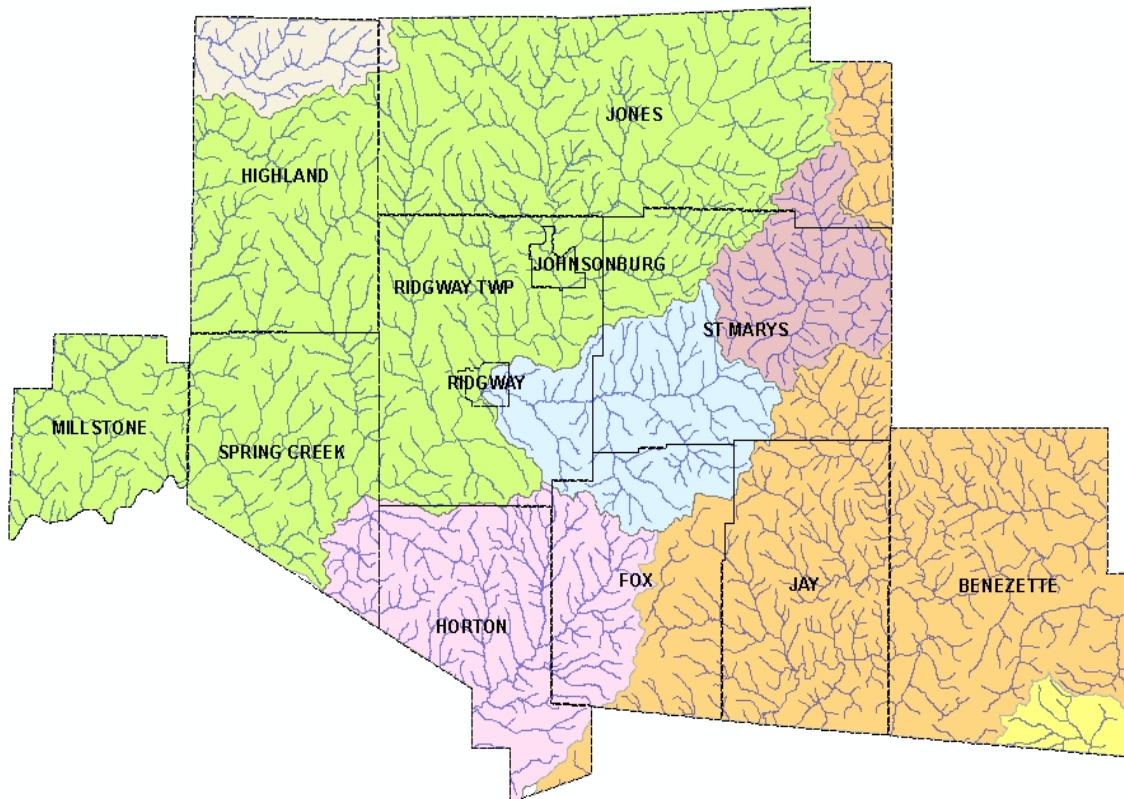


ELK COUNTY
ACT 167 PHASE 2
STORMWATER MANAGEMENT PLAN

VOLUME 2 – PLAN CONTENT



PREPARED FOR:

ELK COUNTY
300 Center Street
Ridgway, PA 15853

PREPARED BY:

ELK COUNTY
PLANNING COMMISSION
300 Center Street
Ridgway, PA 15853

CONSULTANT:

L.R. KIMBALL
415 Moon Clinton Road
Coraopolis, PA 15108

ELK COUNTY WATERSHED PLANNING ADVISORY COMMITTEE (WPAC)

WPAC Member	Organization
Ms. Marylou Walck	Benezette Township
Mr. David Green	City of St. Mary's
Ms. Kathy Mosier	Fox Township
Ms. Leatrice Maze	Highland Township
Mr. Dennis Thompson	Horton Township
Ms. Debbie Leonard	Jay Township
Ms. Mary Polaski	Johnsonburg Borough
Ms. Laurie Storrar	Jones Township
Ms. Johanna Patton	Millstone Township
Mr. Martin Schuller	Ridgway Borough
Ms. Milly Bowers	Ridgway Township
Mr. Richard Wittman	Spring Creek Township
Mr. Bill Sabatose	Toby Creek Watershed Assoc.
Mr. Ken Rowe	Bennett Branch Watershed Assoc.
Mr. Jeff Buchheit	Elk County Freshwater Assoc.
Mr. Barry Mayes	North Central Pennsylvania Regional Planning and Development Commission
Mr. Matt Quesenberry	Elk County Planning Department
Mr. Robert Dippold	County of Elk
Ms. Kim Lanich	County of Elk
Mr. Michael A. McAllister	County of Elk
Mr. Rob Fallon	Marienville Ranger District
Mr. Adam Dellinger	Headwaters RC&D
Mr. Timothy J. Bruno	PA Department of Environmental Protection
Mr. David Matheson	PennDOT Engineering District 2

RESOLUTION

WHEREAS, the Stormwater Management Act 167 of 1978 provides for the regulation of land and water use for flood control and stormwater management, requires the Pennsylvania Department of Environmental Protection to designate watersheds, and provides for grants to be appropriated and administered by the Department for plan preparation and implementation costs, and provides that each county will prepare and adopt a watershed stormwater management plan for each designated watershed; and

WHEREAS, the Elk County Commissioners entered into a reimbursement agreement with the Pennsylvania Department of Environmental Protection to develop a county-wide watershed Stormwater Management Plan; and

WHEREAS, the purpose of the Stormwater Management Plan is to protect public health and safety and to prevent or mitigate the adverse impacts related to the conveyance of excessive rates and volumes of stormwater runoff by providing for the management of stormwater runoff and control of erosion and sedimentation; and

WHEREAS, design criteria and standards of stormwater management systems and facilities within the County shall use the criteria and standards as found in the Stormwater Management Plan;

NOW, THEREFORE, BE IT RESOLVED that the Elk County Commissioners hereby adopt the Stormwater Management Plan, including all volumes, figures, appendices, and Model Ordinance, and forward the Plan to the Stormwater Management Section of the Pennsylvania Department of Environmental Protection for approval.

This Resolution is hereby adopted this _____ day of _____, 2010 by:

ELK COUNTY COMMISSIONERS

June H. Sorg, Chairperson

Daniel R. Freeburg, Commissioner

Ron Beimel, Commissioner

CONTENTS

SECTION I	INTRODUCTION	1
A.	Introduction	1
B.	Stormwater Management	3
C.	Stormwater Management Plan Objectives	3
Table I-1	4
D.	Stormwater Management Plan Strategy	6
SECTION II	ACT 167	9
A.	Stormwater Management Act 167	9
B.	Purpose of the Study	9
SECTION III	GENERAL DESCRIPTION OF WATERSHEDS	10
A.	General County Description	10
B.	Political Jurisdictions	10
C.	NPDES Phase II Involvement	10
D.	Data Collection	12
E.	General Development Patterns	13
F.	Physiography and Geology	14
G.	Climate	14
H.	Soils	15
I.	Water Resources	16
J.	PA Chapter 93 Stream Classifications	19
K.	Obstructions	19
L.	Dams and Impoundments	22
M.	Pollution and Stream Impairments	24
N.	Stormwater Problem Areas	25
O.	Land Use	31
P.	Existing Development in the Flood Hazard Areas	32
SECTION IV	WATERSHED TECHNICAL ANALYSIS	37
A.	Watershed Modeling	37
B.	Modeling Process	39
C.	Calibration	40

SECTION V	STANDARDS AND CRITERIA FOR STORMWATER CONTROL.....	52
A.	Watershed Level Control Philosophy	52
B.	National Pollutant Discharge Elimination System (NPDES), Phase II Requirement	52
C.	Standards and Criteria	53
D.	Release Rate Stormwater Management District Concept (For Overbank and Extreme Events)	74
E.	Structural and Non-Structural BMPs.....	78
SECTION VI	MUNICIPAL ORDINANCE INTRODUCTION	83
A.	Supporting Information	83
B.	Required Ordinance Contents	84
SECTION VII	PRIORITIES FOR IMPLEMENTATION	87
A.	DEP Approval of the Plan.....	87
B.	Publishing the Final Plan	87
C.	Municipal Adoption of Ordinance to Implement the Plan	87
D.	Level of Government Involvement in Stormwater Management.....	88
E.	Correction of Existing Drainage Problems	89
F.	Culvert Replacement	89
G.	PennVEST Funding.....	90
H.	Landowner's/Developer's Responsibilities	91

PLAN FORMAT

The format of the Elk County Stormwater Management Plan consists of three Volumes:

Volume 1 - Executive Summary

Provides an overview of Act 167 and a summary of the standards and criteria developed for the Plan.

Volume 2 – Plan Content

Provides an overview of stormwater management, purpose of the study, data collection, all GIS maps, present conditions, projected land development patterns, calculation methodology, the Model Ordinance and implementation discussion.

Volume 3 – Appendices

Provides supporting data, watershed modeling parameters and modeling runs, peak flows, release rates, the existing municipal ordinance matrix, and obstructions inventory. Due to large volumes of data, one copy of Volume 3 will be on file at the Elk County Department of Planning.

SECTION I INTRODUCTION

A. Introduction

The purpose of this Act 167 Stormwater Management Plan is to:

1. Encourage planning and management of storm water runoff in each watershed that is consistent with sound water and land use practices.
2. Authorize a comprehensive program of storm water management designated to preserve and restore the flood carrying capacity of Commonwealth streams; to preserve to the maximum extent practicable natural storm water runoff regimes and natural course, current and cross-section of water of the Commonwealth; and to protect and conserve ground waters and ground-water recharge areas.
3. Encourage local administration and management of storm water consistent with the Commonwealth's duty as trustee of natural resources and the people's constitutional right to the preservation of natural, economic, scenic, aesthetic, recreational and historic values of the environment.

This Countywide Plan has been prepared for Elk County and applies to all areas located within the boundaries of Elk County, as well as all designated watersheds within the County. This Plan will assist in achieving the effective and efficient stormwater management of all major watersheds within Elk County and provide a single technical source for stormwater management across Elk County.

The need for this Act 167 plan is to assist in the achievement of Elk County's goal to create an overall stormwater management plan document, as well as to achieve compliance with the Pennsylvania Stormwater Management Act of 1978 (Act 167). Specific County goals are identified in Section I.C below. One of the primary objectives of Elk County's Act 167 planning process is to provide a countywide comprehensive program to assist in the planning and management of stormwater. With coordination from the twelve (12) municipalities in Elk County, the resulting stormwater management ordinance will address severe and ongoing stormwater related problems in critical areas throughout the County. In accordance with Section 11.(b) of the Pennsylvania Stormwater management Act of 1978 the following is required:

"Within six months following adoption and approval of the watershed storm water plan, each municipality shall adopt or amend, and shall 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 storm water plan and the provisions of this act."

Various river and stream valleys cut through the landscape of Elk County. All of these either form or are tributaries to the Clarion River or Sinnemahoning Creek. The eastern and southeastern portion of the County lies in the Susquehanna River Basin and is drained by Sinnemahoning Creek and its tributaries. The western and central portions of the County are in the Allegheny River Basin and are drained by the Clarion River and its tributaries.

Clarion River

The Clarion River flows 101 miles through Elk, Forest, Jefferson, and Clarion Counties, emptying into the Allegheny River near Parker, PA. Over half the river is classified as scenic or recreational, with numerous species of wildlife and vegetation along its banks. The Clarion River, from the Allegheny National Forest/State Game Land (ANF/SGL) boundary below Ridgway to the backwater of Piney Dam is located in the unglaciated Allegheny plateau. It is free flowing and relatively slow moving with meanders and a generally steep valley with little floodplain. Tributaries to the River include Wolf Run, Little Wolf Run, Big Mill Creek, Bear Creek, Elk Creek, and Spring Creek.

Sinnemahoning Creek

Sinnemahoning Creek (Native American for “stony lick”) is a tributary of the West Branch Susquehanna River. The Sinnemahoning was once a route for Native Americans and eventually served as a route for 19th century loggers to transport their timber to the West Branch of the Susquehanna River. It is a slow running stream with occasional gentle rapids. Major Elk County tributaries to the Sinnemahoning Creek include Kersey Run, Trout Run, West Creek, and Dents Run.

Figure I-1 below shows the seven watersheds designated under the Act 167 Program, as well as two additional watersheds of concern in Elk County.

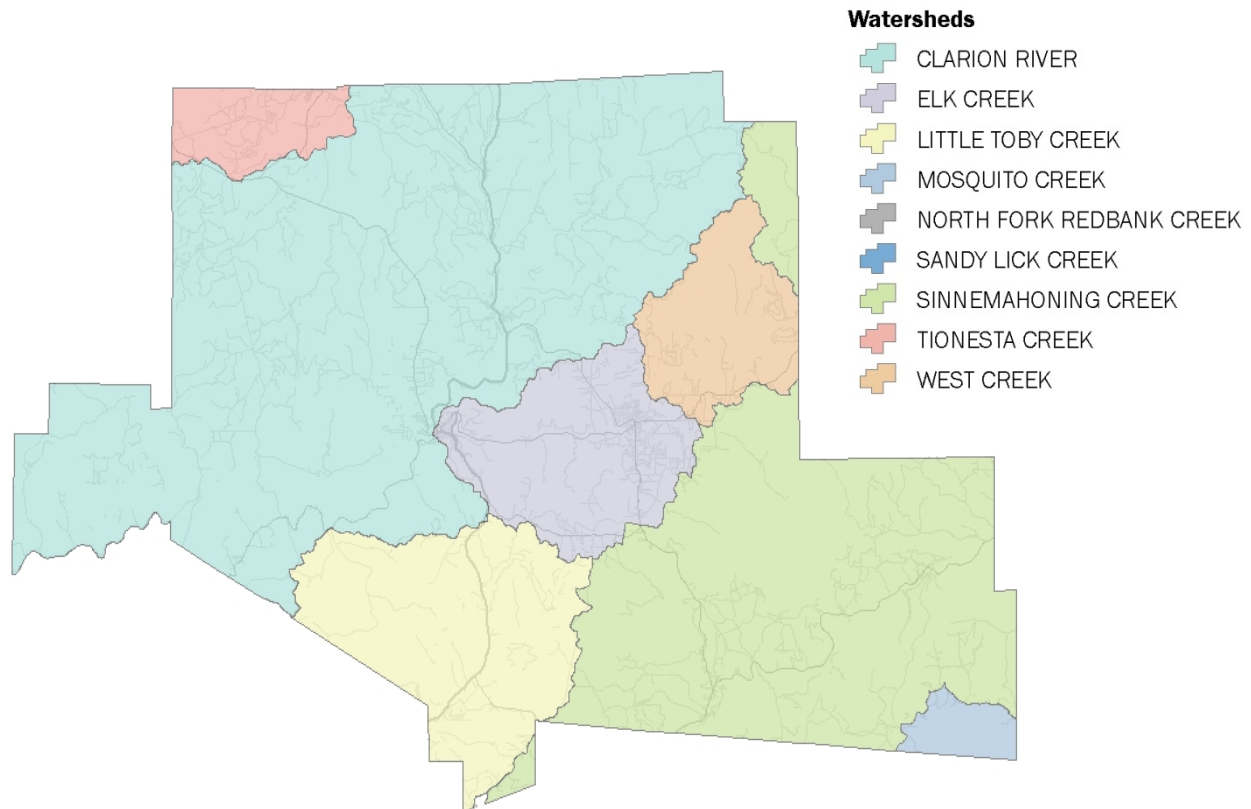


Figure I-1

As a requirement of the development of this plan, a model ordinance has been developed and is included in the Appendix section of this plan. Elk County and PADEP will then review and approve the final Plan document within the necessary timeframe. In accordance with Section 11.(b) of the Pennsylvania Stormwater management Act of 1978 the following is required:

“Within six months following adoption and approval of the watershed storm water plan, each municipality shall adopt or amend, and shall 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 storm water plan and the provisions of this act.”

The County and municipalities must periodically review and revise the Plan at least every five years. PADEP may, for good cause shown, grant an extension of time to the County for the preparation and adoption of a watershed storm water management plan.

B. Stormwater Management

The water that runs off the land into surface waters of the Commonwealth during and immediately following a rainfall or snow/ice melt event is referred to as stormwater. In a watershed undergoing land use conversion or urban expansion, the volume of stormwater resulting from a particular rainfall event increases because of the reduction in pervious land area (i.e., natural land cover being changed to pavement, concrete, buildings, or unmanaged cropland). These surface changes can also substantially degrade stormwater runoff quality, increasing the pollutant load to the rivers and streams. The alteration of natural land cover and land contours to residential, commercial, industrial, and crop land uses results in decreased infiltration of rainfall, an increased rate and volume of runoff, and increased pollutant loadings to surface watercourses.

As the population of an area increases, land development is inevitable. As land disturbance and development has increases, so does the problem of dealing with the increased quantity and decreased quality of stormwater runoff. Failure to properly manage this runoff results in greater flooding, stream channel erosion and siltation, degraded water quality, as well as reduced groundwater recharge. The cumulative effects of development in some areas of a watershed can result in flooding of natural watercourses with associated costly property damages. These impacts can be minimized if the land use and development incorporates appropriate runoff and stormwater management systems and designs.

Individual land disturbance/development projects have historically been viewed as independent or discrete events or impacts, rather than as part of a larger watershed process. This has also been the case when the individual land development projects are scattered throughout a watershed (and in many different municipalities). However, it is now being observed and verified that the cumulative nature of individual land surface changes dramatically affects runoff and flooding conditions. These cumulative effects of development and land disturbance in some areas have resulted in flooding of both small and large streams with associated property damages and even causing loss of life. Therefore, given the distributed and cumulative nature of the land alteration process, a comprehensive approach must be taken if a reasonable and practical management and implementation approach or strategy is to be successful.

C. Stormwater Management Plan Objectives

One of the County goals considered in the preparation of this plan is to produce a countywide model ordinance that will serve as a means of effectively implementing the results of the plan and providing measures that address technical, legal, and governmental issues, as well as achieving additional Countywide objectives noted below.

The final objectives for this Plan were developed based on a review of the objectives within Section 3 of Act 167, a review of water quality impairments in the County, and a review of stormwater management problems identified by the WPAC and through the municipal survey process. Through analysis of the survey results, L.R. Kimball and County staff determined that the three primary stormwater problems within the County are stream corridor flooding, street flooding, and property flooding.

The original Plan objectives included the following:

1. Encourage planning and management of storm water runoff in each watershed that is consistent with sound water and land use practices (Act 167, Section 3).
2. Establish a comprehensive program of storm water management policy to help preserve and restore stream flood carrying capacity, to help preserve as much as possible the natural storm water runoff regimes and

natural course, current and cross-section of waters of the Commonwealth; and to protect and conserve ground waters and ground-water recharge areas (Act 167, Section 3).

3. Establish local administration and management of storm water (Act 167, Section 3).
4. Prepare detailed hydrologic analyses of the following watersheds in order to develop comprehensive approaches to stormwater management controls (as outlined in Table I-1)

Table I-1

Watershed	Rationale	Focus of Modeling Effort
West Creek	Recurrent street flooding and growth area potential	Upper West Creek Watersheds starting at Steinhopper Hollow tributary
Elk Creek	Update existing 167 watershed Plan, multiple and recurrent stormwater problems	Designated Watershed
Little Toby Creek	Growth areas and stream sedimentation problems at structures that cause recurrent flooding; AMD problems exacerbated by stormwater runoff from AMLs	Little Toby Creek and Brandy Camp Creek subwatersheds
Sinnemahoning Creek	Recurrent property flooding and stream bed/bank erosion	Kersey Run subwatershed and Bennett's Branch Sinnemahoning Creek in Jay and Fox Townships
	Recurrent urban flooding in Benezette.	Trout Run subwatershed
	Recurrent street flooding	Wainwright Run / Bennett's Branch Sinnemahoning Creek area in Benezette Township
Clarion River	Growth area, recurrent stormwater problems due to inadequate infrastructure	Wilson Run / West Branch Clarion River in Wilcox, Jones Township
	Stream bed/bank erosion problems	East Branch Spring Creek / Wagner Run Subwatersheds in Highland Township
	Recurrent street flooding and stream sedimentation	Irwin Run subwatershed in Spring Creek Township
	Growth area / stream corridor flooding	Silver Creek / Johnson Run / Powers Run subwatersheds in Johnsonburg Borough area and St Mary's City
	Recurrent street and property flooding, stream corridor flooding / obstruction(s)	Clarion River tributary / Mason Creek / West Main Street / urban tributary subwatersheds in Ridgway Township and Ridgway Borough

These original Plan objectives were determined using the process summarized in Figure I-2.

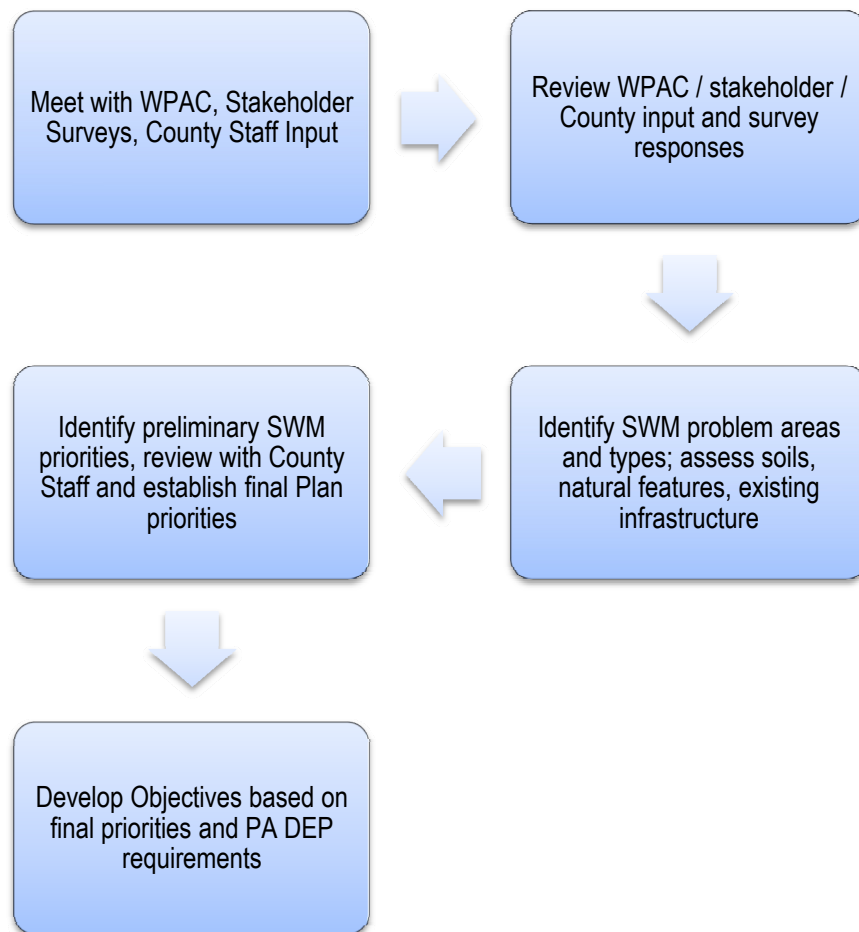


Figure I-2 Original Plan Objectives Setting Process

The final Plan objectives for the current planning cycle take into account the Act 167 Program budget cuts and consequent cuts in funding for the Elk County Plan. These final objectives are based on the reduced funds available as well as the accelerated Plan completion deadline. These changes forced a re-evaluation of the objectives for the current planning cycle, and the final Plan objectives include the following:

1. Encourage planning and management of storm water runoff in each watershed consistent with sound water and land use practices (Act 167, Section 3).
2. Establish a comprehensive program of storm water management policy to help preserve and restore stream flood carrying capacity, to help preserve as much as possible the natural storm water runoff regimes and natural course, current and cross-section of waters of the Commonwealth; and to protect and conserve ground waters and ground-water recharge areas (Act 167, Section 3).
3. Establish local administration and management of storm water (Act 167, Section 3).

4. Prepare detailed hydrologic analyses of the following watersheds in order to evaluate more comprehensive approaches to stormwater management controls (as outlined in Table I-2):

Table I-2		
Watershed	Rationale	Focus of Modeling Effort
Elk Creek	Update existing 167 watershed Plan, multiple and recurrent stormwater problems	Designated Watershed

As noted above, these final Plan objectives were determined by the County based on the amount of remaining funding available in the current state fiscal year for this planning project and based on the new County Plan adoption deadline of June 30, 2010.

D. Stormwater Management Plan Strategy

Preferred Strategies:

1. Administrative / Policy
 - a. Municipal adoption of the Model Ordinance language within this Plan.
Municipalities may adopt a stand-alone ordinance, or may choose to incorporate the language within the Model Ordinance into their existing ordinances
 - b. Municipal implementation and enforcement of the requirements of the Model Ordinance within this Plan. Specific implementation strategies are described in Section VII.
2. Technical (refer to technical discussion in Sections IV and V).
 - a. Maintain groundwater recharge
 - b. Maintain water quality
 - c. Reduce channel erosion
 - d. Manage overbank events
 - e. Manage extreme flood events

Alternative Strategies:

1. Administrative / Policy
 - a. Municipal encouragement of clustered design practices to reduce overall development footprints
 - b. Municipal or County support and funding of SWM BMP pilot projects for technical analysis as well as public education
 - c. Public incentive programs related to Municipal-sponsored education activities
 - i. Rain barrel programs
 - ii. Public handbooks and technical guidance detailing residential BMP implementation

- d. The development of strategic partnerships between adjacent municipalities, key stakeholders and community interest groups.
- 2. Technical (refer to technical discussion in Sections IV and V).
 - a. Correction of existing drainage problems – Individual problem corrections not addressed in the current Plan due to additional technical analysis required. Refer to Section V for general discussion of non-achievable goals.
 - b. Culvert retrofits – Individual retrofits not addressed in the current Plan due to additional technical analysis required. Refer to Section V and the model ordinance for additional discussion of retrofits.
 - c. Stormwater management basin retrofits - Individual retrofits not addressed in the current Plan due to additional technical analysis required. Refer to Section V and the model ordinance for additional discussion of retrofits.
 - i. Modification of outlet structures for additional outflow control
 - ii. Combination of existing basin with new SWM BMPs
 - iii. Addition of sediment forebays
 - iv. Soil amendments for water quality
 - v. Regrading/reshaping basin for more effective management and control of runoff
 - vi. Incorporation of existing basins into surrounding landscaping to serve dual function of SWM practice and provide positive aesthetic and environmental habitat benefits
 - d. Retrofit of existing landscaping and site design features - Individual retrofits not addressed in the current Plan due to additional site investigation and technical analysis required. Refer to Section V and the model ordinance for additional discussion of retrofits.
 - i. Modification of parking islands into bioretention areas
 - ii. Replacement of impervious pavement/concrete with permeable paving and concrete
 - iii. Modification of overflow parking areas into infiltration areas
 - iv. Replacement of traditional tree planters to environmentally beneficial tree planter boxes in streetscape applications
 - e. Agricultural BMP implementation
 - i. Animal waste management
 - 1. Curbing animal confinement areas
 - 2. Grassed filter strips
 - 3. Waste storage
 - a. Lagoons and ponds (higher moisture wastes/slurry)
 - b. Synthetic covers (drier wastes)
 - c. Digestion tanks
 - ii. Land management practices
 - 1. Isolation of livestock from waterways
 - 2. Rotation of pasture/grazing areas

3. Cleaning solids from waterway swales
4. Crop rotation
5. Crop terracing practices
6. Nutrient management plans

SECTION II ACT 167

A. Stormwater Management Act 167

Recognizing the need to address the serious and growing problem of inadequate stormwater management, the Pennsylvania General Assembly enacted Act 167 of 1978. The statement of legislative findings at the beginning of the Pennsylvania Storm Water Management Act (Act 167) sums up the critical interrelationship among land development, accelerated runoff, and floodplain management. Specifically, this statement of legislative findings points out that:

1. Inadequate management of accelerated runoff of stormwater resulting from development throughout a watershed increases flood flows and velocity, contributes to erosion and sedimentation, overtaxes the carrying capacity of streams and storm sewers, greatly increases the cost of public facilities to carry and control stormwater, undermines floodplain management and floodplain control efforts in downstream communities, reduces groundwater recharge, and threatens public health and safety.
2. A comprehensive program of stormwater management, including reasonable regulation of development and activities causing accelerated runoff, is fundamental to the public health, safety, and welfare and the protection of the people of the Commonwealth, their resources, and their environment.

Until the enactment of Act 167, stormwater management had been oriented primarily towards addressing the increase in peak runoff rates discharging from individual land development sites to protect property immediately downstream. Management of stormwater throughout the state paid minimal attention to the effects on locations further downstream (frequently because they were located in another municipality) or to designing stormwater controls within the context of the entire watershed.

B. Purpose of the Study

Stormwater management has typically been regulated at the municipal level, with little or no design consistency (concerning the types or degree of storm runoff control to be practiced) between adjoining municipalities in the same watershed. Act 167 changed this approach by instituting a comprehensive program of watershed stormwater management planning. The Act requires Pennsylvania counties to prepare and adopt stormwater management plans for each designated watershed within the County. The County shall establish, in conjunction with each watershed storm water planning program, a watershed plan advisory committee composed of at least one representative from each municipality within the watershed, the County soil and water conservation district and such other agencies or groups as are necessary and proper to carry out the purposes of the committee. The plans are to provide uniform technical standards and criteria throughout the County's watersheds for the management of stormwater runoff, volume, and quality from new land development sites.

There also exists the opportunity for municipalities to retrofit existing sites to improve existing water quality impairments or existing sources of flooding problems. The types and degree of controls that are prescribed in the stormwater management plan must be based on the expected development pattern and hydrologic characteristics of each individual watershed. The standards and criteria contained within the plan are to be developed from the technical evaluations performed in the planning process in order to respond to the "cause and effect" nature of existing and potential storm runoff impacts in the watershed. The final product of the Act 167 watershed planning process is to be a comprehensive and practical implementation plan, developed with a firm sensitivity to the overall needs (e.g., financial, legal, political, technical, etc.) of the municipalities within Elk County.

SECTION III GENERAL DESCRIPTION OF WATERSHEDS

A. General County Description

Elk County covers approximately 833 square miles and, according to the 2000 census, has a population of 35,112. The largest municipality in Elk County is the City of St. Mary's with a population of 14,502. Ridgway Borough is the second largest in population with 4,591.

B. Political Jurisdictions

The County is comprised of twelve municipalities. The political jurisdictions include nine townships, two boroughs, and one city. All twelve of the municipalities also participate in the National Flood Insurance Program.

Table III-1
County Political Jurisdictions

Townships	Boroughs	Cities
Benezette	Johnsonburg	St. Mary's
Fox	Ridgway	
Highland		
Horton		
Jay		
Jones		
Millstone		
Ridgway		
Spring Creek		

Refer to Figure III-1 for a Base Map of Elk County.

C. NPDES Phase II Involvement

No municipalities in Elk County are included in an Urbanized Area (UA) as designated by the U.S. Census 2000. Therefore, no municipalities are required to comply with the National Pollutant Discharge Elimination System (NPDES) Phase II requirements for operators of municipal separate storm sewer systems (MS4s).



Elk County

Stormwater Management Plan

Phase 2 Plan

FIGURE III-1










Base Map

-  Elk County Boundary
-  Municipal Boundary

Other Features

-  PA
-  US
-  Local Road

Act 167 Watersheds

-  CLARION RIVER
-  ELK CREEK
-  LITTLE TOBY CREEK
-  MOSQUITO CREEK
-  NORTH FORK REDBANK CREEK
-  SANDY LICK CREEK
-  SINNEMAHOING CREEK
-  TIONESTA CREEK
-  WEST CREEK

DISCLAIMER

No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by Elk County, PA.

This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained herein, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.

L.R. KimballSM
ARCHITECTURE • ENGINEERING • COMMUNICATIONS TECHNOLOGY

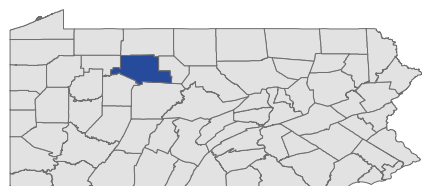
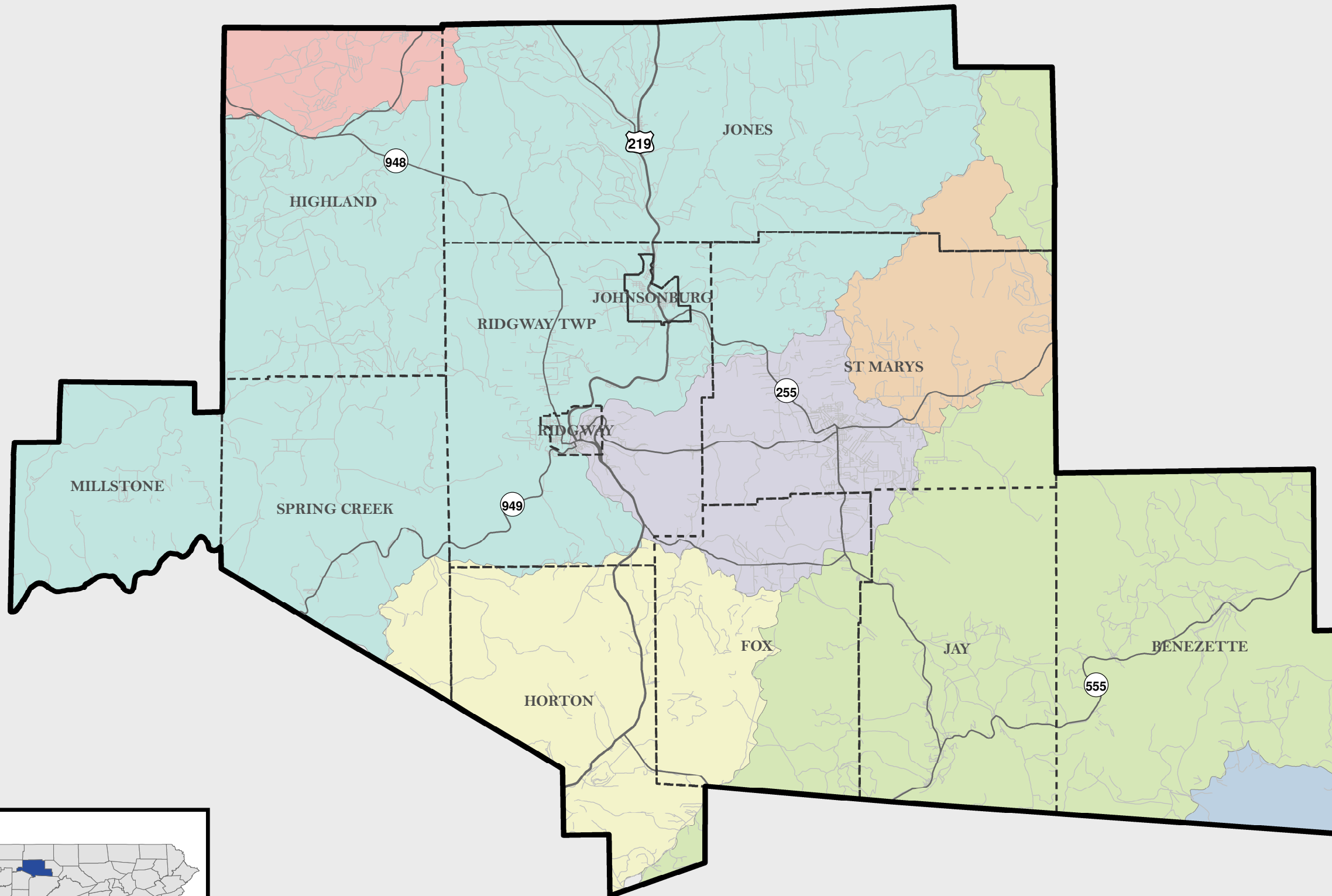
415 Moon Clinton Road Coraopolis, PA 15108-3886

Prepared by: GLF

Date: 03/19/2010

Project Number:

08-1300-0502



Location of Elk County within the state of Pennsylvania.



0 8,750 17,500 35,000
Feet

D. Data Collection

In order to evaluate hydrologic responses of the watersheds, data was collected on the physical features of the watersheds. Data collection varied depending on whether a detailed hydrologic watershed model was to be developed and analyzed for a particular watershed.

1. Base Map: The base map was created using data from a variety of sources:

Data	Source
Designated watershed boundaries	PA DEP
USGS 1:24,000 Quadrangle Maps	USGS
Roads	The Pennsylvania Department of Transportation
Municipal and County Boundaries	The Pennsylvania Department of Transportation
Networked Streams	The Pennsylvania State University / Environmental Resources Research Institute

Data were reviewed against available aerial mapping and each other to check for consistency. Other various datasets were used for compilation of the GIS and stormwater models for analysis. A list of this additional information includes:

2. Topography: USGS digital raster graphic (DRG) formatted topographic maps (1:24,000, 7.5 minute quadrangles) were used to create a watershed-wide DRG. Corresponding 7.5-minute digital elevation models (DEM) were used to create a watershed-wide digital elevation model. Subwatersheds or subareas used in the watershed modeling process were derived from the watershed DEM using HEC-GeoHMS. Subareas, drainage courses, land slopes and lengths, and drainage element lengths and slopes were determined and calculated from the DEM using HEC-GeoHMS.
3. Soils: All soil data was obtained from the United States Department of Agriculture, Natural Resources Conservation Service (NRCS) in digital format. Generalized soils were obtained from the State Soil Geographic Database (STATSGO). STATSGO maps are statewide soil maps made by generalizing the detailed soil survey data. Soil mapping units with similar characteristics are grouped together. Data on hydrologic soil groups (HSG) was derived from the detailed Soil Survey Geographic Database (SSURGO) data. The spatial component of SSURGO data (the soil map) is provided as a GIS data layer. The attribute data (soil information) is provided as a relational Access database. Together the spatial data and relational database are referred to as National Soil Information System (NASIS) data. The NASIS data were processed to extract HSG classifications for the surface horizon of the soil-mapping units within the watershed.
4. Geology: The geology for the watershed was extracted from the statewide bedrock geology coverage produced by Pennsylvania Bureau of Topographic and Geologic Survey, Department of Conservation and Natural Resources (DCNR). The dataset obtained from the DCNR are not intended to be used at any scale finer than 1:250,000. The geology data are displayed for the watershed at a scale larger than 1:250,000. The geology information is provided for illustrative and general information only.
5. Land Cover: The land cover data was derived from the USGS National Land Cover Dataset. The National Land Cover Dataset (NLDC) was compiled from Landsat satellite TM imagery (circa 1992) with a spatial

resolution of 30 meters and supplemented by various ancillary data (where available). The NLCD represents conditions in the early 1990s. This data is intended to provide a general overview of the watershed and to provide input data for modeling stormwater runoff characteristics.

6. Wetlands: Wetlands were obtained from the United States Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) in digital format and incorporated into the overall GIS. NWI maps are compiled from photo interpreted aerial photography from the National Aerial Photography Program (NAPP) 1:40,000 Scale, and the National High Altitude Photography Program (NHAP) 1:58,000 or 1:80,000 Scale. Sources dates range from the 1970's to the present. The minimum mapping unit for treeless areas is 1/4 acres, 1 to 3 acres in general. The wetlands data is provided for illustrative purposes. Other wetland areas likely exist that are not depicted on NWI maps.
7. Development in Floodplains: 100-year floodplain data, or special flood hazard areas, for Elk County was derived from the September 1996 Federal Emergency Management Agency (FEMA) National Flood Insurance Program Q3 Flood Data. The existing land cover was then clipped to these areas to depict the development in floodplains.
8. Obstructions: Bridges, culverts and pipes that convey streams and tributaries under roads, railroads and other similar infrastructure are referred to as obstructions. The obstruction locations and attribute information (size and shape) were determined during field investigations of the county and from Stakeholder Survey information.
9. Problem Areas: Stormwater problems include flooding, erosion, sedimentation, landslides, groundwater impacts, pollution and other potential issues. Data on the location of these problems in the watershed were collected from surveys sent to each municipality within the watersheds and incorporated into the watershed geodatabase. The municipalities were provided a topographic map of their township or borough and a collection of forms. They identified and plotted the locations of the known problem areas on paper maps or in digital format and completed the forms that describe the problems at each location
10. Stormwater Management Facilities: Stormwater management facilities may include detention/retention basins, underground storage and constructed wetlands. These types of facilities were also identified, plotted and described on forms by the municipalities.
11. Stormwater Sewer System Outfalls: Municipalities in urban areas (as defined by the US Census Bureau) are required to map the location of storm sewer outfalls as part of the PA DEP Municipal Separate Storm Sewer System (MS4) program. Since no municipalities within Elk County fall within the MS4 requirements, specific outfall information is not included as a part of this Plan.

E. General Development Patterns

Elk County experienced growth from 1950 to 1980, but the County's economy began to slow after 1980 causing the current emigration trend. The emigration is attributed to limited economic opportunities. Housing construction trends in Elk County indicate a slight increase in residential development over the last decade. However, no great influx of persons can be expected. New construction has been generally scattered.

Steady growth of the powdered metal industry in Elk County continues to be somewhat limited by inadequate supporting infrastructure. The County is currently working with the City of St. Mary's wastewater treatment facility to reduce the effluent copper levels to help facilitate continued growth in the local powdered metal industry.

The County also identified growth boundaries in their latest Comprehensive Plan Update, which encouraged infill development compatible with existing land uses to discourage sprawl. Public infrastructure development outside of these growth boundaries is discouraged by the Plan Update. Redevelopment Areas and Economic Development Corridors are located in Fox Township and the City of St. Mary's.

F. Physiography and Geology

Elk County lies in the north-central part of Pennsylvania in the Allegheny Mountain section of the Appalachian Plateaus Physiographic Province. The county contains the Eastern Continental Divide. The highest elevation is 2,370 feet above Median Sea Level (MSL) at Boone Mountain in southern Elk County, and the lowest elevation of approximately 900 feet above MSL is located at Dents Run and its confluence with Sinnemahoning Creek at the Cameron County line in Eastern Elk County. A significant amount of land in Elk County is classified by the United States Geological Survey mapping as having excessive slopes (exceeding 25%), and therefore is considered unsuitable for development. Variations in aspect, slope, and elevation combine to create a number of different microenvironments throughout the County. Numerous soil types influenced by weathering of underlying bedrock, slope, organic material and climate and sometimes the bedrock itself create the ecological foundation for Elk County.

The bedrock geology in Elk County is of the Pennsylvanian, Mississippian, and Devonian Periods of the Paleozoic Era consisting of Burgoon Sandstone, the Allegheny, Catskill, Glenshaw, Huntley Mountain, Pottsville and Shenango Formations. Minor uplift and folding of sediments during the Permian period caused the formation of broad anticlines and synclines. The axes of the broad anticlines and synclines and the general bedrock strike are oriented in a northeast-southwest direction.

Additionally, Elk County lies on the northern edge of Pennsylvania's main bituminous coal field, and has several bituminous coal seams of the Allegheny Group that have been mined, primarily in surface mining operations. Elk County produces about 1% of the bituminous coal in Pennsylvania, and is the fourth-leading producer of crude oil in PA, yielding approximately 10% of total state production.

Refer to Figure III-2 for a general geology map of Elk County.

G. Climate

Winters are cold and snowy at the higher elevations in the County. They are frequently cold in the valleys, but intermittent thaws preclude a long-lasting snow cover. Summers are relatively warm on the mountain slopes. They are very warm and have occasional very hot days in the valleys. Rainfall is evenly distributed during the year, but it is appreciably heavier on the windward, west-facing slopes than in the valleys. The normal annual precipitation is adequate for all crops, although the summer temperature and the length of the growing season, particularly at the higher elevations, may be inadequate.

In winter, the average temperature is 21 degrees F and the average daily minimum temperature is 13 degrees. The lowest temperature on record is -30 degrees F (Bradford, PA records), on February 11, 1979, and the average daily maximum temperature is 74 degrees F. The highest recorded temperature (Bradford, PA records) is 92 degrees on July 31, 1975.

The total annual precipitation is about 43 inches. Of this, about 23 inches, or nearly 55 percent, usually falls in April through September. The growing season for most crops falls within this period. In 2 years out of 10, the rainfall in April through September is less than 19 inches. The heaviest 1-day rainfall during the period of record was 4.91 inches on September 28, 1967. Thunderstorms occur on about 33 days each year.

The average seasonal snowfall is about 84 inches. The greatest snow depth at any one time during the period of record was 44 inches. On the average, 82 days of the year have at least 1 inch of snow on the ground. The number of such days varies greatly from year to year.

The average relative humidity in mid-afternoon is about 55 percent. Humidity is higher at night, and the average at dawn is about 80 percent. The sun shines 60 percent of the time possible in summer and 40 percent in winter. The prevailing wind is from the west. Average wind speed is highest, 9 miles per hour, in spring.

H. Soils

Soil properties influence the runoff generation process. The USDA, Natural Resources Conservation Service (NRCS) has established a criterion determining how soils will affect runoff by placing all surface horizon soils into four Hydrologic Soil Groups (HSGs) – A through D, based on infiltration rate and depth. Hydrologic soil group A characteristics, which have a high infiltration rate and therefore low runoff potential, are found sporadically throughout Elk County. The majority of the surface horizon soils in the watershed fall in Group B and C. Group B is characterized as having moderate infiltration rates, and it consists primarily of moderately deep to deep, moderately well to well drained soils that exhibit a moderate rate of water transmission. Group C soils have slow infiltration rates when thoroughly wetted and contain fragipans, a layer that impedes downward movement of water and produces a slow rate of water transmission. Found throughout the watershed, D soils are tight, low permeable soils with high runoff potential and are typically clay soils.

Soils in Elk County formed from noncarbonate sedimentary rocks and include a number of silt loams, channery loams and channery silt loams. Much of Elk County soils qualifying as Prime Farmland are characterized as deep, well drained and are level to nearly level soils.

Hazleton-Buchanan-Cookport Association soils are scattered throughout the County area. These soils are very deep and deep, moderately well drained and well drained, nearly level to steep soils and formed in materials weathered from sandstone and siltstone. They occur on rolling hilltops, benches and on steep hillsides in Elk County.

Also scattered throughout the County are Hazleton-Cookport-Buchanan Association soils that are characteristically very deep and deep, moderately well drained and well drained, nearly level to steep soils, and formed in materials weathered from sandstone and siltstone. They are generally located on rolling foot slopes and benches.

Extending from Brockport to East Branch Dam in Elk County are the Harleton-Wharton-Buchanan Association soils that are very deep and deep, moderately well drained and well drained, gently sloping to very steep soils formed in materials weathered from siltstone and shale. The association generally is found on broad hilltops, hillsides, and foot slopes.

Leck Kill-Harleton-Albrights Association upland soils that are characteristically very deep and deep, somewhat poorly drained to well drained, nearly level to very steep, and are formed in materials weathered from shale, sandstone, and siltstone.

Hartleton-Wharton-Udorthents Association soils are located on broad hilltops and hillsides in an area extending from Brockport to Kersey, and from Weedville to Benezette in Elk County. These soils are very deep and deep, moderately well drained and well drained, nearly level to very steep, and are formed in materials weathered from shale, sandstone, and siltstone.

More descriptive breakdowns of each soil in the series can be found below. See soil map for additional information and location on the soils types.

Hazelton Series: The soils of the Hazelton series are loamy-skeletal mixed. They are deep and well drained. They formed residuum of sandstone. Slopes range from 3 to 60 percent. Permeability is moderately-rapid to rapid.

Buchanan Series: The soils of the Buchanan series are fine-loamy, mixed, mesic Aquic Frigidults. They are deep and moderately well drained. They formed in colluvium deposited from sandstone, siltstone, and shale. Slopes range between 3 and 25 percent. They have a slow permeability.

Cookport Series: The soils of the Cookport series are fine loamy, mixed mesic Aquic Frigidults. They are deep and moderately well drained. The slopes range from 0 to 25 percent. They formed in residuum of sandstone and siltstone. The permeability is moderate above the fragipan, but slow within the fragipan.

Hartleton Series: The soils of the Hartleton series are loamy skeletal mixed mesic typic Hapludults. They are deep and well drained and occur on slopes ranging from 3 to 60 percent. They formed in the residuum of sandstone and siltstone. The permeability of the Hartleton series is moderate to moderately rapid.

Wharton Series: The soils of the Wharton series are fine loamy mixed mesic Aquic Hapludults. They are deep and moderately well drained, and are found on uplands. They were formed in residuum of shale and siltstone. The slopes range from 0 to 25 percent and they have a slow to moderately slow permeability.

Leck Kill Series: The soils of the Leck Kill series are fine loamy mixed, mesic type Hapludults. They are deep and well drained and found on uplands. They were formed in residuum of siltstone and shale and slopes range from 3 to 60 percent.

Albrights Series: The soils of the Albright series are fine loamy mixed mesic Aquic Fragidults. These soils are very deep and moderately well drained and found on uplands. They formed in colluvium derived from red shale and sandstone and have slopes ranges between 3 and 25 percent. They have moderately slow permeability.

Udorthents Series: Udorthents consist of very deep well-drained and moderately well drained soils on uplands. They formed in areas where strip mining occurred. They have slope ranges between 0 and 60 percent and their permeability ranges between none and rapid, due to the unknown nature of their contents.

County soils are shown in Figure III-3.

I. Water Resources

Various river and stream valleys cut through the landscape of Elk County. Nearly all of these either form or are tributaries to the Clarion River or Sinnemahoning Creek. The eastern and southeastern portion of the County lies in the Susquehanna River Basin and is drained by Sinnemahoning Creek and its tributaries. The western and central portions of the County are in the Allegheny River Basin and are drained by the Clarion River and its tributaries. There is a very small portion of the County that is tributary to the Tionesta Creek watershed. This area is the upper, northwest corner of the County. See Figure III-4 for watershed locations.

Clarion River Watersheds: Land uses in this watershed include the urbanized or populated areas of St. Mary's and Ridgway Borough, as well as agricultural, forestry, and State and National Forests in Jones, Ridgway, and Spring Creek Townships.

The Clarion River flows 101 miles through Elk, Forest, Jefferson, and Clarion Counties, emptying into the Allegheny River near Parker, PA. Over half the river qualifies as scenic or recreational classification, with numerous species of wildlife and vegetation along its banks. The Clarion River, from the Allegheny National Forest/State Game Land (ANF/SGL) boundary below Ridgway to the backwater of Piney Dam is located in the un-glaciated Allegheny plateau. It is free flowing and relatively slow moving with meanders and a generally steep valley with little floodplain. Tributaries to the River include Wolf Run, Little Wolf Run, Big Mill Creek, Bear Creek, Elk Creek, and Spring Creek.

Sinnemahoning Creek Watersheds: Land uses in this watershed include agriculture, forestry, mining, and State Forest and State Game Lands.

Sinnemahoning Creek (Native American for "stony lick") is a tributary of the West Branch Susquehanna River. The Sinnemahoning was once a route for Native Americans and eventually served as a route for 19th century loggers to transport their timber to the West Branch of the Susquehanna River. It is a slow running stream with occasional gentle rapids. Major Elk County tributaries to the Sinnemahoning Creek include Kersey Run, Trout Run, West Creek, and Dents Run.

Tionesta Creek Watersheds: The Tionesta Creek Watersheds are not included for modeling and detailed analysis as a part of this Plan since the majority of this watershed lies outside of Elk County.

Elk County

Stormwater Management Plan

Phase 2 Plan

FIGURE III-2

Geology

Bedrock

- Allegheny Formation
- Burgoon Sandstone
- Catskill Formation
- Glenshaw Formation
- Huntley Mountain Formation
- Pottsville Formation
- Shenango Formation

Other Features

- PA
- US
- Local Road
- Stream
- Municipal Boundary
- Elk County Boundary

DISCLAIMER

No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by Elk County, PA.

This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained hereon, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.

L.R. KimballSM
ARCHITECTURE • ENGINEERING • COMMUNICATIONS TECHNOLOGY

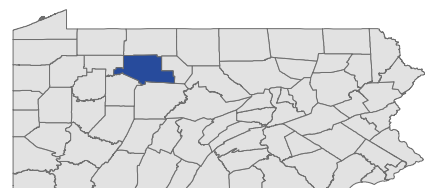
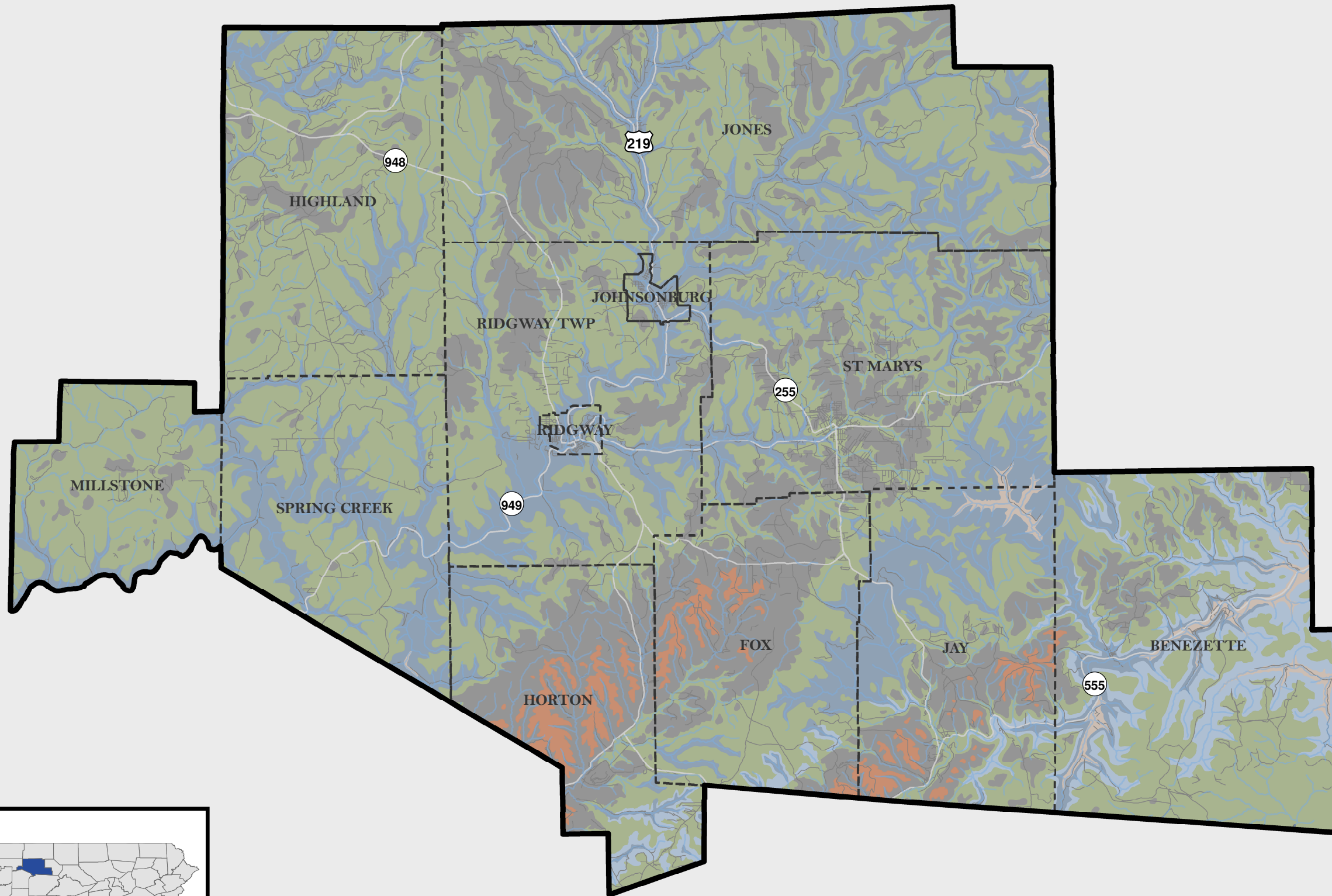
415 Moon Clinton Road Coraopolis, PA 15108-3886

Prepared by: GLF

Date: 03/19/2010

Project Number:

08-1300-0502



Location of Elk County within the state of Pennsylvania.



0 8,750 17,500 35,000
Feet

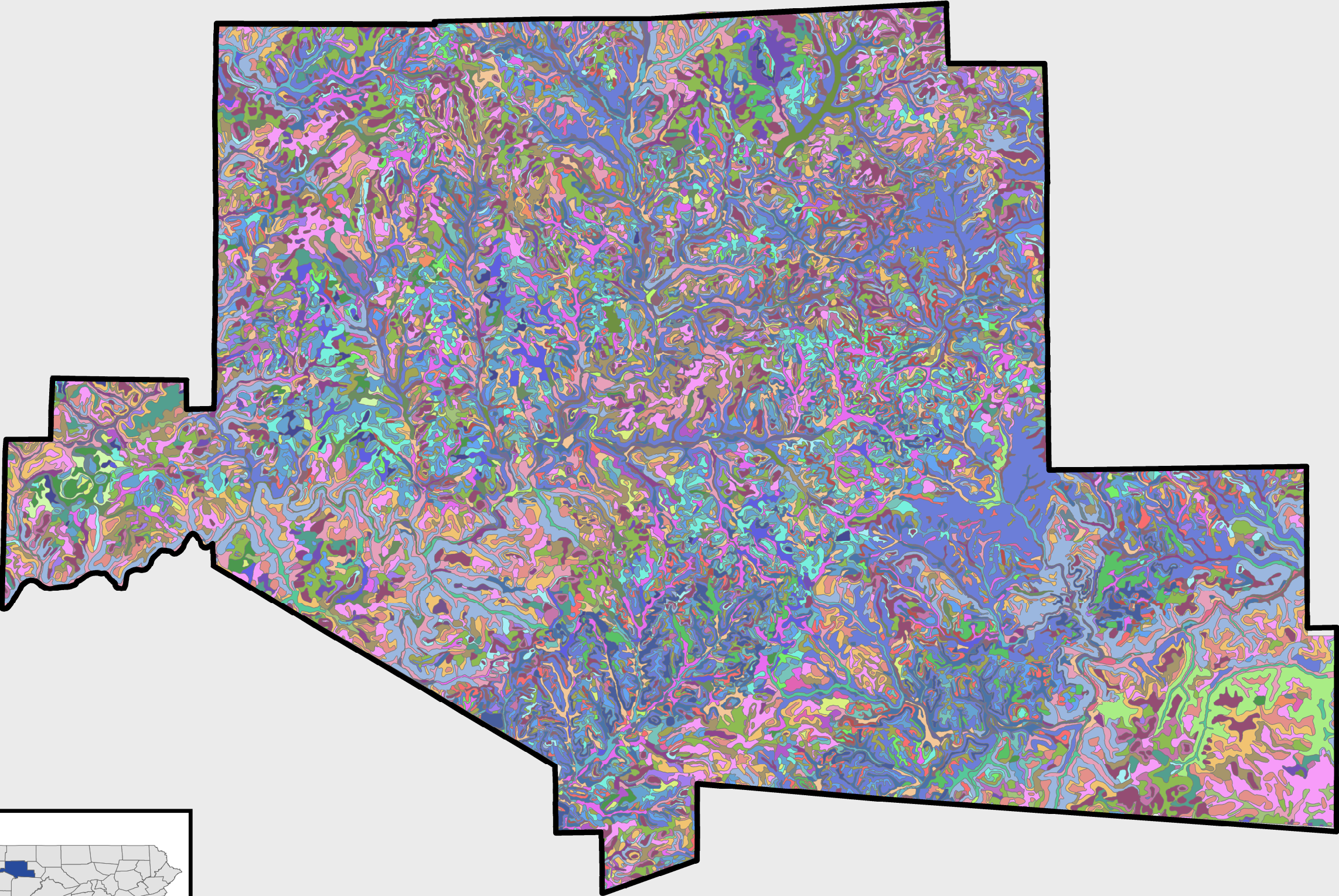
Elk County

Stormwater Management Plan

Phase 2 Plan

FIGURE III-3

Soils

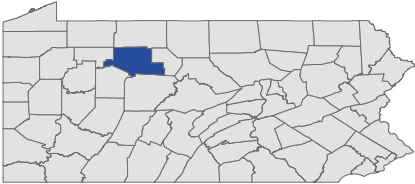


Soil Type	■ CaA	■ HeB	■ NoB
■ AbB	■ CaB	■ HeD	■ NxB
■ AbC	■ CaC	■ HoB	■ Ph
■ AbD	■ CdB	■ HoC	■ Po
■ At	■ CdD	■ HoD	■ Ub
■ Ba	■ CoA	■ HxB	■ Ud
■ Bb	■ CoB	■ HxD	■ Us
■ BrA	■ CoC	■ HxF	■ W
■ BrB	■ CpB	■ HyE	■ WaB
■ BsB	■ CpD	■ LeB	■ WaC
■ BuB	■ DAM	■ LeC	■ WaD
■ BuC	■ HaB	■ LeD	■ WxB
■ BuD	■ HaC	■ LeF	■ WxD
■ BxB	■ HaD	■ MW	
■ BxD	■ HaF	■ NoA	

DISCLAIMER

No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by Elk County, PA.

This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained hereon, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.



Location of Elk County within the state of Pennsylvania.

Designated Act 167 watersheds in Elk County include:

Clarion River
Sinnemahoning Creek
Elk Creek
Tionesta Creek
Mosquito Creek
West Creek
Little Toby Creek

J. PA Chapter 93 Stream Classifications

Current (2008) PA Chapter 93 stream water quality uses are shown on Figure III-4. A summary table of the streams in Elk County based on this data is presented below:

Table III-2
County Chapter 93 Stream Use Summary

Classification	County Stream Miles	Percentage of Overall
Exceptional Value (EV)	43.805	2.77%
High Quality (HQ) Cold Water Fishery (CWF)	801.892	50.64%
Cold Water Fishery (CWF)	709.345	44.80%
Warm Water Fishery (WWF)	28.409	1.79%

K. Obstructions

Locations of significant waterway obstructions (i.e., culverts, bridges, etc.) were obtained by a number of methods. Some of the methods used to properly verify the presence and to further address the integrity of the obstructions was by:

1. Inspection of the United States Geologic Survey (USGS) topographic base mapping
2. Data from the Pennsylvania Department of Transportation (PADOT)
3. FEMA Flood Insurance Studies
4. Phase 1 Stormwater Problem Area survey results
5. Field verification work

The field verification portion of the project was completed by County Planning and Consultant teams. Mapping was created from the intersection of roadway GIS data and stream GIS data indicating likely locations of culverts or bridges. Field crews were then assigned to visually inspect and assess as many of the known structures as possible, as well as additional unknown structures that were discovered during the fieldwork. Information obtained through the field investigations includes:

1. Verification that the structure is present
2. Type of structure

3. Physical characteristics and dimensions of structure
 - a. Diameter/opening width
 - b. Depth from thalweg of channel to top of opening or crown of pipe
 - c. Depth from pipe crown or top of opening to approximate crown of road above
 - d. Bridge piers and abutments
 - e. Pipe/bridge material
4. Structural condition of structure
5. Observed deficiencies with the structure
 - a. Damaged pipe or bridge
 - b. Siltation/sedimentation
 - c. Evidence of insufficient capacity (visual evidence of overtopping)
6. Photographs documenting structure

The field data that was collected at each structure was recorded on field survey forms that can be found in Volume 3 of the Plan.

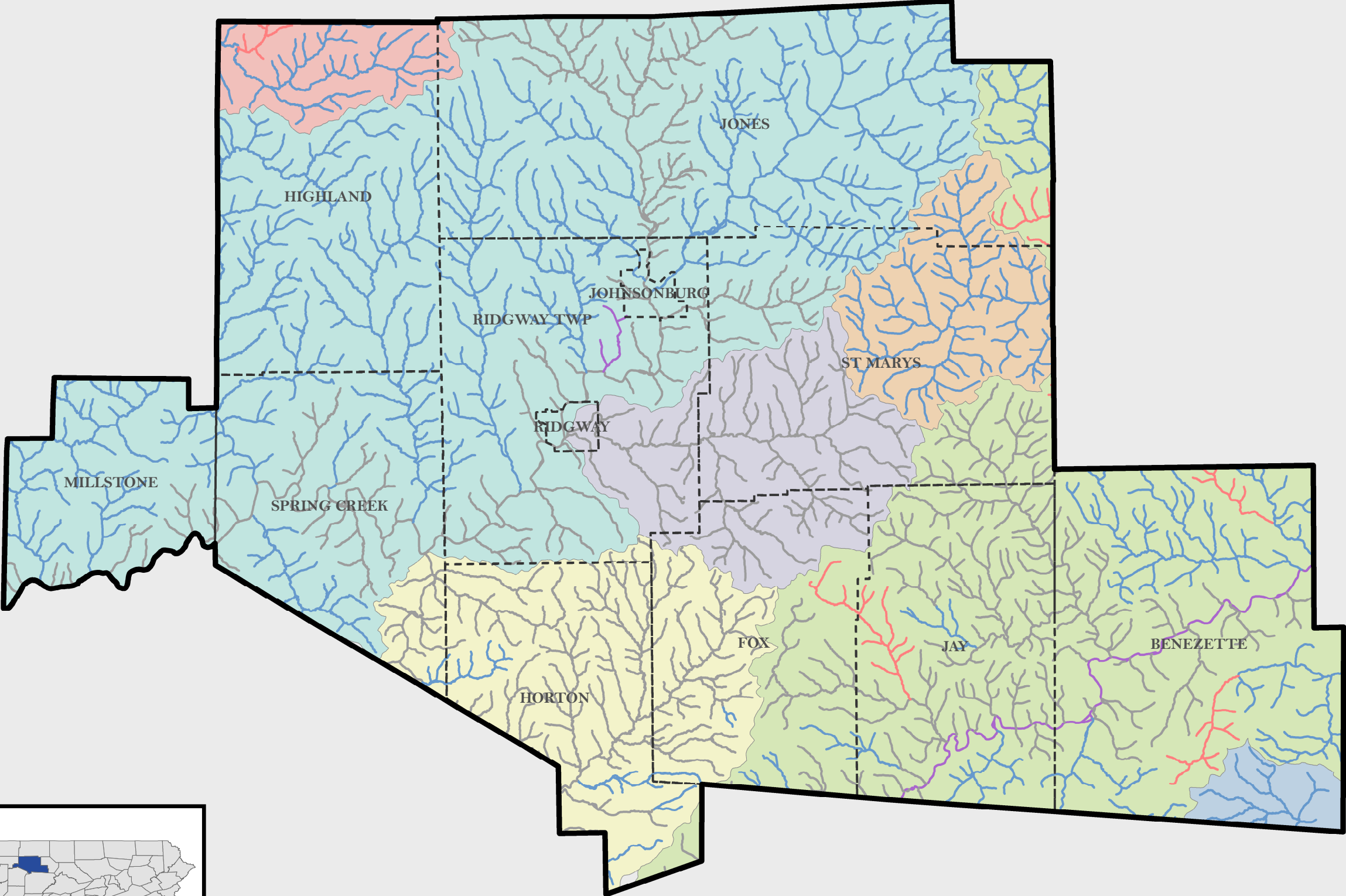
The most common deficiencies discovered during field investigations were structural problems with the pipe/bridge and sedimentation at pipes and bridges. A significant number of structures have some form of structural damage. Damages most often included corroded or missing portions of pipe barrels, partially or near complete crushing of pipe barrels, occasional occurrences of spalling at bridges, reduced flow area (e.g. due to debris within pipe or opening) and damaged appurtenances (e.g. damaged or missing head/end walls). Sedimentation problems were also identified in a number of areas.

Any structure determined to be less than 18 inches in diameter was excluded from the field survey operations. Such structures were omitted from field collection activities due to the time constraints required to determine their locations, assess their physical, and flow conveyance capabilities.

Based upon the limitations of the project and the reduction in scope by PADEP, obstruction hydraulic capacity calculations were not performed. Consequently, capacity calculations for the obstructions are not included as part of this Plan. Future Plan updates should address capacity issues based on the included field data in the Volume 3.

Elk County
Stormwater Management Plan
Phase 2 Plan

FIGURE III-4
Hydrology

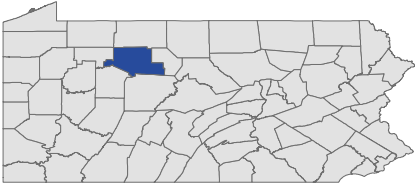


- Elk County Boundary
- Municipal Boundary
- Water Quality Classifications**
- Cold Water Fishes
- Exceptional Value
- High Quality Cold Water Fishes
- Warm Water Fishes
- Act 167 Watersheds**
- CLARION RIVER
- ELK CREEK
- LITTLE TOBY CREEK
- MOSQUITO CREEK
- NORTH FORK REDBANK CREEK
- SANDY LICK CREEK
- SINNEMAHOING CREEK
- TIONESTA CREEK
- WEST CREEK

DISCLAIMER

No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by the Elk County, PA.

This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained hereon, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.



Location of Elk County within the state of Pennsylvania.



415 Moon Clinton Road Coraopolis, PA 15108-3886

Prepared by: GLF Date: 03/19/2010

Project Number: 08-1300-0502

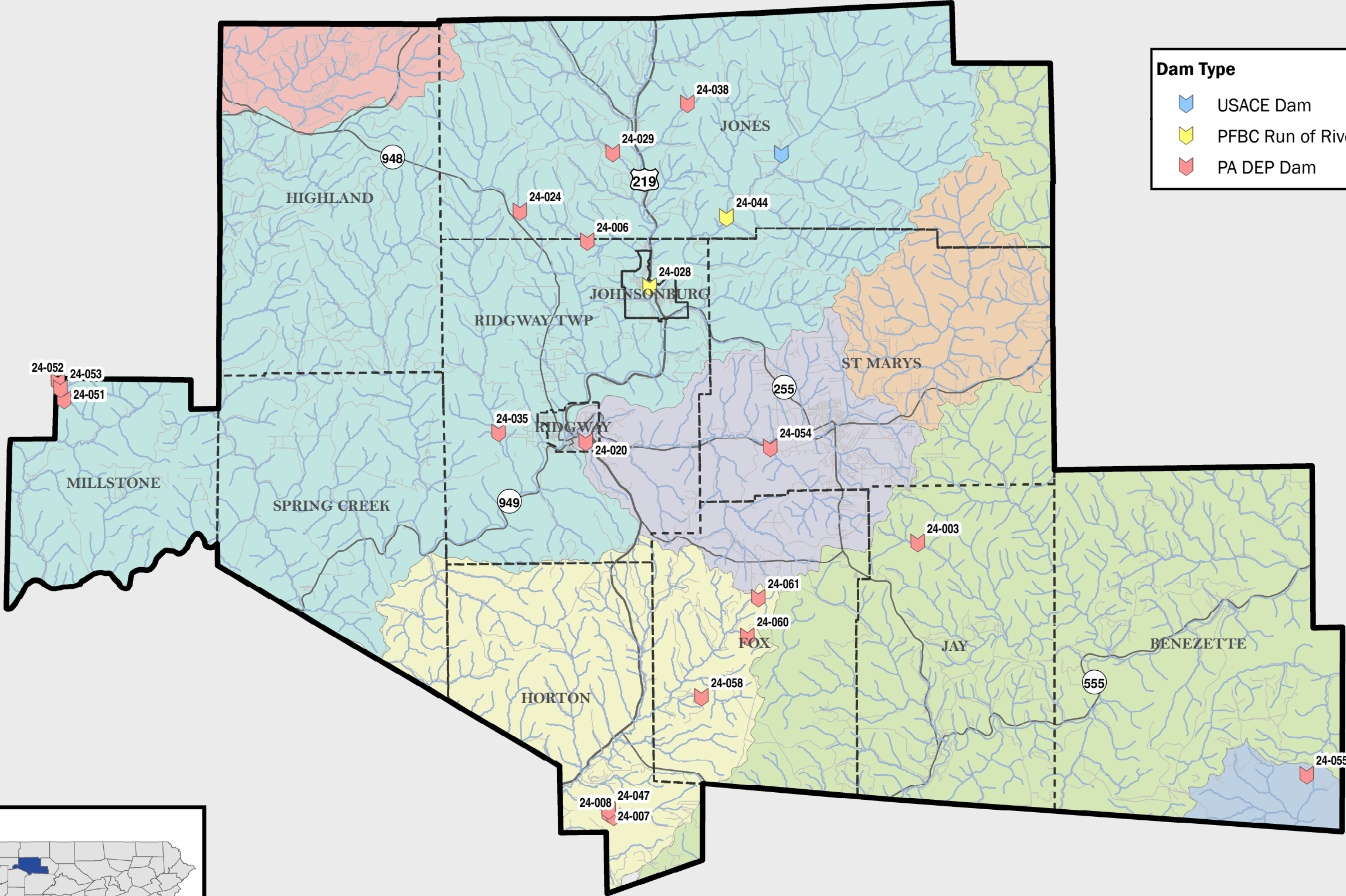
L. Dams and Impoundments

Existing dam locations are shown on Figure III-5 and are listed below. This list includes permitted PADEP dams, a United State Army Corps of Engineers dam, and two PA Fish and Boat Commission run-of-river dams.

Table III-3
Dams and Impoundments

PA DEP DAM No.	Dam Name	Stream Name	Run of River?
24-003	Wolf Lick Run Reservoir	Wolf Lick Run	No
24-006	Storage Dam	Silver Creek	No
24-007	No 1 Dam	Whetstone Run	No
24-008	Brockway Reservoir	Whetstone Run	No
24-020	Rough And Ready Farm Dam	Gallagher Run	No
24-024	Unnamed	Little Mill Creek	No
24-028	Intake (Willamette Industries)	East Branch Clarion River	Yes
24-029	Unnamed	Wolf Run	No
24-035	H B Norton	Big Mill Creek	No
24-038	Unnamed	Oil Creek	No
24-044	Bendigo	East Branch Clarion River	Yes
24-047	Storage (Whetstone No 2)	Whetstone Br Little Toby Creek	No
24-051	Buzzard Swamp No 6	Muddy Fork	No
24-052	Buzzard Swamp No 5	Muddy Fork Trib	No
24-053	Buzzard Swamp No 4	Muddy Fork Trib	No
24-054	Laurel Run	Laurel Run	No
24-055	Beaver Run	Beaver Run	No
24-058	Leachate Equalization Impoundment	Sawmill Run Trib	No
24-060	Intake B	Limestone Run	No
24-061	Little Toby Creek Site Intake	Little Toby Creek	No
NA	East Branch Clarion River	East Branch Clarion River	No

FIGURE III-5
Dams



- Dam Type**
- USACE Dam
 - PFBC Run of River Dam
 - PA DEP Dam

- Act 167 Watersheds**
- CLARION RIVER
 - ELK CREEK
 - LITTLE TOBY CREEK
 - MOSQUITO CREEK
 - NORTH FORK REDBANK CREEK
 - SANDY LICK CREEK
 - SINNEMAHOING CREEK
 - TIONESTA CREEK
 - WEST CREEK

- Other Features**
- US & PA Roads
 - Local Road
 - Stream
 - Municipal Boundary
 - Elk County Boundary

DISCLAIMER

No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by the Elk County, PA.

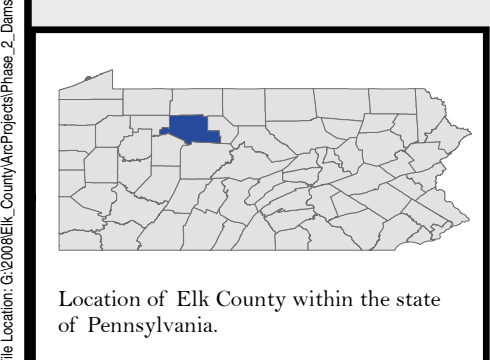
This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained herein, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.

L.R. Kimball
ARCHITECTURE • ENGINEERING • COMMUNICATIONS TECHNOLOGY

415 Moon Clinton Road Coraopolis, PA 15108-3886

Prepared by: GLF Date: 03/19/2010

Project Number: 08-1300-0502



M. Pollution and Stream Impairments

Acid Rain

Acid deposition from rain and snow impact headwater streams in the Allegheny National Forest, such as Big Mill Creek and Bear Creek, as well as streams in the Quehanna Wild Area, most notably Mosquito Creek. WPAC stakeholders believe a more rigorous assessment of the effects of acid deposition on streams countywide should be pursued to quantify the effects and target remediation efforts in the County.

Abandoned Mine Discharges (AMD)

Coal mining has been and still is an integral part of the Pennsylvania economy. Drainage from abandoned coalmines is the single biggest water pollution problem in Pennsylvania, affecting over 2,400 stream miles in the State. The Bennett Branch of Sinnemahoning Creek, draining from its headwaters south of Penfield, to its mouth at Driftwood, has over 30 miles of stream affected by AMD. The locations of existing and proposed AMD assessment and treatment projects within this watershed are shown in Figure III-6. WPAC stakeholders are concerned about the impacts of uncontrolled stormwater runoff over abandoned mine lands.

Additional discussion and detailed information pertaining to pollution and stream impairments are discussed in the water quality portions of the Plan.

Stream Impairments

Table III-4 shows a summary of non-attaining segments of the Streams Integrated List representing stream assessments for the Clean Water Act Section 305(b) reporting and Section 303(d) listing.¹ PA DEP protects four (4) stream water uses: aquatic life, fish consumption, potable water supply, and recreation. Stream segments not attaining any one of its four uses are considered impaired. Based on the 303(d) data, the total number of impaired stream miles in Elk County is approximately 249 miles, although the impaired stream miles caused by stormwater or urban runoff is unknown.

Table III-4
Non-attaining Impaired Stream Lengths

Impairment Source - Impairment Cause	Total (miles)
Abandoned Mine Drainage - Metals	61.345
Abandoned Mine Drainage - Metals ; Abandoned Mine Drainage - pH	89.769
Abandoned Mine Drainage - Metals ; Abandoned Mine Drainage - pH ; Abandoned Mine Drainage - Suspended Solids	12.750
Abandoned Mine Drainage - Metals ; Municipal Point Source - Nutrients ; Source Unknown - Cause Unknown	3.431
Abandoned Mine Drainage - Metals ; Source Unknown - Cause Unknown	8.484
Abandoned Mine Drainage - pH	4.293
Abandoned Mine Drainage - pH ; Abandoned Mine Drainage - Metals	15.356
Abandoned Mine Drainage - pH ; Abandoned Mine Drainage - Metals ; Abandoned Mine Drainage - Suspended Solids	5.134
Abandoned Mine Drainage - Suspended Solids ; Abandoned Mine Drainage - Metals ; Abandoned Mine Drainage - pH	3.978

¹ PA DEP Office of Water Management, Bureau of Water Supply & Wastewater Management, Water Quality Assessment and Standards Division, 2010

Table III-4
Non-attaining Impaired Stream Lengths

Impairment Source - Impairment Cause	Total (miles)
Atmospheric Deposition - pH	17.038
Channelization - Water/Flow Variability	3.549
Municipal Point Source - Nutrients ; Abandoned Mine Drainage - Metals ; Source Unknown - Cause Unknown	0.980
Natural Sources - pH	10.114
Other - Cause Unknown	1.416
Source Unknown - Cause Unknown	10.155
Surface Mining - Metals ; Surface Mining - Siltation	0.606
Surface Mining - Siltation	1.088
Total Impaired Stream Miles:	249.484

Additional discussion and detailed information pertaining to pollution and stream impairments are discussed later in the Plan.

N. Stormwater Problem Areas

Through analysis of survey results received from the County municipalities, the three most common stormwater problem types in Elk County are street flooding, property flooding, and stream corridor flooding.

More detailed information pertaining to problem areas and possible solution strategies are discussed later in this Plan. While it is the initial intent of the Plan to focus on the primary stormwater problems identified above, the planning effort will also include further refinement and prioritization of stormwater problem solutions and strategies. Existing and potential problems caused by excessive stormwater runoff or pollution issues are identified and addressed throughout the Plan. The Plan provides solutions and techniques to help better manage and mitigate existing problems and prevent future problems through proper management techniques and technologies. The problems identified in this section were further combined with other known issues within the County and then used to form the technological approach (discussed later in the Plan) for addressing the specific types of problems the County encounters.

The causes for the problems described above and listed on Figure III-6 range from increases in stormwater volume and velocity, inadequate infrastructure, obstructed waterways, AMD, excessive floodplain development, and illicit discharges. Refer to Figure III-7 for the location of problem causes.

A summary of the survey results indicating the types, frequency, and related severity of damage related to stormwater problems is shown in Table III-5.

Table III-5
Stormwater Management Problem Areas Identified in Survey

ID	Municipality	Problem Type	Problem Cause	Problem Frequency	Damage Type	Descriptions
1	Benezette	8	1	2	3	-
2	Benezette	8	1	2	3	-
3	Benezette	2	1	2	2	Roadway washes out
4	Benezette	7	5	2	3	-
5	Fox Township	2,3	5,3	4	3	lots of blockages, sediment/stream erosion
6	Fox Township	2	-	4	-	-
7	Highland Township	5	3	1	3	-
8	Highland Township	8	2	1	2	Township Route 322
9	Highland Township	8	2	1	2	Route 322
10	Highland Township	8	2	1	2	Route 313-P
11	Horton Township	7	5	2	3	Toby Bridge on State Route Keystone Rd
12	Horton Township	7	5	2	3	Toby Bridge on State Route 153
13	Jay Township	1,2,3	1,3,5,7	3	3	-
14	Jay Township	1,2,3,4	1	4	3	-
15	Jay Township	1,3,4,7,8	1,5	3	3	-
16	Jay Township	1,3,8,5,6,7,9	7	4	2	-
17	Johnsonburg	-	-	-	-	Pump house
18	Johnsonburg	-	-	-	-	Dike
19	Johnsonburg	-	-	-	-	Dike
20	Johnsonburg	-	-	-	-	Pilings
21	Johnsonburg	-	-	-	-	Pilings
22	Jones	2, 3	1,3	2	3	
23	Jones	5	4,5	2	3	-
24	Ridgway	1,2,3	1,2	2	3	-
25	Ridgway	1,2,3	1,2	3	3	-
26	Ridgway	1,2,3	1,2	4	3	-
27	Ridgway	1,2,3	1,2	4	3	-
28	Ridgway	1,3,4,5,7	1,2,5,4	4	3	-
29	Ridgway	1,2,3,6,7,8	1,2,5,4	4	3	-
30	Ridgway	2	-	4	-	-

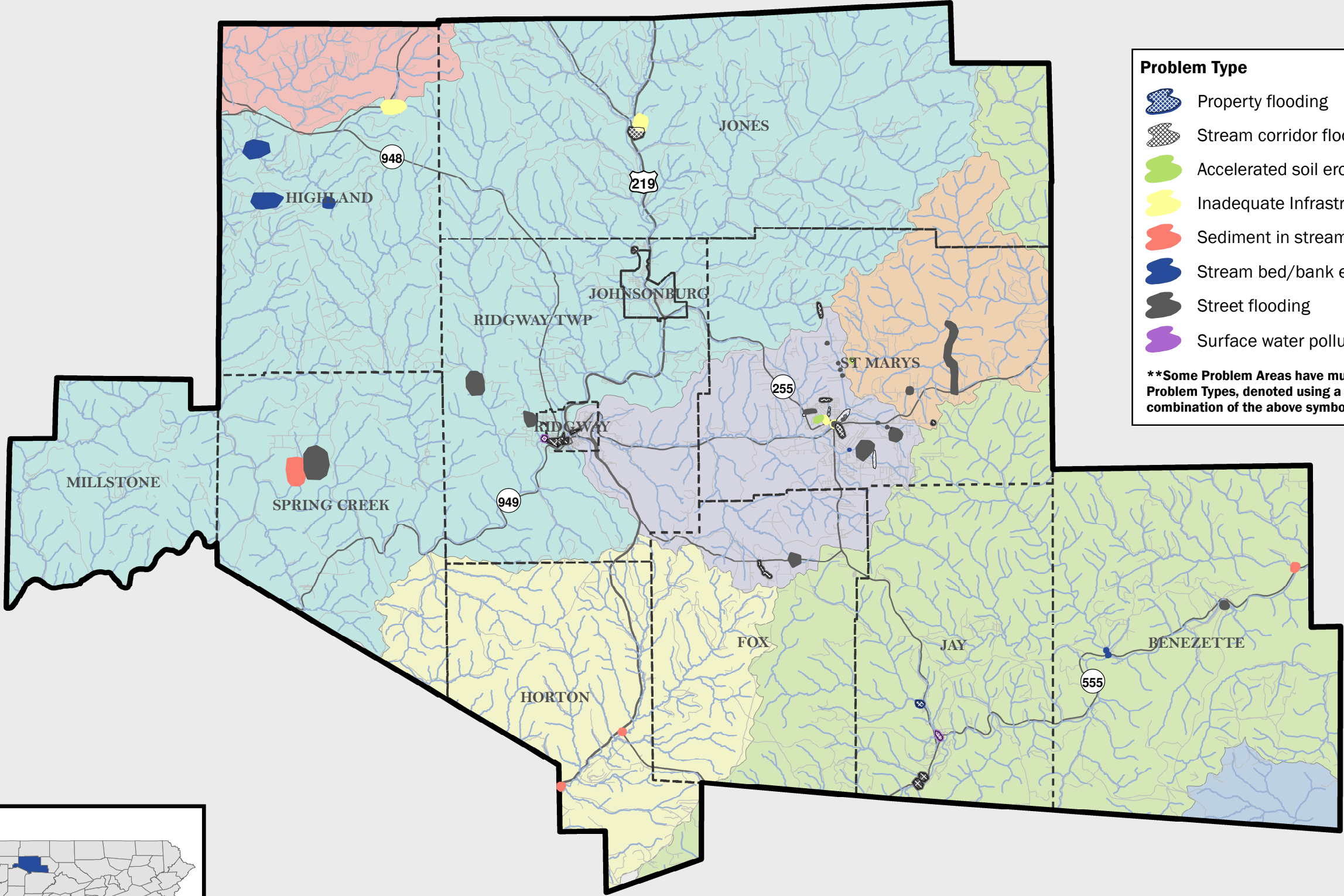
ID	Municipality	Problem Type	Problem Cause	Problem Frequency	Damage Type	Descriptions
31	St. Mary's	8	2	2	3	Erosion of 726 Vine Road, Stream bank needs re-established
32	St. Mary's	1	1	2	3	Gabions failing along Brewery Run
33	St. Mary's	3	6	2	3	Elk Creek watershed. NC Stackpole complex floods
34	St. Mary's	3	1	2	3	Averyville Road residence at 147 floods
35	St. Mary's	5	3	2	3	George and Charles Street need drainage systems
36	St. Mary's	3	7	1	3	852 Cardinal Road residence floods.
37	St. Mary's	2	7	1	2	Vermont Road floods. Property damage also
38	St. Mary's	6	7	2	3	HS track subsidence from stormwater and mines
39	St. Mary's	2,3	1	1	2	Maple Street watershed antiquated and undersize
40	St. Mary's	2,5	3	1	2	Storm sewer collapsed. Water shoots out of ground
41	St. Mary's	2,3	1,3	1	2	Condot Road, new drainage system needed.
42	St. Mary's	2,3	3	1	2	Seicker Road needs larger piping and CBs
43	St. Mary's	2,3	3	1	3	Rosely and Blair Road eroding, need ditches
44	St. Mary's	3,6	1,2	1	3	Wilson Road and Woodbed Inc., pipes direct water across road
45	St. Mary's	2	3	1	3	Harrison Road washes out at cross drain
46	St. Mary's	2	2,3	1	3	Jackson Road, poor drainage, erosion
47	St. Mary's	2	-	4	-	-
48	St. Mary's	2	-	4	-	-

Description Codes			
Problem Types:	Description:	Problem Frequency:	Description:
1	Stream corridor flooding	1	Occurs > 1 per year
2	Street flooding	2	Occurs every 1 to 3 years
3	Property flooding	3	Occurs every 4 to 8 years
4	Surface water pollution	4	Occurs during flood events
5	Inadequate infrastructure (culverts/bridges/etc.)		
6	Accelerated soil erosion		
7	Sediment in streams		
8	Stream bed/bank erosion		
9	Storm sewer outfall erosion		
10	Habitat/water resources loss or damage		
11	Other		
Problem Cause:	Description:	Damage Type:	Description
1	Increase in the amount of stormwater (volume)	1	Loss of life
2	Velocity of stormwater	2	Loss of vital services
3	Poor drainage	3	Property damage
4	Discharge location (direction of flow)		
5	Water obstructions		
6	Floodplain development		
7	Other		

Elk County
Stormwater Management Plan
Phase 2 Plan

FIGURE III-6

Problem Areas: Problem Types



Problem Type

- Property flooding
- Stream corridor flooding
- Accelerated soil erosion
- Inadequate Infrastructure
- Sediment in streams
- Stream bed/bank erosion
- Street flooding
- Surface water pollution

****Some Problem Areas have multiple Problem Types, denoted using a combination of the above symbols.**

Act 167 Watersheds

- CLARION RIVER
- ELK CREEK
- LITTLE TOBY CREEK
- MOSQUITO CREEK
- NORTH FORK REDBANK CREEK
- SANDY LICK CREEK
- SINNEMAHOING CREEK
- TIONESTA CREEK
- WEST CREEK

Other Features

- US & PA Roads
- Local Road
- Stream
- Municipal Boundary
- Elk County Boundary

DISCLAIMER

No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by the Elk County, PA.

This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained herein, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.

L.R. KimballSM
ARCHITECTURE · ENGINEERING · COMMUNICATIONS TECHNOLOGY

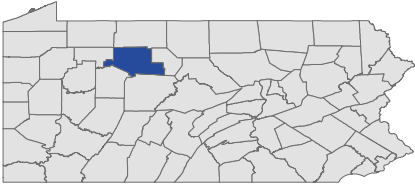
415 Moon Clinton Road Coraopolis, PA 15108-3886

Prepared by: GLF

Date: 03/19/2010

Project Number:

08-1300-0502



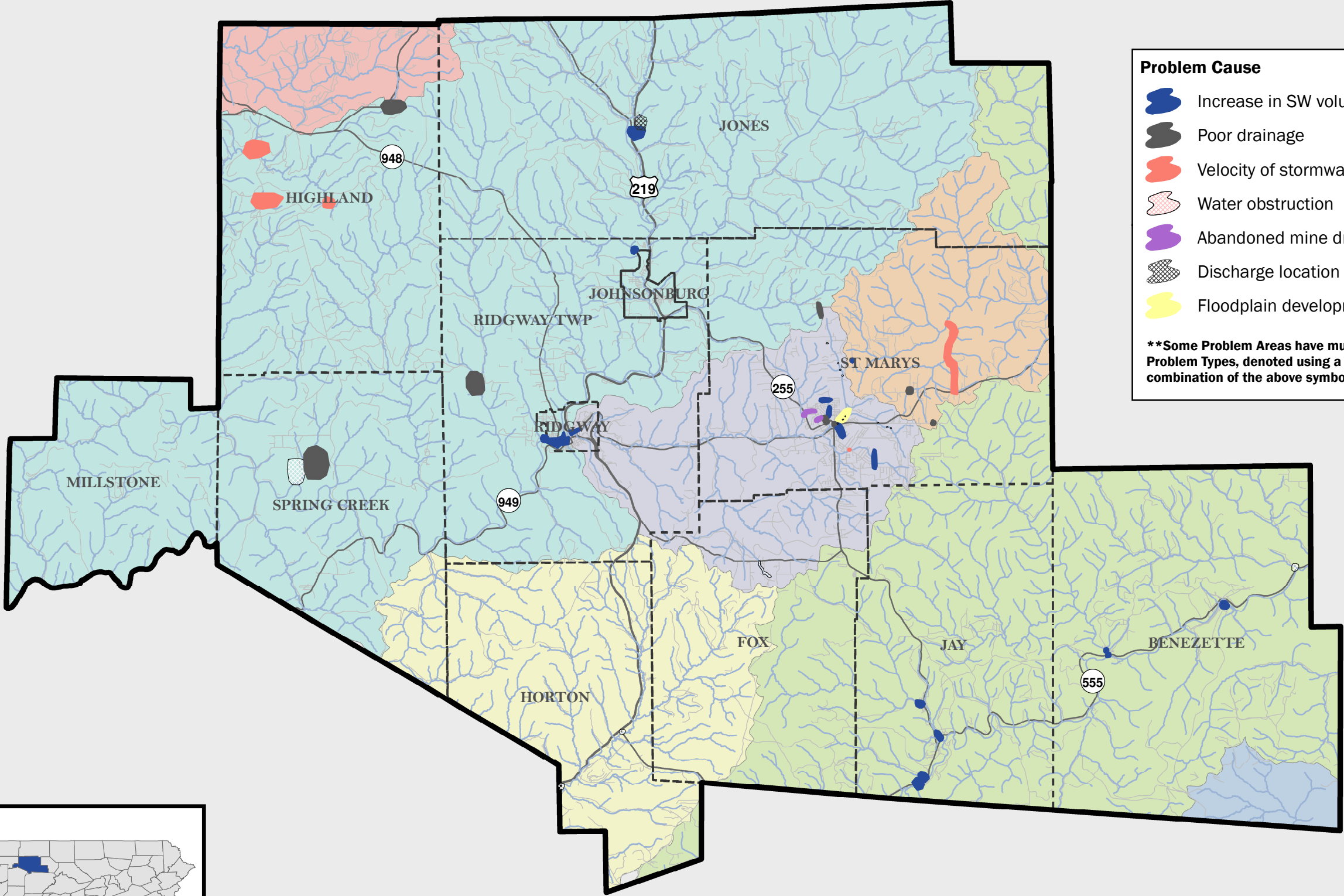
Location of Elk County within the state of Pennsylvania.



0 8,750 17,500 35,000
Feet

Elk County
Stormwater Management Plan
Phase 2 Plan

FIGURE III-7
Problem Areas: Problem Causes



Problem Cause

- Increase in SW volume
- Poor drainage
- Velocity of stormwater
- Water obstruction
- Abandoned mine drainage
- Discharge location
- Floodplain development

****Some Problem Areas have multiple Problem Types, denoted using a combination of the above symbols.**

Act 167 Watersheds

- CLARION RIVER
- ELK CREEK
- LITTLE TOBY CREEK
- MOSQUITO CREEK
- NORTH FORK REDBANK CREEK
- SANDY LICK CREEK
- SINNEMAHOING CREEK
- TIONESTA CREEK
- WEST CREEK

Other Features

- US & PA Roads
- Local Road
- Stream
- Municipal Boundary
- Elk County Boundary

DISCLAIMER

No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by the Elk County, PA.

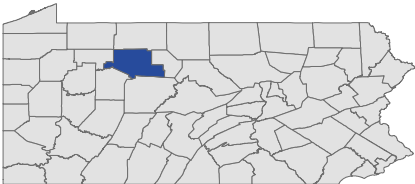
This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained herein, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.



415 Moon Clinton Road Coraopolis, PA 15108-3886

Prepared by: GLF Date: 03/19/2010

Project Number: 08-1300-0502



Location of Elk County within the state of Pennsylvania.



0 8,750 17,500 35,000 Feet

O. Land Use

The information and data (other than the current, existing land use) presented in this section is based upon the contents of the Elk County Comprehensive Plan, originally published in 1968 and then updated in 1999. The study of land use and land use trends is an important component of evaluating and creating stormwater management policy, as well as being imperative to the analysis of existing conditions. It is important to quantify existing development/land use to provide a basis for stormwater management planning; and land use trends can be helpful in site-specific development planning and in the minimization of incompatible land uses. This existing information can further be expanded upon to determine and demarcate areas that are more suitable for future development, areas that could potentially be impacted by stormwater problems, and determining the cause of the problems themselves.

In Elk County, areas with fewer physical restrictions to development have seen sporadic growth, resulting mostly in mixed and unfortunately incompatible land uses. The land use plan for Fox Township, for example, recognized that natural development would be likely to occur in the north portion of the Township (north of Rte. 948) because of fewer physical restrictions and proximity to St. Mary's. Zoning to guide the development for ordered compatible uses and to control sprawl was also a recommendation of the Fox Township plan. Growth and development has continued as predicted, but without the necessary controls as recommended. Therefore, the same incompatibilities still exist, but at a larger scale. With the Townships' proximity to the City of St. Mary's, economic health will depend on building desirable residential areas and desirable industrial areas. This will mean that the Township will need to "implement" the tools necessary to begin to reduce the negative impacts currently felt by the prevalence of incompatible land use. The same tools were recommended for Ridgway Township in previous land use studies. With zoning in place for over forty (40) years, Ridgway Township has seen less of the negative impacts that come with incompatible land uses. The presence and proper implementation of an effective land use plan is imperative to guiding and controlling future growth to the extent that it will not be detrimental to the surrounding areas.

The factors that influence the growth and development of communities are very complex and interrelated. These factors are variable in nature and include such items as economy, cultural rate of growth, and technology. Furthermore, these factors are beyond the control of governmental agencies responsible for land use regulations. Local government can however, stimulate, retard, control, and guide development patterns to productively enhance those variables: growth, cultural enhancement, economy.

It is not the intent of this Plan to analyze land use from a growth impact standpoint, but to consider existing and potential future land use in order to properly analyze the impacts land use has on the existing hydrology of the County. It is also necessary to identify those areas, which currently are adversely impacted by stormwater, and to isolate if a particular land use area is causing a negative impact on stormwater hydrology. The hydrologic modeling done within the County takes into account the existing land uses to accomplish this.

Due to the extensive acreage of publicly held lands in the County, there is limited availability for future development. A significant portion of the county itself is of a very rural and forested nature as well, with over 90% of the overall land use area consisting of a forest-type cover. Land uses are identified and grouped in Table III-6.

**Table III-6
Land Use**

Land Use	Area (Square Miles)	Percentage of County
Commercial Service Areas	0.563	0.07%
Cropland and Pasture	41.735	5.01%
Deciduous Forest Land	756.207	90.77%
Evergreen Forest Land	0.210	0.03%
Forested Wetland	0.127	0.02%
Industrial	1.037	0.12%
Mixed Forest Land	8.616	1.03%
Mixed Urban or Built-up Land	1.682	0.20%
Other Urban or Built-up Land	1.000	0.12%
Reservoirs	2.787	0.33%
Residential	5.406	0.65%
Shrub-brushland Rangeland	0.589	0.65%
Strip Mines, Quarries and Gravel Pits	11.925	1.43%
Transitional Areas	1.084	0.13%
Transportation, Communications and Services	0.167	0.02%
Total:	833.0	

Refer to Figure III-8 for Elk County Land Uses.

P. Existing Development in the Flood Hazard Areas

The U.S. Department of Housing and Urban Development, Federal Insurance Administration, and Federal Emergency Management Agency (FEMA) prepare Flood Insurance Studies (FISs) and floodplain mapping for the municipalities in Elk County. This activity is now a responsibility of the U.S. Department of Homeland Security. Municipalities and the Pennsylvania Department of Community and Economic Development (PADCED) should be contacted as to the latest FIS studies before use.

There are two types of studies conducted in the FIS program: detailed and approximate. Detailed methods included hydrologic computations and detailed hydraulic models. The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction. Areas studied by the approximate methods were areas having low development potential or minimal flood hazards. Map III-9 shows the 100-year floodplains classified as detailed and approximate as taken from the FEMA mapping for the entirety of Elk County.

Encroachments of residential, industrial, urban, transitional, transportation infrastructure, and commercial land covers are shown by overlaying these areas on the floodplain in the GIS.

Approximately 14,851 acres (2.8%) of the County lies within floodplains. Table III-7 provides a summary of floodplain land use within Elk County.

**Table III-7
Floodplain Land Use**

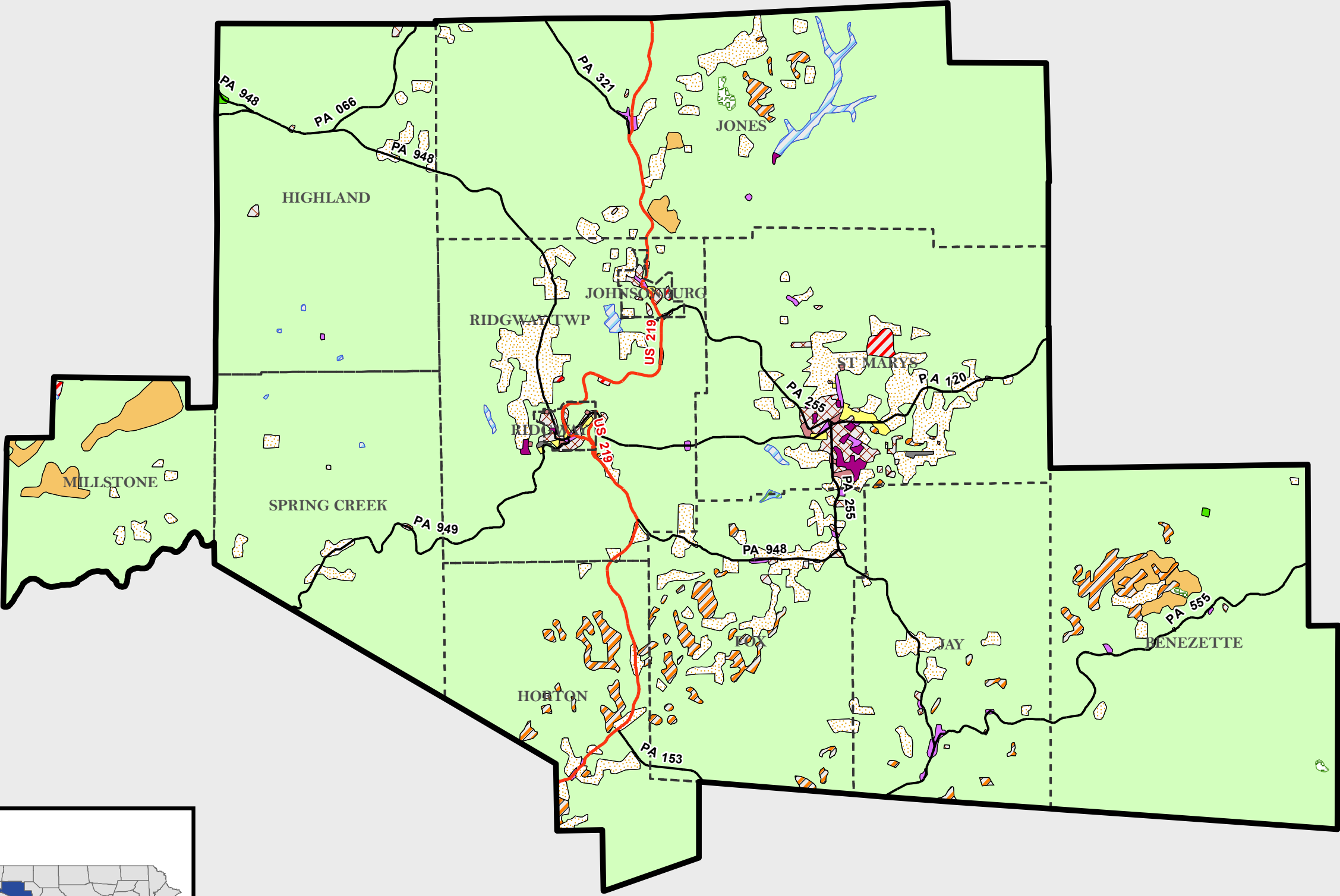
Land Use	Area (Square Miles)
Commercial Service Areas	0.536
Cropland and Pasture	0.583
Deciduous Forest Land	19.131
Forested Wetland	0.077
Industrial	0.214
Mixed Forest Land	0.181
Mixed Urban or Built-up Land	0.200
Other Urban or Built-up Land	0.024
Reservoirs	2.440
Residential	0.223
Strip Mines, Quarries and Gravel Pits	0.024
Transitional Areas	0.033
Transportation, Communications and Services	0.023
Total:	23.205

Refer to Figure III-10 for mapping that overlay the existing, 100-year flood plain locations with the Elk County Land Uses. This map will show the degree to which urbanized development has occurred within the flood plain boundaries.

The evaluation of the returned municipal questionnaires shows occurrences of stream flooding throughout several of the more urbanized areas of the County during major storm events, resulting in property damages. Urbanized development of any kind within delineated flood plain areas is highly discouraged by this Plan. Restoration of existing flood plains and their eventual return to their natural occurring conditions is key to improving the overall County stream conditions and flood-flow capacities.

Elk County
Stormwater Management Plan
Phase 2 Plan

FIGURE III-8
Existing Land Use



- Land Use**
- Commercial and Services
 - Cropland and pasture
 - Deciduous forest land
 - Evergreen forest land
 - Forested wetland
 - Industrial
 - Mixed forest land
 - Mixed urban or built-up land
 - Other urban or built-up land
 - Reservoirs
 - Residential
 - Shrub-brushland rangeland
 - Strip Mine, Quarry/Gravel Pits
 - Transitional areas
 - Transport., Comm., and Services

DISCLAIMER

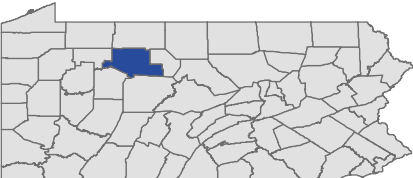
No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by Elk County, PA.

This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained hereon, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.

L.R. KimballSM
ARCHITECTURE • ENGINEERING • COMMUNICATIONS TECHNOLOGY

415 Moon Clinton Road Coraopolis, PA 15108-3886

Prepared by: GLF Date: 03/19/2010
Project Number: 08-1300-0502



Location of Elk County within the state of Pennsylvania.



0 8,750 17,500 35,000
Feet

Elk County
Stormwater Management Plan
Phase 2 Plan

FIGURE III-9

100-Year Flood Plain Areas

- Elk County Streams
- Elk County Boundary
- Municipal Boundary
- 100-Year Flood Plain

DISCLAIMER

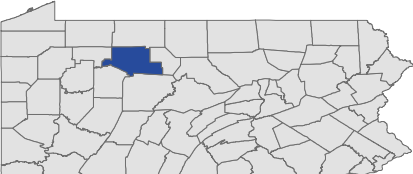
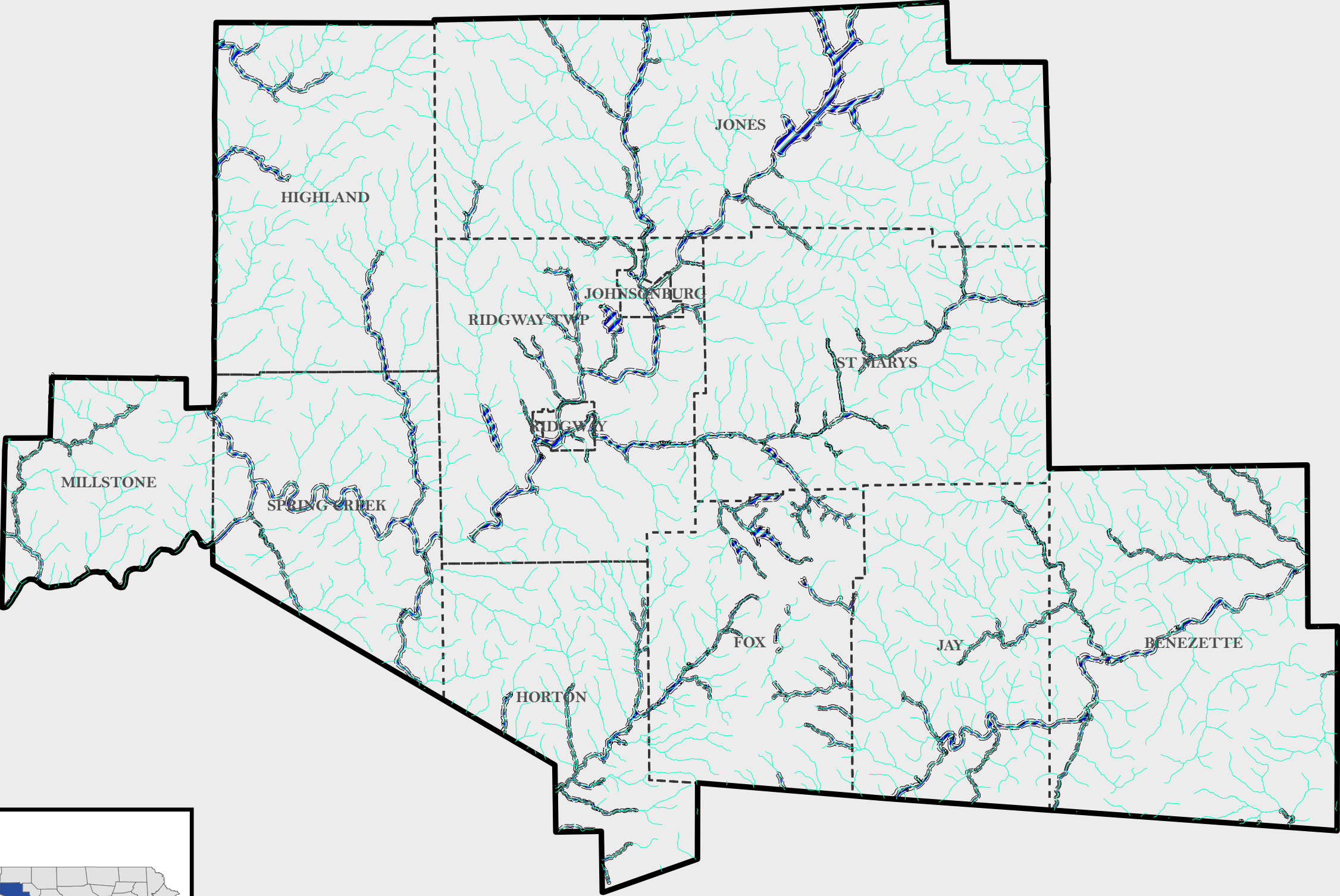
No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by Elk County, PA.

This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained hereon, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.



415 Moon Clinton Road Coraopolis, PA 15108-3886

Prepared by: GLF Date: 03/19/2010
Project Number: 08-1300-0502



Location of Elk County within the state of Pennsylvania.

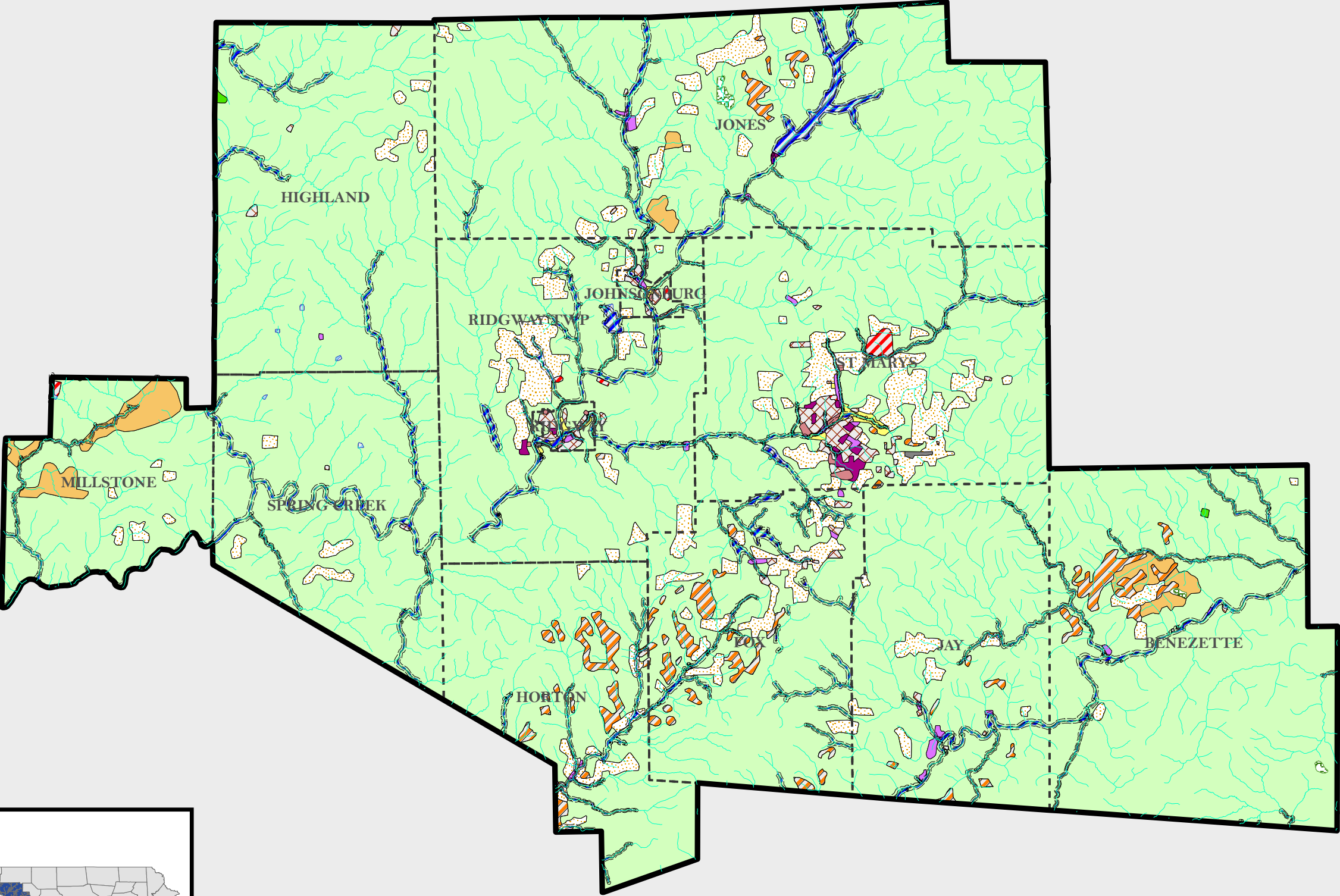


0 8,750 17,500 35,000
Feet

Elk County
Stormwater Management Plan
Phase 2 Plan

FIGURE III-10

Land Use and Flood Plain Areas



- Elk County Streams
- Elk County Boundary
- Municipal Boundary
- 100-Year Flood Plain
- Commercial and Services
- Cropland and pasture
- Deciduous forest land
- Evergreen forest land
- Forested wetland
- Industrial
- Mixed forest land
- Mixed urban or built-up land
- Other urban or built-up land
- Reservoirs
- Residential
- Shrub-brushland rangeland
- Strip Mine, Quarry/Gravel Pits
- Transitional areas
- Transport., Comm., and Services

DISCLAIMER

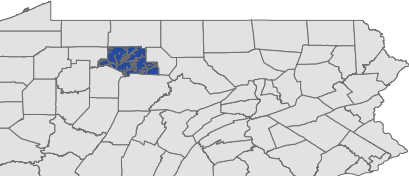
No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by Elk County, PA.

This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained hereon, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.



415 Moon Clinton Road Coraopolis, PA 15108-3886

Prepared by: GLF Date: 03/19/2010
Project Number: 08-1300-0502



Location of Elk County within the state of Pennsylvania.



0 8,750 17,500 35,000
Feet

SECTION IV WATERSHED TECHNICAL ANALYSIS

A. Watershed Modeling

In planning the Act 167 Stormwater Management Phase 2 effort, one of the initial steps was the selection of a computer simulation package that could accurately and efficiently model the County's watersheds.

The selected modeling method and program needed to provide many capabilities related to stormwater modeling, but most importantly, it needed to achieve the following:

- Produce realistic and dependable results, while not requiring a disproportionate amount of input information
- Produce realistic simulations and results in comparison to the overall size of the study area
- Accurately and efficiently account for all pertinent physical properties of the naturally occurring hydrologic process
- Evaluate a variety of rainfall events, durations, and frequencies to generate outflow hydrographs which represented an accurate and realistic representation of the hydrologic conditions in all watersheds being studied

The model chosen for use on this Plan was the U. S. Army Corps of Engineers (USACE), Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS). The standalone HEC-HMS program was supplemented with the use of the USACE GeoHMS software package in order to take better advantage of the growing amount of Countywide Geographic Information System (GIS) data available. The selection of the HEC-HMS and GeoHMS modeling software was based upon the following²:

- It is accepted by the Pennsylvania Department of Environmental Protection
- Provides the ability for combination modeling of the hydrology of natural watersheds as well as developed urban areas
- Provides the ability to represent engineered structures (e.g. pumps, diversions, reservoirs, etc.)
- The software places an equal value on both natural and urban watersheds (one of few software packages available that can model hydrology in watersheds with a mixture of conditions)
- The finalized model can easily be adapted for use in additional applications such as: estimating flood damage reduction, consideration of environmental restoration, future flexibility, and the ability to apply new methods that represent infiltration, new reservoir outlets, and several other components of the hydrologic cycle
- The use of the software allows for integration with other Federal, local, and private entities that are using compatible models produced from USACE software packages

While other commercially and freely developed software packages are available and possess the ability to provide similar results, HEC-HMS was chosen for the reasons outlined above as well HMS's ability to calculate flows for specific sub-watersheds along the stream/river route and then compare these flows with the overall watershed flows.

HEC-HMS has the ability to calculate runoff amounts for each specified storm or return period based on several physical, geological, and meteorological characteristics of the watershed. This flow is then generated and routed through the watershed system based on the stream's hydraulic parameters. This is one of the benefits of using the

² The list is partially adapted from reference material published by the United States Army Corp of Engineers

GeoHMS package in conjunction with HEC-HMS. The watershed's characteristics (listed above) are often available in GIS datasets from the County or other acceptable location. This greatly aids in streamlining the modeling process, increases the modeler's efficiency in producing the results, and helps to diminish the potential for "human error" by reducing the number of calculations that the modeler has to perform without the benefit of the software.

In essence, the amount of flow generated from any watershed is a result of the following contributing factors:

- Basin Slope
- Hydraulic Flow Parameters of Related Streams/Rivers
- Soil Type/Hydrologic Soil Conditions (used for determination of the Soil Conservation Service (SCS) soil curve number)
- Land Use within the Basin (e.g. wooded cover, grassy areas, urbanized areas, open fields, etc.)

Composite SCS curve numbers (CN) are then generated by the software using the available soils and land use information. This information, along with flow travel times, basin slopes, and available rainfall data, are the basis for the resulting watershed and sub-watershed model results.

The map shown in Figure IV-1 shows the overall County watershed areas including the sub-watershed areas that were analyzed and modeled for this Plan.

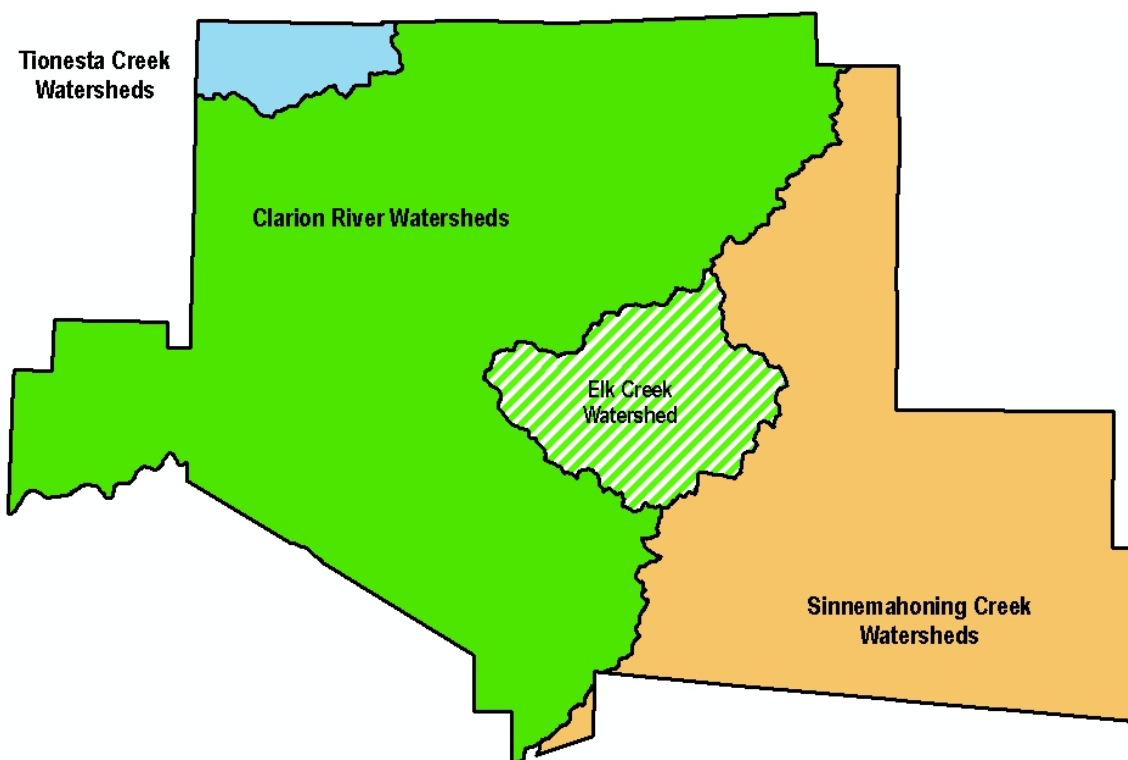


Figure IV-1

As noted in Section I, only one of the watersheds originally identified in the Phase 1 Scope of Study were modeled in Phase 2. The watershed modeled in this planning cycle is Elk Creek.

This watershed is located in the central portion of the County and is tributary to the Clarion River. The municipalities included in the Elk Creek Watershed consist of portions of Ridgway Township, Ridgway Borough, Fox Township, Jay Township, and the City of St. Mary's. Elk Creek flows generally from East to West with an eventual discharge point at its confluence with the Clarion River in Ridgway Borough. The headwaters of the Elk Creek Watershed begin in the City of St. Mary's, a large portion of northern Fox Township and a very small portion of Northwestern Jay Township

B. Modeling Process

After delineation of the major watersheds within Elk County based upon the natural topography of the study areas and using the available GIS data, these major watersheds were then further sub-divided into sub-watersheds for further study and analysis.

The determinations of sub-watershed boundaries were based on a number of factors. Obstructions (e.g. bridges, culverts, and dams), reported problem areas (e.g. flooding, water-quality issues, excessive sedimentation, stream capacity issues, etc.), and confluence points between sub-watersheds were among the factors used in the selection of sub-watershed areas.

The most downstream point of any sub-watershed, the point where the water will leave the sub-watershed and enter another sub-watershed is known as the point of interest (POI). This is the point within each sub-watershed where the most significant results from the model are calculated. This is the point where the overall flow from the sub-watershed is determined. All areas upstream of this point are used to help determine the overall flow at any point of interest.

The point of interest is also selected as a reasonable location for considering how to best and most effectively manage and control the runoff within the watershed contributing to the POI. The watershed's POI acts as a management point, where a specific runoff rate can be determined and upstream management policies can be formulated around this quantifiable number. It also acts as a measurement point in determining any downstream impacts the overall watershed has on adjacent watersheds to which that watershed eventually drains.

All watersheds and sub-watersheds were then modeled to determine the overall runoff amounts for the following 24 - hour storm events:

- 2-year
- 10-year
- 25-year
- 50-year
- 100-year

It is the opinion of the County that the 5-year, 24-hour duration storm event adds very little value to the hydrologic evaluation of a watershed. Therefore, the County proposed to PA DEP that this duration storm be eliminated from hydrologic evaluation. The PA DEP reviewed and agreed with this decision.

An Applicant may still analyze and evaluate the 5-year storm event at their discretion. If the 5-year storm event is included however, it must meet the requirements of Article III – Stormwater Management Standards of the Municipality's local ordinance.

The factors addressed during the modeling process include:

- The peak discharge/overall runoff values at various locations along the stream and its tributaries within each modeled watershed
- The time at which the above mentioned peak discharge is reached (time to peak), and the overall timing of flow through the watershed
- Runoff contributions of individual sub-watersheds and sub-areas within those sub-watersheds at various downstream locations

The results for each individual watershed and the return periods shown can be found in the Technical Appendix of the Volume 3 document. This document is available at the Elk County administrative offices in Ridgway.

C. Calibration

The most appropriate and accurate way to model any watershed is through the proper calibration of the model. The model should be calibrated against known field data and accurate, recent rainfall events collected within the analysis area. An acceptable alternative to the use of known physical and meteorological data is the use of statistical analysis or regression models (Paul A. DeBarry, 2004).

In its simplest form, calibration is the adjustment of model input parameters to converge upon and provide a realistic representation of the actual runoff and time conditions of the watershed based upon known, historical data.

Figure IV-2 shows a theoretical comparison between known, plotted data and the data provided by the model. An acceptably calibrated model will be one that reduces the amount of error between the plotted data when compared to one another. The information in Figure IV-2 is a simple stormwater hydrograph (flow versus time). As the two hydrographs come closer and closer together, and near a point of convergence, the model becomes more representative of realistic conditions within the watershed being modeled.

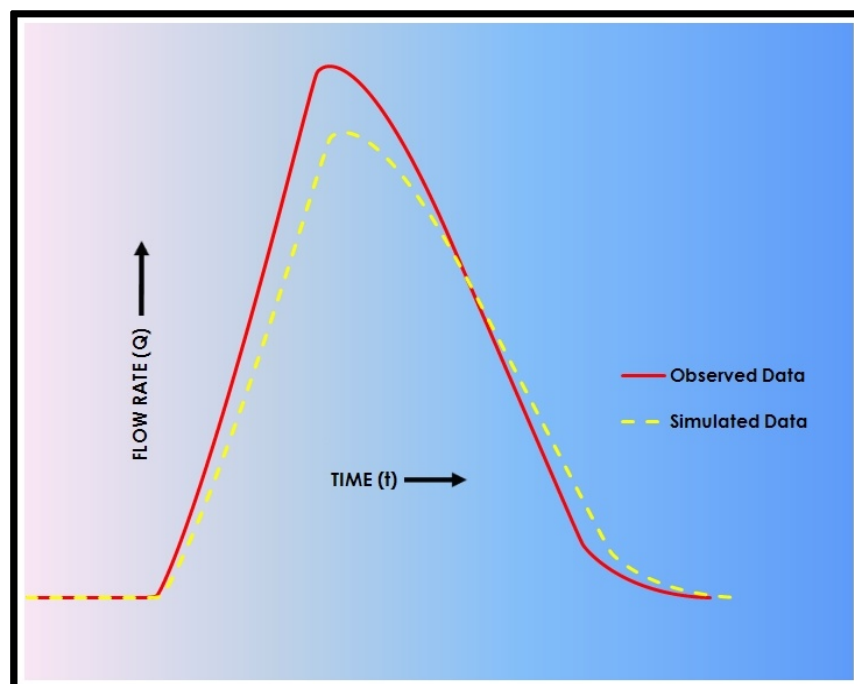


Figure IV-2

Hydrologic model calibration often uses the following procedures:

Table IV-1
Calibration Methods and Priority of Application (Paul A. DeBarry, 2004)

Priority	Data	Advantages	Disadvantages
1	Actual (historically recorded) stream flow data and rainfall hyetographs	Can adequately calibrate peak runoff, watershed timing, and runoff volumes	Historical and recorded data is often not available, especially in more rural areas; method of application is time-consuming
2	Statistical Frequency Analysis	Based on historically recorded data	Can only be used for the calibration of peak runoff amounts only; runoff volumes and watershed timing cannot be calculated The watershed in question may not fit the "regional trend" ³
3	Regression Analysis (Regionally Derived)	Fast and not time-consuming for the modeler	Can only be used for the calibration of peak runoff amounts only; runoff volumes and watershed timing cannot be calculated

When historical precipitation and stream flow data is available, by way of recorded rain gage and stream flow information, the model can then be properly be set up to simulate hydrographs of the watershed.

If the modeler seeks to simulate a specific rainfall event, the model input needs to include information concerning the relative wetness and dryness of the watershed (antecedent moisture content) and the accurate distribution of rainfall throughout the watershed. The flow through any given watershed can be significantly impacted by the continuously changing antecedent moisture content.

Additional modifications to the simulation model are then also made in an effort to replicate the outflow hydrograph (shape and peak flow rates) at various measurement points within the watershed. The use of stream flow and rain gage data during the calibration process can only be used if the data is sufficient in amount as well as being geographically near the watershed. Since watershed distribution can vary quite significantly over relatively small areas, it is imperative that the rain and stream gages are numerous and as close as possible to the watershed in question.

The inclusion of more localized events and occurrences, such as snowmelt conditions, are typically not reliable sources of data for calibration efforts. This is because such data is not historically consistent and can often be unique to the area in question. The variation of this data over time makes it somewhat unreliable to yield realistic model simulation results.

³ Regional trend is meant to indicate the varying flow conditions that can occur from watershed to watershed. Known rainfall data has proven that there is a possibility that precipitation conditions in one portion of a watershed can vary from that of another portion of the same watershed. This can even occur in very small watershed areas.

Elk County Calibration Effort

As noted previously, the only watershed modeled during this Phase 2 planning cycle is Elk Creek. No existing stream gage data or other recorded information is available for Elk Creek, so comparison of the model runs with recorded or statistically analyzed historical data are not options. Past modeling efforts in this specific watershed used regression analysis methods for calibration. Therefore, the use of a regression analysis was also used to calibrate the computer modeling efforts in this Plan.

Current State of Regression Analysis Methodology in Pennsylvania

The most current regression analysis method for Pennsylvania is the *Regression Equations for Estimating Flood Flows at Selected Recurrence Intervals for Ungaged Streams in Pennsylvania*, (Roland & Stuckey, 2008), (Scientific Investigation Report 2008-5102), commonly referred to as USGS 5102. This method was published in 2008, after the planning effort for Elk County had already started. USGS 5102 presents regression equations developed for estimating flood flows at selected recurrence intervals for ungaged streams in Pennsylvania with drainage areas less than 2,000 square miles. These equations were developed using peak-flow data from 322 streamflow-gaging stations within Pennsylvania and surrounding states. All stations used in the development of the equations had 10 or more years of record data and included active and discontinued continuous-record as well as crest-stage partial-record stations. The state was divided into four regions, and regional regression equations were developed to estimate the 2-, 5-, 10-, 50-, 100-, and 500-year recurrence-interval flood flows. The equations were developed by means of a regression analysis that used basin characteristics and flow data associated with the stations. This method established equation variables for the following basin characteristics: drainage area; mean basin elevation; and the percentages of carbonate bedrock, urban area, and storage within a basin. The regression equations can be used to predict the magnitude of flood flows for specified recurrence intervals for most streams in the state; however, they are not valid for streams with drainage areas generally greater than 2,000 square miles or with substantial flow regulation, diversion, or mining activity within the basin.

Regression Analysis Methodology Used During the Current Planning Cycle

Since the Elk County Plan effort started prior to the release of USGS 5102, the calibration efforts described below are based on its predecessor, *Techniques for estimating magnitude and frequency of peak flows for Pennsylvania streams* (Stuckey and Reed, 2000) USGS 4189. This method is still accepted by PennDOT and consequently is still useful for projects that require PennDOT standards be followed.

We recommend, however, that future design projects or calibration efforts use USGS 5102.

Elk County Calibration Results

In order to calibrate the watersheds, a validated flow result within the watershed would need to be known for each event. In this event, consistent stream gage data was unavailable for the entire County. For this reason, the watershed was calibrated by comparing the un-calibrated model results to a regression analysis. The regression analysis used was "*Techniques for estimating magnitude and frequency of peak flows for Pennsylvania streams*" (Stuckey and Reed, 2000). This commonly accepted form of regression analysis presents equations that predict flood frequencies with return intervals or 10, 25, 50, 100, and 500-year intervals for un-gauged streams in Pennsylvania.

Specific basin characteristics were used in the regression analysis formulas depending upon how the watershed being studied correlates with one of two delegated regions within Pennsylvania. These regions were delineated based upon technical evaluations revealing that flooding within Region A seems hydrologically unrelated to the flooding in Region B. See Figure IV-3 below for the Region map.

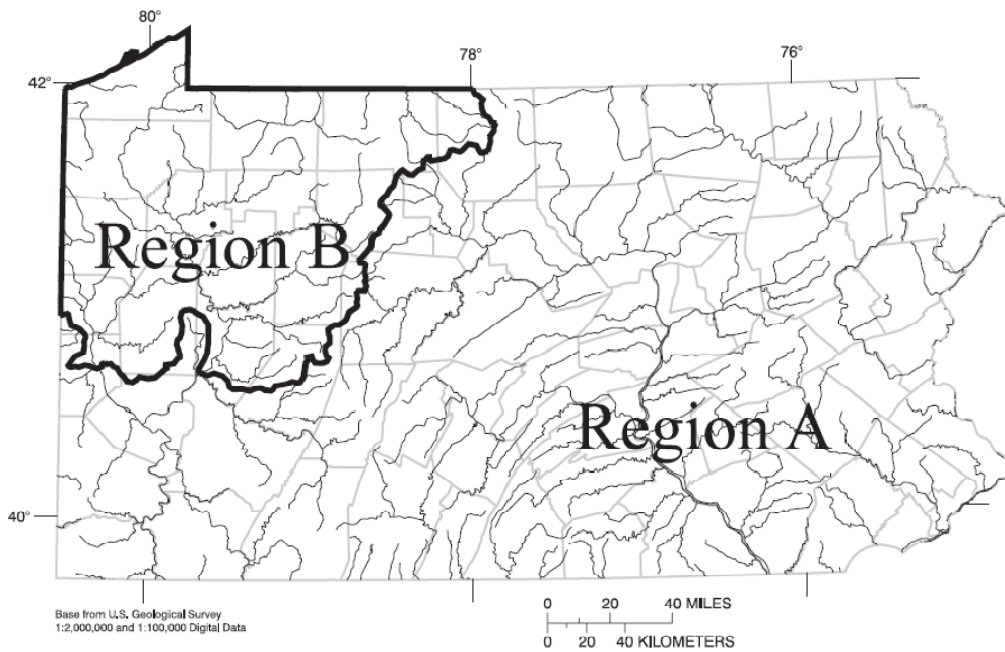


Figure IV-3
(Stuckey and Reed, 2000)

Approximately two-thirds of the County falls within Region B. The remaining southeastern corner of the County falls within Region A. Based on the location of the Elk Creek watershed within the County, the formulas for Region B were used. Regression equations for Region B were developed from 54 stream flow-gauging station records and have two (2) variables, drainage area and the percentage of basin controlled by lakes, swamps, and reservoirs. The area of the State that comprises Region B does not contain any significant areas of carbonate rock coverage (Figure IV-4). The percentage of urban area coverage is consistently low for stream flow-gauging stations in Region B. An overall lack of urban area coverage results in un-meaningful results during analysis. The percentage of forest-type coverage was also not a significant variable and was therefore omitted from the analysis. From this information, each sub-basin area was analyzed using the equations shown in Figure IV-4 below. It was also assumed that CA, or the percentage of basin controlled by lakes, swaps or reservoirs was zero.

Based on the planned and achieved objectives of this Plan, not all the County watersheds were analyzed within the computer model. The watersheds that were analyzed fell within Region B of the County. Future revision cycles of the Plan should include the location of the watershed being studied and the necessary regression formulas should be used based on the geographic region in which the watershed resides.

Q _T return flow (ft ³ /s)	Basin characteristic coefficients						Residual standard error		Coefficient of determination (R ²)
	Intercept (A)	Drainage area (b)	Percentage forested area (c)	Percentage urban development (d)	Percentage carbonate area (e)	Percentage controlled area (f)	Log units	Percent	
Region A									
Q ₁₀	2.5243	0.7770	0.9712	1.0217	1.7184	0.5719	0.18	43	0.93
Q ₂₅	2.7145	.7556	-1.0324	.7608	-1.5302	-.5302	.19	45	.91
Q ₅₀	2.8441	.7414	-1.0821	.5785	-1.3955	-.4980	.21	50	.89
Q ₁₀₀	2.9665	.7278	-1.1342	.4040	-1.2691	-.4637	.23	55	.87
Q ₅₀₀	3.2294	.6994	1.2666	.0208	.9877	.3834	.27	66	.82
Region B									
Q ₁₀	2.3105	.7255	---	---	---	-1.2425	.12	28	.96
Q ₂₅	2.4418	.7108	---	---	---	-1.3700	.13	30	.95
Q ₅₀	2.5276	.7017	---	---	---	-1.4695	.14	33	.94
Q ₁₀₀	2.6069	.6932	---	---	---	-1.5677	.16	38	.92
Q ₅₀₀	2.7673	.6776	---	---	---	-1.8055	.19	45	.89
OR									
Region A									
Q ₁₀	= 334.4 DA ^{.7770} (1 + .01F) ^{-.9712} (1 + .01U) ^{1.0217} (1 + .01C) ^{-1.7184} (1 + .01CA) ^{-.5719}								
Q ₂₅	= 518.2 DA ^{.7556} (1 + .01F) ^{-1.0324} (1 + .01U) ^{.7608} (1 + .01C) ^{-1.5302} (1 + .01CA) ^{-.5302}								
Q ₅₀	= 698.4 DA ^{.7414} (1 + .01F) ^{-1.0821} (1 + .01U) ^{.5785} (1 + .01C) ^{-1.3955} (1 + .01CA) ^{-.4980}								
Q ₁₀₀	= 925.8 DA ^{.7278} (1 + .01F) ^{-1.1342} (1 + .01U) ^{.4040} (1 + .01C) ^{-1.2691} (1 + .01CA) ^{-.4637}								
Q ₅₀₀	= 1,696 DA ^{.6994} (1 + .01F) ^{1.2666} (1 + .01U) ^{.0208} (1 + .01C) ^{.9877} (1 + .01CA) ^{.3834}								
Region B									
Q ₁₀	= 204.4 DA ^{.7255} (1 + .01CA) ^{-1.2425}								
Q ₂₅	= 276.6 DA ^{.7108} (1 + .01CA) ^{-1.3700}								
Q ₅₀	= 337.0 DA ^{.7017} (1 + .01CA) ^{-1.4695}								
Q ₁₀₀	= 404.5 DA ^{.6932} (1 + .01CA) ^{-1.5677}								
Q ₅₀₀	= 585.2 DA ^{.6776} (1 + .01CA) ^{-1.8055}								

DA is drainage area, in square miles;
F is percentage of forest cover, in percent;
U is percentage of urban development, in percent;
C is percentage of basin underlain by carbonate rock, in percent;
CA is percentage of basin controlled by lakes, swamps, or reservoirs, in percent; and
b, c, d, e, f are basin characteristic coefficients of regression.

Figure IV-4
(Stuckey and Reed, 2000)

Calibration results for Elk Creek and its five (5) associated sub-sheds can be found in Tables IV-2 through IV-6 below:

Table IV-2
Elk Creek Watershed - Laurel Run Calibration Results

		10-year Event			50-year Event			100-year Event		
Node or Reach ID	Tributary Drainage Area (mi ²)	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference
W710 / REACH 1	1.8613	320.8	265	17%	521.15	494.2	5%	622.24	616.4	1%
W930 / REACH 2	3.6331	521.15	409.8	21%	833.25	776.6	7%	989.24	974.6	1%
J102	5.4944	703.55	655	7%	1113.86	1233.3	11%	1317.74	1544.2	17%
W690 / REACH 3	0.69337	156.71	125.1	20%	260.64	243.9	6%	313.82	307.1	2%
J127	6.18777	766.9	625.7	18%	1210.74	1169.3	3%	1430.9	1461.7	2%
W620 / REACH4	0.29043	83.35	74	11%	141.53	135.3	4%	171.67	167	3%
J105	6.4782	792.85	641.8	19%	1250.34	1196.8	4%	1477.13	1494.9	1%
SUBBASIN 1 / REACH 5	1.82	315.62	261.8	17%	513.01	485.2	5%	612.63	604.1	1%
J118	8.2982	948.86		100%	1487.58		100%	1753.71	1737.9	1%
OUTLET	8.2982	948.86	755.3	20%	1487.58	1394.8	6%	1753.71	1737.2	1%

Table IV-3
Elk Creek Watershed - Upper Elk Creek Calibration Results

		10-year Event			50-year Event			100-year Event		
Node or Reach ID	Tributary Drainage Area (mi ²)	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference
w800 / reach 13	2.1819	360	315.9	12%	582.63	567.9	3%	694.7	699.3	1%
w810 / reach 12	0.30761	86.9	75.4	13%	147.35	140.1	5%	178.65	173.7	3%
J188	2.48951	396.15	338.7	15%	639.12	597.1	7%	761.21	723.9	5%
w1090 / reach 11	2.4709	394	378.9	4%	635.76	638.5	0%	757.26	770.6	2%
J154	4.96041	653.25	581.7	11%	1036.75	1007.3	3%	1227.58	1220.5	1%
w900 / reach 18	0.11978	43.84	55.5	27%	76.02	81.6	7%	92.91	93.8	1%
J175	5.08019	664.66	571.3	14%	1054.26	978.6	7%	1248.06	1220.5	2%

**Table IV-3
Elk Creek Watershed - Upper Elk Creek Calibration Results (cont.)**

Node or Reach ID	Tributary Drainage Area (mi ²)	10-year Event			50-year Event			100-year Event		
		Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference
w910 / reach 14	0.11071	41.4	48.5	17%	71.93	73	1%	87.97	84.6	4%
w890 / reach 17	0.06137	26.99	32.9	22%	47.55	49	3%	58.44	56.5	3%
j172	5.25227	680.91	583.3	14%	1079.19	995.6	8%	1277.21	1220.8	4%
w920 / reach 19	0.09417	36.82	45.7	24%	64.21	67.5	5%	78.64	77.7	1%
w990 / reach 20	0.12026	43.97	51.4	17%	76.23	79.2	4%	93.17	92.5	1%
j161	5.4667	700.97	597.8	15%	1109.92	1016.5	8%	1313.14	1244.6	5%
w820 / reach 22	0.60873	142.59	142.8	0%	237.88	230.3	3%	286.74	273.7	5%
w950 / reach 21	0.086198	34.53	40.7	18%	60.35	63	4%	73.96	73.7	0%
J164	6.161628	764.55	662.3	13%	1207.14	1114.9	8%	1426.71	1354	5%
w1340 / reach 1	0.11152	41.62	46.3	11%	72.3	76	5%	88.42	90.5	2%
w1360 / reach 2	1.158	227.35	209.3	8%	373.54	358.4	4%	447.8	434.4	3%
J167	1.26952	243.04	226.4	7%	398.43	386.4	3%	477.27	468	2%
w1220 / reach 3	0.73305	163.17	191.6	17%	271.02	293.9	8%	326.16	343.6	5%
J217	2.00257	338.29	341.9	1%	548.6	544.7	1%	654.6	634.4	3%
w1240 / reach 10	0.11449	42.42	39.5	7%	73.65	70.8	4%	90.04	86.6	4%
w1250 / reach 9	1.3039	247.79	215	13%	405.97	397.9	2%	486.19	464.9	4%
J193	1.41839	263.4	226.8	14%	430.67	400.5	7%	515.4	490.2	5%
w1140 / reach 7	0.36377	98.14	101.6	4%	165.75	174.4	5%	200.67	210.9	5%
w1190 / reach 8	0.19396	62.19	74.1	19%	106.61	112.3	5%	129.77	130.6	1%
J144	1.97612	335.04	317.6	5%	543.5	547.2	1%	648.6	666.9	3%
w1120 / reach 5	0.70865	159.21	171.1	7%	264.65	265.5	0%	318.59	311.8	2%
J210	2.68477	418.46	399.5	5%	673.9	663.3	2%	802.12	797.8	1%
J149	4.68734	626.96	589.8	6%	996.37	967	3%	1180.33	1158.6	2%
w1040 / reach 27	0.10527	39.92	45	13%	69.44	69.7	0%	84.95	81.6	4%
w1060 / reach 23	0.10752	40.53	41.4	2%	70.47	71.8	2%	86.21	86.9	1%
w1130 / reach 25	0.54543	131.67	133.5	1%	220.24	215.7	2%	265.72	256.5	3%
OUTLET to Silver Run	11.60719	1210.43	1124.3	7%	1882.56	1864	1%	2213.03	2256.8	2%

**Table IV-4
Elk Creek Watershed - Silver Run Calibration Results**

Node or Reach ID	Tributary Drainage Area (mi ²)	10-year Event			50-year Event			100-year Event		
		Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference
w1160 / REACH 22	1.117876	221.61	142.1	36%	364.41	312.8	14%	436.98	427.3	2%
W1210	0.187099	60.59	42.6	30%	103.95	91.2	12%	126.57	126.9	0%
J10	1.304975	247.94	154.7	38%	406.21	334.5	18%	486.47	464.5	5%
W1170 / REACH 19	0.951047	197.09	182.9	7%	325.34	314.4	3%	390.67	393.2	1%
W1240 / REACH 20	0.135417	47.92	50.2	5%	82.86	81.6	2%	101.16	102.6	1%
J20	1.086464	217.08	215.6	1%	357.19	368.6	3%	428.43	458.3	7%
W1260 / REACH 17	0.361676	97.73	78.4	20%	165.08	151.2	8%	199.87	200.4	0%
W1310 / REACH 16	0.323107	90.06	81.1	10%	152.52	145.7	4%	184.84	186.5	1%
J30	3.076222	461.89	372.4	19%	741.43	699.5	6%	881.48	896.3	2%
W1370 / REACH 13	0.185964	60.32	50.3	17%	103.51	94.4	9%	126.03	125	1%
W1420 / REACH 14	0.152335	52.19	44.2	15%	89.99	80.9	10%	109.76	107.5	2%
W1280 / REACH 15	0.740059	164.3	149.6	9%	272.83	259.3	5%	328.32	324.8	1%
J40	4.15458	574.41	461.2	20%	915.48	844.1	8%	1085.63	1069.1	2%
W1830 / REACH 9	0.702784	158.25	122.3	23%	263.11	240.1	9%	316.76	316.9	0%
FROM UPPER 3 JUNCTION	12.30997	1263.17	1143.5	9%	1961.84	1899.4	3%	2305.07	2293.5	1%
W1390 / REACH 11	0.779751	170.65	132.2	23%	283.02	263.1	7%	340.43	349.8	3%
J60	17.2443	1613.12	1395.1	14%	2485.33	2374.9	4%	2911.8	2811.2	3%
W1820	0.285915	82.41	41.3	50%	139.98	98.4	30%	169.82	144.7	15%
J80	17.53022	1632.48	1398.9	14%	2514.17	2383	5%	2945.18	2819.2	4%
Outlet to UPDOWN	17.81613	1651.76	1398.9	15%	2542.88	2383	6%	2978.4	2819.2	5%

Table IV-5
Elk Creek Watershed - Daguscahonda Run and Other Central Tributaries Calibration Results

Node or Reach ID	Tributary Drainage Area (mi ²)	10-year Event			50-year Event			100-year Event		
		Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference
W2440 / reach 1	0.12696	45.728951	40.7	11%	79.1904798	74.9	5%	96.73428602	96.9	0%
JUP5 / r640	8.42516	959.37378	595.3	38%	1503.51614	1161.8	23%	1772.267627	1484.3	16%
W1520 / reach 3	2.0014	338.14	219.6	35%	548.37	488.3	11%	654.34	664.1	1%
W1300 / reach 5	0.63869	147.65	97.3	34%	246.04	210.3	15%	296.45	287.1	3%
W1490 / none	0.109503	41.08	14.4	65%	71.38	42.6	40%	87.31	64.3	26%
W2340 / none	0.047337	22.352994	9	60%	39.6291753	22.7	43%	48.8162588	33	32%
j304 / r370	28.75209	2337.4673	1986.5	15%	3557.77294	3454.6	3%	4150.191744	4231.2	2%
W1220 / none	1.0527	212.16	92.4	56%	349.37	229.2	34%	419.16	323.7	23%
W1310	0.36026	97.46	52.3	46%	164.63	122.2	26%	199.33	172.8	13%
W2380	0.46639	117.53263	29.6	75%	197.329146	95.2	52%	238.3940941	145.4	39%
j328 / r210	1.87935	323.05276	125.8	61%	524.68794	314.3	40%	626.4128262	559	11%
W1360	0.3582	97.05	33.6	65%	163.97	93.1	43%	198.54	142	28%
j352	30.98964	2468.08	2018.5	18%	3749.87	3515.4	6%	4371.49	4292.9	2%
W2490	0.75119	166.08766	190.3	15%	275.704296	369.2	34%	331.7327018	332.3	0%
W2000 / reach 19	0.30579	86.53	90.6	5%	146.74	147.4	0%	177.92	181.4	2%
W2110 / reach 20	1.0066	205.38	173.8	15%	338.56	319.9	6%	406.35	408.4	1%
W2210 / reach 21	1.5381	279.34326	237.3	15%	455.865762	427.1	6%	545.1753755	541.3	1%
J360	3.60168	517.87549	442.4	15%	828.189169	775.1	6%	983.3041636	1314.3	34%
W1990 / reach 18	0.76126	167.7	152.3	9%	278.29	266.6	4%	334.81	335.8	0%
J266	4.36294	595.17	505.1	15%	947.46	910	4%	1123.09	1123.3	0%
W1940 / reach 16	0.36357	98.1	93.2	5%	165.69	160	3%	200.59	200.5	0%
W2050 / reach 22	2.6372	413.07	383.9	7%	665.5	651.4	2%	792.24	800.8	1%
j263	3.00077	453.64	432.8	5%	728.63	735.6	1%	866.44	891.1	3%
W1870 / reach 15	0.86302	183.68	159.8	13%	303.9	290.2	5%	365.23	368.7	1%
W1930 / reach 17	0.49389	122.52	110.9	9%	205.42	196.5	4%	248.05	250	1%

Table IV-5										
Elk Creek Watershed - Daguscahonda Run and Other Central Tributaries Calibration Results (cont.)										
Node or Reach ID	Tributary Drainage Area (mi ²)	10-year Event			50-year Event			100-year Event		
		Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference
j273	4.35768	594.65	534	10%	946.66	917.4	3%	1122.15	1116	1%
W1900 / reach 14	1.3136	249.13	179.5	28%	408.09	364.5	11%	488.69	479.6	2%
j390	8.67205	979.69	837	15%	1534.3	1456.9	5%	1808.11	1783.9	1%
W1890 / reach 13	0.65221	149.91	138.2	8%	249.68	243.4	3%	300.78	308.9	3%
j276	9.32426	1032.61	868.9	16%	1614.39	1510.3	6%	1901.32	1847.6	3%
W1770 / reach 11	0.19371	62.13	47.6	23%	106.52	96.6	9%	129.65	129.1	0%
W1780 / reach 12	0.32566	90.57	82.6	9%	153.37	150.1	2%	185.85	185	0%
j286	9.84363	1074.03	884.8	18%	1676.98	1537	8%	1974.12	1879.6	5%
W1790	1.3419	253.01	175.7	31%	414.24	382.8	8%	495.97	497.7	0%
j283	11.18553	1178.37	919.6	22%	1834.31	1597.5	13%	2156.99	1955.8	9%
W1230 / reach 9	2.3286	377.41	235.9	37%	609.85	522.1	14%	726.76	714.5	2%
j355	44.50377	3209.17	2638.9	18%	4834.04	4610.2	5%	5618.07	5650.4	1%
W1510	1.3512	254.28	129.6	49%	416.25	300.8	28%	498.35	419	16%
j307	45.85497	3279.57	2651.1	19%	4936.56	4631.5	6%	5735.77	5678	1%
W1550 / reach 23	0.17861	58.58	39.5	33%	100.62	88.4	12%	122.56	122.5	0%
Outlet to Lower	46.03358	3288.83	2647.9	19%	4950.05	4625.8	7%	5751.25	5671.6	1%

Table IV-6										
Elk Creek Watershed - Lower Elk Creek Calibration Results										
Node or Reach ID	Tributary Drainage Area (mi ²)	10-year Event			50-year Event			100-year Event		
		Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference
W2110 / reach 1	0.7269	162.17	116.6	28%	269.42	263.4	2%	324.26	317.5	2%
J389	46.76048	3326.43	4694.7	41%	5004.77	5329.6	6%	5814.05	5693.1	2%
W2650 / reach 2	0.39929	105.01	87.4	17%	176.95	182.2	3%	214.06	216.3	1%
j348	47.15977	3347.01	4699.8	40%	5034.72	5337.6	6%	5848.42	5701.9	3%
W2450 / reach 3	0.10073	38.66	36.3	6%	67.32	69.7	4%	82.4	81.6	1%

**Table IV-6
Elk Creek Watershed - Lower Elk Creek Calibration Results (cont.)**

Node or Reach ID	Tributary Drainage Area (mi ²)	10-year Event			50-year Event			100-year Event		
		Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference
j404	47.2605	3352.2	4701.2	40%	5042.26	5339.8	6%	5857.07	5704.3	3%
W2400	0.17861	58.58	44	25%	100.62	97.1	4%	122.56	118.3	3%
W2630 / reach 5	0.54828	132.17	120.6	9%	221.05	229.5	4%	266.68	267.6	0%
W2710 / reach 6	0.52994	128.95	105	19%	215.83	216.9	0%	260.47	256.9	1%
j327	1.25683	241.27	238.1	1%	395.63	473	20%	473.95	546.3	15%
j362	48.51733	3416.64	4719	38%	5135.99	5367.6	5%	5964.61	5733.5	4%
W1500 / reach 7	1.1351	224.08	200.9	10%	368.34	385.9	5%	441.64	447.1	1%
j397	49.65243	3474.45	4742.1	36%	5220.01	5403.6	4%	6061	5766.2	5%
W2430 / reach 8	0.34749	94.94	69.7	27%	160.51	161.8	1%	194.4	194.8	0%
j355	49.99992	3492.07	4745.9	36%	5245.62	5409.9	3%	6090.38	5773.2	5%
W2000 / reach 10	1.413	262.67	216.7	18%	429.52	473.7	10%	514.04	514.1	0%
W2440 / reach 9	1.5673	283.18	195.4	31%	461.92	438.2	5%	552.33	553.1	0%
j410	52.98022	3641.88	4782.8	31%	5463.12	5470.6	0%	6339.78	5837.1	8%
W2880 / reach 15	1.422	263.88	223.2	15%	431.44	444.4	3%	516.31	513	1%
W2850 / reach 14	0.52549	128.16	121.8	5%	214.56	222.4	4%	258.95	253.9	2%
j306	1.94749	331.51	337.5	2%	537.97	653.8	22%	642.07	752.2	17%
W2830 / reach 13	0.81989	176.97	137.5	22%	293.17	294	0%	352.48	350.5	1%
j434	2.76738	427.76	362.6	15%	688.38	710.3	3%	819.14	821.5	0%
W2790 / reach 12	0.5111	125.6	113.4	10%	210.42	215.4	2%	254.01	251.8	1%
j314	3.27848	483.73	407.5	16%	775.31	796.1	3%	921.26	920.8	0%
W2600 / reach 11	1.5876	285.84	231.5	19%	466.11	490.9	5%	557.28	571.1	2%
j431	4.86608	644.21	517.7	20%	1022.88	1032.3	1%	1211.35	1197.9	1%
j343	57.8463	3881.61	4862.6	25%	5810.57	5600.1	4%	6737.95	5956.3	12%
W2980 / reach 16	2.4546	392.11	289.6	26%	632.82	632	0%	753.79	749.1	1%
j382	60.3009	4000.42	4896	22%	5982.51	5654.3	5%	6934.88	6011	13%
W2970 / reach 17	1.0085	205.66	193.1	6%	339.01	351.9	4%	406.88	406.1	0%

**Table IV-6
Elk Creek Watershed - Lower Elk Creek Calibration Results (cont.)**

Node or Reach ID	Tributary Drainage Area (mi ²)	10-year Event			50-year Event			100-year Event		
		Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference	Regression Peak Flow (CFS)	Calibrated Model Peak Flow (CFS)	% Difference
j384	61.3094	4048.85	4915.8	21%	6052.54	5684.8	6%	7015.07	6038.7	14%
W2270 / reach 18	0.24708	74.13	80	8%	126.35	133.9	6%	153.47	154	0%
W2290	1.612	289.02	217	25%	471.13	465.3	1%	563.2	542.6	4%
j317	1.85908	320.52	297	7%	520.71	599.2	15%	621.72	694.2	12%
j385	63.16848	4137.56	4942.3	19%	6180.75	5726.7	7%	7161.85	6081.5	15%
W1680 / reach 21	2.6039	409.28	348.1	15%	659.59	678.2	3%	785.29	780.5	1%
j394	65.77238	4260.61	4989.8	17%	6358.45	5806.2	9%	7365.23	6149.2	17%
W1880	3.8881	547.44	895.9	64%	873.87	1624.8	86%	1036.87	1043.1	1%
outlet	69.66048	4441.89	5056.9	14%	6619.93	6946.7	5%	7664.37	7307.5	5%

SECTION V STANDARDS AND CRITERIA FOR STORMWATER CONTROL

A. Watershed Level Control Philosophy

Within any watershed, an increase in development or disturbance to the natural hydrology results in an overall increase in peak runoff rates, stormwater runoff volumes, and in many cases, a decrease in overall stormwater runoff quality.

The traditional approach to stormwater management has been the site specific, or on-site control approach. The goal was to create a situation where the post-development peak runoff rates did not exceed those of the pre-development rates. This was often done through on-site collection and then conveyance to a large detention basin (or system of basins), located somewhere on the low point of the site. For many years, this was the methodology and philosophy behind managing stormwater.

However, new regulations (the result of new research) have begun to dictate the mitigation of not only peak runoff rates, but also runoff volumes and the issue of water quality. On-site stormwater management is still a key factor in overall watershed management; however, these new limiting factors can complicate the management process and make the traditional methods of managing stormwater a way of the past. New technologies and implementation practices are becoming the norm and no longer the anomaly.

The management of runoff volumes from a developed site is becoming a very important contributing factor, not only to on-site stormwater management, but also in overall watershed management. On-site volume controls (through various methods such as infiltration, stormwater re-use, bio-retention, limiting the source of runoff, etc.) are greatly reducing the volume of water (and the timing of its conveyance) that needs to be transported by streams through the watershed. This aids significantly in reducing excessive flows and volumes that can result in stream bank erosion and destructive flooding. On-site volume control also helps in the recharge of groundwater tables and aquifers by keeping the water within the watershed, instead of simply releasing it at a slower rate through the watershed and into adjacent, downstream watersheds. This methodology also helps in the management of water quality, an increasingly important issue. By allowing the natural characteristics of the watershed the ability to filter and treat runoff naturally, overall water quality can be greatly improved.

B. National Pollutant Discharge Elimination System (NPDES), Phase II Requirement

"In 1990, the US Environmental Protection Agency (EPA) promulgated federal National Pollutant Discharge Elimination System (NPDES) regulations for stormwater discharges under the Clean Water Act. These regulations, among other discharge requirements, established the federal Phase I NPDES stormwater discharge program that requires permit coverage for all operators of large construction activities proposing to disturb five or more acres of land. Effective October 10, 1992, operators of large construction activities required NPDES permit coverage in Pennsylvania for such activities. In December 1999, EPA promulgated NPDES Phase II regulations that require permit coverage for small construction activities that disturb one to less than five acres, which result in a point source discharge to waters of the United States. Effective December 7, 2002, the Pennsylvania Department of Environmental Protection (DEP) integrated the federal Phase II NPDES requirements into the existing Pennsylvania Phase I NPDES permit for stormwater discharges associated with construction activities (NPDES Construction Permit). An important distinction between Phase I and II is that the small construction activities only require permit coverage when the activity disturbs one to less than five acres and will result in a point source discharge to surface waters of the Commonwealth" (Pennsylvania DEP, 2007).

The National Pollutant Discharge Elimination System (NPDES) Stormwater Program regulates stormwater discharges from three potential sources: municipal separate storm sewer systems (MS4s), construction activities, and industrial activities. Most stormwater discharges are considered point sources, and operators of these sources

may be required to receive an NPDES permit before they can discharge. This permitting mechanism is designed to prevent stormwater runoff from washing harmful pollutants into local surface waters such as streams, rivers, lakes or coastal waters.

The Pennsylvania Department of Environmental Protection (DEP) is responsible for administering the state's stormwater management program. Pennsylvania's stormwater program is closely modeled after the federal NPDES program, which requires stormwater be treated to the maximum extent practicable. Pennsylvania's NPDES stormwater program establishes permitting requirements for construction sites disturbing more than one acre, industrial sites, and MS4s. All MS4s should currently be permitted, or in the permit process. Each permitted MS4 will be responsible for establishing a Stormwater Management Program (SWMP).

There are currently no areas designated as MS4 communities in Elk County. However, future revisions of this Plan should take into account the possible urbanization and growth within the County and include any areas that have since been designated as an MS4.

The Phase II Rule defines a small MS4 stormwater management program as a program comprising six elements that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving water bodies (United States Environmental Protection Agency, Revised, 2005).

All municipalities that are required to implement the MS4 program are required to address the following six minimum control measures (MCM's):

- Public Education and Outreach
- Public Involvement/Participation
- Illicit Discharge Detection and Elimination
- Construction Site Stormwater Runoff Control
- Post-Construction Stormwater Management in New Development and Redevelopment
- Pollution Prevention/Good Housekeeping for Municipal Operations

C. Standards and Criteria

The purpose of the Act 167 and any stormwater management plan is to ensure the proper management of accelerated stormwater runoff and associated issues. The Plan is intended to provide information and guidance to Municipalities to manage stormwater in a manner that is consistent with proven, acceptable, and effective engineering practices and at all times will strive to protect the public welfare through the protection of environmental resources. This would include acceptable land-use management practices as well as additional measures that will conserve and protect existing water sources and all other surface waters of the Commonwealth.

The Plan is also intended to reduce destructive and potentially dangerous flow conditions caused by accelerated surface runoff (due to excessive development) by reducing overall peak flow rates and volumes and return existing stream capacities to a quantity more conducive to their size. The restoration of the flood capacity of such streams is of paramount importance to protecting existing natural features as well as protecting the public and property.

The provisions that shall be implemented concerning the recharging and infiltration of stormwater runoff will help to achieve the goal of returning streams to their natural flow conveyance capacities, but also to help recharge groundwater tables and aquifers that have been diminishing in recent years.

The easiest way to accomplish the goals of the Act 167 Plan is by the implementation of BMPs that will help to return the hydrological flow characteristics of a given watershed to a state comparable to its natural capacity and capabilities.

In order to achieve the desired results of the Act 167 Plan, the following five objectives should be implemented so that the watersheds can be properly conserved and protected:

1. Maintain groundwater recharge
2. Maintain or improve water quality
3. Reduce channel erosion
4. Manage overbank flood events
5. Manage extreme flood events

Refer to Figure V-1 for a schematic approach on how each of the five objectives can be accomplished and how their implementation can be achieved.

The standards were developed to take into account a number of land use and development activities. The standards provide the Municipalities with proven and common stormwater management methods and guidelines for their implementation.

The standards also incorporate information from the following tasks or assessments completed during both Phase 1 and Phase 2 activities:

Mapping of physical characteristics

- Mapping depicting the characteristics of soils, slopes, and vegetative cover have been included in this Plan. These areas were identified using existing spatial data. This information was then streamlined and used as specific impact parameters for the computer model used for analysis of the necessary watersheds. The results of these model analyses were then used to formulate rate release district maps as well as rate release values in these watersheds.

Obstruction Locations

- Mapping depicting the location of known structures and obstructions have been included in this Plan. These obstructions were identified by way of surveys sent to each municipality, through available spatial data, and through field visits. Based on the limited scope of the project and Plan, the identified obstructions have not been analyzed for capacity or potential impacts because of future development. This task will be addressed in more detail during the next planning cycle.

Land Development Patterns

- Extensive future growth is not anticipated in Elk County. A declining population combined with a lack of adequate expansion space for development shall most likely hinder future growth. Only areas in the outlying sections of St. Mary's, Ridgway, and Johnsonburg appear to have potential for future growth. However, these areas are surrounded by undevelopable areas (Federally owned forest) as well as unsuitable terrain. The close proximity of these three areas also will limit further development in the future as the required space for substantial growth is diminishing rapidly.

Flood Hazard Areas

- Based on the reduced scope of the project and Plan development and based on limited historical and future planning, a detailed review of such areas and their impacts on flooding or stormwater runoff has not been included in this Plan. Section III of this Plan identifies those areas that lie within floodplains and the specific land use of those areas. This task will be addressed in more detail during the next planning cycle.

Drainage problems and Solutions

- Mapping depicting the current known problem areas and their location within the county are included within the Plan, and is based on municipal and stakeholder surveys conducted during Phase 1. The means for

addressing these problems are addressed in various locations throughout the Plan and with a detailed description and breakdown of specific BMP measures that can be implemented in order to alleviate a specific problem area's impact on the watershed(s) in which it is located. The most common problems were identified and specific criteria for alleviating their impacts are included in this Plan.

Stormwater Collection and Conveyance Systems

- Based on the reduced scope of the project and Plan development and based on limited historical information pertaining to existing collection and conveyance systems, a detailed review of such systems and their impacts on flooding or stormwater runoff has not been included in this Plan. This task will be addressed in more detail during the next planning cycle.

Alternative Runoff Control Techniques

- Based on the reduced scope of the project and Plan development, specific criteria for identifying alternative runoff control techniques on a watershed-by-watershed basis has not been included in this Plan. These criteria should be considered for future revisions of the Plan. In lieu of prioritization of localized implementation criteria, the Plan shall be used in broader terms and currently contains information on addressing several factors that may or may not be present in each specific watershed. This task will be addressed in more detail during the next planning cycle.

Federal, State, and Local Flood Control Projects

- Eight (8) State and Federal flood control projects were identified within Elk County. These projects were identified from a variety of sources including DEP project lists, U.S. Army Corps of Engineers project information, and FEMA FIS documents and FIRMs. Since no flood control information was provided by the municipalities, the information below is considered as complete as possible based upon the data available for reference. Additional flood control projects should be added or modified within this Plan during the next planning cycle to better reflect County hydrology and efforts to mitigate the damages caused by excessive flooding. These projects and their approximate location or extents are identified below:
 - West Branch Clarion River - Levee in Johnsonburg, off Center Street
 - East Branch Clarion River
 - Dam, off Clarion Avenue
 - Dam, East Branch Clarion River Lake (USACE), East Branch Dam Road, Wilcox
 - Clarion River:
 - Dam, directly downstream of East/West Branch Clarion River confluence, Johnsonburg
 - Dam, directly off North Broad Street, Ridgway Borough
 - Laurel Run - Laurel Run Reservoir, off Old Kersey Road
 - Hoffman Run - Twin Lakes, off T-361
 - Big Mill Creek - Ridgway Reservoir, off T-606, Ridgway

Identification of Areas for Future Stormwater Collection and Conveyance Systems

- Growth in Elk County is slow and sporadic enough that the County and municipalities are primarily in a reactive mode regarding extension of stormwater collection and control facilities. Based on the reduced scope of the project and Plan development, specific criteria designating areas to be served by stormwater collection and control facilities have not been included. Consequently, estimates relating to the design capacity and cost of such facilities are not included in this planning cycle. The Model Stormwater Ordinance within this Plan, and required to be adopted by each municipality (in its simplest form) does contain

information and guidelines related to financing, construction and operation, and institutional arrangements to implement and operate the facilities. The information provided is intended as guidance information only. This task will be addressed in more detail during the next planning cycle.

Location of Flood Plains

- Mapping depicting the current FEMA flood plain and flood hazard areas and their location within the county are included within the Plan.

Criteria and Standards for Stormwater Control

- The Model Stormwater Ordinance contained within this Plan contains specific criteria and standards for the control of stormwater runoff from existing and new developments that are necessary to minimize dangers to property and life and carry out the purposes of the Plan. At its most basic structure, this Model Ordinance is required to be adopted by each municipality (more stringent measures can be enacted on a municipality-by-municipality basis).

Plan Implementation Priorities

- Based on the limited scope of the project and Plan development, specific criteria for implementation on a watershed-by-watershed basis have not been included in this Plan. Specific criteria were only developed for the Elk Creek watershed. All other watersheds identified in the Phase 1 Scope of Study were excluded from this planning cycle. These criteria should be considered for future revisions of the Plan. In lieu of prioritization of specific implementation factors, the Plan shall be used in broader terms and currently contains information on addressing several factors that may or may not be present in each specific watershed. This task will be addressed in more detail during the next planning cycle.

Act 167 requires that the Plan be reviewed and revised in five (5) year cycles in order to identify and address the relevance of the plan as well as addressing the following items that may not be included in the current Plan and are related to mitigation of future problems and consistency with other land use plans:

- This allows for the identification of new problems or areas within the watershed that require attention and potential strategies for alleviating them. Plan revision also allows for the implementation of newer and more efficient technical strategies and procedures for the management of stormwater runoff.
- This allows for the implementation of new regulatory practices and resolutions that may have been enacted at the local, State and Federal levels that influence the management and future management of stormwater runoff. This includes new regulatory guidance and land use plans that impact future development and stormwater runoff management methods and technology.

Detailed stormwater management measures and BMP information can be found in the Pennsylvania Stormwater Best Management Practices Manual, (Document #363-0300-002), prepared by the Pennsylvania Department of Environmental Protection (PADEP BMP Manual). Such information includes:

- | | |
|--|-------------------------------|
| • Selection Criteria | • Construction Specifications |
| • Sizing and Computational Information | • Applicability |
| • Maintenance | • Safety Procedures |

The PADEP BMP Manual is the key source for information concerning acceptable and applicable stormwater management BMP measures in Pennsylvania that will allow the designer to achieve conformance with NPDES Control Guideline 1 (CG-1) or Control Guideline 2 (CG-2.)

In addition, the PADEP shall, in consultation with the Pennsylvania Department of Community Affairs, review all watershed storm water plans and revisions or amendments thereto. The PADEP shall approve the plan if it determines:

- That the plan is consistent with municipal flood plain management plans, State programs which regulate dams, encroachments, and water obstructions, and State and Federal flood control programs; and
- That the plan is compatible with other watershed storm water plans for the basin in which the watershed is located, and is consistent with the policies and purposes of this act.

PennDOT and Pennsylvania Turnpike Commission Projects

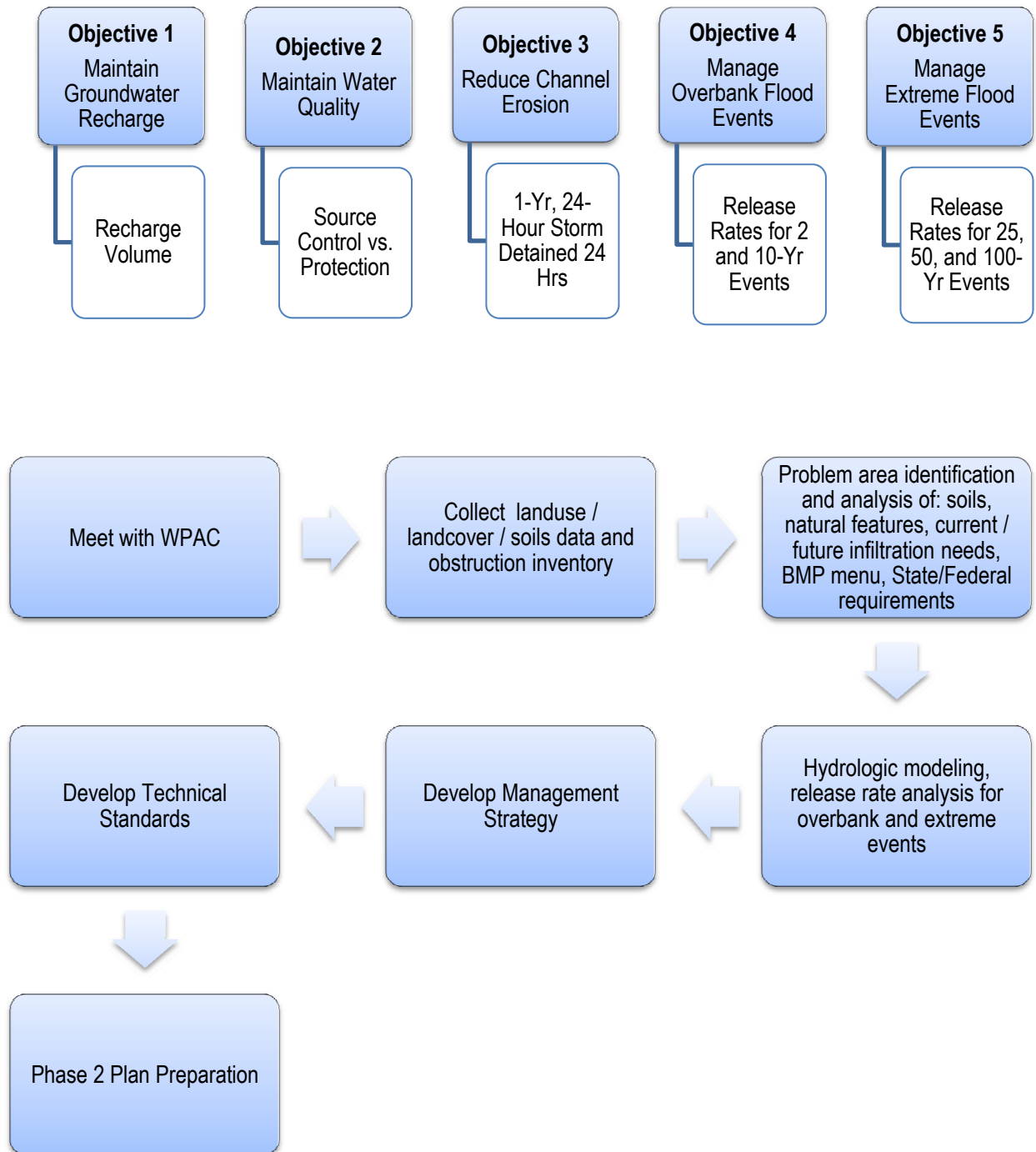
In addition to the information contained herein, for projects regulated by PennDOT or the Pennsylvania Turnpike Commission (PTC), the following shall govern their administration:

For purposes of Act 167 Stormwater Management Plans (Plans), design policy pertaining to stormwater management facilities for PennDOT and PTC roadways and associated facilities are provided in Sections 13.7 (Anti-degradation 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 PADEP. 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 Anti-degradation and Post Construction Stormwater Management) was developed as a cooperative effort between PennDOT and PADEP. 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.

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

Figure V-1
Five Comprehensive Management Objectives and Analysis Process



Objective 1 – Maintain Groundwater Recharge

Surface water reaches the ground surface and then sheet flows to adjacent streams or water bodies. A portion of this surface water returns to the atmosphere through evapotranspiration or sublimation. Yet another percentage of the water returns to the soil through infiltration and groundwater recharge. Typically, water infiltrates through the soil until it is transferred through the evapotranspiration process or it reaches the groundwater table and replenishes the local aquifer.

The movement of water through the sub-surface is complex, and less permeable soils, clay layers, and rock strata are often encountered, especially in areas in the central and western portions of Pennsylvania. This water moving through the soil is typically referred to as one of the following:

- Gravitational water or drainage water
- Capillary Water (water held in soil pores by surface attraction, sometimes called “capillary action”)
- Hygroscopic Water (water tightly held within soil particles and removable only through the physical drying process of the soil)

While capillary water does play a role in evaporation processes, gravitational/drainage water is the primary concern from a stormwater management perspective. Figure V-2 provides an illustrative representation of the water cycle process.

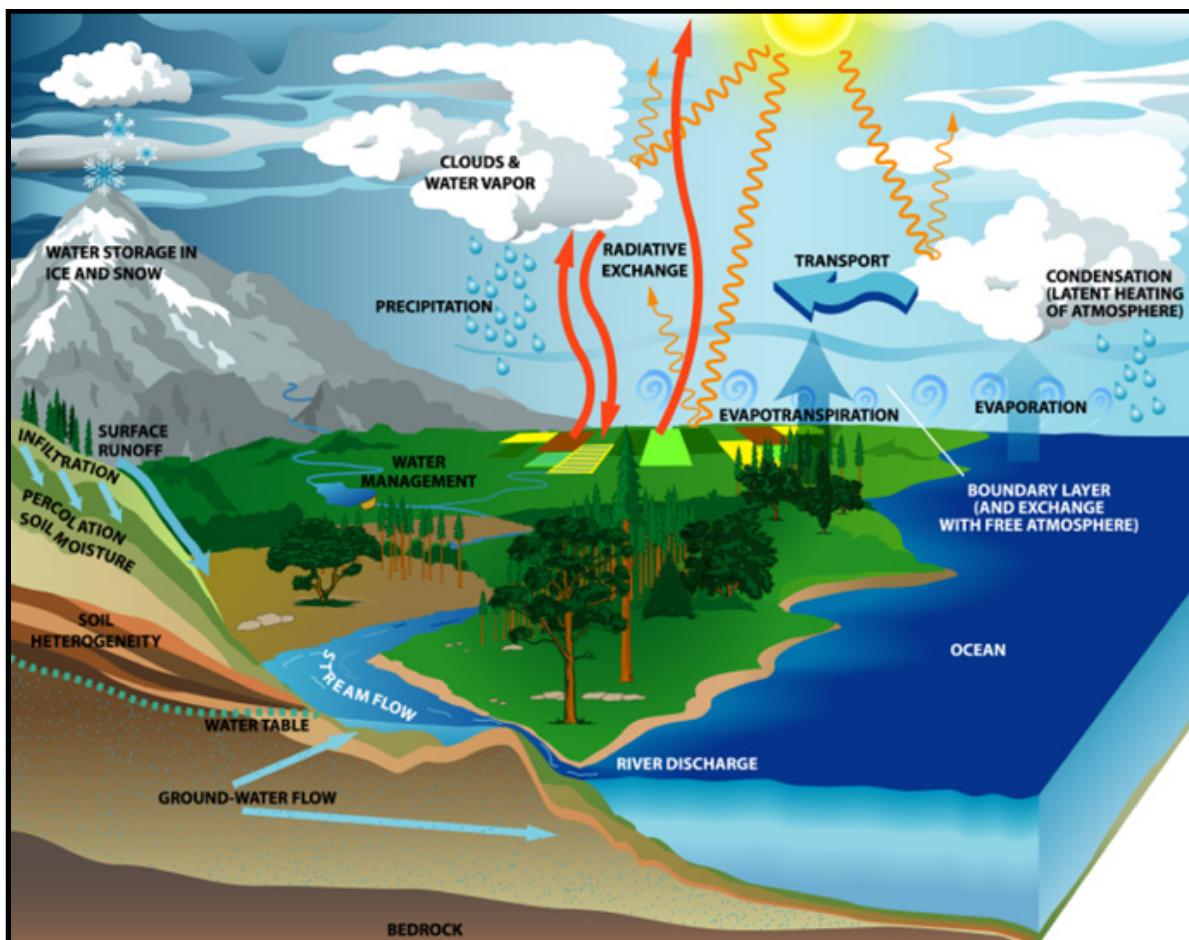


Figure V-2
(US Climate Change Science Program, 2003)

The process and ease by which gravitation water is transmitted through soil layers is based upon several factors. These factors include:

- Layering
- Structure
- Texture
- Presence of macropores (flow pathways within the soil)

The texture of a soil is based upon the ratio of sand, clay, and silt present in the soil. The permeability and hydraulic conductivity of a soil layer is significantly affected by the grain size of the soil layer. In general, these flow characteristics decrease as the grain size of the soil layer decreases. Gravitation or drainage water moves more easily through sand than it does through silty or clay-based soils. The texture of an individual soil layer also influences the shape of the wetting front as water travels through it due to the cohesive forces of both the water and the soil particles themselves.

One of the most critical components of understanding the methods and practice by which the designer will recharge the existing groundwater aquifer is by gaining an understanding of the specific soils on a project site and how their individual characteristics will influence the infiltration and absorption of excess stormwater runoff.

Maintaining groundwater recharge helps maintain watershed hydrology and is a method of meeting specific stormwater management regulations for volume control, peak-rate control, and even water quality.

There are many acceptable and practical methods for infiltrating water and thereby meeting the requirements for ground water recharge. The PADEP BMP Manual breaks BMPs down by the desired function of the designer as well as by structural or non-structural methods. Non-structural methods can be a cost effective means of addressing the infiltration/recharge issue, as well as the other necessary technical objectives when dealing with stormwater runoff. However, there are times when non-structural methods are not practical or cannot provide the necessary results from a quantitative standpoint. Some of the more common structural and non-structural BMP applications are listed in Table V-2.

Table V-2⁴
Recommended BMPs for Groundwater Recharge/Infiltration

Non-Structural BMPs	Structural BMPs
Protection of Sensitive Areas	Infiltration Basins and Trenches
Site Clustering	Subsurface Infiltration Beds
Minimize Soil Compaction	Drywells/Seepage Pits
Reduce Street/Parking Imperviousness	Constructed Filters
Minimize Total Disturbed Area	Rain Gardens
Rooftop Disconnection	Floodplain Restoration Practices

⁴ BMP methods are taken directly from the Pennsylvania DEP's, *Pennsylvania Stormwater Best Management Practices Manual*, and are intended for use in the most commonly encountered site conditions. Specialized BMPs should be used as necessary.

A comprehensive list of non-structural and structural BMPs and their applicability towards a specific technical objective can be found in Figures V-4 and V-5 at the end of this chapter.

The requirements pertaining to the proper and adequate design, sizing and application of stormwater BMPs shall be in strict accordance with local and Commonwealth regulations, as well as the design information contained in the PADEP BMP Manual. The PADEP BMP Manual provides comprehensive information concerning the applicability of specific BMPs as well as other necessary requirements concerning soil testing, case studies, available resources, design formulas, information pertaining to vegetative covers, and other necessary guidance materials. It should be noted however, that while the PADEP BMP Manual is the primary source for proper BMP design in Pennsylvania, it is intended to be used as a guide and should not discourage the experienced design professional from using additional BMPs or to curtail the innovative process and application of stormwater management methods that may not be listed in the current BMP Manual version. While the manual does contain specific guidelines and criteria that must be followed, it is not intended to be the sole source for stormwater management design. Additional and hybrid management methods will be considered by the proper regulatory agency on a case-by-case basis.

Another additional factor to consider during the implementation of recharge/infiltration BMP usage is the surrounding site conditions. Not all sites chosen for development will be sites that have been untouched and undisturbed for several years. There are also specific sites within the Commonwealth that have been identified for their special contribution to the waters of the Commonwealth or have been deemed environmentally sensitive areas. The PADEP BMP Manual refers to these specific types of sites as “special management areas.” The following list identifies some of the more commonly encountered special management areas:

- Karst Areas
- Brownfields
- Previously Mined Areas
- Surface and Well Water Supply Areas
- Highways and Roads
- Special Protection Watersheds (High-Quality and Exceptional Value Watersheds)

Special care and consideration must be taken when these types of sites are encountered. The presence of such sites does not necessarily prohibit the designer from using infiltration practices. However, specific guidelines and overall environmentally sensitive decisions should be exercised when these types of sites are encountered. These types of sites are extremely prevalent in western Pennsylvania, with the possible exception of karst areas, which tend to occur more often in central and southeastern Pennsylvania.

Karst Areas: Karst is the description given to areas underlain by substantial areas of carbonate bedrock (limestone and dolomite) that have been partially dissolved. The movement and shifting motion this specific type of strata over millions of years have caused fractures and faults to develop. These fractures have also undergone substantial chemical weathering by weakly acidic water. This has caused the bedrock to dissolve, leaving behind voids and severely weakened areas. These voids are a major contributor to such anomalies as sinkholes, caves, and surface depressions. These areas are also often related with significant variations in the depth to bedrock and groundwater tables, as well as streams that “disappear” into the subsurface. A decision concerning the use or non-use of infiltration in these areas is a critical one. While infiltration is recommended, it must be done only after careful consideration and selective decision-making has taken place. Extensive subsurface investigation is recommended in these areas and special care should be used when selecting the areas on the development in which to attempt infiltration. The presence of karst topography does not necessarily need to be a prohibitive factor in the decision to infiltrate. Source control (reducing surface runoff at the point it is created) is another important factor. Reducing the overall amount of runoff generated will greatly aid in the design required for the infiltration process.

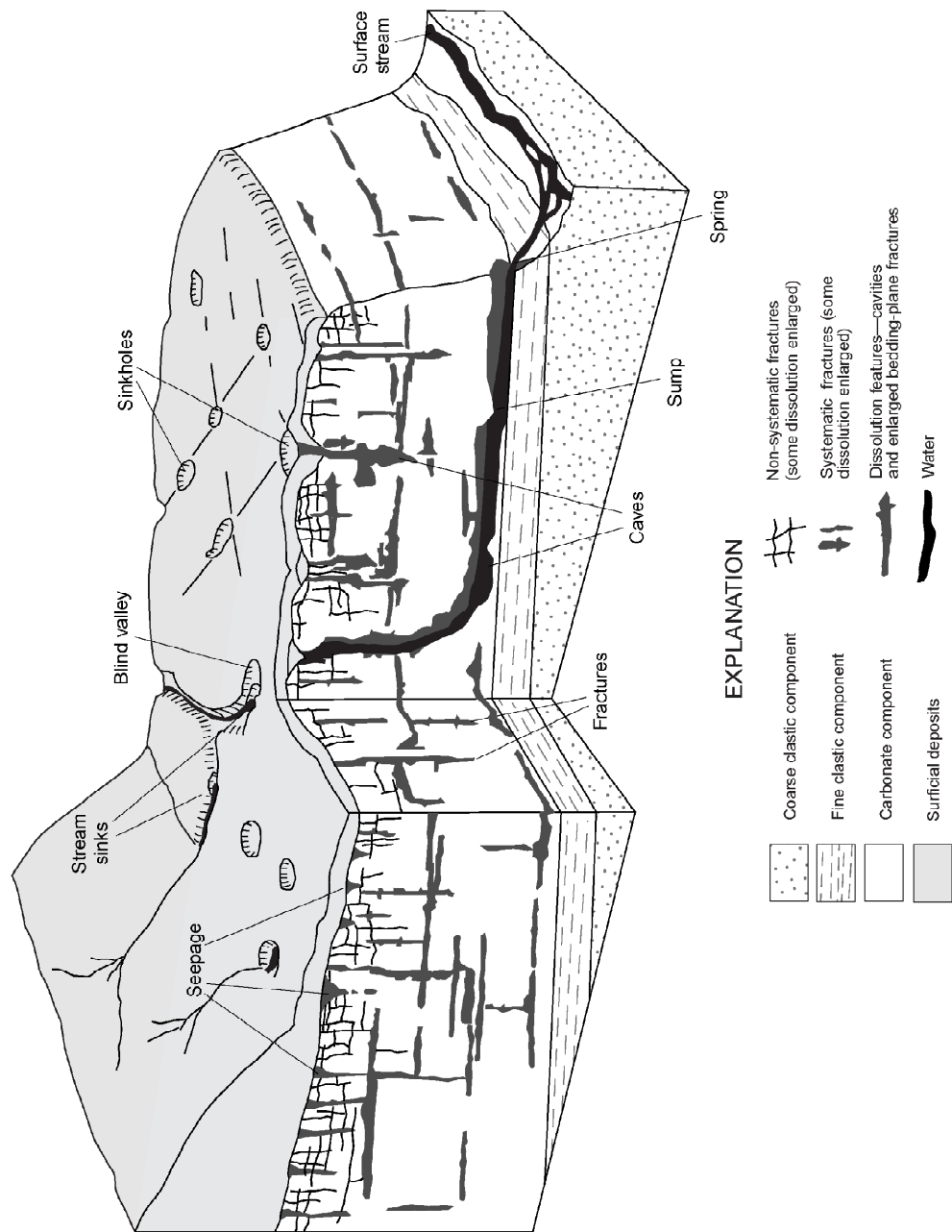


Figure V-3
(Lively, 1995)

The PADEP BMP Manual suggests some of the following BMPs for application in karst areas:

Table V-3⁵
Recommended BMPs for Karst Areas

Increased Storage	Increased Infiltration	Decreased Velocity	Pollution Control / Water Quality
Dry Detention Ponds	Runoff/Level Spreaders	Increased Vegetation Density	Filter Berms
Wet Retention with Lined Settling Ponds	Porous Pavement	Vegetated Swales	Gravel or Sand Filtration Systems
Shallow Detention Ponds	Improved Sinkholes / Class V Injection Wells ⁶	Terraced Slopes	Peat Moss or Activated Carbon Filtration Systems
Vegetated Roofs	Perforated Pipes	Rip Rap (preferably using carbonate rock, e.g. limestone)	Constructed Wetlands (Lined)
	Bioretention Cells/Rain Gardens		Increased Vegetation Density/Rain Gardens
			Compost

Brownfield Areas: Brownfields are areas within the Commonwealth where the potential presence of hazardous materials and pollutants could hinder future development. Applicable laws concerning the classification of brownfields should be consulted prior to beginning the process of any potential development work; however, brownfields can often be found in areas (though not limited to) that fall into the following categories:

- Abandoned steel mill facilities or sites
- Abandoned industrial facilities or sites
- Areas where petroleum or petroleum by-products were stored (e.g. fueling stations)
- Areas related to specific mining activities
- Abandoned commercial facilities or parking facilities

Areas such as these pose a threat to the environment by being contaminated with a number of possible pollutants.

However, while these areas are often considered blight on the community, they are prime locations for the use of smart-growth technologies. The redevelopment of these sites can help revitalize depressed areas, contribute to environmental clean up through mitigation of the hazardous materials, and serve the public interest by providing a mixed-use environment to help the community thrive.

⁵ BMP methods are taken directly from the Pennsylvania DEP's, *Pennsylvania Stormwater Best Management Practices Manual*.

⁶ Class V Injection wells are used to inject non-hazardous fluids underground. The more common types of injection wells include simplistic, gravity-based systems (e.g. stormwater drainage wells, cesspools, septic tanks) and more sophisticated systems such as aquifer storage/recovery wells and geothermal electric power wells. (United States Environmental Protection Agency, 2007)

When applying for any permits for a site deemed as a brownfields site, it is important to disclose the following information, as well as any other necessary or requested information, per the PADEP BMP Manual:

- Existing and previous land uses
- Potential pollutants, along with a summary of sampling data.
- Source and location of the potential pollutant(s) on the Erosion and Sediment Control (E&S) Plan drawings,
- A description of what measures are proposed to manage and control discharges of these pollutants to eliminate the potential for pollution to surface waters of the Commonwealth.

Table V-4⁷
Recommended BMPs for Brownfields

Soil Contact Areas	Non-Soil Contact Areas
Bio-Retention in areas where soil has been remediated or pollutants are NON-SOLUBLE in nature. Soils containing soluble pollutants should be filtered through the bio-retention areas and then allowed to exit via by-pass piping. Infiltration in these areas should not be permitted.	Stormwater Collection/Re-Use <ul style="list-style-type: none"> • Vegetated Roofs • Cisterns • Rain Barrels

Stormwater management options are available for use on brownfield sites where the contaminated soil has been completely removed from the site. These options include minimizing earth disturbance and soil compaction, minimizing impervious areas, maximizing stormwater infiltration (where applicable), and dispersing runoff to BMPs scattered across the site rather than concentrating runoff to just a few locations.

With the exception of structural stormwater infiltration BMPs, the stormwater management BMP measures listed in PADEP BMP Manual are also available for use on brownfield sites where potentially contaminated soil is isolated and sealed, or the contaminated soil was blended with clean soil. Since soil contaminants are still present at these sites, the use of structural stormwater infiltration BMPs should be used only if the residual soil contaminants are non-soluble pollutants.

Refer to the PADEP BMP Manual and supporting documentation for additional information on stormwater management, remediation, and environmental due diligence concerning the development of brownfield sites.

Highways and Roads: Highways and roadways within the Commonwealth have the potential to severely affect the hydrologic integrity of any watershed. The increase of impervious area (a near certainty in new roadway construction) results in excessive peak runoff rates and volumes. The other key issue concerning highway and roadway construction in relationship to stormwater management is that of water quality. The potential for heavy metals, de-icing salts and chemicals, petroleum pollutants, hazardous materials from vehicular spills, as well as thermal impacts during hot-weather months, can all contribute to de-graded water quality. The following table taken from the PADEP BMP Manual lists suggested BMPs available for roadway and highway applications:

⁷ BMP methods are taken directly from the Pennsylvania DEP's, *Pennsylvania Stormwater Best Management Practices Manual*, and are intended for use in the most commonly encountered site conditions. Specialized BMPs should be used as necessary.

Table V-5⁸

Recommended BMPs for Highway and Roadway Applications

Non-Structural BMPs	Structural BMPs
Reduced roadway/cartway widths (as applicable, and in accordance with all local and Federal regulations)	Vegetated Swales and Infiltration Trenches along contours perpendicular to the road and along the right-of-way
Reduction or elimination of curbs and gutters	Bioretention areas along the roadway
Reduction of stormwater collection/conveyance infrastructure (as applicable, and in accordance with all local and Federal regulations)	Bioretention and Bio-Infiltration in cul-de-sac areas
	Catch Basin Inserts and Treatment Devices

Mined Areas: Areas of proposed development that have been previously mined should be treated with special care. Areas that have been strip/ surface mined or are underlain by deep wall mining facilities are an extremely difficult location in which to apply stormwater BMPs. Acid mine drainage caused by previously (and presently) mined areas is one of the largest environmental problems in Pennsylvania. The infiltration and percolation of water through mined areas has resulted in thousands of miles of contaminated streams and waterways. Infiltration and groundwater recharge BMPs are prohibited in such areas, thus rendering most available structural BMPs unusable for development in these areas. There are only a few acceptable and practical structural BMP methods available for use in these areas. BMPs such as vegetated roofs and capture/re-use (e.g. rain barrels) methods are applicable. Limiting and prohibiting infiltration or percolation of stormwater runoff into previously mined sites is of the utmost importance.

The most reasonable solution for the management of runoff is through the re-direction of stormwater runoff from areas contaminated with mine wastes. If this is not entirely feasible then the use of lined BMPs should be considered to separate the runoff from the contaminated soils. Lined detention basins for rate mitigation are an option for storage. Volume reduction in these areas is specifically difficult to achieve. Rate mitigation and water quality should be the primary factors for the designer. The most important item to consider when proposing a plan for development is to provide for the protection and restoration of native vegetative cover to the greatest extent possible. Natural vegetative cover provides the best method of treating and restoring these soils back to their native conditions (Pennsylvania Department of Environmental Protection, 2006).

Groundwater Supply Areas: Any stormwater management practice in areas adjacent to ground water supply sources is of critical importance. It is estimated that approximately half of Pennsylvania's residents receive their drinking water from ground water supply sources (Pennsylvania Department of Environmental Protection, 2006)

In relationship to the protection of groundwater supplies, three (3) zones must be taken into consideration when proposing the use of infiltration practices for new development:

- Zone 1 – The innermost protective zone surrounding a well, spring, or existing infiltrative gallery. This zone ranges from 100 to 400 feet depending on the site-specific source and characteristics of the aquifer (Pennsylvania Department of Environmental Protection, 2006). Proposed infiltration BMPs should not be located in Zone 1 protection areas (Pennsylvania Department of Environmental Protection, 2006).

⁸ BMP methods are taken directly from the Pennsylvania DEP's, *Pennsylvania Stormwater Best Management Practices Manual*, and are intended for use in the most commonly encountered site conditions. Specialized BMPs should be used as necessary.

- Zone 2 – The capture zone that encompasses the area of the aquifer through which it supplies water to a well, spring, or existing infiltration gallery. This zone is determined to be a one-half mile radius around the source unless more extensive hydrogeological testing is done. Extreme care should be used when implementing infiltration BMPs in Zone 2 areas. Aquifers can become easily contaminated, and therefore extensive pretreatment measures should be used to filter and diminish pollutants (Pennsylvania Department of Environmental Protection, 2006).
- Zone 3 – The area beyond the capture zone and contributes significant recharge to the capture zone aquifer in Zone 2 (Pennsylvania Department of Environmental Protection, 2006).

A minimum distance of 50 feet should be used when placing infiltration BMPs adjacent to privately owned wells and water sources serving non-community supply systems (Pennsylvania Department of Environmental Protection, 2006).

As in nearly all instances, some of the best measures available for adequately managing stormwater runoff are to eliminate or reduce the amount of runoff at its source of generation. This can be done by reducing impervious areas or through the capture and re-use of stormwater runoff. Another recommended practice is the scattering of stormwater BMPs across the entire development site. The measure of dispersing stormwater runoff more evenly helps to maintain the hydrological balance within the watershed and helps to prevent the concentration of runoff quantities and pollutants at only a few points within the watershed. The pre-treatment of stormwater runoff prior to dispersing it can make water quality mitigation much easier and more effective.

Table V-6⁹

Recommended BMPs for Areas Adjacent to Ground Water Supply Areas

Non-Infiltrative BMPs
Reduce Parking Imperviousness
Rooftop Disconnection
Vegetated Roof
Rain Gardens/Bioretenion
Capture and Re-Use
Wet Ponds
De-icing alternatives consisting of sand or other inert materials

Surface Water Supply Areas and Special Protection Watersheds: Stormwater management practice in areas adjacent to surface water supply sources and special protection watersheds (exceptional value, EV and high quality, HQ, as determined by the PA DEP) is of critical importance. The PA DEP anti-degradation requirements can be met in these watersheds by infiltrating a volume in the post-development conditions that is equal or greater than that of the pre-development infiltration volume. Another component of this requirement is that the post-development runoff is pre-treated and managed so that it will not degrade the physical, chemical, or biological characteristics of the receiving water body (Pennsylvania Department of Environmental Protection, 2006).

The project should be designed and constructed in a manner that will minimize the amount of impervious area. Any post-development runoff that is generated should then be infiltrated to the maximum extent possible. Water quality BMPs should be implemented across the site for adequate treatment but also to help in spreading the water across

⁹ BMP methods are taken directly from the Pennsylvania DEP's, *Pennsylvania Stormwater Best Management Practices Manual*, and are intended for use in the most commonly encountered site conditions. Specialized BMPs should be used as necessary.

the watershed and not concentrating it at only a few points. The last component is that the final volume and rate of any stormwater discharge must be properly managed to prevent the physical degradation of the receiving waterway, including scour and stream bank stabilization. Appropriate BMPs for pre-treatment and for addressing water quality issues can be found in Table V-7.

While infiltration is a key factor in stormwater management in areas adjacent to surface water supply areas and special protection watersheds, care must be taken during the design process. Any proposed infiltration BMPs within two miles on either side of surface water supply areas or special protection waters must be designed and constructed to provide maximum pollutant removal prior to the runoff being infiltrated or discharged to the receiving stream.

The proximity of infiltration areas and adjacent surface water areas and special protection waters should follow the following guidelines:

- Zone A – Represents a 1/4 mile buffer on either side of the river or stream extending from the area 1/4 mile downstream of the intake upstream to the five hour time-of-travel (TOT) (Pennsylvania Department of Environmental Protection, 2006).
- Zone B – Represents a two-mile buffer on either side of the water body extending from the area 1/4 mile downstream of the intake upstream to the 25 hour TOT. (Pennsylvania Department of Environmental Protection, 2006).
- Zone C – The remainder of the watershed area (Pennsylvania Department of Environmental Protection, 2006).

Objective 2 - Water Quality

Maintained landscape areas and impervious surfaces (e.g. roadways, parking lots, common pedestrian areas, etc.) collect pollutants that are carried in solidified form, or are dissolved and transported via runoff to the surface waters of the Commonwealth. Pollutants such as nitrates, phosphorus, suspended solids, oils, and petroleum by-products can be transported to, and cause the pollution of nearby streams and lakes.

It has been shown in many studies that these pollutants display their heaviest concentrations at the start of a runoff event, often referred to as the “first flush.” Many particulates such as suspended solids, trash/litter, heavy metals, organic particles and clay particles can often be observed in a water body prior to the occurrence on the peak runoff.

Areas where accelerated pollutants are generated in are often referred to as pollutant “hot spots.” These hot spots often occur at the following locations:

- Fueling Stations
- Parking Lots
- Dumpsters and Trash Disposal Areas
- Industrial Sites
- Areas Prone to Heavy Travel and Traffic

While these areas appear obvious as potential sources of pollution, the notion that pervious areas do not generate pollution is a large misconception. Maintained lawns, landscaped areas, gardens, and other “natural” areas can cause pollution due to the use of chemicals and fertilizers. An undisturbed, pervious area can often possess the ability to treat and remove pollutants from direct runoff. However, the previously mentioned areas are often constructed upon heavily compacted soils that do not allow any natural infiltration or surface filtration of potentially polluted runoff. In essence, these heavily compacted areas can often take on the physical characteristics of impervious (e.g. paved, concrete, rooftops, etc.) areas.

The proper approach to managing stormwater quality is a two-phased method. The first phase is control of point source of pollutants, and the second phase is protecting, restoring, and creating the natural systems that are able to capture and remove these pollutants from direct stormwater runoff.

Stormwater quality and quantity are inherently linked. Their singular management can become a simultaneous endeavor, even in situations where this is not the designer's initial intent. This is related to the fact that many stormwater *quantity* BMPs, by the nature and physical process of how they function, actual serve as effective stormwater *quality* BMPs as well.

The two most common types of pollutants found in stormwater runoff are solutes (dissolved particles) or particulates (particles still in solidified form). An example of these two types of pollutants can be found by examining two common fertilizers, phosphorous (often referred to as total phosphorus or TP) and nitrate (NO₃). Stormwater BMPs that rely on filtration or delayed detention are highly effective at the removal of total phosphorous because the pollutant typically remains in particulate form and will bond to colloidal soil particles. This keeps the particulates larger in size, making them more easily captured.

Nitrates on the other hand, tend to be found in soluble form and are not impacted by structural BMPs that rely on filtration or capture of suspended solids. Therefore, it is imperative to consider exactly what types of pollutants are to be targeted.

As with many BMP applications, when compared with their intended use, the use of a cost-benefit analysis can often be a useful tool in determining the most effective means of implementing a BMP treatment design. While it may seem elementary in nature, one additional method of treating pollutants is to curtail the generation of them at the source. The selection of vegetative cover that requires little to no treatment or fertilization, emergency spill management plans, oil/grease separation devices, and any other means that either eliminates/decreases the potential for pollutants, or greatly aids in their immediate capture prior to being introduced to stormwater runoff is a very effective means of treating potential pollutants.

The PADEP BMP Manual offers many non-structural and structural solutions for treating pollutants in stormwater runoff that will help the designer meet the requirements of the technical objectives for water quality. Table V-7 lists some of the more common and recommended BMPs for water quality.

Table V-7¹⁰
Recommended BMPs for Water Quality Treatment

Non-Structural BMPs	Structural BMPs
Protect Sensitive and Special Value Areas	Landscape Restoration
Protect/Conserve/Enhance Riparian Areas	Constructed Wetlands
Cluster Uses at Each Site; Build on Smallest Area Possible	Vegetated Filter Strips
Concentrate Uses Area Wide Through Smart Growth Practices	Constructed Filters
Minimize Soil Compaction in Disturbed Areas	Infiltration Trenches/Infiltration Basins
Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species	Subsurface Infiltration Beds

¹⁰ BMP methods are taken directly from the Pennsylvania DEP's, *Pennsylvania Stormwater Best Management Practices Manual*, and are intended for use in the most commonly encountered site conditions. Specialized BMPs should be used as necessary.

A comprehensive list of non-structural and structural BMPs and their applicability towards a specific technical objective can be found in Figures V-4 and V-5 at the end of this chapter.

Another area of particular concern in regards to water quality is that of impaired waters and total maximum daily/pollutant loadings (TMDLs).

Using the watershed approach requires selection or definition of watershed size, and begins with a comprehensive assessment of water quality problems in the watershed. Pennsylvania has already begun this effort with its Un-assessed Waters Initiative, which will assess over 83,000 miles of surface waters. After water quality problems are identified, a planning process occurs to develop strategies that can successfully address and correct water pollution problems in the watershed. Pennsylvania is using this process, in conjunction with federal Clean Water Act requirements, for establishing TMDLs to clean up polluted streams so that they meet water quality standards. Water quality standards are the combination of water uses, such as water supply, recreation and aquatic life, to be protected and the water quality criteria necessary to protect them.

TMDLs must be developed for several categories¹¹:

- Point sources (permitted sewage and industrial discharges)

Point source TMDL development is very similar to developing water quality-based effluent limitations for water discharge permits. The TMDL is developed to meet water quality standards for the critical period during the summer, when streams are at low flow and the effluent makes up a greater percentage of the water. This method assures that under less severe conditions, water quality will also be protected. DEP has carried out this same type of analysis using several well-established modeling tools for many years under the National Pollutant Discharge Elimination System (NPDES) program. Under this program, DEP calculates limits on the amount of pollutants that sewage and industrial facilities may discharge and still protect water quality. New tools were not needed for these types of TMDLs and most have been completed. By regulation, the TMDLs are implemented through DEP's issuance and enforcement of permits.

- Nonpoint sources (agriculture and urban runoff)

Nonpoint sources are not subject to the same regulatory requirements as point sources. Furthermore, the critical period for nonpoint or runoff sources is not during low flow conditions, but when rainfall washes pollutants across the land and into the streams. For these reasons, the tools that determine TMDLs for point sources do not work for nonpoint sources. DEP has developed a reference watershed approach to develop nonpoint source TMDLs. This method compares an unimpaired watershed of similar size, geology and land use distribution to the impaired watershed. Geographic Information Systems (GIS) technology is employed in the characterization of land use, background pollutant concentrations in soil and groundwater and other physical and chemical properties of each watershed. Computer simulation models are then used to estimate the loading rates in each watershed and to determine the load reductions of pollutants needed to correct the impairment. A load allocation is assigned to each contributing source, and those sources identified as the causes of impairment are given prescribed reductions. The TMDL sets the stage for citizens to define a plan to correct the impairments. DEP will support their efforts to develop the plan and, through Growing Greener grants, will provide funds to put practices in place to correct the problems. For nonpoint source TMDLs, the input of local citizens replaces the regulated implementation procedures for point source TMDLs.

¹¹ Per PA DEP Document 3800-FS-DEP2248

- Lakes

Lakes have characteristics that differentiate TMDLs from other waters. Lakes are not free flowing like streams, but are contained waters that trap pollutants for long periods. Most lake impairments are from high nutrient or sediment loads. Wherever possible, lake TMDLs are developed with the information in the lake study reports that were sponsored by local watershed groups or other local interests. Target acceptable pollutant loads are set at the level of a watershed largely unaffected by human induced impacts. Load allocations are given to the pollutant sources using the same methods as nonpoint source TMDLs. Other indicators of water quality are also considered in the evaluation of a lake. One indicator is the Tropic Status Index (TSI), which refers to the degree of nutrient enrichment in the lake. Nutrient enrichment causes growths of algae that consume oxygen and interfere with the health of the aquatic organisms in the lake. The TSI is affected by factors such as lake volume, water residence time and nutrient loads to the lake. After target loads are set, the TSI is evaluated under reduced nutrient load conditions to assure that the pollutant reductions will bring the TSI into an acceptable range. Implementation of lake TMDLs is best accomplished through local participation.

- Abandoned mine drainage (also called acid mine drainage or AMD)

AMD from abandoned surface and underground coalmines is a leading source of impairment to Pennsylvania waters. AMD can seriously degrade the aquatic habitat and the quality of water supplies because of toxicity, corrosion, incrustation and other effects from dissolved constituents. The TMDL analysis of AMD streams uses a statistical method of determining the in-stream allowable loading rate at the point of interest in the stream. Discharges that are permitted or have a responsible party are point sources, and make up the waste load allocation portion of the TMDL. Nonpoint sources are all other sources and constitute the load allocation. AMD impaired watersheds are evaluated for aluminum, iron, manganese and pH using statistics and Monte Carlo (probability) simulations to model existing conditions, to determine required reductions and to calculate allowable concentrations. When the reductions are met, the water quality standards will be met.

- Specific bio-accumulative chemicals (PCBs and chlordane that contaminate fish, resulting in fish advisories limiting or banning the number of fish that a person can safely consume)

The overall goal of a PCB/chlordane TMDL is to achieve the fishable/swimmable goal of the Clean Water Act. Fish consumption advisories are issued when fish samples exceed certain triggers. For PCBs, the advisory is based on protection of human consumers from neurological effects. A Federal Drug Administration (FDA) action level determines when an advisory for chlordane is issued. Advisories cause the water to be listed as impaired and make TMDLs necessary. The method used for PCB/chlordane TMDLs is to translate the fish tissue concentration into a water column concentration by using a bio-concentration factor. Bio-concentration factors are mathematical expressions that account for fish accumulating the pollutants in their bodies. Accumulation is based on pollutants in the sediment being ingested by small organisms, which are then consumed by larger organisms, small fish and larger fish, each time magnifying the amount of pollutant that is introduced into tissue of the consumer. The TMDL defines how much the loading of pollutant must decrease in order to meet the water quality standard. Meeting the water quality standard in the water means the fish living in the water will be acceptable to consume.

- Complex situations (combinations of different types)

Complex TMDLs draw on the procedures for all the TMDL types previously discussed.

A list of TMDLs currently identified in Elk County by major watershed, along with pertinent information is listed below¹²:

Table V-8
County TMDLs by Major Watershed

Watershed	Information	Status
Bennett Branch Sinnemahoning Creek	County: Elk, Clearfield, Cameron Category: AMD Cause: Metals, pH HUC: 2050202	EPA Approved 4/8/2009
Daguscahonda Run Watershed	County: Elk Category: AMD Cause: Metals, pH HUC: 5010005	EPA Approved 4/8/2005
Dents Run Watershed	County: Elk, Cameron Category: AMD Cause: Metals, pH HUC: 2050202	EPA Approved 4/4/2005
Elk Creek	County: Elk Category: AMD Cause: Other Inorganics, Metals, pH HUC: 5010007	EPA Approved 4/1/2005
Elk Creek TMDL (Elk County)	County: Elk Category: AMD Cause: Cause Unknown, Metals HUC: 5010005	EPA Approved 6/20/2006
Iron Run Watershed	County: Elk Category: AMD Cause: Metals, pH HUC: 2050202, 5010005	EPA Approved 4/4/2005
Little Toby Creek	County: Elk, Clearfield, Jefferson Category: AMD Cause: Metals, pH, Siltation, Suspended Solids HUC: 5010005	EPA Approved 6/9/2009
Spring Run (Elk)	County: Elk Category: AMD Cause: Metals, pH HUC: 2050202	EPA Approved 3/27/2007

¹² PA DEP TMDL Website http://www.dep.state.pa.us/watermanagement_apps/tmdl/default.aspx, more detailed information pertaining to these TMDLs and their physical properties, including locations and quantities can be found on the website

Table V-8
County TMDLs by Major Watershed

Watershed	Information	Status
UNT Trout Run TMDL	County: Elk Category: AMD Cause: Metals, pH HUC: 2050202	EPA Approved 4/4/2005
West Creek	County: Elk Category: AMD Cause: Metals, pH HUC: 2050202	EPA Approved 3/27/2007

Refer to Table III-4 in Section III for a County summary of non-attaining segments of the Streams Integrated List representing stream assessments for the Clean Water Act Section 305(b) reporting and Section 303(d) listing.¹³ PA DEP protects four (4) stream water uses: aquatic life, fish consumption, potable water supply, and recreation. If a stream segment is not attaining any one of its four uses, it is considered impaired.

Objective 3 – Reduce Channel Erosion

Several areas of stream bank erosion were found within Elk County and the associated watersheds during the stakeholder surveys and site visits. As storm flows increase, the corresponding flow velocities in streams also increase, thus exacerbating stream bank erosion problems. Typical stream bank capacities are equivalent to approximately the 1 ½-year storm, and stream banks begin to erode when flows approximate this depth. Therefore, stream flows kept to near the one-year storm flow would minimize stream bank erosion. Detaining the 2-year postdevelopment storm to the one-year predevelopment storm and detaining the 1-year storm a minimum of 24 hours would therefore minimize the number of storms causing stream bank erosion. However, the County does not intend to implement this approach during this planning cycle. Instead, the County will assess the effect of implementing the proposed model ordinance countywide and evaluate whether this approach should be reconsidered during the next planning cycle.

The PADEP BMP Manual's approach to mitigating the 2-yr, 24-hour stormwater runoff volume also greatly assists in achieving this Objective. The on-site retention (through infiltration, re-use, etc.) of this runoff volume interrupts site-specific stormwater runoff events and delays the arrival of any site-specific hydrographs to the watershed's point of interest (POI). The continuous delay of water contribution to a watershed's conveyance stream will greatly decrease the volume of water that the stream must convey at any one time (and flow velocity as well). This delay allows less water to be conveyed over a longer period. This not only helps restore the benefits of the natural water cycle, but also aids in the reduction of stream channel erosion.

¹³ PA DEP Office of Water Management, Bureau of Water Supply & Wastewater Management, Water Quality Assessment and Standards Division, 2010

Table V-9¹⁴

Recommended BMPs for Preventing Stream bank Erosion
(Tennessee Department of Environment and Conservation)

Vegetative BMPs	Structural BMPs
Stream Buffers	Infiltrative Practices to Reduce Overall Volume
Erosion Control Blankets and Netting	Detention/Retention to Delay Time to Peak of Peak Flows
Select Vegetative Covering	Sediment Filtering Devices (silt fence, interceptor devices, sediment basins, constructed wetlands, slope drains, etc.)
Disturbed Area Stabilization (e.g. mulch, sod, etc.)	Check Dams (to reduce flow velocities)
Spray Polymers and Other Binding Agents (for use in areas with very fine soil particles)	Protective Channel Linings (e.g. geotextiles, gabion baskets, rip rap linings, etc.)

Objective 4 – Manage Overbank Flood Events

Overbank and localized flooding events are a common problem in Elk County. Overbank events have the potential to damage conveyance structures and property downstream from the overbank event location. Overbank events are often caused by new development and the subsequent discharge of additional stormwater runoff to adjacent streams that do not have the capacity to convey the flows without exceeding the defined bed and bank of the stream.

The typical stream usually has the capacity to convey storm events up to the 2-year storm. The 2-year event is therefore generally assumed the point where a stream reaches its “bank full” capacity. This is the point where the stream is flowing completely full and is about to spill overbank and encroach into the adjacent flood plain.

An overbank event is typically considered a flooding event that occurs due to a rainfall between the 2-year and 10-year storm events (Center for Watershed Protection, 2000). Anything beyond the 10-year event usually floods to a much greater extent, commonly referred to as an “extreme event,” which will be discussed under the next Objective.

The typical method for preventing overbank events is to properly manage runoff from the 2-year through 10-year storm events. This is most effectively done by not increasing the peak discharge of these storm events from the pre-development to post-development scenarios. Peak rate and volume mitigation of these storm events is a crucial factor in managing and preventing overbank events. In areas where there is a history of excessive overbank event occurrences, additional mitigation might be necessary to address the problem at a watershed level basis.

Managing stormwater to a degree where it is quantitatively equal from the pre-development and post-development conditions may not be adequate. Additional control measures using the “release rate” concept may be required in certain watersheds. The release rate concept will be discussed in more detail later in this Section.

While overbank events can have a detrimental impact on downstream property and structures, they also provide a beneficial effect to the ecosystem within the floodplain. The deposition of suspended sediments can help replenish topsoil to agricultural lands as well as raising the elevation adjacent to streams, which can help prevent further erosion over time. Overbank events that occur in typically rural and non-inhabited areas are often a benefit to the local ecosystem and are generally not considered for extensive mitigation measures.

¹⁴ BMP methods are suggested based upon research and real-world performance, and are intended for use in the most commonly encountered site conditions. Specialized BMPs should be used as necessary.

Objective 5 – Manage Extreme Flood Events

Extreme events are similar to overbank events in that they represent a flooding event caused by the lack of capacity in the conveying stream. However, these extreme events go beyond those of the previously discussed overbank events in their ability to cause damage.

Storm events in excess of the 10-year event have the greatest potential for causing extreme events. The most common storms (based on common modeling practices) that can lead to extreme events are the 25, 50, and 100-year storm events.

It is virtually impossible to eliminate all occurrences of overbank and extreme flooding events. However, it is prudent to control the frequency at which these events occur. The goal is to achieve a balance between the recurrence interval of overbank and extreme events. This balancing point or benchmark is created so that upstream development can occur and yet not create a situation where downstream events occur on a more frequent basis and have more damaging effects.

D. Release Rate Stormwater Management District Concept (For Overbank and Extreme Events)

Throughout the Commonwealth, many of the previously created Act 167 plans implemented a “release rate” approach to stormwater management. The release rate concept is simply a way of managing post-development runoff rates by pre-determining a release rate (as a percentage value of the pre-development peak runoff rates) that is applicable to a specific watershed or portion of a watershed. In fact, the previous Elk Creek Watershed Act 167 Plan developed release rate districts for the watershed.

This release rate value is created to limit the amount of water being discharged from a smaller, sub-watershed area into a larger watershed area downstream. This is typically done in areas where problems already exist and flooding events are more common. Release rates are a way of over-detaining stormwater runoff to help alleviate downstream capacity problems.

A release rate is calculated by analyzing the peak rate of runoff for an overall watershed area, as well as the time at which this flow peaks. This time is then applied to each individual sub-watershed area. The rate of runoff from each individual sub-watershed area (at the overall watershed’s peak time) is documented. The runoff rate from the overall watershed is then divided by the runoff rate from the sub-watershed’s runoff rate (at the peak time of the overall watershed). If the peak runoff rate for the overall watershed is greater than that of the individual sub-watershed, a value that is greater than or equal to 1.0 is achieved. This indicates that no additional rate release constraints need to be applied to the sub-watershed area. However, if the overall watershed’s peak rate of runoff is less than that of any sub-watershed’s peak runoff (at the time to peak of the overall watershed), then a decimal value is achieved (Paul A. DeBarry, 2004)

Release Rate Calculation Example:

In a fictitious watershed consisting of two sub watersheds comprising one overall watershed, the pre-development runoff rates are shown in Figure V-4:

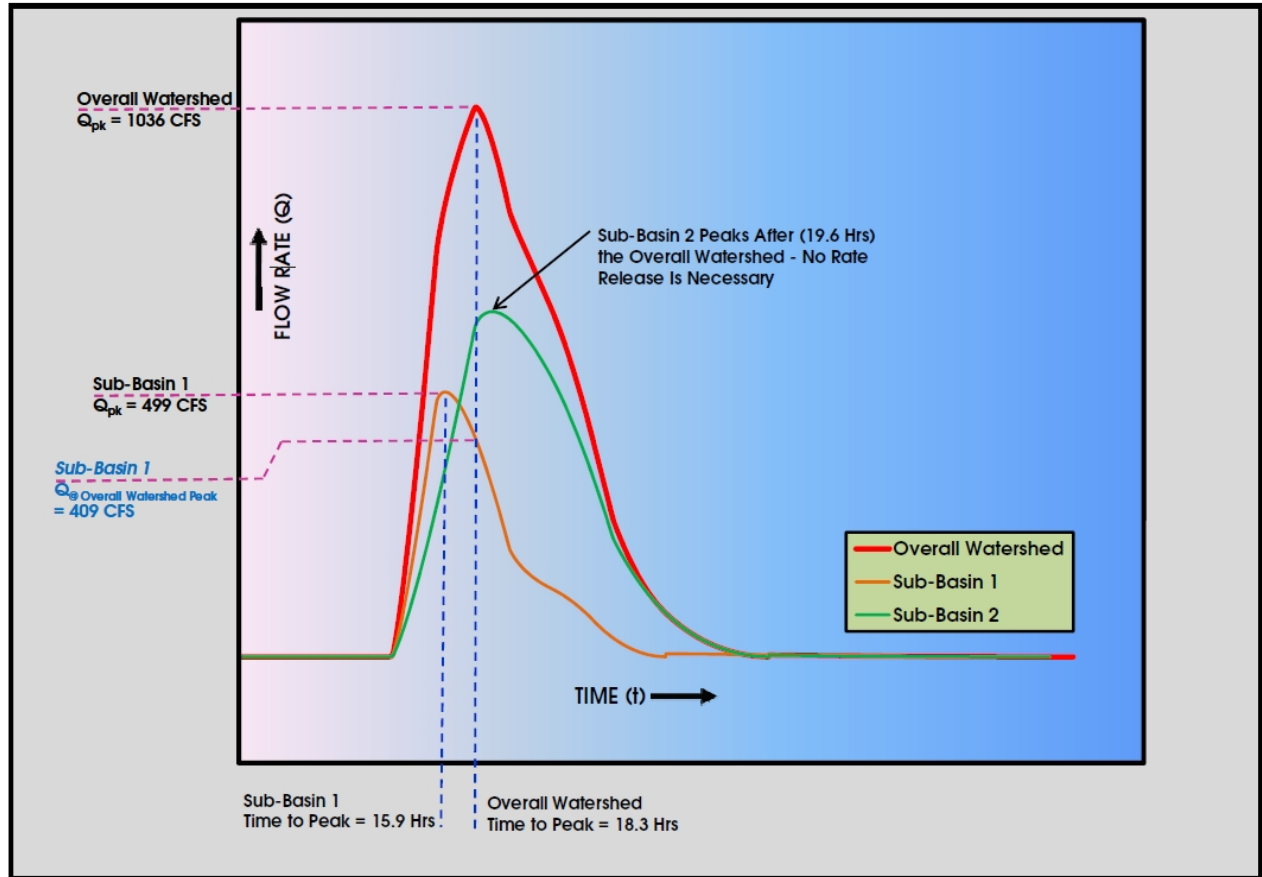


Figure V-4

The pre-development runoff rate of Sub-Basin 1 is 499 CFS and this watershed peaks at 15.9 hours. The pre-development runoff rate of Sub-Basin 2 is 650 CFS and this watershed peaks at 19.6 hours. The pre-development runoff rate of the overall watershed (Sub-Basin 1 and Sub-Basin 2 combined) is 1036 CFS and this watershed peaks at 18.3 hours.

Based upon the fact that Sub-Basin 1 peaks prior to the overall watershed, Sub-Basin 1 contributes a flow of 409 CFS at the time of peak of the overall watershed.

In the rate release method, only sub-watersheds that peak prior to the overall watershed are taken into account. Therefore, Sub-Basin 2 does not require any release controls.

Development within Sub-Basin 1 later occurs which results in an overall increase of runoff from Sub-Basin 1. The flow increases from 499 CFS to 713 CFS. Traditionally, the design of a detention structure would be implemented to control the peak rate of runoff from the developed watershed to ensure that the post-development rate is equal to or less than that of the pre-development conditions. The results of the impacts of the new detention basin that will control flow and limit post-development runoff to 499 CFS (the pre-development flow rate) are shown in Figure V-5.

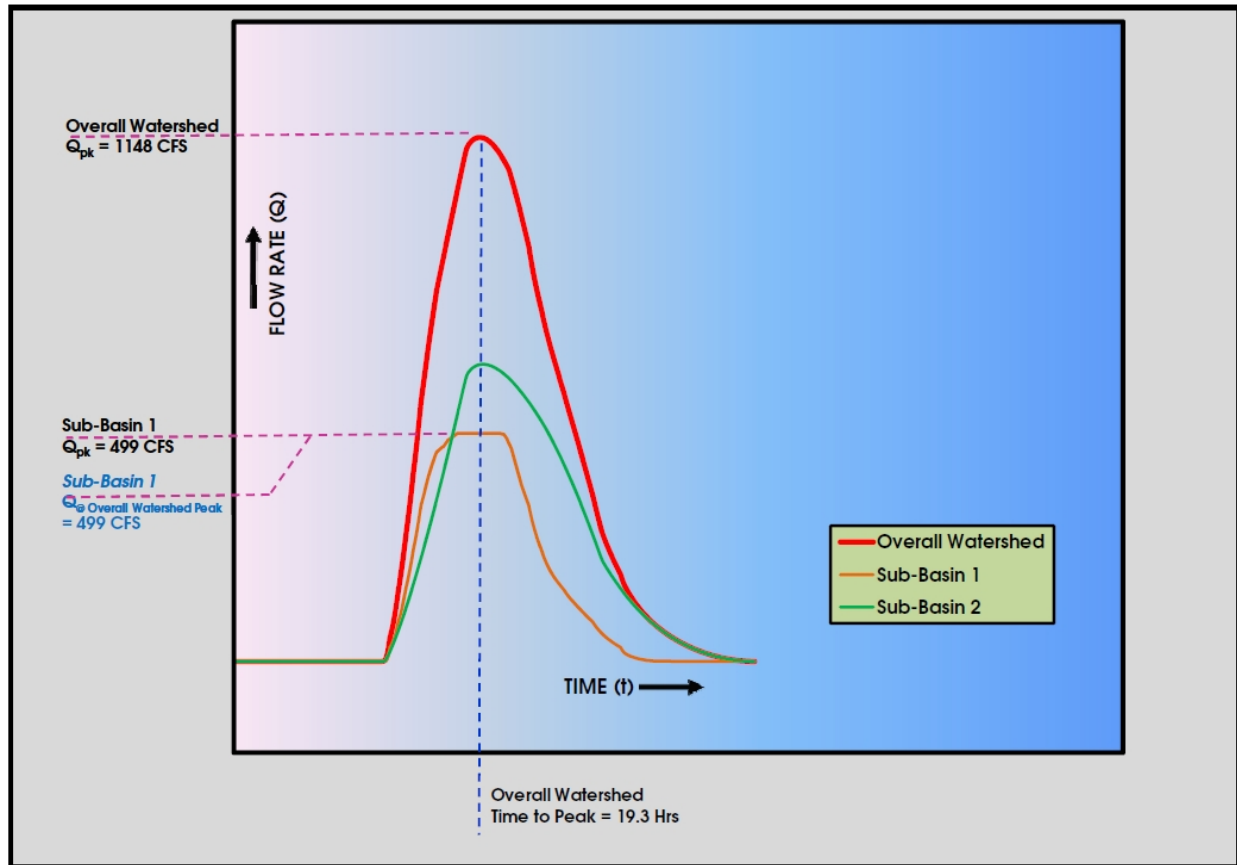


Figure V-5

As shown in Figure V-5, the pre-developed flow rate of 499 CFS from Sub-Basin 1 has been maintained. However, the amount of flow that Sub-Basin 1 contributes to the overall watershed, at the overall watershed's time to peak, has increased by 90 CFS. This is a result of the new detention structure in Sub-Basin 1 releasing a higher volume of water, at a slower rate and over a longer period. While the flow discharging from Sub-Basin 1 is equal between the pre and post-developed conditions, the overall watershed's discharge rate has increased 112 CFS.

Therefore, instead of simply controlling the rate of release of Sub-Basin 1 as a singular entity, it must be analyzed in a more comprehensive manner, as part of the overall watershed.

Taking into account the pre-development runoff rate of Sub-Basin 1 at the time the Sub-Basin peaks (499 CFS) and the amount of runoff from Sub-Basin 1 at the time the overall watershed peaks (409 CFS), this creates the need for rate release control.

The calculation is done by dividing the amount of pre-development runoff from Sub-Basin 1 at the time the overall watershed peaks (in this case 409 CFS) and the peak rate of runoff from Sub-Basin 1. Keeping in mind only sub-basins that peak prior to the overall watershed peaks require rate controls.

Therefore: $409 \text{ CFS} / 499 \text{ CFS} = 81.9\%$

In order to simplify the release rate districts or zones, the calculated release rates can be rounded slightly. In this case, 81.9% will be rounded to **80%**. This is now the allowable release rate for Sub-Basin 1. Any

development that will result in a net increase of runoff from the pre-developed condition to the post-developed condition will require an additional 80% beyond the pre-development peak runoff rate.

A sample development in this example Sub-basin 1 may have a development condition peak flow of 100 CFS. Using the calculated release rate, then the final post-development site can only release a peak flow of 80% of 100 CFS, or 80 CFS.

Looking at the original example, when the 80% release rate is applied to Sub-Basin 1, the following results are achieved:

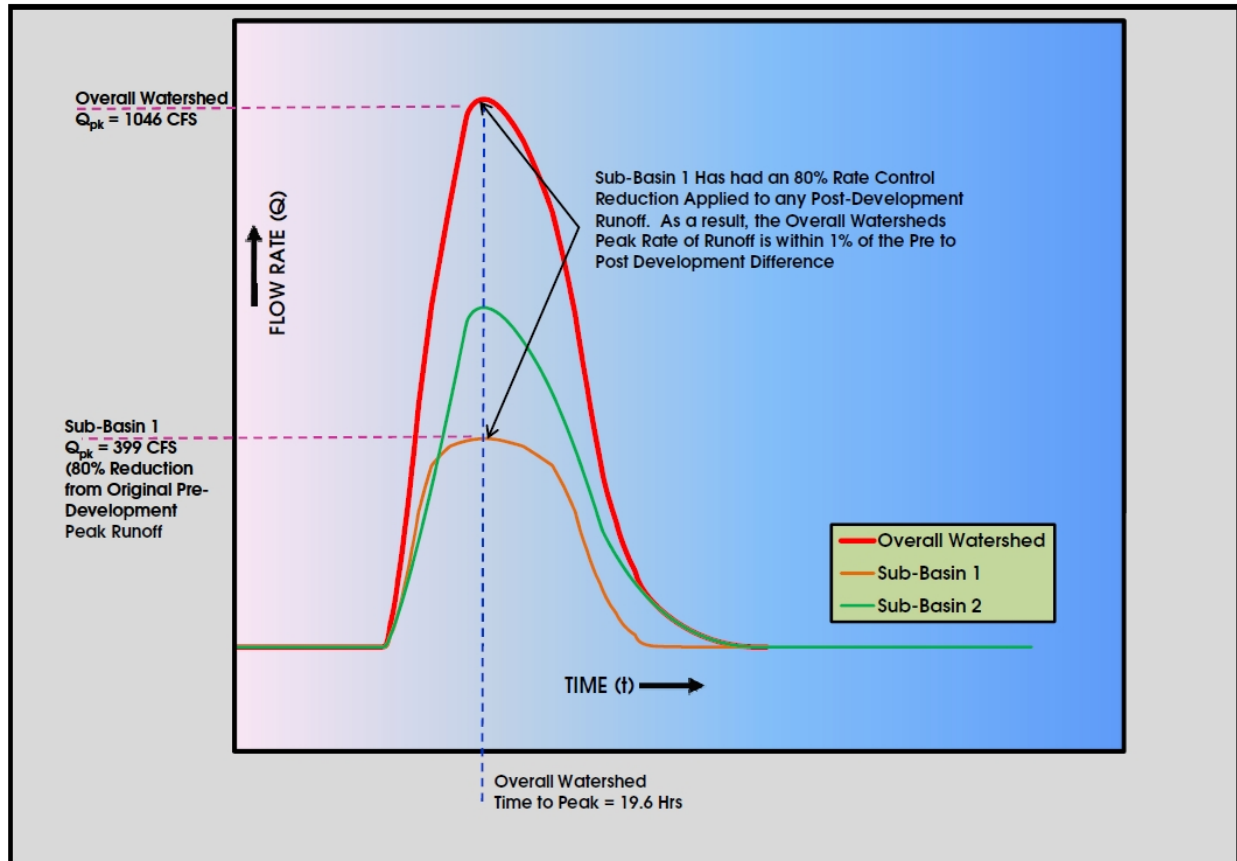


Figure V-6

The overall peak rate of runoff from Sub-Basin 1 is now 399 CFS. Sub-Basin 2 remains un-changed, as it was not necessary to apply rate release controls.

The peak rate of runoff from the overall watershed is now 1046 CFS, an increase of only 10 CFS from the entire watershed. This results in a net change of less than 1% between the pre and post-development runoff rates from the overall watershed. Therefore, the 80% release rate application to Sub-Basin 1 achieved its intended results. Due to the nature of the calculations and specific rounding of values, getting the values to match exactly is nearly impossible. However, a net change of less than 1% is well within the threshold of what the theory is trying to accomplish and it has now been accomplished in this watershed.

The Elk County Act 167 Plan implements this release rate concept in the development of management strategies for post-development stormwater controls. Subareas within Elk Creek are grouped together in release rate districts.

This allows the application of very similar release rate controls to be applied to several adjacent subareas, in lieu of listing a specific rate for each individual sub-area. Based on the hydrologic modeling conducted in the Elk Creek watershed, the model results did not justify any significant changes in the established release rate districts in the watershed. The most significant change is the switch of some Districts from “Provisional No Detention” (PND) in the previous Act 167 Plan to 100% in this Plan. Since a PND District defaulted to 100% in the previous Plan if a lengthy list of “no impact” qualifiers was not met, this change is not viewed as significant. As noted earlier, hydrologic modeling and release rate analyses were not performed on any other watersheds within Elk County due to the reduction in Plan Scope and budget. Future planning cycles will model and evaluate additional watersheds within the County listed in the Phase 1 Scope of Study.

The release rate management districts and criteria for the Elk Creek watershed are presented in Figure V-7.

E. Structural and Non-Structural BMPs

The Figures V-8 and V-9 are a comprehensive listing of structural and non-structural BMPs available for the assistance in mitigation of the four major stormwater functions in Pennsylvania. The BMPs are ranked (in potential efficiency) from high to low for each of the four functions, peak rate mitigation, recharge, volume mitigation, and stormwater quality.

The BMPs come directly from the PADEP BMP Manual and are accompanied by the following acronyms (indicating potential effectiveness when properly applied and administered):

VH	Very High
H	High
HL	High to Low (a special category in which specific parameter dictate a BMPs effectiveness)
MH	Medium to High
LM	Low to Medium
L	Low
VL	Very Low
LN	Low to None
N	None or Not Applicable

The figure(s) can be used by a design professional by determining which desired function is to be mitigated and then working down the chart and selecting BMP(s) that will work singularly or in combination with other BMPs to mitigate a specific function or multiple functions. The most effective means of selecting BMPs is to choose a BMP or multiple BMPs that have moderately high rates of success for all, or some combination, of all the desired functions requiring mitigation.

For example, the use of the BMP dictating the reduction of parking imperviousness is an effective BMP for all four of the mentioned stormwater functions. It rates VH (very high) for three of the functions and H (high) for the fourth. This makes the potential use of this BMP a practical selection.

However, BMP selection is based on a number of criteria including:

- Applicability to existing conditions
- Efficiency
- Cost Benefit
- Maintenance Concerns

Elk County

Stormwater Management Plan

Phase 2 Plan

FIGURE V-7

Release Rate Districts

Legend

Municipal Boundary

Stream

Other Features

PA

US

Local Road

Release Rate Districts

75%

80%

85%

90%

95%

100%

0 5,000 10,000 Feet

DISCLAIMER

No part of this document may be reproduced, stored in a retrieval system or transmitted in any form of by any means, electronic, mechanical, photocopying, recording or otherwise, except as expressly permitted by the Elk County, PA.

This map was digitally compiled for internal maintenance and developmental use by Elk County, PA for reference purposes. Elk County, PA makes no claims as to the completeness, accuracy or content of any data contained herein, and makes no representation of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied or inferred, with respect to the information or data furnished herein.

L.R. Kimball ARCHITECTURE • ENGINEERING • COMMUNICATIONS TECHNOLOGY

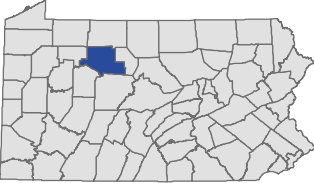
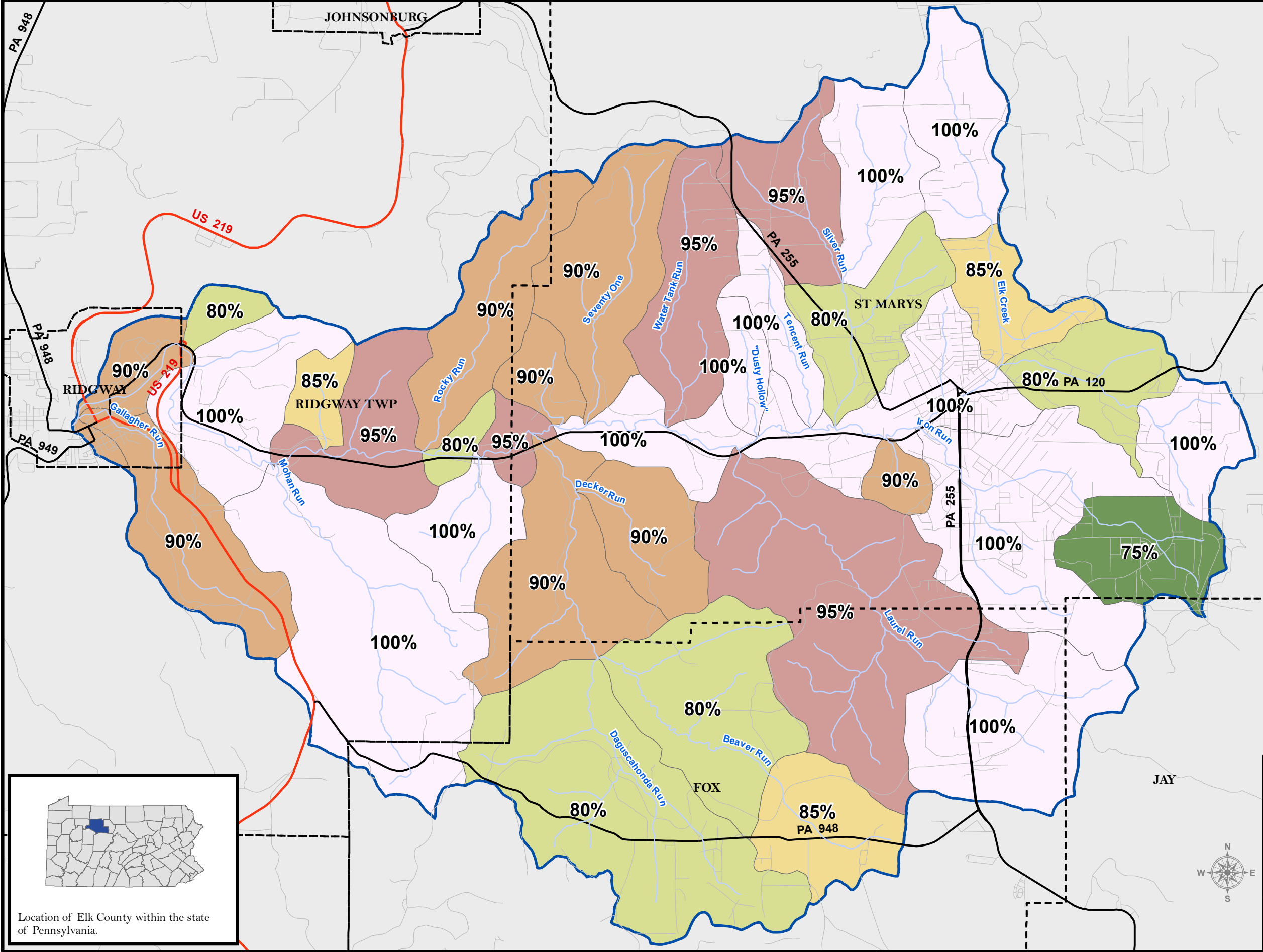
415 Moon Clinton Road Coraopolis, PA 15108-3886

Prepared by: TCD

Date: 04/24/2010

Project Number:

08-1300-0502



Location of Elk County within the state of Pennsylvania.

Non-Structural Best Management Practices (BMPs)			
Stormwater Desired Functions			
Volume Reduction	Recharge	Peak Rate Control	Quality
Protect Sensitive and Special Value Areas (VH)	Protect Sensitive and Special Value Areas (VH)	Protect Sensitive and Special Value Areas (VH)	Protect Sensitive and Special Value Areas (VH)
Cluster Uses at Each Site; Build on Smallest Area Possible (VH)	Cluster Uses at Each Site; Build on Smallest Area Possible (VH)	Cluster Uses at Each Site; Build on Smallest Area Possible (VH)	Protect/Conserve/ Enhance Riparian Areas (VH)
Concentrate Uses Area Wide Thru Smart Growth Practices (VH)	Concentrate Uses Area Wide Thru Smart Growth Practices (VH)	Concentrate Uses Area Wide Thru Smart Growth Practices (VH)	Cluster Uses at Each Site; Build on Smallest Area Possible (VH)
Minimize Soil Compaction in Disturbed Areas (VH)	Minimize Soil Compaction in Disturbed Areas (VH)	Reduce Street Imperviousness (VH)	Concentrate Uses Area Wide Thru Smart Growth Practices (VH)
Reduce Street Imperviousness (VH)	Reduce Street Imperviousness (VH)	Reduce Parking Imperviousness (VH)	Minimize Soil Compaction in Disturbed Areas (VH)
Reduce Parking Imperviousness (VH)	Reduce Parking Imperviousness (VH)	Minimize Total Disturbed Area - Grading (H)	Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species (VH)
Minimize Total Disturbed Area - Grading (H)	Minimize Total Disturbed Area - Grading (H)	Minimize Soil Compaction in Disturbed Areas (H)	Minimize Total Disturbed Area - Grading (H)
Rooftop Disconnection (H)	Rooftop Disconnection (H)	Rooftop Disconnection (H)	Reduce Parking Imperviousness (H)
Disconnection From Storm Sewers (H)	Disconnection From Storm Sewers (H)	Disconnection From Storm Sewers (H)	Streetsweeping (H)
Protect/Conserve/ Enhance Riparian Areas (M)	Protect/Conserve/ Enhance Riparian Areas (M)	Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design (MH)	Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design (M)
Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design (LM)	Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species (LM)	Protect/Conserve/ Enhance Riparian Areas (LM)	Reduce Street Imperviousness (M)
Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species (LM)	Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design (L)	Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species (LM)	Rooftop Disconnection (L)
Streetsweeping (LN)	Streetsweeping (LN)	Streetsweeping (LN)	Disconnection From Storm Sewers (L)

Figure V-8¹⁵

¹⁵ BMP methods are taken directly from the Pennsylvania DEP's, *Pennsylvania Stormwater Best Management Practices Manual*.

Structural Best Management Practices (BMPs)			
Stormwater Desired Functions			
Volume Reduction	Recharge	Peak Rate Control	Quality
Floodplain Restoration (HL)*	Floodplain Restoration (HL)*	Constructed Filter (HL)*	Landscape Restoration (VH)
Constructed Filter (HL)*	Constructed Filter (HL)*	Dry Extended Detention Basin (H)	Constructed Wetlands (H)
Subsurface Infiltration Bed (H)	Dry Well/Seepage Pit (H)	Wet Pond/Retention Basin (H)	Vegetated Filter Strip (H)
Infiltration Basin (H)	Infiltration Trench (H)	Constructed Wetlands (H)	Constructed Filter (H)
Vegetated Roof (MH)	Subsurface Infiltration Bed (H)	Vegetated Swale (MH)	Infiltration Trench (H)
Runoff Capture and Reuse (MH)	Infiltration Basin (H)	Subsurface Infiltration Bed (MH)	Subsurface Infiltration Bed (H)
Riparian Buffer Restoration (M)	Rain Garden/Bioretenion (MH)	Infiltration Basin (MH)	Infiltration Basin (H)
Dry Well/Seepage Pit (M)	Riparian Buffer Restoration (M)	Floodplain Restoration (M)	Riparian Buffer Restoration (MH)
Rain Garden/Bioretenion (M)	Pervious Pavement with Infiltration Bed (M)	Soil Amendment and Restoration (M)	Infiltration Berm and Retentive Grading (MH)
Infiltration Trench (M)	Soil Amendment and Restoration (LM)	Infiltration Berm and Retentive Grading (M)	Vegetated Swale (MH)
Pervious Pavement with Infiltration Bed (M)	Landscape Restoration (LM)	Dry Well/Seepage Pit (M)	Rain Garden/Bioretenion (MH)
Soil Amendment and Restoration (LM)	Vegetated Filter Strip (LM)	Infiltration Trench (M)	Floodplain Restoration (MH)
Landscape Restoration (LM)	Vegetated Swale (LM)	Pervious Pavement with Infiltration Bed (M)	Soil Amendment and Restoration (M)
Infiltration Berm and Retentive Grading (LM)	Level Spreader (L)	Landscape Restoration (LM)	Water Quality Filters and Hydrodynamic Devices (M)
Vegetated Filter Strip (LM)	Wet Pond/Retention Basin (L)	Riparian Buffer Restoration (LM)	Wet Pond/Retention Basin (M)
Vegetated Swale (LM)	Constructed Wetlands (L)	Rain Garden/Bioretenion (LM)	Runoff Capture and Reuse (M)
Level Spreader (L)	Runoff Capture and Reuse (L)	Special Detention Areas - Parking Lot, Rooftop (LM)	Vegetated Roof (M)
Dry Extended Detention Basin (L)	Infiltration Berm and Retentive Grading (L)	Level Spreader (L)	Dry Well/Seepage Pit (M)
Wet Pond/Retention Basin (L)	Special Detention Areas - Parking Lots, Rooftop (VL)	Runoff Capture and Reuse (L)	Pervious Pavement with Infiltration Bed (M)
Constructed Wetlands (L)	Water Quality Filters and Hydrodynamic Devices (N)	Vegetated Roof (L)	Level Spreader (L)
Special Detention Areas - Parking Lots, Rooftop (VL)	Dry Extended Detention Basin (N)	Vegetated Filter Strip (L)	Dry Extended Detention Basin (L)
Water Quality Filters and Hydrodynamic Devices (N)	Vegetated Roof (N)	Water Quality Filters and Hydrodynamic Devices (N)	Special Detention Areas - Parking Lot, Rooftop (L)

Figure V-9¹⁶

¹⁶ BMP methods are taken directly from the Pennsylvania DEP's, *Pennsylvania Stormwater Best Management Practices Manual*.

Additional Means for Objective Achievement

In addition to the criteria listed within this Plan, other methods of achieving the outlined methods may be required. Some of the more common and tangible methods for objective achievement include, but are not limited to:

- Changes, upgrades, and improvements to municipal maintenance policies
 - Including both frequency and method of practice, as well as dedicated funding
- Construction or improvement projects that will increase the efficiency and effectiveness of community stormwater and flood control facilities, collection and conveyance systems, and treatment appurtenances
- Improvements and changes to municipal construction codes and design standards which better implement methods and technologies that will address stormwater at the source and not at the eventual problem area
- Improvements and retrofit scenarios where existing stormwater and flood management facilities are made more efficient and effective in managing stormwater runoff and increasing their ability to support public welfare as well as private and public property

There is not a specific timeframe for completion of these upgrades. However, they should be implemented in a timely fashion and a fashion in which removed constraints allow. New technology, additional funding, increased public support, timely revisions to this Plan will all contribute to the expediting of improvement implementation.

Non-Achievable Objectives

Not all objectives can be immediately met through the implementation of this Plan. It is the intent of the Plan to meet each objective to the greatest extent possible. However, it is not feasible to correct every problem, known or otherwise, within the county.

Some of the potential reasons for not meeting objectives or correcting/mitigating known problems are:

- Reduction in scope in development of the Plan
- Limited technology or inefficient technology
- Financial constraints or limited resources for implementation of technology
- Political and social issues that complicate the corrective action necessary
- Lack of immediate public education and outreach programs (which through implementation of this Plan will better educate and inform the public of the impacts of stormwater)
- Limited historical data

The easiest and most efficient means of correcting and improving upon the limitations previously listed would involve periodic revisions (recommended every five years) of the Plan. This would include the implementation of new local, State, and Federal guidelines and regulations that could alleviate current impediments. Improved and more efficient technology that will augment the mitigation process. Implementation of, and additional analysis of watersheds based on newly acquired data or field gathered historical data that can be used to provide more efficient watershed analyses. Support from both the public and private sectors that will assist in the implementation, funding, and educational aspects of stormwater management methodologies.

The County and municipalities contained therein shall periodically review and revise the Plan at least every five years. It will be through these required revisions that the Plan will remain a feasible and tangible source of information and data that can be used to assist in the mitigation of known problems and to achieve objectives beyond what are outlined in this current revision of the Plan.

SECTION VI MUNICIPAL ORDINANCE INTRODUCTION

A. Supporting Information

Based upon the granted authority set forth in the Storm Water Management Act, October 4, 1978, P.L. 864 (Act 167), 32 P.S. Section 680.1, et. seq., as amended, all municipalities within the Commonwealth of Pennsylvania are empowered to regulate all land use activities within their boundaries.

Act 167 requires the implementation and management of stormwater at the local level, with municipalities taking on the leadership role. In accordance with Act 167, Sections 11 (a) and (b):

1. After adoption and approval of Plan in accordance with Act 167, the location, design and construction within the watershed of storm water management systems, obstructions, flood control projects, subdivisions and major land developments, highways and transportation facilities, facilities for the provision of public utility services and facilities owned or financed in whole or in part by funds from the Commonwealth shall be conducted in a manner consistent with the watershed storm water plan.
2. Within six months following adoption and approval of the Plan, each municipality shall adopt or amend, and shall 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 storm water plan and the provisions of this act.

The adoption of the model ordinance as a stand-alone ordinance may not require the revision of existing subdivision, land development and/or zoning ordinances within individual municipalities; these revisions are already addressed by the repealer clause in Section 106 of the model ordinance.

A model stormwater ordinance has been prepared as a part of this Plan and is available to be accepted, with minor revisions, by each subject municipality. Each municipality is free to accept the model ordinance, or have the freedom to revise the ordinance to enact more stringent requirements than what the model ordinance prescribes.

Each municipality will also be faced with the task of updating and revising any existing land development, zoning, and subdivision ordinances to provide the correlating language that references the adopted stormwater management ordinance. These revisions would need to address to all applicable land use activities within the municipality and direct the potential applicant to the stormwater management ordinance for more detailed guidance.

The most critical of the necessary elements to be included in the model ordinance shall be:

- **The stormwater drainage standards and management criteria** – (Stormwater Management Ordinance, Article III, Section 301 and Appendix A)
- **Technical performance requirements for stormwater management facilities**
 - **Detention/Retention Facilities for Peak Rate Control**– (Stormwater Management Ordinance, Article III, Section 305 and Appendix B)
 - **Volume Control BMPs** - (Stormwater Management Ordinance, Article III, Section 304 and Appendix B)
 - Infiltration BMPs
 - Bioretention BMPs
 - Land Use/Impervious Area Reduction BMPs
 - Stormwater Collection/Re-Use BMPs

- **Water Quality Facilities and BMPs** – (Stormwater Management Ordinance, Article III, Section 301 and Appendix B)

The model ordinance should be understandable and practical in all aspects of its intent. It is not intended to be too rigid and should encourage hybrid solutions and creativity in order to achieve the overall intent, which is to manage stormwater effectively, safely, and efficiently. The ordinance, while it should be stringent in nature, should also not be overly oppressive in a manner in which it could actually limit potential development by creating restrictions that could serve as a deterrent to potential developers. It is not the purpose of the ordinance/stormwater management plan to solve stormwater issues by eliminating development. It is the intent to provide an effective and safe means by which development can continue and expand in a regulated and safe environment where the natural hydrology of the county is not only protected and maintained, but also improved by the use of new technologies that will help mitigate existing problems, as well as preventing future ones.

B. Required Ordinance Contents

- Article I- General Provisions
 - This section is intended to provide information based upon the following items:
 - A short title identifying the ordinance document.
 - A statement of findings indicating general information that reinforces the need and requirements for the creation of a universal stormwater management ordinance.
 - A section identifying the purpose of the ordinance. This will include verbiage addressing topics related to both public welfare legal precedents and requirements for the creation of the document, as well as basic technical information that the document will address.
 - A brief section outlining the statutory authority that the empowerment of the ordinance is based upon.
 - A brief section identifying the applicability of the ordinance and the types of activities the ordinance has the authority to regulate.
 - A section indicating that any additional ordinances within the municipality in question that are not consistent with the provisions of this ordinance, are hereby repealed to the extent of the inconsistencies.
 - A section describing that if any standing court order declares any section of this ordinance invalid, this decision will not affect the validity of the remaining provisions of the ordinance.
 - A statement indicating that compliance with this ordinance does not release the applicant from adherence with any other local codes, laws, or regulations. Nor does it release them from their necessary duty to acquire required permits and approvals from other governing bodies.
- Article II- Definitions
 - This section is intended to provide the appropriate and intended interpretation of certain words, terms and entities included in the ordinance.
- Article III- Stormwater Management Standards
 - This section is intended to clearly present and define the technical regulations for stormwater management within the municipality. This should, at a minimum, include the following:
 - Definition of water quality (WQ) requirements and provisions

- All necessary design criteria and applicable supporting data
- Requirements for meeting erosion and sedimentation control guidelines and regulations
- Acceptable methods and models for preparing calculations
- Information concerning applicable stormwater management districts and the
- implementation of specific control criteria therein
- Small project exemption criteria
- Waiver criteria
- Article IV- Stormwater Management Site Plan Requirements
 - This section is intended to provide an outlined description of the necessary components that will represent an acceptable stormwater management site plan. It shall also include information describing the appropriate procedures for plan submittal, review, approval guidelines and protocol, fees, subsequent follow up, and closeout procedures at project completion.
- Article V-Operation and Maintenance
 - This section defines the municipality's roles and authority in the determination of operation and maintenance of any and all stormwater management facilities. The determination of the ultimate party responsible for such operation and maintenance will be made prior to final plan approval. An appropriate O/M agreement should also be included that defines the owner's responsibility for proper operation and maintenance of the facility and the municipality's rights to enforce the agreement or charge fees associated with maintenance of any facility owned by an entity other than the municipality.
- Article VI-Fees and Expenses
 - This section should outline all costs incurred in the review fee, and that the municipality may charge such fees to an applicant. The review fee may include but not be limited to costs for the following:
 - Administrative/clerical processing.
 - Review of the SWM Site Plan.
 - Attendance at Meetings.
 - Inspections
- Article VII-Prohibitions
 - This section addresses all necessary prohibitions and definition of unacceptable activities that are deemed to not adhere to the language of the ordinance. Items of the following type, but not limited to, should be included in this section:
 - Any illegal and illicit discharges prohibited under the provisions of the ordinance
 - Specific guidelines regulating the installation and function of residential and commercial roof drain systems
 - Specific guidelines regulating the alteration or retrofitting of any existing stormwater management facility or BMP device
- Article VIII-Enforcements and Penalties
 - This section outlines the municipality's rights concerning enforcement of the ordinance guidelines and applicable and allowable penalties. A detailed description of the following items should be included:

- The municipality's right of entry
- The municipality's right of inspection
- The municipality's rights of enforcement of the terms of the ordinance and any associated agreements
- Information concerning suspensions and revocation
- A detailed listing of penalties that are considered in direct violation of the terms of the ordinance and any associated agreements
- A detailed outline of the appeals process available to any applicant
- Article IX- References
 - Supporting documentation used for the creation and formulation of any portion of the ordinance
- Appendix A:
 - Low Impact Development Practices
- Appendix B:
 - Site Conditions Suitable for Infiltration
 - BMPs for Infiltration
 - BMPs for Rate Control
 - BMPs for Evapotranspiration
- Appendix C:
 - Operation and Maintenance Agreement, Stormwater Best Management Practices
- Appendix D:
 - Rational Formula Runoff Coefficients
- Appendix E:
 - Release Rate District Map
- Appendix F:
 - Small Project SWM Plan Application and Worksheets
- Appendix G:
 - Disconnected Impervious Areas
- Attachment A:
 - Additional Ordinance and Technical Guidelines Toolbox

SECTION VII PRIORITIES FOR IMPLEMENTATION

The preparation of the Elk County Act 167 Stormwater Management Plan concludes with the county's final acceptance of the Plan and the submittal of the Plan to the Pennsylvania Department of Environmental Protection (PA DEP) for final review and approval. Once the PA DEP approves the Plan, all County municipalities have six months from final PA DEP approval and acceptance to adopt the necessary ordinances (be it the model ordinance, or a refined and revised ordinance that is more stringent than the accepted Plan) concerning the stormwater management criteria.

A. DEP Approval of the Plan

Once the final Plan is adopted by Elk County, it is then submitted to the PA DEP for approval. A preliminary/draft copy of the stormwater management plan and model ordinance was submitted to the PA DEP prior to the county's adoption. The PA DEP reviews the draft and determines that all necessary components are present and all necessary tasks have been completed. The PA DEP then reviews the Plan for the following additional items:

- Consistency and adherence with floodplain management plans
- Commonwealth regulations concerning the management of dams, waterway encroachments, and all other possible waterway obstructions
- Commonwealth and Federal flood control guidelines

This specific Act 167 Plan was prepared exclusively for Elk County and the municipalities located therein. However, based upon the fact that watersheds boundaries overlap between counties, the Plan must be consistent and compatible with other Act 167 and stormwater management plans and policies that are already in place, or currently being prepared in adjacent jurisdictions.

B. Publishing the Final Plan

The County will publish additional copies of the Plan after receipt of final approval from the PA DEP. The County will provide one copy to each municipality within Elk County at this time. Copies of the Elk County Stormwater Management Model Ordinance will be published for use by all county municipalities.

C. Municipal Adoption of Ordinance to Implement the Plan

The most critical part of implementation of the Act 167 Plan is the adoption of the required stormwater ordinance by each county municipality.

As discussed in previous sections, each municipality would have the ability to accept the model ordinance "as-is," and this would meet the requirements for implementation at the municipal level. In this scenario, the only remaining requirement would be the formal correlation and revision to any existing land development, sub-division, or existing stormwater ordinances. A direct connection between existing ordinances and the new model ordinances would have to take place prior to the implementation process being complete.

The correlating provisions would refer the applicant engaged in any applicable regulated activities (as defined in the ordinance) within the municipality from the previous ordinance(s) to the newly adopted ordinance.

As an additional recommendation to the adopting municipality, it is suggested that the previously determined and approved watershed delineation areas and the management criteria assigned to them (e.g., rate release controls, etc.) be included within the municipality's zoning or sub-division ordinance(s), if they exist. This creates a scenario where the stormwater management requirements will apply to all proposed land use changes and will not be limited by activities that are subject to the provisions outlined in the existing land development and sub-division ordinance(s).

D. Level of Government Involvement in Stormwater Management

The current process for the management of stormwater from a regulatory basis within the Commonwealth of Pennsylvania is a blended mixture of objectives and directives from a number of governing bodies.

Stormwater within a single watershed currently has the potential to be managed and regulated at a federal, state, county and local (municipal) level. Each of these entities can possess their own guidelines and regulations based on their specific intent and place as a stakeholder in the regulatory process. It becomes the responsibility of the developer or applicant to address, adhere, and gain approval from each separate entity based upon their singular guidelines, which at times, can even be in direct conflict or contradiction with another regulatory entities guidelines and regulations. This lack of a sole, regulatory entity, responsible for the implementation of all rules, regulations, reviews, assistance, and approval during the stormwater process makes the process in and of itself extremely difficult to navigate.

Implementation of the Plan guidelines and minimum requirements of Act 167 can be accomplished without significant disruption to the current permitting and approval process in any particular watershed. The most significant action will occur at the municipal and county level. The technical review of stormwater management plans must include the input of a representative municipality. Along with the review and approval of plan applications, intermittent updates to the computer model (created as a product of the Plan preparation, and provided as a final deliverable) are required in order for data to remain current and to indentify new or potential problems. The collection and storage of physical data (new development, changes to the watershed(s), etc.) also will be required in order to have a current inventory of county stormwater infrastructure and impacts to hydrology.

Upon final adoption of the Plan, the following types of projects will be subject to the provisions of the Plan and remain consistent with the rules and regulations set forth in the Plan:

- New Public Facilities
- New Facilities for the Provision of Public Utilities
- New Facilities Owned or Financed by Commonwealth Funds

These public or publically funded facilities are required to comply with the Plan even if they are not subject to any municipal regulation.

The primary role of the municipality will be the implementation of the Plan through ordinance adoption. This process must be completed within six months of PA DEP's approval of the Act 167 Plan. The required model ordinance provisions will be made available to each municipality by the County. The municipal entity will also be responsible for the establishment and implementation of the necessary review procedures.

The necessary evidence that state and federal agencies have been contacted and notified of regulated activities will also be required. This applies in most instances to any impact or potential impact to areas, through acceptable delineation practices, which are considered wetlands. This process is intended to ensure that all Plan guidelines and regulations are being followed and have been implemented.

E. Correction of Existing Drainage Problems

The completion of the stormwater management plan will provide an outline and source of reference for the elimination of existing stormwater management problems within the county. Each municipality will have at its disposal a resource for identifying and addressing these problems at the local level. The municipality will not only have a better framework for addressing and correcting existing problems, but for providing an environment in which future problems are prevented.

The information provided is not intended to be the only approach to correcting problems and in no way is anything listed considered to be mandatory. It is only a list of suggestions for providing an individual municipality a means to correcting existing problems. Since problems, as well as the means to correcting them, vary between municipalities, not every recommendation is applicable in all cases.

- A list of existing stormwater management issues within the municipality should be created and prioritized. This list should take into account the following parameters:
 - Threat to human life
 - Threat to property and existing infrastructure
 - Frequency of occurrence
 - Proximity to other existing problems
 - Financial ramifications
- A technical evaluation of each problem area, costing evaluation to determine repair requirements, and a proposed course of action for the municipality to follow
- Implementation of the corrective action plan should begin and be integrated with the municipal capital or maintenance improvement budget on an annual basis

F. Culvert Replacement

One of the most common drainage problems within the County is flooding caused by unmanaged or insufficiently managed stormwater runoff from development that is tributary to culverts. A large number of these culverts were never designed to pass the higher flows generated by excessive development. These culverts are not able to safely convey these higher flows, resulting in localized flooding, damage to infrastructure, roadway overtopping which results in driving hazards, as well as many other problems.

A culvert replacement plan should be enacted as part of the overall corrective action plan for each municipality. In general, the procedure for determining the proper culvert size is as follows:

- Identify the location of the problem culvert from the obstruction data provided in the Act 167 Plan and its assigned identification number
- Determine the appropriate design storm frequency based upon the PA DEP's Chapter 105 guidelines:
 - In determining flood flows and frequencies for purposes of this subchapter, hydrologic analysis shall be by methods generally accepted in the engineering profession
 - Rural areas—25-year frequency flood flow
 - Suburban areas—50-year frequency flood flow
 - Urban areas—100-year frequency flood flow
- Using the information provided in the Act 167 Plan, locate the appropriate flow (CFS) for the obstruction in question and based upon the return period criteria listed above

- Using sound and acceptable engineering practices, size the culvert based upon the determined parameters and within any ordinance or regulatory agency having jurisdictional control over the culvert replacement
- All necessary local, state, and federal permits and approvals should be obtained prior to construction

Not all obstructions within the county may have been identified and/or modeled. In the event of a known problem obstruction area that is not listed in the Act 167 Plan, sound and acceptable engineering practices should be used in the proper design and replacement of the culvert. Portions of the previously listed method for replacement are still applicable, and should be implemented to the greatest extent possible. The most notable exception is that of calculated flow for the obstruction. This must be calculated by the design engineer for the culvert replacement and should be done in accordance with sound engineering practice as well as all local, state, and federal regulations governing the design of culverts in the municipality in question.

G. PennVEST Funding

PENNVEST has been empowered by Pennsylvania state law, Pennsylvania Infrastructure Investment Authority Act 16 of 1988, to administer and finance the Clean Water State Revolving Fund (CWSRF) and the Drinking Water State Revolving Fund (DWSRF) pursuant to the federal Water Quality Act of 1987, as well as to administer the American Recovery and Reinvestment Act of 2009 (ARRA) funds. PENNVEST also finances, through the issuance of special obligation revenue bonds, water management, solid waste disposal, sewage treatment and pollution control projects undertaken by or on behalf of private entities.

The PENNVEST Clean Water State Revolving Fund (CWSRF) program provides funding to projects throughout PENNSYLVANIA for the construction and maintenance of wastewater treatment facilities, storm water management projects, nonpoint source pollution controls, and watershed and estuary management.

This program offers low interest loans with flexible terms to assist a variety of borrowers that include local governments, municipalities, and privately owned entities and to establish partnerships to leverage other funding sources.

The CWSRF program is managed under the Pennsylvania State Regulations for PENNVEST funding wastewater projects. In partnership with the Pennsylvania Department of Environmental Protection, management occurs during project planning, application submission, contracting and financing, and site inspection and reporting.

The Pennsylvania Code establishes project evaluation criteria for PennVEST funding. The criteria for stormwater projects seeking PennVEST assistance is currently defined as¹⁷:

- Public health and safety
 - Elimination of critical ongoing safety or health hazard
 - Elimination of a chronic safety or health hazard which frequently occurs
 - Elimination of a potential safety or health hazard associated with periodic flooding
- Environmental impact
 - The improvement or prevention of a problem to the environment or to natural resources
 - Whether the project is located in areas of karst topography and susceptible to sinkhole development or has no natural watercourse within the municipal boundaries encompassing the project
- Economic development
 - Development, activity and job creation retention resulting directly or indirectly from a project

¹⁷ The Pennsylvania Code, §963.9a adopted July 7, 1995, effective July 8, 1995, 25 Pa.B. 2720

- Opportunity to use other State programs, such as the Business Infrastructure Development, Site Development and Community Facilities Programs, to fund the project
- Degree of local distress in the county where the project is located
- Compliance
 - Improvement of compliance with existing laws, rules and regulations if compliance will eliminate the necessity to issue an order
 - Compliance with law, an order, decree, agreement or a deadline specified in regulation
- Adequacy and efficiency
 - The extent that the project proposes facility regionalization or system consolidation to improve operation, maintenance or function of the stormwater facility
 - The extent that the project involves multiple-governmental participation
 - The extent that the project has a sponsoring municipal entity which has a population less than or equal to 12,000 residents as reported in the latest census

In order to qualify for funding consideration, the applicant must meet two important factors:

- The project seeking funding must be located within a watershed where a DEP approved and county adopted stormwater management plan is currently in place
- The project seeking funding must be located within a watershed where a stormwater management ordinance has been implemented as is consistent with the guidelines of the county-wide stormwater management plan

H. Landowner's/Developer's Responsibilities

Any landowner and any person engaged in the alteration or development of land that may affect storm water runoff characteristics shall implement such measures consistent with the provisions of the applicable watershed storm water plan as are reasonably necessary to prevent injury to health, safety or other property. Such measures must include such actions as are required:

- To assure that the maximum rate of storm water runoff is no greater after development than prior to development activities; or
- To manage the quantity, velocity and direction of resulting storm water runoff in a manner which otherwise adequately protects health and property from possible injury.

Works Cited

Center for Watershed Protection. (2000). *Overbank Flooding*. Retrieved August 19, 2009, from SMRC Home: <http://www.stormwatercenter.net/Slideshows/sizing-rac/sld042.htm>

Lively, A. a. (1995).

Paul A. DeBarry, P. P. (2004). *Watersheds - Processes, Assessment and Management*. Hoboken: John Wiley and Sons, Inc.

Pennsylvania DEP. (2007). *DEP Fact Sheet - NPDES Permits for Stormwater Discharges Associated with Construction Activities, Document 3930-FS-DEP3042*. Harrisburg, PA: Pennsylvania DEP.

Pennsylvania Department of Environmental Protection. (2006). *Pennsylvania Stormwater Best Management Practices*. Harrisburg, PA.

Stuckey and Reed, M. H. (2000). *Techniques for Estimating Magnitude and Frequency of Peak Flows for Pennsylvania Streams*. Lemoyne, PA: Cooperation with the Pennsylvania Department of Transportation.

Tennessee Department of Environment and Conservation. (n.d.). *TDEC:WPC: Erosion and Sediment Control Handbook*. Retrieved August 6, 2009, from The Official State of Tennessee's Department of Environment and Conservation, State Parks Website: http://www.state.tn.us/environment/wpc/sed_ero_controlhandbook/

United States Environmental Protection Agency. (2007, December 12). *Class V Wells Home*. Retrieved from U.S. Environmental Protection Agency: <http://www.epa.gov/OGWDW/uic/class5/index.html>

United States Environmental Protection Agency. (Revised, 2005). *Stormwater Phase II Final Rule - Small MS4 Stormwater Program Overview - EPA 833-F-00-002*. Washington D.C.: U.S. Environmental Protection Agency.

US Climate Change Science Program. (2003, July). *Chapter 5. Water Cycle. From Strategic Plan of the US Climate Change Science Program (Final Report)*. Retrieved from US Climate Change Science Program: <http://www.climatechange.gov/Library/stratplan2003/final/ccspstratplan2003-chap5.htm>