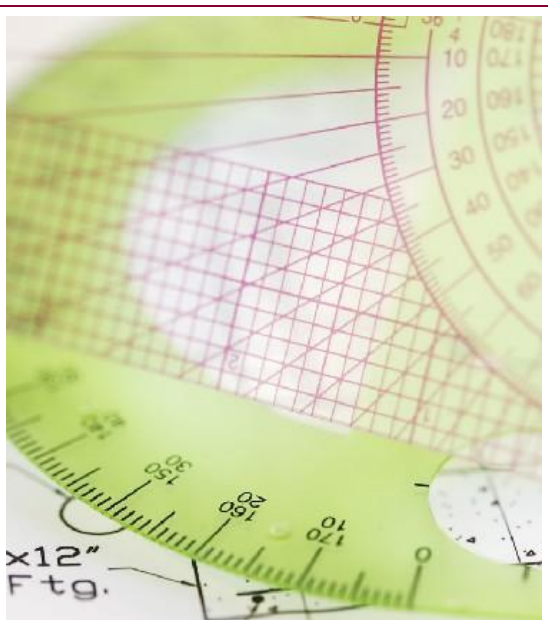
Appendix A – Watershed Modeling Technical Data



This appendix supplements the hydrologic modeling general overview presented in Section 6 – Technical Analysis.

DATA COLLECTION

The GIS data for the hydrologic models was compiled from a variety of sources by county, state, and federal agencies. The data was collected in and processed using GIS software. A description of GIS data collected, the source, and its use are provided in *Table A.1*.

Data	Source	Use
10-m Digital Elevation Model (DEMs)	USGS (2008a)	Watershed delineation, length, basin slope, stream slope, average elevation
High Resolution Streamlines	USGS (2008b)	Watershed delineation, cartography, spatial orientation
National Land Cover Dataset – Land Use 2001	USGS (2008c)	Curve number generation for watershed subareas outside of County
2010 County Land Use	Washington County Planning	Existing conditions curve number generation for watershed subareas within County
2020 County Land Use (hand drawn by County and digitized by HRG)	Washington County Planning	Future conditions curve number generation for watershed subareas within County
SURRGO Soils Data	NRCS (2008)	Curve number generation; analysis of infiltration limitations
Carbonate Bedrock	ERRI (1996)	Calculation of percentage of limestone geology within subwatersheds; analysis of infiltration limitations
Storage (percent of lakes, ponds, and wetlands)	USGS (2008d)	Calculation of parameters for USGS Regression Equations
Roadway Data	Washington County Planning	Cartography, spatial orientation

Table A.1. GIS Data Used in Act 167 Technical Analysis

HYDROLOGIC MODEL PARAMETER DATA

SOILS, LAND USE, AND CURVE NUMBERS

The determination of CNs is a function of soil type and land use. The hydrologic soil groups were defined by NRCS (2008). The 2001 NLCD and County GIS files were simplified to provide an estimate of CNs using the scheme shown in *Table A.2*.

GIS Code	County or NLCD (2001) Land Use	NRCS (1986) Classification	A	B	C	D
11	Open Water	Water	98	98	98	98
21	Developed, Open Space	Open space	39	61	74	80
22	Developed, Low Intensity	Residential - 1 acre	51	68	79	84
23	Developed, Medium Intensity	Residential - 1/2 acre	54	70	80	85
24	Developed, High Intensity	Commercial and Business	89	92	94	95
31	Barren Land (Rock/Sand/Clay)	Newly graded areas	77	86	91	94
41	Deciduous Forest	Woods	30	55	70	77
42	Evergreen Forest	Woods	30	55	70	77
43	Mixed Forest	Woods	30	55	70	77
52	Shrub/Scrub	Brush	30	48	65	73
71	Grassland/Herbaceous	Meadow	30	58	71	78
81	Pasture/Hay	Pasture	39	61	74	80
82	Cultivated Crops	Contoured Row Crops	65	75	82	86
90	Woody Wetlands	Woods	30	55	70	77
95	Emergent Herbaceous Wetlands	Water	98	98	98	98
111	Residential-High Density	Residential - 1/8 acre or less	77	85	90	92
112	Residential-Med Density	Residential - 1/2 acre	54	70	80	85
113	Residential-Med Low Density	Residential - 1/2 acre	54	70	80	85
114	Residential-Low Density Rural	Residential - 1 acre	51	68	79	84
115	Residential-Large Yard	Residential - 1 acre	51	68	79	84
121	Commercial-CBD	Commercial and Business	89	92	94	95
122	Commercial-Strip	Commercial and Business	89	92	94	95
123	Commercial-Commercial and Services	Commercial and Business	89	92	94	95
131	Industrial-Manufacturing	Industrial	81	88	91	93
132	Industrial-Chemical	Industrial	81	88	91	93
133	Industrial-Industrial	Industrial	81	88	91	93
141	Transportation-Major Highways	Industrial	81	88	91	93
142	Transportation-Railroads	Industrial	81	88	91	93
143	Transportation-Airports	Industrial	81	88	91	93
144	Transportation-Docking Ports	Industrial	81	88	91	93
145	Transportation-Dams	Industrial	81	88	91	93
146	Transportation-Substation	Industrial	81	88	91	93
147	Transportation-Powerline Pipeline right of Ways	Industrial	81	88	91	93
148	Transportation-Water Sewage Treatment	Industrial	81	88	91	93
149	Transportation-Water Communication Tower	Industrial	81	88	91	93
151	Industrial and Commercial Complexes-Industrial Complex	Industrial	81	88	91	93

Table A.2. Curve Numbers for Washington County for each Hydrologic Soil Group

GIS Code	County or NLCD (2001) Land Use	NRCS (1986) Classification	A	B	C	D
152	Industrial and Commercial Complexes-Mall	Industrial	81	88	91	93
153	Industrial and Commercial Complexes-Business Complex	Industrial	81	88	91	93
161	Mixed Urban or Built-Up-Mixed Urban	Mixed Urban (assumed 65% impervious)	77	85	90	92
171	Other Urban Built-Up-Open Spaces	Open space	39	61	74	80
172	Other Urban Built-Up-Parks Recreation	Open space	39	61	74	80
173	Other Urban Built-Up-Golf Courses	Open space	39	61	74	80
174	Other Urban Built-Up-Ski Areas	Open space	39	61	74	80
175	Other Urban Built-Up-Institutional	Institutional (assumed 50% impervious)	69	80	86	89
176	Other Urban Built-Up-Historic Sites Regions	Open space	39	61	74	80
177	Other Urban Built-Up-Cemeteries	Open space	39	61	74	80
178	Other Urban Built-Up-Vegetated Buffer	Open space	39	61	74	80
179	Other Urban Built-Up-Non Vegetated Buffer	Open space	39	61	74	80
211	Crop Pasture Orchards Groves-Row Crops	Contoured Row Crops	65	75	82	86
212	Crop Pasture Orchards Groves-Fallow Fields	Pasture	39	61	74	80
213	Crop Pasture Orchards Groves-Orchards Groves	Contoured Row Crops	65	75	82	86
214	Crop Pasture Orchards Groves-Pasture	Pasture	39	61	74	80
215	Crop Pasture Orchards Groves-Vineyards	Contoured Row Crops	65	75	82	86
216	Crop Pasture Orchards Groves-Nurseries	Contoured Row Crops	65	75	82	86
217	Crop Pasture Orchards Groves-Farmstead	Pasture	39	61	74	80
311	Mixed Rangeland-Sparse Tree Crown	Meadow	30	58	71	78
312	Mixed Rangeland-Shrub Brush	Meadow	30	58	71	78
313	Mixed Rangeland-Mixed Rangeland	Meadow	30	58	71	78
431	Mixed Forest-Deciduous	Woods	30	55	70	77
432	Mixed Forest-Coniferous Evergreen	Woods	30	55	70	77
433	Mixed Forest-Mixed Forest	Woods	30	55	70	77
511	Rivers Streams Canals-Rivers	Water	98	98	98	98

Table A.2 (continued). Curve Numbers for Washington County for each Hydrologic Soil Group

GIS Code	County or NLCD (2001) Land Use	NRCS (1986) Classification	A	B	C	D
512	Rivers Streams Canals-Streams	Water	98	98	98	98
513	Rivers Streams Canals-Canals	Water	98	98	98	98
531	Reservoirs Ponds-Reservoirs	Water	98	98	98	98
532	Reservoirs Ponds-Ponds	Water	98	98	98	98
533	Reservoirs Ponds-Lake	Water	98	98	98	98
751	Extraction-Strip Mines	Newly graded areas	77	86	91	94
752	Extraction-Slag Piles	Newly graded areas	77	86	91	94
753	Extraction-Quarries	Newly graded areas	77	86	91	94
754	Extraction-Gravel Pitts	Newly graded areas	77	86	91	94
761	Transitional-Construction	Newly graded areas	77	86	91	94
762	Transitional-Transitional Cleared	Newly graded areas	77	86	91	94
771	Mixed Barren-Mixed Barren	Newly graded areas	77	86	91	94

Table A.2 (continued). Curve Numbers for Washington County for each Hydrologic Soil Group

The CNs presented in the above tables represent "average" antecedent runoff condition (i.e. ARC = 2). In a significant hydrologic event, runoff is often influenced by external factors such as extremely dry antecedent runoff conditions (ARC=1) or wet antecedent runoff conditions (ARC=3). The antecedent runoff conditions of the above CNs were altered during the calibration process so that model results are within a reasonable range of other hydrologic estimates.

INFILTRATION AND HYDROLOGIC LOSS ESTIMATES

Infiltration and all other hydrologic loss estimates (e.g., evapotranspiration, percolation, depression storage, etc.) taken into account within the HEC-HMS model was consistent with the recharge volume criteria contained in CG-1 and CG-2. These losses were modeled in existing conditions as the standard initial abstraction in the NRCS Curve Number Runoff method (i.e., I_a = 0.2S). CG-1 was simulated by modifying the standard initial abstraction using the following procedure.

The runoff volume is computed by HEC-HMS using the following equation:

$$Q_{volume} = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Where P = Rainfall for a specific storm event (in),
I_a = Initial Abstraction (in), and
S = Maximum Retention (in).

S is defined by the following equation which relates runoff volume to curve number:

$$S = \frac{1000}{CN} - 10$$

The standard initial abstraction I_a used in PA is typically *0.2S*. HEC-HMS calculates this automatically if no value is entered by the user. This was the approach used for the existing and future conditions modeling scenarios.

In future conditions with implementation of CG-1, the following equation is applicable. The goal of CG-1 is to ensure there is no discharge volume increase for the 2-year, 24-hour storm event, so

$$Q_{CG1} = Q_{Existing} = \frac{(P - I_a)^2}{(P - I_a) + S_{Proposed}}$$

Where P = rainfall for a specific storm event(in),
I_a = initial abstraction (in), and
$S_{Proposed}$ = maximum retention in proposed conditions as a function of the proposed conditions CN (in).

Assuming $I_a = 0.2S$ as the I_a value is no longer applicable with CG-1 since BMPs are to be installed to control or remove the increase in runoff volume for the 2-year, -24hour storm event. Using the HEC-HMS modeling output for $Q_{Existing}$, the I_a for CG-1 may be calculated using the following equation:

$$I_a = P_{2-year} - \frac{1}{2}(Q_{Existing} \pm \sqrt{Q_{Existing}^2 + 4Q_{Existing}S_{Proposed}})$$ for the 2-year event

Thus, the volume control required by CG-1 is implicitly modeled by overriding the HEC-HMS default for initial abstraction with the above value. The qualitative effect of this will be to eliminate the increase in runoff volume for the 2-year, 24-hour storm event and to reduce the increase in runoff volume of the more extreme events. Increases in the peak flow values are reduced for all storms, but not eliminated, since the T_c for proposed condition are decreased. Figure C.1 shows the effects of implementing a CG-1 policy on an example watershed. In the first figure representing a 2-year, 24-hour storm event, the hydrograph volumes are exactly the same and the peaks are similar. In the second figure representing a 100-year, 24-hour storm event, the hydrograph volumes are not the same since only the 2-year, 24-hour storm event volume is abstracted; consequently there is still a substantial increase in peak flows, although the CG-1 implementation does reduce the peak flow.

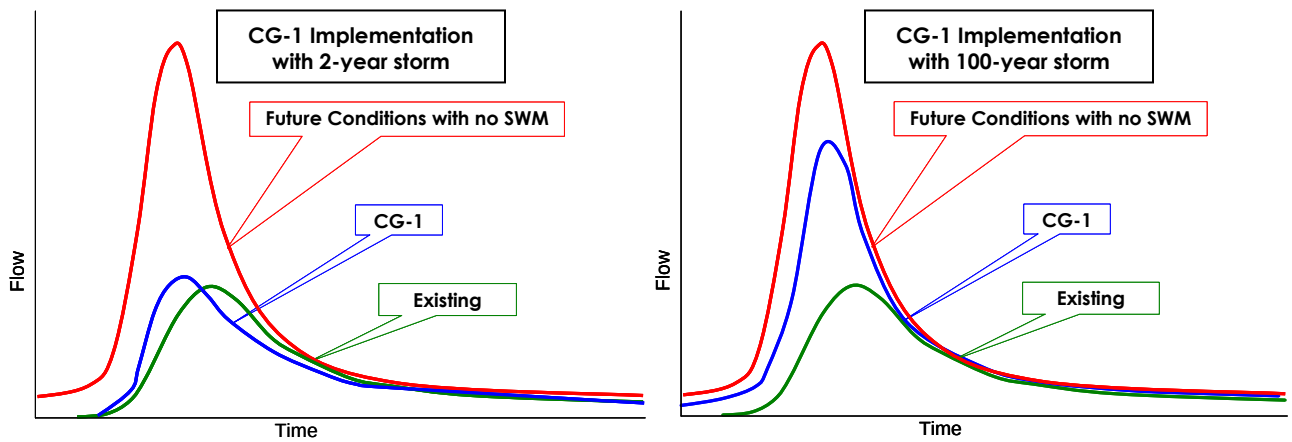


Figure A.1. Typical On-Site Runoff Control Strategy

In the case of this particular sample, release rates might be necessary to prevent increases in peak flow. In situations where there is only a small increase in impervious coverage, however, CG-1 may reduce the proposed conditions peak flow to existing conditions levels without the use of release rates.

For the 2-year, 24-hour storm event, modeling CG-1 with the above equations results in an increased approximation in initial abstraction represented by D:

$$D = I_a^{CG-1} - 0.2S$$

For the every event of greater magnitude (e.g., 10, 25, 50, and 100-year, 24-hour storm events), the I_a is calculated using the sum of the traditional method and the increase in I_a for the 2-year event.

$I_a = 0.2S + D$ for all events greater than the 2-year, 24-hour storm event.

MODEL CALIBRATION

Three (3) parameters were modified to develop a calibrated hydrologic model: CN, T_c, and the Manning's coefficient used in the Muskingum-Cunge routing method.

The antecedent runoff condition was altered for each storm event so that each subbasin and calibration point was within an acceptable range of a target flow. The equation used to modify antecedent runoff condition (Maryland Hydrology Panel, 2006):

For ARC≤2:

$$CN_x = \frac{[10 + 5.8(x - 2)]CN_2}{10 + 0.058(x - 2)CN_2}$$

For ARC>2:

$$CN_x = \frac{[10 + 13(x-2)]CN_2}{10 + 0.013(x-2)CN_2}$$

Thus, a unique ARC and resulting CN was calculated for each subbasin for each storm event. The same ARC was applied in both existing and proposed conditions. The calibrated and future condition CNs for the two (2) watersheds are presented in the Tables at the end of this Appendix.

Additionally, lag times were calculated using both TR-55 and the NRCS lag equation. The initial model runs used the results from the NRCS lag equation. A factor between zero (0) and two (2) was applied to the initial value to obtain a calibrated T_c value. The same T_c was applied to all existing condition storms. The future land use T_c was calculated using the NRCS lag equation with future land CNs. It was subsequently adjusted by the same factor used in existing conditions.

Finally, the Manning's n value for channels and overbank areas was modified to obtain realistic flow values. The respective ranges for the channel and overbank areas were 0.02-0.07 and 0.03-0.2.

MODELING RESULTS

A summary of the hydrologic modeling results has been provided in Section 5 of this Plan. The full modeling results are as presented in the tables at the end of this appendix.

STORMWATER MANAGEMENT DISTRICTS

The regional philosophy used in Act 167 planning introduces a different stormwater management approach than is found in the traditional on-site approach. The difference between the on-site stormwater control philosophy and the Act 167 watershed-level philosophy is the consideration of downstream impacts throughout an individual watershed. The objective of typical on-site design is to control post-development peak flow rates from the site itself; however, a watershed-level design is focused on maintaining existing peak flow rates in the entire drainage basin. The watershed approach requires knowledge of how the site relates to the entire watershed in terms of the timing of peak flows, contribution to peak flows at various downstream locations, and the impact of the additional runoff volume generated by the development of the site. The proposed watershed-level stormwater runoff control philosophy is based on the assumption that runoff volumes will increase with development and the philosophy seeks to manage the increase in volumes such that peak rates of flow throughout the watershed are not increased. The controls implemented in this Plan are aimed at minimizing the increase in runoff volumes and their impacts, especially for the 2-year, 24-hour storm event.

The basic goal of both on-site and watershed-level philosophies is the same, i.e. no increase in the peak rate of stream flow, however, the end products can be very different, as illustrated in the following simplified example.

Presented in *Figure A.2* is a typical on-site runoff control strategy for dealing with the increase in the peak rate of runoff with development. The Existing Condition curve represents the pre-development runoff hydrograph. The Developed Condition curve illustrates three (3) important changes in the site runoff response with development:

A higher peak rate;

A faster occurring peak (shorter time for the peak rate to occur); and

An increase in total runoff volume.

The "Controlled" Developed Condition hydrograph is based on limiting the post-development runoff peak rate to the pre-development level through use of detention facilities; but the volume is still increased. The impact of lowering the post-development peak rate to the pre-development peak rate without reducing the volume causes the peak rate to extend over a longer period of time. The instantaneous pre-development peak has become an extended peak (approximately two (2) hours long in this example) under the "Controlled" Developed Condition.

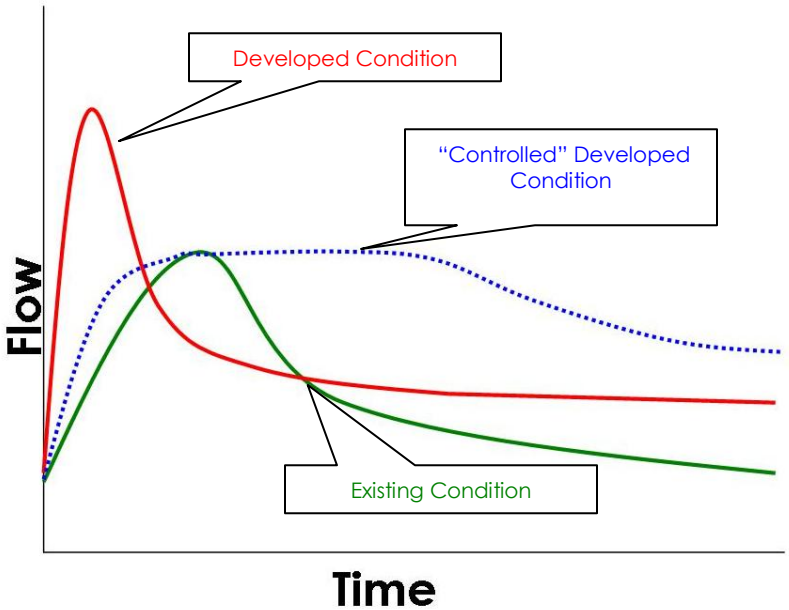


Figure A.2. Typical On-Site Runoff Control Strategy

The maintenance of the existing condition peak rate flow of runoff is an effective management approach, however, *Figures A.3* and *A.4* illustrate the potential detrimental impact of this approach. *Figure A.3* represents the existing hydrograph at the point of confluence of Watershed A and Watershed B. Watershed A peaks more quickly (at time T_{pA}) than the Total Hydrograph, while Watershed B peaks later (at time T_{pB}), than the Total Hydrograph, resulting in a combined time to peak approximately in the middle (at time T_p). Watershed A is an area of significant development pressure and all new development proposals are met with the on-site runoff control philosophy as depicted in *Figure A.2*. Eventually, the end product of the Watershed A development under the "Controlled" Development Condition is an extended peak rate of runoff as shown in *Figure A.4*. The extended Watershed A peak rate flow occurs long enough that it coincides with the peak of Watershed B. Since the Total Hydrograph at the confluence is the summation of Watershed A and Watershed B, the Total Hydrograph peak is increased under these conditions to the "Controlled" Total Hydrograph. The conclusion from the example is that simply controlling peak rates of runoff on-site does not guarantee an effective watershed level of control because of the increase in total runoff volume. The net result is that downstream peaks can increase and extend for longer durations.

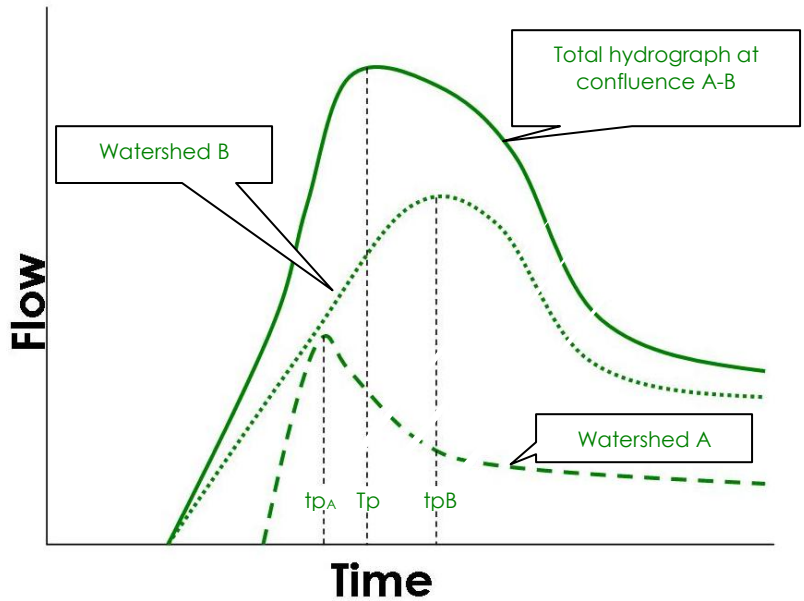


Figure A.3. Existing Hydrograph (Pre-Development)

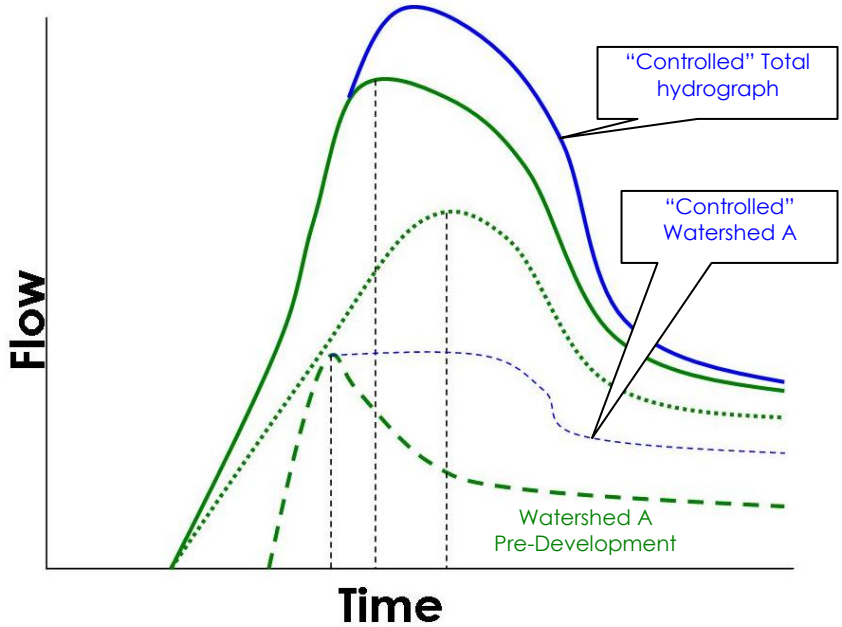


Figure A.4. Controlled Runoff Condition (Post-Development)

RELEASE RATE CONCEPT

The previous example indicated that, in certain circumstances, it is not enough to control post-development runoff peaks to pre-development levels if the overall goal is no increase in peak

runoff at any point in the watershed. The reasons for this potential increase are how the various parts of the watershed interact over a period of time and how the increased rate and volume of runoff associated with development are proportional to increases in impervious surfaces. The critical runoff criteria for a given site or watershed area is not necessarily its own pre-development peak rate of runoff but rather the pre-development contribution of the site or watershed area to the peak flow at a given point of interest.

To account for increases of volume and peak flow resulting from the combination of these post-development hydrographs, stormwater management districts have been assigned to various areas within the county boundary that have more restrictive release rates than the conventional 100% release rate. As shown in Plate 10, some areas within specific watersheds have reduced release rates where CG-1 may be difficult to completely implement.

The specification of a 100% release rate as a performance standard would represent the conventional approach to runoff control philosophy, namely controlling the post-development peak runoff to pre-development levels. This is a well-established and technically feasible control that is effective at-site and, where appropriate, would be an effective watershed-level control.

It is important to acknowledge that there are several problems with the release rate concept. One (1) of the problems is that some areas can reach unreasonably low release rates. This can be seen in the release rate equation, which dictates that sub-watersheds that peak farther away from the entire watershed will have a lower release rate. Indeed, sub-watersheds whose runoff drains almost completely before or after the watershed peak will approach a release rate of zero (0) (because the numerator approaches 0).

Another problem is that release rates are highly dependent on, and sensitive to, the timing of hydrographs. Since natural storms follow a different timing than design storms, it is still possible that watershed-wide controls designed with release rates only will encounter increased runoff problems. This is because the runoff rates are still much higher in the developed condition and increased volume over an extended time can combine to increase peak flow rates. Similar to the traditional on-site detention pond, release rates are purely a peak "rate" type of control.

Development patterns that only use release rates for stormwater control and do not consider volume control may also determine design effectiveness. This is because rates based on timing assume a certain development and rainfall patterns while the model uses uniform parameters across a sub-watershed. In reality, the actual development and rainfall patterns can be highly variable across a sub-watershed and can be quite different than the "Future Full Build Out" land use scenario used in the planning study. This uncertainty can affect any type of control, but controls based on timing alone are especially sensitive to these parameters. Some controls, such as volume controls, are less sensitive since they remove a certain amount of runoff from the storm event wherever development occurs. In a sense, volume controls tend to more closely simulate what occurs in a natural system.

Combining volume controls with peak rate controls, as proposed in this Plan, will be more effective than having only peak rate controls. Volume controls have several advantages, such as:

Increased runoff volume may infiltrate and provide recharge to existing groundwater supplies. This may not happen with rate controls since all of the runoff excess is discharged in a relatively short time frame.

Volume controls tend to mimic natural systems (i.e., excess runoff volume is infiltrated) and are therefore more effective in controlling natural storms since they are not highly sensitive to timing

issues.

Volume controls often have enhanced water quality benefits.

The Design Storm Method and The Simplified Method as implemented in this Plan, provide the benefits described above.

SUMMARY MODEL OUTPUT

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Hydrologic Results for Chartiers Creek HEC-HMS Model

Calibration Results for Detailed HEC-HMS Models with 2010 Land Use

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Brush Run near Canonsburg	W092	1.12	74.6	38.3	78.9	42.1
	W094	0.98	74.5	42.2	78.1	42.2
	W096	1.32	75.4	45.3	77.3	47.6
	W098	0.71	77.0	29.8	78.0	36.2
	W100	1.98	75.8	44.7	79.7	49.7
Brush Run near Thompsonville	W190	1.85	75.6	44.4	75.6	44.4
	W192	0.88	74.3	33.1	74.3	33.1
	W194	2.72	73.7	67.7	73.7	67.7
	W196	1.47	75.8	46.1	75.8	46.1
	W198	1.66	76.9	46.5	76.9	46.5
	W200	1.15	73.3	37.5	73.3	37.5
	W202	0.64	76.8	32.0	76.8	32.0
Catfish Creek	W020	1.08	71.5	30.3	71.5	37.9
	W022	1.30	73.0	34.7	73.0	43.3
	W024	1.04	80.4	31.1	80.4	38.8
	W026	0.80	82.7	28.3	82.7	28.3
	W028	0.47	79.8	30.5	79.8	38.1
Chartiers Creek	W002	0.86	71.5	38.2	71.5	47.7
	W004	1.10	69.1	46.7	70.7	55.9
	W006	2.14	68.6	40.0	69.0	49.5
	W008	0.01	72.3	4.6	72.3	4.6
	W010	0.04	78.4	11.6	78.4	14.5
	W012	1.43	67.9	48.9	68.7	59.9
	W014	1.75	73.2	46.4	73.2	51.5
	W016	1.37	71.8	35.8	71.8	44.8
	W018	0.70	73.4	38.2	73.4	42.4
	W030	1.94	72.1	43.5	72.1	54.4
	W032	2.38	72.1	55.7	72.1	69.6
	W040	2.11	72.9	45.1	72.9	56.4
	W042	0.51	75.6	25.0	76.6	30.3
	W044	1.84	78.1	48.2	78.6	59.3
	W046	1.31	73.5	42.3	77.5	47.1
	W048	1.58	77.8	33.6	84.6	27.0
	W050	1.16	71.0	44.5	78.8	44.4
	W052	2.30	74.7	57.6	74.7	72.1
	W054	2.84	72.6	47.3	82.5	44.0
	W090	0.90	77.8	33.5	83.6	34.7
	W102	2.27	75.6	40.0	84.4	38.0
	W104	0.21	86.1	12.1	87.0	14.6
	W188	2.93	72.0	75.4	79.3	61.1
	W204	1.55	72.6	50.6	72.6	50.6
	W256	0.92	71.6	46.1	71.6	46.1
	W276	1.42	71.9	51.6	71.9	51.6
	W342	1.07	70.4	49.2	70.4	49.2

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Chartiers Creek	W344	1.90	71.0	55.6	71.0	55.6
	W346	2.76	73.5	71.4	73.5	71.4
	W348	0.91	70.9	41.6	70.9	41.6
	W350	1.57	72.3	47.1	72.3	47.1
	W352	1.28	71.5	59.5	71.5	59.5
	W354	1.09	73.9	36.8	73.9	36.8
	W356	0.94	74.0	53.5	74.0	53.5
	W358	2.89	71.1	43.9	73.5	51.4
	W360	1.15	70.7	33.2	70.7	36.9
	W362	0.58	70.8	35.6	70.8	44.5
	W364	0.84	72.5	32.4	72.5	40.5
	W366	0.20	69.2	20.4	73.0	23.0
	W368	0.47	70.6	29.5	83.8	24.8
	W370	2.51	76.3	53.0	76.8	58.0
	W372	0.68	79.0	26.5	79.0	33.1
	W374	0.76	79.5	38.7	79.5	48.4
	W376	0.39	78.1	22.9	78.1	28.6
	W378	0.91	77.2	34.1	77.2	42.6
	W380	0.13	76.7	14.6	76.7	18.3
	W382	0.46	75.8	29.4	81.9	30.6
	W384	0.90	79.0	39.4	79.5	48.6
	W386	0.26	75.1	24.5	77.1	28.9
	W388	0.01	86.9	7.1	86.9	7.1
	W390	2.19	76.0	50.4	80.1	55.7
	W392	0.04	80.9	10.5	80.9	10.5
	W394	0.69	76.2	22.8	76.2	28.5
	W396	1.81	79.1	34.2	80.1	41.5
	W398	1.40	83.1	40.1	84.3	42.8
	W400	1.28	73.8	51.2	86.2	34.6
	W402	0.80	72.4	41.4	82.0	31.1
	W404	1.69	75.0	53.1	75.2	52.7
	W406	0.70	75.6	31.6	75.6	31.6
	W408	2.93	72.7	80.2	72.7	80.2
	W410	1.71	74.6	41.7	74.6	41.7
	W412	0.62	77.5	36.3	77.5	36.3
	W414	0.13	72.3	17.1	72.3	17.1
	W416	1.07	76.2	42.9	76.2	42.9
	W418	0.05	74.4	18.3	74.4	18.3
	W420	0.49	75.8	24.3	75.8	24.3
	W422	0.16	76.9	22.4	76.9	22.4
	W424	0.31	75.8	22.9	75.8	22.9
	W426	0.06	84.0	13.6	84.0	13.6
	W428	0.02	85.0	4.2	85.0	4.2
	W430	0.52	77.5	36.7	77.5	36.7

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Chartiers Creek	W432	1.22	75.8	44.2	75.8	44.2
	W434	0.45	74.6	34.5	74.6	34.5
	W436	1.43	72.8	45.2	72.8	45.2
	W438	0.85	75.7	43.6	75.7	43.6
	W440	1.91	71.8	55.7	71.8	55.7
	W442	1.87	73.8	48.5	73.8	48.5
	W444	0.33	80.9	29.0	80.9	29.0
Chartiers Run	W056	1.45	70.7	35.5	70.7	44.3
	W058	1.16	72.2	29.6	72.2	37.0
	W072	1.38	70.8	44.3	70.8	55.4
	W078	3.14	71.3	50.7	72.1	61.9
	W080	1.58	72.1	50.5	73.3	54.2
	W082	0.79	68.5	32.6	68.5	40.7
	W084	1.74	71.7	47.9	71.7	53.2
	W086	1.44	73.2	43.3	73.2	54.1
	W088	0.04	82.3	11.4	82.3	14.2
Coal Run	W206	2.01	68.4	63.6	68.5	63.4
	W208	1.64	71.6	64.0	71.6	64.0
Dolphin Run	W226	2.09	69.3	51.1	69.3	63.9
Fishing Run	W224	2.12	67.2	55.7	67.2	69.6
Georges Run	W034	3.12	71.8	57.4	71.8	71.7
	W036	3.13	72.6	66.1	72.6	82.7
	W038	1.39	76.0	35.1	76.0	43.9
Graesers Run	W266	2.02	73.0	56.8	73.0	56.8
Half Crown Run	W288	1.23	72.7	41.5	72.7	51.8
	W290	2.30	72.2	54.8	72.2	68.5
	W292	1.01	69.7	46.0	69.7	51.1
	W294	1.40	73.2	44.8	73.2	56.0
	W296	1.00	74.9	45.4	74.9	45.4
	W298	1.24	72.3	49.7	72.3	49.7
	W300	1.86	73.2	51.6	73.2	64.5
	W302	0.37	70.2	22.5	70.2	28.2
	W304	0.69	72.4	27.4	72.4	34.2
	W306	0.63	68.5	43.1	68.5	43.1
	W308	0.35	72.7	26.0	72.7	32.5
	W310	0.43	68.3	26.4	68.3	33.0
	W312	0.45	70.3	28.8	70.3	36.0
Little Chartiers Creek	W108	1.91	68.6	45.3	74.8	47.8
	W110	1.23	71.7	32.6	71.7	40.7
	W112	1.58	69.2	41.4	73.1	46.4
	W114	1.19	70.8	41.5	70.8	51.8
	W116	1.46	69.0	43.6	69.7	53.5
	W118	0.78	63.3	32.0	68.7	34.7
	W120	1.76	73.1	44.2	78.4	47.3

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Little Chartiers Creek	W122	0.83	70.0	32.7	77.2	33.3
	W124	1.16	70.8	48.8	76.8	45.7
	W126	0.45	68.9	35.9	68.9	44.9
	W128	1.57	69.4	62.1	69.4	62.1
	W130	0.16	64.7	17.3	64.7	21.6
	W132	1.20	71.0	33.6	71.0	41.9
	W134	1.33	70.1	44.4	70.1	55.5
	W136	1.93	73.7	43.6	73.8	54.4
	W138	1.72	69.5	47.5	69.7	58.9
	W140	0.31	70.7	24.0	75.3	26.4
	W142	1.85	72.0	57.7	72.0	72.1
	W144	1.89	71.6	54.7	71.7	68.4
	W146	1.29	72.3	36.8	75.8	41.7
	W148	1.54	74.0	38.0	76.6	39.2
	W150	1.39	74.2	42.9	79.3	46.1
	W152	0.09	74.2	16.5	75.1	20.1
	W154	1.77	75.3	39.7	81.6	40.9
	W156	2.84	69.8	59.8	72.3	69.7
	W158	1.65	68.7	36.2	69.0	44.9
	W160	0.12	76.4	12.4	76.4	15.5
	W162	1.68	68.5	43.3	68.6	53.9
	W164	0.15	81.7	18.7	81.7	23.4
	W166	1.23	71.5	41.6	71.5	51.9
	W168	1.67	69.7	58.9	70.1	72.7
	W170	0.22	74.1	23.6	82.9	22.5
	W172	0.97	71.3	40.4	78.6	40.8
	W174	0.82	74.1	34.4	74.1	43.0
	W176	1.23	74.5	45.4	75.1	55.8
	W178	0.00	76.6	3.9	89.8	2.5
	W180	0.90	80.9	28.3	82.4	33.7
	W182	0.12	75.3	17.3	75.5	21.5
	W184	1.36	76.9	43.5	76.9	43.5
	W186	0.01	78.4	8.1	78.4	8.1
McLaughlin Run	W264	1.55	73.6	41.2	73.6	41.2
	W268	1.92	74.4	53.0	74.4	53.0
	W270	2.29	75.4	74.9	75.4	74.9
Millers Run	W210	1.03	70.8	44.6	70.8	55.8
	W212	1.60	70.8	45.1	70.8	50.1
	W214	2.16	72.5	47.5	75.1	55.2
	W216	1.50	73.0	37.7	79.2	39.4
	W218	1.74	68.9	42.7	69.2	53.0
	W220	1.18	69.3	48.8	69.3	54.3
	W222	0.77	68.0	39.3	70.7	45.7
	W228	1.33	69.1	48.3	69.1	60.4

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Millers Run	W230	1.22	72.2	31.8	72.2	39.7
	W232	1.76	69.8	41.0	69.8	51.2
	W234	0.96	74.9	39.0	74.9	43.4
	W236	0.11	69.3	13.4	78.4	12.9
	W238	1.35	74.9	42.5	76.8	40.2
	W240	0.64	73.7	23.3	79.9	24.3
	W242	1.68	72.3	44.2	75.3	50.8
	W244	2.21	68.8	43.5	68.9	54.1
	W246	0.03	75.4	6.3	75.4	7.9
	W248	2.03	69.7	61.2	69.7	61.2
	W250	0.69	70.0	33.5	70.0	41.8
Opossum Run	W106	1.25	70.9	46.7	70.9	58.4
Painters Run	W258	1.28	71.2	53.8	71.2	53.8
	W260	1.49	69.6	47.9	69.6	47.9
	W262	1.64	71.7	57.5	71.7	57.5
	W272	0.72	74.6	33.0	74.6	33.0
Pink Run	W286	0.82	69.1	45.0	69.1	50.0
Pinkertons Run	W314	2.61	71.9	48.0	71.9	60.0
Plum Run	W074	2.43	74.1	45.5	74.1	56.9
	W076	1.66	74.1	41.6	74.1	52.0
Robb Run	W282	1.10	74.5	37.5	74.5	46.9
Robinson Run	W278	1.52	74.9	48.8	74.9	48.8
	W280	1.61	72.8	47.0	72.8	58.8
	W284	1.78	69.6	43.7	69.6	54.6
	W316	0.93	71.2	31.3	71.2	39.2
	W320	1.24	72.7	39.1	72.7	48.8
	W322	2.86	70.6	52.7	70.6	52.7
	W324	0.58	70.0	29.7	70.0	37.2
	W326	0.74	74.4	26.8	74.4	26.8
	W328	1.74	70.0	43.8	70.0	54.8
	W330	0.90	69.4	38.8	69.4	43.1
	W332	1.14	68.3	47.4	68.3	52.6
	W334	2.16	70.7	51.4	70.7	64.3
	W336	0.09	69.3	15.1	69.3	18.9
	W338	2.69	70.1	60.6	70.1	75.8
	W340	1.41	71.6	36.0	71.6	45.0
Scotts Run	W318	1.17	68.5	48.0	68.5	60.0
Scrubgrass Run	W274	1.51	71.6	57.5	71.6	57.5
Thoms Run	W252	1.81	72.7	39.4	72.7	39.4
	W254	1.65	71.5	42.6	71.5	42.6
Westland Run	W060	0.80	70.8	38.9	70.8	38.9
	W062	1.56	69.0	45.3	69.0	56.6
	W064	0.84	74.0	37.6	74.0	37.6
	W066	1.19	70.8	33.8	70.8	42.2

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Drainage Area (mi^2)	Existing Conditions (2010)		Future Conditions (2020)	
			CN	Lag (min)	CN	Lag (min)
Westland Run	W068	0.62	70.4	26.2	70.5	32.8
	W070	0.58	69.8	35.9	69.8	44.8

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Brush Run near Canonsburg	W092	74.6	72.2	70.3	67.9	65.0	64.0
	W094	74.5	71.6	69.8	68.6	67.2	66.0
	W096	75.4	72.3	70.6	68.1	65.2	64.1
	W098	77.0	74.2	72.6	71.4	70.1	69.0
	W100	75.8	72.7	70.8	68.4	65.5	64.4
Brush Run near Thompsonville	W190	75.6	71.7	66.3	64.9	63.4	62.1
	W192	74.3	71.3	69.6	68.3	66.9	65.8
	W194	73.7	72.6	68.2	66.9	65.6	64.4
	W196	75.8	72.1	67.1	65.8	64.3	63.1
	W198	76.9	72.4	67.3	66.0	64.6	63.4
	W200	73.3	71.2	66.1	64.8	63.3	62.2
	W202	76.8	74.0	72.3	71.1	69.8	68.7
Catfish Creek	W020	71.5	70.7	68.2	65.6	62.5	61.2
	W022	73.0	71.2	68.8	66.1	63.0	61.6
	W024	80.4	73.1	71.3	68.5	65.1	64.2
	W026	82.7	80.5	79.1	78.1	77.0	76.1
	W028	79.8	77.3	75.8	74.7	73.5	72.5
Chartiers Creek	W002	71.5	68.4	66.5	65.2	63.8	62.6
	W004	69.1	74.4	72.1	68.4	66.0	64.9
	W006	68.6	68.2	63.7	58.8	55.5	53.4
	W008	72.3	69.2	67.4	66.1	64.7	63.5
	W010	78.4	75.8	74.2	73.0	71.8	70.7
	W012	67.9	72.5	66.9	63.9	60.2	58.4
	W014	73.2	71.6	69.4	66.8	63.8	62.5
	W016	71.8	70.7	68.1	65.3	62.0	60.4
	W018	73.4	70.3	68.5	67.3	65.9	64.7
	W030	72.1	71.5	69.2	66.7	63.7	62.3
	W032	72.1	73.1	70.7	68.4	65.8	64.7
	W040	72.9	71.8	69.7	67.2	64.1	62.9
	W042	75.6	72.8	71.1	69.8	68.5	67.4
	W044	78.1	73.4	71.9	69.4	66.4	65.4
	W046	73.5	71.8	69.6	67.0	64.0	62.7
	W048	77.8	71.6	69.0	66.0	62.4	60.9
	W050	71.0	73.7	70.7	68.6	66.1	65.1
	W052	74.7	73.2	71.7	69.4	66.8	65.7
	W054	72.6	71.7	69.4	66.8	63.8	62.3
	W090	77.8	75.1	73.5	72.3	71.0	69.9
	W102	75.6	71.9	69.6	66.9	63.7	62.4
	W104	86.1	84.2	83.1	82.2	81.3	80.5
	W188	72.0	73.8	68.9	67.7	66.3	65.0
	W204	72.6	71.9	67.6	66.3	65.0	63.8
	W256	71.6	68.5	66.6	65.3	63.9	62.7
	W276	71.9	72.4	68.0	66.9	65.6	64.5
	W342	70.4	73.6	68.1	66.9	65.7	64.7

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Chartiers Creek	W344	71.0	72.5	67.4	66.1	64.6	63.5
	W346	73.5	72.8	68.9	67.6	66.3	65.2
	W348	70.9	67.7	65.9	64.5	63.1	61.9
	W350	72.3	71.7	67.0	65.7	64.4	63.2
	W352	71.5	74.3	69.6	68.6	67.6	66.6
	W354	73.9	71.4	66.4	65.1	63.8	62.7
	W356	74.0	71.0	69.3	68.0	66.6	65.5
	W358	71.1	70.7	68.0	65.2	61.8	60.3
	W360	70.7	70.5	67.8	65.2	62.0	60.8
	W362	70.8	67.6	65.8	64.4	63.0	61.8
	W364	72.5	69.4	67.6	66.3	64.8	63.7
	W366	69.2	65.9	64.0	62.7	61.2	59.9
	W368	70.6	67.4	65.5	64.1	62.7	61.5
	W370	76.3	72.2	70.1	67.2	63.8	62.5
	W372	79.0	76.4	74.8	73.7	72.5	71.4
	W374	79.5	77.0	75.4	74.3	73.1	72.1
	W376	78.1	75.4	73.8	72.6	71.4	70.3
	W378	77.2	74.5	72.8	71.7	70.4	69.3
	W380	76.7	73.9	72.2	71.0	69.7	68.6
	W382	75.8	73.0	71.3	70.1	68.7	67.6
	W384	79.0	76.4	74.8	73.7	72.5	71.4
	W386	75.1	72.2	70.5	69.2	67.9	66.7
	W388	86.9	85.1	84.0	83.2	82.3	81.5
	W390	76.0	73.0	71.5	69.1	66.4	65.3
	W392	80.9	78.5	77.0	76.0	74.8	73.8
	W394	76.2	73.4	71.7	70.5	69.2	68.0
	W396	79.1	72.7	70.6	67.8	64.4	63.3
	W398	83.1	74.5	73.1	70.5	67.3	67.3
	W400	73.8	72.5	70.8	68.5	65.9	64.9
	W402	72.4	69.3	67.5	66.2	64.7	63.6
	W404	75.0	72.6	68.4	67.3	66.1	65.1
	W406	75.6	72.7	71.0	69.8	68.4	67.3
	W408	72.7	74.2	69.9	68.8	67.7	66.7
	W410	74.6	71.7	66.7	65.3	63.8	62.7
	W412	77.5	74.7	73.1	71.9	70.6	69.6
	W414	72.3	69.2	67.4	66.1	64.7	63.5
	W416	76.2	68.0	57.7	57.6	57.4	57.4
	W418	74.4	71.5	69.7	68.4	67.1	65.9
	W420	75.8	72.9	71.2	70.0	68.6	67.5
	W422	76.9	74.1	72.5	71.3	70.0	68.9
	W424	75.8	72.9	71.2	70.0	68.7	67.5
	W426	84.0	81.9	80.6	79.7	78.6	77.8
	W428	85.0	83.0	81.8	80.9	79.9	79.1
	W430	77.5	74.8	73.1	72.0	70.7	69.6

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Chartiers Creek	W432	75.8	72.7	68.5	67.5	66.4	65.5
	W434	74.6	71.7	69.9	68.7	67.3	66.2
	W436	72.8	71.9	67.7	66.6	65.5	64.3
	W438	75.7	72.8	71.1	69.9	68.6	67.4
	W440	71.8	73.3	68.9	67.8	66.7	65.7
	W442	73.8	72.4	68.0	66.9	65.7	64.7
	W444	80.9	78.5	77.0	76.0	74.8	73.8
Chartiers Run	W056	70.7	70.7	68.2	65.6	62.6	61.1
	W058	72.2	70.6	68.1	65.3	62.1	60.7
	W072	70.8	73.3	70.2	67.9	65.2	64.0
	W078	71.3	71.8	69.3	66.6	63.4	62.0
	W080	72.1	72.0	70.1	67.7	64.9	63.8
	W082	68.5	65.1	63.2	61.8	60.3	59.1
	W084	71.7	71.7	69.6	67.2	64.4	63.1
	W086	73.2	72.4	70.7	68.4	65.8	64.8
	W088	82.3	80.0	78.6	77.6	76.5	75.6
Coal Run	W206	68.4	74.1	68.0	66.6	65.0	63.9
	W208	71.6	71.9	69.3	68.2	67.1	66.1
Dolphin Run	W226	69.3	69.8	68.0	65.5	62.7	59.3
Fishing Run	W224	67.2	70.0	68.5	65.8	63.6	60.4
Georges Run	W034	71.8	72.6	70.2	67.7	64.8	63.6
	W036	72.6	73.4	71.4	69.1	66.4	65.3
	W038	76.0	72.1	70.1	67.5	64.4	63.2
Graesers Run	W266	73.0	72.0	67.3	66.0	64.6	63.4
Half Crown Run	W288	72.7	70.7	67.6	65.1	62.2	59.6
	W290	72.2	71.3	68.2	65.7	62.7	60.0
	W292	69.7	70.5	66.6	63.8	60.4	57.7
	W294	73.2	70.9	68.0	65.4	62.3	59.6
	W296	74.9	71.9	70.2	68.9	67.6	66.4
	W298	72.3	70.7	67.7	65.1	62.1	59.6
	W300	73.2	71.3	68.5	66.0	63.2	60.6
	W302	70.2	66.9	65.1	63.7	62.2	61.0
	W304	72.4	69.3	67.5	66.2	64.8	63.6
	W306	68.5	65.2	63.3	61.9	60.4	59.2
	W308	72.7	69.6	67.8	66.5	65.1	63.9
	W310	68.3	64.9	63.0	61.6	60.1	58.9
	W312	70.3	67.1	65.2	63.8	62.4	61.1
Little Chartiers Creek	W108	68.6	73.8	69.7	67.3	65.3	64.2
	W110	71.7	70.8	68.3	66.4	64.3	63.1
	W112	69.2	73.1	68.8	67.1	65.1	63.8
	W114	70.8	72.6	69.7	68.1	66.3	65.3
	W116	69.0	73.9	69.8	67.7	65.9	64.6
	W118	63.3	59.7	57.7	56.2	54.7	53.4
	W120	73.1	71.8	69.8	68.0	66.0	64.9

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Little Chartiers Creek	W122	70.0	66.7	64.8	63.5	62.0	60.8
	W124	70.8	73.2	70.3	68.7	67.0	66.0
	W126	68.9	65.6	63.7	62.3	60.9	59.6
	W128	69.4	74.4	71.7	68.9	67.3	66.2
	W130	64.7	61.2	59.2	57.7	56.2	54.9
	W132	71.0	71.0	68.7	66.9	64.9	63.8
	W134	70.1	73.9	70.4	68.7	67.0	66.0
	W136	73.7	71.9	69.8	68.1	66.2	65.2
	W138	69.5	73.9	70.0	68.0	66.1	65.0
	W140	70.7	67.5	65.6	64.3	62.8	61.6
	W142	72.0	74.1	71.7	70.4	68.8	68.0
	W144	71.6	74.1	71.3	69.8	68.2	67.1
	W146	72.3	71.5	69.4	67.7	65.9	64.8
	W148	74.0	70.0	66.5	64.1	61.4	59.8
	W150	74.2	71.5	68.8	66.8	64.6	63.3
	W152	74.2	71.2	69.5	68.2	66.8	65.7
	W154	75.3	72.0	70.0	68.4	66.5	65.3
	W156	69.8	74.6	70.8	68.6	66.7	65.4
	W158	68.7	72.4	67.9	66.0	63.9	62.6
	W160	76.4	73.6	71.9	70.7	69.4	68.3
	W162	68.5	73.7	70.3	67.7	65.8	64.5
	W164	81.7	79.3	77.9	76.9	75.8	74.8
	W166	71.5	72.7	70.4	68.8	67.1	66.1
	W168	69.7	75.3	74.1	71.7	69.3	68.4
	W170	74.1	71.1	69.3	68.1	66.7	65.5
	W172	71.3	68.1	66.2	64.9	63.4	62.2
	W174	74.1	71.1	69.4	68.1	66.7	65.5
	W176	74.5	73.1	71.8	70.5	69.2	68.3
	W178	76.6	73.8	72.2	71.0	69.7	68.6
	W180	80.9	78.5	77.1	76.0	74.8	73.9
	W182	75.3	72.4	70.7	69.5	68.2	67.0
	W184	76.9	72.4	70.6	69.0	67.1	66.2
	W186	78.4	75.8	74.2	73.0	71.8	70.7
McLaughlin Run	W264	73.6	71.2	65.9	64.5	62.9	61.7
	W268	74.4	72.1	67.4	66.1	64.7	63.6
	W270	75.4	70.8	63.4	61.1	58.5	56.6
Millers Run	W210	70.8	69.8	68.4	66.1	63.4	59.9
	W212	70.8	68.8	66.6	63.8	60.4	56.3
	W214	72.5	69.3	67.3	64.6	61.3	57.0
	W216	73.0	68.8	66.9	64.0	60.5	56.4
	W218	68.9	68.8	66.7	64.0	60.8	57.1
	W220	69.3	69.6	67.9	65.5	62.7	59.3
	W222	68.0	64.6	62.7	61.3	59.8	58.5
	W228	69.1	70.2	68.9	66.7	64.1	61.0

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Millers Run	W230	72.2	68.1	65.6	62.6	59.0	54.5
	W232	69.8	68.6	66.4	63.6	60.3	56.4
	W234	74.9	71.9	70.2	68.9	67.6	66.4
	W236	69.3	66.0	64.1	62.7	61.2	60.0
	W238	74.9	68.6	66.5	63.5	59.9	58.5
	W240	73.7	70.7	68.9	67.7	66.3	65.1
	W242	72.3	69.4	67.7	65.0	61.9	58.0
	W244	68.8	69.1	66.8	64.1	61.0	57.4
	W246	75.4	72.5	70.8	69.5	68.2	67.0
	W248	69.7	70.0	68.3	66.0	63.2	59.8
	W250	70.0	66.7	64.8	63.4	62.0	60.8
Opossum Run	W106	70.9	73.8	70.7	69.3	67.7	66.6
Painters Run	W258	71.2	73.0	68.1	66.9	65.5	64.5
	W260	69.6	72.8	66.5	65.1	63.6	62.3
	W262	71.7	73.2	68.5	67.3	66.0	65.0
	W272	74.6	71.6	69.9	68.6	67.2	66.1
Pink Run	W286	69.1	65.8	63.9	62.5	61.0	59.8
Pinkertons Run	W314	71.9	70.5	67.2	64.5	61.2	58.6
Plum Run	W074	74.1	72.0	69.7	67.0	63.9	62.5
	W076	74.1	72.2	70.3	67.8	64.9	63.8
Robb Run	W282	74.5	70.9	67.7	65.0	61.8	59.1
Robinson Run	W278	74.9	70.6	67.1	64.2	60.8	57.6
	W280	72.8	71.1	68.1	65.5	62.5	60.2
	W284	69.6	71.0	67.0	64.3	61.2	58.4
	W316	71.2	68.0	66.2	64.9	63.4	62.2
	W320	72.7	70.5	67.3	64.7	61.5	58.8
	W322	70.6	69.6	65.7	62.8	59.3	56.3
	W324	70.0	66.8	64.9	63.5	62.1	60.8
	W326	74.4	71.4	69.7	68.4	67.0	65.9
	W328	70.0	70.5	66.9	64.2	61.1	58.5
	W330	69.4	66.1	64.2	62.8	61.3	60.1
	W332	68.3	72.0	68.3	66.0	63.3	61.2
	W334	70.7	71.2	68.0	65.5	62.5	60.0
	W336	69.3	66.0	64.1	62.7	61.2	60.0
	W338	70.1	73.1	69.3	67.0	64.3	61.9
	W340	71.6	70.4	67.4	64.8	61.9	59.4
Scotts Run	W318	68.5	72.7	69.3	67.0	64.9	62.9
Scrubgrass Run	W274	71.6	73.3	68.7	67.5	66.2	65.2
Thoms Run	W252	72.7	70.7	65.2	63.7	62.0	60.6
	W254	71.5	71.0	66.0	64.6	63.1	61.9
Westland Run	W060	70.8	67.6	65.7	64.4	62.9	61.7
	W062	69.0	73.9	70.3	67.2	64.4	63.2
	W064	74.0	71.0	69.3	68.0	66.6	65.4
	W066	70.8	71.1	68.6	66.0	63.0	61.7

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Existing CN (ARC=2)	Calibrated Existing Conditions (Year 2010) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Westland Run	W068	70.4	67.2	65.3	64.0	62.5	61.3
	W070	69.8	66.5	64.6	63.2	61.8	60.5

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Brush Run near Canonsburg	W092	78.9	76.7	75.1	72.9	70.3	69.3
	W094	78.1	75.5	73.9	72.7	71.4	70.4
	W096	77.3	74.4	72.8	70.4	67.6	66.5
	W098	78.0	75.3	73.7	72.5	71.2	70.2
	W100	79.7	77.0	75.3	73.1	70.4	69.4
Brush Run near Thompsonville	W190	75.6	71.7	66.3	64.9	63.4	62.1
	W192	74.3	71.3	69.6	68.3	66.9	65.8
	W194	73.7	72.6	68.2	66.9	65.6	64.4
	W196	75.8	72.1	67.1	65.8	64.3	63.1
	W198	76.9	72.4	67.3	66.0	64.6	63.4
	W200	73.3	71.2	66.1	64.8	63.3	62.2
	W202	76.8	74.0	72.3	71.1	69.8	68.7
Catfish Creek	W020	71.5	70.7	68.2	65.6	62.5	61.2
	W022	73.0	71.2	68.8	66.1	63.0	61.6
	W024	80.4	73.1	71.3	68.5	65.1	64.2
	W026	82.7	80.5	79.1	78.1	77.0	76.1
	W028	79.8	77.3	75.8	74.7	73.5	72.5
Chartiers Creek	W002	71.5	68.4	66.5	65.2	63.8	62.6
	W004	70.7	75.8	73.6	70.1	67.7	66.6
	W006	69.0	68.6	64.1	59.2	56.0	53.9
	W008	72.3	69.2	67.4	66.1	64.7	63.5
	W010	78.4	75.8	74.2	73.0	71.8	70.7
	W012	68.7	73.2	67.6	64.7	61.1	59.3
	W014	73.2	71.6	69.4	66.8	63.8	62.5
	W016	71.8	70.7	68.1	65.3	62.0	60.4
	W018	73.4	70.3	68.5	67.3	65.9	64.7
	W030	72.1	71.5	69.2	66.7	63.7	62.3
	W032	72.1	73.1	70.7	68.4	65.8	64.7
	W040	72.9	71.8	69.7	67.2	64.1	62.9
	W042	76.6	73.9	72.2	71.0	69.7	68.6
	W044	78.6	74.0	72.5	70.0	67.1	66.1
	W046	77.5	76.0	74.0	71.7	68.9	67.6
	W048	84.6	79.8	77.8	75.3	72.2	71.0
	W050	78.8	81.0	78.6	76.9	74.8	73.9
	W052	74.7	73.2	71.7	69.4	66.8	65.7
	W054	82.5	81.8	80.1	78.1	75.7	74.6
	W090	83.6	81.4	80.1	79.2	78.1	77.2
	W102	84.4	81.7	80.0	77.9	75.3	74.3
	W104	87.0	85.2	84.1	83.3	82.4	81.7
	W188	79.3	80.7	76.7	75.6	74.5	73.4
	W204	72.6	71.9	67.6	66.3	65.0	63.8
	W256	71.6	68.5	66.6	65.3	63.9	62.7
	W276	71.9	72.4	68.0	66.9	65.6	64.5
	W342	70.4	73.6	68.1	66.9	65.7	64.7

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Chartiers Creek	W344	71.0	72.5	67.4	66.1	64.6	63.5
	W346	73.5	72.8	68.9	67.6	66.3	65.2
	W348	70.9	67.7	65.9	64.5	63.1	61.9
	W350	72.3	71.7	67.0	65.7	64.4	63.2
	W352	71.5	74.3	69.6	68.6	67.6	66.6
	W354	73.9	71.4	66.4	65.1	63.8	62.7
	W356	74.0	71.0	69.3	68.0	66.6	65.5
	W358	73.5	73.1	70.6	67.9	64.6	63.1
	W360	70.7	70.5	67.8	65.2	62.0	60.8
	W362	70.8	67.6	65.8	64.4	63.0	61.8
	W364	72.5	69.4	67.6	66.3	64.8	63.7
	W366	73.0	69.9	68.1	66.8	65.4	64.3
	W368	83.8	81.6	80.3	79.4	78.3	77.5
	W370	76.8	72.8	70.7	67.9	64.5	63.2
	W372	79.0	76.4	74.8	73.7	72.5	71.4
	W374	79.5	77.0	75.4	74.3	73.1	72.1
	W376	78.1	75.4	73.8	72.6	71.4	70.3
	W378	77.2	74.5	72.8	71.7	70.4	69.3
	W380	76.7	73.9	72.2	71.0	69.7	68.6
	W382	81.9	79.6	78.2	77.1	76.0	75.1
	W384	79.5	76.9	75.4	74.3	73.0	72.0
	W386	77.1	74.3	72.7	71.5	70.2	69.1
	W388	86.9	85.1	84.0	83.2	82.3	81.5
	W390	80.1	77.5	76.1	74.0	71.5	70.5
	W392	80.9	78.5	77.0	76.0	74.8	73.8
	W394	76.2	73.4	71.7	70.5	69.2	68.0
	W396	80.1	73.9	71.9	69.1	65.8	64.7
	W398	84.3	76.1	74.8	72.3	69.3	69.3
	W400	86.2	85.4	84.3	82.8	81.1	80.4
	W402	82.0	79.7	78.3	77.3	76.2	75.2
	W404	75.2	72.8	68.6	67.6	66.4	65.4
	W406	75.6	72.7	71.0	69.8	68.4	67.3
	W408	72.7	74.2	69.9	68.8	67.7	66.7
	W410	74.6	71.7	66.7	65.3	63.8	62.7
	W412	77.5	74.7	73.1	71.9	70.6	69.6
	W414	72.3	69.2	67.4	66.1	64.7	63.5
	W416	76.2	68.0	57.7	57.6	57.4	57.4
	W418	74.4	71.5	69.7	68.4	67.1	65.9
	W420	75.8	72.9	71.2	70.0	68.6	67.5
	W422	76.9	74.1	72.5	71.3	70.0	68.9
	W424	75.8	72.9	71.2	70.0	68.7	67.5
	W426	84.0	81.9	80.6	79.7	78.6	77.8
	W428	85.0	83.0	81.8	80.9	79.9	79.1
	W430	77.5	74.8	73.1	72.0	70.7	69.6

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Chartiers Creek	W432	75.8	72.7	68.5	67.5	66.4	65.5
	W434	74.6	71.7	69.9	68.7	67.3	66.2
	W436	72.8	71.9	67.7	66.6	65.5	64.3
	W438	75.7	72.8	71.1	69.9	68.6	67.4
	W440	71.8	73.3	68.9	67.8	66.7	65.7
	W442	73.8	72.4	68.0	66.9	65.7	64.7
	W444	80.9	78.5	77.1	76.0	74.8	73.9
Chartiers Run	W056	70.7	70.7	68.2	65.6	62.6	61.1
	W058	72.2	70.6	68.1	65.3	62.1	60.7
	W072	70.8	73.3	70.2	67.9	65.2	64.0
	W078	72.1	72.6	70.1	67.5	64.4	63.0
	W080	73.3	73.2	71.4	69.0	66.3	65.2
	W082	68.5	65.1	63.2	61.8	60.3	59.1
	W084	71.7	71.7	69.6	67.2	64.4	63.1
	W086	73.2	72.4	70.7	68.4	65.8	64.8
	W088	82.3	80.0	78.6	77.6	76.5	75.6
Coal Run	W206	68.5	74.2	68.1	66.7	65.1	64.0
	W208	71.6	71.9	69.3	68.2	67.1	66.1
Dolphin Run	W226	69.3	69.8	68.0	65.5	62.7	59.3
Fishing Run	W224	67.2	70.0	68.5	65.8	63.6	60.4
Georges Run	W034	71.8	72.6	70.2	67.7	64.8	63.6
	W036	72.6	73.4	71.4	69.1	66.4	65.3
	W038	76.0	72.1	70.1	67.5	64.4	63.2
Graesers Run	W266	73.0	72.0	67.3	66.0	64.6	63.4
Half Crown Run	W288	72.7	70.7	67.6	65.1	62.2	59.6
	W290	72.2	71.3	68.2	65.7	62.7	60.0
	W292	69.7	70.5	66.6	63.8	60.4	57.7
	W294	73.2	70.9	68.0	65.4	62.3	59.6
	W296	74.9	71.9	70.2	68.9	67.6	66.4
	W298	72.3	70.7	67.7	65.1	62.1	59.6
	W300	73.2	71.3	68.5	66.0	63.2	60.6
	W302	70.2	66.9	65.1	63.7	62.2	61.0
	W304	72.4	69.3	67.5	66.2	64.8	63.6
	W306	68.5	65.2	63.3	61.9	60.4	59.2
	W308	72.7	69.6	67.8	66.5	65.1	63.9
	W310	68.3	64.9	63.0	61.6	60.1	58.9
	W312	70.3	67.1	65.2	63.8	62.4	61.1
Little Chartiers Creek	W108	74.8	79.3	75.8	73.7	71.9	70.9
	W110	71.7	70.8	68.3	66.4	64.3	63.1
	W112	73.1	76.7	72.8	71.2	69.4	68.1
	W114	70.8	72.6	69.7	68.1	66.3	65.3
	W116	69.7	74.5	70.5	68.4	66.6	65.3
	W118	68.7	65.4	63.5	62.1	60.6	59.3
	W120	78.4	77.3	75.5	74.0	72.3	71.2

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Little Chartiers Creek	W122	77.2	74.5	72.8	71.7	70.4	69.3
	W124	76.8	78.9	76.3	75.0	73.4	72.6
	W126	68.9	65.6	63.7	62.3	60.9	59.6
	W128	69.4	74.4	71.7	68.9	67.3	66.2
	W130	64.7	61.2	59.2	57.7	56.2	54.9
	W132	71.0	71.0	68.7	66.9	64.9	63.8
	W134	70.1	73.9	70.4	68.7	67.0	66.0
	W136	73.8	72.0	69.9	68.2	66.3	65.4
	W138	69.7	74.2	70.3	68.3	66.3	65.2
	W140	75.3	72.4	70.7	69.4	68.1	67.0
	W142	72.0	74.2	71.8	70.4	68.9	68.0
	W144	71.7	74.1	71.3	69.9	68.2	67.2
	W146	75.8	75.0	73.0	71.5	69.8	68.8
	W148	76.6	72.8	69.5	67.3	64.6	63.2
	W150	79.3	76.9	74.6	72.8	70.8	69.6
	W152	75.1	72.2	70.5	69.3	67.9	66.8
	W154	81.6	78.9	77.3	75.9	74.3	73.2
	W156	72.3	76.9	73.3	71.2	69.4	68.2
	W158	69.0	72.7	68.2	66.4	64.3	62.9
	W160	76.4	73.6	71.9	70.7	69.4	68.3
	W162	68.6	73.7	70.4	67.8	65.9	64.7
	W164	81.7	79.3	77.9	76.9	75.8	74.8
	W166	71.5	72.7	70.4	68.8	67.1	66.1
	W168	70.1	75.7	74.6	72.2	69.8	68.9
	W170	82.9	80.7	79.3	78.4	77.3	76.4
	W172	78.6	76.0	74.4	73.3	72.0	71.0
	W174	74.1	71.1	69.4	68.1	66.7	65.5
	W176	75.1	73.7	72.4	71.2	69.8	69.0
	W178	89.8	88.3	87.4	86.8	86.0	85.4
	W180	82.4	80.1	78.8	77.8	76.7	75.7
	W182	75.5	72.7	71.0	69.7	68.4	67.3
	W184	76.9	72.4	70.6	69.0	67.1	66.2
	W186	78.4	75.8	74.2	73.0	71.8	70.7
McLaughlin Run	W264	73.6	71.2	65.9	64.5	62.9	61.7
	W268	74.4	72.1	67.4	66.1	64.7	63.6
	W270	75.4	70.8	63.4	61.1	58.5	56.6
Millers Run	W210	70.8	69.8	68.4	66.1	63.4	59.9
	W212	70.8	68.8	66.6	63.8	60.4	56.3
	W214	75.1	72.0	70.1	67.5	64.4	60.2
	W216	79.2	75.6	73.9	71.4	68.3	64.5
	W218	69.2	69.1	67.0	64.3	61.1	57.5
	W220	69.3	69.6	67.9	65.5	62.7	59.3
	W222	70.7	67.4	65.6	64.2	62.8	61.6
	W228	69.1	70.2	68.9	66.7	64.1	61.0

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Millers Run	W230	72.2	68.1	65.6	62.6	59.0	54.5
	W232	69.8	68.6	66.4	63.6	60.3	56.4
	W234	74.9	71.9	70.2	68.9	67.6	66.4
	W236	78.4	75.8	74.2	73.1	71.8	70.8
	W238	76.8	70.9	68.8	65.9	62.4	61.0
	W240	79.9	77.4	75.9	74.8	73.6	72.6
	W242	75.3	72.6	70.9	68.4	65.5	61.7
	W244	68.9	69.2	66.9	64.3	61.1	57.5
	W246	75.4	72.5	70.8	69.5	68.2	67.0
	W248	69.7	70.0	68.3	66.0	63.2	59.8
	W250	70.0	66.7	64.8	63.4	62.0	60.8
Opossum Run	W106	70.9	73.8	70.7	69.3	67.7	66.6
Painters Run	W258	71.2	73.0	68.1	66.9	65.5	64.5
	W260	69.6	72.8	66.5	65.1	63.6	62.3
	W262	71.7	73.2	68.5	67.3	66.0	65.0
	W272	74.6	71.6	69.9	68.6	67.2	66.1
Pink Run	W286	69.1	65.8	63.9	62.5	61.0	59.8
Pinkertons Run	W314	71.9	70.5	67.2	64.5	61.2	58.6
Plum Run	W074	74.1	72.0	69.7	67.0	63.9	62.5
	W076	74.1	72.2	70.3	67.8	64.9	63.8
Robb Run	W282	74.5	70.9	67.7	65.0	61.8	59.1
Robinson Run	W278	74.9	70.6	67.1	64.2	60.8	57.6
	W280	72.8	71.1	68.1	65.5	62.5	60.2
	W284	69.6	71.0	67.0	64.3	61.2	58.4
	W316	71.2	68.0	66.2	64.9	63.4	62.2
	W320	72.7	70.5	67.3	64.7	61.5	58.8
	W322	70.6	69.6	65.7	62.8	59.3	56.3
	W324	70.0	66.8	64.9	63.5	62.1	60.8
	W326	74.4	71.4	69.7	68.4	67.0	65.9
	W328	70.0	70.5	66.9	64.2	61.1	58.5
	W330	69.4	66.1	64.2	62.8	61.3	60.1
	W332	68.3	72.0	68.3	66.0	63.3	61.2
	W334	70.7	71.2	68.0	65.5	62.5	60.0
	W336	69.3	66.0	64.1	62.7	61.2	60.0
	W338	70.1	73.1	69.3	67.0	64.3	61.9
	W340	71.6	70.5	67.4	64.8	61.9	59.4
Scotts Run	W318	68.5	72.7	69.3	67.0	64.9	62.9
Scrubgrass Run	W274	71.6	73.3	68.7	67.5	66.2	65.2
Thoms Run	W252	72.7	70.7	65.2	63.7	62.0	60.6
	W254	71.5	71.0	66.0	64.6	63.1	61.9
Westland Run	W060	70.8	67.6	65.7	64.4	62.9	61.7
	W062	69.0	73.9	70.3	67.2	64.4	63.2
	W064	74.0	71.0	69.3	68.0	66.6	65.4
	W066	70.8	71.1	68.6	66.0	63.0	61.7

Hydrologic Parameters for Chartiers Creek HEC-HMS Model

Subwatershed Name	Subbasin	Future CN (ARC=2)	Calibrated Future Conditions (Year 2020) Curve Numbers				
			2-Year	10-Year	25-Year	50-Year	100-Year
Westland Run	W068	70.5	67.2	65.4	64.0	62.5	61.3
	W070	69.8	66.5	64.6	63.2	61.8	60.5

Hydrologic Results for Chartiers Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
1	J1088	1259328.4	313652.1	3.12	330	728	930	1,015	1,236	330	728	930	1,015	1,236
2	O25	1274450.0	312467.9	1.30	159	353	451	493	603	159	353	451	493	603
3	J1083	1270806.3	312741.1	3.42	425	924	1,173	1,276	1,574	425	924	1,173	1,276	1,574
4	P33-6	1267891.2	316293.8	4.22	500	1,034	1,311	1,444	1,762	500	1,034	1,311	1,444	1,762
5	J4	1255866.8	324856.7	1.94	209	462	594	657	795	209	462	594	657	795
6	J1201	1259783.8	331324.4	6.25	611	1,283	1,642	1,827	2,231	611	1,283	1,642	1,827	2,230
7	J1206	1267162.5	332417.5	2.11	232	509	650	715	873	232	509	650	715	873
8	P38	1278367.1	323945.8	1.58	207	449	559	589	715	525	934	1,136	1,234	1,446
9	J1310	1262152.3	360201.3	1.64	152	376	536	659	804	152	376	536	659	804
10	O29	1263063.2	355191.1	2.83	261	601	826	981	1,199	261	601	826	981	1,199
11	J1301	1265158.4	352822.7	5.01	460	961	1,264	1,468	1,795	460	961	1,264	1,468	1,795
12	J2	1276818.5	351547.4	2.43	268	581	738	805	978	268	581	738	805	978
13	J1254	1256868.8	349907.7	4.59	459	990	1,266	1,385	1,685	497	1,056	1,346	1,475	1,788
14	J1234	1262061.2	346719.4	7.33	661	1,413	1,807	1,986	2,419	715	1,505	1,919	2,112	2,564
15	J1244	1266433.7	348085.8	13.71	1,153	2,457	3,193	3,607	4,402	1,208	2,551	3,307	3,735	4,549
16	J1223	1273630.2	344715.3	16.83	711	1,547	2,061	2,365	2,933	733	1,593	2,118	2,430	3,011
17	J1229	1281555.4	343166.7	22.36	882	1,938	2,614	3,012	3,791	905	1,990	2,680	3,086	3,881
18	J1298	1281464.3	356011.0	2.44	292	651	833	922	1,130	430	874	1,100	1,222	1,472
19	J1283	1285199.2	353278.2	4.13	470	1,037	1,364	1,565	1,907	684	1,387	1,791	2,050	2,462
20	J1080	1286838.9	311283.6	2.99	332	741	1,003	1,178	1,439	523	1,050	1,381	1,608	1,928
21	J1091	1290573.8	313743.2	5.40	578	1,224	1,674	1,984	2,422	915	1,755	2,322	2,720	3,260
22	J1111	1292395.6	318024.6	7.75	816	1,679	2,292	2,719	3,325	1,240	2,347	3,110	3,651	4,442
23	J1126	1294126.4	318844.5	9.66	775	1,595	2,200	2,635	3,261	1,117	2,173	2,927	3,501	4,315
24	J1612	1299091.1	318115.7	0.00	-	-	-	-	-	-	-	-	-	-
25	J1114	1299318.8	318115.7	12.01	586	1,125	1,509	1,811	2,249	749	1,402	1,879	2,269	2,847
26	J1159	1298316.8	330686.7	3.65	443	886	1,185	1,396	1,708	454	903	1,205	1,419	1,735
27	J5	1302416.0	301809.8	2.84	337	603	778	916	1,104	436	754	960	1,125	1,341
28	J1070	1302780.4	307639.9	5.74	571	1,030	1,360	1,607	1,945	684	1,211	1,582	1,864	2,240
29	J1075	1302324.9	309097.4	7.77	680	1,236	1,638	1,945	2,399	865	1,527	2,003	2,372	2,888
30	J1105	1301869.5	316840.4	21.62	1,293	2,488	3,339	4,011	4,985	1,614	3,044	4,073	4,910	6,093
31	J1121	1302233.8	318389.0	22.97	1,250	2,352	3,133	3,753	4,651	1,536	2,841	3,773	4,536	5,620
32	J1143	1301960.6	324947.8	25.53	1,097	1,971	2,559	3,014	3,672	1,299	2,282	2,951	3,496	4,357
33	J1162	1301140.7	330868.9	31.16	1,285	2,340	3,056	3,614	4,439	1,496	2,674	3,483	4,145	5,177
34	J1165	1302507.1	332964.1	33.23	1,349	2,466	3,233	3,836	4,729	1,564	2,809	3,674	4,384	5,479

Hydrologic Results for Chartiers Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
35	J1195	1304511.2	335970.2	36.09	1,287	2,333	3,026	3,555	4,309	1,472	2,613	3,376	3,978	4,876
36	J1198	1301687.3	339887.3	38.20	1,319	2,391	3,102	3,645	4,415	1,507	2,676	3,457	4,073	4,987
37	J1226	1301687.3	346628.3	44.22	1,441	2,633	3,422	4,017	4,866	1,666	2,971	3,839	4,516	5,518
38	J1259	1320088.3	352640.5	3.32	365	620	892	1,099	1,347	365	620	892	1,099	1,347
39	J1269	1314622.7	354098.0	5.86	614	1,074	1,534	1,888	2,308	614	1,074	1,534	1,888	2,308
40	J1288	1311343.3	357377.4	9.73	927	1,626	2,310	2,836	3,461	927	1,626	2,310	2,836	3,461
41	J1088	1259328.4	313652.1	3.12	330	728	930	1,015	1,236	330	728	930	1,015	1,236
42	J1358	1285654.7	377600.4	2.92	231	569	741	819	858	237	579	754	834	874
43	O30	1263883.1	372863.5	1.22	107	267	341	360	344	107	267	341	360	344
44	J1345	1270441.9	371679.2	4.01	325	785	1,011	1,100	1,109	325	785	1,011	1,100	1,109
45	J1332	1274723.3	369310.8	6.57	525	1,225	1,599	1,776	1,853	525	1,225	1,599	1,776	1,853
46	J1335	1276545.2	369766.3	8.84	685	1,602	2,078	2,304	2,384	738	1,689	2,181	2,422	2,519
47	P62	1279460.2	368126.6	10.19	764	1,787	2,313	2,555	2,695	837	1,910	2,460	2,722	2,884
48	J1327	1285017.0	368582.0	12.33	850	1,970	2,546	2,813	2,976	969	2,150	2,760	3,055	3,255
49	J1348	1289571.7	372134.7	17.70	1,113	2,589	3,356	3,721	3,968	1,294	2,872	3,691	4,099	4,402
50	J1361	1294855.2	378146.9	22.03	1,293	2,959	3,819	4,246	4,542	1,491	3,271	4,191	4,667	5,020
51	J1364	1295857.2	378420.2	24.15	1,390	3,160	4,077	4,536	4,859	1,596	3,490	4,472	4,983	5,366
52	J1371	1305331.1	381153.1	27.51	1,491	3,354	4,318	4,809	5,159	1,706	3,727	4,778	5,336	5,759
53	J1108	1265067.3	318206.8	23.41	1,042	2,247	2,886	3,205	3,921	1,063	2,280	2,941	3,312	4,100
54	J1376	1323458.8	383339.3	2.77	312	500	715	880	1,076	312	500	715	880	1,076
55	J1338	1323003.4	371314.9	3.57	345	604	866	1,065	1,308	345	604	866	1,065	1,308
56	J3	1318357.6	377053.8	5.49	527	918	1,311	1,612	1,981	527	918	1,311	1,612	1,981
57	J1379	1314896.0	384068.1	12.19	968	1,572	2,217	2,704	3,312	968	1,572	2,217	2,704	3,312
58	J1464	1273721.3	399007.6	3.09	295	623	811	902	1,018	295	623	811	902	1,018
59	J1472	1276909.6	400829.5	5.76	514	1,078	1,403	1,561	1,758	514	1,078	1,403	1,561	1,758
60	J1494	1280553.4	404199.9	7.46	601	1,242	1,614	1,799	2,033	601	1,242	1,614	1,799	2,033
61	J1505	1283104.0	405566.4	9.49	708	1,463	1,908	2,135	2,422	708	1,463	1,908	2,135	2,422
62	J1502	1285836.8	404928.7	10.84	781	1,611	2,109	2,384	2,726	781	1,611	2,109	2,384	2,726
63	J1489	1288296.4	401193.8	12.51	855	1,755	2,299	2,600	2,983	855	1,755	2,299	2,600	2,983
64	J1396	1263063.2	386163.2	2.76	260	541	694	752	826	260	541	694	752	826
65	P56	1284652.6	346172.8	79.06	2,314	4,664	6,049	6,878	8,396	2,498	5,019	6,522	7,434	9,057
66	J1391	1272901.4	385343.4	7.81	571	1,149	1,476	1,608	1,792	571	1,149	1,476	1,608	1,792
67	J1403	1276909.6	386892.0	9.65	653	1,296	1,663	1,820	2,037	653	1,296	1,663	1,820	2,037
68	J1430	1283104.0	392175.5	13.17	798	1,549	1,985	2,180	2,446	798	1,549	1,985	2,180	2,446

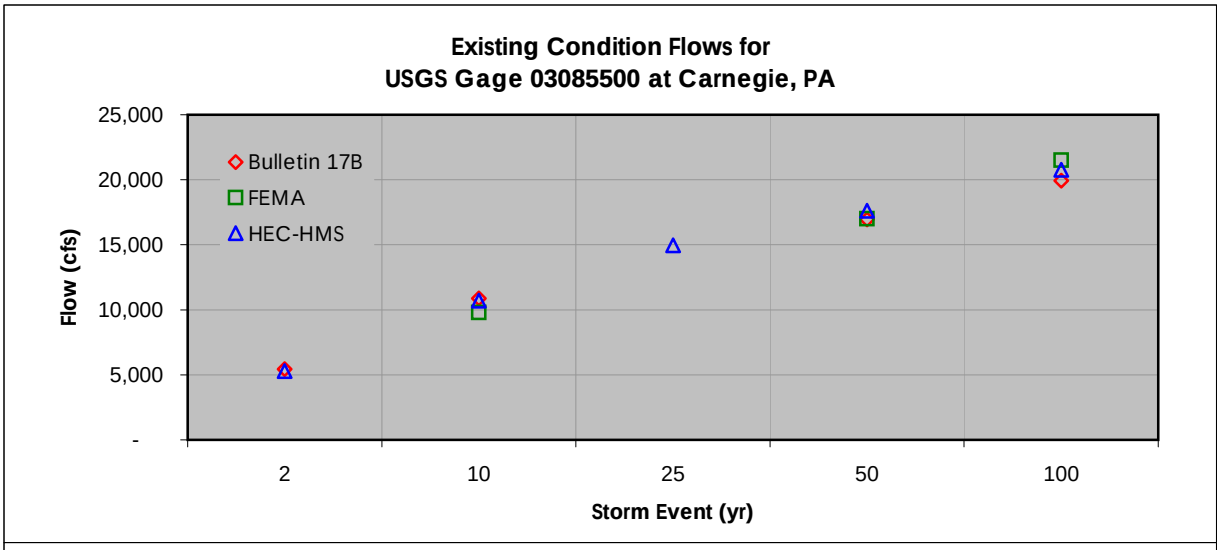
Hydrologic Results for Chartiers Creek HEC-HMS Model

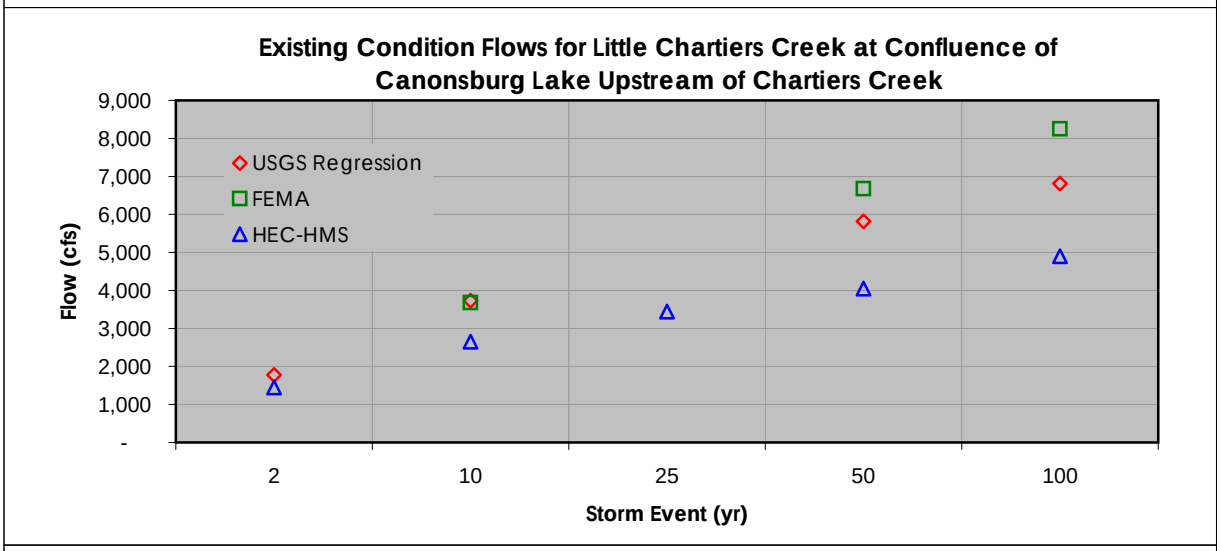
Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
69	J1440	1286930.0	394543.9	14.89	825	1,622	2,094	2,324	2,657	825	1,622	2,094	2,324	2,657
70	J1455	1290573.8	397003.5	28.99	1,697	3,456	4,522	5,101	5,858	1,697	3,456	4,522	5,101	5,858
71	J1461	1297041.5	401467.1	33.76	1,851	3,726	4,865	5,489	6,305	1,851	3,726	4,865	5,489	6,305
72	J1477	1298772.3	401467.1	34.78	1,872	3,766	4,919	5,555	6,384	1,872	3,766	4,919	5,555	6,384
73	J1458	1306606.4	396730.2	38.64	1,962	3,893	5,091	5,761	6,626	1,962	3,893	5,091	5,761	6,626
74	J1514	1313165.2	405839.6	4.66	422	748	1,059	1,297	1,583	422	748	1,059	1,297	1,583
75	J6	1257233.2	294431.2	2.89	284	621	788	845	1,028	389	797	1,000	1,081	1,299
76	USGS 03085217	1258235.2	297528.4	4.04	382	834	1,061	1,144	1,399	495	1,028	1,298	1,407	1,703
77	J1050	1258781.8	299350.3	5.48	477	1,070	1,401	1,564	1,917	589	1,266	1,642	1,832	2,228
78	J1058	1262516.7	301809.8	7.42	351	768	1,016	1,177	1,475	396	859	1,137	1,317	1,653
79	J1053	1264611.8	303085.1	9.77	417	889	1,146	1,318	1,641	466	986	1,272	1,464	1,826
80	J1063	1264885.1	305909.1	11.71	473	994	1,286	1,474	1,835	537	1,111	1,436	1,645	2,045
81	J1098	1262607.8	314471.9	18.04	539	1,054	1,329	1,497	1,812	611	1,181	1,491	1,683	2,061
82	J1133	1263609.8	321304.0	28.49	1,268	2,678	3,482	3,932	4,850	1,283	2,717	3,565	4,057	5,024
83	J1108	1265067.3	318206.8	23.41	1,042	2,247	2,886	3,205	3,921	1,063	2,280	2,941	3,312	4,100
84	J1140	1264611.8	324856.7	36.52	1,925	4,000	5,156	5,800	7,110	1,939	4,051	5,247	5,921	7,267
85	J1148	1268711.1	327771.7	40.05	1,839	3,677	4,704	5,288	6,425	1,858	3,745	4,802	5,412	6,573
86	J1151	1270806.3	328500.5	42.02	1,912	3,814	4,876	5,481	6,658	1,932	3,882	4,973	5,604	6,805
87	J1156	1274176.8	329775.8	43.79	1,725	3,473	4,441	5,000	6,067	1,765	3,556	4,552	5,135	6,224
88	J1172	1279460.2	331779.9	47.43	1,628	3,229	4,109	4,623	5,583	1,707	3,353	4,267	4,810	5,794
89	J1183	1280280.1	333692.9	49.99	1,694	3,354	4,270	4,807	5,806	1,772	3,477	4,426	4,992	6,015
90	J1188	1280371.2	333966.1	52.84	1,757	3,473	4,420	4,976	6,009	1,862	3,730	4,822	5,471	6,567
91	J1211	1282466.4	342529.0	77.43	2,282	4,604	5,968	6,781	8,279	2,458	4,947	6,426	7,320	8,920
92	J1214	1283104.0	343257.8	78.37	2,301	4,641	6,017	6,840	8,350	2,485	4,994	6,487	7,392	9,007
93	P56	1284652.6	346172.8	79.06	2,314	4,664	6,049	6,878	8,396	2,498	5,019	6,522	7,434	9,057
94	J1241	1291849.1	347994.7	86.98	2,455	4,931	6,399	7,288	8,916	2,675	5,342	6,954	7,949	9,728
95	J1249	1295857.2	353915.8	90.86	2,523	5,057	6,563	7,477	9,153	2,769	5,509	7,175	8,204	10,050
96	J1264	1302324.9	353004.9	46.60	1,455	2,657	3,451	4,050	4,903	1,676	2,988	3,860	4,538	5,535
97	J1272	1302324.9	353369.3	138.75	3,918	7,561	9,814	11,283	13,719	4,406	8,365	10,807	12,444	15,114
98	J1293	1304693.4	358652.7	142.48	3,977	7,660	9,948	11,445	13,918	4,486	8,492	10,975	12,644	15,354
99	J1315	1309703.6	361841.0	154.54	4,143	7,924	10,297	11,862	14,421	4,656	8,767	11,345	13,088	15,904
100	J1322	1308337.2	366942.3	156.79	4,167	7,960	10,341	11,915	14,480	4,681	8,803	11,393	13,145	15,969
101	J7	1309703.6	372408.0	159.72	4,193	7,989	10,374	11,954	14,521	4,709	8,835	11,435	13,196	16,025
102	J1351	1310705.6	379057.9	165.08	4,262	8,100	10,521	12,129	14,732	4,781	8,950	11,589	13,380	16,246

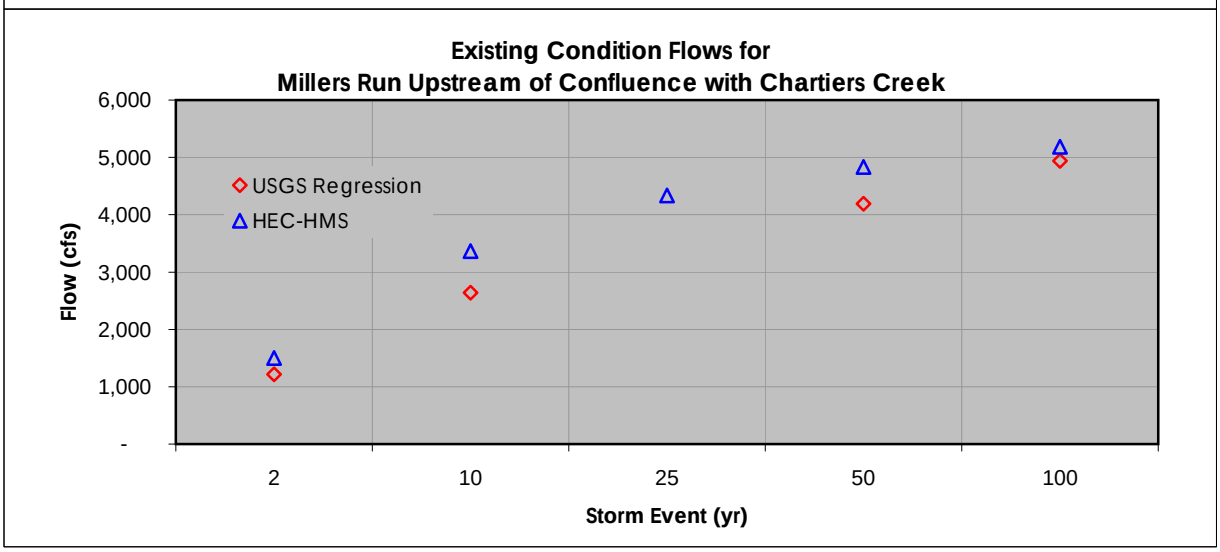
Hydrologic Results for Chartiers Creek HEC-HMS Model

Discharge Point	HEC-HMS Node	Coordinates		Cumulative Area (mi^2)	2010 Discharges with Existing SWM					2020 Discharges with No Future SWM				
		x	y		2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
103	J1384	1308246.1	384887.9	193.90	4,548	8,663	11,233	12,942	15,641	5,111	9,575	12,392	14,304	17,292
104	J1406	1308337.2	387256.4	197.49	4,586	8,726	11,318	13,043	15,763	5,151	9,641	12,482	14,411	17,421
105	J1411	1314349.4	389989.2	199.48	4,603	8,755	11,357	13,092	15,824	5,169	9,671	12,523	14,463	17,486
106	J1416	1315715.8	390353.6	212.44	4,772	9,027	11,716	13,518	16,335	5,345	9,954	12,902	14,914	18,031
107	J1423	1317173.3	392631.0	214.44	4,767	9,034	11,730	13,538	16,362	5,348	9,969	12,930	14,953	18,080
108	J1437	1317446.6	395181.6	216.02	4,764	9,038	11,739	13,553	16,380	5,351	9,980	12,950	14,983	18,116
109	J1445	1313985.0	396548.0	256.38	5,297	10,753	15,019	17,702	20,866	5,916	12,480	17,042	19,946	23,468
110	J1452	1314622.7	397276.8	257.51	5,304	10,738	14,989	17,664	20,825	5,926	12,450	16,997	19,894	23,414
111	USGS 03085500	1314987.1	397459.0	257.53	5,302	10,714	14,953	17,619	20,774	5,925	12,420	16,956	19,844	23,359
112	J1469	1317355.5	400191.8	263.62	5,338	10,682	14,878	17,526	20,692	5,976	12,323	16,819	19,689	23,217
113	J1480	1320179.4	403106.8	266.41	5,337	10,530	14,655	17,256	20,401	5,987	12,126	16,550	19,382	22,894
114	J1497	1318539.7	404928.7	268.14	5,347	10,526	14,641	17,247	20,402	6,000	12,111	16,526	19,367	22,891
115	USGS 03085550	1319815.1	411578.6	269.57	5,356	10,543	14,660	17,274	20,440	6,012	12,124	16,542	19,391	22,928
116	J1521	1318448.6	413127.2	271.51	5,361	10,434	14,461	17,029	20,164	6,021	11,978	16,299	19,103	22,613
117	J9	1318995.2	419230.5	273.42	5,379	10,483	14,524	17,106	20,255	6,040	12,025	16,361	19,177	22,701
118	J1532	1325554.0	420323.7	276.23	5,354	10,211	14,038	16,557	19,727	6,032	11,674	15,837	18,594	22,136
119	J_Outlet_Chartiers	1328241.3	420779.1	276.56	5,342	10,206	13,846	16,309	19,465	6,026	11,571	15,619	18,317	21,838

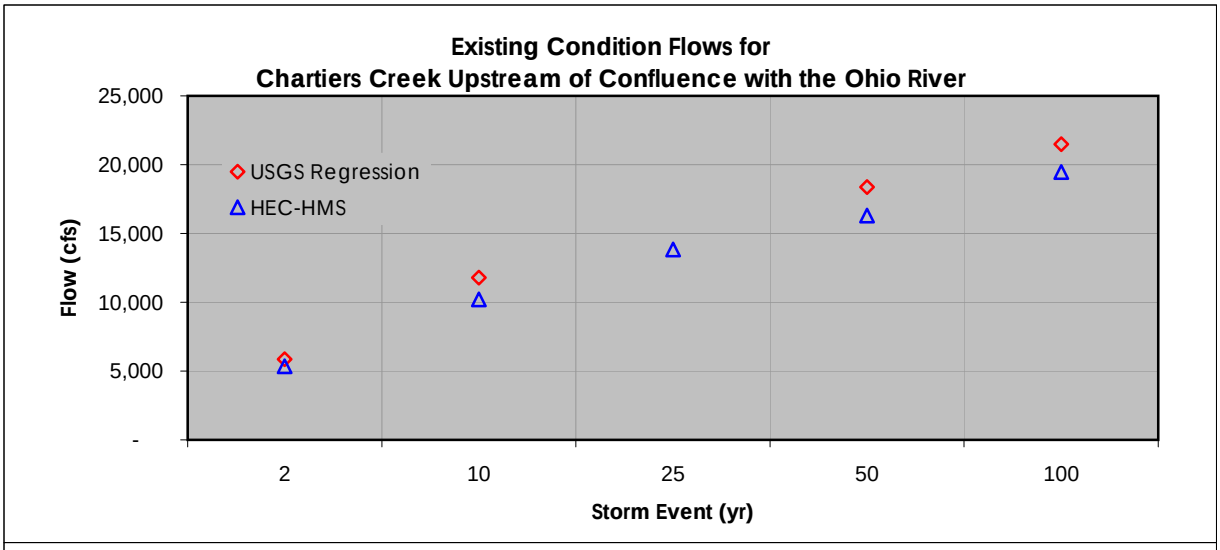
Calibration Results for Chartiers Creek HEC-HMS Model

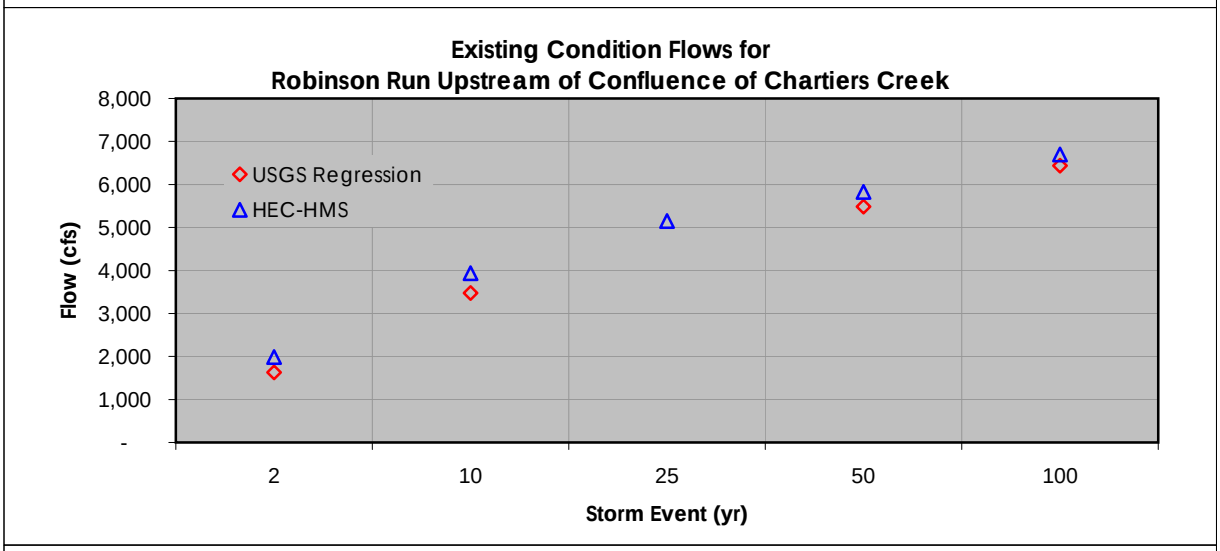


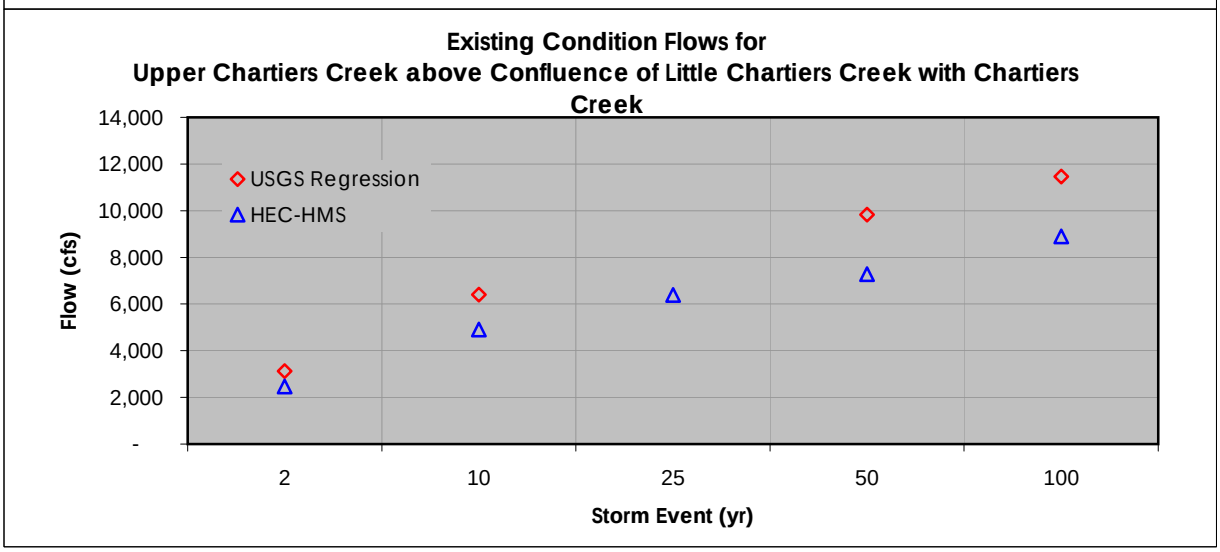




Calibration Results for Chartiers Creek HEC-HMS Model







Appendix B – Supporting Calculations for the Design Example

The *Model Ordinance* has been developed to implement a variety of control standards in order to achieve a holistic approach to stormwater management. The overall design process has been addressed in *Section VIII* of this Plan. The following example calculations have been provided to further clarify the design method. These calculations parallel the calculations that are made on the worksheets provided in the *Pennsylvania Stormwater Best Management Practices Manual* (PA BMP Manual) a copy of which are provided at the back of this appendix.

SUPPORTING CALCULATIONS - DESIGN EXAMPLE 1

NON-STRUCTURAL BMP CREDITS

Protect Sensitive Natural Resources
(Refer to Worksheet 2 & Worksheet 3)

Stormwater Management Area = Total Drainage Area – Protected Area

= 9.78 – 1.31(woods) – 0.37 (minimum disturbance)
= **8.1-Acres**

This is the total area used for pre-development and post-development volume calculations.

Minimum Soil Compaction
(Refer to *Worksheet 3*)

Lawn Area (post development) protected from compaction = 16,165-ft^2

16,165-ft^2 x 1/4" x 1/12 = **337-ft^3**

To be eligible for this credit, areas must not be compacted during construction and be guaranteed to remain protected from compaction. Minimum soil compaction credits for lawn area (Open Space) are applicable for this example because specific measures were utilized to protect the back yard lawn areas of Lots 9 & 10 and this area has been placed in a permanent minimum soil compaction easement. Credits for the meadow area can be applied for areas that are not disturbed during construction and will remain in pre-development vegetated cover condition.

Disconnect Non-Roof Impervious to Vegetated Areas
(Refer to *Worksheet 3*)

Lot Impervious Area = 10 (Lots) x 1,000 (ft^2/lot) = 10,000-ft^2.
10,000-ft^2 x 1/3" x 1/12 = **278-ft^3**

This credit is applied for the impervious surfaces (driveways and sidewalks) which direct runoff to vegetated surfaces and not directly into a stormwater collection system. The 1/3" credit is used because runoff discharges across the lawn area and is received by rain gardens, which

are structures specifically placed to receive and infiltrate runoff. The 1/4" credit would be used for runoff not discharged to a specific infiltration structure or an area that has been protected from soil compaction.

Summation of Non-Structural BMP Credits
= 337-ft^3 + 278-ft^3 = **615-ft^3**

CHANGE IN RUNOFF VOLUME FOR THE 2-YEAR STORM EVENT

(Refer to *Worksheet 4*)

2-year, 24-hour Rainfall Depth = 2.76"

Pre-Development 2-yr Runoff Volume = 5,682 ft^3

Post-Development 2-yr Runoff Volume = 18,281 ft^3

Change in Runoff Volume for the 2-year, 24-hour storm event:

= 18,2813-ft^3 – 5,682-ft^3 = **12,599-ft^3**

This is the volume that must be managed through a combination of non-structural BMP credits and structural BMP credits.

25% LIMIT FOR NON-STRUCTURAL BMP CREDITS

(Refer to *Worksheet 5*)

Per Chapter 8 of the Pennsylvania Stormwater BMP Manual, Non-Structural Credits may be ***no greater than 25%*** *of the total required control volume.*

Check 25% Non-Structural Credit Limit:

= 615-ft^3 / 12,599-ft^3 = **4.9%**

Calculated credits are under the allowable 25% limit for non-structural credits.

STRUCTURAL CONTROL VOLUME REQUIREMENT

(Refer to *Worksheet 5*)

Required Structural BMP infiltration volume:

= Change in Runoff Volume – Non-Structural BMP Credits
= 12,599-ft^3 – 615-ft^3 = **11,984-ft^3**

STRUCTURAL BMP VOLUME CREDITS

The sizing of structural infiltration BMPs is based on two primary criteria:

1. Maximum loading ratios – There are two different loading ratios that are important when determining the size of a structural BMP. These ratios are derived from guidelines found in the *Pennsylvania Stormwater BMP Manual*.
    a. Maximum loading ratio of Impervious Area to Infiltration Area = 5:1
    b. Maximum loading ratio of Total Drainage Area to Infiltration Area = 8:1

2. Expected runoff volume loading – Structural BMPs must be sized to accommodate the runoff volume they are expected to receive from the contributing drainage area. Some of this volume will be removed and the remainder must be safely conveyed through an overflow device. The removed volume, or infiltration volume, is the important component for sizing the infiltration BMP. A good starting point for infiltration volume is to calculate the contributing area runoff volume for the 2-year, 24-hour design storm. This volume may not be suitable for a particular site design, but starting with this volume will usually result in a design that is close to what is appropriate, and it can be adjusted as necessary. Additional design restrictions may exist for certain BMPs, so these should be considered prior to using this sizing method.

Dry Wells
(Example calculations shown for Lot #1; Refer to *Worksheet 5A* for additional calculations)

Surface Area:
Find the minimum dry well surface area for each lot based on the maximum loading ratios.

Maximum impervious area to infiltration area loading ratio = 5:1 (3:1 for Karst areas)
Tributary impervious area = 2,150-ft^2 (typ.)
= 2,150-ft^2 / 5 = **430-ft^2**
= minimum surface area of dry well per impervious loading ratio

Maximum total drainage area to infiltration area loading ratio = 8:1
Total drainage area = 2,590-ft^2 (typ.)
= 2,590-ft^2 / 8 = **324-ft^2**
= minimum surface area of dry well per pervious loading ratio

The larger of the two calculated areas is the total minimum surface area required for each lot. An individual dry well is placed at each of the four major corners of the house to promote distribution of impervious area runoff. However, the total surface area is used throughout the remaining volume credit calculations for simplicity. The surface area of each dry well is calculated below:

Total Minimum Dry Well Surface Area ÷ Number of Dry Wells
=430 ft^2 / 4 = **107.5-ft^2**

Each dry well will be 10' x 11' to meet the minimum surface area requirements.

Volume:
Find the infiltration volume for each dry well based on the expected runoff volume.

Land Use	Soil Type	Area	Area	CN	S	I_a	Runoff Depth$_{2\text{-}yr}$	Runoff Volume$_{2\text{-}yr}$
	(HSG)	(sf)	(acres)			(0.2*S)	(in)	(ft^3)
Open Space (good)	B	110	0.00	61	6.393	1.279	0.28	3
Impervious	B	540	0.01	98	0.204	0.041	2.53	114
TOTAL:		**650**	**0.01**				**2.81**	**116**

Runoff volume = **116-ft^3**

Depth:
Each dry well will be filled with aggregate. The in-place aggregate will have a 40% voids ratio; therefore the volume is divided by the available void space to get a total volume.

Depth = Total Volume / Surface Area

= (116-ft^3 / 0.40) / 110-ft^2 = **2.64-ft or approximately 2'-8"**

An overflow spillway or drain is then sized to convey any runoff that exceeds the design volume to the peak rate management facility.

Rain Gardens
(Example calculations shown for Lot #1; Refer to Worksheet 5A for additional calculations)

Surface Area:
Find the minimum surface area for each rain garden based on the maximum loading ratios.

Maximum impervious area to infiltration area loading ratio = 5:1 (3:1 for Karst areas)
Tributary impervious area = 1,000-ft^2
= 1,000-ft^2 / 5 = **200-ft^2**
= minimum surface area of rain garden per impervious loading ratio

Maximum total drainage area to infiltration area loading ratio = 8:1
Total drainage area = 6,000-ft^2 (typ.)
= 4,775-ft^2 / 8 = **597-ft^2**
= minimum surface area of rain garden per pervious loading ratio

The larger of the two calculated areas is the minimum surface area required for the facility.

Minimum Rain Garden Surface Area = **597-ft^2**

Depth:
Design guidelines, from the *PA BMP Manual*, for rain gardens limit ponding depth within the facility to 12 inches or less. The rain gardens in this example have been designed with a total ponding depth of 12 inches. The overflow outlets are positioned 6 inches above the bottom elevation of the rain gardens and 6 inches of freeboard is provided above the overflow outlets.

Volume:
The total detention volume of the rain garden is calculated by multiplying the surface area of the rain garden by the total depth. The 6 inches of water below the overflow outlet will be infiltrated and the remaining depth is used as short-term retention while flow is regulated through the overflow device. When calculating the infiltration volume, the bottom surface area of the BMP must be used.

Infiltration Volume = Surface Area x Depth
= 700-ft^2 x 0.5-ft = **350-ft^3**

Bioretention
(Refer to *Worksheet 5A* for additional calculations)

Surface Area:
Find the minimum surface area for the bioretention facility based on the maximum loading ratios.

Maximum impervious area to infiltration area loading ratio = 5:1 (3:1 for Karst areas)
Tributary impervious area = 9,700-ft^2 (typ.)
= 9,700-ft^2 / 5 = **1,940-ft^2**
= minimum surface area of Infiltration Trench per impervious loading ratio

Maximum total drainage area to infiltration area loading ratio = 8:1
Total drainage area = 41,400-ft^2
= 41,400-ft^2 / 8 = **5,175-ft^2**
= minimum surface area of Infiltration Trench per pervious loading ratio

The larger of the two calculated areas is the minimum surface area required for the facility.

Minimum Infiltration Trench Surface Area = **5,175-ft^2**

Depth:
The bioretention facility in this example has been designed with a total depth of 18 inches. The overflow outlets are positioned 6 inches above the bottom elevation, and 12 inches of freeboard is provided above the overflow outlets.

Volume:
The total detention volume of the bioretention facility is calculated by multiplying the surface area by the total depth. The 6 inches of water below the overflow outlet will be infiltrated and the remaining depth is used as short-term retention while flow is regulated through the overflow device. When calculating the infiltration volume, the bottom surface area of the BMP must be used.

Infiltration Volume = Surface Area x Depth
= 5,175-ft^2 x 0.5-ft = **2,487.5-ft^3**

STRUCTURAL CONTROL VOLUME REQUIREMENT CHECK

(Refer to *Worksheet 5*)

Check the total structural volume to be certain it is adequate to meet the structural volume requirement.

= Total Structural Volume - Structural Volume Requirement
=14,613-ft^3 – 11,984-ft^3 = 2,629-ft^3

The structural volume requirement has been exceeded by 2,629-ft^3 and no further BMP calculations are necessary.

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Project Name: DESIGN EXAMPLE 1
Project ID: MILL RUN RESIDENTIAL
Owner:
Calculated: Date:
Checked: Date:

WORKSHEET 1. GENERAL SITE INFORMATION

INSTRUCTIONS: Fill out *Worksheet 1* for each watershed

Date: 2/29/2010

Project Name: DESIGN EXAMPLE 1

Municipality: NORTH STRABANE TOWNSHIP

County: WASHINGTON

Total Area (acres): 9.78

Major River Basin: OHIO RIVER BASIN
http://www.dep.state.pa.us/dep/deputate/watermgt/wc/default.htm#newtopics

Watershed: CHARTIERS CREEK

Sub-Basin: OHIO RIVER (from confluence with Allegheny River to Ohio state line)

Nearest Surface Water(s) to Receive Runoff: MILL RUN

Chapter 93 - Designated Water Use: CWF
http://www.pacode.com/secure/data/025/chapter93/chap93toc.html

Impaired according to Chapter 303(d) List? Yes [ ] No [X]
http://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/303d-Report.htm
List Causes of Impairment:

Is project subject to, or part of:

Municipal Separate Storm Sewer System (MS4) Requirements? Yes [ ] No [X]
http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/GeneralPermits/default.htm

Existing or planned drinking water supply? Yes [ ] No [X]

If yes, distance from proposed discharge (miles): _____

Approved Act 167 Plan? Yes [X] No [ ]
http://www.dep.state.pa.us/dep/deputate/watermgt/wc/Subjects/StormwaterManagement/Approved_1.html

Existing River Conservation Plan? Yes [X] No [ ]
http://www.dcnr.state.pa.us/brc/rivers/riversconservation/planningprojects/

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WORKSHEET 2. SENSITIVE NATURAL RESOURCES

INSTRUCTIONS:

1. Provide Sensitive Resources Map according to non-structural BMP 5.4.1 in Chapter 5 of PA Stormwater BMP Manual. This map should identify waterbodies, floodplains, riparian areas, wetlands, woodlands, natural drainage ways, steep slopes, and other sensitive natural areas.

2. Summarize the existing extent of each sensitive resource in the Existing Sensitive Resources Table (below, using Acres). If none present, insert 0.

3. Summarize Total Protected Area as defined under BMPs in Chapter 5.

4. Do not count any area twice. For example, an area that is both a floodplain and a wetland may only be considered once.

EXISTING NATURAL SENSITIVE RESOURCE	MAPPED? yes/no/n/a	TOTAL AREA (Ac.)	PROTECTED AREA (Ac.)
Waterbodies	yes	0.00	
Floodplains	no	0.00	
Riparian Areas	no	0.00	
Wetlands	no	0.00	
Woodlands	yes	2.29	1.31
Natural Drainage Ways	N/A	0.00	
Steep Slopes, 15% - 25%	N/A	0.00	
Steep Slopes, over 25%	N/A	0.00	
Other:	N/A		
Other:	N/A		
TOTAL EXISTING:		**2.29**	**1.31**

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Project Name: DESIGN EXAMPLE 1
Project ID: MILL RUN RESIDENTIAL
Owner:
Calculated: Date:
Checked: Date:

WORKSHEET 3. NON-STRUCTURAL BMP CREDITS

PROTECTED AREA

1.1 Area of Protected Sensitive/Special Value Features (see WS 2)	1.31	Ac.
1.2 Area of Riparian Forest Buffer Protection	0.00	Ac.
3.1 Area of Minimum Disturbance/Reduced Grading	0.37	Ac.
TOTAL	1.68	Ac.

Site Area	*minus*	Protected Area	=	Stormwater Management Area
9.78	-	1.68	=	8.10

VOLUME CREDITS

3.1 Minimum Soil Compaction

Lawn	16,165	ft^2	x 1/4"	x 1/12	=	337 ft^3
Meadow	N/A	ft^2	x 1/3"	x 1/12	=	0 ft^3

3.3 Protect Existing Trees

For Trees within 100 feet of impervious area:

Tree Canopy	N/A	ft^2	x 1/2"	x 1/12	=	0 ft^3

For Trees within 20 feet of impervious area:

Tree Canopy	N/A	ft^2	x 1"	x 1/12	=	0 ft^3

5.1 Disconnect Roof Leaders to Vegetated Areas

For runoff directed to areas protected under 5.8.1 and 5.8.2

Roof Area	N/A	ft^2	x 1/3"	x 1/12	=	0 ft^3

For all other disconnected roof areas

Roof Area	N/A	ft^2	x 1/4"	x 1/12	=	0 ft^3

5.2 Disconnect Non-Roof Impervious to Vegetated Areas

For Runoff directed to areas protected under 5.8.1 and 5.8.2

Impervious Area	10,000	ft^2	x 1/3"	x 1/12	=	278 ft^3

For all other disconnected non-roof impervious areas

Impervious Area	N/A	ft^2	x 1/4"	x 1/12	=	0 ft^3

TOTAL NON-STRUCTURAL VOLUME CREDIT* 615 ft^3

** For use on Worksheet 5*

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Project Name: DESIGN EXAMPLE 1
Project ID: MILL RUN RESIDENTIAL
Owner:
Calculated: Date:
Checked: Date:

WORKSHEET 4. CHANGE IN RUNOFF VOLUME FOR 2-YR STORM EVENT

PROJECT: DESIGN EXAMPLE 1
Drainage Area: 8.10 (acres)
2-Year Rainfall: 2.76 inches *(From NOAA Atlas 14)*

Total Site Area: 9.78 acres
Protected Site Area: 1.68 acres
Stormwater Management Area: 8.10 acres *(From Worksheet 3)*

Existing Conditions:

Land Use	Soil Type (HSG)	Area (sf)	Area (acres)	CN	S	Ia (0.2*S)	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Woods (good)	B	42,500	0.98	55	8.1818	1.6364	0.14	481
Meadow	B	310,255	7.12	58	7.2414	1.4483	0.20	5,201
								-
								-
								-
								-
TOTAL:		352,755	8.10					5,682

Developed Conditions:

Land Use	Soil Type (HSG)	Area (sf)	Area (acres)	CN	S	Ia (0.2*S)	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Meadow	B	54,060	1.24	58	7.2414	1.4483	0.20	906
Open Space (good)	B	243,035	5.58	61	6.3934	1.2787	0.28	5,643
Impervious	B	55,660	1.28	98	0.2041	0.0408	2.53	11,732
								-
								-
								-
TOTAL:		352,755	8.10					18,281

2-Year Volume Increase (ft^3): 12,599

2-Year Volume Increase = Developed Conditions Runoff Volume - Existing Conditions Runoff Volume
= 18,281 - 5,682 = 12,599 ft^3

1. Runoff (in) = $Q = (P - 0.2S)^2 / (P + 0.8S)$ where
   P = 2-Year Rainfall (in)
   S = (1000/ CN)-10

2. Runoff Volume (CF) = Q x Area x 1/12
   Q = Runoff (in)
   Area = Land use area (sq. ft)

Note: Runoff Volume must be calculated for EACH land use type/condition and HSG.
The use of a weighted CN value for volume calculations is not acceptable.

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WORKSHEET 5. STRUCTURAL BMP VOLUME CREDITS

SUB-BASIN: N/A

Check 25% Limit for Non-Structural BMP Credits:		615
	÷	12,599
		4.9%
Required Control Volume (ft^3):		12,599
Allowable Non-structural Volume Credit (ft^3):	-	615
Structural Volume Reqmt (ft^3):		**11,984**

(Required Control Volume minus Non-structural Credit)

Proposed BMP		Area (ft^2)	Infiltration Volume (ft^3)
6.4.1	Porous Pavement		
6.4.2	Infiltration Basin		
6.4.3	Infiltration Bed		
6.4.4	Infiltration Trench		
6.4.5	Rain Garden/Bioretention	11,915	8,827
6.4.6	Dry Well / Seepage Pit	4,400	5,787
6.4.7	Constructed Filter		
6.4.8	Vegetated Swale		
6.4.9	Vegetated Filter Strip		
6.4.10	Berm		
6.5.1	Vegetated Roof		
6.5.2	Capture and Re-use		
6.6.1	Constructed Wetlands		
6.6.2	Wet Pond / Retention Basin		
6.6.3	Dry Extended Detention Basin		
6.6.4	Water Quality Filters		
6.7.1	Riparian Buffer Restoration		
6.7.2	Landscape Restoration / Reforestation		
6.7.3	Soil Amendment		
6.8.1	Level Spreader		
6.8.2	Special Storage Areas		
Other			

Total Structural Volume (ft^3):	14,613
Structural Volume Requirement (ft^3):	11,984
DIFFERENCE:	2,629 *(excess)*

* Complete BMP Design Checklist for each measure proposed
NOTE: Provide supporting Volume Calculations for each Structural BMP

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Project ID: MILL RUN RESIDENTIAL
Owner:
Calculated: Date:
Checked: Date:

WORKSHEET 5.A - INFILTRATION BMP SUPPORTING CALCULATIONS

Instructions: Complete this worksheet for each Point of Interest / Discharge (at a minimum)

Point of Interest / Discharge: *Basin Outfall*
Total Drainage Area to POI: 362,755 ft^2
Total Impervious Area: 55,660 ft^2

Proposed Infiltration BMP(s)	Infiltration Rate: Measured Infilt Rate[1] in/hr	Infiltration Rate: FOS	Infiltration Rate: Design Infilt Rate in/hr	Design Runoff Volume cu. ft.	Infiltration Period: Infilt. Period[2] hrs	Infiltration Period: Active Infilt.[3] hrs	Infiltration Period: Total Infilt Period hrs	Hydraulic Loading: Imperv. Drainage Area Loading: Imperv. DA sq. ft.	Imperv. Drainage Area Loading: % area draining to BMP	Imperv. Drainage Area Loading: Imperv Area Loading Ratio	Imperv. Drainage Area Loading: Imperv Target Area sq. ft.	Total Drainage Area Loading: Total Drainage Area sq. ft.	Total Drainage Area Loading: % area draining to BMP[4]	Total Drainage Area Loading: Total Area Loading Ratio	Total Drainage Area Loading: Total Target Area sq. ft.	Target BMP Area[5] sq. ft.	Actual BMP Area[6] sq. ft.	Computed Infiltration Volume cu. ft.
BMP 6.4.1 Porous Pavement w. Infilt. Bed							*Subtotal:*			*5*				*8*				
BMP 6.4.2 Infiltration Basin							*Subtotal:*			*5*				*8*				
BMP 6.4.3 Subsurface Infiltration Bed							*Subtotal:*			*5*				*8*				
BMP 6.4.4 Infiltration Trench							*Subtotal:*			*5*				*8*				
BMP 6.4.5 Rain Garden/Bioretention							*Subtotal:*	*19,700*		*5*		*59,535*		*8*			*11,915*	*5,527*
Rain Garden (Lot #1)	0.93	2	0.47	350	12.9	6	18.9	1,000	100.0		200	4,775	100.0		597	597	700	513
Rain Garden (Lot #2)	0.95	2	0.48	350	12.6	6	18.6	1,000	100.0		200	5,600	100.0		700	700	700	516
Rain Garden (Lot #3)	0.98	2	0.49	350	12.2	6	18.2	1,000	100.0		200	5,080	100.0		635	635	700	522
Rain Garden (Lot #4)	1.01	2	0.51	300	11.9	6	17.9	1,000	100.0		200	3,625	100.0		453	453	600	452
Rain Garden (Lot #5)	1.02	2	0.51	458	11.8	6	17.8	1,000	100.0		200	7,005	100.0		876	876	915	691
Rain Garden (Lot #6)	1.08	2	0.54	350	11.1	6	17.1	1,000	100.0		200	5,310	100.0		664	664	700	539
Rain Garden (Lot #7)	0.91	2	0.46	300	13.2	6	19.2	1,000	100.0		200	4,395	100.0		549	549	600	437
Rain Garden (Lot #8)	0.99	2	0.50	238	12.1	6	18.1	1,000	100.0		200	3,000	100.0		375	375	475	355
Rain Garden (Lot #9)	1.05	2	0.53	300	11.4	6	17.4	1,000	100.0		200	4,520	100.0		565	565	600	458
Rain Garden (Lot #10)	1.03	2	0.52	375	11.7	6	17.7	1,000	100.0		200	4,975	100.0		622	622	750	568
Bioretention 1	0.92	2	0.46	2588	13.0	6	19.0	9,700	100.0		1,940	41,400	100.0		5,175	5,175	5,175	3,778
BMP 6.4.6 Dry Well / Seepage Pit							*Subtotal:*	*21,500*		*5*		*25,900*		*8*			*4,400*	*5,787*
Dry Well (Lot #1)	0.98	2	0.49	468	26.0	6	32.0	2,150	100.0		430	2,590	100.0		324	430	440	576
Dry Well (Lot #2)	0.91	2	0.46	468	28.1	6	34.1	2,150	100.0		430	2,590	100.0		324	430	440	568
Dry Well (Lot #3)	1.06	2	0.53	468	24.1	6	30.1	2,150	100.0		430	2,590	100.0		324	430	440	585
Dry Well (Lot #4)	1.02	2	0.51	468	25.0	6	31.0	2,150	100.0		430	2,590	100.0		324	430	440	580
Dry Well (Lot #5)	0.93	2	0.47	468	27.4	6	33.4	2,150	100.0		430	2,590	100.0		324	430	440	570
Dry Well (Lot #6)	1.07	2	0.54	468	23.9	6	29.9	2,150	100.0		430	2,590	100.0		324	430	440	586
Dry Well (Lot #7)	0.97	2	0.49	468	26.3	6	32.3	2,150	100.0		430	2,590	100.0		324	430	440	575
Dry Well (Lot #8)	1.01	2	0.51	468	25.3	6	31.3	2,150	100.0		430	2,590	100.0		324	430	440	579
Dry Well (Lot #9)	1.04	2	0.52	468	24.5	6	30.5	2,150	100.0		430	2,590	100.0		324	430	440	582
Dry Well (Lot #10)	1.07	2	0.54	468	23.9	6	29.9	2,150	100.0		430	2,590	100.0		324	430	440	586
BMP 6.4.7 Constructed Filter[7]										5				8				
BMP 6.4.8 Vegetated Swale[7]										5				8				
BMP 6.4.9 Vegetated Filter Strip[7]										5				8				
BMP 6.4.10 Infilt. Berm & Ret. Grading										5				8				
																	TOTAL:	14,613

[1] Assumes a soil testing procedure which finds hydraulic conductivity. (e.g. perc tests may also require a reduction factor)
[2] Time it takes for BMP to empty once it is full. (Minimum = 24 hrs, Maximum = 72 hours; Applicable to retention and detention facilities only.)
[3] Infiltration that occurs during the storm (before becoming full). Not to exceed 6 hours.
[4] A portion of the total area draining to BMP from non-pervious area may be diverted.
[5] Inherent in these calculations are the allowable loading ratios (5:1 and 8:1) from the BMP Manual. Higher loading ratios will need to be justified. In Karst Areas, the max. loading ratio should be 3:1.

PEAK RATE CONTROL ANALYSIS

According to the National Engineering Handbook (NRCS, 2008), the direct runoff for watersheds having more than one hydrologic soil-cover complex can be estimated in either of two ways. Runoff can be estimated for each complex and then weighted to get the watershed average. Alternatively, the CN values can be weighted, based on area, to obtain a single CN value to represent the entire drainage area. Then runoff is estimated with the single CN value. If the CN for the various hydrologic soil-cover complexes are close in value, both methods of weighting give similar results for runoff. However, if there exists a large difference in curve number value, the CN weighting method can provide drastically different results.

As described in the *National Engineering Handbook*, "the method of weighted runoff always gives the correct result (in terms of the given data), but it requires more work than the weighted CN method, especially when a watershed has many complexes. The method of weighted CN is easier to use with many complexes or with a series of storms. However, where differences in CN for a watershed are large, this method either under- or over-estimates runoff, depending on the size of the storm." This often occurs when impervious area exists in a subarea. When the relatively low curve number of lawn areas is combined with the high curve number of impervious areas, the weighted CN method will minimize the impact of the impervious surface and under-estimate the amount of runoff.

The spatial distribution of the different soil-cover complexes becomes the controlling factor in selection of the appropriate method. When different land uses behave as independent watershed the areas should be analyzed as separate drainage subareas. For example, when a large parking area is surrounded by lawn area that all flows to the same collection point, runoff from the impervious surface will occur much differently than runoff from the lawn. However, when impervious area is dispersed amongst other land uses and not directly connected to a stormwater collection system, the weighted CN method may be appropriate. The decision of whether or not to use a weighted curve number is often a site specific judgment that should be discussed between the designer and the Municipal Engineer in the early planning stages of a project.

Pre-Development Soil-Cover Complex Data

Because the wooded area along the north property line will remain unchanged, and will not be tributary to the stormwater facilities, this area has been removed from the peak rate analysis drainage areas. The weighted CN method was used for pre-development calculations in this example because Curve Numbers for the hydrologic soil-cover complexes are close in value. The drainage area and land cover information necessary to calculate the pre-development runoff is shown in the table below:

Land Use	Soil Type (HSG)	Area (ft^2)	Area (acres)	CN
Woods (good)	B	42,500	0.98	55
Meadow	B	310,255	7.12	58
TOTAL:		352,755	8.10	58

Pre-Development Time of Concentration

The *Model Ordinance* requires use of the NRCS Lag Equation for all pre-development time of concentration calculations unless another method is pre-approved by the Municipal Engineer.

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

Where:

T_{lag} = Lag time (hours)
L = Hydraulic length of the watershed (feet)
Y = Average overland slope of watershed (percent)
S = Maximum retention in the watershed, as defined by: S = [(1000/CN) – 10]
CN = NRCS Curve Number for the watershed

Lag time is related to time of concentration by the following equation:

Time of Concentration = T_c = [(T_{lag}/.6) * 60] (minutes)

One method of calculating the average overland slope of a watershed is to select locations that represent the various slopes found in the watershed and weight the slope based on the area it represents. This method is shown in the table on the following page.

Slope	End Elevation		Distance	Slope	Percent of	Product
Line	High	Low	(ft)	(%)	Total Area	(% x %)
AA	909	902	148	4.7%	5%	0.24%
BB	941	909	475	6.7%	50%	3.37%
CC	956	942	245	5.7%	15%	0.86%
DD	960	943	180	9.4%	15%	1.42%
EE	943	930	265	4.9%	15%	0.74%
					Sum of Products =	6.61%

This is an estimation of the land slope value, so the calculated number is rounded to the nearest whole number for use in the Lag Equation. The hydraulic length of the watershed was measured at 1050 ft. Therefore,

$$T_{lag} = (1050)^{0.8} \frac{((1000/CN)-10)+1)^{0.7}}{1900\sqrt{7}}$$

T_{lag} = 0.23 hours

Time of Concentration = T_C = (T_{lag} / 0.6) * 60
= (0.23 / 0.6) * 60
= 23 minutes

Pre-Development Peak Rate Flows

All of this information was used to perform a pre-development peak rate analysis using a software package based on the NRCS TR-20 procedures. The results of the analysis are as follows:

	1-year	2-year	10-year	25-year	50-year	100-year
Peak Runoff Flows (cfs)	0.1	0.6	4.1	7.6	11.1	15.3
Runoff Volume (ac-ft)	0.060	0.136	0.449	0.726	0.997	1.322
Runoff Depth (in)	0.09	0.20	0.66	1.08	1.48	1.96

Table B.1. Pre-Development Runoff Summary

Post-Development Soil-Cover Complex Data

Due to the disconnection of impervious areas and overland flow paths used in this design, the area weighted CN method was deemed appropriate and used to reduce the complexity of the model. The drainage area and land cover information for the drainage sub-area directly tributary to the bioretention facility is shown in the table below:

Land Use	Soil Type (HSG)	Area (ft^2)	Area (acres)	CN
Lawn (good condition)	B	9,700	0.22	61
Impervious	B	31,700	0.73	98
TOTAL:		41,400	0.95	70

Post-Development Time of Concentration

The Segmental Method was used for all post-development time of concentration calculations in this example. This method is covered in more detail in various NRCS publications (NRCS, 1986; NRCS, 2008). The following segments were used to calculate a time of concentration for the drainage sub-area directly tributary to the bioretention facility:

T_t-1: Sheet flow, 100' of lawn at 5% = 10.7 min
T_t-2: Shallow concentrated flow, 110' unpaved at 5.9% = 0.5 min
T_t-3: Channel flow, 80' at 4.0% = 0.2 min
T_t-4: Channel flow, 156' at 3.85% = 0.5 min
T_t-5: Pipe flow, 38' of 15" HDPE pipe at 5.2% = 0.1 min

$T_c = T_t\text{-}1 + T_t\text{-}2 + T_t\text{-}3 + T_t\text{-}4 + T_t\text{-}5 = 12$ minutes

Post-Development Peak Rate Flows

The hydrologic model for this example contains a considerable level of detail. Each structural BMP was modeled as a pond with a unique drainage area and time of concentration. Runoff was routed through each BMP and linked to downstream BMPs for subsequent routing. A detention basin with an outlet control structure was also added to the model. A graphical representation of the model is provided in *Figure B.1*.

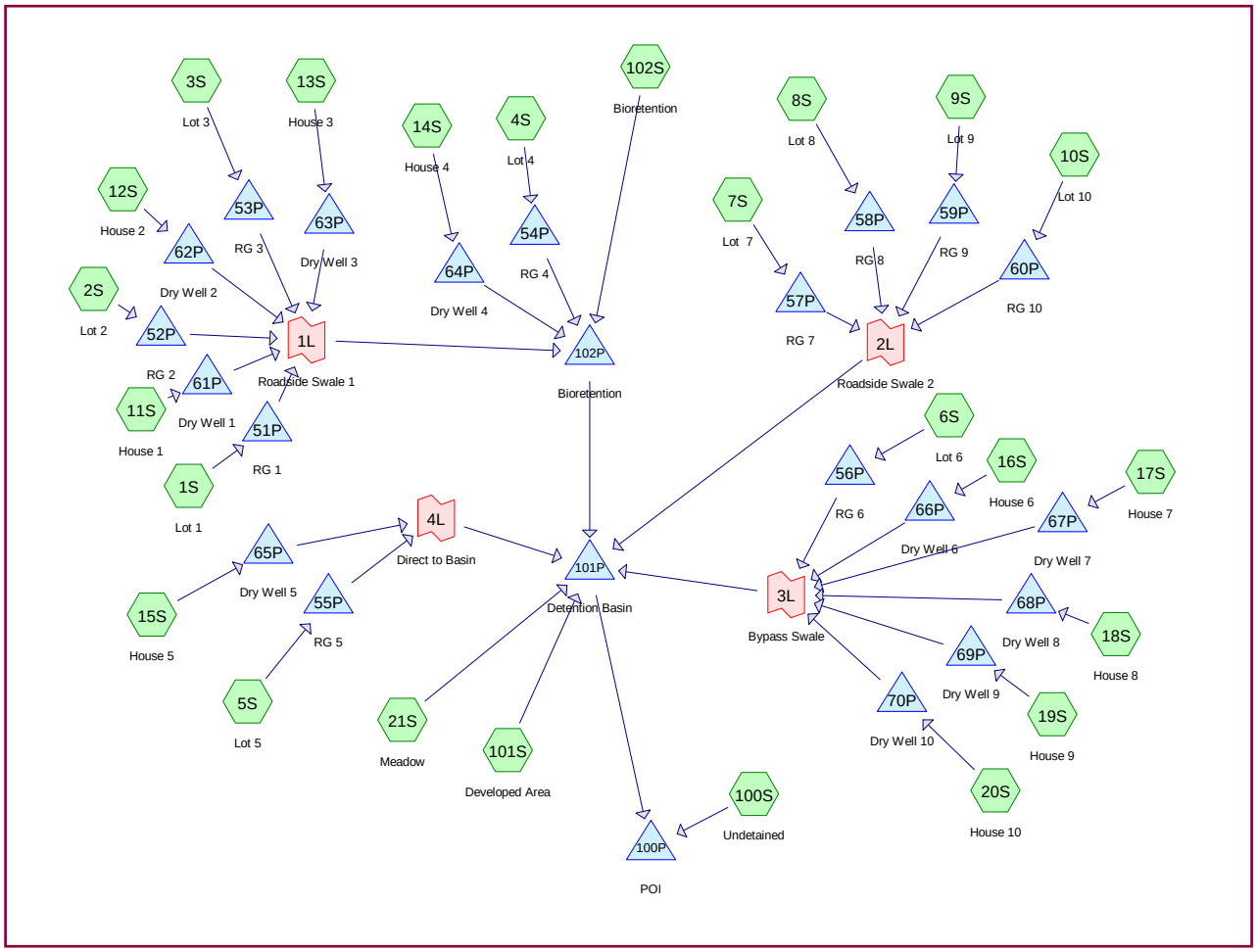


Figure B.1. Hydrologic Model of Post-Development Conditions

This model was used to estimate the post-development peak rate flows. The final configuration of the outlet structure was completed through an iterative process using the results of the model runs. This design meets the peak rate control requirements through a combination of volume removed by the structural `BMPs and the detention basin and outlet control structure. *Table B.2* shows a summary of the runoff results for the final post-development design:

	1-year	2-year	10-year	25-year	50-year	100-year
Peak Runoff Flows (cfs)	0.1	0.4	4.1	7.4	10.6	15.2
Runoff Volume (ac-ft)	0.079	0.147	0.445	0.717	1.011	1.367
Runoff Depth (in)	0.12	0.22	0.66	1.06	1.50	2.03

Table B.2. Summary of Post-Development Runoff with Stormwater Controls

INITIAL CONSTRUCTION COST - DESIGN EXAMPLE

Initial construction costs were estimated for each layout. The estimates include the costs incurred by the developer to complete earthwork, paving and curbing, and stormwater management facilities. All of these costs are summed to determine an initial construction cost for these facilities. This cost was then divided by the total sellable acreage of the project to determine a cost / sellable acre for each layout.

Estimate of Initial Construction Cost
Mill Run Residential – Traditional Layout

ITEM NO.	ITEM & DESCRIPTION	EST.	UNIT	UNIT PRICE	EXTENSION
EARTHWORK				**Subtotal =**	**$ 23,950**
1	Clearing & Grubbing	2.3	AC	$ 6,000.00	$ 13,800
2	Topsoil Removal/Stockpiling	5.8	AC	$ 1,750.00	$ 10,150
STORM DRAINAGE				**Subtotal =**	**$ 102,769**
3	Storm Sewer, 18" HDPE	600	LF	$ 55.00	$ 33,000
4	Storm Inlets	7	EA	$ 2,100.00	$ 14,700
5	Swales	490	LF	$ 10.00	$ 4,900
6	Install Detention Basin	1,525	CY	$ 25.00	$ 38,125
7	Anti Seep Collars	2	EA	$ 775.00	$ 1,550
8	Outlet Structure	1	EA	$ 4,000.00	$ 4,000
9	Outlet Pipe, 18" HDPE	50	LF	$ 55.00	$ 2,750
10	DW Endwall 24"	1	EA	$ 2,750.00	$ 2,750
11	Rip Rap Apron	144	SF	$ 6.90	$ 994
PAVING & CURBING				**Subtotal =**	**$ 138,657**
12	Paving - Final Subgrade, 6" Stone, 3" 19MM, 1-1/2" 9.5mm	2,325	SY	$ 30.00	$ 69,750
13	Curbing w/Excavation & Backfill	1,465	LF	$ 27.00	$ 39,555
14	Sidewalk plain w/4" - stone	4,285	SF	$ 6.85	$ 29,352
				Initial Construction Cost =	**$ 265,376**
				Cost / Sellable Acre =	**$ 42,734**

Table B.3. Estimate of Construction Cost for Residential Design Example (Traditional Layout)

Estimate of Initial Construction Cost *Mill Run Residential – LID Layout*					
ITEM NO.	ITEM & DESCRIPTION	EST.	UNIT	UNIT PRICE	EXTENSION
EARTHWORK				**Subtotal =**	**$ 14,925**
1	Clearing & Grubbing	1.0	AC	$ 6,000.00	$ 6,000
2	Topsoil Removal/Stockpiling	5.1	AC	$ 1,750.00	$ 8,925
STORM DRAINAGE				**Subtotal =**	**$ 114,172**
3	Swales	1,620	LF	$ 10.00	$ 16,200
4	Storm Sewer, 18" HDPE	136	LF	$ 55.00	$ 7,480
5	DW Headwall 18"	1	EA	$ 2,750.00	$ 2,750
6	Storm Inlets	1	EA	$ 2,100.00	$ 2,100
7	Install Detention Basin	600	CY	$ 25.00	$ 15,000
8	Anti Seep Collars	2	EA	$ 775.00	$ 1,550
9	Outlet Structure	1	EA	$ 4,000.00	$ 4,000
10	Outlet Pipe, 18" HDPE	50	LF	$ 55.00	$ 2,750
11	Level Spreader	44	LF	$ 5.50	$ 242
12	Bioretention Area	5,175	SF	$ 12.00	$ 62,100
PAVING & CURBING				**Subtotal =**	**$ 53,790**
13	Paving - Final Subgrade, 6" Stone, 3" 19MM, 1-1/2" 9.5mm	1,645	SY	$ 30.00	$ 49,350
14	Gravel Shoulder	370	SY	$ 12.00	$ 4,440
				Initial Construction Cost =	**$ 182,887**
				Cost / Sellable Acre =	**$ 28,355**

Table B.4. Estimate of Construction Cost for Residential Design Example (LID Layout)

The cost of constructing the stormwater BMPs on each individual lot was not included in the comparison of initial construction costs. This is a cost that will be borne by the owner of each individual lot. This must be included in the cost comparison analysis. *Table B.5* shows an estimate of these costs.

Estimate of Stormwater BMP Construction Cost *Mill Run Residential – LID Layout*					
ITEM NO.	ITEM & DESCRIPTION	EST.	UNIT	UNIT PRICE	EXTENSION
STORMWATER BMPS					
1	Rain Gardens	6,740	SF	$ 10.00	$ 67,400
2	Dry Wells	450	CY	$ 32.00	$ 14,400
				Construction Cost =	**$ 81,800**
				Cost / Sellable Acre =	**$ 12,682**

Table B.5. Estimate of Stormwater BMP Construction Cost

Determining how this additional cost to homeowners will be reflected in the market value of developed land is presumptive at best. For this example, we have assumed that some of the cost of constructing the stormwater BMPs will result in a dollar for dollar reduction in the market value of the sellable land. So, the BMP construction cost per sellable acre is subtracted from the per acre market value price of the land.

The initial construction cost is subtracted from the land sale value to determine the developers profit for each layout.

Cost = Land Sale Value - Initial Construction Cost

Traditional Layout
Cost = $310,500 - $265,376
= $45,124

LID Layout
Cost = $240,701 – $182,887
= $57,814

The final cost comparison is completed by determining the difference in profit between the two layouts. For this example, a total profit increase of $12,690 is realized by the developer using the LID layout with no additional cost to the individual homeowners.

Appendix C – Problem Area Conceptual Solutions

All of the problem areas identified by the PAC members were visited by HRG and county staff to compile a database of locations and information. The problem areas and obstructions were organized into seven categories. A list of each problem area is included in *Section V*.

The following pages show a sample Conceptual Solution for one of seven typical problem types in the County. These typical problems are listed below.

Plate 7 shows the locations of all reported problem areas and obstructions throughout the county.

PROBLEM AREA P24 – BANK EROSION

OBSTRUCTION O21 – SEDIMENT BUILDUP/DEBRIS

PROBLEM AREA P55 – FLOODING – INADEQUATE/NO DRAINAGE SYSTEM

OBSTRUCTION O29 – FLOODING – INADEQUATELY SIZED BRIDGE/CULVERT

PROBLEM AREA P33 – FLOODING – STREAM/FLOODPLAIN OBSTRUCTION

PROBLEM AREA P07 – BRIDGE SCOUR

PROBLEM AREA P14, OBSTRUCTION O14 – MINE DRAINAGE

Washington County Act 167 Plan

Municipality: Cross Creek Township **ID:** P24

Problem Description: Parker Rd near Sugar Camp intersection; Bank Erosion.

Photos:

Photo Description:

Looking downstream from the Parker Road Bridge. Eroded streambank exhibits sloughing in the farm field where riparian vegetation has been removed.

Photo Description:

Note healthy streambanks upstream of the Parker Road bridge. The vegetated floodplains slow floodwaters and help prevent streambank erosion.

Conceptual Solution:

Streambank remediation, consisting of excavation of the steep streambank and armoring with riprap and woody plantings, is warranted downstream of the Parker Road bridge. The underlying problem for this stream is that the riparian zone (the vegetated area along the stream) was disturbed by the removal of native vegetation. The grass planted on the cultivated land facilitates higher flow velocities during floods and its shallow root structure does not retain soil well. This problem was evident through numerous farm fields for approximately a mile downstream.

Washington County Act 167 Plan

Municipality: Donegal Township **ID:** O21

Problem Description: Buck Run filled with tree limbs and debris.

Photos:

Photo Description:

Looking upstream at Buck Run.

Photo Description:

Debris has accumulated upstream of the Buck Run Road crossing.

Conceptual Solution:

The bridge obstructs the flow of floodwaters and collects debris. The debris should periodically be removed by the owner of the bridge as part of a regular maintenance program.

Washington County Act 167 Plan

Municipality: Canonsburg Borough **ID:** P55

Problem Description: Stormwater flooding of Walter's Alley behind Craighead Street.

Photos:

Photo Description:

View along Walter's Alley. The creek flows parallel to the alley just on the other side of the trees on the left. Note that the items along the stream and the garages are likely in the floodplain. These obstructions likely exacerbate flooding upstream.

Photo Description:

Looking upstream. Walter's Alley is to the left of the frame.

Conceptual Solution: During floods, the drainage structures along Walter's Alley likely get surcharged by high water in the stream. During severe floods, water from the stream may overtop the banks and inundate the alley and the buildings across the alley. This situation is fairly typical in urban settings in the county. Property owners should be encouraged to refrain from building in the floodplain, and not to place objects that may get mobilized by floodwaters along the stream. To prevent the alley from flooding, the grade of the road needs to be raised above flood stage. State and Federal permits are required for work in floodplains.

Washington County Act 167 Plan

Municipality: Mount Pleasant Township **ID:** O29

Problem Description: Undersized crossing on Sabo Road causes flooding upstream.

Photos:

Photo Description:

Downstream face of Sabo Road Bridge.

Photo Description:

Upstream face of Sabo Road Bridge.

Conceptual Solution: This bridge may be undersized. The bridge opening may need to be increased to provide an adequate level of flood protection for a low-use local road.

Washington County Act 167 Plan

Municipality: City of Washington **ID:** P33

Problem Description: Catfish Creek needs stream remediation along its entire length.

Photos:

Photo Description:

Looking downstream at a footbridge across Catfish Creek. The bridge acts as an obstruction during storms and collects debris.

Photo Description:

Catfish Creek is conveyed beneath this structure and is constrained by a concrete wall on one side and a steep slope on the other side.

Conceptual Solution:

Catfish Creek flows through a heavily urbanized section of the county. Flooding of properties is not surprising due to numerous structures built in the floodplain. A campaign to acquire properties along the stream and restore a healthy riparian zone would greatly improve the stream, but it would be prohibitively expensive. Small remediation projects could rehabilitate eroded streambanks and remove obstructions from the stream channel and floodplains.

Washington County Act 167 Plan

Municipality: West Pike Run Township **ID:** P07

Problem Description: Scouring of bridge abutment causing weakening of structure along Whitehall Road.

Photos:

Photo Description:

The single-lane Whitehall Road bridge has been closed to all traffic.

Photo Description:

Cut stone abutment shows signs of severe scouring. Note how the stone courses dip toward the middle. The foundation of the abutment may have been undercut by scour.

Conceptual Solution:

This bridge needs to be replaced. The new abutments need to extend beneath the depth of expected scour, or the streambanks through the bridge need to be armored against erosion and scour.

Washington County Act 167 Plan

Municipality: Burgettstown Borough **ID:** P14, O14

Problem Description: The unused railroad bridge obstructs flood flow. Also, the stream appears to be affected by Abandoned Mine Drainage (AMD).

Photos:

Photo Description:

Upstream face of abandoned railroad bridge.

Photo Description:

Downstream face of abandoned railroad bridge.

Conceptual Solution: If the railroad bridge causes flooding, it should be removed and the streambanks should be restored. The orange color of the water indicates AMD. The source of the minerals that are impairing the stream should be traced, and a series of passive treatment ponds should be designed and installed. DEP has programs in place to identify and treat AMD near its source.

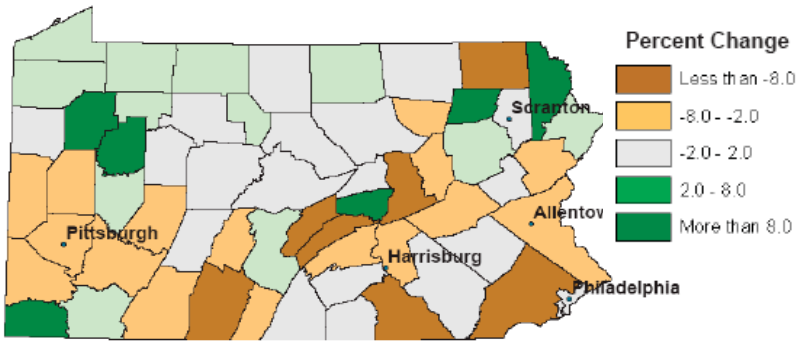
Appendix D – Natural Resource Activities Impacting Water Quality

As demonstrated throughout this Plan, land use is a key factor in both the generation and control of stormwater runoff. In Pennsylvania, most types of land use can be regulated by the county or local government through land use ordinances (e.g. zoning). However, the Pennsylvania Municipalities Planning Code (MPC) limits local government control of certain land use categories. Certain types of natural resource activities such as agriculture, forestry, and mining are among the land uses protected by the MPC. Two land use categories that fall within this category were identified by the Plan Advisory Committee, and the municipalities they represent, as land uses that greatly affect the water resources of the county – timber harvesting and oil and gas wells.

Amendments made to the Pennsylvania Municipalities Planning Code by Act 67 and Act 68 of 2000, limit the regulatory control of municipalities on forestry and timber harvesting. The amendments specify Forestry activities and timber harvesting as "permitted uses by right" in all zoning districts in every municipality. The MPC amendments further clarify that zoning ordinances may not unreasonably restrict forestry activities.

Oil and gas well development in Pennsylvania is regulated by several chapters of the Pennsylvania Code and various state acts. The state's oil and gas laws (Oil and Gas Act – Act 223, Coal and Gas Resource Coordination Act – Act 214, and Oil and Gas Conservation Law – Act 359), as well as environmental protection laws that include the Clean Streams Law, the Dam Safety and Encroachments Act, the Solid Waste Management Act, and the Water Resources Planning Act delegate the authority to regulate these activities to DEP, while limiting the regulatory control of municipalities.

FORESTRY IN PENNSYLVANIA



Change in Forest Land Area, 1989-2004 (McWilliams et al., 2007)

According to U.S. Forest Service inventories, forest once covered more than 90% (27.3 million acres) of Pennsylvania's land area in the pre-European settlement era (1630s). By the early 1900s, industrial timber harvesting and agricultural land clearing had diminished the forest land base to only 32% (9.2 millions acres). Forest land increased steadily from that point forward and has been relatively stable, at 58% of Pennsylvania's total area, for the last quarter century. Although no significant net change in total area has occurred, there have

been losses of acreage to development, agriculture and mining. These losses have been offset by agricultural and other lands naturally reverting back to forests. Slightly more than 70% of the nearly 17 million acres of forests in the state are privately owned, with only a small percentage (< 5%) owned by forest product companies. The remaining 30% of the forest land in Pennsylvania is owned by state and federal government entities.

Pennsylvania is known throughout the world as a leading source of high quality hardwood products. The state leads the nation in the production of hardwood lumber (typically more than one billlion board feet), accounting for about 10% of the country's annual production (Pennsylvania Forest Products Association, 2008). Pennsylvania also ranks nationally in the production of value added wood products such as millwork and flooring; kitchen cabinets; pallets and containers.

The forest products industry is important in Pennsylvania, where it accounts for 11% of all manufacturing jobs. The forest products industry has a significant impact on the state's economy. In 2005, the state's annual forest product industry sales was $16.7 billion. The total economic impact of the forest product industry in the state was $24.7 billion. Three-quarters of this economic impact was generated by sectors depending on locally harvested hardwood timber (Pennsylvania Forest Products Association, 2008). In 2006, there were 2,420 forest prduct establishments in Pennsylvania, employing 79,910 individuals. In many rural parts of the state the forest products industry is the primary source of economic activity.

FORESTRY IN WASHINGTON COUNTY

Although it is not a dominant sector, the wood products industry provides important economic opportunities in the county. In 2007, there were 26 wood products establishments employing between five hundred and one thousand people (U.S. Census Bureau, 2008). Timber management encourages the preservation of open space. Through timber harvesting, forests are able to provide landowners with income that can be an incentive for them to maintain woodland on their property. According to a study conducted by the American Famland Trust, timberland and farmland yield an average of $3 in taxes for every $1 in required governmental services, while residential land costs $1.11 in services for every $1 collected in tax revenue (The Pennsylvania State University, 2004). Additionally, municipalities with publicly owned State Forests, State Game Lands, and State Parks within their borders receive "in lieu of tax" payments from the Commonwealth.

FORESTRY ACTIVITIES AFFECTING WATER QUALITY

As discussed in *Section IX - Water Quality Impairments and Recommendations*, forestry is one of the basic sources of nonpoint source pollution. On a national level, forestry management activities are estimated to contribute approximately 9 percent of the water quality problems in surveyed rivers and streams (EPA, 1996). Water quality concerns related to forestry were addressed in the 1972 Federal Water Pollution Control Act Amendments and later, more comprehensively, as nonpoint sources under section 208 of the 1977 Clean Water Act and section 319 of the 1987 Water Quality Act.

Forestry is listed as the primary cause for impairment in 0.02% of all non-attaining stream miles in Pennsylvania. There are no stream segments in Washington County listed on the *2009 Integrated List of All Waters* as non-attaining, with forestry as the primary source of impairment. However, this does not mean that the potential impacts of forestry operations on water quality can be neglected. Local impacts of timber harvesting and road construction can be severe, especially in smaller headwater streams. Many activities associated with forest management can increase the potential for erosion to occur. For this reason, sediment is the primary pollutant of concern

associated with forestry activities. Other pollutants include nutrients, organic matter, chemicals and others. The fundamental forestry activities with the potential to affect water quality include road construction and use, timber harvesting, mechanical equipment operation, and forest management.

ROAD CONSTRUCTION AND USE

Roads are considered to be the major source of sediment from forested lands. The comparatively small area of roads contributes the vast majority of the total sediment produced from forestry operations. The greatest potential for erosion from roads occurs during road construction and during the first few years afterward. The potential for erosion on forest roads is particularly high because they are exposed to direct rainfall, they are not protected by vegetative cover, road surfaces tend to channelize runoff, and vehicle traffic continually disturb the road surface. Erosion potential is greatly increased when roads are built on cut or fill slopes, when built on steep slopes, and when they are not stabilized with stone or some other means.

Compacted road surfaces also generate increased runoff which compounds erosion problems. Other negative impacts of forest roads include concentrated overland flow on the road surface and in channels, point discharges created by culvert road crossings, and altered subsurface water flow.

TIMBER HARVESTING

Timber harvesting involves many activities that alter the forest landscape. Erosion and sedimentation resulting from these alterations is the primary concern associated with timber harvesting. Facilities used for timber harvesting such as staging (or yarding) areas, skid trails, and access roads are susceptible to increased erosion. These facilities are also at high risk for pollutants such as petroleum products, lubricants, herbicides, pesticides, and other chemicals associated with timber harvesting operations. Many detrimental effects of harvesting are related to the access and movement of vehicles and machinery. These effects include soil disturbance, soil compaction, and direct disturbance of stream channels.

Landscape changes that occur as a result of harvesting can also negatively impact water quality. Timber harvesting disturbs forest litter and changes the vegetative cover which alters the hydrologic response of a watershed. This can lead to increased runoff and erosion. Removing trees from riparian areas disturbs the sensitive ecosystem, exposes the area to pollutants associated with machinery, and reduces shade which can increase water temperatures. Utilizing appropriate timber harvesting and transport practices techniques for a given site can drastically decrease sediment production from these activities.

FOREST MANAGEMENT

Forest management activities such as site preparation for regeneration of harvested sites, prescribed burning, herbicide and pesticide application, and fertilizer application have the potential to negatively affect water quality. Sites that have been intensely harvested can be prepared for regeneration using wheeled or tracked machinery, by prescribed burning, through application of chemicals (i.e. herbicides), or a combination of these methods. These techniques can disturb the soil over large areas, remove vegetation and forest litter, and compact soil. All of these leave the area vulnerable to increased erosion and sedimentation.

FORESTRY POLLUTANTS AND IMPAIRMENTS

Nearly all forestry activities increase the potential for erosion and sediment delivery to streams. Some of these activities have long-term effects (e.g. road building and clear-cutting), while the impacts of others diminish within a few years of the occurrence. Erosion and sedimentation is the

primary water quality concern related to forestry activities. Sedimentation is closely related to nutrient transport. Nutrients that are immobilized in forest soils are transported along with the sediment to surface waters through erosion. Other water quality pollutants resulting from forestry activities include organic debris, nutrients, chemicals, temperature, and flow variability. These pollutants, how they are generated through forestry activities, and their potential impacts on the county's waters are discussed below.

SEDIMENT

Sediment is often the primary pollutant associated with forestry activities. Accelerated overland erosion often occurs in harvested areas due to vast areas that are destabilized by removal of vegetation. Erosion of these areas discharges sediment and fine silt particles into receiving streams. Sediment transported to waterbodies by erosion can be particularly detrimental to the stream ecosystem, especially to many fish species. Suspended sediments in runoff increase water turbidity limiting the ability of sight-feeding fish to find and obtain food. In addition, the increased turbidity limits the depth to which light can penetrate and adversely affecting aquatic vegetation, increase water temperatures and lower dissolved oxygen concentrations. These effects also compromise recreational values.

When suspended sediment settles, it can fill gravel spaces in streambeds, destroying fish spawning areas and food sources. With large areas of accumulated sediment, the flow capacity of stream channels are reduced. The in stream storage capacity is also reduced, which leads to increasing flooding and decreased water supplies. In addition, nutrients and other pollutants may become adsorbed to sediment particles and be subsequently transported downstream.

ORGANIC DEBRIS

Organic material is an important part of a balanced ecosystem. Organic debris includes plant matter, residual logs, leaves, twigs and other forest litter. This material serves as a source of enefgy and provides nutrients for plants and animals. This is the primary source of nutrients for headwater streams, where upstream sources of nutrients are limited. Forestry activities can upset the balance of organic material by creating excess debris during timber havesting or by creating a debris shortage during site preparation for regeneration or by over harvesting in the riparian zone.

Excess organic debris can adversely affect water quality by causing increased biochemical oxygen demand, resulting in decreased dissolved oxygen levels (which are critical for many aquatic species) in watercourses. Logging slash and debris in or near streams can alter stream flows by forming debris dams, and can also redirect flow in the channel, increasing bank cutting and resulting in sedimentation.

NUTRIENTS

Erosion is the primary transport mechanism for nutrient pollution related to forestry activities. Forest soils act as a filter that collects and holds nutrients from decomposing organic matter such as leaves and woody debris. The soil holds many of these nutrients until they are removed by growing plants and used for plant growth. Some nutrients, like nitrogen, are easily dissolved in water and are easily moved throughout the environment. Other nutrients, such as phosphorus, bind to soil particles and are relatively immobile unless relocated by some transport mechanism (e.g. erosion). Excess nutrients in surface waters can result in eutrophication, or a proliferation of plant life, especially algae. Eutrophication causes dissolved oxygen levels to decrease, harming other aquatic organisms.

CHEMICALS

Chemicals such as herbicides, pesticides, and fertilizers used for forestry operations can contaminate surface water through direct application, transport by surface runoff, or groundwater contamination. These chemicals can poison fish and wildlife or kill unintended plant species. Generally speaking, herbicides, pesticides, and fertilizers pose minimal threat to water quality when handled and applied properly. However, improper application and spills can have severe and long lasting effects. The petroleum products and lubricants used for machinery are of greater concern. These chemicals can be toxic to plants and animals and can contaminate drinking water supplies.

TEMPERATURE

Relatively constant water temperature is important for aquatic biota. When too much vegetation is harvested from the area surrounding stream, the loss of shade can result in increased water temperatures. Temperature increases can be dramatic in smaller (lower order) streams, adversely affecting fish and aquatic invertebrates which have adapted to cooler water temperatures. Suspended solids from sedimentation can also lead to increased stream temperatures as darker particles absorb heat (EPA, 1997). As water temperatures rise, dissolved oxygen levels (which are critical for many aquatic species) decrease. Temperature changes can be a substantial contributor to aquatic life impairments.

STREAM FLOW

The hydrologic response of a watershed can change as a result of timber harvesting. The change resulting from large scale removal of vegetation is often increased stream flow that results from more rapid delivery of runoff to streams. When fewer trees are available to perform the function of evaporation and transpiration, more water becomes availabe as surface runoff. Increased runoff results in increased stream flow. The amount of stream flow increase is related to the total area harvested, topography, soil type, and harvesting practices (Curtis et al. 1990). Increased stream flow can lead to a variet of problems including scoured channels, erode streambanks, increase sedimentation, and increase peak flows.

FORESTRY MANAGEMENT MEASURES FOR WATER QUALITY

Current forestry management practices and timber harvest techniques have drasticly reduced the water quality impacts that occurred from practices of the past century. The water quality impacts of forestry activities can be further minimized by implementing appropriate management measures. Management measures are steps to be taken and guidelines for operations (EPA, 2005). Best Management Practices (BMPs) are specific activities, processes, or technologies designed to serve specific functions, which are used to attain a management measure. These are simple, often low cost, practices and techniques that can be incorporated into forestry operations to diminish impacts to water quality. Additional guidance on BMPs can be found in the following resources developed specifically for Pennsylvania forests:

- Timber Harvest Operations Field Guide for Waterways, Wetlands and Erosion Control (3930-BK-DEP4016), 2009. Pennsylvania Department of Environmental Protection.
- Best Management Practices for Pennsylvania Forests, 2001. The Pennsylvania State University.

A brief overview of EPA's (2005) forestry management measures developed to protect water quality throughout the various phases of forestry activites is presented on the following pages.

Preharvest Planning

Purpose	Ensure that forestry activities are planned with water quality considerations in mind and conducted in a manner to minimize delivery of nonpoint source pollutants to surface waters.
Target Pollutant(s)	Primarily sediment. Organic matter, thermal modification, nutrients pesticides and toxics are also controlled.
Description	Preharvest planning includes consideration of all stages of a timber harvest including the road system, the harvesting system, the yarding system, and post harvest activities. Site conditions are considered and appropriate BMPs are prescribed to reduce water quality impacts. Contingency plans are developed to reduce the effects of potential problems.

Streamside Management Areas

Purpose	Protect surface waters, the ecologically sensitive areas in riparian zones and wetlands, and maintain the function of floodplains.
Target Pollutant(s)	Sediment, organic debris, and thermal modification. Nutrients, pesticides and toxics are also controlled.
Description	Establish and maintain a buffer zone along surface waters that includes a sufficient number of canopy species, and is wide enough to shade the water, provide bank stability, and filter runoff. Limit forestry activities within the buffer.

Road Construction

Purpose	Reduce erosion and sedimentation which is common during, and immediately after, construction of forestry roads.
Target Pollutant(s)	Sediment. Petroleum products and lubricants.
Description	Design and construction of roads that are planned for the topography, soils, and drainage patterns of a site. Appropriate construction methods and BMPs are used to minimize erosion from high risk areas such as the road surface, steep slopes, water crossings, and runoff conveyance structures (i.e. culverts, ditches, etc.).

Road Management

Purpose	To ensure that management of existing roads maintains their utility and minimizes polluted runoff from roads and road structures.
Target Pollutant(s)	Sediment. Petroleum products and lubricants.
Description	Minimize use during wet weather and thaw conditions. Perform routine maintenance of road surface, stream crossings, and drainage structures. Immediately repair eroding areas and implement BMPs to address problem areas. Close and decommission roads that are no longer needed.

Timber Harvesting

Purpose	Minimize the likelihood of water quality impacts resulting from timber harvesting operations.
Target Pollutant(s)	Sediment, petroleum products.
Description	Follow the plan for timber harvest operations developed during preharvest planning. Conduct operations to avoid sedimentation to the extent practicable. Use appropriate areas for high risk activities such as equipment maintenance, and petroleum and chemical storage and dispensing.

Site Preparation for Regeneration

Purpose	Minimize erosion and runoff from areas disturbed by site preparation for forest regeneration.
Target Pollutant(s)	Sediment, organic debris, and nutrients.
Description	Select methods of site preparation for regeneration which are suitable for site conditions. Complete site preparation in sensitive areas such as steep slopes and riparian zones using low impact methods and utilizing appropriate BMPs. Leave adequate organic material but protect surface waters from debris and slash material.

Fire Management

Purpose	Minimize nonpoint source pollution and erosion resulting from prescribed burning.
Target Pollutant(s)	Sediment, organic debris, and nutrients.
Description	Use of prescribed fire should be planned and implemented in a manner to protect against excessive erosion. Area to be burned and severity of burn should be prescribed based on site conditions and erosion potential. Appropriate BMPs should be employed to reduce impacts to sensitive areas.

Revegetation of Disturbed Areas

Purpose	Reduce erosion and sedimentation of areas disturbed by forestry activities.
Target Pollutant(s)	Sediment and nutrients.
Description	Reduce erosion and sedimentation by revegetating disturbed areas with appropriate plant species immediately upon completion of earth-disturbing activities. Focus initial efforts on highly susceptible areas such as steep slopes and riparian areas.

Forest Chemical Management

Purpose	Minimize the potential of water pollution by chemicals used for forest management due to environmental transport of chemicals during and after application.
Target Pollutant(s)	Pesticides (i.e. Insecticides, herbicides, and fungicides) and fertilizers.
Description	Risks associated with the use of forest chemicals can be reduced through careful prescription of type and amount of chemicals to be used; delineation of buffer zones; and careful transport and application of chemicals. Spill prevention and contingency plans can reduce the potential impact of spills.

OIL AND GAS DEVELOPMENT IN PENNSYLVANIA

The petroleum (oil and gas) industry has played a significant role in the history of Pennsylvania. In 1859, Edwin L. Drake drilled one of the first successful oil wells near Titusville, PA. In the years that followed, Venango and Crawford Counties became the center of an industry focused on the drilling, refining, and transporting crude oil and oil products (Harper, 1998). Although not the first natural gas well, the Drake Well (which captured natural gas and piped it to Titusville) is also attributed as the beginning of the natural gas industry in America (NaturalGas.org, 2004). Oil and gas wells are a common part of the landscape throughout much of Pennsylvania. Until recently, the petroleum industry in Pennsylvania had faded to a small fraction of what it had been during its prime.

The Marcellus Shale Formation is a Middle Devonian-age (397.5 – 385.3 million years ago), black, low density, carbonaceous shale that lies nearly a mile or more below the surface of approximately two-thirds of Pennsylvania and large portions of New York, West Virginia, and Ohio as well as small areas of Maryland, Kentucky, Tennessee, and Virginia. Organic rich shales, such as the Marcellus Formation, have been known to hold significant reservoirs of natural gas for more than 75 years (Harper, 2008). Once thought cost prohibitive to extract, recent advances in drilling technology and recent price increases for natural gas have increased interest in this extensive gas reservoir. In 2002, the United States Geological Survey's "Assessment of Undiscovered Oil and Gas Resources of the Appalachian Basin Province" calculated that the Marcellus Shale contained an estimated resource of about 1.9 trillion cubic feet of gas (USGS, 2003).

In 2003, Range Resources – Appalachia, LLC drilled a well in Washington County, Pennsylvania and found a promising flow of natural gas from the Marcellus shale. Borrowing drilling and fracturing techniques that had worked in the Barnett Shale of Texas, they began producing Marcellus gas in 2005 (Harper, 2008). In early 2008, Terry Engelder, a geoscience professor at Pennsylvania State University, and Gary Lash, a geology professor at the State University of New York at Fredonia, "said the Marcellus shale conservatively contains 168 trillion cubic feet of natural gas, but the figure might be as high as 516 trillion cubic feet" (UPI, 2008). The recoverable portion of this reserve is estimated to be around 10 percent of this total. By the end of February 2008 more than 450 suspected Marcellus wells had been permitted in Pennsylvania (Harper, 2008). The stage has been set for an extensive Marcellus Shale gas play in Pennsylvania.

OIL AND GAS ACTIVITIES AFFECTING WATER QUALITY

The potential impacts of oil and gas development on water quality are a concern across the Commonwealth. Of particular concern are: water withdrawals, storm water runoff from construction activities, pollution from drilling processes, groundwater contamination from hydraulic fracturing, and disposal of waste fluids. Water quality concerns related to oil and gas operations are addressed by a variety of federal and state regulations. The 1972 Federal Water Pollution Control Act Amendments and the 1977 Clean Water Act were the first regulations to subject the oil and gas producing industry to direct dealings with a federal agency on environmental protection issues (DOE, 2009a). Other regulations such as the Safe Drinking Water Act (1974) and the Resource Conservation and Recovery Act in (1976) authorize further federal regulation of the oil and gas industry. However, regulation of petroleum activities remains primarily a state responsibility.

In Pennsylvania, oil and gas activities are regulated by several chapters of the Pennsylvania Code and various state acts. The state's oil and gas laws (Oil and Gas Act – Act 223, Coal and Gas Resource Coordination Act – Act 214, and Oil and Gas Conservation Law – Act 359), as well

as environmental protection laws that include the Clean Streams Law, the Dam Safety and Encroachments Act, the Solid Waste Management Act, and the Water Resources Planning Act give DEP the authority to regulate these activities while limiting the regulatory control of municipalities.

PERMIT	SOURCE/NOTES
Well Drilling Permit and Addendum	Pursuant to the Oil and Gas Act; an application addendum outlining a water management plan for that operation, pursuant to PA Code, Title 25, Chapter 78.11-33.
Earth Disturbance Permit (ESCGP-1)	Required from PA DEP regulating implementation of E&S controls, including SWM, if disturbance >5 acres. E&S plan is required if under 5 acres. PA Code, Title 25, Chapter 102.
Preparedness, Prevention and Contingency (PPC) Plan	The PPC Plan must address the types of wastes generated, disposal methods and a spill prevention plan. Construction and operation of on-site storage impoundments must also be described.
Water Withdrawal Permits	A permit is required from DEP for all withdrawals of surface or ground water. Separate withdrawal permits for projects in the Delaware or Susquehanna Basin or Susquehanna River Basin Commission.
Chapter 105 Obstruction and Encroachment Permit	Permit from DEP for work in a wetland, stream, or body of water. PA Code, Title 25, Chapter 105 (also required under the Oil and Gas Act).
Water Quality Management Permit	Permit if a centralized impoundment will hold fluids other than fresh water (such as drilling or fracing fluids). The siting, construction, use and closure of temporary pits are regulated under PA Code, Title 25, Chapter 78. Permits are only required if the pit is part of a treatment facility.

Development assciated with the Marcellus shale gas play includes construction of new roads, pipelines, compressors, water impoundments, well sites and other facilities. The development of this resource requires the use of large amounts of water and may expand to cover extensive areas. Marcellus shale gas development in Pennsylvania is a matter of local, regional, and national interest. Petroleum activities are listed as the primary cause for impairment in 0.2% of all non-attaining stream miles in Pennsylvania. Recent interest in the Marcellus shale play has the potential to greatly increase this number.

The large volumes of water required to complete a Marcellus Shale natural gas well, and the resulting large. Directional drilling and hydraulic facturing techniques used to extract gas from the Marcellus shale formation require large volumes of water to complete development of a natural gas well. These approaches require as much as 20 times the water volume as that used in conventional well completions (Harper, 2008). The hydraulic fracturing process for a typical Marcellus shale well uses approximately 3.5 million gallons of water (Harper and Kostelnik, 2010). The resulting large volume of waste water increases the environmental risk of this type of well development.

There are no stream segments in Washington County listed on the *2009 Integrated List of All Waters* as non-attaining, with petroleum activities as the primary source of impairment. However, this does not indicate that water quality impacts from petroleum activities are neglibible. Local impacts to surface water and groundwater resulting from petroleum activities can be severe. Oil and gas development activities with the potential to affect water quality include construction activies, well development, and gas production.

CONSTRUCTION ACTIVITIES

Construction activities related to well development are the primary concern for impacts to surface water. Gas well construction can involve extensive earth disturbance for access roads, pad sites, and pipelines. For deeper wells the drilling pads alone can create a four to six acre disturbed area (Swistock, 2010). Earth disturbances related to well development present the potential for increased erosion and sedimentation in a manner similar to other construction activities. Well sites in remote locations can present increased risk due to the length of roads and pipelines necessary to support the facility. Other site factors such as slope, proximity to surface water, and soil type can increase the potential for impacts to surface water.

WELL DEVELOPMENT

Once the pad site and supporting facilities have been constructed well drilling begins. This is done with a drilling rig through a multi-stage process in which the wellbore is drilled, cased, and encased with concrete. A typical well can be drilled in 15-30 days if the rig is operating 24-hours a day. Well drilling requires a significant amount of water to lubricate and cool the drill bit and remove the cuttings from the borehole. Large quantities of wastewater are generated during this process. Along with the cuttings, present as suspended solids, the wastewater can contain pollutants such as sodium, chloride, iron, manganese, barium, arsenic, and organics used during the drilling process (e.g. surfactants, detergents, oil, grease, benzene, toluene) (Swistock, 2010).

Once a well has been drilled, a process called hydraulic fracturing, or fracing, is used to create additional permeability in the shale to improve the flow of gas toward the wellbore. Fracing involves pumping a fracturing fluid (typically water-based with other additives to improve performance) into a formation to generate fractures in the target formation to improve release of the natural gas trapped in the rock (DOE, 2010b). Additives used for hydraulic fracturing include sand, oils, gels, acids, alcohols, and various other chemicals. Some portion of the frac water (estimated at 10 to 70 percent) returns to the surface as "flow back" wastewater, with the rest remaining underground.

Various stages throughout well development have the potential to negatively impact water resources. Improperly sealed wells can contaminate drinking water sources; storage, transportation, and disposal of wastewater present opportunities for leaks or spills; additives injected with hydrofracing fluid may contaminate groundwater sources; or methane gas can migrate from gas wells into nearby water supply wells.

GAS PRODUCTION

The production phase of well development generally presents the lowest level of risk to water quality. Once well development is complete water continues to be pumped into the well to improve the flow of natural gas. The return fluids, called production fluids, generally contain high concentrations of salts from ancient underground saltwater deposits. Production fluids also contain some of the pollutants noted in drilling and hyrdofracturing fluids.

OIL AND GAS WATER RESOURCE CONCERNS

As previously noted, considerable quantities of water are necessary for the development of a Marcellus Shale gas well. The substantial amount of water utilized presents several challenges in protecting the Commonwealth's water resources. In a report issued by USGS (Soeder and Kappel, 2009), three principal water-resource concerns are noted in regards to Marcellus Shale gas production:

WATER SUPPLY MANAGEMENT

Water for drilling and hydraulic fracturing of wells typically comes from surface water bodies such as lakes. Groundwater sources, municipal water sources, and re-used process water are also sometimes used for these processes. Some concern exists about where the immense volumes of water necessary to sustain large scale well development will be obtained. Other concerns include what the potential consequences might be for local water supplies and the effects of withdrawing this amount of water when it is needed for drilling activities.

The water volumes necessary to sustain petroleum activities are large; however they generally represent a small percentage of the total water used when considered from a basin-wide surface water budget (DOE, 2010b). To put shale gas water use in perspective, the consumptive use of fresh water for electrical generation in the Susquehanna River Basin is nearly 150 million gallons per day, while the projected total demand for peak Marcellus Shale activity in the same basin is 8.4 million gallons per day (Gaudlip et al., 2008). When these withdrawals are examined at a local level, they represent a much larger percentage of the available resource. Rapid withdrawal of large quantities can have short and long-term effects on a water supply. Surface water withdrawal during dry periods could affect aquatic life, recreational activities, potable water supplies, and other industries.

WATER RESOURCE CONTAMINATION

As discussed in the previous section, petroleum activities have the potential to negatively impact water quality at several stages throughout the drilling and production process. Construction activities necessary to construct access roads, pipelines, and prepare well sites have the potential to cause increased erosion and sedimentation. Access roads and well pad sites are rarely, if ever, fully stabilized which increases the duration of potential erosion problems. Similarly, transporting large amounts of equipment, vehicles, and supplies to remote well sites can damage low capacity rural roads (often constructed of dirt and gravel) and cause accelerated erosion. These effects of these activities can be mitigated through use of common construction BMPs.

Other activities such as well drilling, hydraulic fracturing a well, and gas production all present unique challenges to protecting water quality. The various pollutants found in the process water and flowback fluids used during these activities have the potential to contaminate groundwater supplies or impair surface waters if not handled and disposed of properly. These activities require specialized practices to reduce the risk of contaminating water resources.

WASTEWATER DISPOSAL

The wastewater produced during well development and production is one of the main threats to water quality. The large volumes of liquid produced present logistical and economic challenges for recovery and disposal of the wastewater in a manner that minimizes impacts to water resources. In addition, the pollutants often present in the liquid can require wastewater treatment prior to disposal. Although the percentage of chemical additives in a typical hydrofrac fluid is typically less than 0.5 percent by volume, the quantity of fluid used is so large that the additives in an average three million gallon well development would result in about 15,000 gallons of chemicals in the wastewater (Soeder and Kappel, 2009). In addition to the chemical additives found in hydrofrac fluid, the wastewater may contain a variety of naturally occurring pollutants such as brines, organics, heavy metals, and radionuclides removed from subsurface formations. High concentrations of sodium, chloride, and bromide are often found in brine from well drilling.

Common disposal methods include processing them through wastewater treatment plants (the most common method in Pennsylvania), re-injecting the fluids into the ground, and evaporating

the liquid and disposing the remaining solids as dry waste. The effectiveness of standard wastewater treatment for processing wastewater is not well understood. In particular, salts and other dissolved solids are not usually removed by standard treatment processes. Re-injecting the wastewater into the ground (shallow re-injection and deep re-injection) may result in groundwater contamination or other unknown problems. The evaporation method is not a very practical technique in the humid climate of Pennsylvania. Further study of these disposal methods and a better understanding of their effects are necessary to effectively protect the water resources of the Commonwealth.

OIL AND GAS MANAGEMENT PRACTICES FOR WATER QUALITY

Many standard practices in the oil and gas industry are currently being implemented in recognition of the need to protect other natural resources while extracting petroleum resources. The water quality impacts of oil and gas activities can be futher minimized by implementing appropriate management measures and by utilizing suitable Best Management Practices (BMPs). As presented here, management measures are guidance for operations and steps to be taken that will promote the sound, efficient, and environmentally appropriate development of all oil and gas activities, with a particular focus on Marcellus Shale natural gas developments. BMPs are specific activities, processes, or technologies designed to serve specific functions, which are used to attain a management measure.

Management measures and BMPs for activities associated with oil and gas development can determine what resources may be impacted, the extent of the impacts, and mitigation strategies. Use of the following management measures and BMPs does not replace the need to meet Federal and State requirements, their use (when appropriate) will aid in compliance with the applicable regulations:

- Predevelopment Planning
- Wetland and Riparian Management Areas
- Access Road Construction
- Road Management
- Pipeline Construction
- Well Site Development
- Chemical Management

Predevelopment Planning

Purpose	Ensure that oil and gas activities are planned with water quality considerations in mind and conducted in a manner to minimize delivery of nonpoint source pollutants to surface waters and groundwater.
Description	A development plan established during the early stages of anticipated development provides the framework for avoiding or minimizing surface disturbance, protecting other resources, mitigating environmental impacts, and alleviating or addressing concerns of landowners and communities. It serves as a tool for comprehensive, coordinated planning to guide strategic development. It can also assist in meeting the requirements of the Clean Water Act, the Clean Air Act, the Endangered Species Act, and other applicable Federal, and State laws.

GUIDANCE: Develop plans to provide a comprehensive description of the characteristics of the area, along with the anticipated nature of the proposed development. Plans should address potential impacts to water quality, existing natural resources, and the potential for habitat fragmentation in sensitive areas where there are high levels of biodiversity, or sensitive and critical habitats.

Planning needs will differ by location and should be applied in different ways, depending on such things as subsurface geology, terrain, and existing and proposed land use. Plans may be simple or complex, depending upon the circumstances, and will need to be customized to fit the site specific conditions for a project. The following items should be included in the plan:

- Identification of land ownership
- Identification of existing and expected surface uses (including number and spacing of wells, roads, pipelines, water disposal and treatment facilities, compression facilities, gathering and transmission pipelines, etc.)
- Identification of existing and required infrastructure and utility corridors
- Map of the area with location of existing facilities (i.e., wells) and potential (optimal) locations for future facilities, including production facilities (well sites, processing units, etc.), roads, and utility corridors. The map should include geographic features such as streams and other water bodies, and special ecosystems, as well as topographic information.
- Identification of opportunities to avoid, reduce, and mitigate adverse impacts
- Identification of regulatory requirements
- Water management plan (strategy)
- Identification of strategies for reclamation of disturbed areas
- Consider a strategy for establishing a baseline and monitoring and steps to apply monitoring information to existing and future actions

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)
BMP 4.3.1. Background Site Factors
BMP 4.3.2. Site Factors Inventory
BMP 4.3.3. Site Factors Analysis

Wetland and Riparian Management Areas

Purpose	Protect the ecological function and hydrologic features of riparian areas, wetlands, and floodplains.
Description	Establish and maintain a buffer zone along surface waters and wetlands that is wide enough to filter runoff, provide bank stability, and shade the water. Limit oil and gas activities within the buffer.

GUIDANCE: Establish a buffer zone around riparian areas, wetlands, and floodplains. Locate all well pads and other nonlinear facilities outside of the buffer zones.

GUIDANCE: Avoid crossings of wetland and riparian areas by pipelines and roads to the maximum extent practicable. Where crossings cannot be avoided, impacts can be minimized through use of the following measures.

- Develop site-specific avoidance and mitigation plans prior to approval process for all proposed disturbance to wetland/riparian areas, including their buffer areas
- Construct any crossings perpendicular to wetland/riparian areas
- Schedule construction adjacent to wetland areas to minimize the duration of construction activity, and to concentrate such activity during dry conditions, or when the ground is frozen during the winter
- Locate stockpiles outside the buffer areas
- Locate drilling mud pits outside of buffer areas
- Begin reclamation of disturbed wetland/riparian areas as soon as possible after project activities are complete
- Monitor any stream channel for erosion, sedimentation, degradation, and riparian health

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)
BMP 5.4.1 Protect Sensitive and Special Value Features
BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas
BMP 5.4.3 Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design

Access Road Construction

Purpose	Reduce erosion and sedimentation which is common during, and immediately after, construction of oil and gas access roads.
Description	Design and construction of roads that are planned for the topography, soils, and drainage patterns of a site. Appropriate construction methods and BMPs are used to minimize erosion from high risk areas such as the road surface, steep slopes, water crossings, and runoff conveyance structures (i.e. culverts, ditches, etc.).

The location and construction of access roads require careful planning. Special attention should be given to steep slopes, surface waters, soils, and other potential hazards. Access roads should be designed with grades between 2 and 10%, located outside buffers of water features, and should have cuts and fills minimized.

GUIDANCE: Utilize existing roads to the maximum extent possible. Locate new roads in areas that will optimize year-round, all-weather access, and minimize surface disturbance and environmental impacts.

GUIDANCE: Minimize construction of roads where it is operationally feasible and safe. Construct roads to the minimum standard necessary to achieve intended use (i.e. use two-track access roads where possible).

GUIDANCE: Road Construction and Reclamation. Plan, maintain and construct all roads in conformance with road standards. Major access roads to the general development area should be constructed to a higher road standard to avoid excess maintenance caused by poor planning and constructed. Practices that can enhance reclamation include:

- Reclaim and re-vegetate all disturbed surface that will not be used for gas operations in a manner that restores topsoil and minimizes erosion.
- Use re-forestation as a reclamation strategy where forest land was impacted during the development.
- Use only certified and inspected seed that is free of noxious weeds for reclamation/re-vegetation.

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)	
BMP 5.7.1 Reduce Street Imperviousness	
BMP 5.7.2 Reduce Parking Imperviousness	
• Structural (refer to PA Stormwater BMP Manual)	
BMP 6.4.1 Pervious Pavement with Infiltration Bed	
BMP 6.4.7 Constructed Filter	
BMP 6.4.8 Vegetated Swale	
BMP 6.4.9 Vegetated Filter Strip	
• E&S (refer to PA E&S Pollution Control Manual)	
Sediment Barriers and Filters	Compost Filter Sock, Rock Filter Outlet, Super Silt Fence, Sediment Filter Log, Straw Bale Barrier, Rock Filter, Vegetative Filter Strip
Runoff Conveyance BMPs	Broad-based Dip, Access Road Swale, Ditch Relief Culvert, Turnout
Sediment Capture & Treatment	Construction Entrances, Compost Sock Sediment Trap
Stabilization Methods and Standards	

Road Management

Purpose	To ensure that management of existing roads maintains their utility and minimizes polluted runoff from roads and road structures.
Description	Minimize use during wet weather and thaw conditions. Perform routine maintenance of road surface, stream crossings, and drainage structures. Immediately repair eroding areas and implement BMPs to address problem areas. Close and decommission roads that are no longer needed.

GUIDANCE: Plan access routes for heavy equipment and the high volume of trucks to the site with input from the local municipality and PennDOT.

GUIDANCE: Consider operational traffic and plan for the long-term operations of the facility considering maintenance as well as potential issues with dust, compaction, and debris, as well as safety.

Water Quality BMPs:

• E&S (refer to PA E&S Pollution Control Manual)
Sediment Barriers and Filters
Runoff Conveyance BMPs
Stabilization Methods and Standards

Pipeline Construction

Purpose	Reduce erosion and sedimentation during, and immediately after, construction of oil and gas pipelines.
Description	Appropriate design and construction methods are used to minimize erosion from areas disturbed by pipeline construction. BMPs are used in high risk areas such as steep slopes and water crossings.

GUIDANCE: Use existing disturbance corridors whenever possible (ideally following access routes or existing pipeline routes).

GUIDANCE: Locate pipelines in the same trenches, or immediately parallel to, each other. Install pipelines at the same time if possible.

Water Quality BMPs:

• Non-Structural (refer to PA Stormwater BMP Manual)	
BMP 5.4.1 Protect Sensitive and Special Value Features	
BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas	
BMP 5.4.3 Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design	
BMP 5.6.3 Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species	
• E&S (refer to PA E&S Pollution Control Manual)	
Crossings	Roadways, stream, wetlands
Outlet Protection	
Stabilization Methods and Standards	

Well Site Development

Purpose	Minimize the likelihood of water quality impacts resulting from development of oil and gas well sites.
Description	Follow the plan for oil and gas operations developed during predevelopment planning. Conduct operations to avoid sedimentation to the extent practicable. Use appropriate areas for high risk activities such as equipment maintenance, and petroleum and chemical storage and dispensing.

GUIDANCE: Minimize surface disturbance to the maximum extent practicable. Utilize techniques such as drilling multiple wells from the same pad when technically feasible.

GUIDANCE: Remove all equipment not necessary for well operations.

GUIDANCE: Locate well construction activities with the following considerations:

- Locate well sites in stable, non-erosive soil areas, with grass or brush cover and on relatively level areas that minimize pad construction. Choose sites that avoid steep slopes, unstable soils, and close proximity to streams, floodplains, springs, and wetlands.
- Divert surface runoff from entering the constructed pad site to avoid transporting of pollutants.
- Locate facilities and roads away from occupied dwellings.
- Locate in visually acceptable areas (avoid dwelling view sheds) and paint facilities colors that blend in with the natural environment.
- Locate where safe access can be maintained year round.

Water Quality BMP's:

• Non-Structural (refer to PA Stormwater BMP Manual)	
BMP 5.5.1 Cluster Uses at Each Site; Build on the Smallest Area Possible	
BMP 5.6.1 Minimize Total Disturbed Area – Grading	
BMP 5.6.2 Minimize Soil Compaction in Disturbed Areas	
BMP 5.6.3 Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species	
BMP 5.7.2 Reduce Parking Imperviousness	
BMP 5.9 Source Control	
• E&S (*refer* to PA E&S Pollution Control Manual)	
Sediment Barriers and Filters	Compost Filter Sock, Rock Filter Outlet, Super Silt Fence, Sediment Filter Log, Straw Bale Barrier, Rock Filter, Vegetative Filter Strip
Runoff Conveyance BMPs	Channels, Top of Slope Berm, Temporary Slope Pipe
Sediment Capture & Treatment	
Outlet Protection	
Stabilization Methods and Standards	
• *Structural* (refer to PA Stormwater BMP Manual)	
BMP 6.4.1 Pervious Pavement with Infiltration Bed	
BMP 6.4.7 Constructed Filter	
BMP 6.4.8 Vegetated Swale	
BMP 6.4.9 Vegetated Filter Strip	
BMP 6.6.1 Constructed Wetland	
BMP 6.6.2 Wet Pond/Retention Basin	
BMP 6.6.3 Dry Extended Detention Basin	
BMP 6.6.4 Water Quality Filters & Hydrodynamic Devices	
BMP 6.7.1 Riparian Buffer Restoration	
BMP 6.7.2 Landscape Restoration	
BMP 6.7.3 Soil Amendment & Restoration	
BMP 6.7.4 Floodplain Restoration	
BMP 6.8.1 Level Spreader	

Pollution Prevention

Purpose	Minimize the potential of water pollution caused by potential pollutants used for, or generated by, oil and gas operations.
Description	Risks associated with chemicals and other potential pollutants used for, and generate by, oil and gas operations can be reduced through careful transport, storage and use the substances. Spill Preparedness, Prevention, and Contingency Plans can reduce the potential impact of accidental spills.

GUIDANCE: Prepare a site specific Preparedness, Prevention, and Contingency Plan that identifies potential pollutants used or stored on site, outlines operational procedures to reduce the likelihood of accidental spills, and details a pollution incident response plan to be employed in the event of a spill.

GUIDANCE: Conduct personnel training programs to educate all employees of safe handling and disposal methods of all potential pollutants stored or generated on site. Pollution incident response should also be included in the training.

GUIDANCE: Implement pollution prevention practices when feasible. Use pollution source reduction techniques (i.e. alternative chemicals and additives), reduce or eliminate waste generated through process changes, and use new technologies to remove pollutants from wastewater to reduce the pollution potential of oil and gas activities.

Facility Reclamation and Decommissioning

Purpose	Reduce erosion and sedimentation of areas disturbed by oil and gas activities and minimize long-term impacts of oil and gas activities.
Description	Reduce erosion and sedimentation by stabilizing the work area around active facilities and establishing permanent vegetation on the surrounding area immediately upon completion of earth-disturbing activities. Remove and decommission facilities upon completion of planned use. Restore facility sites to pre-disturbance condition, or better.

GUIDANCE: Reduce facility size to the minimum area required for oil and gas production operations by restoring all areas temporarily disturbed during construction activities. Restoration should include the following:

- Re-contour disturbed areas to be compatible with existing grades.
- Replace topsoil to at least the depth and quality that existed prior to disturbance for final reclamation of the site upon abandonment of the well.
- Re-vegetate disturbed areas using native vegetation and including re-forestation.
- Remove all chemicals, equipment, materials, and waste not necessary for sustaining production from the well pad.

GUIDANCE: Stabilize facilities during operations with crushed stone or other appropriate methods.

GUIDANCE: Remove and decommission facilities as soon as reasonably possible after oil and gas production is completed. Restore the disturbed areas to their pre-disturbance condition, or better, by reshaping the site to the original contour, replacing topsoil, and re-establishing native vegetation.

Appendix E – Public Participation

The material included in Appendix E reflects the record of Public Participation required by ther Plan and includes Agendas, sign-in sheets and brief meeting summaries (containing comments and questions) from the Phase 2 PAC and PAC/MEC meetings and the June 2, 2010 Public Hearing.

Appendix E – Public Participation

The material included in Appendix E reflects the record of Public Participation required by ther Plan and includes Agendas, sign-in sheets and brief meeting summaries (containing comments and questions) from the Phase 2 PAC and PAC/MEC meetings and the June 2, 2010 Public Hearing.

WASHINGTON COUNTY
ACT 167, PHASE II
STORMWATER MANAGEMENT PLAN

PAC MEETING #3 AGENDA

I. **Introductions & Opening Remarks**

II. **Plan Advisory Committee (PAC) Membership**
   i. Confirm PAC Membership

III. **Review Phase I**

IV. **Summary of Phase II Tasks**
   Task A – Data Collection/Review/Analysis
   Task B – Technical Analysis
   Task C – Public/Municipal Participation
   Task D – Plan Preparation and Implementation

V. **Problem Areas**
   i. Review problem areas

VI. **Next Steps**
   i. Data gathering, review, analysis
   ii. Field View of problem areas
   iii. Existing Ordinance collection, review, analysis
   iv. Tentative Schedule for PAC meetings

VII. **Questions**
   i. Question and Answer Period

Act 167 Plan Goals

- Provide a comprehensive program of stormwater management.
- Provide uniform standards throughout the County.
- Ensure that existing problem areas are not exacerbated by future development.
- Encourage infiltration of stormwater to maintain groundwater recharge, to prevent degradation of surface and groundwater quality, and to protect water resources.
- Meet legal water quality requirements under State law.

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Cranberry Township, PA 16066
724-779-4777 (phone)

ACT 167, PHASE II WASHINGTON COUNTY
WATERSHEDS
STORMWATER MANAGEMENT PLAN

PAC #3 - JANUARY 26 , 2009

NAME	Municipality	Street Address	City	State	Zip
JRO	Robinson Township	8440 Noblestown Road	McDonald	PA	15057
	Roscoe Borough	P.O. Box 502	Roscoe	PA	15477
	Smith Township	P.O. Box 94	Slovan	PA	15078
	Somerset Township	615 Vanceville Road	Eighty Four	PA	15330
Tom Hart	South Franklin Township	100 Municipal Road	Washington	PA	15301
~~[illegible]~~ DOUG PATTERSON	South Strabane Township	550 Washington Road	Washington	PA	15301
	Speers Borough	300 Phillips Street	Charleroi	PA	15022
	Stockdale Borough	P.O.Box 398 402 Locust Street	Stockdale	PA	15483
	Twilight Borough	8 Chestnut Road	Charleroi	PA	15022
	Union Township	3904 Finley-Eframa Road	Finleyville	PA	15332
MATT STANISZEWSKI, COUNCILMAN	Washington City	55 West Maiden Street	Washington	PA	15301
	West Alexander Borough	P.O. Box 299	West Alexander	PA	15376
	West Bethlehem Township	Box 309	Marianna	PA	15345
JRO	West Brownsville Borough	235 Main Street	West Brownsville	PA	15417
	West Finley Township	401 Beham Ridge Road	West Alexander	PA	15376
	West Middleton Borough	18 West Main Street P.O. Box 95	West Middleton	PA	15379
	West Pike Run Township	238 Pike Run Road	Daisytown	PA	15427
	Wash. Co. Cons. District	100 West Beau St., Ste 105	Washington	PA	15301
	PennDOT District 12	PO Box 459	Uniontown	PA	15401
	Public Safety	100 West Beau St.	Washington	PA	15301
	Flood Task Force	c/o Mackin Engineering RIDC Park West, 117 Industry Dr.	Pittsburgh	PA	15275
Ruth Sitler	DEP, Bureau of Watershed Management	400 Market Street	Harrisburg	PA	17105
	Cooperative Extension	100 West Beau St., Ste 601	Washington	PA	15301
	Washington County Watershed Alliance	159 Canterbury Lane	McMurray	PA	15317
	Watershed Alliance	c/o Redevelopment Authority 100 West Beau St., Ste 603	Washington	PA	15301

NAME	Municipality	Street Address	City	State	Zip
	California University	Dept. of Earth Sciences, California University, 250 University Ave., Box 55	California	PA	15419
	Washington Jefferson College	Environmental Studies Washington and Jefferson College 102 Hall	Washington	PA	15301
	Fish and Boat Commission	236 Lake Road	Somerset	PA	15501
	Army Corps of Engineers	2038 WM S Moorehead Federal Bldg., 100 Liberty Ave.	Pittsburgh	PA	15222
Greg Holesh	PaDEP	400 Waterfront ~~Pgh, PA 1522~~	Pgh	PA	15222
~~John Over~~	~~PA ENGR~~.				
Mike Deafalla					
CITY COUNCILMAN → MATT STANISZEWSKI DIRECTOR OF PUBLIC WORKS BUREAU	CITY OF WASHINGTON	23 BUTTONWOOD AVE WASH PA 15301-3925			

	Municipality	Street Address	City	State	Zip
NAME					
	East Washington Borough	15 Thayer Street	Washinton	PA	15301
	Elco Borough	Box 194	Elco	PA	15434
	Ellsworth Borough	23 Main Street Box 545	Ellsworth	PA	15331
	Fallowfield Township	9 Memorial Drive	Charleroi	PA	15022
	Finleyville Borough	3515 Washington Avenue	Finleyvill	PA	15332
	Green Hills Borough	90 West Chestnut Street Suite 705	Washington	PA	15301
	Hanover Township	11 Municipal Drive	Burgettstown	PA	15021
	Hopewell Township	20 Parkview Road	Avella	PA	15312
	Houston Borough	42 Western Avenue	Houston	PA	15342
	Independence Township	P.O. Box E	Avella	PA	15312
	Jefferson Township	670 Cedar Grove Road	Burgettstown	PA	15021
	Long Branch Borough	440 Mt. Tabor Road	Coal Center	PA	15423
	McDonald Borough	151 School Street	McDonald	PA	15057
	Marianna Borough	Procasky Road P.O Box 368	Marianna	PA	15345
	Midway Borough	304 Noblestown Road P.O Box 574	Midway	PA	15060
	Monongahela City	449 West Main Street	Monongahela	PA	15063
	Morris Township	P.O. Box 34	Prosperity	PA	15329
	Mount Pleasant Township	31 McCarrell Road	Hickory	PA	15340
	New Eagle Borough	157 Main Street	New Eagle	PA	15067
	North Bethlehem Township	P.O. Box 112	Scenery Hill	PA	15360
	North Charleroi Borough	555 Walnut Avenue	North Charleroi	PA	15022
	North Franklin Township	620 Franklin Farms Road	Washington	PA	15301
Joe SITES	North Strabane Township	1929 Route 519 South	Canonsburg	PA	15317
	Nottingham Township	909 Sugar Run Road	Eighty Four	PA	15330
	Peters Township	610 East Mcmurray Road	McMurray	PA	15317

	Municipality	Street Address	City	State	Zip
NAME					
	Allenport Borough	Box 186	Allenport	PA	15412
	Amwell Township	885 Amity Ridge Road	Amity	PA	15311
	Beallsville Borough	82A South Street,Box 6	Beallsville	PA	15313
	Bentleyville Borough	900 Main Street	Bentleyville	PA	15314
	Blaine Township	40 Main Street P.O.Box 128	Taylorstown	PA	15365
	Buffalo Township	400 Buffalo Center Lane	Washington	PA	15301
	Burgettstown Borough	1509 Main Street	Burgettstown	PA	15021
Troy Williams A. Brownfield Richard Miller	California Borough	225 Third Street	California	PA	15419
	Canonsburg Borough	68 E. Pike Street	Canonsburg	PA	15317
	Canton Township	655 Grove Avenue	Washington	PA	15301
Don Barky Tom Rapp Jon Bielbows Jim Harrison	Carroll Township	130 Baird Street	Monongahela	PA	15063
	Cecil Township	3599 Millers Run Road Suite101	Cecil	PA	15321
John Over	Centerville Borough	100 East End Road	Brownsville	PA	15417
	Charleroi Borough	334-338 Fallowfield Avenue	Charleroi	PA	15022
	Chartiers Township	2 Buccaneer Drive	Houston	PA	15342
	Claysville Township	154 Main Street P.O.Box 423	Claysville	PA	15323
	Coal Center Borough	P.O Box 174	Coal Center	PA	15423
	Cokeburg Borough	P.O. Box 474	Cokeburg	PA	15324
JRO	Cross Creek Township	28 Clark Avenue	Avella	PA	15312
	Deemston Borough	1622 Morey Road	Fredericktown	PA	15333
[illegible]	Donegal Township	727 Old National Pike	Claysville	PA	15323
	Donora Borough	603 Meldon Avenue	Donora	PA	15033
	Dunleavy Borough	2 Walnut Street P.O. Box 18	Dunleavy	PA	15432
JRO	East Bethlehem Township	36 Water Street Box 687	Fredericktown	PA	15333
	East Finley Township	1394 East Finley Drive	Claysville	PA	15323

Bruce Large
Doug Bailer

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

200 West Kensinger Drive, Suite 400
Cranberry Township, PA 16066
(724) 779-4777
FAX (724) 779-4711

TO: Washington County Planning Commission

FROM: HRG

DATE: January 27, 2009

SUBJECT: Washington County Act 167 – PAC #3 Meeting Summary

PAC #3 was held on January 26, 2009 at the Washington County Fairgrounds. This memo is an overall summary of the meeting – it does not contain detailed minutes of every point discussed.

After a brief introduction by Lisa Cessna (Washington County Planning Commission), representatives of Herbert, Rowland & Grubic, Inc. (HRG) recapped the Act 167 Plan (Plan) to date, discussed some of the standards that will be incorporated into the model ordinance, and reviewed the Phase II schedule.

- Doug Weikel and John Rusnak of HRG recapped the Phase I process, in which was established the PAC membership and collected input from all of the participating municipalities in the form of questionnaires.

- Next, Mr. Rusnak and Jon Snyder of HRG presented a general overview of the Phase II work in progress. HRG and the County has begun the process of visiting the problem areas identified in Phase I and will present conceptual solutions for the significant ones in the final Phase II Report.

- One of the goals of the Plan is to create a model ordinance, based on one that was released by PADEP in March of 2008, but specifically tailored to the needs of Washington County. Each municipality in the County will be required to adopt stormwater management provisions and standards based on the Ordinance. Throughout this process, the County will continue to request input from the municipalities via PAC meetings.

- John Rusnak explained that Land Use will be an important factor considered in the Plan. Existing land use will be compared to future land use maps (prepared by the Washington County Planning Commission) to help identify areas that may experience stormwater problems in the future due to extensive projected future development.

- Jon Snyder of HRG presented some of the proposed standards that will be incorporated into the model ordinance. Peak rate control has been the standard for stormwater management (SWM) in the past, but now, volume and water quality will be a consideration in SWM plans.

- Before his closing remarks, John Rusnak presented a tentative schedule of the remaining Phase II work.. The project's duration is approximately four (4) years from July 2008 to June 2012. The next meeting will be PAC #4. It has been tentatively scheduled for June 2009. At this meeting, modeling results will be discussed. The presented dates for future meetings have been scheduled for what would be the 5th Monday of the month. The meeting dates are subject to change, but the contract expiration date of June 2012 is firm.

At various points during the meeting, some of the municipal representatives and members of the general public had questions or comments:

Q: How is the Plan funded by PADEP?

Costs for preparing the Phase I an Phase II plans are funded 75% by PADEP, with a 25% match by the County. Washington County will be providing in-kind services to meet their match. The PAC members can be reimbursed for 75% of their costs associated with Plan preparation (including attending meetings)once the Plan is adopted by the County, approved by the DEP and the Ordinance adopted by Resolution of the municipality. One of the handouts (provide by the attendant DEP representatives) includes information on submitting eligible expenses for reimbursement. Ruth Sitler from PADEP mentioned that the regulations for reimbursements can be found at www.pacode.com in Title 25, Chapter 111.

Q: Will funding for construction be available through the same program?

Funding will not be provided through the Plan for design and construction associated with individual problem areas, even if they were identified on questionnaires. The Plan will rank the stormwater problems in the form of a prioritized list. The Commonwealth currently provides funding for stormwater problems through a variety of programs (such as Growing Greener II). The problem areas at the top of the prioritized list may be considered for this funding before lower-ranked problems.

Q: Can municipalities that have not submitted Problem and Obstruction areas do so now?

Yes, as long as the field work for a particular area has not been completed, new problem areas may be added to the Plan list. Members are to ensure they provide the appropriate documentation such as a filled out questionnaire and a rough sketch and description of the problem and/or obstruction area(s)

WASHINGTON COUNTY
ACT 167, PHASE II
STORMWATER MANAGEMENT PLAN

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

Historical Washington County 1781

Act 167 Plan Goals

- Provide a comprehensive program of stormwater management.
- Provide uniform standards throughout the County.
- Ensure that existing problem areas are not exacerbated by future development.
- Encourage infiltration of stormwater to maintain groundwater recharge, to prevent degradation of surface and groundwater quality, and to protect water resources.
- Meet legal water quality requirements under State law.

March 29, 2010
PAC / MEC MEETING AGENDA

I. **Introductions & Opening Remarks**

II. **Primary Goals of the PLAN**
   - i. Review of Primary Goals
   - ii. Budget Impacts

III. **Schedule**

IV. **Cumulative Impact Discussion**

V. **Model Ordinance Discussions**
   - i. Brief Overview / Background
   - ii. Thresholds / Exemptions
   - iii. Minimum Controls
   - iv. Small Example / Worksheet
   - v. Bigger Example / Worksheet
   - vi. Type and Use of BMPs
   - vii. Alternatives

VI. **Questions**
   - i. Questions (and Hopefully... Answers)

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(724) 779-4777
FAX (724) 779-4711

TO: Washington County Planning Commission

FROM: HRG

DATE: March 29, 2010

SUBJECT: Washington County Act 167 – PAC/MEC Meeting Summary

A PAC/MEC meeting was held on March 29, 2010 at the Washington County Fairgrounds. This memo is an overall summary of the meeting – it does not contain detailed minutes of every point discussed.

After a brief introduction, representatives of Herbert, Rowland & Grubic, Inc. (HRG) recapped the Act 167 Plan (Plan) to date, discussed Plan progress thus far, the draft Ordinance and some of the technical issues to be addressed in the Plan. Items discussed or included on the respective power point presentation and hand outs were as follows:

- The Plan's Primary Goals.
- Budget Impacts based on funding issues with the state.
- The remaining schedule for the work was discussed.
- Thresholds for action that were to be considered in the Ordinance were discussed. The DEP model Ordinance anticipates to have new impervious area over 1,000 square feet implement some type of Stormwater Management. There is a potential to have the threshold increased to 2,500 SF of new impervious space created, with a credit system that would allow more impervious area if certain activities (such as BMPs) were constructed.
- The cumulative impact of non-controlled runoff.
- The difference between Rate controls and Volume (quality) controls.
- The Model Ordinance as a tool for Municipalities to manage runoff for smaller developments as well as allowing for enforcement addressing larger development.
- Examples of small to large lot projects and respective requirements for submission under the Model Ordinance.

General questions asked or comments stated are summarized below:

Q: Are relesae rates to be considered and how will release rates be determined?

Release rates will most likely be recommended for the modeled area (Chartiers Creek Watershed). Current land use will be compared to future land use, area hydrologic and hydraulic modeling would be performed and the potential effects of additional runoff caused by increased impervious space due to development would be used as a factor in determining release rates. Other factors such as soils, underlayment geology, slopes will be considered.

Q: Who determines what a High Quality or Exceptional Value stream is?

The DEP has a rating criteria and lists these streams under Chapter 93.

Q: Can the riparian buffer requirements of the Model Ordinance be made optional?

Yes, but they may be instituted in the future if the DEP changes certain requirements on construction adjacent to streams in the Commonwealth.

Q: What is your definition of a "stream" ?

Generally, it is regarded as a watercourse, perennial or intermittant, natural or man made, which has a defined bed and banks.

Q: If an owner (private or large land developer) does not maintain stormwater facilities, will the municipality have to take them over?

Possibly. The Ordinance gives the municipality the tools to address issues such as this and provides for other means of enforcement.

Q: Rain gardens are listed as a BMP. Typically these are expensive. Won't this potentially make the cost for for stormwater management for the individual lot owner unaffordable?

If all work related to addressing stormwater where required is complete in the beginning of a project, costs would be minimal as equipment and material would be already on site.

ACT 167, PHASE II WASHINGTON COUNTY
WATERSHEDS
STORMWATER MANAGEMENT PLAN

PAC / MEC - MARCH 29, 2010

	Municipality	Street Address	City	State	Zip
NAME					
	Allenport Borough	Box 186	Allenport	PA	15412
	Amwell Township	885 Amity Ridge Road	Amity	PA	15311
	Beallsville Borough	82A South Street,Box 6	Beallsville	PA	15313
Kevin Wilmot	Bentleyville Borough	900 Main Street	Bentleyville	PA	15314
	Blaine Township	40 Main Street P.O.Box 128	Taylorstown	PA	15365
- SOI Mounts Jim	Buffalo Township	400 Buffalo Center Lane	Washington	PA	15301
	Burgettstown Borough	1509 Main Street	Burgettstown	PA	15021
	California Borough	225 Third Street	California	PA	15419
	Canonsburg Borough	68 E. Pike Street	Canonsburg	PA	15317
	Canton Township	655 Grove Avenue	Washington	PA	15301
Tom Rapp Dan James Bierhower Barney John Harrison	Carroll Township	130 Baird Street	Monongahela	PA	15063
Don Genusso Dan Deseroth Twp. Engineer	Cecil Township	3599 Millers Run Road Suite101	Cecil	PA	15321
Brian Restovich, Esq	Centerville Borough	100 East End Road	Brownsville	PA	15417
	Charleroi Borough	334-338 Fallowfield Avenue	Charleroi	PA	15022
Dan Slagle Harlan Stoner	Chartiers Township	2 Buccaneer Drive	Houston	PA	15342
	Claysville Township	154 Main Street P.O.Box 423	Claysville	PA	15323
	Coal Center Borough	P.O Box 174	Coal Center	PA	15423
	Cokeburg Borough	P.O. Box 474	Cokeburg	PA	15324
Gary Howard Ken Howard	Cross Creek Township	28 Clark Avenue	Avella	PA	15312
	Deemston Borough	1622 Morey Road	Fredericktown	PA	15333
	Donegal Township	727 Old National Pike	Claysville	PA	15323
	Donora Borough	603 Meldon Avenue	Donora	PA	15033
	Dunleavy Borough	2 Walnut Street P.O. Box 18	Dunleavy	PA	15432
	East Bethlehem Township	36 Water Street Box 687	Fredericktown	PA	15333
	East Finley Township	1394 East Finley Drive	Claysville	PA	15323

ACT 167, PHASE II WASHINGTON COUNTY
WATERSHEDS
STORMWATER MANAGEMENT PLAN

NAME	Municipality	Street Address	City	State	Zip
Pat H. Dickson	East Washington Borough	15 Thayer Street	Washinton	PA	15301
	Elco Borough	Box 194	Elco	PA	15434
	Ellsworth Borough	23 Main Street Box 545	Ellsworth	PA	15331
	Fallowfield Township	9 Memorial Drive	Charleroi	PA	15022
	Finleyville Borough	3515 Washington Avenue	Finleyvill	PA	15332
	Green Hills Borough	90 West Chestnut Street Suite 705	Washington	PA	15301
~~KEITH STRAIGHT~~ DON HOUSLEY Herb Grubbs	Hanover Township	11 Municipal Drive	Burgettstown	PA	15021
	Hopewell Township	20 Parkview Road	Avella	PA	15312
	Houston Borough	42 Western Avenue	Houston	PA	15342
KEN HOWARD	Independence Township	P.O. Box E	Avella	PA	15312
	Jefferson Township	670 Cedar Grove Road	Burgettstown	PA	15021
	Long Branch Borough	440 Mt. Tabor Road	Coal Center	PA	15423
	McDonald Borough	151 School Street	McDonald	PA	15057
	Marianna Borough	Procasky Road P.O Box 368	Marianna	PA	15345
	Midway Borough	304 Noblestown Road P.O Box 574	Midway	PA	15060
	Monongahela City	449 West Main Street	Monongahela	PA	15063
Kathy Leonock, Sec. Treas S. Douglas Smith, Sup.	Morris Township	P.O. Box 34	Prosperity	PA	15329
Marylou Stuebenrau Larry Chorne	Mount Pleasant Township	31 McCarrell Road	Hickory	PA	15340
Bob Laskey	New Eagle Borough	157 Main Street	New Eagle	PA	15067
	North Bethlehem Township	P.O. Box 112	Scenery Hill	PA	15360
	North Charleroi Borough	555 Walnut Avenue	North Charleroi	PA	15022
	North Franklin Township	620 Franklin Farms Road	Washington	PA	15301
Joe Sites	North Strabane Township	1929 Route 519 South	Canonsburg	PA	15317
[illegible] Planner Commissioner	Nottingham Township	909 Sugar Run Road	Eighty Four	PA	15330
Mark Zepaitis	Peters Township	610 East Mcmurray Road	McMurray	PA	15317

ACT 167, PHASE II WASHINGTON COUNTY
WATERSHEDS
STORMWATER MANAGEMENT PLAN

PAC / MEC - MARCH 29, 2010

NAME	Municipality	Street Address	City	State	Zip
Jerry Runtas.	Robinson Township	8440 Noblestown Road	McDonald	PA	15057
	Roscoe Borough	P.O. Box 502	Roscoe	PA	15477
Tom Schilinski JERRY YACOVIGNO	Smith Township	P.O. Box 94	Slovan	PA	15078
	Somerset Township	615 Vanceville Road	Eighty Four	PA	15330
	South Franklin Township	100 Municipal Road	Washington	PA	15301
Michael H. Dotalla D. PATTERSON J. Stickle D. Pratt T. Lonich	South Strabane Township	550 Washington Road	Washington	PA	15301
	Speers Borough	300 Phillips Street	Charleroi	PA	15022
	Stockdale Borough	P.O.Box 398 402 Locust Street	Stockdale	PA	15483
	Twilight Borough	8 Chestnut Road	Charleroi	PA	15022
Andrew Tullai	Union Township	3904 Finley-Elrama Road	Finleyville	PA	15332
Tom Lovell Kevin Wilmot	Washington City	55 West Maiden Street	Washington	PA	15301
	West Alexander Borough	P.O. Box 299	West Alexander	PA	15376
	West Bethlehem Township	Box 309	Marianna	PA	15345
	West Brownsville Borough	235 Main Street	West Brownsville	PA	15417
	West Finley Township	401 Beham Ridge Road	West Alexander	PA	15376
	West Middleton Borough	18 West Main Street P.O. Box 95	West Middleton	PA	15379
	West Pike Run Township	238 Pike Run Road	Daisytown	PA	15427
Gary Fleharty	Wash. Co. Cons. District	100 West Beau St., Ste 105	Washington	PA	15301
	PennDOT District 12	PO Box 459	Uniontown	PA	15401
	Public Safety	100 West Beau St.	Washington	PA	15301
	Flood Task Force	c/o Mackin Engineering RIDC Park West, 117 Industry Dr.	Pittsburgh	PA	15275
	DEP, Bureau of Watershed Management	400 Market Street	Harrisburg	PA	17105
	Cooperative Extension	100 West Beau St., Ste 601	Washington	PA	15301
Joan Jesse	Washington County Watershed Alliance	159 Canterbury Lane	McMurray	PA	15317
Bernie Mazur	Watershed Alliance	c/o Redevelopment Authority 100 West Beau St., Ste 603	Washington	PA	15301

ACT 167, PHASE II WASHINGTON COUNTY WATERSHEDS STORMWATER MANAGEMENT PLAN

NAME	Municipality	Street Address	City	State	Zip
	California University	Dept. of Earth Sciences, California University, 250 University Ave., Box 55	California	PA	15419
	Washington Jefferson College	Environmental Studies Washington and Jefferson College 102 Hall	Washington	PA	15301
	Fish and Boat Commission	236 Lake Road	Somerset	PA	15501
Gary J Livacari	Army Corps of Engineers	2038 WM S Moorehead Federal Bldg., 100 Liberty Ave.	Pittsburgh	PA	15222
Martin Rapsack	PennDot	19 Murtland Ave Washington PA			
Lynne Finnerty	Clairton Municipal Authority		Pittsburgh	PA	
[illegible]	Hanover Twp	891 Steubenville Pike Burgettstown		PA	15021
Steve Widlane	PennDOT 12-0	825 N. Gallatin Ave	Uniontown	PA	15401
Michael Barnick	PennDOT 12-0	825 N. Gallatin Ave Uniontown	Uniontown	PA	15401 Mibarnick@state.pa.us
MATT STANISZEWSKI	WASHINGTON CITY	23 BUTTONWOOD AVE (mailing address)	WASHINGTON	PA	15301
Frank Ludwin	Cecil Twp				
TIMOTHY GERHART	N. BETH TWP	PO Box 2 Scenery Hill PA	Scenery Hill	PA	15360
KEVIN LIRA	PA SOCIETY OF LAND SURVEYORS				

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(724) 779-4777
FAX (724) 779-4711

TO: Washington County Planning Commission

FROM: John Rusnak, P.E. - HRG

DATE: May 24, 2010

SUBJECT: Washington County Act 167 – PAC/MEC Meeting Summary

The final PAC/MEC meeting was held on May 24, 2010 at the Washington County Fairgrounds. This memo is an overall summary of the meeting – it does not contain detailed minutes of every point discussed.

After a brief introduction by Ms. Lisa Cessna, Washington County Planning Director, representatives of Herbert, Rowland & Grubic, Inc. (HRG) recapped the Act 167 Plan (Plan) progress thus far, the draft Ordinance and Volume Control strategies, and remaining technical issues based on questions brough to the County's attention. Items discussed or included on the respective power point presentation and hand outs were as follows:

- Goals.
- Strategies.
- The remaining schedule for the work was discussed.
- Riparian Buffers
- Easement requirements, definitions; etc.
- Thresholds.
- The Model Ordinance.
- Waivers

General questions asked or comments stated are summarized below:

Q: Can the municipality waive requirement on their own?

No. Section 303 in the Ordinance contains requirements that must be met for waivers to be considered. Municipality cannot waive anything that violates state law.

Q: How flexible are release rates?

Municipalities can institute stricter requirements than the Ordinance or Plan contains. Release rates may be one of these requirements that municipalities may revisit.

Q: Why are stormwater easements requirement?

To protect downstream property, ensure stormwater management practices are done correctly, identify a responsible party if damage occurs. Section III of the Ordinance contains provisions allowing for an easement or requires proof that no damage would occur if discharging on adjacent downstream property.

Q: Is there a minimum size of watershed (regardless of whether it is HQ or EV) for riparian buffers to be required?

No.

ACT 167, PHASE II WASHINGTON COUNTY
WATERSHEDS
STORMWATER MANAGEMENT PLAN

NAME	Municipality	Street Address	City	State	Zip
	Allenport Borough	Box 186	Allenport	PA	15412
LARRY HEADLEY	Amwell Township	885 Amity Ridge Road	Amity	PA	15311
	Beallsville Borough	82A South Street,Box 6	Beallsville	PA	15313
	Bentleyville Borough	900 Main Street	Bentleyville	PA	15314
	Blaine Township	40 Main Street P.O.Box 128	Taylorstown	PA	15365
JIM ARBORE Jim Mounts	Buffalo Township	400 Buffalo Center Lane	Washington	PA	15301
	Burgettstown Borough	1509 Main Street	Burgettstown	PA	15021
	California Borough	225 Third Street	California	PA	15419
	Canonsburg Borough	68 E. Pike Street	Canonsburg	PA	15317
	Canton Township	655 Grove Avenue	Washington	PA	15301
Tom BARR DAVE BARKEY Jim BURBOWER	Carroll Township	130 Baird Street	Monongahela	PA	15063
	Cecil Township	3599 Millers Run Road Suite101	Cecil	PA	15321
	Centerville Borough	100 East End Road	Brownsville	PA	15417
	Charleroi Borough	334-338 Fallowfield Avenue	Charleroi	PA	15022
	Chartiers Township	2 Buccaneer Drive	Houston	PA	15342
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	Coal Center Borough	P.O Box 174	Coal Center	PA	15423
	Cokeburg Borough	P.O. Box 474	Cokeburg	PA	15324
Gary Hokes	Cross Creek Township	28 Clark Avenue	Avella	PA	15312
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	Dunleavy Borough	2 Walnut Street P.O. Box 18	Dunleavy	PA	15432
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ACT 167, PHASE II WASHINGTON COUNTY
WATERSHEDS
STORMWATER MANAGEMENT PLAN

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	Hopewell Township	20 Parkview Road	Avella	PA	15312
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KEN HOWARD	Independence Township	P.O. Box E	Avella	PA	15312
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	McDonald Borough	151 School Street	McDonald	PA	15057
	Marianna Borough	Procasky Road P.O Box 368	Marianna	PA	15345
	Midway Borough	304 Noblestown Road P.O Box 574	Midway	PA	15060
	Monongahela City	449 West Main Street	Monongahela	PA	15063
KATHY LESNOCK, Secty S. Doug Las Smith Vice. Sup.	Morris Township	P.O. Box 34	Prosperity	PA	15329
MARY ANN STEVENSON LARRY CHOME	Mount Pleasant Township	31 McCarrell Road	Hickory	PA	15340
BILL CASTLE NAN ENY	New Eagle Borough	157 Main Street	New Eagle	PA	15067
	North Bethlehem Township	P.O. Box 112	Scenery Hill	PA	15360
	North Charleroi Borough	555 Walnut Avenue	North Charleroi	PA	15022
	North Franklin Township	620 Franklin Farms Road	Washington	PA	15301
JOE SITES	North Strabane Township	1929 Route 519 South	Canonsburg	PA	15317
J.A. SANFORD	Nottingham Township	909 Sugar Run Road	Eighty Four	PA	15330
MARK ZEMAITIS MICHAEL S. WEBER	Peters Township	610 East Mcmurray Road	McMurray	PA	15317

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	Union Township	3904 Finley-Elrama Road	Finleyville	PA	15332
	Washington City	55 West Maiden Street	Washington	PA	15301
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	West Brownsville Borough	235 Main Street	West Brownsville	PA	15417
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	West Middleton Borough	18 West Main Street P.O. Box 95	West Middleton	PA	15379
STEPHEN HAJDU	West Pike Run Township	238 Pike Run Road	Daisytown	PA	15427
Gary Hudson	Wash. Co. Cons. District	100 West Beau St., Ste 105	Washington	PA	15301
Stephanie Mullaney Donna Morgan	PennDOT District 12	PO Box 459	Uniontown	PA	15401
	Public Safety	100 West Beau St.	Washington	PA	15301
	Flood Task Force	c/o Mackin Engineering RIDC Park West, 117 Industry Dr.	Pittsburgh	PA	15275
	DEP, Bureau of Watershed Management	400 Market Street	Harrisburg	PA	17105
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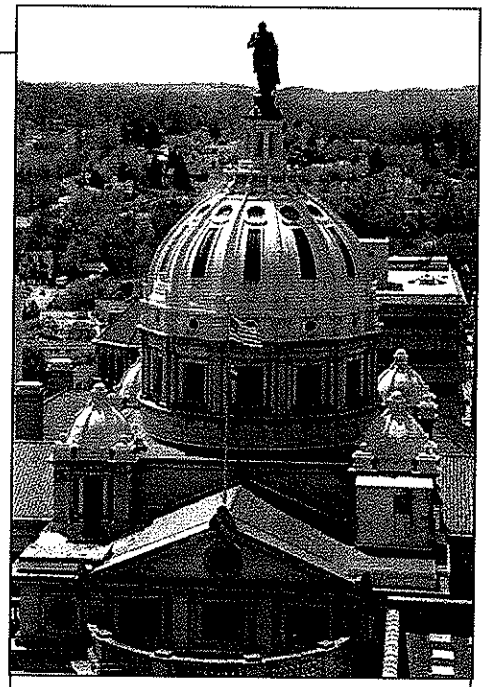
	Washington County Watershed Alliance	159 Canterbury Lane	McMurray	PA	15317
Susan Morgan	Watershed Alliance	c/o Redevelopment Authority 100 West Beau St., Ste 603	Washington	PA	15301

NAME	Municipality	Street Address	City	State	Zip
	California University	Dept. of Earth Sciences, California University, 250 University Ave., Box 55	California	PA	15419
	Washington Jefferson College	Environmental Studies Washington and Jefferson College 102 Hall	Washington	PA	15301
	Fish and Boat Commission	236 Lake Road	Somerset	PA	15501
	Army Corps of Engineers	2038 WM S Moorehead Federal Bldg., 100 Liberty Ave.	Pittsburgh	PA	15222
Ernest Hatton		WC PC			
R. Christopher Willet		W.C.P.C.			
L. Mitla		"			
[illegible]		WCPC.			

Michael N. Defalla S. Strabane TWP.

Washington County Act 167 Stormwater Management Plan



WHAT IS ACT 167? *The Pennsylvania Stormwater Management Act of 1978* (Act 167) provides for the regulation of land and water uses for flood control and stormwater management purposes. The Act authorizes a comprehensive stormwater management program designed to preserve and restore the flood carrying capacity of streams, preserve natural stormwater areas, and encourage planning and management of runoff consistent with sound water and land uses practices. The Act directs each County to prepare and adopt a stormwater management plan for each designated watershed.

WHY DOES THE COUNTY NEED AN ACT 167 PLAN? Before now, no Act 167 Stormwater Management Plans have been prepared for the watersheds in the County. Those wathersheds include the Ohio River, Robinson Run, Chartiers Creek, Raccoon Creek, Wheeling Creek, Cross Creek, Monogahela River, Tenmile Creek, Pike Creek, Pigeon Creek and Peters Creek watersheds. The Act 167 Plan provides an inventory of the many elements that impact stormwater runoff and offers guidance for its management as Washington County moves into the future.

HOW WAS THE PUBLIC INVOLVED? In order the obtain input from the County's municipalities, Plan Advisory Committee (PAC) was formed and met several times during the development of the Plan. With each municipality represented, the PAC acted as a conduit of information to and from the Project Team and the community.

WHO PAID FOR THE PLAN PREPARATION? Washington County has obtained a grant from PA DEP to complete the Phase I which the County matched the grant with 25% in in-kind services. Based on the Phase I Report, PA DEP has developed an agreement with the County to complete Phase II which they will reimburse 75% of the costs with the County matching 25% mostly with in-kind services.

WHAT WILL THE PLAN DO? The Plan is a policy document to manage stormwater runoff. The goals of the Plan were established during the early stages of the project with input from the PAC to meet requirements of the Act 167 Program as well as to meet the needs of Washington County. The Plan develops strategies with these objectives in mind to address each of the Plan's goals. A Model Ordinance was developed through the planning process that must be adopted by all municipalities and will implement the standards and criteria of the Plan.

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Washington County Planning Com.
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Washington, PA 15301
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[e] dweikel@hrg-inc.com

GOAL: Provide a comprehensive program of stormwater management	
Strategy: Manage stormwater runoff created by new development activities by taking into account the cumulative basin-wide stormwater impacts from peak runoff rates and runoff volume	
▪ Develop models of selected watersheds to determine their response to rainfall	Section VI, Appendix A
▪ Determine appropriate stormwater management controls for these basins	Section VI, Appendix A
GOAL: Provide uniform standards throughout Washington County	
Strategy: Criteria and standards used by all municipalities within County	
▪ Develop a Model Stormwater Management Ordinance with regulations specific to the watersheds within the county	Model Ordinance
▪ Adopt and implement the Model Ordinance in every municipality in the County	Model Ordinance
GOAL: Ensure that existing stormwater problem areas are not exacerbated by future development	
Strategy: Understand the source cause of stormwater runoff problems	
▪ Develop an inventory of existing stormwater problem areas	Section V
▪ Analyze problem areas and provide conceptual solutions to the problems	Section V, Appendix B
▪ Develop stormwater management standards and criteria	Model Ordinance
GOAL: Encourage the management of stormwater to maintain groundwater recharge, to prevent degradation of surface and groundwater quality, and to protect water resources	
Strategy: Preserve the existing natural drainage patterns and use Volume Control criteria as a stormwater management standard	
▪ Provide education on the correlation between stormwater and water resources	Section I, Section X
▪ Require use of the Design Storm Method or the Simplified Method for Volume Control	Model Ordinance
▪ Provide education on the function and importance of natural drainage ways	Section I, Section X
▪ Protect these features through provisions in the Model Ordinance	Model Ordinance
GOAL: Meet the legal water quality requirements under Federal and State laws	
Strategy: Understand runoff pollution and develop water quality standards	
▪ Provide recommendations for improving impaired waters within the county	Section IX
▪ Encourage the use of particularly effective stormwater management BMPs	Section VII
▪ Require use of Volume Control criteria to meet water quality standards	Model Ordinance

WATERSHED MODELING: The Plan was developed from data collected on the physical features of the watersheds (existing and future land use, geology, soils, topography, floodplains, impoundments, stream dimensions, and obstructions). Information on existing problem areas was solicited from the PAC which guided the development of the sub-watersheds, identifying points of interests, and understanding the hydrologic flow of the watershed as a whole. All data was compiled into a Geographic Information Systems (GIS) database.

A detailed model of the Chartiers Creek watershed was developed in the Plan. The process of determining how a watershed responds to precipitation is complex. The computer model developed uses all the data gathered to predict runoff flows and was calibrated. The model was then used by running numerous scenarios showing the impacts of future land use changes which were analyzed. The implementation of both volume controls and rate controls were developed to minimize the impacts to the watershed. The analysis also involved modeling different amount of rain that falls over a 24-hour period from a 2-year return frequency through 100-year return frequency.

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WASHINGTON COUNTY ACT 167

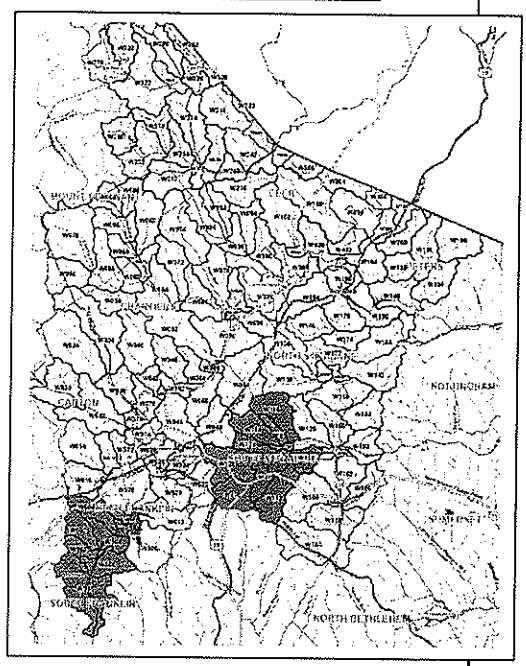
CONTROL CRITERIA: The Control Criteria developed includes both Volume Control alternatives and Rate Control. The following table summarizes the Stormwater Management Controls that are required for all Regulated Activities:

	Sizing Criteria	Description of Stormwater Sizing Criteria
Volume Control	**Design Storm Method** (CG1)	Regulation of the 2-year storm event: -No increase in total runoff volume for the 2-yr/24-yr event -Consider existing non-forest pervious area as meadow -20% of existing impervious area considered as meadow
	Simplified Method (CG2)	Regulation of stormwater runoff from new impervious (1 acre max): -capture of first 2" of runoff -1" of captured runoff shall be permanently removed -½"of captured runoff shall be infiltrated
	Water Quality Calculations	Where infiltration is not possible or desirable (document justification) -Specific BMP's for Pollution Prevention to reduce Total Suspended Solids (TSS) 85% Total Phosphate (TP) 85% Total Nitrate (NO_3) 50%

Peak Rate Controls

A. In identified districts, the post-development peak discharge rate for 2-, 10-, 25- and 100-year storms shall follow the release rate maps.
   1. Red – 50%
   2. Green – 70%

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



EXEMPTIONS:

Single Family Residential activities are exempt from requirements provided:

A. Buildings 75' upstream from property lines

B. Driveways:
   - ✓ Spread discharge onto pervious surface
   - ✓ <1,000 sf of paved surface discharge to any point.
   - ✓ Flow length on pervious more than on paved surface.

The following table summarizes the threshold levels for new Regulated Activities:

New Impervious Area[1, 2] (square footage)	Applicant Must Provide
0 – 2,500	No submission
2,500 – 5,000	Documentation of impervious surfaces (Small Project SWM Application)[3]
> 5,000	Rate Controls, Volume Controls & SWM Site Plan

NOTES:

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

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

[3] The first page of the Small Project Stormwater Management Application included in Appendix E may be used to document new impervious surfaces.

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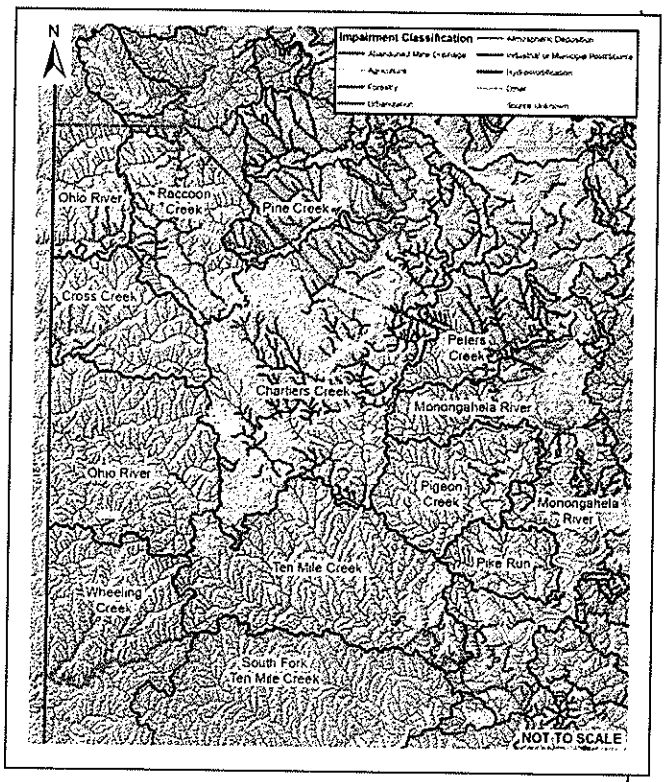
WASHINGTON COUNTY ACT 167

HOW WILL WATER QUALITY BE ADDESSED AND IMPROVED? The Plan shows both the water quality classifications and protected uses of all surface waters within the County as well as identified impaired stream representing those streams not achieving the designated uses. Through the implementation of the Model Ordinance, the Volume Control Criteria will ensure that water quality will not worsen by the impacts of future development. Two important provisions of the Model Ordinance will help ensure future growth will not impact water quality:

- Riparian Buffers consistent with new proposed Chapter 102 requirements.
- Optional Existing Resources and Site Analysis in special protection watersheds.

In addition, the Plan identifies a recommended strategy to improve existing stream impairments.



HOW WILL THE PLAN BE IMPLEMENTED? All municipalities within Washington County will be required to adopt the Washington County Stormwater Management Ordinance. The standards and criteria contained in the Ordinance will apply to all municipalities. County adoption of the Plan is expected to occur in June 2010. Once this occurs, the Plan will be sent to DEP to be approved. Upon DEP approval, each municipality will become responsible for implementation of the Plan, which includes the following:

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

Three basic models for Plan implementation are presented below for the municipalities to consider. In some cases it may be advantageous for multiple municipalities to implement the Plan cooperatively, or even on a county-wide basis.

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

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NAME	Organization/Affiliation	Contact
Carrilee L. Hemington	Chartiers Creek Watershed Association	clhemington@verizon.net
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Berb Grubbs	Hanover Twonship	herbjovg@gmail.com
Steve Henderson	Alliance Consulting, Inc.	shenderson@acl-pa.com
Susan Morgan	Washington County Watershed Alliance	susan.morgan@racw.net
Pam Kelly		724-873-8989
Neil Kelly		724-873-8989
Tom Jennincan		724-587-3371
S. Douglas Smith	Morris Township Supervisors	724-884-6188
Mark Bachmann		724-873-5000
J. Bracken Burns, Sr.	Washington County Commissioners	724-228-6724

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Engineering & Related Services

200 West Kensinger Drive, Suite 400
Cranberry Township, PA 16066
(724) 779-4777
FAX (724) 779-4711

TO: Ms. Lisa Cessna – Washington County Planning Commission

FROM: HRG

DATE: June 2, 2010

SUBJECT: Washington County Act 167 – Public Hearing Summary

The Public Hearing was held on June 2, 2010 in Courthouse Square, Room 104 at the Washington County Government Complex in Washington, PA. A list of those in attendance is attached.

This memo is an overall summary of the meeting – it does not contain detailed minutes of every point discussed. Copies of the Powerpoint slides were distributed to each attendee.

- After a brief introduction by Lisa Cessna, Doug Weikel began by reviewing the project's schedule and goals. The executive summary was presented to theose in attendance. Then he went through some specifics of how the Plan and Model Ordinance fulfill those goals. Then Mr. Weikel presented some of the maps and charts contained in the Plan, and he fielded some technical questions about the maps and charts. He highlighted some of the key parts of the Model Ordinance, and then showed photographs of some example BMPs that have been constructed (including bioretention areas, rain gardens, and extended detention basins).

- Mr. Weikel fielded questions during and after his presentation. The following is a general summary of the questions and the presenter's responses:

  1. **Commissioner Burns asked if HRG could include an analysis of historical floods with their associated damage expressed in dollars.**
     Mr. Weikel indicated that we would add a chart to the plan with that information.

  2. **Are commercial and industrial construction projects treated the same as housing plans under the Model Ordinance?**
     Yes. As long as the area of proposed impervious surfaces is above the thresholds, they will be regulated by the Model Ordinance.

  3. **Will municipal Planning Commissions have any flexibility once a municipality adopts the Ordinance?**
     Yes. The PC can execute waivers as they see fit as long as requirements of Ordinance are met. Section 303 was purposefully written to provide the opportunity for the municipalities to interpret the waivers in different ways.

  4. **Are permeable pavers or pervious paving materials allowed under the Model Ordinance?**
     Yes. These BMPs are described in DEP's BMP Manual, so by reference, they are approved for use under the Plan.

  5. **Is the requirement to provide an easement for concentrated flows onto your neighbor's property for new construction only?**
     Yes. All requirements of the Model Ordinance are for projects reviewed by the municipality after the date that their new SWM Ordinance is adopted.

6. **What is the adoption process after this Public Hearing?**
First, the Washington County Commissioners will (by resolution) formally adopt the Plan which includes the Model Ordinance.
Second, the Plan and Model Ordinance will be sent to DEP for their review. They will have either 60 or 90 days to review and approve Plan.
Third, the Plan and Model Ordinance will be sent to each municipality in Washington County along with a letter stating that the municipality has 6 months from the date the letter is delivered to adopt a stormwater management ordinance that meets the minimum requirements set out in the Model Ordinance.

7. **Is there any grandfathering of projects?**
The municipality will need to enforce their ordinance beginning on the day after it is adopted at the local level. Mr. Weikel suggested that the municipalities consider enforcing the ordinance on the day that that they advertise for the local public hearing. Once again, Mr. Weikel stressed that the Model Ordinance only applies to new construction, so in a sense, all existing development is grandfathered.

8. **Is gravel considered pervious or impervious?**
According to the Model Ordinance, gravel in the existing condition is considered pervious, and gravel in the proposed condition is considered impervious. This is because it can be assumed that the landowner will either pave the gravel area in the future, or he will work to compact the gravel as much as possible to provide a smooth, stable driving surface, in essence making it impervious. Only if the applicant can demonstrate to the municipality that the gravel will be maintained in a loose, permeable condition (for some legitimate reason) can the proposed gravel area be excluded from the impervious area tabulation.

9. **How is long term maintenance of the BMPs addressed?**
Responsibility for maintenance of the BMPs rests with the landowner. The Model Ordinance requires that the developer grant access easements around the BMPs so that the municipality will have the right to enter and inspect or fix the BMPs if problems arise in the future.

10. **Is PENNDOT regulated under Act 167?**
PENNDOT will not be required to submit a plan for municipal approval under our new ordinances. But Mr. Weikel pointed out that their new DM2 will be in accordance with the Act 167 regulations.

11. **Are longwall mining activities regulated by the Model Ordinance?**
Longwall mining will not be regulated, because it consists of the removal of underground coal. The Model Ordinance only regulates activities that propose new impervious areas on the surface of the ground. Even though subsidence due to shallow coal removal may affect streamflow, this Act 167 effort will not regulate longwall mining.

12. **What are the riparian buffer requirements in the Model Ordinance?**
The riparian buffers required by the Model Ordinance are 50 feet from the top of each streambank for all watercourses, even Exceptional Value (EV), High Quality (HQ), and impaired watersheds (as designated by DEP). Previously, the Model Ordinance required 150' buffers on each side in EV, HQ, and impaired watersheds, but that requirement was removed at Washington County's request, due to feedback from the PAC. Mr. Weikel highly recommends the 150' riparian buffers in EV, HQ, and impaired watersheds, because that is consistent with the new Chapter 102 regulations that were passed by Pennsylvania's Environmental Quality Board, and which are now in the hands of the IRRC for review. Mr. Weikel expects the new Chapter 102 requirements to be enforced in the coming months. As it is now written, the Model Ordinance requires the 50' riparian

buffers as a minimum for all streams or as required by other DEP regulations, so when the new Chapter 102 regulations become law, the ordinance will be consistent with the wider buffers.