Swan Creek Watershed

Preliminary Flood Damage and Mitigation Report

January 2007

Technical Assistance Provided by
USDA Natural Resources Conservation Service through
Hunterdon County Soil Conservation District

To

City of Lambertville, New Jersey

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Introduction

The City of Lambertville entered into an agreement with the United States Department of Agriculture - Natural Resource Conservation Service (NRCS) in January of 2006 to study the feasibility of an engineering solution to the Delaware River back-flooding into Swan Creek that impacts neighboring homeowners and businesses. Figure 1 shows the location of the Swan Creek Watershed in the City of Lambertville and neighboring West Amwell.

History of Flooding and Flood Damages

There has been a long history of flooding and flood damages in the Swan Creek watershed. During a two year period there were three major flooding events. These events occurred on September 18, 2004, April 3-4, 2005 and again on June 29, 2006. The flooding has been associated primarily with peak flood stages on the Delaware River and, to a lesser extent, runoff from Swan Creek, a 2025 acre tributary to the Delaware River. Apart from surface water flooding, damages have also resulted from ground water impacts. Many of the historic buildings have stone foundations and, therefore, are susceptible to ground water inflow.

Table 1 – Summary of National Flood Insurance Program Participation, Claims and Dollars Paid in Lambertville City

Number of Insurance Policies	Annual Premium Dollars Paid	Claim Dollars Paid	Repetitive Flood Loss Claims Paid	Number of Repetitive Flood Loss Policies	Dollars Paid Per Repetitive Flood Loss Structure
192	$171,813	$2,293,166	$1,703,763	41	$41,555

Source: National Flood Insurance Program (Fall 2005)

Table 1 summarizes the FEMA National Flood Insurance Program Participation, Premiums Paid, and Repetitive Flood Losses. Information was not yet available to reflect the June 29, 2006 flood event.

Table 2 - Lambertville City National Flood Insurance Program Claims Summary (1983-2005)

Date	Number of Claims	Flood Damages (Dollars)		Repetitive Flood Losses
		Structural	Contents	
4/16/1983	1	794.	195.	-0-
1/20/1996	8	29,706.	16,729.	1
9/16/1999	10	67,448.	846.	2
9/19/2004	50	818,909.	81,779.	6
4/22/2005	87	1,420,653.	80,312.	37
Total	156	2,337,509.	178,842.	41

Source: National Flood Insurance Program, 2005

Table 3 – National Flood Insurance Program Participation

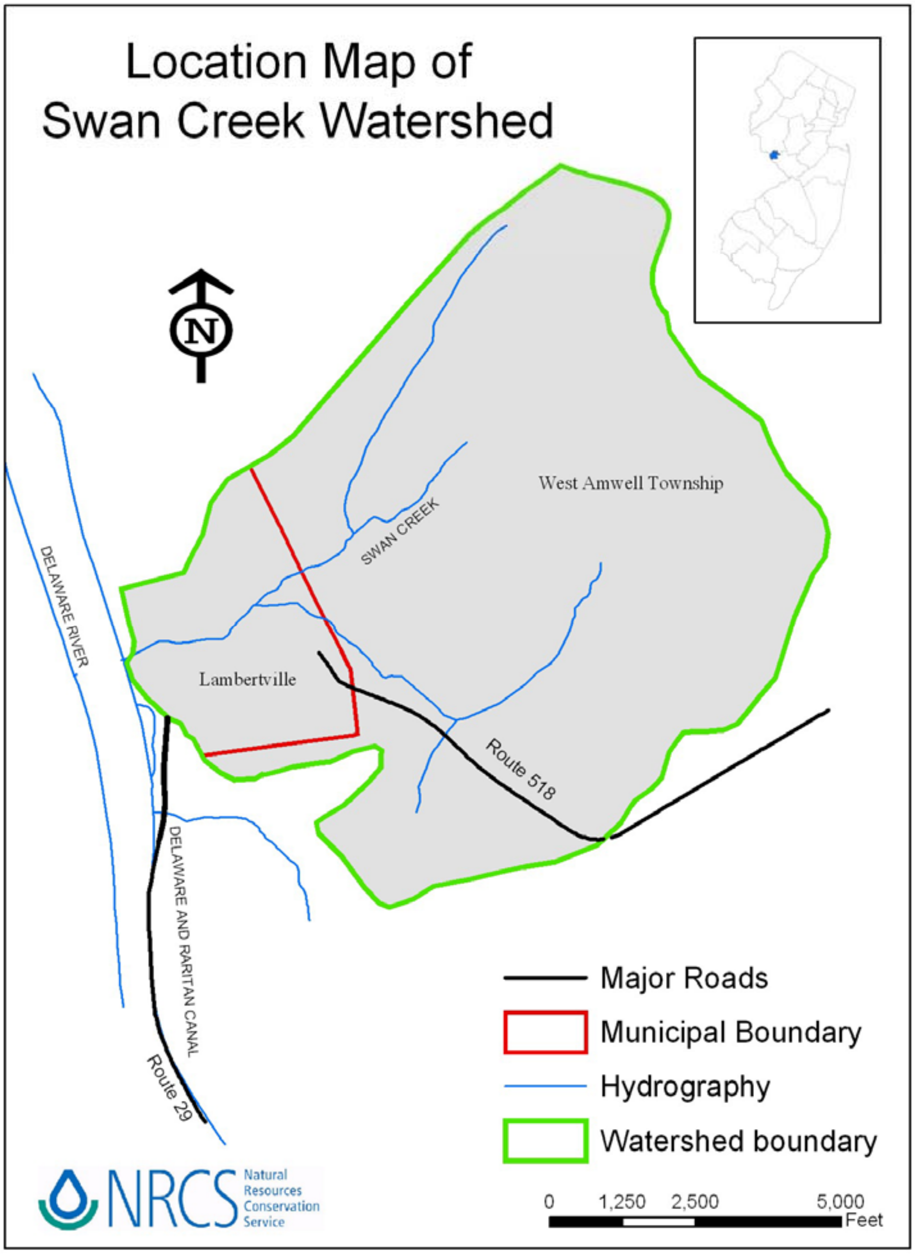
NFIP Participants[1]	Flood Vulnerable Properties[2]
206	102

Source: 1 - Kim Rizzo, FEMA, September 13, 2006
2 – 1997 Biennial Report to FEMA

One life was lost as a result of the June 29, 2006 flood event (Trenton Times, July 7, 2006).

As of September 5, 2006, following the June 29, 2006 event, public assistance requested in Hunterdon County was $104,925.62 of which $94,000 was for housing assistance (structure). Lambertville Sewerage Authority had requested $16,793.99.

Figure 1 - Swan Creek Watershed Location



Survey of Affected Structures

An engineering survey was performed of over 198 structures within the FEMA Flood Insurance Study (FEMA, 1981) 100 year and 500 year flood zones (Figure 2). The survey obtained first floor and, where available, low opening (to the basement) elevations. Flood event elevations used to determine flood vulnerability for each structure were based on those given in the Lambertville Flood Insurance Study (FEMA, 1981). Table 4 shows these flood elevations.

Table 4 – Lambertville Flood Events, Risks and Elevations

Flood Event	**Percent Risk in a Given Year**	**Flood Elevation (feet m.s.l.)**
10 year	10	61.4
50 year	2	66.6
100 year	1	69.2
500 year	0.2	75.0

Source: Lambertville Flood Insurance Study, April 1981

Table 5 shows the number of individual structures which are affected by flooding on their first floor by various risk flood events. Figure 3 shows the location of structures affected by flooding on their first floor by various risk flood events. Figure 4 shows the location of structures affected by flooding at the basement level (through their low opening) by various risk flood events.

Table 5 – Number of Structures Affected by Flooding

Flood Event (Percent Risk*)	**First Floor Only**	**Low Opening Only**	**Both First Floor and Low Opening**	**Total**
50 Year (2)	2	23	1	26
100 Year (1)	18	32	19	69
500 Year (0.2)	93	39	42	174

Source: FEMA Flood Insurance Study, April 1981
NRCS Structure Survey, 2006
*Percent risk flood event will occur in a given year

Figure 2 – Flood Insurance Rate Map

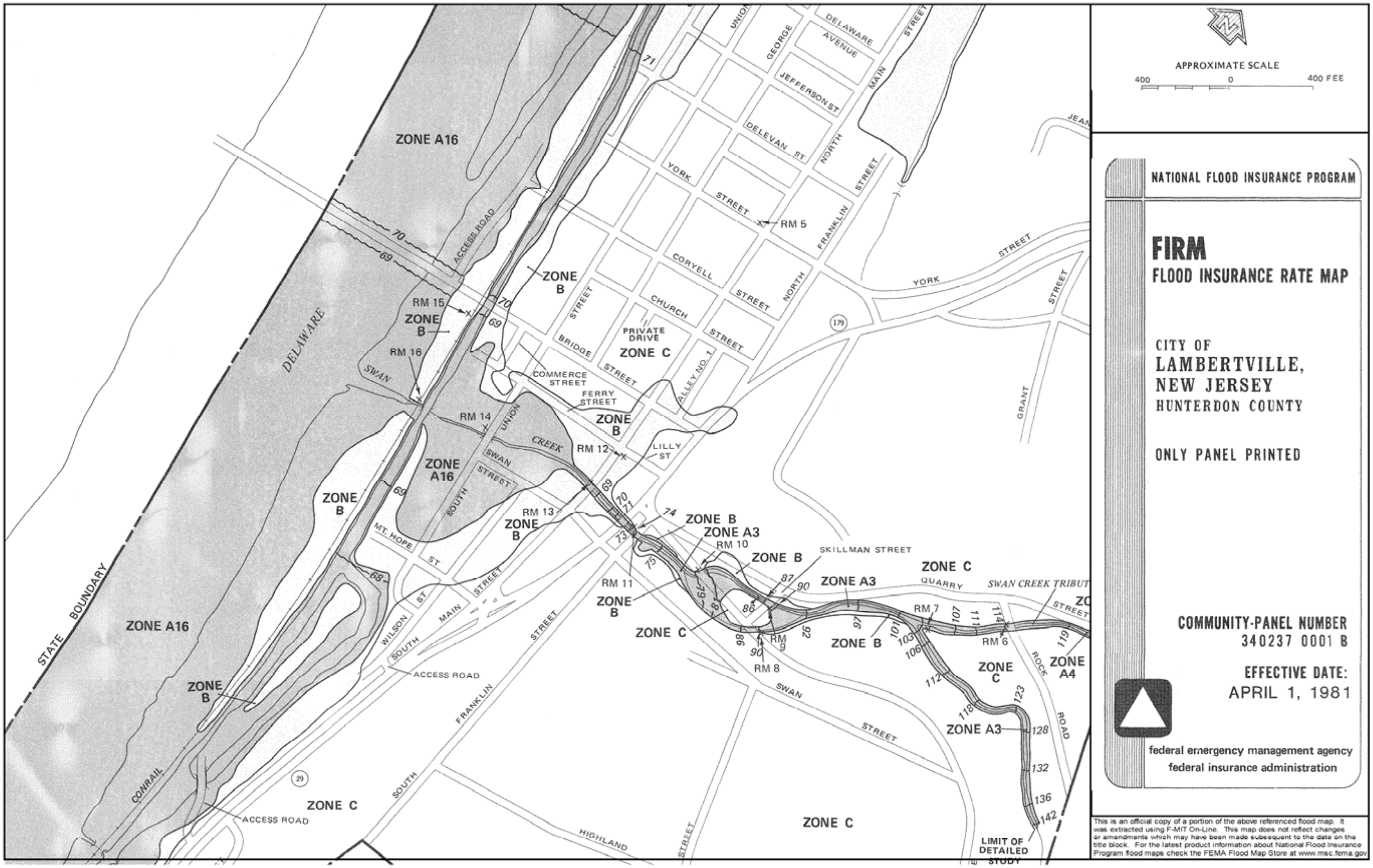


Figure 3 - Location of Structures with First Floor Flooding Under Various Risk Flood Events

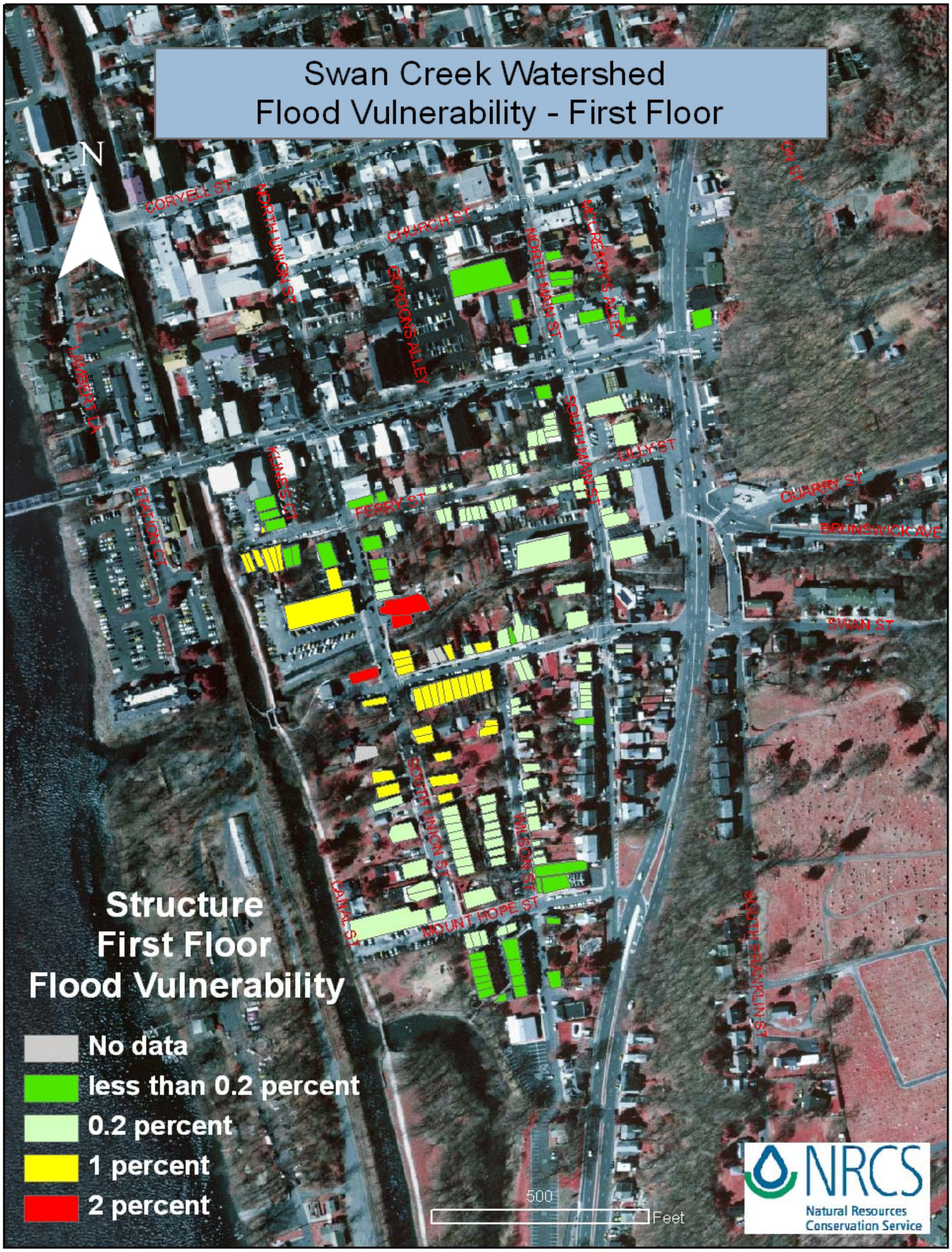
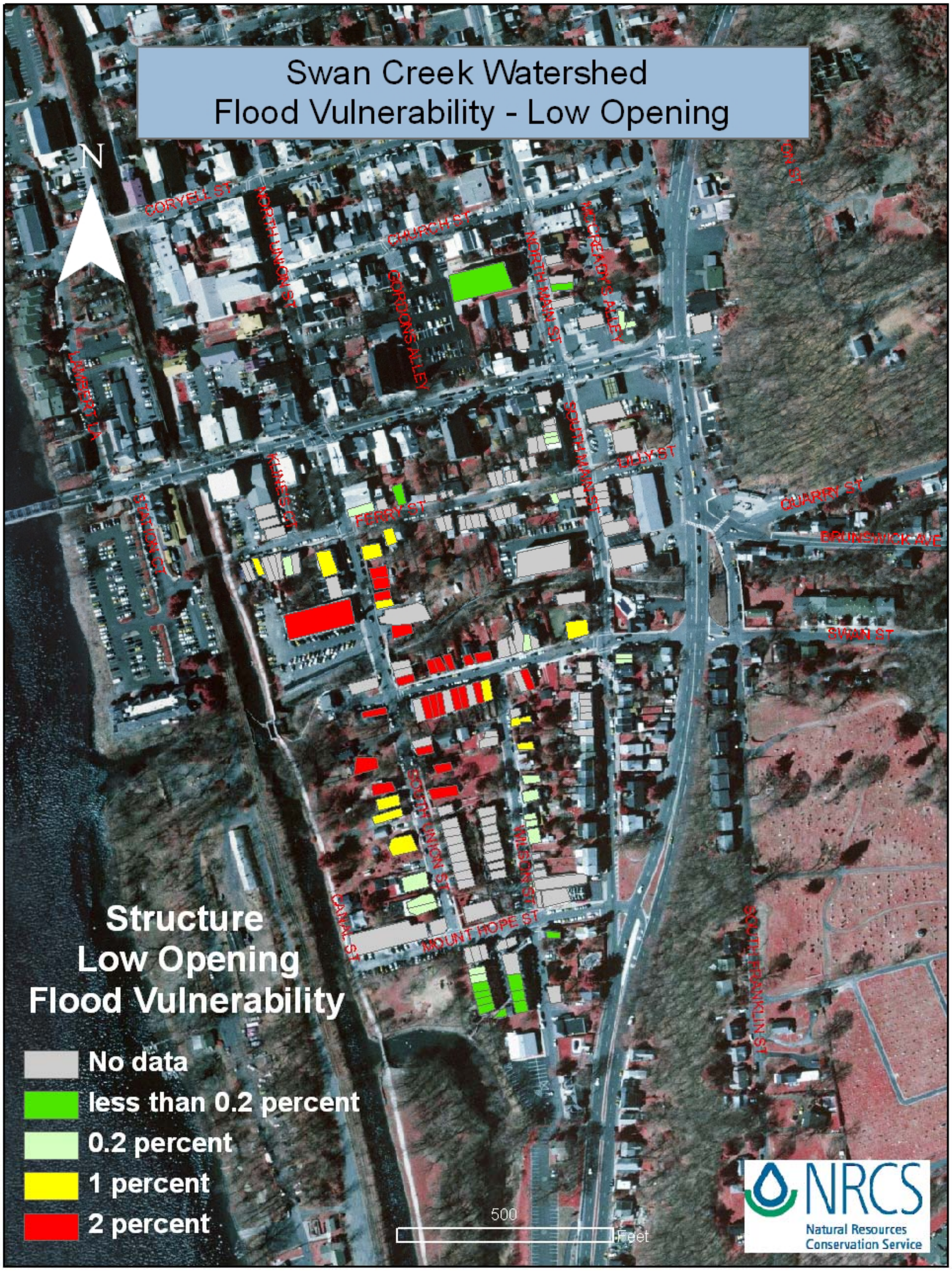


Figure 4 - Location of Structures with Basement Flooding Via Low Opening Various Risk Flood Events



Hydrologic and Hydraulic Modeling

A preliminary hydrologic and hydraulic analysis was conducted to verify the primary source of flooding along Swan Creek in Lambertville. The 1981 Flood Insurance Study (FIS) for the City of Lambertville indicated that for major events, flooding between the canal and Route 29 is more due to backwater from the Delaware River than from storm flows along Swan Creek. This distinction is important when considering alternatives to address the flooding situation.

The NRCS program winTR20 was used to model the Swan Creek watershed. Basic data necessary for the model includes topographic and stream network information for watershed and sub-watershed delineations as well as time of concentration determination; soils and land use information for computation of runoff curve numbers; storm data including rainfall-frequency values; and stream cross sections and structure information for channel and storage routing effects.

The ESRI ArcGIS program Version 9.1 was used for runoff curve number (CN) development. Basic data necessary for the model included delineation of the watershed and subwatersheds on a 1:24,000 topographic map which was then digitized. Hunterdon County SSURGO soils data was used along with NJDEP 2002 landuse/landcover data (draft) to compute runoff curve numbers (CN). The computed CNs were used to develop a composite runoff curve number for each of the subwatersheds. Weighted curve numbers for the various hydrologic soil-cover complexes present in the sub-watershed were based on values presented in National Engineering Handbook (NEH) Part 630, Hydrology. CN values for forested areas with over 50% canopy were developed using a Forest Service procedure, also contained in NEH Part 630. This composite number was calculated by multiplying the area of each polygon times the runoff curve number and then dividing by the total area of the subwatershed (a spatially weighted average). The metadata information is shown in Table 6.

Time of concentration for each of the seven sub-watersheds was determined using the curve number method contained in the NRCS EFH2 (Engineering Field Handbook, Chapter 2) software. Inputs for Tc determination include curve number, longest flow length, and average watershed slope. Rainfall-frequency data was based on averaged values developed by NRCS for Hunterdon County from the updated information in NOAA Atlas 14, Volume 2.

Stream cross section ratings were taken from previous studies developed for Swan Creek. These include the HEC-2 study developed for the 1980 Flood Insurance Study and a HEC-RAS model developed for breach inundation mapping of the United Water Supply dam located in the headwaters of Swan Creek. Structure data for routing flow through the United Water Water Supply reservoir was also based on the inundation study with field verification of elevations and dimensions. Ratings for the Swan Creek arch culvert and the aqueduct box culvert under the Delaware-Raritan Canal were developed using FHA HDS No.5, Hydraulic Design of Highway Culverts. These were developed assuming low tailwater conditions from the Delaware River.

Table 6 - Metadata Information

Name of Metadata	SSURGO	Land Use/Cover	Zoning (Future Land Use)
Originator	USDA Natural Resources Conservation Service	New Jersey Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information Systems (BGIS)	Hunterdon County Planning Department
Publication Date	20060120	20050630	20030422
Title	Soil Survey Geographic (SSURGO) Database for Hunterdon County, New Jersey	Land Use/Cover	Countywide Zoning
Publication Place	Fort Worth, Texas	Trenton, New Jersey	Flemington, New Jersey
Publisher	USDA Natural Resources Conservation Service	New Jersey Department of Environmental Protection	Hunterdon County
Other Details	NJ019	NJDEP 2002 Land use/Land cover Update, Central Delaware Watershed Management Area, WMA-11 (DRAFT) vector digital data	Vector Digital Data
On-line Link	http://SoilDataMart.nrcs.usda.gov/	http://www.state.nj.us/dep/gis/digidownload/zips/lulc02/w11lu02_D.zip	http://www.co.hunterdon.nj.us

The 2,025 acre Swan Creek watershed was broken into seven (7) subwatersheds for the purpose of evaluating the hydrology of the watershed. Figure 4 shows the watershed and subwatershed delineations. Table 7 shows the subwatersheds and their respective acreages.

Table 7 – Swan Creek Watershed Hydrologic Modeling Subwatersheds

Subwatershed Number	**Acres**
1	328
2	361
3	648
4	254
5	81
6	180
7	173
TOTAL	2025

Figure 5 shows the soil map for the watershed. Figure 6 and Figure 7 show the present and future condition in terms of land use.

Peak flow rates for the 10 year and 100 year frequency storm events on Swan Creek were developed using the winTR20 model. The 10 year peak of 680 cfs and 100 year peak of 1675 csf, while both greater than the FIS values of 480 cfs and 1000 cfs respectively, are felt to be reasonable for the watershed.

As the model is preliminary and developed to generally assess the primary flooding source, it does not account for flow from the D&R Canal into Swan Creek. A low stage weir on the east side of the Canal discharges under normal flow conditions approximately 80 cfs into the creek. This normal discharge does not significantly increase the 100 year peak for the purposes of the assessment. The Canal discharge may vary under differing storm or management scenarios and is beyond the scope of this study.

Under the assumption that low tailwater conditions from the Delaware River exist when peak flows pass from Swan Creek, it appears that there is sufficient capacity provided by the two structures under the D&R Canal to contain the FIS 100 year peak flow of 1000 cfs within the stream corridor although localized out of bank flooding does occur. With the NRCS estimated 100 year peak of 1675 cfs, damages would be more significant with several structures receiving basement and first floor flooding. Flooding in the vicinity of Swan Creek, however, becomes much more severe when the Delaware River rises to the 50 year and 100 year flood stages, backing up into Swan Creek and the adjacent neighborhood.

The timing of peak flows occurring on Swan Creek and the Delaware River is important in analyzing the causes of the flooding and when considering measures that will address the situation. While no continuous recording stream gage has been established on Swan Creek, gages do exist on the Delaware and on two regional tributaries; Lockatong Creek and Wickecheoke Creek. Hydrographs for some recent storm events tend to indicate that the tributary streams peak about a day and a half before the peak occurs on the Delaware River. So for large regional storms Swan Creek would also be expected to peak prior to the Delaware. Because of this timing difference, flood control measures that prevent or contain the backwater from the Delaware from backing up Swan Creek into the adjacent neighborhood may be viable. The measures include flood gates at the mouth of Swan Creek with a pump station for upland drainage; or a floodwall to contain backwater within the stream corridor. It should be noted, however, if storms occur where peaks are more coincident, the effectiveness of the flood control measures could be jeopardized. Also, not known at this time and beyond the scope of this study are the influences of discharges from the D&R Canal on the local flooding situation.

Review of conditions during four of the last major storm events supports the finding that backwater from the Delaware has produced greater damages than flooding from flows down Swan Creek. In the two days preceding the June 29, 2006 flood event, 3.73 inches of rainfall were recorded in Lambertville, somewhat greater than the 2 year-24 hour rainfall event. Damages did not occur until flood stage was exceeded on the Delaware with a peak elevation of 68.08 ft. Consistent with local experience, the WINTR20 model predicts that a peak of 350 cfs would result from this rainfall on the Swan Creek watershed. At this low discharge no damages would be expected. Preceding the April 22, 2005 flood event when the Delaware crested at elevation 68.6, no rainfall was recorded in Lambertville. Similarly, only 0.63 inches of rainfall were recorded just prior to the September 19, 2004 flood. Therefore, for these three events, flooding was due to runoff from the upper Delaware basin, not Swan Creek. One event, however, where flood damages were due to flows on Swan Creek was Tropical Storm Floyd in September 1999. Approximately 5.9 inches of rainfall (roughly equivalent to the 25 year-24 hour event) was recorded in Lambertville while the Delaware remained below flood stage. The WINTR20 model predicts a peak discharge of 960 cfs for this rainfall which would result in some localized out of bank flow. This appears consistent with the lower damage level caused by this event.

The winTR20 model was modified to project the impacts of future development within the Swan Creek watershed on the flooding that occurs in Lambertville. Curve numbers were adjusted based on the allowable zoning in the watershed. Generally, most of the area is designated for low or very low density housing except along the Route 179 corridor which permits higher density commercial development. Time of concentration values were adjusted accordingly using the curve number method. To account for stormwater management structures required in new developments, a hypothetical basin was included at the mouth of each sub-watershed. The rating for the basin was designed to hold the existing peak rate of discharge from each sub-watershed while providing storage for any increase in runoff. Only the 100 year storm event was computed with the result indicating a 25% increase in peak flow at the canal (1675 cfs rising to 2100 cfs). Under future development it appears that flooding from Swan Creek will be less severe than that caused by backwater from the Delaware for the 100 year event. Additional analysis is needed for the stream reach through Route 179 to verify where out-of-bank flow may occur that could result in flooding of structures and roadways.

Figure 5 - Swan Creek Watershed Hydrologic Modeling Subwatersheds

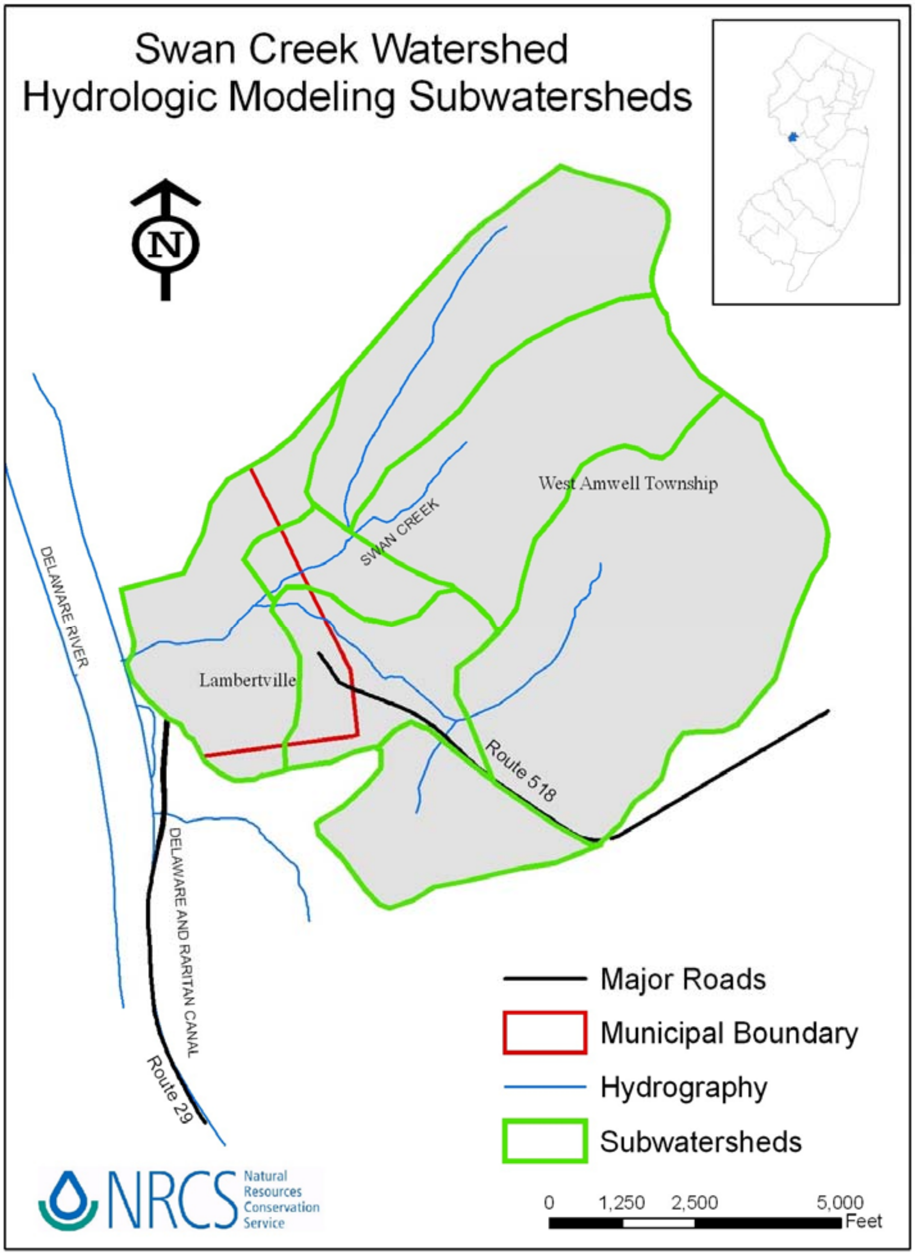


Figure 6 - Swan Creek Watershed Soils Map

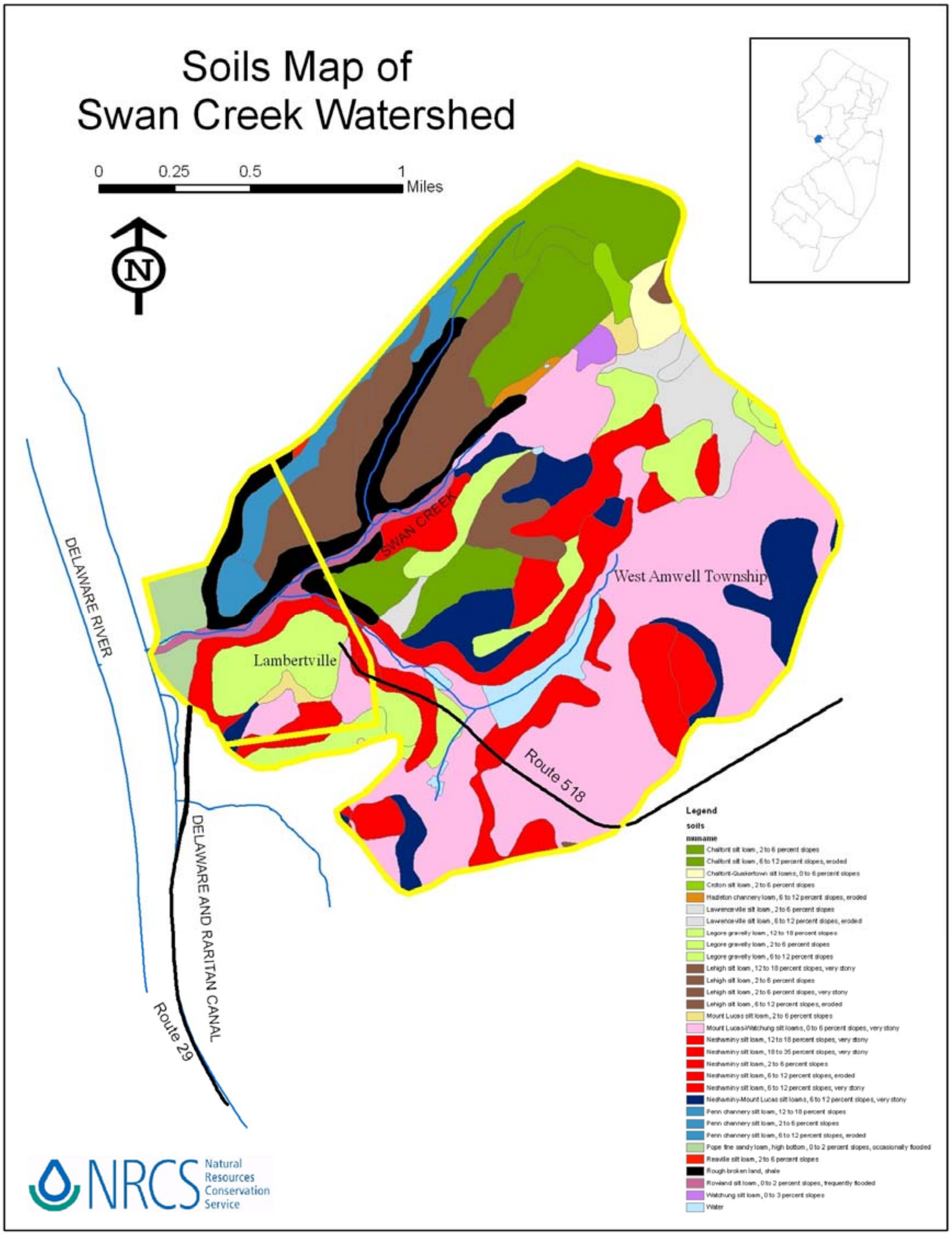


Figure 7 – Swan Creek Watershed Present Land Use

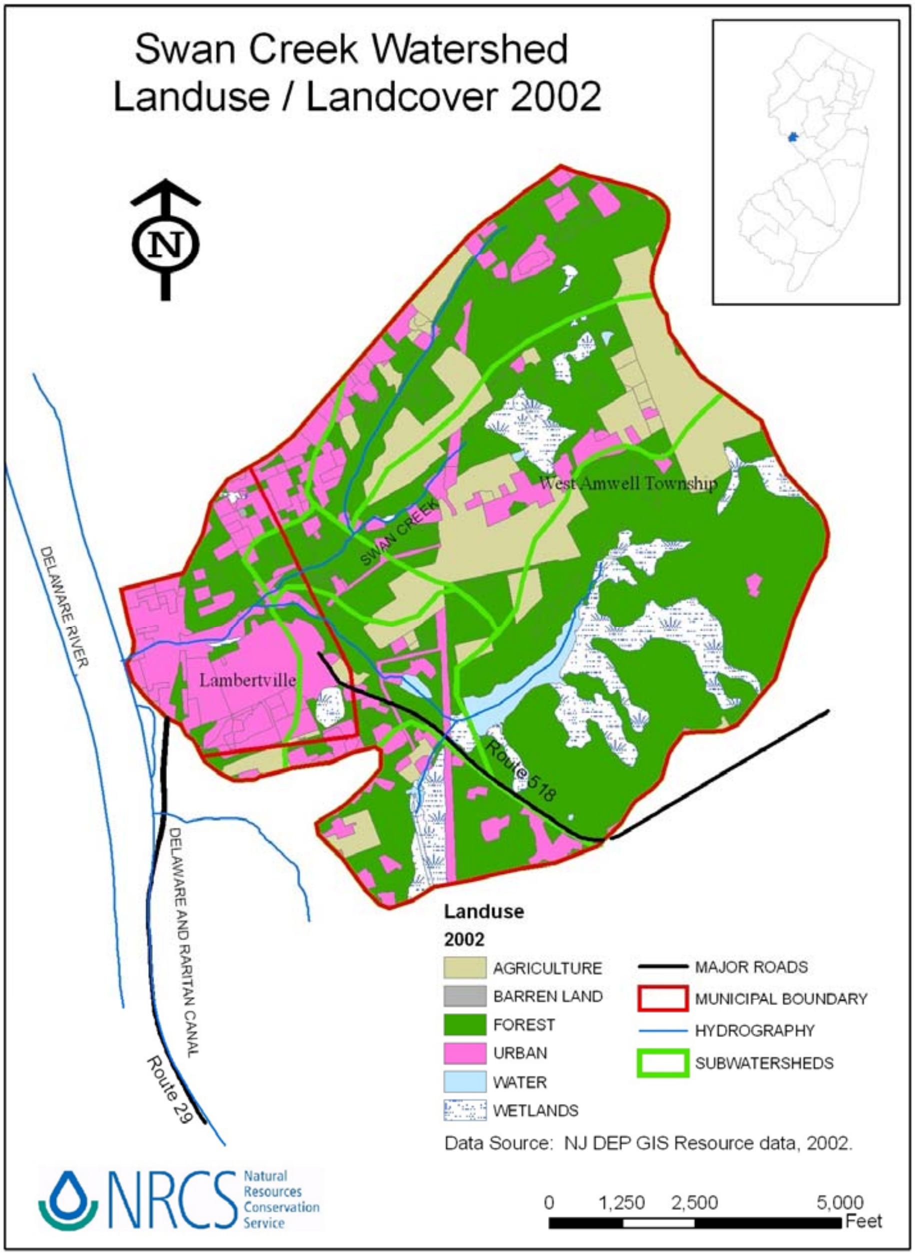
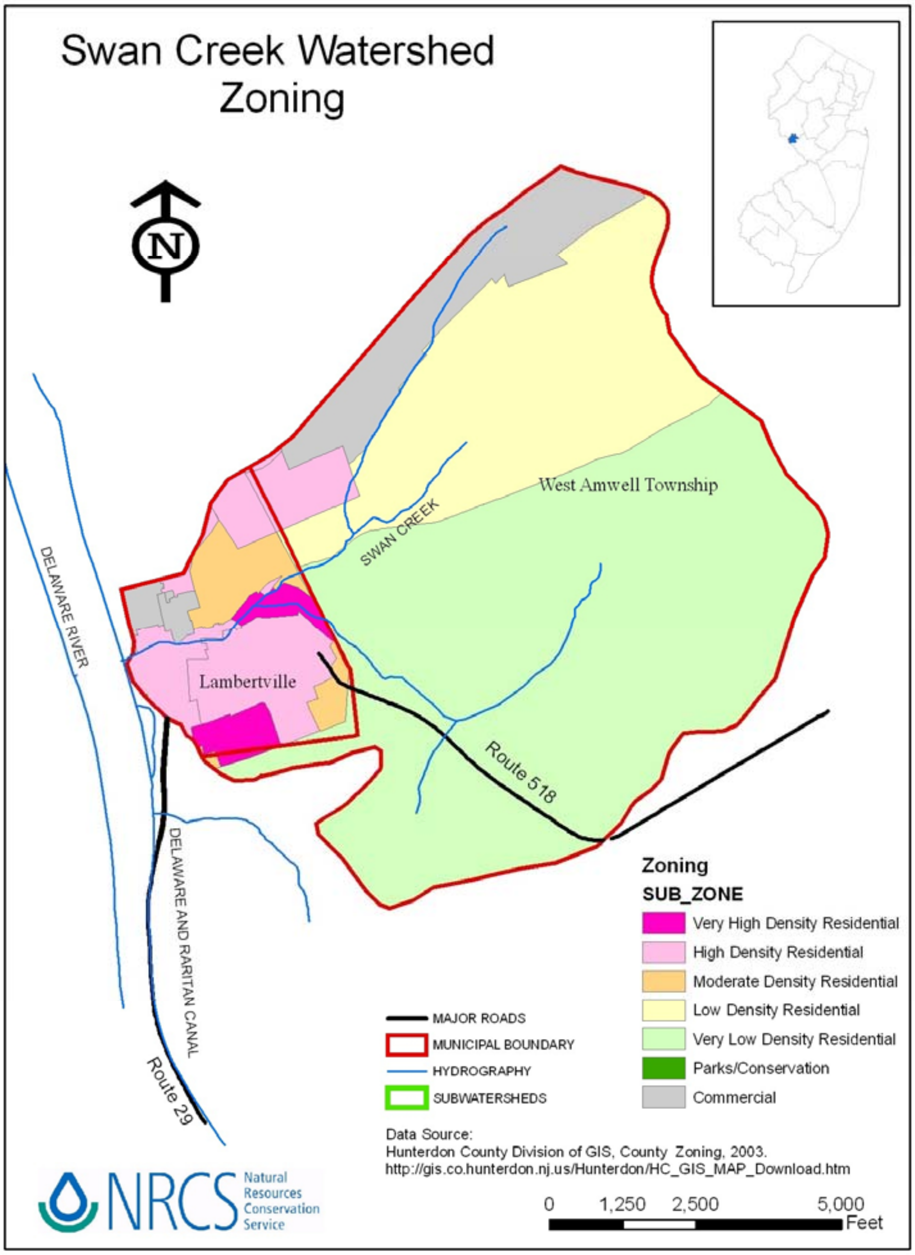


Figure 8 – Swan Creek Watershed Future Land Use



Preliminary Evaluation of Flood Mitigation Alternatives

Modification of Water Supply Reservoir for Flood Control

An existing water supply reservoir, owned and operated by United Water of Lambertville, is situated upstream of the City in the headwaters of the main tributary of Swan Creek. According to the State Dam Safety Section of NJDEP, the dam is in need of rehabilitation. An opportunity could exist to provide additional flood water storage as a part of the rehabilitation plan if it would be effective in mitigating downstream flooding. Also if effective, this option would be favorable in terms of impacts on the historic district since damages would be reduced without visual or aesthetic changes to the neighborhood.

However, with the primary cause of the flooding experienced along Swan Creek due to backwater effects from the Delaware River, a flood water retarding structure on Swan Creek will have little if any impact. Storm peaks from the Swan Creek watershed tend to pass prior to when backwater flood levels are reached. Reducing or delaying the upland runoff will have little positive consequence. To check this, the drainage area to the water supply reservoir was eliminated from the winTR20 model, essentially assuming all contributing runoff could be retained with no resulting discharge. Even under this assumption, peak flows at the Canal would be little altered. While the reservoir controls discharge from approximately 32% of the watershed, the controlled area is heavily wooded and contributes less to the peak than developed portions of the watershed that discharge water more rapidly.

The adverse environmental impacts associated with modifying an existing structure are generally less than those associated with construction of a new flood control measure. Dams, however, typically have negative environmental consequences due to alterations to the riparian ecology, effects on fisheries, increases in water temperature, etc. Public acceptance of an ineffective measure would be negative.

Floodwall

To contain backwater from the Delaware River, floodwalls could be constructed along both sides of Swan Creek from the canal up approximately to Route 29. If constructed to the tow path elevation which ranges from 70.0 to 71.0, the 100 year storm elevation of 69.2 could be contained. Modifications would be necessary at the South Union Street bridge to install walls offset sufficiently not to impede visibility of roadway traffic. Modifications may also be necessary to structures located immediately along the stream banks. Alternately, the bridge could be extended upstream so that the floodwalls would not encroach upon the adjacent homes. The wall which could average 4 to 6 feet in height above the existing top of bank would impact the visual and aesthetic aspects of this historic neighborhood. Public acceptance, therefore, would not be favorable. Issues that would need further investigation include conveyance of stormwater runoff from adjacent yards and roadways, pump requirements to handle localized drainage, impacts on ground water movement, and impacts on stream stability due to changes in hydraulic efficiency.

In terms of environmental impact, construction of floodwalls would be viewed as negative due to disturbance and alteration of the stream channel. Due to the restrictive site conditions, the floodwalls would essentially channelize the stream although the natural bed material could remain. Effects on stream temperature and fisheries would also be considered adverse. Positive environmental impacts would result from reduced contamination associated with out of bank flooding and the submergence of oil tanks, cars, etc.

Flood Gate and Pump (Lift) Station

With the primary cause of flooding due to backwater effects from high flow stages on the Delaware River, a system of flood gates and pumping may be a viable flood control alternative. Gates, either slide type or flap, could be installed downstream of the culverts discharging under the canal. Slide gates would be manually or mechanically closed once peaks have passed from Swan Creek and prior to flood levels being reached on the Delaware. Flap gates operate based on head differential and would close once water levels on the Delaware exceed elevations on Swan Creek, blocking backwater from the Delaware into the creek. Flow from Swan Creek to the Delaware would resume once the water elevation on the creek exceeds that on the Delaware. Structural modifications to the existing culvert outlets or a new structure would be necessary for mounting the gates. Also, a lift station would be required to pump residual flow from Swan Creek into the Delaware following closure of the gates. A preliminary comparison with post-peak or recession flows from regionally gaged watersheds indicates that flow on Swan Creek should attenuate to a point that pumping will be practical for removal of the upland drainage once the gates close.

A significant issue requiring further investigation involves the discharge that takes place from the Canal to Swan Creek. Currently, under major flooding events it does not appear that the discharge from the canal significantly impacts flood levels in Lambertville. Recorded elevations during flood events have been 0.1 to 0.3 feet higher in town than along the river. If gates are installed, particularly at the downstream location, the canal discharge becomes a more significant concern. Either pump capacity will need to be increased to also handle the canal discharge or the aqueduct structure will need to be modified to eliminate the discharge. Alternately, an upstream location for the flood gates could be considered. The additional analysis needed is beyond the scope of this study.

Maintenance will be needed to ensure that gates and pumps will operate properly. Potential for blockages from sediment, debris, or ice should be evaluated and accounted for in the detailed planning or design of the flood control system.

Environmental impacts of this alternative are both positive and negative. Positive impacts result from reduced contamination associated with flooding and submergence of fuel oil tanks, cars, etc. Negative impacts result from alteration of the stream channel and impacts to fisheries from gates and pumps.

Nonstructural Measures

Nonstructural measures entail measures which can be taken by individual property owners or groups of property owners (where they are in attached dwellings) to mitigate flood losses. These measures are all dependent on the voluntary cooperation of individual property owners. Measures include elevation of existing structures above the base flood elevation, relocation of the structure outside of the flood zone and buyout and removal of the structure from the flood zone.

Relocation of structures includes the cost of the moving and reestablishment of a foundation and utilities. This option is often impractical due to the cost of the real estate to which to relocate the structure (s).

Since the April 2005 flood event, at least one property owner within the Swan Creek flood damage area has elevated their structure. Costs associated with this measure involve not only the actual elevation of the structure but also include removal of the existing foundation footings and walls and their replacement with a foundation which allows flood water to pass through it but can withstand the flood water velocity, removal and replacement of existing electric, gas, sewer, water and other utilities, modification of entrances to the structure, residing or rebricking the outside façade of the structure, replacement of landscaping, etc. Costs can vary based on the size of the structure and the complexity of the job. Costs range from less than $100,000 to over $200,000.

Buyouts remove the structure from the flood zone. The land remaining is usually publicly owned and is deed-restricted in terms of future development but, in some cases, may be used for active and/or passive recreation.

Nonstructural measures generally have a neutral or positive environmental effect when used in lieu of structural flood control measures such as dams or channel modification. In terms of flood reduction, nonstructural measures will not reduce the frequency or depth of flooding but can reduce damages by protecting structures and contents.

Flood Gate and Pump (Lift) Station and Nonstructural Measures

This alternative combines the floodgate and pump station option with nonstructural measures. A flood gate and pump station are normally part of a levee system which has been built to protect an area from flooding. The D&R Canal and its associated towpath/road were not built to serve as a levee and, as such, may not have sufficient height, dimension nor the structural integrity to withstand water pressure or overtopping from the Delaware River during a flood. The catastrophic failure of one or both sides of the D&R Canal or its undermining is a possibility and, therefore, this option alone may not adequately protect people or property. In addition, this option alone may give a false sense of security by leading to severe impacts on a potentially unsuspecting population. Levee failure can often be rapid, forceful, extremely damaging, and occurs with little or no warning.

The existing FEMA map shows that the 100 year flood zone occurs on the City side of the Canal within the Swan Creek watershed. This area is likely to continue to be considered to be the 100 year flood zone after the placement of the floodgate and pump station due to the lack of a levee meeting the necessary design and construction standards. As a result, flood insurance premiums are not likely to be reduced for many private property owners.

By combining structural and nonstructural measures, the risk of damages from direct flooding or failure of the flood protection measures can be reduced. The nonstructural option would entail the voluntary elevation, relocation or buyout of affected properties by private property owners. These nonstructural measures would decrease flood losses to both structures and contents in the event of the failure of the flood gate and pump station approach. It would also further decrease the annual flood insurance premium paid by individual property owners.

Table 8 - Swan Creek Watershed Summary of Alternative Flood Mitigation Options

Alternative	Flood Mitigation Impact	Flood Insurance Impact	Environmental Impact	Historic Impact	Public Acceptability
Retrofit of United Water Lambertville Dam	O	O	+/-	+	-
Floodwall	+	+/-	+/-	-	-
Nonstructural	+/-	+	+	-	+/-
Pump Station with Gate	+	+/-	+/-	+/-	+
Nonstructural and Pump Station with Gate	+	+	+/-	+/-	+/-

- Indicates that the alternative would likely have a negative impact on the particular impact category.

+ Indicates that the alternative would likely have a positive impact on the particular impact category.

O Indicates neutral or no impact

Recommendation for Additional Study/Actions

Selection of an alternative to address the flooding experienced in the Swan Creek area of Lambertville should be based on a more detailed analysis of benefits and costs considered along with an environmental assessment of each alternative and its acceptability to the public. This report is intended to provide a framework for that analysis and assessment.

Detailed survey information was collected including first floor and low opening elevations for most, if not all, of the residential and commercial buildings within the FIS damage area. This information may be used in the more detailed analysis of project benefits. A preliminary hydrologic model was prepared for the Swan Creek watershed and may be further calibrated and refined to establish final flood frequency peak discharges if needed. HEC-2 and HEC-RAS hydraulic models of Swan Creek have been developed for previous studies and should be revised for the analysis of alternatives involving structural modifications within the stream corridor including the floodwall and gate/pump alternatives. A geotechnical investigation should be conducted for evaluation soil, foundation, and ground water conditions that may impact the feasibility and cost of an alternative. As indicated in the report, additional study may be needed regarding impacts to the hydraulics and integrity of the canal depending on the alternative under consideration.

Natural Resources Conservation Service Personnel

Name	Title	Years of Service
Gail Bartok	District Conservationist	20
Gary Casabona	GIS Specialist	10
David Lamm	State Conservation Engineer	28
Michael Mirage	Civil Engineer	25
Max Olynyk	Geologist	30
Jina Vandi	Civil Engineer	7
Gregory Westfall	Water Resource Planner	34

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