Appendix IV - Hydrological Modeling

Objective

The objective of the hydrologic analysis conducted for the Monroe County project was to identify runoff generation areas across several watersheds within the county, and then to evaluate the sensitivity of runoff generation to future rainfall conditions and to potential future changes in land use. The analysis results provide observations for consideration in the vulnerability analysis portion of the project.

The analysis was conducted on several subwatersheds selected to be representative of the range of land use conditions in the county. The analysis was limited to evaluating runoff generation areas only and did not include detailed hydrologic modeling for predicting flood flows in streams or detailed hydraulic modeling to identify floodplain extent or a stream crossing performance.

Methods

The analysis approach drew on ideas from a University of Wisconsin-Madison Water Resource Management practicum workshop project conducted on the Rullands Coulee watershed, in southwestern Monroe County. The analysis for this project was conducted within QGIS, an open-source geographic information system analysis package (https://www.qgis.org/en/site/). A QGIS plugin was used to calculate runoff curve numbers for parcels within the watershed using soil characteristics and land cover data. Input data included GIS-based hydrologic soil group delineations and land cover from the National Land Cover Dataset updated in 2019. Runoff curve numbers were calculated using standard NRCS / SCS hydrologic analysis methods as described in the NRCS National Engineering Handbook (https://directives.sc.egov.usda.gov/viewerFS.aspx?id=2572). Runoff depths across each analysis parcel were calculated using the calculated curve numbers and input storm rainfall depth.

5 HUC12 watersheds within Monroe County were selected for evaluating runoff response. The watersheds were selected to be in different drainage basins exiting Monroe County and have a range of land covers representative of conditions within the county. Four of the watersheds selected were in the driftless area, and one with its upstream portion in the driftless area but draining eastward into the Wisconsin sand plain areas in the eastern portion of the county. The watersheds are listed in Table 1 below and shown on Figure 1. The percent of woodland cover is listed for each watershed as it is one of the watershed land use characteristics most related to runoff generation. Watersheds with higher woodland cover are anticipated to produce less runoff from storm events. Maps 1 through 5, below, show the land use distribution in the five analyzed watersheds. For the five watersheds located in the driftless area (maps 1 through 4) agricultural lands are concentrated in the relatively flat upland areas and relatively flat lowland areas adjacent to streams and rivers. The wooded areas are primarily located in the steeper Valley slopes. The Bear Creek watershed is shown on Map 5 and has a substantially different land cover because of the flatter terrain. Woodland and wetland areas dominate the eastern downstream portion of the watershed.

Table 1		
Characteristics of 5 watersheds selected for GIS-based runoff analysis		
HUC 12 Watershed Name	Downstream River	Percent Woodland
Timber Coulee	Coon Creek	36.9
Headwaters Little La Crosse	La Crosse River	48.5
Moore Creek	Kickapoo River	37.3
Rathbone Creek	Black River	69.5
Bear Creek	Lemonweir River	43.4

Existing conditions runoff modeling results

Runoff analyses were conducted through QGIS for the five analysis watersheds for the approximate 2- year, 10-year and 200- year, 24-hour rainfall depths. The storms were selected to provide an evaluation of runoff generation from smaller storms that occur relatively frequently (the 2-year storm) to an extremely large storm (the 200-year storm) that would occur only very rarely. The storm rainfall depths (listed below in Table 2) were selected based on preliminary evaluation of Wisconsin Rainfall Project projections. Note that these rainfall depths are similar to but slightly different than the rainfall depths proposed for using Monroe County based on final output of the Wisconsin Rainfall Project data portal, listed in the climate sections of the report and appendices. Results are presented in Table 2, below. The runoff depths listed are watershed- wide averages.

Table 2 Modeled runoff from 5 watersheds for 3 storm events			
Return Period	2-yr	10-yr	200-yr
Rainfall	2.89	4.56	7.93
Watershed Runoff (inches)			
Timber Coulee	0.52	1.14	2.68
HW Little La Crosse	0.54	1.11	2.55
Moore Creek	0.64	1.36	3.04
Rathbone Creek	0.32	0.61	1.60
Bear Creek	0.90	1.80	3.73

The results listed in Table 2 illustrate the progressive increase in runoff depths as storm rainfall depth increases and show a general correlation with percent woodland cover listed in Table 1.

Maps 6 through 10, attached below, show the distribution of runoff depth generation for each of the land use parcel across the watersheds for the approximate 200-year event. The important observation from these figures is that runoff generation is derived mainly from the non-woodland areas.

Analysis of runoff impacts of potential future conditions scenarios

Analyses of the impact of several potential future conditions scenarios were conducted using the QGIS analysis procedure for the Timber Coulee watershed. one scenario investigated the response of the watershed to the anticipated 2020 storm rainfall under the current land use conditions. three other scenarios were developed to evaluate sensitivity of runoff response to several altered potential future land use conditions. These conditions were not specifically anticipated to occur throughout Monroe County, they were developed to test the runoff sensitivity of potential extreme changes in land use. the potential future land use scenarios were evaluated using the currently defined rainfall (not future rainfall), to enable a clearer comparison of the land use change effects alone. The scenarios evaluated were:

- Conversion of all of the agricultural land two permanent pasture cover;
- Conversion of all of the agricultural land to row crop production; and
- An increase of 20% in the area of forested land.

Results of this sensitivity analysis are shown in Table 3.

Table 3: Results of Preliminary Runoff Modeling for Timber Coulee Watershed					
Return Period, years		2-yr	10-yr	200-yr
Annual Exceedance Frequency		0.5	0.1	0.01
Rainfall Depth, inches		2.89	4.56	7.93
Runoff, inches				
Existing Conditions		0.52	1.14	2.68
Current rainfall, ag land converted to meadow		0.40	0.95	2.39
All Ag Land converted to Row-Crop		0.66	1.37	3.02
Forest Area expanded by 20%		0.45	1.01	2.45
Future rainfall on existing land use		0.56	1.22	2.88
Percent Change in Runoff Depth				
Existing Ag to All Meadow		-23%	-17%	-11%
Existing/All-Row		27%	20%	13%
Existing/20% forest		-14%	-12%	-9%
Existing to future rainfall		7%	7%	8%

The results of this analysis indicate that the variation of potential future conditions could be more important than anticipated changes in storm rainfall in changing watershed runoff. This sensitivity to land use change is particularly apparent for the frequent storms such as the 2-year storm. These smaller storms our most frequent and produce the bulk of watershed runoff response and water quality impacts. This sensitivity is further illustrated in Figure 2, below.
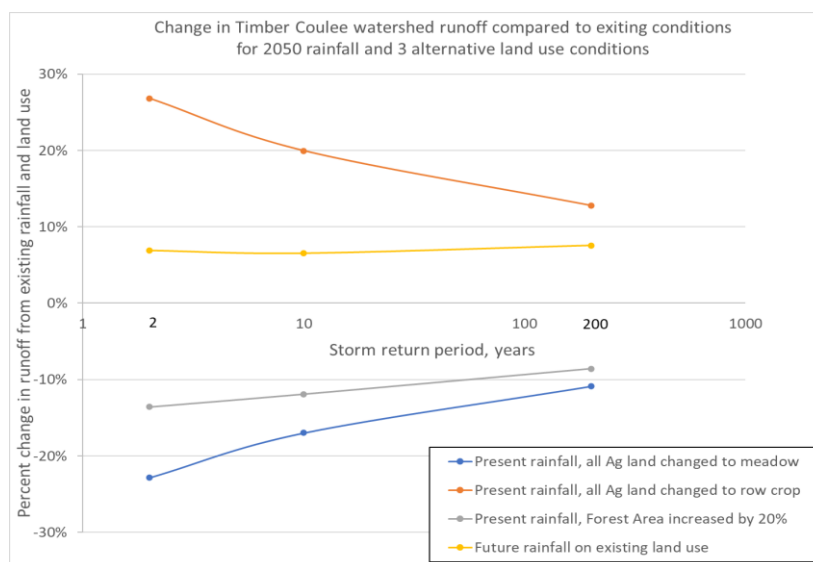

Figure 2: Sensitivity of Timber Coulee runoff response to Future Condition Scenarios

Observations

The most significant results of this analysis include:

- Most of the runoff for both current and future conditions is generated from agricultural lands. Wooded areas produced much less runoff, indicating the importance of woodland areas in promoting interception and infiltration while reducing runoff.
- The runoff effects of potential future land use change were greater than those of increased future rainfall, especially for storms that occur relatively frequently such as the 2-year storm. Changing all agricultural land use to row crop increased runoff volume from existing conditions approximately 25%, whereas changing existing land cover to all pasture cover reduced runoff by more than 20%. These results indicate that that adopting agricultural practices that maximize perennial cover such as pasture or include seasonal cover crops will have beneficial effects in reducing small storm runoff, which has soil conservation and stream water quality benefits.
- Increasing the woodland area by approximately 20% reduced runoff volume by approximately 13% for the 2-year storm and less than 10% for the 200-year storm. These substantial reductions indicate that restoring woodlands in select areas would also reduce runoff depth.
- Changes in land use that may occur by year 2050 could have more impact on watershed hydrologic response than changes in storm rainfall.

Maps

Map Set 1   Land use and areas of runoff generation in the in the Timber Coulee watershed
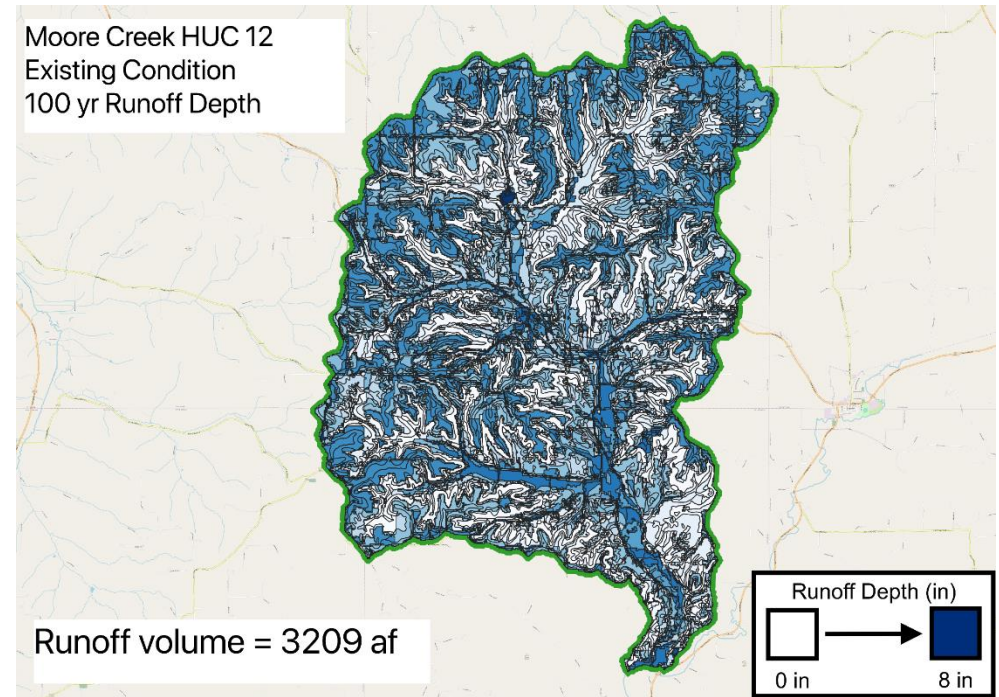
Map Set 2   Land use and areas of runoff generation in the Headwaters Little La crosse river watershed
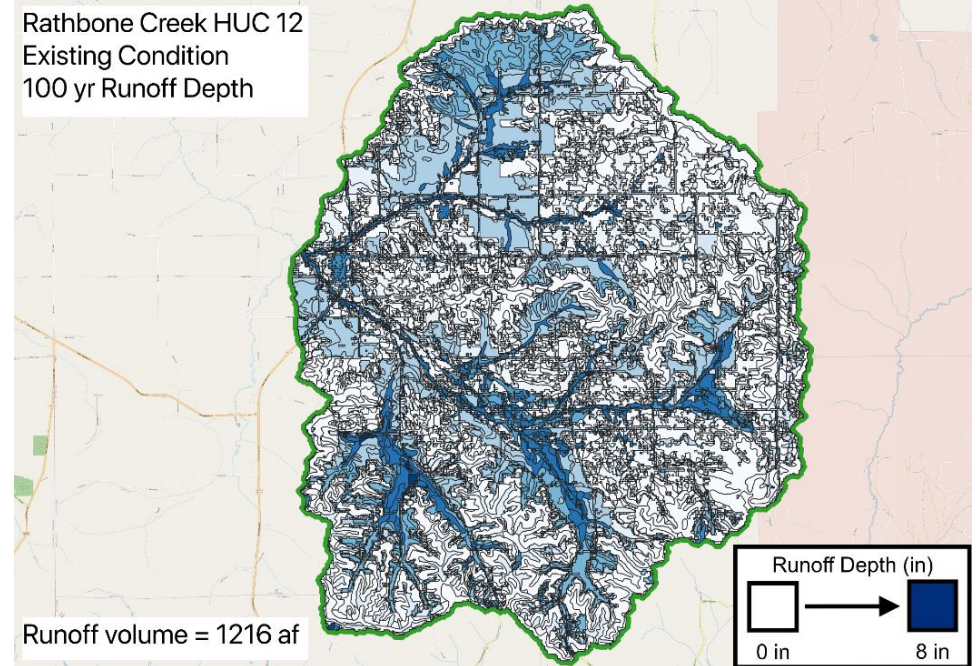
Map Set 3   Land use and areas of runoff generation in the Moore Creek watershed

Map Set 4   Land use and areas of runoff generation in the Rathbone Creek watershed

Map Set 5   Land use and areas of runoff generation in the Bear Creek watershed

Map Set 6   Areas of runoff generation if all agricultural land is converted to pasture (a) or to row crop (b) or if forest cover is increased by 20% (c).
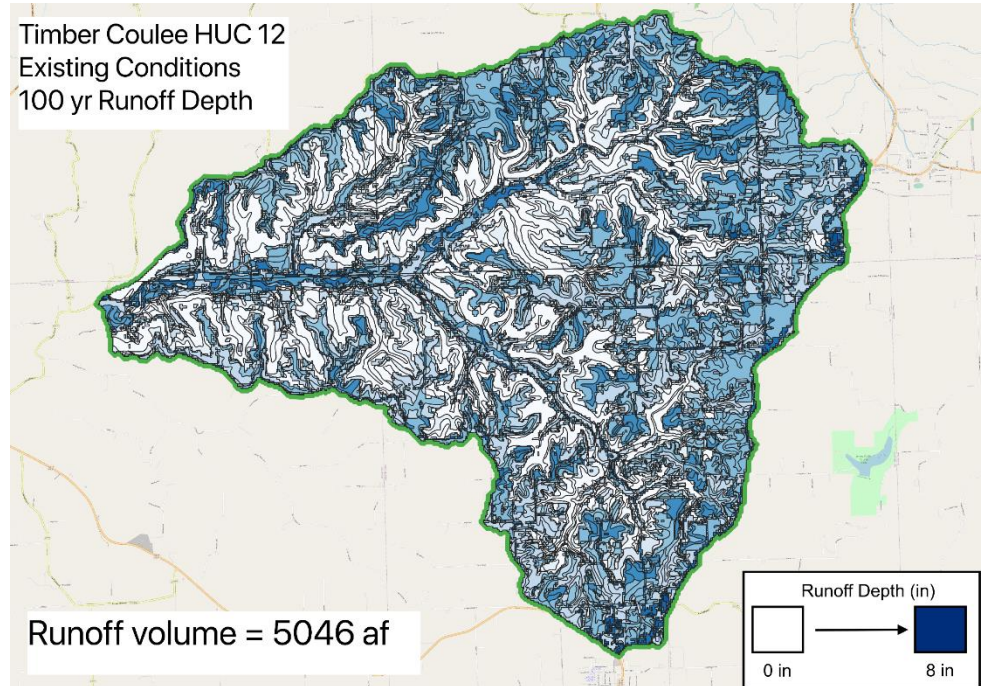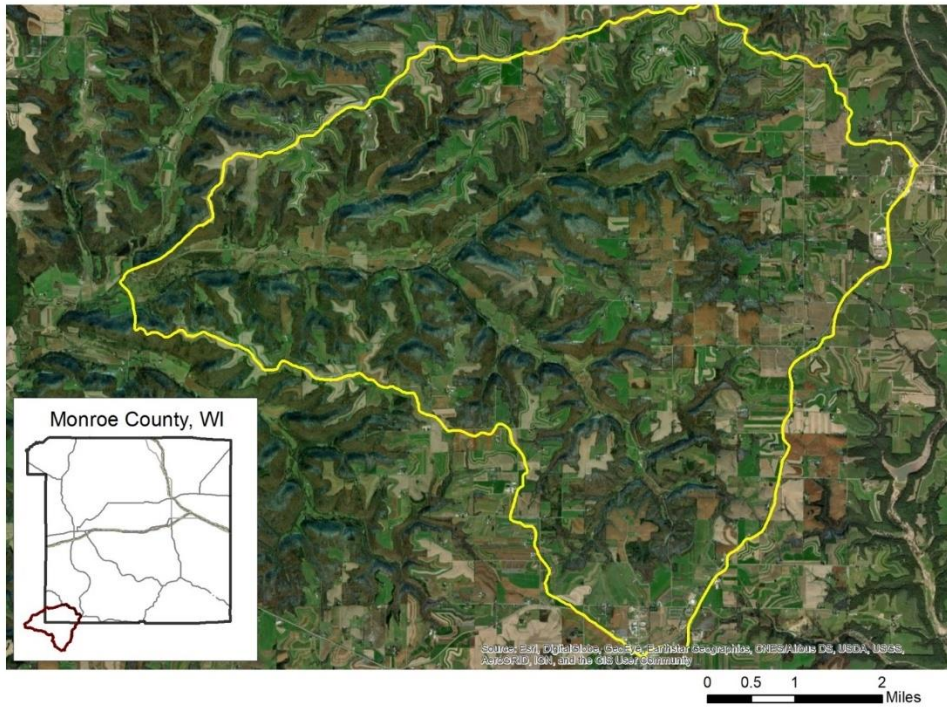
Map Set 1   Land use in the Timber Coulee watershed (left) and areas of runoff generation in the Timber Coulee watershed (right).
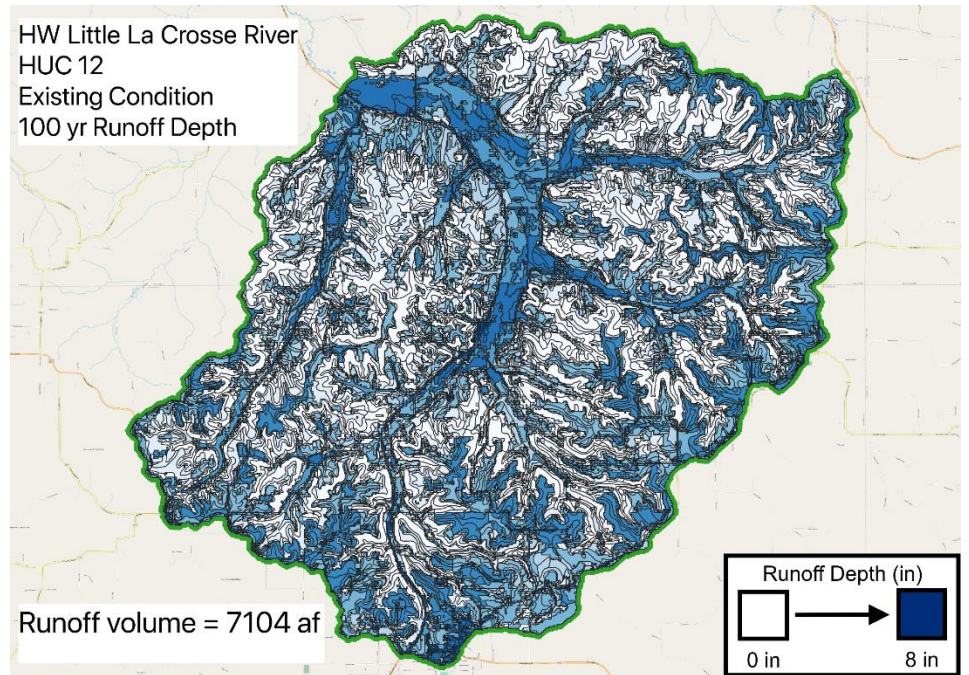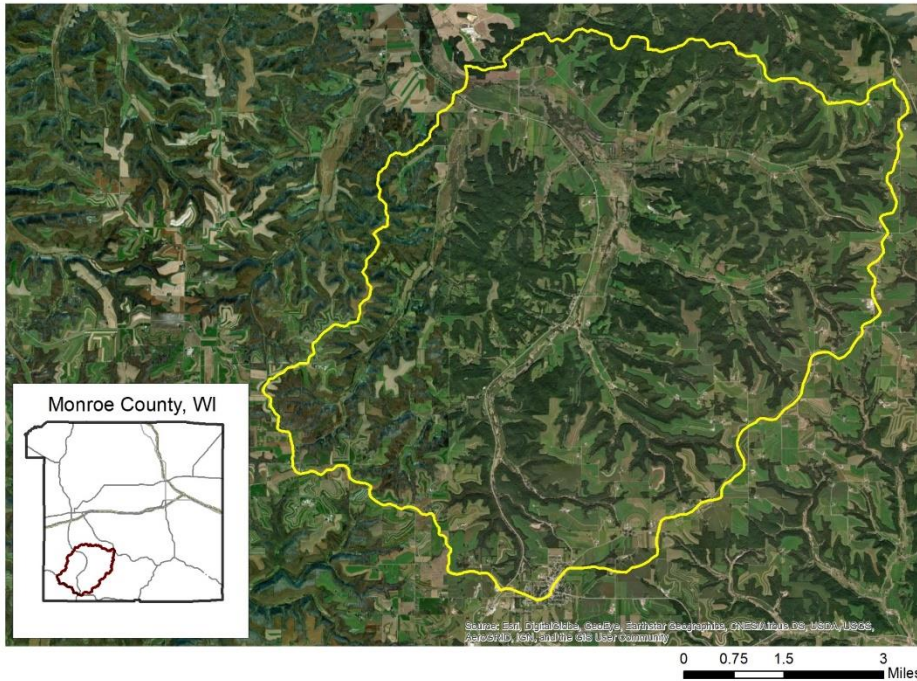
Map Set 2   Land use and areas of runoff generation in the Headwaters Little La Crosse River watershed
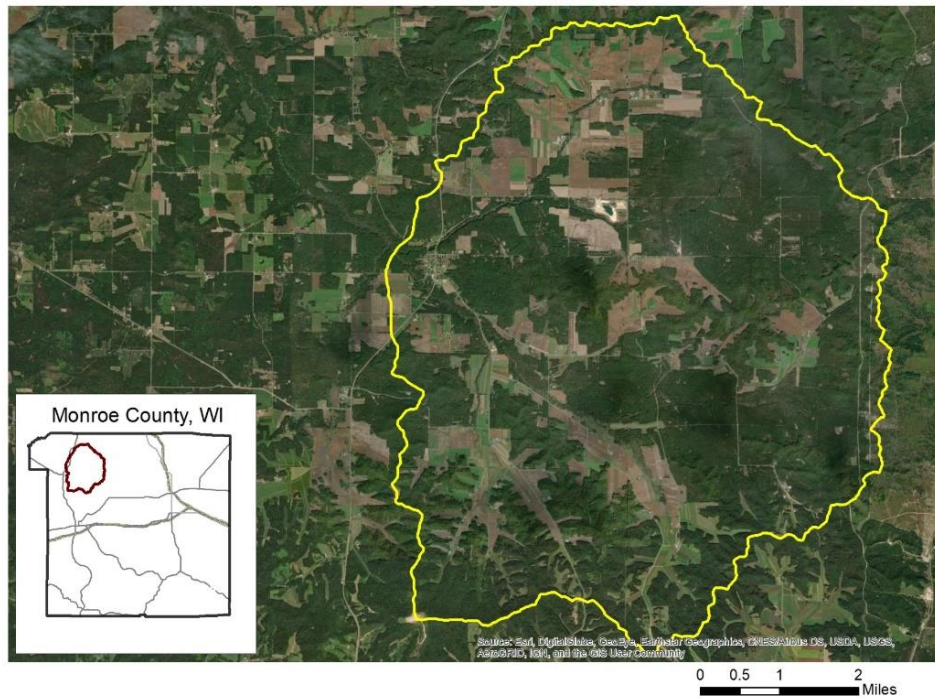
Moore Creek Watershed
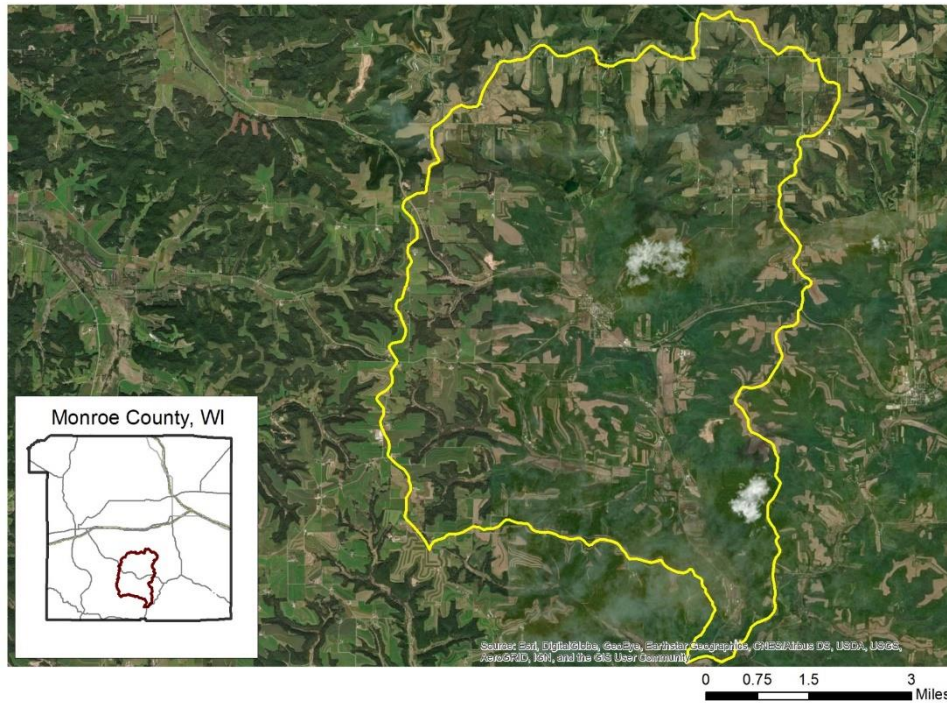
Map Set 3   Land use and areas of runoff generation in the Moore Creek watershed
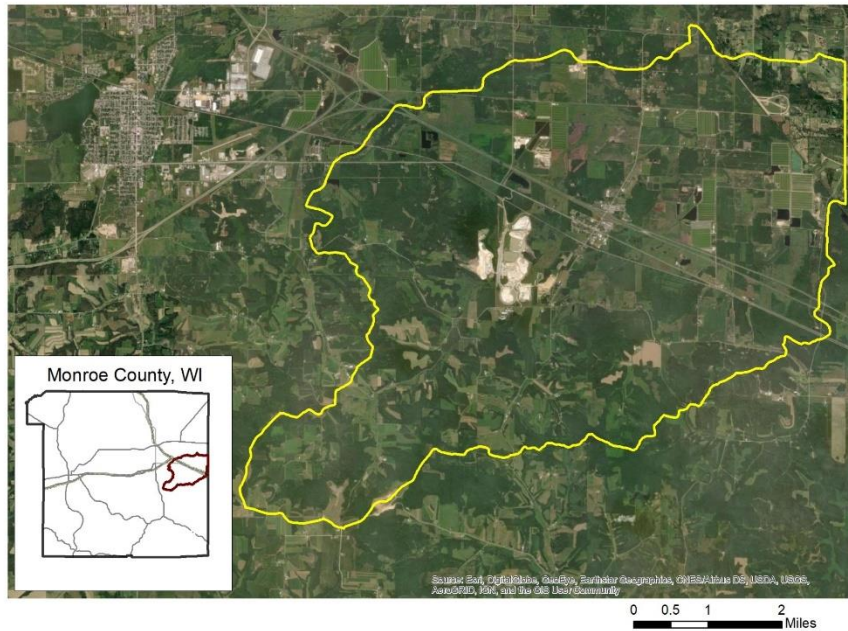
Rathbone Creek Watershed

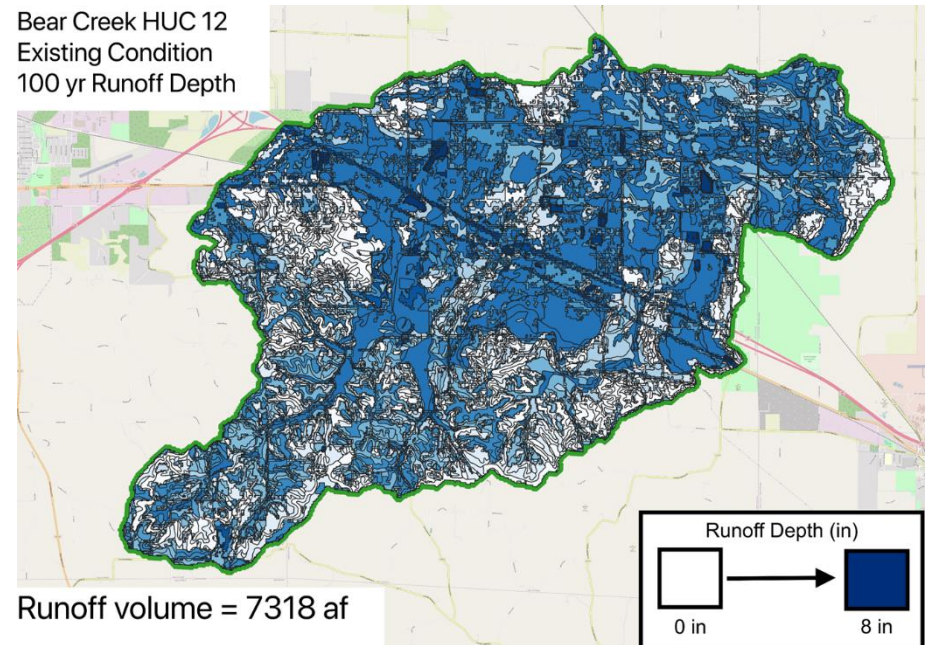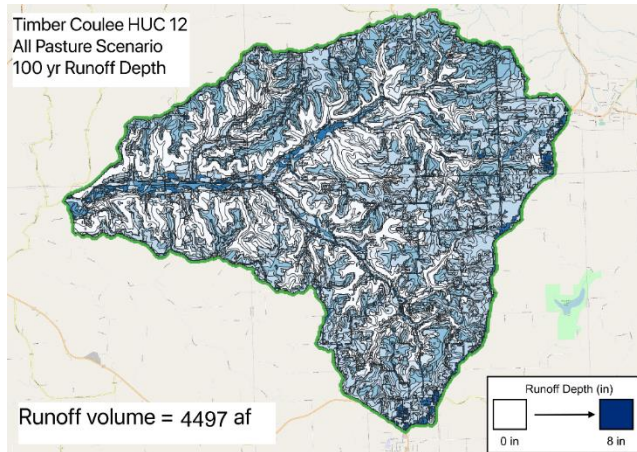

Map Set 4   Land use and areas of runoff generation in the Rathbone Creek watershed

Map Set 5   Land use and areas of runoff generation in the Bear Creek watershed
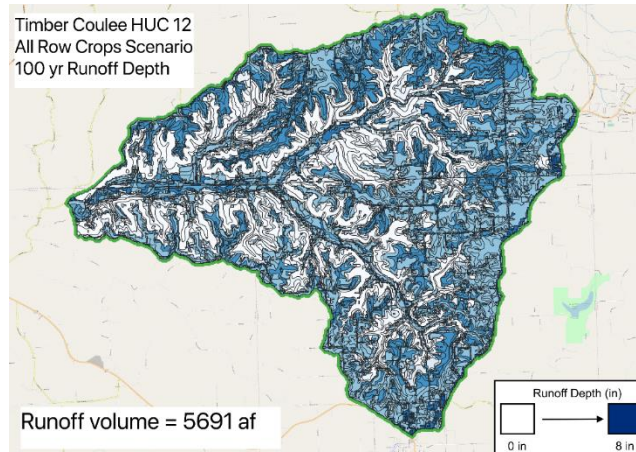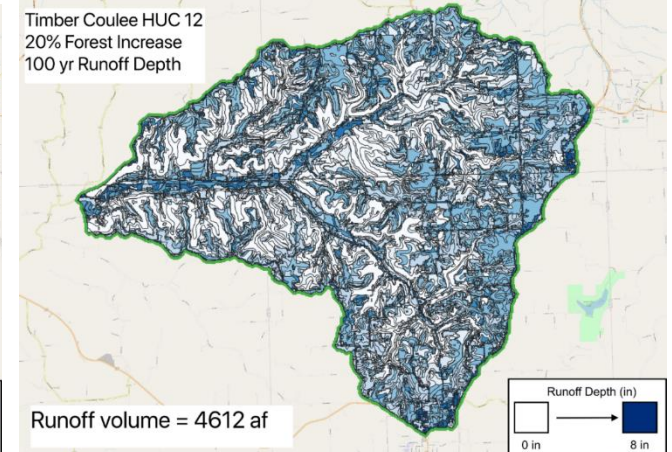
| a | b | c |

Map Set 6   Areas of runoff generation if all agricultural land is converted to pasture (a) or to row crop (b) or a 20% forest increase (c)