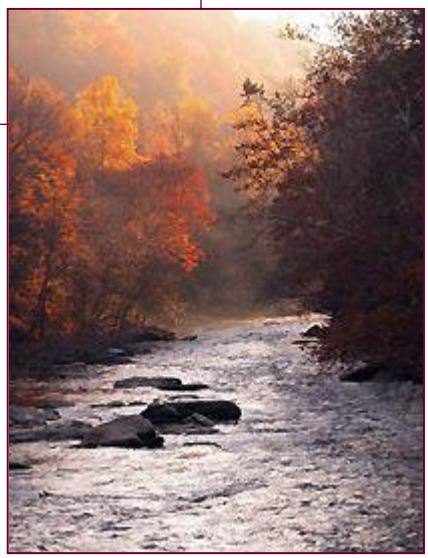
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Butler County Planning Commission

Butler County Act 167 County-Wide Stormwater Management Plan Phase II

August 30, 2010





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BUTLER COUNTY
ACT 167 PLAN PHASE II

ACKNOWLEDGEMENTS

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Section I – Introduction



This stormwater management plan is the product of a collaborative effort between the varied stakeholders located in the Act 167 Designated Watersheds in Butler County, Pennsylvania. The Plan has been developed based on the requirements of the *Pennsylvania Stormwater Management Act*, Act 167 of 1978 and guidelines established by the Pennsylvania Department of Environmental Protection (DEP). The intent of this document is to present the findings of a two-phased multi-year study of the watersheds in the County. Generally, the study was undertaken to develop recommendations for improved stormwater management practices, to mitigate potential negative impacts by future land uses, and to improve conditions of impaired waters. The specific goals of this plan are discussed in detail in the following section. This section introduces some basic concepts relating the physical elements of stormwater management, the hydrologic concepts, and the planning approach used throughout this study.

RAINFALL AND STORMWATER RUNOFF

Precipitation that falls on a natural landscape flows through a complex system of vegetation, soil, groundwater, surface waterways, and other elements as it moves through the hydrologic cycle. Natural events have shaped these components over time to create a system that can efficiently handle stormwater through evaporation, infiltration, and runoff. The natural system often sustains a dynamic equilibrium, where this hydrologic system evolves due to various ranges of flow, sediment movement, temperature, and other variables. Alterations to the natural landscape change the way the system responds to precipitation events. These changes often involve increasing impervious area, which results in decreased evaporation and infiltration and increased runoff. The increase in stormwater runoff is manifested in runoff quantity, or volume, and runoff rate. These two factors cause the natural system to change beyond its natural dynamic equilibrium, resulting in negative environmental responses such as accelerated erosion, greater or more frequent flooding, increased nonpoint source pollution, and degradation of surface waters. Decreased infiltration means less groundwater recharge which in turn leads to altered dry weather stream flow.

Some level of stormwater runoff occurs as the infiltrative capacity of the surface is exceeded. This occurs even in undisturbed watersheds. However, the volume and rate of runoff are substantially increased as land development occurs. Stormwater management is a general term for practices used to reduce the impacts of this accelerated stormwater runoff. Stormwater management practices such as detention ponds and infiltration areas are designed to mitigate the negative impacts of increased runoff. Volume of runoff and rate of runoff are often referred to by the term "water quantity". Water quantity controls have been a mainstream part of stormwater management for years. Another aspect of runoff is water quality. This refers to the physical characteristics of the runoff water. Common water quality traits include temperature, total suspended solids, salts, and dissolved nutrients. Water quality is an emerging topic in stormwater management and the general water resources field. Both water quantity and water quality can contribute to degradation of surface waters.

As development has increased, so has the problem of managing the increased quantity of stormwater runoff. Individual land development projects are frequently viewed as separate incidents, and not necessarily as an interconnected hydrologic and hydraulic system. This school of thought is exacerbated when the individual land development projects are scattered throughout a watershed (and in many different municipalities). However, it is has been observed, and verified, that the cumulative nature of individual land surface changes dramatically, influencing flooding conditions. This cumulative effect of development in some areas has resulted in flooding of both small and large streams, with substantial financial property damage and endangerment of the public health and welfare. Therefore, given the distributed and cumulative nature of the land alteration process, a comprehensive (i.e., watershed-level) approach must be taken if a reasonable and practical management and implementation approach or strategy is to be successful.

Watersheds are an interconnected network in which changes to any portion of the watershed carry throughout the system. There are a variety of factors that influence how runoff from a particular site will affect the overall watershed. Many of the techniques for managing stormwater in a watershed are unique to each watershed. An effective stormwater management plan must be responsive to the existing characteristics of the watershed and must recognize the changing conditions resulting from planned development. In Pennsylvania, stormwater management is generally regulated on the municipal level, with varying degrees of coordination on types and levels of stormwater management required between adjoining municipalities. A watershed-based stormwater management plan can minimize inconsistencies to more effectively address the issues which contribute to a watershed's degradation. While land use regulation remains at the municipal level, the framework established within a watershed plan enables municipalities to see the impact of their regulations on the overall system and coordinate their efforts with other stakeholders in the watershed.

WATERSHED HYDROLOGY

Under natural conditions, watershed hydrology is in dynamic equilibrium. That is, the watershed, its ground and surface water supplies, and resulting stream morphology and water quality evolve and change with the existing rainfall and runoff patterns. This natural state is displayed by stable channels with minimal erosion, relatively infrequent flooding, adequate groundwater recharge, adequate base flows, and relatively high water quality. When all of these conditions are present the streams support healthy, diverse and stable in-stream biological communities. The following is a brief discussion of the impact of development on these steam characteristics:

1. Channel Stability – In an undisturbed watershed, the channels of the stream network have reached an equilibrium over time to convey the runoff from its contributing area within the channels banks. Typically, the channel will be large enough to accommodate the runoff from a storm with a magnitude that will occur approximately every 18-24 months. Disturbances such as development in the watershed disrupt this equilibrium. As development occurs, additional runoff reaches the streams more frequently. This results in the channel becoming unstable as it attempts to resize itself. The resizing occurs through bed and bank erosion, altered flow patterns, and shifting sediment deposits.
2. Flooding – When a watershed is disturbed and channel instability occurs, it results in increased localized flooding and other associated problems. Overbank flows will occur more frequently until the channel reaches a new equilibrium. It is important to realize that this equilibrium may take many years to be attained once the new runoff patterns are in place. In watersheds with continuous development, a new equilibrium may not be reached. Additionally, floodplain encroachment and in-stream sediment deposits from channel erosion may exacerbate flooding.

3. Groundwater Recharge – In an undisturbed watershed, runoff is minimal. Natural ground cover, undisturbed soils, and uneven terrain provide the most advantageous conditions for maximum infiltration to occur. When development occurs, these favorable conditions are diminished or removed, causing more rainfall to become runoff that flows to receiving streams instead of infiltrating. Less water is retained in the watershed to replenish groundwater supplies.
4. Base Flows – Loss of groundwater recharge, as described above, leads to insufficient groundwater available to replenish stream flow during dry weather. As a result, streams that may have an adequate base flow during dry weather under natural conditions may experience reduced flow or become completely dry during periods of low precipitation in developed watersheds. Thermal degradation of the waterbody often accompanies the reduction of base flow originating from groundwater. This source of base flow is generally much cooler than surface water sources. The increase in water temperature can be detrimental to many ecological communities.
5. Water Quality – Stormwater from developed surfaces carries a wide variety of contaminants. Pesticides, herbicides, fertilizers, automotive fluids, hydrocarbons, sediment, detergents, bacteria, increased water temperatures, and other contaminants that are found on land surfaces are carried into streams by runoff. These contaminants affect the receiving streams in different ways, but they all have an adverse impact on the quality of the water in the stream.
6. Stream Biology – Biological communities reflect the overall ecological integrity of a stream. The composition and density of organisms in aquatic communities responds proportionately to stressors placed on their habitat. Communities integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions. The adverse impacts of improperly managed runoff and increased pollution are evident in the biological changes in impacted streams. When biological communities within a waterbody degrade, the overall ecological integrity of the stream is also diminishing.

It is important to understand that watershed hydrology, rainfall, stormwater runoff, and all of the above characteristics are interconnected. The implications of this concept are far reaching. How we manage our watersheds has a direct impact on the water resources of the watershed. Any decision that affects land use has implications on stormwater management and, in turn, impacts the quality of the available water resources. The quality of water resources has an economic consequence as well as an effect on the quality of life in the surrounding areas. This understanding is at the core of current stormwater management approaches.

The stormwater management philosophy of this plan is reflected in the required standards: peak flow management; water quality management; infiltration requirements; and channel protection requirements. The philosophy, and thus the standards, reflects an attempt to manage stormwater in such a way as to maintain the watershed hydrology as near to existing or historical conditions as possible. Maintaining watershed hydrology is essential to maintaining the water resources of the watershed.

STORMWATER MANAGEMENT PLANNING

Historically, the approach to stormwater management was to collect the runoff and deliver it via a system of inlets and pipes as quickly as possible to the nearest receiving waters. The increased volume of stormwater delivered quickly to receiving waters had a detrimental effect on channel morphology. Negative impacts such as severe channel erosion and significant in-stream sediment deposits resulted. These impacts lead to unstable, deepened and widened channels, nuisance flooding, infrastructure damage, increased culvert and bridge maintenance requirements, and have a detrimental affect on the stream quality in terms of habitat for aquatic

organisms. In addition, large amounts of rainfall are lost to the watershed and become unavailable for infiltration and groundwater recharge, and contaminants on the land surface enter the stream untreated. This approach cannot be considered stormwater management in any meaningful terms.

This approach was later replaced with the stormwater management standards that are currently in place in most municipalities. This more-recent approach requires that peak flows from development sites be managed, usually through detention ponds, such that the peak discharge from the site is no greater than 100% of the peak discharge rate from the site prior to development. While this may have helped reduce some stormwater problems, there were two significant failings with this approach.

The first failing of this approach is that it does not consider the watershed as a single interrelated hydrologic unit. An integrated watershed management approach is needed to overcome this situation. Two points are emphasized regarding the need for an overall watershed management approach:

1. Stormwater regulatory responsibility, absent arrangements to the contrary, rests with the municipal governments in Pennsylvania. Therefore, stormwater management regulations, if applied at all, are implemented by a municipality only within the boundaries of its own jurisdiction. There is no guarantee that all municipalities in a given watershed have comparable standards. When standards are implemented by individual municipalities the problems caused by unmanaged stormwater in an area with poor, or no, regulations are conveyed to municipalities downstream. Upstream municipalities often cause stormwater problems for downstream neighbors. In these situations, downstream municipalities are forced to deal with problems associated with increased water volume, increased sediment loads, and increased pollutants which originate in areas over which they have no control.
2. Each area within a watershed is unique in terms of its contribution to the overall watershed hydrology. When the same standards are implemented throughout a municipality and the overall watershed hydrology is not considered, these standards can result in over-management in some areas and under-management in other areas. In some cases, this type of management could actually exacerbate stormwater problems. Further, this "one-size-fits-all" approach does not take into account conditions such as soil infiltration rates, slopes, or channel conditions, which vary throughout a watershed and municipality.

The second key failing is that this approach does not consider the aspects of water quality, channel protection, or the importance of infiltration in the hydrologic cycle. Simply managing the rate at which stormwater leaves a development site does not maintain the overall watershed hydrology. When implementing a peak rate control strategy as the sole method of controlling stormwater runoff, pollutants are still delivered to surface waters, rainfall is still unavailable to the watershed for recharge, and channel erosion and sedimentation still occur.

LOW-IMPACT DEVELOPMENT AND STORMWATER MANAGEMENT

Low-Impact Development (LID) is an approach to land development that uses various land planning and design practices and technologies to simultaneously conserve and protect natural resource systems and reduce infrastructure costs (HUD, 2003). As the term applies to stormwater management, LID is an approach to managing stormwater in a manner similar to nature by managing rainfall at the source using uniformly distributed, decentralized, micro-scale controls (Low Impact Development Center, 2007). These concepts are the origin of many of the strategies identified to achieve the goals presented in this Plan.

As a comprehensive technology-based approach to managing stormwater, LID has developed significantly since its inception, in terms of policy implementation and technical knowledge. The goals and principles of LID, as describe in *Low-Impact Development Design Strategies* (Prince Georges County, 2000) are defined as follows:

- Provide an improved technology for environmental protection of receiving waters.
- Provide economic incentives that encourage environmentally sensitive development.
- Develop the full potential of environmentally sensitive site planning and design.
- Encourage public education and participation in environmental protection.
- Help build communities based on environmental stewardship.
- Reduce construction and maintenance costs of the stormwater infrastructure.
- Introduce new concepts, technologies, and objectives for stormwater management such as micromanagement and multifunctional landscape features (bioretention areas, swales, and conservation areas), mimic or replicate hydrologic functions, and maintain the ecological/biological integrity of receiving streams.
- Encourage flexibility in regulations that allows innovative engineering and site planning to promote smart growth principles.
- Encourage debate on the economic, environmental, and technical viability and applicability of current stormwater practices and alternative approaches.

The overall design concepts and specific design measures for BMPs are derived from the following conceptual framework (Prince Georges County, 2000):

1. The site design should be built around and integrate a site's pre-development hydrology;
2. The design focus should be on the smaller magnitude, higher frequency storm events and should employ a variety of relatively small Best Management Practices (BMPs);
3. These smaller BMPs should be distributed throughout a site so that stormwater is mitigated at its source;
4. An emphasis should be given to non-structural BMPs; and
5. Landscape features and infrastructure should be multifunctional so that any feature (e.g., roof) incorporates detention, retention, filtration, or runoff use.

The LID process is meant to provide an alternative approach to traditional stormwater management. *Table 1.1* highlights the difference between the two approaches. These concepts, as they apply to stormwater, are the basis for the stormwater management approach presented in this Plan.

LID Approach		Traditional Approach	
Approach	Examples	Approach	Examples
1. Integration of Pre-Development Hydrology	A development built around a drainage way outside of functional floodplain	Elimination of all water features from project site	Redirection and conveyance of drainage; alteration of floodplain to meet site design
2. Emphasis on smaller magnitude, higher frequency storm events	Several small BMPs	Large stormwater ponds and facilities that focuses on 10 and 100-year events	A single stormwater pond
3. Stormwater to be mitigated at source	BMPs located near buildings, within parking lot islands	Stormwater to be conveyed to low point in site	A single stormwater pond
4. Use simple, non-structural BMPs	Narrower drive ways, conservation easements, impervious disconnection	Use of pipe and stormwater ponds	A single stormwater pond
5. Use of multifunctional landscape and infrastructure	Green roofs, rain gardens in parking lot islands	Stormwater and site feature kept as separate as possible	No consideration given

Table 1.1. Comparison of LID Versus Traditional Stormwater Management Approach

When implemented at the site level, LID has been found to have a beneficial impact on water quality and in reducing peak flows for more frequent storm events (Bedan and Clausen, 2009; Hood et. al., 2007). There are numerous case studies and pilot projects that emphasize similar findings about the benefits of site level development and of specific LID BMPs (EPA, 2000; DEP, 2006; Low Impact Development Center, 2009).

When implemented at the watershed level, as proposed in this Plan, there are quantifiable benefits in terms of reduced peak discharges coming from future developments (as discussed in *Section VI*). The approach of considering water quality and existing condition hydrology will help address documented stream impairments (as discussed in *Section IX*). Additionally, adopting a LID approach will help alleviate the economic impact of the additional regulations proposed in the model ordinance (as discussed in *Section VIII*). Several other Act 167 Plans that have been recently prepared or are being prepared concurrently with this Plan further support these findings.

Section II – Goals and Objectives of the Act 167 Stormwater Management Plan



This Plan was developed to present the findings of a two-phased multi-year study of the watersheds within the County. Watershed-based planning addresses the full range of hydrologic and hydraulic impacts from cumulative land developments within a watershed rather than simply considering and addressing site-specific peak flows. Although this Plan represents many things to many people, the principal purposes of the Plan are to protect human health and safety by addressing the impacts of future land use on the current levels of stormwater runoff and to recommend measures to control accelerated runoff to prevent increased flood damages or additional water quality degradation.

The overall objective of this Plan is to provide a plan for comprehensive watershed stormwater management throughout Butler County. The Plan is intended to enable every municipality in the County to meet the intent of Act 167 through the following goals:

1. Manage stormwater runoff created by new development activities by taking into account the cumulative basin-wide stormwater impacts from peak runoff rates and runoff volume.

2. Meet the legal water quality requirements under Federal and State laws.

3. Provide uniform stormwater management standards throughout Butler County.

4. Encourage the management of stormwater to maintain groundwater recharge, to prevent degradation of surface and groundwater quality, and to protect water resources.

5. Preserve the existing natural drainage ways and water courses.

6. Ensure that existing stormwater problem areas are not exacerbated by future development and provide recommendations for improving existing problem areas.

These goals provided the focus for the entire planning process. A scope of work was developed in Phase I that focused efforts on gathering the necessary data and developing strategies that address the goals. With the general focus of the Plan determined, Phase II further researched county specific information, provided in-depth technical analysis, and developed a model ordinance to achieve these goals. On the following page, *Table 2.1* shows the preferred strategies to address the goals, and where these strategies are addressed in the Plan:

1. Manage stormwater runoff created by new development activities by taking into account the cumulative basin-wide stormwater impacts from peak runoff rates and runoff volume	
Develop models of selected watersheds to determine their response to rainfall	*Appendix C*
Determine appropriate stormwater management controls for these basins	
2. Meet the legal water quality requirements under Federal and State laws	
Provide recommendations for improving impaired waters within the county	*Section 9*
Encourage the use of particularly effective stormwater management BMPs	*Section 7*
3. Provide uniform standards throughout Butler County	
Develop a Model Stormwater Management Ordinance with regulations specific to the watersheds within the county	*Model Ordinance*
Adopt and implement the Model Ordinance in every municipality in Butler County	*Model Ordinance*
3. Encourage the management of stormwater to maintain groundwater recharge, to prevent degradation of surface and groundwater quality, and to protect water resources	
Provide education on the correlation between stormwater and other water resources	*Section 1, Section 10*
Require use of the Design Storm Method or the Simplified Method	*Model Ordinance*
4. Preserve the existing natural drainage ways and water courses	
Provide education on the function and importance of natural drainage ways	*Section 1, Section 10*
Protect these features through provisions in the Model Ordinance	*Model Ordinance*
5. Ensure that existing stormwater problem areas are not exacerbated by future development and provide recommendations for improving existing problem areas	
Develop an inventory of existing stormwater problem areas	*Section 5, Appendix B*
Analyze problem areas and provide conceptual solutions to the problems	*Section 5, Appendix B*

Table 2.1. Preferred Strategies to Address Plan Goals

STORMWATER PLANNING AND THE ACT 167 PROCESS

Recognizing the increasing need for improved stormwater management, the Pennsylvania legislature enacted the *Stormwater Management Act* (Act 167 of 1978). Act 167, as it is commonly referred to, enables the regulation of development and activities causing accelerated runoff. It encourages watershed based planning and management of stormwater runoff that is consistent with sound water and land use practices, and authorizes a comprehensive program of stormwater management intended to preserve and restore the Commonwealth's water resources.

The Act designates the Department of Environmental Resources as the public agency empowered to oversee implementation of the regulations and defines specific duties required of the Department. The Department of Environmental Resources was abolished by Act 18 of 1995. Its functions were transferred to the Pennsylvania Department of Conservation and Natural Resources (DCNR) and the Department of Environmental Protection (DEP). Duties related to stormwater management became the responsibility of DEP (Act 18 of 1995).

As described in Act 167, each county must prepare and adopt a watershed stormwater management plan for each watershed located in the county, as designated by the department, in consultation with the municipalities located within each watershed, and shall periodically review and revise such plan at least every five years. Within six months following adoption and approval of the watershed stormwater plan, each municipality must adopt or amend, and must implement such ordinances and regulations, including zoning, subdivision and development,

building code, and erosion and sedimentation ordinances, as are necessary to regulate development within the municipality in a manner consistent with the applicable watershed stormwater plan and the provisions of the Act.

Section 5 of Act 167 sets forth the Plan contents required for each Stormwater Management Plan. Section 5.b lists 13 elements to include in the Plan and Section 5.c lists an additional two elements for inclusion. The following table addresses these elements in Section 5 of Act 167, and present the necessary information to inventory and address issues with stormwater management in the County.

SECTION 5b
(1) A survey of existing runoff characteristics in small as well as large storms, including the impact of soils, slopes, vegetation and existing development;
Section 3 identifies and analyzes factors that impact the hydrologic response of the identified watershed for including existing and future land use conditions. Section 6 discusses the technical analysis performed on the on focused watersheds. The other watersheds within the County should be considered in future Plans. Appendix A details the modeling completed to perform the technical analysis. In addition, relevant details of the factors and elements impacting the hydrologic response of the watersheds are shown graphically in the Plates.
(2) A survey of existing significant obstructions and their capacities;
The municipalities, through the PAC, responded to a survey which compiled an inventory of obstructions. Section 5 provides the inventory as well as a discussion. Capacities of the obstructions were not fully developed as budgetary impacts reduced the scope of the Plan. Plate 7 shows the identified obstructions.
(3) An assessment of projected and alternative land development patterns in the watershed, and the potential impact of runoff;
A hydrologic model was developed and used to assess the impacts future land development alternatives in order to address the potential impacts of increased runoff, as discussed in Sections 6 and 7 as well as Appendix A.
(4) An analysis of present and projected development in the flood hazard areas, and its sensitivity to damages from future flooding or increased runoff;
Federal flood insurance studies have been used as reference for the location of flood plain areas as identified in Plate 8. Section 3 provides a discussion and an analysis showing damages to existing development due to flood hazard areas caused by increased runoff in the watershed. Recommendations where made with measures to mitigate future damages in Section 7.
(5) Survey of existing drainage problems and proposed solutions;
The municipalities, through the PAC, responded to a survey which compiled an inventory of existing problem areas. Section 5 provides the inventory as well as a discussion. Plate 7 shows the identified problem areas as well as Appendix C.
(6) A review of existing and proposed stormwater collection systems;
The more urbanized areas of the County contain storm sewer systems, as do the many roadways that traverse the County. Storm sewer collection systems have a significant effect on the hydrologic response of a watershed as pipe networks rapidly increase runoff rate. If stormwater control facilities do not intercept runoff from storm sewer systems, flooding often increases, as well as other stormwater problems such as streambank erosion and sedimentation. Plate 7 shows the collection systems as identified by the municipalities through the PAC.
(7) An assessment of alternative runoff control techniques and their efficiency in the particular watershed;
Section 7 of the Plan identifies a variety of runoff control techniques are available for use in all watersheds in the County. It references and expands upon the Pennsylvania Stormwater Best Practices Manual to identify innovative methods of controlling runoff. In addition, traditional engineering solutions such as drainage structure replacement, streambank restoration, etc. were also identified in situations where alternative runoff controls are not applicable.

(8) An identification of existing and proposed state, federal and local flood control projects located in the watershed and their design capacities;
Section 3 lists the local, state, and federal flood control projects in the County which was shown on Plate 8. Where the effectiveness in mitigating flooding or design capacity data was readily available, this information was also documented.
(9) A designation of those areas to be served by stormwater collection and control facilities within a 10-year period, an estimate of the design capacity and costs of such facilities, a schedule and an identification of the existing or proposed institutional arrangements to implement and operate the facilities;
Stormwater control facilities were identified and documented by municipalities and through the completion of the Questionnaire. The data was compiled and tabulated for those municipalities which provided data. Sections 7 and 9 identify recommended strategies to address runoff impacts from future development.
(10) An identification of flood plains within the watershed;
Flood insurance studies prepared under the National Flood Insurance Program were identified in Section 3 and shown on Plate 8.
(11) Criteria and standards for the control of stormwater runoff from existing and new development which are necessary to minimize dangers to property and life and carry out the purposes of this act;
Standards and criteria were developed in Section 7 which are to be implemented through the Model Ordinance.
(12) Priorities for implementation of action within each plan; and
Section 11 details the preparation process completed and the County adoption of the draft Plan with submission to DEP for approval. This will initiate the mandatory schedule of adoption of ordinances needed to implement stormwater management criteria.
(13) Provisions for periodically reviewing, revising and updating the plan.
Section 11 discusses the requirement of Section 5(a) of the Act that each plan must be reviewed and any necessary revisions made at least every five years after its initial adoption.
SECTION 5b
(1) Contain such provisions as are reasonably necessary to manage stormwater such that development or activities in each municipality within the watershed do not adversely affect health, safety and property in other municipalities within the watershed and in basins to which the watershed is tributary; and
With the adoption of the Model Stormwater Management Ordinance provided with this Plan, each municipality must enforce development, redevelopment, and other regulated activities consistent with the standards and criteria contained in the Model Ordinance. These standards and criteria have been developed to ensure regulated activities will not adversely affect health, safety, and property in the County.
(2) Consider and be consistent with other existing municipal, county, regional and State environmental and land-use plans.
Section 3 identifies several planning efforts which the County conducted in the past. These include watershed Act 167 Plans, comprehensive planning including open space planning and land use plans, and hazard mitigation planning.

Table 2.2. Elements of Act 167

PLAN ADVISORY COMMITTEES

Public participation by local stakeholders is an integral part of comprehensive stormwater management planning. Coordination amongst these various groups facilitates a more inclusive Plan, which is able to better address the variety of issues experienced throughout the County. Several Plan Advisory Committee meetings were facilitated throughout the development of this Plan.

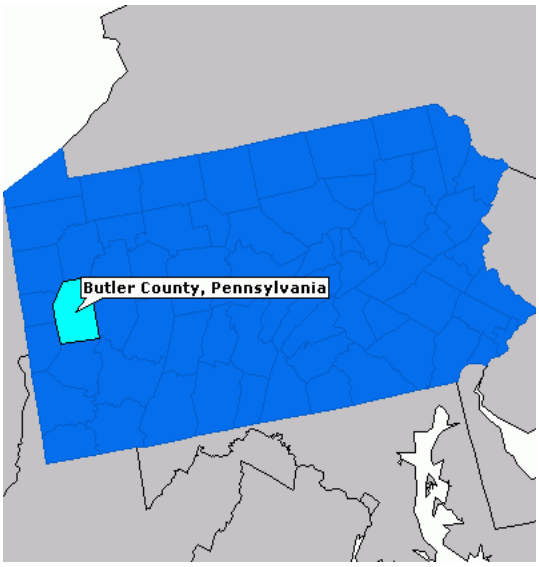
A Plan Advisory Committee (PAC) was formed at the beginning of the planning process, as required by the Stormwater Management Act. The purpose of the PAC is to serve as an access for municipal input, assistance, voicing of concerns and questions, and to serve as a mechanism to ensure that inter-municipal coordination and cooperation is secured. The PAC consists of at least one representative from each of the municipalities within the County, the County Conservation District, and other representatives as appropriate. A full list of the PAC members can be found in the Acknowledgements section at the beginning of this Plan.

As per Act 167, the PAC is responsible for advising the County throughout the planning process, evaluating policy and project alternatives, coordinating the watershed stormwater plans with other municipal plans and programs, and reviewing the Plan prior to adoption. *Table 2.3* is a summary of the PAC meetings that were held throughout the planning process.

Meeting	Purpose of Meeting	Meeting Dates
PAC	Phase 2 Start-up Meeting: Introduce the Phase 2 planning process. Emphasize the importance of full municipal involvement. Present summary of the data collection questionnaire from Phase I.	April 29, 2009
PAC MEC	Technical review of Draft Model Ordinance: Review technical comments. (Draft Model Ordinance sent to municipalities prior to meeting).	March 11, 2010
PAC MEC	Pre-hearing meeting: Review comments and responses to comments. Plan and revised Draft Model Ordinance posted on County web site. Revised Draft Model Ordinance provided to PAC members. Summarize implementation.	June 15, 2010
Public Hearing	Conduct Hearing as required by Act 167 to present the PLAN to the public.	July 7, 2010

Table 2.3. Summary of PAC Meetings

Section III – Butler County Description



Butler County was formed from part of Allegheny County on March 12, 1800. The County was named in honor of General Richard Butler, a hero of the American Revolution. Butler County is situated on the Allegheny Plateau in Western Pennsylvania. The County encompasses 508,800 acres (795 square miles) and is approximately 23 miles wide by 34 miles long. Butler County occupies the high divide between the Allegheny and Beaver Rivers. The County is part of the Allegheny Plateau and is characterized by irregular terrain, having both sharp hills and valleys along with pockets of moderately sloped terrain. Only the extreme northwest part of the County has been glaciated. Elevations range from 1,500 feet on the summits in the Northern part of the County to 750 feet at the riverbeds in the southern part of the County. Butler County has a diverse landscape with both rural and urban settings. This is reflected by high-density residential and commercial areas, such as the City of Butler and Cranberry Township, coupled with large land tracts of open space and agricultural land within the County.

POLITICAL JURISDICTIONS

The County is comprised of 57 municipalities. The political jurisdictions include 23 boroughs, one first class township (Butler Township), 32 second class townships, and the City of Butler (the County seat). Butler County is classified as a fourth class county and is ranked 20th of 67 counties with a population of 174,083, according to the 2000 census. The 57 municipalities in Butler County and their associated land area are as follows:

TOWNSHIPS	AREA (mi^2)	BOROUGHS	AREA (mi^2)
Adams Twp	22.6	Bruin Boro	1.7
Allegheny Twp	24.2	Callery Boro	0.5
Brady Twp	16.9	Cherry Valley Boro	2.9
Buffalo Twp	24.2	Chicora Boro	0.6
Butler Twp	21.6	Connoquenessing Boro	1.4
Center Twp	24.4	East Butler Boro	1.0
Cherry Twp	25.9	Eau Claire Boro	1.4
Clay Twp	25.2	Evans City Boro	0.8
Clearfield Twp	23.4	Fairview Boro	0.1
Clinton Twp	23.8	Harmony Boro	0.4
Concord Twp	24.9	Harrisville Boro	0.8
Connoquenessing Twp	22.5	Karns City Boro	0.4
Cranberry Twp	22.8	Mars Boro	0.4
Donegal Twp	23.0	Petrolia Boro	0.4
Fairview Twp	24.1	Portersville Boro	0.8
Forward Twp	23.3	Prospect Boro	4.8
Franklin Twp	20.8	Saxonburg Boro	0.9
Jackson Twp	21.2	Seven Fields Boro	0.8

TOWNSHIPS	AREA (mi²)	BOROUGHS	AREA (mi²)
Jefferson Twp	23.4	Slippery Rock Boro	1.7
Lancaster Twp	23.4	Valencia Boro	0.4
Marion Twp	25.5	West Liberty Boro	3.9
Mercer Twp	12.7	West Sunbury Boro	0.1
Middlesex Twp	23.0	Zelienople Boro	2.1
Muddy Creek Twp	21.8		
Oakland Twp	22.9		
Parker Twp	23.6	**CITIES**	**AREA (mi²)**
Penn Twp	24.2	Butler City	2.7
Slippery Rock Twp	25.8		
Summit Twp	22.3		
Venango Twp	20.8		
Washington Twp	25.0		
Winfield Twp	24.4		
Worth Twp	24.3		

Table 3.1. Butler County Municipalities

LAND USE

GENERAL DEVELOPMENT PATTERNS

According to the Butler County Comprehensive Plan, most of Butler County is undeveloped, wooded or agricultural land. Only about 20% of Butler's area is subject to intensive development. The Comprehensive Plan determined that different attributes resulted in opportunities for future land use potential in areas throughout the County. These attributes included natural features, access, existing development and other characteristics present in each portion of the County. They helped to identify "growth areas" in Butler County where economic growth and development could be sustained. The Comprehensive Plan identified eight potential growth areas located throughout Butler County. These areas are as follows: Southern Butler County (Cranberry Township), City of Butler, Zelienople, Route 356 Corridor, Route 228 Corridor, Route 68 Corridor, Route 528 Corridor and nearly the entire Interstate 79 Corridor. Each of these areas will have a significant impact on land use and economic development in Butler County.

TRANSPORTATION

Butler County has an excellent geographic location in regard to road networks. The County is served by a number of important major transportation routes, including three interstate highways. Interstate 79 is a four-lane limited-access freeway, which traverses the County in a north/south direction. This road provides a convenient interstate link between Pittsburgh and Erie. Interstate 80 passes through the northeast corner of the County. I-80 is an arterial highway that crosses the United States in an east/west direction from coast to coast. Interstate 76, part of the Pennsylvania Turnpike System, traverses the state and County in an east/west direction. In addition to the Interstate highways, several other road systems play roles in the County's transportation network. Other major road networks serving areas in Butler County include US Route 422, Route 8, Perry Highway (US-19) and the Allegheny Valley Expressway (Route 28). Overall Butler County has excellent transportation networks serving the most developed segments of the County.

While the Greater Pittsburgh International Airport handles most of the Tri-State's major air traffic, Butler County has four public airports to meet the needs of its residents. These airports and

locations are as follows: Butler County Airport (Penn Township); Butler Farm Show Airport (City of Butler); Zelienople Municipal Airport (Borough of Zelienople); and Lakehill Airport (Mars Borough).

Rail is still an important means of transportation in Butler County and the United States. The longest active line is the CXS, which travels the P&W Subdivision from Allegheny County to Lawrence County. The Main Line of the Bessemer and Lake Erie is the second longest line traveling from Mercer County to Allegheny County. The other two railroads are part of the Buffalo and Pittsburgh lines. The Main Line, the larger of the two lines, travels from Eidenau to Armstrong County. The Northern Subdivision travels from Wadesworth to Burin. The final active line is a part of the Western Allegheny Line of the Bessemer and Lake Erie Railroad. It travels from Butler to Armstrong County.

FARMLANDS

Prime farmland, as defined by the U.S. Department of Agriculture (USDA) in the National Soil Survey Handbook, is the land that is best suited to producing food, feed, forage, and fiber and oilseed crops. It has the soil quality, growing season, and water supply needed to economically produce a sustained high yield of crops when it is treated and managed using acceptable farming methods (NRCS, 2007). In 1972, the USDA assigned the Soil Conservation Service the task of inventorying the prime and unique farmlands and farmlands of state and local importance. This inventory was designed to assist planners and other officials in their decision making to avoid unnecessary, irrevocable conversion of good farmland to other uses. On the USDA's important farmland inventory map, the farmlands are categorized into four classifications: prime farmland, unique farmland, additional farmland of statewide importance, and additional farmland of local importance. According to the USDA, prime farmland soils are usually classified as capability Class I or II. Of Butler County's total land area, 327 acres (0.06%) are classified as Class I soils and 106,604 acres (20.98%) are classified as Class II soils as identified in the *Soil Survey of Butler County, Pennsylvania* (SCS, 1989).

Farmland soils of statewide importance are soils that are predominantly used for agricultural purposes within a given state, but have some limitations that reduce their productivity or increase the amount of energy and economic resources necessary to obtain productivity levels similar to prime farmland soils. These soils are usually classified as capability Class II or III.

According to USDA's National Agriculture Statistic Service, there are 1,170 active farms in Butler County covering over 142,000 acres. This agricultural land accounts for 28% of the total land area of the County.

The importance of identifying farmland and planning accordingly is significant. The loss of good farmland is often accompanied by such environmental problems as surface water runoff and interference with the natural recharging of groundwater. Furthermore, when prime agricultural areas are no longer available, farmers will be forced to move to marginal lands, usually on steeper slopes with less fertile soils, which are more apt to erode and less likely to produce. Clearly, decision makers must be able to make informed judgments about the development of farmland. Actions that put high quality agricultural areas into irreversible uses should only be initiated if the actions are carefully considered and are clearly for the benefit of public good.

CLIMATE

Butler County is situated on the Allegheny Plateau in Western Pennsylvania and the climate is classified as humid continental. Most weather systems that affect the area originate in Canada or the Central Plains of the United States and are moved eastward by the prevailing westerlies. The primary source of moisture is the Gulf of Mexico although minor effects of the Great Lakes, Lake Erie in particular, are sometimes experienced. The mean temperature for Butler County is

51°F with a maximum mean monthly temperature of 71°F in July and mean monthly low of 29°F in January. About 56% of the annual precipitation falls during the spring and summer. Precipitation averages approximately 40 inches per year and is fairly evenly distributed throughout the year. June is the wettest month with an average of 4.7 inches per year and February is the driest month with approximately 2.3 inches per year of precipitation. Snowfall averages 40.2 inches per year with most of it falling between January and March.

RAINFALL

Figures 3.1 and 3.2 show the rainfall statistics for Butler County. The average rainfall shown in Figure 3.1 portrays the amount of precipitation throughout each year since 1949. Note the significant variation in the annual rainfall total (between 25 and 53 inches). While this variation can have a major impact on water supply and vegetative growth, it is the quantity of rain in a relatively short time period (1-hour, 6-hour, 24-hour, 48-hour) that receives the focus of most stormwater regulations.

Figure 3.2 show the annual maximum rainfall events recorded over the same time period graphed and the NOAA Atlas 14 values for the 2-year and 100-year storm events, derived using partial series data. The annual maximum rainfall for a station is constructed by extracting the highest precipitation amount for a particular duration in each successive year of record. A partial duration series is a listing of period of record greatest observed precipitation depths for a given duration at a station, regardless of how many occurred in the same year. Thus, a partial data series accounts for various storms that may occur in a single year.

Historical focus on the annual maximum rainfall and the larger magnitude, low frequency storm events as done in previous stormwater planning efforts throughout Pennsylvania has led to neglect of 1) the majority of storm events that are smaller than the annual maximum and their subsequent value to the landscape in terms of volume and water quality and 2) the fact that inclusion of every storm may increase the 24-hour rainfall total typically used in design.

The majority of rainfall volume in Butler County comes from storms with low magnitudes. Only 10% of the daily rainfall values between 1949 and 2009 exceeded 0.65 inches, which is below any design standards currently being used in the County. Thus, any stormwater policy should incorporate provisions such as water quality, infiltration, or retention BMPs that account for these small events. It is important to acknowledge that many of these smaller **rainfall** events lead to larger **runoff** events as they may be saturating the soils prior to a larger storm or occurring within a short time period that still overwhelm existing conveyance facilities.

For the gage shown in Figure 3.1 and 3.2, the NOAA Atlas 24-hour, 2-year storm event total of 2.42 inches was exceeded 22 times in more than 61 years of data. When analyzing only the annual maximum series, the NOAA Atlas 24-hour, 2-year storm was exceeded only 16 times. Thus, viewing only the annual maximum series neglects a substantial number of significant historical rainfall events. The implication for stormwater policy in Butler County is that best management practices should incorporate the NOAA Atlas 14, partial duration data series to ensure the best available data is being used for design purposes.

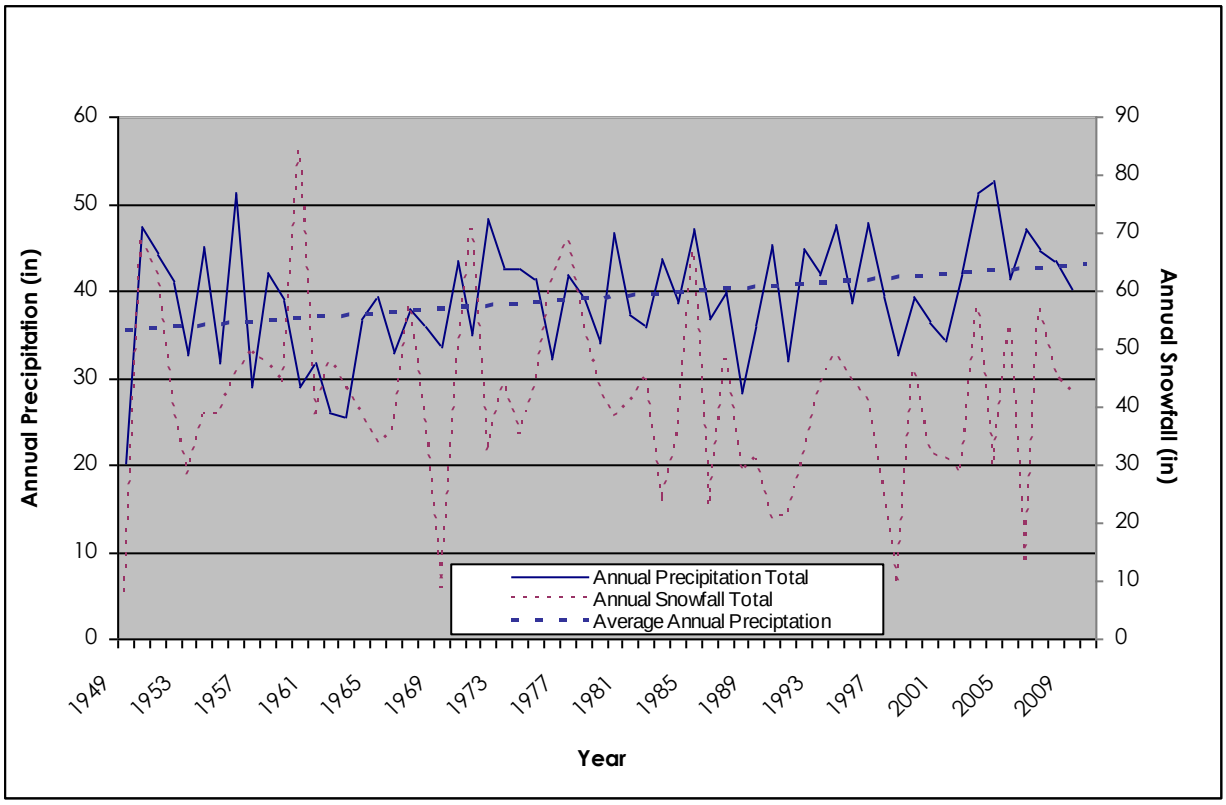


Figure 3.1. Annual Precipitation at Slippery Rock, Pennsylvania (Coop ID # 368184)

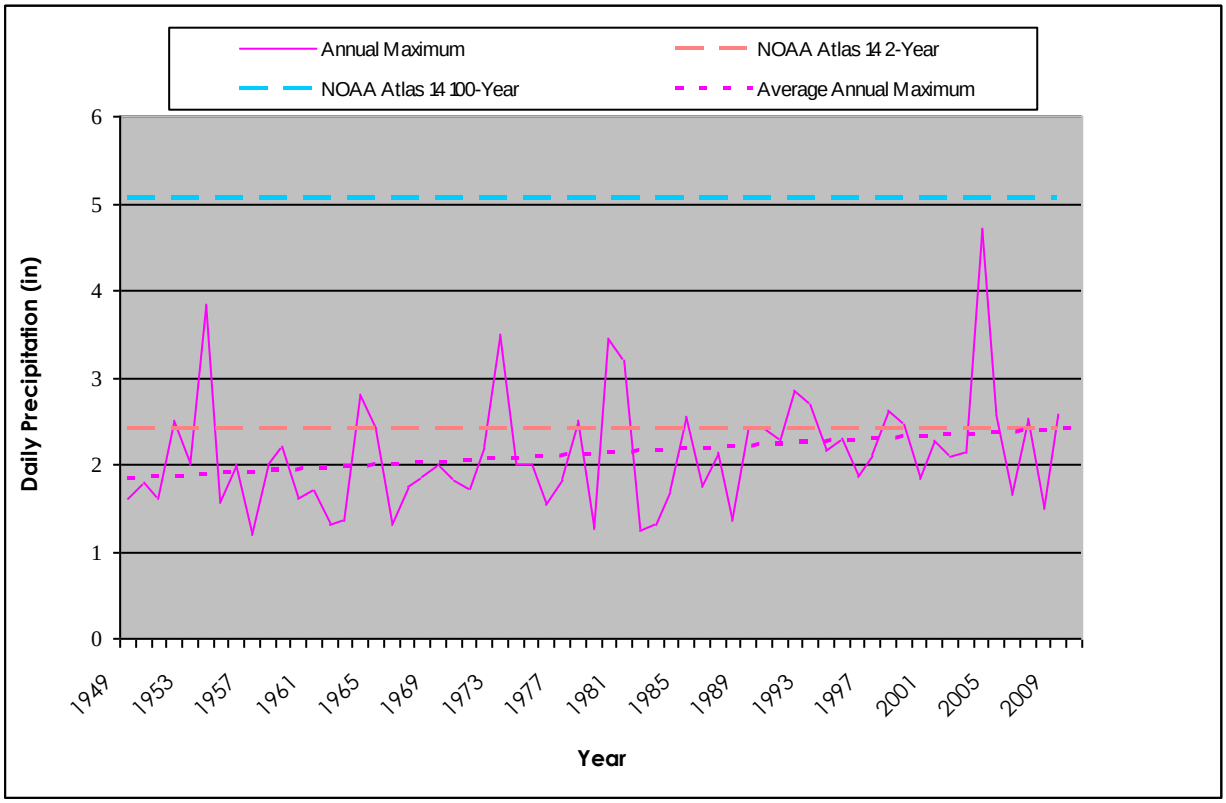


Figure 3.2. Daily Precipitation at Slippery Rock, Pennsylvania (Coop ID # 368184)

GEOLOGY

Butler County is situated in the Allegheny Plateau Province of Pennsylvania, which is characterized as a highland eroded by streams to create deep valleys and hilly topography. The smooth to irregular undulating surface, the narrow and relatively shallow valleys, strip mines and reclaimed lands of shale, sandstone, siltstone, limestone and coal are evident in this region. The bedrock of the Allegheny Plateau is nearly horizontal; therefore only one kind of rock is exposed at the surface. The dominant physiography of Butler County is rolling and hilly and consists of broad to narrow ridge tops and many steep-walled valleys. The Connoquenessing Creek has carved a deep, broad valley across the south-central part of the County. The northwest part of the County is smooth to rolling and consists of many low rounded hills and ridges. Poorly drained depressions are scattered throughout the County. The valleys occupied by Slippery Rock and Wolf Creeks are steep sided (Barnes and Sevon, 2002).

BEDROCK FORMATIONS

The bedrock of Butler County was formed in the Pennsylvania Period, 280 million to 310 million years ago. The bedrock is divided into three major groups based upon the age of the rocks; they are the Pottsville, Allegheny, and Conemaugh groups. The County is underlain by flat lying, generally thin, but locally thick limestone beds. These rocks can affect the environment in three ways: as hazards, as mineral resources, and as groundwater reservoirs. This type of bedrock is also susceptible to landslides. The formation names are as follows (PA Geological Survey, 2010):

Formation	Dominant Lithology
Conemagh Group	Shale
Allegheny Formation	Sandstone
Pottsville Formation	Sandstone

Table 3.2. Geologic Formations

OUTSTANDING AND UNIQUE FEATURES

Pennsylvania's outstanding and unique scenic geological features have been identified by the *Outstanding Scenic Geological Features of Pennsylvania* (Geyer and Bolles, 1979). Butler County contains two of these resources as identified below.

Lake Arthur – Located in Muddycreek, Brady, Franklin, and Worth Townships, this manmade lake occupies the site of a glacial lake that existed here over 10,000 years ago, when a continental glacier covered much of northwestern Pennsylvania. The glacial ice, whose eastern edge was at Harrisville and Slippery Rock, dammed the westward-flowing Slippery Rock and Muddy Creeks, forming lakes in their valleys; in the latter, Lake Arthur was formed.

West Liberty Esker/Miller Esker/West Liberty Hogback – Located in Worth Township, this 3-mile-long esker is probably the best remaining example of this type of glacial deposit in western Pennsylvania. The esker was formed during the close of the Wisconsonian glaciation, and is also known as the Miller Esker and West Liberty "Hogback."

Eskers are ridge-shaped sand and gravel deposits formed during the melting of a glacier. The ridge form marks the trace of a glacial meltwater stream that is confined within the ice mass. Esker ridges are always associated with the stagnation phase of the glacial episodes.

The West Liberty Esker is believed to be a crevasse filling (as opposed to a sinuous shaped ice tunnel esker) for the following reasons:

- Straight-line segments of the ridge are connected by sharp bends.
- Glaciofluvial gravels are present across the whole ridge.
- Numerous normal, ice-contact faults occur along the edge of the ridge.
- No till blanket has been observed on the ridge.

SLOPES

Slopes play a significant role when determining the extent and type of development that is being planned. Land with slopes in excess of 15% begins to cause problems for development. If these steep slopes are disturbed or vegetation is removed, the soils will become prone to erosion. Butler County's soils have high clay content and with the amount of rainfall in the area, the soils are slip prone. Slopes greater than 15% are prevalent throughout Butler County as shown in the Comprehensive Plan. Slope values are broken into four categories and shown in *Table 3.3* below. Also shown is the total area in Butler County within each category, the total area as a percentage of all land in the County, and the general slope restrictions associated with each category. Note that almost three-quarters of the County is comprised of slopes of 15% or less. This indicates that for the most part, slope does not preclude the development potential of the land surface.

Slope Classification	Slope Range	Land Area (mi^2)	Portion of Total Area	Slope Restrictions
Flat to Moderate	0-8%	327.00	41.18%	Capable of all normal development for residential, commercial, and industrial uses; involves minimum amount of earth moving; suited to row crop agriculture, provided that terracing, contour planting, and other conservation practices are followed
Rolling Terrain and Moderate Slopes	8 - 15%	248.32	31.28%	Generally suited only for residential development; site planning requires considerable skill; care is required in street layout to avoid long sustained gradients; drainage structures must be properly designed and installed to avoid erosion damage; generally suited to growing of perennial forage crops and pastures with occasional small grain plantings
Steep slopes	15 - 25%	145.25	18.29%	Generally unsuited for most urban development; individual residences may be possible on large lot areas, uneconomical to provide improved streets and utilities; overly expensive to provide public services; foundation problems and erosion usually present; agricultural uses should be limited to pastures and tree farms
Severe and Precipitous Slopes	> 25%	73.46	9.25%	No development of an intensive nature should be attempted; land not to be cultivated; permanent tree cover should be established and maintained; adaptable to open space uses (recreation, game farms, & watershed protection)

Table 3.3. Summary of Slopes in Butler County

SOILS

The behavior of a soil's response to rainfall and infiltration is a critical input to the hydrologic cycle and in the formation of a coherent stormwater policy. The soils of Butler County have variable drainage characteristics and have various restrictions on their ability to drain, promote vegetative growth, and allow infiltration. They are generally moderately to poorly drained and have a high runoff potential. The following describes the predominant soil series in Butler County (NRCS, 2008).

Series Name	Map Symbols	Hydrologic Soil Group	% of County	Restrictions
Andover	AnA, AnB, AnC, AoB, AoC	D	1.7	Fragipan (16-28in.)
Arents	Ar		0.9	
Atkins	At	B/D	5.2	Lithic bedrock (60-99in.)
Braceville	BeA, BeB, BeC	C	0.5	Fragipan (15-30in.)
Brinkerton	BrA, BrB, BrC	C/D	4.2	Fragipan (15-30in.)
Buchanan	BuB, BuC, BxB, BxD	C	7.4	Fragipan (20-36in.)
Canadice	Cd	D	0.6	
Caneadea	CeA, CeB, CeC, CeD	D	0.7	
Canfield	CfB, CfC, CfD	C/D	0.5	Fragipan (15-30in.)
Cavode	ClA, ClB, ClC, ClD	C/D	6.1	Paralithic bedrock (40-72in.)
Clymer	CmB, CmC	B	0.6	Lithic bedrock (40-84in.)
Cookport	CoA, CoB, CoC, CoD	C/D	4.8	Fragipan (20-32in.)
Dams	DAM		<0.1	
Dumps	Dd, Dm		0.1	
Ernest	ErB, ErC, ErD	C/D	4.6	Fragipan (20-36in.)
Fluvaquents	Fc	D	<0.1	
Fredon	FeA, FeB	C	0.3	
Frenchtown	FrA, FrB	D	0.7	Fragipan (15-32in.)
Gilpin	GlB, GlC, GmD	C	4.2	Lithic bedrock (20-40in.)
Upshur	GnC, GnD	D	0.2	Lithic bedrock (40-70in.)
Weikert	GoB	C	1.2	Lithic bedrock (10-20in.)
Gilpin	GoC	C	1.4	Lithic bedrock (20-40in.)
Weikert	GoD	C	2.2	Lithic bedrock (10-20in.)
Gilpin	GoF, GpC, GpD	C	12.5	Lithic bedrock (20-40in.)
Gresham	GrA, GrB, GrC	C	1.5	Fragipan (15-26in.)
Hazleton	HaB, HaC, HaD, HaE, HbB, HgD, HgF	A	17.4	Lithic bedrock (40-60in.)
Monongahela	MoB, MoC	C/D	0.3	Fragipan (25-35in.)
Philo	Ph	B	0.6	
Pits	Pn	A	0.1	
Pope	Po	B	0.1	
Ravenna	RaA, RaB, RaC	D	0.6	Fragipan (14-30in.)
Riverhead	RdB, RdC	B	0.4	
Tilsit	TaA, TaB	C	1.9	Lithic bedrock (40-40in.)
Titusville	TeB, TeC, TrD	C	1.5	Fragipan (16-28in.)
Urban land	UB		<0.1	Dense material (10-10in.)
Bethesda	UaB, UaD, UaF	C	6.2	
Fairpoint	UcD, UcF	C	0.3	

Series Name	Map Symbols	Hydrologic Soil Group	% of County	Restrictions
Urban land	UeB, UeC, UgD	D	0.6	
Vandergrift	VcB, VcC, VcD	C	0.9	Lithic bedrock (40-72in.)
Water	W		1.1	
Wharton	WaA, WaB, WaC	C	5.6	Paralithic bedrock (40-40in.)
Wheeling	WhA, WhB	B	0.2	
Wooster	WoB, WoC, WoD, WoF	C	0.1	Fragipan (18-36in.)

Table 3.4. Soil Characteristics of Butler County (NRCS, 2008)

One of the impediments to drainage throughout Butler County is the presence of fragipan soils and lithic bedrock. A fragipan soil layer is typically composed of loamy, brittle soil that has minimal porosity and organic content and has a low to moderate amount of clay content but a high amount of silt or very fine sand. With fragipans, upwards of 60% of input water moves laterally above the fragipan layer which is typically 14-36 inches below the surface in Butler County (Ciolkosz and Waltman, 2000; NRCS, 2008). Lithic bedrock is composed of a solid rock layer that is relatively shallow (10 to 75 inches beneath the surface). It is a relatively homogeneous layer of rock containing few fractures, and it does not readily facilitate infiltration into the water table.

In areas of fragipan and lithic bedrock, higher runoff rates and reduced infiltration capacity can be expected. Additional impediments to subsurface drainage include paralithic bedrock (i.e., weathered or broken layers of bedrock) and dense material. *Table 3.5* displays a list of soil restrictions in Butler County (DCNR, 2001).

Restrictions	% of County
Dense material	< 0.1
Fragipan	28.4
Lithic bedrock	47.6
Paralithic bedrock	11.7
None Identified	12.2

Table 3.5. Soil Restrictions in Butler County

An additional indicator of the response to rainfall of the soils in Butler County is the hydrologic soil group assigned to each soil. This classification varies between "A" which has very low runoff potential and high permeability and "D" which typically has very high runoff potential. *Table 3.6* shows a summary of the hydrologic soil groups for Butler County. Some soils have variable runoff potential depending on whether or not they are drained or undrained. For example, an agricultural field with tile drainage may decrease the runoff potential from hydrologic soil group D to hydrologic soil group A. Approximately three quarters of the soils in Butler County are hydrologic soil group C or D indicating a moderate to high runoff potential (Refer to *Plate 4 – Hydrologic Soils*).

Hydrologic Soil Group	Runoff Potential	% of County
A	Low	17.5
B	Moderate to low	1.9
B/D		5.2
C	Moderate to High	47.7
C/D		20.5
D	High	5.1
Unidentified		2.1

Table 3.6. Hydrologic Soil Groups of Butler County

HYDRIC SOILS

The analysis of hydric soils has recently become an important consideration when performing almost any kind of development review. These soils are important to identify and locate because they provide an approximate location where wet areas may be found. Wetland areas are lands where water resources are the primary controlling environmental factor as reflected in hydrology, vegetation, and soils. Thus, the location of hydric soils is one indication of the potential existence of a wetland area. Wetland areas are now protected by DEP and should be examined before deciding on any type of development activity. According to NRCS, the following table lists the hydric soils found in Butler County:

Andover Loam	Cookport Loam	Pope Loam
Arents-Urban Land Complex	Dumps, Industrial Waste	Ravenna Silt Loam
Atkins Silt Loam	Dumps, Mine	Tilsit Silt Loam
Braceville Loam	Ernest Silt Loam	Titusville Silt Loam
Brinkerton Silt Loam	Fluvaquents, Coal Overwash	Udorthents, Acid Material
Buchanan Loam	Fredon Loam	Urban Land – Ernest Complex
Canadice Silty Clay Loam	Frenchtown Silt Loam	Vandergrift-Cavode Silt Loams
Caneadea Silt Loam	Gresham Silt Loam	Wharton Silt Loam
Canfield Silt Loam	Hazleton Loam	
Cavode Silt Loam	Philo Loam	

Table 3.7. Hydric Soils

WATERSHEDS

Surface waters include rivers, streams and ponds, which provide aquatic habitat, carry or hold runoff from storms, and provide recreation and scenic opportunities. Surface water resources are a dynamic and important component of the natural environment. However, ever-present threats such as pollution, construction, clear-cutting, mining, and overuse have required the protection of these valuable resources.

Watersheds are delineated and subdivided for the sake of management and analysis. The physical boundaries of a watershed depend on the purpose of the delineation. Oftentimes a watershed is called a "basin" but is also a "subbasin" to an even larger watershed. This indistinct nature often leads to confusion when trying to categorize watersheds. As show in *Figure 3.4*, DEP has divided Pennsylvania into seven different major river basins, based upon the major waterbody to which they are tributary. These include: Lake Erie Basin, Ohio River Basin, Genesee River Basin, Susquehanna River Basin, Potomac River Basin, Elk & Northeast/Gunpowder Rivers Basin, and Delaware River Basin.

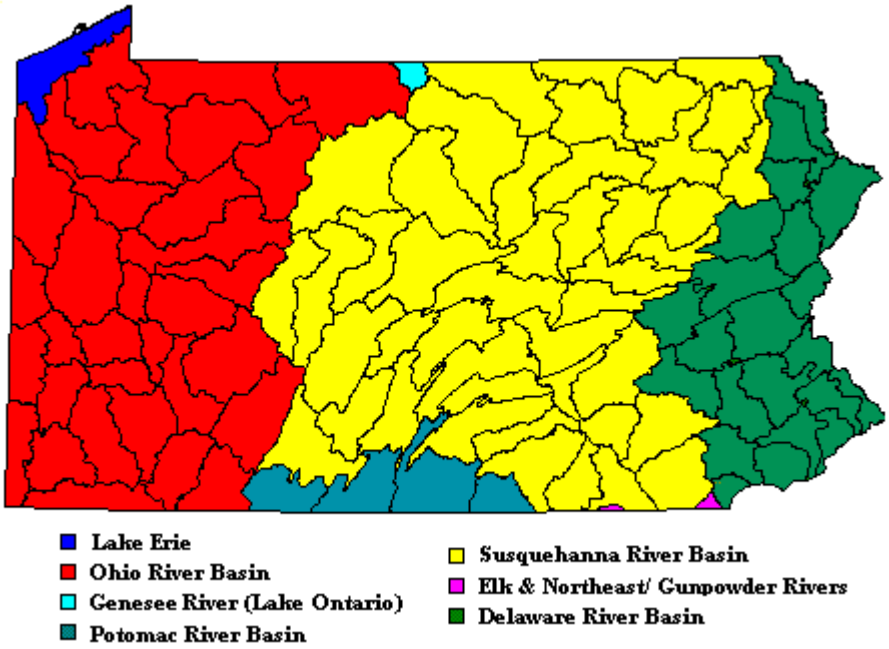


Figure 3.3. Pennsylvania's Major River Basins as Delineated by DEP (DEP, 2009)

For the purpose of this Plan, these are the largest basins in the Commonwealth. The major river basins are further divided into "subbasins" and "Act 167 Designated Watersheds" for stormwater management purposes. Act 167 divided the Commonwealth into 29 subbasins and 357 designated watersheds. Butler County lies completely in the Ohio River Basin, but is tributary to two different subbasins: Allegheny River (From Kiskiminetas River to Confluence with Ohio River) and Beaver River (From Ohio State Line to Confluence with Ohio River). Butler County contains at least a portion of nine different Act 167 Designated Watersheds. This classification of the County's watersheds is summarized in the following table:

Major River Basin	Subbasin	Act 167 Designated Watershed
Ohio River	Beaver River	Sullivan Run
		Breakneck Creek
		Wolf Creek
		Slippery Rock Creek
		Connoquenessing Creek
	Allegheny River	Buffalo Creek
		Bull Creek
		Deer Creek
		Allegheny River (Direct Discharge)

Table 3.8. Classification of Butler County Watersheds

ACT 167 DESIGNATED WATERSHEDS

Most of Butler County (72.6%) is in the Beaver River Subbasin with the eastern edge of the County draining to the Allegheny River Subbasin. No previous Act 167 Stormwater Management Plans have been completed for any of the nine Act 167 Designated Watersheds in the County. *Figure 3.4* shows the Act 167 Designated Watersheds.

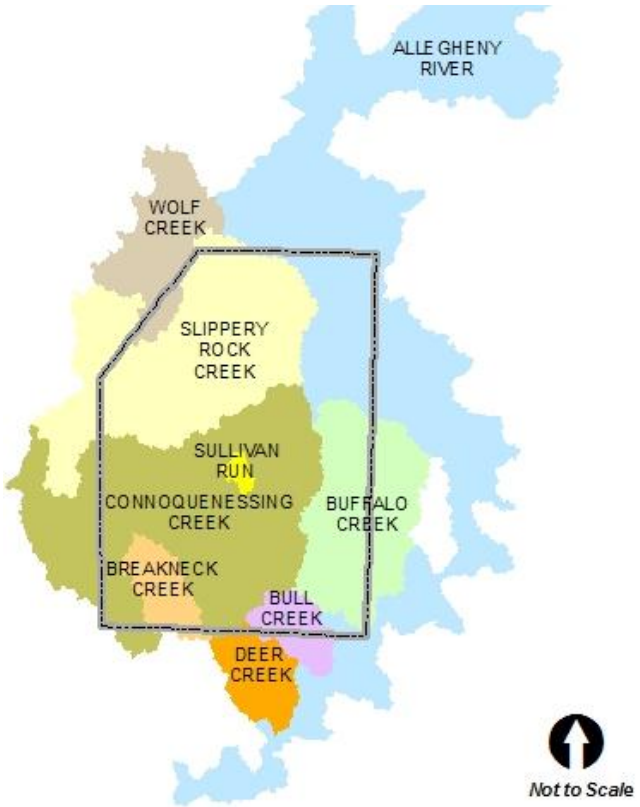


Figure 3.4. Act 167 Watersheds in Butler County

Connoquenessing Creek Watershed

The Connoquenessing Creek Watershed covers the southwest quadrant of Butler County. It drains an area of approximately 382 square miles, of which 296 square miles are located in Butler County. Table 3.9 details the municipalities at least partially in the watershed, and their contributing area:

Watershed	Municipality	Area (mi^2)
Connoquenessing Creek	Adams Township	5.6
	Butler Township	18.6
	Center Township	20.6
	City of Butler	1.2
	Clay Township	1.7
	Clearfield Township	1.1
	Clinton Township	4.9
	Concord Township	10.9
	Connoquenessing Borough	1.4
	Connoquenessing Township	23.1
	Cranberry Township	17.0
	Donegal Township	1.5
	East Butler Borough	1.0
	Forward Township	19.0
	Franklin Township	7.5
	Harmony Borough	0.4

Jackson Township	13.7
Jefferson Township	18.5
Lancaster Township	23.2
Middlesex Township	20.7
Muddycreek Township	11.0
Oakland Township	22.7
Penn Township	24.1
Portersville Borough	0.5
Prospect Borough	3.1
Saxonburg Borough	0.6
Seven Fields Borough	<0.1
Summit Township	20.1
Zelienople Borough	2.0

Table 3.9. Connoquenessing Creek Watershed

The headwaters of the Connoquenessing Creek are in Butler County, and it flows westward into Beaver County en route to its confluence with the Beaver River. The watershed encompasses the Sullivan Run Watershed and the Breakneck Creek Watershed, but they are considered separately from Connoquenessing Creek for Act 167 purposes.

The Connoquenessing Creek Watershed (including its tributary watersheds: Slippery Rock Creek, Wolf Creek, Sullivan Run, and Breakneck Creek) was studied in detail as part of this Plan. One result of that study was the establishment of Stormwater Management Districts. Each Stormwater Management District has a release rate to be applied whenever a new construction project adds impervious area. The decision to incorporate release rates was based on the following factors:

1. Numerous problem areas exist in a pattern that indicates systemic stormwater problems.

2. Historic, repeated flooding has been observed.

3. Future planning projections indicate growth patterns that have historically contributed to documented problems.

4. The size of the watercourse – Release rates are to be designated on higher order watersheds only. Larger downstream areas with well established bed-and-bank streams are not as affected by relatively small scale development and therefore do not benefit from release rates.

Only one small section of the watershed in the southern part of the County meets the above criteria for applying release rates. The hydrologic study of the Connoquenessing Creek Watershed is reviewed in detail in *Section VI – Technical Analysis – Modeling.*

Buffalo Creek Watershed

The Buffalo Creek Watershed is located along Butler County's eastern border. Buffalo Creek flows eastward into Armstrong County where it discharges into the Allegheny River. It drains an area of approximately 171 square miles, of which 102 square miles are located in Butler County. *Table 3.9* details the municipalities at least partially in the watershed, and their contributing area:

Watershed	Municipality	Area (mi^2)
Connoquenessing Creek	Buffalo Township	16.6
	Chicora Borough	0.5
	Clearfield Township	22.4
	Clinton Township	2.7
	Concord Township	< 0.1
	Donegal Township	21.5
	Fairview Township	5.7
	Jefferson Township	4.9
	Oakland Township	0.4
	Saxonburg Borough	0.2
	Summit Township	2.2
	Winfield Township	24.5
	Buffalo Township	16.6
	Chicora Borough	0.5
	Clearfield Township	22.4
	Clinton Township	2.7

Table 3.10. Buffalo Creek Watershed

The Buffalo Creek Watershed was studied in detail as part of this Plan, but none of the subwatersheds met the criteria for applying Stormwater Management Districts. The hydrologic study of the Buffalo Creek Watershed is reviewed in detail in *Section VI – Technical Analysis – Modeling.*

IMPOUNDMENTS

There are numerous dams and impoundments scattered throughout Butler County. *Figure 3.5* shows their locations and whether or not they have any flood control potential.

Dams with small storage volumes (less than 100 acre-feet) and dams that are completely filled during minor runoff events (0.3 inches of runoff) were considered generally "run-of-the-river dams" that would only affect the immediate area near the dam. Their impacts to the overall watershed hydrology are negligible. Any impoundments that exceed the above parameters can be considered "flood control dams" for the purpose of this Plan.

There are six major water impoundments that affect flooding in Butler County. Their flood control properties have been incorporated into the release rate analysis that was performed for Chartiers Creek. Details of the hydraulic modeling are presented *Section VI – Technical Analysis – Modeling.*

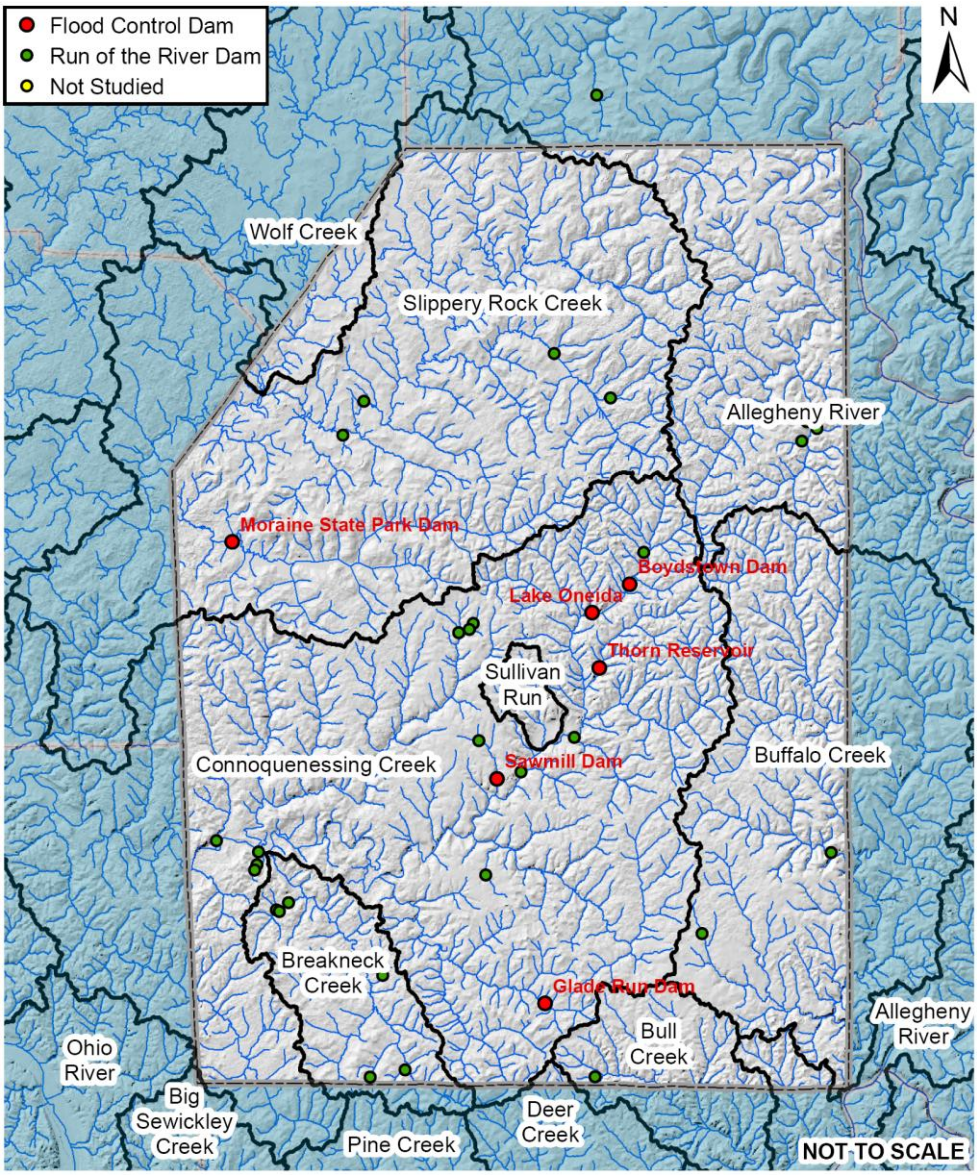


Figure 3.5. Butler County Impoundments

SURFACE WATER QUALITY

Water Quality Standards for the Commonwealth are addressed in *The Pennsylvania Code, Title 25, Chapter 93*. In Chapter 93, all surface waters are classified according to their water quality criteria and protected water uses. According to the antidegradation requirements of §93.4a, "Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected." Certain waterbodies which exhibit exceptional water quality and other environmental features, as established in §93.4b, are referred to as "Special Protection Waters." These waters are classified as High Quality or Exceptional Value waters and are among the most valuable surface waters in the Commonwealth. Activities that could adversely affect surface water are more stringently regulated in those watersheds than waters of lower protected use classifications. The existing water quality regulations are discussed in more detail in *Section IV – Existing Stormwater Regulations and Related Plans*.

Butler County streams are shown with their Chapter 93 protected use classification in *Figure 3.5* below. (This figure is provided for reference only; the official classification may change and should be checked at: http://www.pacode.com/index.html.) An explanation of the protected use classifications can be found in *Section IV*.

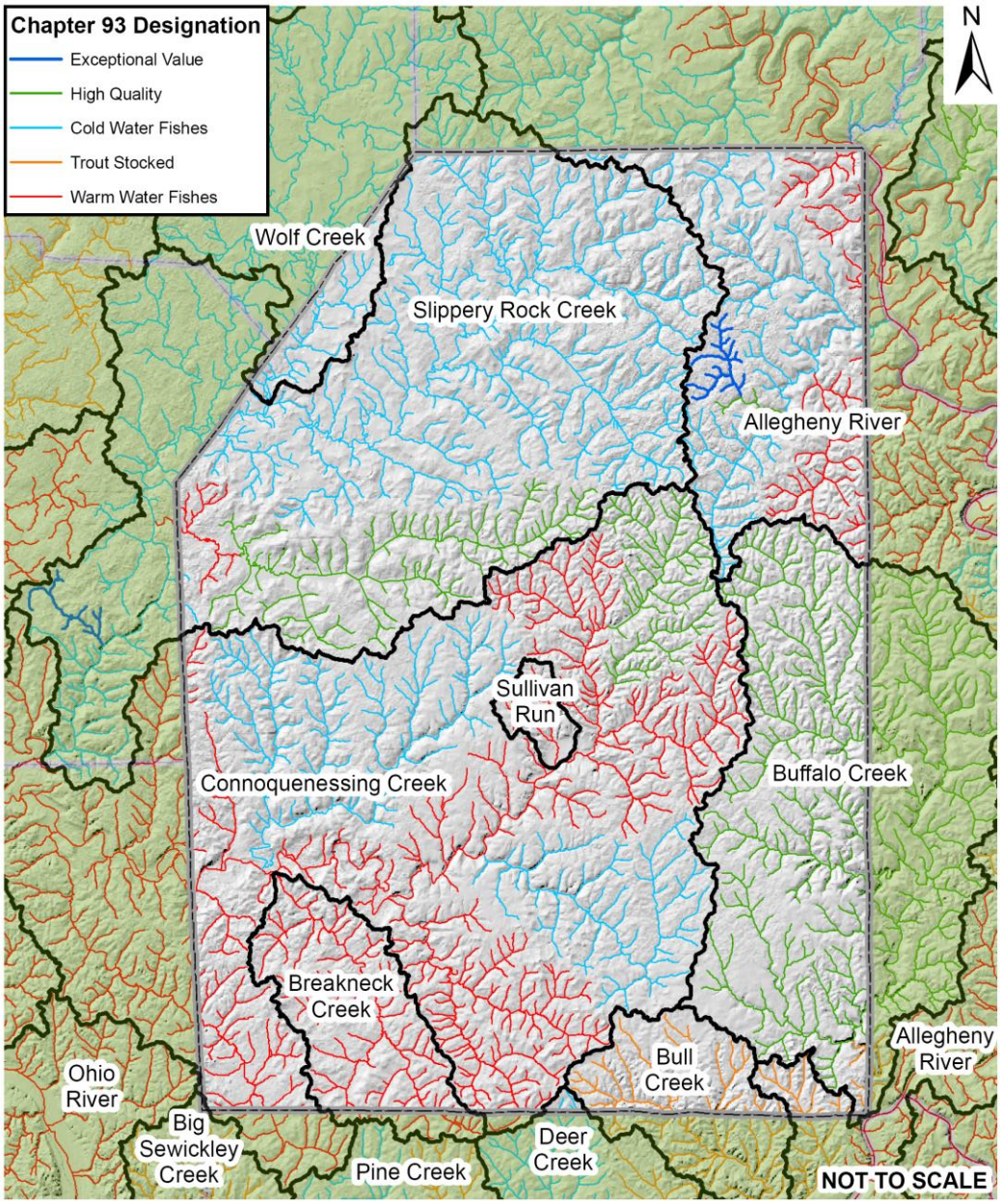


Figure 3.4. Chapter 93 Classification of Butler County Streams

In Pennsylvania, bodies of water that are not attaining designated and existing uses are classified as "impaired". Water quality impairments are addressed in *Section IX* of this Plan.

FLOODPLAIN DATA

A flood occurs when the capacity of a stream channel to convey flow within its banks is exceeded and water flows out of the main channel onto and over adjacent land. This adjacent land is known as the floodplain. For convenience in communication and regulation, floods are characterized in terms of return periods, e.g., the 50-year flood event. In regulating floodplains, the standard is the 100-year floodplain, the flood that is defined as having a 1% chance of being equaled or exceeded during any given year. These floodplain maps, or Flood Insurance Rate Maps (FIRMs), are provided to the public (http://msc.fema.gov/) for floodplain management and insurance purposes.

In 2007, the Pennsylvania Emergency Management Agency (PEMA) completed a statewide study to determine damage estimates for all major flood events. The study computed damages in dollars for total economic loss, building and content damage, and also estimated the number of damaged structures (PEMA, 2009). *Table 3.11* summarizes the findings from this study.

Storm Event	Number of Buildings at Least Moderately Damaged	Total Economic Loss
10	107	$61 million
50	127	$97 million
100	128	$113 million

Table 3.11. Potential Impact Due to Flooding (PEMA, 2009)

Detailed Studies

There are various levels of detail in floodplain mapping. Detailed studies (Zones AE and A1-A30 on the floodmaps) are conducted at locations where FEMA and communities have invested in engineering studies that define the base flood elevation and often distinguish sections of the floodplain between the floodway and flood fringe. See *Figure 3.5* below for a graphical representation of these terms. For a proposed development, most ordinances state that there shall be no increase in flood elevation anywhere within the floodway; the flood fringe is defined so that any development will not cumulatively raise that water surface elevation by more than a designated height (set at a maximum of 1'). Development within the flood fringe is usually allowed but most new construction is required to be designed for flooding (floodproofing, adequate ventilation, etc).

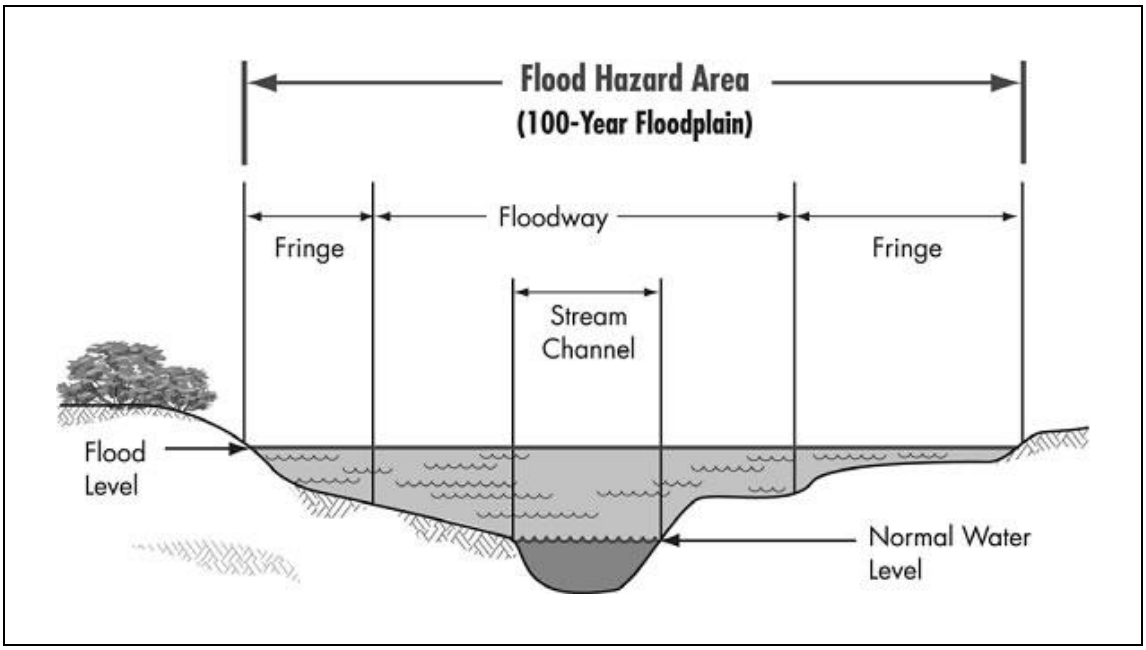


Figure 3.5. Floodplain Cross Section and Flood Fringe (NH Floodplain, 2007)

A review of the Preliminary Flood Insurance Study for Butler County revealed that Butler County contains several 100-year floodplains for the main streams draining the County. Detailed studies that clearly define the 100-year flood elevation and the floodway are provided in the locations indicated in *Table 3.12*.

Waterbody	Source
Bonnie Brooke	Approximately 0.3 mile downstream of East Butler Road to approximately 0.6 mile upstream of East Butler Road.
Breakneck Creek	Confluence with Connoquenessing Creek to approximately 120 feet upstream of Three Degree Road.
Brush Creek	Approximately 0.7 mile downstream of Powell Road to approximately 0.8 mile upstream of Commonwealth Drive.
Buffalo Creek	Confluence with Allegheny River to approximately 815 feet upstream of the railroad.
Butcher Run	Confluence with Connoquenessing Creek to approximately 0.4 mile upstream of William Flynn Highway.
Coal Run above Brush Creek	Confluence with Brush Creek to approximately 0.3 mile upstream of Canterbury Trail.
Coal Run above Connoquenessing Creek	Confluence with Connoquenessing Creek to approximately 700 feet upstream of Zeigler Avenue.
Connoquenessing Creek	Approximately 0.7 mile downstream of New Castle Street to approximately 0.9 mile upstream of Franklin Glass Access Road, and from just upstream of Armco Plant Road to approximately 150 feet upstream of Pine Tract Road.
Glade Run	Approximately 1.0 mile downstream of Sheldon Road to just upstream of the Glade Lake Dam.
Little Bull Creek	Approximately 0.8 mile downstream of Hranica Road to approximately 0.3 mile downstream of Hranica Road.

Little Connoquenessing Creek	Confluence with Connoquenessing Creek to approximately 0.4 mile upstream of Little Creek Road.
Scholars Run	Confluence with Connoquenessing Creek to approximately 0.7 mile upstream of Fanker Road.
Shanks Hollow Run	Confluence with Sullivan Run to approximately 400 feet upstream of Wicks Street.
Shearer Run	Confluence with Connoquenessing Creek to approximately 0.4 mile upstream of Shearer Road.
South Branch Bear Creek	Approximately 1000 feet downstream of the railroad to approximately 500 feet upstream of Nesbit Street.
Sullivan Run	Confluence with Connoquenessing Creek to approximately 0.3 mile upstream of North 6th Avenue.

Table 3.12. Detailed Method Studies

Approximate Studies and Non-delineated Floodplains

Approximate studies (Zone A on the DFIRM) delineate the flood hazard area, but are prepared using approximate methods that result in the delineation of a floodplain without providing base flood elevations or a distinction between floodway and flood fringe. If no detailed study information is available, some ordinances allow the base flood elevation to be determined based on the location of the proposed development relative to the approximated floodplain; at times, a municipality may find it necessary to have the developer pay for a detailed study at the location in question.

Approximated floodplains were delineated based mainly on the size of the contributory watershed. The U.S. Geological Survey (USGS) used a regional regression analysis consisting of basin areas compared to the flood depth observed in similar gaged streams for the one-percent-annual-chance (100-year) flood. Then the backwater due to bridges and culverts was approximated.

One limitation of FIRMs and older Flood Insurance Rate Maps is the false sense of security provided to home owners or developers who are technically not in the floodplain, but are still within an area that has a potential for flooding. Headwater streams or smaller tributaries located in undeveloped areas do not normally have FEMA delineated floodplains. This leaves these areas unregulated at the municipal level and somewhat susceptible to uncontrolled development. Flooding due to natural phenomena as well as increased stormwater runoff generated by land development is not restricted only to main channels and large tributaries. In fact, small streams and tributaries may be more susceptible to flooding from increased stormwater runoff due to their limited channel capacities.

Pennsylvania's Chapter 105 regulations partially address the problem of non-delineated floodplains. Chapter 105 regulations prohibit encroachments and obstructions, including structures, in the regulated floodway without first obtaining a state Water Obstruction and Encroachment permit. The floodway is the portion of the floodplain adjoining the stream required to carry the 100-year flood event with no more than a one foot increase in the 100-year flood level due to encroachment in the floodplain outside of the floodway. Chapter 105 defines the floodway as the area identified as such by a detailed FEMA study or, where no FEMA study exists, as the area from the stream to 50-feet from the top of bank, absent evidence to the contrary. These regulations provide a measure of protection for areas not identified as floodplain by FEMA studies.

Levees and other flood control structures

As administrator of the National Flood Insurance Program (NFIP), FEMA has a series of policies and guidelines concerning the protection of life and property behind levees. Periodically, FEMA updates the effective FIRMs as new hydrologic and hydraulic data become available and to reflect changes within the community. In the ongoing map update process, FEMA issued Procedure Memorandum 43 (PM 43) – Guidelines for Identifying Provisionally Accredited Levees (PALs) (FEMA, 2007). For communities with levees, PM 43 has potential to substantially impact the communities protected by levees. A PAL is a levee that has previously been accredited with providing 1-percent-annual-chance flood protection on an effective FIRM. After being designated as a PAL, levee owners will have up to 24 months to obtain and submit documentation that the levee will provide adequate protection against a 1-percent-annual-chance flood. If the levee cannot be certified as providing protection from the 1-percent-annual-chance flood, the areas currently being protected by the levees will be mapped and managed as if they were within the floodplain (i.e., in most cases, the residents and businesses currently being protected by the levees would be forced to purchase flood insurance in accordance with the NFIP).

There is one levee project in Butler County:

Project (Year Constructed)	Owner	Waterbody	PAL Levee Status
City of Butler (1966)	**Connoquenessing Creek Flood Control Authority**	**Connoquenessing Creek**	**N/A**

Table 3.15. Levee Systems in Butler County

Community Rating System (CRS)

To reduce flood risk beyond what is accomplished through the minimum federal standards, the NFIP employs the Community Rating System to give a credit to communities that reduce their community's risk through prudent floodplain management measures. Several of these measures coincide with the goals and objectives of this plan: regulation of stormwater management, preservation of open space, and community outreach for the reduction of flood-related damages.

Flood insurance premiums can be reduced by as much as 45% for communities that obtain the highest rating. Only 28 of the Commonwealth's 2500+ municipalities participate in the CRS. Currently, none of Butler County's municipalities participate in the CRS.

FIRM Updates

As new information becomes available, FEMA periodically updates the FIRMs to reflect the best available data and to address any new problem areas. Butler County is currently undergoing the preliminary FIRM update process. Final FIRM maps are expected to be completed by March 2011. This is part of the effort by DCED to have all municipalities adopt and implement a new floodplain model ordinance that conforms to federal and state requirements.

Section IV – Existing Stormwater Regulations and Related Plans



It is often helpful to assess the current regulations when undertaking a comprehensive planning effort. An understanding of current and past regulations, what has worked in the past, and what has failed, is a key component of developing a sound plan for the future. Regulations affecting stormwater management exist at the federal, state, and local level. At the federal level the regulations are generally broad in scope, and aimed at protecting health and human welfare, protecting existing water resources and improving impaired waters. Regulations generally become more specific as their jurisdiction becomes smaller. This system enables specific regulations to be developed which are consistent with national policy, yet meet the needs of the local community.

EXISTING FEDERAL REGULATIONS

Existing federal regulations affecting stormwater management are very broad in scope and provide a national framework within which all other stormwater management regulations are developed. An overview of these regulations is provided below in *Table 4.1*.

Clean Water Act	Section 303	Requires states to establish Total Maximum Daily Loads for point sources of pollution that are allowable to maintain water quality and protect stream flora and fauna. Other water quality standards (e.g., thermal) are also regulated.
Clean Water Act	Section 404	Regulates permitting of discharge of dredged or fill material into the waters of the United States. Includes regulation of discharge of material into lakes, navigable streams and rivers, and wetlands.
Clean Water Act	Section 401/402	Authorizes the Commonwealth to grant, deny, or condition Water Quality Certification for any licensed activity that may result in a discharge into navigable waters. Established the National Pollutant Discharge Elimination System (NPDES) that regulates any earth disturbance activity of 5 acres (or more) or 1 acre (or more) with a point source discharge.
Rivers and Harbors Act of 1899	Section 10	Regulates activities that obstruct or alter any navigable waters of the United States.
Federal Emergency Management Act		Requires that any proposed structure within the floodplain boundaries of a stream cannot cause a significant increase in the 100-year flood height of the stream.

Table 4.1. Existing Federal Regulations

EXISTING STATE REGULATIONS

Pennsylvania has developed stormwater regulations that meet the federal standards and provide a statewide system for stormwater regulation. State regulations are much more specific than federal regulations. Statewide standards include design criteria and state issued permits. State regulations cover a variety of stormwater related topics. A brief review of the existing state regulations is provided below in *Table 4.2*.

Chapter 92	Discharge Elimination	Regulates permitting of point source discharges of pollution under the National Pollutant Discharge Elimination System (NPDES). Storm runoff discharges at a point source draining 5 or more acres of land or 1 or more acres with a point source discharge are regulated under this provision.
Chapter 93	Water Quality Standards	Establishes the Water Use Protection classification (i.e., water quality standards) for all streams in the state. Stipulates anti-degradation criteria for all streams.
Chapter 96	Water Quality Implementation Standards	Establishes the process for achieving and maintaining water quality standards applicable to point source discharges of pollutants. Authorizes DEP to establish Total Mass Daily Loads (TMDLs) and Water Quality Based Effluent Limitations (WQBELs) for all point source discharges to waters of the Commonwealth.
Chapter 102	Erosion and Sediment Control	Requires persons proposing or conducting earth disturbance activities to develop, implement and maintain Best Management Practices to minimize the potential for accelerated erosion and sedimentation. Current DEP policy requires preparation and implementation of a post-construction stormwater management (PCSM) plan for development areas of 5 acres or more or for areas of 1 acre or more with a point source discharge.
Chapter 105	Dam Safety and Waterway Management	Regulates the construction, operation, and maintenance of dams on streams in the Commonwealth. Also regulates water obstructions and encroachments (e.g., road crossings, walls, etc.) that are located in, along, across or projecting into a watercourse, floodway, wetland, or body of water.
Chapter 106	Floodplain Management	Manages the construction, operation, and maintenance of structures located within the floodplain of a stream if owned by the State, a political subdivision, or a public utility.

Table 4.2. Existing State Regulations

STATE WATER QUALITY STANDARDS

Water Quality Standards for the Commonwealth are addressed in *The Pennsylvania Code, Title 25, Chapter 93*. Within Chapter 93, all surface waters are classified according to their water quality criteria and protected water uses. The following is an abbreviated explanation of these standards and their respective implications to this Act 167 plan.

General Provisions (§93.1 - §93.4)

The general provisions of Chapter 93 provide definitions, citation of legislative authority (scope), and the definition of protected and statewide water uses. DEP's implementation of Chapter 93 is authorized by the Clean Streams Law, originally passed in 1937 to "preserve and improve the purity of the waters of the Commonwealth for the protection of public health, animal and aquatic life, and for industrial consumption, and recreation" and subsequently amended. *Table 4.3* is a summary of the protected water uses under Chapter 93 that are applicable to Butler County.

Protected Use	Relative Level of Protection	Description
Aquatic Life		
Warm Water Fishes (WWF)	Lowest	Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
Trout Socking (TSF)		Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
Cold Water Fishes (CWF)		Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.
Special Protection		
High Quality Waters (HQ)		A surface water that meets at least one of chemical or biological criteria defined in §93.4b
Exceptional Value Waters (EV)	Highest	A surface water that meets at least one of chemical or biological criteria defined in §93.4b and additional criteria defined in §93.4b.(b)

Table 4.3. Chapter 93 Designations in Butler County

Antidegradation Requirements (§93.4a - §93.4d)

According to the antidegradation requirements of §93.4a, "Existing in-stream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected". Certain waterbodies which exhibit exceptional water quality and other environmental features, as established in §93.4b and summarized in *Table 4.3*, are referred to

as "Special Protection Waters." Activities that could adversely affect surface water are more stringently regulated in those watersheds than waters of lower protected use classifications. For WWF, TSF, or CWF waterbodies, many of the antidegradation requirements can be addressed using guidance provided in this plan and the DEP BMP Manual; for HQ or EV watersheds, the current regulations follow DEP's antidegradation policy.

For a new, or additional, point discharge with a peak flow increase to an HQ or EV water, the developer is required to use a non-discharge alternative that is cost-effective and environmentally sound compared with the costs of the proposed discharge. If a non-discharge alternative is not cost-effective and environmentally sound, the developer must use the best available combination of treatment, pollution prevention, and wastewater reuse technologies and assure that any discharge is non-degrading. In the case where allowing lower water quality discharge is necessary to accommodate important economic or social development in an area, DEP may approve a degrading discharge after satisfying a multitude of intergovernmental coordination and public participation requirements (DEP, 2003).

Water Quality Criteria (§93.6 - §93.8c)

In general, the water discharged from either a point source or a nonpoint source discharge may contain substances in a concentration that would be inimical or harmful to a protected water use. The specific limits for toxic substances, metals, and other chemicals are listed in this section.

Designated Water Uses and Water Quality Criteria (§93.9)

The designated use and water quality criteria for each stream reach or watershed is specified. On the following page, *Table 4.4* shows the Chapter 93 designated uses for Butler County as defined by §93.9. The majority of watersheds in Butler County have watershed designated as cold water fisheries.

Water Quality Impairments and Recommendations

Additional to the Chapter 93 regulations, DEP has an ongoing program to assess the qualities of water in Pennsylvania and identify stream and other bodies of water that are not attaining the required water quality standards. These "impaired" streams, their respective designations, and the subsequent recommendations are discussed in *Section IX*.

Drainage List Q – Allegheny River Basin, Tunungwant Creek to Clarion River	
Lowrey Run	WWF
Drainage List S – Allegheny River Basin, Clarion River to Kiskiminetas River	
North Branch Bear Creek	CWF
Rays Run	CWF
Silver Creek (LR 10079 Bridge at Walley Mill to Mouth)	HQ-CWF
Silver Creek (source to LR 10079 (SR 1004) Bridge at Walley Mill)	EV
South Branch Bear Creek	WWF
UNT to Bear Creek	CWF
Drainage List U – Allegheny River Basin, Kiskiminetas River to Monongahela River	
Buffalo Creek (Little Buffalo Creek to mouth)	TSF
Buffalo Creek (Little Buffalo Run to Little Buffalo Creek)	HQ-TSF
Buffalo Creek (Source to Little Buffalo Run)	HQ-CWF
Little Buffalo Creek	HQ-TSF

Drainage List W – Confl. of Monongahela and Alleg. Rivers to PA-OH State Border	
Bonnie Brook	WWF
Breakneck Creek	WWF
Brush Creek	WWF
Butcher Run	WWF
Camp Run	WWF
Coal Run	WWF
Connoquenessing Creek (source to Oneida Dam)	HQ-WWF
Doe Run	WWF
Glade Run	WWF
Hazen Run	WWF
Little Connoquenessing Creek	CWF
Muddy Creek (source to Moraine State Park Dam)	HQ-CWF
Muntz Run	WWF
Pine Run	WWF
Rocklick Run	WWF
Sawmill Run	WWF
Scholars Run	WWF
Stony Run	WWF
Sullivan Run	WWF
Thorn Creek	CWF
Thorn Creek (source to Thorn Dam)	HQ-WWF
Thorn Creek (Thorn Dam to mouth)	WWF
UNT to Connoquenessing Creek (Oneida Dam to mouth)	WWF

Table 4.4. Butler County Designated Water Uses

EXISTING MUNICIPAL REGULATIONS

In Pennsylvania, stormwater management regulations usually exist at the municipal level. A review of the existing municipal regulations helps us unravel the complex system of local regulation and develop watershed wide policy that both fits local needs and provides regional benefits. *Table 4.3* provides a summary of existing regulations for Butler County's 57 municipalities.

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT (SALDO)	ZONING	FLOODPLAIN MANAGEMENT
Adams Twp	No	Yes	Yes	Yes
Allegheny Twp	No	No (County)	No	No
Brady Twp	No	Yes	Yes	No
Bruin Boro	No	No (County)	No	No
Buffalo Twp	Yes	Yes	Yes	Yes
Butler City	No	No (County)	Yes	No
Butler Twp	No	Yes	Yes	Yes
Callery Boro	No	Yes	Yes	No
Center Twp	No	Yes	Yes	Yes
Cherry Twp	No	No (County)	No	No
Cherry Valley Boro	No	No (County)	No	No
Chicora Boro	No	No (County)	No	No
Clay Twp	No	Yes	No	No
Clearfield Twp	No	Yes	No	Yes

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT (SALDO)	ZONING	FLOODPLAIN MANAGEMENT
Clinton Twp	Yes	Yes	Yes	No
Concord Twp	No	No (County)	No	No
Connoquenessing Bor	No	Yes	Yes	No
Connoquenessing Twp	Yes	Yes	No	Yes
Cranberry Twp	Yes	Yes	Yes	Yes
Donegal Twp	No	Yes	No	No
East Butler Boro	No	No (County)	Yes	Yes
Eau Claire Boro	No	No (County)	No	No
Evans City Boro	No	No (County)	No	Yes
Fairview Boro	No	No (County)	No	No
Fairview Twp	No	No (County)	No (County)	No
Forward Twp	No	Yes	No	No
Franklin Twp	Yes	Yes	Yes	No
Harmony Boro	Yes	Yes	Yes	Yes
Harrisville Boro	No	No (County)	No (County)	No
Jackson Twp	Yes	Yes	Yes	No
Jefferson Twp	No	Yes	No	No
Karns City Boro	No	No (County)	No	No
Lancaster Twp	No	Yes	Yes	No
Marion Twp	No	Yes	No	No
Mars Boro	No	Yes	Yes	No
Mercer Twp	Yes	No (County)	No (County)	No
Middlesex Twp	No	Yes	Yes	No
Muddy Creek Twp	No	Yes	No	No
Oakland Twp	No	Yes	No	No
Parker Twp	No	No (County)	No (County)	No
Penn Twp	Yes	Yes	Yes	Yes
Petrolia Boro	No	No (County)	No	No
Portersville Boro	No	No	Yes	No
Prospect Boro	No	Yes	Yes	Yes
Saxonburg Boro	No	Yes	Yes	No
Seven Fields Boro	Yes	Yes	Yes	No
Slippery Rock Boro	No	Yes	Yes	No
Slippery Rock Twp	No	Yes	Yes	No
Summit Twp	No	Yes	Yes	Yes
Valencia Boro	No	No (County)	No	Yes
Venango Twp	No	No (County)	No	No
Washington Twp	No	No (County)	No	No
West Liberty Boro	No	Yes	No	No

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT (SALDO)	ZONING	FLOODPLAIN MANAGEMENT
West Sunbury Boro	No	No (County)	No	No
Winfield Twp	No	Yes	Yes	Yes
Worth Twp	No	Yes	No	No
Zelienople Boro	No	Yes	Yes	No

Table 4.3. Butler County Municipal Ordinance Matrix

Table 4.4 shown on the following pages is a brief summary of the results of an ordinance review of the existing municipal regulations and the stormwater management provisions contained in each ordinance.

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
Adams Township	No separate ordinance found. Addressed in SALDO.	Article V, section 504 & 508 addresses Storm Drainage requirements, impoundments, and erosion and sedimentation control measures.	Defines floodplain, floodway & flood fringe.	Article IX defines wetlands, floodway delineation, flood plain restrictions & slope requirements.
Allegheny Township	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
Brady Township	Article VII addresses roadway drainage, post < or = to pre construction runoff, compliance with Act 167, detention facilities, & compliance with PENNDOT standards.	Article VII addresses roadway drainage, post < or = to pre construction runoff, compliance with Act 167, detention facilities, & compliance with PENNDOT standards.	No SW reference found.	No separate ordinance found.
Bruin Borough	No separate ordinance found. Addressed in SALDO.	No ordinance. Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
Buffalo Township	SWM Ordinance #112, is comprehensive which includes requirements for E&S control, water quality, infiltration, BMP, calculations, inspections, maintenance, easements, roof drains and enforcement.	Article IV refers to compliance with SWM ordinance #112, township grading ordinance, and DEP regulations for SW.	Article V addresses compliance with township standards, and requires plan approval by townships engineers.	FM ordinance #56 with amendments 1, 2, & 3 define floodplain, setback requirements, flood proofing, design & construction standards of SW facilities and existing conditions.
Butler City	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	Chapter 148 addresses groundwater regulations. Chapter 231 regulates SW prohibitions, E&S control, post < or = to pre construction runoff, BMP, and enforcement. Chapter 254 regulates waterway contamination & dangerous obstructions.	No separate ordinance found.

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
Butler Township	No separate ordinance found. Addressed in SALDO.	Article V, Chapter 252, addresses flood prone areas, E & S plan, grading drainage and SWM.	Chapter 300; definitions	Chapter 183 addresses Flood plain areas, technical provisions, existing structures, elevations, setbacks, flood proofing, design and construction standards. Chapter 188 regulates grading & excavating, maintenance, E & S, drainage facilities, and flood plain management.
Callery Borough	No separate ordinance found. Addressed in SALDO & Zoning.	Article VI addresses SW easements, natural water courses, storm drainage, SW control measures design, use of "Urban Hydrology for Small Watersheds", continuing maintenance, E & S control, submittal of an approved plan, and inspection. Appendix A-22; Roof drain sump detail.	Section 513 regulates site grading, SW handling, SW retention vessels, assistance from BC Conservation District, and post < or = to pre construction runoff.	No separate ordinance found except restriction of building in the 100 year floodplain.
Center Township	No separate ordinance found. Addressed in SALDO.	Section 14-803, addresses grading & drainage requirements, on-lot SW detention sump, SW management facilities, runoff, storm drains, natural water courses, and compliance with PA DER E & S Control Handbook.	No SW reference found.	Chapter 2, Article 5 addresses Floodplain regulations.
Cherry Township	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
Cherry Valley Borough	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
Chicora Borough	Ordinance # 255 addresses SW handling as part of the building permit process, and borough Engineer approval. Post < or = to pre construction runoff.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
Clay Township	No separate ordinance found. Addressed in SALDO.	Section 104.3 addresses drainage easements, E & S control DEP permitting, drainage, natural water courses, and 15' min dia pipes.	None	No separate ordinance found.

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
Clearfield Township	No separate ordinance found. Addressed in SALDO.	Section 500 addresses drainage easements, storm drainage, detention, plan submittal, post < or = to pre construction runoff, design stds, use of "Urban Hydrology for Small Watersheds", E & S control, wetland conservation, and future maintenance.	None	Ordinance 06-91-01 regulates flood plain requirements & resolution 77-03-01 addresses flood zone rules, delineation and management.
Clinton Township	Ordinance #90-01/95-03 requires a SW plan, and addresses construction stds, retention, permit procedure, review & penalties.	Section 4.0 addresses drainage easements and E&S control. Section 5.0 requires adherence to SW ordinance #95-03.	FN Article IX identifies 100 year floodplain areas, flood elevations, technical requirements, dangers, MH park requirements, floodplain restrictions, existing structures, variances and definitions.	Addressed in Zoning Ordinance.
Concord Township	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
Connoquenessing Borough	No separate ordinance found. Addressed in SALDO.	Section 22-609 SW, standards of compliance w/ Act 167, plan approved by the Boro Engineer, location, materials, maintenance, fees, and provision to transfer ownership to the boro. Section 22-617 addresses E&S control. Appendix A has design specifications for SW facilities.	Section 27-1002 addresses drainage requirements, retention and collection.	No separate ordinance found.
Connoquenessing Township	Chapter 26, SWM definitions, plan submission, building permit, local standards, reduction measures, SW runoff delaying, penalties & enforcement.	Section 908, Storm Drainage & Facilities, Twp engineer specified, location & standards of construction, plan submission for approval. Section 912, E & S control.	None	Chapter 8 includes administration, identification, technical requirements, special permitting, existing structures, and definitions.
Cranberry Township	Section 87.402, SWM Public & Private, facilities, specifications & details	Section 96.614 Grading, E & S control. Section 96.617 SWM facilities, conform with Act 167, post < or = to pre construction runoff, subsurface drainage, storm sewers, minimum pipe size, roof & foundation drains, detention, fees maintenance, easements and access.	Section 108, steep slope limitations, impervious surfaces, floodplain areas, and regulations.	SALDO section 96.620, prohibited development in floodplain.
Donegal Township	No separate ordinance found. Addressed in SALDO.	Chapter 17, Storm Sewer specifications.	None	No separate ordinance found.
East Butler Borough	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	Article 10, Site Development rules for drainage & flood prone areas.	Ordinance prohibits all new construction & development in the floodplain.

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
Eau Claire Borough	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
Evans City Borough	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	Ordinance 388 restricts new construction & development in areas subject to flooding.
Fairview Borough	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
Fairview Township	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None Addressed by County	No separate ordinance found.
Forward Township	No separate ordinance found. Addressed in SALDO.	Section 505, Storm Sewer specifications.	No SW reference found.	No separate ordinance found.
Franklin Township	Ordinance #38, comprehensive SWM regulations.	Section 505 Storm sewer specifications.	No SW reference found.	No separate ordinance found.
Harmony Borough	Ordinance #303, Chapter 8, codification.	Section 609 SWM compliance with Act 167, and comprehensive specifications.	Section 1001j, use of flood prone land, and compliance with ordinance # 303.	Chapters 8, codification, floodplain regulations, flood proofing measures, and building permits.
Harrisville Borough	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None Addressed by County	No separate ordinance found.
Jackson Township	Ordinance dated 1996, general requirements, definitions, standards, BMP, maintenance and administration.	Part 6, section 22-6089, SWM & Floodplain controls, compliance with Twp SW ordinance, building on floodplain, storm drainage, and E & S controls.	Part 15, Floodplain overlay district, identification, standards, specifications, and requirements.	No separate ordinance found.
Jefferson Township	No separate ordinance found. Addressed in SALDO.	Part 4, Identification of floodplain, Part 5, technical provisions, Part 6 special permitting, Part 7 Existing structures in the floodplain, and Part 8 Variances.	None	No separate ordinance found.
Karns City Borough	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
Lancaster Township	No separate ordinance found. Addressed in SALDO.	Ordinance #86, requires plan approval and PENDOT form 408. Storm sewer, facility requirements, and standards for MH parks.	No SW reference found.	No separate ordinance found.
Marion Township	No separate ordinance found. Addressed in SALDO.	Section 700, Storm sewers, grading storm drainage, easements, SW facilities, and floodplain restrictions.	None	No separate ordinance found.
Mars Borough	No separate ordinance found. Addressed in SALDO.	Section 100, Storm drainage, county regulations, DEP regulations, and, post < or = to pre construction runoff.	No SW reference found.	No separate ordinance found.
Mercer Township	Ordinance #34, Requires building permit, SW plan, Co. Conservation District approval, and adopts "Urban Hydrology for Small Watersheds.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None Addressed by County	No separate ordinance found.
Middlesex Township	No separate ordinance found. Addressed in SALDO.	Ordinance # 96, compliance, prohibits construction that would increase flood height, development criteria, and MH park grading requirements.	Ordinance 21, sections 1100 & 1200, min. area for a SW facility, prohibits mineral removal from flood prone land, grading, standing water, and plan submission.	No separate ordinance found.
Muddy Creek Township	No separate ordinance found. Addressed in SALDO.	Section 500 grading, easements, storm drain lines, plan submission, and prohibits MH park in a floodplain.	None	No separate ordinance found.
Oakland Township	No separate ordinance found. Addressed in SALDO.	Section 19, plan submission, specifications, and SWM plan for MH parks.	No SW reference found.	No separate ordinance found.
Parker Township	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None Addressed by County	No separate ordinance found.
Penn Township	Ordinances #97-112, SW plan submission, requirements, standards, and review by Co. Conservation district.	Ordinance #119, prohibits MH park in a floodplain, and drainage of a MH park.	Ordinance #115, Article XII, No standing SW, post < or = to pre construction runoff, velocity, And compliance with Ord. 97-112.	Ordinance # 79, Article 3, building permits, plan submission, construction requirements, notification and approvals.
Petrolia Borough	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
Portersville Borough	No separate ordinance found. Addressed in SALDO.	No separate ordinance found.	Section 97, grading for SW drainage.	No separate ordinance found.
Prospect Borough	No separate ordinance found. Addressed in SALDO.	Chapter 22, section 500, prohibits development on flood prone land, SW requirements, construction standards, and protection of natural watercourses.	Chapter 27, part 5, drainage, facilities, and prohibits floodplain building.	Chapter 8, Part 4, prohibits floodplain development and provides variances.

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
Saxonburg Borough	No separate ordinance found. Addressed in SALDO.	Ordinance 405, requires SW be drained to streets, and plan review by township engineer.	Section 600, prohibits disturbance of natural drainage areas with in 100' of centerline.	No separate ordinance found.
Seven Fields Borough	Ordinance #67, Adopts DEP NPDES requirements for SW discharges.	Ordinance #30, section 602, requires flows be in accordance with sound engineering practices.	Ordinance #32, Sets requirements for floodplains & flood districts, and plan approval by borough engineer.	No separate ordinance found.
Slippery Rock Borough	No separate ordinance found. Addressed in SALDO.	Appendix B, Plan submission, calculation methods, 'No harm evaluation," and maintenance responsibilities.	No SW reference found.	No separate ordinance found.
Slippery Rock Township	Resolution 04-125, requires roadway drainage and construction standards.	Section 600 & 700, SW standards, compliance with PA SW management Act 167, drainage easements, existing watercourse drainage, and SW facilities specifications.	Section 400, Parking lot drainage, preservation of large trees for SW assistance, and compliance with SW resolution 04-125.	No separate ordinance found.
Summit Township	No separate ordinance found. Addressed in SALDO & Zoning.	Chapter 22, section 103 #12, Storm drainage, approval by Twp. Engineer & Supervisors.	Section 3 & 11, Building permits for SW facilities, storm drain system requirements, and performance bond requirements for SW facilities.	Chapter 8, Permits, time limits, inspections, identification of flood plain, technical requirements, standards, prohibited uses, and existing structures in the floodplain.
Valencia Borough	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	Ordinance #203, Building permits, Co. Conservation District review, time limits, fees, floodplain management, minimization of flood damage, facility restrictions, and MH requirements,
Venango Township	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
Washington Township	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.
West Liberty Borough	No separate ordinance found. Addressed in SALDO.	Ordinance #91872B, Section 500 & 600, Floodplain regulations, and storm sewer construction.	None	No separate ordinance found.
West Sunbury Borough	No separate ordinance found. Addressed in SALDO.	Regulated by the County SALDO. Article VII addresses E&S control measures, storm drainage systems, storm water detention facilities, and drainage easements.	None	No separate ordinance found.

MUNICIPALITY	STORMWATER MANAGEMENT	SUBDIVISION & LAND DEVELOPMENT	ZONING	FLOODPLAIN MANAGEMENT
Winfield Township	Ordinance 97-03, Building permits, and plan submission requirements.	Section 1000 & 2000, Storm drainage effects, bonding, facility design, grading, easements, storm drains, and storm drain requirements.	No SW reference found.	Ordinance #982, Prohibits building in a floodplain.
Worth Township	Ordinance 04-08-98-02, Requires building permits, construction not to affect runoff, plan submission, Adhere to "Urban Hydrology for small watersheds," and standards for design.	Sections 500 to 1000, Requirements for Drainage E & S control plan, compliance with Act 167, no standing SW, easements, facilities, proper Sw devices, plan submission, and conservation buffer requirements.	None	No separate ordinance found.
Zelienople	No separate ordinance found. Addressed in SALDO & Zoning.	Section 900 & 1000, Storm sewer requirements, and detention facility requirements.	Section 609, Floodplain district identification, building permit requirement, natural watercourse preservation, new construction rules, storm drain functions, and infiltration.	No separate ordinance found.

Table 4.4. Municipal Ordinance Review

EXISTING RELATED PLANS

Review of previous planning efforts is another important component of regional planning. An analysis of previous plans, and the results achieved through implementation of recommendations of those plans, provides invaluable information for current and future planning efforts. The following table is a summary of related plans:

PLAN TITLE	*DATE*	*AUTHOR*
The County of Butler Comprehensive Plan	2002	Butler County Planning Commission
Connoquenessing Creek Watershed: Nomination for Critical Water Planning Area Under Pennsylvania State Water Plan	August 2009	Pennsylvania Department of Environmental Protection

Table 4.5. Related Plans Review

Section V – Significant Problem Areas and Obstructions



One of the stated goals of this Plan is to "ensure that existing stormwater problem areas are not exacerbated by future development and provide recommendations for improving existing problem areas." The strategy for achieving this goal required identification of the existing significant stormwater problem areas and obstructions, and than evaluation of the identified problem areas and obstructions.

The first task was to identify the location and nature of existing drainage problems within the study area, and where appropriate, gather field data to be used for further analysis of the problem. The geographical location data was used to plot all of the problem areas and obstructions on a single map (Reference Plate 9 – Problem Areas & Obstructions). Mapping these locations in this manner enables one to identify and isolate problems and determine which minor problems are part of more systemic problems. Systemic problems are often an indication that larger stormwater management problems exist, which may warrant more restrictive stormwater regulations. This information was used when modeling the watersheds and determining appropriate stormwater management controls.

The second part of this task was to analyze individual problem areas and obstructions, determine potential solutions for the most significant problems, and provide recommendations that can be implemented through the Butler County Stormwater Management Plan. ***This part of the task was not fully completed as part of the Plan due to funding difficulties with the Act 167 Program.***

IDENTIFICATION OF PROBLEM AREAS AND OBSTRUCTIONS

Identification and review of existing information concerning Butler County's stormwater systems, streams, and tributary drainage basins within the project limits was conducted during Phase I and Phase II of this Plan. During Phase I, questionnaires were distributed to all of the municipalities in the County. The questionnaire enabled the municipalities to report all of the known problem areas and obstructions within their municipality. Of the 57 municipalities in Butler County, 36 participated in the assessment process by returning completed questionnaires. The responses were summarized and reported in the Phase I report of this Plan. The responses were reviewed during Phase II of the Act 167 planning process. Field reconnaissance was subsequently conducted to confirm problem area locations, assess existing conditions, identify the general drainage patterns and gather data to complete a planning level analysis.

All of the reported problem areas, obstructions, and structures are listed in *Table 5.1* on the following pages.

These problem areas were then ranked in accordance with the criteria described in this Section. Conceptual solutions for the top ten problem areas were then determined. These Conceptual solutions for the top ten sites are contained in *Appendix C – Significant Problem Area Modeling and Recommendations.*

ID	Municipality	Location	Description
P1	Clinton Twp.	Wylie Rd South of Elm Ln	Bank Erosion
P2	Clinton Twp.	Anderson Rd	Flooding Water, Erosion
P3	Clinton Twp.	Callen Rd	Erosion
P4	Clinton Twp.	Ivywood Rd at Brewer Rd	Water Ponding
P5	Clinton Twp.	Deer Creek before Jack Rd	Erosion
P6	Clinton Twp.	Tower Rd (2 Locations)	Road Surface Sinking
P7	Clinton Twp.	Westminster Rd near Rt 228	Water Ponding
P8	Clinton Twp.	Miller Rd near Brewer Rd	Water Ponding
P9	Clinton Twp.	Goldscheitter Rd near Stark Rd	2 Undersized Pipes
P10	Clinton Twp.	Victory Rd	Erosion
P11	Clinton Twp.	Lardintown Rd South of Rt 228	Flooding
P12	Clinton Twp.	Saxonburg Blvd	Unapproved Driveway Blocking Flow
P13	Concord Twp.	Manuel Rd	Low Lying Area
P14	Concord Twp.	Kuhn Rd	Excess Runoff
P15	Concord Twp.	Kauf Rd	Excess Runoff
P16	Concord Twp.	Stoops Rd	Flooding
P17	Concord Twp.	Campbell Rd	Excess Runoff
P18	Concord Twp.	Cartwright Rd	Excess Runoff
P19	Valencia Boro.	Three Degree Rd	Flow Restrictions at Bridge
P20	Valencia Boro.	Breakneck Creek	Increase in Flow
P21	Penn Twp.	Creek Rd in Village of Renfrew	Flooding
P22	Penn Twp.	Behind Houses in Village of Renfrew	Excess Runoff
P23	Penn Twp.	Village of Renfrew East of Hicks	Road Flooding
P24	Penn Twp.	McBride St at Rt 8	Excess Runoff
P25	Penn Twp.	Beacon Rd West of Meadowbrook	Excess Runoff
P26	Penn Twp.	Winters Rd	Excess Runoff
P27	Penn Twp.	Mushrush Rd at Crisswell Rd	Excess Runoff
P28	Penn Twp.	Morgan Rd	Erosion
P29	Penn Twp.	Golden City at Twp. Line	Erosion
P30	Penn Twp.	N. Dutchtown	Excess Runoff
P31	Penn Twp.	Stone Quarry	Excess Runoff, Sediment Build-up
P32	Penn Twp.	Brownsdale Rd to Orchard Rd	Flooding
P33	Penn Twp.	Hamel Rd	Erosion
P34	Penn Twp.	Meridian North of Smith	Excess Runoff
P35	Penn Twp.	Crowe Rd	Excess Runoff, Erosion
P36	Penn Twp.	Church Rd	Excess Runoff, Erosion
P37	Penn Twp.	Rockdale Rd	Erosion
P38	Penn Twp.	Royal Oak Dr	Erosion
P39	Jackson Twp.	Peters Cove / Hartman Rd	Flooding
P40	Jackson Twp.	Evergreen Mill Rd	Flooding
P41	Jackson Twp.	Village Acres	Flooding
P42	Callery Boro.	Kline Rd	Erosion
P43	Callery Boro.	Main St Extension	Undersized Pipes
P44	Callery Boro.	Kline Rd – Mars/Evans City area	Flooding, Bank Erosion
P45	Callery Boro.	Center St	Flooding, Bank Erosion
P46	Cherry Twp.		Runoff/Erosion
P47	Cherry Twp.		Ponding/Flooding
P48	Cherry Twp.		Runoff/Erosion
P49	Cherry Twp.		Runoff/Erosion
P50	Cherry Twp.		Ponding/Flooding
P51	Cherry Twp.		Undersized Culvert
P52	Cherry Twp.		Streambank Erosion
P53	Cherry Twp.		Runoff/Erosion
P54	Franklin Twp.	Grindel Rd near Miller Ln	Stream Overflows
P55	Franklin Twp.	Unionville Rd near County Club Rd	Stream Overflows
P56	Franklin Twp.	Country Club Rd near Boys Club	Stream Overflows
P57	Franklin Twp.	Swamp Run Rd near Chestnut Ridge Rd	Stream Overflows

ID	Municipality	Location	Description
P58	Franklin Twp.	Ridge Rd near Hewitt Ln	Stream Overflows
P59	Franklin Twp.	W. Old Rt 422 near Franklin Village	Stream Overflows
P60	Jefferson Twp.	Multiple Locations	Undersized Pipes
P61	Mercer Twp.	Harmony Rd	Stream Overflows
P62	Mercer Twp.	Wick Rd	Erosion
P63	Mercer Twp.	Creek	Stream Overflows
P64	Mercer Twp.	Rt 8	Erosion at Railroad Underpass
P65	Mercer Twp.		Ditch Erosion
P66	Mercer Twp.		Ditch Erosion
P67	Mercer Twp.		Property Flooding
P68	City of Butler	City Storm Sewer System	Hydraulically Overloaded
P69	City of Butler	City Storm Sewer System	Obstruction of Pipes
P70	City of Butler	City Storm Sewer System	Undersized Culvert
P71	City of Butler	City Storm Sewer System	Stream Overflow
P72	City of Butler	City Storm Sewer System	Unknown System
P73	City of Butler	City Storm Sewer System	Deep Crossovers
P74	City of Butler	City Storm Sewer System	Ponding
P75	City of Butler	City Storm Sewer System	Ponding
P76	City of Butler	City Storm Sewer System	Stream Beneath Home
P77	City of Butler	City Storm Sewer System	Stream Overflows
P78	City of Butler	City Storm Sewer System	Stream in Poor Condition
P79	City of Butler	City Storm Sewer System	Erosion
P80	City of Butler	City Storm Sewer System	Subsidence
P81	Harmony Boro.	Spring St/First St	Flooding
P82	Harmony Boro.	Jackson St/Mercer St	Flooding
P83	Harmony Boro.	Jackson St/Mercer St	Flooding
P84	Harmony Boro.	Moose Front Yard	Flooding
P85	Harmony Boro.	Seneca Dr	Undersized Pipes
P86	Harmony Boro.	Wood St	Ponding
P87	Harmony Boro.	Various Locations	Streambank Erosion
P88	Harmony Boro.	Creekside Manor	Flooding
P89	Harmony Boro.	Harmony Heights Dr	Detention Pond
P90	Harmony Boro.	Spring St	Stormwater Issues
P91	Harmony Boro.	Division St between Center/Beaver St	Flooding
P92	Harmony Boro.	Various Locations	Undersized Catch Basins
P93	Cherry Valley Boro.	Porter Rd	Flooding
P94	Cherry Valley Boro.	Oneida Valley Rd near Borchert Rd	Flooding
P95	Cherry Valley Boro.	Oneida Valley Rd near Young Ln	Flooding
P96	Brady Twp.	Beatty Rd	Undersized Culvert
P97	Brady Twp.	Various Locations in Twp.	Culvert Replacement
P98	Brady Twp.	Alexander Rd	Debris in Culvert
P99	Brady Twp.	Turk Rd	Debris in Culvert
P100	Brady Twp.	Lindey Rd	Culvert Replacement
P101	Brady Twp.	McBride Rd	Culvert Replacement
P102	Evans City Boro.	Mahan Rd near South St	Restricted Stream Flow
P103	Evans City Boro.	N. Jackson St near Harmony Al	Ponding in Streets
P104	Evans City Boro.	N. Jackson St	Ponding in Streets
P105	Evans City Boro.	N. Washington St	Restricted Stream Flow
P106	Evans City Boro.	Near Pioneer Rd	Streambed Obstruction
P107	Summit Twp.	State Route 38	Flooding
P108	Summit Twp.	Kaiser Rd	Flooding
P109	Summit Twp.	Wendelin Rd	Flooding
P110	Summit Twp.	Herman Rd	Flooding
P111	Summit Twp.	Private Driveways	Flooding
P112	Summit Twp.	Stutz Rd	Sedimentation
P113	Summit Twp.	Stutz Rd	Sedimentation
P114	Summit Twp.	Saxonburg Rd	Flooding

ID	Municipality	Location	Description
P115	Summit Twp.	Shepard Ln	Flooding
P116	Muddy Creek Twp.	Yellowcreek Rd at Stanford Rd	Flooding
P117	Muddy Creek Twp.	Fisher Rd at Book Rd	Flooding
P118	Muddy Creek Twp.	Bloomfield School Rd	Erosion
P119	Muddy Creek Twp.	Cheeseman Rd	Mine Drainage
P120	Muddy Creek Twp.	Rt 19 North	Flooding
P121	Saxonburg Boro.	Carol Dr near Dinnerbell Rd	Flooding
P122	Saxonburg Boro.	Dinnerbell Rd	Flooding
P123	Saxonburg Boro.	Cooper Cabin Parking Lot	Flooding
P124	Saxonburg Boro.	Short St near Butler St	Flooding
P125	Saxonburg Boro.	South of Water St near Butler St	Flooding
P126	Saxonburg Boro.	Water St at Butler St	Flooding
P127	Saxonburg Boro.	Thelma Dr and N Isabella St	Flooding
P128	Saxonburg Boro.	North of Water St	Flooding
P129	Saxonburg Boro.	Constitution Ave at Thelma Dr	Flooding
P130	Saxonburg Boro.	Constitution Ave near Fisher Rd	Flooding
P131	Saxonburg Boro.	Aderhold Rd	Flooding
P132	Saxonburg Boro.	Aderhold Rd near Oakwood Ln	Flooding
P133	Prospect Boro.	Bearcreek Rd	Retention Pond
P134	Prospect Boro.	Prospect Pl	Retention Pond
P135	Prospect Boro.	Commercial Development	Lack of Retention
P136	Winfield Twp.	Long Run Rd	Scouring
P137	Winfield Twp.	Little Buffalo Stream	Erosion
P138	Winfield Twp.	Winfield Rd	Erosion
P139	Winfield Twp.	Brose Rd	Erosion
P140	Winfield Twp.	Gerner Rd	Sediment Runoff
P141	Winfield Twp.	Moorehead Rd at Bauer Rd	Erosion
P142	Winfield Twp.	Cornplanter Stream	Sedimentation
P143	Winfield Twp.	Becker Rd	Sedimentation
P144	Winfield Twp.	Cabot Area of Little Buffalo Stream	Erosion
P145	Winfield Twp.	Rough Run Stream	Erosion
P146	Adams Twp.	Hespenheide Rd	High Detergents
P147	Adams Twp.	Mars/Evans City Rd near Hutchman Rd	Positive Coliform Count
P148	Adams Twp.	Naser Ln	Nitrate/Phosphate Contamination
P149	Adams Twp.	Breakneck Creek	Flooding
P150	Adams Twp.	Meredith Dr	Sedimentation
P151	Adams Twp.	Three Degree Rd	Flooding
P152	Adams Twp.	Sunset Ct	Erosion/Flooding
P153	Adams Twp.	Hespenheide Rd	Inadequate Storm Sewer System
P154	Mars Boro.	Spring Ave at Clarks Ln	Flooding
P155	Mars Boro.	Crowe Ave near Reserve Alley	Erosion
P156	Mars Boro.	Off Pittsburgh St near Gilkey Rd	Pipe Collapse
P157	Butler Twp.	Sylvan Dr to Pierce Ave	Flooding
P158	Butler Twp.	Havenhill Dr	Flooding
P159	Butler Twp.	Butler Rd from Ferguson Ave to Schaffner	Flooding
P160	Butler Twp.	Acre Ave from Whitestone to Rt 68	Flooding
P161	Butler Twp.	Valley St at E. Brady	Flooding
P162	Butler Twp.	Cupps Rd from Meredian Rd to Conn Twp	Flooding
P163	Butler Twp.	Plateau St	Flooding
P164	Butler Twp.	Clark Ave near Oliver Dr	Flooding
P165	Butler Twp.	Pittsburgh Pike Rd	Flooding
P166	Butler Twp.	Brady St near Delwood Rd	Flooding
P167	Butler Twp.	Colonial Ave to S. Duffy Rd	Flooding
P168	Butler Twp.	Willard Ave near Gregden Rd	Flooding
P169	Butler Twp.	Miller St near Highland Ave	Flooding
P170	Butler Twp.	Cecilia St near Hansen Ave	Flooding
P171	Butler Twp.	Sawmill Run Rd near Miller St	Flooding

ID	Municipality	Location	Description
P172	Butler Twp.	Bullcreek Rd near Green Manor Dr	Flooding
P173	Butler Twp.	Cottage Ave near Harrison Ave	Flooding
P174	Butler Twp.	Bellefield Rd near Beverly Rd	Flooding
P175	Butler Twp.	Evergreen St near Logan St	Flooding
P176	Butler Twp.	Meadow Ave near Evergreen St	Flooding
P177	Butler Twp.	Alameda Rd south of Rt 356	Flooding
P178	Butler Twp.	Thornwood Rd	Flooding
P179	Butler Twp.	S. Eberhary Rd	Flooding
P180	Butler Twp.	Bessermer Ave at Acton Rd	Flooding
P181	Harrisville Boro.	W. Prairie St	Flooding
P182	Forward Twp.	Horseshoe Ln at end of Wahl Rd	Flooding
P183	Forward Twp.	Needlepoint Rd	Erosion/Flooding
P184	Forward Twp.	Evans City Park Rd	Erosion/Flooding
P185	Forward Twp.	Community Park Rd at Needlepoint Rd	Insufficient Structures
P186	Forward Twp.	Ash Stop Rd	Flooding
P187	Forward Twp.	Ash Stop Rd near Spithaler Rd	Flooding
P188	Forward Twp.	Eckstein Rd	Flooding
P189	Forward Twp.	Glenwood Ave	Flooding
P190	Forward Twp.	Glade Run at Leisie Rd	Flooding
P191	Forward Twp.	John School Rd at Glade Run	Flooding
P192	Forward Twp.	Valencia Rd at Glade Run	Flooding
P193	Forward Twp.	Creek Rd near Renfrew	Flooding
P194	Forward Twp.	Old Rt 68 near Connoquenessing Ck	Flooding
P195	Middlesex Twp.	Sandy Hill Rd	Flooding
P196	Connoquenessing Boro.	Off Tulip Dr near Harmony St	Runoff
P197	Connoquenessing Boro.	Along Dogwood Ln	Runoff
P198	Center Twp.	Brewster Rd	Flooding
P199	Center Twp.	Moore Rd	Flooding
P200	Center Twp.	Rt 38 along Connoquenessing Creek	Flooding
P201	Donegal Twp.	Conerty Rd	Flooding
P202	Donegal Twp.		Flooding
P203	Donegal Twp.	Hickey Bottom Rd	Flooding
P204	Donegal Twp.	Rt 68 from Chicora to Bish Rd	Flooding
P205	Marion Twp.	Dematteis Rd along Slippery Rock Creek	Flooding
P206	Marion Twp.	Ray Rd along Slippery Rock Creek	Flooding
P207	Marion Twp.	Boyers Rd	Flooding
P208	Karns City Boro.		Acid Mine Drainage
P209	Karns City Boro.		Runoff
P210	Buffalo Twp.	Kepple Rd	Flooding
P211	Buffalo Twp.	Monroe Rd	Flooding
P212	Buffalo Twp.	Old Pike Rd	Acid Mine Drainage
P213	Parker Twp.		Flooding
P214	Parker Twp.		Flooding
P215	Parker Twp.		Flooding
P216	Parker Twp.		Acid Mine Drainage
P217	Parker Twp.		Flooding
P218	Parker Twp.		Poor Water Quality
P219	Parker Twp.		Flooding
P220	Parker Twp.		Flooding
P221	Clay Twp.		Flooding
P222	Clay Twp.		Flooding
P223	Clay Twp.		Flooding
P224	Clay Twp.		Flooding
P225	Clay Twp.		Flooding
P226	Clay Twp.		Flooding

ID	Municipality	Location	Description
P227	Clay Twp.		Flooding
P228	Washington Twp.		Flooding
P229	Washington Twp.		Flooding
P230	Washington Twp.		Flooding
P231	Washington Twp.		Flooding
P232	Washington Twp.		Flooding
P233	Slippery Rock Twp.	University Baseball Field	Overflowing Pond
P234	Bruin Boro.	Bear Creek	Flooding
P235	Bruin Boro.		Acid Mine Drainage
P236	Bruin Boro.		Runoff
P237	Bruin Boro.		Flooding
P238	Bruin Boro.	Post Office	Flooding
P239	Lancaster Twp.	Little Yellow Creek Rd	Flooding
P240	Lancaster Twp.	Yellow Creek Rd	Flooding
P241	Lancaster Twp.	Little Creek Rd	Flooding
P242	Lancaster Twp.	Little Creek Rd	Flooding
P243	Lancaster Twp.	Scott Ridge Rd at Victory Terrace Dr	Erosion
P244	Zelienople Boro.	W New Castle St near Market St	Undersized Pipe
P245	Zelienople Boro.	Fairlawn Blvd and Wayne Ave	Flooding
P246	Zelienople Boro.	Between E New Castle St and E Spring St	Flooding
P247	Zelienople Boro.	North View and Clay	Flooding
P248	Zelienople Boro.	Green Ln to New Castle St	Ponding
P249	Zelienople Boro.	Spruce St	Undersized Pipe
P250	Zelienople Boro.	Jefferson St at Beaver St	Flooding
P251	Zelienople Boro.	Beaver St between Main & Clay St	Ponding
P252	Zelienople Boro.	Hazel St	Flooding
P253	Zelienople Boro.	Pine St	Flooding
P254	Zelienople Boro.	Market St between Rt 68 & Chestnut St	Ponding
P255	Zelienople Boro.	Market St at Ziegler St	Ponding
P256	Zelienople Boro.	Peach St between McKim & Pine St	Ponding
P257	Zelienople Boro.	Park Ln between Short & Main St	Flooding
P258	Zelienople Boro.	Northview Dr between Short & Main St	Flooding
P259	Zelienople Boro.	Oliver Ave between Grandview & Maria	Erosion/Flooding
P260	Zelienople Boro.	Perry Way from Main to Boro Line	Flooding
P261	Zelienople Boro.	Division St between Beaver & Spring St	Ponding
P262	Zelienople Boro.	Spring St between Division & High St	Ponding
P263	Zelienople Boro.	New Castle St between Oliver & Main St	Ponding
P264	Zelienople Boro.	Main St between Grandview & Culvert	Flooding
P265	Zelienople Boro.	New Castle St between Main & Market St	Flooding
P266	Zelienople Boro.	Jefferson St between New Castle & Spring	Flooding
P267	Zelienople Boro.	Railroad Tracks between Rt 19 & Green Ln	Flooding
P268	Zelienople Boro.	Madison Dr between Rt 588 & Rt 288	Flooding
P269	Zelienople Boro.	Halstead Blvd between Grandview/NCastle	Undersized Ditches
P270	Zelienople Boro.	Peach St at Ziegler Ext	Ponding
P271	Zelienople Boro.	Walnut St between Green Ln & Front St	Flooding
P272	Zelienople Boro.	Rosewood Plan	Flooding
P273	Zelienople Boro.	Timberbrook Plan	Flooding
P274	Zelienople Boro.	Muntz Rd between Jackson Twp/Rt 68	Runoff/Erosion
P275	Zelienople Boro.	Benvenue Rd between Marion Twp/Rt 68	Runoff/Erosion
P276	Zelienople Boro.	Lower Areas of Boro near Conn. Creek	Flooding
P277	Slippery Rock Boro.	Intersection of Kelly Blvd & N Main St	Flooding
P278	West Sunbury Boro.	S Main St	Runoff
P279	West Sunbury Boro.	Washington St	Flooding/Runoff
P280	West Sunbury Boro.	Russell Ave at Washington St	Overflows
P281	West Sunbury Boro.	E Church St	Erosion
P282	Cranberry Twp.	Fox Run	Flooding

ID	Municipality	Location	Description
P283	Cranberry Twp.	Brookston	Flooding
P284	Cranberry Twp.	Powell & Holiday	Flooding
O1	Clinton Twp.	Wylie Rd near Elm Ln	Undersized 12" CMP
O2	Clinton Twp.	Stark Rd at Hidden Hill	Undersized 24" Concrete Pipe
O3	Clinton Twp.	Westminster Rd at Miller Rd	Undersized Concrete Pipe
O4	Clinton Twp.	Westminster Dr	Erosion
O5	Concord Twp.	Old State Rd	
O6	Penn Twp.	Dodds Rd at Rockdale Rd	Flooding
O7	Penn Twp.	McBride St at Rt 8	Undersized Facilities
O8	Penn Twp.	Rt 8	Water Ponding, Undersized Pipe
O9	Penn Twp.	Meridian Rd at Monroe	Undersized 36" Pipe
O10	Penn Twp.	N. Crisswell Rd	Stream Flooding
O11	Penn Twp.	Dodds Rd at Woodland	Undersized Pipes
O12	Penn Twp.	Anderson at Welsh	Undersized Pipes
O13	Penn Twp.	Robinson Run Rd	Driveway Runoff
O14	Penn Twp.	Plank Rd	Undersized 30" Pipe
O15	Jackson Twp.	Senns Bridge on Evergreen Mill Rd	Flooding at Bridge
O16	Callery Boro.	Elgin Ln	Undersized Pipes
O17	Callery Boro.	Breakneck St	Undersized, Deteriorating Pipes
O18	Franklin Twp.	Mt. Chestnut G.C. along Purvis Rd	Runoff, Undersized Pipe
O19	East Butler Boro.	Grant Ave	Bridge
O20	East Butler Boro.	Sherman Ave near Old E. Butler Rd	Bridge
O21	City of Butler	Sullivan Run	Flooding/Erosion
O22	City of Butler	City Storm Sewer System	Erosion
O23	City of Butler	City Storm Sewer System	Filled with Debris
O24	City of Butler	Sullivan Run	Bank Erosion
O25	City of Butler	West Penn St Bridge	Sediment Accumulation
O26	City of Butler	West Brady St Bridge	Sediment Accumulation
O27	City of Butler	West New Castle St Bridge	Sediment Accumulation
O28	City of Butler	West Cunningham St Bridge	Sediment Accumulation
O29	City of Butler	City Storm Sewer System	Undersized Pipes
O30	City of Butler	City Storm Sewer System	Undersized Pipes
O31	City of Butler	City Storm Sewer System	Siltation
O32	City of Butler	City Storm Sewer System	Siltation
O33	City of Butler	City Storm Sewer System	Clogged Pipes
O34	City of Butler	City Storm Sewer System	Clogged Pipes
O35	City of Butler	City Storm Sewer System	Obstructions
O36	Harmony Boro.	Germain St to Mercer St	Undersized 24" Pipe
O37	Clearfield Twp.	Various Locations throughout Twp.	Debris in Creek Beds
O38	Clearfield Twp.	Various Locations throughout Twp.	Maintaining Culverts
O39	Brady Twp.	Various Locations in Twp.	Obstructed Ditches
O40	Evans City Boro.	Jefferson St at S. Washington St	Bridge Obstruction
O41	Evans City Boro.	Along S. Washington St	Encroachment along Stream
O42	Summit Twp.	Osche Rd	Undersized Culverts
O43	Summit Twp.	Osche Rd	Undersized Culverts
O44	Summit Twp.	Star Grill Rd	Undersized Culverts
O45	Summit Twp.	Schnur Rd	Undersized Culverts
O46	Summit Twp.	Carbon Center Rd	Undersized Culverts
O47	Summit Twp.	McGrady Hollow Rd	Undersized Culverts
O48	Summit Twp.	Keck Rd	Sediment in Stream
O49	Summit Twp.	Keck Rd	Undersized Culverts
O50	Summit Twp.	Giebel Rd	Flooding
O51	Summit Twp.	Giebel Rd	Flooding
O52	Muddy Creek Twp.	Stanford Rd	Undersized Pipes
O53	Muddy Creek Twp.	Sawyer Rd	Undersized Pipes
O54	Muddy Creek Twp.	Baudermill Rd to Levis Rd	Undersized Pipes
O55	Muddy Creek Twp.	Stonechurch Rd	Undersized Pipes

ID	Municipality	Location	Description
O56	Muddy Creek Twp.	Hufnagel Rd at Baudermill Rd	Undersized Pipes
O57	Muddy Creek Twp.	Rt 19 at Johnson Rd	Ponding Water
O58	Saxonburg Boro.	Carol Dr near Dinnerbell Rd	Undersized Pipes
O59	Saxonburg Boro.	State St at Constitution Ave	Sediment Build Up
O60	Prospect Boro.	Wilson Ln	Stream Crossing
O61	Venango Twp.	S. Erico Rd	Beaver Dam
O62	Venango Twp.	McJunkin Rd	Undersized Pipes
O63	Middlesex Twp.	Parks Rd near Rt 228	Undersized Pipe
O64	Clay Twp.	Beaver Dam	Beaver Dam
O65	Clay Twp.	Under Bridge	Siltation
O66	Washington Twp.	Bridge	Low Bridge
O67	Lancaster Twp.	Crab Run Rd Bridge	Flooding
O68	Lancaster Twp.	Little Creek Rd Bridge	Flooding
O69	Zelienople Boro.	Community Park to Spring St	Undersized Pipes
O70	Zelienople Boro.	Walnut St Bridge	Undersized Pipes
O71	Zelienople Boro.	Linden St	Undersized Pipes
O72	Zelienople Boro.	Front St	Undersized Pipes
O73	Zelienople Boro.	Front St	Undersized Pipes
O74	Zelienople Boro.	New Castle St between Division & Oliver	Undersized Pipes
O75	West Sunbury Boro.	Along E Concord St	Runoff
O76	Cranberry Twp.	Franklin Rd	Undersized Culvert
O77	Cranberry Twp.	Rochester Rd	Undersized Culverts
O78	Cranberry Twp.	Freedom Rd	Undersized Culverts
O79	Cranberry Twp.	Rolling Rd	Undersized Culvert

Table 5.1. Reported Problem Areas and Obstructions

The following figure provides a summary of the problem area types.

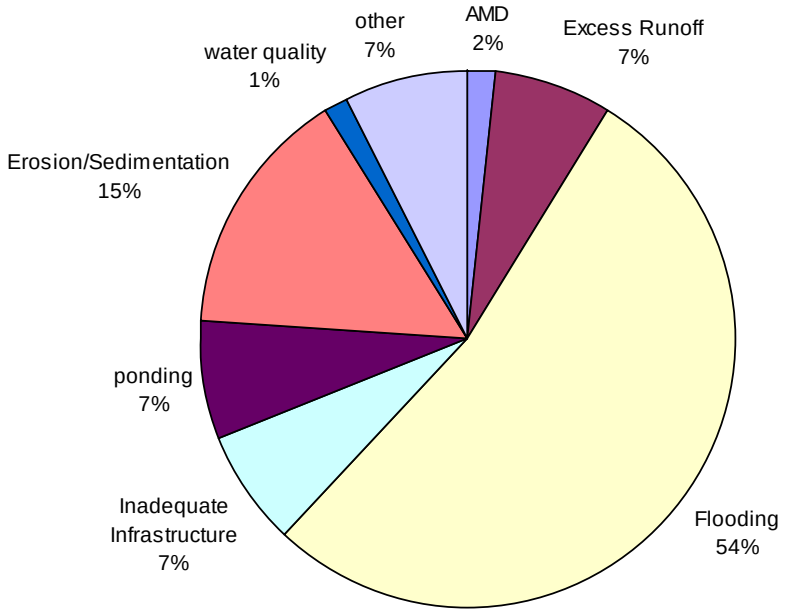


Figure 5.1. Overview of Problem Area Types

HYDRAULIC MODELING

Potential solutions were initially discussed by the municipality or the project engineer for every identified problem based on a field view of the area. The locations of these problem areas were a factor in determining that certain portions of the Connoquenessing Creek and Buffalo Creek watersheds encounter systemic flooding, and that release rates should be investigated. The analyses of the Connoquenessing Creek and Buffalo Creek watersheds are presented in *Section VI*.

PROBLEM AREA ASSESSMENT

Due to budgetary constraints related to this Act 167 effort, no detailed technical analyses or modeling was conducted for individual problem areas and obstructions. However, upon completion of the watershed hydraulic models and a brief review of the problem areas and obstructions, it was determined that an objective method would be needed to assess the order (or priority) in which a conceptual solution to a problem should be implemented by the County or a municipality.

For the purposes of example, the following criteria was used to develop a list of the top ten (or highest priority) problem areas. ***However, as with any prioritization approach, this assessment could not encompass all factors in the decision making process and should be considered as a guide to County and respective municipalities for future planning and funding efforts.***

Criteria from a stormwater problem prioritization assessment completed in Columbus, Ohio were used to establish a system for prioritization (Tickle, 2008). *Table 5.2* provides a list of criteria that could be used to assess each problem area or obstruction. Each problem could be assigned a rating between 1 and 10 for each of the six criteria. The six criteria would be equally weighted in order to calculate a single relative rating between 1 and 10 for each problem.

Criteria	Description	Rating
Health & Safety	To what extent will the problem endanger human life?	1 to 10
Non-health & Safety Human Impact	How will the problem affect financial aspects of the surrounding areas?	1 to 10
Environmental Impact	To what extent will the problem contribute to erosion and sediment pollution?	1 to 10
Expected Life of Existing System	When will the system associated with the problem fail?	1 to 10
Frequency of Problem	How likely will the problem occur based on a 2-yr storm event?	1 to 10
Cost of Solution	Will the solution cost thousand's, hundreds of thousands, or millions of dollars to resolve?	1 to 10

Table 5.2. Problem Area/Obstruction Rating Criteria (Adapted from Tickle, 2008)

Each of the obstructions and problem areas would then be categorized in one of three categories based on their composite score: 1) Highest Priority Problem, 2) Significant Problem, or 3) General Problem. A composite rating between of 7 and 10 would classify a problem area or obstruction as a Highest Priority Problem. A composite rating between 4 and 6.9 would classify a problem area or obstruction as a Significant Problem and a rating between 1 and 3.9 would be classified as a General Problem. Because each problem area could be evaluated

independently, each municipality can use this assessment as the basis to develop their own problem area prioritization list.

The top ten problem areas that were categorized as Highest Priority Problems, based upon the criteria provided in Table 5.2, are listed in Table 5.3. The evaluation summary tables and respective data sheets listing Conceptual Solutions aree included in *Appendix C*.

ID	Municipality	Location	Problem	Appendix C Page Location
P90	Harmony Borough	Spring Street	Inadequate Infrastructure	8
P205 / P207	Marion Township	Boyers Road / Dematteis Road	Flooding	9
O64	Clay Township	Creek	Flooding - Beaver Dam	10
O40, O41, P102, P105, P106	Evans City Borough	Breakneck Creek	Flooding	11
P107	Summit Township	Connoquenessing Creek / SR 38	Flooding	12
P19, P20	Valencia Borough	Three Degree Road	Erosion, flooding	13
P293	Washington Township	Hilliards	Inadequate Infrastructure	14
P230 / P229	Washington Township	Calico Road	Flooding – Beaver Dam	15
P21/P23	Penn Township	Renfrew Road / Thorn creek	Flooding	16
P200	Center Township	Connoquenessing Creek / SR 38	Flooding	17

Table 5.3 Highest Priority Problem Listing

RECOMMENDATIONS

With the data collected for the identified problem areas, a comprehensive assessment should be completed by applying the rating criteria provided in the preceeding section.

A generalized analysis of the reported stormwater problems within the study area can be attributed to one, or more, of several principal causes:

1. A storm sewer, culvert or bridge has insufficient hydraulic capacity or is in poor condition.

   General Recommendation: The best method of dealing with the immense costs associated with bridge and culvert replacement it to first develop a prioritization system that highlight were the limited funds that are available can be spent. On ongoing program of inspection and maintenance is recommended so that the highest priority problem areas (i.e., the ones that endanger public health and welfare) are clearly identified and resolved as soon as funding is identified.

2. There is a severe erosion and deposition problem in a stream or man-made channel.

   General Recommendation: Each stream, channel, or obstruction that has erosion or deposition problems should be individually evaluated so the source of each problem is correctly identified. Detailed stream assessments should be performed for every action that involves moving or redirecting a stream. Blindly excavating sediment in an upstream area

may remove sediment in one location, but it may lead to much more significant erosion or sedimentation upstream or downstream of a particular site. Streambank restoration either through natural design methodologies or traditional engineered armor will be needed in appropriate locations to correct adverse impacts. Re-establishment of riparian buffers will offer protection of the stream channels to help mitigate adverse impacts.

3. There is an incomplete collection and conveyance system or a lack of a formal/comprehensive maintenance program for the existing storm drain system.

   General Recommendation: As with bridge and culvert replacement, the costs associated with installing or replacing existing storm drain system are substantial. A prioritization system as discussed above for culverts and bridge is perhaps the best approach to addressing these problem areas. Another important consideration is to consider is the regional wide impact (i.e., county or watershed-wide) of a storm drain system. The inclination is to remove water immediately from a housing development or a business district, but the question should be asked of each potential solution: what about the downstream property?

4. Problem areas are located in the floodplain area.

   General Recommendation: Problem areas within the floodplain are going to flood since they are located in flood prone areas. Prudent, regional-wide floodplain management measures, as discussed further is *Section 10*, offer the best solution for mitigating problem in flood prone areas.

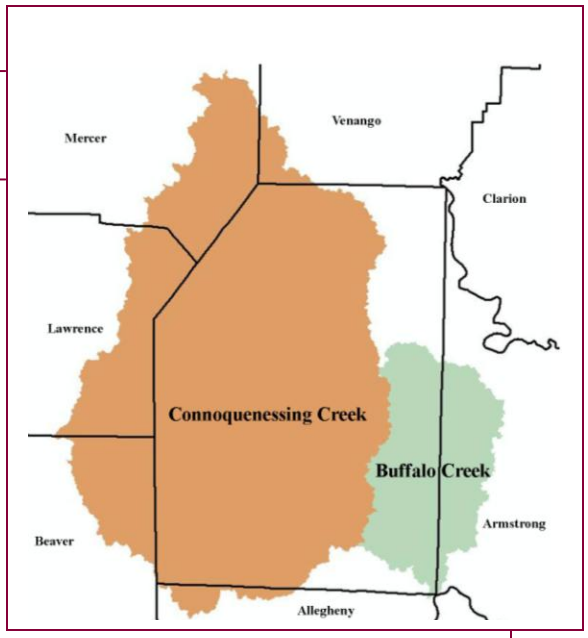
In addition, the problem areas mentioned in this section are more pronounced in the more populated/developed areas. This is most likely due to encroachments into floodplain areas and undersized culverts or bridges. Also, a large number of these stormwater related problems have been traced back to uncontrolled runoff from local and upstream areas, inadequate culverts or bridges, and obstructions in the system that are blocking the natural flow of stormwater.

This study has identified some drainage problems that occur on a yearly basis. While a certain amount of flooding is natural in streams during heavy rain, periodic maintenance can prevent some of the identified problems with flooding and erosion. A stormwater facility maintenance program should be developed and implemented as part of the strategy to correct existing problems and alleviate future problem areas.

Continued improper development within the county will amplify these problems. Remedial actions will be necessary to correct existing drainage problems. In the long term, a comprehensive approach is needed to tackle these problems. This approach will have to incorporate regulations and development standards into local zoning, consider both on-site and off-site drainage, provide a consistent approach between communities, use natural elements for the transport and storage of stormwater, consider both quantity and quality of water, and treat the watershed as a whole.

Stormwater master planning is one way to address all of the needs and potential threats to a watershed. However, implementation of these practices can be difficult and may not be economically feasible for many communities. Looking ahead, it is expected that the status of the current stormwater infrastructure will keep deteriorating with time. In addition to imposing stronger regulations to control new development, increased expenditures for maintenance and other improvements is necessary, or the systems will continue to deteriorate faster than the ability to fix and maintain them.

Section VI – Technical Analysis – Modeling



TECHNICAL APPROACH

To provide technical guidance in the Act 167 planning process, hydrologic models were prepared for specific watersheds identified by the municipalities, Butler County and DEP. The results from these models increase the overall understanding of watershed response to rainfall and help guide policy. Through the development and analysis of a hydrologic model, effective and fair regulations can be applied on a county-wide basis, while addressing specific issues identified by the individual communities in Butler County. The hydrologic methodology used in the technical approach is the Natural Resource Conservation Service (NRCS) Rainfall-Runoff Method described in various NRCS publications (NRCS, 2008a). This method was chosen since it is the most common method used by designers in Pennsylvania and has widely available data (NRCS, 2008b). Additionally, this method is the basis for which many of the guidelines were developed in the PA Stormwater BMP Manual. The calculations for this methodology were performed with HEC-HMS, the US Army Corps of Engineers' Hydrologic Modeling System.

The modeling approach in this study was to:

1. Establish a reasonable estimate of rainfall-runoff response under existing conditions.

2. Establish a reasonable estimate or rainfall-runoff response under an assumed future condition land development.

3. Provide an examination of the impact with the implementation of guidelines from the PA Stormwater BMP Manual (i.e., Design Storm Method and Simplified Method).

4. Develop stormwater management districts where it is determined necessary to do so.

Information from PAC meetings has been incorporated to direct the focus of this modeling effort and to ensure the most current DEP regulations are successfully incorporated throughout the entire county.

HYDROLOGIC MODEL PREPARATION

Two watersheds within the county were selected for hydrologic modeling: Buffalo and Connoquenessing Creek. These watersheds were delineated into subwatersheds based on problem areas, significant obstructions, and natural subwatershed divides. The delineation of these subwatershed areas created points of interest at junctions where the subwatersheds were hydraulically connected in the HEC-HMS model.

BUFFALO CREEK MODEL

The Buffalo Creek watershed has a drainage area of 170.6 square miles and was divided into 99 subwatersheds for the HEC-HMS model. Approximately 63.8 square miles of Buffalo Creek lies within Armstrong County. Figure 6.1 shows the Buffalo Creek subwatersheds and cumulative discharge points.

This watershed contains one dam that was considered to have a significant impact on the hydrology of the watershed. Dams with small storage volumes (generally less than 100 acre-feet) and dams that are completely filled during minor runoff events (0.3 inches of runoff) were generally considered "run-of-the-river dams" that would only affect the immediate area near the dam. Their impacts to the overall watershed hydrology within Butler County would be negligible and were not included in this study.

The only dam that was included in the hydrologic modeling effort was Saxony Dam located on Sarver Run. Outflow data for the dam was provided by DEP in the form of archived design files. This information was used to model the flows from the dam within the HEC-HMS model. The following table summarizes the impoundment within the watershed.

Impoundment	Stream	Location	Owner	Storage (acre-ft)
Saxony Dam	Sarver Run	Jefferson Twp.	Saxony Farms	46

Table 6.1. Impoundments within the Buffalo Creek Watershed

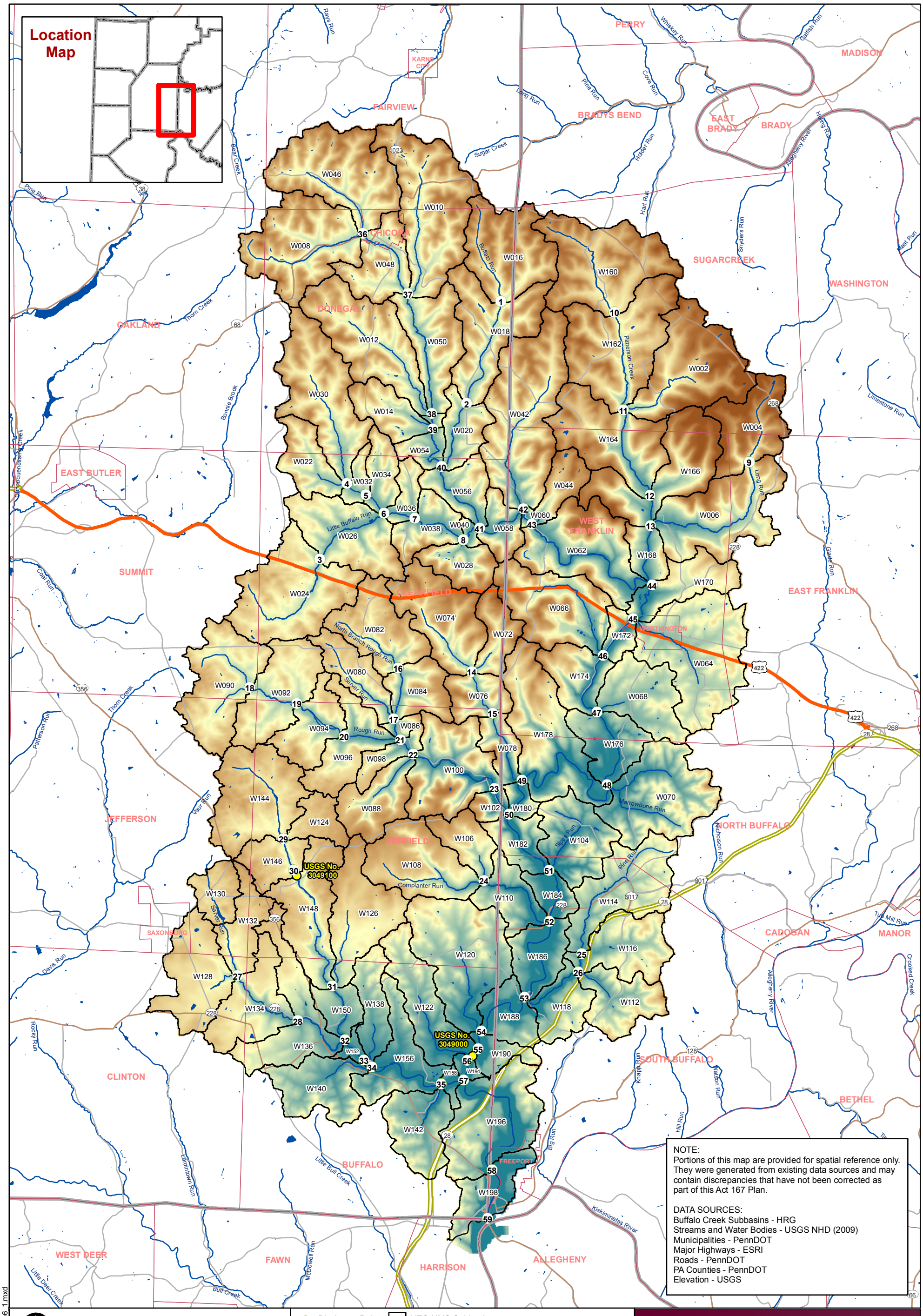
CONNOQUENESSING CREEK MODEL

The Connoquenessing Creek watershed has a total drainage area of 838.3 square miles. A large portion (about 260 mi^2) of this watershed lies outside of Butler County in Beaver, Lawrence, Mercer, and Venango Counties. The watershed was divided into 366 subwatersheds for the HEC-HMS model. Figure 6.2 shows the Connoquenessing Creek subwatersheds and cumulative discharge points.

This watershed contains five dams that were considered to have a significant enough impact on the hydrology of the watershed. The following table summarizes the impoundments within the Connoquenessing Creek watershed.

Impoundment	Stream	Location	Owner	Storage (acre-ft)
Moraine State Park	Muddy Creek	Muddy Creek	PA Dept. of Forests and Waters	38,054
Boydstown Dam	Connoquenessing Creek	Oakland Twp.	Butler Water Company	221
Sawmill Dam	Sawmill Run	Butler Twp.	Armco Steel Corporation	144
Thorn Reservoir	Thorn Creek	Oakland Twp.	Butler Water Company	632
No. 2 Dam	Tributary Likens Run	Jackson Twp.	Evansburg Borough Municipal Authority	37

Table 6.2. Impoundments within the Connoquenessing Creek Watershed



NOTE:
Portions of this map are provided for spatial reference only. They were generated from existing data sources and may contain discrepancies that have not been corrected as part of this Act 167 Plan.

DATA SOURCES:
Buffalo Creek Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - USGS

1.75 0 1.75 Miles

- Discharge Points
- USGS Gauges
- Streams
- Water bodies
- Limited Access
- Highway
- Major Road
- Local Road
- HEC-HMS Subbasins
- Municipalities
- Counties

Elevation
High : 1570 Feet
Low : 740 Feet

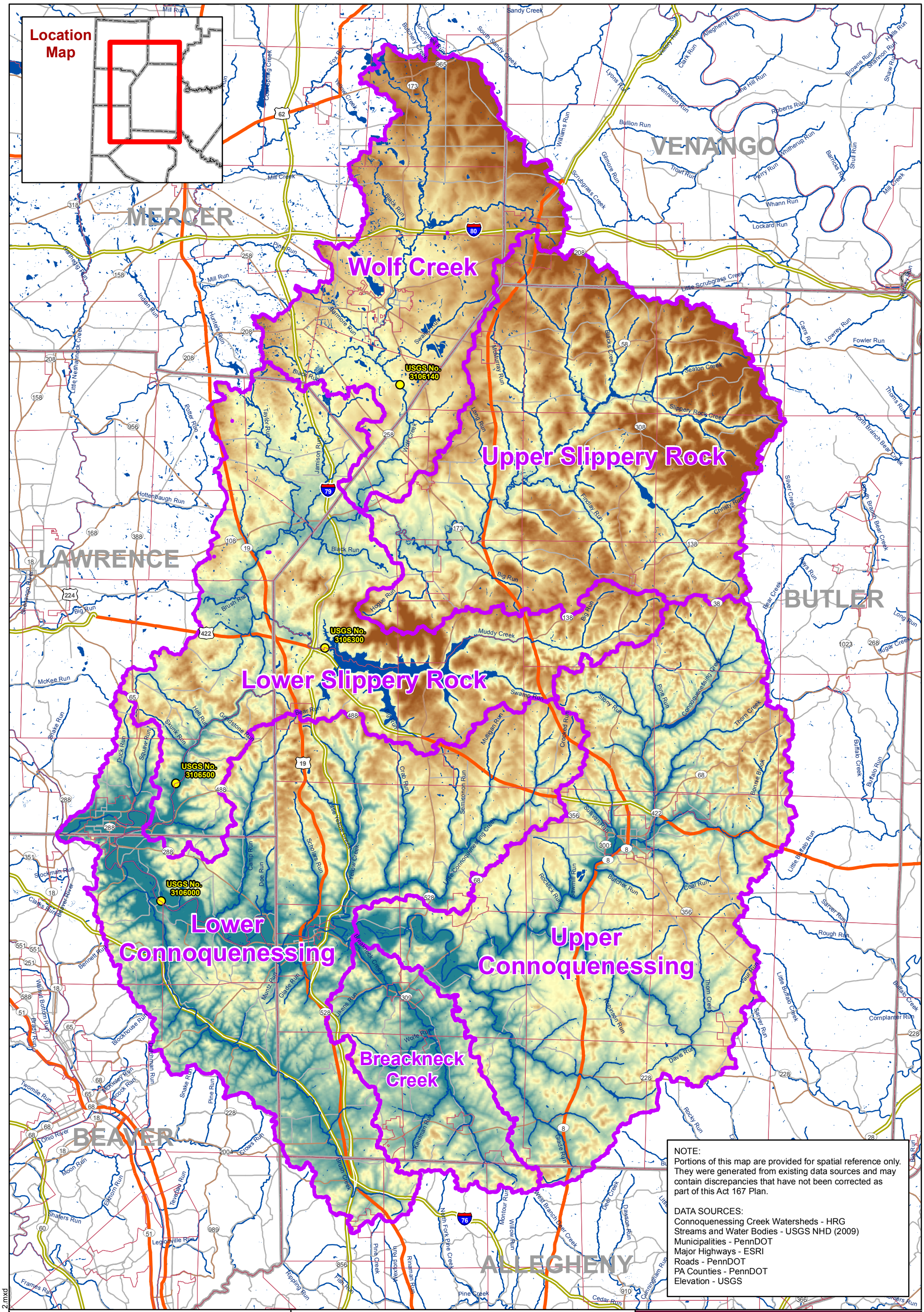
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Figure 6.1
Buffalo Creek HEC-HMS Model
Butler County, Pennsylvania

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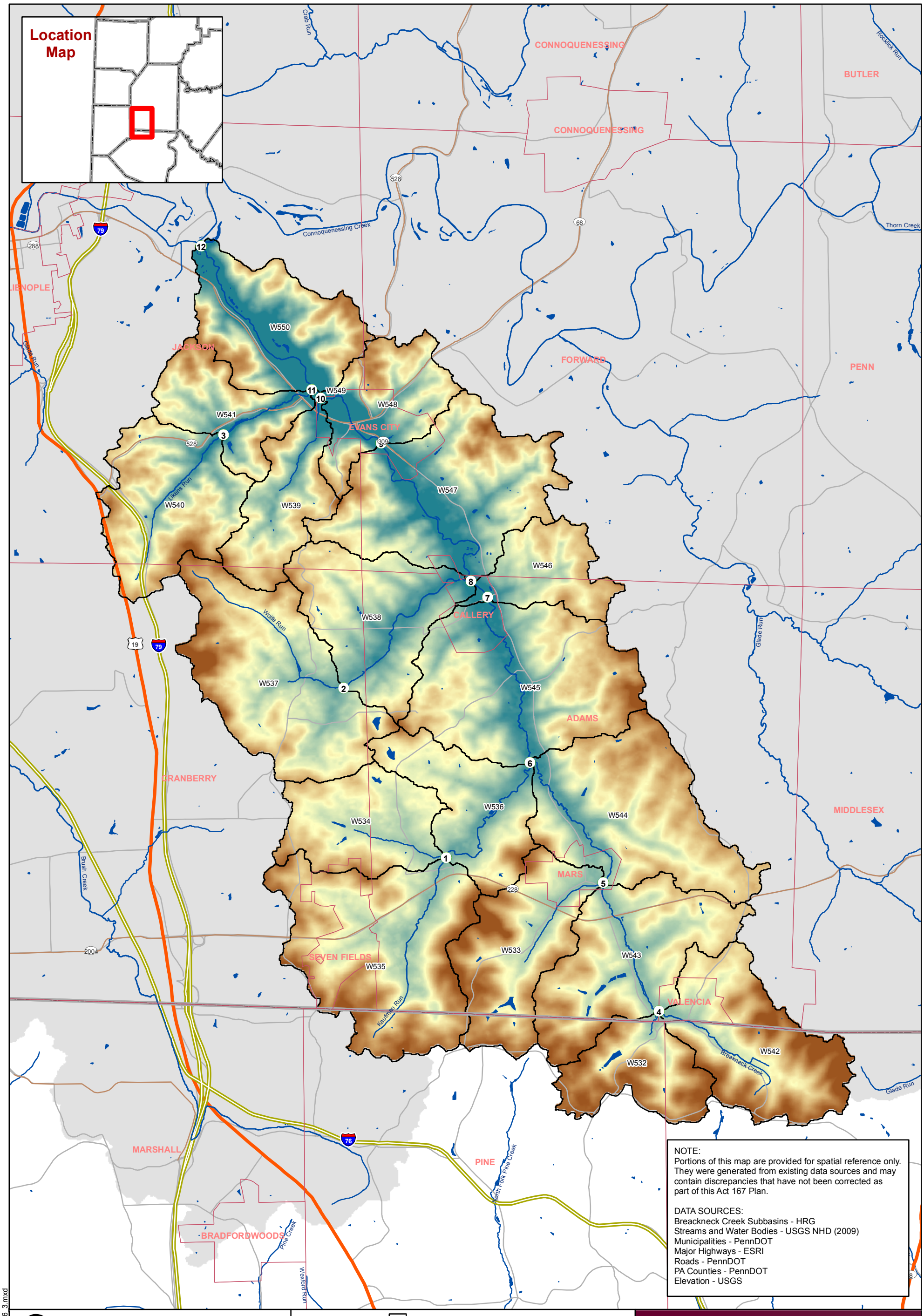
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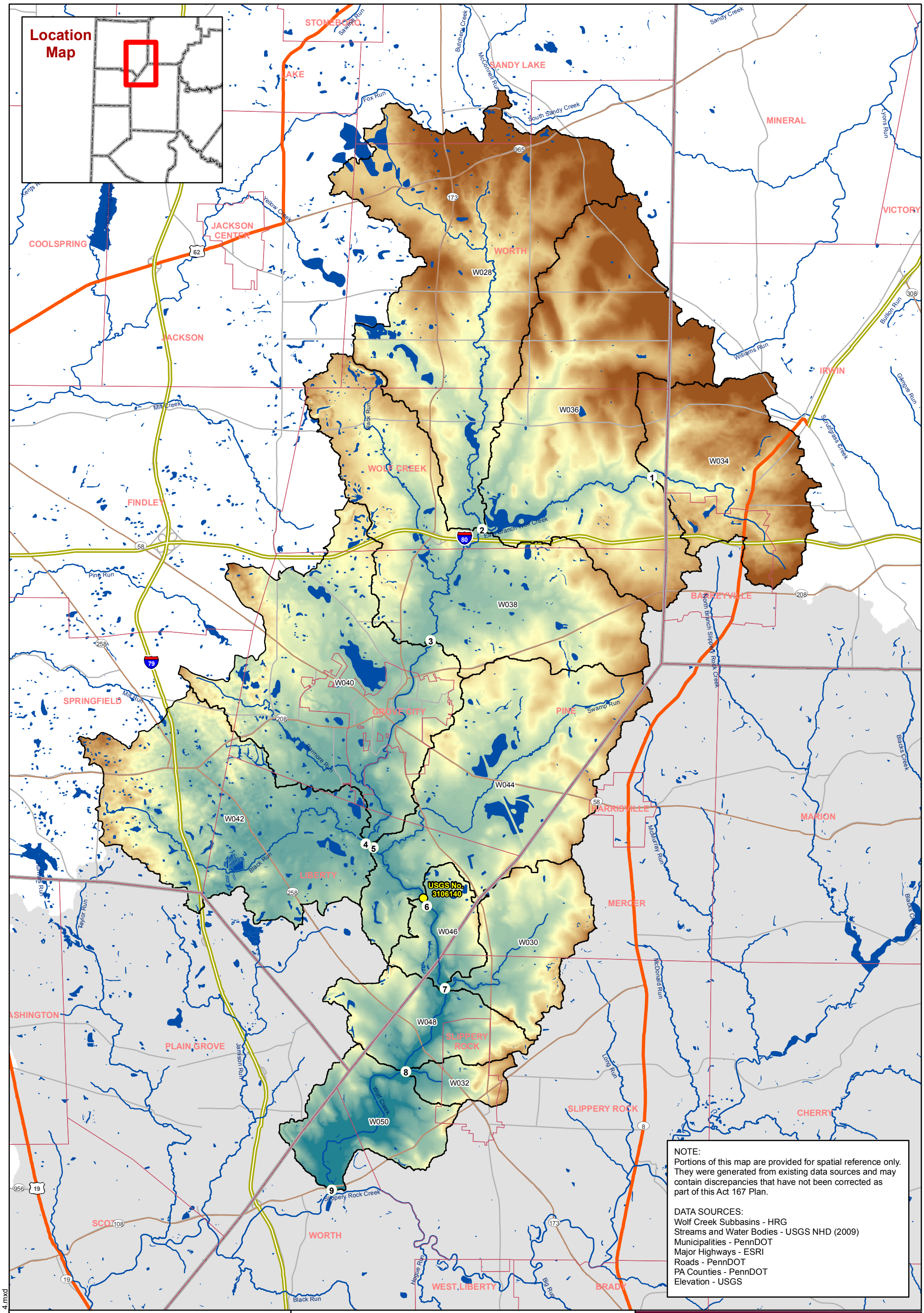
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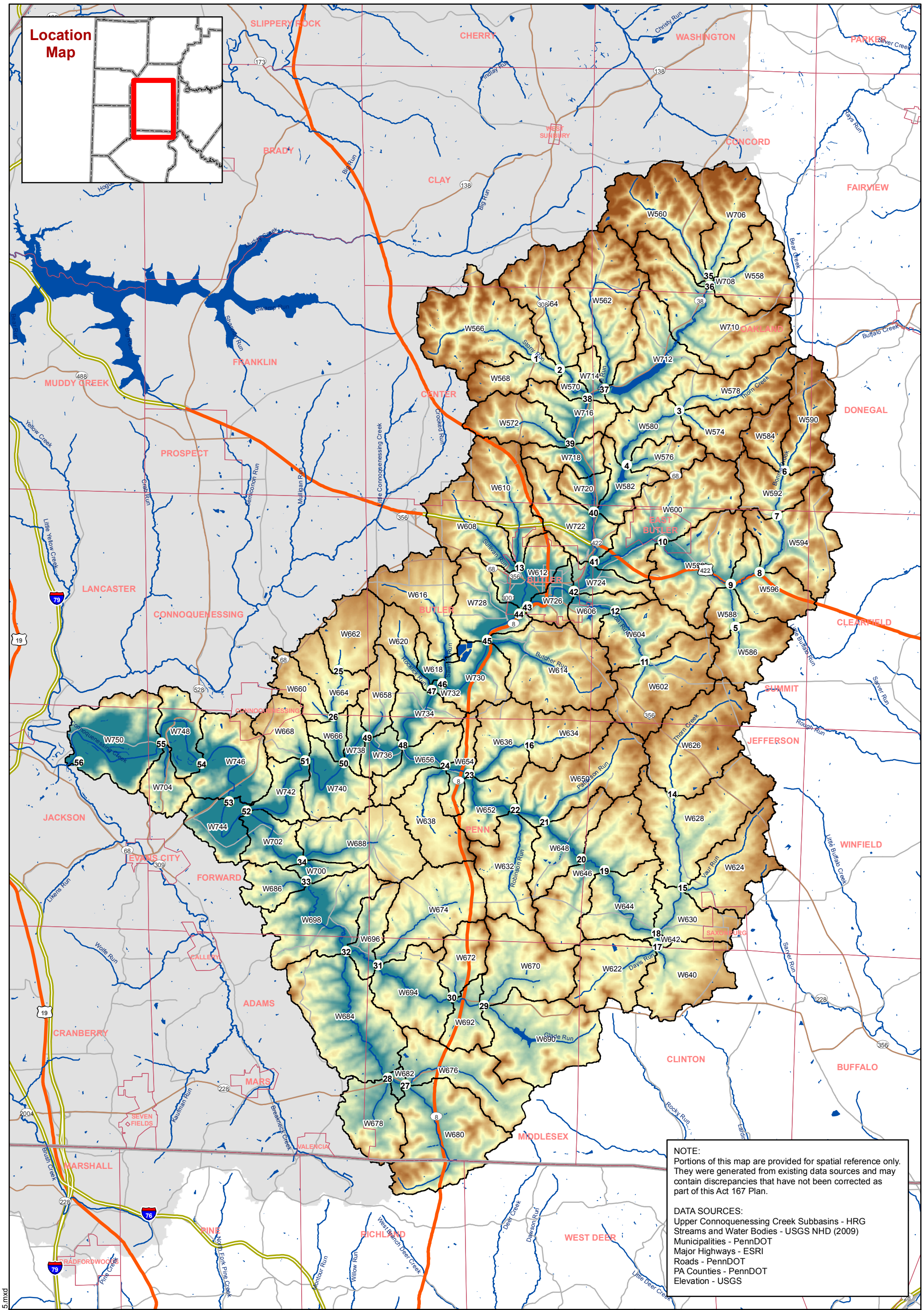
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Figure 6.2
Connoquenessing Creek HEC-HMS Models
Butler County, Pennsylvania

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Location Map
CONNOQUENESSING
BUTLER
CONNOQUENESSING
Crab Run
Rocklick Run
Connoquenessing Creek
528
68
Thorn Creek
79
288
12
W550
JACKSON
FORWARD
PENN
Cheese Run
11
10
W549
W548
W541
EVANS CITY
3
528
309
9
Likens Run
W540
W539
W547
W546
8
7
CALLERY
Wolfe Run
W538
19
79
Glade Run
W537
2
W545
ADAMS
6
CRANBERRY
W536
W534
W544
MIDDLESEX
1
MARS
5
228
Brush Creek
2004
SEVEN FIELDS
W535
W533
W543
Kaufman Run
VALENCIA
4
W542
W532
Breakneck Creek
Glade Run
MARSHALL
76
PINE
North Fork Pine Creek
BRADFORDWOODS
Pine Creek
Wexford Run
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DATA SOURCES:
Breakneck Creek Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - USGS
1 0 1 Miles
Discharge Points
USGS Gauges
Streams
Water bodies
Limited Access
Highway
Major Road
Local Road
HEC-HMS Subbasins
Municipalities
Counties
Elevation
High : 1400 Feet
Low : 870 Feet
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Figure 6.3
Breakneck Creek HEC-HMS Model
Butler County, Pennsylvania
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Location Map
STONEBORO
LAKE
SANDY LAKE
MINERAL
VICTORY
JACKSON CENTER
COOLSPRING
WORTH
JACKSON
IRWIN
WOLF CREEK
FINDLEY
BARKEYVILLE
SPRINGFIELD
GROVE CITY
PINE
HARRISVILLE
MARION
LIBERTY
MERCER
PLAIN GROVE
SLIPPERY ROCK
CHERRY
WEST LIBERTY
W028
W036
W034
W038
W040
W044
W042
W046
W030
W048
W032
W050
USGS No. 3106140
Sawmill Run
Butchery Creek
McConnell Run
Sandy Creek
Fox Run
South Sandy Creek
Lyons Run
Yellow Creek
Mill Creek
Black Run
Williams Run
Bullion Run
Glimpse Run
Springgrass Creek
Pine Run
Big Branch Wolf Creek
North Branch Slippery Rock Creek
Swamp Run
Beaver Run
Blacks Creek
McMurray Run
McDonald Run
Jamison Run
Long Run
Wolf Creek
Slippery Rock Creek
Hogue Run
Big Run
Taylor Run
Thorn Run
Kents Run
1.5 0 1.5 Miles
04/07/2010
R001803.0425
Discharge Points
USGS Gauges
Streams
Water bodies
Limited Access
Highway
Major Road
Local Road
HEC-HMS Subbasins
Municipalities
Counties
Elevation
High : 1620 Feet
Low : 1090 Feet
NOTE:
Portions of this map are provided for spatial reference only. They were generated from existing data sources and may contain discrepancies that have not been corrected as part of this Act 167 Plan.
DATA SOURCES:
Wolf Creek Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - USGS
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Figure 6.4
Wolf Creek HEC-HMS Model
Butler County, Pennsylvania
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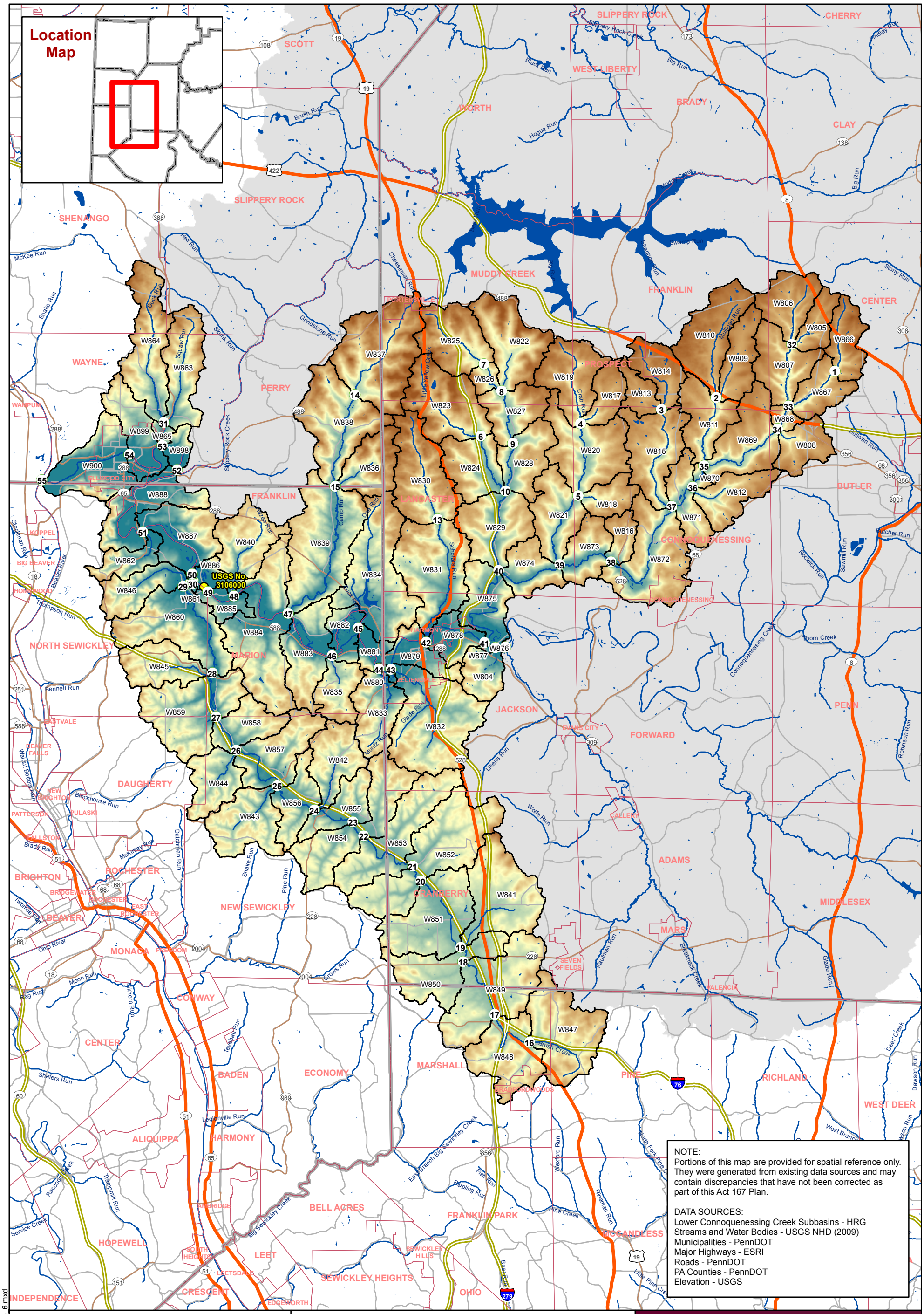
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Figure 6.5
Upper Connoquenessing Creek HEC-HMS Model
Butler County, Pennsylvania

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NOTE:
Portions of this map are provided for spatial reference only. They were generated from existing data sources and may contain discrepancies that have not been corrected as part of this Act 167 Plan.

DATA SOURCES:
Lower Connoquenessing Creek Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - USGS

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Figure 6.6
Lower Connoquenessing Creek HEC-HMS Model
Butler County, Pennsylvania

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Location Map

NOTE:
Portions of this map are provided for spatial reference only. They were generated from existing data sources and may contain discrepancies that have not been corrected as part of this Act 167 Plan.

DATA SOURCES:
Upper Slippery Rock Creek Subbasins - HRG
Streams and Water Bodies - USGS NHD (2009)
Municipalities - PennDOT
Major Highways - ESRI
Roads - PennDOT
PA Counties - PennDOT
Elevation - USGS

1.75 0 1.75 Miles

04/07/2010 | R001803.0425

Discharge Points
USGS Gauges
Streams
Water bodies
Limited Access
Highway
Major Road
Local Road
HEC-HMS Subbasins
Municipalities
Counties

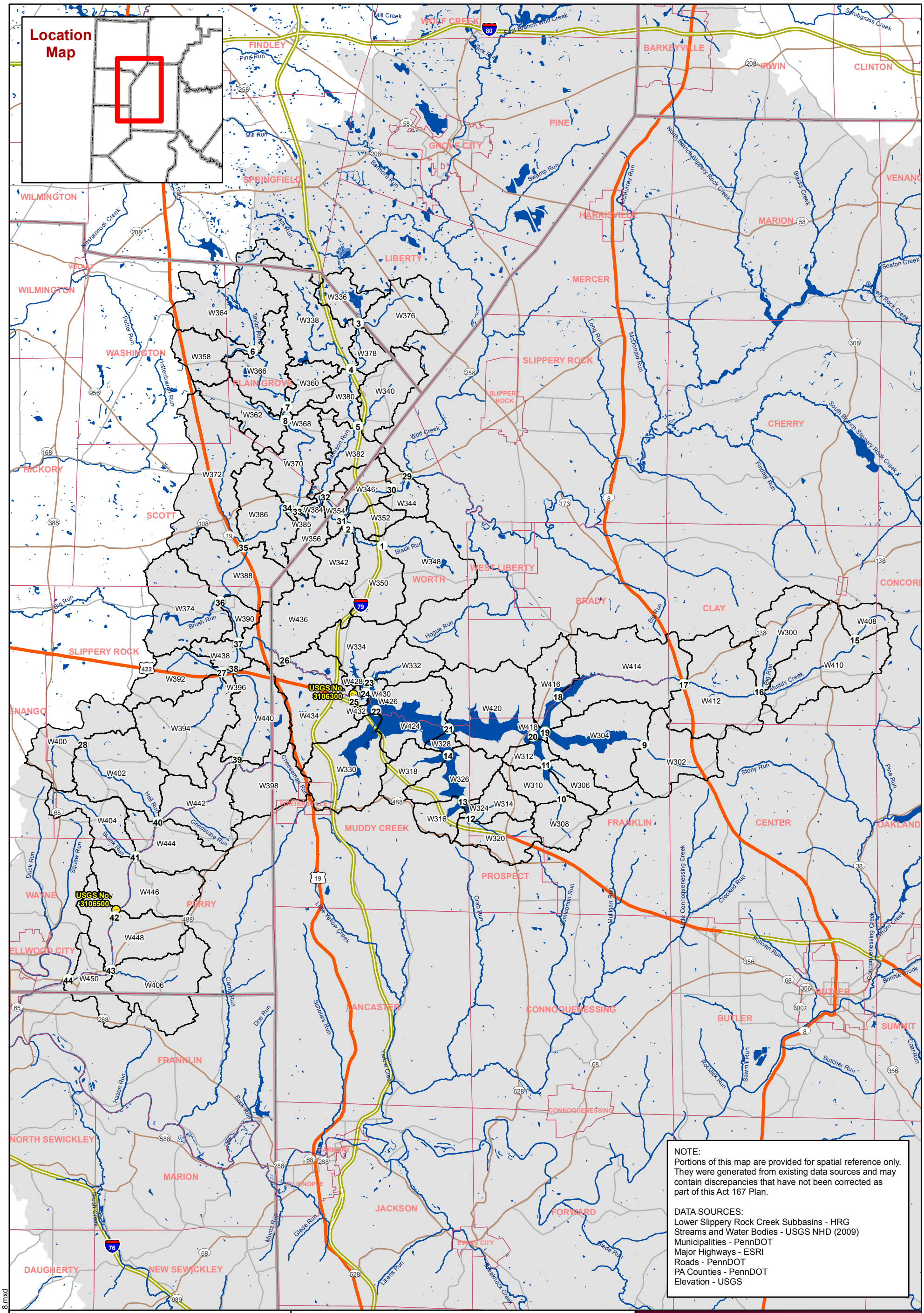
Elevation
High : 1620 Feet
Low : 1090 Feet

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Figure 6.7
Upper Slippery Rock Creek HEC-HMS Model
Butler County, Pennsylvania

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Figure 6.8
Lower Slippery Rock Creek HEC-HMS Model
Butler County, Pennsylvania

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HYDROLOGIC MODEL PARAMETERS

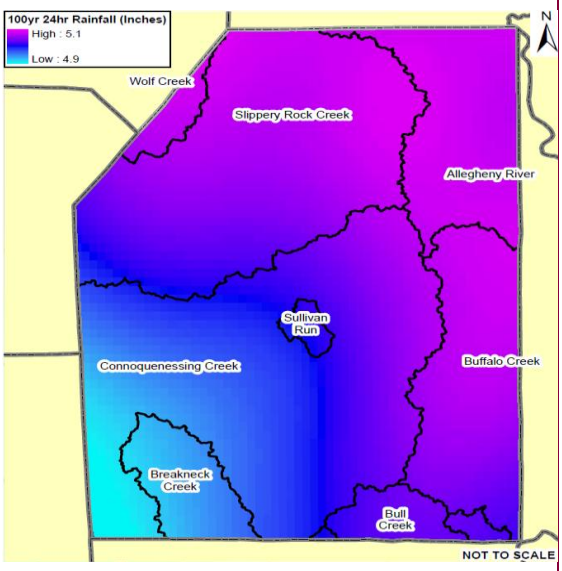
The various parameters entered into the hydrologic models include subwatershed area, soil-type, land cover, lag time, reach lengths and slopes, reach cross sectional dimensions, and design rainfall depths. These parameters are discussed in further detail in the technical appendix. A brief description of these components follows.

RAINFALL DATA

Rainfall data used in this modeling effort incorporates rainfall runoff data from the NOAA Atlas 14. NOAA Atlas 14 provides the most up to date precipitation frequency estimates, with associated confidence limits, for the United States and is accompanied by additional information such as temporal distributions and seasonality. Rainfall depths were obtained from a single point at the approximate geographic center of the county. The following table provides the rainfall estimates used for various design storm frequencies for Butler County (NOAA, 2008):

Design Storm (years)	24-hr Rainfall Depth (in)
2	2.42
10	3.39
25	4.01
50	4.52
100	5.05

Table 6.3. Rainfall Values for Butler County



NOAA Atlas 14 100-year, 24-hour Rainfall

It was assumed in all of the following analyses that these single rainfall quantities could be applied uniformly over the entire watershed area. Additionally, the rainfall quantities were applied to the NRCS Type II storm distribution. Although this combination of Atlas 14 data with the NRCS Type II storm distribution results in a relatively conservative rainfall pattern, this approach is consistent with the guidelines in *PA Stormwater BMP Manual* (2006).

SUBWATERSHED AREA

Generally, the subwatershed area for the modeled watersheds was 1-5 mi^2. The drainage areas may be slightly larger or smaller depending on hydrologic characteristics and location of problem areas. Subwatersheds with an area less than one square mile were included in the model if they formed a junction between two larger basins or were tributary to a defined problem area.

Basins with drainage area outside of Butler County were beyond the scope of study so they were not studied at the same level of detail as portions of the watershed within the County. They were delineated into areas between 1 and 5 mi^2 and were assumed to have only negligible changes in hydrology due to future land use.

SOILS

Soil properties, specifically infiltration rate and subsurface permeability, are an important factor in runoff estimates. Runoff potential of different soils can vary considerably. Soils are classified into

four Hydrologic Soil Groups (A, B, C, and D) according to their minimum infiltration rate (SCS 1986). HSG A refers to soils with relatively high permeability and favorable drainage characteristics; HSG D soils have relatively low permeability and poor drainage characteristics. The runoff potential increases dramatically in order of group A (lowest), B, C, and D (highest). Soil cover data was used in conjunction with land use cover data within GIS to develop composite curve numbers for each subwatershed in the models.

Table 3.5 show the relative percentage of hydrologic soil groups in Butler County. Generally, the runoff potential of soils in the northwestern portion of the County is very high; the location of these soil types corresponds to the location of many of the counties' identified problem areas.

LAND USE

Existing land use was derived from the National Land Cover Dataset (USGS, 2008). This data was converted to land uses that correspond to NRCS curve number tables (NRCS, 1986). The land use categories that were used are listed in *Table 6.3*.

Future land uses for the year 2020 were provided by the Butler County Planning Department and were later digitized for the purposes of this study. The future land use data reflects an estimate of future land use considering current trends and policies.

Land Use	Existing Land Use		Proposed Land Use		Change Future - Existing
	Acres	%	Acres	%	%
Brush[1]	16.3	0.0%	16.3	0.0%	0.0
Commercial and Business	6698.2	1.0%	6698.2	1.0%	0.0
Contoured Row Crops[1]	103760.5	16.1%	101990.8	15.8%	-1.1
Industrial	5169.3	0.8%	5169.3	0.8%	0.0
Institutional (assumed 50% impervious)	1365.3	0.2%	1365.3	0.2%	0.0
Meadow[1]	24128.2	3.7%	23755.4	3.7%	0.0
Mixed Urban (assumed 65% impervious)	216.3	0.0%	2649.4	0.4%	0.4
Newly graded areas	4602.6	0.7%	4545.0	0.7%	0.0
Open space[1]	22985.2	3.6%	27646.6	4.3%	0.7
Pasture[1]	70322.6	10.9%	69671.0	10.8%	-0.1
Residential - 1 acre	10227.8	1.6%	10227.8	1.6%	0.0
Residential - 1/2 acre	66439.6	10.3%	66439.6	10.3%	0.0
Residential - 1/8 acre or less	584.0	0.1%	584.0	0.1%	0.0
Water	8189.5	1.3%	8189.461	1.3%	0.0
Woods[1]	321045.1	49.7%	316802.3	49.1%	0.0
Total	**645750.4**	**100.0%**	**645750.4**	**100.0%**	**n/a**

Notes: [1] In Good Condition

Table 6.4. Existing and Future Land Use for Modeled Watersheds within Butler County

LAG TIME

Lag time is the transform routine when using the NRCS Curve Number Runoff Method. Lag can be related to time of concentration using the empirical relation:

$$T_{Lag} = 0.6 * T_C$$

Lag time values for the subwatersheds were based on NRCS Lag Equation and altered as described in *Appendix A*:

$$T_{Lag} = L^{0.8} \frac{(S+1)^{0.7}}{1900\sqrt{Y}}$$

Where: T_{lag} = Lag time (hours)

L = Hydraulic length of watershed (feet)

Y = Average overland slope of watershed (percent)

S = Maximum retention in watershed as defined by: S = [(1000/CN) – 10]

CN = Curve Number (as defined by the NRCS Rainfall-Runoff Method)

For comparison purposes, a lag time was also calculated for each subwatershed using the TR-55 segmental method. Given the rural landscape of Butler County, the best estimate for time of concentration calculation was provided by the NRCS lag equation.

INFILTRATION AND HYDROLOGIC LOSS ESTIMATES

Infiltration and all other hydrologic loss estimates (e.g., evapotranspiration, percolation, depression storage, etc.) were modeled using the standard initial abstraction in the NRCS Rainfall-Runoff Method (i.e., Ia = 0.2S) for the existing conditions and future conditions models. For the future conditions with stormwater controls model, these losses were taken into account using a modified initial abstraction value. This modified value was developed to be consistent with, and account for, the volume removal criteria under the Design Storm Method and the Simplified Method (CG-1 and CG-2). A detailed explanation of this modeling effort is described in *Appendix A*.

REACH LENGTHS, SLOPES, AND CROSS SECTION DIMENSIONS

Reach lengths and slopes were determined within GIS. Channel baseflow widths and depths for each river reach were estimated based on drainage area and percent carbonate using the methodology outlined in *Development of Regional Curves Relating Bankfull-Channel Geometry and Discharge to Drainage Area for Streams in Pennsylvania and Selected Areas of Maryland* (USGS, 2005). Dimensions for the overbank area were visually determined from FEMA floodplains or visual inspection of topographic data. *Figure 6.3* shows the dimensions as they are approximated.

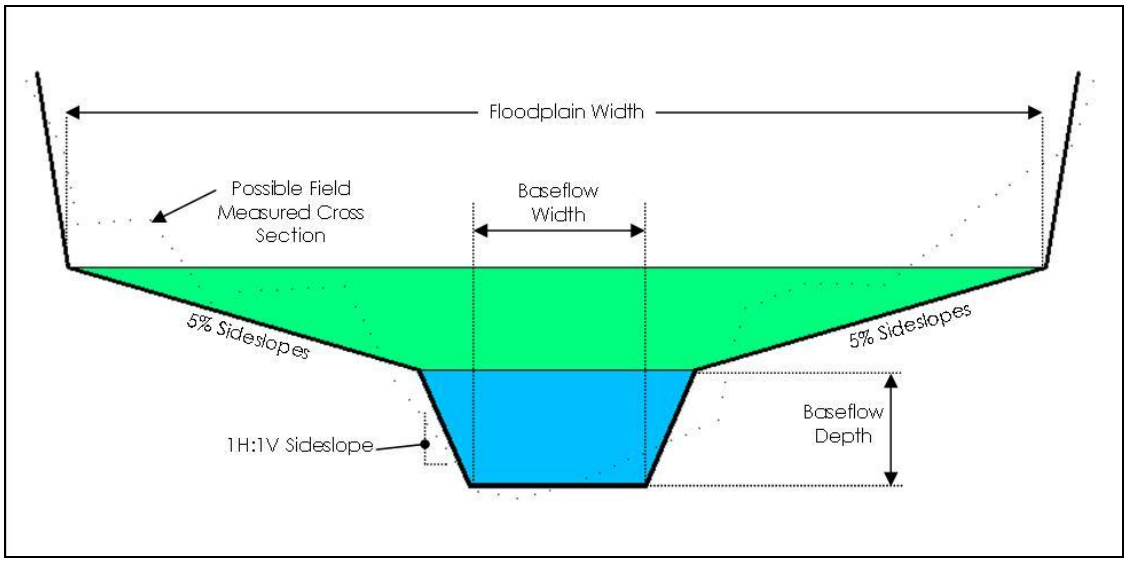


Figure 6.9. Cross Sections Used for Reaches in HEC-HMS Model

The reaches were modeled using the Muskingum-Cunge routing procedure. This procedure is based on the continuity equation and the diffusion form of the momentum equation. Manning's Roughness Coefficient *n* values were assumed to be 0.055 in channel; overbank channel values were assumed to be 0.08. When necessary for calibration, Manning's *n* values and the overbank sideslopes were altered so that realistic discharge values could be obtained. The data used for each specific reach is available within the HEC-HMS Model.

MODEL CALIBRATION

The HEC-HMS models incorporate a number of user-defined variables to generate runoff hydrographs. The accuracy of the model remains unknown unless it is calibrated to another source of runoff information. Possible sources of information include stream gage data, high water marks (where detailed survey is available to facilitate hydraulic analysis), and other hydrologic models. The most desirable source of calibration information is stream gage data as this provides an actual measure of the runoff response of the watershed during real rain events.



USGS Gage 03106000 Connoquenessing Creek near Zelienople, PA
Source: USGS, 2010

There are five USGS stream gages with adequate record located in Butler County. The following table lists these gages and their respective statistics.

USGS Stream Gage No.	Site Name	Drainage Area mi^2	Number of Gage Years at Gage	Used in HEC-HMS Model
03049000	Buffalo Creek near Freeport, PA	137.0	67	Used
03049100	Little Buffalo Creek at Cabot, PA	4.7	22	Used
03106140	Wolf Creek at Slippery Rock, PA	86.6	6	Not Used
03106300	Muddy Creek near Portersville, PA	51.2	45	Used
03106500	Slippery Rock Creek at Wurtemburg, PA	398.8	96	Used
03106000	Connoquenessing Creek near Zelienople, PA	356.0	93	Used

Table 6.5. USGS Stream Gages in Butler County

The only gage within the watersheds not being analyzed for this study is USGS Gage 03106140. Flow estimates were derived at this gage using the Bulletin 17B methodology outlined in USGS (1982). This method produces estimates for storms of all of the frequencies desired in this study (between the 1 and 100 year storm events) for any gage that has more than 10 years of data.

When no stream gage data is available, the next most desirable source of data for purposes of comparison is other hydrologic studies prepared by local, state, or federal agencies. FEMA Flood Insurance Studies (FIS) often provide discharge estimates at specific locations within FEMA floodplains. The estimates provided in FEMA FISs are valid sources for comparison but should be carefully considered when used for calibration since they are sometimes dependent on outdated methodology, or focus exclusively on the 100-year event for flood insurance purposes.

The third available source of information that may be used for calibration is regression equation estimates. The regression equations were developed on the basis of peak flow data collected at numerous stream gages throughout Pennsylvania. This procedure is the most up-to-date method and takes into account watershed average elevation, carbonate (limestone) area, and minor surface water storage features such as small ponds and wetlands. The methodology for developing regression equation estimates within Pennsylvania is outlined in USGS Scientific Investigations Report 2008-5102 (USGS, 2008). Drainage Area, Mean Elevation, Percent Carbonate Rock, and Percent Storage, the applicable parameters within Butler County, were calculated using GIS from layers supplied from USGS Digital Elevation Model (DEM) data, Environmental Resources Research Institute (1996), and USGS (2008).

The target flow rates were determined from one of these three sources. The HEC-HMS models were then calibrated to the target flow rates at the overall watershed level, at subwatersheds where significant hydrologic features were identified (e.g., confluences, dams, USGS Gages), and at each individual subbasin. This approach was used so that a flow value anywhere in the model would compare favorably to the best available data source. The parameters of calibration for the entire overall watershed were the antecedent runoff condition, lag time, and reach routing coefficients. Detailed calibration results are provided in *Appendix A*.

The following figures (*Figures 6.4-6.20*) show the overall watershed calibration results for Buffalo Creek and Connoquenessing Creek. As can be shown, the calibration results are in general agreement with the range of values for other hydrologic studies. The HEC-HMS Models were within 10% of the USGS Gage points and within the standard error for the Regression values (28-38%). USGS Gages that were affected by upstream regulation had a higher percent error. Detailed calibration results and model input are provided in *Appendix A*.

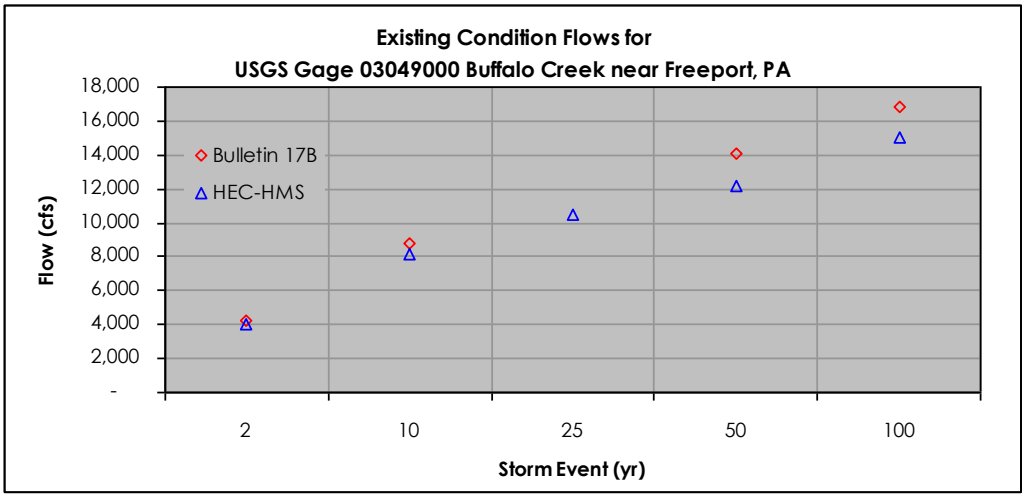


Figure 6.10

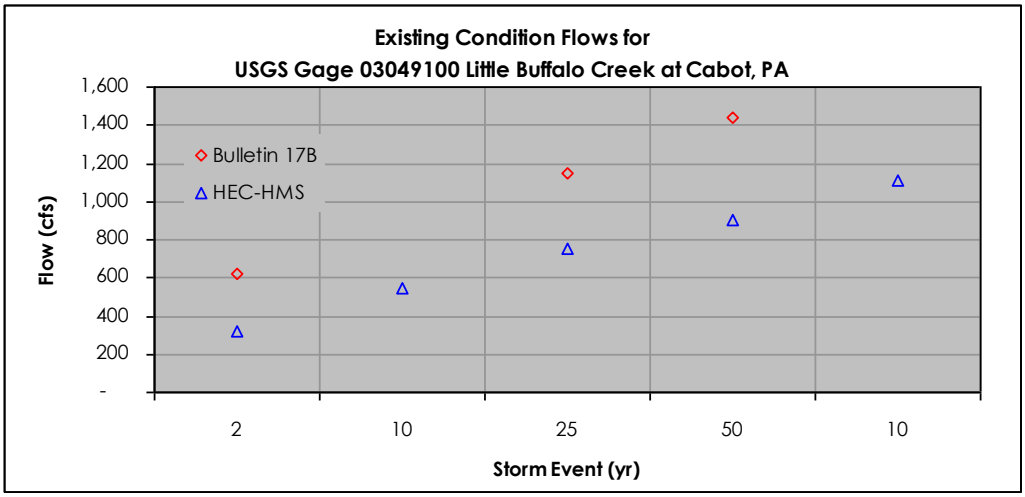


Figure 6.11

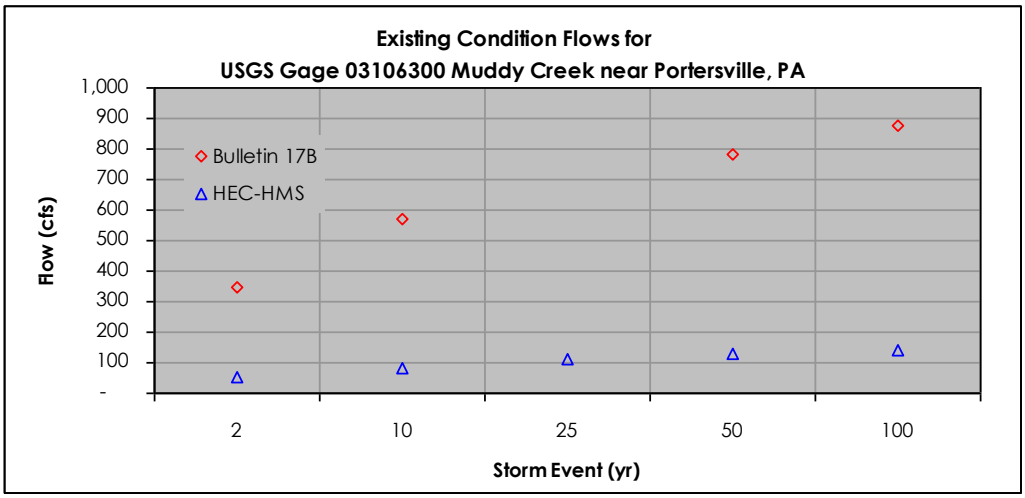


Figure 6.12

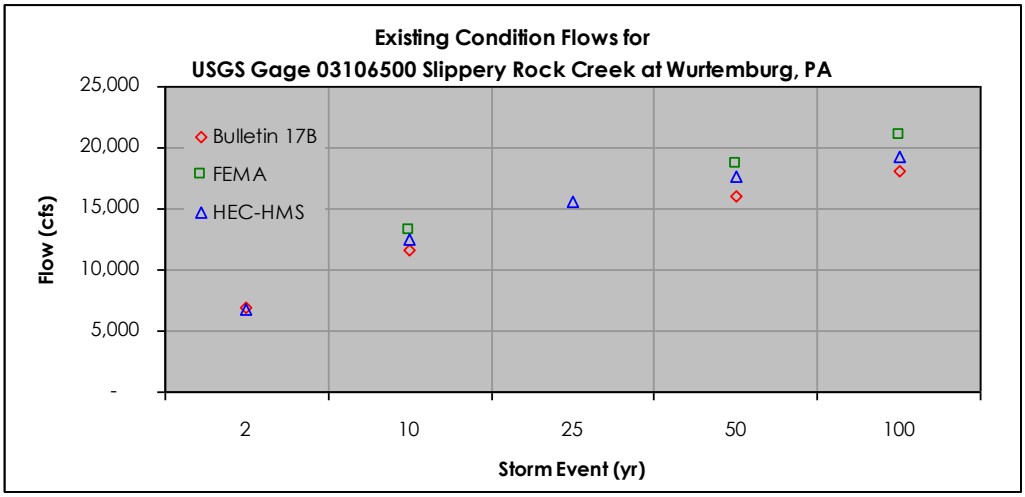


Figure 6.13

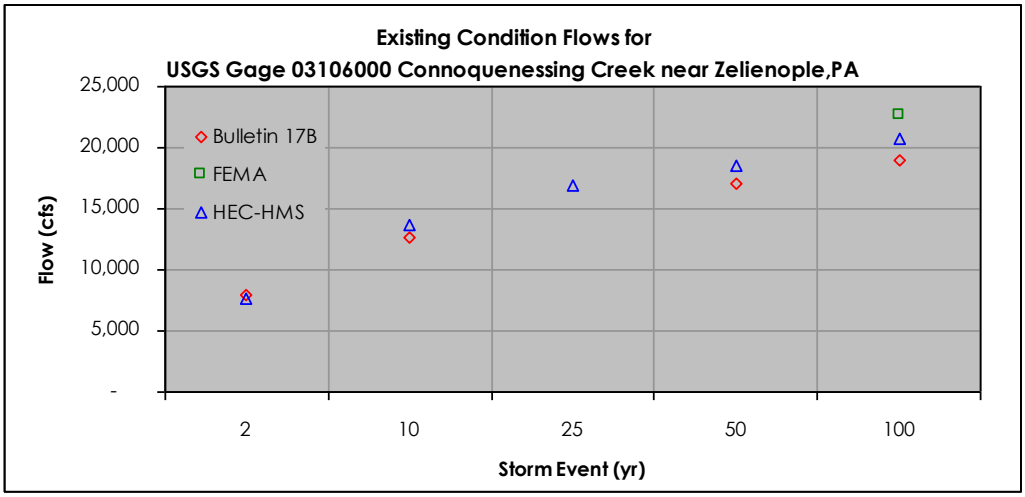


Figure 6.14

MODELING RESULTS

Once the existing conditions model was calibrated and the existing conditions peak flows were established, additional models were developed to assist in determining appropriate stormwater management controls for the watersheds. Based on a comparison of existing and future land use, most subbasins will experience varying degrees of development through the full build-out future condition.

The following simulations were performed with HEC-HMS (2, 10, 25, 50 and 100-year) for Buffalo and Connoquenessing Creeks:

Existing Conditions (Ex)

An existing conditions model was developed and analyzed using the using the calibration procedures described above. Results from the existing conditions model reflect the estimated land uses from 2010. The existing condition flows are provided in *Appendix A* for both watersheds.

Future Conditions with No Stormwater Controls (F-1)

A future conditions model was developed and analyzed using the projected future land use coverage for the year 2020 provided by Butler County. The revised land use resulted in an increased curve number and a decreased time of concentration for several subbasins. It was assumed that there was no required detention or any other stormwater controls in this simulation.

Future Conditions with Design Storm Method and Release Rates as Stormwater Controls (CG-1R)

A future conditions model with Stormwater Controls was developed by modifying the future conditions model to include the effects of peak rate controls and the volume removal requirements of the Design Storm Method.

The effects of peak rate controls, through detention of post development flows, was estimated by routing the post development flow for each subbasin through a simulated reservoir. The reservoirs were designed so that they could release no more than the pre-development flow estimate. This approach was assumed to simulate the additive effect of all of the individual detention facilities within a sub-basin. The volume removal requirements of the Design Storm Method were simulated using modified initial abstraction values as described above and in *Appendix A*.

The approach in this Act 167 Plan was to 1) estimate the effects of detention of post development flows and 2) apply release rates to subwatershed wherever there is a significant increases in peak flow at the points of interest. The results for each watershed are presented below; detailed results of the modeling are provided in *Appendix A*.

BUFFALO CREEK AND CONNOQUENESSING CREEK WATERSHEDS

The flow increases within the Buffalo Creek and Connoquenessing Creek watersheds are located towards the bottom of the watersheds, as shown in *Figures 6.15 and 6.16*.

	Effects of Future Condition on Discharges		
Storm Event (year)	Maximum % Increase in Future Conditions	Average % Increase in Future Conditions[1]	Portion of subbasins with Increase (%)
2	76.7	1.3	19.8
10	60.3	1.0	19.8
25	56.5	1.0	19.6
50	57.1	1.0	19.6
100	55.6	1.0	19.4

Notes: [1] Area weighted averages

Table 6.6. Future Condition Flows with No Stormwater Management Controls for Modeled Watersheds within Butler County

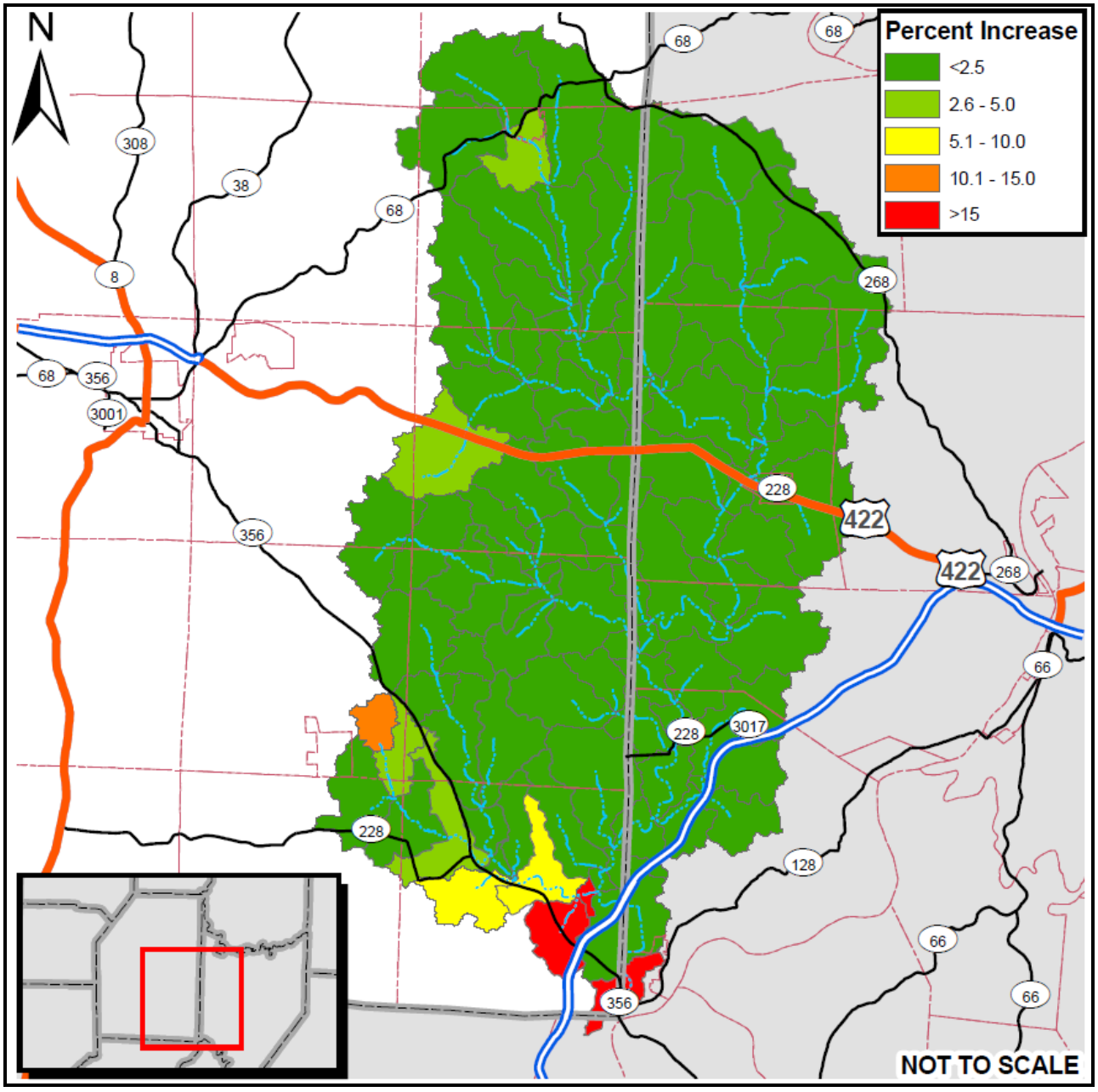


Figure 6.15 Increase in Flow for 2-Year Storm Event with No SWM Controls for Buffalo Creek

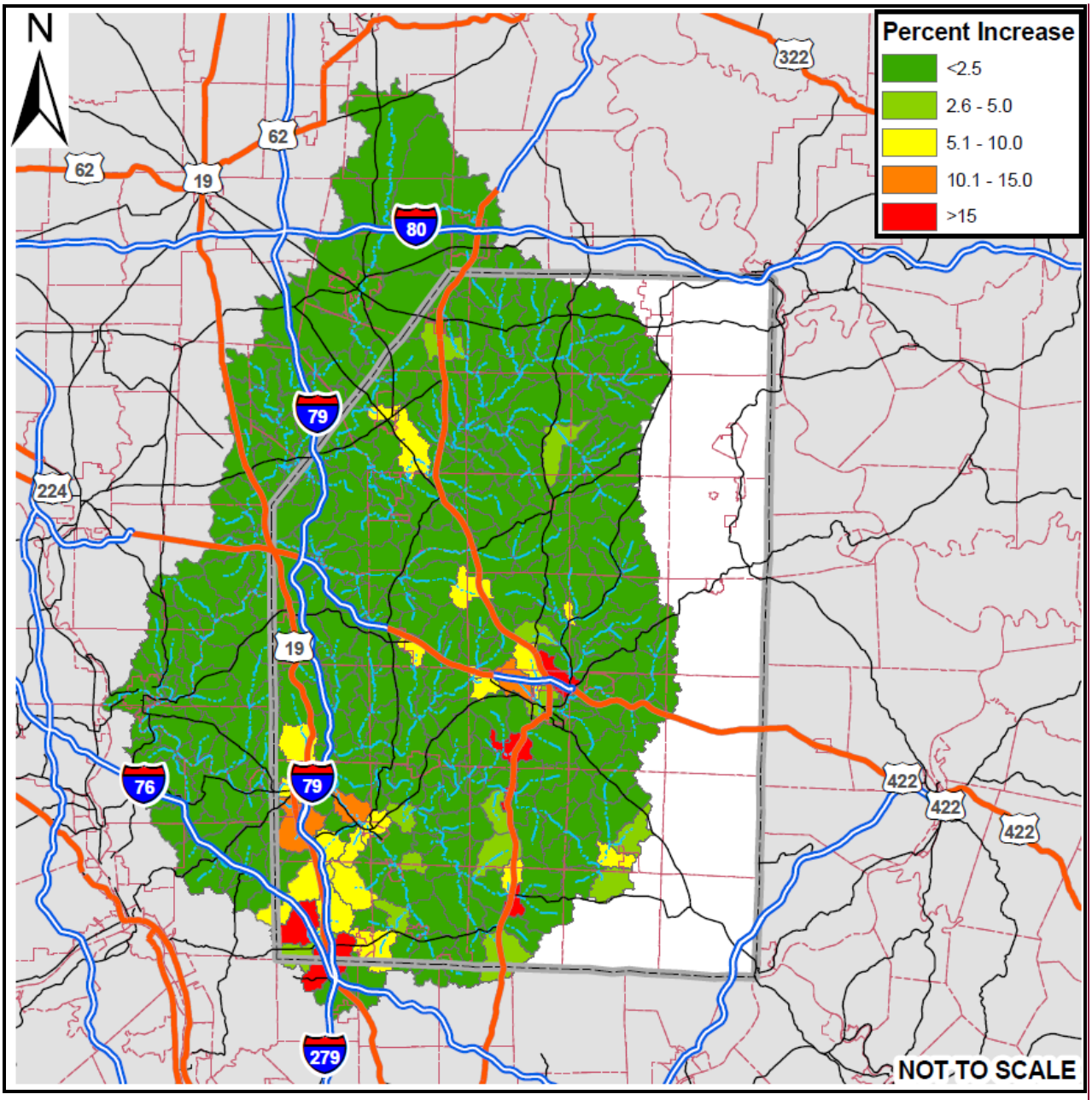


Figure 6.16 Increase in Flow for 2-Year Storm Event with No SWM Controls for Connoquenessing Creek

Table 6.7 shows the reduction in peak flows that would occur if only the Design Storm Method were implemented without any peak rate controls. The flows for the lower magnitude events are substantially reduced compared to future conditions with no stormwater management controls with the implementation of the Design Storm Method. The flows for the higher magnitude events are moderately reduced with implementation of the Design Storm Method, but significant increases still occur.

Storm Event (year)	Effects of CG-1 on Discharges		
	Maximum % Increase with CG1	Average % Increase with CG1[1]	Portion of subbasins with Increase (%)
2	1.6	0.3	22.4
10	17.4	0.4	16.6
25	23.7	0.4	15.3
50	27.4	0.5	15.7
100	30.1	0.6	16.8

Notes: [1]Area weighted averages

Table 6.7 Future Subbasin Flows with Design Storm Method Only – No peak control for Modeled Watershed within Butler County

If there was a significant increase at a point of interest, the allowable release rate was reduced until the increase in peak flow at the points of interest was reduced to acceptable values. Tables 6.8 and 6.9 reflect the allowable release rates with the implementation of the Design Storm Method.

Storm Event (year)	Release Rates with the Design Storm Method
	Release Rates (%)[1]
2	100
10	100
25	100
50	100
100	100

Notes: 1For the 10, 25, 50, and 100 year storms.

Table 6.8. Future Subbasin Flows with Design Storm Method Implementation and Release Rates for Buffalo Creek

Storm Event (year)	Release Rates with the Design Storm Method
	Release Rates (%)[1]
2	100
10	85-90-100
25	85-90-100
50	85-90-100
100	85-90-100

Notes: 1For the 10, 25, 50, and 100 year storms.

Table 6.9. Future Subbasin Flows with Design Storm Method Implementation and Release Rates for Connoquenessing Creek

STORMWATER MANAGEMENT DISTRICTS

When substantial increases are found in the HEC-HMS model due to additive effects of future development, it may be necessary to restrict post development discharges to a fraction of pre-development flow. The fraction has historically ranged between 50% and 100% of the pre-development flow in previous Act 167 efforts. A 75% release rate district would indicate that any

future development within the district be required to restrict post-development flows to 75% of pre-development flows.

Release rate theory and the designation of stormwater management districts are not substantially supported in stormwater literature. The calculation of release rates is heavily dependent on timing and growth projections, both of which involve a high degree of uncertainty. Additionally, it has been observed that localized stormwater measures do not typically capture and detain entire tributary areas (Emerson, 2003). Given these limitations with release rates, the following criteria were examined before applying release rates to the modeled watersheds:

1. Numerous problem areas exist in a pattern that indicates systemic stormwater problems.

2. Historic, repeated flooding has been observed.

3. Future planning projections indicate growth patterns that have historically contributed to documented problems.

4. Release rates are to be designated on higher order watersheds only; larger downstream areas with well established bed-and-bank streams are not as affected by relatively small scale development and therefore do not benefit from release rates.

When the above criteria indicate a need for additional stormwater management controls, release rates are considered. The results from hydrologic models are used as guidance to establish appropriate release rates. Ultimately, reasonable hydrologic judgment is used in the final designation of release rates.

BUFFALO CREEK

The Buffalo Creek watershed was evaluated on the above criteria for implementation of stormwater management districts. The anticipated future development is concentrated in the lowest part of the watershed, near Laneville and Freeport. In this regard, there would be little benefit to restricting upstream development any more than ensuring that all post-development discharges be limited to pre-development levels. In considering the additional criteria it was determined that stormwater management districts would not be implemented.

CONNOQUENESSING CREEK

Evaluation of the Connoquenessing Creek watershed indicates a need for stormwater management districts. The watershed has had numerous problems areas in patterns indicative of systemic problems in some focused areas around Cooperstown and Glade Mills within the Glade Run Watershed. Additionally, future growth is projected throughout the watershed and in the area of the release rate districts. Sub-basins outside of Butler County within the Brush Creek watershed play a major role in future flow increases. When release rates were applied to the particular sub-basins within Brush Creek the future flow increases became higher. No problem areas were reported within the Brush Creek subbasin and release rates were not applied. Stormwater management districts have been developed for other portions of the watershed, which have potential development, with release rates ranging between 85 and 100%.

The location of the stormwater management districts is shown on *Plate 10 - Stormwater Management Districts*, which also identifies the location for potential regional stormwater facilities.

RECOMMENDATIONS

The modeling results discussed in this and previous sections provide technical guidance on provisions that should be included in the model ordinance. The following recommendations follow from the technical analysis and data collection efforts in preparing this Plan.

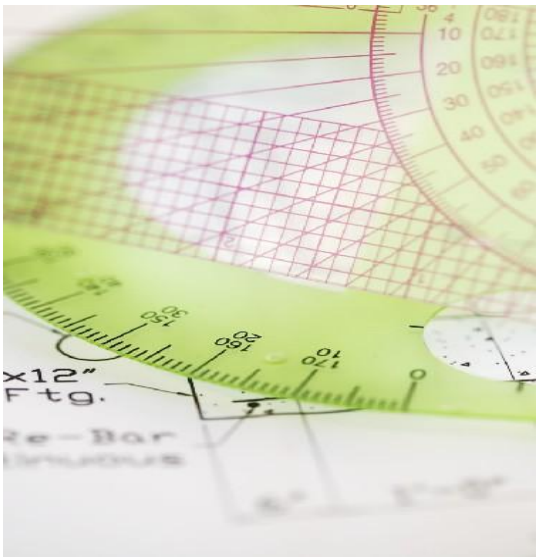
Curve number and time of concentration methodologies should be restricted to reflect the observed runoff response in the hydrologic models. For storm events greater than the 10-year storm events, the runoff response to NOAA Atlas 14 rainfall in Butler County was lower than standard NRCS methods predict. This has the potential to allow designers to undersize their stormwater facilities and to increase peak discharges for the higher magnitude events. It is recommended for curve number calculations to assume 'good conditions' when using any curve number table, which is consistent with proposed control guidance. It is recommended for time of concentration computations to use the maximum value provided by 1) the TR-55 segmental method and 2) the NRCS Lag Equation.

Implement a volume control policy in addition to a traditional peak rate methodology. The modeling results show a definite reduction in peak discharge in all storm events with the implementation of the control guidance criteria. The control guidance criteria will provide a direct benefit with volume reduction and also an indirect benefit of channel protection.

Implement and enforce a flexible yet clearly documented release rate policy for specified watershed. The stormwater management districts are provided on Plate 10. These should be used to determine the allowable post-development peak flow rate. The use of strategically placed regional facilities and watershed-scale conservation, drainage way, and critical recharge area easements should also be considered as an alternative to release rate implementation.

Provide a clear alternative volume-control and peak-rate control strategy for areas with poorly drained soils or areas with geologic restrictions. Butler County has a substantial number of potential limitations to infiltration facilities: fragipans, shallow bedrock, Hydric soils, floodplains, and documented problem areas. Section 7 provides a recommended procedure for sites with these limitations.

Section VII – Technical Standards and Criteria for Control of Stormwater Runoff



TECHNICAL STANDARDS FOR STORMWATER MANAGEMENT

The field of stormwater management has evolved rapidly in recent years as additional research has increased our comprehension of how stormwater runoff is interrelated with the rest of our natural environment. Even now this relationship is not completely understood. Stormwater management practices will continue to evolve as additional knowledge becomes available. Effective resource management involves balancing the positive and negative effects of all potential actions. These actions are considered, and the individual management techniques which provide the best known balance are chosen for implementation. The goal of this Plan is to manage stormwater as a valuable resource, and to manage all aspects of this resource as effectively as possible. This Plan contains technical standards that seek to achieve this goal through four different methods. These standards are summarized as follows:

1. Peak Discharge Rate Standards – Peak discharge rate standards are implemented primarily to protect areas directly downstream of a given discharge by attenuating peak discharges from large storm events. These standards are also intended to attenuate peak flows throughout the watershed during large storm events. Peak discharge rate controls are applied at individual development sites. Controlling peak discharge rates from the sites entails collection, detention, and discharge of the runoff at a prescribed rate. This is an important standard for achieving stable watersheds.

2. Volume Control Standards – The standards in this Plan that address increased stormwater volume are intended to benefit the overall hydrology of the watershed. The increased volume of runoff generated by development is the primary cause of stormwater related problems. Increased on-site runoff volume commonly results in a sustained discharge at the designed peak discharge rate, as well as an increased volume and duration of flows experienced after the peak discharge rate. Permanently removing a portion of the increased volume from a developed site is key in mitigating these problems and maintaining groundwater recharge levels. Meeting this standard generally involves providing and utilizing infiltration capacity at the development site, although alternative methods may be used.

3. Channel Protection Standards – Channel protection standards are designed to reduce the erosion potential from stormwater discharges to the channels immediately downstream. Even though peak discharge rate controls are implemented for larger design storms, they do not provide controls for the smaller storms. These storms account for the vast majority of the annual precipitation volume. Past research has shown that channel formation in developed watersheds is largely controlled by these small storm events. The increased volume and rate of stormwater runoff during small storms forces stream channels to change in order to accommodate the increased flows. Channel protection standards will be achieved through implementation of permanent removal of increased volume from discharges during low flow storm events.

4. Water Quality Standards – The water quality standards contained in this Plan are meant to provide a level of pollutant removal from runoff prior to discharge to receiving streams. Stormwater runoff can deliver a wide range of contaminants to the receiving stream, which leads to a variety of negative impacts. Water quality standards can be achieved through reducing the source of pollutants and utilizing natural and engineered systems that are capable of removing the pollutants.

Beyond the standards discussed above, other measures may be taken to ensure that stormwater is properly managed. Some of these measures are discussed later in *Section X, Additional Recommendations*. These measures are included as recommendations because they are beyond the regulatory scope of this Plan. Municipalities should consider these recommendations seriously.

Stormwater management is an issue that is entwined with land use decisions and has social and economic implications. To maximize the effectiveness of a stormwater management program, a holistic approach is needed. Stormwater management should be a consideration in any ordinance decisions that affect how land is used.

CRITERIA FOR CONTROL OF STORMWATER RUNOFF

The principal purpose of this Plan was to develop criteria for control of stormwater runoff that are specific to the watersheds within Butler County. Mathematical modeling techniques, as discussed in the previous chapter, were used to simulate the existing conditions throughout the county and to determine the effects anticipated future development will have on stormwater runoff within these watersheds. The models were used to determine the outcome of a variety of different stormwater control scenarios. These results were then used to determine a group of control criteria that provides the best results on a watershed wide basis. The outcome of each analysis is stormwater control criteria that are appropriate and applicable to that watershed.

The process of developing unique controls for individual watersheds is complicated by the reality that regulations must be implemented and enforced across varying jurisdictions. The more site specific and complicated a regulatory structure is, the more difficult it becomes to implement the regulations. For this reason it is most advantageous to develop a system of controls that are similar in structure but can also be adjusted as necessary to meet the specific needs of each watershed. The need for balance between these two important concepts has lead to the system of stormwater control criteria contained within this Plan.

A broad and uniform approach has been developed for implementation of water quality, volume control, and channel protection controls. These criteria have been developed with adequate latitude in implementation to be applicable to most watersheds statewide. Peak discharge rate control standards, which are unique to each watershed, have been developed to achieve watershed specific controls.

PEAK DISCHARGE RATE CONTROLS

Peak discharge rate controls have been the primary method of implementing stormwater management controls for many years. However, peak rate controls are generally applied to individual sites with little to no consideration given to how the site discharge impacts overall stream flows. It is necessary to consider the cumulative effects of site level peak rate controls, and their contribution to the overall watershed hydrology, in order to control regional peak flows. This is accomplished through mathematical modeling of the watershed. The intent of the modeling is to analyze the flow patterns of the watershed, the impact of development on those patterns, and, if necessary, develop a release rate for various subwatersheds such that the rate of release of the increased volumes of runoff generated is not detrimental to downstream areas.

In some subbasins, it is necessary to implement strict release rates that require sites to discharge at flows much lower than those calculated for pre-development flows. This is due to the timing of the peak flows from all of the subbasins, and how flows from the subbasin in question impact the overall stream flows. Variable release rates for subbasins throughout a watershed are an important part of achieving regional peak flow controls. The proposed release rates calculate no peak flow increase above the existing condition peak flows at any point throughout the county watersheds. Strict release rates for the more frequent design storms are necessary to meet this criterion in some subwatersheds. The proposed release rates for this Plan fall into two categories:

1. Areas not covered by a Release Rate Map:

   Post-development discharge rates shall not exceed the predevelopment discharge rates for the 2-, 10-, 25-, 50-, and 100-year storms. If it is shown that the peak rates of discharge indicated by the post-development analysis are less than or equal to the peak rates of discharge indicated by the pre-development analysis for 2-, 10-, 25-, 50-, and 100-year, 24-hour storms, then the requirements of this section have been met. Otherwise, the applicant shall provide additional controls as necessary to satisfy the peak rate of discharge requirement.

2. Areas covered by a Release Rate Map:

   For the 2-, 10-, 25-, 50-, and 100-year storms, the post-development peak discharge rates will follow the applicable approved release rate maps. For any areas not shown on the release rate maps, the post-development discharge rates shall not exceed the predevelopment discharge rates.

VOLUME CONTROLS

Developed sites experience an increased volume of runoff during all precipitation events. The increased volume of stormwater is the cause of several related problems such as increased chanel erosion, increased main channel flows, and reduced water available for groundwater recharge. Reducing the total volume of runoff is key in minimizing the impacts of development. Volume reduction can be achieved through reuse, infiltration, transpiration, and evaporation. When infiltration is used as a stormwater management technique, multiple goals are achieved through implementation of a single practice. Infiltrating runoff reduces release rates, reduces release volumes, increases groundwater recharge, and provides a level of water quality improvement. These opportunities will be provided by use of Best Management Practices (BMPS) such as infiltration structures, replacement of pipes with swales, and disconnecting roof drains. Other methods that may be used are decreased impervious cover, maximizing open space, and preservation of soils with high infiltration rates.

The proposed volume controls for this Plan include two pieces:

1. Reduction of runoff generated through utilization of low impact development practices to the maximum extent practicable.

2. Permanent removal of a portion of the runoff volume generated from the total runoff flow.

The permanent removal of runoff volume is to be achieved through one of three available methods:

1. *The Design Storm Method* (CG-1 in the SWM Manual[1]) is applicable to any size of Regulated Activity. This method requires detailed modeling based on site conditions.

   A. Do not increase the post-development total runoff volume for all storms equal to or less than the 2-year 24-hour duration precipitation.

   B. For modeling purposes:

      i) Existing (pre-development) non-forested pervious areas must be considered meadow or its equivalent.

      ii) Twenty percent of existing impervious area, when present, shall be considered meadow in the model for existing conditions.

2. *The Simplified Method* (CG-2 in the SWM Manual[1]) provided below is independent of site conditions and should be used if the Design Storm Method is not followed. This method is not applicable to Regulated Activities greater than one acre or for projects that require design of stormwater storage facilities. For new impervious surfaces:

   A. Stormwater facilities shall capture at least the first two inches of runoff from all new impervious surfaces.

   B. At least the first one inch of runoff from new impervious surfaces shall be permanently removed from the runoff flow -- i.e. it shall not be released into the surface waters of this Commonwealth. Removal options include reuse, evaporation, transpiration, and infiltration.

   C. Wherever possible, infiltration facilities should be designed to accommodate infiltration of the entire permanently removed runoff; however, in all cases at least the first one-half inch of the permanently removed runoff should be infiltrated.

   D. This method is exempt from the requirements of Section 304, Rate Controls.

3. Alternatively, in cases where it is not possible, or desirable, to use infiltration-based best management practices to partially fulfill the volume control requirements the following procedure shall be used:

   A. The following water quality pollutant load reductions will be required for all disturbed areas within the proposed development:

Pollutant Load	Units	Required Reduction (%)
Total Suspended Solids (TSS)	Pounds	85
Total Phosphorous (TP)	Pounds	85
Total Nitrate (NO_3)	Pounds	50

   B. The performance criteria for water quality best management practices shall be determined from the *Pennsylvania Stormwater Best Management Practices Manual*, most current version (DEP, 2006).

WATER QUALITY CONTROLS

Urban runoff is one of the primary contributors to water pollution in developed areas. The most effective method for controlling non-point source pollution is through reduction, or elimination, of the sources. However, it is not reasonable to assume that all sources of pollution can be reduced or eliminated. For this reason, implementation of natural and engineered systems must be used to achieve the desired results. The water quality control standards will be achieved through the use of various BMPs to reduce the sources of water pollution and treat those that cannot be eliminated.

A combination of source reduction measures through non-structural BMPs and water quality treatment through use of structural BMPs is the proposed water quality control strategy of this Plan. Reducing the amount of runoff to be treated is the preferred strategy to meet this goal:

- Minimize disturbance to floodplains, wetlands, natural slopes over 8%, and existing native vegetation.
- Preserve and maintain trees and woodlands. Maintain or extend riparian buffers and protect existing forested buffer. Provide trees and woodlands adjacent to impervious areas whenever feasible.
- Establish and maintain non-erosive flow conditions in natural flow pathways.
- Minimize soil disturbance and soil compaction. Over disturbed areas, replace topsoil to a minimum depth equal to the original depth or four inches, whichever is greater. Use tracked equipment for grading when feasible.
- Disconnect impervious surfaces by directing runoff to pervious areas, wherever possible.

Treating the runoff that cannot be eliminated is the secondary strategy for attaining the water quality standards. By directing runoff through one or more BMPs, runoff will receive some treatment for water quality, thereby reducing the adverse impact of contaminants on the receiving body of water.

CONTROLS FOR ROADWAY PROJECTS

For purposes of Act 167 Stormwater Management Plans (Plans), design policy pertaining to stormwater management facilities for Pennsylvania Department of Transportation (PennDOT), and Pennsylvania Turnpike Commission (PTC) roadways and associated facilities are provided in Sections 13.7 (Antidegradation and Post Construction Stormwater Management Policy) of *PennDOT Publication No. 13M, Design Manual Part 2* (August 2009), as developed, updated, and amended in consultation with DEP. As stated in DM-2.13.7.D (Act 167 and Municipal Ordinances), PennDOT and PTC roadways and associated facilities shall be consistent with Act 167 Plans. DM-2.13.7.B (Policy on Antidegradation and Post Construction Stormwater Management) was developed as a cooperative effort between PennDOT and DEP. DM-2.13.7.C (Project Categories) discusses the anticipated impact on the quality, volume, and rate of stormwater runoff.

Where standards in Act 167 Plans are impracticable, PennDOT or PTC may request assistance from DEP, in consultation with the County, to develop an alternative strategy for meeting state water quality requirements and the goals and objectives of the Act 167 Plans.

Municipal roadway projects are regulated by municipal stormwater ordinances but Municipalities are exempt from the requirement to file an Operations and Maintenance (O&M) agreement with themselves.

For purposes of this Act 167 Plan, road maintenance activities are regulated under 25 Pa Code Chapter 102.

RECOMMENDED BEST MANAGEMENT PRACTICES

As previously stated, the preferred strategy for achieving the goals of this plan is to reduce or eliminate the sources of non-point source pollution. "The treatment of runoff is not as effective as the removal of runoff needing treatment" (Reese, 2009). This is an important concept, in that the most effective way to reduce the number of stormwater runoff problems is to reduce the amount of runoff generated. There are a wide variety of non-structural practices that are used to reduce the amount of runoff generated and to minimize the potential negative impacts of runoff that is generated. All of these BMPs are intended to minimize the interruption of the natural hydrologic cycle caused by development. The relative effectiveness of each non-structural BMP listed in the *Pennsylvania Stormwater Best Management Practices Manual* in *Table 7.1* below. These practices should be used where applicable to decrease the need for less cost effective structural BMPs.

Non-Structural Best Management Practice	Stormwater Functions[1]			
	Peak Rate Control	Volume Reduction	Recharge	Water Quality
Protect Sensitive/Special Value Features	Very High	Very High	Very High	Very High
Protect/Conserve/Enhance Riparian Areas	Low/Med.	Medium	Medium	Very High
Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design	Med./High	Low/Med.	Low	Medium
Cluster Uses at Each Site; Build on the Smallest Area Possible	Very High	Very High	Very High	Very High
Concentrate Uses Areawide through Smart Growth Practices	Very High	Very High	Very High	Very High
Minimize Total Disturbed Area – Grading	High	High	High	High
Minimize Soil Compaction in Disturbed Areas	High	Very High	Very High	Very High
Re-Vegetate and Re-Forest Disturbed Areas using Native Species	Low/Med.	Low/Med.	Low/Med.	Very High
Reduce Street Imperviousness	Very High	Very High	Very High	Medium
Reduce Parking Imperviousness	Very High	Very High	Very High	High
Rooftop Disconnection	High	High	High	Low
Disconnection from Storm Sewers	High	High	High	Low
Streetsweeping	Low/None	Low/None	Low/None	High

NOTES:
[1] All Stormwater function values from *PA Stormwater BMP Manual*

Table 7.1. Stormwater Functions of Structural Best Management Practices

When non-structural practices are unable to achieve the stormwater standards, it may be necessary to employ structural practices. Generally, structural BMPs are chosen to address specific stormwater functions. Some BMPs are better suited for particular stormwater functions than others. The relative effectiveness of structural BMPs at addressing individual stormwater functions varies, as shown in *Table 7.2*. This table contains all of the structural BMPs listed in the *Pennsylvania Stormwater Best Management Practices Manual* and their stated effectiveness for

each stormwater function. Additional information on each practice can be found in the *Pennsylvania Stormwater Best Management Practices Manual*.

Structural Best Management Practice	Stormwater Functions[1]			
	Peak Rate Control	Volume Reduction	Recharge	Water Quality
Porous Pavement with Infiltration Bed	Medium	Medium	Medium	Medium
Infiltration Basin	Med./High	High	High	High
Subsurface Infiltration Bed	Med./High	High	High	High
Infiltration Trench	Medium	Medium	High	High
Rain Garden/Bioretention	Low/Med.	Medium	Med./High	Med./High
Dry Well/Seepage Pit	Medium	Medium	High	Medium
Constructed Filter	Low-High*	Low-High*	Low-High*	High
Vegetated Swale	Med./High	Low/Med.	Low/Med.	Med./High
Vegetated Filter Strip	Low	Low/Med.	Low/Med.	High
Infiltration Berm and Retentive Grading	Medium	Low/Med.	Low	Med./High
Vegetated Roof	Low	Med./High	None	Medium
Rooftop Runoff – Capture and Reuse	Low	Med./High	Low	Medium
Constructed Wetland	High	Low	Low	High
Wet Pond / Retention Basin	High	Low	Low	Medium
Dry Extended Detention Basin	High	Low	None	Low
Water Quality Filter	None	None	None	Medium
Riparian Buffer Restoration	Low/Med.	Medium	Medium	Med./High
Landscape Restoration	Low/Med.	Low/Med.	Low/Med.	Very High
Soils Amendment and Restoration	Medium	Low/Med.	Low/Med.	Medium

NOTES:
[1] All Stormwater function values from *PA Stormwater BMP Manual*
[2] Depends on if infiltration is used

Table 7.2. Stormwater Functions of Structural Best Management Practices

The table above shows the qualitative effect of individual BMPs when used as stand alone treatment practices. The overall effectiveness of a stormwater system can be improved when several, smaller BMPs are dispersed throughout a given site. The combination of different BMPs enables each BMP to complement each other by providing a particular stormwater function then allowing the runoff to pass downstream to another BMP that is used to address different criteria. This allows designers to better mimic the site's existing hydrologic features, which are not typically isolated to one area of the site. The "treatment train" system of utilizing multiple BMPs on a single site is an effective technique that, in some cases, may be used to meet all of the stormwater criteria.

Several of the structural BMPs are particularly effective at achieving the criteria for control of stormwater presented in this Plan. The following practices should be considered where appropriate:

RAIN GARDENS & BIORETENTION

A rain garden, also referred to bioretention, is an excavated shallow surface depression planted with native, water-resistant, drought and salt tolerant plants with high pollutant removal potential that is used to capture and treat stormwater runoff. Rain gardens treat stormwater by collecting and pooling water on the surface and allowing filtering and settling of suspended solids and

sediment prior to infiltrating the water. Rain gardens are generally constructed to provide 12 inches or less of pending depth with shallow side slopes (3:1 max). They are designed to reduce runoff volume, filter pollutants and sediments through the plant material and soil particles, promote groundwater recharge through infiltration, reduce stormwater temperature impacts, and enhance evapotranspiration. Their versatility has proved extremely successful in most applications including urban and suburban areas (Pennsylvania Stormwater Best Management Practices Manual, 2006).

Construction of rain gardens varies depending on site specific conditions. However, they all contain the same general components: appropriate native vegetation, a layer of high organic content mulch, a layer of planting soil, and an overflow structure. Often times, an infiltration bed is added under the planting soil to provide additional storage and infiltration volume. Also, perforated pipe can be installed under the rain garden to collect water that has filtered through the soil matrix and convey it to other stormwater facilities. Rain gardens can be integrated into a site with a high degree of flexibility and can be used in coordination with a variety of other structural best management practices. They can also enhance the aesthetic value of a site through the selection of appropriate native vegetation.

DRY WELL/ROOF SUMP

A dry well, sometime referred to as a roof sump, is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from the roofs of structures. Roof runoff is generally considered "clean" runoff, meaning that it contains few or no pollutants. However, roofs are one of the primary sources of increased runoff volume from developed areas. This runoff is ideal for infiltration and replenishment of groundwater sources due to the relatively low concentration of pollutants. By decreasing the volume of stormwater runoff, dry wells can also reduce runoff rate thereby improving water quality.

Roof drains are connected directly into the dry well, which can be an excavated pit filled with uniformly graded aggregate wrapped in geotextile or a prefabricated storage chamber. Runoff is collected during rain events and slowly infiltrated into the surrounding soils. An overflow mechanism such as an overflow outlet pipe, or connection to an additional infiltration area, is provided as a safety measure in the event that the facility is overwhelmed by extreme storm events or other surcharges (Pennsylvania Stormwater Best Management Practices Manual, 2006). Dry wells are not recommended within a specified distance to structures or subsurface sewage disposal systems.

VEGETATED SWALES

Vegetated swales are broad, shallow channels, densely planted with a diverse selection of native, close-growing, water-resistant, drought and salt tolerant plants with high pollutant removal potential. Plant selection can include grasses, shrubs, or even trees. These swales are designed to slow runoff, promote infiltration, and filter pollutants and sediments while conveying runoff to additional stormwater management facilities. Swales can be trapezoidal or parabolic, but should have broad bottoms, shallow side slopes (3:1 to 5:1 ratio), and relatively flat longitudinal slopes (1-6%). Check-dams can be utilized on steeper slopes to reduce flow velocities. Check-dams can also provide limited detention storage and increase infiltration volume. Vegetated swales provide many benefits over conventional curb and gutter conveyance systems. They reduce flow velocities, provide some flow attenuation, provide increased opportunity for infiltration, and providing some level of pretreatment by removing sediment, nutrients and other pollutants from runoff. A key feature of vegetated swales is that they can be integrated into the landscape character of the surrounding area. They can often enhance the aesthetic value of a site through the selection of appropriate native vegetation.

A vegetated swale typically consists of a band of dense vegetation, underlain by at least 24 inches of permeable soil. Swales constructed with an underlying 12 to 24 inch aggregate layer provide significant volume reduction and reduce the stormwater conveyance rate. The permeable soil media should have a minimum infiltration rate of 0.5 inches per hour and contain a high level of organic material to enhance pollutant removal. A nonwoven geotextile should completely wrap the aggregate trench (Pennsylvania Stormwater Best Management Practices Manual, 2006). There are several variations of the vegetated swale that include installing perforated pipe under the swale to collect water that has filtered through the soil matrix and convey it to other stormwater facilities or combining the swale with an infiltration bed to provide additional infiltration volume.

SUBSURFACE INFILTRATION FACILITIES

Subsurface infiltration beds are created by placing storage facilities below the proposed surface grade that collects stormwater and provides temporary storage and allows water to slowly infiltrate. Infiltration facilities are designed to provide significant volume reduction through temporary storage and infiltration, which also benefits peak rate control and water quality. Subsurface beds are ideally suited for expansive, generally flat open spaces, such as lawns, playfields, and other recreational areas (DEP, 2006). These systems are also well suited for cold climates as they can function year-round if constructed below the frost line.

An infiltration bed usually consists of a layer of highly pervious planting soil and vegetation, underlain by a storage facility. Storage can be provided by an excavated pit filled with uniformly graded aggregate wrapped in geotextile or a prefabricated storage chamber. An overflow structure should be included to provide protection in case of extreme storm events or system failure. Additionally, inspection ports are often added to ease monitoring and maintenance. The bottom of the infiltration bed must be level and distribution systems must be added to larger facilities to ensure that water is infiltrated evenly over the entire surface area. The soil layer and vegetation provide water quality through filtration and increase evapotranspiration. A popular variation of this facility is an infiltration trench, which is the same concept applied as a linear facility. Infiltration trenches are often more shallow than infiltration beds and are designed for smaller flows than infiltration beds. These facilities provide groundwater recharge while also preserving or creating valuable open space and recreation areas.

IMPLEMENTATION OF STORMWATER MANAGEMENT CONTROLS

From a regulatory perspective, the standards and criteria developed in this Plan will be implemented through municipal adoption of the Model Stormwater Management Ordinance developed as part of the Plan. The Model Ordinance contains provisions to realize the standards and criteria outlined in this section. Providing uniform stormwater management standards throughout the county is one of the stated goals of this Plan. This goal will be achieved through adoption of the Model Ordinance by all of the municipalities in Butler County.

From the pragmatic development viewpoint, the stormwater management controls will be put into practice through use of comprehensive stormwater management site planning and various stormwater BMPs. Site designs that integrate a combination of source reducing non-structural BMPs and runoff control structural BMPs will be able to achieve the proposed standards. A design example has been included in *Section VIII* and *Appendix B* to demonstrate how to incorporate the various aspects of the Model Ordinance into the stormwater management design process.

Section VIII – Economic Impact of Stormwater Management Planning



IMPLEMENTATION OF STORMWATER STANDARDS

The economic impact of managing urban stormwater runoff is a major concern. For example, the U.S. EPA has estimated the costs of controlling combined sewer overflows (CSO) throughout the U.S. at approximately $56 billion (MacMullan and Reich, 2007). Developing and implementing stormwater management programs and urban-runoff controls will cost an additional $11 to $22 billion (Kloss and Calarusse, 2006). There are direct economic impacts associated with implementation of stormwater management regulations, regardless of the type of stormwater control standards that are proposed. The design example provided in this section has been developed to highlight a site design approach that can reduce the costs of employing the proposed stormwater management control measures and, at the same time, maximize the benefits they are intended to provide. The design example is compared to a similar site design that uses traditional peak rate stormwater controls in order to provide an illustration of the direct economic impact of the proposed regulations using initial construction costs.

Site planning that integrates comprehensive stormwater management into the development process from the initial stages often results in efficiencies and cost savings. Examples of efficiencies include: reduction in area necessary for traditional detention basins; less redesign to retrofit water quality and infiltration measures into a plan; and reduced costs for site grading and preparation. Planning for stormwater management early in the development process may decrease the size and cost of structural solutions since nonstructural alternatives are more feasible early in the process. In the vast majority of cases, the U.S. EPA has found that implementing well-chosen LID practices, like the proposed stormwater management methods, saves money for developers, property owners, and communities while protecting and restoring water quality (EPA, 2007).

DESIGN EXAMPLE 1

The following design example illustrates the methods used to design stormwater management facilities and structural BMPs in accordance with the volume and peak rate control strategies developed within this Plan. The design process encouraged by the *PA BMP Manual* is used to determine non-structural BMP credits and perform the calculations necessary to determine if the requirements of the *Model Ordinance* have been met. The 2-year, 24-hour storm event is utilized to illustrate the methods used to meet the volume requirements of the Ordinance. The SCS Runoff Curve Number Method is used for runoff volume calculations as suggested by the *PA BMP Manual*. Refer to this document for additional guidance, rules and limitations applicable to these methods, and the design of structural and non-structural BMPs.

For the following example, LID techniques are utilized to address the volume control and rate control requirements of the *Model Ordinance*. The example addresses these requirements for the entire development, not any single lot, thereby superseding the requirements of the *Small Project Stormwater Management Application*.

PRE-DEVELOPMENT CONDITIONS

The design example is a 10-lot single family residential subdivision on an 8.1 acre parcel with a total drainage area of 9.78 acres. The existing land use is partially wooded (2.29 acres) with a fallow agricultural field covering the remaining acreage. The entire site is tributary to the hypothetical stream known as Mill Run, which flows near the back of the property. All on-site soils are classified in hydrologic soil group B.

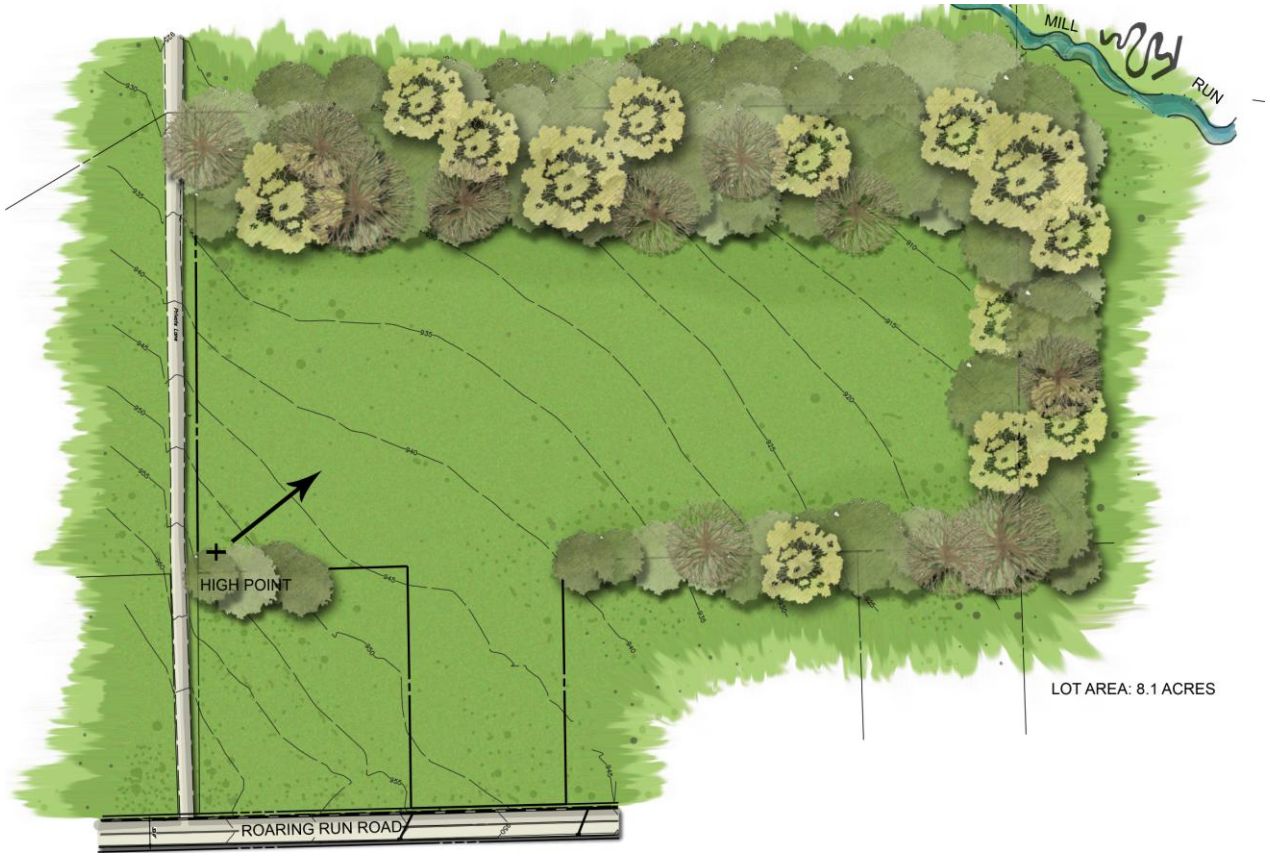


Figure 8.1. Design Example 1 – Pre-Development Conditions

Watershed:	Mill Run
Total Drainage Area:	9.78 acres
Existing Land Use:	Meadow = 7.49 acres
	Woods = 2.29 acres
Hydrologic Soil Group:	'B' – Entire Site
Parcel Size:	8.1 acres
On-Site Sensitive Natural Resources:	Woods (2.18 acres)
Pre-Development Drainage Area:	Meadow = 7.12 acres
	Woods = 0.98 acres
	Total = 8.10 acres

Table 8.1. Pre-Development Data

POST-DEVELOPMENT CONDITIONS

All of the lots will be accessed by a single cul-de-sac road to be constructed for the subdivision. Each house has an assumed 2,150-sf impervious footprint. Various LID techniques were used in the site design. A large portion of the existing woodlands (1.31 acres) was preserved during construction and will remain wooded through a permanent easement on lots 6-9, the back portion of lots 9-10 were protected from compaction during construction and will remain protected through an easement, roof drains are disconnected from the storm sewer system and directed to dry wells, and rain gardens will be installed on each lot. Runoff from the roadway is collected by swales and conveyed to a bioretention area.



Figure 8.2. Design Example 1 – Post-Development Conditions

Proposed Land Use:	Meadow = 1.61 acres
	Woods = 1.32 acre
	Open Space = 5.43 acres
	Impervious = 1.13 acres
	Ponds as Impervious = 0.31 acres
Protected Sensitive Natural Resources:	Woods (1.31 acre)
Other Protected Areas:	Minimum Disturbance (0.37 acre)
Post-Development Drainage Area:	SWM Area = 7.74 acres
	Undetained = 0.36 acres
	Total = 8.10 acres
Proposed Lot Impervious Areas:	2,150 ft^2 / house
	1,000 ft^2 / lot

Table 8.2. Post-Development Data

DESIGN PROCESS FOR VOLUME CONTROLS

The following is a summary of the design process used for implementation of the volume control and rate control requirements of the *Model Ordinance*. This is an outline of the sequence of steps that are used to implement the *Design Storm Method* through a combination of Non-Structural BMP Credits and Structural BMPs that remove volume through infiltration. Detailed calculations and example Worksheets are provided in *Appendix B* for additional clarification of the design process.

Step 1

The first task of the design process is to gather the pertinent site information as it relates to stormwater management. This general information determines which Model Ordinance provisions are applicable to the stormwater management design for the project. *Worksheet 1* is used for this task.

Step 2

The next step is to determine the sensitive natural resources that are present on the site. *Worksheet 2* is used to inventory these resources. These areas should be considered as the site layout is determined, and should be protected to the maximum extent practicable (MEP).

Step 3

As the site layout is being completed, thought should be given to which non-structural BMPs are appropriate for the site in order to reduce the need for stormwater management through structural BMPs. Once the site layout has been finalized and non-structural BMPs have been determined, the designer can begin the stormwater management calculations. The first calculation is to determine the "Stormwater Management Area". This is the land area that must be evaluated for volume of runoff in both pre-development and post-development conditions. Sensitive natural resources that have been protected are not used in the ensuing pre- or post-development volume calculations, just as one would not incorporate offsite areas into volume calculations. The top of *Worksheet 3* shows this information. In the example, the acre of protected woodland is removed from the Stormwater Management Area. This will reduce cost by reducing the total volume needed in the peak-rate management facility.

Step 4

The next step is to calculate the volume "credits" for the non-structural BMPs that have been incorporated into the design. This reduces the total volume that is required to be infiltrated by structural BMPs. There are three practices used in the example: a meadow area and a lawn area have been protected from soil compaction and roof drains have been disconnected from the storm sewer system. The areas protected from compaction facilitate higher infiltration rates and disconnecting the roof leaders for the storm sewer system allows infiltration of some stormwater as it flows across the pervious surface. These calculations are completed on *Worksheet 3*.

The total non-structural credits are limited to 25% of the total required infiltration volume. This does not limit the amount of practices that can be implemented, only the amount of credit that can be used to reduce the total required infiltration volume. The total credits calculated must be checked to ensure the 25% threshold has not been exceeded.

Step 5

Worksheet 4 is completed to calculate the difference in the 2-year, 24-hour storm event runoff volume from pre-development conditions to post-development conditions. The 2-year, 24-hour storm event volume increase, minus the volume credits for non-structural BMPs, represents the volume that must be managed through structural BMPs.

Step 6

Determine the type of structural BMPs that may be appropriate for the site and decide which practices will be used. Use *Worksheet 5.A* to calculate the volume of water that will be infiltrated by each BMP. *Worksheet 5* is used to summarize the volume that will be infiltrated through structural practices. If the total structural volume is greater than (or equal to) the required volume, the volume control requirements of the *Model Ordinance* have been met.

Summary of Results

The design process outlined above was followed to design the facilities necessary to meet the volume control and peak rate control requirements of the *Model Ordinance*. The total required permanently removed volume is 12,599 ft^3. A summary of the results for Design Example 1 is provided in the table below:

Description of Stormwater Best Management Practice	Size (ft^3)	Volume Credit (ft^3)
Minimum Soil Compaction	16,200	337
Disconnect Non-Roof Impervious to Vegetated Areas	10,000	278
Total Non-Structural Volume:		615
On-Lot Rain Gardens (10)	6,740	5,049
On-Lot Dry Wells (10)	4,400	5,787
Bioretention	5,175	3,778
Total Structural Volume:		14,613
Total Volume Removed:		**15,228**

Table 8.3. Summary of BMP Credits

DESIGN OF PEAK RATE CONTROLS

In this example, additional stormwater control facilities are necessary to manage the increase in peak rate flows that would otherwise result from the development activities. Peak rate control facilities are designed to reduce post-development peak flows to, or below, pre-development peak flows. In release rate districts, post-development flows are further reduced to a given percentage of the pre-development peak flows. Design of peak rate controls necessitates flood routing, for which a flood hydrograph is required (PennDOT, 2008). A suitable hydrologic method is needed to generate runoff hydrographs for flood routing.

The Rational Equation (i.e., Q = C x I x A) was originally developed to estimate peak runoff flows. The Modified Rational Method is an adaptation of the Rational Method which is used to estimate runoff hydrographs and volumes. While this method is useful for estimating peak flows from relatively small, highly developed drainage areas, various sources document the shortcomings of this method in developing hydrographs and estimating volume (PennDOT, 2008; DEP 2006). For this reason, use of the Rational Method is strongly discouraged for the volume-sensitive routing calculations necessary tor design detention facilities and outlet controls.

The SCS Unit Hydrograph Method was developed to be used in conjunction with the Curve Number Runoff Method of generating runoff depths to estimate peak runoff rates and runoff hydrographs. While these methods have numerous limitations, the principle application of this method is in estimating runoff volume in flood hydrographs, or in relation to flood peak rates (NRCS, 2008). Therefore, the NRCS Rainfall-Runoff Method (i.e. using the Curve Number Runoff Method and SCS Unit Hydrograph Method together to produce rainfall-runoff response estimates) is the preferred method to calculate runoff peak rates and for rate control facility design calculations.

Various computer software programs are available for modeling rainfall-runoff simulations to perform peak rate control analyses for development projects. Most of the available computer modeling software is based on the NRCS Rainfall-Runoff Method. These models include the U.S. Army Corps of Engineers' Hydrologic Modeling System (HEC-HMS), SCS/NRCS Technical Release No. 20: Computer Program for Project Formulation Hydrology (TR-20) and Technical Release 55 (TR-55), NRCS National Engineering Handbook 650, Engineering Field Handbook, Chapter 2 (EFH2), and U.S. Environmental Protection Agency's Storm Water Management Model (SWMM). These modeling packages are further described in the *Pennsylvania Stormwater BMP Manual* (2006). There are also a variety of other commercially available software packages that complete many of the same functions. Designers should be careful when determining which software should be used to model a particular project to ensure that appropriate methods are being used (i.e., review the modeling method restrictions contained in the *Model Ordinance*).

DESIGN PROCESS FOR PEAK RATE CONTROLS

The peak rate analysis is carried out by completing a comparison of the post-development runoff peak rate to the pre-development runoff peak rate to determine if the rate controls of the *Model Ordinance* have been satisfied. Additional stormwater facilities, such as a detention basin and outlet structure, may be necessary to reduce post-development peak flow rates to the required peak flow rates. The volume of runoff removed by BMPs should be removed from the total runoff volume when completing peak rate calculations. This is necessary in order to size peak rate control facilities appropriately.

Step 1

The first step is to delineate the pre-development drainage area. This area should include all areas that will be tributary to any proposed stormwater facilities, including any off-site area. Any areas on site that have no proposed land-use changes, and are not tributary to the proposed stormwater facilities, can be removed from the drainage areas. Once the drainage area has been delineated, determine the soil-cover complex and the corresponding curve number for each subarea. If the drainage area contains multiple soil-cover complexes, the designer must determine the appropriate runoff estimation method. (A comparison of the two most prevalent methods is covered in *Appendix B*).

Step 2

The next step is to determine a time of concentration for the pre-development drainage area(s). The *Model Ordinance* requires use of the NRCS Lag Equation for all pre-development time of concentration calculations unless another method is pre-approved by the Municipal Engineer. The average watershed land slope of the pre-development drainage area(s) must be calculated for use in the Lag Equation.

Step 3

Use the information from the previous two steps to calculate the pre-development peak runoff rates for each design storm. Use design storm rainfall depths from NOAA Atlas 14

specific to the area of interest, or the values provided in the *Model Ordinance*. Any appropriate method of estimating peak runoff rates and runoff hydrographs can be used; however use of hydrologic modeling software is the most common method.

Step 4

Delineate the post-development drainage area(s) and any sub-areas. Post-development sites generally have several drainage sub-areas with multiple soil-cover complex groups in each subarea. The designer must determine a suitable level of detail to be included in the post-development model based on the site design and site conditions. The runoff estimation method chosen for multiple soil-cover complexes should be appropriate for the level of detail that is modeled.

Step 5

Determine T_C values for the post-development drainage area(s). The NRCS Segmental Method is the preferred method for all post-development T_C calculations. The Segmental Method is used to calculate travel times for individual segments of sheet flow, shallow concentrated flow, and open channel flow which are summed to calculate the T_C. The *Model Ordinance* allows the NRCS Lag Equation to be used for residential, cluster, or other low impact designs less than or equal to 20% impervious area.

Step 6

Use the information from the previous two steps and relevant stormwater facility information (e.g. BMP size and outlet configuration, detention facility stage-discharge data, etc.) to calculate the post-development peak runoff rates for each design storm. This is most often done by using hydrologic modeling software to develop a model of the post-development site, which is used to estimate peak runoff rates and runoff hydrographs.

The hydrologic model is used to finalize the design of the peak rate control facilities such as the detention basin and the outlet control structure. Steps 4-6 must be revisited whenever additional BMPs are added or moved or any change to the site design alters drainage areas.

Summary of Results

For this example, the peak rate control analysis was completed with hydrologic modeling software that is based on TR-20 modeling procedures. Every component of the stormwater design (including each structural BMP) was included in the model. This helped account for peak flow attenuation and permanent volume removal that was provided by the BMPs. The runoff volume removed by the BMPs was removed from the total runoff volume by using an option within the software. A detention basin providing 8,600 ft^3 of storage (plus the required freeboard depth) and associated outlet controls was necessary to reduce the 100-year post-development peak rate flows to the pre-development flow rate. If the effects of the individual BMPs had been ignored in the post-development model, the design would have needed a basin that provided 23,850 ft^3 of storage (plus the required freeboard depth) to achieve the required flow reduction for the 100-year storm. As shown in *Table 8.4* the peak rate control requirements of the *Model Ordinance* have been achieved.

	Design Storm					
	1-year	2-year	10-year	25-year	50-year	100-year
Pre-Development	0.1	0.6	4.1	7.6	11.1	15.3
Post-Development with No SWM	2.5	5.2	14.5	21.9	28.8	36.6
Post-Development	0.1	0.4	4.1	7.4	10.6	15.3

Table 8.4. Summary of Peak Rate Flows

ECONOMIC IMPACT OF STORMWATER MANAGEMENT STANDARDS

Stormwater management standards are necessary to mitigate the adverse affects of increased stormwater runoff from developing areas. Implementation of these standards comes at a cost to regulators and developers alike. These costs are only a fraction of the costs associated with mitigating mismanaged or unmanaged runoff. Since activities within a watershed do not always exhibit a direct and measurable cause and effect relationship, identifying some of the costs associated with stormwater management can be difficult and somewhat subjective. It can be similarly difficult to quantify certain costs and altogether impossible to assign an economic value to outcomes such as environmental benefits.

There are three principle methods available to assess the economics of implementing the proposed stormwater management regulations:

1. Cost Comparison – This is the most basic type of analysis. It is completed by comparing initial construction costs and other direct costs, such as land value. This type of analysis is incomplete in scope in that it captures the benefits of improved stormwater management or variances in life-cycle costs, such as O&M and life expectancy.

2. Life-Cycle Cost Analysis – A life-cycle cost analysis includes all costs throughout the projects period of service. This includes: planning; design; installation; O&M; and life expectancy. A life-cycle analysis gives a more complete financial comparison than a cost comparison, but again excludes the environmental and other benefits of improved stormwater management.

3. Cost-Benefit Analysis – This is the most thorough method of analysis and considers the full range of costs and benefits for each alternative. A cost-benefit analysis considers the same project costs as a life-cycle analysis, but includes the environmental and other benefits of improved stormwater management practices in the assessment. This method of analysis is very difficult because it requires valuation of costs and benefits not easily measured in monetary terms (i.e. environmental goods and services such as clean air, reduced erosion, or improved aquatic habitat). It is difficult to quantify the value of these non-market goods and services.

The amount of information required to perform a life-cycle cost or cost-benefit analysis makes use of these two methods impractical for this discussion. These methods are also complicated by the fact that costs and benefits are often realized by different parties. As an example, a developer/owner pays for initial construction costs, the owner can benefit from potential life-cycle cost savings, and the general public benefits from potential environmental benefits like improved water quality. The flexibility, availability of data, and simplicity of cost comparisons make this the most commonly used method of comparison. A cost comparison will give a relatively accurate representation of the economic impact of the initial cost of implementing the proposed stormwater management controls.

A cost comparison has been completed for two conceptual stormwater management designs to provide an example of the direct costs associated with implementation of the standards contained within this Plan. The stormwater designs are based on the site used in the Design Example. The site layout is similar for both designs to reduce the number of variables. The first plan was designed to meet traditional peak-rate stormwater management standards of reducing the post-development peak flow rates to those present in pre-development conditions for all design storms. The second plan follows the design procedures found in this Plan and meets the volume control requirements of the *Model Ordinance*.

TRADITIONAL SUBDIVISION LAYOUT WITH PEAK RATE CONTROL DESIGN

The layout for this example is typical of conventional subdivision designs. All of the existing woodlands were converted to lawns and no measures were taken to reduce impervious area (e.g. front yard setbacks were not reduced to decrease driveway lengths). The roadway has a 24' cartway with concrete curbs and there is a sidewalk on one side of the street. The traditional cul-de-sac is entirely paved. The stormwater design utilizes a conventional stormwater collection and conveyance system that uses the concrete curb to direct runoff towards inlets. An HDPE pipe network carries runoff to a detention basin which is located at the low point on the property. A swale is placed near the downstream edge of the property to collect runoff that is not tributary to the storm sewer network and convey it to the detention basin. In the detention basin, a concrete outlet structure is designed to reduce peak flow rates before discharging to an outlet pipe. A rock rip-rap apron energy dissipater is installed at the pipe outfall.

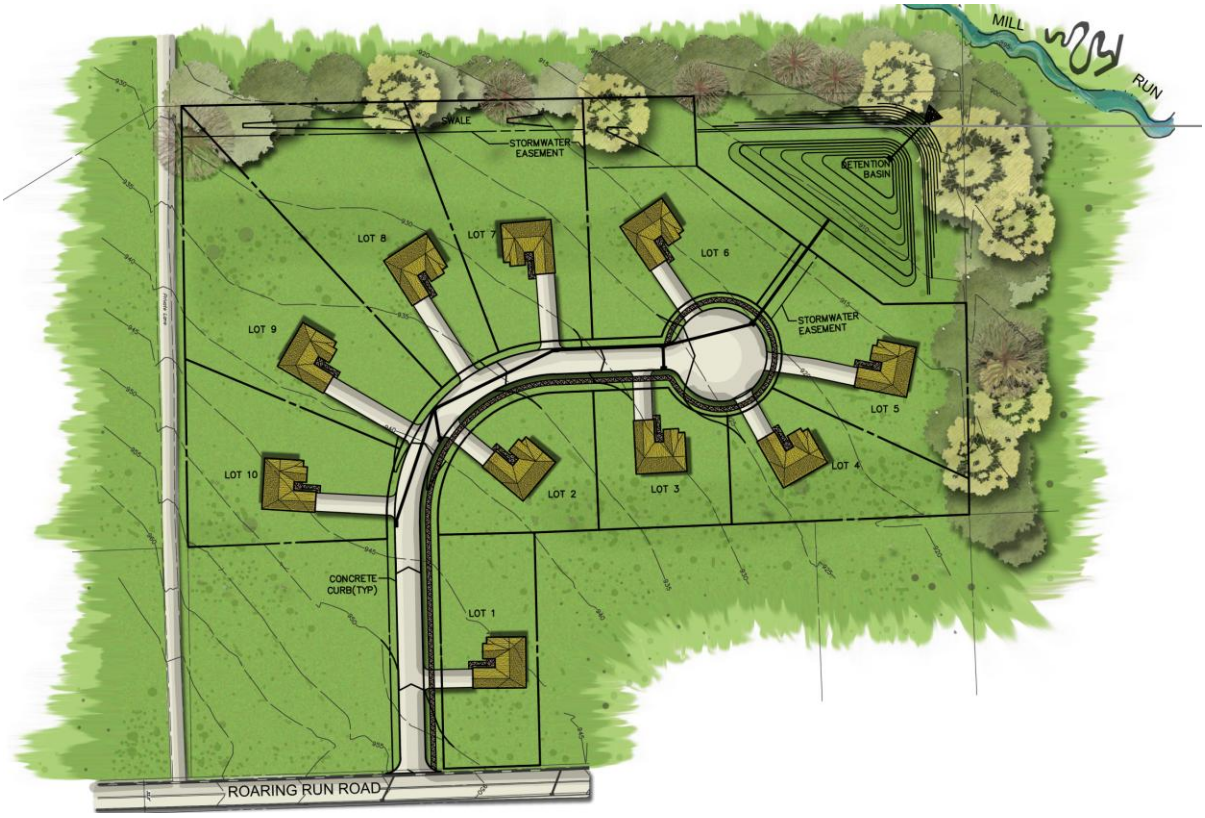


Figure 8.3. Traditional Subdivision Layout (Designed for Peak Rate Control)

LID SUBDIVISION LAYOUT WITH VOLUME CONTROL DESIGN

This design is the post-construction layout that was presented in the Design Example (see *Figure 8.2*). Several LID techniques were used to reduce runoff. This includes: reducing impervious

area; preserving existing woodlands where possible; and protecting areas from soil compaction. The roadway is reduced to an 18' cartway with 3' gravel shoulders and swales are employed to collect and convey roadway runoff. Roof runoff is directed to dry wells on each lot, rain gardens are installed on each lot to collect the runoff from on-lot impervious areas as well as part of the lawn runoff. A larger bioretention facility is used to treat runoff from common areas, such as the roadway, and remove additional runoff volume. A detention basin and concrete outlet structure is used to control the peak discharge rates. A level spreader installed at the end of the outfall serves as an energy dissipater and distributes flow.

COST COMPARISON

A cost comparison was completed for the two designs described above. This comparison consists of two components: 1) initial construction costs for the developer, and 2) land value in the form of sale price. Construction costs were calculated for only the design elements which differ between the two examples (i.e. earthwork, paving, and stormwater management facilities). Other construction costs were considered to be similar for both layouts and were omitted from the analysis. An itemized estimate of the initial construction cost is included in *Appendix* B. The results are summarized in *Table 8.5*.

Description	Traditional Layout	LID Layout
Earthwork	$ 23,950	$ 14,925
Storm Drainage	$ 102,769	$ 114,172
Paving & Curbing	$ 138,657	$ 53,790
Initial Construction Cost:	$ 265,376	$ 182,887
Cost / Sellable Acre:	$ 42,734	$ 28,355

Table 8.5. Results of Cost Comparison for Initial Construction Costs

The cost analysis performed for this example shows a cost savings of $14,379 per sellable acre in initial construction cost for the developer. These results must be combined with a land value comparison to provide a more accurate comparison.

The value of land is highly variable depending on various influencing factors. A value of $50,000/acre was assumed for this example as the cost per acre of developed land. This assumed value was used in the cost comparison to provide a more complete cost comparison. For this example, we have also assumed that some of the cost of constructing the stormwater BMPs will result in a dollar for dollar reduction in the market value of the sellable land. *Table 8.6* shows the total land sale value for each layout after subtracting the cost of BMP construction from market value.

Description	Traditional Layout	LID Layout
Total Acres For Sale	6.21	6.45
2009 Market Value / Acre	$ 50,000	$ 50,000
BMP Cost / Acre	$ 0	$ 12,682
Calculated Market Value / Acre	$ 50,000	$ 37,318
Total Land Sale Value:	$ 310,500	$ 240,701

Table B.6. Land Sale Value

A final cost comparison is completed by subtracting the initial construction cost from the land sale value to determine the cost difference between the two layouts. For this example, the developer realizes an increase in total profit of $12,690 by using the LID layout with no additional cost to individual homeowners.

Description	Traditional Layout	LID Layout
Land Sale Value	$ 310,500	$ 240,701
Initial Construction Cost	$ 265,376	$ 182,887
Total Profit for Project:	$ 45,124	$ 57,814

Table B.7. Project Profit

Discussion of Costs

The cost comparison completed for the design example resulted in similar initial construction costs for each design, with a small final cost advantage for the volume control design. The proposed methods for implementing the proposed stormwater standards can cost less to install, have lower operations and maintenance (O&M) costs, and provide more cost-effective stormwater management and water quality services than conventional stormwater management controls (MacMullan and Reich, 2007). The costs and benefits of implementing the proposed stormwater management standards can be site-specific and will vary based on the BMPs used to meet the standards and site characteristics, such as topography, soils, and intensity of the proposed development. In a 2007 report summarizing 17 case studies of developments that include LID practices, U.S. EPA concludes that "applying LID techniques can reduce project costs and improve environmental performance". The report shows total capital cost savings ranged from 15% to 80% when LID methods were used. There were a few exceptions in which LID project costs were higher than conventional stormwater management costs. All benefits and costs associated with each option must be considered to find the true cost of implementation on a particular site.

Section IX – Water Quality Impairments and Recommendations



The Clean Water Act is a series of federal legislative acts that form the foundation for protection of U.S. water resources. These include the Water Quality Act of 1965, Federal Water Pollution Control Act of 1972, Clean Water Act of 1977, and Water Quality Act of 1987. The goal of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters". Section 305(b) of the Federal Clean Water Act requires each state to prepare a Watershed Assessment Report for submission to the United States Environmental Protection Agency (EPA). The reports include a description of the water quality of all waterbodies in the state and an analysis of the extent to which they are meeting their water quality standards. The report must also recommend any additional action necessary to achieve the water quality standards, and for which waters that action is necessary.

Section 303(d) of the Act requires states to list all impaired waters not meeting water quality standards set by the state, even after appropriate and required water pollution control technologies have been applied (EPA, 2008). The law also requires that states establish priority rankings for waters on the list and develop Total Maximum Daily Loads (TMDLs) for these waters. A TMDL is the maximum amount of pollutant that a water body can receive and still safely meet the state's water quality standards for that pollutant. TMDLs are a regulatory tool used by states to meet water quality standards in impaired waterbodies where other water quality restoration strategies have not achieved the necessary corrective results.

IMPAIRED STREAMS

Pursuant to the provisions of the Clean Water Act, DEP has an ongoing program to assess the quality of waters in Pennsylvania and identify streams, and other bodies of water, that are not attaining designated and existing uses as "impaired". Water quality standards are comprised of the uses that waters can support, and goals established to protect those uses. Each waterbody must be assessed for four different uses, as defined in DEP's rules and regulations: aquatic life; fish consumption; potable water supply; and recreation.

The established goals are numerical, or narrative, water quality criteria that express the in-stream levels of substances that must be achieved to support the uses. This assessment effort is used to support water quality reporting required by the Clean Water Act. DEP uses an integrated format for the Clean Water Act Section 305(b) reporting and Section 303(d) listing in a biennial report called the "Pennsylvania Integrated Water Quality Monitoring and Assessment Report". The narrative report contains summaries of various water quality management programs including water quality standards, point source control and nonpoint source control. In addition to the narrative, the water quality status of Pennsylvania's waters is presented using a five-part characterization of use attainment status (DEP, 2008). The listing categories are:

Category 1: Waters attaining all designated uses.

Category 2: Waters where some, but not all, designated uses are met. Attainment status of the remaining designated uses is unknown because data are insufficient to categorize the water.

Category 3: Waters for which there are insufficient or no data and information to determine if designated uses are met.

Category 4: Waters impaired for one or more designated use but not needing a TMDL. These waters are placed in one of the following three subcategories:

Category 4A: TMDL has been completed.

Category 4B: Expected to meet all designated uses within a reasonable timeframe.

Category 4C: Not impaired by a pollutant and not requiring a TMDL.

Category 5: Waters impaired for one or more designated uses by any pollutant. Category 5 includes waters shown to be impaired as the result of biological assessments used to evaluate aquatic life use. Category 5 constitutes the Section 303(d) list submitted to EPA for final approval

BUTLER COUNTY IMPAIRMENTS

If a stream segment is not attaining any one of its designated uses, it is then considered to be "impaired". *Figure 9.1* shows the non-attaining stream segments in Butler County and identifies the primary source of the impairment listing.

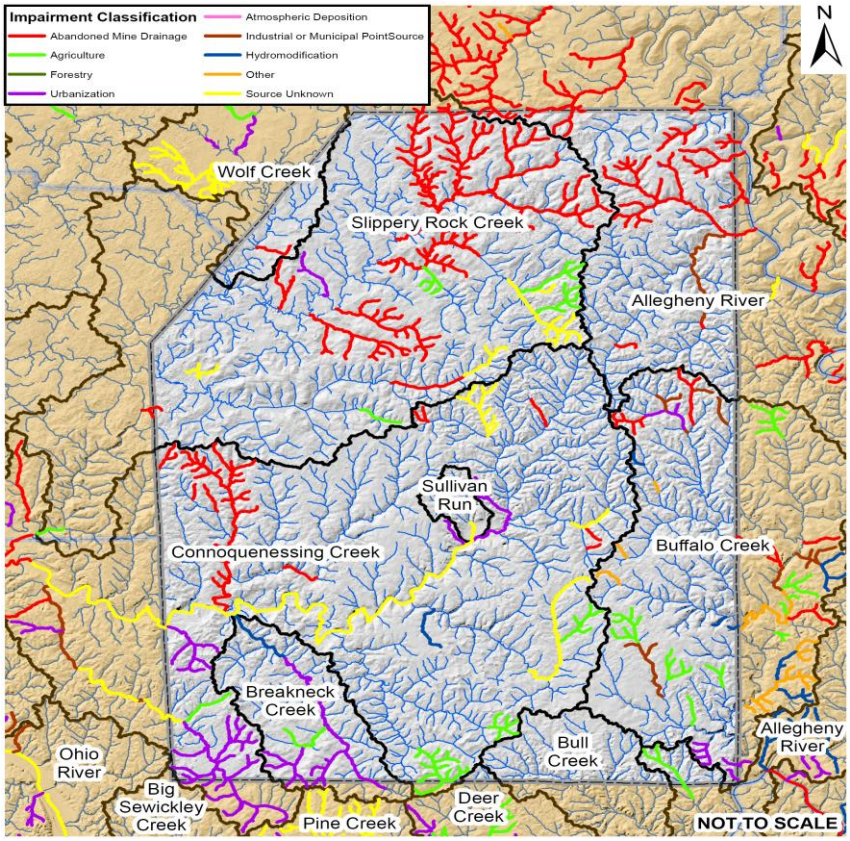


Figure 9.1. Impaired Stream Segments in Butler County

In Butler County, all of the non-attaining streams were for Aquatic Life use attainment, which is reflective of any component of the biological community (i.e. fish or fish food organisms). The source-cause of impairment varies from stream to stream. Oftentimes, there are multiple source-causes attributed for impairment of a particular stream segment. *Table 9.1* shows a summary of the primary source of impairment in each Act 167 Designated Watershed within the County. This table does not reflect streams that have multiple source-causes of impairment.

		Act 167 Watersheds (stream miles where not indicated) →									
Classification	**Category**	Allegheny River	Breakneck Creek	Buffalo Creek	Bull Creek	Connoquenessing Creek	Deer Creek	Slippery Rock Creek	Wolf Creek	Entire County	Percent of County
Impaired (miles)	Abandoned Mine Drainage	50.0	--	7.9	--	40.6	--	127.3	1.9	227.6	12.5%
	Agriculture	3.8	4.2	13.6	--	20.8	--	18.0	--	60.4	3.3%
	Atmospheric Deposition	--	--	--	--	--	--	--	--	0.0	0.0%
	Forestry	--	--	--	--	--	--	--	--	0.0	0.0%
	Hydromodification	--	--	--	--	--	--	--	--	0.0	0.0%
	Industrial or Municipal Point Source	7.4	--	9.3	--	0.2	--	--	--	17.0	0.9%
	Urbanization	--	19.2	7.5	--	41.3	--	3.3	--	71.3	3.9%
	Source Unknown	--	--	--	--	49.3	--	16.9	--	66.2	3.6%
	Other	--	6.5	4.4	--	2.8	--	--	--	13.7	0.8%
	Total Impaired	61.3	29.9	42.7	0.0	154.9	0.0	165.5	1.9	456.0	25.0%
	Percent of Total	13.4%	6.6%	9.4%	0.0%	34.0%	0.0%	36.3%	0.4%	100.0%	

Table 9.1. Summary of Impaired Segments by Watershed

Stream Name	**Source - Cause**	**Act 167 Watershed**	**Length** (miles)
UNT Allegheny River	Abandoned Mine Drainage	Allegheny River	4.99
Bear Creek	Abandoned Mine Drainage	Allegheny River	0.68
Bear Creek	Industrial or Mun. Point Source	Allegheny River	3.11
UNT Bear Creek	Abandoned Mine Drainage	Allegheny River	1.12
Fowler Run	Abandoned Mine Drainage	Allegheny River	3.36
UNT Fowler Run	Abandoned Mine Drainage	Allegheny River	2.97
Little Bull Creek	Agriculture	Allegheny River	2.85
UNT Little Bull Creek	Agriculture	Allegheny River	0.99
Little Scrubgrass Creek	Abandoned Mine Drainage	Allegheny River	2.44
UNT Little Scrubgrass Creek	Abandoned Mine Drainage	Allegheny River	3.71
Lowrey Run	Abandoned Mine Drainage	Allegheny River	2.57
UNT Lowrey Run	Abandoned Mine Drainage	Allegheny River	1.55
North Branch Bear Creek	Abandoned Mine Drainage	Allegheny River	8.45
UNT North Branch Bear Creek	Abandoned Mine Drainage	Allegheny River	14.5
UNT Scrubgrass Creek	Abandoned Mine Drainage	Allegheny River	2.68
South Branch Bear Creek	Abandoned Mine Drainage	Allegheny River	0.29

Stream Name	Source - Cause	Act 167 Watershed	Length (miles)
South Branch Bear Creek	Industrial or Mun. Point Source	Allegheny River	4.33
Thoms Run	Abandoned Mine Drainage	Allegheny River	0.69
Breakneck Creek	Other	Breakneck Creek	6.53
Breakneck Creek	Urbanization	Breakneck Creek	9.8
UNT Breakneck Creek	Urbanization	Breakneck Creek	3.54
Kaufman Run	Agriculture	Breakneck Creek	2.78
Kaufman Run	Urbanization	Breakneck Creek	2.35
UNT Kaufman Run	Agriculture	Breakneck Creek	1.4
UNT Kaufman Run	Urbanization	Breakneck Creek	3.48
Buffalo Creek	Abandoned Mine Drainage	Buffalo Creek	1.88
Buffalo Creek	Industrial or Mun. Point Source	Buffalo Creek	0.26
Buffalo Creek	Urbanization	Buffalo Creek	2.36
UNT Buffalo Creek	Abandoned Mine Drainage	Buffalo Creek	5.42
UNT Buffalo Creek	Agriculture	Buffalo Creek	1.92
UNT Buffalo Creek	Industrial or Mun. Point Source	Buffalo Creek	2.77
UNT Buffalo Creek	Urbanization	Buffalo Creek	2.07
Buffalo Run	Industrial or Mun. Point Source	Buffalo Creek	1.5
Little Buffalo Creek	Agriculture	Buffalo Creek	2.2
Little Buffalo Creek	Industrial or Mun. Point Source	Buffalo Creek	3.29
UNT Little Buffalo Creek	Agriculture	Buffalo Creek	9.48
UNT Little Buffalo Creek	Industrial or Mun. Point Source	Buffalo Creek	1.46
UNT Little Buffalo Creek	Urbanization	Buffalo Creek	3.11
Little Buffalo Run	Other	Buffalo Creek	0.77
UNT Little Buffalo Run	Abandoned Mine Drainage	Buffalo Creek	0.56
UNT Little Buffalo Run	Other	Buffalo Creek	0.86
Rough Run	Other	Buffalo Creek	1.48
UNT Rough Run	Other	Buffalo Creek	1.27
Bonnie Brook	Source Unknown	Connoquenessing Cr	2.37
UNT Bonnie Brook	Abandoned Mine Drainage	Connoquenessing Cr	1.62
Brush Creek	Industrial or Mun. Point Source	Connoquenessing Cr	0.23
Brush Creek	Source Unknown	Connoquenessing Cr	1.14
Brush Creek	Urbanization	Connoquenessing Cr	6.11
UNT Brush Creek	Agriculture	Connoquenessing Cr	2.73
UNT Brush Creek	Urbanization	Connoquenessing Cr	17.28
Camp Run	Abandoned Mine Drainage	Connoquenessing Cr	1.44
UNT Camp Run	Abandoned Mine Drainage	Connoquenessing Cr	0.59
Connoquenessing Creek	Abandoned Mine Drainage	Connoquenessing Cr	0.05
Connoquenessing Creek	Source Unknown	Connoquenessing Cr	27.2
Connoquenessing Creek	Urbanization	Connoquenessing Cr	5.3
UNT Connoquenessing Creek	Abandoned Mine Drainage	Connoquenessing Cr	1.53
UNT Connoquenessing Creek	Urbanization	Connoquenessing Cr	4.49
Glade Run	Agriculture	Connoquenessing Cr	3.59
Glade Run	Source Unknown	Connoquenessing Cr	0.06
Glade Run	Urbanization	Connoquenessing Cr	3.06
UNT Glade Run	Agriculture	Connoquenessing Cr	9.9
UNT Glade Run	Urbanization	Connoquenessing Cr	5.05
Little Connoquenessing Creek	Abandoned Mine Drainage	Connoquenessing Cr	5.33
UNT Little Connoquenessing Cr.	Abandoned Mine Drainage	Connoquenessing Cr	1.39
Little Yellow Creek	Abandoned Mine Drainage	Connoquenessing Cr	2.46

Stream Name	Source - Cause	Act 167 Watershed	Length (miles)
UNT Stony Run	Abandoned Mine Drainage	Connoquenessing Cr	1.55
UNT Stony Run	Source Unknown	Connoquenessing Cr	7.43
Sullivan Run	Source Unknown	Connoquenessing Cr	2.07
Thorn Creek	Source Unknown	Connoquenessing Cr	9.01
UNT Thorn Creek	Agriculture	Connoquenessing Cr	4.54
UNT Thorn Creek	Other	Connoquenessing Cr	2.77
Yellow Creek	Abandoned Mine Drainage	Connoquenessing Cr	9.46
UNT Yellow Creek	Abandoned Mine Drainage	Connoquenessing Cr	15.14
Big Run	Abandoned Mine Drainage	Slippery Rock Creek	5.21
UNT Big Run	Abandoned Mine Drainage	Slippery Rock Creek	6.92
Blacks Creek	Abandoned Mine Drainage	Slippery Rock Creek	5.27
UNT Blacks Creek	Abandoned Mine Drainage	Slippery Rock Creek	12.26
Christy Run	Agriculture	Slippery Rock Creek	3.57
UNT Christy Run	Agriculture	Slippery Rock Creek	5.53
Findlay Run	Agriculture	Slippery Rock Creek	2.21
UNT Findlay Run	Agriculture	Slippery Rock Creek	2.19
UNT Glade Run	Abandoned Mine Drainage	Slippery Rock Creek	13.4
Muddy Creek	Abandoned Mine Drainage	Slippery Rock Creek	3.46
Muddy Creek	Source Unknown	Slippery Rock Creek	2.73
UNT Muddy Creek	Source Unknown	Slippery Rock Creek	3.23
UNT N. Branch Slippery Rock Cr.	Abandoned Mine Drainage	Slippery Rock Creek	6.33
UNT N. Branch Slippery Rock Cr.	Abandoned Mine Drainage	Slippery Rock Creek	14.48
Seaton Creek	Abandoned Mine Drainage	Slippery Rock Creek	4.15
UNT Seaton Creek	Abandoned Mine Drainage	Slippery Rock Creek	7.19
Slippery Rock Creek	Abandoned Mine Drainage	Slippery Rock Creek	13.46
UNT Slippery Rock Creek	Abandoned Mine Drainage	Slippery Rock Creek	15.09
UNT Slippery Rock Creek	Urbanization	Slippery Rock Creek	3.25
S. Branch Slippery Rock Creek	Abandoned Mine Drainage	Slippery Rock Creek	10.06
S. Branch Slippery Rock Creek	Source Unknown	Slippery Rock Creek	5.02
UNT S. Branch Slippery Rock Cr.	Abandoned Mine Drainage	Slippery Rock Creek	10.01
UNT S. Branch Slippery Rock Cr.	Agriculture	Slippery Rock Creek	2.49
UNT S. Branch Slippery Rock Cr.	Source Unknown	Slippery Rock Creek	5.91
Swamp Run	Agriculture	Slippery Rock Creek	2.05
UNT Wolf Creek	Abandoned Mine Drainage	Wolf Creek	1.86

Table 9.2. Non-Attaining Streams in Butler County

TMDL DISCUSSION

Once a waterbody is listed on the EPA approved 303(d) list, it is required to be scheduled for development of a TMDL. TMDLs are expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a water quality standard. They can be developed to address individual pollutants or groups of pollutants, if it is appropriate for the source of impairment.

A TMDL must identify the link between the use impairment, the cause of the impairment, and the load reductions needed to achieve the applicable water quality standards. However, a precise implementation plan is not part of the approved TMDL. A TMDL is developed by determining how much of the pollutant causing the impairment can enter the waterbody without exceeding the water quality standard for that particular pollutant. The calculated pollutant load is then distributed among all the pollutant sources as follows:

$$TMDL = WLA + LA + MOS$$

Where: TMDL = Total Maximum Daily Load

WLA = Waste Load Allocation; from point sources such as industrial discharges and wastewater treatment plants

LA = Load Allocation; from nonpoint sources such as stormwater, agricultural runoff and natural background levels

MOS = Margin of Safety

TMDLs are developed by the state and submitted to EPA for review and approval. Once a TMDL has been approved, it becomes a tool to implement pollution controls. It does not provide for any new implementation authority. The point source component of the TMDL must be implemented through existing federal programs with enforcement capabilities (e.g. National Pollution Discharge Elimination System, NPDES). Implementation of the Load Allocations for nonpoint sources can happen through a voluntary approach or by means of existing state or local regulations. *Table 9.2* lists all the TMDLs in Butler County.

Waterbody	TMDL Category	Cause	Status
Blacks Creek	AMD	Metals, pH	EPA Approved 1-19-2005
Brush Creek	Point Source	DO/BOD, Organic Enrichment/Low DO, Pathogens	EPA Approved 4-9-1999
Fowler Run	AMD	Other Inorganics, Metals, pH	EPA Approved 4-9-2003
Little Connoquenessing Creek Watershed	AMD	Cause Unknown, Metals	EPA Approved 4-9-2003
Little Scrubgrass Creek	AMD	Metals, pH	EPA Approved 5-15-2007
North Branch Bear Creek	AMD	Metals	EPA Approved 5-19-2008
Scrubgrass Creek Watershed	AMD	Other Inorganics, Metals, pH	EPA Approved 5-19-2008
Seaton Creek	AMD	Other Inorganics, Metals, pH	EPA Approved 1-19-2005
UNT Connoquenessing Creek	AMD	Suspended Solids	EPA Approved 4-9-2009

Table 9.2. TMDLs in Butler County

CRITICAL SOURCES OF IMPAIRMENT

The primary causes of water quality impairment are sediment/siltation, nutrients, metals, and pathogens. Nonpoint source (NPS) pollution is a general term for water pollution generated by diffuse land use activities rather than from an identifiable or discrete facility. In Pennsylvania the leading nonpoint sources of impairment are:

- Agriculture

- Abandoned Mine Drainage (AMD)
- Urbanization (Runoff/Storm Sewers)

Some of these sources are regulated by stormwater ordinances and have been covered in previous section. However, several of these categories are more appropriately addressed by other regulations. Although these activities cannot be regulated by the provisions within the stormwater management ordinance of this Plan, they play a major role in the water quality of surface waters. The following is a summary of the nonpoint sources and causes for impairment that affect Butler County waters:

AGRICULTURAL ACTIVITIES

Agricultural land use has many beneficial effects on a landscapes response to rainfall and properly managed agricultural activities provide many positive environmental benefits. However, when improperly managed, these activities can cause significant degradation of water quality. Agricultural activities that can cause NPS pollution include confined animal facilities, grazing, plowing, pesticide spraying, irrigation, fertilizing, planting, and harvesting. The major pollutants that result from these activities are sediment and siltation, nutrients, pathogens, and pesticides. Agricultural activities can also damage habitat and stream channels.

SEDIMENT/SILTATION

The most common agricultural cause for surface water impairment is sediment and siltation. Of the 110 miles of impaired streams in Butler County, agriculture related siltation is attributed for 94.1 miles of impairment. This pollutant results from typical agricultural practices such as plowing and tilling, livestock grazing, and livestock access to waterbodies. When appropriate conservation practices are implemented, these activities can be continued while reducing erosion and enhancing and protecting water quality.

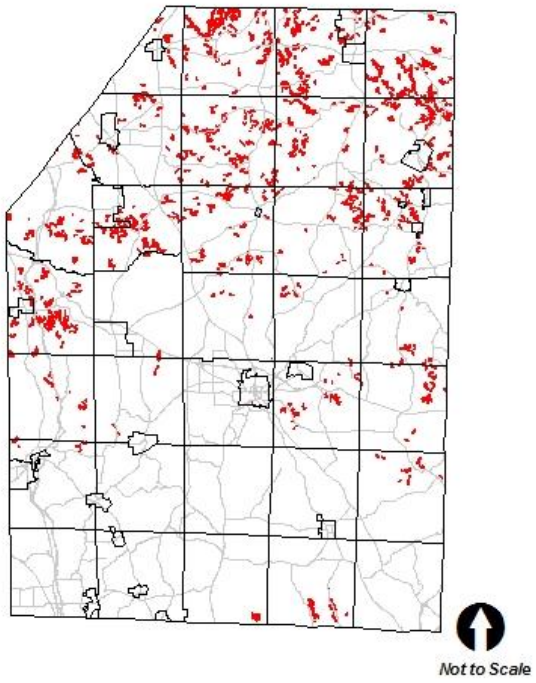
Controlling sheet and gully erosion is the first step in addressing siltation impairments. The majority of erosion problems are a result of plowing and tilling activities and concentrated livestock areas. In Pennsylvania, a written Erosion and Sediment Control Plan is required for all agricultural plowing or tilling activities that disturb 5,000 square feet or more of land. The implementation and maintenance of erosion and sediment control BMPs to minimize the potential for accelerated erosion and sedimentation is also a requirement for all agricultural activities regardless of disturbed area. In addition to reducing sediment pollution, controlling erosion also decreases the transport factors for other pollutants such as nutrients and pesticides.

NUTRIENTS

The second most common agricultural cause for surface water impairment is nutrients. Agricultural activity related nutrients account for 64.9 miles of the 110 miles of impaired streams in Butler County. Nutrients such as nitrogen, phosphorus, potassium and other micronutrients are essential to proper plant growth and development. However, when the available nutrients exceed those required for plant development, or when nutrients are improperly applied, they pose potential environmental hazards. Nutrient pollution results from agricultural activities such as fertilizer and manure application, livestock access to waterbodies, and animal concentration areas.

Nutrient management regulations have been developed in Pennsylvania in response to nutrient pollution problems. All livestock operations with animal densities higher than 2,000 pounds of live animal weight per acre of land available for nutrient application are required to have a Nutrient Management Plan (NMP). A NMP is a tool to help producers allocate nutrients from fertilizer and

manure in a manner that maintains adequate nutrient levels for desired crop production and reduces the likelihood of nutrient pollution. Addressing agricultural nutrient impairments requires consideration of where the nutrients are coming from, also called nutrient source factors, and how they get to surface waters, or nutrient transport factors.



Butler County Abandoned Mine Lands

ABANDONED MINE DRAINAGE (AMD)

Contaminated water seeping from abandoned coal mine areas (commonly known as abandoned mine drainage, or AMD) is the most prevalent and severe water pollution problem in Pennsylvania. AMD, impairing nearly 198 miles of surface waters within the county, is the leading cause of impairment in Butler County. Impacting 74.6% of the impaired waters within the county, AMD is, by far, the principal impairment concern. Abandoned mine sites have left dangerous highwalls, open pits, coal refuse spoil piles, old mine openings, and miles of streams polluted by abandoned mine drainage. Past coal mining practices have led to erosion, landslides, polluted water supplies, destruction of fish and wildlife habitat, and an overall reduction in natural beauty.

Vast bituminous coal deposits underlie western and north-central Pennsylvania, including Butler County. Indeed, bituminous coal mining and coke making dominated much of western Pennsylvania's economy during the late nineteenth and early twentieth century. The Pennsylvania bituminous industry peaked in 1918 when the industry started to encounter rising competition from other states and shrinking markets due to competing fuel sources such as petroleum and natural gas. This began a long-term decline in Pennsylvania's coal industry that continues today. Bituminous coal was primarily mined through surface mining techniques or "strip mining". Through this process, the overburden (soils and other bedrock layers) is removed and relocated to expose the coal for extraction. Although this method was usually cheaper, it caused severe environmental problems that went unregulated until state law required land restoration in 1963. Years of coal mining that was conducted before the regulation of the industry, and a sharp decline in production, have left behind a multitude of abandoned mine sites that host a variety of environmental and safety issues.

Many strip mines were not backfilled or re-vegetated, allowing water to infiltrate through acidic spoil, settle into impoundments and contaminate groundwater supplies. Strip mine activities often removed the outcrop barrier allowing groundwater to flow unimpeded to the surface over the old strip pit. The refuse produced from mining activities (consisting of high sulfur material) was usually just stockpiled, another source of pollution. The problems caused by Abandoned Mine Sites can be classified in several categories:

SAFETY PROBLEMS – Abandoned mine land (AML) sites have contributed to deaths in several states. Highwalls, open shafts, dilapidated mine structures, and water-filled pits present serious health and safety threats.

ECONOMIC PROBLEMS – These lands are often located in the most economically depressed areas of our nation. All that remains in many once populated mining communities are scarred lands and a few residents who are willing to commute to larger cities for employment. The AML sites make it difficult to compete for industry and tourism.

AESTHETIC PROBLEMS – The sparse vegetation (if any), stagnant water and illegal trash dumps characterization of AML sites have a negative effect on everyone. The appearance of the site tends to depress land value and detract from the tax base. The environmental scars contribute to an apathetic attitude toward the condition of these areas.

WATER PROBLEMS – Acid run-off and sedimentation from abandoned mine sites contaminate thousands of miles of streams nationwide. This contaminated water eventually serves as potable water supply; therefore, an increase in water treatment costs is needed. Acid mine drainage also leads to increased road maintenance costs, due to the corrosive effects of this drainage on culverts. Streams and drainage systems are often clogged by sedimentation from abandoned mine sites, which, in turn, may cause flooding as a secondary result.

Pennsylvania has an estimated 2,500 miles of streams polluted by acid mine drainage; 250,000 acres of unreclaimed surface mine land; 100 million cubic feet of burning coal refuse; and potential subsidence problems for hundreds of thousands of acres (DEP, 1996). The majority of AMD water related problems are a product of the reaction between a metal sulfide (often pyrite), water, and oxygen. A series of chemical reactions occur when these three elements are present, resulting in contaminants such as ferrous iron, ferric iron, and hydrogen (H^+) ions which increase the acidity of water.

ACIDITY (pH)

Healthy streams, as measured by biodiversity indicators, generally have a pH close (i.e. within one point) to neutral (pH = 7). As the pH drops below 6, the aquatic life diversity within the waterbody decreases as acid intolerant species either die off and other species begin to loose their food supply. Because pH is measured on a logarithmic scale, each declining unit represents 10 times more acidity. In AMD impaired waters, oxidation of metal sulfides results in an increase in H^+ ions. As the presence of H^+ ions increase the water becomes more acidic (i.e. the pH becomes lower). Extremely acidic mine waters have been documented with pH values as low as -3.6 (Nordstrom et al., 2000). While this level of extreme acidity is rare, most streams impacted by AMD have some degree of impairment cause by low pH.

METALS

Abandoned mine drainage often contains high concentrations of metals. As the acidity of water increases, more metals (iron, copper, zinc, etc.) can be dissolved from the rocks and go into solution in the water. AMD from coal mines typically contains elevated levels of iron and aluminum, although other metals including manganese and zinc may also be present. Waters with excessive amounts of dissolved metals can be toxic to aquatic organisms.

In addition to dissolved metals, metal precipitates become problematic downstream as AMD mixes with other water sources and in-stream acidity levels decrease. Iron and other metals precipitates out of solution as the pH of the water increase. This metal precipitate, sometimes referred to as "yellowboy", forms the characteristic red, orange, or yellow sediments often seen in the bottom of streams containing mine drainage. Metals degrade water quality and limit the beneficial uses of the surface waters. Beneficial uses that may be affected extend beyond

aquatic life support to impact human activities that include drinking water supply, swimming, fishing, and other recreation.

SILTATION AND SUSPENDED SOLIDS

Abandoned mine drainage can result in different forms of suspended solids in receiving waters. Accelerated overland erosion often occurs in mine areas due to vast areas that are unstabilized by vegetation. These areas often remain for many years after active mining operations cease due to the unfavorable conditions for vegetative growth. Erosion of these areas discharges sediment and fine silt particles into receiving streams. Other suspended solids include metal precipitates formed through the chemical processes of oxidation as previously described.

Elevated levels of suspended solids can have a direct negative impact on aquatic species, as well as leading to increased stream temperatures as darker particles absorb heat (EPA, 1997). As water temperatures rise, dissolved oxygen levels (which are critical for many aquatic species) decrease. These changes caused by sediment and siltation are all substantial contributors to aquatic life impairments.

URBANIZATION

This is a broad category that includes the following three critical sources of impairment listed earlier in this section: 1) Urban Runoff/Storm Sewers, 2) Road Runoff, and 3) Small Residential Runoff. These sources have been grouped together because they are all types of urbanization, or human development activities. When development activities replace forests, fields, and meadows with impervious surfaces the landscape's capacity for initial abstraction is greatly reduced and surface runoff increases. This topic has been the focus of this Plan. The quantity of runoff from urbanized areas and the water quality characteristics of the runoff are the two base causes of surface water impairments. These two primary pollutants translate into surface water impairments in several different forms.

SEDIMENT/SILTATION

As stormwater flows over land it collects silt and sediment and carries them to surface waters. Urbanization decreases the opportunity for natural filtration of runoff through vegetation and often concentrates flow in discharges that cause increased overland erosion. The increased rate of stormwater flow and increased sediment load delivered to the stream combine to raise the in-stream energy. This in turn changes the physical structure of the receiving streams by causing increased bank erosion as well as scour of the streambed and sedimentation when the water finally slows down. Increased sediment loading in a stream contributes to increased total suspended solids and turbidity, which can in turn lead to increased stream temperatures as darker particles absorb heat (EPA, 1997). As water temperatures rise, dissolved oxygen levels (which are critical for many aquatic species) decrease. These changes caused by sediment and siltation are all substantial contributors to aquatic life impairments.

HABITAT ALTERATIONS

Natural channels are composed of alternating sequences of pools, riffles, and runs. The diverse characteristics of each of these features provide unique habitats that allow various aquatic species to live, feed, and reproduce (EPA, 2007). The elevated stream power that occurs when additional runoff and sediment loading are experienced causes physical alterations to the stream channel. The increased energy carries large debris downstream, erodes streambeds and banks, creates scour holes at existing structures, and deposits new sediment in the channel as flows subside. These changes can drastically alter the structure of pools, riffles, and runs and eventually diminish the quality of the habitat to a point where the stream can long longer support aquatic life.

NUTRIENTS AND METALS

As runoff flows over impervious surfaces it picks up various pollutants and transports them to waterbodies. This includes oil and grease from automobiles; fertilizers, herbicides and pesticides from lawns; fecal matter from pet waste and malfunctioning septic tanks; chlorides from winter road maintenance; and heavy metals from tires, shingles, paints, and metal surfaces. These pollutants degrade water quality and limit the beneficial uses of the surface waters. Beneficial uses that may be impacted include drinking water supply, swimming, fishing, other recreation, and aquatic life support.

RECOMMENDATIONS

Addressing water quality impairments is achieved most effectively through watershed wide planning and implementation. The water quality based approach is a common method of addressing impairments. The "Integrated Waters List" identifies impaired streams and identifies source-causes of impairment. The next step towards improving the water quality in these streams is to identify the critical areas within the impacted watershed. Critical areas are the geographic regions within a watershed that directly contribute pollutants to the stream. The primary purpose for identifying critical areas is to develop a strategy that effectively addresses the sources of water quality impairment.

An inventory of each watershed that identifies the critical areas allows time, effort, and funds to be targeted towards those sites that most negatively impact water quality. This stage should be completed by a watershed planner with the technical knowledge necessary to accurately identify critical areas and the ability to provide a technical assessment of the severity of each source. The planner will need to prioritize the inventoried sites within the critical area based on the degree to which the sites contribute to the impairment and the overall objectives of the community.

It is important to involve the stakeholders within the watershed at this point in the form of a steering committee. A group such as a local watershed group or the County Conservation District would be able to assist in identifying the stakeholders and coordinating everyone's efforts. The planner and steering committee will work together to develop a comprehensive watershed plan and an implementation strategy to address the sites within the critical areas. The goal is to address the most severe sources of pollutants in an efficient manner. The next step in developing a comprehensive watershed plan is to set definable water quality goals based on the detailed inventory.

Developing an implementation strategy and determining specific BMPs to treat specific sites is the last step. Existing water quality programs should be considered as the implementation strategy is developed. These programs can be coordinated with the implementation strategy in order to achieve a common goal. Thought must also be given to potential funding sources and how they can be used to implement portions of the overall water quality improvement plans. As projects are implemented, the plan should be reviewed and revised as necessary to ensure that the water quality goals are eventually obtained.

RECOMMENDED AGRICULTURAL CONSERVATION PRACTICES

A variety of agricultural conservation practices are available to help achieve producer's goals while also protecting natural resources. These practices are used to reduce soil erosion and improve and protect water quality. These practices are intended to address specific resource concerns. Individual BMPs are most effective when used together to create a conservation system. A conservation system addresses all of the resource concerns on a particular farm through a combination of different management practices and BMPs that work together.

Planning a conservation system ensures that the maximum benefits can be obtained from the individual components, and that the overall management goals are accomplished. Conservation planning services are offered by a variety of private consultants as well as state and federal agencies including the local county conservation district and USDA Natural Resource Conservation Service staff. The following BMPs have been identified as particularly well suited to address the impairments identified in Butler County:

Streambank Protection

Streambank protection provides direct water quality results by reducing the amount of sediment, animal waste and nutrients entering the stream. Protection is implemented by excluding livestock from the stream and establishing buffer zones of vegetation around the stream (see *Riparian Buffers*). The practice can be implemented with or without fencing; however it is much more effective when fencing is installed. This BMP usually requires installation of an alternate watering source for livestock and an animal crossing to allow animals access to pasture on both sides of the stream. According to the *Chesapeake Bay Program Best Management Practices, Agricultural BMPS – Approved for CBP Watershed Model* (DEP, 2007) the pollutant removal efficiency of this practice, with fencing and off-stream watering applied, is 60% (Nitrogen), 60% (Phosphorus), and 75% (Sediment). Without fencing, the efficiency is reduced to 30%, 30%, and 38% for nitrogen, phosphorus, and sediment respectively. This practice is eligible for several funding programs.

Riparian Buffers

Riparian areas, land situated along the bank of a water source, typically occur as natural buffers between uplands and adjacent water bodies. They act as natural filters of nonpoint source pollutants before they reach surface waters. In agricultural areas many riparian buffers have been removed by agricultural activity to increase tillable acreage and provide animal access to water (see *Streambank Protection*). Re-establishing riparian buffers by planting forest buffer or grass buffers adjacent to water bodies provides significant water quality benefits. In addition to the filtering benefits that grass buffers provide, forested buffers provide shade to the stream helping to reduce negative thermal impacts.

Additionally, wetlands and riparian areas also help decrease the need for costly stormwater and flood protection facilities. The efficiency of riparian buffers varies by hydrologic setting. This practice can be implemented with several funding programs such as CREP.

Riparian buffers are part of a larger group of practices referred to as Conservation Buffers. This general practice is any area or strip of land maintained in permanent vegetation to help reduce erosion and filter nonpoint source pollutants. This group also includes contour buffer strips, field borders, filter strips, vegetative barriers, and windbreaks (NRCS, 1999).

Barnyard Runoff Control

Animal concentration areas (ACA) are a principal source of sediment and nutrient pollution on agricultural operations. Barnyard runoff control is used to manage stormwater runoff from animal concentration areas to reduce the sediment and nutrients that reach surface waters. Runoff control can be achieved with a variety of methods, but the principals are the same for all of the methods. These principals are keeping "clean" water away from the barnyard and collecting runoff from the barnyard and filtering it with an appropriate BMP or storing it in a manure storage facility for field application. Clean water

is diverted away from ACAs with roof runoff structures, diversions, and drainage structures. When barnyard runoff control is implemented without storage the pollutant removal efficiency is 20% (Nitrogen), 20% (Phosphorus), and 40% (Sediment) (DEP, 2007). When the practice is implemented in conjunction with a manure storage the nitrogen and phosphorus efficiencies are both reduced to 10% and the sediment efficiency remains the same.

Nutrient Management

Nutrient management is planning for, and implementation of, the application of organic and inorganic materials to provide sufficient nutrients for crop production in a manner that limits negative environmental impact of their use (NRCS, 1999). A nutrient management plan accounts for all nutrient sources and details the location, timing, rate, and method of nutrient application to crop fields. Implementing a nutrient management plan provides benefit to the farmer by allocating the available nutrients to where they are needed the most to maintain crop yields while also limiting excess nutrients that would otherwise be susceptible to transport eventually contributing to NPS pollution. Pollutant delivery reductions achieved by implemented nutrient management plans are greatly varied by individual agricultural operations and there is no efficiency directly associated with this practice. Several cost-share programs are available to assist costs associated with plan development and implementation.

Animal Waste Management Systems

Animal waste management systems are used for the proper handling, storage, and application of animal waste generated on livestock operations. Wastes are collected from animal confinement areas, and transferred to an appropriate waste storage facility. The waste storage facility enables the producer to store manure during adverse weather conditions when manure nutrients are most likely to reach surface waters. Manure is then field applied when conditions are most conducive to plant nutrient uptake. Waste storage facilities have a nitrogen and phosphorus efficiency of 75%. This practice is eligible for funding through a few of the cost-share programs.

Cover Crops

Cover crops are planted in the fall after the primary crop has been harvested. The cover crop grows through the fall and provides ground cover for the field throughout the winter months and early spring when the soil is extremely susceptible to erosion. The cover crop also provides nitrogen removal benefits as it utilizes excess nitrogen in the soil. The cover crop can either be harvested as a commodity crop in the spring or it can be killed and left as ground cover prior to spring planting. Cover crops provide excellent soil erosion protection when the fields need it most. The County Conservation District has several cost incentive programs to encourage use of cover crops. The efficiency of cover crops varies based on when the crop is planted and whether or not the crop is harvested.

Conservation Tillage

Conservation tillage is a crop production system that results in minimal disturbance of the surface soil. Maintaining soil cover with crop residue is an important part of conservation tillage. Maintaining ground cover throughout the year has many benefits to crop production, but the most significant water quality benefit is reduction in soil erosion. No-till farming is one form of conservation tillage in which crops are planted directly into ground cover with no disturbance of the surface soil. Minimum tillage farming is another method

that involves minor disturbance of the soil, but maintains much of the ground cover on the surface. There is no efficiency associated with this practice. The effects of each tillage system can be calculated by the Revised Universal Soil Loss Equation (RUSLE), which will give an estimation of the annual soil loss for each field.

RECOMMENDATIONS FOR ABANDONED MINE DRAINAGE

As discussed previously in this section, the challenges associated with improving AMD impairments are significant. It is generally extremely difficult and cost prohibitive to remediate an AMD source. Because of this, treating the cause of impairment is oftentimes the only option for remediation. Two methods can be used to treat AMD impairments, active treatment and passive treatment. Active treatment methods use alkaline chemicals such as limestone, hydrated lime, soda ash, caustic soda, and ammonia to neutralize acidic AMD impaired water and decrease the solubility of dissolved metals (EPA, 2008b). Active treatment systems are designed and operated to treat specific contaminants at a given site. These treatment systems are very effective at improving water quality, but they are a long-term undertaking. They require ongoing doses of expensive chemicals and are expensive to construct and operate. Passive treatment systems employ chemical and biological reactions (most often employing limestone) in systems that require minimal maintenance to minimize AMD. While passive systems are generally less effective at total treatment than active systems, they are much less expensive to construct and operate. However, they will all accumulate metal precipitates and eventually require maintenance or need to be replaced. Several simple, time-proven passive systems that may be useful in remediating AMD impaired waters are as follows:

Open Limestone Channels/Anoxic Limestone Drains

Open limestone channels can be constructed off-line with mine drainage diverted through the constructed channel, or limestone can simply be placed in the existing stream. This simple passive treatment method uses placed limestone to add alkalinity to the water. The dissolution of the limestone raises the pH of the water. This type of system requires large quantities of limestone for long-term operation (DEP, 2010). One drawback of this system is that iron and aluminum precipitates can coat the limestone and reduce the dissolution of the limestone. This is sometimes referred to as armoring. High flow velocities and turbulent flow can improve the performance of limestone channels by keeping precipitates in suspension and reducing the amount of armoring that can occur. Anoxic drains operate on the same principal as open channels, except they are constructed underground to reduce contact with atmospheric oxygen. Keeping oxygen out of the water prevents oxidation of metals and reduces armoring of the limestone (DEP, 2010). Anoxic drains are also useful for treating subsurface mine water flows.

Diversion Wells

Diversion wells also utilize the technique of using limestone to add alkalinity to contaminated waters. Acidic water is diverted from the stream into a cylindrical well containing limestone aggregate. The water enters the well near the bottom and the hydraulic force of in incoming water agitates and abrades the aggregate. The turbulence in the water increases dissolution and reduces armoring on the limestone. "Treated" water is drawn off the top of the well and directed back into the stream where it mixes with contaminated water. This simple system works well, but requires periodic replenishment of limestone.

Constructed Wetlands

Constructed wetlands are a passive system that utilizes precipitation of metals and natural processes associated with wetland plants to remove dissolved metals from mine drainage within the controlled environment of the treatment system. Constructed wetlands can be aerobic (with oxygen) or anaerobic (without oxygen) which refers to the conditions in which the chemical reactions are occurring. Aerobic wetlands are used primarily for removing metals from contaminated water. They are shallow (1- to 3-foot deep) ponds that may be lined or unlined, used to facilitate natural oxidation of the metals and precipitate iron, manganese, and other metals (Ford, 2003). Anaerobic wetlands are used to neutralize acidity and reduce metals to the sulfide form. Anaerobic wetlands are shallow ponds filled with organic matter, such as compost, and underlain by limestone gravel. Water percolates through the compost and becomes anaerobic and metals precipitate from the water as sulfides. Microorganisms facilitate this reaction by first consuming oxygen (Ford, 2003).

Initial design and construction of wetland treatment systems can be expensive. However, this step is important as proper initial sizing of wetlands is critical to their success. Constructed wetlands are also sensitive to system stressors such as lack of flow, drastic flow variations, and extreme cold temperatures. These systems are also more maintenance intensive than the previously mentioned treatment systems.

The Surface Mining Conservation and Reclamation Act of 1971, and the Federal Surface Mining Control and Reclamation Act of 1977 have generated regulations intended to eliminate and control adverse conditions resulting from mining operations. Still today, the county lives with the legacy of coal mining. According to DEP, there are 393 documented Abandoned Mine Land sites and 2,135 un-reclaimed AML Features which cover 15,227 acres in Butler County. There have been many reclamation projects completed In Butler County and more are in progress. According to DEP (Webb, 2009), a total of 60 reclamation projects involving 1,620 acres have been undertaken within the county, at a cost of $9,611,036.

POTENTIAL FUNDING SOURCES

Butler County has a variety of potential sources for funding projects and individual practices that will help improve water quality. Some of these programs are county-wide and others are targeted specifically at impaired watersheds. This is a review of the major funding programs available for projects addressing water quality impairments, and not an all-inclusive listing. Funding sources available throughout the county include:

Conservation Reserve Enhancement Program (CREP) – This funding program offered by USDA's Farm Service Agency provides financial incentives to protect environmentally sensitive land by removing it from agricultural production and placing it in a conservation easement planted with permanent vegetation. CREP supports installation of conservation buffers, wetlands, and retirement of highly erodible land.

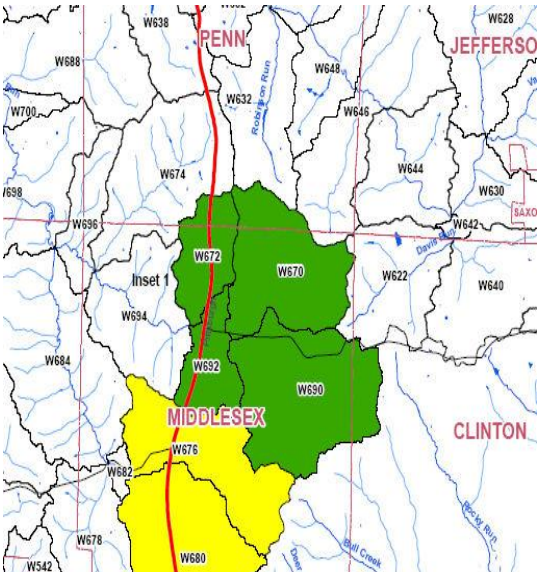
Conservation Security Program (CSP) – The CSP is a program administered by USDA-NRCS that rewards farmers who have already adopted good conservation systems by providing substantial incentives to expand or enhance current conservation efforts.

Environmental Quality Incentive Payment (EQIP) – This is a USDA – NRCS voluntary conservation program that promotes agricultural production and environmental quality as compatible goals. EQIP offers financial and technical help to assist eligible participants install or implement structural

and management practices on eligible agricultural land. Most agricultural BMPs are eligible for cost-share payments under this program

Section 319 Funds – This funding source is administered by EPA. Under Section 319 of the Clean Water Act, State, Territories, and Indian Tribes receive grant money which support a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific nonpoint source implementation projects.

Section X – Additional Recommendations and Considerations



The stormwater management standards developed in this Plan are the basis for sound stormwater management throughout Butler County. However, there are many activities that fall outside the scope of stormwater management regulations that have a significant impact on stormwater runoff and the goals of sound stormwater management planning. Generally, standards for many of these activities are contained within Zoning Regulations and Subdivision and Land Development Ordinances. Some of these activities and their impact on stormwater management are discussed below.

These measures are included here because they are beyond the regulatory scope of this Plan but may provide valuable tools in obtaining the goals discussed in *Section II*. It is suggested that all municipalities consider these additional recommendations, and determine whether adoption of some of these policies could be beneficial to their respective communities. Municipalities with substantial stormwater problem areas could especially benefit from regulation of some, or all, of these activities. A holistic approach that considers all land use policies, and how they impact stormwater runoff, is necessary to maximize the effectiveness of a stormwater management program.

MUNICIPAL ZONING

Municipal zoning is perhaps the single most influential factor on a stormwater management program. This is because the rainfall-runoff response of a given geographical area is directly linked to land use. In this manner, zoning regulations can help achieve the goals of a stormwater program or they can be a hinderance to successful implentation of the program. Only 34% of rural municpalites have enacted zoning ordinances and the majority of these are located in the southeast portion of the Commonwealth (Center for Rural Pennsylvania, 2001). Instituting new zoning regulations, or even changes to existing regulations, can be very difficult. Potential obstacles may include political backlash from a perceived overreach in municipal regulation, increased enforcement costs, and a lack of professional staffing (often related to a lack of financial resources) in the development of regulations.

Despite the difficulties associated with implementing zoning regulation changes, this is a vital element of a successful stormwater management program. This being said, the impacts of zoning regulation reach far beyond stormwater management. Zoning changes should be developed with careful consideration of all of the potential effects of the ordinance changes.

Recommendations for Improved Municipal Zoning

The following zoning tools are recommended by the Center for Watershed Protection that, if possible to implement, may aid in achieving the stated goals of this Plan (Center for Watershed Protection, 1999):

- **Watershed Based Zoning** – Master planning efforts and zoning incorporate recommendations for individual watershed, with watershed specific regulations. Long-

term monitoring and evaluation of the effectiveness of the regulations should be part of the program.

- **Overlay Zoning** – With this option, specific criteria can be applied to isolated areas without the limitations of underlying base zoning. Overlay zoning superimposes additional regulatory standards, specifies permitted uses, or applies specific development criteria onto existing zoning provisions. Overlay zones may take up only part of an underlying zone or may encompass several underlying zones. An example of watershed-releated overlay zoning may be "Impervious Overlay Zoning" in areas with documented stormwater problems, which sets a maximum impervious area cap.
- **Performance Zoning** – This technique requires a proposed development to ensure a desired level of performance within a given area. This method has been used to control traffic or noise limits, light requirements, and architectual styles. Watershed-related performance zoning might provide precise limits on storwater quality and quantity. This may be one option to address impaired waters.
- **Large Lot Zoning** – This type of zoning district requires development to occur at very low densities to disperse impervious cover. This helps disperse the stormwater impacts of future development, but may contribute to urban sprawl.
- **Urban Growth Boundaries** – Growth boundaries set dividing lines for areas designated for urban and suburban development and areas appropriate for traditionally rural land uses, such as agriculture and forest preservation. Growth boundaries are typically set for up a specific time period (e.g. 10 to 20 years) and re-evaluated at appropriate intervals.
- **Infill Community Redevelopment** – This strategy encourages use of vacant or under-used land within existing growth centers for urban redevelopment. This practice is one method used to reduce the negative impacts of urban sprawl and minimize additional impervious area by miximizing utilization of existing infrastructure.
- **Transfer of Development Rights** – This allows transfer of development rights from sensitive subwatersheds (where the potential for adverse impacts is relatively high) to other watersheds designated for growth (where the potential for adverse impacts are relatively low).

RIVER CORRIDOR PROTECTION

River corridor protection is a very broad term that encompasses several closely related river (the term river is used loosely here to include all rivers, streams, creeks, etc.) management approaches. River corridors provide an important spatial context for maintaining and restoring the river processes and dynamic equilibrium associated with high quality aquatic habitats (Kline, 2008). The river corridor includes the existing channel, the floodplain, and the adjacent riparian zone. The basic concept behind river corridor protection is recognizing the natural functions of rivers and streams and managing them to resolve conflicts between the natural systems and human land use.

Rivers and streams adjust over time through dynamic fluvial processes in response to the varying inputs of water, sediment, and debris. Natural adjustments to these inputs are occuring continually in rivers and streams. These adjustments are generally minor and occur over long time periods. The result of these processes is evidenced in streambank erosion, channel incision, meadering stream channels, and the inevitable conflict between the stream and nearby human infrastructure. The more significant changes, such as channel relocation, usually occur during large flood events. River corridor protection includes the following management strategies to complement a stormwater management program:

FLOODPLAIN MANAGEMENT

There is a direct relationship between stormwater management and floodplain management. Stormwater management policy focuses on future development and reducing the likelihood of increased flooding while floodplain management focuses on preventive and corrective measures to reduce flood damage. Implementation of the Model Stormwater Management Ordinance will reduce the probability of new flooding problems, but will have only minor impacts on existing problems. Examples of these problems are documented in *Section V – Significant Problem Areas and Obstructions*. Many of these problems are due to historic development that has occurred in the floodplain and inadequately sized infrastructure. Floodplains are necessary to convey and attenuate the natural peak flows that occur during major hydrologic events.

As discussed in *Section III*, Butler County incurs a substantial economic loss in major hydrologic events (as much as $61 million in a 10-year storm event). Floodplain management policy serves to minimize the impact of such events by reducing the conflicts between human infrastructure and floodplains. While improved stormwater management will greatly reduce the occurrence of nuisance flooding, floodplains are necessary to attenuate flood waters from events that exceed the intended scope of stormwater policy. The most effective floodplain management policy provides preventive provisions that restrict future development within floodplains and corrective measures that reduce flood damage in existing problem areas.

Recommendations for Floodplain Management

- **Adopt and enforce the Pennsylvania Department of Community and Economic Development (DCED) Model Floodplain Ordinance.** When the FIRMs in Butler County were updated, it was strongly recommended by DCED that each municipality adopt the DCED model ordinance. This will ensure that the local ordinance addresses the minimum state and federal requirements of the NFIP and provide a consistent basis of floodplain management between all of municipalities in the county.
- **Participate in the Community Rating System.** The CRS gives communities credit for reducing the risk of flood hazards. By implementing many of the same principles that are discussed in this Plan, municipalities can reduce flood insurance rates for residents inside of floodplains by up to 45%.
- **Provide open space preservation in floodplain areas.** Open space preservation may also provide credits to future developments by reducing impervious area and thereby reducing stormwater requirements.
- **Acquire and relocate flood-prone buildings so they are no longer within the floodplain.** Repetitive loss properties (properties for which two or more claims of at least $1000 have been paid by the NFIP within any 10-year period since 1978) constitute a large portion of the NFIP flood insurance claims. Nationally, less than 2% of all properties have accounted for 33% of flood insurance claims since 1978 (FEMA, 2002). Removing these and any other structure that incurs flood risk on an annual basis reduces the overall risk of the NFIP and reduces the community's exposure to flood damage. It is usually more economical to remove properties, particularly in the more rural areas of Butler County, than to install structural alternatives such as levies, diversion projects, or dams.
- **Implement a drainage system maintenance program.** As noted in *Section V*, there are numerous locations where clogged or poorly maintained facilities result in flooding of areas not normally prone to flooding. Most engineering design calculations for stormwater detention and conveyance facilities, assume full function of a bridge or culvert. Implement a systematic inspection and maintenance program where periodic

inspections are conducted on all channels, conveyance and storage facilities and remove debris and perform maintenance as necessary.

RIVER CORRIDOR PLANNING

River corridor planning is a process for selecting and implementing river corridor management alternatives in which all aspects of the river are considered. The process is accomplished through river specific assessments and planning that is able to characterize the river and identify important features as well as the areas that are susceptible to potential threats to those features. This is a form of land use planning that focuses on the impacts of land use on the river system.

One particularly useful aspect of river corridor planning is to use the assessment information to designate corridors along the rivers where natural river changes are most likely to occur resulting in accelerated erosion or bank failures. These areas are sometimes referred to as "fluvial erosion hazard zones" and are responsible for a large portion of the damage to human infrastructure during flood events (Dolan, 2008). Once these areas are identified and mapped, land use planning mechanisms are used to protect identified sensitive areas and limit future development within this zone. Keeping infrastructure, such as roads and utilities, out of the high risk areas greatly reduces the cost of protecting and maintaining this infrastructure.

Recommendations for River Corridor Planning

- **Identify areas that could benefit river corridor planning and initiate the planning process.** Identifying areas that could benefit from improved river corridor management can protect river resources and greatly reduce the economic impact caused by major hydrologic events. River corridor planning can be especially beneficial in areas with special value, areas that are likely to receive considerable future development near the river, or areas that currently experience persistent flood damage.
- **Identify and protect fluvial erosion hazard zones.** Flood damage may also occur as a stream channel changes course and meanders. The channel changes may result from either naturally occurring geologic processes or human-induced changes to watershed hydrology or hydraulics. A geomorphic assessment can identify the areas that are most likely to experience channel changes through erosion. These areas can then form the basis for an overlay zoning district or area with specified stream buffers for additional protection. Another option that has been implemented in the state of Vermont, is to integrate Fluvial Erosion Zones into the floodplain mapping process, so that all of the tools of floodplain management are available for the specified areas (Vermont Agency of Natural Resources, 2009).

RIPARIAN ZONE PROTECTION

The riparian zone is the transitional zone between the aquatic zone and adjacent uplands. It generally includes the streambanks, flood plain, and any adjacent wetlands. The riparian zone is often overlapping with the river corridor, but has a slightly different connotation. The term riparian zone does not refer to an explicit width, rather a width that varies along the length of a given stream depending on the geography of the area. Natural riparian zones are typically covered with trees, shrubs, and other types of local vegetation, all of which provide a natural buffer between waterways and human land use as well as providing vital and unique natural habitat.

Riparian zones provide two principal benefits in regards to stormwater management. They offer flood protection by providing temporary storage area, slowing the velocity of flood waters, and provide a small amount of volume reduction through infiltration and permanent retention of water by disconnected low lying areas. The second primary benefit of riparian zones is the water

quality functions they offer. The vegetation in the riparian zone provides shade that reduces water temperature, traps and removes pollutants from stormwater, and provides protection from streambank erosion.

Recommendations for Riparian Zone Protection

- **Adopt and enforce the riparian buffer provisions of the Model Stormwater Management Ordinance.** The Model Ordinance includes provisions to require establishment of riparian buffers on all new development that occurs near watercourses. These requirements are in accord with the recently proposed changes to the statewide erosion and sediment pollution control regulations (Pennsylvania Code, Chapter 102). This will provide riparian zone protection by creating buffers between stream segments and all future development.
- **Establish a riparian zoning overlay district.** Identify critical riparian areas in which existing land uses may not be achieving water quality, floodplain management, and stormwater management objectives. Use this inventory of critical riparian zones to create a riparian zoning overlay district that establishes regulations on activities inside the zoning district.
- **Adopt stream specific guidelines where appropriate.** Where numerous problems areas have been identified and a riparian buffer is identified as a potential solution, a municipality may wish to adopt a stream specific set of guidelines that consider the specific fluvial geomorphological processes of that stream. A stream corridor study may be prepared that designates varying widths along a reach of stream. An ordinance that uses a stream corridor study as it basis will establish buffer widths using the best available scientific data. Some buffer ordinances have zones that vary between 75' and 1000' depending on the scientific and economic justification (Wenger and Fowler, 2000).
- **Encourage voluntary establishment of riparian buffers.** A regulatory approch will limit future development within the riparian zone, but will have little affect on existing land uses in critical riparian areas. There are numerous existing incentive programs that offer technical and/or financial assistance to encourage land owners to alter existing land uses and establish riparian buffers. These include agricultural land retirement programs such as USDA's Conservation Reserve Enhancement Program (CREP) program, cost-share programs such as USDA's Environmental Quality Incentives Program (EQIP), as well as grant and loan programs.

WETLAND PROTECTION

Wetlands play an essential role in stormwater management and water quality protection, as well as providing other valuable ecological and cultural functions. Some of the functions wetlands provide relevant to stormwater include: storm flow modification, erosion reduction, flood control, water quality protection, sediment and nutrient retention, and groundwater replenishment. Wetlands associated with lakes and streams provide temporary storage of floodwater by spreading the water over large flat areas, essentially acting as natural detention basins. This decreases peak flows, reduces flow velocity, and increases the time period for the water to reach the watersheds outlet. Novitzki (1979, 1989) found that basins with 30% or more areal coverage by lakes and wetlands have flood peaks that are 60% to 80% lower than the peaks in basins with no lake or wetland area.

Wetlands can also maintain good quality water and improve degraded water. Wetland vegetation also decreases water velocities causing suspended solids to drop out of suspension, thus decreasing the erosive power of the water. Wetlands also trap, precipitate, transform,

recycle, and export sediment, as well as nutrients, trace metals, and organic material. Water leaving a wetland can differ noticeably from that entering (Mitsch and Gosselink, 1993; Elder, 1987).

Recommendations for Wetland Protection

- **Identify and protect special value wetlands.** Due to the diversity of the benefits provided by wetlands, they are protected through various levels of federal and state regulations. These regulations protect wetlands from development; however, they permit minor wetland encroachments for certain activities. Some wetlands provide specific ecological or stormwater related benefits to an area. These wetlands should be identified and further protected through municipal regulations.

LOW-IMPACT DEVELOPMENT SITE DESIGN

The basic principles and concepts of LID were covered in *Section I* along with some of the benefits of implementing LID stormwater management practices. These concepts have been further developed throughout this Plan. This information has primarily discussed LID concepts as they relate to stormwater management. However, there are many non-stormwater LID practices that can have a very positive impact on a stormwater management program.

Development alters the natural landscape with human infrastructure like buildings, roads, sidewalks, parking lots, and other impervious surfaces. As previously discussed, all of these "improvements" alter the natural hydrology of a site and generate increased runoff. LID site design concepts include reducing impervious surface area, minimizing the amount of natural area disturbed during development, decentralizing stormwater management facilities, and generally attempting to minimize the effects of development on natural resources. Stormwater management can be improved by encouraging use of additional LID practices.

LIMIT IMPERVIOUS COVER

Increased impervious area within a watershed is a direct contributor to increased storm flows and decreased water quality. Research in recent years has consistently shown a strong relationship between the percentage of impervious cover in a watershed and the health of the receiving stream (USEPA, 2009). Various studies have indicated that as overall watershed imperviousness approaches 10% biological indicators of stream quality begin to show degradation. Limiting impervious cover is one method of reducing the impact of development on the hydrologic cycle.

Recommendations to Limit Impervious Cover

Some alternative development approaches within the LID approach include cluster development, reduction in street widths, reduction in parking space requirements (number and/or sizes), and creating a maximum impervious percentage on individual lots. Some specific elements within the LID framework include the following:

- **Road Widths** – These are usually specified based on the anticipated road use category (e.g., major, minor, collector). Most ordinances assume a standard 12-foot wide travel lane and then add width for shoulders, parking lanes, bicycle lanes, and other considerations. Reducing the travel lane width to 11 feet for minor roads (e.g., roads within a subdivision development) could reduce the impervious cover of those roadways by up to 8%.

- **On-Street Parking** – Parking lanes are often specified to be 8 or 10 feet wide. Standardizing the maximum width of these lanes to 8 feet would reduce runoff. Also, limiting parking to one side of a street, particularly in subdivisions, could result in a significant reduction in total runoff. Another option would be to require that the parking lanes be constructed of pervious pavement, grid blocks or another pervious surface.
- **Sidewalks** – In instances where ordinances require sidewalks, consideration should be given to only requiring them on one side of the street in order to reduce impervious cover. Also, sidewalks should be separated from the roadway surface by a "green strip" (e.g., grass or shrubs) to allow runoff from the impervious surface an opportunity to infiltrate before entering the roadway drainage system. In fact, the sidewalks could, in some instances, be laid out so that they do not parallel the roadway, providing even greater opportunity for infiltration.
- **Curb and Gutter Systems With Storm Sewers** – In heavy residential areas, many ordinances require the developer to install curb and gutters along roadways and to use inlets and storm sewers to remove and transport the runoff from the roads. Ordinances should be modified to allow roadside swales that would provide additional infiltration opportunity and some water quality benefit through filtration. This option would have the added benefits of significantly reducing development costs and minimizing future maintenance requirements.
- **Parking Requirements and Parking Stall Dimensions** – Consideration should be given to reducing the number of parking spaces that must be provided on-street or in parking lots for residential, commercial, educational, and industrial developments. Furthermore, stall sizes in parking lots should be set to 8-feet wide by 18-feet long. In addition, consideration could be given to requiring that larger parking lots establish special areas for compact cars with stall sizes reduced to 7-feet wide by 15-feet long. Finally, the ordinances should include requirements for a minimum amount of "green space" in parking lots which should allow runoff from the impervious surfaces to flow over them so that infiltration and water quality filtration would be enhanced.
- **Lot Sizes and Total Impervious Cover** – Most ordinances establish minimum lot sizes for various types of development and the number of "units" permitted on each lot. However, the ordinances do not always limit the amount of impervious cover that can be built on a specific lot, particularly in residential developments. Limits should be established and those limits should be used in determining the "post-development" runoff condition when designing the proposed storm water management systems. In addition, requirements should be established for the minimum amount of "green space" that should be provided in commercial, educational, and industrial developments and these "green spaces" should be designed so that runoff from the impervious surfaces can flow over them to the maximum extent practical.
- **Lot Setbacks** – There are at least two schools of thought regarding lot setbacks as they relate to stormwater management: 1) Minimizing lot setbacks will reduce driveway lengths and, thereby, reduce total impervious cover and 2) Maximizing lot setbacks will allow runoff from impervious surfaces (e.g., roof tops) greater opportunity to infiltrate prior to reaching roadway drainage systems. Either method could be beneficial as long as the method works in coordination with the other Ordinance requirements.

LIMIT DISTURBANCE OR COMPACTION OF TOPSOIL

Topsoil is an absorbant top layer that provides significant stormwater management functions through initial abstraction. During rainfall events, no runoff occurs until the topsoil becomes saturated and the initial holding capacity of the soil is exceeded. The void spaces in undisturbed

topsoil can provide significant water storage. The ability for initial abstraction can alter drastically from one soil type to another or because of varied site conditions. However, soil compaction plays a significant role in the ability of a given soil type to hold water. As topsoil is disturbed, or compacted, the holding capacity of the soil is drastically reduced, thus limiting its effectiveness in reducing runoff. Previous studies (Gregory, 2006) have shown that compacted pervious area effectively approaches the infiltration behavior of an impervious surface.

Recommendations for Topsoil Management

- **Adopt ordinance language that discourages the common practice of removing all topsoil from development sites during construction.** The area of disturbance during a project should be limited to the minimum area necessary to complete the project. This provides the dual benefit of limiting erosion during construction and improving post construction stormwater management.
- **Adopt ordinance provisions that limit soil compaction where possible.** Areas that are not disturbed should be protected from compaction by construction activities to the maximum extent practicable. These areas should be designated on site plans and demarcated and protected by in-field measures. This is especially important for areas intended for infiltration based stormwater management facilities.

IMPEDIMENTS TO LID IMPLEMENTATION

The LID concept has been around for a long time, but has been slow to catch on in mainstream implementation. In an effort to assess the impediments to LID in Chesapeake Bay portion of Virginia, Lassiter (2007) identified and ranked several impediments to LID implementation. The two most important impediments identified were 1) lack of education about the LID concept and 2) existing development rules that conflict with LID principles.

Other recent studies have found that existing municipal regulations are often a significant impediment to LID implementation (*Chesapeake Bay Program, 2002*). Many existing municipal regulations were developed to provide adequate infrastructure to meet the needs of growing communities. Often times these standards encourage use of unnecessary impervious surfaces such as extra wide streets in small residential areas, parking spaces for "worst-case scenarios" that get used only a few times a year and dead-end sidewalks. Municipalities are encouraged to review their ordinances for regulations that conflict with low-impact development and revise them to encourage the use of LID site design. There are many direct economic, environmental, aesthetic, and social benefits for a municipality adopting LID-friendly Ordinances.

Recommendations to Remove LID Impediments

- **Provide education activities and training workshops to various stakeholder groups.** As decision makers, and the group responsible for setting policy, municipal and county officials should be encouraged to obtain additional education on LID practices. Other stakeholders such as developers, builders, and homeowners should also have educational resources available to increase awareness and encourage implementation of LID practices. Education is the key to successful implementation of LID practices.
- **Promote guidance documents such as this Plan and included references.** There are a variety of publications and internet sites that discuss LID and offer design solutions: Low Impact Development Center (2009), DEP (2006), and Prince George's County (2000). These resources should be made available through municipal offices, websites, or trainings.

- **Alter existing Subdivision and Land Development Ordinances and Zoning Ordinances to allow for successful LID implementation.** Adoption of the Model Stormwater Management Ordinance in this Plan is an important tool in accomplishing the goals of LID. However, it is recommended that municipalities modify and enhance ordinances in order to provide enough flexibility to allow these innovative design methods to be employed by developers in order to advance the goals of this Plan. Potential alterations that may help create flexibility include: 1) creation of overlay zoning, 2) providing amendments to Ordinances to support LID efforts (i.e. reducing impervious cover and limiting topsoil compaction), or 3) creating an expedited waiver process for LID-specific requests.
- **Provide incentives for LID implementation.** Lassiter (2007) identifies tax credits, allowing for higher density developments, mitigation credits, and reduced land development fees for sites with LID developments as potential incentives to encourage developers to use LID.
- **Keep an inventory of LID efforts to help provide County-specific recommendations and successful BMP installation.** While considerable documentation exists on specific BMPs (e.g. National Research Council, 2008; DEP, 2006), very little scientific data exists within this region, and particularly this County. A valuable part of LID, one that is too often neglected, is the component of encouraging debate and expanding the LID knowledge base. Having an agency with a central role in land development permitting such as the Conservation District would be invaluable to developers and design professional in determining what may or may not work in Butler County.

SUMMARY

Implementation of the standards developed in this Plan are a necessary step toward developing a holistic stormwater management plan, but much more can be done to improve how we manage water resources. There are many opportunities for local governments to improve the way this resource is managed and protected, and the benefits are vast for those who undertake the challenge. There are a substantial number of technical resources available to guide development of regulations for proactive thinking municipalities.

Section XI – Plan Adoption, Implementation and Update Procedures



PLAN REVIEW AND ADOPTION

The opportunity for local review of the draft Stormwater Management Plan is a prerequisite to Butler County adoption of the Plan. Local review of the Plan is composed of several parts, namely the Plan Advisory Committee review (with focused assistance from others including Legal Advisors and Municipal Engineer's review, Municipal review), and County review. Local review of the draft Plan is initiated with the completion of the Plan by the County and distribution to the aforementioned parties. Presented below is a chronological listing and brief narrative of the required local review steps through County adoptions.

1. Plan Advisory Committee Review – This body has been formed to assist in the development of the Butler County Act 167 Stormwater Management Plan. Municipal members of the Committee have provided input data to the process in the form of storm drainage problem area documentation, storm sewer documentation, proposed solutions to drainage problems, etc. The Committee met on three occasions to review the progress of the Plan. Municipal representatives on the Committee have the responsibility to report on the progress of the Plan to their respective municipalities. Review of the draft Plan by the PAC will be expedited by the fact that the members are already familiar with the objectives of the Plan, the runoff control strategy employed, and the basic contents of the Plan. The output of the PAC review will be a revised draft Plan for Municipal and County consideration.

    a. Municipal Engineers Review – This body has been formed to focus on the technical aspects of the Plan and to educate the Municipal Engineers on the ordinance adoption and implementation requirements of the Plan. The group met twice to solicit input as well as to receive comments and direction in the development of the model ordinance. The result of this is a revised draft model ordinance for Municipal and County consideration.

2. Municipal Review – Act 167 specifies that prior to adoption of the draft Plan by the County, the planning commission and governing body of each municipality in the study area must review the Plan for consistency with other plans and programs affecting the study area. Of primary concern during the municipal review would be the Butler County Stormwater Management Model Ordinance that would implement the Plan through municipal adoption. The output of the municipal review will be a letter directed to the County outlining the municipal suggestions, if any, for revising the draft Plan (or Ordinance) prior to adoption by the County.

3. County Review and Adoption – Upon completion of the review by the Plan Advisory Committee, with assistance from the Municipal Engineers focus groups, and each municipality, the draft Plan will be submitted to the County Board of Commissioners for their consideration.

The Butler County review of the draft Plan will include a detailed review by the County Board of Commissioners and an opportunity for public input through the holding of a public hearing. Public hearings on the draft Plan must be held with a minimum two-week notice period with copies of the draft Plan available for inspection by the general public. Any modifications to the draft Plan would be made by the County based upon input from the public hearings, comments received from the municipalities in the study area, or their own review. Adoption of the draft Plan by Butler County would be by resolution and require an affirmative vote of the majority of the members of the County Board of Commissioners.

The County will then submit the adopted Plan to DEP for their consideration for approval. The review comments of the municipalities will accompany the submission of the adopted Plan to DEP.

IMPLEMENTATION OF THE PLAN

Upon final approval by DEP, each municipality within the county will become responsible for implementation of the Plan. Plan implementation, as used here, is a general term that encompasses the following activities:

- Adoption of municipal ordinances that enable application of the Plans provisions.
- Review of Drainage Plans for all activities regulated by the Plan and the resulting ordinances.
- Enforcement of the municipal regulations.

Each municipality will need to determine how to best implement the provisions of this Plan within their jurisdiction. Three basic models for Plan implementation are presented in *Table 11.1* below. In some cases it may be advantageous for multiple municipalities to implement the Plan cooperatively, or even on a county-wide basis.

Individual Municipal Model	Each municipality passes, implements, and enforces the SWM ordinance individually.
Multi-Municipal Model	Several municipalities cooperate through a new, or existing, service-sharing agreement (COG, Sewage Association, etc.)
County Service Provider Model	County department, or office, (e.g. County Planning Entity or County Conservation District) provides SWM ordinance implementation and enforcement services to municipalities.

Table 11.1. Models for Municipal Plan Implementation

Regardless of what model is used for implementation, each municipality will need to adopt regulations that enable the chosen implementation strategy. For municipalities that choose the Individual Municipal Model, this means municipal adoption of the Model Ordinance or integration of the Plan's provisions into existing municipal regulations. For the other two models, this will require ordinance provisions that designate the regulatory authority and adoption of an inter-municipal agreement or service-sharing agreement.

It is important that the standards and criteria contained in the Plan are implemented correctly, especially if the municipality chooses to integrate the standards and criteria into existing regulations. In either case, it is recommended that the resulting regulatory framework be reviewed by the local planning commission, the municipal solicitor, the Butler County Planning Commission and/or the Butler County Conservation District for compliance with the provisions of the Plan and consistency among the various related regulations.

PROCEDURE FOR UPDATING THE PLAN

Act 167 specifies that the County must review and, if necessary, revise the adopted and approved study area plan every five years, at a minimum. Any proposed revisions to the Plan would require municipal and public review prior to County adoption consistent with the procedures outlined above. An important aspect of the Plan is a procedure to monitor the implementation of the Plan and initiate review and revisions in a timely manner. The process to be used for the Butler County Act 167 Stormwater Management Plan will be as outlined below.

1. Monitoring of the Plan Implementation – The Butler County Planning Commission (BCPC) will be responsible for monitoring the implementation of the Plan by maintaining a record of all development activities within the study area. Development activities are defined and included in the recommended Municipal Ordinance. Specifically, the BCPC will monitor the following data records:

    a. All subdivision and land developments subject to review per the Plan which have been approved within the study area.
    b. All building permits subject to review per the Plan which have been approved within the study area.
    c. All DEP permits issued under Chapter 105 (Dams and Waterway Management) and Chapter 106 (Floodplain Management) including location and design capacity (if applicable).

2. Review of Adequacy of Plan – The PAC will be convened periodically to review the Plan and determine if the Plan is adequate for minimizing the runoff impacts of new development. At a minimum, the information to be reviewed by the PAC will be as follows:

    a. Development activity data as monitored by the BCPC.
    b. Information regarding additional storm drainage problem areas as provided by the municipal representatives to the Watershed Plan Advisory Committee.
    c. Zoning amendments within the study area.
    d. Information associated with any regional detention alternatives implemented within the study area.
    e. Adequacy of the administrative aspects of regulated activity review.

The PAC will review the above data and make recommendations to the County as to the need for revision to the Butler County Act 167 Stormwater Management Plan. Butler County will review the recommendations of the PAC and determine if revisions are to be made. A revised Plan would be subject to the same rules of adoption as the original Plan preparation. Should the County determine that no revisions to the Plan are required for a period of five consecutive years, the County will adopt resolutions stating that the Plan has been reviewed and been found satisfactory to meet the requirements of Act 167 and forward the resolution to DEP.

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HRG
Herbert, Rowland & Grubic, Inc.
Engineering & Related Services

Model Stormwater Management Ordinance

Butler County
Act 167 County-Wide
Stormwater Management Plan

June 2010 (rev December 2010)

200 West Kensinger Drive• Cranberry Township, Pennsylvania 16066 • 724.779.4777 [phone]

Using The Model Stormwater Management Ordinance

Municipal Requirements: This Model Stormwater Management Ordinance was developed during the *Butler County Act 167 Stormwater Management Plan*. The Pennsylvania Stormwater Management Act (Act 167) requires that each municipality adopt a stormwater management ordinance to implement the stormwater management plan. Section 11(b) of Act 167 states:

> "Within six months following the DEP's approval of the this plan, each municipality is required to adopt new and/or amend existing stormwater ordinances or other ordinances, including zoning, subdivision and development, building code, and erosion and sedimentation ordinances, as are necessary to regulate development in a manner consistent with plan."

Any ordinance(s) adopted or amended by the municipality to comply with the stormwater management standards and criteria of the *Butler County Act 167 Stormwater Management Plan* must be sent by a municipal official to the DEP with the municipal ordinance number and including the date the ordinance was enacted.

Enacting and Amending Municipal Ordinances: It is recommended that municipalities enact the Model Ordinance as a stand-alone ordinance. In addition, it is recommended that municipalities review existing ordinances (subdivision and land development, zoning, etc.) and consider amending them to refer to and coordinate with the new municipal stormwater management ordinance.

Ordinance Provisions: Ordinances adopted by municipalities are the legal instrument that implements the standards and criteria of this stormwater management plan.

- The text ***[Municipality]*** in the Model Ordinance should be replaced by the name of the individual municipality.
- Provisions with **[OPTIONAL]** is recommended but may be modified or deleted by the municipality. When deleting an **[OPTIONAL]** Article, the municipality should consider leaving the Article as "Reserved for future use".

The final ordinance adopted by the municipality should be developed in conjunction with, reviewed by, and agreed upon by the municipal solicitor, engineer, and governing body.

STORMWATER MANAGEMENT MODEL ORDINANCE

Implementing the Requirements of the

Butler County Stormwater Management Plan

ORDINANCE NO. _____ OF_____

_____, BUTLER COUNTY, PENNSYLVANIA

Adopted at a Public Meeting Held on
_____, 2010

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ARTICLE I - GENERAL PROVISIONS

Section 101. Short Title

This Ordinance shall be known and may be cited as the "***[Municipality]*** Stormwater Management Ordinance."

Section 102. Statement of Findings

The governing body of ***[Municipality]*** finds that:

A. Inadequate management of accelerated stormwater runoff resulting from development throughout a watershed increases flood flows and velocities, contributes to erosion and sedimentation, overtaxes the carrying capacity of existing streams and storm sewers, greatly increases the cost of public facilities to convey and manage stormwater, undermines floodplain management and flood reduction efforts in upstream and downstream communities, reduces groundwater recharge, threatens public health and safety, and increases non-point source pollution of water resources.

B. A comprehensive program of stormwater management, including reasonable regulation of development and activities causing accelerated runoff, is fundamental to the public health, safety, welfare, and the protection of the people of Municipality and all the people of the Commonwealth, their resources, and the environment.

C. Inadequate planning and management of stormwater runoff resulting from land development and redevelopment throughout a watershed can also harm surface water resources by changing the natural hydrologic patterns; accelerating stream flows (which increase scour and erosion of streambeds and stream banks thereby elevating sedimentation); destroying aquatic habitat; and elevating aquatic pollutant concentrations and loadings such as sediments, nutrients, heavy metals, and pathogens. Groundwater resources are also impacted through loss of recharge.

D. Stormwater is an important water resource which provides groundwater recharge for water supplies and base flow of streams, which also protects and maintains surface water quality.

E. Public education on the control of pollution from stormwater is an essential component in successfully addressing stormwater issues.

F. Federal and state regulations require certain municipalities to implement a program of stormwater controls. These municipalities are required to obtain a permit for stormwater discharges from their separate storm sewer systems under the National Pollutant Discharge Elimination System (NPDES).

G. Non-stormwater discharges to municipal separate storm sewer systems can contribute to pollution of Waters of the Commonwealth.

Section 103. Purpose

The purpose of this Ordinance is to promote health, safety, and welfare within ***[Municipality]***, Butler County, by minimizing the harms and maximizing the benefits described in Section 102 of this Ordinance through provisions intended to:

A. Meet legal water quality requirements under state law, including regulations at 25 PA Code Chapter 93 to protect, maintain, reclaim, and restore the existing and designated uses of the Waters of the Commonwealth.

B. Manage accelerated runoff and erosion and sedimentation problems close to their source, by regulating activities that cause these problems.

C. Preserve the natural drainage systems as much as possible.

D. Maintain groundwater recharge, to prevent degradation of surface and groundwater quality, and to otherwise protect water resources.

E. Maintain existing flows and quality of streams and watercourses.

F. Preserve and restore the flood-carrying capacity of streams and prevent scour and erosion of stream banks and streambeds.

G. Manage stormwater impacts close to the runoff source, with a minimum of structures and a maximum use of natural processes.

H. Provide procedures, performance standards, and design criteria for stormwater planning and management.

I. Provide proper operations and maintenance of all temporary and permanent stormwater management facilities and Best Management Practices (BMPs) that are constructed and implemented.

J. Provide standards to meet the NPDES permit requirements.

[FOR MS4 PERMITTEES]

K. Implement an "illegal discharge detection and elimination program" in MS4 permanent urbanized areas to address non-stormwater discharges into ***[Municipality's]*** separate storm sewer system.

Section 104. Statutory Authority

A. Primary Authority: ***[Municipality]*** is empowered to regulate these activities by the authority of the Act of October 4, 1978, 32 P.S., P.L. 864 (Act 167), 32 P.S. Section 680.1 et seq., as amended, the "Storm Water Management Act", and the ***[applicable Municipal Code]***.

B. Secondary Authority: ***[Municipality]*** also is empowered to regulate land use activities that affect runoff by the authority of the Act of July 31, 1968, P.L. 805, No. 247, The Pennsylvania Municipalities Planning Code, as amended.

Section 105. Applicability

In ***[Municipality]***, all regulated activities and all activities that may affect stormwater runoff, including land development and earth disturbance activity, are subject to regulation by this Ordinance.

Earth disturbance activities and associated stormwater management controls are also regulated under existing state law and implementing regulations. This Ordinance shall operate in coordination with those parallel requirements; the requirements of this Ordinance shall be no less restrictive in meeting the purposes of this Ordinance than state law.

"Regulated Activities" are any earth disturbance activities or any activities that involve the alteration or development of land in a manner that may affect stormwater runoff. "Regulated Activities" include, but are not limited to, the following listed items:

A. Earth Disturbance Activities
B. Land Development
C. Subdivision
D. Construction of new or additional impervious or semi-pervious surfaces
E. Construction of new buildings or additions to existing buildings
F. Diversion or piping of any natural or man-made stream channel

G. Installation of stormwater management facilities or appurtenances thereto
H. Installation of stormwater BMPs

See Section 302 of this Ordinance for Exemption/Modification Criteria.

Section 106. Repealer

Any ordinance, ordinance provision(s), or regulation of ***[Municipality]*** inconsistent with any of the provision(s) of this Ordinance is hereby repealed to the extent of the inconsistency only.

Section 107. Severability

In the event that a court of competent jurisdiction declares any section(s) or provision(s) of this Ordinance invalid, such decision shall not affect the validity of any of the remaining section(s) or provision(s) of this Ordinance.

Section 108. Compatibility with Other Ordinance Requirements

Approvals issued and actions taken pursuant to this Ordinance do not relieve the Applicant of the responsibility to comply with or to secure required permits or approvals for activities regulated by any other applicable codes, laws, rules, statutes, or ordinances. To the extent that this Ordinance imposes more rigorous or stringent requirements for stormwater management, the specific requirements contained in this Ordinance shall be followed.

Section 109. Duty of Persons Engaged in the Development of Land

Notwithstanding any provision(s) of this Ordinance, including exemptions, any landowner or any person engaged in the alteration or development of land which may affect stormwater runoff characteristics shall implement such measures as are reasonably necessary to prevent injury to health, safety, or other property. Such measures also shall include actions as are required to manage the rate, volume, direction, and quality of resulting stormwater runoff in a manner which otherwise adequately protects health, property, and water quality.

Section 110. Municipal Liability Disclaimer

A. Neither the granting of any approval under this Ordinance, nor the compliance with the provisions of this Ordinance, or with any condition imposed by a municipal official hereunder, shall relieve any person from any responsibility for damage to persons or property resulting there from, or as otherwise imposed by law nor impose any liability upon the Municipality for damages to persons or property.

B. The granting of a permit which includes any storm water management facilities shall not constitute a representation, guarantee or warranty of any kind by the Municipality, or by an official or employee thereof, of the practicability or safety of any structure, use or other plan proposed, and shall create no liability upon or cause of action against such public body, official or employee for any damage that may result pursuant thereto.

ARTICLE II - DEFINITIONS

For the purpose of this Ordinance, certain terms and words used herein shall be interpreted as follows:

A. Words used in the present tense include the future tense; the singular number includes the plural; and the plural number includes the singular; words of masculine gender include feminine gender; and words of feminine gender include masculine gender.

B. The word "includes" or "including" shall not limit the term to the specific example but is intended to extend its meaning to all other instances of like kind and character.

C. The word "person" includes an individual, firm, association, organization, partnership, trust, company, corporation, or any other similar entity.

D. The words "shall" and "must" are mandatory; the words "may" and "should" are permissive.

E. The words "used or occupied" include the words "intended, designed, maintained, or arranged to be used, occupied or maintained".

Accelerated Erosion - The removal of the surface of the land through the combined action of human activity and natural processes at a rate greater than would occur because of the natural process alone.

Agricultural Activities - Activities associated with agriculture such as agricultural cultivation, agricultural operation, and animal heavy use areas. This includes the work of producing crops, tillage, land clearing, plowing, disking, harrowing, planting, harvesting crops, or pasturing and raising of livestock and installation of conservation measures. Construction of new buildings or impervious area is not considered an Agricultural Activity.

Alteration - As applied to land, a change in topography as a result of the moving of soil and rock from one location or position to another; changing of surface conditions by causing the surface to be more or less impervious; land disturbance.

Applicant - A landowner, developer, or other person who has filed an application for approval to engage in any Regulated Activities at a project site within the municipality.

Best Management Practices (BMPs) - Activities, facilities, designs, measures or procedures used to manage stormwater impacts from Regulated Activities, to meet State Water Quality Requirements, to promote groundwater recharge and to otherwise meet the purposes of this Ordinance. Stormwater BMPs are commonly grouped into one of two broad categories or measures: "non-structural" or "structural". "Non-structural" BMPs are measures referred to as operational and/or behavior-related practices that attempt to minimize the contact of pollutants with stormwater runoff whereas "structural" BMPs are measures that consist of a physical device or practice that is installed to capture and treat stormwater runoff. "Structural" BMPs include, but are not limited to, a wide variety of practices and devices, from large-scale retention ponds and constructed wetlands, to small-scale underground treatment systems, infiltration facilities, filter strips, low impact design, bioretention, wet ponds, permeable paving, grassed swales, riparian or forested buffers, sand filters, detention basins, and manufactured devices. "Structural" stormwater BMPs are permanent appurtenances to the project site.

Channel Erosion - The widening, deepening, and headward cutting of small channels and waterways, due to erosion caused by moderate to large floods.

Cistern - An underground reservoir or tank used for storing rainwater.

Conservation District - The Butler County Conservation District. The Butler County Conservation District has the authority under a delegation agreement executed with the Department of Environmental Protection to administer and enforce all or a portion of the regulations promulgated under 25 PA Code Chapter 102.

Culvert - A structure with appurtenant works that carries a stream and/or stormwater runoff under or through an embankment or fill.

Dam - An artificial barrier, together with its appurtenant works, constructed for the purpose of impounding or storing water or another fluid or semifluid, or a refuse bank, fill or structure for highway, railroad or other purposes which does or may impound water or another fluid or semifluid.

Design Storm - The magnitude and temporal distribution of precipitation from a storm event measured in probability of occurrence (e.g., a 25-year storm) and duration (e.g., 24-hours), used in the design and evaluation of stormwater management systems. Also see Return Period.

Designee - The agent of this municipality and/or agent of the governing body involved with the administration, review or enforcement of any provisions of this Ordinance by contract or memorandum of understanding.

Detention Basin - An impoundment structure designed to manage stormwater runoff by temporarily storing the runoff and releasing it at a predetermined rate.

Detention Volume - The volume of runoff that is captured and released into Waters of the Commonwealth at a controlled rate.

Developer - A person, partnership, association, corporation, or other entity, or any responsible person therein or agent thereof, that undertakes any Regulated Activity of this Ordinance.

Development Site - **(Site)** - The specific tract of land for which a Regulated Activity is proposed. Also see Project Site.

Disturbed Area - An unstabilized land area where an Earth Disturbance Activity is occurring or has occurred.

Downslope Property Line - That portion of the property line of the lot, tract, or parcels of land being developed located such that all overland or pipe flow from the site would be directed toward it.

Drainage Conveyance Facility - A stormwater management facility designed to convey stormwater runoff and shall include streams, channels, swales, pipes, conduits, culverts, storm sewers, etc.

Drainage Easement - A right granted by a landowner to a grantee, allowing the use of private land for stormwater management, drainage, or conveyance purposes.

Drainageway - Any natural or artificial watercourse, trench, ditch, pipe, swale, channel, or similar depression into which surface water flows.

Earth Disturbance Activity - A construction or other human activity which disturbs the surface of the land, including, but not limited to, clearing and grubbing, grading, excavations, embankments, land

development, agricultural plowing or tilling, timber harvesting activities, road maintenance activities, mineral extraction, and the moving, depositing, stockpiling, or storing of soil, rock or earth materials.

Erosion - The movement of soil particles by the action of water, wind, ice, or other natural forces.

Erosion and Sediment Pollution Control Plan - A plan which is designed to minimize accelerated erosion and sedimentation.

Exceptional Value Waters - Surface waters of high quality, which satisfies PA Code Title 25 Environmental Protection, Chapter 93 Water Quality Standards 93.4b(b) (relating to anti-degradation).

Existing Conditions - The initial condition of a project site prior to the proposed construction. If the initial condition of the site is undeveloped land and not forested, the land use shall be considered as "meadow" unless the natural land cover is documented to generate lower Curve Numbers or Rational "C" Coefficient.

FEMA - The Federal Emergency Management Agency.

Flood - A general but temporary condition of partial or complete inundation of normally dry land areas from the overflow of streams, rivers, and other Waters of the Commonwealth.

Flood Fringe - The remaining portions of the 100-year floodplain outside of the floodway boundary.

Floodplain - Any land area susceptible to inundation by water from any natural source or delineated by applicable Department of Housing and Urban Development, Federal Insurance Administration Flood Hazard Boundary - mapped as being a special flood hazard area. Included are lands adjoining a river or stream that have been or may be inundated by a 100-year flood. Also included are areas that comprise Group 13 Soils, as listed in Appendix A of the Pennsylvania Department of Environmental Protection (PADEP) Technical Manual for Sewage Enforcement Officers (as amended or replaced from time to time by PADEP).

Floodway - The channel of the watercourse and those portions of the adjoining floodplains that are reasonably required to carry and discharge the 100-year frequency flood. Unless otherwise specified, the boundary of the floodway is as indicated on maps and flood insurance studies provided by FEMA. In an area where no FEMA maps or studies have defined the boundary of the 100-year frequency floodway, it is assumed - absent evidence to the contrary - that the floodway extends from the stream to 50 feet landward from the top of the bank of the stream.

Forest Management/Timber Operations - Planning and activities necessary for the management of forestland. These include timber inventory and preparation of forest management plans, silvicultural treatment, cutting budgets, logging road design and construction, timber harvesting, site preparation and reforestation.

Freeboard - A vertical distance between the elevation of the design high water and the top of a dam, levee, tank, basin, or diversion ridge. The space is required as a safety margin in a tank, pond or basin.

Grade - A slope, usually of a road, channel or natural ground specified in percent and shown on plans as specified herein.

(To) Grade - To finish the surface of a roadbed, top of embankment or bottom of excavation.

Groundwater Recharge - Replenishment of existing natural underground water supplies.

HEC-HMS Model Calibrated - (Hydrologic Engineering Center Hydrologic Modeling System) A computer-based hydrologic modeling technique adapted to the watershed(s) in Butler County for the Act 167 Plan. The model has been calibrated by adjusting key model input parameters.

High Quality Waters - Surface water having quality, which exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water by satisfying PA Code Title 25 Environmental Protection, Chapter 93 Water Quality Standards 93.4b(a).

Hydrologic Soil Group (HSG) - Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into one of four HSG (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. The Natural Resource Conservation Service (NRCS) of the US Department of Agriculture defines the four groups and provides a list of most of the soils in the United States and their group classification. The soils in the area of interest may be identified from a soil survey report from the local NRCS office or the County Conservation District.

Impervious Surface (Impervious Area) - A surface that prevents the infiltration of water into the ground. Impervious surface (or areas) include, but is not limited to: roofs, additional indoor living spaces, patios, garages, storage sheds and similar structures, parking or driveway areas, and any new streets and sidewalks. Any surface areas proposed to initially be gravel or crushed stone shall be assumed to be impervious surfaces.

Impoundment - A retention or detention basin designed to retain stormwater runoff and release it at a controlled rate.

Infiltration Structures - A structure designed to direct runoff into the ground (e.g., french drains, seepage pits, seepage trench, etc.).

Inlet - A surface connection to a closed drain. A structure at the diversion end of a conduit. The upstream end of any structure through which water may flow.

Land Development (Development) - (i) The improvement of one lot or two or more contiguous lots, tracts or parcels of land for any purpose involving (a) a group of two or more buildings, or (b) the division or allocation of land or space between or among two or more existing or prospective occupants by means of, or for the purpose of streets, common areas, leaseholds, condominiums, building groups, or other features; (ii) Any subdivision of land; (iii) Development in accordance with Section 503(1.1) of the PA Municipalities Planning Code.

Low Impact Development (LID) - an approach to land development that uses various land planning and design practices and technologies to simultaneously conserve and protect natural resource systems and reduce infrastructure costs. LID still allows land to be developed, but in a cost-effective manner that helps mitigate potential environmental impacts.

Main Stem (Main Channel) - Any stream segment or other runoff conveyance facility used as a reach in the Butler County Act 167 watershed hydrologic model(s).

Manning Equation (Manning Formula) - A method for calculation of velocity of flow (e.g., feet per second) and flow rate (e.g., cubic feet per second) in open channels based upon channel shape, roughness, depth of flow and slope. "Open channels" may include closed conduits so long as the flow is not under pressure.

Municipality - ***[Municipality]***, Butler County, Pennsylvania.

National Pollutant Discharge Elimination System (NPDES) - The federal government's system for issuance of permits under the Clean Water Act, which is delegated to PADEP in Pennsylvania.

NOAA Atlas 14: - Precipitation-Frequency Atlas of the United States, Atlas 14, Volume 2, US Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Hydrometeorological Design Studies Center, Silver Spring, Maryland (2004). NOAA's Atlas 14 can be accessed at Internet address http://hdsc.nws.noaa.gov/hdsc/pfds/.

Non-point Source Pollution - Pollution that enters a water body from diffuse origins in the watershed and does not result from discernible, confined, or discrete conveyances.

NRCS - Natural Resource Conservation Service (previously Soil Conservation Service (SCS)).

Open Channel - A drainage element in which stormwater flows with an open surface. Open channels include, but shall not be limited to, natural and man-made drainageways, swales, streams, ditches, canals, and pipes not under pressure.

Outfall - (i) Point where water flows from a conduit, stream, or drain; (ii) "Point Source" as described in 40 CFR § 122.2 at the point where the Municipality's storm sewer system discharges to surface Waters of the Commonwealth.

Outlet - Points of water disposal from a stream, river, lake, tidewater, or artificial drain.

PADEP - The Pennsylvania Department of Environmental Protection.

Parking Lot Storage - Involves the use of impervious parking areas as temporary impoundments with controlled release rates during rainstorms.

Peak Discharge - The maximum rate of stormwater runoff from a specific storm event.

Person - An individual, partnership, public or private association or corporation, or a governmental unit, public utility or any other legal entity whatsoever which is recognized by law as the subject of rights and duties.

Pervious Area - Any area not defined as impervious.

Pipe - A culvert, closed conduit, or similar structure (including appurtenances) that conveys stormwater.

Planning Commission - The Planning Commission of ***[Municipality]***.

Point Source - Any discernible, confined, or discrete conveyance, including, but not limited to: any pipe, ditch, channel, tunnel, or conduit from which stormwater is or may be discharged, as defined in State regulations at 25 Pennsylvania Code § 92.1.

Probable Maximum Flood (PMF) - The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in any area. The PMF is derived from the probable maximum precipitation (PMP) as determined on the basis of data obtained from the National Oceanographic and Atmospheric Administration (NOAA).

Project Site - The specific area of land where any Regulated Activities in the Municipality are planned, conducted, or maintained.

Qualified Professional - Any person licensed by the Pennsylvania Department of State or otherwise qualified by law to perform the work required by the Ordinance.

Rational Formula - A rainfall-runoff relation used to estimate peak flow.

Redevelopment - Earth disturbance activities on land, which has previously been developed.

Regulated Activities - Any earth disturbance activities or any activities that involve the alteration or development of land in a manner that may affect stormwater runoff.

Regulated Earth Disturbance Activity - Activity involving Earth Disturbance subject to regulation under 25 PA Code Chapter 92, Chapter 102, or the Clean Streams Law.

Release Rate - The percentage of pre-development peak rate of runoff from a site or subwatershed area to which the post-development peak rate of runoff must be reduced to protect downstream areas.

Release Rate District - Those subwatershed areas in which post-development flows must be reduced to a certain percentage of pre-development flows as required to meet the plan requirements and the goals of Act 167.

Retention Basin - An impoundment in which stormwater is stored and not released during the storm event. Stored water may be released from the basin at some time after the end of the storm.

Retention Volume/Removed Runoff - The volume of runoff that is captured and not released directly into the surface Waters of this Commonwealth during or after a storm event.

Return Period - The average interval, in years, within which a storm event of a given magnitude can be expected to recur. For example, the 25-year return period rainfall would be expected to recur on the average once every twenty-five years; or stated in another way, the probability of a 25-year storm occurring in any one given year is 0.04 (i.e. a 4% chance).

Riparian Buffer - A vegetated area bordering perennial and intermittent streams and wetlands, that serves as a protective filter to help protect streams/wetlands from the impacts of adjacent land uses.

Riser - A vertical pipe extending from the bottom of a pond that is used to control the discharge rate from the pond for a specified design storm.

Road Maintenance - Earth disturbance activities within the existing road right-of-way, such as grading and repairing existing unpaved road surfaces, cutting road banks, cleaning or clearing drainage ditches, and other similar activities. Road maintenance activities that do not disturb the subbase of a paved road (such as milling and overlays) are not considered earth disturbance activities.

Rooftop Detention - Temporary ponding and gradual release of stormwater falling directly onto flat roof surfaces by incorporating controlled-flow roof drains into building designs.

Runoff - Any part of precipitation that flows over the land surface.

Runoff Capture Volume - The volume of runoff that is captured (retained) and not released into surface Waters of the Commonwealth during or after a storm event.

Sediment - Soils or other materials transported by surface water as a product of erosion.

Sediment Basin - A barrier, dam, retention or detention basin located and designed to retain rock, sand, gravel, silt, or other material transported by stormwater runoff.

Sediment Pollution - The placement, discharge, or any other introduction of sediment into Waters of the Commonwealth occurring from the failure to properly design, construct, implement or maintain control measures and control facilities in accordance with the requirements of this Ordinance.

Sedimentation - The process by which mineral or organic matter is accumulated or deposited by the movement of water.

Seepage Pit/Seepage Trench - An area of excavated earth filled with loose stone or similar coarse material, into which surface water is directed for infiltration into the ground.

Separate Storm Sewer System - A conveyance or system of conveyances (including roads with drainage systems, Municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) primarily used for collecting and conveying stormwater runoff.

Sheet Flow - Runoff that flows over the ground surface as a thin, even layer - not concentrated in a channel.

Soil Cover Complex Method - A method of runoff computation developed by the NRCS that is based on relating soil type and land use/cover to a runoff parameter called Curve Number (CN).

Spillway (Emergency) - A depression in the embankment of a pond or basin, or other overflow structure, that is used to pass peak discharges greater than the maximum design storm controlled by the pond or basin.

State Water Quality Requirements - The regulatory requirements to protect, maintain, reclaim, and restore water quality under Title 25 of that Pennsylvania Code and the Clean Streams Law.

Storage Indication Method - A reservoir routing procedure based on solution of the continuity equation (inflow minus outflow equals the change in storage) with outflow defined as a function of storage volume and depth.

Storm Frequency - The number of times that a given storm "event" occurs or is exceeded on the average in a stated period of years. See also Return Period.

Storm Sewer - A system of pipes and/or open channels that convey intercepted runoff and stormwater from other sources, but excludes domestic sewage and industrial wastes.

Stormwater - Runoff from the surface of the land resulting from precipitation, snow, or ice melt.

Stormwater Hotspot - A land use or activity that generates higher concentrations of hydrocarbons, trace metals, or toxicants than are found in typical stormwater runoff.

Stormwater Management Facilities - Any structure, natural or man-made, that, due to its condition, design, or construction, conveys, stores, or otherwise affects stormwater runoff. Typical stormwater management facilities include, but are not limited to: detention and retention basins, open channels, storm sewers, pipes and infiltration facilities.

Stormwater Management Plan - The Butler County Stormwater Management Plan for managing stormwater runoff in Butler County as required by the Act of October 4, 1978, P.L. 864, (Act 167) and known as the "Storm Water Management Act".

Stormwater Management Site Plan (SWM Site Plan) - The plan prepared by the Applicant or his representative indicating how stormwater runoff will be managed at the project site in accordance with this Ordinance.

Stream Enclosure - A bridge, culvert, or other structure in excess of 100 feet in length upstream to downstream which encloses a regulated Waters of the Commonwealth.

Subwatershed Area - The smallest drainage unit of a watershed for which stormwater management criteria has been established in the Stormwater Management Plan.

Subdivision - The division or re-division of a lot, tract, or parcel of land by any means, into two or more lots, tracts, parcels or other divisions of land including changes in existing lot lines for the purpose, whether immediate or future, of lease, transfer of ownership, or building or lot development, provided; however, that the subdivision by lease of land for agricultural purposes into parcels of more than ten acres, not involving any new street or easement of access or any residential dwellings, shall be exempt {Pennsylvania Municipalities Planning Code, Act of July 31, 1968, P.L. 805, No. 247}.

Swale - A low-lying stretch of land that gathers or carries surface water runoff.

Timber Operations - See "Forest Management".

Time of Concentration (T_c) - The time for surface runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed. This time is the combined total of overland flow time and flow time in pipes or channels, if any.

USDA - The United States Department of Agriculture.

Watercourse - A channel or conveyance of surface water, such as a stream or creek, having defined bed and banks, whether natural or artificial, with perennial or intermittent flow.

Waters of the Commonwealth - Rivers, streams, creeks, rivulets, impoundments, ditches, watercourses, storm sewers, lakes, dammed water, wetlands, ponds, springs and other bodies or channels of conveyance of surface and underground water, or parts thereof, whether natural or artificial, within or on the boundaries of the Commonwealth of Pennsylvania.

Watershed - Area drained by a river, watercourse, or other surface water, whether natural or artificial.

Wetland - Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions, including swamps, marshes, bogs and similar areas. (The term includes but is not limited to wetland areas listed in the State Water Plan, the United States Forest Service Wetlands Inventory of Pennsylvania and a wetland area designated by a river basin commission. This definition is used by the United States Environmental Protection Agency and the United States Army Corps of Engineers.)

ARTICLE III - STORMWATER MANAGEMENT STANDARDS

Section 301. General Requirements

A. For all Regulated Activities, unless specifically exempted in Section 302:

1. Preparation and implementation of an approved SWM Site Plan is required.
2. No Regulated Activities shall commence until the municipality issues written approval of a SWM Site Plan, which demonstrates compliance with the requirements of this Ordinance.
3. The SWM Site Plan shall demonstrate that adequate capacity will be provided to meet the Volume and Rate Control Requirements, as described under Sections 304 and 305 of this Ordinance.
4. The SWM Site Plan approved by the municipality, shall be on-site throughout the duration of the Regulated Activities.

B. For all Regulated Earth Disturbance Activities, erosion and sediment control BMPs shall be designed, implemented, operated, and maintained during the Regulated Earth Disturbance Activities (e.g., during construction) to meet the purposes and requirements of this Ordinance and to meet all requirements under Title 25 of the Pennsylvania Code (including, but not limited to Chapter 102 Erosion and Sediment Control) and the Clean Streams Law. Various BMPs and their design standards are listed in the *Erosion and Sediment Pollution Control Program Manual* (E&S Manual), No. 363-2134-008 (April 15, 2000), as amended and updated.

C. For all Regulated Activities, stormwater BMPs shall be designed, installed, implemented, operated, and maintained to meet the purposes and requirements of this Ordinance and to meet all requirements under Title 25 of the Pennsylvania Code and the Clean Streams Law, conform to the State Water Quality Requirements, meet all requirements under the Storm Water Management Act and any more stringent requirements as determined by the municipality.

D. The municipality may, after consultation with PADEP and the Conservation District, approve measures for meeting the State Water Quality Requirements other than those in this Ordinance, provided that they meet the minimum requirements of, and do not conflict with state law, including, but not limited to, the Clean Streams Law.

E. All Regulated Activities shall include, to the maximum extent practicable, measures to:

1. Protect health, safety, and property.
2. Meet the water quality goals of this Ordinance by implementing measures to:
    a. Minimize disturbance to floodplains, wetlands, natural slopes, existing native vegetation and woodlands.
    b. Create, maintain, or extend riparian buffers and protect existing forested buffers.
    c. Provide trees and woodlands adjacent to impervious areas whenever feasible.
    d. Minimize the creation of impervious surfaces and the degradation of Waters of the Commonwealth and promote groundwater recharge.
    e. Protect natural systems and processes (drainageways, vegetation, soils, and sensitive areas) and maintain, as much as possible, the natural hydrologic regime.
    f. Incorporate natural site elements (wetlands, stream corridors, mature forests) as design elements.

g. Avoid erosive flow conditions in natural flow pathways.
h. Minimize soil disturbance and soil compaction.
i. Minimize thermal impacts to Waters of the Commonwealth.
j. Disconnect impervious surfaces by directing runoff to pervious areas, wherever possible and decentralize and manage stormwater at its source.

F. Impervious Areas:
1. The measurement of impervious areas shall include all of the impervious areas in the total proposed development, even if development is to take place in stages.
2. For developments taking place in stages, the entire development plan must be used in determining conformance with this Ordinance.
3. [OPTION] For projects that add impervious area to a parcel, the total impervious area on the parcel is subject to the requirements of this Ordinance.

G. If diffused flow is proposed to be concentrated and discharged onto adjacent property, the Applicant must document that adequate downstream conveyance facilities exist to safely transport the concentrated discharge, or otherwise prove that no erosion, sedimentation, flooding, or other harm will result from the concentrated discharge.
1. Applicant must provide an easement for proposed concentrated flow across adjacent properties to a drainage way or public right-of-way.
2. Such stormwater flows shall be subject to the requirements of this ordinance.

H. Stormwater drainage systems shall be provided in order to permit unimpeded flow along natural watercourses, except as modified by stormwater management facilities or open channels consistent with this Ordinance.

I. Where watercourses traverse a development site, drainage easements (with a minimum width of 20 feet and include the 100-year water surface) shall be provided conforming to the line of such watercourses. The terms of the easement shall prohibit excavation, the placing of fill or structures, and any alterations that may adversely affect the flow of stormwater within any portion of the easement. Also, maintenance, including mowing of vegetation within the easement may be required, except as approved by the appropriate governing authority.

J. When it can be shown that, due to topographic conditions, natural drainageways on the site cannot adequately provide for drainage, open channels may be constructed conforming substantially to the line and grade of such natural drainageways. Work within natural drainage ways shall be subject to approval by PADEP under regulations at 25 PA Code Chapter 105 through the Joint Permit Application process, or, where deemed appropriate by PADEP, through the General Permit process.

K. Any stormwater management facilities or any facilities that constitute water obstructions (e.g., culverts, bridges, outfalls, or stream enclosures, etc.) that are regulated by this Ordinance, that will be located in or adjacent to Waters of the Commonwealth (including wetlands), shall be subject to approval by PADEP under regulations at 25 PA Code Chapter 105 through the Joint Permit Application process, or, where deemed appropriate by PADEP, the General Permit process. When there is a question whether wetlands may be involved, it is the responsibility of the Applicant or his agent to show that the land in question cannot be classified as wetlands; otherwise, approval to work in the area must be obtained from PADEP.

L. Should any stormwater management facility require a dam safety permit under PADEP Chapter 105, the facility shall be designed in accordance with Chapter 105 and meet the regulations of Chapter 105 concerning dam safety.

M. Any stormwater management facilities regulated by this Ordinance that will be located on, or discharged onto State highway rights-of-ways shall be subject to approval by the Pennsylvania Department of Transportation (PENNDOT).

N. Minimization of impervious surfaces and infiltration of runoff through seepage beds, infiltration trenches, etc., are encouraged, where soil conditions and geology permit, to reduce the size or eliminate the need for detention facilities.

O. Infiltration BMPs should be dispersed throughout the site, made as shallow as practicable, and located to maximize use of natural on-site infiltration features while still meeting the other requirements of this Ordinance.

P. The design of facilities over karst shall include an evaluation and implementation of measures to minimize adverse effects.

Q. Roof drains shall not be connected to streets, sanitary or storm sewers, or roadside ditches in order to promote overland flow and infiltration/percolation of stormwater where it is advantageous to do so. When it is more advantageous to connect directly to streets or storm sewers, then the Municipality shall permit it on a case-by-case basis.

R. Applicants are encouraged to use Low Impact Development Practices to reduce the costs of complying with the requirements of this Ordinance and the State Water Quality Requirements.

S. When stormwater management facilities are proposed within 1,000 feet of a downstream Municipality, the Developer shall notify the downstream Municipality and provide a copy of the SWM Plan, if requested, for review and comment.

Section 302. Exemptions/Modifications

A. Under no circumstance shall the Applicant be exempt from implementing such measures as necessary to:

1. Meet State Water Quality Standards and Requirements.
2. Protect health, safety, and property.
3. Meet special requirements for High Quality (HQ) and Exceptional Value (EV) watersheds.

B. The Applicant must demonstrate that the following BMPs are being utilized to the maximum extent practicable to receive consideration for the exemptions:

1. Design around and limit disturbance of Floodplains, Wetlands, Natural Slopes over 15%, existing native vegetation, and other sensitive and special value features.
2. Maintain riparian and forested buffers.
3. Limit grading and maintain non-erosive flow conditions in natural flow paths.
4. Maintain existing tree canopies near impervious areas.
5. Minimize soil disturbance and reclaim disturbed areas with topsoil and vegetation.
6. Direct runoff to pervious areas.

C. The Applicant must demonstrate that the proposed development/additional impervious area will not adversely impact the following:

1. Capacities of existing drainageways and storm sewer systems.
2. Velocities and erosion.

3. Quality of runoff if direct discharge is proposed.
4. Existing known problem areas.
5. Safe conveyance of the additional runoff.
6. Downstream property owners.

D. An Applicant proposing Regulated Activities may be eligible for exemption from Rate Control, Volume Control, or Stormwater Management Site Plan requirements in this Ordinance according to the following table:

Table 302.1 – Exemptions and Submission Requirements

New Impervious Area[1, 2] (square footage)	Applicant Must Provide
0 < 2,500	No submission is required
2,500 < 5,000	Documentation of new impervious surfaces[3]
5,000 and greater	Rate Controls, Volume Controls & SWM Site Plan

NOTES:

[1] New Impervious Area since the date of Adoption of this Ordinance.

[2] Gravel in existing condition shall be considered pervious and gravel in proposed condition shall be considered impervious.

[3] The Small Project Stormwater Management Application included in Appendix E shall be used to document new impervious surfaces.

E. Single Family Residential activities are exempt from these requirements provided the construction:
   1. Comply with Sections 301.G, 302.A, 302.B, 302.C, and
   2. Have building setback 75 feet from downstream property lines, and
   3. Driveways:
      a. Runoff must discharge onto pervious surface with a gravel strip or other spreading device.
      b. No more than 1,000 square feet of paved surface may discharge to any one point.
      c. The length of flow on the pervious must exceed the length of the paved surface flow.
   4. The municipality can require more information or require mitigation of certain impacts through installation of stormwater management BMP's if there is a threat to property, health, or safety.

F. An Applicant proposing Regulated Activities, after demonstrating compliance with Sections 302.A, 302.B, and 302.C, may be exempted from various requirements of this Ordinance if documentation can be provided that a downstream man-made water body (i.e., reservoir, lake, or man-made wetlands) has been designed or modified to address the potential stormwater flooding impacts of the proposed development.

G. The purpose this section is to ensure consistency of stormwater management planning between local ordinances and NPDES permitting (when required) and to ensure that the Applicant has a single and clear set of stormwater management standards to which the Applicant is subject. The Municipality may accept alternative stormwater management controls under this section provided that:

   1. The Municipality, in consultation with the PADEP (or Delegated Authority), determines that meeting the Volume Control requirements (See Section 304) is not possible or places an undue hardship on the Applicant.

2. The alternative controls are documented to be acceptable to PADEP (or Delegated Authority), for NPDES requirements pertaining to post construction stormwater management requirements.
3. The alternative controls are in compliance with all other sections of this ordinance, including but not limited to Sections 301.D and 302.A-C.

H. Agricultural activities are exempt from the rate control and SWM Site Plan preparation requirements of this Ordinance provided the activities are performed according to the requirements of 25 PA Code Chapter 102.

I. Forest management and timber operations are exempt from the Rate and Volume Control requirement and SWM Site Plan preparation requirement of this Ordinance provided the activities are performed according to the requirements of 25 PA Code Chapter 102. It should be noted that temporary roadways are not exempt.

J. The municipality may deny or revoke any exemption pursuant to this Section at any time for any project that the municipality believes may pose a threat to public health, safety, property or the environment.

Section 303. Waivers

A. The provisions of this Ordinance are the minimum standards for the protection of the public welfare.

B. All waiver requests must meet the provisions of Section 303.G. and H. Waivers shall not be issued from implementing such measures as necessary to:

1. Meet State Water Quality Standards and Requirements.
2. Protect health, safety, and property.
3. Meet special requirements for High Quality (HQ) and Exceptional Value (EV) watersheds.

Municipalities will then consider waivers in accordance with Section 301.D.

C. If an Applicant demonstrates to the satisfaction of the governing body of the Municipality that any mandatory provision of this Ordinance is unreasonable or causes unique or undue unreasonableness or hardship as it applies to the proposed Project, or that an alternate design may result in a superior result within the context of Section 102 and 103 of this Ordinance, the governing body of the Municipality upon obtaining the comments and recommendations of the Municipal Engineer may grant a waiver or relief so that substantial justice may be done and the public interest is secured; provided that such waiver will not have the effect of nullifying the intent and purpose of this Ordinance.

D. The Applicant shall submit all requests for waivers in writing and shall include such requests as a part of the plan review and approval process. The Applicant shall state in full the facts of unreasonableness or hardship on which the request is based, the provision or provisions of the Ordinance that are involved, and the minimum waiver or relief that is necessary. The Applicant shall state how the requested waiver and how the Applicant's proposal shall result in an equal or better means of complying with the intent or Purpose and general principles of this Ordinance.

E. The Municipality shall keep a written record of all actions on waiver requests.

F. The Municipality may charge a fee for each waiver request, which shall be used to offset the administrative costs of reviewing the waiver request. The Applicant shall also agree to reimburse the Municipality for reasonable and necessary fees that may be incurred by the Municipal Engineer in any review of a waiver request.

G. In granting waivers, the Municipality may impose reasonable conditions at will, in its judgment, secure substantially the objectives of the standards or requirements that are to be modified.

H. The Municipality may grant applications for waivers when the following findings are made, as relevant:

1. That the waiver shall result in an equal or better means of complying with the intent of this Ordinance.
2. That the waiver is the minimum necessary to provide relief.
3. That the applicant is not requesting a waiver based on cost considerations.
4. That existing down gradient stormwater problems will not be exacerbated.
5. That runoff is not being diverted to a different drainage area.
6. That increased flooding or ponding on off-site properties or roadways will not occur.
7. That potential icing conditions will not occur.
8. That increase of peak flow or volume from the site will not occur.
9. That erosive conditions due to increased peak flows or volume will not occur.
10. That adverse impact to water quality will not result.
11. That increased 100-Year Floodplain levels will not result.
12. That increased or unusual municipal maintenance expenses will not result from the waiver.
13. That the amount of stormwater generated has been minimized to the greatest extent allowed.
14. That infiltration of runoff throughout the proposed site has been provided where practicable and pre-development ground water recharge protected.
15. That peak flow attenuation of runoff has been provided.
16. That long term operation and maintenance activities are established.
17. That the receiving streams and/or water bodies will not be adversely impacted in flood carrying capacity, aquatic habitat, channel stability and erosion and sedimentation.

Section 304. Volume Controls

A. The Low Impact Development Practices provided in the BMP Manual and in Appendix B of this Ordinance shall be utilized for all Regulated Activities to the maximum extent practicable.

B. Stormwater runoff Volume Controls shall be implemented using the *Design Storm Method* or the *Simplified Method* as defined below. For Regulated Activity areas equal or less than one (1) acre that do not require hydrologic routing to design the stormwater facilities, this Ordinance establishes no preference for either method; therefore, the Applicant may select either method on the basis of economic considerations, the intrinsic limitations on applicability of the analytical procedures associated with each methodology, and other factors.

1. The *Design Storm Method* (CG-1 in the BMP Manual) is applicable to any sized Regulated Activity. This method requires detailed modeling based on site conditions.

    a. Do not increase the post-development total runoff volume when compared to the pre-development total runoff volume for the 2-year/24-hour storm event.

    b. For hydrologic modeling purposes:

i. Existing non-forested pervious areas must be considered meadow (good condition) for pre-development hydrologic calculations.
ii. Twenty (20) percent of existing impervious area, when present within the proposed project site, shall be considered meadow (good condition) for pre-development hydrologic calculations for re-development.

2. The *Simplified Method* (CG-2 in the BMP Manual) is independent of site conditions and should be used if the *Design Storm Method* is not followed. This method is not applicable to Regulated Activities greater than 1 acre or for projects that require detailed design of stormwater storage facilities. For new impervious surfaces:

    a. Stormwater facilities shall capture at least the first 2 inches of runoff from all new impervious surfaces.
    b. At least the first 1 inch of runoff from new impervious surfaces shall be permanently removed from the runoff flow, i.e. it shall not be released into surface Waters of the Commonwealth. Removal options include reuse, evaporation, transpiration, and infiltration.
    c. Wherever possible, infiltration facilities should be designed to accommodate infiltration of the entire permanently removed runoff; however, in all cases at least the first 0.5 inch of the permanently removed runoff should be infiltrated.
    d. Actual field infiltration tests at the location of the proposed elevation of the stormwater BMPs are required. Infiltration test shall be conducted in accordance with the BMP Manual. Notification of the Municipality shall be provided to allow witnessing of the testing.

3. In cases where it is not possible or desirable to use infiltration-based best management practices to partially fulfill the requirements in either Section 304.B.1 or 304.B.2, the following procedure shall be used:

    a. At a minimum, the following documentation shall be provided to justify the decision to not use infiltration BMPs:
        i. Description of and justification for field infiltration/permeability testing with respect to the type of test and test locations).
        ii. An interpretive narrative describing existing site soils and their structure as these relate to the interaction between soils and water occurring on the site. In addition to providing soil and soil profile descriptions, this narrative shall identify depth to seasonal high water tables and depth to bedrock, and provide a description of all subsurface elements (fragipans and other restrictive layers, geology, etc.) that influence the direction and rate of subsurface water movement.
        iii. A qualitative assessment of the site's contribution to annual aquifer recharge shall be made, along with identification of any restrictions or limitations associated with the use of engineered infiltration facilities.
        iv. The provided documentation must be signed and sealed by a professional engineer or geologist.

b. The following water quality pollutant load reductions will be required for all disturbed areas within the proposed development:

Pollutant Load	Units	Required reduction (%)
Total Suspended Solids (TSS)	Pounds	85
Total Phosphorous (TP)	Pounds	85
Total Nitrate (NO_3)	Pounds	50

c. The performance criteria for water quality best management practices shall be determined from the Pennsylvania Stormwater Best Management Practices Manual, most current version.

C. The applicable Worksheets from the BMP Manual must be used in calculations to establish Volume Control.

Section 305. Rate Controls

A. Lands contained within Butler County that have not had release rates established under an approved Act 167 Stormwater Management Plan:

1. Post-development discharge rates shall not exceed the pre-development discharge rates for the 1-year, 2-year, 10-year, 25-year, 50-year, and 100-year storms.

B. Lands contained within Butler County that have had release rates established under an approved Act 167 Stormwater Management Plan:

1. The post-development peak discharge rates shall be in accordance with the approved release rate map for the following watersheds (see Appendices for Release Rate Map):
    a. Connoquenessing Creek Watershed

Section 306. Sensitive Areas and Stormwater Hotspots

A. Sensitive areas and water quality sensitive developments as defined below which require special consideration with regard to stormwater management.

1. Sensitive areas are defined as those areas that, if developed, have the potential to endanger a water supply. These areas consist of the delineated 1-year zone of contribution and direct upslope areas tributary to the water supply wells. Municipalities may update the sensitive area boundaries based on new research or studies as required.
2. Stormwater Hotspots are defined as a land development project that has a high potential to endanger local water quality, and could potentially threaten ground water reservoirs. The Municipal Engineer will determine what constitutes these classifications on a case-by-case basis. The PADEP wellhead protection contaminant source list shall be used as a guide in these determinations. Industrial manufacturing site and hazardous material storage areas must provide NPDES SIC codes.

B. Performance Standards

1. The location of the boundaries of sensitive areas is set by drainage areas tributary to any public water supply. The exact location of these boundaries as they apply to a given development site, shall be determined using mapping at a scale which accurately defines the limits of the sensitive area. If the project site is within the sensitive

area (in whole or in part), 2-foot contour interval mapping shall be provided to define the limits of the sensitive area. If the project site is adjacent to but within 500 linear feet of a defined Sensitive Area, a 5-foot contour interval map defining the limits of the Sensitive Area shall be included in the Stormwater Management Plan to document the site's location relative to the sensitive area.

2. Stormwater Hotspots may be required to prepare and implement a stormwater pollution prevention plan and file notice of intent as required under the provision of the EPA Industrial Stormwater NPDES Permit Requirements.
3. Stormwater Hotspots must use an acceptable pre-treatment BMP prior to volume control and/or rate control BMPs. Acceptable pre-treatment BMPs for these developments include those based on filtering, settling, or chemical reaction processes such as coagulation.

ARTICLE IV - E&S STANDARDS [OPTIONAL]

The following E&S Standards are recommended to reinforce the importance of BMPs during the construction process. As E&S Standards are regulated through PA DEP and Conservation Districts as well as required through other municipal Ordinances, this Article may be redundant.

Section 401. Erosion and Sedimentation Requirements During Earth Disturbance Activities

A. The applicant shall meet requirements as contained in 25 PA Code, Chapters 92 and 102 as required and applicable as follows:

1. The implementation and maintenance of erosion and sediment control BMPs.
2. Development of written plans.
3. Submission of plans for approval.
4. Obtaining Erosion and Sediment Control and NPDES permits.
5. Maintaining plans and permits on site.

B. Evidence of any necessary plan or permit approval for Earth Disturbance activities from PADEP or the Butler County Conservation District must be provided to the Municipality.

C. A copy of the approved Erosion and Sediment Control Plan and any other permit, as required by PADEP or the Butler County Conservation District, shall be available at the project site at all times if required under Chapter 102.

D. Construction of temporary roadways (e.g., for utility construction, timber harvesting, etc.) shall comply with all applicable standards for erosion and sedimentation control and stream crossing regulations under 25 PA Code, Chapters 102 and 105. The Erosion and Sedimentation Control Plan shall be submitted to the Butler County Conservation District for approval and shall address the following, as applicable:

1. Design of the roadway system, including haul roads, skid roads, landing areas, trails, and storage and staging areas.
2. Runoff control structures (e.g., diversions, culverts, detention ponds, etc.).
3. Stream crossings for both perennial and intermittent streams.
4. Access to public roadways, including design of rock construction entrance for mud and debris control.
5. A remediation plan for restoring the disturbed area through re-grading, topsoil placement, reseeding, and other stabilization techniques, as required.

E. Additional erosion and sedimentation control design standards and criteria that must be applied where infiltration BMPs are proposed include the following:

1. Areas proposed for infiltration BMPs shall be protected from sedimentation and compaction during the construction phase, as to maintain their maximum infiltration capacity.
2. Infiltration BMPs shall be protected from receiving sediment-laden runoff.
3. The source of protection for infiltration BMPs shall be identified (i.e. orange construction fence surrounding the perimeter of the BMP).

ARTICLE V – PROTECTED WATERSHED STANDARDS

Section 501. Protected Watershed Requirements

A. For any Regulated Activity within a protected watershed (High Quality or Exceptional Value), the applicant shall meet requirements as contained in 25 PA Code, Chapters 93 as required and applicable.

B. Existing Resources and Site Analysis Plan. Shall be prepared to provide the developer and the Municipality with a comprehensive analysis of existing conditions, both on the proposed development site and within 500 feet of the site. Conditions beyond the parcel boundaries may be described on the basis of existing published data available from governmental agencies and from aerial photographs. The Municipality shall review the plan to assess its accuracy, conformance with Municipal ordinances, and likely impact upon the natural and cultural resources on the property. The following information shall be required:

1. Complete current perimeter boundary survey of the property to be subdivided or developed prepared by a registered surveyor, showing all courses, distances, and area and tie-ins to all adjacent intersections.

2. A vertical aerial photograph enlarged to a scale not less detailed than one inch equals 400 feet, with the site boundaries clearly marked.

3. Natural features, including:
    a. Contour lines at intervals of not more than two feet. (Ten-foot intervals are permissible beyond the parcel boundaries, interpolated from USGS published maps.) Contour lines shall be based on information derived from a topographic survey for the property, evidence of which shall be submitted, including the date and source of the contours. Datum to which contour elevations refer and references to known, established benchmarks and elevations shall be included on the plan.
    b. Steep slopes in the following ranges: 15% to 25%, 25% and greater. The location of these slopes shall be graphically depicted by category on the plan. Slope shall be measured over three or more two-foot contour intervals.
    c. Areas within the floodway, flood fringe, and approximated floodplain.
    d. Watercourses, either continuous or intermittent and named or unnamed, and lakes, ponds or other water features as depicted on the USGS Quadrangle Map, most current edition.
    e. Wetlands and wetland margins.
    f. Riparian buffers.
    g. Soil types and their boundaries, as mapped by the USDA Natural Resource Conservation Service, including a table listing the soil characteristics pertaining to suitability for construction and, in un-sewered areas, for septic suitability. Alluvial and hydric soils shall specifically be depicted on the plan.
    h. Existing vegetation, denoted by type, including woodlands, hedgerows, tree masses, tree lines, individual freestanding trees over six inches DBH, wetland vegetation, pasture or croplands, orchards, permanent grass land, old fields, and any other notable vegetative features on the site. Vegetative types shall be described by plant community, relative age, and condition.
    i. Any identified Pennsylvania Natural Diversity Inventory (PNDI) site conflicts.
    j. Geologic formations on the tract, including rock outcroppings, cliffs, sinkholes, and fault lines, based on available published information or more detailed data obtained by the applicant.

4. Existing man-made features, including:
    a. Location, dimensions, and use of existing buildings and driveways.
    b. Location, names, widths, center line courses, paving widths, identification numbers, and rights-of-way, of existing streets and alleys.
    c. Location of trails that have been in public use (pedestrian, equestrian, bicycle, etc.).
    d. Location and size of existing sanitary sewage facilities.
    e. Location and size of drainage facilities.
    f. Location of water supply facilities, including wellhead protection areas.
    g. Any easements, deed restrictions, rights-of-way, or any other encumbrances upon the land, including location, size, and ownership.
    h. Site features or conditions such as hazardous waste, dumps, underground tanks, active and abandoned wells, quarries, landfills, sandmounds, and artificial land conditions.

5. Total acreage of the tract, the adjusted tract area, where applicable, and the constrained land area with detailed supporting calculations.

C. Stormwater Management System Concept Plan. A written and graphic concept plan of the proposed post-development stormwater management system shall be prepared and include:
    1. Preliminary selection and location of proposed structural stormwater controls;
    2. Location of existing and proposed conveyance systems such as grass channels, swales, and storm drains;
    3. Location of floodplain/floodway limits;
    4. Relationship of site to upstream and downstream properties and drainages.
    5. Preliminary location of proposed stream channel modifications, such as bridge or culvert crossings.

D. Consultation Meeting. Prior to any stormwater management permit application submission, the land owner or developer shall meet with the Municipality for a consultation meeting on a concept plan for the post-development stormwater management system to be utilized in the proposed project. This consultation meeting shall take place at the time of the preliminary plan or other early step in the development process. The purpose of this meeting is to discuss the post-development stormwater management measures necessary for the proposed project, as well as to discuss and assess constraints, opportunities and potential ideas for stormwater management designs before the formal site design engineering is commenced.

E. All proposed Regulated Activities within a protected watershed shall utilize, to the maximum extent possible, Low Impact Development Practices as contained in Appendix B.

    1. SWM Plan and Report shall address the following:
        a. Design using nonstructural BMPs
            i. Lot configuration and clustering.
                (a) Reduced individual lot impacts by concentrated/clustered uses and lots
                (b) Lots/development configured to avoid critical natural areas
                (c) Lots/development configured to take advantage of effective mitigative stormwater practices
                (d) Lots/development configured to fit natural topography

            ii. Minimum disturbance

(a) Define disturbance zones (excavation/grading) for the site and individual lots to protect maximum total site area from disturbance
(b) Barriers/flagging proposed to protect designated non-disturbance areas
(c) Considered mitigative practices for minimal disturbance areas (e.g., Soil Restoration)
(d) Considered re-forestation and re-vegetation opportunities

iii. Reduce Impervious coverage
(a) Reduced road width
(b) Reduced driveway lengths and widths
(c) Reduced parking ratios and sizes
(d) Utilized porous surfaces for applicable features

iv. Stormwater disconnected from impervious area
(a) Disconnected drives/walkways/small impervious areas to natural areas
(b) Use rain barrels and/or cisterns for lot irrigation

b. Apply structural BMP selection process that meets runoff quantity and quality needs.
i. Manage close to source with collection with conveyance minimized
ii. Consistent with site factors (e.g., soils, slope, available space, amount of sensitive areas, pollutant removal needs)
iii. Minimize footprint and integrate into already disturbed areas/other building program components (e.g., recharge beneath parking areas, vegetated roofs)
iv. Consider other benefits such as aesthetic, habitat, recreational and educational benefits
v. BMP's select based on maintenance needs that fit owner/users
vi. BMP's sustainable using a long-term maintenance plan

ARTICLE VI – RIPARIAN BUFFER STANDARDS [OPTIONAL]

The following Riparian Buffer Standards are recommended to assist municipalities and developers to avoid and minimize impacts to water bodies. In addition, Riparian Buffers can improve the existing water quality of impaired water bodies. The standards and criteria provided is consistent with the proposed Chapter 102 regulations expected to be implemented in 2010.

Section 601. Riparian Buffer Requirements

Where a Riparian Buffer is required for a Regulated Activity, the Riparian Buffer shall be established as follows:

A. The buffer shall be measured perpendicularly from the top of the stream bank landward.
    1. High Quality or Exceptional Value Watersheds - a minimum of 150 feet;
    2. Impaired Watersheds – a minimum of 150 feet;
    3. All other watersheds - a minimum of 50 feet; or
    4. As determined by a stream corridor study approved by PADEP and the Municipality.

B. The riparian buffer shall be located on both sides of all perennial and intermittent streams. The perennial and intermittent streams and the riparian buffer boundaries shall be shown on all applications for Building Permits, subdivision, or land development. Existing uses within the buffer are permitted to continue but not be expanded. Placement of new structures or roadways within the riparian buffer shall be prohibited. Where a wetland exists within the buffer area, the buffer shall be extended landward to provide a minimum buffer of 25 feet, as measured perpendicularly from the wetland boundary.

C. The buffer shall be undisturbed forest consisting of appropriate native species.

D. Where wetlands are located partially or entirely within a buffer, the buffer shall be extended to encompass the wetland and shall be widened by a distance sufficient to provide a 25 foot forested buffer measured perpendicularly from the wetland boundary.

E. The following uses shall be permitted in the buffer:

    1. Footpaths, trails and bike paths provided that:
        a. Width is limited to 5 feet;
        b. Width may be increased provided a corresponding increase in the buffer is provided;
        c. Construction shall have minimal impact to the buffer.
    2. Stream crossings, provided the crossing is designed and constructed in such a manner as to minimize the impact to the buffer. The Riparian Buffer shall be restored to its original condition, to the maximum extent practical, upon completion of construction.
    3. Utility lines, provided that the crossing is designed and constructed in such a manner as to minimize the impact to the inner buffer and provided that there is no practical alternative to locating the utility line within the buffer. The Riparian Buffer shall be restored to its original condition, to the maximum extent practical, upon completion of construction.
    4. Maintenance and restoration of the Riparian Buffer.
    5. Projects conducted with the objective of improvement, stabilization, restoration, or enhancement of the stream bank, stream channel, floodplain, watershed hydrology, riparian buffers, or aquatic habitat and maintenance activities associated with such projects. These projects include, but are not limited to agricultural and stormwater

management best management practices. Such projects must receive appropriate permits and approvals from PADEP prior to starting the project.

6. Minor private recreational uses for the property owner. Such uses include benches, fire rings, and similar uses. Such uses do not include structures such as cabins, sheds, pavilions, garages, dwellings or similar structures.

F. Disturbance of the Riparian Buffer shall be limited to the area necessary to perform an allowable use.

G. Where possible and practical, disturbances shall be phased with each phase restored prior to beginning the next phase.

H. Allowable activities shall not cause stormwater flow to concentrate.

I. Any vegetation removed for an allowable activity shall be replaced immediately upon completion of the activity. Where mature trees are removed, such trees shall be replaced with the largest practical tree of acceptable native species.

J. Erosion and sediment pollution control shall be installed and maintained during construction. Evidence of an approved Erosion and Sediment Control Plan, NPDES Permit or other PADEP permit, where required, shall be submitted prior to issuance of local permits.

K. Riparian buffers shall be maintained in a manner consistent with sound forest management practices. In the absence of a site specific management plan, the following maintenance guidelines apply:

1. Buffers shall be inspected periodically for evidence of excessive sediment deposition, erosion or concentrated flow channels. Prompt action shall be taken to correct these problems and prevent future occurrence.
2. Trees presenting an unusual hazard of creating downstream obstructions shall be removed. Such material shall be removed from the floodplain or the riparian buffer (whichever is widest); or cut into sections small enough so as to prevent the possibility of creating obstructions downstream. Wherever possible, large stable debris should be conserved.
3. Vegetation should be inspected periodically to ensure diverse vegetative cover and vigorous plant growth consistent with buffering objectives.
    a. Remove invasive plant species that may threaten the integrity of the buffer.
    b. Periodic cutting of trees may be necessary to promote vigorous growth and encourage regeneration.
4. Excessive use of fertilizers, pesticides, herbicides, and other chemicals shall be avoided. These products should be used only when absolutely necessary to maintain buffer vegetation.

Section 602. Riparian Buffer Easement

For all Riparian Buffers, an easement shall be provided:

A. Easements shall be in accordance with Section 901 and recorded in accordance with Section 1403 of this Ordinance.

ARTICLE VII - DESIGN CRITERIA

Section 701. Design Criteria for Stormwater Management & Drainage Facilities

A. General Design Guidelines:

1. Stormwater shall not be transferred from one watershed to another, unless (1) the watersheds are sub-watersheds of a common watershed which join together within the perimeter of the property; (2) the effect of the transfer does not alter the peak rate discharge onto adjacent lands; or (3) easements from the affected landowner(s) are provided.

2. Consideration shall be given to the relationship of the subject property to the drainage pattern of the watershed. A concentrated discharge of stormwater to an adjacent property shall be within an existing watercourse or confined in an easement or returned to a pre-development flow type condition.

3. Innovative stormwater BMPs and recharge facilities are encouraged (e.g., rooftop storage, drywells, cisterns, recreation area ponding, diversion structures, porous pavements, holding tanks, infiltration systems, in-line storage in storm sewers, and grading patterns). They shall be located, designed, and constructed in accordance with the latest technical guidance published by PADEP, provided they are accompanied by detailed engineering plans and performance capabilities and supporting site specific soils, geology, runoff and groundwater and infiltration rate data to verify proposed designs. Additional guidance from other sources may be accepted at the discretion of the Municipal Engineer (a pre-application meeting is suggested).

4. All existing and natural watercourses, channels, drainage systems and areas of surface water concentration shall be maintained in their existing condition unless an alteration is approved by the appropriate regulatory agency.

5. The design of all stormwater management facilities shall incorporate sound engineering principles and practices. The Municipality shall reserve the right to disapprove any design that would result in the continuation or exacerbation of a documented adverse hydrologic or hydraulic condition within the watershed, as identified in the Plan.

6. The design and construction of multiple use stormwater detention facilities are strongly encouraged. In addition to stormwater management, facilities should, where appropriate, allow for recreational uses including ball fields, play areas, picnic grounds, etc. Consultation with the Municipality, and prior approval are required before design. Provision for permanent wet ponds with stormwater management capabilities may also be appropriate.

    a. Multiple use basins should be constructed so that potentially dangerous conditions are not created.
    b. Water quality basins or recharge basins that are designed for a slow release of water or other extended detention ponds are not permitted for recreational uses, unless the ponded areas are clearly separated and secure.

7. Should any stormwater management facility require a dam safety permit under PADEP Chapter 105, the facility shall be designed in accordance with Chapter 105 and meet the regulations of Chapter 105 concerning dam safety.

The following Stormwater Management Design Criteria provide a compilation of components recommended for effective stormwater management. The criteria reflect a moderate level of restrictions in its standards and are based on technically sound principles. The design criteria are provided to assist both municipalities and designers to implement good stormwater management systems.

B. **[OPTIONAL]** Stormwater Management Facility Design Considerations: All stormwater management facilities shall meet the following design requirements:

1. No outlet structure from a stormwater management facility, or swale, shall discharge directly onto a Municipal or State roadway without approval from the Municipality or PennDOT.

2. The top, or toe, of any slope shall be located a minimum of 10 feet from any property line.

3. The minimum horizontal distance between any stormwater holding facility shall be 25 feet. The lowest floor elevation of any structure constructed immediately adjacent to a detention basin or other stormwater facility shall be a minimum of 2 feet above the 100-year water surface elevation.

4. Stormwater management facility bottom (or surface of permanent pool) elevations must be greater than adjacent floodplain elevations (FEMA or HEC-RAS analysis). If no floodplain is defined, bottom elevations must be greater than existing ground elevations 50 feet from top of stream bank in the facilities' vicinity.

5. Basin outflow culverts discharging into floodplains must account for tailwater. Tailwater corresponding to the 100-year floodplain elevation must be used for all design storms, or the Applicant may elect to determine flood elevations of the adjacent watercourse for each design storm. The floodplain is assumed to be 50 feet from top of stream bank in areas where a floodway is not designated, or no other evidence is provided.

6. The invert of all stormwater management facilities and underground infiltration/storage facilities shall be located a minimum of 2 feet above the seasonal high groundwater table. The invert of stormwater facilities may be lowered if adequate sub-surface drainage is provided. Flows from underdrains need not be accounted for in Volume or Rate Control calculations.

7. Whenever possible the side slopes and basin shape shall be amenable to the natural topography. Vertical side slopes and rectangular basins shall be avoided whenever possible.

8. Exterior slopes of compacted soil shall not exceed 3:1, and may be further reduced if the soil has unstable characteristics.

9. Interior slopes of the basin shall not exceed 3:1.

10. Unless specifically designed as a volume control facility, all stormwater management facilities shall have a minimum slope of 2% extending radially out from the principal outlet structure. Facilities designed as water quality / infiltration BMPs may have a bottom slope of zero.

11. Impervious low-flow channels are not permitted within stormwater management facilities.

12. Unless specifically designed as a Volume Control or water quality facility, all stormwater management facilities must empty over a period of time not less than 24 hours and not more than 72 hours from the end of the facility's inflow hydrograph. Infiltration tests performed at the facility locations and proposed basin bottom depths, in accordance with the BMP Manual, must support time-to-empty calculations if infiltration is a factor.

13. Energy dissipators and/or level spreaders shall be installed at points where pipes or drainageways discharge to or from basins. Discharges to drainage swales shall be dissipated, or piped, to an acceptable point.

14. Landscaping and planting specifications must be provided for all stormwater management basins and be specific for each type of basin.

    a. Minimal maintenance, saturation tolerant vegetation must be provided in basins designed as water quality / infiltration BMPs.

15. A safety fence may be required, at the discretion of the Municipality, for any stormwater management facility. The fence shall be a minimum of 4 feet high, and of a material acceptable to the Municipality. A gate with a minimum opening of 10 feet shall be provided for maintenance access.

16. Principal Outlet Structures: The primary outlet structure shall be designed to pass all design storms (up to and including the 100-year event) without discharging through the emergency spillway. All principal outlet structures shall:
    a. Be constructed of reinforced concrete or an alternative material approved by the Municipal Engineer. When approved for use, all metal risers shall:
        i. Be suitably coated to prevent corrosion.
        ii. Have a concrete base attached with a watertight connection. The base shall be sufficient weight to prevent flotation of the riser.
        iii. Provide a trash rack or similar appurtenance to prevent debris from entering the riser.
        iv. Provide an anti-vortex device, consisting of a thin vertical plate normal to the basin berm.
    b. Provide trash racks to prevent clogging of primary outflow structure stages for all orifices.
    c. Provide outlet aprons and shall extend to the toe of the basin slope at a minimum.

17. Emergency Spillways: Any stormwater management facility designed to store runoff shall provide an emergency spillway designed to convey the 100-year post-development peak rate flow with a blocked primary outlet structure. The emergency spillway shall be designed per the following requirements:
    a. The top of embankment elevation shall provide a minimum 1 foot of freeboard above the maximum water surface elevation. This is to be calculated when the spillway functions for the 100-year post-development inflow, with a blocked outlet structure.
    b. Avoid locating on fill areas, whenever possible.
    c. The spillway shall be armored to prevent erosion during the 100-year post-development flow, with a blocked primary outlet structure.
        i. Synthetic liners or riprap may be used, and calculations sufficient to support proposed armor must be provided. An earthen plug must be used to accurately control the spillway invert if riprap is the proposed

armoring material. Emergency spillway armor must extend up the sides of the spillway, and continue at full width to a minimum of 10 feet past the toe of slope.

d. Municipal Engineer may require the use of additional protection when slopes exceed 4:1 and spillway velocities might exceed NRCS standards for the particular soils involved.
e. Any underground stormwater management facility (pipe storage systems) must have a method to bypass flows higher than the required design (up to a 100-year post-development inflow) without structural failure, or causing downstream harm or safety risks.

18. Stormwater Management Basins: Design of stormwater management facilities having 3 feet or more of water depth (measured vertically from the lowest elevation in the facility to the crest of the emergency spillway) shall meet the following additional requirements:

a. The maximum water depth within any stormwater management facility shall be no greater than 8 feet when functioning through the primary outlet structure.
b. The top of embankment width shall be:
    i. For embankments up to 4', width shall be at least 6 feet;
    ii. For embankments between 4 and 6 feet, width shall be at least 8 feet;
    iii. For embankments over 6 feet, width shall be at least 10 feet.
c. A 10 foot wide access to the basin bottom must be provided with a maximum longitudinal slope of 10%.
d. Berms shall be constructed using soils that conform to the unified soil classification of CH, MH, CL or ML. Soils used shall be tested to determine its density analysis per ASTM 698. The embankments will be constructed in a maximum of 6 inch lifts. The lifts will each be compacted to a density at least 98% of it's the maximum dry density. Each layer of compacted fill shall be tested to determine its density per ASTM 2922 or ASTM 3017. One test per 50 cubic yards of material placed (at least one per layer) shall be performed by an Independent Testing Agency.
e. A cutoff and key trench of impervious material shall be provided under all embankments 4 feet or greater in height. The cutoff trench shall run the entire length of the embankment and tie into undisturbed natural ground.
f. Anti-seep collars, or a PADEP approved alternative, must be provided on all outflow culverts in accordance with the methodology contained in the latest edition of the PADEP E&S Manual. An increase in seepage length of 15 percent must be used in accordance with the requirements for permanent anti-seep collars.

19. Construction of Stormwater Management Facilities:

a. Basins used for rate control only shall be installed prior to or concurrent with any earthmoving or land disturbances, which they will serve. The phasing of their construction shall be noted in the narrative and on the plan.
b. Basins that include water quality or recharge components shall have those components installed in such a manner as to not disturb or diminish their effectiveness.
c. Compaction test reports shall be kept on file at the site and be subject to review at all times with copies being forwarded to the Municipal Engineer upon request.

d. Temporary and permanent grasses or stabilization measures shall be established on the sides and base of all earthen basins within 15 days of construction.

20. Exceptions to these requirements may be made at the discretion of the Municipality for BMPs that retain or detain water, but are of a much smaller scale than traditional stormwater management facilities.

C. Stormwater Carrying Facilities:

1. All storm sewer pipes, grass waterways, open channels, swales and other stormwater carrying facilities that service drainage areas within the site must be able to convey post-development runoff from the 10-year design storm.

2. Stormwater management facilities that convey off-site water through the site shall be designed to convey the 25-year storm event (or larger events, as determined by the Municipal Engineer).

3. All developments shall include provisions that allow for the overland conveyance and flow of the post-development 100-year storm event without damage to public or private property.

4. Storm Sewers:

a. Storm sewers must be able to convey post-development runoff without surcharging inlets for the 10-year storm event.

b. When connecting to an existing storm sewer system, the Applicant must demonstrate that the proposed system will not exacerbate any existing stormwater problems and that adequate downstream capacity exists.

c. Inlets, manholes, pipes, and culverts shall be constructed in accordance with the specifications set forth in PENNDOT's Publication 408, and as detailed in the PENNDOT's Publication 72M - Standards for Roadway Construction (RC) or other detail approved by the Municipal Engineer. All material and construction details (inlets, manholes, pipe trenches, etc.), must be shown on the SWM Site Plan, and a note added that all construction must be in accordance with PENNDOT's Publication 408 and PENNDOT's Publication 72M, latest edition. A note shall be added to the plan stating that all frames, concrete top units, and grade adjustment rings shall be set in a bed of full mortar according to Publication 408.

d. A minimum pipe size of fifteen (15) inches in diameter shall be used in all roadway systems (public or private) proposed for construction in the Municipality. Pipes shall be designed to provide a minimum velocity of 2-1/2 feet per second when flowing full, but in all cases, the slope shall be no less then 0.5%. Arch pipe of equivalent cross-sectional area may be substituted in lieu of circular pipe where cover or utility conflict conditions exist.

e. All storm sewer pipes shall be laid to a minimum depth of 1 foot from subgrade to the crown of pipe.

f. In curbed roadway sections, the maximum encroachment of water on the roadway pavement shall not exceed half of a through travel lane or one (1)

inch less than the depth of curb during the ten (10) year design storm of five (5) minute duration. Gutter depth shall be verified by inlet capture/capacity calculations that account for road slope and opening area.

i. Inlets shall be placed at a maximum of 400 feet apart.
ii. Inlets shall be placed so drainage cannot cross intersections or street centerlines.

g. Standard Type "C" inlets with 8 inch hoods shall be used along curbed roadway networks. Type "C" inlets with 10 inch hoods that provide a 2 inch sump condition may be used with approval of the Municipal Engineer when roadway longitudinal slopes are 1.0% or less.

h. For inlets containing a change in pipe size, the elevation for the crown of the pipes shall be the same or the smaller pipe's crown shall be at a higher elevation.

i. All inlets shall provide a minimum 2 inch drop between the lowest inlet pipe invert elevation and the outlet pipe invert elevation.

j. On curbed sections, a double inlet shall be placed at the low point of sag vertical curves, or an inlet shall be placed on each side of the low point at a distance not to exceed 100 feet, or at an elevation not to exceed 0.2 feet above the low point.

k. At all roadway low points, swales and easements shall be provided behind the curb or swale and through adjacent properties to channelize and direct any overflow of stormwater runoff away from dwellings and structures.

l. All inlets in paved areas shall have heavy duty bicycle safe grating. A note to this effect shall be added to the SWM Site Plan or inlet details therein.

m. Inlets must be sized to accept the specified pipe sizes without knocking out any of the inlet corners. All pipes entering or exiting inlets shall be cut flush with the inside wall of the inlet. A note to this effect shall be added to the SWM Site Plan or inlet details therein.

n. Inlets shall have weep holes covered with geotextile fabric placed at appropriate elevations to completely drain the sub grade prior to placing the base and surface course on roadways.

o. Inlets, junction boxes, or manholes greater then five (5) feet in depth shall be equipped with ladder rungs and shall be detailed on the SWM Site Plan.

p. Inlets shall not have a sump condition in the bottom (unless designed as a water quality BMP or specifically approved by the Municipality). Pipe shall be flush with the bottom of the box or concrete channels shall be poured.

q. Accessible drainage structures shall be located on continuous storm sewer system at all vertical dislocations, at all locations where a transition in storm sewer pipe sizing is required, at all vertical and horizontal angle points exceeding 5 degrees, and at all points of convergence of 2 or more storm sewer pipes.

r. All storm drainage piping shall be provided with either reinforced concrete headwalls or end sections of compatible material as the pipe involved at its entrance and discharge.

s. Outlet protection and energy dissipaters shall be provided at all surface discharge points in order to minimize erosion consistent with the E&S Manual.
    i. Flow velocities and volumes from any storm sewer shall not result in a degradation of the receiving channel.

t. Stormwater roof drains and pipes shall not be connected to storm sewers or discharge onto impervious areas without approval by the Municipal Engineer.

5. Swale Conveyance Facilities:
    a. Swales must be able to convey post-development runoff from a 10-year design storm with 6 inches of freeboard to top of the swale.

    b. Swales shall have side slopes no steeper than 3:1.

    c. All swales shall be designed, labeled on the SWM Site Plan, and details provided to adequately construct and maintain the design dimension of the swales.

    d. Swales shall be designed for stability using velocity or shear criteria. Velocity criteria may be used for channels with less than 10% slope. Shear criteria may be used for all swales. Documentation must be provided to support velocity and/or shear limitations used in calculations.

    e. Where swale bends occur, the computed velocities or shear stresses shall be multiplied by the following factor for the purpose of designing swale erosion protection:
        i. 1.75 – When swale bend is 30 to 60 degrees
        ii. 2.00 – When swale bend is 60 to 90 degrees
        iii. 2.50 – When swale bend is 90 degrees or greater

    f. Manning's "n" values used for swale capacity design must reflect the permanent condition.

Section 702. Calculation Methodology

A. All calculations shall be consistent with the guidelines set forth in the BMP Manual, as amended herein.

B. Stormwater runoff from all development sites shall be calculated using either the Rational Method or the NRCS Rainfall-Runoff Methodology. Other methods shall be selected by the design professional based on the individual limitations and suitability of each method for a particular site and approved by the Municipal Engineer.

C. Rainfall Values:

    1. Rational Method – The Pennsylvania Department of Transportation Drainage Manual, Intensity-Duration-Frequency Curves, Publication 584, Chapter 7A, latest edition, shall be used in conjunction with the appropriate time of concentration and return period.

2. NRCS Rainfall-Runoff Method – The Soil Conservation Service Type II, 24-hour rainfall distribution shall be used in conjunction with rainfall depths from NOAA Atlas 14 or be consistent with the following table:

Return Interval (Year)	24-hour Rainfall Total (inches)
1	2.02
2	2.41
10	3.38
25	4.00
50	4.50
100	5.03

D. Runoff Volume:

1. Rational Method – Not to be used to calculate runoff volume.

2. NRCS Rainfall-Runoff Method – This method shall be used to estimate the change in volume due to Regulated Activities. Combining Curve Numbers for land areas proposed for development with Curve Numbers for areas unaffected by the proposed development into a single weighted curve number is NOT acceptable.

E. Peak Flow Rates:

1. Rational Method – This method may be used for design of conveyance facilities only. Extreme caution should be used by the design professional if the watershed has more then one main drainage channel, if the watershed is divided so that hydrologic properties are significantly different in one versus the other, if the time of concentration exceeds 60 minutes, or if stormwater runoff volume is an important factor. The combination of Rational Method hydrographs based on timing shall be prohibited.

2. NRCS Rainfall-Runoff Method – This method is recommended for design of stormwater management facilities and where stormwater runoff volume must be taken into consideration. The following provides guidance on the model applicability:

    a. NRCS's TR-55 – limited to 100 acres in size
    b. NRCS's TR-20, WinTR-20, WinTR-55,HEC-HMS – no watershed size limitations
    c. Other models as pre-approved by the Municipal Engineer

    The NRCS antecedent runoff condition II (ARC II, previously AMC II) must be used for all simulations. The use of continuous simulation models that vary the ARC are not permitted for stormwater management purposes.

3. For comparison of peak flow rates, flows shall be rounded to a tenth of a cubic foot per second (cfs).

F. Runoff Coefficients:

1. Rational Method – Use Table C-1 (Appendix C).

2. NRCS Rainfall-Runoff Method – Use Table C-2 (Appendix C). Curve Numbers (CN) should be rounded to tenths for use in hydrologic models as they are a design tool with

statistical variability. For large sites, CN's should realistically be rounded to the nearest whole number.

3. For the purposes of pre-development peak flow rate and volume determination, existing non-forested pervious areas conditions shall be considered as meadow (good condition).

4. For the purposes of pre-development peak flow rate and volume determination, 20 percent of existing impervious area, when present, shall be considered meadow (good condition).

G. Design Storm:

1. All stormwater management facilities shall be verified by routing the proposed 1-year, 2-year, 10-year, 25-year, 50-year, and 100-year hydrographs through the facility using the storage indication method or modified puls method. The design storm hydrograph shall be computed using a calculation method that produces a full hydrograph.

2. The stormwater management and drainage system shall be designed to safely convey the post development 100-year storm event to stormwater detention facilities, for the purpose of meeting peak rate control.

3. All structures (culvert or bridges) proposed to convey runoff under a Municipal road shall be designed to pass the 50-year design storm with a minimum 1 foot of freeboard measured below the lowest point along the top of the roadway.

H. Time of Concentration:

1. The Time of Concentration is to represent the average condition that best reflects the hydrologic response of the area. The following Time of Concentration (T_c) computational methodologies shall be used unless another method is pre-approved by the Municipal Engineer:

a. Pre-development – NRCS's Lag Equation:

Time of Concentration = T_c = [(T_{lag}/.6) * 60] (minutes)

$$T_{lag} = L^{0.8} \frac{(S+1)^{0.7}}{1900\sqrt{Y}}$$

Where:

T_{lag} = Lag time (hours)
L = Hydraulic length of watershed (feet)
Y = Average overland slope of watershed (percent)
S = Maximum retention in watershed as defined by: S = [(1000/CN) – 10]
CN = NRCS Curve Number for watershed

b. Post-development; commercial, industrial, or other areas with large impervious areas (>20% impervious area) – NRCS Segmental Method. The length of sheet flow shall be limited to 100 feet. T_c for channel and pipe flow shall be computed using Manning's equation.
c. Post-development; residential, cluster, or other low impact designs less than or equal to 20% impervious area – NRCS Lag Equation or NRCS Segmental Method.

2. Additionally, the following provisions shall apply to calculations for Time of Concentration:

    a. The post-development T_c shall never be greater that the pre-development T_c for any watershed or sub-watershed. This includes when the designer has specifically used swales to reduce flow velocities. In the event that the designer believes that the post-development T_c is greater, it will still be set by default equal to the pre-development T_c for modeling purposes.
    b. The minimum T_c for any watershed shall be 5 minutes.
    c. The designer may choose to assume a 5 minute T_c for any post development watershed or subwatershed without providing any computations.
    d. The designer must provide computations for all pre-development T_c paths. A 5 minute T_c can not be assumed for pre-development.
    e. Undetained fringe areas (areas that are not tributary to a stormwater facility but where a reasonable effort has been made to convey runoff from all new impervious coverage to best management practices) may be assumed to represent the pre-development conditions for purpose of T_c calculation.

I. Drainage areas tributary to sinkholes or closed depressions in areas underlain by limestone or carbonate geologic features shall be excluded from the modeled point of analysis defining pre-development flows. If left undisturbed during construction activities, areas draining to closed depressions may also be used to reduce peak runoff rates in the post-development analysis. New, additional contributing runoff should not be directed to existing sinkholes or closed depressions.

J. Where uniform flow is anticipated, the Manning's equation shall be used for hydraulic computations and to determine the capacity of open channels, pipes, and storm sewers. The Manning's equation should not be used for analysis of pipes under pressure flow or for analysis of culverts. Manning's "n" values shall be obtained from PENNDOT's Drainage Manual, Publication 584. Inlet control shall be checked at all inlet boxes to ensure the headwater depth during the 10-year design event is contained below the top of grate for each inlet box.

K. The Municipality has the authority to require that computed existing runoff rates be reconciled with field observations, conditions and site history. If the designer can substantiate, through actual physical calibration, that more appropriate runoff and time of concentration values should be utilized at a particular site, then appropriate variations may be made upon review and recommendation of the Municipality.

ARTICLE VIII - SWM SITE PLAN & REPORT REQUIREMENTS

Section 801. General Requirements

For any of the activities regulated by this Ordinance and not eligible for the exemptions provided in Section 302, the final approval of subdivision and/or land development plans, the issuance of any building or occupancy permit, or the commencement of any land disturbance activity, may not proceed until the Applicant has received written approval of a SWM Site Plan from the Municipality.

Section 802. SWM Site Plan & Report Contents

The SWM Site Plan & SWM Site Report shall consist of all applicable calculations, maps, and plans. All SWM Site Plan materials shall be submitted to the Municipality in a format that is clear, concise, legible, neat and well organized; otherwise, the SWM Site Plan shall be rejected.

Appropriate sections from the Municipal Subdivision and Land Development Ordinance, and other applicable local ordinances, shall be followed in preparing the SWM Site Plan.

A. SWM Site Plan shall include, but not be limited to:

1. Plans shall be of one size and in a form that meets the requirements for recording in the Office of the Recorder of Deeds of Butler County.
    a. Plans for tracts of less than 20 acres shall be drawn at a scale of one inch equals no more than 50 ft.;
    b. Plans for tracts of 20 acres or more, plans shall be drawn at a scale of one inch equals no more than 100 ft;
    c. Lettering shall be drawn to a size to be legible if the plans are reduced to ½ size.

2. The name of the development; name and location address of the property site; name, address, and telephone number of the Applicant/Owner of the property; and name, address, telephone number, email address, and engineering seal of the individual preparing the SWM Site Plan.

3. The date of submission and dates of all revisions.

4. A graphical and written scale on all drawings and maps.

5. A north arrow on all drawings and maps.

6. A location map at a minimum scale of one (1) inch equals one-thousand (1,000) feet and illustrates the project relative to highways, municipalities or other identifiable landmarks.

7. Metes and bounds description of the entire tract perimeter.

8. Existing and final contours at intervals:

    a. Slopes less than 5%: no greater than one (1) foot;
    b. Slopes between 5 and 15%: no greater than two (2) feet;
    c. Steep slopes (greater than 15%), 5-foot contour intervals may be used.

9. Perimeters of existing waterbodies within the project area including stream banks, lakes, ponds, springs, field delineated wetlands or other bodies of water, sinkholes, flood hazard boundaries (FEMA delineated floodplains and floodways), areas of natural

vegetation to be preserved, the total extent of the upstream area draining through the site, and overland drainage paths. In Addition, any areas necessary to determine downstream impacts, where required for proposed stormwater management facilities must be shown.

10. The location of all existing and proposed utilities, on-lot wastewater facilities, water supply wells, sanitary sewers, and water lines on and within fifty (50) feet of property lines including inlets, manholes, valves, meters, poles, chambers, junction boxes, and other utility system components.

11. A key map showing all existing man-made features beyond the property boundary that may be affected by the project.

12. Soil names and boundaries with identification of the Hydraulic Soil Group classification including rock outcroppings.

13. Proposed impervious surfaces (structures, roads, paved areas, and buildings), including plans and profiles of roads and paved areas and floor elevations of buildings.

14. Existing and proposed land use(s).

15. Horizontal alignment, vertical profiles, and cross sections of all open channels, pipes, swales and other BMPs.

16. The location and clear identification of the nature of permanent stormwater BMPs.

17. The location of all erosion and sedimentation control facilities, shown on a separate from the SWM Site Plan (typically an E&S Plan).

18. A minimum twenty (20) foot wide access easement around all stormwater management facilities that would provide ingress to and egress from a public right-of-way. In lieu of providing an easement to the public right-of-way, a note may be added to the plan granting the Municipality or their designees access to all easements via the nearest public right-of-way.

19. Construction details for all drainage and stormwater BMPs.

20. Construction sequence.

21. Identification of short-term and long-term ownership, operations, and maintenance responsibilities.

22. Notes and Statements:

    a. A statement, signed by the landowner, acknowledging that the stormwater BMPs are fixtures that cannot be altered or removed without prior approval by the Municipality.
    b. A statement referencing the Operation and Maintenance (O&M) Agreement and stating that the O&M Agreement is part of the SWM Site Plan.
    c. A note indicating that Record Drawings will be provided for all stormwater facilities prior to occupancy, or the release of the surety bond.
    d. The following signature block for the registered professional preparing the Stormwater Management Plan:

"I, _____, hereby certify that the Stormwater Management Plan meets all design standards and criteria of the ***[Municipality's]*** Stormwater Management Ordinance."

e. The following signature block for the Municipal Engineer reviewing the Stormwater Management Plan:

"I, _____, have reviewed this Stormwater Management Plan in accordance with the Design Standards and Criteria of the ***[Municipality's]*** Stormwater Management Ordinance."

B. SWM Site Report shall include (but not limited to):

1. General data including:
    a. Project Name
    b. Project location - address of the property site
    c. Name, address, and telephone number of the Applicant/Owner of the property;
    d. Name, address, telephone number, email address, and engineering seal of the individual preparing the SWM Site Report;
    e. Date of submission and revisions.

2. Project description narrative that clearly discusses the project and provides the following information, where applicable:
    a. Narrative
        - Statement of the regulated activity describing what is being proposed. Overall stormwater management concept with description of permanent stormwater management techniques, including construction specifications and materials to be used for stormwater management facilities.
        - Expected project schedule
        - Location map showing the project site and its location relative to release rate districts.
        - Detailed description of the existing site conditions including a site evaluation completed for projects proposed in areas of carbonate geology or karst topography, and other environmentally sensitive areas such as brownfields.
        - Total site area – pre and post, which must be equal or have an explanation as to why it is not
        - Total site impervious area
        - Total off-site areas
        - Number and description of stormwater management facilities
        - Type of development
        - Pre-development land use
        - Whether site is a water quality sensitive (WQS) development
        - Whether site is in a defined sensitive area
        - Types of water quality and recharge systems used, if applicable
        - Complete hydrologic, hydraulic, and structural computations for all stormwater management facilities.
        - A written maintenance plan for all stormwater features including detention facilities and other stormwater management elements.
        - Identification of ownership and maintenance responsibility for all permanent stormwater management facilities.
        - Other pertinent information, as required

b. Summary Tables
   - Pre-development Hydrologic soil group (HSG) assumptions, curve numbers (CN), Computation of average slope, hydraulic length, computed time of concentration
   - Existing conditions runoff volume & peak rate of runoff
   - Post-development runoff volume & peak rate of runoff
   - Undetained areas, areas to ponds
   - Land use for each subarea
   - Hydrologic soil group (HSG) assumptions, curve numbers (CN)
   - Time of concentration computed for each subarea
   - Post-development peak rate of runoff routed to ponds and out
   - Pond maximum return period design data including: maximum water surface elevation, berm elevation, and emergency spillway elevation
   - Water quality depth and volume requirements

c. Calculations
   - Complete hydrologic, hydraulic and structural computations, calculations, assumptions, and criteria for the design of all stormwater BMPs.
   - Details of the berm embankment and outlet structure indicating the embankment top elevation, embankment side slopes, top width of embankment, emergency spillway elevation, perforated riser dimensions, pipe barrel dimensions and dimensions and spacing of antiseep collars.
   - Design computations for the control structures (pipe barrel and riser, etc).
   - A plot or table of the stage-storage (volume vs. elevation) and all supporting computations.
   - Routing computations.

d. Drawings
   - Drainage area maps for all watersheds and inlets depicting the time of concentration path for both existing conditions and post developed condition.
   - All stormwater management facilities must be located on a plan and described in detail including easements and buffers boundaries.

3. Reports that do not clearly indicate the above information may be rejected for review by the Municipality and will be returned to the applicant.

4. Description of, justification, and actual field results for infiltration testing with respect to the type of test and test location for the design of infiltration BMPs.

5. The effect of the project (in terms of runoff volumes, water quality, and peak flows) on surrounding properties and aquatic features and on any existing municipal stormwater collection system that may receive runoff from the project site.

6. Description of the proposed changes to the land surface and vegetative cover including the type and amount of impervious area to be added.

7. Identification of short-term and long-term ownership, operation, and maintenance responsibilities as well as schedules and costs for inspection and maintenance activities for each permanent stormwater or drainage BMP, including provisions for permanent access or maintenance easements.

C. Supplemental information to be provided prior to recording of the SWM Site Plan, as applicable:

1. Signed and executed Operations and Maintenance Agreement (Appendix A).
2. Signed and executed easements, as required for all on-site and off-site work.
3. An Erosion and Sedimentation Control Plan & approval letter from the Butler County Conservation District.
4. A NPDES Permit.
5. Permits from PADEP and ACOE.
6. Geologic Assessment.
7. Soils investigation report, including boring logs, compaction requirements, and recommendations for construction of detention basins.
8. A Highway Occupancy Permit from PENNDOT when utilization of a PENNDOT storm drainage system is proposed or when proposed facilities would encroach onto a PENNDOT right-of-way.

Section 803. SWM Site Plan & Report Submission

A. The Applicant shall submit the SWM Site Plan & Report for the Regulated Activity.

B. Five (5) copies of the SWM Site Plan & Report shall be submitted and be distributed as follows:

1. Two (2) copies to the Municipality accompanied by the requisite executed Review Fee Reimbursement Agreement, as specified in this Ordinance
2. One (1) copy to the Municipal Engineer
3. One (1) copy to the Butler County Planning Department**[OPTIONAL]**
4. One (1) copy to the Butler County Conservation District **[OPTIONAL]**

C. Additional copies shall be submitted as requested by the Municipality or PADEP.

Section 804. SWM Site Plan & Report Review

A. The Municipality shall require receipt of a complete SWM Site Plan & Report as specified in this Ordinance. The Municipality shall review the SWM Site Plan & Report for consistency with the purposes, requirements, and intent of this Ordinance.

B. The Municipality shall not approve any SWM Site Plan & Report that is deficient in meeting the requirements of this Ordinance. At its sole discretion and in accordance with this Article, when a SWM Site Plan & Report is found to be deficient, the Municipality may disapprove the submission and require a resubmission, or in the case of minor deficiencies, the Municipality may accept submission of modifications.

C. The Municipality shall notify the Applicant in writing within forty-five (45) calendar days whether the SWM Site Plan & Report is approved or disapproved if the SWM Site Plan & Report is not part of a Subdivision or Land Development Plan. If the SWM Site Plan & Report involves a Subdivision or Land Development Plan, the timing shall following the Subdivision and Land Development process according to the Municipalities Planning Code.

D. The Municipal Building Permit Office shall not issue a building permit for any Regulated Activity if the SWM Site Plan & Report has been found to be inconsistent with this Ordinance, as determined by the Municipality. All required permits from PADEP must be obtained prior to issuance of a building permit.

Section 805. Modification of Plans

A. A modification to a submitted SWM Site Plan & Report for a development site that involves a change in stormwater management facilities or techniques, or that involves the relocation or re-design of stormwater management facilities, or that is necessary because soil or other conditions are not as stated on the SWM Site Plan as determined by the Municipality, shall require a resubmission of the modified SWM Site Plan in accordance with this Ordinance.

Section 806. Resubmission of Disapproved SWM Site Plan & Report

A. A disapproved SWM Site Plan & Report may be resubmitted with the revisions addressing the Municipality's concerns documented in writing, to the Municipality in accordance with this Ordinance. The applicable Municipal Review Fee must accompany a resubmission of a disapproved SWM Site Plan & Report.

Section 807. Authorization to Construct and Term of Validity

A. The Municipality's approval of a SWM Site Plan & Report authorizes the Regulated Activities contained in the SWM Site Plan for a maximum term of validity of five (5) years following the date of approval. The Municipality may specify a term of validity shorter than five (5) years in the approval for any specific SWM Site Plan. Terms of validity shall commence on the date the Municipality signs the approval for a SWM Site Plan. If stormwater management facilities included in the approved SWM Site Plan have not been constructed, or if an Record Drawing of these facilities has not been approved within this time, then the Municipality may consider the SWM Site Plan disapproved and may revoke any and all permits or approvals.

Section 808. Record Drawings, Completion Certificate and Final Inspection

A. The Applicant shall be responsible for providing Record Drawings of all stormwater BMPs included in the approved SWM Site Plan. The Record Drawing and an explanation of any discrepancies with the approved SWM Site Plan shall be submitted to the Municipality as a prerequisite for the release of the guarantee or issuance of an occupancy permit.

B. The Record Drawing shall include a certification of completion signed by a Qualified Professional verifying that all permanent stormwater BMPs have been constructed according to the approved SWM Site Plan & Report.
    1. Drawings shall show all approved revisions and elevations and inverts to all manholes, inlets, pipes, and stormwater control facilities.
    2. Submission shall include a comparison of the constructed stage-storage (volume vs. elevation) of all above ground and below ground stormwater storage facilities to the approved design.

C. After receipt of the Record Drawing and certification of completion by the Municipality, the Municipality may conduct a final inspection.

ARTICLE IX - EASEMENTS

Section 901. Easements

A. Easements shall be established to accommodate the existence of drainageways.

B. Where a tract is traversed by a watercourse, drainage-way, channel or stream, there shall be provided an easement paralleling the line of such watercourse, drainage-way, channel or stream with a width adequate to preserve the unimpeded flow of natural drainage in the 100-year floodplain.

C. Easements shall be established for all on-site stormwater management or drainage facilities, including but not limited to: detention facilitates (above or below ground), infiltration facilities, all stormwater BMPs, drainage swales, and drainage facilities (inlets, manholes, pipes, etc.).

D. Easements are required for all areas used for off-site stormwater control.

E. All easements shall be a minimum of 20 feet wide and shall encompass the 100-year surface elevation of the proposed stormwater facility.

F. Easements shall provide ingress to, and egress from, a public right-of-way. In lieu of providing an easement to the public right-of-way, a note may be added to the plan granting the Municipality or their designees access to all easements via the nearest public right-of-way able for vehicle ingress and egress on grades of less than 10% for carrying out inspection or maintenance activities.

G. Where possible, easements shall be centered on side and/or rear lot lines.

H. Nothing shall be planted or placed within the easement which would adversely affect the function of the easement, or conflict with any conditions associated with such easement.

I. All easement agreements shall be recorded with a reference to the recorded easement indicated on the site plan. The format and content of the easement agreement shall be reviewed and approved by the Municipal Engineer and Solicitor.

ARTICLE X - MAINTENANCE RESPONSIBILITIES

Section 1001. Financial Guarantee

A. The Applicant shall provide a Financial Guarantee to the Municipality for the timely installation and proper construction of all stormwater management controls as required by the approved SWM Site Plan and this Ordinance, equal to 110% of the full construction cost of the required controls in accordance with the Municipalities Planning Code.

B. At the completion of the project and as a prerequisite for the release of the Financial Guarantee, the Applicant shall:

1. Provide a certification of completion from an engineer, architect, surveyor or other qualified person, verifying that all permanent facilities have been constructed according to the SWM Site Plan & Report and approved revisions thereto.

2. Provide a set of Record Drawings.

3. Request a final inspection from the Municipality to certify compliance with this Ordinance, after receipt of the certification of completion and Record Drawings by the Municipality.

Section 1002. Maintenance Responsibilities

A. The SWM Site Plan & Report for the project site shall describe the future operation and maintenance responsibilities. The operation and maintenance description shall outline required routine maintenance actions and schedules necessary to ensure proper operation of the stormwater control facilities.

B. The SWM Site Plan & Report for the project site shall establish responsibilities for the continuing operating and maintenance of all proposed stormwater control facilities, consistent with the following principals:

1. If a development consists of structures or lots that are to be separately owned and in which streets, sewers, and other public improvements are to be dedicated to the Municipality, stormwater control facilities/BMPs may also be dedicated to and maintained by the Municipality.

2. If a development site is to be maintained in a single ownership or if sewers and other public improvements are to be privately owned and maintained, then the ownership and maintenance of stormwater control facilities/BMPs shall be the responsibility of the owner or private management entity.

3. Facilities, areas, or structures used as stormwater BMPs shall be enumerated as permanent real estate appurtenances and recorded as deed restrictions or easements that run with the land.

4. The SWM Site Plan & Report shall be recorded as a restrictive deed covenant that runs with the land.

5. The Municipality may take enforcement actions against an Applicant for failure to satisfy any provision of this Ordinance.

C. The Municipality, upon recommendation of the Municipal Engineer, shall make the final determination on the continuing maintenance responsibilities prior to final approval of the SWM Site Plan & Report. The Municipality may require a dedication of such facilities as part of the requirements for approval of the SWM Site Plan. Such a requirement is not an indication that the Municipality will accept the facilities. The Municipality reserves the right to accept or reject the ownership and operating responsibility for any portion of the stormwater management controls.

D. If the Municipality accepts ownership of stormwater BMPs, the Municipality may, at its discretion, require a fee from the Applicant to the Municipality to offset the future cost of inspections, operations, and maintenance.

E. It shall be unlawful to alter or remove any permanent stormwater BMP required by an approved SWM Site Plan, or to allow the property to remain in a condition, which does not conform to an approved SWM Site Plan, unless the Municipality grants an exception in writing.

Section 1003. Maintenance Agreement for Privately Owned Stormwater Facilities

A. Prior to final approval of the SWM Site Plan & Report, the Applicant shall sign the Operation and Maintenance (O&M) Agreement (Appendix A) covering all stormwater control facilities that are to be privately owned. The Operation and Maintenance (O&M) Agreement shall be recorded with the SWM Site Plan and made a part hereto.

B. Other items may be included in the Operation and Maintenance (O&M) Agreement where determined necessary to guarantee the satisfactory operation and maintenance of all BMP facilities. The Operation and Maintenance (O&M) Agreement shall be subject to the review and approval of the Municipality and the Municipal Solicitor.

C. The owner is responsible for operation and maintenance of the stormwater BMPs. If the owner fails to adhere to the Operation and Maintenance (O&M) Agreement, the Municipality may perform the services required and charge the owner appropriate fees. Non-payment of fees may result in a lien against the property.

ARTICLE XI - INSPECTIONS

Section 1101. Schedule of Inspections

A. PADEP or its designees normally ensure compliance with any permits issued, including those for stormwater management. In addition to PADEP compliance programs, the Municipality or their municipal assignee may inspect all phases of the installation of temporary or permanent stormwater management facilities.

B. During any stage of Earth Disturbance Activities, if the Municipality determines that the stormwater management facilities are not being installed in accordance with the approved SWM Site Plan, the Municipality shall revoke any existing permits or approvals until a revised SWM Site Plan is submitted and approved as specified in this Ordinance.

C. Stormwater BMPs shall be inspected by the landowner, or the landowner's designee according to the inspection schedule described on the SWM Site Plan for each BMP.

1. The Municipality may require copies of the inspection reports, in a form as stipulated by the Municipality.

2. If such inspections are not conducted or inspection reports not submitted as scheduled, the Municipality, or their designee, may conduct such inspections and charge the owner appropriate fees. Non-payment of fees may result in a lien against the property.

    a. Prior to conducting such inspections, the Municipality shall inform the owner of its intent to conduct such inspections. The owner shall be given thirty (30) days to conduct required inspections and submit the required inspection reports to the Municipality.

Section 1102. Right-of-Entry

A. Upon presentation of proper credentials, duly authorized representatives of the Municipality may enter at reasonable times, upon any property within the Municipality, to inspect the implementation, condition, or operations and maintenance of the stormwater BMPs in regard to any aspect governed by this Ordinance.

B. Stormwater BMP owners and operators shall allow persons working on behalf of the Municipality ready access to all parts of the premises for the purposes of determining compliance with this Ordinance.

C. Persons working on behalf of the Municipality shall have the right to temporarily locate on any stormwater BMP in the Municipality such devices, as are necessary, to conduct monitoring and/or sampling of the discharges from such stormwater BMP.

D. Unreasonable delay in allowing the Municipality access to a stormwater BMP is a violation of this Ordinance.

ARTICLE XII - ENFORCEMENT AND PENALTIES

Section 1201. Notification

A. In the event that a person fails to comply with the requirements of this Ordinance, an approved SWM Site Plan, or fails to conform to the requirements of any permit or approval issued hereunder, the Municipality shall provide written notification of the violation. Such notification shall set forth the nature of the violation(s) and establish a time limit for correction of these violation(s).

B. Failure to comply within the time specified shall subject such person to the Penalties Provisions of this Ordinance. All such penalties shall be deemed cumulative and shall not prevent the Municipality from pursuing any and all other remedies. It shall be the responsibility of the owner of the real property on which any Regulated Activity is proposed to occur, is occurring, or has occurred, to comply with the terms and conditions of this Ordinance.

Section 1202. Enforcement

A. The municipal governing body is hereby authorized and directed to enforce all of the provisions of this Ordinance. The approved SWM Site Plan shall be on file at the project site throughout the duration of the construction activity. The Municipality or their designee may make periodic inspections during construction.

B. Adherence to Approved SWM Site Plan

1. It shall be unlawful for any person, firm, or corporation to undertake any Regulated Activity on any property except as provided for by an approved SWM Site Plan and pursuant to the requirements of this Ordinance.

2. It shall be unlawful to alter or remove any control structure required by the SWM Site Plan pursuant to this Ordinance.

3. It shall be unlawful to allow a property to remain in a condition that does not conform to an approved SWM Site Plan.

Section 1203. Public Nuisance

A. A violation of any provision of this Ordinance is hereby deemed a Public Nuisance.

B. Each day that a violation continues shall constitute a separate violation.

Section 1204. Suspension and Revocation

A. Any approval or permit issued by the Municipality may be suspended or revoked for:

1. Non-compliance with or failure to implement any provision of the approved SWM Site Plan or Operation & Maintenance (O&M) Agreement.

2. A violation of any provision of this Ordinance or any other applicable law, Ordinance, rule or regulation relating to the Regulated Activity.

3. The creation of any condition or the commission of any act, during the Regulated Activity which constitutes or creates a hazard or nuisance, pollution, or which endangers the life or property of others.

B. A suspended approval or permit may be reinstated by the Municipality when:

1. The Municipality or their designee has inspected and approved the corrections to the violation(s) that caused the suspension.

2. The Municipality is satisfied that the violation(s) has been corrected.

C. An approval that has been revoked by the Municipality cannot be reinstated. The Applicant may apply for a new approval under the provisions of this Ordinance.

Section 1205. Penalties

[Municipalities should ask their solicitors to provide appropriate wording for this section.]

A. Anyone violating the provisions of this Ordinance shall be guilty of a summary offense and upon conviction, shall be subject to a fine of not more than $ ____ for each violation, recoverable with costs. Each day that the violation continues shall be a separate offense and penalties shall be cumulative.

B. In addition, the Municipality, through its solicitor, may institute injunctive, mandamus, or any other appropriate action or proceeding at law or in equity for the enforcement of this Ordinance. Any court of competent jurisdiction shall have the right to issue restraining orders, temporary or permanent injunctions, mandamus, or other appropriate forms of remedy or relief.

Section 1206. Appeals

A. Any person aggrieved by any action of the Municipality or its designee, relevant to the provisions of this Ordinance, may appeal to the Municipality within thirty (30) days of that action.

B. Any person aggrieved by any decision of the Municipality, relevant to the provisions of this Ordinance, may appeal to the Butler County Court of Common Pleas within thirty (30) days of the Municipality's decision.

ARTICLE XIII - PROHIBITIONS

Section 1301. Prohibited Discharges and Connections

A. Any drain (including indoor drains and sinks), or conveyance whether on the surface or underground, that allows any non-stormwater discharge including sewage, process wastewater, and wash water to enter the Municipality's separate storm sewer system or Waters of the Commonwealth is prohibited.

B. Any drain or conveyance connected from a commercial or industrial land use to the Municipality's separate storm sewer system, which has not been documented in plans, maps, or equivalent records, and approved by the Municipality is prohibited.

C. No person shall allow, or cause to allow, discharges into the Municipality's separate storm sewer system or into surface Waters of the Commonwealth, which are not composed entirely of stormwater, except: (1) as provided in subsection 1301.D below, and (2) discharges allowed under a state or federal permit.

D. The following discharges are authorized unless they are determined to be significant contributors to pollution to the Waters of the Commonwealth:

-Discharges from fire fighting activities
-Potable water sources including dechlorinated water line and fire hydrant flushings
-Irrigation drainage
-Air conditioning condensate
-Springs
-Water from crawl space pumps
-Pavement wash waters where spills or leaks of toxic or hazardous materials have not occurred (unless all spill material has been removed) and where detergents are not used
-Flows from riparian habitats and wetlands
-Uncontaminated water from foundations or from footing drains
-Lawn watering
-Dechlorinated swimming pool discharges
-Uncontaminated groundwater
-Water from individual residential car washing
-Routine external building washdown (which does not use detergents or other compounds)

E. In the event that the Municipality or PADEP determines that any of the discharges identified in subsection 1301.D, significantly contribute to pollution of Waters of the Commonwealth, or is so notified by PADEP, the Municipality will notify the responsible person(s) to cease the discharge.

F. Upon notice provided by the Municipality or PADEP under subsection 1301.E, the discharger will have a reasonable time, as determined by the Municipality or PADEP, to cease the discharge, consistent with the degree of pollution caused by the discharge.

G. Nothing in this Section shall affect a discharger's responsibilities under Commonwealth Law.

Section 1302. Roof Drains

A. Roof drains and sump pumps shall discharge to infiltration areas, vegetative BMPs, or pervious areas to the maximum extent practicable.

Section 1303. Alteration of BMPs

A. No person shall modify, remove, fill, landscape, or alter any existing stormwater BMP, facilities, areas, or structures unless it is part of an approved maintenance program, without the written approval of the Municipality.

B. No person shall place any structure, fill, landscaping, or vegetation into a stormwater BMP, facilities, areas, structures, or within a drainage easement which would limit or alter the functioning of the BMP without the written approval of the Municipality.

ARTICLE XIV - FEES AND EXPENSES

Section 1401. General

A. The fee required by this Ordinance is the Municipal Review Fee. The Municipal Review Fee shall be established by the Municipality to defray review costs incurred by the Municipality and the Municipal Engineer. The Applicant shall pay all fees.

Section 1402. Expenses Covered by Fees

A. The fees required by this Ordinance shall, at a minimum, cover:

1. Administrative and Clerical Costs.
2. Review of the SWM Site Plan & Report by the Municipality.
3. Pre-construction meetings.
4. Inspection of stormwater management facilities/BMPs and drainage improvements during construction.
5. Final inspection upon completion of the stormwater management facilities/BMPs and drainage improvements presented in the SWM Site Plan.
6. Any additional work required to enforce any permit provisions regulated by this Ordinance, correct violations, and assure proper completion of stipulated remedial actions.

Section 1403. Recording of Approved SWM Site Plan and Related Agreements

A. The owner of any land upon which permanent BMPs will be placed, constructed, or implemented, as described in the SWM Site Plan, shall record the following documents in the Office of the Recorder of Deeds of Butler County, within (__) days of approval of the SWM Site Plan by the Municipality:

1. The SWM Site Plan.
2. Operations and Maintenance (O&M) Agreement (Appendix A).
3. Easements under Section 901.
4. Riparian buffers under Section 602.

B. The Municipality may suspend or revoke any approvals granted for the project site upon discovery of the failure of the owner to comply with this Section.

(ORDINANCE NAME)

(ORDINANCE NUMBER)

ENACTED and ORDAINED at a regular meeting of the

_____

on this _____ day of _____, 20_____.

This Ordinance shall take effect immediately.

_____
(Name) (Title)

_____
(Name) (Title)

_____
(Name) (Title)

ATTEST:

_____
Secretary

I hereby certify that the foregoing Ordinance was advertised in the [name of newspaper] on [date], a newspaper of general circulation in the Municipality and was duly enacted and approved as set forth at a regular meeting of the [name of municipal governing body] held on [date].

_____
Secretary

APPENDIX A - OPERATION AND MAINTENANCE AGREEMENT

OPERATION AND MAINTENANCE (O&M) AGREEMENT
STORMWATER MANAGEMENT BEST MANAGEMENT PRACTICES (SWM BMPs)

THIS AGREEMENT, made and entered into this _____ day of _____, 20___, by and between _____, (hereinafter the "Landowner"), and _____, Butler County, Pennsylvania, (hereinafter "Municipality");

WITNESSETH

WHEREAS, the Landowner is the owner of certain real property as recorded by deed in the land records of Butler County, Pennsylvania, Deed Book _____ at Page _____, (hereinafter "Property").

WHEREAS, the Landowner is proceeding to build and develop the Property; and

WHEREAS, the SWM Site Plan approved by the Municipality (hereinafter referred to as the "Plan") for the property identified herein, which is attached hereto as Appendix A and made part hereof, as approved by the Municipality, provides for management of stormwater within the confines of the Property through the use of BMPs; and

WHEREAS, the Municipality, and the Landowner, his successors and assigns, agree that the health, safety, and welfare of the residents of the Municipality and the protection and maintenance of water quality require that on-site SWM BMPs be constructed and maintained on the Property; and

WHEREAS, the Municipality requires, through the implementation of the SWM Site Plan, that stormwater BMPs as required by said Plan and the Municipal Stormwater Management Ordinance be constructed and adequately operated and maintained by the Landowner, successors and assigns.

NOW, THEREFORE, in consideration of the foregoing promises, the mutual covenants contained herein, and the following terms and conditions, the parties hereto agree as follows:

1. The Landowner shall construct the BMPs in accordance with the plans and specifications identified in the SWM Site Plan.
2. The Landowner shall operate and maintain the BMPs as shown on the Plan in good working order in accordance with the specific maintenance requirements noted on the approved SWM Site Plan.
3. The Landowner hereby grants permission to the Municipality, its authorized agents, and employees, to enter upon the property, at reasonable times and upon presentation of proper credentials, to inspect the BMPs whenever necessary. Whenever possible, the Municipality shall notify the Landowner prior to entering the property.
4. In the event the Landowner fails to operate and maintain the BMPs per paragraph 2, the Municipality or its representatives may enter upon the Property and take whatever action is deemed necessary to maintain said BMPs. It is expressly understood and agreed that the Municipality is under no obligation to maintain or repair said facilities, and in no event shall this Agreement be construed to impose any such obligation on the Municipality.
5. In the event the Municipality, pursuant to this Agreement, performs work of any nature, or expends any funds in performance of said work for labor, use of equipment, supplies, materials, and the like, the Landowner shall reimburse the Municipality for all expenses (direct and indirect) incurred within ten (10) days of receipt of invoice from the Municipality.
6. The intent and purpose of this Agreement is to ensure the proper maintenance of the onsite BMPs by the Landowner; provided, however, that this Agreement shall not be deemed to create or effect any additional liability of any party for damage alleged to result from or be caused by stormwater runoff.
7. The Landowner, its executors, administrators, assigns, and other successors in interests, shall release the Municipality from all damages, accidents, casualties, occurrences or claims which might arise

or be asserted against said employees and representatives from the construction, presence, existence, or maintenance of the BMPs by the Landowner or Municipality.

8. The Municipality may inspect the BMPs at a minimum of once every three years to ensure their continued functioning.

This Agreement shall be recorded at the Office of the Recorder of Deeds of Butler County, Pennsylvania, and shall constitute a covenant running with the Property and/or equitable servitude, and shall be binding on the Landowner, his administrators, executors, assigns, heirs and any other successors in interests, in perpetuity.

ATTEST:

WITNESS the following signatures and seals:

(SEAL)

For the Municipality:

_____

For the Landowner:

_____

ATTEST:

_____ (City, Borough, Township)

County of Butler, Pennsylvania

I, _____, a Notary Public in and for the County and State aforesaid, whose commission expires on the _____ day of _____, 20_____, do hereby certify that _____ whose name(s) is/are signed to the foregoing Agreement bearing date of the _____ day of _____, 20_____, has acknowledged the same before me in my said County and State.

GIVEN UNDER MY HAND THIS _____ day of _____, 20_____.

_____ _____

NOTARY PUBLIC **(SEAL)**

APPENDIX B – LOW IMPACT DEVELOPMENT PRACTICES

LOW IMPACT DEVELOPMENT PRACTICES
ALTERNATIVE APPROACHES FOR MANAGING STORMWATER RUNOFF

Natural hydrologic conditions may be altered radically by poorly planned development practices, such as introducing unneeded impervious surfaces, destroying existing drainage swales, constructing unnecessary storm sewers, and changing local topography. A traditional drainage approach of development has been to remove runoff from a site as quickly as possible and capture it in a detention basin. This approach leads ultimately to the degradation of water quality, as well as expenditure of additional resources for detaining and managing concentrated runoff at some downstream location.

The recommended alternative approach is to promote practices that will minimize post-development runoff rates and volumes, which will minimize needs for artificial conveyance and storage facilities. To simulate pre-development hydrologic conditions, forced infiltration is often necessary to offset the loss of infiltration by creation of impervious surfaces. The ability of the ground to infiltrate runoff depends upon the soil types and its conditions.

Preserving natural hydrologic conditions requires careful alternative site design considerations. Site design practices include preserving natural drainage features, minimizing impervious surface area, reducing the hydraulic connectivity of impervious surfaces, and protecting natural depression storage. A well-designed site will contain a mix of all those features. The following describes various techniques to achieve the alternative approaches:

- **Preserving Natural Drainage Features**. Protecting natural drainage features, particularly vegetated drainage swales and channels, is desirable because of their ability to infiltrate and attenuate flows and to filter pollutants. However, this objective is often not accomplished in land development. In fact, commonly held drainage philosophy encourages just the opposite pattern - streets and adjacent storm sewers typically are located in the natural headwater valleys and swales, thereby replacing natural drainage functions with a completely impervious system. As a result, runoff and pollutants generated from impervious surfaces flow directly into storm sewers with no opportunity for attenuation, infiltration, or filtration. Developments designed to fit site topography also minimize the amount of grading on site.

- **Protecting Natural Depression Storage Areas.** Depressional storage areas have no surface outlet, or drain very slowly following a storm event. They can be commonly seen as ponded areas in farm fields during the wet season or after large runoff events. Traditional development practices eliminate these depressions by filling or draining, thereby obliterating their ability to reduce surface runoff volumes and trap pollutants. The volume and release-rate characteristics of depressions should be protected in the design of the development site. The depressions can be protected by simply avoiding the depression or by incorporating its storage as additional capacity in required detention facilities.

- **Avoiding Introduction of Impervious Areas.** Careful site planning should consider reducing impervious coverage to the maximum extent possible. Building footprints, sidewalks, driveways, and other features producing impervious surfaces should be evaluated to minimize impacts on runoff.

- **Reducing the Hydraulic Connectivity of Impervious Surfaces**. Impervious surfaces are significantly less of a problem if they are not directly connected to an impervious conveyance system (such as storm sewer). Two basic ways to reduce hydraulic connectivity are: routing of roof runoff over lawns; and reducing the use of storm sewers.

Site grading should promote increasing travel time of stormwater runoff and should help reduce concentration of runoff to a single point in the development.

- **Routing Roof Runoff Over Lawns.** Roof runoff can be easily routed over lawns in most site designs. The practice discourages direct connections of downspouts to storm sewers or parking lots. The practice also discourages sloping driveways and parking lots to the street. The routing of roof drains and crowning the driveway to allow runoff to discharge to pervious areas is desirable as the pervious area essentially acts as a filter strip.

- **Reducing the Use of Storm Sewers.** By reducing the use of storm sewers for draining streets, parking lots, and back yards, the potential for accelerating runoff from the development can be greatly reduced. The practice requires greater use of swales and may not be practical for some development sites, especially if there are concerns for areas that do not drain in a "reasonable" time. The practice requires educating local citizens and public works officials, who expect runoff to disappear shortly after a rainfall event.

- **Reducing Street Widths.** Street widths can be reduced by either eliminating on-street parking or by reducing cartway widths. Municipal planners and traffic designers should encourage narrower neighborhood streets, which ultimately could lower maintenance and maintenance related costs.

- **Limiting Sidewalks to One Side of the Street.** A sidewalk on one side of the street may suffice in low-traffic neighborhoods. The lost sidewalk could be replaced with bicycle/recreational trails that follow back-of-lot lines. Where appropriate, backyard trails should be constructed using pervious materials.

- **Using Permeable Paving Materials.** These materials include permeable interlocking concrete paving blocks or porous bituminous concrete. Such materials should be considered as alternatives to conventional pavement surfaces, especially for low use surfaces such as driveways, overflow parking lots, and emergency access roads.

- **Reducing Building Setbacks.** Reducing building setbacks reduces driveway and entry walks and is most readily accomplished along low-traffic streets where traffic noise is not a problem.

- **Constructing Cluster Developments.** Cluster developments can also reduce the amount of impervious area for a given number of lots. The biggest savings is in street length, which also will reduce costs of the development. Cluster development "clusters" the construction activity onto less-sensitive areas without substantially affecting the gross density of development.

In summary, careful consideration of the existing topography and implementation of a combination of the above mentioned techniques may avoid construction of costly stormwater control measures. Other benefits include: reduced potential of downstream flooding, reduced water quality degradation of receiving streams and water bodies, enhancement of aesthetics, and reduction of development costs. Beneficial results include: more stable baseflows in receiving streams, improved groundwater recharge, reduced flood flows, reduced pollutant loads, and reduced costs for conveyance and storage.

APPENDIX C - STORMWATER MANAGEMENT DESIGN CRITERIA

TABLE C-1 - RATIONAL METHOD RUNOFF COEFFICIENTS

Hydraulic Soil Group	Storm	A			B			C			D		
Slope Range		0-2%	2-6%	+6%	0-2%	2-6%	+6%	0-2%	2-6%	+6%	0-2%	2-6%	+6%
Cultivated	<25yr	0.08	0.13	0.16	0.11	0.15	0.21	0.14	0.19	0.26	0.18	0.23	0.31
Land	≥25yr	0.14	0.08	0.22	0.16	0.21	0.28	0.2	0.25	0.34	0.24	0.29	0.41
Pasture	<25yr	0.12	0.2	0.3	0.18	0.28	0.37	0.24	0.34	0.44	0.3	0.4	0.5
	≥25yr	0.15	0.25	0.37	0.23	0.34	0.45	0.3	0.42	0.52	0.37	0.5	0.62
Meadow	<25yr	0.10	0.16	0.25	0.14	0.22	0.3	0.2	0.28	0.36	0.24	0.3	0.4
	≥25yr	0.14	0.22	0.3	0.2	0.28	0.37	0.26	0.35	0.44	0.3	0.4	0.5
Forest	<25yr	0.05	0.08	0.11	0.08	0.11	0.14	0.1	0.13	0.16	0.12	0.16	0.2
	≥25yr	0.08	0.11	0.14	0.1	0.14	0.18	0.12	0.16	0.2	0.15	0.2	0.25
Residential													
1/8 Acre	<25yr	0.25	0.28	0.31	0.27	0.3	0.35	0.3	0.33	0.38	0.33	0.36	0.42
	≥25yr	0.33	0.37	0.4	0.35	0.39	0.44	0.38	0.42	0.49	0.41	0.45	0.54
1/4 Acre	<25yr	0.22	0.26	0.29	0.24	0.29	0.33	0.27	0.31	0.36	0.3	0.34	0.4
	≥25yr	0.3	0.34	0.37	0.33	0.37	0.42	0.36	0.4	0.47	0.38	0.42	0.52
1/3 Acre	<25yr	0.19	0.23	0.26	0.22	0.26	0.3	0.25	0.29	0.34	0.28	0.32	0.39
	≥25yr	0.28	0.32	0.35	0.3	0.35	0.39	0.33	0.38	0.45	0.36	0.4	0.5
1/2 Acre	<25yr	0.16	0.2	0.24	0.19	0.23	0.28	0.22	0.27	0.32	0.26	0.3	0.37
	≥25yr	0.25	0.29	0.32	0.28	0.32	0.36	0.31	0.35	0.42	0.34	0.38	0.48
1 Acre	<25yr	0.14	0.19	0.22	0.17	0.21	0.26	0.2	0.25	0.31	0.24	0.29	0.35
	≥25yr	0.22	0.26	0.29	0.24	0.28	0.34	0.28	0.32	0.4	0.31	0.35	0.46
Industrial	<25yr	0.67	0.68	0.68	0.68	0.68	0.69	0.68	0.69	0.69	0.69	0.69	0.7
	≥25yr	0.85	0.85	0.86	0.85	0.86	0.86	0.86	0.86	0.87	0.86	0.86	0.88
Commercial	<25yr	0.71	0.71	0.72	0.71	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
	≥25yr	0.88	0.88	0.89	0.89	0.89	0.89	0.89	0.89	0.9	0.89	0.89	0.9
Streets	<25yr	0.7	0.71	0.72	0.71	0.72	0.74	0.72	0.73	0.76	0.73	0.75	0.78
	≥25yr	0.76	0.77	0.79	0.8	0.82	0.84	0.84	0.85	0.89	0.89	0.91	0.95
Open Space	<25yr	0.05	0.1	0.14	0.08	0.13	0.19	0.12	0.17	0.24	0.16	0.21	0.28
	≥25yr	0.11	0.16	0.2	0.14	0.19	0.26	0.18	0.23	0.32	0.22	0.27	0.39
Parking or	<25yr	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87
Impervious	≥25yr	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97

Source: Rawls, W.J., S.L. Long, and R.H. McCuen, 1981. Comparison of Urban Flood Frequency Procedures. Preliminary Draft Report prepared for the Soil Conservation Service, Beltsville, Maryland.

For simplification, a designer may use 0.3 for all pervious areas and 0.95 for all impervious areas.

TABLE C-2 - RUNOFF CURVE NUMBERS (FROM NRCS (SCS) TR-55)

Runoff Curve Numbers for Urban Areas					
Cover Description		**Curve Numbers for Hydrologic Soil Groups**			
Cover Type and Hydrologic Condition	***Average Percent Impervious Area***	***A***	***B***	***C***	***D***
Fully Developed Urban Areas (Vegetation Established)					
Open Space (lawns, parks, golf courses, etc):					
Poor Condition (grass cover < 50%)		68	79	86	89
Fair Condition (grass cover 50% to 75%)		49	69	79	84
Good Condition (grass cover > 75%)		39	61	74	80
Impervious Areas:					
Paved Parking Lots, Roofs, Driveways, etc.		98	98	98	98
Streets and Roads:					
Paved: Curbed and Storm Sewers		98	98	98	98
Paved: Open Ditches		83	89	92	93
Gravel		76	85	89	91
Dirt		72	82	87	89
Urban Districts:					
Commercial and Business	85%	89	92	94	95
Industrial	72%	81	88	91	93
Residential Districts by Average Lot Size:					
1/8 Acres or less	65%	77	85	90	92
1/4 Acre	38%	61	75	83	87
1/3 Acre	30%	57	72	81	86
1/2 Acre	25%	54	70	80	85
1 Acre	20%	51	68	79	84
2 Acres	12%	46	65	77	82

Runoff Curve Numbers for Cultivated Agricultural Lands						
Cover Description			**Curve Numbers**			
Cover Type	***Treatment***	***Hydrologic Condition***	***A***	***B***	***C***	***D***
Fallow	Bare Soil	--	77	86	91	94
	Crop Residue Cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row Crops	Straight Row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & Terraced (C & T)	Poor	66	74	80	82
		Good	62	71	78	81
	C & T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small Grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C & T	Poor	61	72	79	82
		Good	59	70	78	81
	C & T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close Seeded or Broadcast Legumes Or Rotation Meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C & T	Poor	63	73	80	83
		Good	51	67	76	80
Runoff Curve Numbers for Other Agricultural Lands						
Pasture, Grassland, or Range – Continuous Forage for Grazing		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
Meadow – Continuous Grass, Protected from Grazing and Generally Mowed for Hay		--	30	58	71	78
Woods – Grass Combination (orchard or tree farm)		Poor	57	73	82	86
		Fair	43	65	76	82
		Good	32	58	72	79
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	30	55	70	77
Farmsteads – Buildings, Lanes, Driveways and Surrounding Lots.		--	59	74	82	86

APPENDIX D – REVIEW FEE REIMBERSEMENT AGREEMENT

THIS AGREEMENT MUST BE COMPLETED AND SIGNED BY THE DEVELOPER/APPLICANT PRIOR TO SUBMISSION OF THE SUBDIVISION/LAND DEVELOPMENT APPLICATION AND PLANS, SKETCH PLANS, CONDITIONAL USE APPLICATIONS OR ANY OTHER SUBMISSION WHICH REQUIRES MUNICPAL CONSULTANT REVIEW.

REVIEW FEE REIMBERSEMENT AGREEMENT

THIS AGREEMENT, made and entered into this _____ day of _____, 20___, by and between _____, (hereinafter the "Landowner"), and _____, Butler County, Pennsylvania, (hereinafter "Municipality");

WITNESSETH

WHEREAS, the Landowner is the owner of certain real property as recorded by deed in the land records of Butler County, Pennsylvania, Deed Book _____ at Page _____, (hereinafter "Property").

WHEREAS, the Landowner is proceeding to build and develop the Property; and

WHEREAS, the Landowner has submitted a SWM Site Plan for review and approval by the Municipality (hereinafter referred to as the "Plan") for the property identified herein; and

WHEREAS, the Developer has requested and/or required the Municipality approval and/or review of its proposed plans, and the Municipality is willing to authorize its professional consultants to review said Plan and/or proposal upon execution of this agreement, and upon deposit of an escrow account according to the current Fee Schedule.

NOW, THEREFORE, in consideration of the foregoing promises, the mutual covenants contained herein, and the following terms and conditions, the parties hereto agree as follows:

1. The Landowner and Municipality hereby authorize and direct the Municipality's professional consultants, as defined at Section 107 of the Pennsylvania Municipalities Planning Code to review Landowner's plans or proposals to use its property, and to make such recommendations and specifications as may be necessary with respect to such plans in accordance with all applicable Municipality ordinances, and State and Federal rules and regulations.
2. The Landowner and Municipality acknowledge that the Municipality will incur costs and fees relating to the review of Landowner's plans by its professional consultants, and Landowner agrees to pay and/or reimburse the Municipality for such costs in accordance with this agreement.
3. The Landowner shall pay the professional consultant's charges and fees for the following: (a) review of any and all Stormwater Management Plans, studies, or other correspondence relating to the Landowners submission; (b) attendance at any and all meetings relating to Landowner's planl; (c) preparation of any reports, legal documents, or other correspondence relating to Landowner's plan or proposal; (d) administrative cost and incurred expenses relating to the administration of this agreement and (e) Professional Consultant's fees associated with construction activities. It is understood by the execution of this agreement that the Landowner specifically accepts the Fee Schedule currently in effect in the Municipality.
4. The Landowner hereby agrees to deposit with the Municipality the sum of _____ Dollars ($_____), payable as cash in U.S. Dollars or check drawn on a Pennsylvania bank, as security for the payment of all costs and expenses, charges and fees as set forth in Paragraph 3 above, upon execution of this agreement, which shall be held in a noninterest- bearing account by the Municipality. In the event that the above deposited escrow fund shall fall below fifty percent (50%) of the original deposit, the Landowner shall immediately, upon receipt

of written notice from the Municipality or its agent(s), deposit sums with the Municipality necessary to replenish the account to its original balance. In the event that this is insufficient to pay current Municipality incurred expenses, Landowner agrees to pay the total amount currently due for Municipality incurred expenses without delay in addition to re-establishing the base escrow account balance. The Municipality will use its best efforts to advise the Landowner of the impending likelihood that its costs have exceeded the required escrow account sums as described above.

5. Landowner and Municipality agree that upon completion of the Municipality's review of Landowner's plan or proposal, all unused portions of the escrow account as described above shall be returned to the applicant upon written request to the Municipality.

6. Landowner and Municipality acknowledge that the Ordinance and appropriate fee schedules require Landowner to pay Municipality's professional consultant fees relating to this plan or project, and in the even that Landowner fails to provide sufficient funds in the above-described revolving escrow account upon fifteen (15) days written notice to the Landowner or make the initial deposit payment described above within five (5) days of the date of this agreement, Landowner shall be in default of this agreement and in violation of the above Sections of Ordinance. In the event of Landowner's default as described above, the Municipality may refuse to issue any permit or grant any approval necessary to further improve or develop the subject site until such time as the terms of this Agreement are strictly met by Landowner. Moreover, final approval or further review may be denied or delayed until such time as the terms of this agreement are strictly met by Landowner.

7. Landowner and the Municipality further agree that all fees or costs arising out of this Agreement shall be paid prior to the issuance of any permit, occupancy or otherwise, for the use, improvement or construction of the buildings as proposed on the Landowner's plan. The Landowner agrees and acknowledges that no permit, occupancy or otherwise, or recordable plans, shall be released by the Municipality until all outstanding professional consultant fees and costs are paid to the Municipality, and provided that the Landowner is not in default under this agreement.

8. The Landowner may at any time terminate all further obligations under this Agreement by giving fifteen (15) days written notice to the Municipality that it does not desire to proceed with the development as set forth on the plan and upon receipt of such written notice by the Landowner to the Municipality, the Landowner shall be liable to the Municipality for its costs and expenses incurred to the date and time of its receipt of the notice, plus the applicable administrative costs and expenses as outlined in Paragraph 3 above.

9. The Landowner and the Municipality further agree that the Municipality shall have the right and privilege to sue the Landowner or then property owner in assumpsit for reimbursement or to lien the property or both, in its sole discretion, for any expense in excess of the then current balance of funds on deposit with the Municipality in accordance with this agreement incurred by the Municipality by reason of any review, supervision and inspection of Landowner's project by its professionals including, but not limited to, the Municipality Engineer and Solicitor. The Municipality's election of its remedies under this paragraph shall not constitute a waiver of any other remedies the Municipality may have.

10. The Landowner and the Municipality acknowledge that this agreement represents their full understanding as to the Municipality's reimbursement for professional or consultant services.

11. This agreement shall be binding on and insure to the benefit of the successors and assigns of Landowner. The Municipality shall receive thirty (30) days advance written notice from Landowner of any proposed assignment of Landowner's rights and responsibilities under this Agreement.

ATTEST:

WITNESS the following signatures and seals:

(SEAL)

For the Municipality:

_____

For the Landowner:

_____

ATTEST:

_____ (City, Borough, Township)

County of Butler, Pennsylvania

I, _____, a Notary Public in and for the County and State aforesaid, whose commission expires on the _____ day of _____, 20_____, do hereby certify that _____ whose name(s) is/are signed to the foregoing Agreement bearing date of the _____ day of _____, 20_____, has acknowledged the same before me in my said County and State.

GIVEN UNDER MY HAND THIS _____ day of _____, 20_____.

_____ _____

NOTARY PUBLIC **(SEAL)**

APPENDIX E – SMALL PROJECT SWM APPLICATION

[MUNICIPALITY]

Small Project Stormwater Management Application

Per ***[Municipality]***'s Act 167 Stormwater Management Ordinance, an Applicant is required to submit this Small Project Application whenever Regulated Activities involving the creation of new impervious surfaces equal to, or greater than 2,500 square feet and less than 5,00 square feet. Impervious surfaces are areas that prevent the infiltration of water into the ground and shall include, but not be limited to, roofs, patios, garages, storage sheds and similar structures, and any new streets or sidewalks.

To Calculate Impervious Surfaces Please Complete This Table					
Surface Type	**Length (feet)**	**X**	**Width (feet)**	**=**	**Proposed Impervious Area**
Building (area per downspout)		x		=	
		x		=	
		x		=	
		x		=	
Driveway		x		=	
		x		=	
		x		=	
Parking Areas		x		=	
		x		=	
		x		=	
Patios/Walks		x		=	
		x		=	
		x		=	
		x		=	
Other		x		=	
		x		=	
		x		=	
Total Impervious Surface Area to be managed (sum of all areas)					

For all Regulated Activities that involve creation of new impervious surface areas EQUAL TO or GREATER than 5,000 square feet, the Applicant MUST submit a Stormwater Management Site Plan and Report as defined in Article VIII of the Ordinance and implement volume and rate controls.

If the Total Impervious Surface Area is LESS THAN 5,000 square feet, or the proposed development is a Single Family Residential Activity implementing the minimum measures in Section 302.E. read, acknowledge and sign below.

Based upon information you have provided, a Stormwater Management Site Plan and Report **IS NOT** required for this Regulated Activity. ***[Municipality]*** may request additional information and/or a SWM Site Plan for any reason.

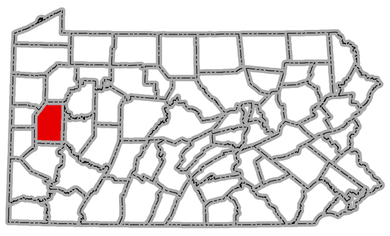
Applicant or Property Owner certifies that Sections 302.A., 302.B., and 302.C. have been adequately addressed and acknowledges that submission of inaccurate information may result in a stop work order or permit revocation. Acknowledgement of such is by signature below. I declare that I am the Owner or Owner's legal representative. I further acknowledge that the information provided is accurate and employees of ***[Municipality]*** are granted access to the above described property for review and inspection as they deem necessary.

Owner **Date:**

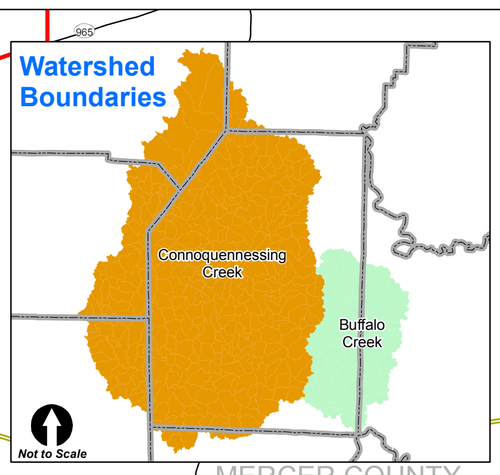
_____ _____

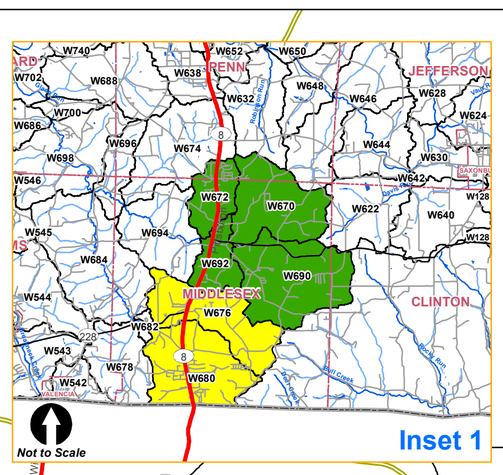
APPENDIX F – RELEASE RATE MAP

Location Map



Watershed Boundaries





MERCER COUNTY

VENANGO COUNTY

CLARION COUNTY

LAWRENCE COUNTY

ARMSTRONG COUNTY

BEAVER COUNTY

ALLEGHENY COUNTY

WESTMORELAND COUNTY

MERCER
MARION
VENANGO
CHERRY VALLEY
EAU CLAIRE
ALLEGHENY
HARRISVILLE
SLIPPERY ROCK
SLIPPERY ROCK BOROUGH
CHERRY
WASHINGTON
PARKER
BRUIN
PETROLIA
FAIRVIEW
WEST LIBERTY
WORTH
BRADY
WEST SUNBURY
CLAY
CONCORD
KARNS CITY
FAIRVIEW
MUDDY CREEK
PORTERSVILLE
FRANKLIN
CENTER
OAKLAND
DONEGAL
CHICORA
PROSPECT
LANCASTER
CONNOQUENESSING
BUTLER
BUTLER CITY
EAST BUTLER
SUMMIT
CLEARFIELD
JACKSON
ELLENPOLE
HARMONY
FORWARD
EVANS CITY
RENN
JEFFERSON
WINFIELD
ADAMS
CRANBERRY
CALLERY
MARS
SEVEN FIELDS
VALENCIA
MIDDLESEX
CLINTON
BUFFALO
SAXONBURG
Inset 1

Major Streams
Minor Streams
Water Bodies
Limited Access
Highway
Major Road
Municipal Boundaries
County Boundaries

Detailed Subbasins

Allowable Release Rates for 10, 25, 50 and 100 Year Storms

85%
90%
100%

1.5 0 1.5 Miles

08/31/2010 | R001803.0425

HRG
Herbert, Rowland & Grubic, Inc.
Engineering & Related Services
200 West Kensinger Drive, Suite 400
Cranberry Township, PA 16066
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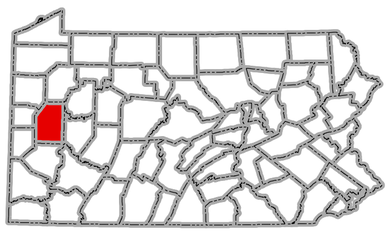
NOTE:
Portions of this map are provided for spatial reference only. They were generated from existing sources and may contain discrepancies that have not been corrected as part of this ACT 167 Plan.

DATA SOURCES:
Local Roads - PennDOT
Streams and Water Bodies - USGS NHD
Municipalities - PennDOT
Pennslyvania Counties - PennDOT
Major Highways - ESRI
Stormwater Management Districts - HRG

[BUILDING RELATIONSHIPS. DESIGNING SOLUTIONS.]

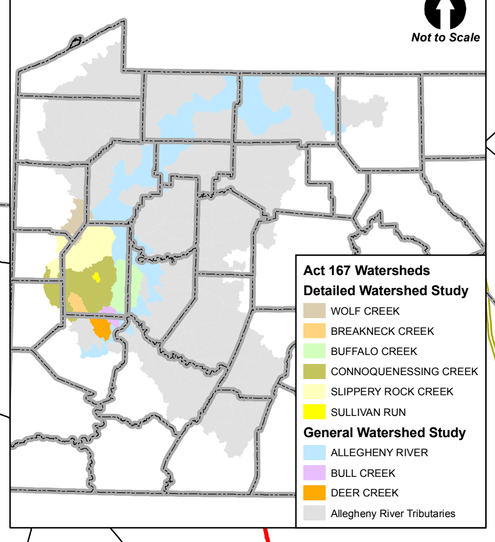
Plate 10.
Stormwater Management
Districts Map
Countywide Act 167
Butler County, Pennsylvania

Location Map



Physical Watershed Extents

Not to Scale



Act 167 Watersheds

Detailed Watershed Study
- WOLF CREEK
- BREAKNECK CREEK
- BUFFALO CREEK
- CONNOQUENESSING CREEK
- SLIPPERY ROCK CREEK
- SULLIVAN RUN

General Watershed Study
- ALLEGHENY RIVER
- BULL CREEK
- DEER CREEK
- Allegheny River Tributaries

MERCER COUNTY
VENANGO COUNTY
CLARION COUNTY
LAWRENCE COUNTY
ARMSTRONG COUNTY
BEAVER COUNTY
ALLEGHENY COUNTY
WESTMORELAND COUNTY

MERCER
MARION
VENANGO
CHERRY VALLEY
EAU CLAIRE
ALLEGHENY
HARRISVILLE
SLIPPERY ROCK
SLIPPERY ROCK BOROUGH
CHERRY
WASHINGTON
PARKER
BRUIN
PETROLIA
FAIRVIEW
KARNS CITY
WEST SUNBURY
WORTH
WEST LIBERTY
BRADY
CLAY
CONCORD
FAIRVIEW
MUDDY CREEK
PORTERSVILLE
FRANKLIN
CENTER
OAKLAND
DONEGAL
CHICORA
PROSPECT
LANCASTER
CONNOQUENESSING
BUTLER
BUTLER CITY
EAST BUTLER
SUMMIT
CLEARFIELD
WINFIELD
HARMONY
ZELIENOPLE
JACKSON
FORWARD
PENN
JEFFERSON
EVANS CITY
CALLERY
ADAMS
CRANBERRY
MIDDLESEX
CLINTON
BUFFALO
SAXONBURG
MARS
SEVEN FIELDS
VALENCIA

William Flynn Highway
Pittsburgh
Slippery Rock Creek
Wolf Creek
Black Run
Hogue Run
Muddy Creek
Big Run
Findley Run
South Branch Slippery Rock Creek
Christy Run
Silver Creek
Rays Run
Carrs Run
Lowrey Run
Fowler Run
Seaton Creek
Blacks Creek
McMurray Run
Main
McDonald Run
Long Run
Thorns Run
Sugar Creek
Long Run
Bear Creek
Coxcomb Hill Creek
Chiadarro Run
Swamp Run
Chesesman Run
Camp Run
Little Yellow Creek
Scholars Run
Yellow Creek
Glade Run
Likens Run
Wolfe Run
Crab Run
Semiconon Run
Muddy Creek Branch
Crooked Run
Benjamin Franklin
Sutbury Run
Coal Run
Rocklick Run
Sawmill Run
Butcher Run
Thorn Creek
Pine Run
Stony Run
Robinson Run
Davis Run
Bonnie Brook
Little Buffalo Run
North Branch Rough Run
Sarver Run
Rough Run
Pattonson Run
Vaur Run
Buffalo Creek
Little Buffalo Creek
Rocky Run
Laurintown Run
McDowell Run
Bull Creek
Deer Creek
Brush Creek
Breakneck Creek
Mahoning Creek
Beaver
Monaca
Conhocton
Ohio River
Jordan
Perry
Wilson Flynn

1.5 0 1.5 Miles

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HRG Herbert Rowland & Grubic Inc Engineering & Related Services
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Major Streams
Minor Streams
Water Bodies
Limited Access
Highway
Major Road
Municipal Boundaries
County Boundaries

Act 167 Watersheds

Detailed Watershed Study
- Wolf Creek
- Breakneck Creek
- Buffalo Creek
- Connoquenessing Creek
- Slippery Rock Creek
- Sullivan Run

General Watershed Study
- Allegheny River
- Bull Creek
- Deer Creek

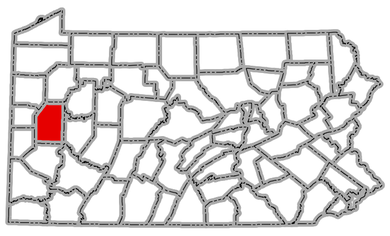
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Major Highways - ESRI

[BUILDING RELATIONSHIPS. DESIGNING SOLUTIONS.]

Plate 1.
Base Map
Countywide Act 167
Butler County, Pennsylvania

Location Map



MERCER COUNTY
VENANGO COUNTY
CLARION COUNTY
LAWRENCE COUNTY
ARMSTRONG COUNTY
BEAVER COUNTY
ALLEGHENY COUNTY
WESTMORELAND COUNTY

MERCER
HARRISVILLE
MARION
VENANGO
CHERRY VALLEY
EAU CLAIRE
ALLEGHENY
SLIPPERY ROCK BOROUGH
SLIPPERY ROCK
CHERRY
WASHINGTON
PARKER
BRUIN
PETROLIA
FAIRVIEW
KARNS CITY
WEST SUNBURY
WORTH
WEST LIBERTY
BRADY
CLAY
CONCORD
FAIRVIEW
CHICORA
PORTERSVILLE
MUDDY CREEK
FRANKLIN
CENTER
OAKLAND
DONEGAL
PROSPECT
EAST BUTLER
BUTLER CITY
LANCASTER
CONNOQUENESSING
BUTLER
SUMMIT
CLEARFIELD
HARMONY
ZELIENOPLE
JACKSON
FORWARD
PENN
JEFFERSON
WINFIELD
EVANS CITY
SAXONBURG
CALLERY
ADAMS
CRANBERRY
MIDDLESEX
CLINTON
BUFFALO
MARS
SEVEN FIELDS
VALENCIA

1.5 0 1.5 Miles

08/31/2010 | R001803.0425

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- Major Streams
- Minor Streams
- Water Bodies
- Limited Access
- Highway
- Major Road
- Municipal Boundaries
- County Boundaries

Act 167 Land Use

- Industrial
- Institutional (assumed 50% impervious)
- Mixed Urban (assumed 65% impervious)
- Newly graded areas
- Commercial and Business
- Residential - 1/8 acre or less
- Residential - 1/2 acre
- Residential - 1 acre
- Open space - Good Condition
- Meadow - Good Condition
- Contoured Row Crops - Good Condition
- Pasture - Good Condition
- Woods - Good Condition
- Water

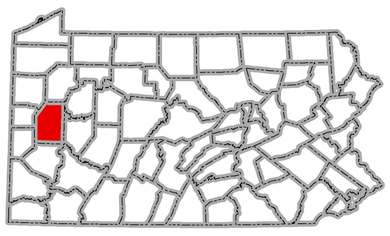
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DATA SOURCES:
Local Roads - PennDOT
Streams and Water Bodies - USGS NHD
Municipalities - PennDOT
Pennsylvania Counties - PennDOT
Major Highways - ESRI
Land Use - Butler County

[BUILDING RELATIONSHIPS. DESIGNING SOLUTIONS.]

Plate 2.
2010 Land Use Map
Countywide Act 167
Butler County, Pennsylvania

Location Map



MERCER COUNTY
VENANGO COUNTY
CLARION COUNTY
LAWRENCE COUNTY
ARMSTRONG COUNTY
BEAVER COUNTY
ALLEGHENY COUNTY
WESTMORELAND COUNTY

MERCER
HARRISVILLE
MARION
VENANGO
CHERRY VALLEY
EAU CLAIRE
ALLEGHENY
SLIPPERY ROCK BOROUGH
SLIPPERY ROCK
CHERRY
WASHINGTON
PARKER
BRUIN
PETROLIA
FAIRVIEW
KARNS CITY
WEST SUNBURY
WEST LIBERTY
WORTH
BRADY
CLAY
CONCORD
FAIRVIEW
CHICORA
PORTERSVILLE
MUDDY CREEK
FRANKLIN
CENTER
OAKLAND
DONEGAL
PROSPECT
EAST BUTLER
BUTLER CITY
LANCASTER
CONNOQUENESSING
BUTLER
SUMMIT
CLEARFIELD
HARMONY
ZELIENOPLE
JACKSON
FORWARD
PENN
JEFFERSON
WINFIELD
EVANS CITY
SAXONBURG
CALLERY
ADAMS
CRANBERRY
MIDDLESEX
CLINTON
BUFFALO
MARS
SEVEN FIELDS
VALENCIA

1.5 0 1.5 Miles

08/31/2010 | R001803.0425

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- Major Streams
- Minor Streams
- Water Bodies
- Limited Access
- Highway
- Major Road
- Municipal Boundaries
- County Boundaries

Act 167 Future Land Use

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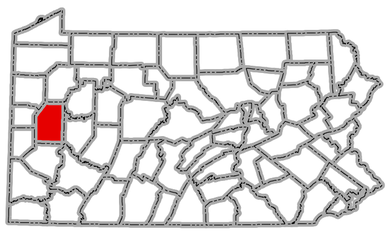
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Major Highways - ESRI
Land Use - Butler County

[BUILDING RELATIONSHIPS. DESIGNING SOLUTIONS.]

Plate 2.
2020 Land Use Map
Countywide Act 167
Butler County, Pennsylvania

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Location Map



MERCER COUNTY
VENANGO COUNTY
CLARION COUNTY
LAWRENCE COUNTY
ARMSTRONG COUNTY
BEAVER COUNTY
ALLEGHENY COUNTY
WESTMORELAND COUNTY

MERCER
HARRISVILLE
MARION
VENANGO
CHERRY VALLEY
EAU CLAIRE
ALLEGHENY
SLIPPERY ROCK BOROUGH
SLIPPERY ROCK
CHERRY
WASHINGTON
PARKER
BRUIN
PETROLIA
FAIRVIEW
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CRANBERRY
MIDDLESEX
CLINTON
BUFFALO
MARS
SEVEN FIELDS
VALENCIA

1.5 0 1.5 Miles

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- Minor Streams
- Water Bodies
- Limited Access
- Highway
- Major Road
- Municipal Boundaries
- County Boundaries

Act 167 Future Land Use

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- Institutional (assumed 50% impervious)
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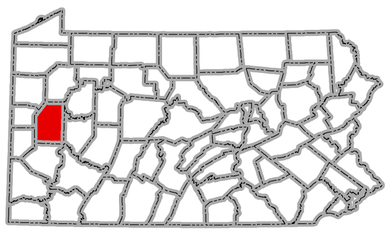
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Major Highways - ESRI
Land Use - Butler County

[BUILDING RELATIONSHIPS. DESIGNING SOLUTIONS.]

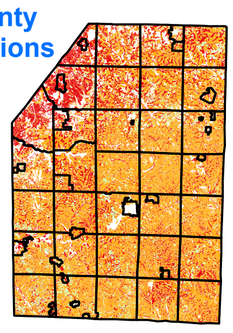
Plate 2.
2020 Land Use Map
Countywide Act 167
Butler County, Pennsylvania

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Location Map



Butler County Soil Restrictions



Municipal Boundaries

Restrictions

- None Identified
- Paralithic bedrock
- Lithic bedrock
- Fragipan

Not to Scale

MERCER COUNTY
VENANGO COUNTY
CLARION COUNTY
LAWRENCE COUNTY
ARMSTRONG COUNTY
ALLEGHENY COUNTY
WESTMORELAND COUNTY

HARRISVILLE
MARION
VENANGO
CHERRY VALLEY
EAU CLAIRE
ALLEGHENY
MERCER
SLIPPERY ROCK BOROUGH
SLIPPERY ROCK
CHERRY
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WINFIELD
EVANS CITY
SAXONBURG
CALLERY
ADAMS
CRANBERRY
MIDDLESEX
CLINTON
BUFFALO
MARS
SEVEN FIELDS
VALENCIA

Series Name	Map Symbols	Hydrologic Soil Group	% of County	Restrictions
Andover	AnA, AnB, AnC, AoB, AoC	D	1.7	Fragipan (16-28in.)
Arents	Ar		0.9	
Atkins	At	B/D	5.2	Lithic bedrock (60-99in.)
Braceville	BeA, BeB, BeC	C	0.5	Fragipan (15-30in.)
Brinkerton	BrA, BrB, BrC	C/D	4.2	Fragipan (15-30in.)
Buchanan	BuB, BuC, BxB, BxD	C	7.4	Fragipan (20-36in.)
Canadice	Cd	D	0.6	
Caneadea	CeA, CeB, CeC, CeD	D	0.7	
Canfield	CfB, CfC, CfD	C/D	0.5	Fragipan (15-30in.)
Cavode	ClA, ClB, ClC, ClD	C/D	6.1	Paralithic bedrock (40-72in.)
Clymer	CmB, CmC	B	0.6	Lithic bedrock (40-84in.)
Cookport	CoA, CoB, CoC, CoD	C/D	4.8	Fragipan (20-32in.)
Dams	DAM		<0.1	
Dumps	Dd, Dm		0.1	
Ernest	ErB, ErC, ErD	C/D	4.6	Fragipan (20-36in.)
Fluvaquents	Fc	D	<0.1	
Fredon	FeA, FeB	C	0.3	
Frenchtown	FrA, FrB	D	0.7	Fragipan (15-32in.)
Gilpin	GlB, GlC, GmD	C	4.2	Lithic bedrock (20-40in.)
Upshur	GnC, GnD	D	0.2	Lithic bedrock (40-70in.)
Weikert	GoB	C	1.2	Lithic bedrock (10-20in.)
Gilpin	GoC	C	1.4	Lithic bedrock (20-40in.)
Weikert	GoD	C	2.2	Lithic bedrock (10-20in.)
Gilpin	GoF, GpC, GpD	C	12.5	Lithic bedrock (20-40in.)
Gresham	GrA, GrB, GrC	C	1.5	Fragipan (15-26in.)
Hazleton	HaB, HaC, HaD, HaE, HbB, HgD,	A	17.4	Lithic bedrock (40-60in.)
Monongahela	MoB, MoC	C/D	0.3	Fragipan (25-35in.)
Philo	Ph	B	0.6	
Pits	Pn	A	0.1	
Pope	Po	B	0.1	
Ravenna	RaA, RaB, RaC	D	0.6	Fragipan (14-30in.)
Riverhead	RdB, RdC	B	0.4	
Tilsit	TaA, TaB	C	1.9	Lithic bedrock (40-60in.)
Titusville	TeB, TeC, TrD	C	1.5	Fragipan (16-28in.)
Urban land	UB		<0.1	Dense material (10-10in.)
Bethesda	UaB, UaD, UaF	C	6.2	
Fairpoint	UcD, UcF	C	0.3	
Urban land	UeB, UeC, UgD	D	0.6	
Vandergrift	VcB, VcC, VcD	C	0.9	Lithic bedrock (40-72in.)
Water	W		1.1	
Wharton	WaA, WaB, WaC	C	5.6	Paralithic bedrock (40-40in.)
Wheeling	WhA, WhB	B	0.2	
Wooster	WoB, WoC, WoD, WoF	C	0.1	Fragipan (18-36in.)

Restrictions	% of County
Dense material	0
Fragipan	23.9
Lithic bedrock	57.7
Paralithic bedrock	6.3
None Identified	12.1

Hydrologic Soil Group	Runoff Potential	% of County
A	Low	15.6
B	Moderate to low	3.7
B/D		5.2
C	Moderate to High	41.5
C/D		26.4
D	High	5.6
Unidentified		2.1

1.5 0 1.5 Miles

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- Major Streams
- Minor Streams
- Water Bodies
- Limited Access
- Highway
- Major Road
- Municipal Boundaries
- County Boundaries

Hydrologic Soil Groups

A - Low runoff potential
- A

B - Low to moderate runoff potential
- B
- B/D

C - Moderate to high runoff potential
- C
- C/D

D - High runoff potential
- D

Water

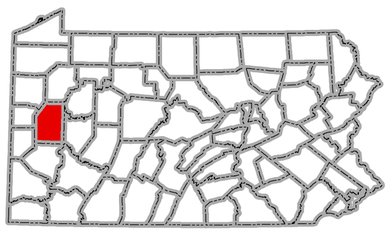
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DATA SOURCES:
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Streams and Water Bodies - USGS NHD
Municipalities - PennDOT
Pennslyvania Counties - PennDOT
Major Highways - ESRI
Soils - NRCS (2009)

[BUILDING RELATIONSHIPS, DESIGNING SOLUTIONS.]

Plate 4.
Hydrologic Soils Map
Countywide Act 167
Butler County, Pennsylvania

Location Map



MERCER COUNTY
VENANGO COUNTY
CLARION COUNTY
LAWRENCE COUNTY
ARMSTRONG COUNTY
BEAVER COUNTY
ALLEGHENY COUNTY
WESTMORELAND COUNTY

HARRISVILLE
MARION
CHERRY VALLEY
EAU CLAIRE
VENANGO
ALLEGHENY
MERCER
SLIPPERY ROCK BOROUGH
SLIPPERY ROCK
CHERRY
WASHINGTON
PARKER
BRUIN
WEST LIBERTY
WORTH
BRADY
WEST SUNBURY
CLAY
CONCORD
FAIRVIEW
PETROLIA
FAIRVIEW
KARNS CITY
CHICORA
PORTERSVILLE
MUDDY CREEK
FRANKLIN
PROSPECT
CENTER
OAKLAND
DONEGAL
EAST BUTLER
BUTLER CITY
LANCASTER
CONNOQUENESSING
BUTLER
SUMMIT
CLEARFIELD
HARMONY
ZELIENOPLE
JACKSON
FORWARD
PENN
JEFFERSON
WINFIELD
EVANS CITY
SAXONBURG
CALLERY
ADAMS
CRANBERRY
MIDDLESEX
CLINTON
BUFFALO
MARS
SEVEN FIELDS
VALENCIA

Major Streams
Minor Streams
Water Bodies
Limited Access
Highway
Major Road
Municipal Boundaries
County Boundaries

Elevation
High : 1620 Feet
Low : 750 Feet

1.5 0 1.5 Miles

08/31/2010 | R001803.0425

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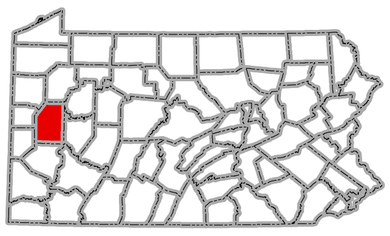
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Pennslyvania Counties - PennDOT
Major Highways - ESRI
DEM - USGS

[BUILDING RELATIONSHIPS. DESIGNING SOLUTIONS.]

Plate 5.
Digital Elevation Model Map
Countywide Act 167
Butler County, Pennsylvania

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Location Map



MERCER COUNTY
VENANGO COUNTY
CLARION COUNTY
LAWRENCE COUNTY
BEAVER COUNTY
ARMSTRONG COUNTY
ALLEGHENY COUNTY
WESTMORELAND COUNTY

HARRISVILLE
MARION
CHERRY VALLEY
EAU CLAIRE
VENANGO
ALLEGHENY
MERCER
SLIPPERY ROCK BOROUGH
SLIPPERY ROCK
CHERRY
WASHINGTON
PARKER
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CONCORD
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SAXONBURG
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CALLERY
CRANBERRY
ADAMS
MIDDLESEX
CLINTON
BUFFALO
MARS
SEVEN FIELDS
VALENCIA

Major Streams
Minor Streams
Water Bodies
Limited Access
Highway
Major Road
Municipal Boundaries
County Boundaries

Geology

- Allegheny Formation
- Burgoon Sandstone through Cuyahoga Group, undifferentiated
- Casselman Formation
- Glenshaw Formation
- Pottsville Formation

1.5 0 1.5 Miles

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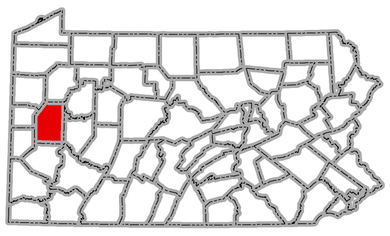
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Pennsylvania Counties - PennDOT
Major Highways - ESRI
Geology - PA Geological Survey

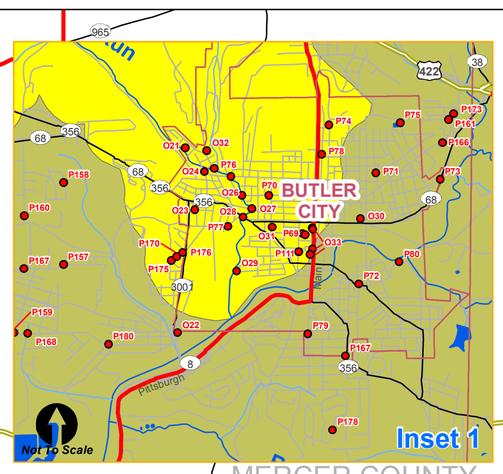
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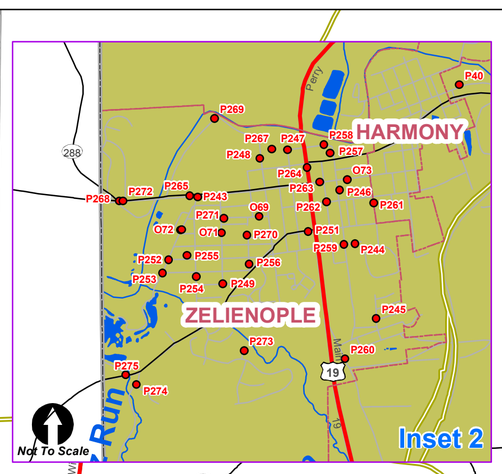
Plate 6.
Geology Map
Countywide Act 167
Butler County, Pennsylvania

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Location Map







MERCER COUNTY

VENANGO COUNTY

CLARION COUNTY

LAWRENCE COUNTY

BEAVER COUNTY

ARMSTRONG COUNTY

ALLEGHENY COUNTY

WESTMORELAND COUNTY

MERCER
MARION
VENANGO
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FORWARD
PENN
JEFFERSON
WINFIELD
CRANBERRY
ADAMS
MIDDLESEX
CLINTON
BUFFALO
SEVEN FIELDS
MARS
VALENCIA

Harmony
Zelienople
Inset 1

Problem Area
Major Streams
Minor Streams
Water Bodies
Limited Access
Highway
Major Road
Local Roads
Municipal Boundaries
County Boundaries

Act 167 Watersheds

Detailed Watershed Study
- Wolf Creek
- Breakneck Creek
- Buffalo Creek
- Connoquenessing Creek
- Slippery Rock Creek
- Sullivan Run

General Watershed Study
- Allegheny River
- Bull Creek
- Deer Creek

1.5 0 1.5 Miles

08/31/2010 | R001803.0425

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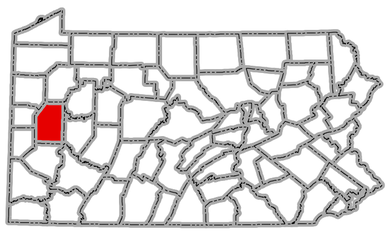
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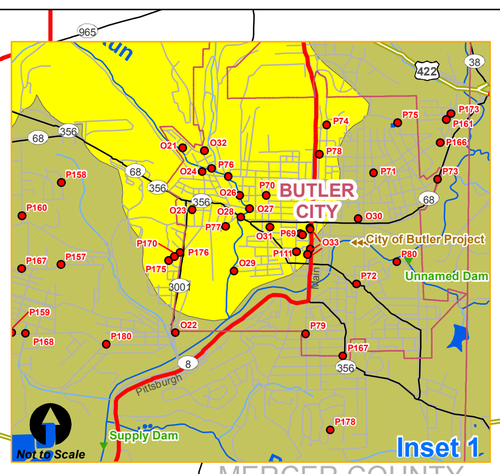
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Major Highways - ESRI
Problem Areas - Butler County

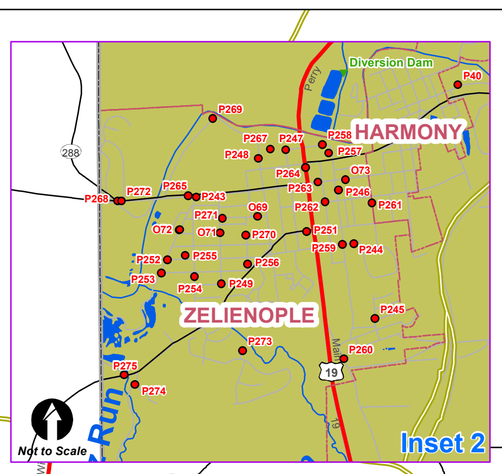
[BUILDING RELATIONSHIPS. DESIGNING SOLUTIONS.]

Plate 7.
Problem Areas Map
Countywide Act 167
Butler County, Pennsylvania

Location Map







MERCER COUNTY

VENANGO COUNTY

CLARION COUNTY

LAWRENCE COUNTY

ARMSTRONG COUNTY

BEAVER COUNTY

ALLEGHENY COUNTY

WESTMORELAND COUNTY

MERCER
MARION
VENANGO
CHERRY VALLEY
EAU CLAIRE
ALLEGHENY
HARRISVILLE
SLIPPERY ROCK BOROUGH
SLIPPERY ROCK
CHERRY
WASHINGTON
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WEST LIBERTY
BRADY
CLAY
CONCORD
FAIRVIEW
Park Dam
Crolls Dam
Moraine State Park Dam
USGS No. 3106500
Peaceful Valley Dam
Koppers Dam
Daugherty Dam
PORTERSVILLE
MUDDY CREEK
FRANKLIN
CENTER
Upper Dam
Miller Dam
Fischer Dam
Pine Lake
Boydstown Dam
Lake Oneida
OAKLAND
CHICORA
DONEGAL
PROSPECT
Thorn Reservoir
Preston Dam
BUTLER
BUTLER CITY
CONNOQUENESSING
LANCASTER
SUMMIT
CLEARFIELD
Sawmill Dam
Inset 1
HARMONY
ZELIENOPLE
Inset 2
Unnamed Dam
Conway Dam
Upper Dam
JACKSON
FORWARD
County Club Dam
PENN
JEFFERSON
WINFIELD
Penn Dixie Dam
USGS No. 3049100
Supply Dam
No. 2 Dam
Liken Supply Dam
ADAMS
Hein Dam
CRANBERRY
MIDDLESEX
Glade Run Dam
CLINTON
BUFFALO
Saxony Dam
MARS
SEVEN FIELDS
Drosnes Dam
Treesdale Lake
VALENCIA
Greisinger Dam
USGS No. 3049000

1.5 0 1.5 Miles

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Engineering & Related Services
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Cranberry Township, PA 16066
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Offices Statewide

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Dams
- Major Impoundments
- Run of the River Dam
- Not Included in this Study
- Levees
- USGS_Gauges
- Problem Area

- Major Streams
- Minor Streams
- Water Bodies
- Limited Access
- Highway
- Major Road
- Local Roads
- Municipal Boundaries
- County Boundaries

Act 167 Watersheds

Detailed Watershed Study
- Wolf Creek
- Breakneck Creek
- Buffalo Creek
- Connoquenessing Creek
- Slippery Rock Creek
- Sullivan Run

General Watershed Study
- Allegheny River
- Bull Creek
- Deer Creek

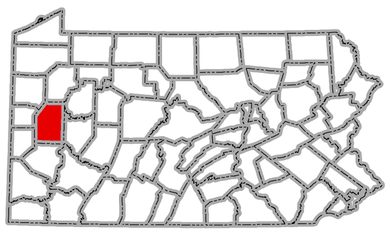
NOTE:
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DATA SOURCES:
Local Roads - PennDOT
Streams and Water Bodies - USGS NHD
Municipalities - PennDOT
Pennslyvania Counties - PennDOT
Major Highways - ESRI
Problem Areas - Butler County
USGS Gauges - USGS
Dams - HRG

[BUILDING RELATIONSHIPS. DESIGNING SOLUTIONS.]

Plate 8.
Flood Control Facilities Map
Countywide Act 167
Butler County, Pennsylvania

Location Map



MERCER COUNTY
VENANGO COUNTY
CLARION COUNTY
LAWRENCE COUNTY
ARMSTRONG COUNTY
BEAVER COUNTY
ALLEGHENY COUNTY
WESTMORELAND COUNTY

MERCER
MARION
VENANGO
CHERRY VALLEY
EAU CLAIRE
ALLEGHENY
HARRISVILLE
SLIPPERY ROCK
SLIPPERY ROCK BOROUGH
CHERRY
WASHINGTON
PARKER
BRUIN
PETROLIA
FAIRVIEW
KARNS CITY
WEST SUNBURY
WORTH
WEST LIBERTY
BRADY
CLAY
CONCORD
FAIRVIEW
CHICORA
PORTERSVILLE
MUDDY CREEK
FRANKLIN
CENTER
OAKLAND
DONEGAL
PROSPECT
LANCASTER
CONNOQUENESSING
BUTLER
BUTLER CITY
EAST BUTLER
SUMMIT
CLEARFIELD
HARMONY
ZELIENOPLE
JACKSON
FORWARD
EVANS CITY
PENN
JEFFERSON
WINFIELD
SAXONBURG
CALLERY
ADAMS
CRANBERRY
MIDDLESEX
CLINTON
BUFFALO
SEVEN FIELDS
MARS
VALENCIA

William Flynn
Pittsburgh
Old
Perry
McMurray Run
Main
Marin
Blacks Creek
Seaton Creek
Carrs Run
Lowrey Run
Fowler Run
Thorna Run
Long Run
McDonald Run
Wolf Creek
Slippery Rock Creek
Flaylay Run
South Branch Slippery Rock Creek
Christy Run
Silver Creek
Black Run
Hoglue Run
Big Run
Muddy Creek
Conoquenessing Creek
Bear Creek
Sugar Creek
Long Run
Keys Run
Swamp Run
Shannon Run
Stony Run
Pine Run
Thorn Creek
Buffalo Run
Camp Run
Little Yellow Creek
Scholars Run
Yellow Creek
Crab Run
Semiconon Run
Brush Run
Crooked Run
Benjamin Franklin
Sullivan Run
Coal Run
Little Buffalo Run
North Branch Rough Run
Sarver Run
Rough Run
Rocklick Run
Sawmill Run
Butcher Run
Patterson Run
Robinson Run
Vaur Run
Davis Run
Sarver Run
Little Buffalo Creek
Buffalo Creek
Little Buff Creek
McDowell Run
Rocky Run
Laurintown Run
Bull Creek
Deer Creek
Brush Creek
Breakneck Creek
Kaufman Run
Glade Run
Likens Run
Wolfe Run
Murtis Run
Harmony
Main
New Castle
Beaver
Monaca
Conhocton
Ohio River
Jordan

1.5 0 1.5 Miles

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- Major Streams
- Minor Streams
- Water Bodies
- Limited Access
- Highway
- Major Road
- Municipal Boundaries
- County Boundaries

Floodplains
- Zone A or Zone AE: Special Flood Hazard Area
- Zone X: Area Inndated by 0.2-Percent Chance Flood

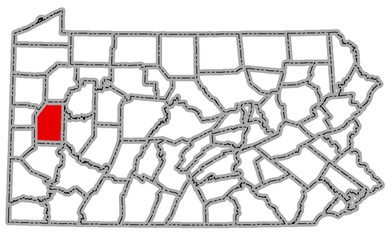
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DATA SOURCES:
Local Roads - PennDOT
Streams and Water Bodies - USGS NHD
Municipalities - PennDOT
Pennsylvania Counties - PennDOT
Major Highways - ESRI
Floodplains - DEP (1996)

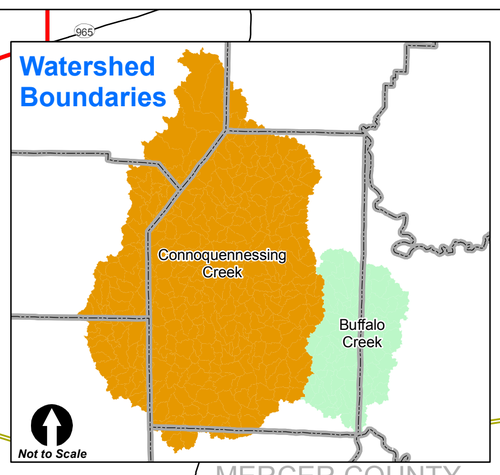
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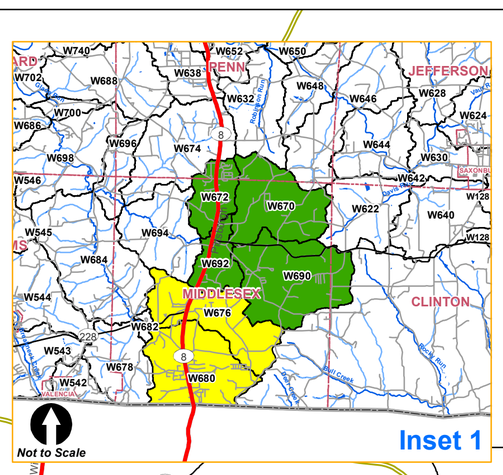
Plate 9.
Floodplains Map
Countywide Act 167
Butler County, Pennsylvania

Location Map



Watershed Boundaries





MERCER COUNTY

VENANGO COUNTY

CLARION COUNTY

LAWRENCE COUNTY

ARMSTRONG COUNTY

BEAVER COUNTY

ALLEGHENY COUNTY

WESTMORELAND COUNTY

MERCER
MARION
VENANGO
CHERRY VALLEY
EAU CLAIRE
ALLEGHENY
HARRISVILLE
SLIPPERY ROCK
SLIPPERY ROCK BOROUGH
CHERRY
WASHINGTON
PARKER
BRUIN
PETROLIA
FAIRVIEW
WEST LIBERTY
WORTH
BRADY
WEST SUNBURY
CLAY
CONCORD
KARNS CITY
FAIRVIEW
MUDDY CREEK
PORTERSVILLE
FRANKLIN
CENTER
OAKLAND
DONEGAL
CHICORA
PROSPECT
LANCASTER
CONNOQUENESSING
BUTLER
BUTLER CITY
EAST BUTLER
SUMMIT
CLEARFIELD
JACKSON
ELLENPOLE
HARMONY
FORWARD
EVANS CITY
RENN
JEFFERSON
WINFIELD
ADAMS
CRANBERRY
CALLERY
MARS
SEVEN FIELDS
VALENCIA
MIDDLESEX
CLINTON
BUFFALO
SAXONBURG
Inset 1

Major Streams
Minor Streams
Water Bodies
Limited Access
Highway
Major Road
Municipal Boundaries
County Boundaries

Detailed Subbasins

Allowable Release Rates for 10, 25, 50 and 100 Year Storms

85%
90%
100%

1.5 0 1.5 Miles

08/31/2010 | R001803.0425

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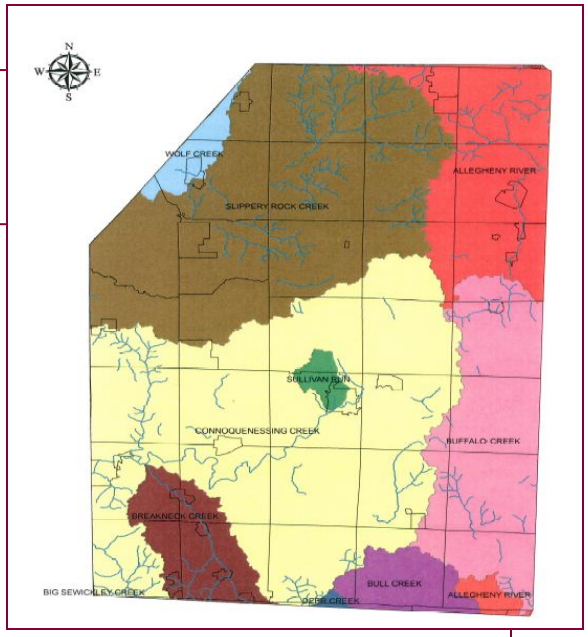
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DATA SOURCES:
Local Roads - PennDOT
Streams and Water Bodies - USGS NHD
Municipalities - PennDOT
Pennslyvania Counties - PennDOT
Major Highways - ESRI
Stormwater Management Districts - HRG

[BUILDING RELATIONSHIPS. DESIGNING SOLUTIONS.]

Plate 10.
Stormwater Management
Districts Map
Countywide Act 167
Butler County, Pennsylvania

Appendix A – Watershed Modeling Technical Data



An overview of the process that was used to complete the hydrologic modeling in preparation of this Plan is presented in *Section 6 – Technical Analysis* of this report. The following technical data is included here to supplement the general information provided in that section.

DATA COLLECTION

The GIS data for the hydrologic models was compiled from a variety of sources by county, state, and federal agencies. The data was collected in and processed using GIS software. A description of GIS data collected, the source and its use is provided in *Table A.1*.

Data	Source	Use
10-m Digital Elevation Model (DEMs)	USGS (2008a)	Watershed delineation, length, basin slope, stream slope, average elevation
High Resolution Streamlines	USGS (2008b)	Watershed delineation, cartography, spatial orientation
National Land Cover Dataset – Land Use 2001	USGS (2008c)	Curve number generation for watershed subareas outside of County
2010 Land Use for Butler County	Southwestern Planning Commission	Curve number generation for watershed subareas inside of County for year 2010
2010 Land Use for Butler County (digitized by HRG from redlines)	Butler County Planning Department	Curve number generation for watershed subareas inside of County for year 2020
SURRGO Soils Data	NRCS (2008)	Curve number generation; analysis of infiltration limitations
Storage (percent of lakes, ponds, and wetlands)	USGS (2008d)	Calculation of parameters for USGS Regression Equations
Roadway Data	PennDOT (2009)	Cartography, spatial orientation

Table A.1. GIS Data Used in Act 167 Technical Analysis

HYDROLOGIC MODEL PARAMETER DATA

SOILS, LAND USE, AND CURVE NUMBERS

The determination of curve numbers is a function of soil type and land use. The hydrologic soil groups were defined by NRCS (2008). The 2001 NLCD was simplified to provide an estimate of curve numbers using the scheme shown in *Table A.2*.

GIS Value	NLCD (2001) Description	NRCS (1986) Description	A	B	C	D
11	Open Water	Water	98	98	98	98
21	Developed, Open Space	Open space	39	61	74	80
22	Developed, Low Intensity	Residential - 1 acre	51	68	79	84
23	Developed, Medium Intensity	Residential - 1/2 acre	54	70	80	85
24	Developed, High Intensity	Commercial and Business	89	92	94	95
31	Barren Land (Rock/Sand/Clay)	Newly graded areas	77	86	91	94
41	Deciduous Forest	Woods	30	55	70	77
42	Evergreen Forest	Woods	30	55	70	77
43	Mixed Forest	Woods	30	55	70	77
52	Shrub/Scrub	Brush	30	48	65	73
71	Grassland/Herbaceous	Meadow	30	58	71	78
81	Pasture/Hay	Pasture	39	61	74	80
82	Cultivated Crops	Contoured Row Crops	65	75	82	86
90	Woody Wetlands	Woods	30	55	70	77
95	Emergent Herbaceous Wetlands	Water	98	98	98	98
111	Residential-High Density	Residential - 1/8 acre or less	77	85	90	92
112	Residential-Med Density	Residential - 1/2 acre	54	70	80	85
113	Residential-Med Low Density	Residential - 1/2 acre	54	70	80	85
114	Residential-Low Density Rural	Residential - 1 acre	51	68	79	84
115	Residential-Large Yard	Residential - 1 acre	51	68	79	84
121	Commercial-CBD	Commercial and Business	89	92	94	95
122	Commercial-Strip	Commercial and Business	89	92	94	95
123	Commercial-Commercial and Services	Commercial and Business	89	92	94	95
131	Industrial-Manufacturing	Industrial	81	88	91	93
132	Industrial-Chemical	Industrial	81	88	91	93
133	Industrial-Industrial	Industrial	81	88	91	93
141	Transportation-Major Highways	Industrial	81	88	91	93
142	Transportation-Railroads	Industrial	81	88	91	93
143	Transportation-Airports	Industrial	81	88	91	93
144	Transportation-Docking Ports	Industrial	81	88	91	93
145	Transportation-Dams	Industrial	81	88	91	93
146	Transportation-Substation	Industrial	81	88	91	93
147	Transportation-Powerline Pipeline right of Ways	Industrial	81	88	91	93
148	Transportation-Water Sewage Treatment	Industrial	81	88	91	93
149	Transportation-Water Communication Tower	Industrial	81	88	91	93
151	Industrial and Commercial Complexes-Industrial Complex	Industrial	81	88	91	93
152	Industrial and Commercial Complexes-Mall	Industrial	81	88	91	93
153	Industrial and Commercial Complexes-Business Complex	Industrial	81	88	91	93

Notes: All TR-55 land use designations assumed good condition (e.g., woods in conditions)

Table A.2. Curve Number Determination for each Hydrologic Soil Group for Butler County

GIS Value	NLCD (2001) Description	NRCS (1986) Description	A	B	C	D
161	Mixed Urban or Built-Up-Mixed Urban	Mixed Urban (assumed 65% impervious)	77	85	90	92
171	Other Urban Built-Up-Open Spaces	Open space	39	61	74	80
172	Other Urban Built-Up-Parks Recreation	Open space	39	61	74	80
173	Other Urban Built-Up-Golf Courses	Open space	39	61	74	80
174	Other Urban Built-Up-Ski Areas	Open space	39	61	74	80
175	Other Urban Built-Up-Institutional	Institutional (assumed 50% impervious)	69	80	86	89
176	Other Urban Built-Up-Historic Sites Regions	Open space	39	61	74	80
177	Other Urban Built-Up-Cemeteries	Open space	39	61	74	80
178	Other Urban Built-Up-Vegetated Buffer	Open space	39	61	74	80
179	Other Urban Built-Up-Non Vegetated Buffer	Open space	39	61	74	80
211	Crop Pasture Orchards Groves-Row Crops	Contoured Row Crops	65	75	82	86
212	Crop Pasture Orchards Groves-Fallow Fields	Pasture	39	61	74	80
213	Crop Pasture Orchards Groves-Orchards Groves	Contoured Row Crops	65	75	82	86
214	Crop Pasture Orchards Groves-Pasture	Pasture	39	61	74	80
215	Crop Pasture Orchards Groves-Vineyards	Contoured Row Crops	65	75	82	86
216	Crop Pasture Orchards Groves-Nurseries	Contoured Row Crops	65	75	82	86
217	Crop Pasture Orchards Groves-Farmstead	Pasture	39	61	74	80
311	Mixed Rangeland-Sparse Tree Crown	Meadow	30	58	71	78
312	Mixed Rangeland-Shrub Brush	Meadow	30	58	71	78
313	Mixed Rangeland-Mixed Rangeland	Meadow	30	58	71	78
431	Mixed Forest-Deciduous	Woods	30	55	70	77
432	Mixed Forest-Coniferous Evergreen	Woods	30	55	70	77
433	Mixed Forest-Mixed Forest	Woods	30	55	70	77
511	Rivers Streams Canals-Rivers	Water	98	98	98	98
512	Rivers Streams Canals-Streams	Water	98	98	98	98
513	Rivers Streams Canals-Canals	Water	98	98	98	98
531	Reservoirs Ponds-Reservoirs	Water	98	98	98	98
532	Reservoirs Ponds-Ponds	Water	98	98	98	98
533	Reservoirs Ponds-Lake	Water	98	98	98	98
751	Extraction-Strip Mines	Newly graded areas	77	86	91	94
752	Extraction-Slag Piles	Newly graded areas	77	86	91	94
753	Extraction-Quarries	Newly graded areas	77	86	91	94
754	Extraction-Gravel Pitts	Newly graded areas	77	86	91	94
761	Transitional-Construction	Newly graded areas	77	86	91	94
762	Transitional-Transitional Cleared	Newly graded areas	77	86	91	94
771	Mixed Barren-Mixed Barren	Newly graded areas	77	86	91	94

Notes: All TR-55 land use designations assumed good condition (e.g., woods in conditions)

Table A.2 (continued). Curve Number Determination for each Hydrologic Soil Group for Butler County

The curve numbers presented in the above tables represent "average" antecedent runoff condition (i.e. ARC = 2). In a significant hydrologic event, runoff is often influenced by external factors such as extremely dry antecedent runoff conditions (ARC=1) or wet antecedent runoff conditions (ARC=3). The antecedent runoff conditions of the above curve numbers were altered during the calibration process so that model results are within a reasonable range of other hydrologic estimates.

INFILTRATION AND HYDROLOGIC LOSS ESTIMATES

Infiltration and all other hydrologic loss estimates (e.g., evapotranspiration, percolation, depression storage, etc.) taken into account within the HEC-HMS model was consistent with the recharge volume criteria contained in Control Guidance 1 and 2 (CG-1 and CG-2). These losses were modeled in existing conditions as the standard initial abstraction in the NRCS Curve Number Runoff method (i.e., $I_a = 0.2S$). CG1 was simulated by modifying the standard initial abstraction using the following procedure.

The runoff volume is computed by HEC-HMS using the following equation:

$$Q_{volume} = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Where P = rainfall for a specific storm event (in),
I_a = initial abstraction (in), and
S = maximum retention (in).

S is defined by the following equation which relates runoff volume to curve number:

$$S = \frac{1000}{CN} - 10$$

The standard initial abstraction I_a used in Pennsylvania is typically $0.2S$. HEC-HMS calculates this automatically if no value is entered by the user. This was the approach used for the existing and future conditions modeling scenarios.

In future conditions with implementation of CG-1, the following equation is applicable. The goal of CG-1 is to ensure there is no discharge volume increase for the 2-year storm event, so

$$Q_{CG1} = Q_{Existing} = \frac{(P - I_a)^2}{(P - I_a) + S_{Proposed}}$$

Where P = rainfall for a specific storm event(in),
I_a = initial abstraction (in), and
$S_{Proposed}$ = maximum retention in proposed conditions as a function of the proposed conditions curve number (in).

Assuming $I_a = 0.2S$ as the Initial abstraction is no longer applicable with CG-1 since BMPs are to be installed to control or remove the increase in runoff volume for the 2-year storm. Using the

HEC-HMS modeling output for $Q_{Existing}$, the initial abstraction for CG-1 may be calculated using the following equation:

$$I_a = P_{2-year} - \frac{1}{2}(Q_{Existing} \pm \sqrt{Q_{Existing}^2 + 4Q_{Existing}S_{Proposed}}) \text{ for the 2-year event}$$

Thus, the volume control required by CG-1 is implicitly modeled by overriding the HEC-HMS default for initial abstraction with the above value. The qualitative effect of this will be to eliminate the increase in runoff volume for the 2-year storm and to reduce the increase in runoff volume of the more extreme events. Increases in the peak flow values are reduced for all storms, but not eliminated, since the time of concentrations for proposed condition are decreased. Figure C.1 shows the effects of implementing a CG-1 policy on an example watershed. In the first figure representing a 2-year storm event, the hydrograph volumes are exactly the same and the peaks are similar. In the second figure representing a 100-year storm event, the hydrograph volumes are not the same since only the 2-year volume is abstracted; consequently there is still a substantial increase in peak flows, although the CG-1 implementation does reduce the peak flow.

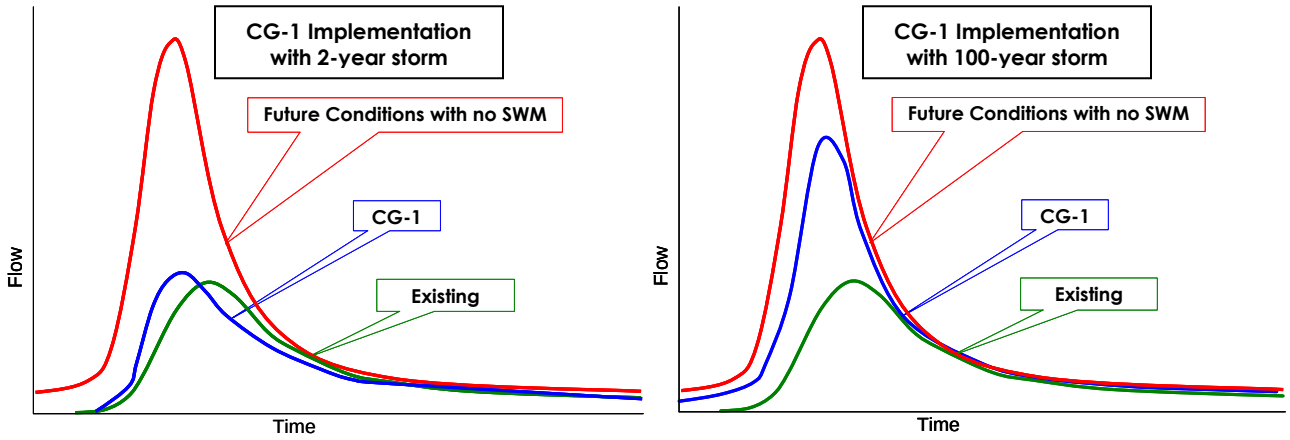


Figure A.1. Typical On-Site Runoff Control Strategy

In the case of this particular sample, release rates might be necessary to prevent increases in peak flow. In situations where there is only a small increase in impervious coverage, however, CG-1 may reduce the proposed conditions peak flow to existing conditions levels without the use of release rates.

For the 2-year event, modeling CG-1 with the above equations results in an increased approximation in initial abstraction represented by D:

$$D = I_a^{CG-1} - 0.2S$$

For the every event of greater magnitude (e.g., 10, 25, 50, and 100-year events), the initial abstraction is calculated using the sum of the traditional method and the increase in initial abstraction for the 2-year event.

$I_a = 0.2S + D$ for all events greater than the 2-year event.

MODEL CALIBRATION

Three parameters were modified to develop a calibrated hydrologic model: the curve number, the time of concentration, and the Manning's coefficient used in the Muskingum-Cunge routing method.

The antecedent runoff condition was altered for each storm event so that each subbasin and calibration point was within an acceptable range of a target flow. The equation used to modify antecedent runoff condition (Maryland Hydrology Panel, 2006):

For ARC≤2:

$$CN_x = \frac{[10 + 5.8(x - 2)]CN_2}{10 + 0.058(x - 2)CN_2}$$

For ARC>2:

$$CN_x = \frac{[10 + 13(x - 2)]CN_2}{10 + 0.013(x - 2)CN_2}$$

Thus a unique ARC and resulting curve number was calculated for each subbasin for each storm event. The same ARC was applied in both existing and proposed conditions. The calibrated and future condition curve numbers for the two watersheds are presented in the Tables at the end of this appendix.

Additionally, lag times were calculated using both TR-55 and the NRCS lag equation. The initial model runs used the results from the NRCS lag equation. A factor between 0 and 2 was applied to the initial value to obtain a calibrated time of concentration value. The same time of concentration was applied to all existing condition storms. The future land use time of concentration was calculated using the NRCS lag equation with future land curve numbers and it was subsequently adjusted by the same factor used in existing conditions.

Finally the Manning's n value for channels and overbank areas was modified to obtain realistic flow values. The respective ranges for the channel and overbank areas were 0.02-0.07 and 0.03-0.2.

MODELING RESULTS

A summary of the hydrologic modeling results has been provided in Section 5 of this Plan. The full modeling results are as presented in the tables at the end of this appendix.

STORMWATER MANAGEMENT DISTRICTS

The regional philosophy used in Act 167 planning introduces a different stormwater management approach than is found in the traditional on-site approach. The difference between the on-site stormwater control philosophy and the Act 167 watershed-level philosophy is the consideration of downstream impacts throughout an individual watershed. The objective of typical on-site design is to control post-development peak flow rates from the site itself; however, a watershed-level design is focused on maintaining existing peak flow rates in the entire drainage basin. The watershed approach requires knowledge of how the site relates to

the entire watershed in terms of the timing of peak flows, contribution to peak flows at various downstream locations, and the impact of the additional runoff volume generated by the development of the site. The proposed watershed-level stormwater runoff control philosophy is based on the assumption that runoff volumes will increase with development and the philosophy seeks to manage the increase in volumes such that peak rates of flow throughout the watershed are not increased. The controls implemented in this Plan are aimed at minimizing the increase in runoff volumes and their impacts, especially for the 2-year storm event.

The basic goal of both on-site and watershed-level philosophies is the same, i.e. no increase in the peak rate of stream flow. The end products, however, can be very different as illustrated in the following simplified example.

Presented in *Figure A.2* is a typical on-site runoff control strategy for dealing with the increase in the peak rate of runoff with development. The Existing Condition curve represents the pre-development runoff hydrograph. The Developed Condition hydrograph illustrates three important changes in the site runoff response with development:

A higher peak rate,

A faster occurring peak (shorter time for the peak rate to occur), and

An increase in total runoff volume

The "Controlled" Developed Condition hydrograph is based on limiting the post-development runoff peak rate to the pre-development level through use of detention facilities; but the volume is still increased. The impact of "squashing" the post-development runoff to the pre-development peak without reducing the volume is that the peak rate occurs over a much longer period of time. The instantaneous pre-development peak has become an extended peak (approximately two (2) hours long in this example) under the "Controlled" Developed Condition.

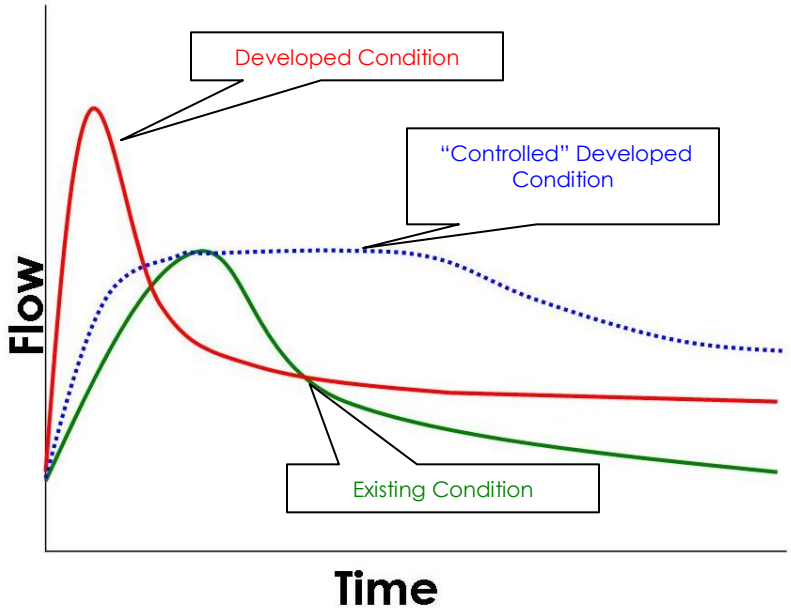


Figure A.2. Typical On-Site Runoff Control Strategy

Considering the outflow from the site only, the maintenance of the pre-development peak rate of runoff is an effective management approach. However, *Figures A.3* and *A.4* illustrate the potential detrimental impact of this approach. *Figure A.3* represents the existing hydrograph at the point of confluence of Watershed A and Watershed B. The timing relationship of the watersheds is that Watershed A peaks more quickly (at time T_{pA}) than the Total Hydrograph, while Watershed B peaks later (at time T_{pB}), than the Total Hydrograph, resulting in a combined time to peak approximately in the middle (at time T_p). Watershed A is an area of significant development pressure, and all new development proposals are met with the on-site runoff control philosophy as depicted in *Figure A.2*. The eventual end product of the Watershed A development under the "Controlled" Development Condition is an extended peak rate of runoff as shown in *Figure A.4*. The extended Watershed A peak occurs long enough so that it coincides with the peak of Watershed B. Since the Total Hydrograph at the confluence is the summation of Watershed A and Watershed B, the Total Hydrograph peak is increased under these conditions to the "Controlled" Total Hydrograph. The conclusion from the example is that simply controlling peak rates of runoff on-site does not guarantee an effective watershed level of control because of the increase in total runoff volume. The net result is that downstream peaks can increase and extend for longer durations.

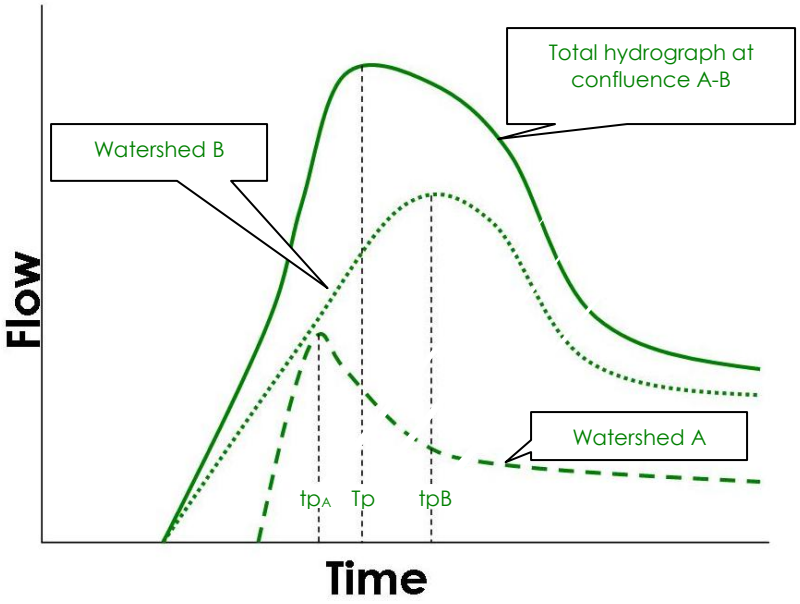


Figure A.3. Existing Hydrograph (Pre-Development)

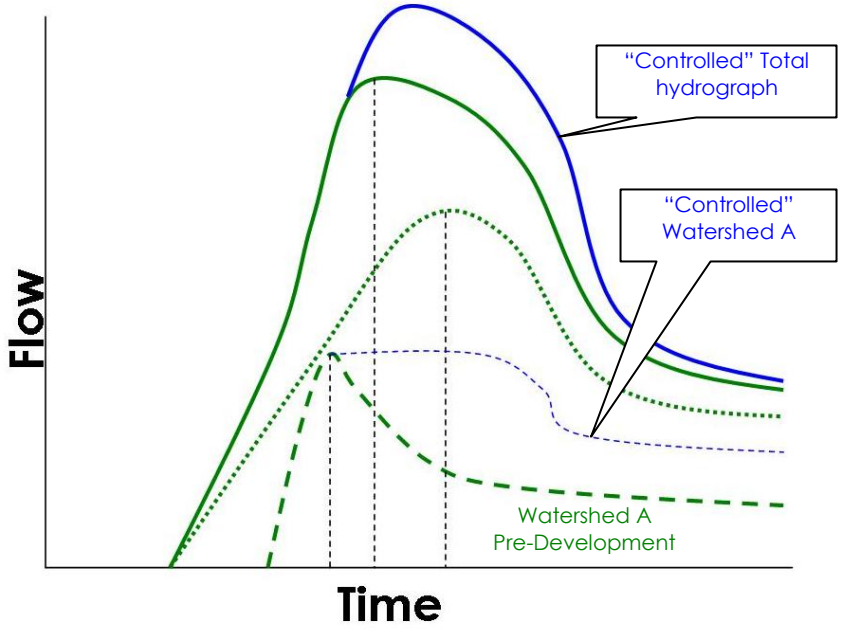


Figure A.4. Controlled Runoff Condition (Post-Development)

RELEASE RATE CONCEPT

The previous example indicated that, in certain circumstances, it is not enough to control post-development runoff peaks to pre-development levels if the overall goal is no increase in peak runoff at any point in the watershed. The reasons for this potential increase are how the various parts of the watershed interact, in time, with one another and the increased rate and volume of runoff associated with development and increases in impervious surfaces. The critical runoff criteria for a given site or watershed area is not necessarily its own pre-development peak rate of runoff but rather the pre-development contribution of the site or watershed area to the peak flow at a given point of interest.

To account for increases of volume and peak flow resulting from the combination of these post-development hydrographs, stormwater management districts have been assigned to various areas within the county boundary that have more restrictive release rates than the conventional 100% release rate. As shown in Plate 10, some areas within specific watersheds have reduced release rates where CG-1 may be difficult to completely implement.

The specification of a 100% release rate as a performance standard would represent the conventional approach to runoff control philosophy, namely controlling the post-development peak runoff to pre-development levels. This is a well-established and technically feasible control that is effective at-site and, where appropriate, would be an effective watershed-level control.

It is important to acknowledge that there are several problems with the release rate concept. One of the problems is that some areas can reach unreasonably low release rates. This can be seen in the release rate equation, which dictates that sub-watersheds that peak farther away from the entire watershed will have a lower release rate. Indeed, sub-watersheds whose runoff drains almost completely before or after the watershed peak will approach a release rate of zero (because the numerator approaches zero).

Another problem is that release rates are highly dependent on, and sensitive to, the timing of

hydrographs. Since natural storms follow a different timing than design storms, it is still possible that watershed wide controls designed with release rates only, will encounter increased runoff problems. This is because the runoff rates are still much higher in the developed condition, and increased volumes over an extended time can combine to increase peak flow rates. Similar to the traditional on-site detention pond, release rates are purely a peak "rate" type of control.

Patterns of development may also determine how effective designs are that use only release rates, or any control based on timing. This is because rates based on timing assume a certain development and rainfall patterns, and the model uses uniform parameters across a sub-watershed. In reality, the actual development and rainfall patterns can be highly variable across a sub-watershed and can be quite different than the "Future Full Build Out" land use scenario used in the planning study. This uncertainty can affect any type of control, but controls based on timing alone are especially sensitive to these parameters. Some controls, such as volume controls, are less sensitive since they remove a certain amount of runoff from the storm event wherever development occurs. In a sense, volume controls tend to more closely simulate what occurs in a natural system.

Combining volume controls with peak rate controls, as proposed in this plan, will be more effective than having only peak rate controls. Volume controls have several advantages such as:

Increased runoff volume may infiltrate and provide recharge to existing groundwater supplies. This may not happen with rate controls since all of the runoff excess is discharged in a relatively short time frame.

Volume controls tend to mimic natural systems (i.e., excess runoff volume is infiltrated) and thus are more effective in controlling natural storms since they are not highly sensitive to timing issues.

Volume controls often have enhanced water quality benefits.

The Design Storm Method and The Simplified Method as implemented in this Plan, provide the benefits described above.

SUMMARY MODEL OUTPUT

For data management purposes, the HEC-HMS models for Butler County were broken into seven different models. The modeling input and output is provided with the following pages. In order that they occur, they include:

BUFFALO CREEK HEC-HMS MODELS:

Hydrologic Parameters for Buffalo Creek HEC-HMS Model
Hydrologic Results for Buffalo Creek HEC-HMS Model

CONNEQUENESSING CREEK HEC-HMS MODELS:

Hydrologic Parameters for Wolf Creek HEC-HMS Model
Hydrologic Results for Wolf Creek HEC-HMS Model

Hydrologic Parameters for Upper Slippery Rock Creek HEC-HMS Model
Hydrologic Results for Upper Slippery Rock Creek HEC-HMS Model

Hydrologic Parameters for Lower Slippery Rock Creek HEC-HMS Model
Hydrologic Results for Lower Slippery Rock Creek HEC-HMS Model

Hydrologic Parameters for Upper Connoquenessing Creek HEC-HMS Model
Hydrologic Results for Upper Connoquenessing Creek HEC-HMS Model

Hydrologic Parameters for Lower Connoquenessing Creek HEC-HMS Model
Hydrologic Results for Lower Connoquenessing Creek HEC-HMS Model

Hydrologic Parameters for Breakneck Creek HEC-HMS Model
Hydrologic Results for Breakneck Creek HEC-HMS Model

Calibration Results for Detailed HEC-HMS Models with 2010 Land Use

Hydrologic Parameters for Buffalo Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Buffalo Creek	W008	3.34	71.3	67.0	71.3	67.0
	W010	3.87	64.6	94.6	64.6	94.6
	W012	3.13	62.0	105.7	62.0	105.7
	W014	1.14	64.2	57.4	64.2	57.4
	W042	4.43	65.0	102.0	65.0	102.0
	W044	0.86	68.8	48.4	68.8	48.4
	W046	3.43	66.1	71.7	66.1	71.7
	W048	1.59	66.7	52.4	67.1	51.9
	W050	2.03	59.0	80.2	59.0	80.2
	W052	0.09	66.1	20.9	66.1	20.9
	W054	0.54	62.7	50.3	62.7	50.3
	W056	1.10	58.7	62.9	58.7	62.9
	W058	0.84	66.1	44.7	66.1	44.7
	W060	0.09	70.7	14.5	70.7	14.5
	W062	3.04	70.9	77.1	70.9	77.1
	W064	3.94	76.3	70.5	76.3	70.5
	W066	2.78	72.0	53.9	72.0	67.4
	W068	1.90	76.8	45.8	76.8	50.8
	W072	1.00	71.2	48.8	71.2	48.8
	W074	2.48	67.8	73.9	67.8	73.9
	W076	0.98	59.5	42.8	59.5	42.8
	W078	0.77	64.3	40.4	64.3	40.4
	W120	3.60	75.3	57.5	75.3	71.8
	W122	2.04	74.1	62.0	74.0	69.0
	W170	1.47	71.8	69.5	71.8	69.5
	W172	0.52	73.3	27.5	73.3	27.5
	W174	1.30	72.5	42.1	72.5	42.1
	W176	1.49	74.5	53.5	74.5	53.5
	W178	3.44	70.7	83.4	70.7	83.4
	W180	0.35	59.5	28.2	59.5	28.2
	W182	0.96	65.2	43.3	65.2	43.3
	W184	0.65	73.4	33.1	73.4	33.1
	W186	1.29	70.6	51.7	70.6	51.7
	W188	1.10	68.9	45.1	68.9	45.1
	W190	0.65	64.5	50.3	64.5	50.3
	W192	0.00	52.9	3.4	52.9	3.4
	W194	0.20	59.4	25.1	59.4	25.1
	W196	3.10	69.8	68.8	69.9	68.6
	W198	1.25	70.6	43.7	71.9	42.1
Buffalo Run	W016	2.67	65.4	64.1	65.4	64.1
	W018	2.66	63.3	83.0	63.3	83.0
	W020	1.00	66.3	52.9	66.3	52.9
Cornplanter Run	W106	1.01	70.0	55.5	70.0	55.5
	W108	2.44	71.7	79.0	71.7	79.0

Hydrologic Parameters for Buffalo Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Cornplanter Run	W110	1.23	73.8	35.1	73.8	43.9
Little Buffalo Creek	W124	0.78	80.5	47.4	80.5	47.4
	W126	2.42	79.2	141.0	79.2	94.0
	W138	1.16	78.8	85.9	78.7	57.4
	W140	1.81	75.0	80.7	75.3	53.2
	W142	1.72	75.8	66.8	77.0	43.0
	W144	2.97	78.4	106.3	78.6	70.6
	W146	1.01	78.2	75.1	78.2	50.1
	W148	2.38	74.3	141.4	74.4	94.0
	W150	0.76	76.3	60.9	76.4	40.5
	W152	0.23	67.5	50.8	67.5	33.8
	W154	0.01	59.7	12.6	59.7	8.4
	W156	1.82	70.8	95.6	71.2	63.0
	W158	0.20	55.2	41.5	55.6	27.4
Little Buffalo Run	W022	1.22	60.2	63.1	60.2	63.1
	W024	3.54	77.1	73.7	77.4	73.2
	W026	2.44	69.4	64.0	69.4	64.0
	W028	1.06	69.3	32.4	69.3	32.4
	W030	3.19	60.1	112.4	60.1	112.4
	W032	0.39	63.2	42.3	63.2	42.3
	W034	0.85	59.6	56.2	59.6	56.2
	W036	0.59	63.0	40.0	63.0	40.0
	W038	1.16	66.0	53.9	66.0	53.9
	W040	0.16	61.3	23.2	61.3	23.2
Long Run	W004	1.98	68.0	54.9	68.0	54.9
	W006	3.16	71.1	73.0	71.1	73.0
Marrowbone Run	W070	3.14	71.9	51.7	71.9	51.7
North Branch Rough Run	W082	2.09	72.2	47.3	72.2	59.1
	W084	1.21	62.4	42.8	62.4	53.5
	W086	0.22	61.5	28.7	61.5	28.7
Patterson Creek	W002	3.33	62.8	98.7	62.8	98.7
	W160	3.46	73.4	67.7	73.4	67.7
	W162	3.61	70.9	74.9	70.9	74.9
	W164	2.87	70.5	70.0	70.5	70.0
	W166	2.75	68.7	70.8	68.7	70.8
	W168	0.71	69.7	37.1	69.7	37.1
Pine Run	W112	1.55	71.9	46.1	71.9	46.1
	W114	2.62	72.5	64.9	72.5	81.1
	W116	1.84	71.9	58.4	71.9	58.4
	W118	1.20	71.0	34.8	71.0	43.5
Rough Run	W088	1.53	68.0	60.1	68.0	60.1
	W090	2.74	76.1	56.3	76.1	56.3
	W092	2.23	76.2	50.4	76.2	50.4
	W094	1.44	71.5	43.0	71.5	53.8

Hydrologic Parameters for Buffalo Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Rough Run	W096	1.71	67.6	70.9	67.6	70.9
	W098	0.59	70.5	43.3	70.5	43.3
	W100	2.66	60.1	71.0	60.1	71.0
	W102	0.40	50.1	33.2	50.1	33.2
Sarver Run near Dennys Mills	W080	1.24	67.5	75.6	67.5	75.6
Sarver Run near Sarverville	W128	2.27	79.5	115.9	79.4	77.4
	W130	0.88	78.3	77.9	79.2	50.5
	W132	1.24	78.7	106.8	79.0	70.5
	W134	2.05	76.1	103.4	76.0	69.1
	W136	2.31	79.7	138.5	80.1	91.4
Sipes Run	W104	1.95	71.6	32.6	71.6	40.7

Hydrologic Parameters for Buffalo Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Buffalo Creek	W008	71.3	71.3	68.5	66.5	64.2	63.4
	W010	64.6	74.0	71.9	69.8	67.3	66.5
	W012	62.0	74.0	72.8	71.0	69.0	68.4
	W014	64.2	72.1	70.8	68.5	65.9	64.2
	W042	65.0	74.2	72.3	70.2	67.7	66.9
	W044	68.8	68.6	66.9	65.1	63.0	62.3
	W046	66.1	73.4	70.4	66.4	64.0	63.1
	W048	66.7	72.0	68.6	65.6	63.4	62.5
	W050	59.0	72.4	71.0	69.1	66.9	66.3
	W052	66.1	65.8	64.1	62.2	60.1	59.4
	W054	62.7	62.4	60.6	58.7	56.5	55.7
	W056	58.7	71.8	70.5	68.6	66.4	65.6
	W058	66.1	65.8	64.1	62.2	60.0	59.3
	W060	70.7	70.4	68.8	67.0	65.0	64.3
	W062	70.9	72.9	69.6	67.8	65.8	65.0
	W064	76.3	71.7	69.7	67.1	64.1	63.1
	W066	72.0	70.2	69.2	66.8	64.0	63.2
	W068	76.8	70.5	69.4	66.7	63.4	62.6
	W072	71.2	70.6	68.9	66.6	64.0	63.3
	W074	67.8	72.2	70.9	67.2	64.8	64.0
	W076	59.5	59.2	57.4	55.4	53.2	52.4
	W078	64.3	64.0	62.2	60.3	58.1	57.4
	W120	75.3	70.8	69.7	67.3	64.4	63.5
	W122	74.1	71.8	70.7	68.3	65.5	64.9
	W170	71.8	71.7	70.6	68.6	66.4	65.9
	W172	73.3	73.0	71.5	69.8	67.9	67.2
	W174	72.5	69.9	67.9	65.2	62.1	61.2
	W176	74.5	71.1	69.5	67.0	64.1	63.4
	W178	70.7	72.4	69.9	67.8	65.3	64.6
	W180	59.5	59.2	57.4	55.3	53.1	52.4
	W182	65.2	64.9	63.2	61.3	59.1	58.4
	W184	73.4	73.1	71.6	69.9	68.0	67.4
	W186	70.6	70.3	68.6	66.4	63.7	63.0
	W188	68.9	70.8	67.8	65.4	62.6	61.9
	W190	64.5	64.2	62.4	60.5	58.3	57.6
	W192	52.9	52.6	50.7	48.7	46.5	45.7
	W194	59.4	59.0	57.2	55.2	53.0	52.2
	W196	69.8	71.6	68.9	66.5	63.6	62.7
	W198	70.6	69.8	67.9	65.4	62.4	61.4
Buffalo Run	W016	65.4	72.9	70.2	66.4	63.7	62.7
	W018	63.3	73.4	71.5	69.4	66.9	66.1
	W020	66.3	72.4	71.0	67.5	64.9	64.2
Cornplanter Run	W106	70.0	71.8	69.4	67.4	65.0	64.4
	W108	71.7	71.7	70.5	68.4	66.1	65.4

Hydrologic Parameters for Buffalo Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Cornplanter Run	W110	73.8	69.8	68.5	66.0	63.0	62.1
Little Buffalo Creek	W124	80.5	80.3	79.1	77.7	76.2	75.6
	W126	79.2	72.3	70.1	69.6	69.1	68.9
	W138	78.8	70.8	68.0	67.3	66.6	66.1
	W140	75.0	69.5	65.9	64.9	63.8	62.8
	W142	75.8	69.0	65.0	63.8	62.4	61.6
	W144	78.4	70.7	64.8	63.5	62.0	61.1
	W146	78.2	70.4	64.5	63.1	61.6	60.7
	W148	74.3	71.8	69.7	69.1	68.5	68.1
	W150	76.3	76.1	74.7	73.1	71.3	70.7
	W152	67.5	67.2	65.5	63.7	61.6	60.9
	W154	59.7	59.4	57.5	55.5	53.3	52.6
	W156	70.8	69.6	66.8	65.8	64.7	63.8
	W158	55.2	54.8	53.0	50.9	48.7	48.0
Little Buffalo Run	W022	60.2	72.3	70.6	68.6	66.3	65.3
	W024	77.1	72.1	70.5	68.4	66.0	65.3
	W026	69.4	71.7	68.6	66.7	64.5	63.7
	W028	69.3	68.7	66.2	63.9	61.4	60.4
	W030	60.1	73.8	72.9	71.3	69.6	69.1
	W032	63.2	62.9	61.1	59.2	57.0	56.3
	W034	59.6	59.3	57.5	55.4	53.2	52.5
	W036	63.0	62.7	60.9	58.9	56.8	56.0
	W038	66.0	72.2	70.6	67.0	64.5	63.7
	W040	61.3	61.0	59.2	57.2	55.0	54.3
Long Run	W004	68.0	71.7	67.7	65.7	63.3	62.5
	W006	71.1	72.1	69.2	67.3	65.2	64.3
Marrowbone Run	W070	71.9	69.8	67.3	64.5	61.2	60.3
North Branch Rough Run	W082	72.2	70.1	68.9	66.5	63.7	62.9
	W084	62.4	70.5	69.8	66.8	63.3	62.4
	W086	61.5	61.2	59.4	57.4	55.2	54.5
Patterson Creek	W002	62.8	73.9	72.1	70.2	68.0	67.3
	W160	73.4	71.6	69.1	67.0	64.5	63.7
	W162	70.9	72.2	69.1	67.2	65.0	64.1
	W164	70.5	71.3	69.1	67.1	64.9	64.2
	W166	68.7	72.8	69.2	67.0	64.9	64.1
	W168	69.7	69.4	67.8	66.0	63.9	63.3
Pine Run	W112	71.9	70.0	67.9	65.3	62.3	61.4
	W114	72.5	71.9	70.7	68.6	66.3	65.6
	W116	71.9	70.8	68.9	66.6	63.9	63.1
	W118	71.0	69.2	67.8	65.3	62.5	61.7
Rough Run	W088	68.0	72.0	69.9	66.7	64.2	63.6
	W090	76.1	70.4	69.2	66.4	63.1	62.3
	W092	76.2	70.1	68.9	66.1	62.9	61.8
	W094	71.5	70.0	68.9	66.5	63.8	63.0

Hydrologic Parameters for Buffalo Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Rough Run	W096	67.6	72.4	72.0	68.0	65.6	65.0
	W098	70.5	70.2	68.6	66.8	64.8	64.1
	W100	60.1	71.2	69.8	67.1	63.8	62.7
	W102	50.1	49.8	47.9	45.9	43.6	42.9
Sarver Run near Dennys Mills	W080	67.5	73.9	73.2	70.6	67.5	67.0
Sarver Run near Sarverville	W128	79.5	71.5	68.9	68.1	67.3	66.8
	W130	78.3	78.1	76.7	75.3	73.6	73.0
	W132	78.7	71.8	69.5	69.0	68.5	68.1
	W134	76.1	70.5	67.7	66.8	65.9	65.2
	W136	79.7	72.5	70.2	69.7	69.2	69.0
Sipes Run	W104	71.6	68.7	66.8	64.0	60.7	59.8

Hydrologic Parameters for Buffalo Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Buffalo Creek	W008	71.3	71.3	68.6	66.5	64.2	63.4
	W010	64.6	74.0	71.9	69.8	67.3	66.5
	W012	62.0	74.0	72.8	71.0	69.0	68.4
	W014	64.2	72.1	70.8	68.5	65.9	64.2
	W042	65.0	74.2	72.3	70.2	67.7	66.9
	W044	68.8	68.6	66.9	65.1	63.0	62.3
	W046	66.1	73.4	70.4	66.4	64.0	63.1
	W048	67.1	72.4	69.0	66.0	63.8	62.9
	W050	59.0	72.4	71.0	69.1	66.9	66.3
	W052	66.1	65.8	64.1	62.2	60.1	59.4
	W054	62.7	62.4	60.6	58.7	56.5	55.7
	W056	58.7	71.8	70.5	68.6	66.4	65.6
	W058	66.1	65.8	64.1	62.2	60.0	59.3
	W060	70.7	70.4	68.8	67.0	65.0	64.3
	W062	70.9	72.9	69.6	67.8	65.8	65.0
	W064	76.3	71.7	69.7	67.1	64.1	63.1
	W066	72.0	70.2	69.2	66.8	64.0	63.2
	W068	76.8	70.5	69.4	66.7	63.4	62.6
	W072	71.2	70.6	68.9	66.6	64.0	63.3
	W074	67.8	72.2	70.9	67.2	64.8	64.0
	W076	59.5	59.2	57.4	55.4	53.2	52.4
	W078	64.3	64.0	62.2	60.3	58.1	57.4
	W120	75.3	70.8	69.7	67.3	64.4	63.5
	W122	74.0	71.7	70.6	68.2	65.4	64.8
	W170	71.8	71.7	70.6	68.6	66.4	65.9
	W172	73.3	73.0	71.5	69.8	67.9	67.2
	W174	72.5	69.9	67.9	65.2	62.1	61.2
	W176	74.5	71.1	69.5	67.0	64.1	63.4
	W178	70.7	72.4	69.9	67.8	65.3	64.6
	W180	59.5	59.2	57.4	55.3	53.1	52.4
	W182	65.2	64.9	63.2	61.3	59.1	58.4
	W184	73.4	73.1	71.6	69.9	68.0	67.4
	W186	70.6	70.3	68.6	66.4	63.7	63.0
	W188	68.9	70.8	67.8	65.4	62.6	61.9
	W190	64.5	64.2	62.4	60.5	58.3	57.6
	W192	52.9	52.6	50.7	48.7	46.5	45.7
	W194	59.4	59.0	57.2	55.2	53.0	52.2
	W196	69.9	71.7	69.0	66.5	63.7	62.8
	W198	71.9	71.2	69.4	66.9	64.0	63.0
Buffalo Run	W016	65.4	72.9	70.2	66.4	63.7	62.7
	W018	63.3	73.4	71.5	69.4	66.9	66.1
	W020	66.3	72.4	71.0	67.5	64.9	64.2
Cornplanter Run	W106	70.0	71.8	69.4	67.4	65.0	64.4
	W108	71.7	71.7	70.5	68.4	66.1	65.4

Hydrologic Parameters for Buffalo Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Cornplanter Run	W110	73.8	69.8	68.5	66.0	63.0	62.1
Little Buffalo Creek	W124	80.5	80.3	79.1	77.7	76.2	75.6
	W126	79.2	72.3	70.1	69.6	69.1	68.9
	W138	78.7	70.7	67.9	67.2	66.5	66.0
	W140	75.3	70.0	66.4	65.4	64.3	63.3
	W142	77.0	70.3	66.5	65.2	63.9	63.1
	W144	78.6	70.9	65.0	63.6	62.2	61.3
	W146	78.2	70.4	64.5	63.1	61.6	60.7
	W148	74.4	71.9	69.9	69.2	68.6	68.2
	W150	76.4	76.2	74.8	73.2	71.4	70.8
	W152	67.5	67.2	65.5	63.7	61.6	60.9
	W154	59.7	59.4	57.5	55.5	53.3	52.6
	W156	71.2	70.1	67.3	66.2	65.1	64.3
	W158	55.6	55.3	53.4	51.3	49.1	48.4
Little Buffalo Run	W022	60.2	72.3	70.6	68.6	66.3	65.3
	W024	77.4	72.4	70.8	68.7	66.3	65.6
	W026	69.4	71.7	68.6	66.7	64.5	63.7
	W028	69.3	68.7	66.2	63.9	61.4	60.4
	W030	60.1	73.8	72.9	71.3	69.6	69.1
	W032	63.2	62.9	61.1	59.2	57.0	56.3
	W034	59.6	59.3	57.5	55.4	53.2	52.5
	W036	63.0	62.7	60.9	58.9	56.8	56.0
	W038	66.0	72.2	70.6	67.0	64.5	63.7
	W040	61.3	61.0	59.2	57.2	55.0	54.3
Long Run	W004	68.0	71.7	67.7	65.7	63.3	62.5
	W006	71.1	72.1	69.2	67.3	65.2	64.3
Marrowbone Run	W070	71.9	69.8	67.3	64.5	61.2	60.3
North Branch Rough Run	W082	72.2	70.1	68.9	66.5	63.7	62.9
	W084	62.4	70.5	69.8	66.8	63.3	62.4
	W086	61.5	61.2	59.4	57.4	55.2	54.5
Patterson Creek	W002	62.8	73.9	72.1	70.2	68.0	67.3
	W160	73.4	71.6	69.1	67.0	64.5	63.7
	W162	70.9	72.2	69.1	67.2	65.0	64.1
	W164	70.5	71.3	69.1	67.1	64.9	64.2
	W166	68.7	72.8	69.2	67.0	64.9	64.1
	W168	69.7	69.4	67.8	66.0	63.9	63.3
Pine Run	W112	71.9	70.0	67.9	65.3	62.3	61.4
	W114	72.5	71.9	70.7	68.6	66.3	65.6
	W116	71.9	70.8	68.9	66.6	63.9	63.1
	W118	71.0	69.2	67.8	65.3	62.5	61.7
Rough Run	W088	68.0	72.0	69.9	66.7	64.2	63.6
	W090	76.1	70.4	69.2	66.4	63.1	62.3
	W092	76.2	70.1	68.9	66.1	62.9	61.8
	W094	71.5	70.0	68.9	66.5	63.8	63.0

Hydrologic Parameters for Buffalo Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Rough Run	W096	67.6	72.4	72.0	68.0	65.6	65.0
	W098	70.5	70.2	68.6	66.8	64.8	64.1
	W100	60.1	71.2	69.8	67.1	63.8	62.7
	W102	50.1	49.8	47.9	45.9	43.6	42.9
Sarver Run near Dennys Mills	W080	67.5	73.9	73.2	70.6	67.5	67.0
Sarver Run near Sarverville	W128	79.4	71.4	68.8	68.0	67.2	66.7
	W130	79.2	79.0	77.7	76.3	74.6	74.1
	W132	79.0	72.1	69.9	69.4	68.9	68.5
	W134	76.0	70.4	67.6	66.7	65.8	65.1
	W136	80.1	72.9	70.7	70.1	69.6	69.4
Sipes Run	W104	71.6	68.7	66.8	64.0	60.7	59.8

Hydrologic Results for Buffalo Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
1	J1530	1430993.6	587638.0	2.67	268	532	621	704	867	268	532	621	704	867
2	P201	1427453.7	577072.1	5.33	492	993	1,215	1,378	1,696	492	993	1,215	1,378	1,696
3	P292	1412261.2	560961.6	3.54	295	651	849	971	1,203	306	668	871	996	1,231
4	J1490	1415060.4	568805.0	4.41	305	658	870	1,018	1,245	305	658	870	1,018	1,245
5	P287	1417034.7	567616.9	4.80	313	681	901	1,055	1,292	313	681	901	1,055	1,292
6	J1331	1418906.3	565722.1	11.63	778	1,689	2,239	2,599	3,221	789	1,708	2,263	2,626	3,252
7	P288	1422083.5	565184.3	12.22	779	1,684	2,231	2,590	3,227	789	1,702	2,253	2,615	3,257
8	J1303	1427117.2	562975.0	14.44	831	1,770	2,330	2,702	3,374	841	1,787	2,351	2,725	3,405
9	J1500	1456694.4	571033.2	1.98	196	367	493	573	715	196	367	493	573	715
10	J1527	1442745.2	586508.6	3.46	292	611	806	923	1,146	292	611	806	923	1,146
11	J1518	1443691.4	576405.4	10.40	841	1,714	2,259	2,604	3,215	841	1,714	2,259	2,604	3,215
12	J1497	1446408.0	567584.1	13.27	1,022	2,090	2,760	3,188	3,955	1,022	2,090	2,760	3,188	3,955
13	J1487	1446499.6	564440.1	21.16	1,654	3,275	4,340	5,032	6,240	1,654	3,275	4,340	5,032	6,240
14	J1452	1428002.3	549331.0	3.48	286	647	783	897	1,117	286	647	783	897	1,117
15	P136	1430161.7	545034.7	4.46	300	699	862	994	1,251	300	699	862	994	1,251
16	O037	1420385.3	549693.5	2.09	192	477	618	691	863	192	477	618	691	863
17	J1300	1419913.6	544416.7	4.54	407	984	1,250	1,373	1,714	407	984	1,250	1,373	1,714
18	J1447	1405048.7	547682.7	2.74	229	559	705	763	959	229	559	705	763	959
19	J1444	1409901.9	546034.5	4.97	395	960	1,217	1,320	1,653	395	960	1,217	1,320	1,653
20	J1436	1414816.2	542615.8	6.41	483	1,161	1,478	1,614	2,022	483	1,161	1,478	1,614	2,022
21	J1429	1420615.6	542280.1	12.88	1,001	2,365	2,962	3,268	4,083	1,001	2,365	2,962	3,268	4,083
22	J1422	1421958.7	540784.4	15.00	1,115	2,618	3,279	3,663	4,597	1,115	2,618	3,279	3,663	4,597
23	P145	1430345.3	537231.9	17.66	1,292	3,021	3,787	4,220	5,293	1,292	3,021	3,787	4,220	5,293
24	J1392	1429253.8	527720.4	3.45	272	606	796	914	1,136	272	606	796	914	1,136
25	J1395	1439387.6	520150.5	2.62	235	536	702	805	994	235	536	702	805	994
26	J1374	1439021.3	518258.1	6.01	515	1,173	1,531	1,734	2,159	515	1,173	1,531	1,733	2,159
27	J1371	1403797.2	517861.3	4.39	204	422	608	766	949	206	425	612	770	953
28	J1366	1410024.0	513221.7	6.44	312	641	922	1,159	1,436	313	642	924	1,161	1,439
29	J1404	1408528.3	532054.7	3.75	253	441	591	705	858	255	445	597	712	867
30	USGS 03049100	1409874.4	528212.8	4.76	321	551	753	908	1,114	323	555	759	915	1,122
31	J1386	1413595.2	516793.0	9.56	546	1,022	1,447	1,792	2,218	551	1,030	1,458	1,805	2,233
32	J1356	1414907.8	511237.7	19.07	1,022	1,990	2,828	3,521	4,357	1,034	2,010	2,853	3,550	4,390
33	J1353	1417380.2	508948.4	20.46	1,079	2,105	2,988	3,719	4,602	1,091	2,124	3,013	3,748	4,635
34	J1344	1417685.4	508429.5	22.28	1,147	2,238	3,173	3,948	4,883	1,161	2,260	3,202	3,981	4,921

Hydrologic Results for Buffalo Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
35	J1336	1424858.4	506689.7	25.82	1,271	2,480	3,507	4,356	5,384	1,292	2,512	3,545	4,400	5,433
36	J1533	1416708.6	594658.4	6.77	605	1,208	1,491	1,723	2,143	606	1,209	1,493	1,724	2,145
37	J1536	1421378.7	588431.6	12.23	1,026	2,039	2,555	2,939	3,634	1,029	2,044	2,561	2,944	3,640
38	J1511	1423851.1	576039.1	17.39	1,338	2,686	3,403	3,925	4,848	1,341	2,691	3,410	3,932	4,856
39	J1506	1423973.2	574421.3	18.62	1,335	2,671	3,383	3,923	4,854	1,339	2,676	3,390	3,931	4,863
40	J1503	1424858.4	570544.8	25.49	1,718	3,481	4,397	5,080	6,313	1,723	3,488	4,406	5,090	6,325
41	J1472	1428795.9	564165.4	41.19	2,525	5,188	6,635	7,666	9,494	2,538	5,209	6,662	7,696	9,526
42	J1482	1433343.9	566180.0	46.46	2,748	5,617	7,190	8,300	10,307	2,762	5,639	7,218	8,331	10,342
43	J1479	1434198.6	564592.8	47.41	2,643	5,459	7,001	8,089	10,029	2,655	5,480	7,027	8,117	10,061
44	J_UpperBuffalo_PattersonCk	558689.1	: J1467	72.32	3,417	6,914	8,955	10,383	12,917	3,431	6,938	8,985	10,417	12,959
45	J1455	1444668.2	554825.2	77.73	3,541	7,149	9,259	10,727	13,336	3,554	7,173	9,289	10,761	13,379
46	J1458	1441585.3	551009.8	81.03	3,452	7,057	9,155	10,605	13,170	3,463	7,078	9,181	10,635	13,206
47	J1439	1440944.3	545149.3	84.23	3,501	7,149	9,270	10,736	13,329	3,512	7,170	9,296	10,765	13,365
48	J1419	1442012.6	537640.5	88.86	3,470	7,038	9,111	10,526	13,111	3,480	7,056	9,133	10,550	13,142
49	J1318	1433191.3	538098.4	97.53	3,603	7,284	9,421	10,885	13,549	3,613	7,301	9,442	10,909	13,580
50	J1414	1431878.8	534588.2	115.94	3,909	7,870	10,157	11,719	14,575	3,918	7,887	10,179	11,744	14,606
51	J1409	1435999.5	528758.2	118.85	3,940	7,927	10,230	11,801	14,671	3,950	7,945	10,251	11,825	14,702
52	J1389	1436028.1	523497.0	124.18	3,908	7,910	10,218	11,785	14,632	3,917	7,926	10,237	11,807	14,659
53	J1377	1433466.0	515633.1	132.68	4,017	8,108	10,468	12,070	14,970	4,026	8,123	10,487	12,091	14,998
54	J1363	1429009.6	512122.9	137.38	4,075	8,214	10,601	12,220	15,149	4,084	8,230	10,620	12,241	15,176
55	USGS 03049000	1428119.2	509623.8	138.03	4,033	8,159	10,534	12,143	15,049	4,041	8,173	10,552	12,163	15,075
56	J1297	1427941.3	509589.4	140.07	4,060	8,209	10,599	12,215	15,137	4,068	8,224	10,617	12,235	15,163
57	J1339	1427178.2	507086.5	166.29	4,552	9,137	11,903	13,834	17,198	4,564	9,156	11,926	13,860	17,230
58	P212	1430115.8	497782.0	169.39	4,587	9,197	11,979	13,920	17,297	4,599	9,217	12,003	13,946	17,330
59	J_Outlet_BuffaloCk	1429681.2	492769.8	170.64	4,531	9,116	11,888	13,815	17,168	4,544	9,136	11,912	13,841	17,201

Hydrologic Parameters for Wolf Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Black Run	W042	11.08	71.8	207.2	71.8	207.2
East Branch Wolf Creek	W034	7.18	77.1	102.8	77.1	102.8
	W036	15.42	75.7	197.7	75.7	197.7
Wolf Creek	W028	16.28	73.0	283.3	73.0	283.3
	W030	4.15	77.4	109.4	77.2	110.1
	W032	1.09	79.5	57.6	79.9	57.0
	W038	12.86	75.6	196.4	75.6	196.4
	W040	12.45	71.7	266.7	71.7	266.7
	W044	11.77	73.4	243.9	73.4	243.9
	W046	2.09	73.3	79.8	73.3	79.8
	W048	3.63	76.5	82.1	76.5	82.0
	W050	3.93	76.9	93.8	77.0	93.6

Hydrologic Parameters for Wolf Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Black Run	W042	71.8	68.1	63.4	60.6	57.4	54.9
East Branch Wolf Creek	W034	77.1	69.6	67.5	66.0	64.3	63.1
	W036	75.7	69.5	65.9	63.7	61.2	58.9
Wolf Creek	W028	73.0	69.1	64.6	62.0	58.9	56.4
	W030	77.4	71.0	70.0	68.8	67.5	66.4
	W032	79.5	69.9	68.7	67.6	66.6	65.8
	W038	75.6	68.4	63.9	61.4	58.5	56.6
	W040	71.7	70.8	67.5	65.2	62.5	60.3
	W044	73.4	70.8	67.6	65.4	63.0	60.9
	W046	73.3	69.6	67.7	66.2	64.6	63.3
	W048	76.5	68.7	66.1	64.4	62.5	60.8
	W050	76.9	70.6	69.2	67.9	66.6	65.7

Hydrologic Parameters for Wolf Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Black Run	W042	71.8	68.1	63.4	60.6	57.4	54.9
East Branch Wolf Creek	W034	77.1	69.6	67.5	66.0	64.3	63.1
	W036	75.7	69.5	65.9	63.7	61.2	58.9
Wolf Creek	W028	73.0	69.1	64.6	62.0	58.9	56.4
	W030	77.2	70.8	69.7	68.5	67.2	66.1
	W032	79.9	70.4	69.1	68.1	67.0	66.3
	W038	75.6	68.4	63.9	61.4	58.5	56.6
	W040	71.7	70.8	67.5	65.2	62.5	60.4
	W044	73.4	70.8	67.6	65.4	63.0	60.9
	W046	73.3	69.6	67.7	66.2	64.6	63.3
	W048	76.5	68.7	66.1	64.4	62.6	60.9
	W050	77.0	70.7	69.3	68.0	66.7	65.8

Hydrologic Results for Wolf Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
1	J103	1348302.9	694134.5	7.18	364	821	1,142	1,381	1,666	365	821	1,142	1,381	1,667
2	J4707	1333254.8	689494.9	38.88	1,179	2,334	3,113	3,592	4,159	1,180	2,334	3,113	3,592	4,160
3	J102	1328706.8	679666.3	51.74	1,342	2,532	3,334	3,813	4,409	1,342	2,532	3,334	3,814	4,410
4	J4671	1322968.4	661657.5	64.19	1,622	3,036	3,983	4,550	5,259	1,622	3,037	3,983	4,551	5,259
5	J101	1323639.9	661291.2	75.27	1,804	3,349	4,384	4,995	5,765	1,804	3,350	4,384	4,995	5,765
6	USGS 03106140	1327943.7	656895.8	87.04	2,065	3,831	5,014	5,719	6,605	2,066	3,831	5,014	5,720	6,605
7	J4544	1329988.8	648837.6	93.28	2,139	3,963	5,183	5,917	6,835	2,139	3,963	5,183	5,917	6,834
8	J4497	1326539.6	641481.4	98.00	2,184	4,042	5,284	6,034	6,970	2,184	4,042	5,284	6,034	6,970
9	J_WolfCreek_Outlet	1319971.5	630995.8	101.93	2,219	4,101	5,356	6,117	7,066	2,219	4,101	5,356	6,118	7,066

Hydrologic Parameters for Upper Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Big Run near Slippery Rock Park	W254	2.32	67.0	81.0	67.1	80.7
	W256	1.40	71.0	49.0	71.0	49.0
	W258	3.36	72.3	82.8	72.5	82.5
Blacks Creek	W166	3.04	70.7	87.5	70.7	87.5
	W168	4.33	70.1	101.8	70.1	101.8
	W170	1.48	71.1	59.7	71.1	59.7
Christy Run	W200	2.83	70.3	85.7	70.3	85.7
Findlay Run	W210	1.63	64.9	79.1	64.9	79.1
	W212	1.63	69.0	74.7	69.0	74.7
	W214	2.89	68.3	83.9	68.3	83.9
Hogue Run	W260	1.12	73.4	50.1	73.4	50.1
	W262	4.15	69.9	96.7	69.9	96.7
	W264	2.19	73.6	101.9	73.6	101.9
Long Run	W244	3.83	74.8	109.0	74.9	108.7
McDonald Run	W238	3.95	74.1	111.9	74.1	111.9
McMurray Run	W184	3.62	77.3	92.3	77.3	92.3
	W186	1.16	73.2	59.5	73.2	59.5
	W188	2.49	76.8	101.1	76.8	101.1
	W190	2.82	74.3	100.8	74.6	100.0
	W192	1.29	72.5	64.7	72.5	64.7
	W194	1.84	70.8	73.8	70.8	73.8
North Branch Slippery Rock Creek	W172	3.27	69.7	95.7	69.7	95.7
	W174	1.02	64.9	64.6	64.9	64.6
	W176	4.08	74.2	85.5	74.2	85.5
	W178	3.17	69.6	113.7	69.6	113.7
	W180	3.53	67.5	107.6	67.5	107.6
	W182	1.08	70.4	59.5	70.4	59.5
Seaton Creek	W158	4.35	69.9	85.8	69.9	85.8
	W160	3.52	67.4	78.6	67.4	78.6
	W162	0.73	59.1	57.5	59.1	57.5
	W164	1.89	69.2	63.2	69.2	63.2
Slippery Rock Creek	W150	2.25	66.8	71.7	66.8	71.7
	W152	2.94	67.0	60.6	67.0	60.6
	W154	1.00	66.0	49.0	66.0	49.0
	W156	1.74	64.8	63.8	64.8	63.8
	W240	1.88	68.5	81.3	68.5	81.3
	W242	1.15	69.7	54.1	69.7	54.1
	W246	1.56	74.5	86.5	74.6	86.3
	W248	1.31	72.4	64.3	72.4	64.3
	W250	4.05	68.0	114.7	68.0	114.7
	W252	2.25	70.7	79.7	70.7	79.7
	W266	3.45	63.2	86.3	63.2	86.3
	W268	2.01	62.7	86.8	62.7	86.8
	W270	0.82	63.8	46.3	63.8	46.3

Hydrologic Parameters for Upper Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Slippery Rock Creek	W272	2.41	65.6	72.0	65.6	72.0
	W274	1.30	70.4	74.2	70.4	74.2
	W276	1.53	69.2	63.3	69.2	63.3
	W278	2.58	69.1	92.3	69.1	92.3
	W280	1.05	72.9	76.6	72.9	76.6
	W282	0.16	70.7	34.6	70.7	34.6
	W284	0.90	70.1	64.1	70.1	64.1
	W286	0.31	71.8	41.5	71.8	41.5
	W288	0.11	71.0	31.0	71.1	31.0
	W290	1.32	74.8	60.6	74.8	60.6
	W292	3.96	76.8	124.8	77.3	123.2
	W294	2.11	75.6	88.2	75.6	88.2
	W296	2.63	79.1	104.3	79.2	104.0
	W298	2.44	76.7	73.8	76.7	73.8
South Branch Slippery Rock Creek	W196	2.23	72.7	54.0	72.7	54.0
	W198	2.44	74.2	76.3	74.2	76.3
	W202	1.58	64.2	62.2	64.2	62.2
	W204	0.46	75.7	31.8	75.7	31.8
	W206	2.27	67.9	77.8	67.9	77.8
	W208	1.57	71.2	67.7	71.2	67.7
	W216	3.22	73.5	62.1	73.5	62.1
	W218	3.47	74.5	79.2	74.5	79.2
	W220	0.14	76.7	25.0	76.7	25.0
	W222	0.00	68.0	3.5	68.0	3.5
	W224	2.45	73.0	69.9	73.0	69.9
	W226	3.39	70.5	104.7	70.9	103.6
	W228	4.48	71.0	101.4	71.0	101.4
	W230	0.44	68.2	36.7	68.2	36.7
	W232	0.16	70.3	24.3	70.3	24.3
	W234	1.55	66.7	74.0	66.7	74.0
	W236	0.74	67.2	63.1	67.2	63.1

Hydrologic Parameters for Upper Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Big Run near Slippery Rock Park	W254	67.0	74.7	72.7	68.2	64.9	62.0
	W256	71.0	71.5	68.7	65.8	62.3	58.8
	W258	72.3	72.1	69.4	66.3	62.6	58.6
Blacks Creek	W166	70.7	71.8	68.7	66.4	63.9	60.3
	W168	70.1	73.3	69.4	67.3	64.9	61.5
	W170	71.1	67.8	62.7	59.3	55.3	53.2
Christy Run	W200	70.3	74.3	69.8	67.0	63.6	60.3
Findlay Run	W210	64.9	73.4	70.8	65.5	62.1	58.7
	W212	69.0	75.2	72.7	68.4	65.7	62.7
	W214	68.3	73.9	67.9	64.8	61.1	57.1
Hogue Run	W260	73.4	72.1	69.8	67.0	63.7	60.2
	W262	69.9	75.6	71.9	68.3	65.2	62.0
	W264	73.6	75.9	74.1	71.9	69.6	67.0
Long Run	W244	74.8	74.3	72.9	70.5	67.6	64.4
McDonald Run	W238	74.1	74.4	72.7	70.3	67.4	64.1
McMurray Run	W184	77.3	72.7	70.6	68.6	66.3	62.5
	W186	73.2	71.4	69.3	67.4	65.2	61.9
	W188	76.8	73.7	72.2	70.5	68.6	65.7
	W190	74.3	72.9	71.2	69.4	67.2	64.1
	W192	72.5	71.7	69.9	67.9	65.7	62.8
	W194	70.8	71.6	68.9	66.7	64.2	61.0
North Branch Slippery Rock Creek	W172	69.7	73.7	69.9	67.8	65.5	62.5
	W174	64.9	72.5	70.6	68.2	65.5	62.9
	W176	74.2	71.1	68.2	65.7	62.9	58.5
	W178	69.6	74.7	72.8	69.6	67.8	65.1
	W180	67.5	73.1	70.3	66.5	63.9	60.7
	W182	70.4	69.3	65.4	62.7	59.5	54.9
Seaton Creek	W158	69.9	71.9	68.2	66.0	63.4	59.8
	W160	67.4	71.9	66.7	64.2	61.4	57.7
	W162	59.1	60.4	57.1	54.2	51.0	47.4
	W164	69.2	67.4	62.2	58.8	54.7	49.6
Slippery Rock Creek	W150	66.8	72.1	68.9	65.6	63.1	60.0
	W152	67.0	71.3	65.9	63.5	60.6	57.0
	W154	66.0	67.1	64.0	61.3	58.2	54.7
	W156	64.8	71.1	68.0	64.0	61.5	58.0
	W240	68.5	75.3	73.4	68.7	65.9	63.0
	W242	69.7	72.7	68.5	65.6	62.1	58.5
	W246	74.5	74.4	73.2	71.0	68.5	65.8
	W248	72.4	73.1	70.8	68.2	65.2	62.2
	W250	68.0	75.9	74.4	70.8	67.2	64.5
	W252	70.7	75.0	71.7	68.7	65.8	62.9
	W266	63.2	71.0	67.7	63.3	60.9	57.4
	W268	62.7	71.6	68.6	65.8	62.6	59.3
	W270	63.8	65.0	61.8	59.1	55.9	52.3

Hydrologic Parameters for Upper Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Slippery Rock Creek	W272	65.6	68.6	61.8	58.4	54.3	49.5
	W274	70.4	67.5	61.9	58.6	54.7	51.7
	W276	69.2	67.8	62.8	59.6	55.7	50.6
	W278	69.1	68.8	64.1	60.9	57.1	52.0
	W280	72.9	71.9	69.6	67.5	65.1	61.8
	W282	70.7	71.8	68.9	66.4	63.5	60.1
	W284	70.1	71.2	68.3	65.8	62.8	59.4
	W286	71.8	72.8	70.0	67.5	64.6	61.3
	W288	71.0	72.1	69.3	66.8	63.8	60.4
	W290	74.8	73.1	71.4	68.9	65.9	62.6
	W292	76.8	75.2	73.9	71.6	68.7	65.4
	W294	75.6	74.1	72.6	70.1	67.2	64.1
	W296	79.1	72.9	69.4	65.9	61.4	61.4
	W298	76.7	73.1	70.7	67.7	63.9	59.7
South Branch Slippery Rock Creek	W196	72.7	70.9	67.7	64.3	60.1	55.7
	W198	74.2	72.5	70.0	67.0	63.2	59.3
	W202	64.2	72.3	68.2	62.9	59.0	55.2
	W204	75.7	76.6	74.1	71.8	69.1	65.9
	W206	67.9	74.8	72.1	67.4	64.4	61.3
	W208	71.2	73.9	70.5	68.0	65.0	62.0
	W216	73.5	71.8	69.1	66.1	62.4	58.4
	W218	74.5	71.9	68.8	65.3	61.0	56.4
	W220	76.7	77.7	75.2	73.0	70.3	67.2
	W222	68.0	69.1	66.1	63.5	60.5	57.0
	W224	73.0	70.9	67.3	63.4	59.2	54.2
	W226	70.5	71.5	67.1	63.3	59.1	54.2
	W228	71.0	73.9	69.9	67.0	63.5	59.8
	W230	68.2	69.3	66.3	63.7	60.6	57.1
	W232	70.3	71.4	68.5	65.9	63.0	59.5
	W234	66.7	73.9	70.5	65.6	62.2	58.7
	W236	67.2	68.3	65.3	62.6	59.5	56.0

Hydrologic Parameters for Upper Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Big Run near Slippery Rock Park	W254	67.1	74.8	72.8	68.4	65.1	62.1
	W256	71.0	71.5	68.7	65.8	62.3	58.8
	W258	72.5	72.3	69.6	66.5	62.8	58.8
Blacks Creek	W166	70.7	71.8	68.7	66.4	63.9	60.3
	W168	70.1	73.3	69.4	67.3	64.9	61.5
	W170	71.1	67.8	62.7	59.3	55.3	53.2
Christy Run	W200	70.3	74.3	69.8	67.0	63.6	60.3
Findlay Run	W210	64.9	73.4	70.8	65.5	62.1	58.7
	W212	69.0	75.2	72.7	68.4	65.7	62.7
	W214	68.3	73.9	67.9	64.8	61.1	57.1
Hogue Run	W260	73.4	72.1	69.8	67.0	63.7	60.2
	W262	69.9	75.6	71.9	68.3	65.2	62.0
	W264	73.6	75.9	74.1	71.9	69.6	67.0
Long Run	W244	74.9	74.4	73.0	70.6	67.7	64.5
McDonald Run	W238	74.1	74.4	72.7	70.3	67.4	64.1
McMurray Run	W184	77.3	72.7	70.6	68.6	66.3	62.5
	W186	73.2	71.4	69.3	67.4	65.2	61.9
	W188	76.8	73.7	72.3	70.5	68.6	65.7
	W190	74.6	73.2	71.5	69.6	67.5	64.4
	W192	72.5	71.7	69.9	67.9	65.7	62.8
	W194	70.8	71.6	68.9	66.7	64.2	61.0
North Branch Slippery Rock Creek	W172	69.7	73.7	69.9	67.8	65.5	62.5
	W174	64.9	72.5	70.6	68.2	65.5	62.9
	W176	74.2	71.1	68.2	65.7	62.9	58.5
	W178	69.6	74.7	72.8	69.6	67.8	65.1
	W180	67.5	73.1	70.3	66.5	63.9	60.7
	W182	70.4	69.3	65.4	62.7	59.5	54.9
Seaton Creek	W158	69.9	71.9	68.2	66.0	63.4	59.8
	W160	67.4	71.9	66.7	64.2	61.4	57.7
	W162	59.1	60.4	57.1	54.2	51.0	47.4
	W164	69.2	67.4	62.2	58.8	54.7	49.6
Slippery Rock Creek	W150	66.8	72.1	68.9	65.6	63.1	60.0
	W152	67.0	71.3	65.9	63.5	60.6	57.0
	W154	66.0	67.1	64.0	61.3	58.2	54.7
	W156	64.8	71.1	68.0	64.0	61.5	58.0
	W240	68.5	75.3	73.4	68.7	65.9	63.0
	W242	69.7	72.7	68.5	65.6	62.1	58.5
	W246	74.6	74.5	73.3	71.1	68.6	65.9
	W248	72.4	73.1	70.8	68.2	65.2	62.2
	W250	68.0	75.9	74.4	70.8	67.2	64.5
	W252	70.7	75.0	71.7	68.7	65.8	62.9
	W266	63.2	71.0	67.7	63.3	60.9	57.4
	W268	62.7	71.6	68.6	65.8	62.6	59.3
	W270	63.8	65.0	61.8	59.1	55.9	52.3

Hydrologic Parameters for Upper Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Slippery Rock Creek	W272	65.6	68.6	61.8	58.4	54.3	49.5
	W274	70.4	67.5	61.9	58.6	54.7	51.7
	W276	69.2	67.8	62.8	59.6	55.7	50.6
	W278	69.1	68.8	64.1	60.9	57.1	52.0
	W280	72.9	71.9	69.6	67.5	65.1	61.8
	W282	70.7	71.8	68.9	66.4	63.5	60.1
	W284	70.1	71.2	68.3	65.8	62.8	59.4
	W286	71.8	72.8	70.0	67.5	64.6	61.3
	W288	71.1	72.1	69.3	66.8	63.8	60.4
	W290	74.8	73.1	71.4	68.9	65.9	62.6
	W292	77.3	75.6	74.4	72.1	69.3	66.0
	W294	75.6	74.1	72.6	70.1	67.2	64.1
	W296	79.2	73.0	69.6	66.0	61.5	61.5
	W298	76.7	73.1	70.7	67.7	63.9	59.7
South Branch Slippery Rock Creek	W196	72.7	70.9	67.7	64.3	60.1	55.7
	W198	74.2	72.5	70.0	67.0	63.2	59.3
	W202	64.2	72.3	68.2	62.9	59.0	55.2
	W204	75.7	76.6	74.1	71.8	69.1	65.9
	W206	67.9	74.8	72.1	67.4	64.4	61.3
	W208	71.2	73.9	70.5	68.0	65.0	62.0
	W216	73.5	71.8	69.2	66.1	62.5	58.4
	W218	74.5	71.9	68.8	65.3	61.0	56.4
	W220	76.7	77.7	75.2	73.0	70.3	67.2
	W222	68.0	69.1	66.1	63.5	60.5	57.0
	W224	73.0	70.9	67.3	63.4	59.2	54.2
	W226	70.9	71.9	67.6	63.7	59.6	54.7
	W228	71.0	73.9	69.9	67.0	63.5	59.8
	W230	68.2	69.3	66.3	63.7	60.6	57.1
	W232	70.3	71.4	68.5	65.9	63.0	59.5
	W234	66.7	73.9	70.5	65.6	62.2	58.7
	W236	67.2	68.3	65.3	62.6	59.5	56.0

Hydrologic Results for Upper Slippery Rock Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
1	P228	1394210.2	644442.2	2.94	258	436	577	646	673	258	436	577	646	673
2	P061	1386670.9	659917.6	3.52	274	458	603	679	702	274	458	603	679	702
3	J4646	1383832.2	659063.0	8.60	535	968	1,275	1,444	1,506	535	968	1,275	1,444	1,506
4	J4651	1372965.9	662420.6	7.37	534	994	1,306	1,493	1,581	534	994	1,306	1,493	1,581
5	J4686	1355323.3	674813.1	4.08	276	564	732	818	811	276	564	732	818	811
6	J4689	1362160.6	668342.1	10.52	765	1,484	1,878	2,157	2,281	765	1,484	1,878	2,157	2,281
7	J4618	1365457.1	655674.9	15.07	973	1,857	2,318	2,656	2,828	973	1,857	2,318	2,656	2,828
8	J4674	1349401.7	659765.0	2.49	192	406	533	620	676	192	406	533	621	677
9	J4615	1353522.4	655461.2	8.93	646	1,349	1,770	2,049	2,187	652	1,359	1,783	2,064	2,203
10	J4583	1356147.4	650485.9	11.38	560	1,121	1,462	1,690	1,808	564	1,128	1,470	1,700	1,820
11	P229	1387861.3	631713.9	1.58	152	277	291	302	308	152	277	291	302	308
12	J4389	1369852.5	625334.5	3.26	327	632	690	760	818	327	633	690	760	819
13	J4344	1388563.4	620511.8	5.45	494	1,016	1,252	1,301	1,300	495	1,018	1,253	1,303	1,302
14	J4358	1385083.7	626463.9	11.36	967	1,962	2,400	2,480	2,467	967	1,963	2,402	2,482	2,469
15	J4418	1384195.2	629037.4	16.37	1,210	2,314	2,801	2,928	2,970	1,211	2,315	2,802	2,930	2,971
16	J4431	1380047.3	632721.2	18.82	1,031	1,916	2,311	2,420	2,448	1,032	1,916	2,312	2,421	2,449
17	J4479	1376170.8	637849.2	24.48	1,335	2,496	2,992	3,140	3,167	1,341	2,508	3,006	3,156	3,184
18	P047	1365029.8	638734.3	28.96	1,131	1,995	2,367	2,500	2,553	1,136	2,002	2,376	2,510	2,563
19	J4463	1364633.0	636841.9	30.97	1,169	2,060	2,449	2,592	2,653	1,174	2,068	2,457	2,601	2,663
20	J4415	1363595.2	635010.5	37.28	1,339	2,375	2,822	3,005	3,097	1,345	2,383	2,832	3,016	3,108
21	P050	1357948.3	637421.8	38.83	1,300	2,305	2,736	2,920	3,019	1,305	2,313	2,745	2,930	3,029
22	P051	1355933.8	630523.5	1.88	197	390	427	475	521	197	390	427	475	521
23	J4341	1352881.4	620420.2	5.36	430	851	1,012	1,083	1,190	430	851	1,012	1,083	1,190
24	P099	1350073.3	616146.9	2.32	232	461	512	555	604	235	467	519	562	612
25	J4334	1347082.0	617093.2	3.72	334	671	776	837	899	338	677	784	846	908
26	J4324	1333743.2	614926.0	5.27	463	821	973	1,068	1,145	463	821	973	1,068	1,145
27	J4564	1393935.5	649264.9	5.70	414	817	953	1,098	1,170	414	817	953	1,098	1,170
28	J4549	1388593.9	650394.3	11.65	651	1,234	1,539	1,740	1,844	651	1,234	1,539	1,740	1,844
29	J4561	1385968.9	650455.4	14.21	662	1,251	1,550	1,752	1,859	662	1,251	1,550	1,752	1,859
30	J4569	1378612.7	655186.5	27.11	1,316	2,411	3,065	3,438	3,585	1,316	2,411	3,065	3,438	3,585
31	J4598	1371744.9	655064.4	37.26	1,849	3,370	4,309	4,840	5,075	1,849	3,370	4,309	4,840	5,075
32	J4589	1367593.7	650333.3	54.94	2,878	5,315	6,729	7,608	8,016	2,878	5,315	6,729	7,608	8,016
33	J4554	1357765.2	642916.1	70.74	2,675	4,917	6,182	6,963	7,351	2,677	4,920	6,186	6,967	7,357
34	J_Northern_Slippery_Rock	1353515.3	637123.9	71.79	2,437	4,432	5,554	6,248	6,604	2,439	4,435	5,558	6,253	6,609

Hydrologic Results for Upper Slippery Rock Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
35	J4476	1353583.5	636567.2	111.36	3,704	6,678	8,218	9,093	9,548	3,711	6,689	8,230	9,106	9,563
36	J4460	1351385.8	637147.1	115.47	3,784	6,826	8,403	9,301	9,776	3,791	6,836	8,416	9,315	9,791
37	J4428	1350195.3	631561.3	119.40	3,712	6,657	8,193	9,103	9,585	3,719	6,667	8,206	9,116	9,600
38	J4451	1346746.2	633209.6	123.54	3,786	6,791	8,361	9,293	9,793	3,793	6,801	8,374	9,307	9,808
39	J4446	1346196.8	632385.4	125.21	3,801	6,823	8,401	9,339	9,846	3,808	6,833	8,414	9,352	9,861
40	J4364	1343785.4	624357.8	134.14	3,818	6,902	8,508	9,460	10,000	3,825	6,912	8,521	9,473	10,014
41	J4367	1337894.4	622831.6	145.18	3,938	7,097	8,741	9,716	10,282	3,946	7,109	8,756	9,731	10,299
42	J4383	1331057.1	624846.1	147.29	3,957	7,126	8,777	9,759	10,331	3,965	7,138	8,791	9,774	10,348
43	J4399	1327760.6	626097.6	157.38	4,042	7,273	8,958	9,960	10,569	4,051	7,285	8,972	9,975	10,586
44	J_UpperSlipperyRock_Outlet	1320177.9	630849.7	159.82	4,041	7,269	8,956	9,959	10,570	4,049	7,280	8,970	9,974	10,587

Hydrologic Parameters for Lower Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Bear Run	W330	3.41	74.7	76.2	74.7	76.2
Big Run near Lake Arthur	W314	1.11	75.0	55.4	75.0	55.4
	W316	0.90	68.1	46.5	68.1	46.5
	W318	1.31	69.5	63.6	69.5	63.6
	W320	1.64	74.2	60.1	74.2	60.1
	W324	0.10	83.5	15.9	83.5	15.9
	W326	2.03	73.2	61.7	73.2	61.7
	W328	0.30	83.7	26.6	83.7	26.6
Black Run	W342	1.22	76.5	43.3	76.5	43.3
	W348	3.54	74.6	88.3	74.6	88.3
	W350	2.18	74.2	86.4	74.2	86.4
	W352	0.76	79.9	53.5	79.9	53.5
Cheeseman Run	W398	2.34	76.1	54.8	76.1	54.8
Hell Run	W400	2.50	77.3	71.7	77.3	71.7
	W402	3.49	73.6	84.3	73.6	84.3
Jamison Run	W336	1.27	71.7	78.0	71.7	78.0
	W338	3.21	75.8	116.7	75.8	116.7
	W340	2.11	78.2	88.8	78.2	88.8
	W376	2.38	77.2	128.5	77.2	128.5
	W378	0.71	77.3	59.9	77.3	59.9
	W380	1.06	74.8	66.6	74.8	66.6
	W382	1.71	71.3	89.6	71.3	89.6
Muddy Creek	W300	2.49	59.4	102.8	59.4	102.8
	W332	1.34	65.1	63.6	65.1	63.6
	W334	2.07	68.9	78.2	68.8	78.4
	W408	0.90	71.8	44.0	71.8	44.0
	W410	4.31	67.2	99.0	67.2	99.0
	W412	4.56	65.3	85.0	65.3	85.0
	W414	4.75	66.1	107.5	66.1	107.5
	W416	1.84	72.9	59.6	72.9	59.6
	W418	0.09	90.1	17.0	90.1	17.0
	W420	4.21	73.0	71.7	73.0	71.7
	W424	2.65	77.9	85.8	77.9	85.8
	W426	0.35	79.6	49.8	79.6	49.8
	W428	0.01	98.0	14.6	98.0	14.6
	W430	0.03	98.0	89.9	98.0	692.8
	W432	0.13	78.4	30.5	78.4	30.5
	W434	3.73	74.0	93.6	74.0	93.4
	W436	3.51	74.0	95.5	73.9	95.7
Shannon Run	W306	1.00	72.6	64.5	72.6	64.5
	W308	1.45	71.6	52.6	71.5	52.8
	W310	1.08	68.9	63.0	68.9	63.0
	W312	0.66	75.4	37.8	75.4	37.8
Skunk Run	W404	1.74	74.2	68.2	74.2	68.2

Hydrologic Parameters for Lower Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Slippery Rock Creek	W344	1.03	72.3	49.0	72.3	49.0
	W346	1.18	74.9	63.5	74.9	63.5
	W354	0.52	72.2	38.0	72.2	38.0
	W356	1.25	72.2	62.8	72.2	62.8
	W372	4.92	75.3	108.2	75.4	108.2
	W374	3.51	73.1	107.4	73.1	107.4
	W384	0.16	67.8	42.6	67.8	42.6
	W385	0.05	64.3	19.9	64.3	19.9
	W386	2.43	69.2	83.6	69.2	83.6
	W388	3.07	71.1	88.2	71.1	88.2
	W390	0.63	69.1	48.9	69.1	48.9
	W392	1.86	76.2	79.3	76.2	79.3
	W394	4.02	75.3	79.7	75.3	79.7
	W396	0.12	74.0	24.8	74.0	24.8
	W406	3.49	70.8	65.9	70.8	65.9
	W438	0.74	68.7	46.9	68.7	46.9
	W440	2.98	74.7	63.6	74.8	63.3
	W442	3.02	72.6	55.1	72.6	55.1
	W444	2.35	71.4	49.5	71.4	49.5
	W446	3.09	69.7	59.6	69.7	59.6
	W448	2.94	70.7	55.9	70.7	55.9
	W450	1.66	69.6	50.9	69.6	50.9
Swamp Run	W302	2.72	66.2	72.2	66.6	71.3
	W304	3.78	71.3	80.4	71.3	80.4
Taylor Run	W358	1.58	77.9	59.8	77.9	59.8
	W360	1.12	76.4	62.8	76.4	62.8
	W362	1.70	78.1	71.8	78.1	71.8
	W364	4.08	76.8	87.4	76.8	87.4
	W366	2.33	77.0	90.5	77.0	90.5
	W368	0.08	69.6	19.7	69.6	19.7
	W370	2.52	68.6	104.8	68.6	104.8

Hydrologic Parameters for Lower Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Bear Run	W330	74.7	68.6	62.0	59.0	55.3	55.3
Big Run near Lake Arthur	W314	75.0	71.6	68.2	65.8	63.1	58.3
	W316	68.1	66.7	63.3	60.9	58.3	54.0
	W318	69.5	69.1	64.2	61.1	57.5	51.5
	W320	74.2	71.5	68.0	65.7	63.1	57.9
	W324	83.5	82.6	80.4	78.7	76.8	73.5
	W326	73.2	67.7	60.7	57.3	53.4	53.4
	W328	83.7	82.8	80.5	78.9	77.0	73.8
Black Run	W342	76.5	71.3	67.6	65.3	62.6	58.1
	W348	74.6	72.5	69.4	67.2	64.7	59.8
	W350	74.2	73.0	70.3	68.4	66.2	61.9
	W352	79.9	78.8	76.2	74.3	72.2	68.5
Cheeseman Run	W398	76.1	71.7	68.0	65.7	63.0	58.8
Hell Run	W400	77.3	72.9	70.0	67.9	65.5	61.6
	W402	73.6	72.6	69.8	67.7	65.4	60.0
Jamison Run	W336	71.7	68.5	62.1	58.2	54.2	52.0
	W338	75.8	73.9	71.4	69.4	67.1	62.7
	W340	78.2	74.3	72.4	70.6	68.6	64.5
	W376	77.2	75.8	74.8	73.5	72.1	68.8
	W378	77.3	76.1	73.3	71.3	69.0	65.1
	W380	74.8	73.3	71.3	69.7	67.9	63.8
	W382	71.3	76.1	73.7	71.0	69.4	66.4
Muddy Creek	W300	59.4	71.8	68.6	66.0	62.9	58.0
	W332	65.1	71.6	64.7	61.9	58.7	53.0
	W334	68.9	72.1	66.4	63.8	60.7	55.5
	W408	71.8	70.5	67.3	65.0	62.5	58.3
	W410	67.2	73.1	67.2	64.7	61.9	57.2
	W412	65.3	72.1	66.7	63.3	60.3	55.0
	W414	66.1	72.1	65.1	62.2	58.8	53.6
	W416	72.9	68.2	61.7	57.7	53.7	53.0
	W418	90.1	89.5	88.0	86.9	85.6	83.3
	W420	73.0	67.0	59.7	56.7	53.2	53.2
	W424	77.9	67.7	62.8	61.3	59.7	59.7
	W426	79.6	78.6	75.9	74.1	71.9	68.2
	W428	98.0	97.9	97.5	97.3	97.0	96.4
	W430	98.0	97.9	97.5	97.3	97.0	96.4
	W432	78.4	77.4	74.6	72.6	70.4	66.6
	W434	74.0	72.8	70.0	67.8	65.3	60.3
	W436	74.0	73.3	70.8	69.0	66.8	62.8
Shannon Run	W306	72.6	71.5	68.0	65.7	63.1	58.4
	W308	71.6	71.0	67.7	65.5	63.0	58.0
	W310	68.9	70.8	65.3	62.6	59.4	54.3
	W312	75.4	74.2	71.2	69.1	66.7	62.7
Skunk Run	W404	74.2	72.6	70.1	68.2	66.1	62.0

Hydrologic Parameters for Lower Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Slippery Rock Creek	W344	72.3	70.8	67.2	64.8	62.1	56.9
	W346	74.9	73.1	70.9	69.3	67.4	63.5
	W354	72.2	70.9	67.7	65.4	62.9	58.7
	W356	72.2	69.9	65.0	62.1	58.7	53.8
	W372	75.3	73.5	71.0	69.1	66.8	62.1
	W374	73.1	75.0	72.1	70.5	68.7	65.5
	W384	67.8	66.4	63.0	60.6	57.9	53.6
	W385	64.3	62.9	59.3	56.8	54.1	49.7
	W386	69.2	74.8	71.7	68.6	66.6	63.3
	W388	71.1	74.2	70.1	68.2	66.1	61.6
	W390	69.1	67.8	64.4	62.0	59.4	55.1
	W392	76.2	73.6	71.3	69.5	67.5	63.2
	W394	75.3	72.5	69.4	67.2	64.6	59.8
	W396	74.0	72.8	69.7	67.5	65.0	60.9
	W406	70.8	71.8	68.0	65.9	63.4	58.5
	W438	68.7	67.3	63.9	61.6	58.9	54.6
	W440	74.7	71.0	66.9	64.3	61.3	56.7
	W442	72.6	70.7	67.0	64.6	61.8	55.9
	W444	71.4	70.6	66.9	64.6	62.0	57.3
	W446	69.7	72.0	67.4	65.2	62.6	57.7
	W448	70.7	70.9	67.5	65.2	62.5	58.4
	W450	69.6	72.8	68.1	66.1	63.9	59.8
Swamp Run	W302	66.2	73.1	69.3	65.6	63.3	59.1
	W304	71.3	68.0	61.7	57.2	53.4	51.1
Taylor Run	W358	77.9	72.6	69.5	67.3	64.7	60.7
	W360	76.4	73.1	70.7	68.9	66.9	62.1
	W362	78.1	73.4	70.9	68.9	66.7	63.1
	W364	76.8	72.6	69.0	66.7	63.9	59.4
	W366	77.0	74.1	72.0	70.2	68.2	63.9
	W368	69.6	68.2	64.9	62.5	59.9	55.6
	W370	68.6	75.0	72.0	68.7	66.8	62.6

Hydrologic Parameters for Lower Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Bear Run	W330	74.7	68.6	62.0	59.0	55.4	55.4
Big Run near Lake Arthur	W314	75.0	71.6	68.2	65.8	63.1	58.3
	W316	68.1	66.7	63.3	60.9	58.3	54.0
	W318	69.5	69.1	64.2	61.1	57.5	51.5
	W320	74.2	71.5	68.0	65.7	63.1	57.9
	W324	83.5	82.6	80.4	78.7	76.8	73.5
	W326	73.2	67.7	60.7	57.3	53.4	53.4
	W328	83.7	82.8	80.5	78.9	77.0	73.8
Black Run	W342	76.5	71.3	67.6	65.3	62.6	58.1
	W348	74.6	72.5	69.4	67.2	64.7	59.8
	W350	74.2	73.0	70.3	68.4	66.2	61.9
	W352	79.9	78.8	76.2	74.3	72.2	68.5
Cheeseman Run	W398	76.1	71.7	68.0	65.7	63.0	58.8
Hell Run	W400	77.3	72.9	70.0	67.9	65.5	61.6
	W402	73.6	72.6	69.8	67.7	65.4	60.0
Jamison Run	W336	71.7	68.5	62.1	58.2	54.2	52.0
	W338	75.8	73.9	71.4	69.4	67.1	62.7
	W340	78.2	74.3	72.4	70.6	68.6	64.5
	W376	77.2	75.8	74.8	73.5	72.1	68.8
	W378	77.3	76.1	73.3	71.3	69.0	65.1
	W380	74.8	73.2	71.3	69.7	67.9	63.8
	W382	71.3	76.1	73.7	71.0	69.4	66.4
Muddy Creek	W300	59.4	71.8	68.6	66.0	62.9	58.0
	W332	65.1	71.6	64.7	61.9	58.7	53.0
	W334	68.8	72.0	66.4	63.7	60.6	55.4
	W408	71.8	70.5	67.3	65.0	62.5	58.3
	W410	67.2	73.1	67.2	64.7	61.9	57.2
	W412	65.3	72.1	66.7	63.3	60.3	55.0
	W414	66.1	72.1	65.1	62.2	58.8	53.6
	W416	72.9	68.2	61.7	57.7	53.7	53.0
	W418	90.1	89.5	88.0	86.9	85.6	83.3
	W420	73.0	67.0	59.7	56.7	53.2	53.2
	W424	77.9	67.7	62.8	61.3	59.7	59.7
	W426	79.6	78.6	75.9	74.1	71.9	68.2
	W428	98.0	97.9	97.5	97.3	97.0	96.4
	W430	98.0	97.9	97.5	97.3	97.0	96.4
	W432	78.4	77.4	74.6	72.6	70.4	66.6
	W434	74.0	72.9	70.0	67.9	65.4	60.4
	W436	73.9	73.2	70.8	68.9	66.8	62.7
Shannon Run	W306	72.6	71.5	68.0	65.7	63.1	58.4
	W308	71.5	70.9	67.6	65.4	62.9	57.9
	W310	68.9	70.8	65.3	62.6	59.4	54.3
	W312	75.4	74.2	71.2	69.1	66.7	62.7
Skunk Run	W404	74.2	72.6	70.1	68.2	66.1	62.0

Hydrologic Parameters for Lower Slippery Rock Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Slippery Rock Creek	W344	72.3	70.8	67.2	64.8	62.1	56.9
	W346	74.9	73.1	70.9	69.3	67.4	63.5
	W354	72.2	70.9	67.7	65.4	62.9	58.7
	W356	72.2	69.9	65.0	62.1	58.7	53.8
	W372	75.4	73.5	71.0	69.1	66.8	62.1
	W374	73.1	75.0	72.1	70.5	68.7	65.5
	W384	67.8	66.4	63.0	60.6	57.9	53.6
	W385	64.3	62.9	59.3	56.8	54.1	49.7
	W386	69.2	74.8	71.7	68.6	66.6	63.3
	W388	71.1	74.2	70.1	68.2	66.1	61.6
	W390	69.1	67.8	64.4	62.0	59.4	55.1
	W392	76.2	73.6	71.3	69.5	67.5	63.2
	W394	75.3	72.5	69.4	67.2	64.6	59.8
	W396	74.0	72.8	69.7	67.5	65.0	60.9
	W406	70.8	71.8	68.0	65.9	63.4	58.5
	W438	68.7	67.3	63.9	61.6	58.9	54.6
	W440	74.8	71.2	67.1	64.5	61.4	56.8
	W442	72.6	70.7	67.0	64.6	61.8	55.9
	W444	71.4	70.6	66.9	64.6	62.0	57.3
	W446	69.7	72.0	67.4	65.2	62.6	57.7
	W448	70.7	70.9	67.5	65.2	62.5	58.4
	W450	69.6	72.8	68.1	66.1	63.9	59.8
Swamp Run	W302	66.6	73.5	69.8	66.1	63.8	59.6
	W304	71.3	68.0	61.7	57.2	53.4	51.1
Taylor Run	W358	77.9	72.6	69.5	67.3	64.7	60.7
	W360	76.4	73.1	70.7	68.9	66.9	62.1
	W362	78.1	73.4	70.9	68.9	66.7	63.1
	W364	76.8	72.6	69.0	66.7	63.9	59.4
	W366	77.0	74.1	72.0	70.2	68.2	63.9
	W368	69.6	68.2	64.9	62.5	59.9	55.6
	W370	68.6	75.0	72.0	68.7	66.8	62.6

Hydrologic Results for Lower Slippery Rock Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
1	J4370	1316375.3	621763.3	3.54	268	526	686	779	753	268	526	686	779	753
2	J4361	1311918.9	623991.5	6.94	454	881	1,155	1,322	1,302	454	881	1,155	1,322	1,302
3	J4586	1313261.9	650699.5	3.65	237	463	600	693	750	237	463	600	693	750
4	J4532	1312315.7	644716.9	7.57	503	969	1,255	1,440	1,505	503	969	1,255	1,440	1,505
5	J4509	1313200.9	637299.7	10.74	697	1,335	1,732	1,993	2,068	697	1,335	1,732	1,993	2,068
6	J4539	1299526.3	647097.8	5.66	450	854	1,109	1,249	1,245	450	854	1,109	1,250	1,246
7	J4502	1304043.8	639802.7	9.11	687	1,320	1,724	1,966	1,972	687	1,320	1,724	1,967	1,973
8	J4486	1303799.6	638062.8	10.89	790	1,517	1,983	2,267	2,290	790	1,517	1,983	2,268	2,291
9	P057	1350470.1	595970.9	2.72	254	466	550	640	640	267	486	574	668	669
10	P054	1339664.7	588950.5	1.45	137	278	369	423	399	135	274	366	419	395
11	J4212	1337619.7	593376.4	3.53	302	576	761	861	813	300	573	757	856	809
12	J4185	1327852.1	586417.1	2.75	256	501	658	746	702	256	500	658	745	702
13	J4201	1326875.4	588614.7	3.75	236	470	626	715	679	236	470	626	714	679
14	J4228	1324921.9	594566.8	7.09	283	518	682	756	788	283	518	682	756	788
15	P226	1377758.1	609614.9	0.90	92	189	252	289	289	92	189	252	289	289
16	J4307	1365335.0	602869.2	7.70	539	934	1,218	1,366	1,332	539	934	1,218	1,366	1,332
17	J4282	1355537.0	603784.9	12.26	710	1,200	1,540	1,724	1,666	710	1,200	1,540	1,724	1,666
18	J4287	1339206.9	602197.7	17.01	624	1,000	1,259	1,398	1,353	624	1,000	1,259	1,398	1,353
19	J4244	1337528.1	597588.7	25.35	782	1,260	1,564	1,743	1,724	785	1,264	1,569	1,748	1,730
20	J4236	1335940.9	597039.2	29.63	849	1,376	1,713	1,914	1,898	852	1,380	1,718	1,920	1,905
21	J4251	1324982.9	598016.0	41.23	975	1,600	2,010	2,247	2,276	978	1,606	2,016	2,255	2,285
22	J4233	1315581.7	600335.8	47.29	1,025	1,689	2,125	2,371	2,462	1,029	1,694	2,131	2,378	2,470
23	J4276	1314452.3	603937.5	48.98	1,043	1,714	2,154	2,402	2,500	1,047	1,719	2,160	2,409	2,507
24	J4279	1314299.7	603479.7	51.06	1,070	1,755	2,206	2,459	2,562	1,073	1,760	2,212	2,466	2,569
25	USGS 03106300	1312651.4	602594.5	51.22	51	84	115	132	144	51	84	115	132	144
26	J4273	1303708.1	606959.4	54.95	280	550	718	818	786	282	554	722	824	792
27	J4290	1295527.8	605341.6	5.88	499	983	1,289	1,478	1,455	499	983	1,289	1,478	1,455
28	J4239	1277488.4	595970.9	2.50	230	452	593	680	699	230	452	593	680	699
29	J4425	1319606.3	630829.2	264.21	6,206	11,357	14,308	16,075	17,635	6,215	11,369	14,322	16,091	17,652
30	P289	1317596.3	629150.0	265.24	6,215	11,371	14,326	16,094	17,654	6,223	11,383	14,340	16,110	17,672
31	J4386	1311064.2	625059.8	274.12	6,191	11,295	14,217	15,964	17,500	6,199	11,306	14,231	15,979	17,517
32	J4394	1308988.6	628142.7	287.09	6,298	11,466	14,427	16,204	17,761	6,307	11,477	14,441	16,219	17,777
33	J4402	1305203.7	626250.2	288.50	6,310	11,484	14,449	16,229	17,786	6,318	11,495	14,463	16,244	17,803
34	J4331	1304043.8	626738.1	301.96	6,446	11,714	14,739	16,561	18,143	6,455	11,726	14,753	16,577	18,160

Hydrologic Results for Lower Slippery Rock Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
35	J4139	1298335.9	621580.1	309.31	6,522	11,842	14,897	16,743	18,337	6,530	11,854	14,911	16,758	18,354
36	J4321	1295314.1	614498.7	315.89	6,590	11,953	15,036	16,904	18,512	6,598	11,965	15,050	16,919	18,529
37	J4312	1297694.9	609126.5	374.98	6,625	12,036	15,151	17,038	18,656	6,633	12,047	15,164	17,053	18,673
38	J4295	1297084.5	605891.0	381.72	6,686	12,140	15,281	17,187	18,814	6,694	12,151	15,295	17,202	18,831
39	J4220	1297542.3	594047.9	387.04	6,724	12,213	15,372	17,289	18,923	6,733	12,224	15,386	17,304	18,940
40	J4209	1287255.9	585898.2	396.05	6,792	12,347	15,540	17,480	19,122	6,800	12,358	15,554	17,496	19,139
41	J4180	1284325.6	581380.7	400.14	6,799	12,387	15,594	17,542	19,187	6,807	12,399	15,607	17,558	19,205
42	USGS 03106500	1281792.2	574604.5	403.23	6,811	12,428	15,646	17,602	19,250	6,819	12,440	15,660	17,618	19,267
43	J4059	1281151.2	566668.4	409.66	6,741	12,360	15,606	17,573	19,219	6,750	12,371	15,620	17,588	19,237
44	J_LowerSlipperyRock_Outlet	1275587.5	565396.1	411.32	6,742	12,374	15,631	17,603	19,254	6,751	12,385	15,644	17,619	19,271

Hydrologic Parameters for Upper Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Bonnie Brook	W584	1.11	70.8	46.0	70.8	46.0
	W586	1.84	70.1	52.4	70.1	52.4
	W588	0.74	65.1	48.8	65.1	48.8
	W590	2.30	63.7	74.2	63.7	74.2
	W592	1.58	60.9	55.1	60.9	55.1
	W594	3.14	66.2	77.0	66.2	77.0
	W596	1.95	67.0	67.8	67.0	67.8
	W598	3.48	68.1	84.1	68.2	84.1
	W600	4.17	67.5	98.7	67.5	98.6
Butcher Run	W614	4.12	75.6	74.7	75.7	74.6
Coal Run	W602	3.32	74.5	54.9	74.5	54.9
	W604	2.21	67.0	75.6	67.0	75.6
	W606	1.02	73.9	46.1	74.0	46.0
Connoquenessing Creek	W558	2.33	65.1	63.1	65.1	63.1
	W560	3.79	65.1	87.0	65.2	86.7
	W572	1.86	73.9	56.6	74.1	56.2
	W658	1.18	71.7	71.1	71.7	71.1
	W660	1.02	73.8	77.7	73.6	78.2
	W662	1.93	76.8	85.8	76.8	85.8
	W664	1.43	72.3	71.0	72.4	70.7
	W666	0.60	59.2	51.7	59.1	51.8
	W668	1.36	70.5	56.0	70.1	56.6
	W704	1.04	72.1	43.6	72.1	43.6
	W706	2.49	69.3	65.4	69.3	65.4
	W708	0.04	67.0	19.6	67.0	19.6
	W710	4.68	67.4	80.2	67.4	80.2
	W712	2.89	68.4	78.3	68.4	78.3
	W714	0.49	64.0	45.9	64.4	45.4
	W716	1.50	70.1	50.7	70.1	50.7
	W718	1.08	71.7	44.4	71.7	44.4
	W720	0.75	71.5	33.2	71.6	33.2
	W722	2.22	74.9	55.6	76.6	52.9
	W724	0.89	73.4	57.5	73.4	57.5
	W726	0.90	85.3	34.1	85.3	34.1
	W728	2.09	79.4	47.9	79.4	47.9
	W730	1.83	75.3	47.5	76.8	45.4
	W732	0.06	68.3	15.9	68.3	15.9
	W734	1.52	65.3	57.6	65.3	57.6
	W736	0.77	66.3	35.7	66.3	35.7
	W738	0.54	60.3	48.3	60.4	48.3
	W740	1.85	64.0	78.6	64.0	78.6
	W742	1.22	60.7	75.4	60.7	75.4
	W744	1.57	77.9	49.2	78.1	48.9
	W746	2.87	66.3	99.5	66.3	99.4

Hydrologic Parameters for Upper Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Connoquenessing Creek	W748	1.53	64.9	63.4	64.9	63.4
	W750	3.53	73.1	84.0	73.1	84.0
Davis Run	W622	2.44	73.2	66.9	73.1	67.0
	W640	2.66	78.2	63.4	78.4	63.0
	W642	0.12	70.0	16.5	70.0	16.5
Glade Run	W670	3.04	72.0	74.7	72.0	74.6
	W672	1.33	72.9	55.3	73.3	54.6
	W674	3.47	73.7	90.0	74.0	89.1
	W676	2.93	74.3	80.3	74.5	79.9
	W678	2.13	70.5	65.3	70.6	65.1
	W680	4.47	71.2	89.7	71.5	88.9
	W682	0.19	61.9	35.2	61.9	35.2
	W684	4.81	67.6	107.9	67.7	107.7
	W686	1.05	72.3	47.0	72.3	46.9
	W688	3.27	68.9	91.2	68.6	92.0
	W690	4.00	72.2	84.7	72.2	84.7
	W692	1.20	77.6	47.9	79.0	45.9
	W694	2.63	72.3	68.5	72.3	68.5
	W696	1.20	64.9	64.4	64.9	64.4
	W698	3.53	68.3	80.0	68.3	79.9
	W700	0.47	64.7	38.4	64.7	38.4
	W702	1.32	67.4	55.0	67.3	55.1
Patterson Run	W650	3.59	69.2	88.1	69.2	88.2
Pine Run	W562	3.84	68.5	83.7	68.5	83.7
Robinson Run	W632	2.52	70.1	74.6	70.3	74.3
Rocklick Run	W620	1.10	72.6	57.7	72.6	57.7
Sawmill Run	W616	2.82	76.5	78.7	76.5	78.7
	W618	0.48	74.6	31.3	79.8	26.8
Stony Run	W564	3.08	70.2	71.1	70.2	71.1
	W566	4.36	68.3	75.0	68.3	74.9
	W568	1.34	70.4	61.7	70.4	61.7
	W570	0.38	59.9	37.9	59.9	37.9
Sullivan Run	W608	2.43	76.2	56.0	77.0	54.7
	W610	2.62	75.4	61.3	76.0	60.4
	W612	1.55	83.6	38.2	83.9	38.0
Thorn Creek	W574	1.29	74.2	41.4	74.2	41.4
	W576	1.04	70.7	40.6	70.7	40.6
	W578	2.63	65.7	78.6	65.7	78.6
	W580	1.51	71.8	50.0	71.8	50.0
	W582	1.22	70.1	51.1	70.2	51.1
	W626	3.96	78.8	77.8	78.8	77.8
	W628	4.56	78.6	82.4	78.6	82.4
	W630	1.64	78.9	62.9	79.5	61.7
	W634	1.84	77.8	48.2	77.8	48.2

Hydrologic Parameters for Upper Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Thorn Creek	W636	2.10	69.5	67.1	69.6	67.0
	W638	2.17	75.0	87.6	75.3	87.0
	W644	2.37	73.5	70.4	73.5	70.4
	W646	3.73	73.0	64.6	73.0	64.6
	W648	1.96	72.1	57.7	72.1	57.7
	W652	1.44	64.4	56.4	64.4	56.4
	W654	0.95	72.8	45.1	74.0	43.6
	W656	1.58	66.0	57.3	66.0	57.2
Vaur Run	W624	2.73	79.5	77.8	79.7	77.3

Hydrologic Parameters for Upper Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Bonnie Brook	W584	70.8	70.1	65.9	63.5	60.6	57.8
	W586	70.1	70.0	65.7	63.2	60.5	57.5
	W588	65.1	64.6	60.8	58.1	54.9	52.8
	W590	63.7	72.0	67.5	64.6	62.6	60.8
	W592	60.9	70.6	66.0	63.1	60.3	58.7
	W594	66.2	72.4	67.1	64.5	62.2	59.7
	W596	67.0	72.7	67.8	65.3	63.1	60.9
	W598	68.1	72.9	67.7	65.5	63.0	60.3
	W600	67.5	73.7	69.4	66.8	65.0	62.8
Butcher Run	W614	75.6	71.5	67.1	62.9	58.8	57.2
Coal Run	W602	74.5	70.1	65.0	62.2	58.9	57.1
	W604	67.0	72.9	68.1	65.6	63.5	60.9
	W606	73.9	70.4	65.7	63.1	60.0	57.5
Connoquenessing Creek	W558	65.1	71.8	66.6	63.8	61.5	58.9
	W560	65.1	72.4	67.6	64.5	62.6	60.3
	W572	73.9	70.8	66.4	63.8	60.8	58.1
	W658	71.7	73.2	69.8	67.2	64.2	62.2
	W660	73.8	73.2	71.1	68.7	65.9	64.7
	W662	76.8	73.2	70.3	67.4	63.7	61.3
	W664	72.3	72.2	69.2	66.4	63.2	60.8
	W666	59.2	58.6	54.7	51.9	48.7	46.5
	W668	70.5	71.3	67.3	64.2	60.5	59.1
	W704	72.1	70.4	66.4	63.1	59.2	56.8
	W706	69.3	71.8	66.5	64.1	61.4	59.5
	W708	67.0	66.4	62.8	60.1	57.0	54.8
	W710	67.4	72.1	66.1	63.5	60.4	57.4
	W712	68.4	68.7	62.2	58.8	54.7	50.8
	W714	64.0	63.4	59.7	56.9	55.9	51.6
	W716	70.1	70.6	66.4	64.1	61.4	60.0
	W718	71.7	70.4	66.3	63.9	61.3	58.9
	W720	71.5	71.0	67.6	65.0	62.1	60.0
	W722	74.9	70.7	66.0	63.3	60.2	57.2
	W724	73.4	72.9	69.6	67.1	64.3	62.2
	W726	85.3	84.9	82.8	81.1	79.1	77.6
	W728	79.4	71.5	66.6	64.6	62.4	61.8
	W730	75.3	69.1	62.5	59.9	56.8	56.1
	W732	68.3	67.8	64.2	61.5	58.5	56.4
	W734	65.3	72.1	67.2	63.8	61.2	59.1
	W736	66.3	65.8	62.1	59.3	56.2	54.1
	W738	60.3	59.7	55.8	53.0	49.8	47.7
	W740	64.0	73.0	69.6	65.9	62.8	61.1
	W742	60.7	72.9	70.3	67.3	63.6	60.7
	W744	77.9	72.0	67.9	63.9	59.7	59.7
	W746	66.3	74.3	70.8	67.3	64.8	63.5

Hydrologic Parameters for Upper Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Connoquenessing Creek	W748	64.9	72.6	68.4	64.7	62.5	60.8
	W750	73.1	72.3	68.9	65.9	62.2	59.3
Davis Run	W622	73.2	71.4	67.4	64.0	59.9	58.3
	W640	78.2	71.9	67.5	64.4	60.8	60.5
	W642	70.0	69.5	66.0	63.4	60.4	58.3
Glade Run	W670	72.0	71.4	67.7	64.5	60.7	58.0
	W672	72.9	71.2	67.4	64.2	60.3	57.7
	W674	73.7	72.5	69.2	66.1	62.4	60.0
	W676	74.3	72.0	68.5	65.3	61.3	58.1
	W678	70.5	72.0	67.6	64.5	60.9	58.6
	W680	71.2	72.5	68.3	65.3	61.5	59.5
	W682	61.9	61.3	57.4	54.6	51.4	49.3
	W684	67.6	74.0	70.0	66.8	64.5	62.5
	W686	72.3	70.8	67.0	63.9	60.0	56.9
	W688	68.9	73.8	69.2	66.4	63.4	61.2
	W690	72.2	70.9	66.4	62.2	57.9	55.3
	W692	77.6	71.6	67.5	63.4	59.2	59.2
	W694	72.3	71.4	67.7	64.5	60.6	58.3
	W696	64.9	72.7	68.9	64.9	62.8	61.3
	W698	68.3	73.3	68.1	65.3	61.9	61.4
	W700	64.7	64.1	60.4	57.6	54.5	52.3
	W702	67.4	72.6	67.7	64.8	61.7	59.4
Patterson Run	W650	69.2	73.5	68.4	65.4	61.9	59.5
Pine Run	W562	68.5	73.1	67.6	65.4	62.9	60.7
Robinson Run	W632	70.1	72.4	67.6	64.6	60.9	57.7
Rocklick Run	W620	72.6	71.5	68.1	65.2	61.6	58.6
Sawmill Run	W616	76.5	71.9	67.8	63.6	59.4	57.8
	W618	74.6	74.1	70.9	68.5	65.7	63.7
Stony Run	W564	70.2	71.5	66.9	64.5	61.8	59.5
	W566	68.3	72.2	66.3	63.7	60.8	58.4
	W568	70.4	72.2	67.8	65.7	63.4	60.8
	W570	59.9	59.3	55.4	52.5	49.3	47.2
Sullivan Run	W608	76.2	71.1	66.4	63.8	60.8	59.3
	W610	75.4	71.1	66.7	64.1	61.1	58.9
	W612	83.6	72.8	71.0	69.9	68.8	68.2
Thorn Creek	W574	74.2	70.1	65.4	62.8	59.8	58.2
	W576	70.7	69.4	64.7	62.0	59.0	56.5
	W578	65.7	72.7	67.9	65.1	63.3	60.9
	W580	71.8	70.0	65.4	62.8	59.7	57.7
	W582	70.1	69.4	64.2	61.3	58.0	55.7
	W626	78.8	72.2	67.5	64.8	61.6	60.9
	W628	78.6	72.5	68.2	65.1	61.3	61.0
	W630	78.9	72.6	68.7	65.6	61.7	61.1
	W634	77.8	71.0	66.2	63.4	60.2	59.5

Hydrologic Parameters for Upper Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Thorn Creek	W636	69.5	72.7	67.4	64.4	60.9	57.6
	W638	75.0	72.8	69.6	66.7	63.2	60.4
	W644	73.5	71.8	68.2	65.1	61.3	58.4
	W646	73.0	70.6	66.1	62.1	58.1	56.1
	W648	72.1	70.9	66.8	63.6	59.6	56.7
	W652	64.4	71.9	67.1	63.5	61.0	58.1
	W654	72.8	72.3	69.0	66.5	63.6	61.6
	W656	66.0	72.0	67.1	63.9	60.7	57.9
Vaur Run	W624	79.5	72.9	68.9	66.0	62.6	62.6

Hydrologic Parameters for Upper Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Bonnie Brook	W584	70.8	70.1	65.9	63.5	60.6	57.8
	W586	70.1	70.0	65.7	63.2	60.5	57.5
	W588	65.1	64.6	60.8	58.1	54.9	52.8
	W590	63.7	72.0	67.5	64.6	62.6	60.8
	W592	60.9	70.6	66.0	63.1	60.3	58.7
	W594	66.2	72.4	67.1	64.5	62.2	59.7
	W596	67.0	72.7	67.8	65.3	63.1	60.9
	W598	68.2	73.0	67.8	65.6	63.1	60.3
	W600	67.5	73.7	69.4	66.8	65.0	62.8
Butcher Run	W614	75.7	71.5	67.2	63.0	58.9	57.3
Coal Run	W602	74.5	70.1	65.0	62.2	58.9	57.1
	W604	67.0	72.9	68.1	65.6	63.5	60.9
	W606	74.0	70.5	65.8	63.2	60.2	57.6
Connoquenessing Creek	W558	65.1	71.8	66.6	63.8	61.5	58.9
	W560	65.2	72.5	67.7	64.6	62.7	60.5
	W572	74.1	71.0	66.7	64.1	61.1	58.4
	W658	71.7	73.2	69.8	67.2	64.2	62.2
	W660	73.6	73.0	70.8	68.4	65.6	64.5
	W662	76.8	73.2	70.3	67.4	63.7	61.3
	W664	72.4	72.3	69.3	66.6	63.3	60.9
	W666	59.1	58.5	54.6	51.7	48.5	46.4
	W668	70.1	70.8	66.8	63.7	60.0	58.6
	W704	72.1	70.4	66.4	63.1	59.1	56.8
	W706	69.3	71.8	66.5	64.1	61.4	59.5
	W708	67.0	66.4	62.8	60.1	57.0	54.8
	W710	67.4	72.1	66.1	63.5	60.4	57.4
	W712	68.4	68.7	62.2	58.8	54.7	50.8
	W714	64.4	63.8	60.1	57.3	56.3	52.0
	W716	70.1	70.7	66.4	64.1	61.5	60.0
	W718	71.7	70.4	66.3	63.9	61.3	58.9
	W720	71.6	71.0	67.7	65.1	62.2	60.1
	W722	76.6	72.6	68.1	65.5	62.4	59.5
	W724	73.4	72.9	69.6	67.1	64.3	62.2
	W726	85.3	84.9	82.8	81.1	79.1	77.6
	W728	79.4	71.5	66.6	64.6	62.4	61.8
	W730	76.8	70.8	64.5	61.9	58.8	58.2
	W732	68.3	67.8	64.2	61.5	58.5	56.4
	W734	65.3	72.1	67.2	63.8	61.2	59.1
	W736	66.3	65.8	62.1	59.3	56.2	54.1
	W738	60.4	59.7	55.9	53.0	49.8	47.7
	W740	64.0	73.0	69.6	65.9	62.8	61.1
	W742	60.7	72.9	70.3	67.3	63.6	60.7
	W744	78.1	72.2	68.1	64.1	60.0	60.0
	W746	66.3	74.3	70.9	67.3	64.8	63.5

Hydrologic Parameters for Upper Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Connoquenessing Creek	W748	64.9	72.6	68.4	64.7	62.5	60.8
	W750	73.1	72.3	68.9	65.9	62.2	59.3
Davis Run	W622	73.1	71.3	67.3	64.0	59.9	58.3
	W640	78.4	72.1	67.7	64.7	61.1	60.8
	W642	70.0	69.5	66.0	63.4	60.4	58.3
Glade Run	W670	72.0	71.4	67.7	64.6	60.7	58.0
	W672	73.3	71.6	67.9	64.7	60.8	58.2
	W674	74.0	72.8	69.5	66.5	62.8	60.4
	W676	74.5	72.2	68.7	65.5	61.5	58.3
	W678	70.6	72.1	67.7	64.7	61.0	58.8
	W680	71.5	72.8	68.7	65.6	61.9	59.9
	W682	61.9	61.3	57.4	54.6	51.4	49.3
	W684	67.7	74.1	70.0	66.8	64.6	62.5
	W686	72.3	70.9	67.1	63.9	60.1	57.0
	W688	68.6	73.6	68.9	66.1	63.0	60.8
	W690	72.2	71.0	66.4	62.2	57.9	55.3
	W692	79.0	73.2	69.3	65.3	61.2	61.2
	W694	72.3	71.4	67.7	64.5	60.6	58.4
	W696	64.9	72.7	68.9	64.9	62.8	61.3
	W698	68.3	73.3	68.2	65.4	62.0	61.4
	W700	64.7	64.1	60.4	57.6	54.5	52.3
	W702	67.3	72.6	67.6	64.8	61.6	59.4
Patterson Run	W650	69.2	73.5	68.3	65.4	61.9	59.5
Pine Run	W562	68.5	73.1	67.6	65.4	62.9	60.7
Robinson Run	W632	70.3	72.5	67.8	64.7	61.1	57.9
Rocklick Run	W620	72.6	71.5	68.1	65.2	61.6	58.6
Sawmill Run	W616	76.5	71.9	67.8	63.6	59.4	57.8
	W618	79.8	79.3	76.6	74.5	72.0	70.2
Stony Run	W564	70.2	71.5	66.9	64.5	61.8	59.5
	W566	68.3	72.2	66.3	63.8	60.9	58.4
	W568	70.4	72.2	67.8	65.7	63.4	60.8
	W570	59.9	59.3	55.4	52.5	49.3	47.2
Sullivan Run	W608	77.0	72.0	67.4	64.9	61.9	60.4
	W610	76.0	71.7	67.3	64.8	61.9	59.6
	W612	83.9	73.1	71.3	70.3	69.1	68.6
Thorn Creek	W574	74.2	70.1	65.4	62.8	59.8	58.2
	W576	70.7	69.4	64.7	62.0	59.0	56.5
	W578	65.7	72.7	67.9	65.1	63.3	60.9
	W580	71.8	70.0	65.4	62.8	59.7	57.7
	W582	70.2	69.4	64.2	61.3	58.0	55.7
	W626	78.8	72.2	67.5	64.8	61.6	60.9
	W628	78.6	72.5	68.2	65.1	61.3	61.0
	W630	79.5	73.4	69.5	66.4	62.6	62.0
	W634	77.8	71.0	66.2	63.4	60.2	59.5

Hydrologic Parameters for Upper Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Thorn Creek	W636	69.6	72.8	67.5	64.5	60.9	57.6
	W638	75.3	73.0	69.9	67.0	63.5	60.7
	W644	73.5	71.8	68.2	65.1	61.3	58.4
	W646	73.0	70.6	66.1	62.1	58.1	56.1
	W648	72.1	70.9	66.8	63.6	59.6	56.7
	W652	64.4	71.9	67.1	63.5	61.0	58.1
	W654	74.0	73.5	70.3	67.8	65.0	63.0
	W656	66.0	72.0	67.2	63.9	60.8	58.0
Vaur Run	W624	79.7	73.1	69.1	66.3	62.9	62.9

Hydrologic Results for Upper Connoquenessing Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
1	J4223	1373912.1	590171.4	4.36	363	568	746	834	948	364	571	750	837	951
2	J4206	1376720.3	588828.4	8.78	723	1,204	1,591	1,799	2,043	725	1,207	1,595	1,803	2,048
3	J4171	1390822.1	583975.2	3.92	301	524	674	794	918	301	524	674	794	918
4	J4136	1384625.9	577504.2	6.47	421	736	951	1,096	1,273	421	736	951	1,096	1,273
5	O050	1397476.2	558396.5	1.84	156	296	395	447	489	156	296	395	447	489
6	J4142	1403275.7	576863.2	3.41	268	487	626	734	849	268	487	626	734	849
7	P109	1402390.5	571552.1	4.99	393	712	914	1,059	1,239	393	712	914	1,059	1,239
8	J4079	1400345.5	564867.5	8.13	641	1,113	1,434	1,660	1,920	641	1,113	1,434	1,660	1,920
9	J4041	1396926.8	563432.9	12.66	865	1,495	1,933	2,230	2,561	865	1,495	1,933	2,230	2,561
10	J4053	1388899.1	568530.3	16.14	983	1,670	2,159	2,483	2,830	984	1,671	2,160	2,484	2,831
11	J3993	1386762.5	554367.4	3.32	275	485	630	685	823	275	485	630	685	823
12	P111	1383282.8	560319.5	5.53	470	817	1,059	1,189	1,389	470	817	1,059	1,189	1,389
13	J4093	1371989.1	565447.4	5.05	446	805	1,052	1,168	1,381	490	875	1,139	1,265	1,491
14	J3965	1390059.0	538739.4	3.96	319	555	711	778	995	319	555	711	778	995
15	J3856	1391280.0	527659.3	11.25	879	1,542	1,939	2,082	2,703	884	1,550	1,948	2,092	2,715
16	P030	1373149.0	544508.3	1.84	185	330	426	465	603	184	329	426	464	602
17	J4710	1388288.7	520669.4	5.10	442	812	1,007	1,048	1,331	447	820	1,017	1,060	1,344
18	J3839	1388136.1	522256.7	18.11	1,339	2,361	2,939	3,117	4,016	1,355	2,385	2,967	3,148	4,051
19	J4743	1382031.4	529643.4	20.48	1,408	2,521	3,150	3,344	4,268	1,423	2,547	3,181	3,378	4,307
20	J3862	1379314.8	530986.4	24.21	1,546	2,779	3,463	3,671	4,665	1,562	2,807	3,497	3,708	4,707
21	J3859	1374949.9	535412.3	26.17	1,602	2,880	3,589	3,805	4,816	1,619	2,909	3,624	3,844	4,863
22	J3886	1371500.8	536846.9	32.28	1,671	3,008	3,763	4,004	4,992	1,687	3,036	3,797	4,041	5,035
23	J3889	1366067.6	540998.1	37.66	1,800	3,213	4,017	4,285	5,323	1,817	3,242	4,053	4,324	5,369
24	J3912	1363198.4	542066.4	40.78	1,815	3,211	4,001	4,278	5,280	1,833	3,240	4,035	4,319	5,326
25	J4004	1350561.6	553238.0	1.93	161	312	385	408	461	161	312	385	408	461
26	J3971	1349981.7	547835.4	4.38	365	722	905	979	1,126	364	721	904	978	1,125
27	J4621	1358497.7	504278.3	7.40	562	1,032	1,275	1,334	1,505	579	1,060	1,308	1,370	1,546
28	J4654	1356422.1	505102.5	9.72	625	1,136	1,410	1,481	1,681	641	1,162	1,442	1,516	1,721
29	J4659	1367807.4	513710.1	7.04	498	921	1,097	1,121	1,261	499	923	1,099	1,123	1,263
30	J4662	1364022.5	514686.8	9.57	663	1,227	1,466	1,502	1,724	677	1,247	1,490	1,529	1,754
31	J3833	1355262.3	518441.2	15.67	1,079	2,008	2,429	2,514	2,887	1,108	2,053	2,484	2,574	2,956
32	J4717	1351507.9	520059.0	31.40	1,952	3,535	4,307	4,587	5,247	1,987	3,589	4,373	4,661	5,331
33	J3842	1346776.7	528361.4	35.98	2,096	3,757	4,579	4,884	5,617	2,132	3,813	4,648	4,961	5,704
34	J3850	1346288.3	530711.7	39.72	2,219	3,978	4,861	5,200	5,986	2,254	4,034	4,929	5,276	6,072

Hydrologic Results for Upper Connoquenessing Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
35	J4300	1394301.8	599450.6	6.28	491	830	1,061	1,242	1,441	496	838	1,071	1,252	1,453
36	J4262	1394423.9	598687.5	8.65	651	1,096	1,405	1,645	1,894	655	1,103	1,414	1,655	1,905
37	J4217	1382000.8	586508.6	20.06	916	1,544	2,005	2,311	2,621	919	1,549	2,011	2,318	2,629
38	J4188	1379986.3	585409.8	29.71	1,272	2,122	2,796	3,173	3,599	1,275	2,128	2,800	3,181	3,607
39	J4161	1377941.2	580129.2	33.07	1,353	2,268	2,987	3,382	3,820	1,356	2,273	2,993	3,389	3,828
40	J4131	1380718.8	571948.9	42.59	828	1,945	2,692	3,141	3,625	834	1,953	2,702	3,151	3,637
41	J4084	1380810.4	566149.5	65.12	1,894	3,105	3,961	4,711	5,539	1,901	3,115	3,977	4,731	5,562
42	J4023	1378368.5	562578.2	72.56	2,166	3,549	4,520	5,207	6,073	2,174	3,560	4,533	5,225	6,096
43	J_UpperConno_ButlerCity	1372434.0	560573.1	80.06	2,386	3,922	5,004	5,707	6,581	2,400	3,943	5,029	5,735	6,611
44	J4033	1372280.2	560287.4	80.06	2,386	3,922	5,004	5,707	6,581	2,400	3,943	5,029	5,735	6,611
45	J3996	1368143.2	556809.3	86.27	2,491	4,145	5,280	6,010	6,933	2,509	4,174	5,315	6,046	6,969
46	J4009	1362862.6	551711.8	91.40	2,502	4,181	5,381	6,150	7,176	2,527	4,219	5,425	6,196	7,225
47	J3978	1361611.1	550887.7	92.56	2,512	4,204	5,409	6,184	7,216	2,538	4,244	5,455	6,231	7,267
48	J4349	1358223.0	544477.8	136.44	4,357	7,473	9,476	10,516	12,521	4,406	7,550	9,567	10,618	12,635
49	J3962	1353980.3	545363.0	138.39	4,265	7,278	9,192	10,250	12,195	4,316	7,356	9,287	10,354	12,311
50	J3947	1351233.1	542310.6	143.91	4,364	7,467	9,431	10,511	12,501	4,417	7,547	9,528	10,619	12,621
51	J3925	1346654.6	542585.3	147.12	4,404	7,526	9,497	10,581	12,577	4,456	7,606	9,594	10,689	12,698
52	J3853	1339725.8	536633.2	189.38	5,659	9,855	12,391	13,675	16,179	5,752	9,993	12,563	13,866	16,393
53	P186	1337650.2	537732.1	190.95	5,619	9,728	12,203	13,462	15,886	5,708	9,861	12,366	13,642	16,088
54	P184	1334414.7	542219.0	193.82	5,666	9,797	12,278	13,547	15,979	5,755	9,930	12,440	13,727	16,181
55	J3940	1329653.0	544660.9	196.39	5,491	9,396	11,737	12,950	15,198	5,572	9,514	11,879	13,107	15,373
56	J_UpperConnoqueness_Outlet	1319920.0	542429.9	199.92	5,524	9,441	11,787	13,004	15,248	5,605	9,558	11,928	13,159	15,422

Hydrologic Parameters for Lower Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Brush Creek	W841	3.49	80.6	71.1	81.0	70.1
	W842	2.00	72.2	57.1	72.2	57.1
	W843	2.45	72.5	51.1	72.5	51.1
	W844	1.75	73.4	46.0	73.4	46.0
	W845	1.88	74.6	52.6	74.6	52.6
	W846	1.69	73.8	51.9	73.8	51.9
	W847	3.50	70.3	70.0	70.3	70.0
	W848	2.73	70.8	91.2	70.8	91.2
	W849	4.23	78.5	79.9	79.5	77.3
	W850	2.64	81.0	65.3	81.3	64.7
	W851	3.57	79.3	82.8	80.7	79.4
	W852	4.74	78.0	61.2	78.4	60.4
	W853	3.47	76.4	74.1	76.4	73.9
	W854	3.44	75.1	59.8	75.1	59.8
	W855	1.53	74.3	49.1	74.3	49.1
	W856	1.61	72.8	48.6	72.8	48.6
	W857	2.47	72.9	72.3	72.9	72.3
	W858	1.57	73.1	55.6	73.1	55.6
	W859	3.72	73.5	57.0	73.5	57.0
	W860	3.67	73.5	61.2	73.5	61.2
	W861	0.06	74.4	18.0	74.4	18.0
Camp Run	W836	1.86	68.8	48.4	68.8	53.8
	W837	4.64	73.3	59.7	73.3	66.3
	W838	3.64	70.6	65.8	70.6	73.1
	W839	4.66	72.8	95.6	72.8	106.2
Connoquenessing Creek	W804	1.19	71.5	35.4	71.5	39.3
	W835	1.43	72.9	40.1	72.9	44.6
	W862	1.11	72.5	45.8	72.5	45.8
	W876	0.02	76.2	9.2	76.2	10.2
	W877	0.06	77.5	11.7	77.5	13.0
	W878	1.15	78.7	40.0	78.7	44.4
	W879	1.32	81.4	42.4	81.8	46.5
	W881	0.64	75.4	33.0	75.4	36.6
	W882	0.99	74.5	40.2	74.5	44.7
	W883	2.49	74.8	54.5	74.8	60.6
	W884	4.73	73.2	79.8	73.2	88.7
	W885	0.77	75.5	41.4	75.5	46.0
	W886	0.46	72.4	32.7	72.4	32.7
	W887	2.42	73.5	60.6	73.5	60.6
	W888	2.55	75.3	67.3	75.3	67.3
	W898	0.57	71.2	25.5	71.2	25.5
	W899	2.02	75.6	52.8	75.6	52.8
	W900	2.89	73.5	64.4	73.5	64.4
Crab Run	W817	1.13	72.6	59.4	72.6	66.0

Hydrologic Parameters for Lower Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Crab Run	W818	1.07	69.1	46.9	69.1	52.1
	W819	2.38	70.9	64.0	70.9	71.2
	W820	3.17	73.6	66.4	73.6	73.6
	W821	2.18	67.1	66.0	67.1	73.3
Crooked Run	W866	1.51	73.7	46.9	73.7	52.1
	W867	1.42	75.8	44.0	75.8	48.9
Doe Run	W834	4.41	74.6	71.8	74.7	79.6
Duck Run	W864	3.21	73.6	91.6	73.6	91.6
	W865	0.23	72.2	18.3	72.2	18.3
Glade Run	W832	4.70	77.6	65.6	78.1	71.6
Hazen Run	W840	2.33	71.1	59.3	71.1	65.9
Little Connoquenessing Creek	W805	1.03	73.5	48.4	73.5	53.7
	W806	1.82	73.4	52.1	73.4	57.9
	W807	2.12	67.5	66.3	67.5	73.7
	W808	1.42	81.2	38.9	81.5	42.9
	W812	1.76	71.1	58.5	71.1	65.0
	W816	0.80	60.4	53.0	60.4	58.8
	W868	0.37	72.9	22.3	73.5	24.3
	W869	2.71	72.6	77.4	72.6	85.9
	W870	0.20	61.4	24.7	61.4	27.5
	W871	1.53	68.4	48.6	68.5	53.9
	W872	3.78	65.8	80.6	65.8	89.6
	W873	1.54	63.8	52.7	63.8	58.5
	W874	1.49	60.2	61.9	60.2	68.8
	W875	1.97	74.8	72.2	74.8	80.2
Little Yellow Creek	W823	3.14	70.9	62.5	71.0	69.2
	W824	2.02	64.0	59.2	64.0	65.8
Mulligan Run	W809	1.64	72.0	82.6	72.1	91.5
	W810	2.81	75.1	90.6	75.2	100.3
	W811	1.98	68.2	73.4	68.3	81.3
Muntz Run	W833	2.01	73.3	50.0	73.4	55.6
	W880	0.12	76.0	20.3	76.0	22.6
Scholars Run	W830	3.23	67.5	70.3	67.5	78.1
	W831	3.82	72.8	74.7	73.5	81.4
Semiconon Run	W813	0.86	75.6	55.4	75.6	61.5
	W814	1.50	73.3	66.7	73.8	73.1
	W815	2.78	68.7	86.9	68.7	96.6
Squaw Run	W863	2.44	73.0	70.7	73.0	70.7
Yellow Creek	W822	2.79	64.6	69.0	64.6	76.7
	W825	2.48	74.4	47.6	74.5	52.8
	W826	0.45	70.1	31.2	70.1	34.7
	W827	1.75	68.3	48.6	68.3	53.9
	W828	1.86	67.9	62.1	67.9	69.0
	W829	2.66	66.7	59.7	66.7	66.4

Hydrologic Parameters for Lower Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Brush Creek	W841	80.6	71.9	70.7	68.5	65.9	63.2
	W842	72.2	70.2	68.5	66.5	64.1	61.8
	W843	72.5	69.6	67.4	65.2	62.6	60.1
	W844	73.4	69.7	67.8	65.6	63.1	60.7
	W845	74.6	70.4	68.6	66.5	64.0	61.6
	W846	73.8	70.3	68.8	66.8	64.5	62.3
	W847	70.3	70.2	68.2	66.1	63.6	61.3
	W848	70.8	73.5	71.6	69.5	67.6	65.8
	W849	78.5	71.8	70.6	68.5	66.1	63.8
	W850	81.0	72.1	70.9	68.8	66.3	63.9
	W851	79.3	72.5	71.6	69.7	67.5	65.3
	W852	78.0	70.5	68.4	65.9	63.1	60.4
	W853	76.4	71.4	70.2	68.1	65.8	63.4
	W854	75.1	70.3	68.3	66.0	63.4	61.0
	W855	74.3	70.4	68.8	66.7	64.3	62.3
	W856	72.8	70.1	68.3	66.3	63.9	61.8
	W857	72.9	71.4	70.2	68.3	66.2	64.2
	W858	73.1	70.6	69.2	67.3	65.1	62.9
	W859	73.5	69.8	67.7	65.4	62.7	60.0
	W860	73.5	70.2	68.3	66.0	63.4	61.1
	W861	74.4	71.5	70.1	67.4	64.3	60.3
Camp Run	W836	68.8	68.1	65.9	61.4	57.4	50.0
	W837	73.3	68.1	65.5	62.2	58.2	56.4
	W838	70.6	69.1	67.1	62.7	58.6	51.9
	W839	72.8	71.3	70.5	67.5	63.7	57.5
Connoquenessing Creek	W804	71.5	67.8	65.7	61.0	56.8	52.0
	W835	72.9	68.1	65.9	60.6	56.6	55.1
	W862	72.5	68.7	67.0	65.7	64.3	63.2
	W876	76.2	73.4	72.0	69.5	66.4	62.6
	W877	77.5	74.8	73.5	71.0	68.0	64.3
	W878	78.7	69.5	68.4	65.6	62.3	61.4
	W879	81.4	69.6	68.4	68.0	67.7	65.4
	W881	75.4	72.6	71.2	68.6	65.5	61.6
	W882	74.5	71.6	70.2	67.5	64.4	60.5
	W883	74.8	69.2	67.6	62.9	58.7	57.1
	W884	73.2	70.3	68.9	65.4	61.0	56.7
	W885	75.5	72.7	71.3	68.8	65.7	57.4
	W886	72.4	69.3	67.9	65.1	61.9	57.8
	W887	73.5	68.4	66.0	64.4	62.7	61.3
	W888	75.3	69.2	67.4	66.0	64.4	63.2
	W898	71.2	68.0	66.5	63.7	60.4	56.4
	W899	75.6	69.1	67.5	66.2	64.8	63.9
	W900	73.5	69.6	68.2	67.0	65.7	64.6
Crab Run	W817	72.6	70.1	68.8	65.6	61.7	55.3

Hydrologic Parameters for Lower Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Crab Run	W818	69.1	68.7	67.0	63.6	59.3	52.6
	W819	70.9	69.2	67.5	63.5	59.4	53.2
	W820	73.6	69.4	67.6	63.0	58.8	55.5
	W821	67.1	69.7	68.5	64.9	61.5	53.5
Crooked Run	W866	73.7	68.4	66.3	61.0	56.9	55.0
	W867	75.8	68.4	66.5	63.4	59.6	58.4
Doe Run	W834	74.6	68.3	65.3	61.2	57.2	55.3
Duck Run	W864	73.6	70.8	69.6	68.5	67.2	66.1
	W865	72.2	69.1	67.6	64.9	61.6	57.6
Glade Run	W832	77.6	69.4	67.7	64.4	60.5	59.2
Hazen Run	W840	71.1	69.3	67.6	63.7	59.6	52.4
Little Connoquenessing Creek	W805	73.5	68.7	66.7	61.8	57.6	56.1
	W806	73.4	68.6	66.4	60.7	56.9	55.0
	W807	67.5	69.6	68.0	64.6	60.9	51.2
	W808	81.2	68.7	66.9	65.7	64.5	64.5
	W812	71.1	69.3	67.8	63.9	59.8	52.8
	W816	60.4	56.8	55.1	51.9	48.6	44.4
	W868	72.9	69.9	68.4	65.7	62.5	58.5
	W869	72.6	70.5	69.2	65.9	61.8	54.9
	W870	61.4	57.9	56.2	53.1	49.6	45.4
	W871	68.4	68.7	66.7	63.2	58.9	49.3
	W872	65.8	69.4	67.4	63.6	60.1	51.5
	W873	63.8	68.7	67.1	63.0	60.3	53.0
	W874	60.2	69.3	68.6	64.1	59.8	52.8
	W875	74.8	71.4	71.0	68.2	64.7	58.6
Little Yellow Creek	W823	70.9	68.5	66.0	60.9	56.8	52.2
	W824	64.0	68.9	67.5	63.3	60.5	57.4
Mulligan Run	W809	72.0	71.4	70.8	68.0	64.6	56.6
	W810	75.1	71.2	70.3	66.9	62.7	59.0
	W811	68.2	70.3	69.3	66.0	62.7	57.4
Muntz Run	W833	73.3	68.5	66.3	61.3	57.1	55.3
	W880	76.0	73.2	71.9	69.3	66.2	62.4
Scholars Run	W830	67.5	69.4	67.4	64.0	59.8	50.7
	W831	72.8	69.9	68.3	64.2	60.0	55.6
Semiconon Run	W813	75.6	72.8	71.4	68.7	65.7	61.8
	W814	73.3	70.0	68.5	65.0	60.6	56.2
	W815	68.7	70.8	69.6	66.3	63.0	55.4
Squaw Run	W863	73.0	69.7	68.2	66.8	65.4	64.4
Yellow Creek	W822	64.6	69.3	67.6	63.5	60.5	52.0
	W825	74.4	67.6	64.9	61.4	57.3	55.3
	W826	70.1	66.9	65.4	62.4	59.2	55.1
	W827	68.3	68.3	66.1	62.3	58.2	51.3
	W828	67.9	69.8	68.2	65.0	61.4	52.9
	W829	66.7	68.9	67.0	63.6	59.7	51.0

Hydrologic Parameters for Lower Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Brush Creek	W841	81.0	72.5	71.3	69.1	66.6	63.9
	W842	72.2	70.2	68.5	66.5	64.1	61.8
	W843	72.5	69.6	67.4	65.2	62.6	60.1
	W844	73.4	69.7	67.8	65.6	63.1	60.7
	W845	74.6	70.4	68.6	66.5	64.0	61.6
	W846	73.8	70.3	68.8	66.8	64.5	62.3
	W847	70.3	70.2	68.2	66.1	63.6	61.3
	W848	70.8	73.5	71.6	69.5	67.6	65.8
	W849	79.5	73.1	71.9	69.9	67.6	65.3
	W850	81.3	72.5	71.3	69.2	66.7	64.3
	W851	80.7	74.2	73.3	71.5	69.4	67.2
	W852	78.4	71.0	68.9	66.5	63.7	61.0
	W853	76.4	71.5	70.2	68.2	65.8	63.5
	W854	75.1	70.3	68.3	66.1	63.5	61.0
	W855	74.3	70.4	68.8	66.7	64.3	62.3
	W856	72.8	70.1	68.3	66.3	63.9	61.8
	W857	72.9	71.4	70.2	68.3	66.2	64.2
	W858	73.1	70.6	69.2	67.3	65.1	62.9
	W859	73.5	69.8	67.7	65.4	62.7	60.0
	W860	73.5	70.2	68.3	66.0	63.4	61.1
	W861	74.4	71.5	70.1	67.4	64.3	60.3
Camp Run	W836	68.8	68.1	65.9	61.4	57.4	50.0
	W837	73.3	68.1	65.5	62.2	58.2	56.4
	W838	70.6	69.1	67.1	62.7	58.6	51.9
	W839	72.8	71.3	70.5	67.5	63.7	57.5
Connoquenessing Creek	W804	71.5	67.8	65.7	61.0	56.8	52.0
	W835	72.9	68.1	65.9	60.6	56.6	55.1
	W862	72.5	68.7	67.0	65.7	64.3	63.2
	W876	76.2	73.4	72.0	69.5	66.4	62.6
	W877	77.5	74.8	73.5	71.0	68.0	64.3
	W878	78.7	69.5	68.4	65.6	62.3	61.4
	W879	81.8	70.2	69.0	68.6	68.2	66.0
	W881	75.4	72.6	71.2	68.6	65.5	61.6
	W882	74.5	71.6	70.2	67.5	64.4	60.5
	W883	74.8	69.2	67.6	62.9	58.7	57.1
	W884	73.2	70.3	68.9	65.4	61.0	56.7
	W885	75.5	72.7	71.3	68.8	65.7	57.4
	W886	72.4	69.3	67.9	65.1	61.9	57.8
	W887	73.5	68.4	66.0	64.4	62.7	61.3
	W888	75.3	69.2	67.4	66.0	64.4	63.2
	W898	71.2	68.0	66.5	63.7	60.4	56.4
	W899	75.6	69.1	67.5	66.2	64.8	63.9
	W900	73.5	69.6	68.2	67.0	65.7	64.6
Crab Run	W817	72.6	70.1	68.8	65.6	61.7	55.3

Hydrologic Parameters for Lower Connoquenessing Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Crab Run	W818	69.1	68.7	67.0	63.6	59.3	52.6
	W819	70.9	69.2	67.5	63.5	59.3	53.2
	W820	73.6	69.5	67.7	63.1	58.9	55.6
	W821	67.1	69.7	68.5	64.9	61.5	53.5
Crooked Run	W866	73.7	68.4	66.3	61.0	56.9	55.0
	W867	75.8	68.4	66.5	63.4	59.6	58.4
Doe Run	W834	74.7	68.4	65.4	61.3	57.3	55.4
Duck Run	W864	73.6	70.8	69.6	68.5	67.2	66.1
	W865	72.2	69.1	67.6	64.9	61.6	57.6
Glade Run	W832	78.1	70.2	68.4	65.2	61.3	60.0
Hazen Run	W840	71.1	69.3	67.6	63.7	59.6	52.4
Little Connoquenessing Creek	W805	73.5	68.7	66.7	61.8	57.6	56.1
	W806	73.4	68.6	66.4	60.7	56.9	55.0
	W807	67.5	69.6	68.0	64.6	60.9	51.2
	W808	81.5	69.1	67.3	66.1	64.9	64.9
	W812	71.1	69.3	67.8	63.9	59.8	52.8
	W816	60.4	56.8	55.1	51.9	48.6	44.4
	W868	73.5	70.5	69.1	66.4	63.2	59.2
	W869	72.6	70.5	69.2	65.9	61.8	55.0
	W870	61.4	57.9	56.2	53.1	49.6	45.4
	W871	68.5	68.8	66.8	63.3	59.1	49.4
	W872	65.8	69.4	67.4	63.6	60.1	51.5
	W873	63.8	68.7	67.1	63.0	60.3	53.0
	W874	60.2	69.3	68.6	64.2	59.8	52.8
	W875	74.8	71.4	71.0	68.2	64.7	58.6
Little Yellow Creek	W823	71.0	68.7	66.2	61.1	57.1	52.4
	W824	64.0	69.0	67.6	63.3	60.5	57.4
Mulligan Run	W809	72.1	71.5	70.9	68.1	64.7	56.7
	W810	75.2	71.3	70.4	67.1	62.9	59.2
	W811	68.3	70.4	69.4	66.1	62.8	57.5
Muntz Run	W833	73.4	68.5	66.3	61.3	57.1	55.3
	W880	76.0	73.2	71.9	69.3	66.2	62.4
Scholars Run	W830	67.5	69.4	67.4	64.0	59.8	50.7
	W831	73.5	70.7	69.0	65.0	60.8	56.4
Semiconon Run	W813	75.6	72.8	71.4	68.7	65.7	61.8
	W814	73.8	70.5	69.0	65.6	61.2	56.8
	W815	68.7	70.8	69.6	66.3	63.0	55.4
Squaw Run	W863	73.0	69.7	68.2	66.8	65.4	64.4
Yellow Creek	W822	64.6	69.3	67.6	63.5	60.5	52.0
	W825	74.5	67.6	64.9	61.5	57.3	55.4
	W826	70.1	66.9	65.4	62.4	59.2	55.1
	W827	68.3	68.3	66.1	62.3	58.2	51.3
	W828	67.9	69.8	68.2	65.0	61.4	52.9
	W829	66.7	68.9	67.0	63.6	59.7	51.0

Hydrologic Results for Lower Connoquenessing Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
1	P198	1362496.3	578816.7	1.51	114	280	291	294	355	114	280	291	294	355
2	J4150	1346746.2	575337.0	4.45	300	713	871	909	843	304	721	880	919	854
3	J4117	1339481.6	573719.3	2.36	197	455	555	581	582	206	470	574	601	603
4	J4101	1328737.3	571887.9	3.51	248	602	713	727	606	248	601	712	727	606
5	J4026	1328432.1	562303.5	7.75	492	1,157	1,340	1,365	1,254	494	1,160	1,344	1,370	1,259
6	J4090	1315490.1	570209.1	3.14	197	456	487	495	462	202	464	497	506	472
7	P052	1315886.9	579732.4	2.48	165	398	491	494	592	167	401	495	498	597
8	J4147	1318237.2	576161.2	5.72	358	868	1,036	1,101	1,018	360	870	1,039	1,104	1,023
9	P240	1319763.4	569201.8	7.47	433	1,027	1,224	1,294	1,174	435	1,030	1,228	1,297	1,179
10	J4062	1318756.1	562883.4	14.49	809	1,867	2,173	2,296	2,096	815	1,877	2,186	2,309	2,111
11	J3883	1318450.9	542066.4	241.67	6,364	11,226	13,978	15,368	17,914	6,460	11,372	14,154	15,564	18,134
12	J3917	1317443.6	542096.9	242.88	6,376	11,249	14,003	15,395	17,942	6,472	11,395	14,180	15,591	18,162
13	J100	1309751.7	559129.1	3.23	206	484	590	598	375	206	483	589	598	375
14	J4126	1298763.3	575672.8	4.64	285	669	830	849	1,028	286	670	831	850	1,030
15	J4071	1296168.8	563493.9	10.14	570	1,288	1,523	1,561	1,589	571	1,289	1,525	1,563	1,591
16	J4518	1321991.6	489688.1	3.50	247	564	748	860	978	247	564	748	860	978
17	J4515	1317382.6	493381.4	6.23	453	975	1,278	1,482	1,697	453	975	1,278	1,482	1,697
18	J4523	1313170.3	500401.8	10.46	421	867	1,132	1,315	1,509	430	878	1,146	1,333	1,530
19	J4635	1312834.6	502294.3	16.59	830	1,887	2,451	2,791	3,125	920	2,038	2,637	3,001	3,361
20	J4576	1307523.5	511115.6	20.16	1,094	2,467	3,203	3,657	4,104	1,228	2,685	3,469	3,957	4,440
21	J4643	1306455.2	513099.6	24.90	1,158	2,594	3,373	3,848	4,321	1,283	2,804	3,632	4,140	4,649
22	J4692	1299953.7	517098.2	28.37	1,305	2,905	3,779	4,313	4,848	1,433	3,119	4,043	4,613	5,185
23	J4704	1298519.1	518960.1	31.81	1,316	2,898	3,765	4,296	4,831	1,432	3,088	3,998	4,560	5,127
24	J3836	1293391.1	520516.8	35.34	1,412	3,094	4,020	4,589	5,166	1,529	3,287	4,259	4,860	5,472
25	J4736	1288446.3	523752.3	39.40	1,493	3,241	4,209	4,804	5,410	1,609	3,432	4,443	5,071	5,711
26	J3845	1282982.6	528452.9	43.62	1,594	3,437	4,462	5,097	5,745	1,710	3,628	4,698	5,366	6,049
27	J3868	1280327.1	532878.8	45.19	1,520	3,345	4,357	4,984	5,626	1,619	3,511	4,562	5,219	5,891
28	J3871	1279838.7	538708.8	50.79	1,527	3,292	4,271	4,881	5,507	1,610	3,426	4,435	5,067	5,716
29	J3955	1276511.6	550796.1	56.15	1,606	3,443	4,466	5,104	5,762	1,690	3,577	4,629	5,290	5,971
30	J_BrushCreek	1277420.3	551047.9	56.21	1,597	3,416	4,429	5,061	5,713	1,679	3,547	4,587	5,242	5,916
31	J4153	1273367.7	571948.9	5.65	352	834	1,166	1,424	1,728	352	834	1,166	1,424	1,728
32	J4168	1356818.9	582388.0	2.85	208	504	521	535	652	208	504	521	535	653
33	J4156	1356361.1	574207.7	7.90	525	1,250	1,387	1,436	1,494	525	1,250	1,387	1,436	1,494
34	J4087	1354896.0	571155.3	9.69	593	1,384	1,575	1,663	1,768	596	1,386	1,578	1,666	1,772

Hydrologic Results for Lower Connoquenessing Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
35	J4096	1345128.4	566271.5	18.83	1,134	2,612	3,099	3,276	3,222	1,142	2,626	3,116	3,294	3,240
36	J4038	1343632.8	563432.9	20.79	1,207	2,768	3,292	3,480	3,389	1,215	2,782	3,309	3,498	3,408
37	J4044	1340855.2	560868.9	27.46	1,556	3,549	4,294	4,562	4,307	1,569	3,575	4,328	4,601	4,345
38	J3990	1332797.0	553482.2	32.04	1,085	2,343	2,792	2,966	2,781	1,094	2,358	2,810	2,985	2,801
39	J3999	1325990.2	553146.4	43.51	1,315	2,809	3,357	3,576	3,339	1,324	2,825	3,376	3,598	3,361
40	J3983	1317871.0	552322.3	62.15	1,762	4,053	4,762	5,032	4,314	1,770	4,068	4,781	5,053	4,335
41	J3920	1316009.0	542737.9	307.06	7,703	14,028	17,291	18,902	21,320	7,814	14,195	17,497	19,131	21,574
42	J3935	1308256.1	542799.0	315.26	7,588	13,766	16,967	18,550	20,839	7,693	13,923	17,158	18,763	21,075
43	J3895	1303555.4	539166.7	321.28	7,649	13,884	17,113	18,712	21,024	7,756	14,045	17,308	18,928	21,265
44	J3892	1301937.7	539258.3	323.41	7,636	13,856	17,075	18,670	20,970	7,742	14,015	17,268	18,884	21,208
45	J3909	1299221.1	544691.4	328.46	7,560	13,732	16,948	18,544	20,824	7,663	13,887	17,137	18,754	21,056
46	J3906	1295710.9	540998.1	330.88	7,569	13,742	16,957	18,554	20,830	7,671	13,896	17,144	18,762	21,061
47	J3932	1289911.4	546614.4	348.17	7,752	14,088	17,367	18,993	21,283	7,855	14,243	17,555	19,203	21,516
48	J3950	1282707.9	548934.2	355.23	7,632	13,839	17,045	18,639	20,822	7,729	13,985	17,222	18,835	21,039
49	USGS 03106000	1278678.8	550155.1	356.00	7,577	13,747	16,945	18,535	20,699	7,672	13,891	17,119	18,729	20,914
50	J3968	1277579.9	551131.9	412.67	8,434	15,480	19,174	21,069	23,496	8,544	15,649	19,379	21,297	23,751
51	J4014	1270590.1	557419.7	416.20	8,456	15,522	19,227	21,132	23,568	8,566	15,691	19,432	21,360	23,822
52	J4056	1275107.5	565661.1	830.07	14,257	26,487	33,417	37,361	41,546	14,352	26,633	33,597	37,564	41,772
53	J4076	1273184.6	568896.6	836.52	14,298	26,581	33,538	37,502	41,709	14,394	26,728	33,719	37,706	41,936
54	J4108	1268789.2	567706.2	838.54	14,287	26,592	33,552	37,518	41,728	14,383	26,738	33,733	37,722	41,955
55	J_ConnoquenessingOutlet	1257201.6	564306.8	841.43	14,293	26,630	33,602	37,577	41,797	14,390	26,777	33,783	37,781	42,024

Hydrologic Parameters for Breakneck Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Breakneck Creek	W532	1.37	67.0	50.5	67.0	50.5
	W533	2.14	74.5	59.3	74.6	59.2
	W539	1.43	72.5	57.4	73.2	56.4
	W542	2.46	70.2	71.1	70.2	71.1
	W543	2.71	76.2	63.2	76.2	63.2
	W544	3.17	74.6	87.1	74.7	86.8
	W545	3.68	76.7	77.1	76.7	77.1
	W546	1.15	75.8	49.6	76.0	49.3
	W547	3.38	76.0	67.1	76.0	67.0
	W548	1.53	76.9	43.4	77.2	43.0
	W549	0.01	71.2	11.6	71.2	11.6
	W550	2.22	72.8	56.4	73.6	55.2
Kaufman Run	W534	1.75	77.9	64.9	78.0	64.9
	W535	3.71	74.4	70.7	74.8	69.8
	W536	1.78	75.7	61.5	75.8	61.2
Likens Run	W540	2.28	75.6	48.3	76.0	47.8
	W541	1.34	71.3	50.2	71.3	50.2
Wolfe Run	W537	3.34	76.0	61.0	76.3	60.4
	W538	2.30	75.3	74.6	75.3	74.5

Hydrologic Parameters for Breakneck Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Breakneck Creek	W532	67.0	68.3	66.2	63.5	60.3	57.8
	W533	74.5	69.1	67.2	64.3	60.8	58.0
	W539	72.5	69.5	68.0	65.4	62.4	60.1
	W542	70.2	69.5	67.7	65.2	62.2	59.7
	W543	76.2	69.2	67.5	64.5	60.8	57.7
	W544	74.6	70.7	69.6	67.2	64.3	61.7
	W545	76.7	70.0	68.6	65.7	62.2	59.6
	W546	75.8	69.1	67.7	64.9	61.6	59.1
	W547	76.0	69.4	67.7	64.8	61.3	58.4
	W548	76.9	68.5	66.6	64.3	61.7	59.9
	W549	71.2	65.8	64.1	61.2	57.8	52.1
	W550	72.8	68.9	67.2	64.4	61.2	58.4
Kaufman Run	W534	77.9	70.1	69.0	66.3	63.1	60.4
	W535	74.4	69.2	67.1	64.2	60.6	57.8
	W536	75.7	69.7	68.5	65.7	62.5	60.1
Likens Run	W540	75.6	68.2	65.9	62.7	58.8	56.6
	W541	71.3	68.8	67.0	64.3	61.2	58.7
Wolfe Run	W537	76.0	68.7	66.6	63.4	59.6	57.1
	W538	75.3	70.5	69.4	67.0	64.2	61.8

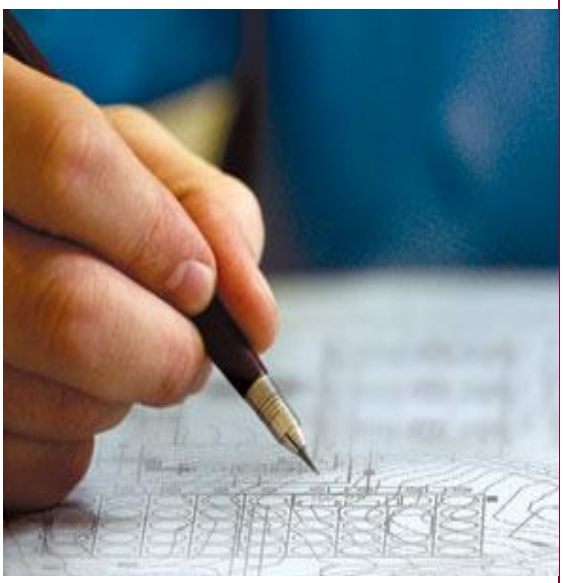
Hydrologic Parameters for Breakneck Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Breakneck Creek	W532	67.0	68.3	66.2	63.5	60.3	57.8
	W533	74.6	69.2	67.3	64.4	60.9	58.1
	W539	73.2	70.1	68.7	66.1	63.2	60.9
	W542	70.2	69.5	67.7	65.2	62.2	59.7
	W543	76.2	69.2	67.5	64.5	60.8	57.7
	W544	74.7	70.8	69.8	67.3	64.4	61.8
	W545	76.7	70.0	68.6	65.7	62.2	59.6
	W546	76.0	69.4	67.9	65.1	61.8	59.3
	W547	76.0	69.4	67.8	64.9	61.4	58.4
	W548	77.2	68.8	67.0	64.7	62.1	60.3
	W549	71.2	65.8	64.1	61.2	57.8	52.1
	W550	73.6	69.7	68.0	65.3	62.1	59.4
Kaufman Run	W534	78.0	70.1	69.0	66.3	63.1	60.4
	W535	74.8	69.7	67.7	64.7	61.2	58.4
	W536	75.8	69.9	68.7	66.0	62.7	60.3
Likens Run	W540	76.0	68.7	66.3	63.1	59.3	57.1
	W541	71.3	68.8	67.0	64.3	61.2	58.7
Wolfe Run	W537	76.3	69.0	66.9	63.8	60.0	57.5
	W538	75.3	70.6	69.5	67.1	64.3	61.8

Hydrologic Results for Breakneck Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
1	J4638	1333163.2	505712.9	5.46	359	856	1,082	1,163	1,289	376	887	1,120	1,205	1,336
2	J4699	1327119.6	515724.6	3.34	217	519	649	678	766	229	541	675	707	798
3	Dam_No. 2 Dam	1320007.6	530681.2	2.28	165	398	497	516	598	175	416	520	540	625
4	J4624	1345738.9	496647.5	3.83	244	585	759	840	948	244	585	759	840	948
5	J4512	1342442.4	504247.8	8.68	423	987	1,272	1,393	1,561	424	988	1,273	1,395	1,563
6	J4679	1338108.0	511329.3	19.09	977	2,345	3,009	3,278	3,662	995	2,381	3,052	3,326	3,715
7	J4724	1335605.1	521096.8	22.77	1,068	2,510	3,201	3,485	3,891	1,088	2,545	3,243	3,532	3,943
8	J4727	1334628.4	522043.0	29.56	1,211	2,838	3,621	3,943	4,418	1,234	2,878	3,670	3,998	4,479
9	P102	1329317.3	530192.8	32.94	1,221	2,792	3,545	3,860	4,320	1,241	2,829	3,589	3,909	4,375
10	J3865	1325746.0	532848.3	35.90	1,265	2,880	3,656	3,985	4,465	1,287	2,918	3,702	4,037	4,523
11	J3878	1325227.1	533336.7	39.53	1,299	2,934	3,735	4,075	4,573	1,321	2,973	3,782	4,128	4,632
12	J_BreakneckCreek_Outlet	1318684.1	541824.9	41.75	1,324	2,972	3,780	4,126	4,629	1,347	3,012	3,828	4,180	4,690

Appendix B – Supporting Calculations for the Design Example



The *Model Ordinance* has been developed to implement a variety of control standards in order to achieve a holistic approach to stormwater management. The overall design process has been addressed in *Section VIII* of this Plan. The following example calculations have been provided to further clarify the design method. These calculations parallel the calculations that are made on the worksheets provided in the *Pennsylvania Stormwater Best Management Practices Manual* (PA BMP Manual) a copy of which are provided at the back of this appendix.

SUPPORTING CALCULATIONS - DESIGN EXAMPLE 1

NON-STRUCTURAL BMP CREDITS

Protect Sensitive Natural Resources
(Refer to Worksheet 2 & Worksheet 3)

Stormwater Management Area = Total Drainage Area – Protected Area

= 9.78 – 1.31(woods) – 0.37 (minimum disturbance)
= **8.1-Acres**

This is the total area used for pre-development and post-development volume calculations.

Minimum Soil Compaction
(Refer to *Worksheet 3*)

Lawn Area (post development) protected from compaction = 16,165-ft^2

16,165-ft^2 x 1/4" x 1/12 = **337-ft^3**

To be eligible for this credit, areas must not be compacted during construction and be guaranteed to remain protected from compaction. Minimum soil compaction credits for lawn area (Open Space) are applicable for this example because specific measures were utilized to protect the back yard lawn areas of Lots 9 & 10 and this area has been placed in a permanent minimum soil compaction easement. Credits for the meadow area can be applied for areas that are not disturbed during construction and will remain in pre-development vegetated cover condition.

Disconnect Non-Roof Impervious to Vegetated Areas
(Refer to *Worksheet 3*)

Lot Impervious Area = 10 (Lots) x 1,000 (ft^2/lot) = 10,000-ft^2.
10,000-ft^2 x 1/3" x 1/12 = **278-ft^3**

This credit is applied for the impervious surfaces (driveways and sidewalks) which direct runoff to vegetated surfaces and not directly into a stormwater collection system. The 1/3" credit is used because runoff discharges across the lawn area and is received by rain gardens, which

are structures specifically placed to receive and infiltrate runoff. The 1/4" credit would be used for runoff not discharged to a specific infiltration structure or an area that has been protected from soil compaction.

Summation of Non-Structural BMP Credits
= 337-ft^3 + 278-ft^3 = **615-ft^3**

CHANGE IN RUNOFF VOLUME FOR THE 2-YEAR STORM EVENT

(Refer to *Worksheet 4*)

2-year, 24-hour Rainfall Depth = 2.76"

Pre-Development 2-yr Runoff Volume = 5,682 ft^3

Post-Development 2-yr Runoff Volume = 18,281 ft^3

Change in Runoff Volume for the 2-year, 24-hour storm event:

= 18,2813-ft^3 – 5,682-ft^3 = **12,599-ft^3**

This is the volume that must be managed through a combination of non-structural BMP credits and structural BMP credits.

25% LIMIT FOR NON-STRUCTURAL BMP CREDITS

(Refer to *Worksheet 5*)

*Per Chapter 8 of the Pennsylvania Stormwater BMP Manual, Non-Structural Credits may be **no greater than 25%** of the total required control volume.*

Check 25% Non-Structural Credit Limit:

= 615-ft^3 / 12,599-ft^3 = **4.9%**

Calculated credits are under the allowable 25% limit for non-structural credits.

STRUCTURAL CONTROL VOLUME REQUIREMENT

(Refer to *Worksheet 5*)

Required Structural BMP infiltration volume:

= Change in Runoff Volume – Non-Structural BMP Credits
= 12,599-ft^3 – 615-ft^3 = **11,984-ft^3**

STRUCTURAL BMP VOLUME CREDITS

The sizing of structural infiltration BMPs is based on two primary criteria:

1. Maximum loading ratios – There are two different loading ratios that are important when determining the size of a structural BMP. These ratios are derived from guidelines found in the *Pennsylvania Stormwater BMP Manual*.
    a. Maximum loading ratio of Impervious Area to Infiltration Area = 5:1
    b. Maximum loading ratio of Total Drainage Area to Infiltration Area = 8:1

2. Expected runoff volume loading – Structural BMPs must be sized to accommodate the runoff volume they are expected to receive from the contributing drainage area. Some of this volume will be removed and the remainder must be safely conveyed through an overflow device. The removed volume, or infiltration volume, is the important component for sizing the infiltration BMP. A good starting point for infiltration volume is to calculate the contributing area runoff volume for the 2-year, 24-hour design storm. This volume may not be suitable for a particular site design, but starting with this volume will usually result in a design that is close to what is appropriate, and it can be adjusted as necessary. Additional design restrictions may exist for certain BMPs, so these should be considered prior to using this sizing method.

Dry Wells
(Example calculations shown for Lot #1; Refer to *Worksheet 5A* for additional calculations)

Surface Area:
Find the minimum dry well surface area for each lot based on the maximum loading ratios.

Maximum impervious area to infiltration area loading ratio = 5:1 (3:1 for Karst areas)
Tributary impervious area = 2,150-ft^2 (typ.)
= 2,150-ft^2 / 5 = **430-ft^2**
= minimum surface area of dry well per impervious loading ratio

Maximum total drainage area to infiltration area loading ratio = 8:1
Total drainage area = 2,590-ft^2 (typ.)
= 2,590-ft^2 / 8 = **324-ft^2**
= minimum surface area of dry well per pervious loading ratio

The larger of the two calculated areas is the total minimum surface area required for each lot. An individual dry well is placed at each of the four major corners of the house to promote distribution of impervious area runoff. However, the total surface area is used throughout the remaining volume credit calculations for simplicity. The surface area of each dry well is calculated below:

Total Minimum Dry Well Surface Area ÷ Number of Dry Wells
=430 ft^2 / 4 = **107.5-ft^2**

Each dry well will be 10' x 11' to meet the minimum surface area requirements.

Volume:
Find the infiltration volume for each dry well based on the expected runoff volume.

Land Use	Soil Type	Area	Area	CN	S	I_a	Runoff Depth$_{2\text{-yr}}$	Runoff Volume$_{2\text{-yr}}$
	(HSG)	(sf)	(acres)			(0.2*S)	(in)	(ft^3)
Open Space (good)	B	110	0.00	61	6.393	1.279	0.28	3
Impervious	B	540	0.01	98	0.204	0.041	2.53	114
TOTAL:		**650**	**0.01**				**2.81**	**116**

Runoff volume = **116-ft^3**

Depth:
Each dry well will be filled with aggregate. The in-place aggregate will have a 40% voids ratio; therefore the volume is divided by the available void space to get a total volume.

Depth = Total Volume / Surface Area

= (116-ft^3 / 0.40) / 110-ft^2 = **2.64-ft or approximately 2'-8"**

An overflow spillway or drain is then sized to convey any runoff that exceeds the design volume to the peak rate management facility.

Rain Gardens
(Example calculations shown for Lot #1; Refer to Worksheet 5A for additional calculations)

Surface Area:
Find the minimum surface area for each rain garden based on the maximum loading ratios.

Maximum impervious area to infiltration area loading ratio = 5:1 (3:1 for Karst areas)
Tributary impervious area = 1,000-ft^2
= 1,000-ft^2 / 5 = **200-ft^2**
= minimum surface area of rain garden per impervious loading ratio

Maximum total drainage area to infiltration area loading ratio = 8:1
Total drainage area = 6,000-ft^2 (typ.)
= 4,775-ft^2 / 8 = **597-ft^2**
= minimum surface area of rain garden per pervious loading ratio

The larger of the two calculated areas is the minimum surface area required for the facility.

Minimum Rain Garden Surface Area = **597-ft^2**

Depth:
Design guidelines, from the *PA BMP Manual*, for rain gardens limit ponding depth within the facility to 12 inches or less. The rain gardens in this example have been designed with a total ponding depth of 12 inches. The overflow outlets are positioned 6 inches above the bottom elevation of the rain gardens and 6 inches of freeboard is provided above the overflow outlets.

Volume:
The total detention volume of the rain garden is calculated by multiplying the surface area of the rain garden by the total depth. The 6 inches of water below the overflow outlet will be infiltrated and the remaining depth is used as short-term retention while flow is regulated through the overflow device. When calculating the infiltration volume, the bottom surface area of the BMP must be used.

Infiltration Volume = Surface Area x Depth
= 700-ft^2 x 0.5-ft = **350-ft^3**

Bioretention
(Refer to *Worksheet 5A* for additional calculations)

Surface Area:
Find the minimum surface area for the bioretention facility based on the maximum loading ratios.

Maximum impervious area to infiltration area loading ratio = 5:1 (3:1 for Karst areas)
Tributary impervious area = 9,700-ft^2 (typ.)
= 9,700-ft^2 / 5 = **1,940-ft^2**
= minimum surface area of Infiltration Trench per impervious loading ratio

Maximum total drainage area to infiltration area loading ratio = 8:1
Total drainage area = 41,400-ft^2
= 41,400-ft^2 / 8 = **5,175-ft^2**
= minimum surface area of Infiltration Trench per pervious loading ratio

The larger of the two calculated areas is the minimum surface area required for the facility.

Minimum Infiltration Trench Surface Area = **5,175-ft^2**

Depth:
The bioretention facility in this example has been designed with a total depth of 18 inches. The overflow outlets are positioned 6 inches above the bottom elevation, and 12 inches of freeboard is provided above the overflow outlets.

Volume:
The total detention volume of the bioretention facility is calculated by multiplying the surface area by the total depth. The 6 inches of water below the overflow outlet will be infiltrated and the remaining depth is used as short-term retention while flow is regulated through the overflow device. When calculating the infiltration volume, the bottom surface area of the BMP must be used.

Infiltration Volume = Surface Area x Depth
= 5,175-ft^2 x 0.5-ft = **2,487.5-ft^3**

STRUCTURAL CONTROL VOLUME REQUIREMENT CHECK

(Refer to *Worksheet 5*)

Check the total structural volume to be certain it is adequate to meet the structural volume requirement.

= Total Structural Volume - Structural Volume Requirement
=14,613-ft^3 – 11,984-ft^3 = 2,629-ft^3

The structural volume requirement has been exceeded by 2,629-ft^3 and no further BMP calculations are necessary.

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Project Name: DESIGN EXAMPLE 1
Project ID: MILL RUN RESIDENTIAL
Owner:
Calculated: Date:
Checked: Date:

WORKSHEET 1. GENERAL SITE INFORMATION

INSTRUCTIONS: Fill out *Worksheet 1* for each watershed

Date: 2/29/2010

Project Name: DESIGN EXAMPLE 1

Municipality: ADAMS TOWNSHIP

County: BUTLER

Total Area (acres): 9.78

Major River Basin: OHIO RIVER BASIN
http://www.dep.state.pa.us/dep/deputate/watermgt/wc/default.htm#newtopics

Watershed: BREAKNECK CREEK

Sub-Basin: BEAVER RIVER (from Ohio state line to confluence with Ohio River)

Nearest Surface Water(s) to Receive Runoff: MILL RUN

Chapter 93 - Designated Water Use: CWF
http://www.pacode.com/secure/data/025/chapter93/chap93toc.html

Impaired according to Chapter 303(d) List?
http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/303d-Report.htm
Yes [ ]
No [X]

List Causes of Impairment:

Is project subject to, or part of:

Municipal Separate Storm Sewer System (MS4) Requirements?
http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/GeneralPermits/default.htm
Yes [ ]
No [X]

Existing or planned drinking water supply?
Yes [ ]
No [X]

If yes, distance from proposed discharge (miles): _____

Approved Act 167 Plan?
http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/Approved_1.html
Yes [X]
No [ ]

Existing River Conservation Plan?
http://www.dcnr.state.pa.us/brc/rivers/riversconservation/planningprojects/
Yes [ ]
No [X]

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Project Name: DESIGN EXAMPLE 1
Project ID: MILL RUN RESIDENTIAL
Owner:
Calculated: Date:
Checked: Date:

WORKSHEET 2. SENSITIVE NATURAL RESOURCES

INSTRUCTIONS:

1. Provide Sensitive Resources Map according to non-structural BMP 5.4.1 in Chapter 5 of PA Stormwater BMP Manual. This map should identify waterbodies, floodplains, riparian areas, wetlands, woodlands, natural drainage ways, steep slopes, and other sensitive natural areas.

2. Summarize the existing extent of each sensitive resource in the Existing Sensitive Resources Table (below, using Acres). If none present, insert 0.

3. Summarize Total Protected Area as defined under BMPs in Chapter 5.

4. Do not count any area twice. For example, an area that is both a floodplain and a wetland may only be considered once.

EXISTING NATURAL SENSITIVE RESOURCE	MAPPED? yes/no/n/a	TOTAL AREA (Ac.)	PROTECTED AREA (Ac.)
Waterbodies	yes	0.00	
Floodplains	no	0.00	
Riparian Areas	no	0.00	
Wetlands	no	0.00	
Woodlands	yes	2.29	1.31
Natural Drainage Ways	N/A	0.00	
Steep Slopes, 15% - 25%	N/A	0.00	
Steep Slopes, over 25%	N/A	0.00	
Other:	N/A		
Other:	N/A		
TOTAL EXISTING:		**2.29**	**1.31**

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Project Name: DESIGN EXAMPLE 1
Project ID: MILL RUN RESIDENTIAL
Owner:
Calculated: Date:
Checked: Date:

WORKSHEET 3. NON-STRUCTURAL BMP CREDITS

PROTECTED AREA

1.1 Area of Protected Sensitive/Special Value Features (see WS 2)	1.31	Ac.
1.2 Area of Riparian Forest Buffer Protection	0.00	Ac.
3.1 Area of Minimum Disturbance/Reduced Grading	0.37	Ac.
TOTAL	1.68	Ac.

Site Area	*minus*	Protected Area	=	Stormwater Management Area
9.78	-	1.68	=	8.10

VOLUME CREDITS

3.1 Minimum Soil Compaction

Lawn	16,165	ft^2	x 1/4"	x 1/12	=	337 ft^3
Meadow	N/A	ft^2	x 1/3"	x 1/12	=	0 ft^3

3.3 Protect Existing Trees

For Trees within 100 feet of impervious area:

Tree Canopy	N/A	ft^2	x 1/2"	x 1/12	=	0 ft^3

For Trees within 20 feet of impervious area:

Tree Canopy	N/A	ft^2	x 1"	x 1/12	=	0 ft^3

5.1 Disconnect Roof Leaders to Vegetated Areas

For runoff directed to areas protected under 5.8.1 and 5.8.2

Roof Area	N/A	ft^2	x 1/3"	x 1/12	=	0 ft^3

For all other disconnected roof areas

Roof Area	N/A	ft^2	x 1/4"	x 1/12	=	0 ft^3

5.2 Disconnect Non-Roof Impervious to Vegetated Areas

For Runoff directed to areas protected under 5.8.1 and 5.8.2

Impervious Area	10,000	ft^2	x 1/3"	x 1/12	=	278 ft^3

For all other disconnected non-roof impervious areas

Impervious Area	N/A	ft^2	x 1/4"	x 1/12	=	0 ft^3

TOTAL NON-STRUCTURAL VOLUME CREDIT* 615 ft^3

** For use on Worksheet 5*

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Project Name: DESIGN EXAMPLE 1
Project ID: MILL RUN RESIDENTIAL
Owner:
Calculated: Date:
Checked: Date:

WORKSHEET 4. CHANGE IN RUNOFF VOLUME FOR 2-YR STORM EVENT

PROJECT: DESIGN EXAMPLE 1
Drainage Area: 8.10 (acres)
2-Year Rainfall: 2.76 inches *(From NOAA Atlas 14)*

Total Site Area: 9.78 acres
Protected Site Area: 1.68 acres
Stormwater Management Area: 8.10 acres *(From Worksheet 3)*

Existing Conditions:

Land Use	Soil Type (HSG)	Area (sf)	Area (acres)	CN	S	Ia (0.2*S)	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Woods (good)	B	42,500	0.98	55	8.1818	1.6364	0.14	481
Meadow	B	310,255	7.12	58	7.2414	1.4483	0.20	5,201
								-
								-
								-
								-
TOTAL:		352,755	8.10					5,682

Developed Conditions:

Land Use	Soil Type (HSG)	Area (sf)	Area (acres)	CN	S	Ia (0.2*S)	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Meadow	B	54,060	1.24	58	7.2414	1.4483	0.20	906
Open Space (good)	B	243,035	5.58	61	6.3934	1.2787	0.28	5,643
Impervious	B	55,660	1.28	98	0.2041	0.0408	2.53	11,732
								-
								-
								-
TOTAL:		352,755	8.10					18,281

2-Year Volume Increase (ft^3): 12,599

2-Year Volume Increase = Developed Conditions Runoff Volume - Existing Conditions Runoff Volume
= 18,281 - 5,682 = 12,599 ft^3

1. Runoff (in) = $Q = (P - 0.2S)^2 / (P + 0.8S)$ where
   P = 2-Year Rainfall (in)
   S = (1000/ CN)-10

2. Runoff Volume (CF) = Q x Area x 1/12
   Q = Runoff (in)
   Area = Land use area (sq. ft)

Note: Runoff Volume must be calculated for EACH land use type/condition and HSG. The use of a weighted CN value for volume calculations is not acceptable.

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Project Name: DESIGN EXAMPLE 1
Project ID: MILL RUN RESIDENTIAL
Owner:
Calculated: Date:
Checked: Date:

WORKSHEET 5. STRUCTURAL BMP VOLUME CREDITS

SUB-BASIN: N/A

Check 25% Limit for Non-Structural BMP Credits:		615
	÷	12,599
		4.9%
Required Control Volume (ft^3):		12,599
Allowable Non-structural Volume Credit (ft^3):	-	615
Structural Volume Reqmt (ft^3):		**11,984**

(Required Control Volume minus Non-structural Credit)

Proposed BMP		Area (ft^2)	Infiltration Volume (ft^3)
6.4.1	Porous Pavement		
6.4.2	Infiltration Basin		
6.4.3	Infiltration Bed		
6.4.4	Infiltration Trench		
6.4.5	Rain Garden/Bioretention	11,915	8,827
6.4.6	Dry Well / Seepage Pit	4,400	5,787
6.4.7	Constructed Filter		
6.4.8	Vegetated Swale		
6.4.9	Vegetated Filter Strip		
6.4.10	Berm		
6.5.1	Vegetated Roof		
6.5.2	Capture and Re-use		
6.6.1	Constructed Wetlands		
6.6.2	Wet Pond / Retention Basin		
6.6.3	Dry Extended Detention Basin		
6.6.4	Water Quality Filters		
6.7.1	Riparian Buffer Restoration		
6.7.2	Landscape Restoration / Reforestation		
6.7.3	Soil Amendment		
6.8.1	Level Spreader		
6.8.2	Special Storage Areas		
Other			

Total Structural Volume (ft^3):	14,613
Structural Volume Requirement (ft^3):	11,984
DIFFERENCE:	2,629 *(excess)*

* Complete BMP Design Checklist for each measure proposed
NOTE: Provide supporting Volume Calculations for each Structural BMP

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Project Name: DESIGN EXAMPLE 1
Project ID: MILL RUN RESIDENTIAL
Owner:
Calculated: Date:
Checked: Date:

WORKSHEET 5.A - INFILTRATION BMP SUPPORTING CALCULATIONS

Instructions: Complete this worksheet for each Point of Interest / Discharge (at a minimum)

Point of Interest / Discharge: *Basin Outfall*
Total Drainage Area to POI: 362,755 ft²
Total Impervious Area: 55,660 ft²

Proposed Infiltration BMP(s)	Infiltration Rate			Design Runoff Volume cu. ft.	Infiltration Period			Hydraulic Loading: Imperv. Drainage Area Loading				Hydraulic Loading: Total Drainage Area Loading				Target BMP Area[6] sq. ft.	Actual BMP Area[6] sq. ft.	Computed Infiltration Volume cu. ft.
	Measured Infilt Rate[1] in/hr	FOS	Design Infilt Rate in/hr		Infilt. Period[2] hrs	Active Infilt.[3] hrs	Total Infilt Period hrs	Imperv. DA sq. ft.	% area draining to BMP	Imperv Area Loading Ratio	Imperv Target Area sq. ft.	Total Drainage Area sq. ft.	% area draining to BMP[4]	Total Area Loading Ratio	Total Target Area sq. ft.			
BMP 6.4.1 Porous Pavement w. Infilt. Bed						Subtotal:				5				8				
BMP 6.4.2 Infiltration Basin						Subtotal:				5				8				
BMP 6.4.3 Subsurface Infiltration Bed						Subtotal:				5				8				
BMP 6.4.4 Infiltration Trench						Subtotal:				5				8				
BMP 6.4.5 Rain Garden/Bioretention						Subtotal:		19,700		5		59,585		8			11,915	5,527
Rain Garden (Lot #1)	0.93	2	0.47	350	12.9	6	18.9	1,000	100.0		200	4,775	100.0		597	597	700	513
Rain Garden (Lot #2)	0.95	2	0.48	350	12.6	6	18.6	1,000	100.0		200	5,600	100.0		700	700	700	516
Rain Garden (Lot #3)	0.98	2	0.49	350	12.2	6	18.2	1,000	100.0		200	5,080	100.0		635	635	700	522
Rain Garden (Lot #4)	1.01	2	0.51	300	11.9	6	17.9	1,000	100.0		200	3,625	100.0		453	453	600	452
Rain Garden (Lot #5)	1.02	2	0.51	458	11.8	6	17.8	1,000	100.0		200	7,005	100.0		876	876	915	691
Rain Garden (Lot #6)	1.08	2	0.54	350	11.1	6	17.1	1,000	100.0		200	5,310	100.0		664	664	700	539
Rain Garden (Lot #7)	0.91	2	0.46	300	13.2	6	19.2	1,000	100.0		200	4,395	100.0		549	549	600	437
Rain Garden (Lot #8)	0.99	2	0.50	238	12.1	6	18.1	1,000	100.0		200	3,000	100.0		375	375	475	355
Rain Garden (Lot #9)	1.05	2	0.53	300	11.4	6	17.4	1,000	100.0		200	4,520	100.0		565	565	600	458
Rain Garden (Lot #10)	1.03	2	0.52	375	11.7	6	17.7	1,000	100.0		200	4,975	100.0		622	622	750	568
Bioretention 1	0.92	2	0.46	2588	13.0	6	19.0	9,700	100.0		1,940	41,400	100.0		5,175	5,175	5,175	3,778
BMP 6.4.6 Dry Well / Seepage Pit						Subtotal:		21,500		5		25,900		8			4,400	5,787
Dry Well (Lot #1)	0.98	2	0.49	468	26.0	6	32.0	2,150	100.0		430	2,590	100.0		324	430	440	576
Dry Well (Lot #2)	0.91	2	0.46	468	28.1	6	34.1	2,150	100.0		430	2,590	100.0		324	430	440	568
Dry Well (Lot #3)	1.06	2	0.53	468	24.1	6	30.1	2,150	100.0		430	2,590	100.0		324	430	440	585
Dry Well (Lot #4)	1.02	2	0.51	468	25.0	6	31.0	2,150	100.0		430	2,590	100.0		324	430	440	580
Dry Well (Lot #5)	0.93	2	0.47	468	27.4	6	33.4	2,150	100.0		430	2,590	100.0		324	430	440	570
Dry Well (Lot #6)	1.07	2	0.54	468	23.9	6	29.9	2,150	100.0		430	2,590	100.0		324	430	440	586
Dry Well (Lot #7)	0.97	2	0.49	468	26.3	6	32.3	2,150	100.0		430	2,590	100.0		324	430	440	575
Dry Well (Lot #8)	1.01	2	0.51	468	25.3	6	31.3	2,150	100.0		430	2,590	100.0		324	430	440	579
Dry Well (Lot #9)	1.04	2	0.52	468	24.5	6	30.5	2,150	100.0		430	2,590	100.0		324	430	440	582
Dry Well (Lot #10)	1.07	2	0.54	468	23.9	6	29.9	2,150	100.0		430	2,590	100.0		324	430	440	586
BMP 6.4.7 Constructed Filter[7]										5				8				
BMP 6.4.8 Vegetated Swale[7]										5				8				
BMP 6.4.9 Vegetated Filter Strip[7]										5				8				
BMP 6.4.10 Infilt. Berm & Ret. Grading										5				8				
																	TOTAL:	14,613

[1] Assumes a soil testing procedure which finds hydraulic conductivity. (e.g. perc tests may also require a reduction factor)
[2] Time it takes for BMP to empty once it is full. (Minimum = 24 hrs, Maximum = 72 hours; Applicable to retention and detention facilities only.)
[3] Infiltration that occurs during the storm (before becoming full). Not to exceed 6 hours.
[4] A portion of the total area draining to BMP from non-pervious area may be diverted.
[5] Inherent in these calculations are the allowable loading ratios (5:1 and 8:1) from the BMP Manual. Higher loading ratios will need to be justified. In Karst Areas, the max. loading ratio should be 3:1.

PEAK RATE CONTROL ANALYSIS

According to the National Engineering Handbook (NRCS, 2008), the direct runoff for watersheds having more than one hydrologic soil-cover complex can be estimated in either of two ways. Runoff can be estimated for each complex and then weighted to get the watershed average. Alternatively, the CN values can be weighted, based on area, to obtain a single CN value to represent the entire drainage area. Then runoff is estimated with the single CN value. If the CN for the various hydrologic soil-cover complexes are close in value, both methods of weighting give similar results for runoff. However, if there exists a large difference in curve number value, the CN weighting method can provide drastically different results.

As described in the *National Engineering Handbook*, "the method of weighted runoff always gives the correct result (in terms of the given data), but it requires more work than the weighted CN method, especially when a watershed has many complexes. The method of weighted CN is easier to use with many complexes or with a series of storms. However, where differences in CN for a watershed are large, this method either under- or over-estimates runoff, depending on the size of the storm." This often occurs when impervious area exists in a subarea. When the relatively low curve number of lawn areas is combined with the high curve number of impervious areas, the weighted CN method will minimize the impact of the impervious surface and under-estimate the amount of runoff.

The spatial distribution of the different soil-cover complexes becomes the controlling factor in selection of the appropriate method. When different land uses behave as independent watershed the areas should be analyzed as separate drainage subareas. For example, when a large parking area is surrounded by lawn area that all flows to the same collection point, runoff from the impervious surface will occur much differently than runoff from the lawn. However, when impervious area is dispersed amongst other land uses and not directly connected to a stormwater collection system, the weighted CN method may be appropriate. The decision of whether or not to use a weighted curve number is often a site specific judgment that should be discussed between the designer and the Municipal Engineer in the early planning stages of a project.

Pre-Development Soil-Cover Complex Data

Because the wooded area along the north property line will remain unchanged, and will not be tributary to the stormwater facilities, this area has been removed from the peak rate analysis drainage areas. The weighted CN method was used for pre-development calculations in this example because Curve Numbers for the hydrologic soil-cover complexes are close in value. The drainage area and land cover information necessary to calculate the pre-development runoff is shown in the table below:

Land Use	Soil Type (HSG)	Area (ft^2)	Area (acres)	CN
Woods (good)	B	42,500	0.98	55
Meadow	B	310,255	7.12	58
TOTAL:		352,755	8.10	58

Pre-Development Time of Concentration

The *Model Ordinance* requires use of the NRCS Lag Equation for all pre-development time of concentration calculations unless another method is pre-approved by the Municipal Engineer.

$$T_{lag} = L^{0.8} \frac{(S+1)^{0.7}}{1900\sqrt{Y}}$$

Where:

T_{lag} = Lag time (hours)
L = Hydraulic length of the watershed (feet)
Y = Average overland slope of watershed (percent)
S = Maximum retention in the watershed, as defined by: S = [(1000/CN) – 10]
CN = NRCS Curve Number for the watershed

Lag time is related to time of concentration by the following equation:

Time of Concentration = T_c = [(T_{lag}/.6) * 60] (minutes)

One method of calculating the average overland slope of a watershed is to select locations that represent the various slopes found in the watershed and weight the slope based on the area it represents. This method is shown in the table on the following page.

Slope	End Elevation		Distance	Slope	Percent of	Product
Line	High	Low	(ft)	(%)	Total Area	(% x %)
AA	909	902	148	4.7%	5%	0.24%
BB	941	909	475	6.7%	50%	3.37%
CC	956	942	245	5.7%	15%	0.86%
DD	960	943	180	9.4%	15%	1.42%
EE	943	930	265	4.9%	15%	0.74%
					Sum of Products =	6.61%

This is an estimation of the land slope value, so the calculated number is rounded to the nearest whole number for use in the Lag Equation. The hydraulic length of the watershed was measured at 1050 ft. Therefore,

$$T_{lag} = (1050)^{0.8} \frac{((1000/CN)-10)+1)^{0.7}}{1900\sqrt{7}}$$

T_{lag} = 0.23 hours

Time of Concentration = T_C = (T_{lag} / 0.6) * 60
= (0.23 / 0.6) * 60
= 23 minutes

Pre-Development Peak Rate Flows

All of this information was used to perform a pre-development peak rate analysis using a software package based on the NRCS TR-20 procedures. The results of the analysis are as follows:

	1-year	2-year	10-year	25-year	50-year	100-year
Peak Runoff Flows (cfs)	0.1	0.6	4.1	7.6	11.1	15.3
Runoff Volume (ac-ft)	0.060	0.136	0.449	0.726	0.997	1.322
Runoff Depth (in)	0.09	0.20	0.66	1.08	1.48	1.96

Table B.1. Pre-Development Runoff Summary

Post-Development Soil-Cover Complex Data

Due to the disconnection of impervious areas and overland flow paths used in this design, the area weighted CN method was deemed appropriate and used to reduce the complexity of the model. The drainage area and land cover information for the drainage sub-area directly tributary to the bioretention facility is shown in the table below:

Land Use	Soil Type (HSG)	Area (ft^2)	Area (acres)	CN
Lawn (good condition)	B	9,700	0.22	61
Impervious	B	31,700	0.73	98
TOTAL:		41,400	0.95	70

Post-Development Time of Concentration

The Segmental Method was used for all post-development time of concentration calculations in this example. This method is covered in more detail in various NRCS publications (NRCS, 1986; NRCS, 2008). The following segments were used to calculate a time of concentration for the drainage sub-area directly tributary to the bioretention facility:

T_t-*1*: Sheet flow, 100' of lawn at 5% = 10.7 min
T_t-*2*: Shallow concentrated flow, 110' unpaved at 5.9% = 0.5 min
T_t-*3*: Channel flow, 80' at 4.0% = 0.2 min
T_t-*4*: Channel flow, 156' at 3.85% = 0.5 min
T_t-*5*: Pipe flow, 38' of 15" HDPE pipe at 5.2% = 0.1 min

$T_c = T_t\text{-}1 + T_t\text{-}2 + T_t\text{-}3 + T_t\text{-}4 + T_t\text{-}5$ = 12 minutes

Post-Development Peak Rate Flows

The hydrologic model for this example contains a considerable level of detail. Each structural BMP was modeled as a pond with a unique drainage area and time of concentration. Runoff was routed through each BMP and linked to downstream BMPs for subsequent routing. A detention basin with an outlet control structure was also added to the model. A graphical representation of the model is provided in *Figure B.1*.

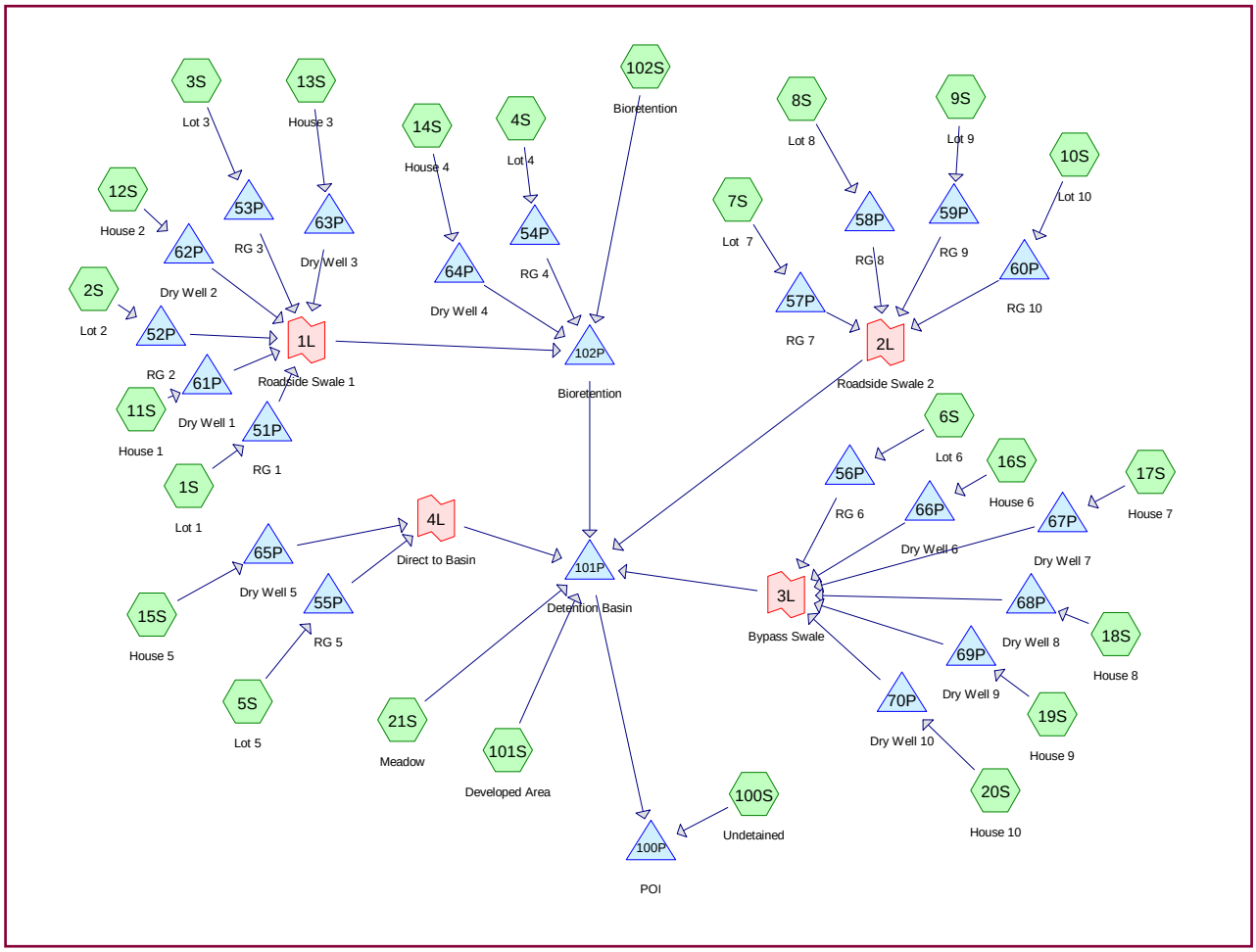


Figure B.1. Hydrologic Model of Post-Development Conditions

This model was used to estimate the post-development peak rate flows. The final configuration of the outlet structure was completed through an iterative process using the results of the model runs. This design meets the peak rate control requirements through a combination of volume removed by the structural `BMPs and the detention basin and outlet control structure. *Table B.2* shows a summary of the runoff results for the final post-development design:

	1-year	2-year	10-year	25-year	50-year	100-year
Peak Runoff Flows (cfs)	0.1	0.4	4.1	7.4	10.6	15.2
Runoff Volume (ac-ft)	0.079	0.147	0.445	0.717	1.011	1.367
Runoff Depth (in)	0.12	0.22	0.66	1.06	1.50	2.03

Table B.2. Summary of Post-Development Runoff with Stormwater Controls

INITIAL CONSTRUCTION COST - DESIGN EXAMPLE

Initial construction costs were estimated for each layout. The estimates include the costs incurred by the developer to complete earthwork, paving and curbing, and stormwater management facilities. All of these costs are summed to determine an initial construction cost for these facilities. This cost was then divided by the total sellable acreage of the project to determine a cost/sellable acre for each layout.

Estimate of Initial Construction Cost
Mill Run Residential – Traditional Layout

ITEM NO.	ITEM & DESCRIPTION	EST.	UNIT	UNIT PRICE	EXTENSION
EARTHWORK				**Subtotal =**	**$ 23,950**
1	Clearing & Grubbing	2.3	AC	$ 6,000.00	$ 13,800
2	Topsoil Removal/Stockpiling	5.8	AC	$ 1,750.00	$ 10,150
STORM DRAINAGE				**Subtotal =**	**$ 102,769**
3	Storm Sewer, 18" HDPE	600	LF	$ 55.00	$ 33,000
4	Storm Inlets	7	EA	$ 2,100.00	$ 14,700
5	Swales	490	LF	$ 10.00	$ 4,900
6	Install Detention Basin	1,525	CY	$ 25.00	$ 38,125
7	Anti Seep Collars	2	EA	$ 775.00	$ 1,550
8	Outlet Structure	1	EA	$ 4,000.00	$ 4,000
9	Outlet Pipe, 18" HDPE	50	LF	$ 55.00	$ 2,750
10	DW Endwall 24"	1	EA	$ 2,750.00	$ 2,750
11	Rip Rap Apron	144	SF	$ 6.90	$ 994
PAVING & CURBING				**Subtotal =**	**$ 138,657**
12	Paving - Final Subgrade, 6" Stone, 3" 19MM, 1-1/2" 9.5mm	2,325	SY	$ 30.00	$ 69,750
13	Curbing w/Excavation & Backfill	1,465	LF	$ 27.00	$ 39,555
14	Sidewalk plain w/4" - stone	4,285	SF	$ 6.85	$ 29,352
				Initial Construction Cost =	**$ 265,376**
				Cost / Sellable Acre =	**$ 42,734**

Table B.3. Estimate of Construction Cost for Residential Design Example (Traditional Layout)

Estimate of Initial Construction Cost *Mill Run Residential – LID Layout*					
ITEM NO.	ITEM & DESCRIPTION	EST.	UNIT	UNIT PRICE	EXTENSION
EARTHWORK				**Subtotal =**	**$ 14,925**
1	Clearing & Grubbing	1.0	AC	$ 6,000.00	$ 6,000
2	Topsoil Removal/Stockpiling	5.1	AC	$ 1,750.00	$ 8,925
STORM DRAINAGE				**Subtotal =**	**$ 114,172**
3	Swales	1,620	LF	$ 10.00	$ 16,200
4	Storm Sewer, 18" HDPE	136	LF	$ 55.00	$ 7,480
5	DW Headwall 18"	1	EA	$ 2,750.00	$ 2,750
6	Storm Inlets	1	EA	$ 2,100.00	$ 2,100
7	Install Detention Basin	600	CY	$ 25.00	$ 15,000
8	Anti Seep Collars	2	EA	$ 775.00	$ 1,550
9	Outlet Structure	1	EA	$ 4,000.00	$ 4,000
10	Outlet Pipe, 18" HDPE	50	LF	$ 55.00	$ 2,750
11	Level Spreader	44	LF	$ 5.50	$ 242
12	Bioretention Area	5,175	SF	$ 12.00	$ 62,100
PAVING & CURBING				**Subtotal =**	**$ 53,790**
13	Paving - Final Subgrade, 6" Stone, 3" 19MM, 1-1/2" 9.5mm	1,645	SY	$ 30.00	$ 49,350
14	Gravel Shoulder	370	SY	$ 12.00	$ 4,440
				Initial Construction Cost =	**$ 182,887**
				Cost / Sellable Acre =	**$ 28,355**

Table B.4. Estimate of Construction Cost for Residential Design Example (LID Layout)

The cost of constructing the stormwater BMPs on each individual lot was not included in the comparison of initial construction costs. This is a cost that will be borne by the owner of each individual lot. This must be included in the cost comparison analysis. *Table B.5* shows an estimate of these costs.

Estimate of Stormwater BMP Construction Cost *Mill Run Residential – LID Layout*					
ITEM NO.	ITEM & DESCRIPTION	EST.	UNIT	UNIT PRICE	EXTENSION
STORMWATER BMPS					
1	Rain Gardens	6,740	SF	$ 10.00	$ 67,400
2	Dry Wells	450	CY	$ 32.00	$ 14,400
				Construction Cost =	**$ 81,800**
				Cost / Sellable Acre =	**$ 12,682**

Table B.5. Estimate of Stormwater BMP Construction Cost

Determining how this additional cost to homeowners will be reflected in the market value of developed land is presumptive at best. For this example, we have assumed that some of the cost of constructing the stormwater BMPs will result in a dollar for dollar reduction in the market value of the sellable land. So, the BMP construction cost per sellable acre is subtracted from the per acre market value price of the land.

The initial construction cost is subtracted from the land sale value to determine the developers profit for each layout.

Cost = Land Sale Value - Initial Construction Cost

Traditional Layout
Cost = $310,500 - $265,376
= $45,124

LID Layout
Cost = $240,701 – $182,887
= $57,814

The final cost comparison is completed by determining the difference in profit between the two layouts. For this example, a total profit increase of $12,690 is realized by the developer using the LID layout with no additional cost to the individual homeowners.

Appendix C – Significant Problem Area Modeling and Recommendations



The following pages contain more detailed overview for selected priority problem areas and/or obstructions.

Figure C.1 illustrates the location of the reported problem areas and obstructions throughout the county.

Tables C.1 through C.5 are the summary evaluation tables that show the results of applying the prioritization criteria set forth in Section V used to the problem and obstructions in the County.

Conceptual solutions are then presented for the highest priority problem and obstructions.

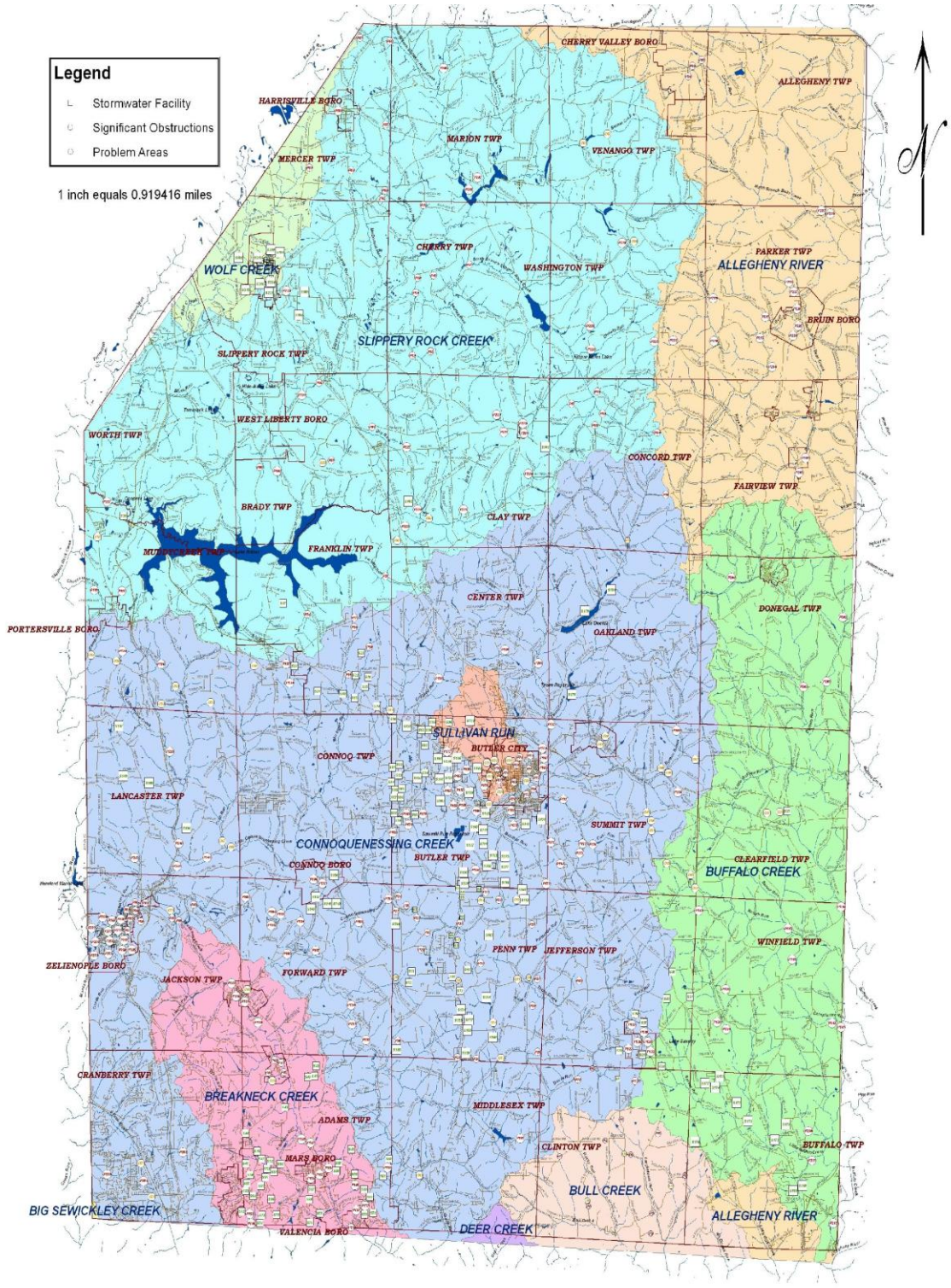
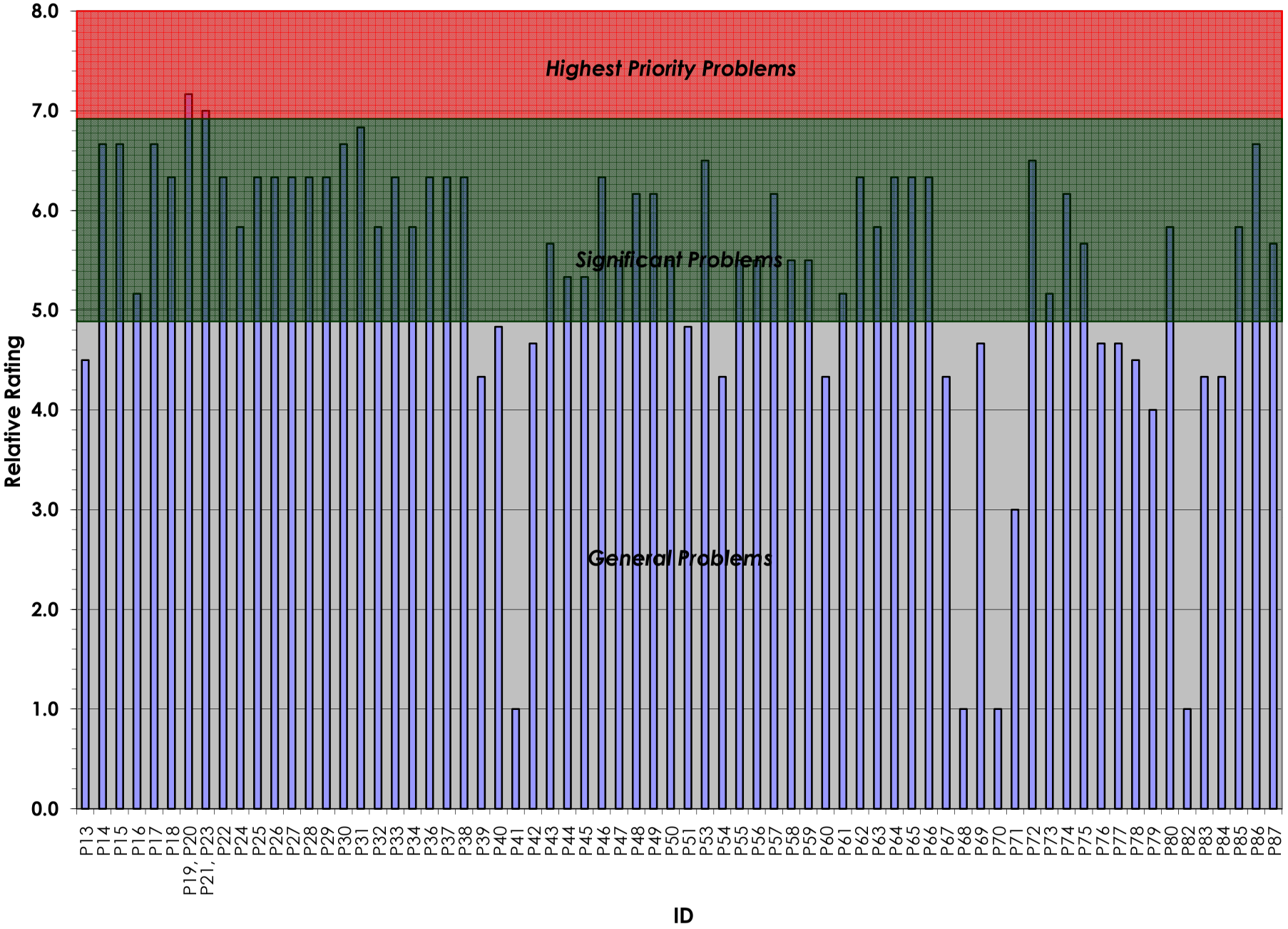
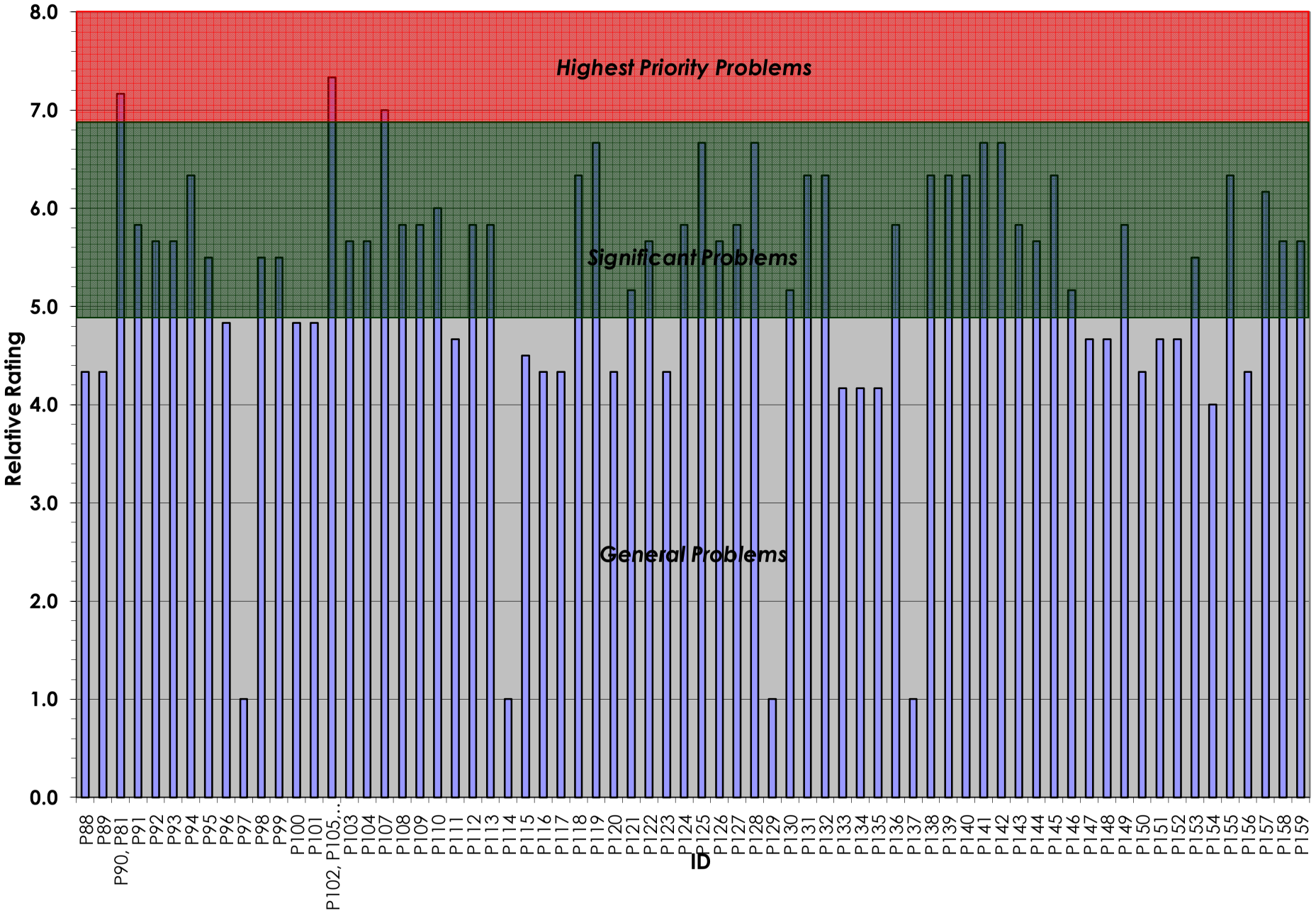


Figure C.1 – Locations of Problem Areas and Obstructions within Butler County


Highest Priority Problems
Significant Problems
General Problems
Relative Rating
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
P13
P14
P15
P16
P17
P18
P19, P20
P21, P23
P22
P24
P25
P26
P27
P28
P29
P30
P31
P32
P33
P34
P36
P37
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P39
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P76
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P78
P79
P80
P82
P83
P84
P85
P86
P87
ID


Highest Priority Problems
Significant Problems
General Problems
Relative Rating
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ID
P88
P89
P90, P81
P91
P92
P93
P94
P95
P96
P97
P98
P99
P100
P101
P102, P105...
P103
P104
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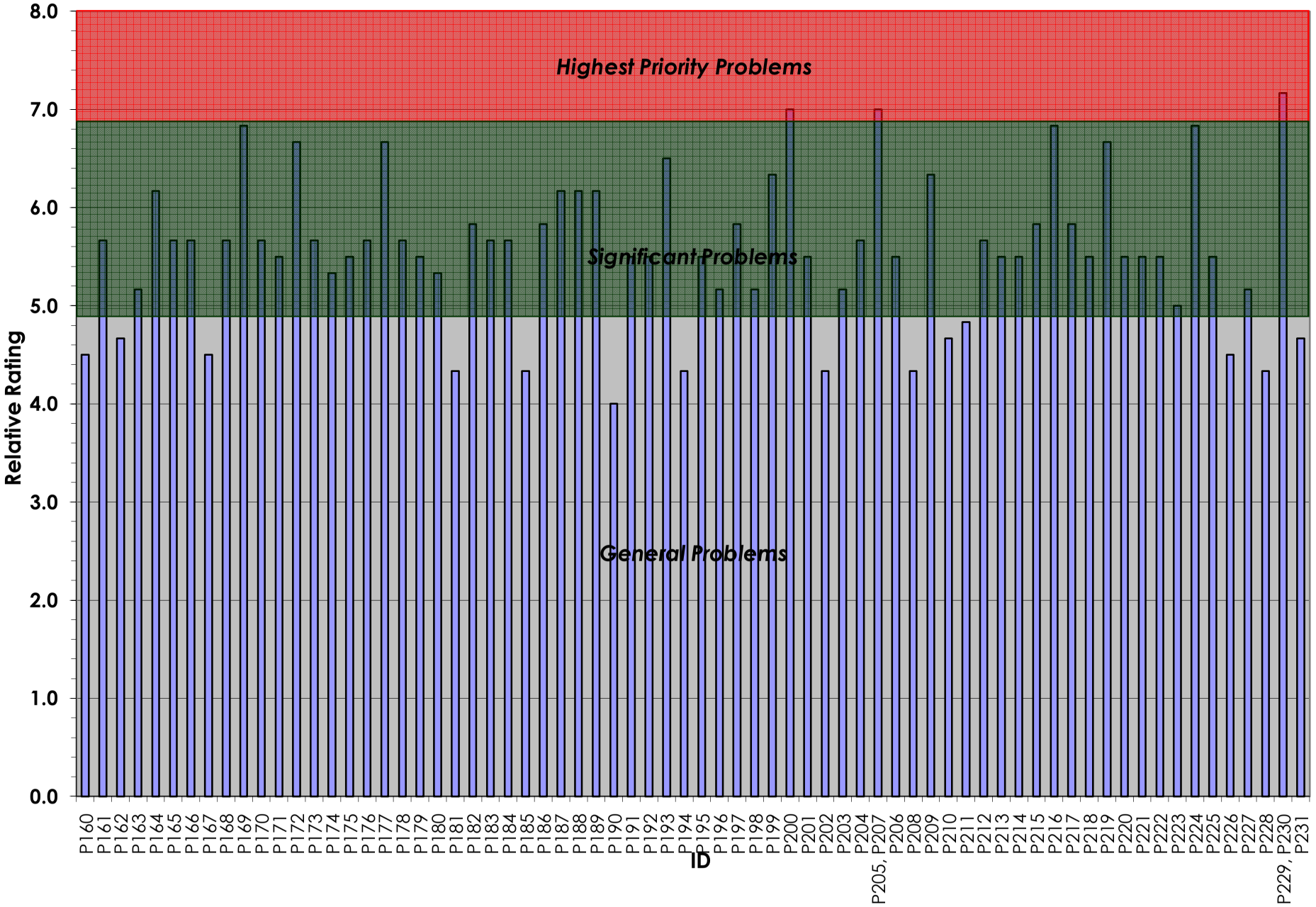
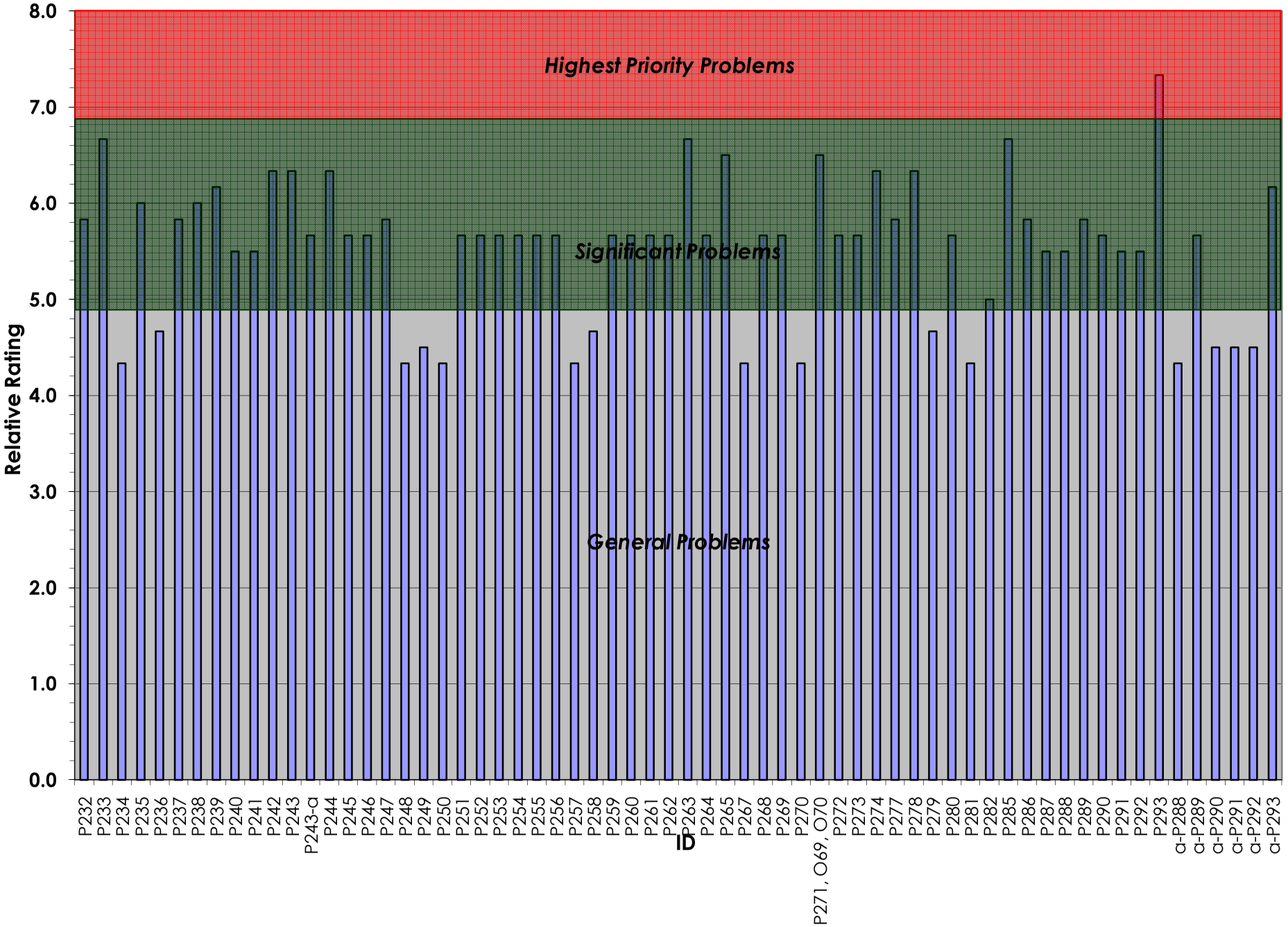
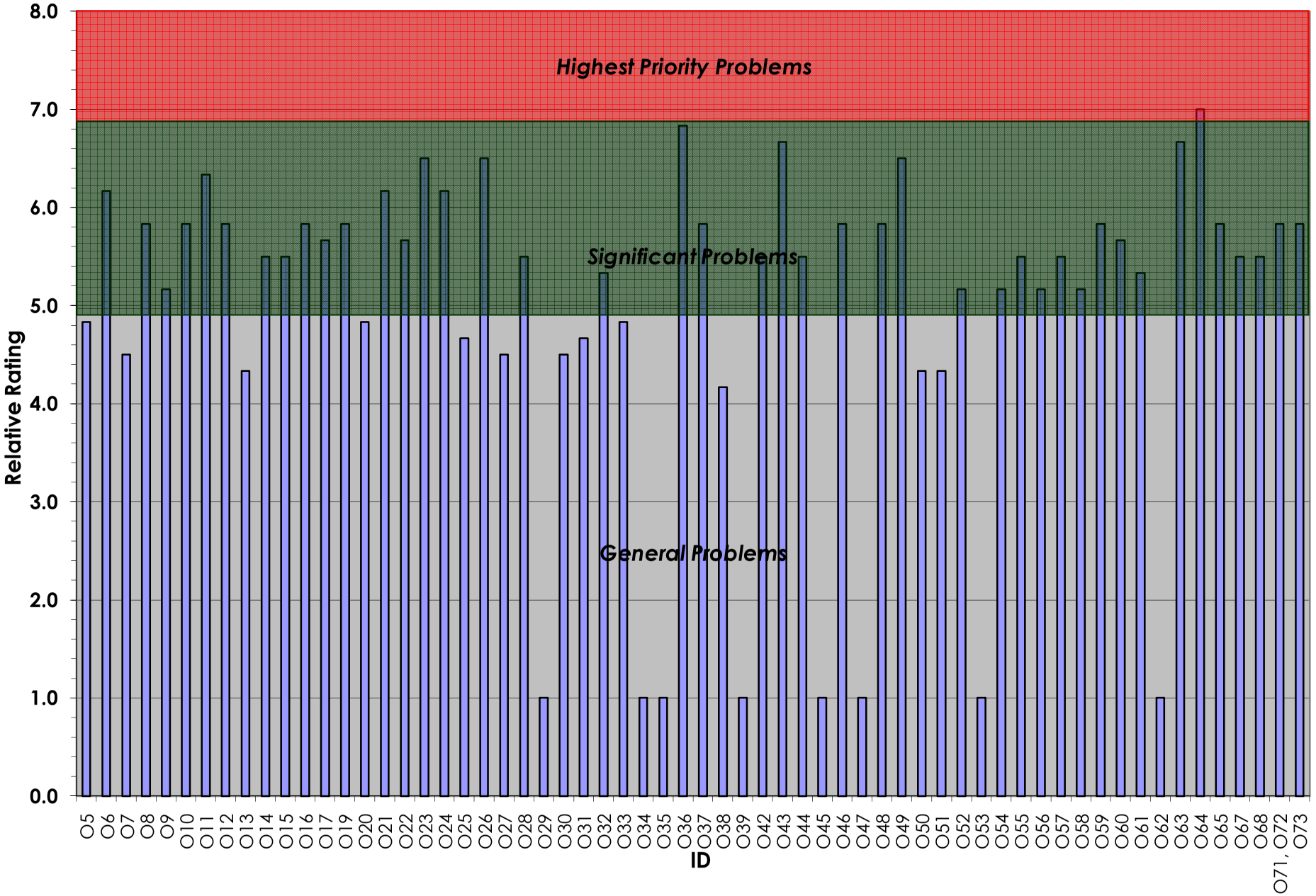


Table C.3 - Problem and Obstruction Evaluation Summary Table


Highest Priority Problems
Significant Problems
General Problems
Relative Rating
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ID
P232
P233
P234
P235
P236
P237
P238
P239
P240
P241
P242
P243
P243-a
P244
P245
P246
P247
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P272
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P274
P277
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P282
P285
P286
P287
P288
P289
P290
P291
P292
P293
a-P288
a-P289
a-P290
a-P291
a-P292
a-P293


Highest Priority Problems
Significant Problems
General Problems
Relative Rating
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
O5 O6 O7 O8 O9 O10 O11 O12 O13 O14 O15 O16 O17 O19 O20 O21 O22 O23 O24 O25 O26 O27 O28 O29 O30 O31 O32 O33 O34 O35 O36 O37 O38 O39 O42 O43 O44 O45 O46 O47 O48 O49 O50 O51 O52 O53 O54 O55 O56 O57 O58 O59 O60 O61 O62 O63 O64 O65 O67 O68 O71, O72 O73
ID

Butler County Act 167 Plan

Municipality: Harmony Borough **ID:** P90

Problem Description: The Borough indicates that the problem is Stormwater issues. The elliptical CMP may not have adequate capacity to convey the full stream flow beneath Spring Street.

Photos:



Photo Description:

Upstream end of elliptical CMP crosspipe beneath Spring Street. The small stream may flow over the street during storms.



Photo Description:

Looking upstream from the elliptical CMP. The stream is the outflow from a farm pond.

Conceptual Solution:

The capacity of the elliptical CMP should be analyzed to determine if the pipe is large enough. Upstream development may have increased the discharge in the stream. Possibly the farm pond could be modified to store floodwaters during the highest flood peaks to reduce flooding at this location and downstream where the creek flows through the town of Harmony. This solution would require the cooperation of the private landowner, the Borough, and DEP.

Butler County Act 167 Plan

Municipality: Marion Township **ID:** P205 / P207

Problem Description: There are two sites along Boyers Road and DeMatteis Road that have always flooded frequently. Homes were possibly built in the floodplain.

Photos:



Photo Description:

Looking upstream from Dematteis Road bridge.



Photo Description:

Looking downstream from Boyers Road bridge.

Conceptual Solution:

The bridges may be undersized and act as obstructions during storms, but no debris or sedimentation was reported at either bridge. The problem may be that buildings were constructed in the streams' floodplains. One solution to the problem is for the Township or the County to purchase the properties for public use. A regional flood control facility may not be justified to protect a small number of residents, and it may not be effective since the streams are small and are near the top of the watershed.

Municipality: Clay Township **ID:** O64

Problem Description: Beaver Dam Road - Dams are causing the roadway to flood, and even at dry time, water is almost to roadway level.

Photos:



Photo Description:

Ponded water caused by a beaver dam. The adjacent road floods during storms.

Conceptual Solution:

Contact the Pennsylvania Game Commission to determine the best way to relocate the beaver population. For public safety, the roadway may need to be raised above flood stage.

Butler County Act 167 Plan

Municipality: Evans City Borough **ID:** O40, O41, P102, P105, P106

Problem Description: Flooding and Obstructions along stream through the town. Siltation, bank erosion, bridge scour.

Photos:



Photo Description:

Looking upstream at Breakneck Creek. Note the railroad on the right and the buildings along the stream on the left.



Photo Description:

The far bank of Breakneck Creek shows signs of streambank erosion.

Conceptual Solution: Breakneck Creek is highly channelized through the borough. A rail line runs along one bank. The railbed is supported by a concrete and cut stone retaining wall along the stream channel. The wall appears to be failing in places and causing obstructions. The opposite bank is an eroded slope, with structures constructed in the floodplain. Sediment and debris have built up in the stream channel. The historic solution to flooding problems was likely to dredge the creek, but dredging causes channelization, increased flow velocities, erosion, and debris issues. Certainly, any obstructions should be removed from the channel, but a regional flood control facility may be warranted upstream to reduce the flood peak in the borough.

Butler County Act 167 Plan

Municipality: Summit Township **ID:** P107

Problem Description: Frequent flooding of roadway - Connoquenessing Creek is close to SR 38.

Photos:



Photo Description:

The creek floods this low portion of Route 38.

Conceptual Solution:

There is heavy vegetation in the Connoquenessing Creek floodplain. Typically, this is a desirable situation, because healthy riparian foliage increases water quality and decreases overall flooding by slowing flood waters. However, for public safety reasons, the vegetation could be removed at this problem area and downstream to reduce local flooding of the highway. The streambanks and floodplain may need to be armored due to increased flow velocity. Alternatively, the road could be raised, or a regional detention facility could be installed upstream in the creek to store floodwaters.

Butler County Act 167 Plan

Municipality: Valencia Borough **ID:** P19 / P20

Problem Description: The Borough indicates that the problems are increased flow in the creek and flow restriction at the Three Degree Road bridge. The structures upstream of the bridge have been constructed adjacent to the stream channel, and they occasionally get flooded.

Photos:



Photo Description:

Looking upstream from the Three Degree Road bridge. Note the house built along the streambank on the left. There is also a concrete block commercial building located across the stream from the house.



Photo Description:

Looking upstream at the Three Degree Road Bridge. The bridge appears to be relatively clear of obstructions.

Conceptual Solution:

Development in the upstream watershed may cause increased flow in the creek. An upstream regional flood control facility may reduce the highest flood peaks. Alternatively, the Borough may choose to acquire any properties in the stream's floodplain as part of a comprehensive floodplain management project. That way, the Borough could protect and restore the stream's riparian zone while providing a natural public area for its residents to enjoy.

Butler County Act 167 Plan

Municipality: Washington Township **ID:** P293

Problem Description: Hilliards - The Township re-routed the stream to a new location with a culvert in the roadway. The stream now forms two "L's" and will soon undercut the road. The old County bridge is now underlain with dirt.

Photos:



Photo Description:

View toward the low area of the roadway.

Conceptual Solution:

The stream's historic route should be restored. The county's bridge may need to be replaced if it is deficient or undersized. Alternatively, the culvert could be analyzed to determine if it is adequately sized, and the stream's new route could be stabilized with riprap and a healthy riparian zone to prevent erosion and downstream sedimentation .

Butler County Act 167 Plan

Municipality: Washington Township **ID:** P230 / P229

Problem Description: Calico Road - Beaver dams have water at road level, and the roadway is being washed out.

Photos:



Photo Description:

Manmade pond adjacent to Calico Road



Photo Description:

Outfall from the manmade pond has been dammed by beavers. Overflow is causing erosion of the unimproved roadway.

Conceptual Solution:

Contact the Pennsylvania Game Commission to determine the best way to relocate the beaver population. For public safety, the roadway may need to be raised above flood stage.

Butler County Act 167 Plan

Municipality: Penn Township **ID:** P21 & P23

Problem Description: Village of Renfrew and Renfrew Road. Low area next to Thorn Creek.

Photos:



Photo Description:

Looking downstream at Thorn Creek.

Photo Description:

Conceptual Solution:

Structures and properties along Thorn Creek flood during storm events. If possible, the Township sould consider acquiring flood-prone properties and designating them for public use. Alternately, constructing a regional flood control facility upstream would mitigate some of the frequent flooding.

Municipality: Center Township **ID:** P200

Problem Description: Flooding of Connoquenessing Creek at various locations along State Route 38.

Photos:



Photo Description:

A portion of the Connoquenessing Creek floodplain.

Conceptual Solution:

For public safety reasons, SR 38 may need to be raised at various locations to prevent dangerous flooding. Or a regional detention facility could be constructed upstream in the creek to store floodwaters.

Appendix D – Natural Resource Activities Impacting Water Quality



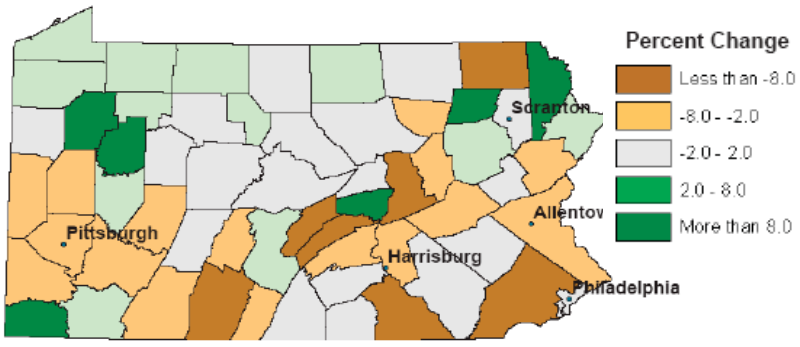
As demonstrated throughout this Plan, land use is a key factor in both the generation and control of stormwater runoff. In Pennsylvania, most types of land use can be regulated by the county or local government through land use ordinances (e.g. zoning). However, the Pennsylvania Municipalities Planning Code (MPC) limits local government control of certain land use categories. Certain types of natural resource activities such as agriculture, forestry, and mining are among the land uses protected by the MPC. Two land use categories that fall within this category were identified by the Plan Advisory Committee, and the municipalities they represent, as land uses that greatly affect the water resources of the county – timber harvesting and oil and gas wells.

Amendments made to the Pennsylvania Municipalities Planning Code by Act 67 and Act 68 of 2000, limit the regulatory control of municipalities on forestry and timber harvesting. The amendments specify Forestry activities and timber harvesting as "permitted uses by right" in all zoning districts in every municipality. The MPC amendments further clarify that zoning ordinances may not unreasonably restrict forestry activities.

Oil and gas well development in Pennsylvania is regulated by several chapters of the Pennsylvania Code and various state acts. The state's oil and gas laws (Oil and Gas Act – Act 223, Coal and Gas Resource Coordination Act – Act 214, and Oil and Gas Conservation Law – Act 359), as well as environmental protection laws that include the Clean Streams Law, the Dam Safety and Encroachments Act, the Solid Waste Management Act, and the Water Resources Planning Act delegate the authority to regulate these activities to DEP, while limiting the regulatory control of municipalities.

FORESTRY IN PENNSYLVANIA

According to U.S. Forest Service inventories, forest once covered more than 90% (27.3 million acres) of Pennsylvania's land area in the pre-European settlement era (1630s). By the early 1900s, industrial timber harvesting and agricultural land clearing had diminished the forest land base to only 32% (9.2 millions acres). Forest land increased steadily from that point forward and has been relatively stable, at 58% of Pennsylvania's total area, for the last quarter century. Although no significant net change in total area has occurred, there have



Change in Forest Land Area, 1989-2004 (McWilliams et al., 2007)

been losses of acreage to development, agriculture and mining. These losses have been offset by agricultural and other lands naturally reverting back to forests. Slightly more than 70% of the nearly 17 million acres of forests in the state are privately owned, with only a small percentage (< 5%) owned by forest product companies. The remaining 30% of the forest land in Pennsylvania is owned by state and federal government entities.

Pennsylvania is known throughout the world as a leading source of high quality hardwood products. The state leads the nation in the production of hardwood lumber (typically more than one billlion board feet), accounting for about 10% of the country's annual production (Pennsylvania Forest Products Association, 2008). Pennsylvania also ranks nationally in the production of value added wood products such as millwork and flooring; kitchen cabinets; pallets and containers.

The forest products industry is important in Pennsylvania, where it accounts for 11% of all manufacturing jobs. The forest products industry has a significant impact on the state's economy. In 2005, the state's annual forest product industry sales was $16.7 billion. The total economic impact of the forest product industry in the state was $24.7 billion. Three-quarters of this economic impact was generated by sectors depending on locally harvested hardwood timber (Pennsylvania Forest Products Association, 2008). In 2006, there were 2,420 forest prduct establishments in Pennsylvania, employing 79,910 individuals. In many rural parts of the state the forest products industry is the primary source of economic activity.

FORESTRY IN BUTLER COUNTY

Although it is not a dominant sector, the wood products industry provides important economic opportunities in the county. In 2007, there were 22 wood products establishments employing several hundred people (U.S. Census Bureau, 2008). Timber management encourages the preservation of open space. Through timber harvesting, forests are able to provide landowners with income that can be an incentive for them to maintain woodland on their property. According to a study conducted by the American Famland Trust, timberland and farmland yield an average of $3 in taxes for every $1 in required governmental services, while residential land costs $1.11 in services for every $1 collected in tax revenue (The Pennsylvania State University, 2004). Additionally, municipalities with publicly owned State Forests, State Game Lands, and State Parks within their borders receive "in lieu of tax" payments from the Commonwealth.

FORESTRY ACTIVITIES AFFECTING WATER QUALITY

As discussed in *Section IX - Water Quality Impairments and Recommendations*, forestry is one of the basic sources of nonpoint source pollution. On a national level, forestry management activities are estimated to contribute approximately 9 percent of the water quality problems in surveyed rivers and streams (EPA, 1996). Water quality concerns related to forestry were addressed in the 1972 Federal Water Pollution Control Act Amendments and later, more comprehensively, as nonpoint sources under section 208 of the 1977 Clean Water Act and section 319 of the 1987 Water Quality Act.

Forestry is listed as the primary cause for impairment in 0.02% of all non-attaining stream miles in Pennsylvania. There are no stream segments in Butler County listed on the *2009 Integrated List of All Waters* as non-attaining, with forestry as the primary source of impairment. However, this does not mean that the potential impacts of forestry operations on water quality can be neglected. Local impacts of timber harvesting and road construction can be severe, especially in smaller headwater streams. Many activities associated with forest management can increase the potential for erosion to occur. For this reason, sediment is the primary pollutant of concern associated with forestry activities. Other pollutants include nutrients, organic matter, chemicals

and others. The fundamental forestry activities with the potential to affect water quality include road construction and use, timber harvesting, mechanical equipment operation, and forest management.

ROAD CONSTRUCTION AND USE

Roads are considered to be the major source of sediment from forested lands. The comparatively small area of roads contributes the vast majority of the total sediment produced from forestry operations. The greatest potential for erosion from roads occurs during road construction and during the first few years afterward. The potential for erosion on forest roads is particularly high because they are exposed to direct rainfall, they are not protected by vegetative cover, road surfaces tend to channelize runoff, and vehicle traffic continually disturb the road surface. Erosion potential is greatly increased when roads are built on cut or fill slopes, when built on steep slopes, and when they are not stabilized with stone or some other means.

Compacted road surfaces also generate increased runoff which compounds erosion problems. Other negative impacts of forest roads include concentrated overland flow on the road surface and in channels, point discharges created by culvert road crossings, and altered subsurface water flow.

TIMBER HARVESTING

Timber harvesting involves many activities that alter the forest landscape. Erosion and sedimentation resulting from these alterations is the primary concern associated with timber harvesting. Facilities used for timber harvesting such as staging (or yarding) areas, skid trails, and access roads are susceptible to increased erosion. These facilities are also at high risk for pollutants such as petroleum products, lubricants, herbicides, pesticides, and other chemicals associated with timber harvesting operations. Many detrimental effects of harvesting are related to the access and movement of vehicles and machinery. These effects include soil disturbance, soil compaction, and direct disturbance of stream channels.

Landscape changes that occur as a result of harvesting can also negatively impact water quality. Timber harvesting disturbs forest litter and changes the vegetative cover which alters the hydrologic response of a watershed. This can lead to increased runoff and erosion. Removing trees from riparian areas disturbs the sensitive ecosystem, exposes the area to pollutants associated with machinery, and reduces shade which can increase water temperatures. Utilizing appropriate timber harvesting and transport practices techniques for a given site can drastically decrease sediment production from these activities.

FOREST MANAGEMENT

Forest management activities such as site preparation for regeneration of harvested sites, prescribed burning, herbicide and pesticide application, and fertilizer application have the potential to negatively affect water quality. Sites that have been intensely harvested can be prepared for regeneration using wheeled or tracked machinery, by prescribed burning, through application of chemicals (i.e. herbicides), or a combination of these methods. These techniques can disturb the soil over large areas, remove vegetation and forest litter, and compact soil. All of these leave the area vulnerable to increased erosion and sedimentation.

FORESTRY POLLUTANTS AND IMPAIRMENTS

Nearly all forestry activities increase the potential for erosion and sediment delivery to streams. Some of these activities have long-term effects (e.g. road building and clear-cutting), while the impacts of others diminish within a few years of the occurrence. Erosion and sedimentation is the primary water quality concern related to forestry activities. Sedimentation is closely related to

nutrient transport. Nutrients that are immobilized in forest soils are transported along with the sediment to surface waters through erosion. Other water quality pollutants resulting from forestry activities include organic debris, nutrients, chemicals, temperature, and flow variability. These pollutants, how they are generated through forestry activities, and their potential impacts on the county's waters are discussed below.

SEDIMENT

Sediment is often the primary pollutant associated with forestry activities. Accelerated overland erosion often occurs in harvested areas due to vast areas that are destabilized by removal of vegetation. Erosion of these areas discharges sediment and fine silt particles into receiving streams. Sediment transported to waterbodies by erosion can be particularly detrimental to the stream ecosystem, especially to many fish species. Suspended sediments in runoff increase water turbidity limiting the ability of sight-feeding fish to find and obtain food. In addition, the increased turbidity limits the depth to which light can penetrate and adversely affecting aquatic vegetation, increase water temperatures and lower dissolved oxygen concentrations. These effects also compromise recreational values.

When suspended sediment settles, it can fill gravel spaces in streambeds, destroying fish spawning areas and food sources. With large areas of accumulated sediment, the flow capacity of stream channels are reduced. The in stream storage capacity is also reduced, which leads to increasing flooding and decreased water supplies. In addition, nutrients and other pollutants may become adsorbed to sediment particles and be subsequently transported downstream.

ORGANIC DEBRIS

Organic material is an important part of a balanced ecosystem. Organic debris includes plant matter, residual logs, leaves, twigs and other forest litter. This material serves as a source of enefgy and provides nutrients for plants and animals. This is the primary source of nutrients for headwater streams, where upstream sources of nutrients are limited. Forestry activities can upset the balance of organic material by creating excess debris during timber havesting or by creating a debris shortage during site preparation for regeneration or by over harvesting in the riparian zone.

Excess organic debris can adversely affect water quality by causing increased biochemical oxygen demand, resulting in decreased dissolved oxygen levels (which are critical for many aquatic species) in watercourses. Logging slash and debris in or near streams can alter stream flows by forming debris dams, and can also redirect flow in the channel, increasing bank cutting and resulting in sedimentation.

NUTRIENTS

Erosion is the primary transport mechanism for nutrient pollution related to forestry activities. Forest soils act as a filter that collects and holds nutrients from decomposing organic matter such as leaves and woody debris. The soil holds many of these nutrients until they are removed by growing plants and used for plant growth. Some nutrients, like nitrogen, are easily dissolved in water and are easily moved throughout the environment. Other nutrients, such as phosphorus, bind to soil particles and are relatively immobile unless relocated by some transport mechanism (e.g. erosion). Excess nutrients in surface waters can result in eutrophication, or a proliferation of plant life, especially algae. Eutrophication causes dissolved oxygen levels to decrease, harming other aquatic organisms.

CHEMICALS

Chemicals such as herbicides, pesticides, and fertilizers used for forestry operations can contaminate surface water through direct application, transport by surface runoff, or groundwater contamination. These chemicals can poison fish and wildlife or kill unintended plant species. Generally speaking, herbicides, pesticides, and fertilizers pose minimal threat to water quality when handled and applied properly. However, improper application and spills can have severe and long lasting effects. The petroleum products and lubricants used for machinery are of greater concern. These chemicals can be toxic to plants and animals and can contaminate drinking water supplies.

TEMPERATURE

Relatively constant water temperature is important for aquatic biota. When too much vegetation is harvested from the area surrounding stream, the loss of shade can result in increased water temperatures. Temperature increases can be dramatic in smaller (lower order) streams, adversely affecting fish and aquatic invertebrates which have adapted to cooler water temperatures. Suspended solids from sedimentation can also lead to increased stream temperatures as darker particles absorb heat (EPA, 1997). As water temperatures rise, dissolved oxygen levels (which are critical for many aquatic species) decrease. Temperature changes can be a substantial contributor to aquatic life impairments.

STREAM FLOW

The hydrologic response of a watershed can change as a result of timber harvesting. The change resulting from large scale removal of vegetation is often increased stream flow that results from more rapid delivery of runoff to streams. When fewer trees are available to perform the function of evaporation and transpiration, more water becomes availabe as surface runoff. Increased runoff results in increased stream flow. The amount of stream flow increase is related to the total area harvested, topography, soil type, and harvesting practices (Curtis et al. 1990). Increased stream flow can lead to a variet of problems including scoured channels, erode streambanks, increase sedimentation, and increase peak flows.

FORESTRY MANAGEMENT MEASURES FOR WATER QUALITY

Current forestry management practices and timber harvest techniques have drasticly reduced the water quality impacts that occurred from practices of the past century. The water quality impacts of forestry activities can be further minimized by implementing appropriate management measures. Management measures are steps to be taken and guidelines for operations (EPA, 2005). Best Management Practices (BMPs) are specific activities, processes, or technologies designed to serve specific functions, which are used to attain a management measure. These are simple, often low cost, practices and techniques that can be incorporated into forestry operations to diminish impacts to water quality. Additional guidance on BMPs can be found in the following resources developed specifically for Pennsylvania forests:

- Timber Harvest Operations Field Guide for Waterways, Wetlands and Erosion Control (3930-BK-DEP4016), 2009. Pennsylvania Department of Environmental Protection.
- Best Management Practices for Pennsylvania Forests, 2001. The Pennsylvania State University.

A brief overview of EPA's (2005) forestry management measures developed to protect water quality throughout the various phases of forestry activites is presented on the following pages.

Preharvest Planning

Purpose	Ensure that forestry activities are planned with water quality considerations in mind and conducted in a manner to minimize delivery of nonpoint source pollutants to surface waters.
Target Pollutant(s)	Primarily sediment. Organic matter, thermal modification, nutrients pesticides and toxics are also controlled.
Description	Preharvest planning includes consideration of all stages of a timber harvest including the road system, the harvesting system, the yarding system, and post harvest activities. Site conditions are considered and appropriate BMPs are prescribed to reduce water quality impacts. Contingency plans are developed to reduce the effects of potential problems.

Streamside Management Areas

Purpose	Protect surface waters, the ecologically sensitive areas in riparian zones and wetlands, and maintain the function of floodplains.
Target Pollutant(s)	Sediment, organic debris, and thermal modification. Nutrients, pesticides and toxics are also controlled.
Description	Establish and maintain a buffer zone along surface waters that includes a sufficient number of canopy species, and is wide enough to shade the water, provide bank stability, and filter runoff. Limit forestry activities within the buffer.

Road Construction

Purpose	Reduce erosion and sedimentation which is common during, and immediately after, construction of forestry roads.
Target Pollutant(s)	Sediment. Petroleum products and lubricants.
Description	Design and construction of roads that are planned for the topography, soils, and drainage patterns of a site. Appropriate construction methods and BMPs are used to minimize erosion from high risk areas such as the road surface, steep slopes, water crossings, and runoff conveyance structures (i.e. culverts, ditches, etc.).

Road Management

Purpose	To ensure that management of existing roads maintains their utility and minimizes polluted runoff from roads and road structures.
Target Pollutant(s)	Sediment. Petroleum products and lubricants.
Description	Minimize use during wet weather and thaw conditions. Perform routine maintenance of road surface, stream crossings, and drainage structures. Immediately repair eroding areas and implement BMPs to address problem areas. Close and decommission roads that are no longer needed.

Timber Harvesting

Purpose	Minimize the likelihood of water quality impacts resulting from timber harvesting operations.
Target Pollutant(s)	Sediment, petroleum products.
Description	Follow the plan for timber harvest operations developed during preharvest planning. Conduct operations to avoid sedimentation to the extent practicable. Use appropriate areas for high risk activities such as equipment maintenance, and petroleum and chemical storage and dispensing.

Site Preparation for Regeneration

Purpose	Minimize erosion and runoff from areas disturbed by site preparation for forest regeneration.
Target Pollutant(s)	Sediment, organic debris, and nutrients.
Description	Select methods of site preparation for regeneration which are suitable for site conditions. Complete site preparation in sensitive areas such as steep slopes and riparian zones using low impact methods and utilizing appropriate BMPs. Leave adequate organic material but protect surface waters from debris and slash material.

Fire Management

Purpose	Minimize nonpoint source pollution and erosion resulting from prescribed burning.
Target Pollutant(s)	Sediment, organic debris, and nutrients.
Description	Use of prescribed fire should be planned and implemented in a manner to protect against excessive erosion. Area to be burned and severity of burn should be prescribed based on site conditions and erosion potential. Appropriate BMPs should be employed to reduce impacts to sensitive areas.

Revegetation of Disturbed Areas

Purpose	Reduce erosion and sedimentation of areas disturbed by forestry activities.
Target Pollutant(s)	Sediment and nutrients.
Description	Reduce erosion and sedimentation by revegetating disturbed areas with appropriate plant species immediately upon completion of earth-disturbing activities. Focus initial efforts on highly susceptible areas such as steep slopes and riparian areas.

Forest Chemical Management

Purpose	Minimize the potential of water pollution by chemicals used for forest management due to environmental transport of chemicals during and after application.
Target Pollutant(s)	Pesticides (i.e. Insecticides, herbicides, and fungicides) and fertilizers.
Description	Risks associated with the use of forest chemicals can be reduced through careful prescription of type and amount of chemicals to be used; delineation of buffer zones; and careful transport and application of chemicals. Spill prevention and contingency plans can reduce the potential impact of spills.

OIL AND GAS DEVELOPMENT IN PENNSYLVANIA

The petroleum (oil and gas) industry has played a significant role in the history of Pennsylvania. In 1859, Edwin L. Drake drilled one of the first successful oil wells near Titusville, PA. In the years that followed, Venango and Crawford Counties became the center of an industry focused on the drilling, refining, and transporting crude oil and oil products (Harper, 1998). Although not the first natural gas well, the Drake Well (which captured natural gas and piped it to Titusville) is also attributed as the beginning of the natural gas industry in America (NaturalGas.org, 2004). Oil and gas wells are a common part of the landscape throughout much of Pennsylvania. Until recently, the petroleum industry in Pennsylvania had faded to a small fraction of what it had been during its prime.

The Marcellus Shale Formation is a Middle Devonian-age (397.5 – 385.3 million years ago), black, low density, carbonaceous shale that lies nearly a mile or more below the surface of approximately two-thirds of Pennsylvania and large portions of New York, West Virginia, and Ohio as well as small areas of Maryland, Kentucky, Tennessee, and Virginia. Organic rich shales, such as the Marcellus Formation, have been known to hold significant reservoirs of natural gas for more than 75 years (Harper, 2008). Once thought cost prohibitive to extract, recent advances in drilling technology and recent price increases for natural gas have increased interest in this extensive gas reservoir. In 2002, the United States Geological Survey's "Assessment of Undiscovered Oil and Gas Resources of the Appalachian Basin Province" calculated that the Marcellus Shale contained an estimated resource of about 1.9 trillion cubic feet of gas (USGS, 2003).

In 2003, Range Resources – Appalachia, LLC drilled a well in Washington County, Pennsylvania and found a promising flow of natural gas from the Marcellus shale. Borrowing drilling and fracturing techniques that had worked in the Barnett Shale of Texas, they began producing Marcellus gas in 2005 (Harper, 2008). In early 2008, Terry Engelder, a geoscience professor at Pennsylvania State University, and Gary Lash, a geology professor at the State University of New York at Fredonia, "said the Marcellus shale conservatively contains 168 trillion cubic feet of natural gas, but the figure might be as high as 516 trillion cubic feet" (UPI, 2008). The recoverable portion of this reserve is estimated to be around 10 percent of this total. By the end of February 2008 more than 450 suspected Marcellus wells had been permitted in Pennsylvania (Harper, 2008). The stage has been set for an extensive Marcellus Shale gas play in Pennsylvania.

OIL AND GAS ACTIVITIES AFFECTING WATER QUALITY

The potential impacts of oil and gas development on water quality are a concern across the Commonwealth. Of particular concern are: water withdrawals, storm water runoff from construction activities, pollution from drilling processes, groundwater contamination from hydraulic fracturing, and disposal of waste fluids. Water quality concerns related to oil and gas operations are addressed by a variety of federal and state regulations. The 1972 Federal Water Pollution Control Act Amendments and the 1977 Clean Water Act were the first regulations to subject the oil and gas producing industry to direct dealings with a federal agency on environmental protection issues (DOE, 2009a). Other regulations such as the Safe Drinking Water Act (1974) and the Resource Conservation and Recovery Act in (1976) authorize further federal regulation of the oil and gas industry. However, regulation of petroleum activities remains primarily a state responsibility.

In Pennsylvania, oil and gas activities are regulated by several chapters of the Pennsylvania Code and various state acts. The state's oil and gas laws (Oil and Gas Act – Act 223, Coal and Gas Resource Coordination Act – Act 214, and Oil and Gas Conservation Law – Act 359), as well

as environmental protection laws that include the Clean Streams Law, the Dam Safety and Encroachments Act, the Solid Waste Management Act, and the Water Resources Planning Act give DEP the authority to regulate these activities while limiting the regulatory control of municipalities.

PERMIT	SOURCE/NOTES
Well Drilling Permit and Addendum	Pursuant to the Oil and Gas Act; an application addendum outlining a water management plan for that operation, pursuant to PA Code, Title 25, Chapter 78.11-33.
Earth Disturbance Permit (ESCGP-1)	Required from PA DEP regulating implementation of E&S controls, including SWM, if disturbance >5 acres. E&S plan is required if under 5 acres. PA Code, Title 25, Chapter 102.
Preparedness, Prevention and Contingency (PPC) Plan	The PPC Plan must address the types of wastes generated, disposal methods and a spill prevention plan. Construction and operation of on-site storage impoundments must also be described.
Water Withdrawal Permits	A permit is required from DEP for all withdrawals of surface or ground water. Separate withdrawal permits for projects in the Delaware or Susquehanna Basin or Susquehanna River Basin Commission.
Chapter 105 Obstruction and Encroachment Permit	Permit from DEP for work in a wetland, stream, or body of water. PA Code, Title 25, Chapter 105 (also required under the Oil and Gas Act).
Water Quality Management Permit	Permit if a centralized impoundment will hold fluids other than fresh water (such as drilling or fracing fluids). The siting, construction, use and closure of temporary pits are regulated under PA Code, Title 25, Chapter 78. Permits are only required if the pit is part of a treatment facility.

Development assciated with the Marcellus shale gas play includes construction of new roads, pipelines, compressors, water impoundments, well sites and other facilities. The development of this resource requires the use of large amounts of water and may expand to cover extensive areas. Marcellus shale gas development in Pennsylvania is a matter of local, regional, and national interest. Petroleum activities are listed as the primary cause for impairment in 0.2% of all non-attaining stream miles in Pennsylvania. Recent interest in the Marcellus shale play has the potential to greatly increase this number.

The large volumes of water required to complete a Marcellus Shale natural gas well, and the resulting large. Directional drilling and hydraulic facturing techniques used to extract gas from the Marcellus shale formation require large volumes of water to complete development of a natural gas well. These approaches require as much as 20 times the water volume as that used in conventional well completions (Harper, 2008). The hydraulic fracturing process for a typical Marcellus shale well uses approximately 3.5 million gallons of water (Harper and Kostelnik, 2010). The resulting large volume of waste water increases the environmental risk of this type of well development.

There are 0.56 miles of stream in Butler County listed on the *2009 Integrated List of All Waters* as non-attaining, with petroleum activities as the primary source of impairment. This represents about 2.2 percent of all impaired stream miles in the county. However, this does not indicate that water quality impacts from petroleum activities are neglibible. Local impacts to surface water and groundwater resulting from petroleum activities can be severe. Oil and gas

development activities with the potential to affect water quality include construction activies, well development, and gas production.

CONSTRUCTION ACTIVITIES

Construction activities related to well development are the primary concern for impacts to surface water. Gas well construction can involve extensive earth disturbance for access roads, pad sites, and pipelines. For deeper wells the drilling pads alone can create a four to six acre disturbed area (Swistock, 2010). Earth disturbances related to well development present the potential for increased erosion and sedimentation in a manner similar to other construction activities. Well sites in remote locations can present increased risk due to the length of roads and pipelines necessary to support the facility. Other site factors such as slope, proximity to surface water, and soil type can increase the potential for impacts to surface water.

WELL DEVELOPMENT

Once the pad site and supporting facilities have been constructed well drilling begins. This is done with a drilling rig through a multi-stage process in which the wellbore is drilled, cased, and encased with concrete. A typical well can be drilled in 15-30 days if the rig is operating 24-hours a day. Well drilling requires a significant amount of water to lubricate and cool the drill bit and remove the cuttings from the borehole. Large quantities of wastewater are generated during this process. Along with the cuttings, present as suspended solids, the wastewater can contain pollutants such as sodium, chloride, iron, manganese, barium, arsenic, and organics used during the drilling process (e.g. surfactants, detergents, oil, grease, benzene, toluene) (Swistock, 2010).

Once a well has been drilled, a process called hydraulic fracturing, or fracing, is used to create additional permeability in the shale to improve the flow of gas toward the wellbore. Fracing involves pumping a fracturing fluid (typically water-based with other additives to improve performance) into a formation to generate fractures in the target formation to improve release of the natural gas trapped in the rock (DOE, 2010b). Additives used for hydraulic fracturing include sand, oils, gels, acids, alcohols, and various other chemicals. Some portion of the frac water (estimated at 10 to 70 percent) returns to the surface as "flow back" wastewater, with the rest remaining underground.

Various stages throughout well development have the potential to negatively impact water resources. Improperly sealed wells can contaminate drinking water sources; storage, transportation, and disposal of wastewater present opportunities for leaks or spills; additives injected with hydrofracing fluid may contaminate groundwater sources; or methane gas can migrate from gas wells into nearby water supply wells.

GAS PRODUCTION

The production phase of well development generally presents the lowest level of risk to water quality. Once well development is complete water continues to be pumped into the well to improve the flow of natural gas. The return fluids, called production fluids, generally contain high concentrations of salts from ancient underground saltwater deposits. Production fluids also contain some of the pollutants noted in drilling and hyrdofracturing fluids.

OIL AND GAS WATER RESOURCE CONCERNS

As previously noted, considerable quantities of water are necessary for the development of a Marcellus Shale gas well. The substantial amount of water utilized presents several challenges in protecting the Commonwealth's water resources. In a report issued by USGS (Soeder and Kappel, 2009), three principal water-resource concerns are noted in regards to Marcellus Shale gas production:

WATER SUPPLY MANAGEMENT

Water for drilling and hydraulic fracturing of wells typically comes from surface water bodies such as lakes. Groundwater sources, municipal water sources, and re-used process water are also sometimes used for these processes. Some concern exists about where the immense volumes of water necessary to sustain large scale well development will be obtained. Other concerns include what the potential consequences might be for local water supplies and the effects of withdrawing this amount of water when it is needed for drilling activities.

The water volumes necessary to sustain petroleum activities are large; however they generally represent a small percentage of the total water used when considered from a basin-wide surface water budget (DOE, 2010b). To put shale gas water use in perspective, the consumptive use of fresh water for electrical generation in the Susquehanna River Basin is nearly 150 million gallons per day, while the projected total demand for peak Marcellus Shale activity in the same basin is 8.4 million gallons per day (Gaudlip et al., 2008). When these withdrawals are examined at a local level, they represent a much larger percentage of the available resource. Rapid withdrawal of large quantities can have short and long-term effects on a water supply. Surface water withdrawal during dry periods could affect aquatic life, recreational activities, potable water supplies, and other industries.

WATER RESOURCE CONTAMINATION

As discussed in the previous section, petroleum activities have the potential to negatively impact water quality at several stages throughout the drilling and production process. Construction activities necessary to construct access roads, pipelines, and prepare well sites have the potential to cause increased erosion and sedimentation. Access roads and well pad sites are rarely, if ever, fully stabilized which increases the duration of potential erosion problems. Similarly, transporting large amounts of equipment, vehicles, and supplies to remote well sites can damage low capacity rural roads (often constructed of dirt and gravel) and cause accelerated erosion. These effects of these activities can be mitigated through use of common construction BMPs.

Other activities such as well drilling, hydraulic fracturing a well, and gas production all present unique challenges to protecting water quality. The various pollutants found in the process water and flowback fluids used during these activities have the potential to contaminate groundwater supplies or impair surface waters if not handled and disposed of properly. These activities require specialized practices to reduce the risk of contaminating water resources.

WASTEWATER DISPOSAL

The wastewater produced during well development and production is one of the main threats to water quality. The large volumes of liquid produced present logistical and economic challenges for recovery and disposal of the wastewater in a manner that minimizes impacts to water resources. In addition, the pollutants often present in the liquid can require wastewater treatment prior to disposal. Although the percentage of chemical additives in a typical hydrofrac fluid is typically less than 0.5 percent by volume, the quantity of fluid used is so large that the additives in an average three million gallon well development would result in about 15,000 gallons of chemicals in the wastewater (Soeder and Kappel, 2009). In addition to the chemical additives found in hydrofrac fluid, the wastewater may contain a variety of naturally occurring pollutants such as brines, organics, heavy metals, and radionuclides removed from subsurface formations. High concentrations of sodium, chloride, and bromide are often found in brine from well drilling.

Common disposal methods include processing them through wastewater treatment plants (the most common method in Pennsylvania), re-injecting the fluids into the ground, and evaporating

the liquid and disposing the remaining solids as dry waste. The effectiveness of standard wastewater treatment for processing wastewater is not well understood. In particular, salts and other dissolved solids are not usually removed by standard treatment processes. Re-injecting the wastewater into the ground (shallow re-injection and deep re-injection) may result in groundwater contamination or other unknown problems. The evaporation method is not a very practical technique in the humid climate of Pennsylvania. Further study of these disposal methods and a better understanding of their effects are necessary to effectively protect the water resources of the Commonwealth.

OIL AND GAS MANAGEMENT PRACTICES FOR WATER QUALITY

Many standard practices in the oil and gas industry are currently being implemented in recognition of the need to protect other natural resources while extracting petroleum resources. The water quality impacts of oil and gas activities can be futher minimized by implementing appropriate management measures and by utilizing suitable Best Management Practices (BMPs). As presented here, management measures are guidance for operations and steps to be taken that will promote the sound, efficient, and environmentally appropriate development of all oil and gas activities, with a particular focus on Marcellus Shale natural gas developments. BMPs are specific activities, processes, or technologies designed to serve specific functions, which are used to attain a management measure.

Management measures and BMPs for activities associated with oil and gas development can determine what resources may be impacted, the extent of the impacts, and mitigation strategies. Use of the following management measures and BMPs does not replace the need to meet Federal and State requirements, their use (when appropriate) will aid in compliance with the applicable regulations:

- Predevelopment Planning
- Wetland and Riparian Management Areas
- Access Road Construction
- Road Management
- Pipeline Construction
- Well Site Development
- Chemical Management

Predevelopment Planning

Purpose	Ensure that oil and gas activities are planned with water quality considerations in mind and conducted in a manner to minimize delivery of nonpoint source pollutants to surface waters and groundwater.
Description	A development plan established during the early stages of anticipated development provides the framework for avoiding or minimizing surface disturbance, protecting other resources, mitigating environmental impacts, and alleviating or addressing concerns of landowners and communities. It serves as a tool for comprehensive, coordinated planning to guide strategic development. It can also assist in meeting the requirements of the Clean Water Act, the Clean Air Act, the Endangered Species Act, and other applicable Federal, and State laws.

GUIDANCE: Develop plans to provide a comprehensive description of the characteristics of the area, along with the anticipated nature of the proposed development. Plans should address potential impacts to water quality, existing natural resources, and the potential for habitat fragmentation in sensitive areas where there are high levels of biodiversity, or sensitive and critical habitats.

Planning needs will differ by location and should be applied in different ways, depending on such things as subsurface geology, terrain, and existing and proposed land use. Plans may be simple or complex, depending upon the circumstances, and will need to be customized to fit the site specific conditions for a project. The following items should be included in the plan:

- Identification of land ownership
- Identification of existing and expected surface uses (including number and spacing of wells, roads, pipelines, water disposal and treatment facilities, compression facilities, gathering and transmission pipelines, etc.)
- Identification of existing and required infrastructure and utility corridors
- Map of the area with location of existing facilities (i.e., wells) and potential (optimal) locations for future facilities, including production facilities (well sites, processing units, etc.), roads, and utility corridors. The map should include geographic features such as streams and other water bodies, and special ecosystems, as well as topographic information.
- Identification of opportunities to avoid, reduce, and mitigate adverse impacts
- Identification of regulatory requirements
- Water management plan (strategy)
- Identification of strategies for reclamation of disturbed areas
- Consider a strategy for establishing a baseline and monitoring and steps to apply monitoring information to existing and future actions

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)
BMP 4.3.1. Background Site Factors
BMP 4.3.2. Site Factors Inventory
BMP 4.3.3. Site Factors Analysis

Wetland and Riparian Management Areas

Purpose	Protect the ecological function and hydrologic features of riparian areas, wetlands, and floodplains.
Description	Establish and maintain a buffer zone along surface waters and wetlands that is wide enough to filter runoff, provide bank stability, and shade the water. Limit oil and gas activities within the buffer.

GUIDANCE: Establish a buffer zone around riparian areas, wetlands, and floodplains. Locate all well pads and other nonlinear facilities outside of the buffer zones.

GUIDANCE: Avoid crossings of wetland and riparian areas by pipelines and roads to the maximum extent practicable. Where crossings cannot be avoided, impacts can be minimized through use of the following measures.

- Develop site-specific avoidance and mitigation plans prior to approval process for all proposed disturbance to wetland/riparian areas, including their buffer areas
- Construct any crossings perpendicular to wetland/riparian areas
- Schedule construction adjacent to wetland areas to minimize the duration of construction activity, and to concentrate such activity during dry conditions, or when the ground is frozen during the winter
- Locate stockpiles outside the buffer areas
- Locate drilling mud pits outside of buffer areas
- Begin reclamation of disturbed wetland/riparian areas as soon as possible after project activities are complete
- Monitor any stream channel for erosion, sedimentation, degradation, and riparian health

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)
BMP 5.4.1 Protect Sensitive and Special Value Features
BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas
BMP 5.4.3 Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design

Access Road Construction

Purpose	Reduce erosion and sedimentation which is common during, and immediately after, construction of oil and gas access roads.
Description	Design and construction of roads that are planned for the topography, soils, and drainage patterns of a site. Appropriate construction methods and BMPs are used to minimize erosion from high risk areas such as the road surface, steep slopes, water crossings, and runoff conveyance structures (i.e. culverts, ditches, etc.).

The location and construction of access roads require careful planning. Special attention should be given to steep slopes, surface waters, soils, and other potential hazards. Access roads should be designed with grades between 2 and 10%, located outside buffers of water features, and should have cuts and fills minimized.

GUIDANCE: Utilize existing roads to the maximum extent possible. Locate new roads in areas that will optimize year-round, all-weather access, and minimize surface disturbance and environmental impacts.

GUIDANCE: Minimize construction of roads where it is operationally feasible and safe. Construct roads to the minimum standard necessary to achieve intended use (i.e. use two-track access roads where possible).

GUIDANCE: Road Construction and Reclamation. Plan, maintain and construct all roads in conformance with road standards. Major access roads to the general development area should be constructed to a higher road standard to avoid excess maintenance caused by poor planning and constructed. Practices that can enhance reclamation include:

- Reclaim and re-vegetate all disturbed surface that will not be used for gas operations in a manner that restores topsoil and minimizes erosion.
- Use re-forestation as a reclamation strategy where forest land was impacted during the development.
- Use only certified and inspected seed that is free of noxious weeds for reclamation/re-vegetation.

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)	
BMP 5.7.1 Reduce Street Imperviousness	
BMP 5.7.2 Reduce Parking Imperviousness	
• Structural (refer to PA Stormwater BMP Manual)	
BMP 6.4.1 Pervious Pavement with Infiltration Bed	
BMP 6.4.7 Constructed Filter	
BMP 6.4.8 Vegetated Swale	
BMP 6.4.9 Vegetated Filter Strip	
• E&S (refer to PA E&S Pollution Control Manual)	
Sediment Barriers and Filters	Compost Filter Sock, Rock Filter Outlet, Super Silt Fence, Sediment Filter Log, Straw Bale Barrier, Rock Filter, Vegetative Filter Strip
Runoff Conveyance BMPs	Broad-based Dip, Access Road Swale, Ditch Relief Culvert, Turnout
Sediment Capture & Treatment	Construction Entrances, Compost Sock Sediment Trap
Stabilization Methods and Standards	

Road Management

Purpose	To ensure that management of existing roads maintains their utility and minimizes polluted runoff from roads and road structures.
Description	Minimize use during wet weather and thaw conditions. Perform routine maintenance of road surface, stream crossings, and drainage structures. Immediately repair eroding areas and implement BMPs to address problem areas. Close and decommission roads that are no longer needed.

GUIDANCE: Plan access routes for heavy equipment and the high volume of trucks to the site with input from the local municipality and PennDOT.

GUIDANCE: Consider operational traffic and plan for the long-term operations of the facility considering maintenance as well as potential issues with dust, compaction, and debris, as well as safety.

Water Quality BMPs:

• E&S (refer to PA E&S Pollution Control Manual)
Sediment Barriers and Filters
Runoff Conveyance BMPs
Stabilization Methods and Standards

Pipeline Construction

Purpose	Reduce erosion and sedimentation during, and immediately after, construction of oil and gas pipelines.
Description	Appropriate design and construction methods are used to minimize erosion from areas disturbed by pipeline construction. BMPs are used in high risk areas such as steep slopes and water crossings.

GUIDANCE: Use existing disturbance corridors whenever possible (ideally following access routes or existing pipeline routes).

GUIDANCE: Locate pipelines in the same trenches, or immediately parallel to, each other. Install pipelines at the same time if possible.

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)
BMP 5.4.1 Protect Sensitive and Special Value Features
BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas
BMP 5.4.3 Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design
BMP 5.6.3 Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species
• E&S (refer to PA E&S Pollution Control Manual)
Crossings Roadways, stream, wetlands
Outlet Protection
Stabilization Methods and Standards

Well Site Development

Purpose	Minimize the likelihood of water quality impacts resulting from development of oil and gas well sites.
Description	Follow the plan for oil and gas operations developed during predevelopment planning. Conduct operations to avoid sedimentation to the extent practicable. Use appropriate areas for high risk activities such as equipment maintenance, and petroleum and chemical storage and dispensing.

GUIDANCE: Minimize surface disturbance to the maximum extent practicable. Utilize techniques such as drilling multiple wells from the same pad when technically feasible.

GUIDANCE: Remove all equipment not necessary for well operations.

GUIDANCE: Locate well construction activities with the following considerations:

- Locate well sites in stable, non-erosive soil areas, with grass or brush cover and on relatively level areas that minimize pad construction. Choose sites that avoid steep slopes, unstable soils, and close proximity to streams, floodplains, springs, and wetlands.
- Divert surface runoff from entering the constructed pad site to avoid transporting of pollutants.
- Locate facilities and roads away from occupied dwellings.
- Locate in visually acceptable areas (avoid dwelling view sheds) and paint facilities colors that blend in with the natural environment.
- Locate where safe access can be maintained year round.

Water Quality BMP's:

• Non-Structural (refer to PA Stormwater BMP Manual)	
BMP 5.5.1 Cluster Uses at Each Site; Build on the Smallest Area Possible	
BMP 5.6.1 Minimize Total Disturbed Area – Grading	
BMP 5.6.2 Minimize Soil Compaction in Disturbed Areas	
BMP 5.6.3 Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species	
BMP 5.7.2 Reduce Parking Imperviousness	
BMP 5.9 Source Control	
• E&S (*refer* to PA E&S Pollution Control Manual)	
Sediment Barriers and Filters	Compost Filter Sock, Rock Filter Outlet, Super Silt Fence, Sediment Filter Log, Straw Bale Barrier, Rock Filter, Vegetative Filter Strip
Runoff Conveyance BMPs	Channels, Top of Slope Berm, Temporary Slope Pipe
Sediment Capture & Treatment	
Outlet Protection	
Stabilization Methods and Standards	
• *Structural* (refer to PA Stormwater BMP Manual)	
BMP 6.4.1 Pervious Pavement with Infiltration Bed	
BMP 6.4.7 Constructed Filter	
BMP 6.4.8 Vegetated Swale	
BMP 6.4.9 Vegetated Filter Strip	
BMP 6.6.1 Constructed Wetland	
BMP 6.6.2 Wet Pond/Retention Basin	
BMP 6.6.3 Dry Extended Detention Basin	
BMP 6.6.4 Water Quality Filters & Hydrodynamic Devices	
BMP 6.7.1 Riparian Buffer Restoration	
BMP 6.7.2 Landscape Restoration	
BMP 6.7.3 Soil Amendment & Restoration	
BMP 6.7.4 Floodplain Restoration	
BMP 6.8.1 Level Spreader	

Pollution Prevention

Purpose	Minimize the potential of water pollution caused by potential pollutants used for, or generated by, oil and gas operations.
Description	Risks associated with chemicals and other potential pollutants used for, and generate by, oil and gas operations can be reduced through careful transport, storage and use the substances. Spill Preparedness, Prevention, and Contingency Plans can reduce the potential impact of accidental spills.

GUIDANCE: Prepare a site specific Preparedness, Prevention, and Contingency Plan that identifies potential pollutants used or stored on site, outlines operational procedures to reduce the likelihood of accidental spills, and details a pollution incident response plan to be employed in the event of a spill.

GUIDANCE: Conduct personnel training programs to educate all employees of safe handling and disposal methods of all potential pollutants stored or generated on site. Pollution incident response should also be included in the training.

GUIDANCE: Implement pollution prevention practices when feasible. Use pollution source reduction techniques (i.e. alternative chemicals and additives), reduce or eliminate waste generated through process changes, and use new technologies to remove pollutants from wastewater to reduce the pollution potential of oil and gas activities.

Facility Reclamation and Decommissioning

Purpose	Reduce erosion and sedimentation of areas disturbed by oil and gas activities and minimize long-term impacts of oil and gas activities.
Description	Reduce erosion and sedimentation by stabilizing the work area around active facilities and establishing permanent vegetation on the surrounding area immediately upon completion of earth-disturbing activities. Remove and decommission facilities upon completion of planned use. Restore facility sites to pre-disturbance condition, or better.

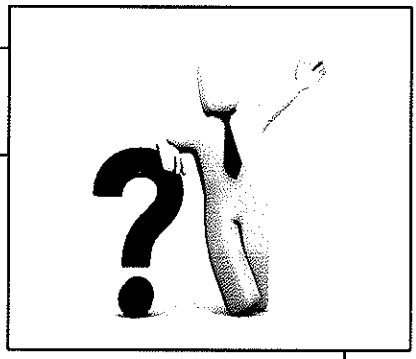
GUIDANCE: Reduce facility size to the minimum area required for oil and gas production operations by restoring all areas temporarily disturbed during construction activities. Restoration should include the following:

- Re-contour disturbed areas to be compatible with existing grades.
- Replace topsoil to at least the depth and quality that existed prior to disturbance for final reclamation of the site upon abandonment of the well.
- Re-vegetate disturbed areas using native vegetation and including re-forestation.
- Remove all chemicals, equipment, materials, and waste not necessary for sustaining production from the well pad.

GUIDANCE: Stabilize facilities during operations with crushed stone or other appropriate methods.

GUIDANCE: Remove and decommission facilities as soon as reasonably possible after oil and gas production is completed. Restore the disturbed areas to their pre-disturbance condition, or better, by reshaping the site to the original contour, replacing topsoil, and re-establishing native vegetation.

Comment - Response



PUBLIC HEARING

Duing the Public Hearing held on July 7, 2010, several comments and questions were presented. The following summarizes the comments and questions as well as responses:

Comment **Must municipalities enact a strormwater ordinance? What would happen if one doesn't?**

Response Municipalities must enact or modify their current ordinances to meet recommendations of the Plan. Section 12 of the Act 167 also addresses the subject.

Comment **Are there credits for tree planting? How many cubic feet should there be per tree? How is this converted to the area?**

Response The tree planting credit is provided to offset runoff volume impacts. Appendix E of the Ordinance addresses this issue.

Comment **Act 167 was passed by the state in 1978 and contains no date to implement the provisions of the Act. Why does the County have to implement this Act now?**

Response Act 167 requires all Counties to provide for stormwater planning for each of the +350 watersheds within the state. Previously, plans were completed on individual watershed basis. As funding of the Act 167 program has been limited, DEP has recently allowed plans to be developed for all watersheds within a County allowing plan development to be more efficient. DEP also increased funding of the Act 167 program which all Counties in the northwest region of the state took advantage. Act 167 provides for DEP to fund Plan activities with a 75% reimbursement. The County portion of the funding is 25%. This was a large factor in Butler County participating in program.

Comment **There is still some confusion with the reimbursement requirement as it relates to implementation of the Plan by individual municipalities. Although the model Ordinance includes an agreement document, reimbursement is seen as problematic.**

Response The Model Ordinance includes provisions for municipalities to charge fees for implementation of the Model Ordinance. It also includes a Reimbursement Agreement for municipalities to use with Developers. This document may be used by any municipality to be reimbursed by a Developer for reviewing a SWM Plan if one is required. If the Municipality experiences a loss in implementing the Plan, the municipality can seek, on an annual basis, reimbursement up to 75% of the difference of eligible costs from the state.

Comment **Driveway area are considered impervious, can there be an exemption for this?**

Response The Ordinance provides for single family residential activity exemption criteria which addresses driveways.

Comment **The Butler Township Commissioner stated that the new Stormwater Management Ordinance, once in effect, will require additional people being hired to implement the Ordinance. This is a major concern.**

Response Duly noted.

Comment **There were comments about the Mercer Township supervisor's recent letter in the Butler Eagle. The environment should be protected; however, it will be an extreme burden for rural municipalities. It will add costs to building construction. Reference to the pending residential building sprinkler system requirements and requiring farmers to chlorinate their stormwater runoff as examples. In rural areas this is "over the top". At a minimum can the requirements be relaxed for more rural population municipalities? The speaker considered this Act an abuse of power like the CWA of 1978. They want County Commissioners to stand up against unnecessary regulations.**

Response Duly noted.

Comment **Please elaborate on whether the Act and\or the Model Ordinance applies to forest/timber operations.**

Response The Model Ordinance states that forest management and timber operations are exempt from the Rate and Volume Control requirement and SWM Site Plan preparation requirement of this Ordinance provided the activities are performed according to the requirements of 25 PA Code Chapter 102. It should be noted that temporary roadways are not exempt.

Comment **Please comment on easement requirements on one's own land vs. on downstream property.**

Response If a new stormwater discharge is proposed to an existing drainage way and the existing drainage way has sufficient capacity to accommodate the projected flow, no easement required. If one plans to concentrate previously diffused runoff onto adjacent property where a defined drainage way does not exist, then one has to get permission from the downstream owner. Permission is in the form of an easement. Options exist so one does not need to get an easement such as spreading runoff out on ones property so that it is not concentrated at one location at the downstream property line, infiltrate all flow using BPM's; etc.

Comment **What is the process for requiring water quality testing?**

Response The Model Ordinance provides for alternatives when infiltration may not be possible or recommended to meet Volume Control criteria. The Model Ordinance provides provisions based on the BMP Manual guidance for calculation methodology to document pollutant loads and reductions from installed BMPs. It is noted that the installation of Volume Control assumes that water quality requirements are met.

Comment **Has DEP "re-thought" the 150' riparian buffer requirements in EV/HQ watersheds?**

Response As of today, the buffer distance is as stated in the Ordinance which is consistent with the regulations we understand DEP will be implementing in the near future.

Comment **How does this Plan and Ordninance address work performed by PennDOT?**

Response All state agencies have to follow the requirements of the Plan; however, with sovereign immunity, state agencies do not need municipal approvals.

Comment **It was the opinion of one Attorney in the audience that PennDOT is exempt from Act 167 requirements. A case citation was provided.**

Response Duly noted.

Comment **What is considered the point of discharge on a property?**

Response The property line or any point along it where runoff flows or is directed.

Comment **Is Venango Township required to pass this Ordinance?**
Response Butler County must adopt a resolution adopting the plan. The Township would then have six months after DEP approval of the County Plan to adopt the provisions of the Model Ordinance or revise its current ordinance to implement recommendations of the Plan.

Comment **Are there any comments from the County Commissioners?**
Response Commissioner Pinkerton, Lokheiser and Kennedy were in attendance and are listening to public input as part of what they will use to make a decision. Commissioner Pinkerton commented that there was a county up north (McKean) that has a 10,000 square foot impervious area threshold and that will be taken into consideration.

Comment **In regards to soil types, does one size stormwater management planning fit all?**
Response Soil characteristics are an important factor in stormwater management. The Plan identifies the soil characteristics across the County. It is important to note that stormwater management criteria is provided for the land use change due to Regulated Activities, not soil type change.

Comment **Does the model Ordinance take a more restrictive approach than DEP requires?**
Response No. The Ordinance is consistent with existing BMP Manual and other DEP requirements. The Ordinance provides flexibility and guidance for both municipalities and land owners.

Comment **How are the farmers impacted?**
Response Agricultural activities (tilling, plowing, etc.) are exempt from requirements of this Ordinance provided the activities are performed according to the requirements of 25 PA Code Chapter 102. It was noted that the construction of a barn or other impervious surfaces are regulated through the Model Ordinance.

Comment **The following items were presented for consideration:**

- **Suggest increasing threshold to 10 K SF min, – less is too restrictive**
- **Have to consider growth – Ordinance is pointed at small individual**
- **Current Stormwater Management in municipalities who have good controls should be kept in place – no changes.**
- **Cumulative effect of no Stormwater management**
- **People think it is too restrictive – why not let Townships pass own "more stringent" if they want**

Mercer Township wishes to be put on record of being against this Ordinance and wants it less restrictive. This needs changed to fit the residents of Butler County.
Response Duly noted.

Comment **How many engineers are in the room? Do they understand the Plan?**
Response Five or six people raised hands. Most nodded in the affirmative that they understood the plan requirements.

Attorney Stepanian provided additional comments

- **Reference the Penalties provision, Section 12.05. Commented on penalties vs. Injunctive relief.**
- **Section 12.06, Appeals. There is no provision in Act 167 to allow for appeals to Twp. Appeals can only go directly to courts.**
- **In his opinion there will be a substantial number of appeals.**

Response Duly noted.

Comment **Is there a BMP guide available for residential owners?**

Response Section 7 of the Plan provides a discussion and guide for BMP's. The PA BMP Manual is referenced.

Comment **Are there any guarantees that the Township will not have to spend money in implementing the Plan?**

Response By implementing the provisions of the Plan through the Model Ordinance, future runoff problems can be addressed before they become problems where capital funding is needed. Costs to municipalities can be defrayed by use of the Reimbursement Agreement in the Model Ordinance. Municipalities will be responsible for implementation of the Ordinance. There is no guarantee that the municipalities will not spend additional money to implement.

Comment **Concord Township agrees with Mercer Township and wishes to go on record as opposed to the Ordinance as written.**

Response Duly noted.

Comment **Page 1 of the Ordinance states the Model Ordinance must be adopted. This will cost the Township in that the Solicitor will need to review. Is it possible that the County may have overdone it, i.e. MS4's communities would need more restriction and non MS4 communities could get a bit more leeway?**

Response Options on how to implement are available to Townships. It is recommended that each Township have Solicitors review current ordinances/draft new.

Comment **This effort is clipping away at Township rights and freedoms. Mercer Township does not need same Ordinance as Connoquenessing Township. No one knows the full cost to the municipalities after adoption. For instance it has been discussed that Allegheny County would love Butler County to adopt this plan. More restrictions in Butler County may mean less people moving to Butler County.**

Response Duly noted.

Comment **Is DEP using a set of criteria to write Ordinance? Can they have it?**

Response The draft checklist the DEP uses to review County Plans will be sent to all in attendance via email.

Comment **Stormwater management is important. Butler Township has been implementing management for 20 years and has success. They did support how the Plan effort started off. Please explain how we got to a compressed time period.**

Response During the passage of last years state budget, the Act 167 program funding was cut and work was stopped for a time until the effort was re-scoped by the County and DEP so that Plans can be completed by the end June 2010.

Comment **The statement of findings language portion of the Model Ordinance was "read into the record". Disagree with this language because certain Townships address stormwater and do not find it is an issue. Is this "semantics"?**

Response The statement of findings does not say that municipalities allow or condone inadequate management of runoff; it merely states that inadequate SWM leads to problems which almost everyone can agree.

Comment **Act 167 does not provide the same authority that Act 247 (the MPC). As such, the provisions of the Model SWM Ordinance should be in the Subdivision and Land Development Ordinance to allow for enforcement per the MPC. Stand alone SWM Ordinance may be very problematic as it does not have the same specific authority that the MPC has. Discuss Township liability.**

Response Statutory Authority is provided for in Section 104 of the Model Ordinance which includes reference to the MPC.

Comment **How about a "compromise 7,500 SF threshold if 10,000 SF will not be acceptable to the DEP?**

Response Since the initiation of this planning effort over two years ago, the thresholds were discussed. At that time, the guidance provided was between 250 to 1,000 SF for thresholds. It is noted that all runoff from new impervious area is required to be managed; the thresholds relate to a point where approval from the municipality is needed. During the development of the Plan, alternatives were discussed concerning the threshold to meet the impacts of new impervious surfaces effectively within the County. It was noted that situations are different in each County but impacts of inadequate management of runoff is still problematic.

Comment **If 10, 000 SF threshold, would Cranberry Township be satisfied?**

Response Cranberry Township already enforces a lower threshold.

Comment **Oakland Township wants to increase to 10, 000 SF.**

Response Duly noted.

Comment **How big is 5, 000 SF vs 10, 000 SF. Give a scale.**

Response 10, 000 SF is approximately ¼ acre