Urban Build-Out and Stormwater BMP Analysis for the Galien River Watershed

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1. Introduction

Under contract to the Southwest Michigan Planning Commission, Kieser & Associates, LLC (K&A) has completed a "build-out" analysis for the Galien River watershed. The Galien River is a 10-digit HUC watershed located in southwest Michigan and northwest Indiana. This analysis was limited to the Michigan section of the watershed. The build-out analysis provides an estimate of the impact of urban development on pollutant loads that is used to address the U.S. Environmental Protection Agency's nine-element requirements for watershed management plans. The build-out analysis for the Galien River Watershed quantifies current and future pollutant loads and runoff volumes at different levels of build-out, highlighting areas that may become important for maintaining or improving water quality.

The Galien River Watershed is predominantly agricultural with some significant areas of wetlands and forests along the western and eastern boundaries. The main urban centers are the city of New Buffalo (pop. 2,200), on Lake Michigan's shoreline and the village of Three Oaks (pop. 1,829), both located in Berrien County. Berrien County experienced a 1.2% decrease in population between 2000 and 2009 (US Census Bureau[1]), this can be compared to a 0.3% estimated growth for the State of Michigan. While not all new development pressure occurs as retrofits to existing infrastructure these percentages aid in understanding the development pressure currently experienced by Berrien County managers. While most of the estimated non-point source pollution in the watershed is attributed to agricultural areas, it has been shown that urban areas contribute significantly to pollutant loadings (e.g., K&A, 2001; DeGraves, 2005). Where new development pressures exist, pollutant loads will increase unless policies are in place to mitigate the impacts of new development. Therefore, understanding and quantifying the impact of future urban development on water quality is key to developing adequate land use management plans that meet watershed management goals.

This analysis assesses the impact of zoning and future land use management on runoff volume and pollutant loads in the Galien River Watershed. A simple empirical approach, similar to the one used by K&A in the St Joseph Watershed Management Plan (DeGraves, 2005), the Paw Paw River Watershed Management Plan (SWMPC, 2008), and the Black River Watershed Management Plan (Fuller, 2009), was used to calculate current and future runoff volumes and non-point source pollutant loads. Pollutant loads and runoff volumes were calculated using average annual runoff depth values calculated by the Long-term Hydrologic Impact Assessment model (L-THIA), and appropriate pollutant event mean concentration values from recognized citation sources. Four hypothetical scenarios, simulating urban build-out at a rate of 25, 50, 75 and 100% were defined to estimate the impact of urban development on water quality and quantity. In addition, implementation costs and cost efficiency were estimated for five commonly used stormwater BMPs. Results are reported in this document.

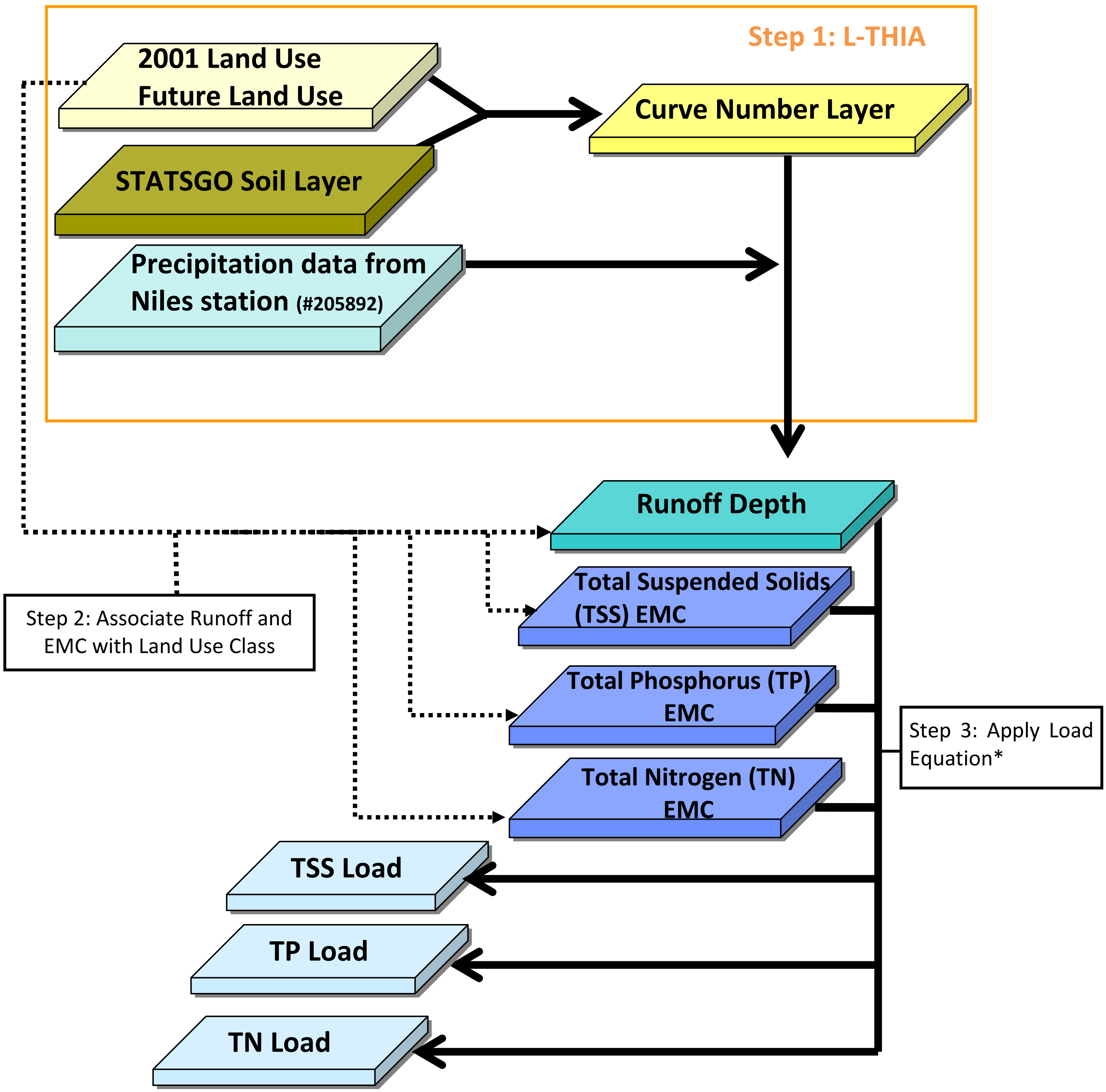
[1] http://quickfacts.census.gov/qfd/states/26/26021.html

2. Build-out Modeling Methods

The build-out model developed for the Galien River Watershed uses the same data sources used in the Paw Paw River and the Black River WMPs in order to provide consistency in results for the southwest Michigan region. Land use, soil and boundaries data layers are combined and analyzed using L-THIA, a rainfall-runoff model, to provide spatial information about runoff volumes and pollutant loads.

2.1 Base GIS Build-out Layer

The build-out analysis is based on the development of a complex GIS layer where multiple data layers (land use, soils, political boundaries, etc.) are overlaid and each unique record (i.e., polygon) is assigned individual runoff and event mean concentration (EMC) values as well as specific management characteristics. The conceptual design is presented in Figure 1.



*Runoff Depth (in/yr) x EMC (mg/L) x 0.2266 x polygon area = total annual load (lbs)

Figure 1: L-THIA/Build-Out Non-Point Source Modeling Flow Chart.

The following layers were used to create the base GIS build-out layer:

- 2001 IFMAP land use: the 2001 IFMAP land use/land cover layer[2] was reclassified into nine broad categories to match, as much as feasible, land use categories with known event mean concentration values and land use categories available in L-THIA (Table 1).
- STATSGO soil layer: The STATSGO soil data layer[3] provided information on the hydrologic soil group for each soil type.
- 12-digit hydrologic unit code (HUC) subwatersheds[4].
- Municipalities[5].

Table 1: Reclassification of IFMAP land use categories.

2001 IFMAP Classification		***Reclassified Values***	
Land Use Value	**Land Use Category**	***Reclassified Value***	***Reclassified Description***
1	Low intensity urban	1	Low density urban
2	High intensity urban	2	High density urban
4	Road/parking lot	3	Transportation
5	Non-vegetated farmland	4	Agriculture
6	Row crops	4	Agriculture
7	Forage crops/non-tilled herbaceous agriculture	4	Agriculture
9	Orchard/vineyard/nursery	4	Agriculture
10	Herbaceous openland	5	Rural open
12	Upland shrub/low density trees	5	Rural open
13	Parks/golf courses	6	Urban open
14	Northern hardwood association	7	Forest
15	Oak association	7	Forest
16	Aspen association	7	Forest
17	Other upland deciduous	7	Forest
18	Mixed upland deciduous	7	Forest
19	Pines	7	Forest
20	Other upland conifers	7	Forest
22	Upland mixed forest	7	Forest
23	Water	8	Water
24	Lowland deciduous forest	9	Wetlands
25	Lowland coniferous forest	9	Wetlands
26	Lowland mixed forest	9	Wetlands
27	Floating aquatic	9	Wetlands
28	Lowland shrub	9	Wetlands
29	Emergent wetland	9	Wetlands
30	Mixed non-forest wetland	9	Wetlands
31	Sand/soil	5	Rural open

[2] Available from the Michigan Geographic Data Library at http://www.mcgi.state.mi.us/mgdl/
[3] Downloaded from the USDA NRCS Soil Data Mart at: http://soildatamart.nrcs.usda.gov/USDGSM.aspx
[4] Downloaded from the NRCS-USDA Geospatial Data Gateway at: http://datagateway.nrcs.usda.gov/
[5] Available from the Michigan Geographic Data Library at http://www.mcgi.state.mi.us/mgdl/

2001 IFMAP Classification		*Reclassified Values*	
Land Use Value	**Land Use Category**	***Reclassified Value***	***Reclassified Description***
35	Other bare/sparsely vegetated	5	Rural open

The Southwest Michigan Planning Commission (SWMPC) provided the following layers:

- 'No Change Layer': This layer includes protected lands, including preserves owned by land conservancies, easements held by either Chikaming Open Lands or Southwest Michigan Land Conservancy and municipal and county parks.
- 'Intermediate Layer': This layer maps MDEQ regulated wetlands.
- 'Future Land Use': This layer, created by SWMPC from municipalities' future land use maps and master plans, is used to predict future land use categories within the watershed (see Table 2).

As previously noted, the scope of this project only includes the Galien River Watershed within the State of Michigan and therefore, the analysis is limited to the portion of the watershed in Michigan[6].

Table 2: Dates of Future Land Use maps used in the build-out analysis (compiled in Dec. 2005 and updated in April 2010 by SWMPC from community master plans)

Municipality	Master Plan Future Land Use Map Date
BarodaTwp	1993
Bertrand Twp	2003
Buchanan Twp	2002
Chikaming Twp	2008
Galien Twp	No future land use as of 2005
Village of Galien	No plan available
City of New Buffalo	2003
New Buffalo Twp	2008
Oronoko Twp	1999
Three Oaks Twp	2004
Village of Three Oaks	2002
Weesaw Twp	1999

All layers (in shapefile format) were overlaid and processed through ESRI ArcGIS 9.3® to create one complex GIS layer with an extensive attribute table, including fields for current and future land use category, soil type and hydrologic soil group, subwatershed and township name, regulated wetlands or "no change" classification.

2.2 Pollutant Load Calculations

Both land use and soil layers were processed using the L-THIA GIS ArcView® extension to calculate runoff depth. L-THIA is a rainfall-runoff model developed by Purdue University[7]. It uses the SCS (Soil Conservation Service, now

[6] 73% of the total watershed area is located within Michigan, with the remaining area in Indiana.
[7] For more information, visit L-THIA website at: http://www.ecn.purdue.edu/runoff/lthianew/Index.html

named the Natural Resources Conservation Service) Curve Number method and long-term precipitation data to calculate average annual runoff depths for each unique combination of soil and land use. Standard curve numbers from the TR-55 Manual (USDA, 1986) were selected for each land use based on land use definition and imperviousness (Table 3). The average annual runoff calculated by L-THIA for each land use and hydrologic soil group combination is presented in Table 4.

Table 3: Curve numbers selected for L-THIA modeling.

	Curve Number for Hydrologic Soil Group			
Land Use Category	**A**	**B**	**C**	**D**
Agriculture	64	75	82	85
Forest	30	55	70	77
Rural Open	39	61	74	80
Urban Open	49	69	79	84
Transportation/Highways	89	92	94	95
Commercial	89	92	94	95
Industrial	81	88	91	93
Low Density Residential	54	70	80	85
Medium Density Residential	61	75	83	87
High Density Residential	77	85	90	92

Table 4: Runoff calculated by L-THIA per land use and soil combination.

Hydrologic Soil Group	Land Use	Runoff (in inches/year)
A	Agriculture	0.78
B	Agriculture	2.23
C	Agriculture	4.27
A	Forest	0.00
B	Forest	0.29
C	Forest	1.39
A	Rural Open	0.03
B	Rural Open	0.57
C	Rural Open	2.03
A	Transportation	8.41
B	Transportation	11.58
C	Transportation	14.61
A	High Density Residential	2.68
B	High Density Residential	5.67
C	High Density Residential	9.33
A	Medium Density Residential	0.57
B	Medium Density Residential	2.23
C	Medium Density Residential	4.69
A	Low Density Residential	0.26

Hydrologic Soil Group	Land Use	Runoff (in inches/year)
B	Low Density Residential	1.39
C	Low Density Residential	3.54
A	Commercial	8.41
B	Commercial	11.58
C	Commercial	14.61
A	Industrial	3.89
C	Industrial	10.38
A	Urban Open	0.14
C	Urban Open	3.23
A	Water/Wetlands	0.00
B	Water/Wetlands	0.00
C	Water/Wetlands	0.00

Event Mean Concentrations (EMC) values from the Rouge River were used in this analysis. The Rouge River National Wet Weather Demonstration Project conducted an extensive assessment of stormwater pollutant loading factors per land use class (Cave et al., 1994) and recommended EMC values for 10 broad land use classes (Table 5). These EMC values are used for many Michigan applications and have since been incorporated into the Michigan Trading Rules (Part 30) to calculate pollutant loads from urban stormwater nonpoint sources. Runoff depth calculated through L-THIA, and event mean concentration values presented in Table 5, were added as attributes to the build-out layer and used to calculate current and future pollutant loads.

Pollutant loads were calculated using the simple equation:

$$EMC_L \times R_L \times A_L \times 0.2266 = L_L$$

Runoff volume was calculated as follows:

$$R_L \times A_L \times 0.0833 = R_v$$

Where:

- EMC_L = Event mean concentration for land use L in mg/L (Table 5).
- R_L = Runoff per land use L from L-THIA in inches/year.
- A_L = Area of land use L in acres.
- 0.2266 = Unit conversion factor.
- L_L = Annual load per land use L in lbs/yr.
- R_v = Runoff volume in acre-feet/yr.

Table 5: Event mean concentrations for land use categories used in the build-out analysis.

Original Land Use Category (Rouge River)	2001 Reclassified Land Use Category	Future Land Use Category	Percent Impervious	TSS (mg/L)	TP (mg/L)	TN (mg/L)
Forest/rural open	Forest/rural open	N/a	0.5% (1)	51	0.11	1.74
Urban open	Urban open	Urban open	0.5%	51	0.11	1.74
Agricultural	Agriculture	N/a	3% (2)	145	0.37	5.98
N/a	N/a	Agricultural	3% (2)	varies(3)	varies(3)	varies(3)
Low density residential	Low density urban	Low density residential	10%	70 (4)	0.52 (4)	5.15 (4)
N/a	N/a	Rural residential (5)	varies	varies	varies	varies
Medium density residential	N/a	Medium density residential	30%	70	0.52	5.15
N/a	High density urban (6)	N/a	85%	120 (6)	0.31 (6)	3.54 (6)
High density residential	N/a	High density residential	85% (7)	97	0.24	3.29
Commercial	N/a	Commercial	90%	77	0.33	2.97
Industrial	N/a	Industrial	80%	149	0.32	3.97
Highways	Transportation	Highways	90%	141	0.43	2.65
Water/ wetlands	Water and Wetlands	Water/ Wetlands	0%	6	0.08	1.38

N/a: not applicable

Notes:

(1) Imperviousness for forest/rural open is considered similar to the Urban Open category value as it includes forested/open space areas where roads have been assigned to the Highways category.

(2) This value is based on density of farm roads, field access roads and farmsteads in the agricultural land use category.

(3) The agricultural category is defined by SWMPC as a function of Low Density Residential and current land use.

(4) Low density residential category values will be applied to smaller parcel single family dwellings of less than two acres in size.

(5) This category includes parcels greater than 2 acres. The EMC value for Low Density Residential will be used to calculate the loading and runoff for 33% of the area of these polygons (corresponding to the homestead and associated acreage developed). The loading and runoff for the remaining 67% should be calculated using the EMC value of the current land cover (IFMAP) category in the polygon.

(6) This land use was defined as 60% industrial, 25% commercial and 15% high density residential in the Paw Paw River Watershed. This ratio was determined by comparing areas identified in IFMAP as High Intensity Urban to 2003 and 2005 digital ortho-photographs and the 1978 MIRIS Land Use dataset. Event mean concentration values were re-calculated by weighting High Density Urban land use area using the above ratio.

(7) The High Density Residential land use range nationwide is from 50–100 percent imperviousness: the land use category determined from the Rouge River study defined it as high-rise apartment and condominium buildings that are four or more stories in height. These structures when combined with adequate parking reflect commercial or industrial land use category values.

3. Baseline Results

The 2001 IFMAP land use map was used as the baseline to calculate current runoff volume and pollutant load conditions in the Galien River Watershed.

1.1 Urban Areas in the Galien River Watershed

Figure 2 shows that the only urban subwatershed (-0208) is located at the mouth of the Galien watershed. Urban land uses occupy almost 30% of this subwatershed area (Table 6). Urban areas in this subwatershed include parts of the city of New Buffalo, as well as lakeshore development areas. The South Branch subwatershed (-0206), directly adjacent to the mouth of the watershed, could be classified as urbanizing with about 9% of the land area in urban land use; it includes part of Highway I-94 and the village of Three Oaks. The remaining land area in the watershed is mainly agricultural, with some forested and wetlands areas in the eastern part of the watershed and alongside the Galien River in subwatershed -0207.The 2001 land use breakdown by subwatershed is shown in Table 6.

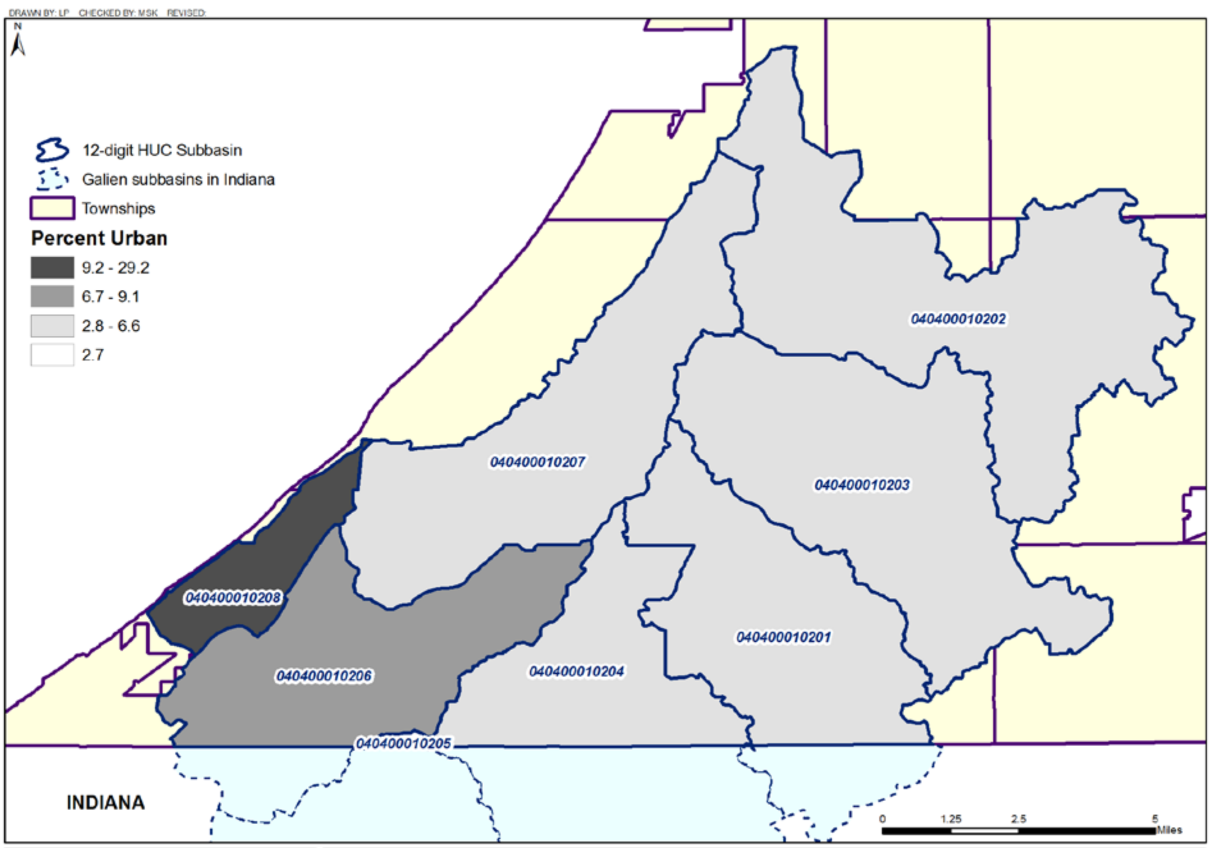


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Figure 2: Percentage of urban land use per 12-digit HUC subwatershed (based on 2001 IFMAP land use).

Table 6: 2001 Land use breakdown (%) per 12-digit HUC subwatershed.

Subwatershed Name	12-Digit HUC	Low Density Urban	High Density Urban	Transport.	Agriculture	Rural Open	Urban Open	Forest	Water	Wetlands	*Total urban*
Dowling Creek	40400010201	0.8	0.3	3.0	76.9	4.6	-	8.2	-	6.1	4.2
East Branch Galien River	40400010202	1.5	0.2	2.6	56.2	10.3	0.3	17.7	0.5	10.7	4.7
Blue Jay Creek-Galien River	40400010203	1.2	0.4	3.1	66.2	7.1	-	11.1	0.1	10.8	4.7
Spring Creek	40400010204	1.2	0.5	3.6	66.3	5.8	-	12.3	0.0	10.3	5.2
Headwaters South Branch Galien River	40400010205	0.5	-	2.1	44.2	8.1	-	23.9	-	21.1	2.7
South Branch-Galien River	40400010206	2.3	2.0	4.9	40.6	10.6	-	22.7	0.0	16.9	9.1
Kirktown Creek-Galien River	40400010207	2.1	0.5	4.0	47.9	10.7	-	23.8	0.0	11.0	6.6
Galien River	40400010208	7.7	4.7	16.9	3.8	13.0	-	30.2	-	23.7	29.2
Total % for the entire watershed		*1.8*	*0.7*	*4.0*	*56.3*	*8.7*	*0.1*	*16.8*	*0.1*	*11.5*	*100.0*

1.2 Baseline Pollutant Load and Runoff Results

Pollutant loads for Total Phosphorus (TP), Total Nitrogen (TN), Total Suspended Sediment (TSS) and runoff volume per land use were calculated for the Galien River Watershed under current conditions (i.e., 2001 land use). Modeling results (Table 7) show that, while agriculture remains the largest non-point source of pollutants and runoff within the Galien River Watershed, urban land uses contribute over 20% of the TSS and TP loads, and runoff volume, although they occupy only 6.5% of the land area (see Table 6).

Table 7: Percentage of pollutant load and runoff volume per land use for the Galien River Watershed.

	% of total load/volume			
Land Use Category	**TSS**	**TP**	**TN**	**Runoff**
Agriculture	74.0	70.6	83.5	68.4
Forest	2.0	1.6	1.8	5.1
Rural Open	1.5	1.2	1.4	4.0
High Density Urban	1.8	1.8	1.5	2.1
Low Density Urban	0.8	2.2	1.6	1.5
Transportation	19.9	22.7	10.2	18.9
Urban Open	0.0	0.0	0.0	0.0
Water	0.0	0.0	0.0	0.0
Wetlands	0.0	0.0	0.0	0.0

Total runoff volumes and pollutant loads were also calculated for each subwatershed and townships within the Galien River. All values are presented in Appendix A and B.

Runoff and pollutant loads are derived by assessments of land use characteristics being assigned EMC values and hydrologic consideration including imperviousness and soil infiltration capacity. Almost 50% of the Galien River Watershed is in soils with hydrologic soil group C that are characterized by relatively poor drainage and medium to high runoff potential (Figure 3). The impact of this type of soil is visible on the figures below (Figure 4 to Figure 7) presenting average annual runoff, and TSS, TP and TN baseline loading per subwatershed. In Figures 3 through 7, subwatersheds -0203 and -0207 have a large proportion of agricultural land use on C soils, therefore when the assessment methodology combines the higher agricultural EMC values with the high runoff estimates (as a result of relatively limited infiltration), pollutant loads increase. Urban areas, which would generally produce the highest runoff volumes, are mostly located at the mouth of the watershed on soils within the Hydrologic Group A, i.e. well drained soils, that have higher infiltration rates and therefore, lower runoff.

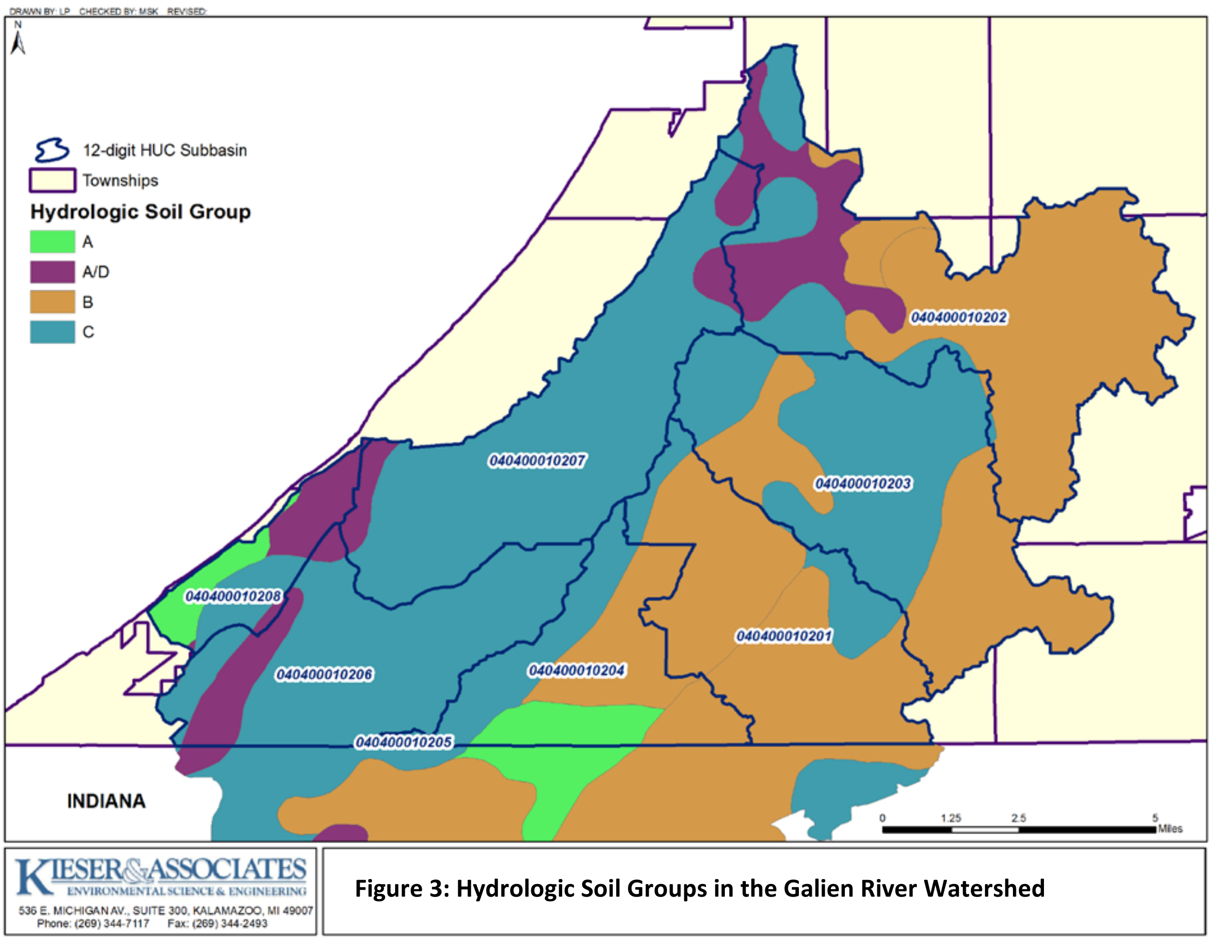

Figure 3: Hydrologic Soil Groups in the Galien River Watershed

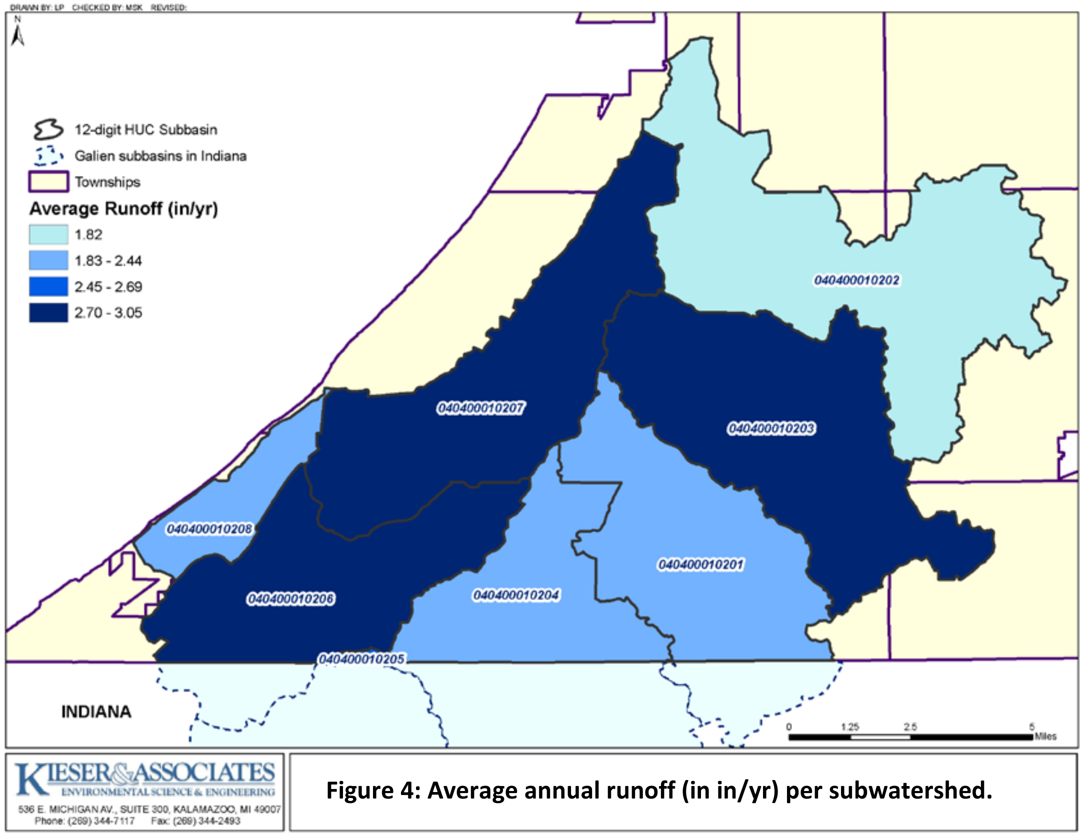

Figure 4: Average annual runoff (in in/yr) per subwatershed.

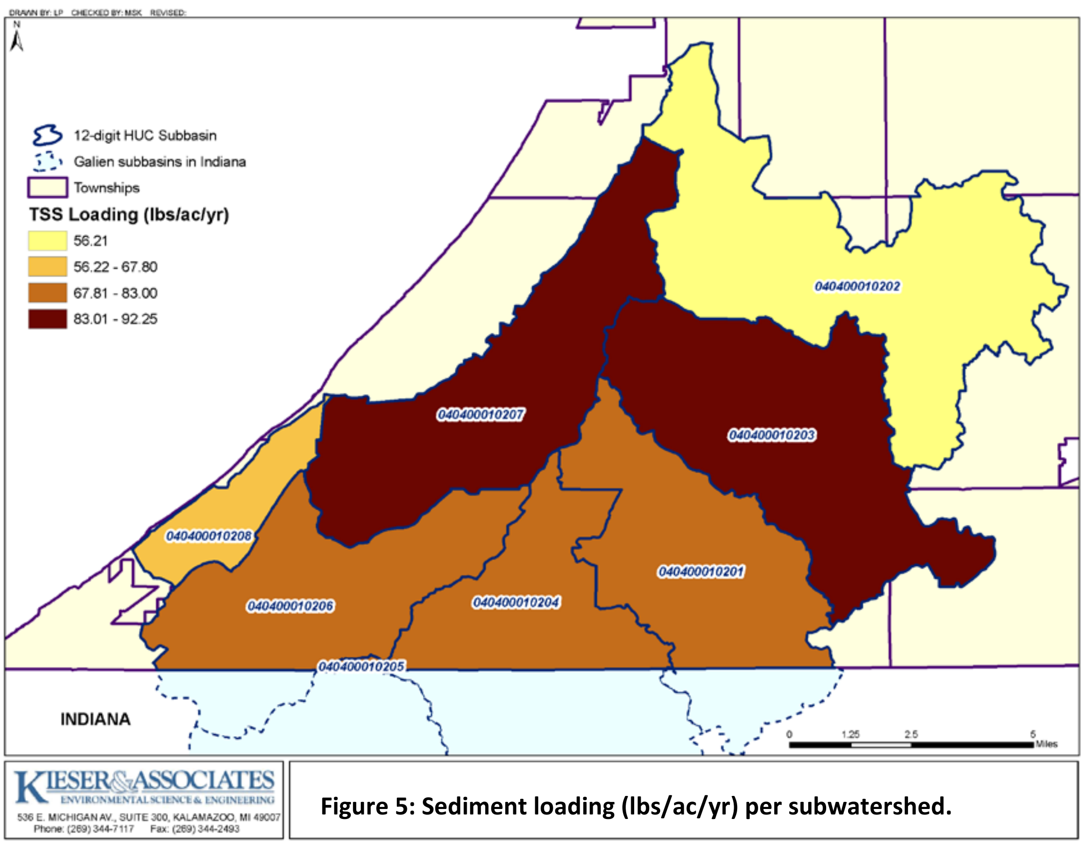

Figure 5: Sediment loading (lbs/ac/yr) per subwatershed.

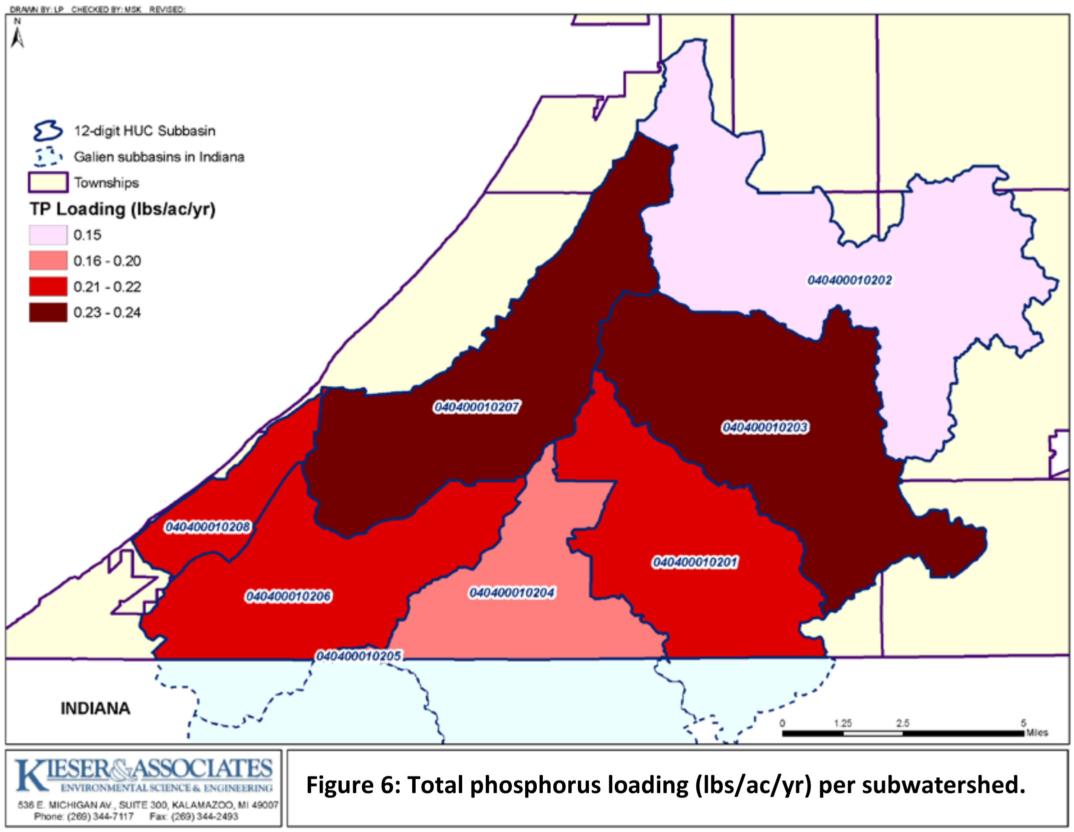

Figure 6: Total phosphorus loading (lbs/ac/yr) per subwatershed.

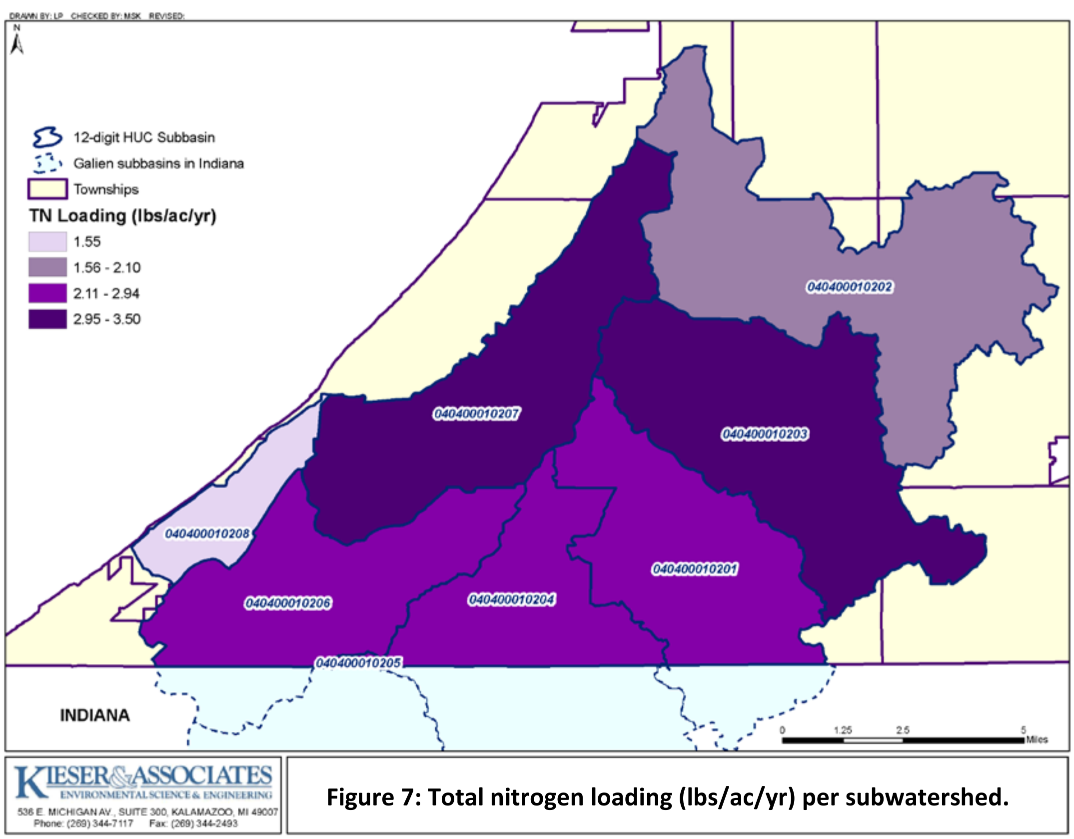

Figure 7: Total nitrogen loading (lbs/ac/yr) per subwatershed.

Figure 8 shows the distribution of pollutant loading and runoff volumes per land use category for the two highest loading subwatersheds and the urban subwatershed. In the Kirktown Creek and Blue Jay Creek subwatersheds (-0207,-0203), 60 to 90% of the pollutant loads and runoff come from agriculture, while urban land uses contribute from 15 to 25% of the TSS and TP loads. In the New Buffalo subwatershed (-0208), as expected, urban areas are the main source of pollutants and runoff, contributing over 80% of the loads. Urban land uses contributed disproportionately high loads of TSS, TP and runoff when compared to the fraction of the area they occupy. For instance, in the New Buffalo subwatershed, urban areas contribute about 91% of the TP load while they only represent about 29% of the total acreage.

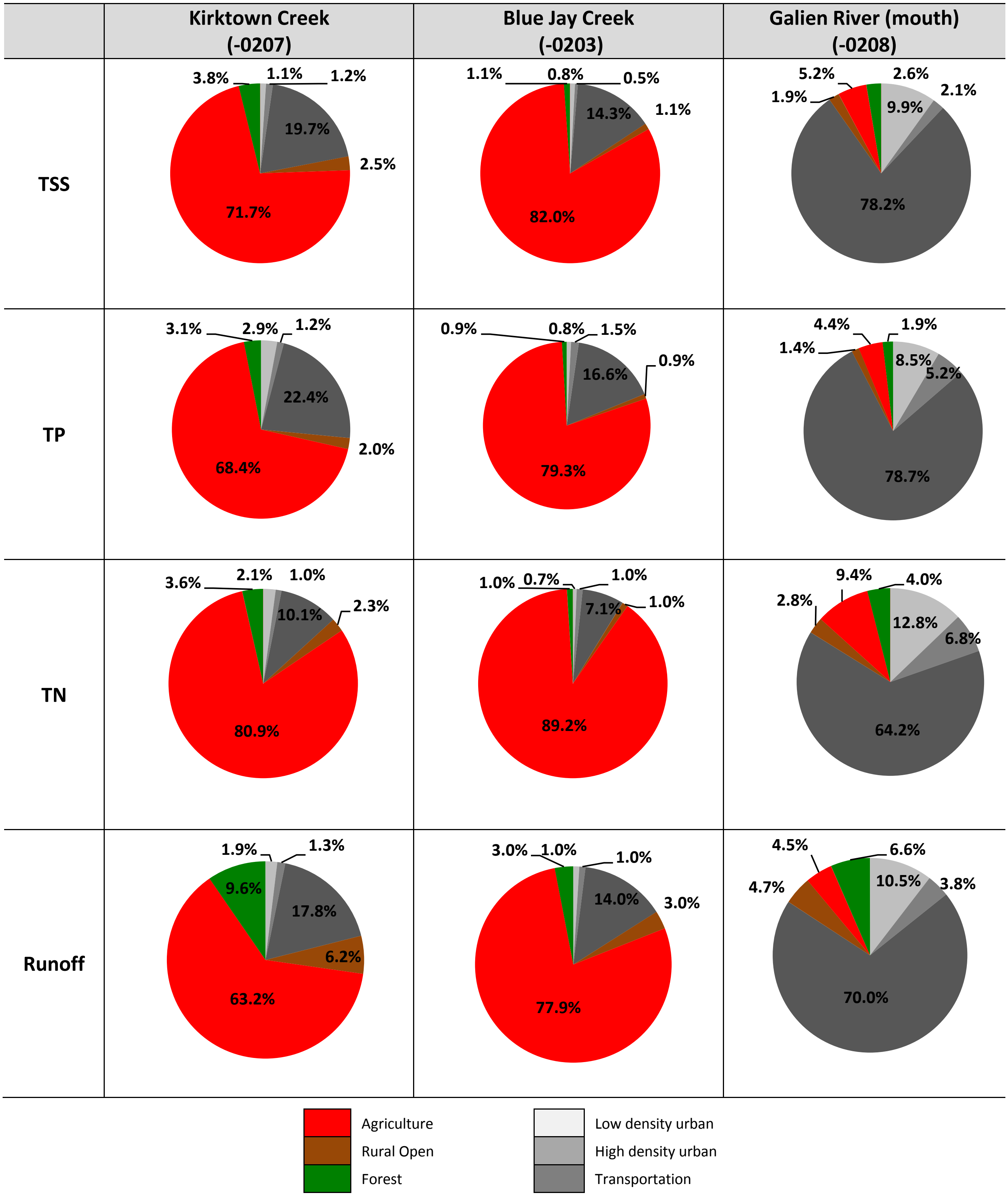

Figure 8: Loads and runoff breakdown per land use per selected subwatershed.

4. Build-out Modeling Tool and Scenarios

This section discusses the approach used for creating build-out scenarios that are compared to the 'current' loads associated with the 2001 land cover data.

4.1 Build-out Rules

The build-out analysis for the Galien River Watershed was based on detailed Future Land Use maps compiled by SWMPC from township masterplans where available (Figure 9). Four build-out scenarios were defined to simulate increasing rates of urban development (25%, 50%, 75% and 100%) and were based on the zoned land use category (called Future Land Use). Within each scenario, SWMPC specified rules based on current and future land uses that either: allowed, prohibited or limited development, as described below and in Table 8.

<u>Build-out rules narrative</u>
For each build-out scenario, and within each polygon in the GIS build-out layer:

- The following land uses cannot be altered in the build-out: water, protected lands, utility easements, cemeteries.
- Regulated wetlands will be built out at a lower rate than the scenario's rate (as defined by SWMPC – see Table 8).
- When two rules apply to a defined polygon (e.g., Rural Residential or Agricultural Future Land Use within a regulated wetland), the build-out rates will be compounded. For instance, under the 25% build-out scenario, the final build-out rate for Agricultural Future Land Use within a regulated wetland will be calculated as follows: 6.25% (wetland rate) x 6.25% (agricultural rate) = 0.0039% (final build-out rate).
- Build-out change (for instance, increase in low density residential) will be applied to each individual polygon in the build-out GIS layer (note: each polygon contains one land use and one future land use category). The total area changed will correspond to 25%, 50%, 75%, and 100% of the area of Future Land Use polygons.
- Build-out can only occur from a non-urban or lower urban category to a higher urban category (see classes and rules in Table 8). For instance, highways or high density residential cannot be changed to low density residential, but low density residential can be changed to high density residential.

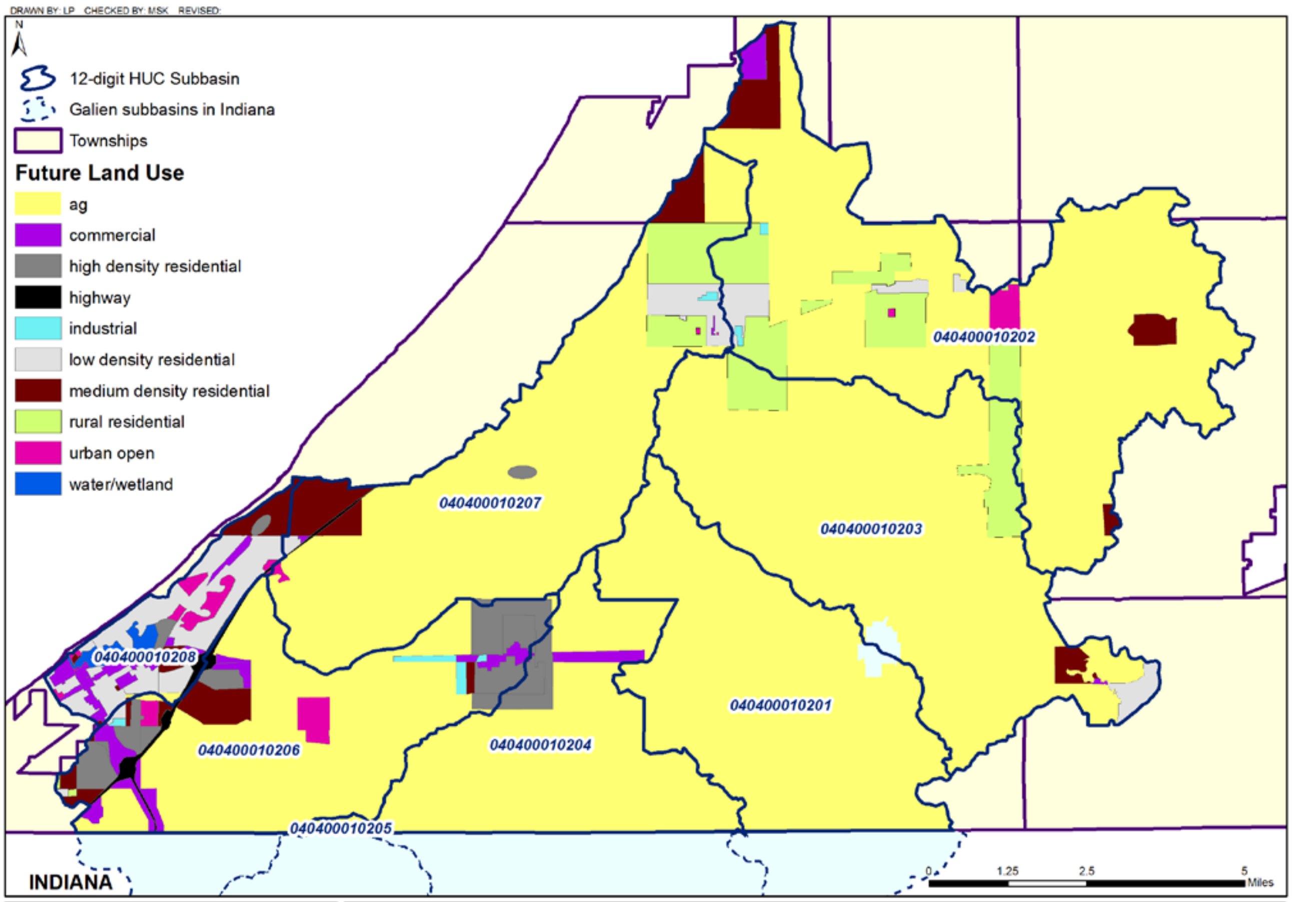

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Figure 9: Future Land Use categories based on local plans and defined by SWMPC.

Table 8: Future Land Use build-out rules defined by SWMPC.

Class		Scenario 1	Scenario 2	Scenario 3	Complete Build Out
	NO CHANGE LAYER: Hydro, SWMPC Protected Lands, Cemeteries, Utility Easements	**25.00%**	**50.00%**	**75.00%**	
	Water	100% IFMAP	100% IFMAP	100% IFMAP	100% IFMAP
	Protected Lands	100% IFMAP	100% IFMAP	100% IFMAP	100% IFMAP
	Utility Easements	100% IFMAP	100% IFMAP	100% IFMAP	100% IFMAP
	Cemeteries	100% IFMAP	100% IFMAP	100% IFMAP	100% IFMAP
	INTERMEDIATE LAYER:				
	Regulated Wetlands	6.25% FLU; 93.75% IFMAP	12.5% FLU; 87.5% IFMAP	18.75% FLU; 81.25% IFMAP	25% FLU; 75% IFMAP
Class	**FUTURE LAND USE (FLU)**				
1	Urban Open	25% Urban Open; 75% IFMAP	50% Urban Open; 50% IFMAP	75% Urban Open; 25% IFMAP	100% Urban Open
1	Agricultural	6.25% LD Res; 93.75% IFMAP	12.5% LD Res; 87.5% IFMAP	18.75% LD Res; 81.25% IFMAP	25% LD Res; 75% IFMAP
1	Rural Res	8.25% LD Res; 91.75% IFMAP	16.5% LD Res; 83.5% IFMAP	24.75% LD Res; 75.25% IFMAP	33% LD Res; 67% IFMAP
2	Low Density Residential	25% LD Res; 75% IFMAP	50% LD Res; 50% IFMAP	75% LD Res; 25% IFMAP	100% LD Residential
2	Medium Density Residential	25% MD Res; 75% IFMAP	50% MD Res; 50% IFMAP	75% MD Res; 25% IFMAP	100% MD Residential
2	High Density Residential	25% HD Res; 75% IFMAP	50% HD Res; 50% IFMAP	75% HD Res; 25% IFMAP	100% HD Residential
2	Commercial	25% Commercial; 75% IFMAP	50% Commercial; 50% IFMAP	75% Commercial;25% IFMAP	100% Commercial
2	Industrial	25% Industrial; 75% IFMAP	50% Industrial; 50% IFMAP	75% Industrial; 25% IFMAP	100% Industrial
2	Highways	25% Highways; 75% IFMAP	50% Highways; 50% IFMAP	75% Highways; 25% IFMAP	100% Highways
2	Transportation Corridor	100% IFMAP	100% IFMAP	100% IFMAP	100% IFMAP

Class	IFMAP LAND COVER
1	Water/Wetlands
1	Forest/Rural Open
1	Urban Open/Parks
1	Agricultural
2	Low Intensity Urban
3	High Intensity Urban
3	Transportation/Highways

RULES (apply in ALL scenarios):

When NO CHANGE LAYER features are present, loading values are based on IFMAP land cover.
When INTERMEDIATE LAYER features are present, build-out occurs at rates specified above.
When FLU is Class 1 and IFMAP land cover Class is >= 2, loading values are based on IFMAP land cover.
When IFMAP land cover is Class 3 loading values are based on IFMAP land cover.

4.2 Build-out Modeling Results

The build-out load and runoff calculations for the 25, 50, 75, and 100% scenarios were conducted using a Visual Basic (VBA) code within the GIS environment. The VBA code was used to calculate the acreage of future and current land use for each record[8] in the build-out layer, under a defined scenario and according to the rules defined in Table 8. Once the acreage was known, total runoff volume and loads were calculated for each record using the equations presented in section 2.2 above and the GIS field calculator function.

For each scenario, six fields were created in the attribute table of the GIS build-out layer:

- New land use acreage under scenario xx% (e.g. 25%) (N_ACRES_xx)
- Remaining land use acreage (R_ACRES_xx)
- New TP, TN and TSS loads (Fxx_TPLD, Fxx_TNLD, Fxx_TSSLD)
- New runoff volume (Fxx_ROVOL)

Total pollutant load and runoff results per 12-digit HUC subwatershed are presented in Appendix A. The 25% build-out scenario was chosen to illustrate the impact of urban development on runoff and pollutant loads. Figures 10 to 13 present the percentage change in runoff volume and pollutant loads for the 25% build-out scenario compared to the baseline.

Under the 25% build-out scenario, the southwest portion of the watershed (subwatersheds -0208 and -0206) would experience the largest changes in runoff volume and pollutant loads. This area, currently the most urbanized in the watershed, would continue to develop under the current zoning and land use development plans. Under the 25% scenario, TP load and runoff volume for the entire watershed would increase by 5 and 2.5% respectively while TSS and TN loads would decrease by 1 and 2.5% respectively. Overall, most subwatersheds would experience varying increases in TP load and runoff volume, while only urban or urbanizing subwatersheds would experience an increase in TSS and TN loads.

With the exception of the mouth of the watershed (west of I-94), the majority of the Galien River Watershed is zoned as “agricultural” or “rural residential”. Therefore, all subwatersheds but one will not only experience a lower rate of development but to some extent lower runoff and loads as the “agricultural” and “rural residential” categories are defined using a proportion of low density residential land use (this land use has a lower curve number than agriculture as well as lower TN and TSS EMCs).

Total pollutant load and runoff results for the build-out analysis were also calculated per township. These results are provided in Appendix B.

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[8] As explained in section 2 above, each record only contains one current and one future land use category as well as specific information as to whether it falls within a regulated wetland or a “no change” area.

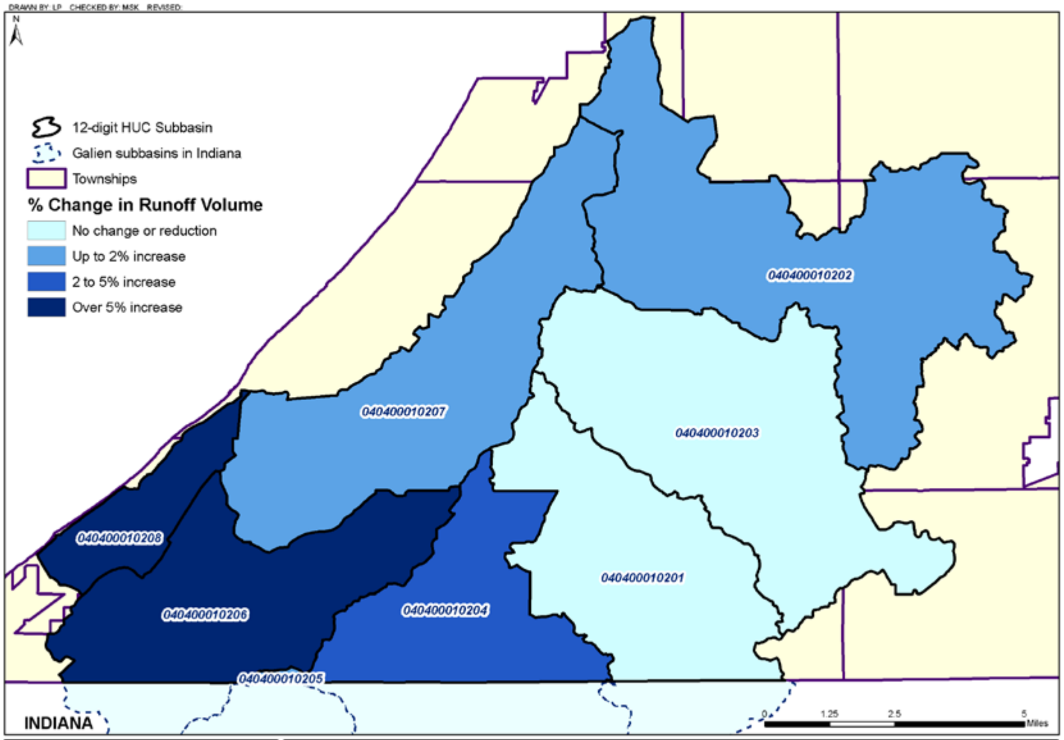

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Figure 10: Percentage change in runoff volume per subwatershed under the 25% build-out scenario.

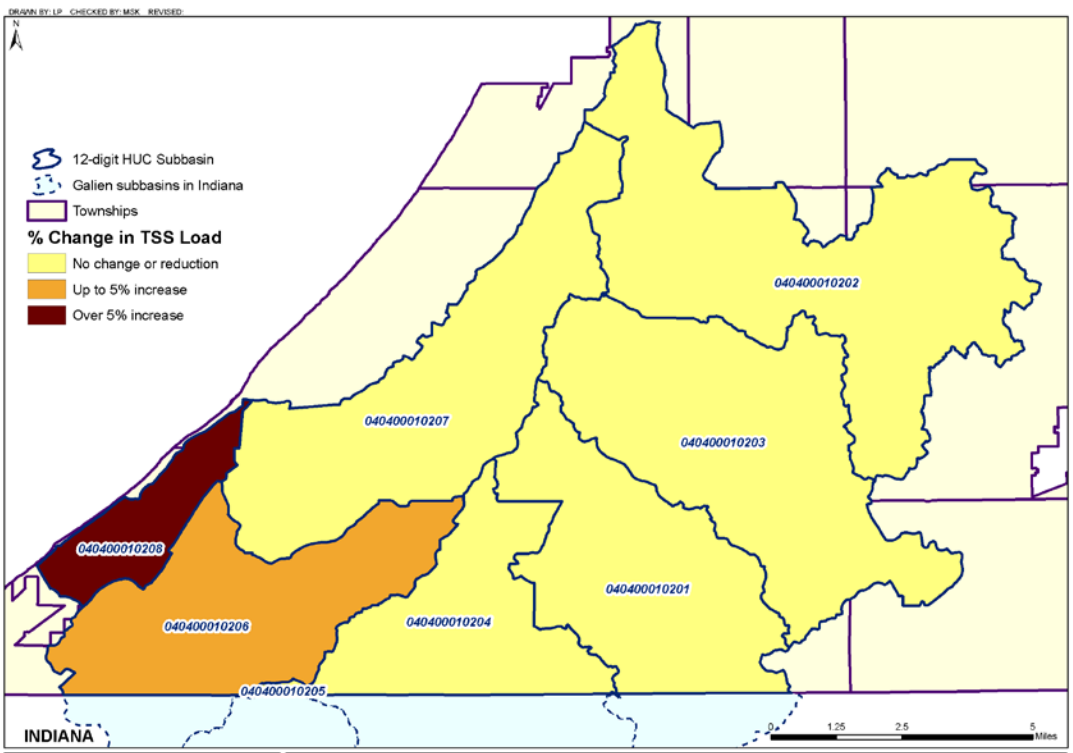

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Figure 11: Percentage change in TSS load per subwatershed under the 25% build-out scenario.

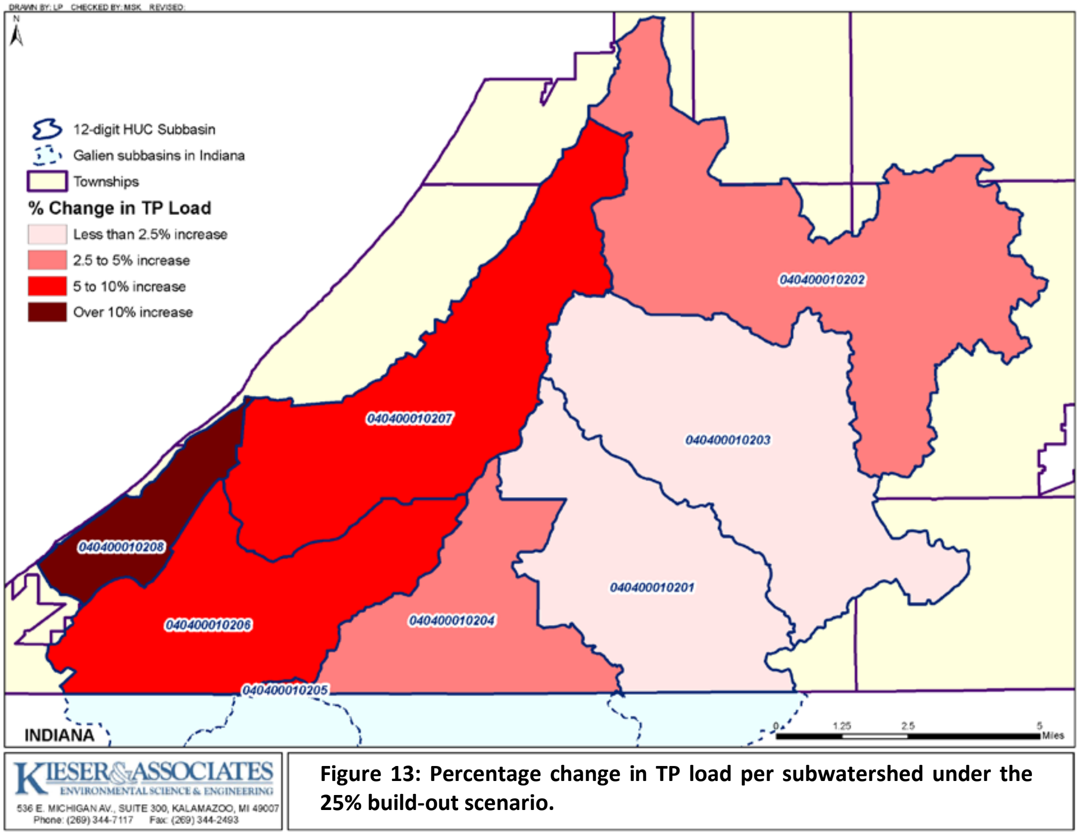

Figure 13: Percentage change in TP load per subwatershed under the 25% build-out scenario.

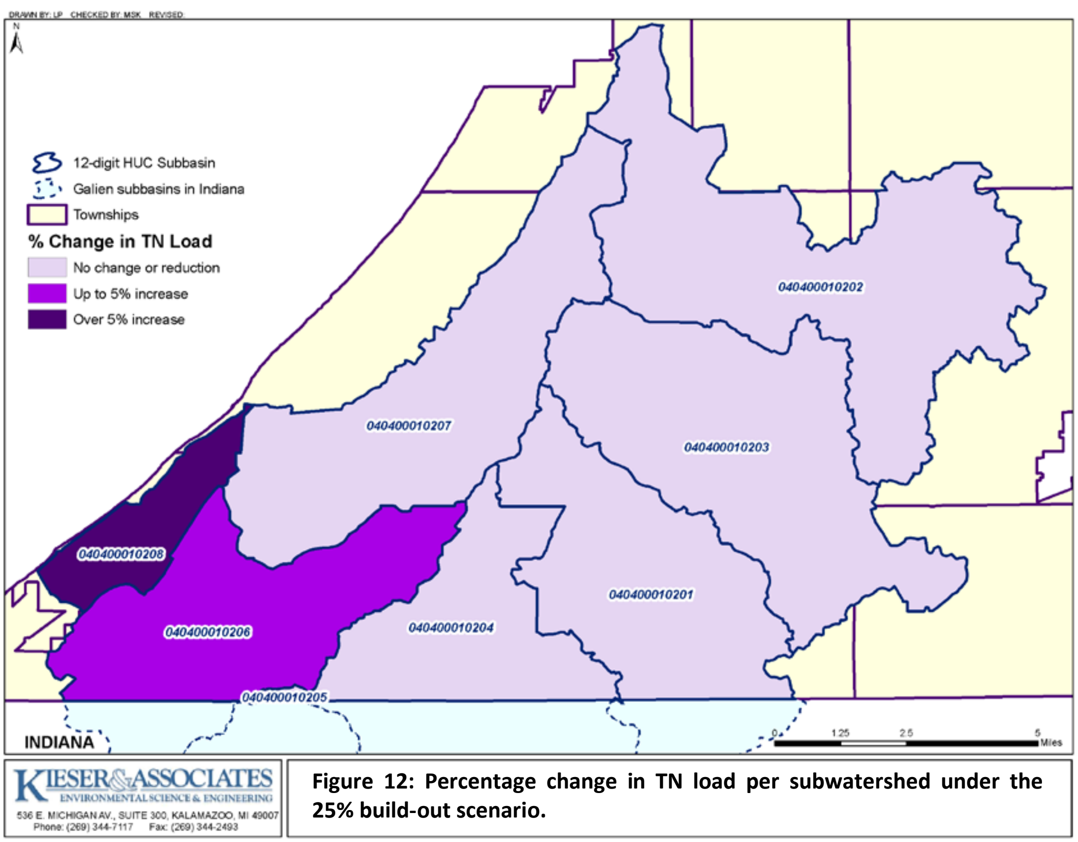

Figure 12: Percentage change in TN load per subwatershed under the 25% build-out scenario.

5. Stormwater BMP Analysis

The following analysis was conducted using the Galien River Watershed Land Use Change and BMP Tool. The BMP Tool is a Microsoft Excel workbook developed to estimate the impact of land use change and zoning regulations on pollutant loads and runoff volumes. The tool can also be used to estimate general cost-efficiency of commonly used urban best management practices (BMPs). The tool should not be used to provide site-specific BMP costs, pollutant loads or treatment design.

This workbook was designed as a separate tool from the build-out analysis above and as such, it cannot be used to replicate results provided in Section 4 above. The workbook uses the same current and future land use categories to standardize comparisons between current and future land use scenarios and to provide a better description and load estimation for urban areas (in the build-out analysis, current land use categories came from the 2001 IFMAP land use layer).

5.1 Data input

The BMP analysis was conducted only for urban areas in the Galien River Watershed. Urban land use breakdown was calculated using the 2001 IFMAP land use obtained from the Michigan Geographic Data Library[9]. The 2001 IFMAP urban land categories were then modified as follows to match land use categories used in the Galien River BMP Tool.

Table 9: Reclassified urban land use categories.

2001 Land use categories	Land use categories used in Galien River BMP Tool
Low Intensity Urban	Low Density Residential
High Intensity Urban (see note)	HD Residential
	Commercial
	Industrial
Roads/Parking Lots	Roads/Parking Lots

Note: High Intensity Urban was defined as 60% industrial, 25% commercial and 15% high density residential by SWMPC for the build-out analysis. These ratios were also used here.

Pollutant loads were calculated using the same methodology and equations used in the Galien River Build-out Analysis; i.e., using event mean concentrations from the Michigan Trading Rules (MI-ORR, 2002) (or as defined by SWMPC) and runoff rates calculated by L-THIA (see section 2.2 of the Build-out report).

The distribution of urban land uses by hydrologic soil group (Table 10) was calculated to improve accuracy of loads and BMP calculations. Pollutant loads and runoff were calculated for current conditions then selected urban BMPs were applied to estimate their impact on water quality.

[9] Available at: http://www.mcgi.state.mi.us/mgdl/

Table 10: Urban land use categories by hydrologic soil groups in the Galien River Watershed.

	Hydrologic Soil Group			
Land Use	**A**	**B**	**C**	**Total**
Low Density Residential	380	348	730	*1,458*
High Density Residential	25	12	55	*92*
Commercial	41	20	92	*154*
Industrial	99	48	221	*368*
Urban Open	32	-	26	*59*
Roads/Parking Lot	878	889	1,520	*3,288*
Total	*578*	*428*	*1,125*	*2,131*

5.2 BMP data

Commonly used stormwater BMPs were selected for this analysis. BMP treatment efficiencies and total costs were estimated using various sources (see Table 11). BMP definitions are included in Appendix C.

Table 11: BMP efficiencies and costs.

BMP	**% Efficiency** (1)			**Base Cost**(2)
	TP	**TN**	**TSS**	**($ per acre treated)**
Vegetated Swale	40%	90%	80%	3,000
Dry Detention	30%	20%	90%	3,000
Wet Detention	90%	30%	90%	3,000
Rain Garden (Neighborhood)(3)	100%	100%	100%	69,914
Constructed Wetlands	49%	30%	76%	42,254

(1) Efficiency values for extended dry detention, wet detention and swale are taken from the Michigan Trading Rules. Efficiency values for constructed wetlands were taken from EPA (2005), rain gardens are assumed to trap 100% of runoff and pollutants.

(2) Base cost and cost adjustment values are provided in WERF's BMP and LID Whole Life Cost Worksheets (2009b). The medium value of $3,000 per acre is used for wet and dry detention and swale.
For rain gardens, the cost per area treated is $16.05 (cost per sq. ft of rain garden) x 20% (rain garden area ratio to drainage area) =$3.21 per sq. foot treated (or $139,828 per acre treated). The assumption used in this tool is that rain gardens will be installed at a neighborhood scale, therefore providing economies of scale. The WERF neighborhood discount factor (50%) was applied to give a value per acre treated of $69,914.
The base BMP cost of $42,254 per acre (effective drainage area) for curb-contained bioretention is used for constructed wetlands.

(3) The assumption used in this tool is that rain gardens will be installed at a neighborhood scale, therefore providing economies of scale.

5.3 Results

Stormwater BMPs were applied separately to the total urban land use area within the watershed using the following assumptions:

- Swales, extended dry detention and wet detention basins were applied to treat 50% of the total urban area (all urban land uses included).
- Rain gardens were applied to treat 10% of the urban area including LD Residential, HD Residential, Commercial and Industrial. This BMP is not commonly used to treat runoff from roads/parking lots.
- Constructed wetlands were applied to treat 50% of the urban area including LD Residential, HD Residential, Commercial and Industrial. This BMP is not commonly used to treat runoff from roads/parking lots.

Table 12: BMP load reductions and costs.

	Load Reductions (lbs/yr)			Total cost	Cost ($) per lb reduced		
BMP	**TP**	**TN**	**TSS**	**($)**	**TP**	**TN**	**TSS**
Swale	932	14,488	590,463	10,155,000	10,896	701	17
Extended Dry Detention	699	3,220	664,271	10,155,000	14,528	3,154	15
Wet Detention	2,098	4,829	664,271	10,155,000	4,840	2,103	15
Rain Garden (Neighborhood)	77	821	20,076	14,913,565	193,683	18,165	743
Constructed Wetlands	189	1,231	76,289	54,692,521	289,378	44,429	717

Of the various BMPs examined here, the most cost-effective BMPs for TP and TN are respectively wet detention and swale. The most cost-efficient BMPs for TSS are extended dry detention, wet detention basins and swales.

It should be noted that these results only provide coarse estimates of cost and load reductions as BMPs were applied watershed-wide without taking into account site-specific analyses, local construction costs nor land acquisition costs.

Conclusions

Using a runoff model (L-THIA) and pollutant EMC values, a GIS build-out layer was developed to allow analysis of land use development and its impact on water quality within the Galien River Watershed. The baseline analysis results indicate that two agricultural subwatersheds (-0207, -0203) currently have the highest pollutant loading per acre and the highest average annual runoff, because of a combination of agricultural land use and clay soils with low infiltration. The urban subwatershed at the mouth of the watershed (including part of the city of New Buffalo) has actually lower loadings per acre because it is mostly located over sandy soils with low runoff potential. Although agriculture currently is the largest non-point source of pollutants and runoff in the Galien River Watershed, urban land use contributes over 20% of the total phosphorus and sediment loads, and runoff volume.

Based on available master plans, the analysis of a hypothetical 25% build-out scenario showed that the two subwatersheds located at the mouth of the watershed (-0206 and -0208) would experience a significant increase in pollutant loads and runoff volume. Development will likely occur because of the residential and commercial expansion of the city of New Buffalo, proximity to Lake Michigan, the I-94 corridor and the village of Three Oaks. Results from this scenario clearly emphasize the increasing importance of urban stormwater as a non-point source of pollution.

In conclusion, preserving water quality in the Galien River Watershed will require the implementation of practices and regulations addressing both agricultural and urban land uses such as: agricultural best management practices, stormwater best management practices and ordinances promoting infiltration, retention, reduction in impervious surfaces; zoning regulations promoting mixed land uses and smart growth.

Results presented in this report are not intended to give an absolute representation of the current and future situation in the Galien River Watershed. They are instead meant to be used as estimates to guide the development and implementation of the watershed management plan. These results can be reliably used to inform discussions and decisions by local units of government and watershed managers regarding zoning and land use management needs.

Note: A separate, easy-to-use, load calculator and BMP tool and documentation have also been provided to the Southwest Michigan Planning Commission as a part of this project to help estimate changes in loads from land use management policies and the cost-efficiency of several commonly used stormwater BMPs.

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Appendix A

Pollutant Loads and Runoff Volume per Subwatershed

Table A-1: Pollutant loads (in lbs/year) per subwatershed under baseline conditions and build-out scenarios.

	Baseline Loading			25% Buildout Loading			50% Buildout Loading			75% Buildout Loading			100% Buildout Loading		
HUC12	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TN (lbs/yr)**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TN (lbs/yr)**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TN (lbs/yr)**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TN (lbs/yr)**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TN (lbs/yr)**
040400010201	876,655	2,312	33,132	849,218	2,325	31,432	821,809	2,338	29,729	794,427	2,353	28,022	767,072	2,368	26,311
040400010202	1,054,834	2,805	39,386	1,033,814	2,918	38,236	1,012,921	3,033	37,083	992,153	3,150	35,927	971,512	3,268	34,767
040400010203	1,486,037	3,923	56,370	1,444,963	4,006	53,792	1,404,120	4,091	51,210	1,363,508	4,180	48,623	1,323,127	4,272	46,031
040400010204	606,094	1,615	22,400	603,628	1,674	21,786	601,257	1,734	21,171	598,983	1,795	20,555	596,805	1,857	19,938
040400010205	9,946	26	378	9,774	27	359	9,612	29	340	9,460	30	321	9,318	32	302
040400010206	926,772	2,511	32,814	966,186	2,756	33,514	1,006,050	3,006	34,216	1,046,364	3,259	34,919	1,087,129	3,516	35,624
040400010207	1,248,764	3,342	45,670	1,228,616	3,524	44,393	1,208,855	3,709	43,122	1,189,481	3,897	41,855	1,170,494	4,089	40,593
040400010208	225,369	683	5,156	240,519	774	5,979	255,670	865	6,802	270,822	957	7,625	285,973	1,048	8,448
Total	*6,434,472*	*17,218*	*235,305*	*6,376,718*	*18,005*	*229,491*	*6,320,295*	*18,806*	*223,672*	*6,265,197*	*19,621*	*217,846*	*6,211,430*	*20,450*	*212,015*

Table A-2: Runoff volume (in acre-feet/year) per subwatershed under baseline conditions and build-out scenarios.

	Runoff Volume (acre-feet/year)				
HUC12	**Baseline**	**25%**	**50%**	**75%**	**100%**
040400010201	2,284	2,258	2,233	2,208	2,184
040400010202	2,843	2,880	2,916	2,953	2,992
040400010203	3,966	3,956	3,949	3,943	3,939
040400010204	1,606	1,666	1,727	1,788	1,850
040400010205	29	29	30	30	31
040400010206	2,670	2,926	3,185	3,446	3,709
040400010207	3,596	3,651	3,709	3,769	3,831
040400010208	657	732	807	882	957
Total	*17,651*	*18,099*	*18,554*	*19,019*	*19,492*

Appendix B

Pollutant Loads and Runoff Volume per Township

Table B-3: Pollutant loads (in lbs/year) per township under baseline conditions and build-out scenarios.

	Baseline Loading			25% Buildout Loading			50% Buildout Loading			75% Buildout Loading			100% Buildout Loading		
Municipality	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TN (lbs/yr)**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TN (lbs/yr)**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TN (lbs/yr)**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TN (lbs/yr)**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TN (lbs/yr)**
Baroda	15,312	41	541	14,807	41	519	14,302	40	496	13,796	40	474	13,289	40	451
Bertrand	78,714	216	2,636	76,647	228	2,587	74,616	241	2,537	72,620	254	2,487	70,660	267	2,437
Buchanan	365,135	980	13,260	358,854	1,017	12,752	352,694	1,055	12,242	346,652	1,094	11,731	340,731	1,134	11,218
Chikaming	618,523	1,677	21,803	615,219	1,778	21,329	612,118	1,880	20,856	609,220	1,985	20,382	606,526	2,090	19,909
Galien	926,208	2,463	34,458	900,235	2,487	32,766	874,366	2,513	31,070	848,600	2,541	29,372	822,938	2,569	27,669
Lake	253,103	677	9,473	249,816	751	9,577	246,525	826	9,680	243,231	901	9,782	239,933	975	9,882
New Buffalo	639,705	1,757	20,979	667,475	1,973	21,897	695,613	2,191	22,817	724,119	2,413	23,738	752,993	2,638	24,661
New Buffalo, City of	91,968	280	2,113	99,619	323	2,500	107,270	367	2,886	114,921	410	3,272	122,572	453	3,658
Oronoko	23,261	62	871	22,596	62	827	21,932	63	783	21,268	64	738	20,604	65	694
Three Oaks	1,448,418	3,868	53,846	1,454,437	4,040	52,567	1,460,760	4,215	51,285	1,467,388	4,393	50,002	1,474,319	4,573	48,717
Weesaw	1,974,127	5,198	75,324	1,917,013	5,305	72,172	1,860,099	5,415	69,021	1,803,383	5,529	65,869	1,746,865	5,645	62,717
Total	*6,434,472*	*17,218*	*235,305*	*6,376,718*	*18,005*	*229,491*	*6,320,295*	*18,806*	*223,672*	*6,265,197*	*19,621*	*217,846*	*6,211,430*	*20,450*	*212,015*

Table B-4: Runoff volume (in acre-feet/year) per township under baseline conditions and build-out scenarios.

	Runoff Volume (acre-feet/year)				
Municipality	**Baseline**	**25%**	**50%**	**75%**	**100%**
Baroda	39	39	38	37	36
Bertrand	213	217	221	226	230
Buchanan	1,002	1,011	1,021	1,032	1,043
Chikaming	1,835	1,875	1,916	1,958	2,001
Galien	2,451	2,432	2,413	2,396	2,379
Lake	687	727	767	807	847
New Buffalo	1,893	2,073	2,256	2,441	2,628
New Buffalo, City of	270	305	341	377	413
Oronoko	62	61	61	61	60
Three Oaks	3,944	4,121	4,300	4,481	4,664
Weesaw	5,255	5,237	5,219	5,204	5,191
Total	*17,651*	*18,099*	*18,554*	*19,019*	*19,492*

Appendix C

BMP Definitions

The definitions below were extracted from the Low Impact Development Manual (SEMCOG, 2008).

Vegetated swale:
Shallow stormwater channel that is densely planted with a variety of grasses, shrubs, and/or trees designed to slow, filter, and infiltrate stormwater runoff. Check dams can be used to improve performance and maximize infiltration, especially in steeper areas.

Detention Basins:
Detention basins are surface (or underground) stormwater structures that provide temporary storage of stormwater runoff to prevent downstream flooding. The primary purpose of the detention basin is the attenuation of stormwater runoff peaks. Generally, detention basins may be dry ponds, wet ponds, constructed wetlands or underground systems.

Dry detention:
Dry ponds are earthen structures that provide temporary storage of runoff and release the stored volume of water over time to help reduce flooding. They are constructed either by impounding a natural depression or excavating existing soil, and are intended to enhance the settlement process in order to maximize water quality benefits, while achieving reduced runoff volume.

Wet detention:
Wet ponds include a permanent pool for water quality treatment and additional capacity above the permanent pool for temporary storage. The pond perimeter should generally be covered by a dense stand of emergent wetland vegetation. While they do not achieve significant groundwater recharge of volume reduction, wet ponds can be effective for pollutant removal and peak rate mitigation.

Constructed wetlands:
Shallow marsh systems planted with emergent vegetation designed to treat stormwater runoff. While they are one of the best BMPs for pollutant removal, constructed wetlands can also mitigate peak rates and even reduce runoff volume to a certain degree.

Rain garden (or bioretention):
Shallow surface depressions planted with specially selected native vegetation to capture and treat stormwater runoff from rooftops, streets and parking lots.