Flood Risk Management Planning for the Squaw Run Watershed

O’Hara Township & Fox Chapel Borough, PA

Prepared for:

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Abbreviations & Acronyms

Ac.-ft.	Acre-Feet
ACE	Annual Chance Exceedance
BFE	Base Flood Elevation
DFE	Design Flood Elevation
EMS	Emergency Medical Services
EO	Executive Order
FC	Fox Chapel Borough
FEMA	Federal Emergency Management Agency
GIS	Geographic Information Systems
HEC-HMS	Hydraulic Engineering Center Hydrologic Modeling System
HEC-RAS	Hydraulic Engineering Center River Analysis System
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	Heating, Ventilation, and Air Conditioning
ID	Structure Identification Code
Q	Discharge
nQ	Normalized Discharge
No.	Number
ObV	Overbank Water Volume
OH	O'Hara Township
PEMA	Pennsylvania Emergency Management Agency
RIDC	Regional Industrial Development Corporation
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USPS	United States Postal Service

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1 Introduction

1.1 Background & Objectives

Flooding represents the most frequent and damaging natural disaster within Pennsylvania (Pennsylvania Emergency Management Agency, 2018). Communities were historically established within floodplains to provide easy access to streams and the many services they provide (e.g., drinking water, wastewater assimilation, and transportation). However, individuals and communities located within the floodplain have elevated flood risk, including socioeconomic damages and risks to life and safety. There is growing consensus that effectively managing flood risk within many communities will require a holistic approach that seeks to lower risk through strategic actions taken across multiple spatial scales (i.e., local and watershed scales). These holistic, large-scale approaches often necessitate coordination among multiple state and/or local entities to ensure individual actions are coordinated and implemented in a way to maximally reduce flood risk.

Flooding along Squaw Run within O’Hara Township and Fox Chapel Borough, Allegheny County, Pennsylvania represents one such case where effectively managing flood risk will likely require coordination across municipal boundaries. Squaw Run has a history of flooding, including events associated with hurricanes (e.g., Hurricane Ivan, 2004), as well as more recent, localized precipitation events (i.e., events of July 2018 and July 2019). The majority of the Squaw Run watershed is located within Fox Chapel Borough; however, only a few structures are located within the floodplain throughout Fox Chapel. O’Hara Township is situated further downstream in the watershed and has historically experienced the greatest flood-related impacts. Flood waters have reached the first floor of several structures, with numerous other structures experiencing water in their basement multiple times per year.

O’Hara Township and Fox Chapel Borough jointly requested flood risk management assistance from U.S. Army Corps of Engineers (USACE), Pittsburgh District. In response to this request, USACE Pittsburgh District initiated a study through the Floodplain Management Services program with the goal of providing O’Hara Township and Fox Chapel Borough with the technical tools needed to make informed flood risk management decisions. The *specific objectives* of the current study were:

1. Create hydrologic and hydraulic models to characterize existing conditions within the Squaw Run watershed;
2. Identify optional non-structural measures to reduce flood risk along Squaw Run;
3. Identify and assess potential structural measures to reduce flood risk along Squaw Run.

The non-structural and structural measures included and analyzed in this report represent a subset of possible actions that could be taken by O’Hara Township, Fox Chapel Borough, and their residents to minimize flood risk. ***The intent of this study was not to identify and recommend one or more feasible actions for reducing flood risk within the Squaw Run watershed. Rather, the goal of this study was to develop the technical tools necessary for, and provide a starting point for, the development of a flood risk management plan for the Squaw Run watershed.***

1.2 Coordination

The current study was conducted under the Floodplain Management Services Program [Section 206 of the 1960 Flood Control Act (Public Law 86-645)], which authorizes USACE to provide technical services and planning guidance to regional, state, or local government in support of effective floodplain management. Studies conducted under the Floodplain Management Services Program are conducted at 100 percent Federal expense. The study was led by USACE, Pittsburgh District. USACE, Huntington District provided support for the non-structural assessment.

1.3 Study Area

Squaw Run drains an approximately 8.6-square mile watershed northeast of Pittsburgh, Pennsylvania (Fig. 1-1). Approximately 75% (6.5 square miles) of the watershed is located within Fox Chapel Borough. Squaw Run drains south toward O'Hara Township, which is located at the mouth of Squaw Run near its confluence with the Allegheny River. The study area includes portions of O'Hara Township and Fox Chapel Borough, where development within the floodplain results in elevated flood risk (Fig. 1-2).

Fig. 1-1. Location of Squaw Run watershed relative to the municipalities it intersects.

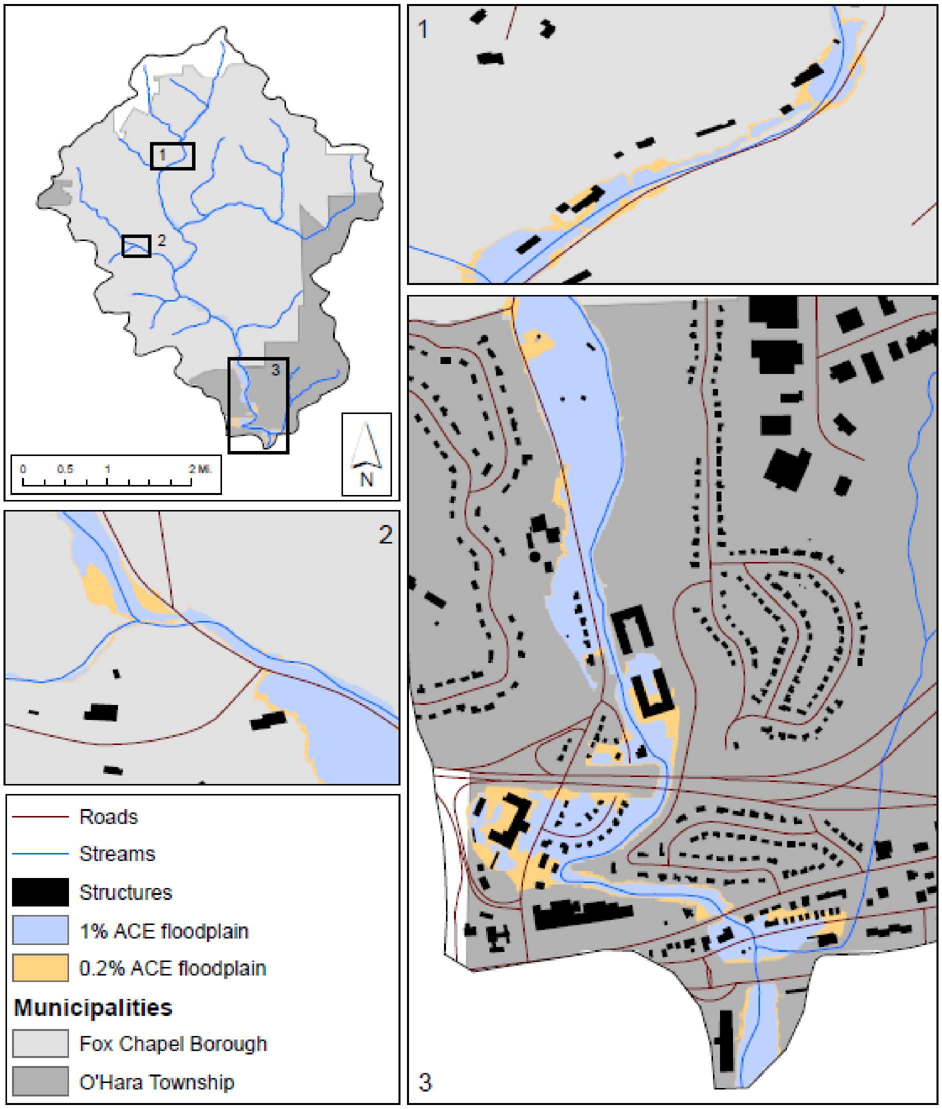


Fig. 1-2. Target areas and associated 1% annual chance exceedance (100-year) and 0.2% (500-year) annual chance exceedance (ACE) floodplains along Squaw Run within O'Hara Township and Fox Chapel Borough. Roads and structures are also shown.

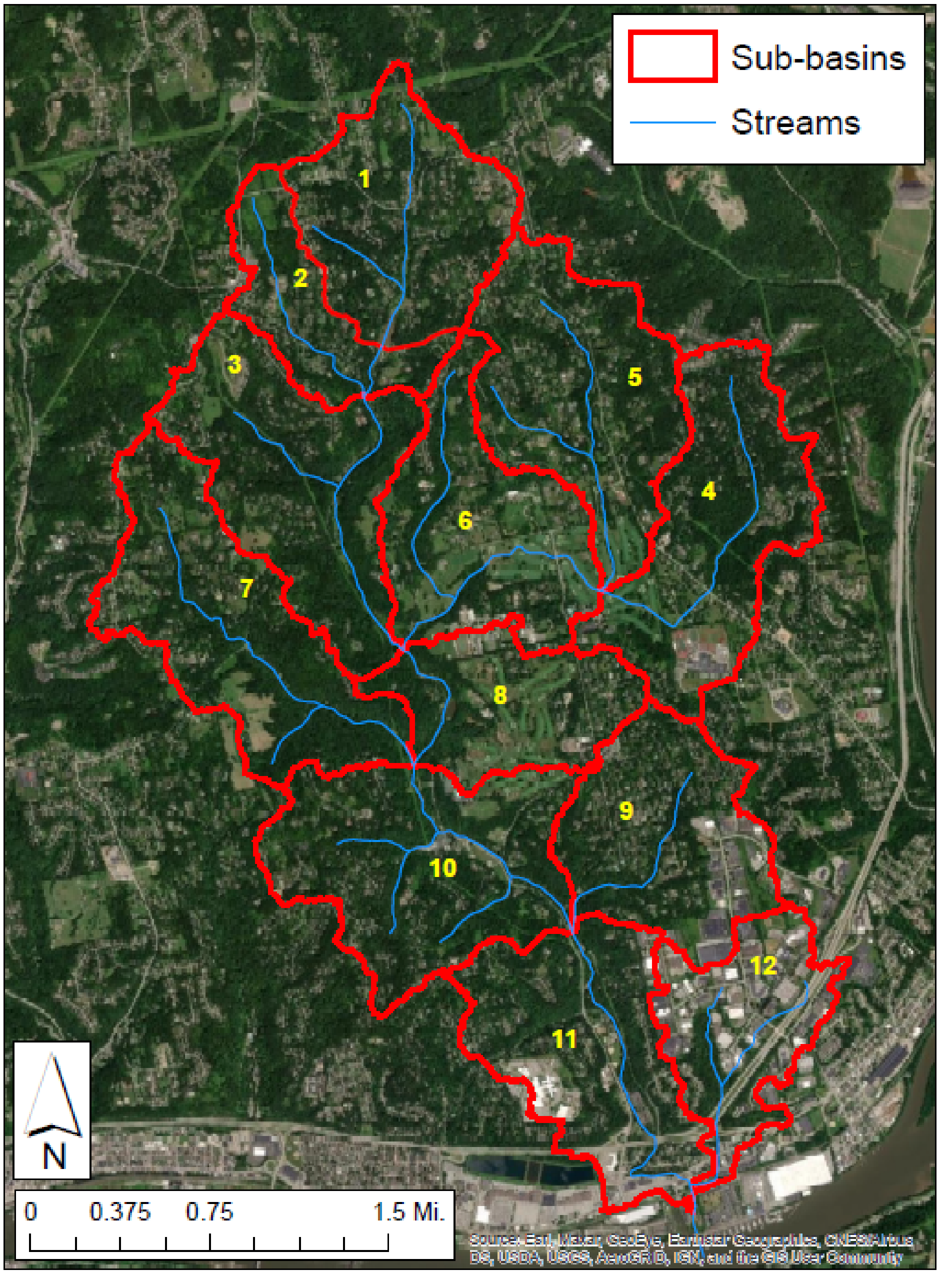
2 Model Development & Existing Conditions

2.1 Hydrologic Analyses

Hydrology is the scientific study of the movement (i.e., precipitation, evaporation, infiltration, surface water runoff, and groundwater flow) and distribution of water. Hydrologic models are simplifications of real-world systems that are used to characterize and predict how these hydrologic processes control the volume and timing of water arriving at a point of interest during specific storm events. The following sections briefly discuss the methods used to model hydrology within the Squaw Run watershed and the resulting simulation of existing conditions for flows with annual chance exceedances (ACE) between 50% (i.e., recurrence interval of two years) and 0.2% (i.e., recurrence interval of 500 years).

2.1.1 Methods

All hydrologic analyses were completed using geographic information systems (GIS) (ArcGIS, version 10.5; Environmental Systems Research Institute, Redlands, California) and the USACE Hydraulic Engineering Center Hydrologic Modeling System (HEC-HMS) software. The final model provided discharge estimates for 12 sub-basins and the outlet of Squaw Run (Fig. 2-1) during the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flow events. A complete description of the methodologies, data, and assumptions used to generate and evaluate the hydrologic model can be found in Appendix A, Hydrologic Model Development and Analyses.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Fig. 2-1. Extents of the HEC-HMS modeling area and delineated sub-basins.

There are no records of observed flows on Squaw Run available for calibration or verification of the model. To provide a check on model validity, modeled peak discharges for Squaw Run were compared with annual peak flows from nearby United States Geological Survey (USGS) stream gauges on Little Pine Creek (USGS Gauge #03049800) and Thompson Run (USGS Gauge #03084800) and with values from the regression equations used in the USGS StreamStats program for Region 4 of Pennsylvania. Flows were normalized by drainage area (i.e., peak flow divided by drainage area) to enable direct comparison.

2.1.2 Results

Modeled peak discharges for each of the 12 sub-basins under the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE events are presented in Table 2-1.

Table 2-1. Modeled peak discharges (Q) by recurrence interval for the outflows of the 12 sub-basins within the Squaw Run watershed. All peak discharges are presented in cubic feet per second. Sub-basin IDs correspond to those presented in Fig. 2-1.

Sub-Basin Name	**Sub-Basin ID**	$Q_{50\%}$	$Q_{10\%}$	$Q_{4\%}$	$Q_{2\%}$	$Q_{1\%}$	$Q_{0.5\%}$	$Q_{0.2\%}$
Squaw HW-US	1	125.7	309.9	440.6	551.7	665.8	790.8	965.6
Squaw HW-DS	2	49.9	130.9	189.7	240.4	292.7	351.2	432.3
Squaw HW-Mid	3	106.2	289.4	427.2	546.5	670.4	807.1	996.8
Glade-HW	4	83.0	219.7	321.0	409.7	503.0	606.4	750.5
Glade-Mid	5	91.6	261.8	390.7	503.0	619.8	749.0	928.5
Glade	6	96.6	265.1	390.9	499.2	611.5	735.1	906.1
Stony Camp	7	95.3	262.5	388.3	498.7	613.9	741.4	918.9
Squaw-Mid	8	71.0	198.6	292.8	375.1	460.6	554.4	684.3
East Trib	9	122.7	302.4	429.4	537.0	647.3	767.8	932.8
Squaw-MidLow	10	99.2	289.0	433.6	559.7	691.1	836.5	1038.9
Squaw-Low	11	57.2	141.4	201.5	252.9	305.8	363.8	443.6
RDIC Trib	12	136.6	290.1	393.1	478.5	564.8	658.0	783.8
Squaw-Outlet		496.9	1367.3	2204.9	2959.1	3702.9	4670.3	6150.7

Normalized peak discharges for Squaw Run simulated by the HEC-HMS model were generally within the range of normalized flow values observed within Thompson Run and Little Pine Creek, as well as the estimated peak discharges developed using the USGS StreamStats regression equations (Table 2-2).

Table 2-2. Comparison of peak discharge estimates (Q) and peak discharge estimates normalized by basin area (nQ, cfs/mi^2) derived from the HEC-HMS modeling for Squaw Run, the StreamStats regression for Region 4 in Pennsylvania, and USGS gauge data for Little Pine Creek and Thompson Run for flows associated with each recurrence interval.

Flow	**HEC-HMS**[1]		**StreamStats**[2]		**Little Pine Creek**[3]		**Thompson Run**[4]	
	Q	**nQ**	**Q**	**nQ**	**Q**	**nQ**	**Q**	**nQ**
$Q_{50\%}$	497	61	407	48	230	40	743	41
$Q_{10\%}$	1367	167	956	112	903	156	2094	116
$Q_{2\%}$	2959	362	1650	194	2496	432	3450	192

Flow	**HEC-HMS**[1]		**StreamStats**[2]		**Little Pine Creek**[3]		**Thompson Run**[4]	
	Q	**nQ**	**Q**	**nQ**	**Q**	**nQ**	**Q**	**nQ**
$Q_{1\%}$	3703	453	2010	236	3726	645	4073	227
$Q_{0.2\%}$	6151	753	3050	358	9019	1560	5635	313

[1] HEC-HMS modeling with drainage area of 8.17 mi^2.

[2] StreamStats estimate for Region 4 for drainage area of 8.52mi^2 and urbanization at 59%.

[3] USGS Gauge #03049800 with 57 years of data. Drainage area of 5.78 mi^2.

[4] USGS Gauge #03084800 with 10 years of data. Drainage area of 17.98 mi^2.

Given that normalized peak discharges for Squaw Run simulated in HEC-HMS were within the range of values observed at nearby sites, it was concluded that the HEC-HMS values of peak discharges developed in this study are reasonable and appropriate for characterizing existing flood risk and assessing potential flood risk management opportunities within the Squaw Run watershed.

2.2 Hydraulic Analyses

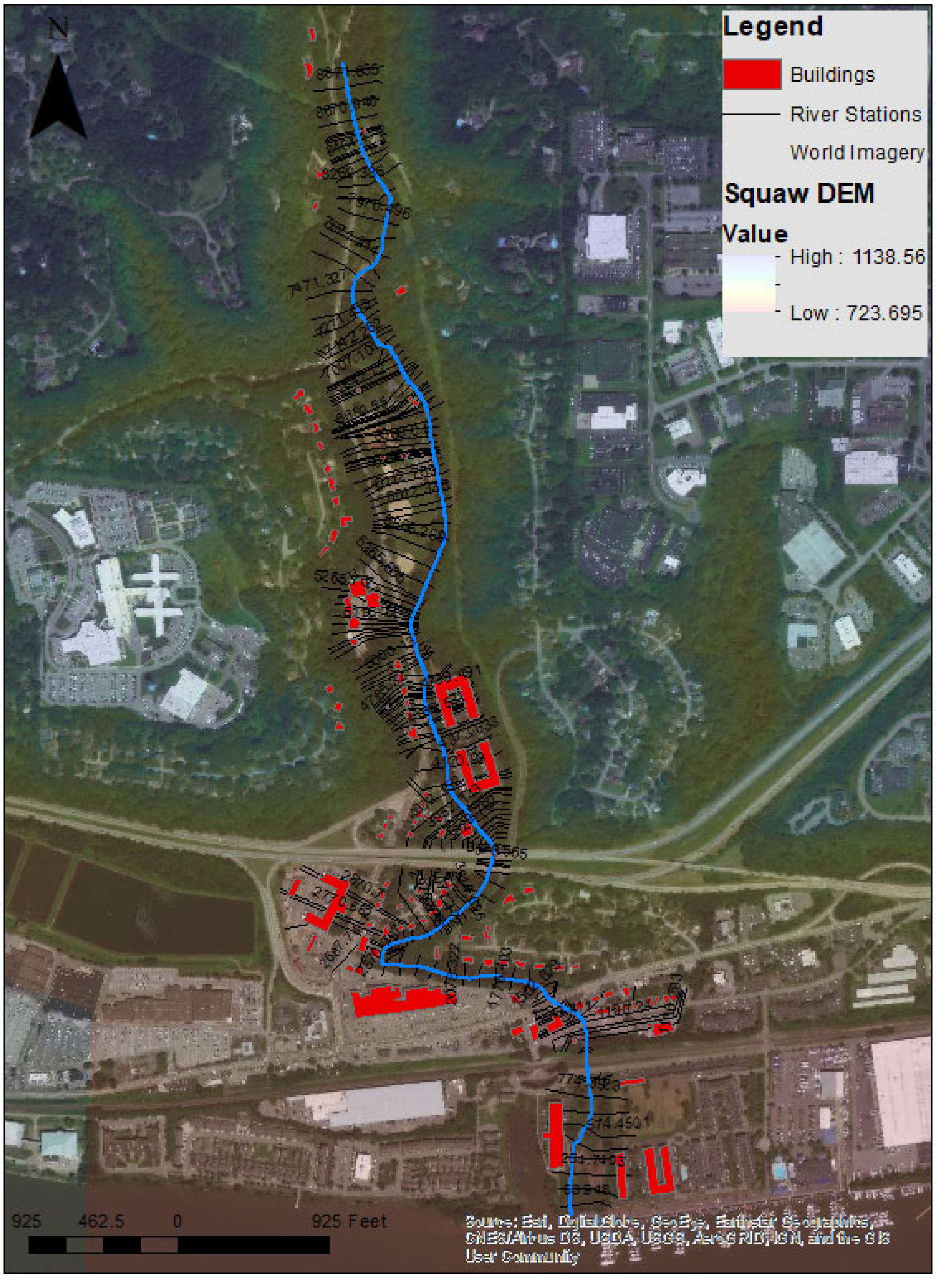
Hydraulics is the scientific study of the behavior of water in physical systems (e.g., pipes, stream channels). Hydraulic models are simplifications of real-world systems that are used to characterize and predict how water moves from one point to the next (e.g., water depths, extents, and velocities). The following sections briefly discuss the methods used to model hydraulics for at-risk areas along Squaw Run and the resulting simulation of existing conditions for flows with ACE between 50% (i.e., recurrence interval of two years) and 0.2% (i.e., recurrence interval of 500 years).

2.2.1 Methods

2.2.1.1 O'Hara Township

The current Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) shows Squaw Run from the boundary of O'Hara Township with the Borough of Fox Chapel downstream to Route 28 to be in Zone A (i.e., subject to 1% ACE (i.e., 100-year) flooding as determined by approximate methods) (FEMA, 2014). The entire reach of Squaw Run downstream of Route 28 is in the backwater of the Allegheny River for the 1% ACE flood and is designated as Zone AE (i.e., having a high risk of flooding) so that the Base Flood Elevation (BFE), or elevation associated with the 1% ACE flood, for that reach of Squaw Run is the same as that of the Allegheny River. But because flood flows on Squaw Run can peak well before the Allegheny does, local flood elevations may be higher along Squaw Run than shown on the mapping. As such, no hydraulic modeling capable of fully informing flood risk analyses had been created for targeted areas along Squaw Run within O'Hara Township prior to the current study.

A new hydraulic model was created for Squaw Run within O'Hara Township that extends approximately 9,000 feet upstream from its confluence with the Allegheny River (Fig. 2-2). The hydraulic model was created using the USACE Hydraulic Engineering Center River Analysis System (HEC-RAS) software (version 5.0.7) and based on digital elevation data with 1-meter resolution. Peak discharges as defined by the hydrologic model (see Section 2.1) were used as input into the HEC-RAS model. The model was calibrated to a known high-water mark located on 222 N Margery Dr. A complete description of the methodologies and assumptions used to generate and evaluate the hydraulic model can be found in Appendix B, Hydraulic Model Development and Analyses.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Fig. 2-2. Map showing the extent of the hydraulic model created for Squaw Run within O'Hara Township. Location and extent of cross sections (i.e., river stations) developed to characterize the flow carrying capacity of the stream and associated floodplain are also shown.

Inundation profiles (i.e., flood depths and extents) were created for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flows events. The number of structures impacted under each event were identified and summarized. Structures wholly or partially within the 1% ACE floodplain ─ the event used by FEMA to determine flood insurance requirements and to which subsequent non-structural flood risk mitigation measures are generally designed ─ were specifically identified.

2.2.1.2 Fox Chapel Borough

Hydraulic models were developed for the targeted areas along Squaw Run within Fox Chapel Borough (see Fig. 1-2) as part of a FEMA Flood Insurance Study completed in September 2014 (FEMA, 2014). Output from these models was utilized to inform subsequent analyses for Fox Chapel Borough. These existing models were used to inform the development of non-structural flood risk mitigation measures. Structures wholly or partially within the 1% ACE floodplain ─ the event used by FEMA to determine flood insurance requirements and to which subsequent non-structural flood risk mitigation measures are generally designed ─ were specifically identified for target areas within Fox Chapel Borough (see Fig. 1-2).

2.2.2 Results

2.2.2.1 O'Hara Township

The backwater flood elevation within Squaw Run associated with the 1% (i.e., 100-year) ACE flood along the Allegheny River is 739.5 ft (North American Vertical Datum 1988). Simulated 1% ACE flood elevations impacting structures within the targeted areas along Squaw Run were consistently greater than the 1% ACE elevation associated with Allegheny River backwater flooding. Therefore, subsequent analyses and discussion within this report focus on reducing risk associated with flooding along Squaw Run. Risk associated with Allegheny River backwater flooding is characterized for structures included in the non-structural assessment within Appendix C, Non-Structural Data and Assessment Datasheets.

The number of structures predicted to be inundated as a result of flooding along Squaw Run within O'Hara Township ranged from one during the 50% (i.e., 2-year) to 59 during the 0.2% (i.e., 500-year) ACE event (Table 2-3).

Table 2-3. Number of structures inundated along Squaw Run within O'Hara Township during peak discharges (Q) associated with the 50% (2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flows events.

Event	**Buildings Inundated (No.)**
$Q_{50\%}$	1
$Q_{10\%}$	7
$Q_{4\%}$	27
$Q_{2\%}$	36
$Q_{1\%}$	46
$Q_{0.5\%}$	52
$Q_{0.2\%}$	59

Inundation grids for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flows are provided as electronic appendices. Inundation boundaries for the 1% and 0.2% ACE events are shown below in Fig. 2-3. Structures identified as intersecting the 1% ACE floodplain are presented below in Table 2-4.

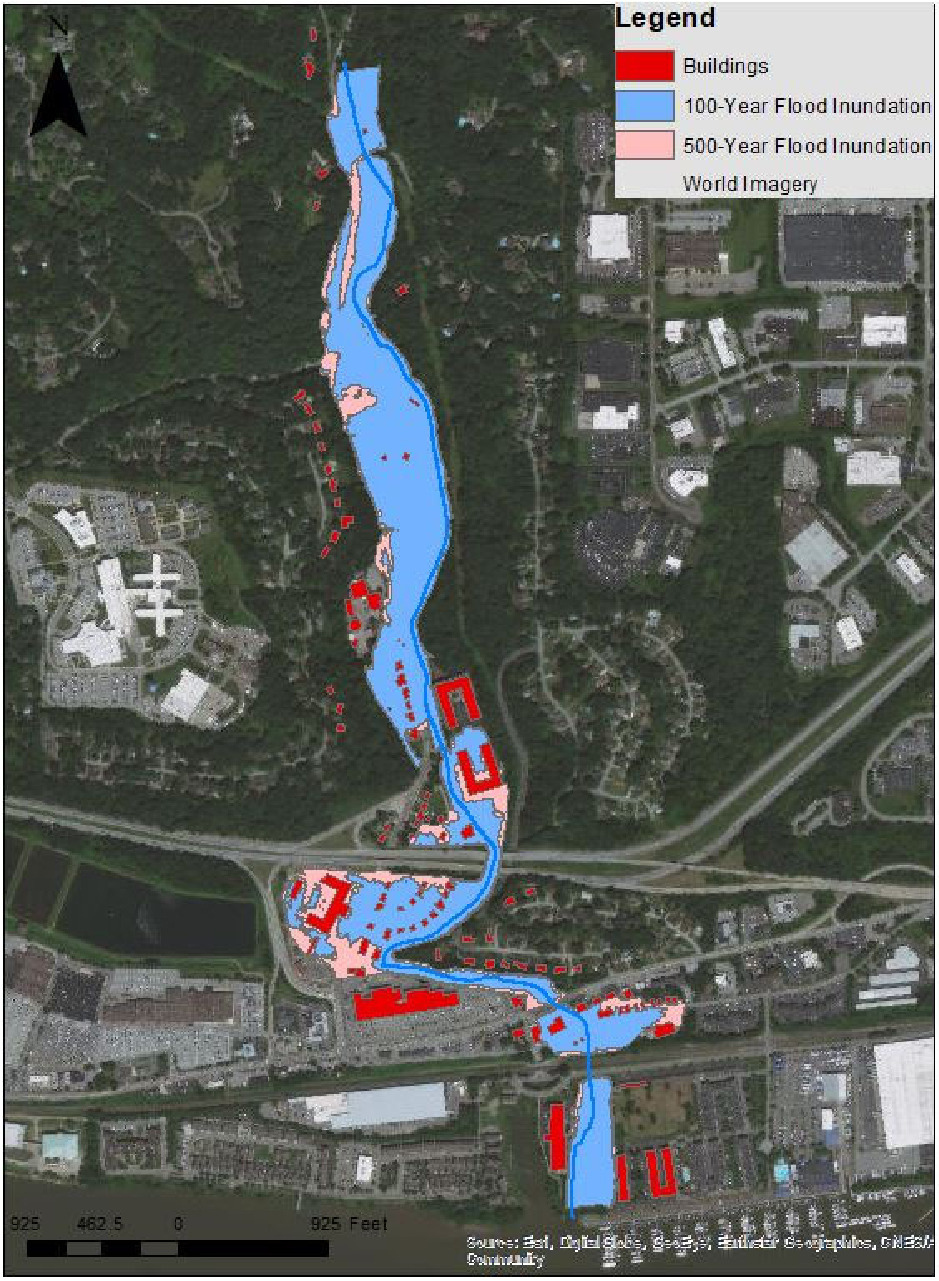


Fig. 2-3. Existing conditions inundation extents for the 1% (i.e., 100-year) and 0.2% (i.e., 500-year) ACE flood events for the modeled area along Squaw Run within O'Hara Township.

Table 2-4. Addresses of residential, commercial, and public structures identified as intersecting the 1% (i.e., 100-year) floodplain along Squaw Run within O'Hara Township. Structures requested for inclusion in the subsequent non-structural flood risk mitigation assessment based on historic flood risk are noted. Note: park facilities (3) and utility structures (2) are not included in this table.

Address	**Non-structural assessment**
1153 Old Freeport Rd.	Yes
1200 Old Freeport Rd.	Yes
1250 Old Freeport Rd.	Yes
1296 Old Freeport Rd.	Yes

Address	**Non-structural assessment**
1310 Old Freeport Rd.	Yes
1311 Old Freeport Rd.	Yes
1315 Old Freeport Rd.	Yes
1317 Old Freeport Rd.	Yes
1319 Old Freeport Rd.	Yes
1321 Old Freeport Rd.	Yes
1323 Old Freeport Rd.	Yes
200 S Margery Dr.	Yes
204 S Margery Dr.	Yes
206 S Margery Dr.	Yes
208 S Margery Dr.	Yes
209 S Margery Dr.	Yes
210 S Margery Dr.	Yes
211 S Margery Dr.	Yes
212 S Margery Dr.	Yes
213 S Margery Dr.	Yes
214 S Margery Dr.	Yes
215 S Margery Dr.	Yes
216 S Margery Dr.	Yes
218 S Margery Dr.	Yes
222 N Margery Dr.	Yes
227 N Margery Dr.	Yes
51 Fox Chapel Rd.[*]	No
100 Fox Chapel Rd.	Yes
200 Fox Chapel Rd.	Yes
202 Fox Chapel Rd.	Yes
204 Fox Chapel Rd.	Yes
300 Fox Chapel Rd.	No
306 Fox Chapel Rd.	Yes
308 Fox Chapel Rd.	Yes
310 Fox Chapel Rd.	Yes
312 Fox Chapel Rd.	Yes
314 Fox Chapel Rd.	Yes
316 Fox Chapel Rd.	Yes

[*] This address has 4 structures associated with it that intersect the 1% ACE floodplain.

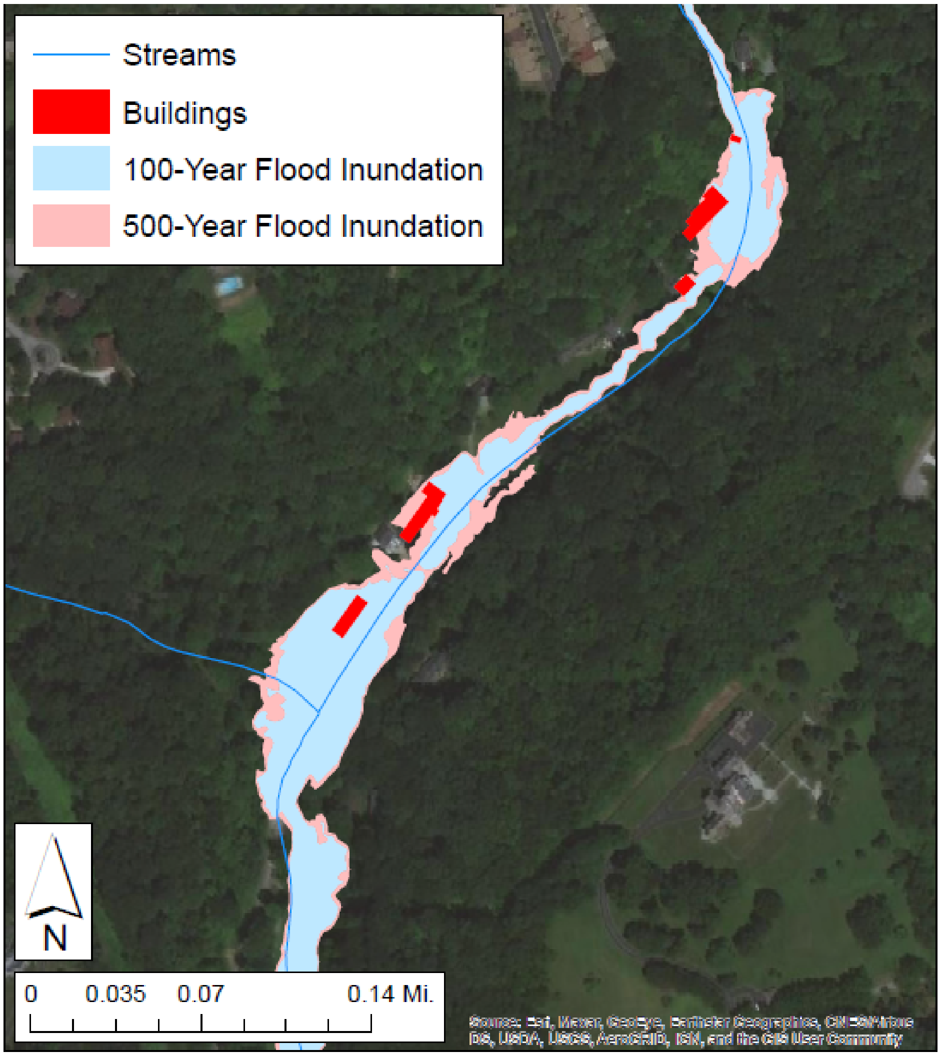
Water surface elevation simulated by the calibrated HEC-RAS model compared favorably to the single historical high-water mark at 222 N Margery Drive. The modeled water surface elevation at the location of the high-water mark (755.03 ft.; North American Vertical Datum of 1988) had a 0.01-ft (0.50%) difference from elevation of the high-water mark (755.02 ft). It was determined that the hydraulic modeling results are appropriate for characterizing existing flood risk and assessing potential flood risk management opportunities within the Squaw Run watershed.

2.2.2.2 Fox Chapel Borough

A total of three homes were identified as being within the 1% (i.e., 100-year) ACE floodplain as characterized by the existing FEMA model (FEMA, 2014) (Table 2-5, Fig. 2-4).

Table 2-5. Addresses of structures identified as within the 1% (i.e., 100-year) floodplain along Squaw Run within the targeted area of Fox Chapel Borough (see Fig. 1-2). Structures requested for inclusion in the subsequent non-structural flood risk mitigation assessment based on historic flood risk are noted.

Address	Non-structural assessment
505 Old Mill Rd.	Yes
507 Old Mill Rd.	Yes
535 Old Mill Rd.	Yes



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Fig. 2-4. Existing conditions inundation extents for the 1% (i.e., 100-year) and 0.2% (i.e., 500-year) ACE flood events for the targeted areas along Squaw Run within Fox Chapel Borough.

3 Structural Flood Risk Management Measures

Structural flood risk management measures are physical modifications of the channel or floodplain designed to reduce the frequency of flood damage by altering the nature and/or extent of the flooding. The USACE study team, in coordination with O'Hara Township and Fox Chapel Borough identified the following structural measures for evaluation in this study: 1) stormwater management ponds to increase storage throughout the watershed, 2) floodwalls to reduce flooding within O'Hara Township, 3) channel modifications to reduce flooding within O'Hara Township, and 4) modification of the bridge on Old Freeport Road within O'Hara Township.

The structural measures described in this report are meant to be conceptual in nature. As such, no design information or estimated costs are provided. Factors contributing to ultimate feasibility, including real estate and permitting requirements, impacts to existing infrastructure, residual risk, and ongoing operation and maintenance requirements were not assessed. ***Thus, the intent of these analyses was to serve as an initial assessment of a subset of potential flood risk management alternatives, not to identify and recommend one or more feasible actions.*** If one or more of these measures is pursued, preliminary design work and subsequent final design engineering will need to be conducted by a licensed engineer. Design and implementation of flood risk management measures, such as those presented here, could be pursued through USACE's Section 205 Continuing Authorities Program.

3.1 Conceptual Alternatives & Analytical Methods

3.1.1 Stormwater Management Ponds

The study team identified locations for two conceptual stormwater management ponds in an effort to characterize and quantify the potential benefits of reducing downstream flooding through storm water management. Locations for the conceptual stormwater management ponds were determined based on the absence of topographic constraints and anticipated storage potential. Other considerations such as potential real estate requirements and impacts to existing infrastructure (e.g., roadways) were not assessed. ***Thus, the intent of this assessment was not to identify and recommend specific locations for implementation of stormwater management ponds, but rather to characterize the potential benefits of such actions.*** A full description of the conceptual design, associated assumptions, and technical analyses associated with each stormwater pond can be found in Appendix A, Hydrologic Model Development & Analyses.

The first conceptual stormwater management pond (subsequently referred to as Stormwater Pond 1; Fig. 3-1) is located on an unnamed tributary of Glade Run (sub-basin no. 6 in Fig. 2-1 and Table 2-1). The second conceptual stormwater pond (referred to as Stormwater Pond 2; Fig. 3-2) is located at the confluence of Stony Camp Run and Squaw Run (sub-basin no. 7, Fig. 2-1, Table 2-1). These conceptual ponds would reduce flood risk along Squaw Run within O'Hara Township (Fig. 2-3) but are upstream of the identified at risk homes within Fox Chapel Borough (Fig. 2-4).

The potential effects of each stormwater pond on hydrology within the Squaw Run watershed were assessed by adding reservoir elements within and revising the appropriate parameters of the associated sub-basins within the existing conditions hydrologic model (see Section 2.1). The updated hydrologic model was then run to provide peak discharges under the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year)

0.2% (500-year) ACE flows events. Updated peak discharges were then used as inputs into the existing conditions hydraulic model (see Section 2.2) to determine the effect of each stormwater pond on downstream flood elevations.

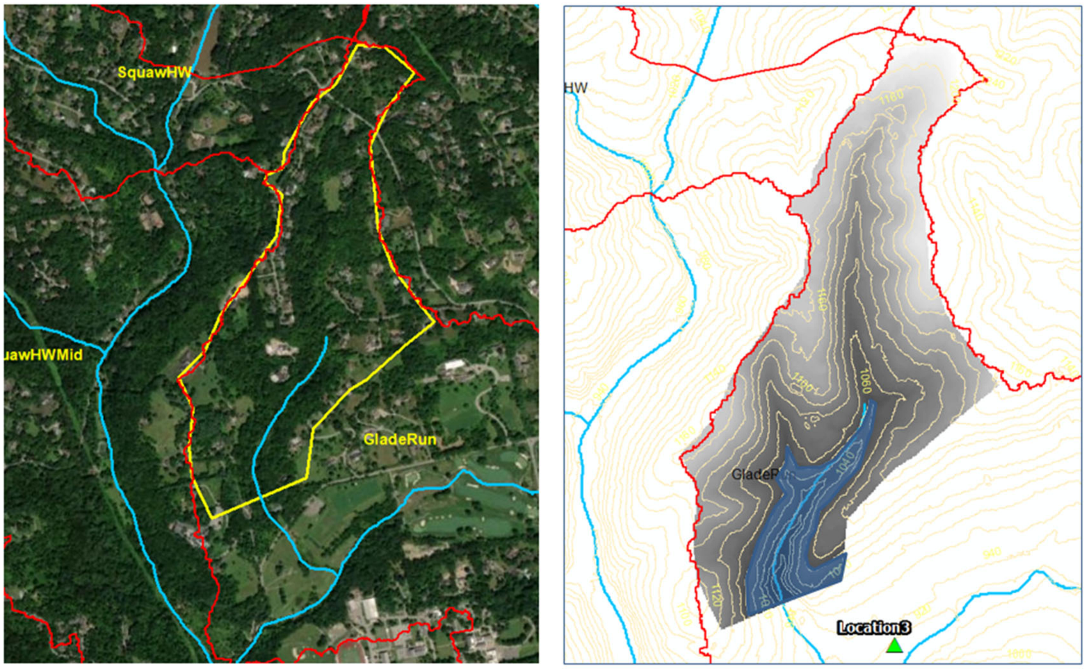


Fig. 3-1. Aerial photo view (left panel) and 20-foot contours (right) with approximate footprint of Stormwater Pond 1 at maximum depth.

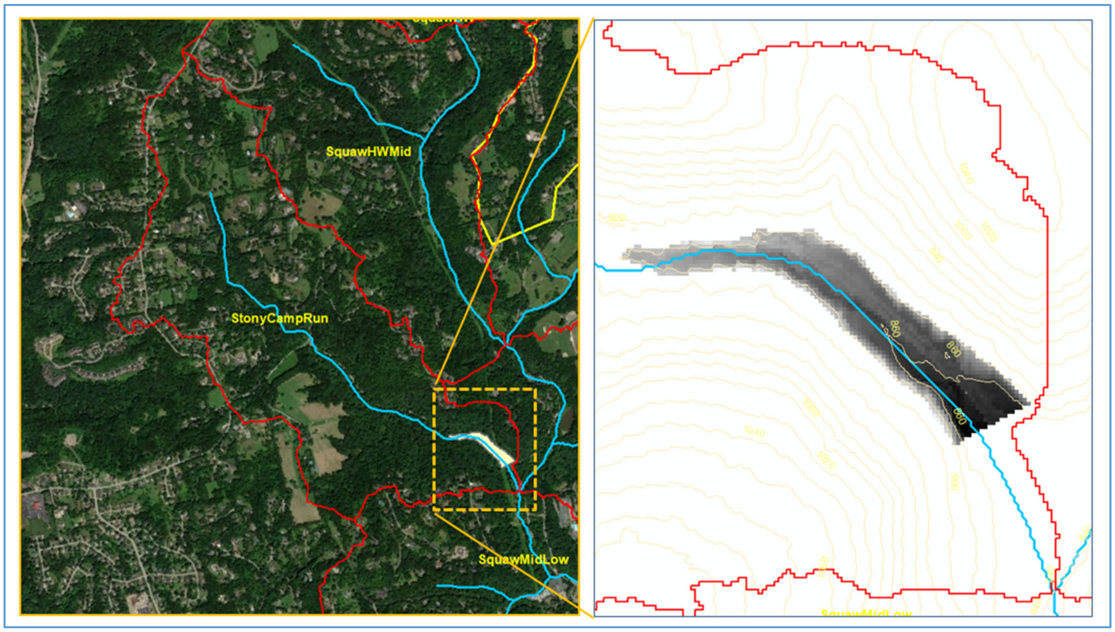


Fig. 3-2. Aerial photo view (left panel) and 20-foot contours (right) with approximate footprint of Stormwater Pond 2 at maximum depth.

3.1.2 Floodwalls

Two conceptual floodwalls were assessed for their ability to reduce risk to high-density housing along Squaw Run within O'Hara Township ─ one between Squaw Run and Fox Chapel Road to reduce risk to six homes located on the west of Fox Chapel Road (subsequently referred to as Floodwall 1), and one to reduce risk to 23 structures along Fox Chapel Road and S. Margery Drive (subsequently referred to as Floodwall 2) (Fig. 3-3).

The geometry of each floodwall was incorporated into the cross sections within the hydraulic model as a levee element. The model was rerun to characterize changes in inundation extents and depths associated with each individual floodwall and their combination for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flows events. Both floodwalls were modeled to reduce risks associated with the 0.2% (i.e., 500-year) ACE flood event. The height of any implemented floodwall should be a risk-informed decision based on a cost-benefit analysis.

Fig. 3-3. Maps showing the extents of conceptual floodwalls 1 (left panel) and 2 (right panel).

3.1.3 Channel Modification

Two conceptual channel modifications were assessed for their ability reduce risk to high-density housing along Squaw Run in O'Hara Township. The upstream section (subsequently referred to as Channel 1) was located along Fox Chapel Road to reduce risk to the six homes located on the west of Fox Chapel Road (Fig. 3-4). The downstream (subsequently referred to as Channel 2) was located downstream of Route 28 along and immediately downstream of S. Margery Drive (Fig. 3-4).

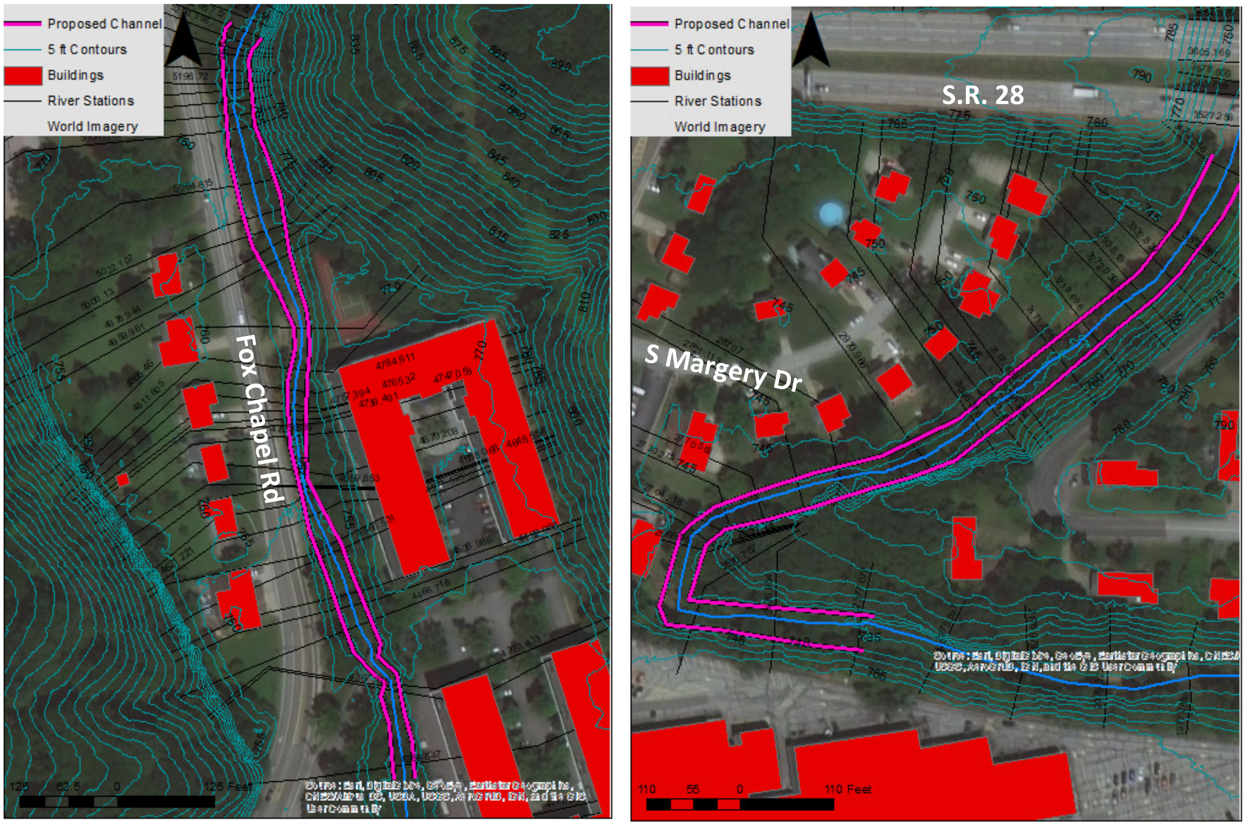


Fig. 3-4. Maps showing the extents of conceptual channel modifications 1 (left panel) and 2 (right panel).

Each channel modification would include excavation of the channel bottom by approximately two feet and smooth the channel slope (Fig. 3-5). Each channel would be lined with riprap to avoid channel bottom erosion. Each conceptual channel modification was intended to reduce flood risk by increasing channel capacity and improving hydraulic conductivity.

The geometry of each channel modification was incorporated into the specific cross sections within the hydraulic model by revising channel geometry. The model was then rerun to characterize changes in inundation extents and depths for each channel modification during the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flows.

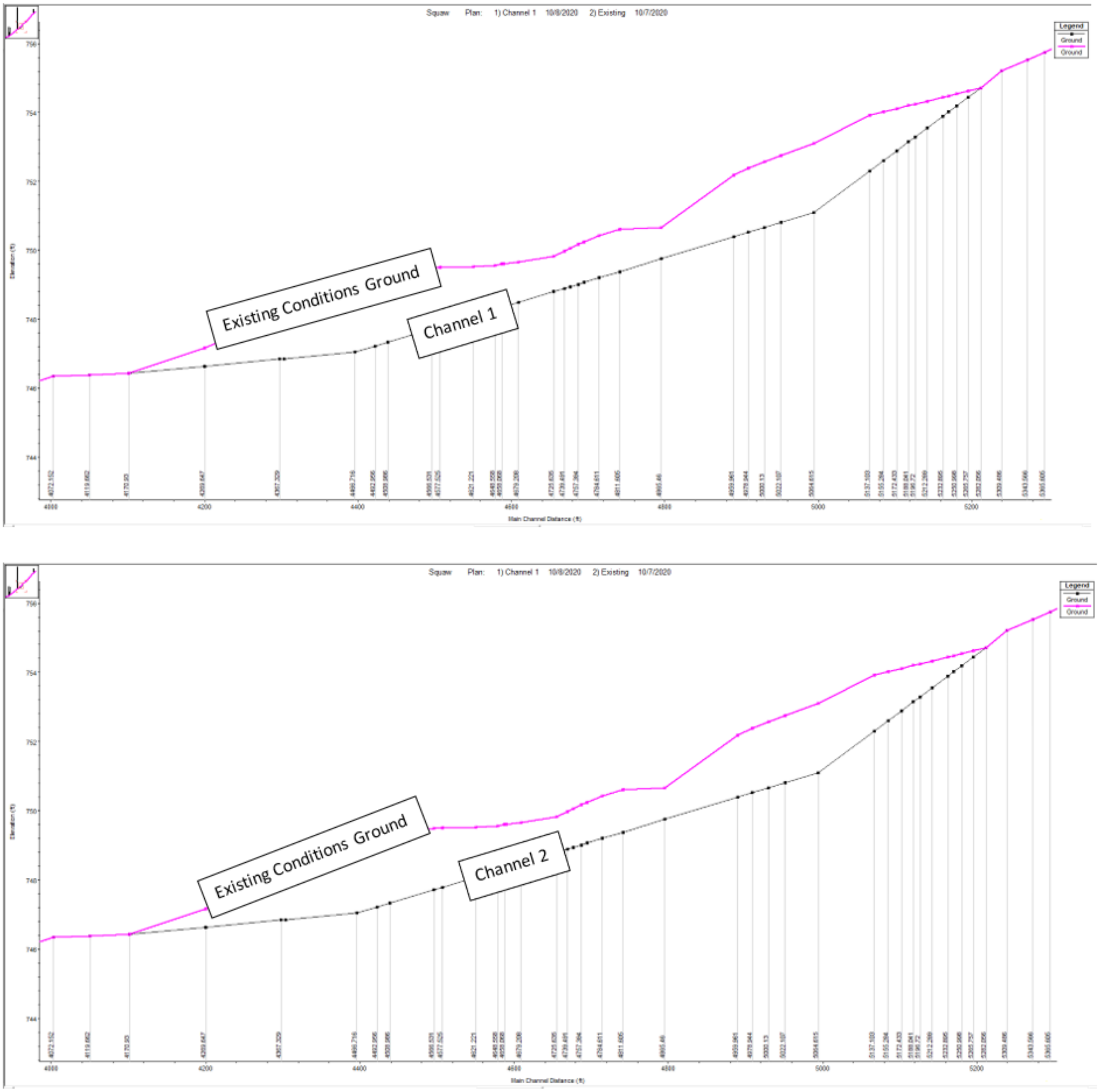


Fig. 3-5. Profile view of conceptual channel modifications 1 (top panel) and 2 (bottom panel).

3.1.4 Bridge Modification

A conceptual modification to the bridge on Old Freeport Road was assessed for its ability to reduce flood risk upstream of Old Freeport Road (see Fig. 1-2). The conceptual modification included raising the top of the bridge 1.25 feet (Fig. 3-6). The updated bridge geometry was incorporated into the hydraulic model. The model was then rerun to characterize changes in inundation extents and depths for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flows events.

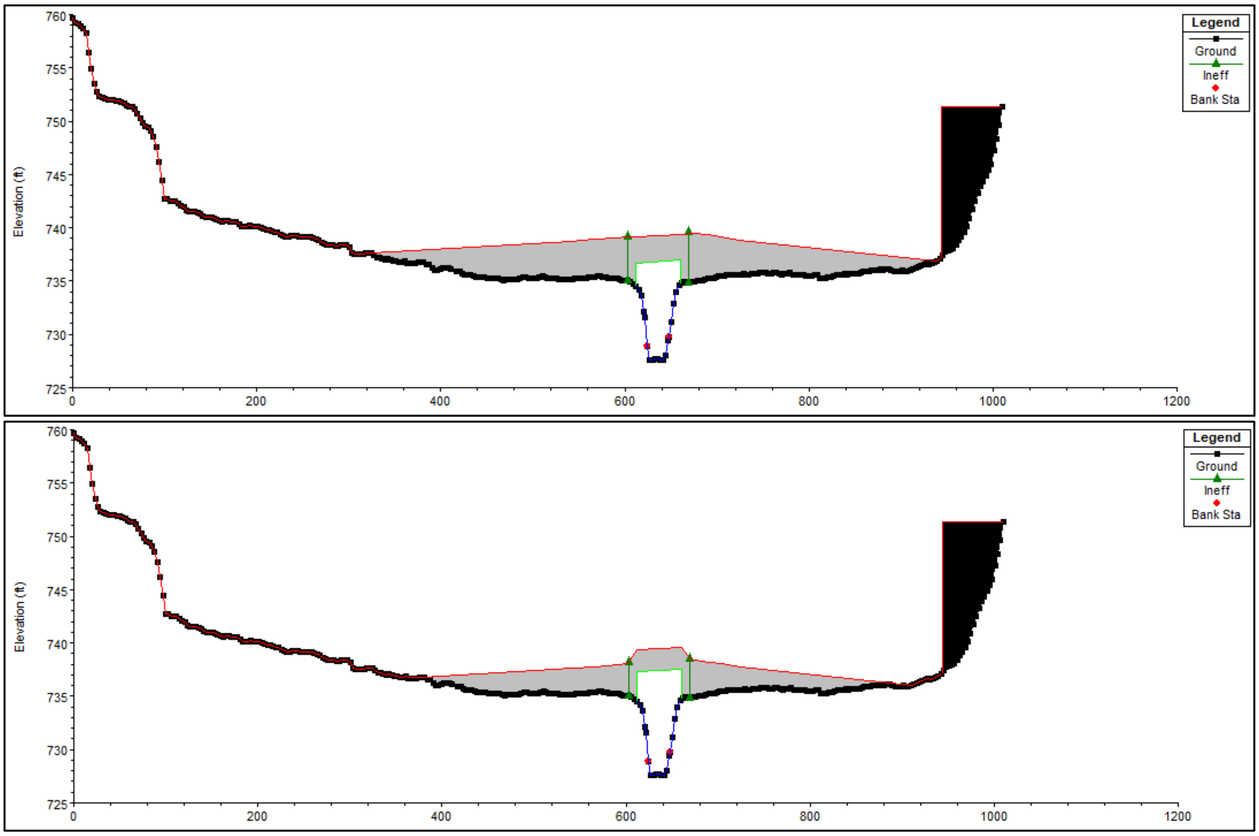


Fig. 3-6. Cross sections showing the existing (top panel) and conceptual (bottom panel) geometry of the bridge on Old Freeport Road.

3.2 Results

3.2.1 Stormwater Management Ponds

Both stormwater ponds resulted in reduced discharges at the outflow of Squaw Run (Table 3-1). Discharges are shown for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE events. Reductions resulting from Stormwater Pond 1 ranged from 1.9%, for the 0.2% ACE event, to 6.0%, for the 50% ACE event. Stormwater Pond 2 resulted in peak discharge reductions ranging from 5.7%, for the 0.2% ACE event, to 21.3%, for the 50% ACE event. Detailed hydrologic results associated with implementing stormwater management ponds can be found in Appendix A, Hydrologic Model Development and Analyses.

Table 3-1. Peak discharges (Q) at the outflow of Squaw Run under existing conditions and following the simulated implementation of conceptual Stormwater Ponds 1 and 2. Results are shown for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flood events.

	Existing Conditions		**Stormwater Pond 1**			**Stormwater Pond 2**	
Event	**Q (cfs)**		**Q (cfs)**	**Change (%)**		**Q (cfs)**	**Change (%)**
$Q_{50\%}$	497		477	-4.0		391	-21.3
$Q_{10\%}$	1367		1279	-6.4		1135	-17.0

	Existing Conditions		**Stormwater Pond 1**			**Stormwater Pond 2**	
Event	**Q (cfs)**		**Q (cfs)**	**Change (%)**		**Q (cfs)**	**Change (%)**
$Q_{4\%}$	2205		2072	-6.0		1880	-14.7
$Q_{2\%}$	2959		2798	-5.4		2636	-10.9
$Q_{1\%}$	3703		3566	-3.7		3453	-6.8
$Q_{0.5\%}$	4670		4556	-2.4		4393	-5.9
$Q_{0.2\%}$	6151		6036	-1.9		5801	-5.7

The reductions in peak discharges associated with each stormwater pond resulted in simulated reductions in overbank water volume and number of inundated structures (Table 3-2). Reductions in overbank water volume ranged from 0.44 acre-feet to 17.15 acre-feet for Stormwater Pond 1 and 2.26 acre-feet to 35.91 acre-feet for Stormwater Pond 2. Changes in overbank water volume translated to a reduction in number of structures inundated ranging from 0 to 2 for Stormwater Pond 1 and 0 to 10 for Stormwater Pond 2. Inundation maps for the 1% (100-year) and 0.2% (500-year) ACE events are presented in Appendix B, Hydraulic Model Development and Analyses.

Table 3-2. Changes in overbank volume (ObV; acre-feet) and number of inundated structures (Struct.) associated with implementation of stormwater ponds 1 and 2. Results are shown for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flood events.

	Stormwater Pond 1			**Stormwater Pond 2**	
Event	**Δ ObV (ac-ft)**	**Δ Struct. (no.)**		**Δ ObV (ac-ft)**	**Δ Struct. (no.)**
$Q_{50\%}$	-0.44	0		-2.26	0
$Q_{10\%}$	-3.41	-1		-8.50	-3
$Q_{4\%}$	-7.09	-1		-17.96	-10
$Q_{2\%}$	-8.09	-2		-18.16	-3
$Q_{1\%}$	-7.10	-2		-15.33	-5
$Q_{0.5\%}$	-6.45	0		-18.99	-1
$Q_{0.2\%}$	-17.15	-2		-35.91	-3

3.2.2 Floodwalls

Both floodwalls would be expected to result in reductions in overbank water volume and number of inundated structures (Table 3-3). Reductions in overbank water volume during the various flood events ranged from 0.17 acre-feet to 9.05 acre-feet Floodwall 1 and 0.00 acre-feet to 34.82 acre-feet for Floodwall 2. Changes in overbank water volume translated to a reduction in number of structures inundated ranging from 0 to 7 for Floodwall 1 and 0 to 22 for Floodwall 2. The combined effect of Floodwalls 1 and 2 was also assessed. The construction of both floodwalls would result in a combined reduction in overbank flow ranging from 0.18 acre-feet to 41.79 acre-feet, which translated into a reduction in the number of impacted structures ranging from 0 to 28. Inundation maps for the 1% (100-year) and 0.2% (500-year) ACE events under each floodwall scenario are presented in Appendix B, Hydraulic Model Development and Analyses.

Table 3-3. Changes in overbank volume (ObV; acre-feet) and number of inundated structures (Struct.) associated with implementation of floodwalls 1 and 2, as well as their combination. Results are shown for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flood events.

	Floodwall 1			**Floodwall 2**			**Floodwalls 1 & 2**	
Event	**ΔObV (ac-ft)**	**Δ Struct. (no.)**		**Δ ObV (ac-ft)**	**Δ Struct. (no.)**		**Δ ObV (ac-ft)**	**Δ Struct. (no.)**
$Q_{50\%}$	-0.17	0		0.00	0		-0.18	0
$Q_{10\%}$	-2.57	-1		-0.31	-3		-2.87	-3
$Q_{4\%}$	-6.92	-7		-0.99	-7		-7.92	-14
$Q_{2\%}$	-8.26	-7		-2.80	-11		-11.06	-18
$Q_{1\%}$	-9.05	-7		-7.16	-18		-16.21	-25
$Q_{0.5\%}$	-8.89	-7		-18.07	-21		-26.95	-28
$Q_{0.2\%}$	-6.92	-5		-34.82	-22		-41.79	-27

3.2.3 Channel Modification

Channel 1 resulted in simulated reductions in overbank water volume during the 50% (2-year), 10% (10-year), and 4% (25-year), but resulted in increases in overbank water volume during all higher-flow events (Table 3-4). Channel 1 did not result in a reduction in the number of structures inundated ─ rather, it resulted in a simulated increase in up to two impacted structures.

Channel 2 resulted in consistent simulated reductions in overbank water volume during all flow events, ranging from 0.33 acre-feet to 3.06 acre-feet. Reductions in overbank water volume associated with Channel 2 translated to a reduction in number of structures inundated ranging from 0 to 4. Inundation maps for the 1% (100-year) and 0.2% (500-year) ACE events are presented for each channel in Appendix B, Hydraulic Model Development and Analyses.

Table 3-4. Changes in overbank volume (ObV; acre-feet) and number of inundated structures (Struct.) associated with implementation of channels 1 and 2. Results are shown for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flood events.

	Channel 1			**Channel 2**	
Event	**Δ ObV (ac-ft)**	**Δ Struct. (no.)**		**Δ ObV (ac-ft)**	**Δ Struct. (no.)**
$Q_{50\%}$	-0.41	0		-0.33	0
$Q_{10\%}$	-2.15	0		-2.36	-3
$Q_{4\%}$	-2.40	2		-2.60	-4
$Q_{2\%}$	3.87	1		-2.15	0
$Q_{1\%}$	9.77	0		-3.06	-4
$Q_{0.5\%}$	19.5	1		-2.49	0
$Q_{0.2\%}$	34.53	2		-2.16	-1

3.2.4 Bridge Modification

Increasing the elevation of the bridge on Old Freeport Road had minimal impact on overbank water volumes, which ranged from a reduction of 0.47 acre-feet to an increase of 0.56 acre-feet (Table 3-5). The number of structures affected during each flow event ranged from 0 to 1.

Table 3-5. Changes in overbank volume (ObV; acre-feet) and number of inundated structures (Struct.) associated with elevating the deck of the bridge on Old Freeport Road. Results are shown for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flood events.

Event	**Δ ObV (ac-ft)**	**Δ Struct. (no.)**
$Q_{50\%}$	0.00	0
$Q_{10\%}$	0.00	-1
$Q_{4\%}$	-0.47	-1
$Q_{2\%}$	-0.01	-1
$Q_{1\%}$	0.55	-1
$Q_{0.5\%}$	0.56	0
$Q_{0.2\%}$	0.56	0

3.2.5 Combinations of Structural Measures

Given the results of the simulated implementation of individual types of structural measures, the study team simulated the combined implementation of the stormwater ponds and floodwalls ─ the two types of measures with the greatest and most consistent benefits ─ to estimate the maximum possible benefit. Specifically, the team looked at combining Stormwater Pond 2 and Floodwall 1, Stormwater Pond 2 and Floodwall 2, and Stormwater Pond 2 and Floodwalls 1 and 2.

Simulated implementation of Stormwater Pond 2 and Floodwall 1 resulted in overbank water volume reductions ranging from 2.26 to 43.42 acre-feet and reductions in the number of impacted structures ranging from 0 to 16 (Table 3-6). Combined implementation of Stormwater Pond 2 and Floodwall 2 resulted in overbank water volume reductions ranging from 2.26 to 61.09 acre-feet and reductions in the number of impacted structures ranging from 0 to 25. Combined implementation of Stormwater Pond 2 and Floodwall 1 and 2 resulted in overbank water volume reductions ranging from 2.33 to 68.60 acre-feet and reductions in the number of impacted structures ranging from 0 to 31. Inundation maps for the 1% (100-year) and 0.2% (500-year) ACE events are presented for each channel in Appendix B, Hydraulic Model Development and Analyses.

Table 3-6. Changes in overbank volume (ObV; acre-feet) and number of inundated structures (Struct.) associated with the combination of stormwater pond and floodwall measures. Results are shown for the 50% (i.e., 2-year recurrence interval), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.5% (200-year) 0.2% (500-year) ACE flood events.

	Stormwater Pond 2 + Floodwall 1			**Stormwater Pond 2 + Floodwall 2**			**Stormwater Pond 2 + Floodwalls 1 & 2**	
Event	**ΔObV (ac-ft)**	**Δ Struct. (no.)**		**Δ ObV (ac-ft)**	**Δ Struct. (no.)**		**Δ ObV (ac-ft)**	**Δ Struct. (no.)**
$Q_{50\%}$	-2.26	0		-2.26	0		-2.33	0
$Q_{10\%}$	-8.50	-3		-8.63	-5		-10.38	-5
$Q_{4\%}$	-17.96	-16		-18.73	-14		-23.39	-20
$Q_{2\%}$	-26.15	-10		-19.94	-13		-27.93	-20
$Q_{1\%}$	-24.24	-12		-20.71	-21		-29.62	-28
$Q_{0.5\%}$	-28.00	-8		-33.94	-22		-42.94	-29
$Q_{0.2\%}$	-43.42	-9		-61.09	-25		-68.60	-31

4 Optional Non-Structural Flood Risk Management Measures

4.1 General Overview

Non-structural flood risk management measures represent optional actions that reduce flood damage and risks without significantly altering the nature or extent of the flooding by changing the use of floodplains or by accommodating existing uses to the flood hazard. Non-structural flood risk management measures are effective for both short- and long-term flood risk and damage reduction and can be very cost effective when compared to other types of flood risk management measures (e.g., structural). Non-structural measures can also be implemented in economically feasible increments, with each increment producing a higher degree of risk reduction benefit. Non-structural measures are developed on a structure-by-structure basis; however, collective implementation of non-structural measures reduces total cumulative impacts of flooding across the affected area. Benefits, costs, and potential consequences (e.g., maintenance burden, altered tax base) of implementing non-structural measures are dependent upon local socioeconomic and environmental context. Thus, non-structural measures must be compatible with, and designed within the context of, local socioeconomic and environmental conditions in order to be effective.

Non-structural assessments and resulting flood risk management measures are compliant with Executive Order 11988 (EO 11988)–Floodplain Management, which was issued by President Carter on 24 May 1977. EO 11988 requires federal agencies to avoid, to the extent possible, short- and long-term impacts associated with the occupancy and modification of floodplains, and to avoid direct and indirect support of floodplain development wherever there are practicable alternatives.

4.2 Overview of Optional Non-structural Measures

This section provides detailed descriptions of optional non-structural flood risk management measures identified for residential and non-residential structures in the Squaw Run Watershed. As previously discussed, only measures designed to modify characteristics of residential and commercial structures were considered. Additional information on all non-structural measures can be found at: https://www.usace.army.mil/Missions/Civil-Works/Project-Planning/nfpc/.

When possible, non-structural measures should be implemented to reduce risks associated with flooding equivalent to the design flood elevation (DFE). The DFE is a locally-adopted regulatory flood elevation that is generally greater than the BFE, or elevation associated with the 1% ACE (i.e., 100-year) flood, and is meant to account for factors that can act to increase the elevation of floodwaters (e.g., wave action and watershed development).

4.2.1 Acquisition

This measure consists of purchasing at-risk structures and associated land from the owner. The structures are generally demolished, and residents relocated outside of the floodplain. Development sites, if needed, can be considered as part of the project in order to have locations where displaced people can construct new homes or businesses (Fig. 4-1).

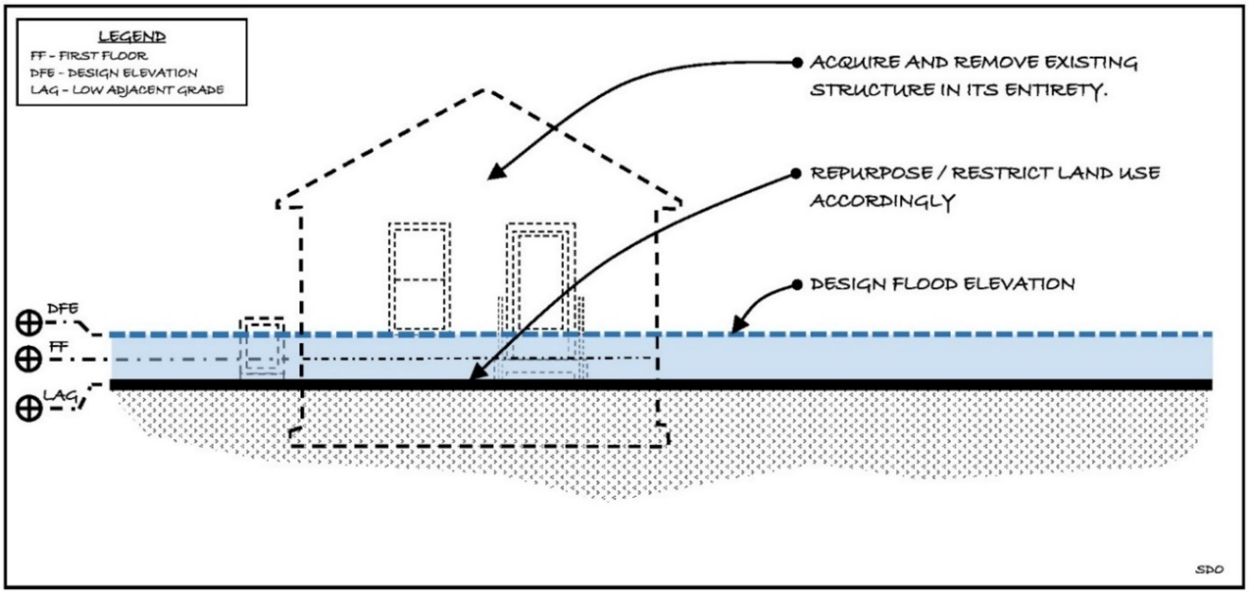


Fig. 4-1. Diagram depicting acquisition. Diagram not to scale.

4.2.2 Relocation

This measure consists of physically moving the at-risk structure and acquiring the land upon which the structure is located. This measure achieves a high level of flood risk reduction when structures can be relocated from a high flood hazard area to an area that is located completely outside of the floodplain. Development of relocation sites where structures could be moved to achieve the planning objectives of reducing flood risk and retaining community cohesion can be considered as part of the project (Fig. 4-2).

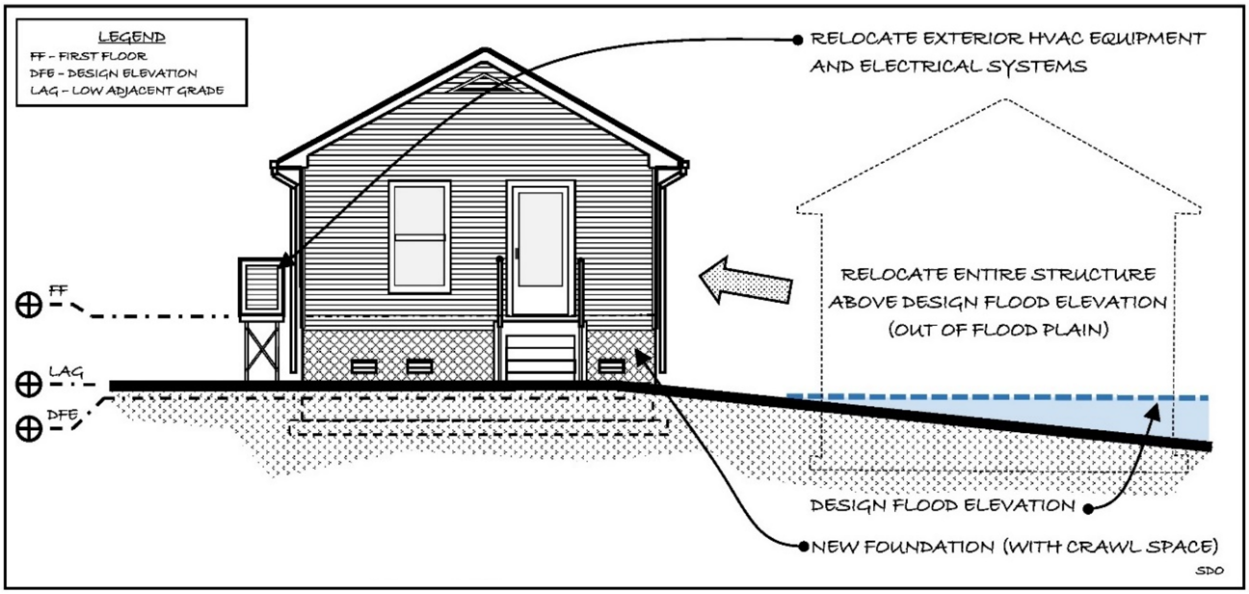


Fig. 4-2. Diagram depicting building relocation. Diagram not to scale.

4.2.3 Basement Abandonment

This measure consists of relocation of the basement/crawlspace storage, utilities, mechanical equipment, electrical panels and circuits to above BFE or DFE. Placing an addition onto the structure as part of the measure to compensate for the loss of habitable basement space and to house the furnace, water heater, water softener and other utilities and appliances is a consideration (Figs. 4-3 and 4-4).

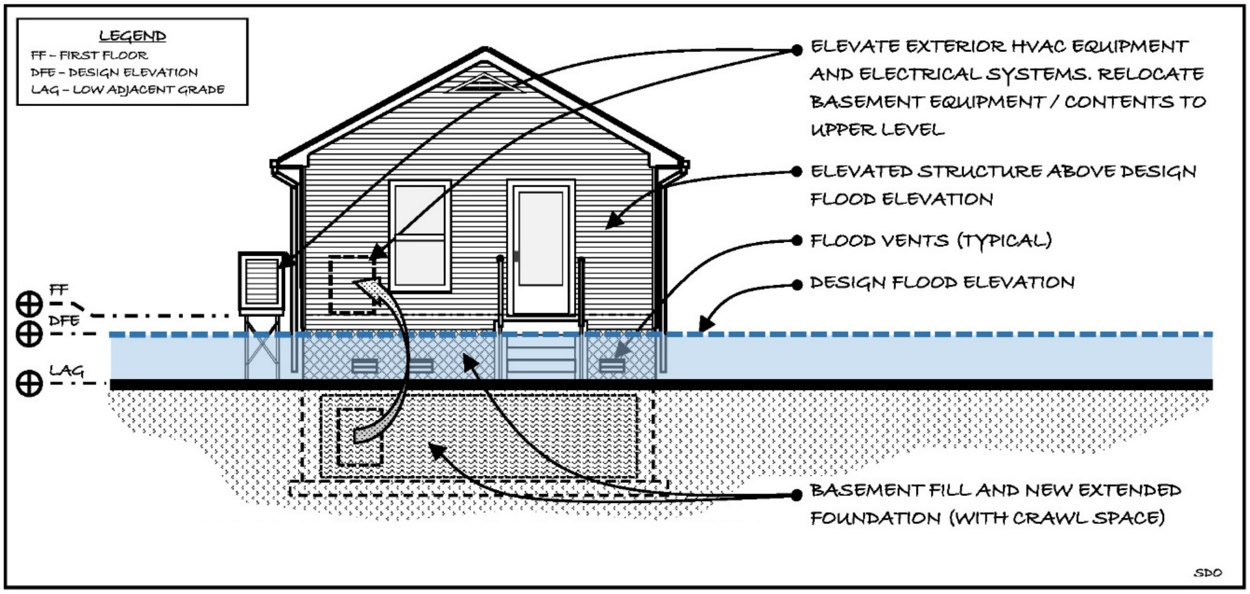


Fig. 4-3. Diagram depicting basement abandonment. Diagram not to scale.

Fig. 4-4. Structure before basement abandonment, with basement and utilities located below DFE (left). Structure after mitigation, including installation of flood louvers, construction of addition to main structure to replace lost basement space, and elevation of HVAC unit (right).

4.2.4 Structure Elevation

This measure consists of lifting the entire structure or the habitable area above a specified flood elevation. Elevating the entire structure above the DFE substantially reduces flood risk and is one of the more common and successful actions taken. The higher the lift the greater the resilience to flood events above the DFE. If a basement exists it should be abandoned and filled (Figs. 4-5 and 4-6).

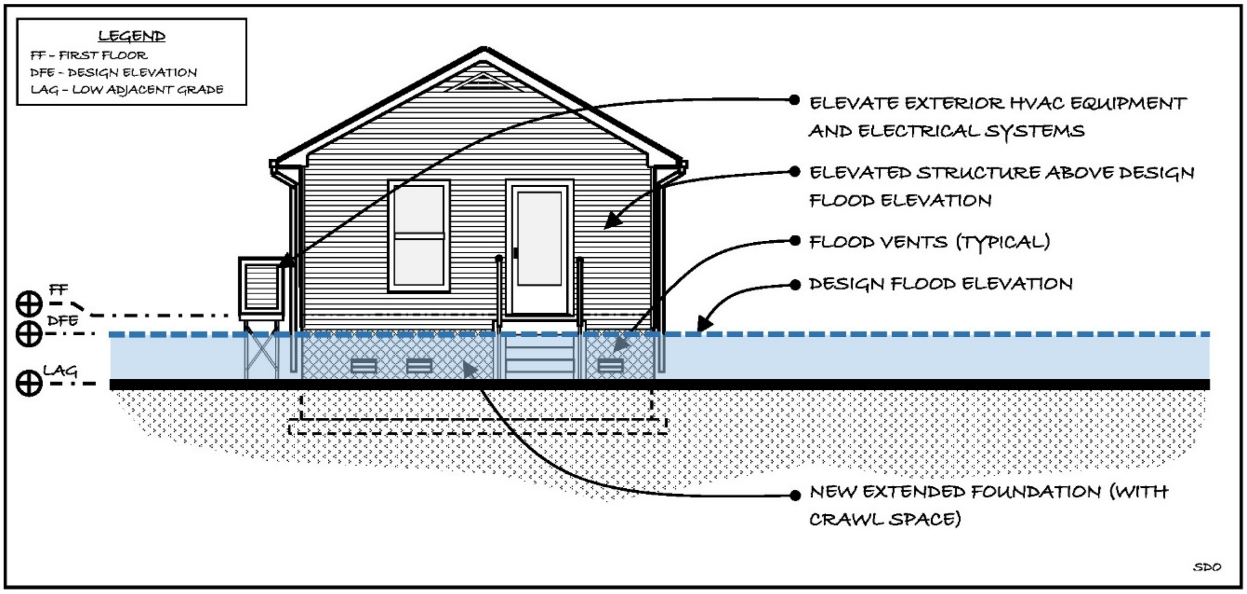


Fig. 4-5. Diagram depicting actions associated with structure elevation. Diagram not to scale.

Fig. 4-6. Example of structure before (left) and after (right) structure elevation mitigation.

4.2.5 Elevation of First Floor

This measure consists of elevating all or a portion of the habitable interior first floor above a specified flood elevation. Elevating the entire structure may not be feasible and or desirable. If headroom allows, elevation of the first floor above DFE may be a potential measure to reduce flood risk. This measure is very useful when mitigating historically sensitive structures (Figs. 4-7 and 4-8).

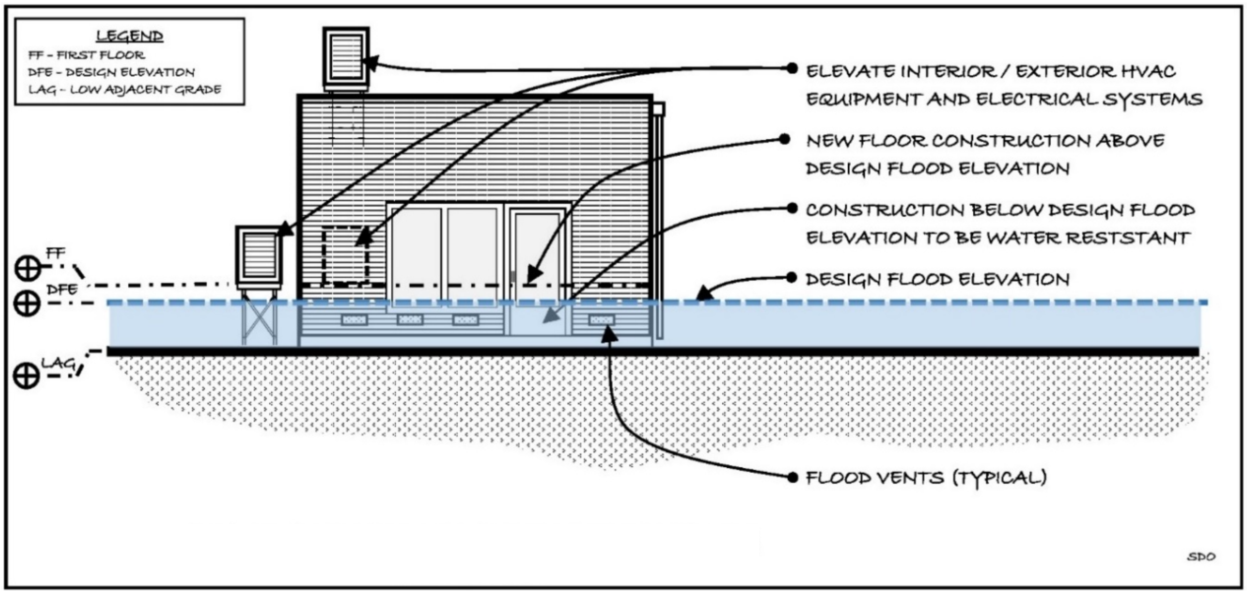


Fig. 4-7. Diagram depicting first floor elevation. Diagram not to scale.

Fig. 4-8. Example of structure before (left) and after (right) first floor elevation.

4.2.6 Dry Flood-Proofing

This measure consists of waterproofing the entire structure or portions of the structure. This measure achieves flood risk reduction benefits for non-residential structures, but it is not recognized by the National Flood Insurance Program for any flood insurance premium rate reduction if applied to residential structures. Based upon testing, a "conventional" built structure can generally be dry flood-proofed up to between 3 to 4 feet on the exterior walls. A structural analysis of the wall strength would be required if it was desired to achieve a higher level of protection. A sump pump and drain system may be required as part of the project to remove seepage or interior drainage. Closure panels are required for all openings (Figs. 4-9 and 4-10).

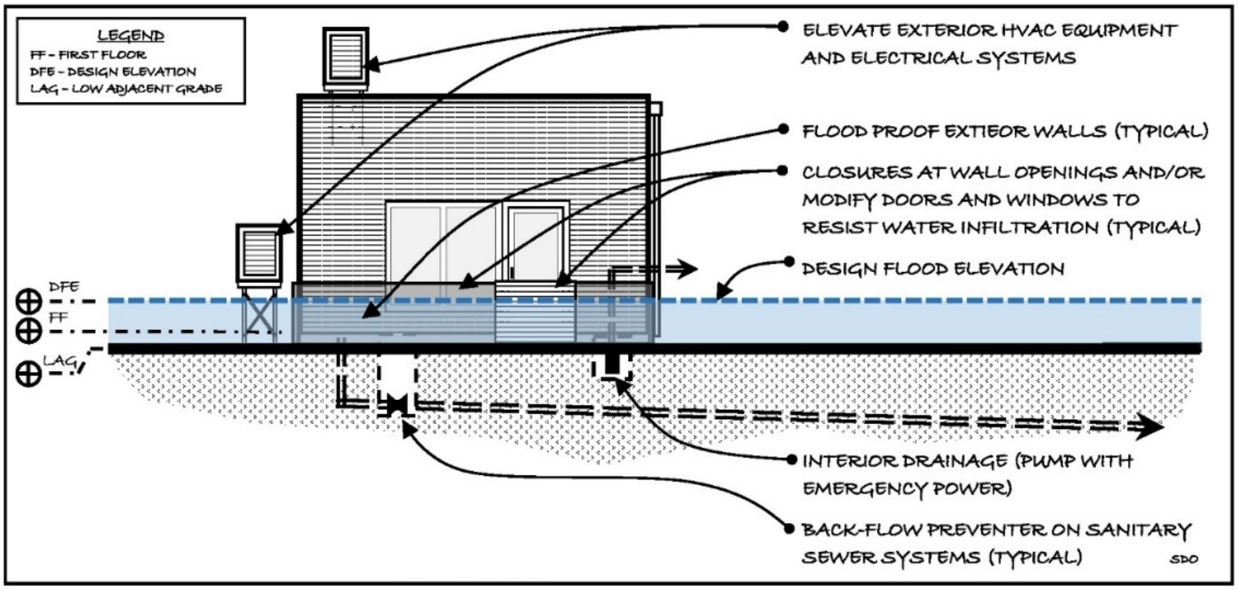


Fig. 4-9. Diagram depicting actions associated with dry flood-proofing. Diagram not to scale.

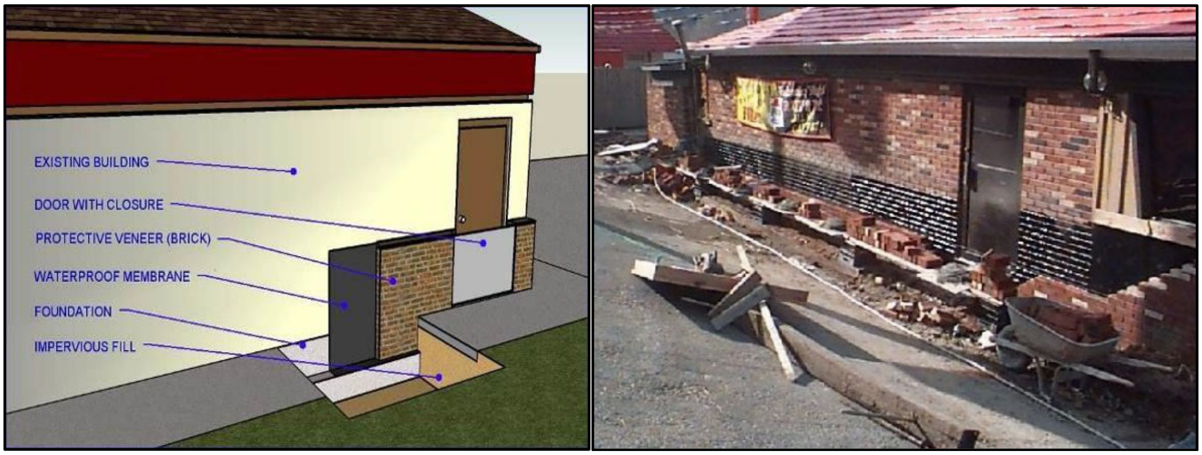


Fig. 4-10. Diagram (left) and photo (right) depicting veneer wall and waterproof membrane used in dry flood-proofing.

4.2.7 Wet Flood-Proofing

This measure consists of allowing flood water to enter all or part of a structure. Construction materials and finishes are be water/flood resistant to a height above the DFE. Wet flood-proofing may be applicable to commercial and industrial structures and should be considered in combination with flood warning, flood preparedness, and flood response planning. It may be considered as a stand-alone measure or in combination with other non-structural measures such as elevation or dry flood-proofing. All Structure systems and utilities must be elevated above the DFE. Wet flood-proofing of residential structures is generally not recommended or allowed by FEMA's National Flood Insurance Program (Figs. 4-11 and 4-12).

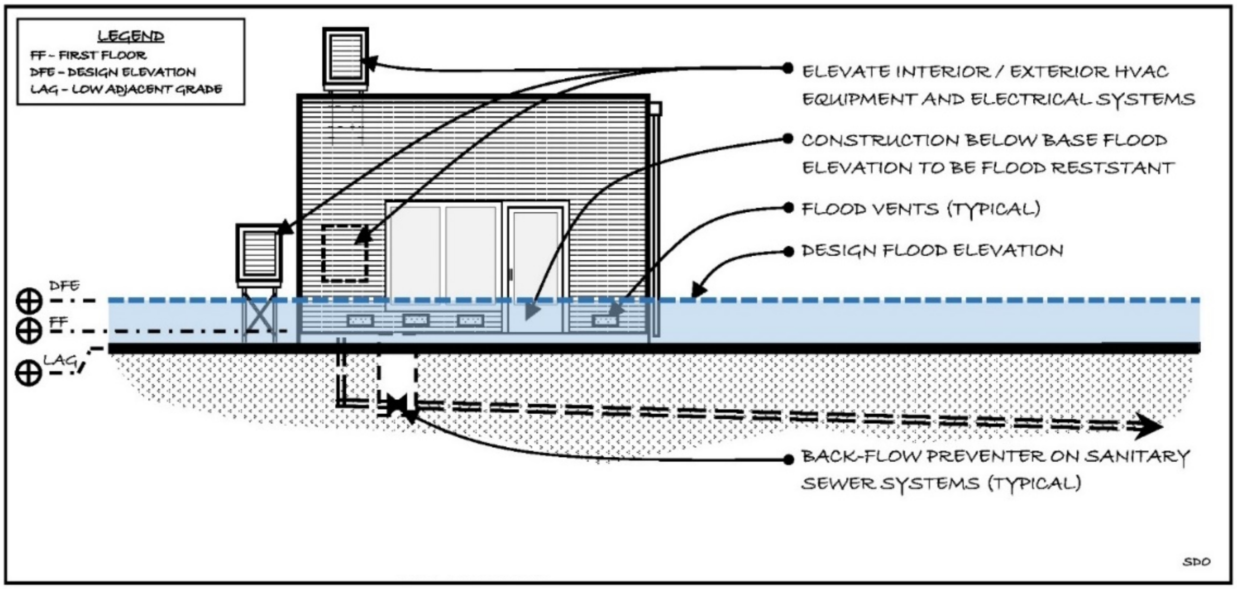


Fig. 4-11. Diagram depicting specific actions associated with wet flood-proofing measures. Diagram not to scale.

Fig. 4-12. Example of exterior (left) and interior (right) wet flood-proofing of a fire station.

4.2.8 Permanent Barriers: Berms and Walls

This measure consists of providing a permanent unattached barrier around an individual structure or a portion of a structure (Figs. 4-13 and 4-14) and can be appropriate for non-residential structures. Although small-scale permanent barriers can be considered structural measures, they are often included in non-structural assessments because they represent viable options for reducing flood risk in certain situations (FEMA, 2015). This measure can sometimes be applied to individual structures without adversely impacting the floodplain by increasing stages, velocities, or durations.

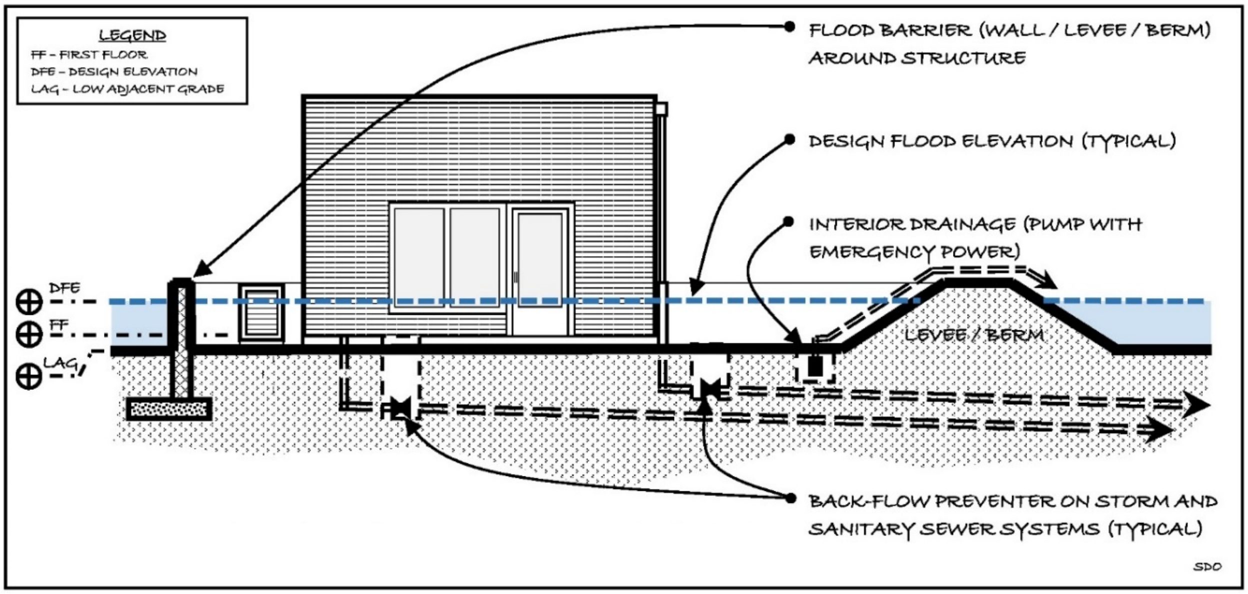


Fig. 4-13. Diagram depicting permanent barriers, berms and walls. Diagram not to scale.

Fig. 4-14. Example of wall (left) and earthen berm (right) as permanent barriers.

4.2.9 Special Considerations – Critical Facilities

Critical structures and facilities are those that are essential during a flood because they provide human safety, health, and welfare. Loss of, or damage to, critical facilities would result in additional adverse impact or hardship on affected communities. Critical structures and facilities include police and fire stations, emergency operations centers, evacuation sites, and medical sites. Facilities that house the elderly and/or disabled individuals, or those requiring extensive evacuation time also represent critical facilities. Facilities that could add to the severity of the disaster if flooding, such as power stations, wastewater treatment plants, and toxic material storage sites, are also considered critical. As established in EO 11988, each critical facility should be located on a flood-free site. When this is not possible or practicable, the facility should be located external to the 0.2% ACE floodplain. At a minimum, all critical facilities must be protected so they can function during all floods up to and equal to a 0.2% ACE event.

4.3 Squaw Run Watershed Non-structural Assessment

The primary objective of the non-structural assessment was to provide potential mitigation actions that reduce both flood risk and insurance premiums to the maximum extent possible. In some cases, secondary actions with greater residual risk that may not lower flood insurance premiums were developed. ***In all cases, the potential non-structural actions developed as part of this report are optional and are intended to provide residents with a greater understanding of their risk and potential actions that can be taken to reduce that risk.***

4.3.1 Methods

A total of 43 structures were identified for inclusion in the non-structural assessment ─ 39 within O'Hara Township and four within Fox Chapel Borough (see Table 2-4). Each of the 43 structures was visually assessed during a field investigation. The following data were obtained: number of stories, structural corners, and pedestrian doorways; foundation and exterior wall construction; presence or absence of a basement, chimney, outdoor HVAC units, and decks; and type and location of utilities. Structural condition (i.e., good, fair, or poor) were visually assessed and photos of each structure were obtained. Structures were observed from the exterior only. Structural footprint, length, width, and perimeter distance were measured in Google Earth Pro. Surveying equipment was used to obtain first-floor, lowest opening, and lowest adjacent grade elevations for each structure.

Hydrologic and hydraulic models were used to determine floodplain extents and water surface elevations required to inform non-structural recommendations. Modeling was available for targeted areas along Squaw Run within Fox Chapel Borough through FEMA (FEMA, 2014). These existing models were used to develop non-structural recommendations within Fox Chapel Borough. Detailed modeling was not available for Squaw Run within O'Hara Township. Therefore, hydrology and hydrologic engineers within USACE, Pittsburgh District developed hydrologic and hydraulic models for the purpose of calculating inundation extents and water surface elevations under various flood frequencies. A detailed description of the modeling effort can be found in Section 2 and Appendices A and B of this report.

Modeled flood elevations along both Squaw Run were used to determine the DFE for each structure. The DFE for non-critical facilities within O'Hara Township is defined as the BFE (i.e., 1% ACE, or 100-year flood elevation) plus an additional two feet. The DFE for non-critical facilities (i.e., residential homes and commercial facilities) within Fox Chapel Borough is defined as the BFE plus an additional 1.5 feet [Standard Pennsylvania Code provided by the Pennsylvania Emergency Management Agency (PEMA)]. The DFE for critical facilities within both O'Hara Township and Fox Chapel Borough is defined as the 0.2% ACE flood elevation. Structural elevations (i.e., first floor, lowest opening, and lowest adjacent grade) were compared to the DFE to assess flood risk and vulnerability and identify the most appropriate non-structural measure for each structure to reduce risks associated with flooding along Squaw Run. Preliminary non-structural recommendations for each structure were field verified by the USACE Huntington District's non-structural flood risk management specialist.

Cost estimates for implementing recommended non-structural measures were prepared by the USACE Huntington District's, Cost Engineering Branch. Basement removal and structure elevation costs were prepared using nServo ─ a software program developed by the USACE

Huntington District and verified by the USACE Walla Walla District. nServo is a cost estimating tool that supports efficient consideration of alternative non-structural measures. Due to limited access to structures, estimated costs were based on the assumption that basements are unfinished and contain HVAC equipment, water heater, electrical equipment, and storage space. Basement utilities, equipment, and storage are proposed to be relocated to the interior of the existing structure above the DFE. A more detailed investigation is required to determine if additional space is required to accommodate these items.

4.3.2 Results

Structures included in the non-structural assessment consisted of residential (28), commercial (6), and public (5) properties within O'Hara Township and residential (3) and public (1) properties within Fox Chapel Borough. Structures within both municipalities had a variety of construction types and characteristics (Table 4-1).

Table 4-1. Inventory of the 43 structures within O'Hara Township and Fox Chapel Borough included in the non-structural assessment with respect to general construction type and characteristics. Data are presented separately for residential, commercial, and public structures within each municipality.

Structural Characteristics	**No.**
O'Hara Township	
Residential	
1-story with basement	6
1-story without basement or crawl space	2
2-story with basement	20
Commercial	
1-story without basement or crawl space	2
2-story without basement or crawl space	4
Public	
1-story without basement or crawl space	4
2-story with basement	1
Fox Chapel Borough	
Residential	
1-story with crawl space	1
1-story without basement or crawl space	1
2-story without basement or crawl space	1
Public	
1-story without basement or crawl space	1

Given the general differences in non-structural recommendations for residential, commercial, and public structures, results are summarized separately for each structure type.

4.3.2.1 Residential Structures

A total of 31 residential structures ─ 28 in O'Hara Township and three in Fox Chapel Borough ─ were included in the non-structural assessment. Table 4-2 summarizes primary recommendations (i.e., measures designed to maximally reduce flood risk and lower insurance rates) for each home. Detailed descriptions of non-structural recommendations for each home are provided in Appendix

C (Non-Structural Data and Assessment Sheets), including potential secondary recommendations when appropriate.

Of the 28 residential structures included in the non-structural assessment within O'Hara Township, 27 were identified as being located wholly or partially within the 1% ACE floodplain. Non-structural recommendations for these 27 homes include: acquisition and relocation (1); filling the adjacent grade to remove the home from the floodplain (1); elevating the home and HVAC units if present (1); filling the basement and elevating HVAC units if present (1); filling the basement and wet flood-proofing the garage (5); filling the basement and elevating the home and HVAC units if present (8); and filling the basement, elevating the home and HVAC unit if present, and wet flood-proofing the garage (10). One home (ID OH-22) was located outside of the 1% ACE floodplain and does not require mitigation to reduce risk associated with the 1% ACE flood. However, a backflow preventer and sump pump with emergency power are recommended for this home given prior occurrence of basement flooding. Estimated costs to implement recommended non-structural measures for individual homes within O'Hara Township ranged from $25,000 to $341,000. No cost is provided for acquiring and relocating home ID OH-29.

All three residential structures included in the non-structural assessment within Fox Chapel Borough were located within the 1% ACE floodplain. Non-structural recommendations for these three homes include: installing a flood-proof barrier and flood-proof doors around the home, wet flood-proofing the garage, and elevating HVAC units (1); and elevating the home and HVAC units and wet flood-proofing the garage (2). Estimated costs to implement recommended non-structural measures for individual homes within Fox Chapel Borough ranged from $225,000 to $244,000.

Table 4-2. Non-structural recommendations and estimated cost for each of the 31 residential structures within O'Hara Township and Fox Chapel Borough included in the non-structural assessment. Street address is provided for each structure. ID corresponds to the data and assessment sheets presented in Appendix C.

ID	Street Address	Non-structural recommendation	Est. Cost[a]
		O'Hara Township	
OH-06	1315 Old Freeport Rd.	Fill basement. Wet flood-proof garage.	$107,000
OH-07	1317 Old Freeport Rd.	Fill basement. Wet flood-proof garage.	$106,000
OH-08	1319 Old Freeport Rd.	Fill basement. Wet flood-proof garage.	$109,000
OH-09	1321 Old Freeport Rd.	Fill basement. Wet flood-proof garage.	$107,000
OH-10	1323 Old Freeport Rd.	Fill basement. Wet flood-proof garage.	$109,000
OH-14	204 S. Margery Dr.	Fill basement. Elevate structure. Wet flood-proof garage.	$341,000
OH-15	206 S. Margery Dr.	Fill basement. Elevate structure.	$250,000
OH-16	208 S. Margery Dr.	Fill basement. Elevate structure & HVAC.	$182,000
OH-17	210 S. Margery Dr.	Fill basement. Elevate structure & HVAC. Wet flood-proof garage.	$205,000
OH-18	212 S. Margery Dr.	Fill basement. Elevate structure & HVAC.	$199,000
OH-19	214 S. Margery Dr.	Fill basement. Elevate structure & HVAC. Wet flood-proof garage.	$237,000
OH-20	216 S. Margery Dr.	Fill basement. Elevate structure & HVAC. Wet flood-proof garage.	$211,000

ID	Street Address	Non-structural recommendation	Est. Cost[a]
OH-21	218 S. Margery Dr.	Fill basement. Elevate structure & HVAC. Wet flood-proof garage.	$214,000
OH-22[b]	215 S. Margery Dr.	Install backflow preventer/sump pump.	$25,000
OH-23	213 S. Margery Dr.	Fill basement. Elevate HVAC.	$101,000
OH-24	211 S. Margery Dr.	Fill basement. Elevate structure & HVACs.	$313,000
OH-25	209 S. Margery Dr.	Fill basement. Elevate structure & HVAC.	$200,000
OH-26	200 Fox Chapel Rd.	Fill basement. Elevate structure & HVAC. Wet flood-proof garage.	$208,000
OH-27	202 Fox Chapel Rd.	Fill basement. Elevate structure & HVAC. Wet flood-proof garage.	$212,000
OH-28	204 Fox Chapel Rd.	Fill basement. Elevate structure.	$176,000
OH-29	222 N. Margery Dr.	Acquisition & relocation.	No Data
OH-30	306 Fox Chapel Rd.	Fill basement. Elevate structure & HVAC. Wet flood-proof garage.	$295,000
OH-31	308 Fox Chapel Rd.	Fill basement. Elevate structure & HVAC.	$232,000
OH-32	310 Fox Chapel Rd.	Elevate structure & HVAC.	$168,000
OH-33	312 Fox Chapel Rd.	Fill basement. Elevate structure & HVAC. Wet flood-proof garage.	$262,000
OH-34	314 Fox Chapel Rd.	Fill basement. Elevate structure & HVAC. Wet flood-proof garage.	$285,000
OH-35	316 Fox Chapel Rd.	Fill basement. Elevate structure & HVAC.	$248,000
OH-39	227 N. Margery Dr.	Fill grade to remove home from floodplain.	$65,000
		Fox Chapel Borough	
FC-02	505 Old Mill Rd.	Install barrier. Flood-proof doors. Elevate HVACs. Wet flood-proof garage.	$225,000
FC-03	507 Old Mill Rd.	Elevate structure & HVACs. Wet flood-proof garage.	$244,000
FC-04	535 Old Mill Rd.	Elevate structure & HVAC. Wet flood-proof garage.	$229,000

[a] = Costs include 25% contingency and were rounded up to the nearest $1,000.

[b] = Structure falls outside of the 1% ACE floodplain and does not require mitigation to reduce risk associated with the 1% ACE flood event. However, secondary mitigation actions are recommended to further reduce risk.

4.3.2.2 Commercial Structures

Six commercial structures were included in the non-structural assessment ─ all of which are located within O'Hara Township. Table 4-3 summarizes primary recommendations (i.e., measures designed to maximally reduce flood risk and lower insurance rates) for each structure. Detailed descriptions of non-structural recommendations for each structure are provided in Appendix C (Non-Structural Data and Assessment Sheets), including secondary recommendations when appropriate.

All six commercial structures were identified as being located within the 1% ACE floodplain. Non-structural flood risk reduction measures were developed for five of the six commercial structures (Table 4-3). Non-structural recommendations for these five commercial structures include: wet flood-proofing (1); dry flood-proofing (2); and a combination of elevating the first floor, dry flood-proofing, and wet flood-proofing (2). The remaining structure has minimal risk associated with an 1% ACE flood event (i.e., first floor elevation was above the DFE). Estimated costs to implement recommended non-structural measures for individual commercial structures ranged from $21,000 to $411,000.

Table 4-3. Non-structural recommendations and estimated cost for each of the six commercial structures within O'Hara Township included in the non-structural assessment. No commercial structures within Fox Chapel were included in the assessment. Street address is provided for each structure. ID corresponds to the data and assessment sheets presented in Appendix C.

ID	Street Address	Non-structural recommendation	Est. Cost[a]
		O'Hara Township	
OH-01[b]	1153 Old Freeport Rd.	Dry flood-proof.	$260,000
OH-02[b]	1200 Old Freeport Rd.	Dry flood-proof.	$411,000
OH-03	1250 Old Freeport Rd.	Elevate first floor of and dry flood-proof main building. Wet flood-proof or remove garage. Elevate HVACs.	$318,000
OH-04	1296 Old Freeport Rd.	Wet flood-proof. Install backflow preventer.	$21,000
OH-05	1311 Old Freeport Rd.	Elevate first floor of and dry flood-proof garage. Wet flood-proof office/display area. Elevate HVACs.	$179,000
OH-12	100 Fox Chapel Rd.	No mitigation required.	$0

[a] = Costs include 25% contingency and were rounded up to the nearest $1,000.

[b] = Structures for which secondary recommendations (i.e., not maximally decreasing flood risk and/or insurance premiums) represent the most likely and/or economically feasible option. See Appendix C (Non-Structural Data and Assessment Sheets) for primary non-structural recommendations.

4.3.2.3 Public Structures

Six public structures ─ five in O'Hara Township and one in Fox Chapel Borough ─ were included in the non-structural assessment. Table 4-4 summarizes primary recommendations (i.e., measures designed to maximally reduce flood risk and lower insurance rates) for each home. Detailed descriptions of non-structural recommendations for each home are provided in Appendix C (Non-Structural Data and Assessment Sheets), including appropriate secondary recommendations.

Four of the five public structures within O'Hara Township represent critical facilities, including the Parkview Emergency Medical Services (EMS) Station located at 200 S. Margery Dr. and O'Hara Municipal Building and associated garages located at 325 Fox Chapel Rd. Only one of these critical facilities ─ the Parkview EMS Station ─ was identified as being within the 0.2% ACE floodplain. The primary recommendation for all critical facilities located within the 0.2% ACE floodplain is relocation. However, the secondary recommendation of filling the basement, elevating the structure and HVAC up to the 0.2% ACE flood elevation, and wet flood-proofing the garage is also provided. No non-structural mitigation action is required for the O'Hara Municipal Building complex. The one non-critical public structure within O'Hara ─ the United States Postal Service (USPS) Office located at 1310 Old Freeport Rd. ─ is within the 1% ACE floodplain. The primary recommendation for the USPS Office is dry flood-proofing.

The public facility in Fox Chapel Borough ─ the Foxwall EMS Station located at 145 Squaw Run Rd. ─ represents a critical facility and is within the 0.2% ACE floodplain. However, the first-floor elevation is above the 0.2% ACE flood elevation. Therefore, no mitigation is required.

Table 4-4. Non-structural recommendations and estimated costs for each of the six public structures within O'Hara Township and Fox Chapel Borough included in the non-structural assessment. Street address is provided. ID corresponds to those presented in Appendix C.

ID	Street Address	Non-structural recommendation	Est. Cost[a]
		O'Hara Township	
OH-11	1310 Old Freeport Rd.	Dry flood-proof.	$363,000
OH-13[b]	200 S. Margery Dr.	Fill basement. Elevate structure & HVAC. Wet flood-proof garage.	$396,000
OH-36	325 Fox Chapel Rd. (Main Building)	No mitigation required.	$0
OH-37	325 Fox Chapel Rd. (Garage #1)	No mitigation required.	$0
OH-38	325 Fox Chapel Rd. (Garage #2)	No mitigation required.	$0
		Fox Chapel Borough	
FC-02	145 Squaw Run Rd.	No mitigation required.	$0

[a] = Costs include 25% contingency and were rounded up to the nearest $1,000.

[b] = critical structures for which relocation outside of the 0.2% ACE floodplain represents the primary recommendation. Secondary non-structural recommendations are presented for cases when relocation is not feasible.

4.3.2.4 Summary of Results

Non-structural mitigation measures were developed for 35 structures within O'Hara Township, including 28 homes (total cost of $5,167,000), five commercial structures ($1,189,000), and two public facilities ($759,000) (Table 4-5). Estimated total cost of implementing non-structural measures across all 34 structures within O'Hara Township is $7,115,000. Non-structural mitigation measures were developed for three homes within Fox Chapel Borough at a total estimated cost of $698,000.

Table 4-5. Total number and estimated cost of non-structural recommendations for residential, commercial, and public structures within O'Hara Township and Fox Chapel Borough.

Structure Type	No.	Est. Cost[a]
	O'Hara Township	
Residential	28	$5,167,000[b]
Commercial	5	$1,189,000
Public	2	$759,000
Total	*35*	*$7,115,000*[b]
	Fox Chapel Borough	
Residential	3	$698,000
Commercial	0	$0
Public	0	$0
Total	*3*	*$698,000*

[a] = Costs include 25% contingency and were rounded up to the nearest $1,000.
[b] = Cost excludes the cost of acquiring and relocating structure ID OH-29.

5 Summary & Conclusions

5.1 Hydraulic & Hydrologic Analyses

This study resulted in the development of hydrologic and hydraulic models for the Squaw Run watershed. These models were calibrated and validated by the study team to be appropriate for assessing current flood risk throughout the watershed and evaluating the impact of the selected structural and non-structural flood risk management measures. These models will be provided to O'Hara Township and Fox Chapel Borough as electronic appendices and can be utilized by each municipality to inform future studies or analyses.

5.2 Non-structural Assessment

A non-structural assessment was conducted for 43 at-risk structures within O'Hara Township and Fox Chapel Borough, Pennsylvania. Optional non-structural measures were developed for 38 at-risk structures, including homes, businesses, and public facilities. ***The potential non-structural actions developed as part of this report are optional and are intended to provide residents with a greater understanding of their risk and actions that can be taken to reduce that risk.***

Implementation of the optional non-structural measures would have immediate and long-term socioeconomic benefits associated with both decreased flood insurance premiums and minimizing flood risk and damage. Despite these benefits, there are several factors potentially limiting implementation. Most notably, the cost of implementing potential mitigation measures for individual residential structures ranged from $25,000 to $341,000. The estimated combined cost of implementing the optional non-structural measures for all residential and non-residential structures included within the study was $7,813,000. These costs may not be economically feasible for individual owners and may exceed the value of some structures. Moreover, the probability of meeting or exceeding a 1% ACE (i.e., 100-year) flow event is relatively low. Thus, implementing optional actions to mitigate damages associated with high magnitude, low frequency floods may not seem cost-effective in the short-term even though their long-term benefits may outweigh the initial investment. Given these potential limitations, community-based flood risk management funding, such as grant programs provided by FEMA, may provide the best avenue for implementing the optional non-structural measures.

5.3 Structural Measures

A series of potential structural flood risk management measures were developed and analyzed, including actions to manage flood risk at both the local- (i.e., floodwalls, channel modification, and bridge modification) and watershed- (i.e., stormwater management ponds) scales. The structural measures described and analyzed in this report are meant to be conceptual in nature. As such, no design information or estimated costs are provided. Factors contributing to ultimate feasibility, including potential real estate and permitting requirements, impacts to existing infrastructure, residual risk, and operation and maintenance requirements were not assessed. ***Thus, the intent of these analyses was to serve as an initial assessment of a subset of potential flood risk management alternatives, not to identify and recommend one or more feasible actions.***

Simulated implementation of floodwalls along Squaw Run within O'Hara Township had the greatest benefit of the more localized structural measures analyzed as part of this study, with the potential to decrease the number of impacted structures by 52% during the 4% (25-year) ACE event and 54% during the 1% (100-year) ACE event. The analyses indicate that channel modification and bridge modification would have minimal benefit.

Simulated implementation of the two conceptual stormwater management ponds reduced the number of impacted structures within O'Hara Township by 37% during the 4% (25-year) ACE event and 11% during the 1% (100-year) ACE event. ***The intent of this assessment was not to identify and recommend specific locations for implementation of stormwater management ponds, but rather to characterize the potential benefits of such actions.*** These results demonstrate the potential for stormwater management measures implemented at the watershed-scale to reduce flood risk further down in the watershed. O'Hara Township and Fox Chapel Borough have begun to identify potential sites for implementation of stormwater management ponds not assessed in this report, including locations along Epsilon Drive (sub-basin no. 9 in Fig. 2-1 and Table 2-1) and Gamma Drive (sub-basin no. 12 in Fig. 2-1 and Table 2-1) within the Regional Industrial Development Corporation (RIDC) Industrial Park, O'Hara Township and within Hardie Valley Park, Fox Chapel (sub-basin no. 3 in Fig. 2-1 and Table 2-1). Together, these actions would also reduce peak stormwater flows downstream. The hydrologic and hydraulic models developed as part of this study can be used to quantify the benefits of these and other potential stormwater management actions taken throughout the watershed and aid in future planning efforts.

Combined implementation of stormwater ponds and floodwalls would result in a 74% decrease in the number of structures inundated during the 4% (25-year) ACE event and a 56% decrease in the number of structures inundated during the 1% (100-year) ACE event. These results demonstrate the potential benefit of combining flood risk management efforts across multiple scales.

5.4 Conclusions

This study represents an important step toward managing flood risk along Squaw Run within O'Hara Township and Fox Chapel Borough. The hydrologic and hydraulic models developed during this study provide O'Hara Township and Fox Chapel Borough with a greater understanding of current flood risk and can be used to aid future multi-municipal planning efforts and to conduct targeted assessments of potential future actions not included in this study. The non-structural and structural measures included and analyzed in this report represent a subset of possible actions that could be taken by O'Hara Township, Fox Chapel Borough, and their residents to minimize flood risk and could be used as a starting point for future analyses and planning efforts.

Although structural and non-structural measures are presented separately in this report, actions taken to reduce flood risk within the Squaw Run watershed will likely be most successful if developed and implemented as part of a holistic flood risk management strategy. Actions taken in one part of the Squaw Run watershed may alter flood risk and required mitigation actions within another part of the watershed. For example, implementation of stormwater management ponds, such as those being considered within RIDC Industrial Park and Hardie Valley Park, could reduce the cost of optional non-structural measures downstream. Such holistic plans also benefit from other strategies not included in this study, such as land use planning and implementation of floodplain management plans and stormwater ordinances.

The goal of any flood risk management effort should be to provide long-term risk reduction. The structural and non-structural recommendations provided herein reflect possible actions to address risks associated with historic and contemporary environmental conditions (i.e., climatic and hydrologic) and alterations (e.g., land use). However, recent evidence suggests global and regional climates are significantly deviating from historic norms — a trend that is expected to continue and intensify through the 21st century. Most notably, this region is expected to experience more extreme precipitation and flow events (Drum et al. 2017). Thus, ensuring long-term risk reduction will require actions designed to withstand anticipated changes in environmental conditions. The models and analyses developed during this study can serve as tools to assist such efforts.

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Glossary of Terms

- 100-year flood–The 1% annual chance exceedance expressed as a return period.
- Annual chance exceedance (ACE) flood–Flood with a (stated percent - %) chance of being exceeded in any given year (e.g., 1% annual chance exceedance or 100-year flood).
- Base flood elevation (BFE)–The elevation of surface water resulting from a flood that has a 1% annual chance exceedance in any given year (i.e., 100-year flood event).
- Berms/levees and floodwalls–Freestanding structure(s) that prevents the encroachment of floodwaters. Berms and levees refer to raised embankments constructed of earthen materials. Floodwalls are primarily vertical barriers built to prevent inundation by water.
- Closure panel/shield–Dry flood-proofing method that closes openings in flood barriers. They can be of a variety of shapes, sizes, and materials. In some cases, closures are permanently attached using hinges so that they can remain open when there is no flood threat. They may also be portable and slipped into place during a flood threat.
- Consequences (of inundation)–The effect, result, or outcome of inundation/flooding as reflected in life and economic loss and/or adverse social - environmental impacts.
- Design flood elevation (DFE)–The elevation of the highest flood that a retrofitting method is designed to protect against. Generally defined as the base flood elevation plus freeboard
- Flood–An overflow of water that submerges land or structures which is normally dry.
- Flood insurance–Insurance to assist in recovery from a flood event. Typically, not included with homeowner’s insurance policy.
- Flood louver–Permanent openings in a wall that allow unobstructed passage of water thereby preventing water pressure buildup (hydrostatic pressure) that can damage or destroy foundations and bearing walls.
- Flood risk–The likelihood of, and consequences that may arise from, a flood event.
- Flood risk management–Policies and programs intended to reduce the likelihood of flood impacts and the exposure and vulnerability of persons and property.
- Flood-frequency–The probability of the flood variable of interest (e.g., peak flow, peak stage, 3-hour volume, etc.) being exceeded at least once in a given water year.
- Freeboard–An additional factor of safety incorporated into floodplain ordinances that defines the elevation ─ usually expressed in feet above the base flood elevation ─ to which the lowest floor of new structures and/or retrofitted existing structures must be designed to. Freeboard provides a margin of safety against extraordinary or unknown flood risks (e.g., wave action, bridge or culvert openings being blocked by debris, future floodplain development).
- National Flood Insurance Program–Federal program under which flood-prone areas are identified and flood insurance is made available to property owners in participating communities.
- Non-structural measures–Measures taken to reduce flood risk, decrease flood damage, and eliminate life-loss by modifying characteristics of vulnerable residential and commercial structures and/or the behavior of residents occupying the floodplain. Non-structural measures do not influence flood probability or frequency.
- nServo–A web-based parametric cost estimating tool that supports efficient consideration of non-structural alternatives. The tool and associated methodologies are consistent with current cost guidance and are coordinated through the Cost Engineering Directory of Expertise.
- Probability–A quantitative measure of the likelihood of a particular event occurring.

- Return period–Also termed the ‘recurrence interval’, the return period is the average time interval, usually expressed in years, between occurrences of an event of a certain magnitude. Calculated as the reciprocal of the annual chance exceedance.
- Risk–Probability and severity of undesirable consequences.
- Structural measures–Flood risk reduction measures constructed to reduce the flood hazard (such as reservoirs and levees) from measures that might be directed to reducing consequences.