraska

Julie Ramirez
Hydraulic Engineer, Roadway Design
Nebraska Department of Transportation
402-479-3992, julie.ramirez@nebraska.gov

Nevada

Charles Wolf
Chief Hydraulic Engineer, Roadway Design
Nevada Department of Transportation
775-888-7622, cwolf@dot.nv.gov

North Carolina

Matt Lauffer
Assistant State Hydraulics Engineer,
Hydraulics
North Carolina Department of
Transportation

919-621-0443, mslauffer@ncdot.gov

Oklahoma

Leslie Lewis
State Hydraulic Engineer, Bridge Division
Oklahoma Department of Transportation
405-521-6500, llewis@odot.org

Rhode Island

Robert Rocchio
Chief Engineer, Infrastructure
Rhode Island Department of Transportation
401-563-4000, robert.rocchio@dot.ri.gov

Utah

Brandon Cox
Statewide Hydraulic Engineer
Utah Department of Transportation
385-321-2608, brandoncox@utah.gov

Virginia

John Matthews
Senior Hydraulics Engineer
Virginia Department of Transportation
804-786-4031,
john.matthews@vdot.virginia.gov

Wyoming

Jeff Brown
State Highway Development Engineer
Wyoming Department of Transportation
307-777-4134, jeff.brown@wyo.gov

Appendix A: Survey Questions

The following survey was distributed to members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Design.

Survey on Passive Flood Barrier

Note: The response to the question below determined how a respondent was directed through the survey.

(Required) Does your agency **use** or **has it considered using** passive flood barrier to protect segments of roadways and infrastructure in low-lying areas such as maintenance stations; park-and-ride facilities; and underground facilities such as storage, parking, pumping or transfer stations, equipment and water quality treatment?

Response Options:

- Yes. Our agency uses passive flood barrier to protect segments of roadways and infrastructure. (Directed the respondent to the **Agencies Using Passive Flood Barrier** section of the survey and the sections that follow it.)
- No. While our agency does not use passive flood barrier, it **is considering** using this device. (Directed the respondent to the **Agencies Considering the Use of Passive Flood Barrier** section of the survey.)
- No. Our agency **has never used** and **is not considering using** passive flood barrier. (Directed the respondent to the **Agencies Not Using Passive Flood Barrier** section of the survey.)

Agencies Not Using Passive Flood Barrier

Please briefly describe why your agency is not using passive flood barrier.

Note: After responding to the question above, the respondent was directed to the **Wrap-Up** section of the survey.

Agencies Considering the Use of Passive Flood Barrier

Please briefly describe your agency's discussions or plans to use passive flood barrier.

Note: After responding to the question above, the respondent was directed to the **Wrap-Up** section of the survey.

Agencies Using Passive Flood Barrier

The next sections of the survey ask you to describe the passive flood barrier devices your agency uses. The survey gives you the opportunity to describe three different devices. If your agency uses more than three devices, please describe the **three most frequently used**.

Passive Flood Barrier System 1

General Information

1. (Required) Please provide the name of the passive flood barrier device that your agency uses and the name of the vendor providing this device.
2. What was your agency's objective or plan for installing the passive barrier?
3. Please briefly describe the device, including its dimensions.
4. Please describe the applications where the passive flood barrier is used. Select all that apply.
 - On low-lying roadways.
 - Around low-lying buildings.
 - Around infrastructure, including remote service buildings.
 - At vent and access shafts for underground infrastructure, such as subways or utilities.
 - On top of levees or waterfront promenades.
 - Other transportation.
5. Please identify the issues the device was installed to defend against. Select all that apply.
 - Coastal flooding
 - River flooding
 - Wetlands flooding
 - Urban flooding
 - Other (Please describe.)
6. If available, please provide links to documentation about the passive flood barrier. Send any files not available online to carol.rolland@ctcandassociates.com.

Design Considerations

1. Please describe any site-specific issues for using the device (for example, utilities, public right of way, private property, potential for debris).
2. What is the maximum flood depth the barrier is designed to protect?
3. Is the device used in combination with any other site protection (for example, floodwalls)?
 - Not applicable.
 - I don't know.
 - No.
 - Yes. (Please describe.)
4. Please describe any permitting and jurisdictional requirements for installing and using the device.

Implementation

1. How long has your agency been using this device?
2. What were the initial costs to obtain and install the device?
3. What are the ongoing or long-term costs to operate and maintain the system?
4. What is the estimated life expectancy of the device?

Operation

1. How frequently has the passive flood barrier been self-activated?
2. At what storm event does activation occur?
3. How long does it take to fully activate and fully retract/reactivate?
4. Please describe any issues your agency has had deploying the device.

Maintenance

1. Please describe the maintenance required for the device, including the frequency that maintenance is performed.
2. Does debris hamper deployment and/or the self-retracting action (if applicable) of the device?
 - Not applicable.
 - I don't know.
 - No.
 - Yes. (Please describe.)
3. Are there any environmental conditions (for example, salt water, corrosive soils, etc.) that affect deployment of the device?
 - Not applicable.
 - I don't know.
 - No.
 - Yes. (Please describe.)
4. If available, please provide links to documentation about your agency's policies and practices for selecting, installing and maintaining passive flood barrier. Send any files not available online to carol.rolland@ctcandassociates.com.

Traffic Safety

1. Can the device be deployed along the roadway?
 - Not applicable.
 - I don't know.
 - No.
 - Yes.
2. Can the device be deployed across the roadway (for example, at the entrance to an underground tube or in a gap in a levee)?
 - Not applicable.
 - I don't know.
 - No.
 - Yes.
3. What impact does the barrier have on traffic safety?
4. Are automated warning systems for motorists and pedestrians used along with the device?
 - Not applicable.
 - I don't know.
 - No.
 - Yes. (Please describe.)

Assessment and Evaluation

1. Based on your use and assessment, what are the benefits of using this passive flood barrier?
2. Based on your use and assessment, what are the limitations of using this passive flood barrier?
3. Please rate your agency's general level of satisfaction with this passive flood barrier's ability to meet agency objectives using the rating scale of 1 = not at all satisfied and 5 = extremely satisfied.
4. What are your top three recommendations for other agencies considering the use of passive flood barrier?

Other Barrier Types

Our agency uses a **second/third** passive flood barrier system.

- Yes (Directed the respondent to **Passive Flood Barrier System 2/Passive Flood Barrier System 3** questions.)
- No (Directed the respondent to the **Wrap-Up** section.)

Note: In the online survey, the question blocks presented above for **Passive Flood Barrier System 1** were repeated for **Passive Flood Barrier System 2** and **Passive Flood Barrier System 3**. The closing question under **Other Barrier Types** was modified, as needed, for each set of questions. Respondents providing information for all three sets of barrier questions were directed to the **Wrap-Up** section after responding to the questions under **Passive Flood Barrier System 3**.

Wrap-Up

1. If available, please provide contact information for other agencies or communities that have encountered flooding that we may contact to obtain more information about their experience using passive flood barrier.
2. Please use this space to provide any comments or additional information about your previous responses.