DEPARTMENT OF NATURAL RESOURCES

Technical Memorandum

Date: July 24, 2018

To: Suzanne S. Rhees, AICP
Conservation Projects Coordinator
MN Board of Water and Soil Resources

From: Dan Reinartz, P.E.
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Re: Shakopee Creek Watershed Land Use Conversion

This technical memo revises the previous memo issued on April 27th, 2018 for the Shakopee Creek watershed study. The revisions include the following:

1- The conversion to perennial cover is based on 30% marginal agricultural areas and not all marginal areas. After applying the perennial cover conversion, cover crops were applied to 40% of the remaining agricultural areas. As a result, the total perennial conversion areas were reduced from 13.5 to 3.71 mi^2 and cover crop areas were increased from 14.7 to 15.1 mi^2. The table below summarizes the areas for each land conversion criteria.

Table One: Summary of land use changes

	Revised Criteria (mi^2)	Previous Criteria (mi^2)
Total Watershed	105	105
Total Marginal	45	45
total Ag	41.2	41.2
Ag (marginal)	12.4	12.4
Ag (non-marginal)	28.8	28.8
Total Proposed perennial	**3.71**	13.5
Proposed perennial in ag	**3.71**	10.7
Cover Crop	**15.1**	14.7
Cover Crop in ag	**15.1**	14.7

2- The results are based on continuous simulations starting in 2000 where simulations for growing and non-growing seasons were linked through 'hot-starts' so that the initial condition of each run was based on final conditions from the previous one, for channel depth, channel discharge, overland run-off, moisture content and groundwater table elevation. In the previous memo, the results were reported from 'stochastic' simulations where the initial conditions were not based on 'hot-starts'.

In this study, the Gridded Subsurface Surface Hydrological Analysis (GSSHA) model was used to apply the two land conversion criteria listed below:

- Convert 30% of marginal agricultural land to perennial crops based on LCC values greater than 1, 2 and partial 3. For LCC of 3, the conversion is limited to slope gradients greater than 6.
- Apply cover crop on the remaining 40% agricultural land.

Using this information, the proposed land use changes were summarized as shown in the Venn diagram below.

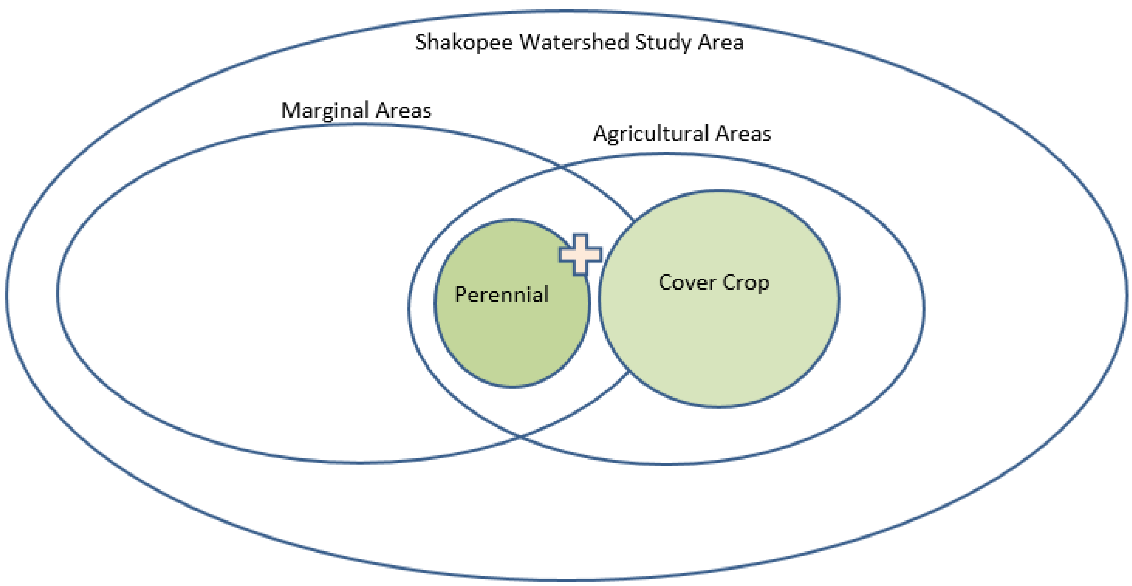

Figure 1: Venn diagram summarizing the land use changes

The results show that after running the simulations for a period of nine years (based on the simulation results at the date of the memo) for both the existing and modified conditions, we saw surface water run-off reductions ranging from 2.7% up to 27.4%, depending on whether the simulation represents the growing or non-growing period. The reductions were more significant for the non-growing season due to improving the fallow conditions of the soil. Below is a summary of the methodology and results.

Study Model:

Figure 2 below shows the different models developed for the upper Shakopee watershed area. The Huse Creek watershed model was developed by Dan Reinartz while the Shakopee Creek Watershed model was developed by Greg Eggers. The HSPF model developed by PCA included the whole area as shown, extending to the study outlet. Dan combined these areas to form a larger GSSHA domain model extending all the way to the Chippewa River outlet as shown in Figure 3. The Chippewa outlet was used to calibrate the model.

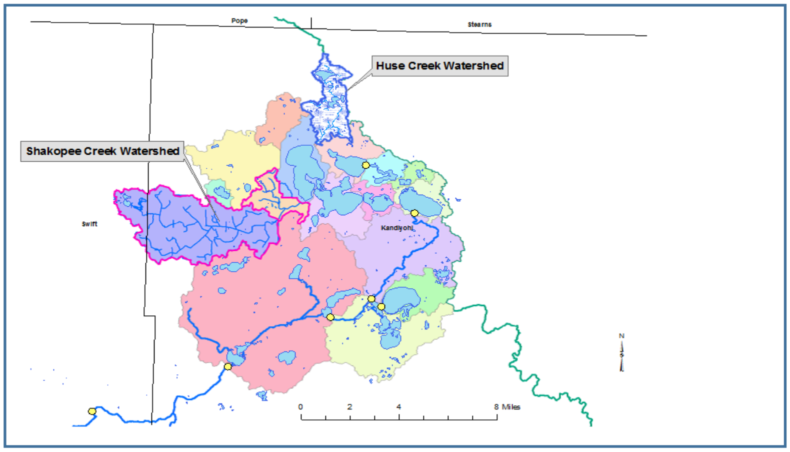

Figure 2: HSPF and GSSHA models for the Upper Shakopee Watersheds

The larger model covers a total drainage area of 345 square miles represented by 200 meter grid cells, as shown in the figure below.

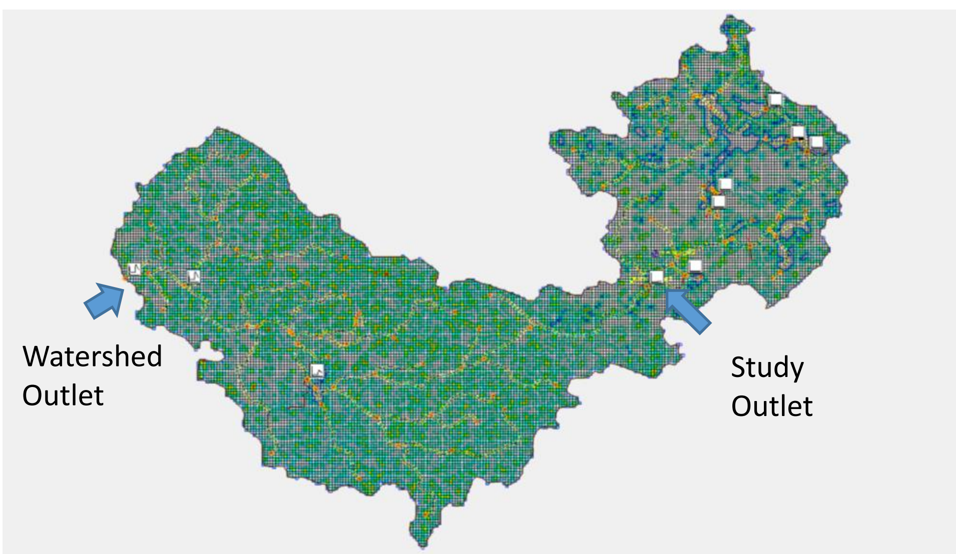

Figure 3: Larger Shakopee Watershed model

As part of this exercise, the existing model was further modified to address the following:

- The Cultivated Crop layer was broken down into the following specific crop conditions: fallow, corn, soybean, small grains and alfalfa. This was important in order to do the land use conversion based on specific crop type. The original existing model lumped all crop types into "cultivated crop" with an NLCD index value of 82.
- ET values were assigned for the specific crops. After obtaining the crop values from literature, they were further adjusted as part of the calibration in order to give acceptable ranges of ET values, consistent with the range of values provided in the literature.
- Please note, that due to the nature of modeling in general and GSSHA in particular, the model will always be subject to further revisions and modifications, especially as better crop data becomes available. However, any revisions made to the model will be shared.

Proposed Conditions:

The following steps were taken to prepare the proposed conditions:

1- The proposed conditions were applied using the ArcGIS Procedure for Working Lands Project, developed by Andrew Keller and Dr. William Lazarus (9/8/17). The procedure involved using the SSURGO data to obtain the weighted averages for the slope gradient, LCC and CPI based on the individual components of their respective soil mapping unit. Then using the proposed land use conversion criteria, the guidelines illustrated how to apply those changes in the GIS layers.

2- After generating the raster files with the LCC values, the raster files were broken into two individual raster files, one representing the watershed areas upstream of the study node and the other downstream extending to Chippewa River outlet. Breaking them into two raster files was necessary in order to apply the changes only to the study area, which is a part of the model domain.

3- The perennial crop was applied on 30% of agricultural marginal land starting with the lowest CPI values.

4- After extensive GIS processing, the study area raster file was prepared and converted to shapefile along with the raster file representing the downstream area. Both shapefiles were then combined and re-converted back to a one raster file, which after combining with the LULC layer was imported into GSSHA.

5- Then after all the index values were assigned to the grid cells to match the assigned LULC index numbers, the soil properties were processed using the *Soil Parameter Value Estimation and Mapping Tool* developed by Dan Reinartz. This tool has also been expanded to automate the data population for the soil infiltration, run-off, retention, evapotranspiration and erosion.

6- The proposed land use conversions were applied as stated below.

   a. Based on this criteria, each simulation was broken down into growing season (May 15 to September 15) and non-growing season (September 15 to the May 15). The non-growing season included snow melt. In order to represent the benefits of cover crop conditions, it was important to simulate existing fallow conditions during the non-growing season and other situations where cover crop was not applied. The goal of this task was to reasonably simulate the effects of crop cover applications using a consistent baseline.

   b. The land use conversion to perennial and crop cover application was conducted using the WEPP method, where the saturated hydraulic (KSAT) parameter is adjusted based on the crop type. However, capturing the benefits of land use by only changing the KSAT is limiting since the other parameters that contribute to infiltration, such as capillary pressure, field capacity, wilting point and porosity, is also known to physically change. If the organic matter of the soil is known, the changes to these parameters can be computed using the physical processes that govern the infiltration. These values have been known to change based on the organic matter content of the soil.

   c. The evapotranspiration, surface roughness and retention were also adjusted accordingly based on the crop values.

Simulation Runs:

In this study, 19 models for each of the existing and proposed conditions (38 total) were connected to run in sequence from 2000 to 2010. The models were linked through boundary conditions represented by files referred to as 'hotstart' files, so that the initial conditions of each model is based on the final conditions of the preceding one. The hot-start files represented the following boundary conditions: groundwater head, channel depth, channel discharge, overland run-off and soil moisture. Thus, each simulation would generate these 'hotstart' files in the last time step for the next simulation period to read as initial condition in the first time step, and so on. This would allow for a continuous simulation to occur between the models as they alternate between the growing and non-growing seasons. The growing and non-growing seasons were represented by two different models in order to capture the different crop types and land use conditions. For example cultivated crops in the growing season were replaced with fallow conditions outside of that window. This enables us to better determine the benefits of cover crops when they are applied in fallow conditions, outside the growing season. Currently, GSSHA does not allow for changing some critical model parameters within the same simulation, necessitating the breakdown of the simulation.

Results:

Table Two below summarizes the results of run-off total volume reductions. Based on these results, most benefits due to crop cover applications and land-use conversion to perennial crops occur within the non-growing season, where the ground would otherwise be fallow under existing conditions. Based on the reported runs, the runoff volume reductions due to the land-use conversions outside of the growing season range from a minimum of 10.5% to a maximum of near 27.4%. The total volume reductions in run-off are less during the growing season.

Table Two: Summary of results

Simulation Period		Precipitation (in)	RO Reduction%	ET Increases %
Growing Season 5/15 to 9/15	Non-growing Season 9/15 to 5/15			
2000		10.90	3.1	10
	2000 to 2001	18.64	10.5	120
2001		11.50	- 0.9	10
	2001 to 2002	10.80	26.0	150
2002		13.53	8.7	10
	2002 to 2003	7.63	27.4	110
2003		11.45	-2.7	10
	2003 to 2004	6.13	25.3	100
2004		14.40	10.6	10
	2004 to 2005	12.55	13.7	130
2005		16.24	6.2	10
	2005 to 2006	14.95	10.6	130
2006		7.90	19.1	0
	2006 to 2007	13.45	23.7	140
2007		7.57	21.9	10
	2007 to 2008	13.57	21.4	140
2008		10.21	14.7	10

	2008 to 2009	11.80	17.8	130
2009		9.1	23.0	3
	2009 to 2010	15.7	9.5	128

Table Three summarizes the average percent reductions for total run-off volumes and the increase in the ET volumes.

Table Three: Average effects of land use changes on volume runoff and ET increase.

Average Simulation	Run-off Reduction	ET Increase
Growing	10.4%	10%
Non-Growing	18.6%	130%

From Table Two, we notice that the percent amount of surface run-off reductions are not consistently related to the total amount of precipitation. For example, according to the model, a precipitation of 11.45-inches in the 2003-growing season yielded a -2.7 % reduction (in other words, no reduction) while a comparable precipitation of 11.4-inches in the 2004-growing season yielded a 10.6% reduction. In order to understand the variations between the two simulation periods, it is important to examine not only the total amount of precipitation but also rainfall intensity and distribution. Figures 4 and 5 compare the existing and proposed hydrographs and rainfall conditions between 2003 and 2004 respectively.

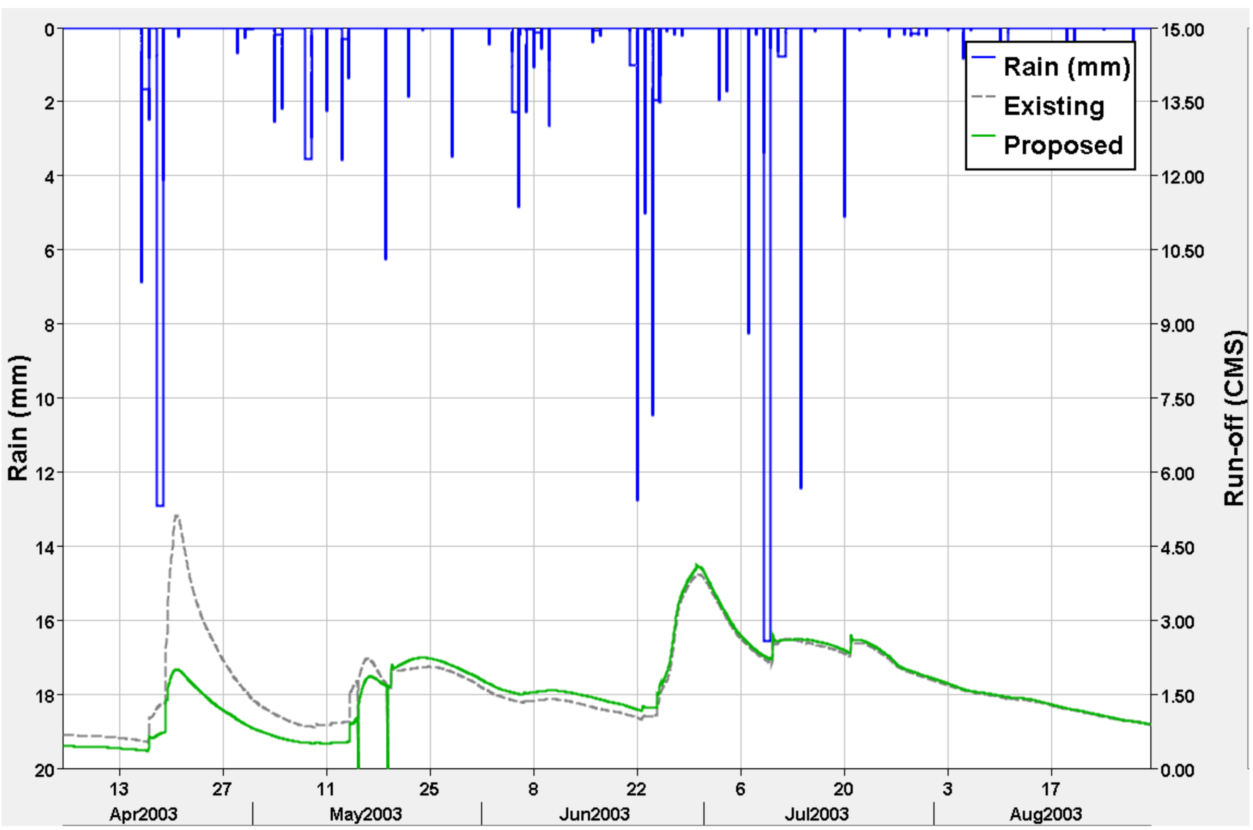

Figure 4: Existing versus proposed hydrographs for growing season of 2003

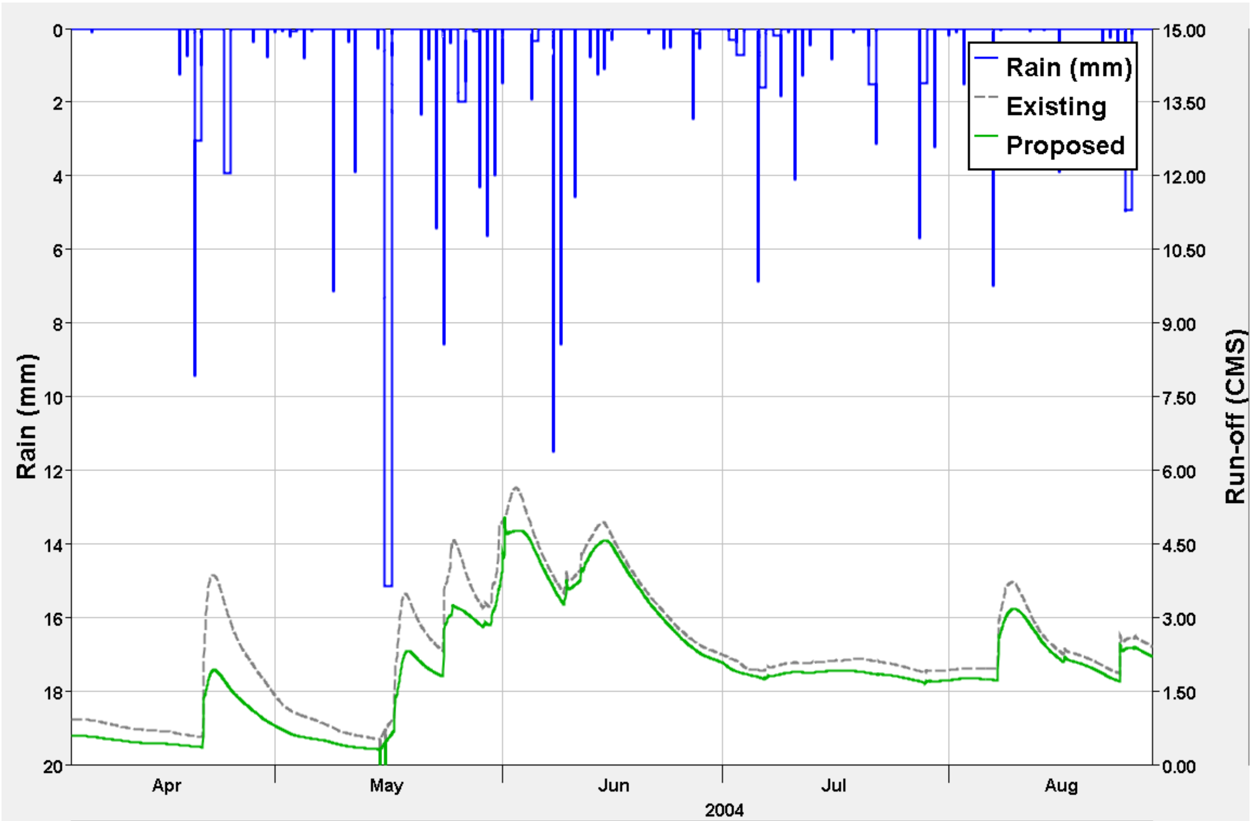

Figure 5: Existing versus proposed hydrographs for growing season of 2004

According to the two figures above, the 2004 growing season is dominated by less intense and more distributed rain events than that of 2003. This shows that in 2004, the improvement in soil health played a more important role in infiltrating the precipitation when the antecedent soil moisture conditions were higher due to the distribution of rainfall events. In 2003, the dryer soil conditions helped infiltrate the precipitation regardless of the soil health benefits.

Future steps:

- Report and discuss the results of the other simulations currently still running.
- Expand our criteria to include the following:
    - Apply the criteria to the whole Shakopee Watershed (345 mi^2).
    - Apply cover crops to 100% of agricultural areas.
    - Simulate sediment transport.
- Utilize the University of Minnesota's super computer: Currently we are working with the university in order to use their super computer capability, which require some code changes to make GSSHA compatible with their system. By using their computer facility, the time it takes to run each simulation is expected to decrease significantly.