Appendix: Watershed Modeling: Estimating Impact of Future Land Use Change on Water Quantity and Quality

Submitted by Molly Ramsey

Orange County is currently the fastest-growing county in NY State and management of water quality and quantity is a major concern in terms of drinking water, erosion, and flood control. As the Moodna Creek watershed includes much of Orange County, effects from urbanization are of particular concern for watershed stakeholders. Water quality is impacted by urbanization with several areas in the watershed showing symptoms of nutrient enrichment and other pollution (Nolan 2000). Water quantity is also impacted by urbanization, as large portions of the Moodna basin are dependent on groundwater for drinking water. Certain areas, including the Village of Washingtonville, use wells directly connected to Moodna Creek. During a dry spell in 2005, the Village was forced to tap emergency wells and implement water conservation requirements due to low water levels; yet, this dry spell was not considered a real drought. Ongoing development is expected to exacerbate the potential for water shortages both by increasing water demand and creating new impervious surfaces. Localized flooding and severe erosion has also been a problem in areas with downhill from new development as well as areas along the banks of the tributaries and main stem of the Moodna. Increases in impervious surfaces reduce infiltration of precipitation to groundwater as well as increase the flashiness of stream discharge and volumes and rates of runoff water and sediment.

Computer watershed models can estimate the effects of different land use change scenarios on the water resources of the Moodna Creek watershed. How the rates of simulated streamflow, groundwater, and runoff vary with the location and intensity of urbanization can help inform future economic development and water and land resource management plans.

With funding from the New York Water Resources Institute (http://wri.eas.cornell.edu/wrihomepage.html), a watershed modeling project was initiated in 2006 by Molly Ramsey, a graduate student at SUNY College of Environmental Science and Forestry, and Simon Gruber, environmental consultant for the Orange County Water Authority. The project is supported by the Orange County Office of Planning and Orange County Water Authority.

The first phase of the modeling project involves using simple watershed models (i.e. spatially-aggregated, minimal input variables) to estimate the effects of development on the hydrology and water quality of the Moodna Creek watershed.   Preliminary results from this first phase of the project are provided below. These results are simulations only and have not been validated with measured streamflow data. The next step in the project is to validate the modeled results with measured streamflow and water quality monitoring data from a nearby analog watershed, the Ramapo watershed (outlet at Suffern, NY). Because these results have not been validated it is important to consider them as preliminary only; their value is in presenting general trends of hydrology and water quality that may be expected for the different land use scenarios tested.

The next tasks of the first phase of the modeling project involve running the nutrient and sediment component of GWLF for the four different land use change scenarios. In the second phase, the modeled results will also be validated with data from the Ramapo watershed in New York.

The second phase of the project is the installation of a stream gage along the Moodna Creek outlet (See Appendix #, Figure 3) and the calibration and validation of a physically-distributed, water routing model (surface and subsurface flows). This more data intensive, spatially-explicit watershed model will better inform water and land resource management for the watershed. A stream gage data on the Moodna will also provide important hydrological data for characterizing the watershed and how it may change with increased urbanization (i.e. increase in impervious area and withdrawals from groundwater), including, peak discharge or streamflow that can be used to develop flood frequencies for the watershed. Flood frequency analyses will allow the calculation of probabilities of exceeding peak flow rates, in this way predicting flood recurrences. An understanding of how these relate to changes in land use patterns is therefore another useful tool for developing future water and land resource management. For example, predicted streamflow rates for different land use change scenarios can be compared to measured discharge rates representing flooded conditions.

Watershed Models

Generalized Watershed Loading Function Model

The Generalized Watershed Loading Function model (GWLF) is a hydrologic model that simulates water (including stream water flow, infiltration, runoff, and storage; groundwater will be estimated by difference) and loading of sediments and nutrients to receiving watersheds. Although the model is not spatially explicit, spatial approximations can be made by breaking up the watershed into sub-catchments and running the model separately in each of these. The model can be used to represent multiple land uses including forest, wetland, meadow, and urban with varying degrees of imperviousness. Output is simulated on a daily time step and averaged on monthly and annual time steps. Key model parameters are the Soil Conservation Service curve number for simulating runoff and the Universal Soil Loss Equation for simulating erosion. A schematic of the model is included in Appendix #, Figure #, pg. #.

The model has been used for similar purposes, although it has been more widely used for simulating sediment and nutrient loads, including the Hudson River (Swaney et al. 1996), the Choptank River (Lee et al. 2000, 2001), the Cannonsville watershed in New York (Schneiderman et al. 200), and the Susquehanna River (Chang et al. 2001). Similar studies estimating freshwater discharge, sediment and organic carbon loads from tributaries of the Hudson River reported that the GWLF model gave similar results to measured rates (Howarth et al. 1991, Swaney et al. 1996).

The model used in this project was actually the Regional Nutrient Management (ReNuMa) Model, a recently-developed model, based on GWLF (http://www.eeb.cornell.edu/biogeo/nanc/usda/renuma.htm; Swaney and Hong 200#). The hydrological framework of ReNuMa is the same as GWLF. The advantage to using ReNuMa for this project is that the model could be run a single time for all of the sub-watersheds, i.e. it could be run in batch-mode. A hydrologic connectivity sub-routine is built into ReNuMa which is not part of GWLF, therefore, hydrological inputs from the different subwatersheds were routed to downstream subwatersheds and considered in their output.

Integrated Watershed Condition Model

The Integrated Watershed Condition Model is a statistical model predicts how watershed urbanization affects a large suite of water quality and biological variables. The modeled stream water quality is derived from multiple linear regression relationships calculated from stream water quality monitoring data and the land use characteristics of the associated watersheds obtained from the USGS NAWQA (National Water Quality Assessment Program) dataset (http://water.usgs.gov/nawqa) (Hong et al. 200#). The dataset used in this model is restricted to the NY/NJ/PA area so that sufficient data sets could be analyzed without compromising specific characteristics of the region (Hong and Limburg, in preparation).

The Integrated Watershed Condition Model has been applied to the Wappinger and Fishkill Creek watersheds in Dutchess County, NY (Hong et al. 200#, 200#).

Land Use Change Scenarios

Generalized Watershed Loading Function (GWLF) Model

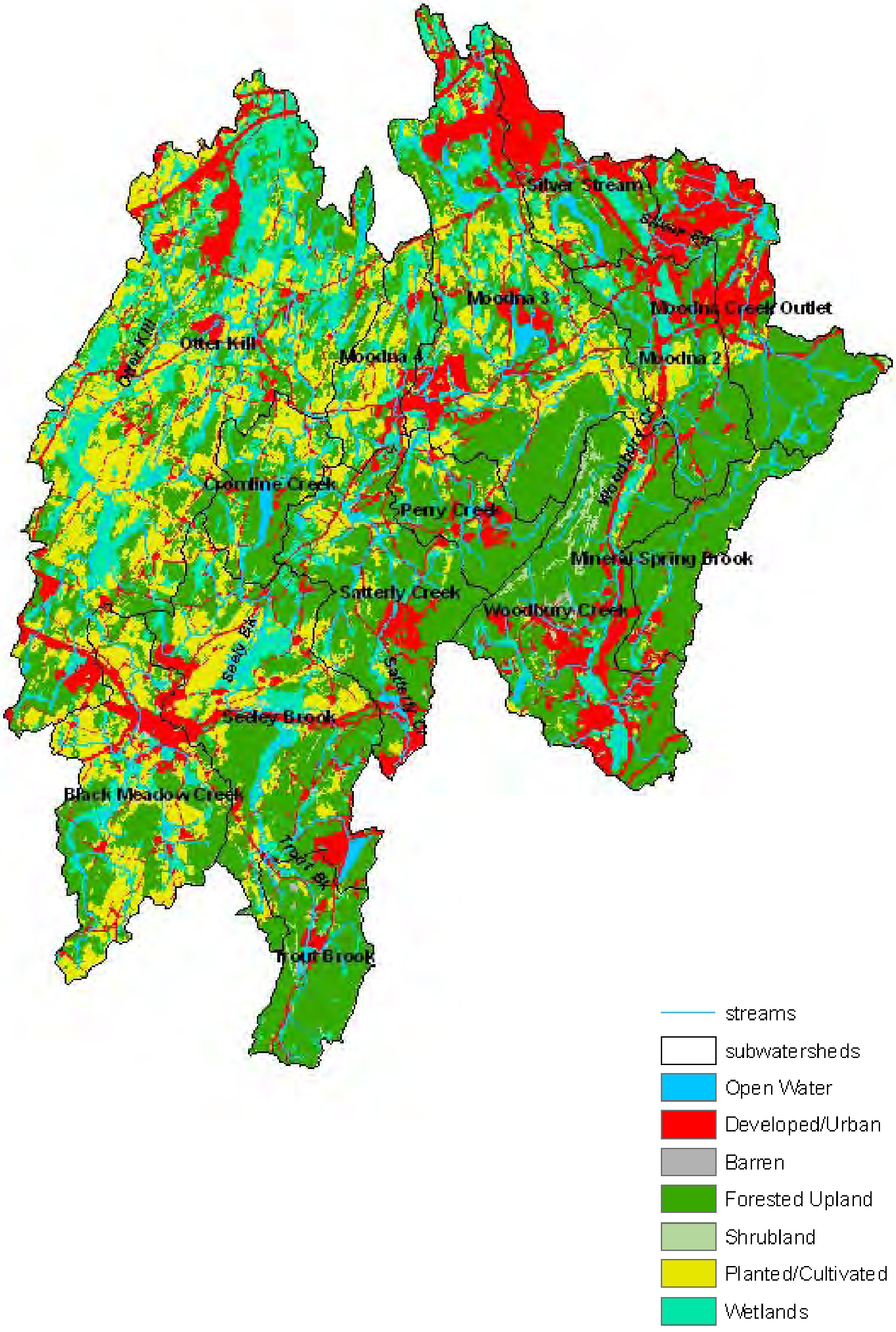
Four different land use change scenarios were run in the GWLF model:

1) all forested
2) all urbanized (i.e. 100% impervious surface)
3) current land use pattern, based on 2001 National Land Use Dataset
4) 15% increase in urbanization.

These scenarios were applied to the major subwatersheds of the Moodna (Figure 1). GWLF has a range of 7 different land uses (with corresponding model parameter values such as runoff curve numbers, erosion coefficients) including open water, developed/urban, planted/cultivated, shrubland, barrenland, and forested. Figure 2 shows the land use pattern used in GWLF representing the current land use of the Moodna watershed based on the 2001 National Land Use Dataset. Table # in Appendix # describes the different subwatersheds and the surface area per land use for the land use change scenarios simulated in GWLF.

Figure 1: Subwatershed designation for Moodna Creek Watershed. The 14 subwatersheds simulated in the watershed models include the Moodna Creek Outlet, Moodna Creek 2, Silver Stream, Mineral Spring Brook, Woodbury Creek, Moodna Creek 3, Moodna Creek 4, Perry Creek, Satterly Creek, Cromline Creek, Otter Kill, Seeley Brook, Trout Brook, and Black Meadow Creek.

Figure 2: Classification of current land use pattern for GWLF, based on 2001 National Land Use Dataset



Integrated Watershed Condition Model

The Integrated Watershed Condition Model considers three different land use types: forested, urban, and agriculture. The current land use pattern (based on the 2001 National Land Use Dataset) for the Moodna watershed were re-classified into the three land use types. Simulated water quality including surface water chemistry and biological health indices were calculated for each of the subwatersheds. The model was also run for 3 additional land use scenarios for the Woodbury subcatchment: all forested, all agriculture, and all developed/urban.

Spatial Aggregation in GWLF

The streamflow, runoff, and groundwater simulated by GWLF represents conditions at the outflow of a subcatchment. Each subcatchment has one simulated streamflow, runoff, and groundwater rate per time-step. The different land uses within each subcatchment affect hydrological conditions; for example, runoff rates will be higher in subcatchments where a higher percentage of the land surface is developed versus a subcatchment dominated by forest.

GWLF is not a physically-distributed model; the consideration of land use effects with respect to watershed position, recharge areas, proximity to stream channel within a subcatchment cannot be evaluated using GWLF.

Preliminary Results

Hydrological Component of GWLF

Average annual groundwater rates (Figure #; averaged over 16 years based on weather record from 1990 – 2006) were slightly lower for the 15% buildout scenario compared to the current land use. The 100% impervious or urban land use had the lowest groundwater rates overall with annual average rates barely above zero. The 100% forested scenario had the highest groundwater rates. The subcatchments varied somewhat with the Silver Spring subcatchment, with the highest percentage of urbanized land, having the lowest groundwater annual average rates and the Mineral Spring Brook with the highest percentage of forested land having the highest groundwater annual average rates. Simulated streamflow rates (Figure #) were consistent between subcatchments and land uses except for the 100% urban. In this land use scenario, streamflow was higher reflecting the higher runoff coefficients used for this land use in the model. As impervious surfaces cover the land in urbanized settings, precipitation hits the land surface and instead of infiltrating into the soil and potentially being stored in groundwater, the water runs off and downslope to the stream. Runoff rates were very high relative to other land use scenarios for the 100% urban (Figure #). The 15% buildout had slightly higher annual average rates versus the current land use. The lowest runoff rates were for the Mineral Spring Brook subcatchment with the highest percentage of forested land and vice versa for the subcatchment with the highest percentage of urbanized land, Silver Spring.

The GWLF simulations showed only small differences between the current land use and 15% buildout for all of the subcatchments. This trend was reflected in the annual average rates as well as the monthly averages. An analysis of each subcatchment was calculated with results shown in figures for the Moodna Outlet (Figures # - #) below, and for the Silver Spring subcatchment (Appendix #, Figures # - #) and the Woodbury subcatchment (Appendix #, Figures # - #). An attempt was made to determine if there was a higher annual or monthly (not averaged) frequency of time-steps with zero groundwater or peak streamflow rates between the two scenarios but this was not found. This is most likely an artefact of the aggregated, non-spatially explicit nature of GWLF. As experienced in the Moodna, flooding can be localized and most likely varies with watershed topographic position and proximity to recharge areas and/or streambank. This cannot be simulated appropriately with GWLF. It is possible that with a larger buildout, more significant differences will be simulated between the land use scenarios. However, the GWLF output does support the hypothesis of a general trend of greater runoff and lower groundwater rates with increased urbanization. This modeling exercise underscored the need for a physically-based, spatially-explicit water routing model.

Figure # 3: Average annual groundwater (equivalent depth per subcatchment) simulated by GWLF for the four different land use scenarios.

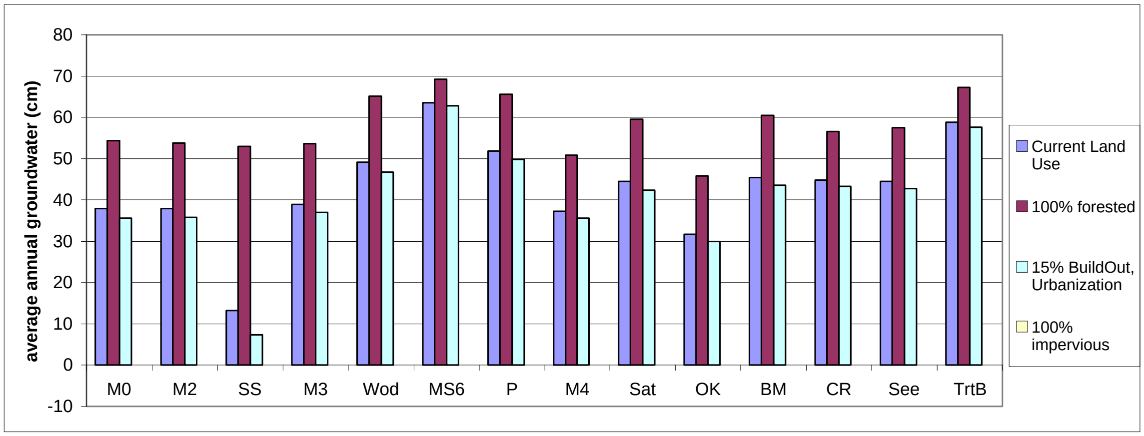


Figure # 4: Average annual streamflow (equivalent depth per subcatchment) simulated by GWLF for the four different land use scenarios.

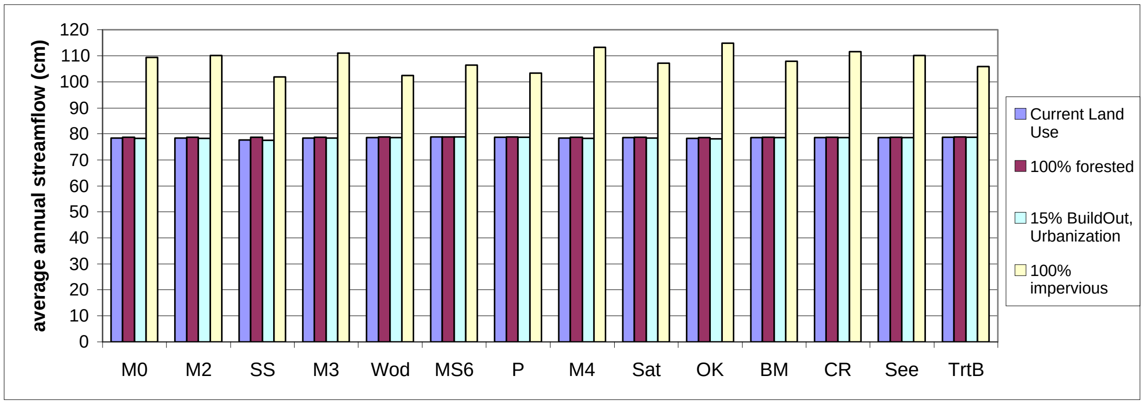


Figure # 5: Average annual runoff (equivalent depth per subcatchment) simulated by GWLF for the four different land use scenarios.

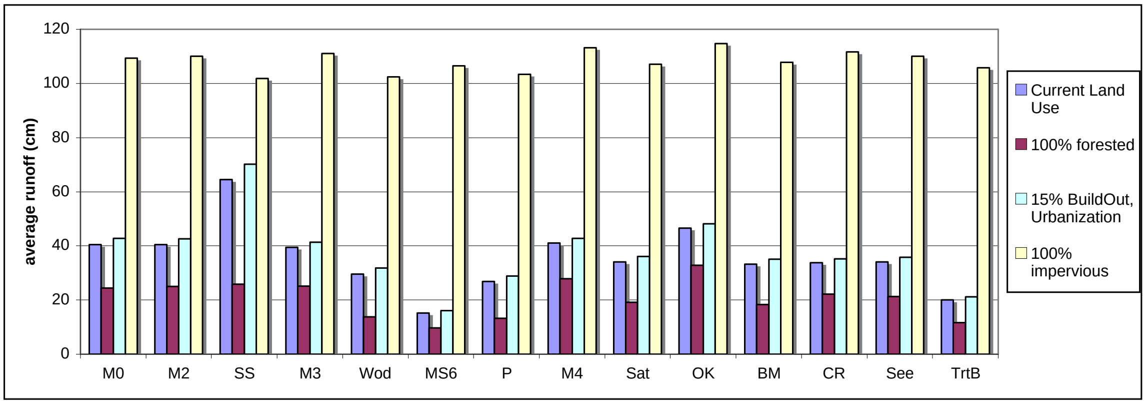


Figure # 6: Average monthly streamflow (equivalent depth per subcatchment) simulated by GWLF for the Moodna Creek Outlet subcatchment for the current and 15% buildout land use scenario.

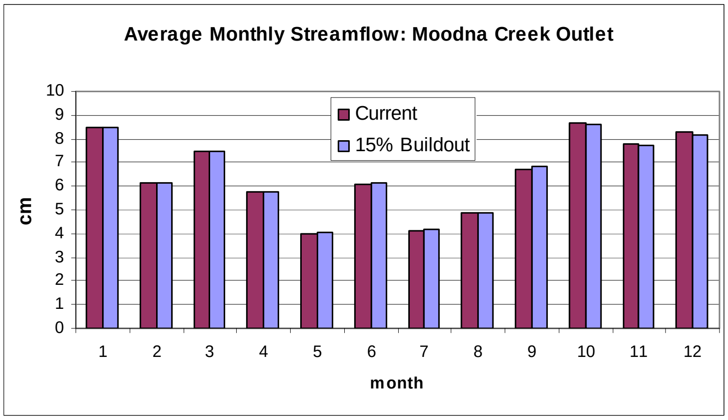


Figure # 7: Average monthly groundwater (equivalent depth per subcatchment) simulated by GWLF for the Moodna Creek Outlet subcatchment for the current and 15% buildout land use scenario.

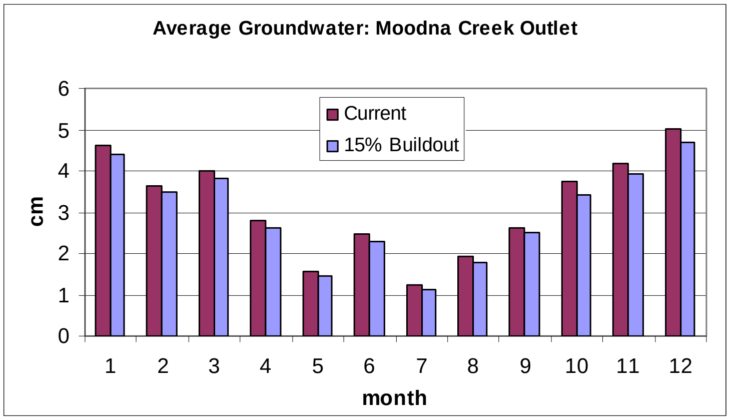


Figure # 8: Average monthly runoff (equivalent depth per subcatchment) simulated by GWLF for the Moodna Creek Outlet subcatchment for the current and 15% buildout land use scenario.

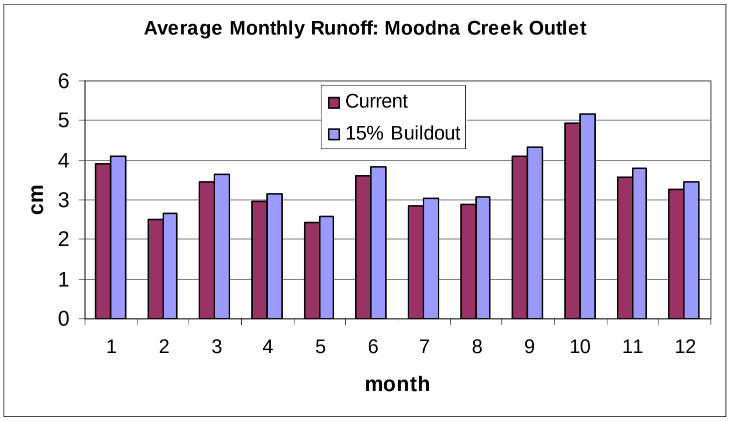
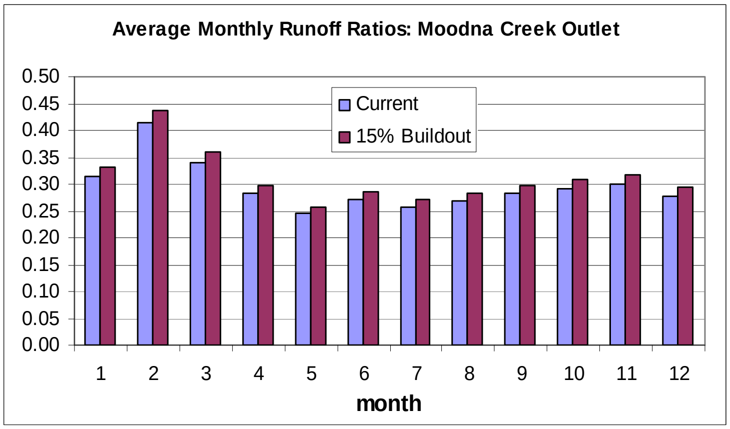


Figure # 9: Runoff ratio calculated for the Moodna Creek Outlet subcatchment using GWLF runoff and precipitation rates for the current and 15% buildout land use scenario.



Integrated Watershed Condition

Chloride concentrations in streamwater are highest for the subcatchment with the highest percentage of urbanized land, Silver Spring (Figures # and #). While not a strong relationship, a few subcatchments with lower urbanized land had higher chloride concentrations. This may be due to a relatively higher percentage of agricultural land. The model was run for the Woodbury subcatchment for four different land use scenarios: current, 100% forested, 100% agriculture, and 100% urban (Figure #). Chloride concentrations were much higher for the 100% urbanized followed by the current land use and then the 100% agriculture. Dissolved phosphorous and nitrogen concentrations were simulated as highest in the current land use scenario for the Woodbury (Figures # and #). Contributions from forested land plus the agriculture and urban may be the reason for the higher concentrations in the current land use versus the single land use type of the 100% urban and 100% agriculture.

The simulated water quality conditions for the current land use for each subwatershed are presented in Appendix #, Table #. The general trends included a higher biological index, lower nutrient concentration, higher dissolved oxygen content, and lower temperature for the subcatchments with the most forested land (for example, Mineral Spring Brook). The subcatchments with a higher proportion of agricultural land (e.g. Otter Kill) had the lowest dissolved oxygen concentrations. While, the subcatchements with the highest proportion of urbanized land (e.g. Silver Spring), had the highest proportion of nutrients and heavy metal concentrations. It will be helpful to compare these individual subcatchments with further analyses and how their water quality changes with different land use scenarios but particularly with water quality data collected from the Moodna Creek and its tributaries. Although the statistical relationships of the model were derived from regional watersheds, a more accurate understanding will only be gained when the modeled results are validated with field data.

Figure # 10: Chloride concentrations simulated from the Integrated Watershed Condition Model versus % urban land use per subcatchment for the current land use change scenario.

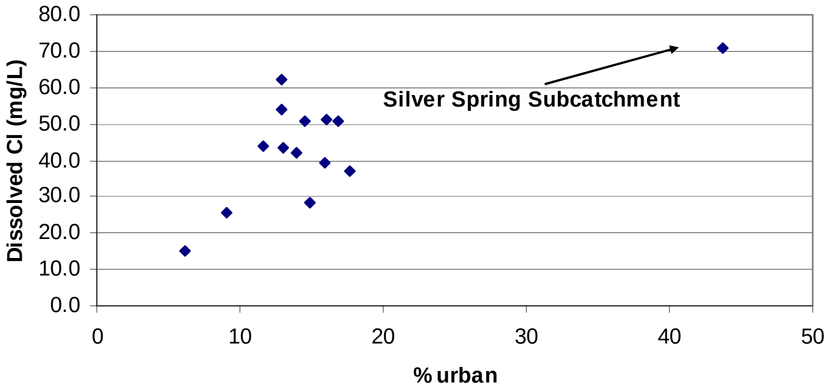


Figure # 11: Chloride concentrations simulated from the Integrated Watershed Condition Model for the current land use change scenario.

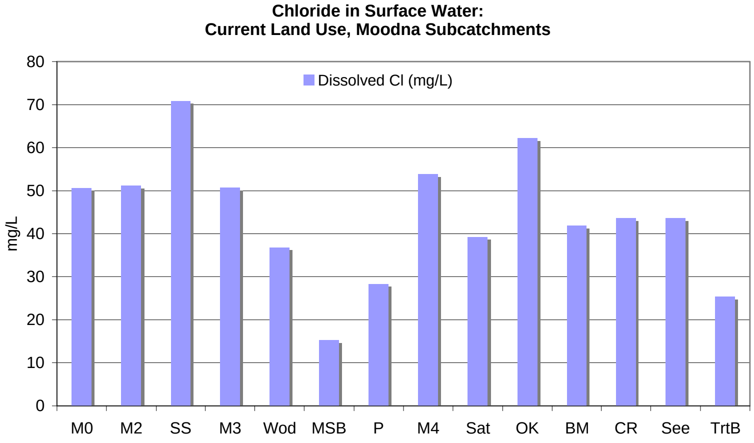


Figure # 12: Chloride concentrations simulated from the Integrated Watershed Condition Model for the Woodbury subcatchment for four different land use change scenarios: current, 100% forested, 100% urban, and 100% agriculture.

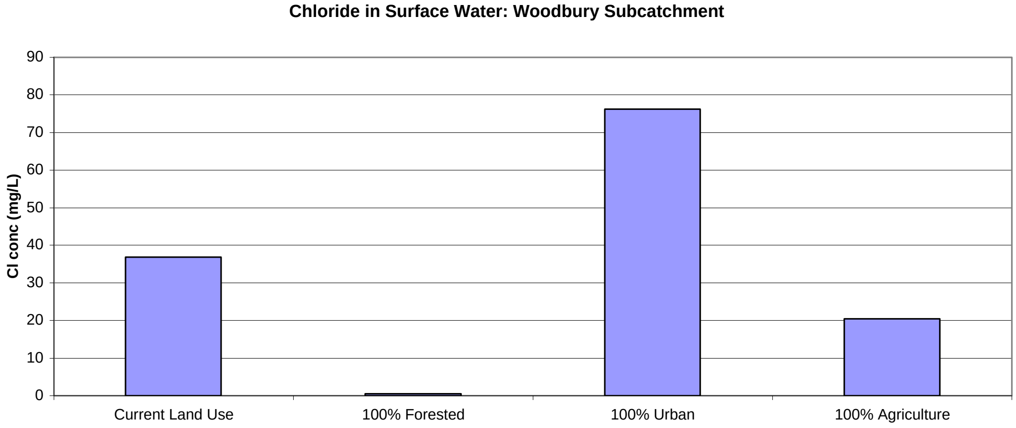


Figure # 13: Inorganic phosphorous concentrations simulated from the Integrated Watershed Condition Model for the Woodbury subcatchment for four different land use change scenarios: current, 100% forested, 100% urban, and 100% agriculture.

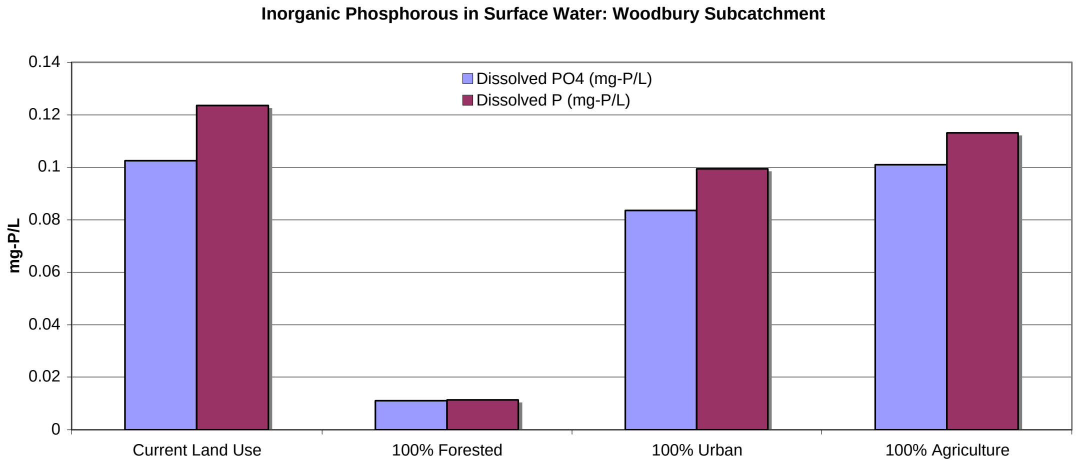


Figure # 14: Inorganic nitrogen concentrations simulated from the Integrated Watershed Condition Model for the Woodbury subcatchment for four different land use change scenarios: current, 100% forested, 100% urban, and 100% agriculture.

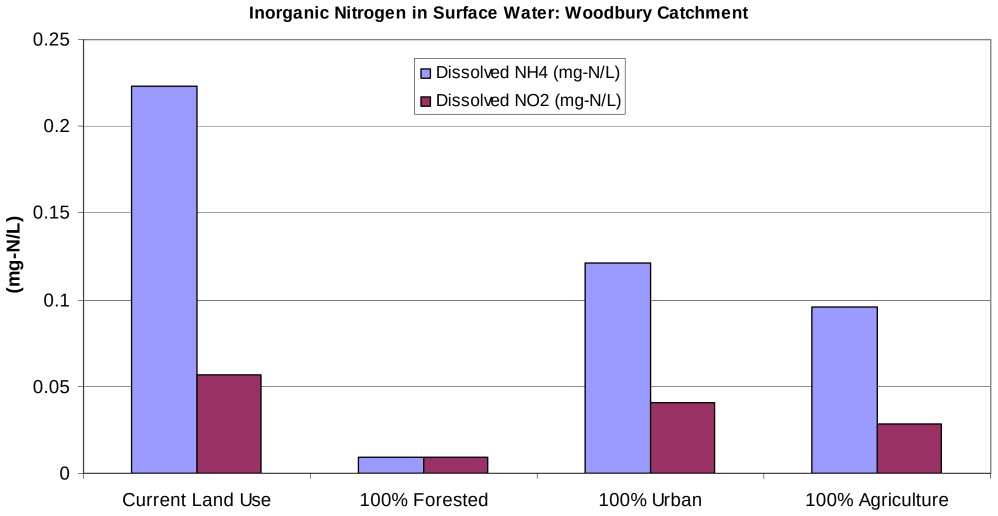


Figure # 15: Schematic of the model, Generalized Watershed Loading Function (GWLF) Model (Haith and Shoemaker 1987).

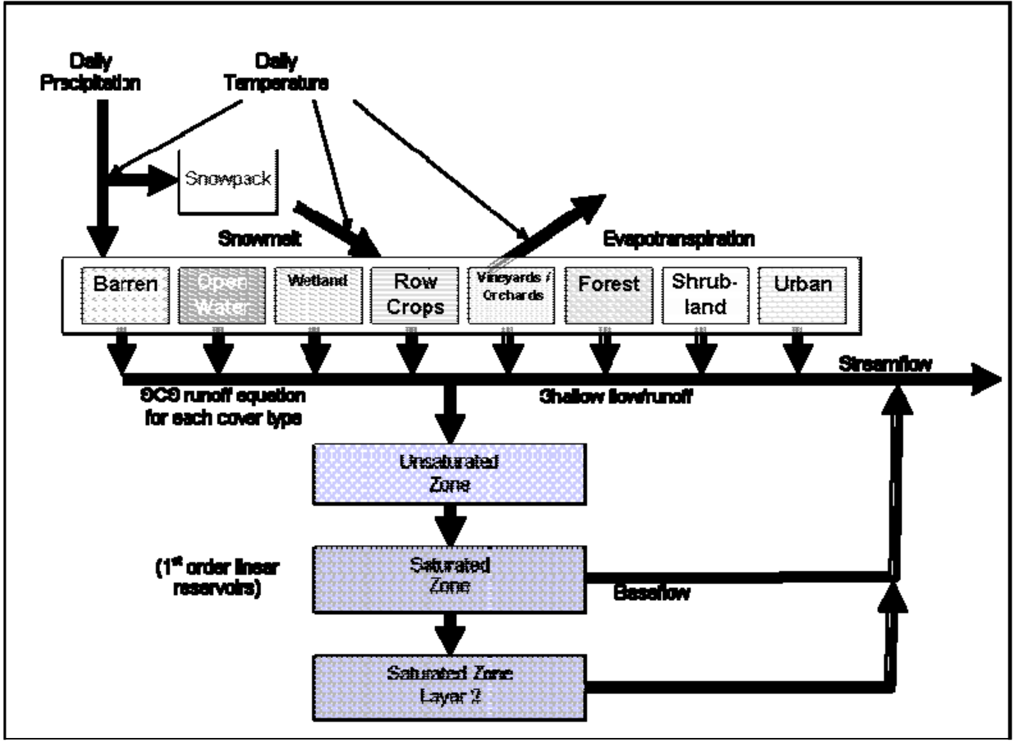


Figure # 16: Hydrologic connectivity of subwatersheds designated for GWLF modeling.

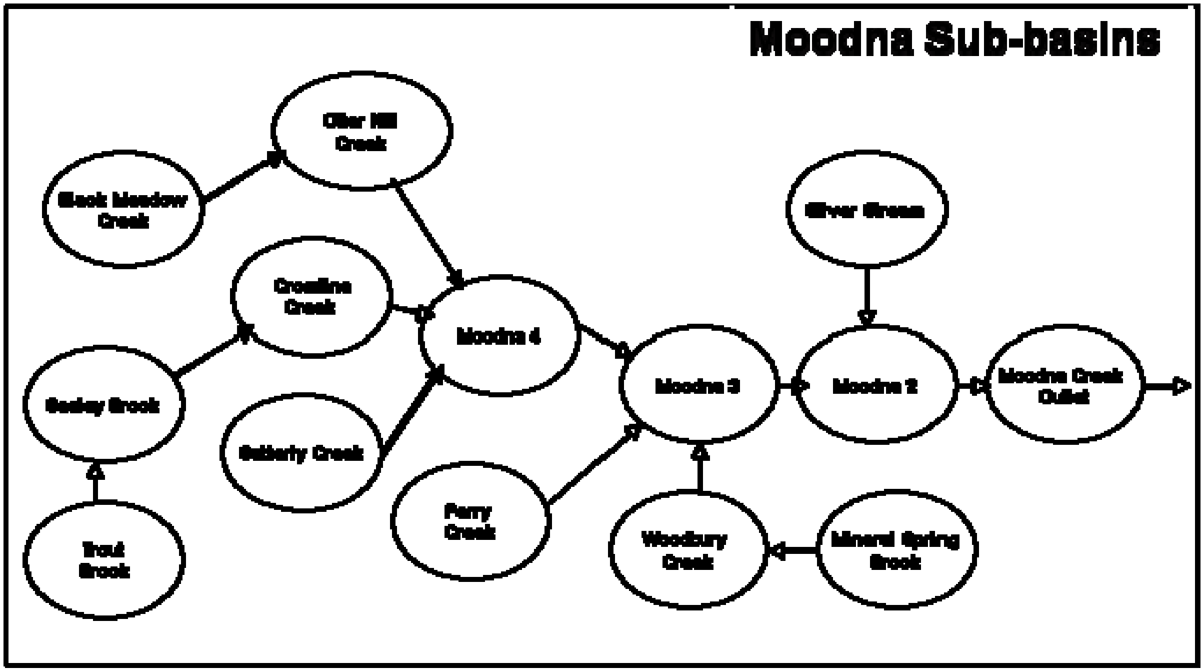


Table # 1: Data Inputs to GWLF model.

Model Parameter	Input Value
Weather	Westpoint, NY (1990 – 2006); NOAA
Recession Constant	0.2
Erosivity Coefficient	0.68 (May – Oct)) 0.18 (Nov – April)
Sediment Delivery Ratio	0.1
Runoff Curve Number	Planted/Cultivated = 72 Orchards/Vineyards = 58 Shrubland = 48 Barren = 82 Forested Upland = 55 Developed/Urban = 98 Open Water = 100 Wetlands = 100
Evapotranspiration Cover Factor	0.9 (November - April) 1.0 (May – October)

Figure # 17: Size and land use pattern of subwatersheds in Moodna Creek watershed.

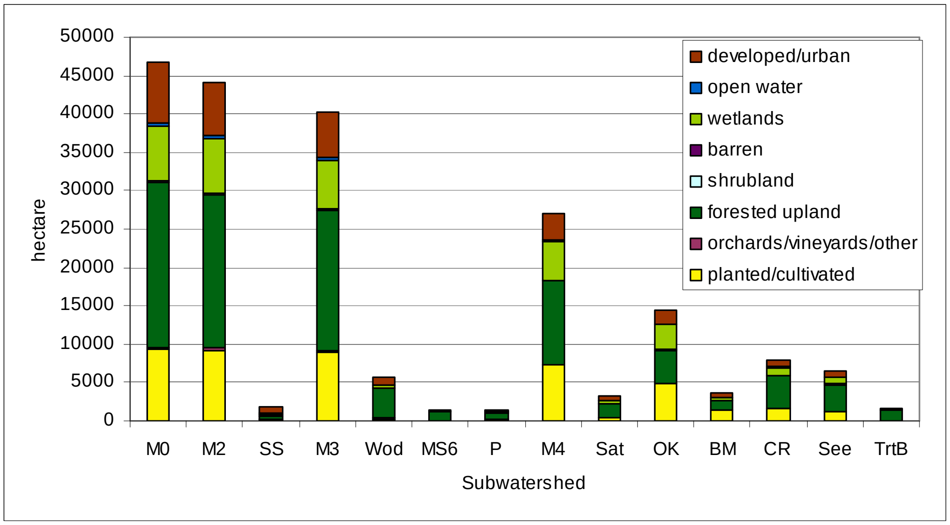
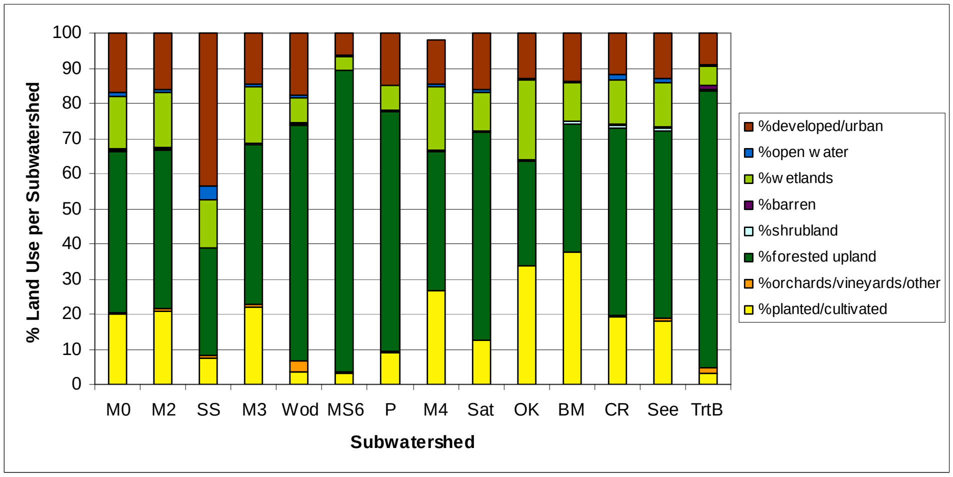


Figure # 18: Current land use pattern per subwatershed of the Moodna Creek watershed.



Figures # 19 - 21: GWLF output for the Woodbury subcatchment; comparison of current and 15% land use.

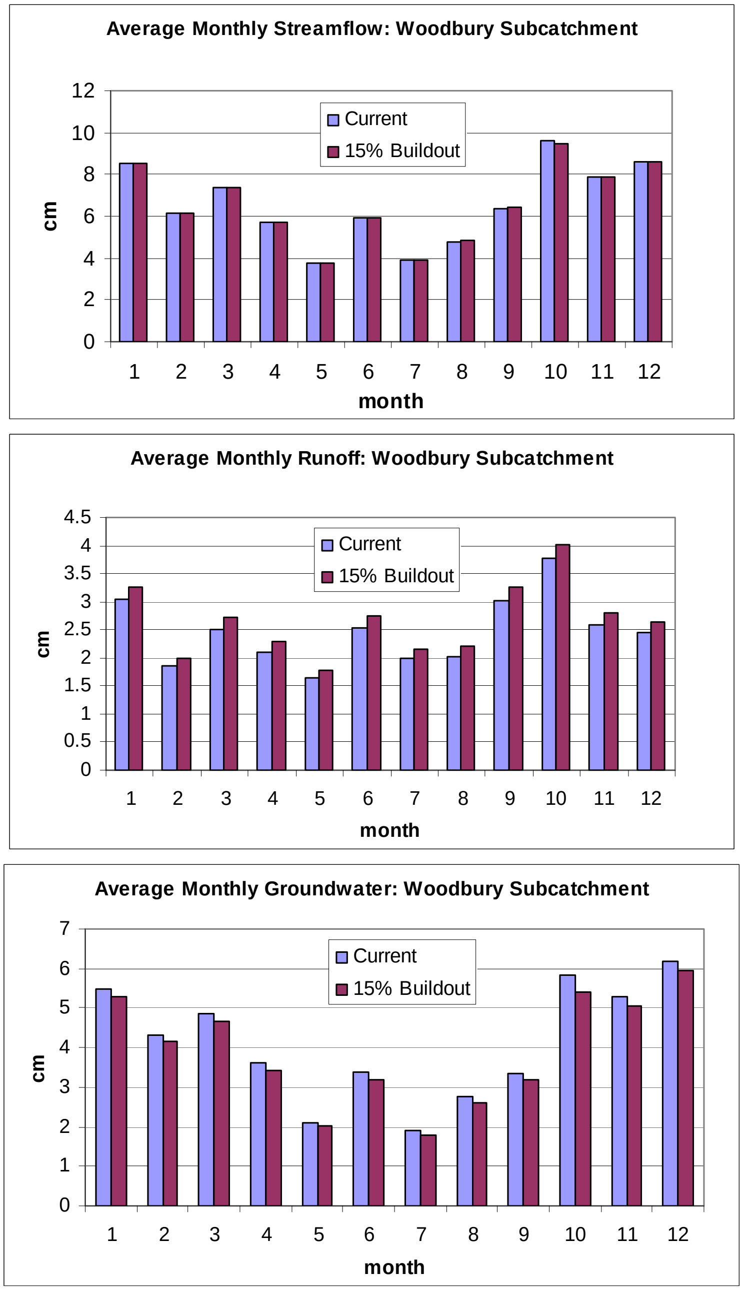
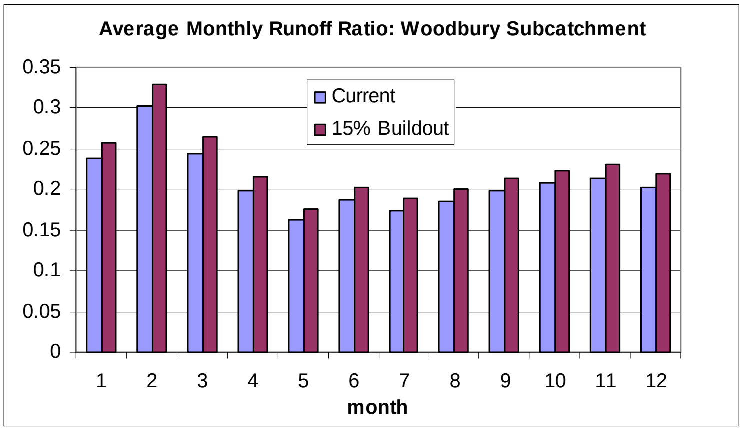
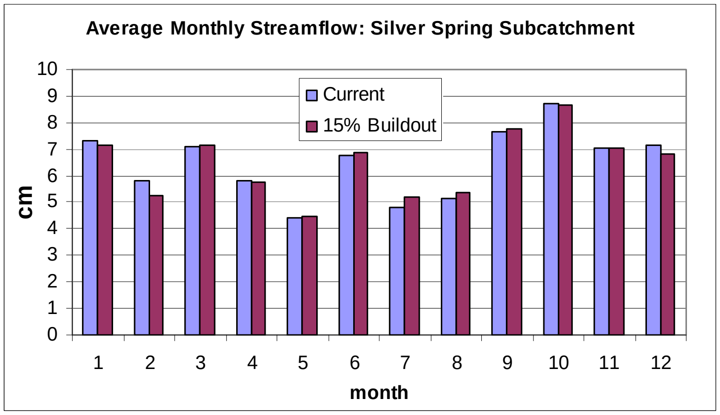
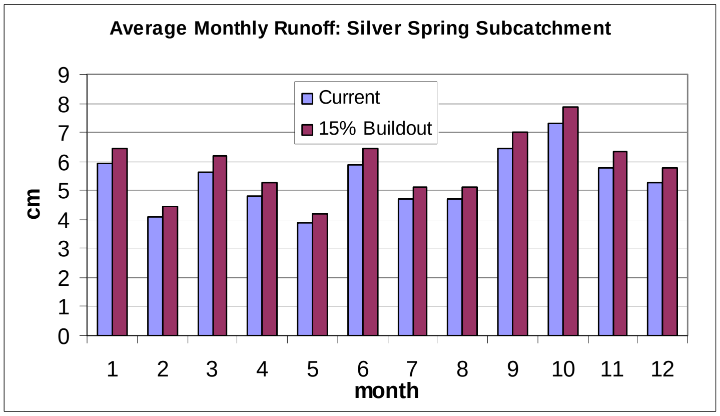


Figure # 22: Runoff ratio calculated for the Woodbury subcatchment using GWLF runoff and precipitation rates.



Figures 23 - 24: GWLF output for the Silver Spring subcatchment; comparison of current and 15% land use.





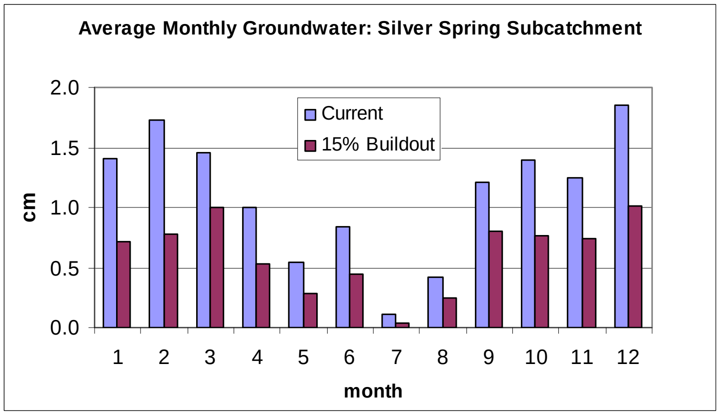


Figure #25: Runoff ratio calculated for the Woodbury subcatchment using GWLF runoff and precipitation rates.

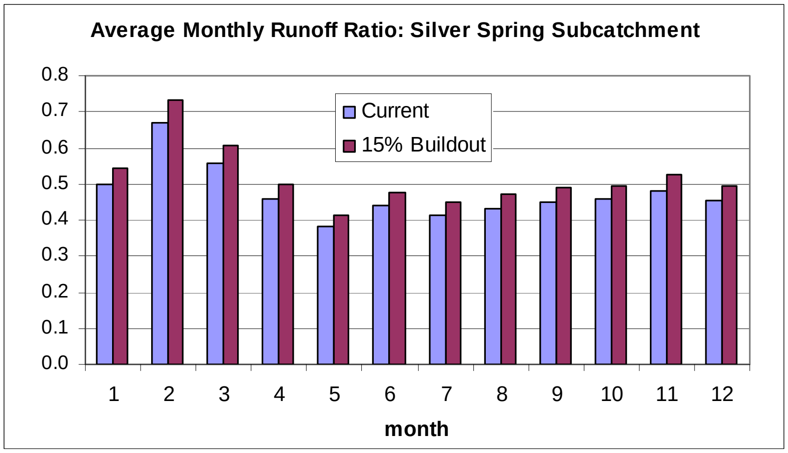


Table #2: Input data for the Integrated Watershed Condition Model. Land use is the input data for the model. The area per land use is converted to number of cells (each cell = ## area).

	% Forested	% Agriculture	% Urban
Moodna Outlet (MO)	45.84	19.97	16.86
Moodna 2 (M2)	45.26	20.87	15.99
Silver Spring (SS)	30.35	7.34	43.69
Moodna 3 (M3)	45.26	22.14	14.55
Woodbury (Wod)	67.14	3.63	17.72
Mineral Spring (MS)	85.73	3.24	6.14
Perry Creek (P)	68.38	9.11	14.90
Moodna 4 (M4)	40.19	27.10	12.87
Satterly Creek (Sat)	59.01	12.51	15.96
Otter Kill (OK)	29.91	33.67	12.91
Black Meadow Creek (BM)	36.49	37.46	13.90
Cromline Creek (CR)	53.33	19.17	11.65
Seeley Brook (See)	53.45	18.09	13.08
Trout Brook (TrtB)	78.69	3.21	9.10

Table # 3: Results from Integrated Watershed Condition Model, Current Land Use Scenario.

Variable	M0	M2	SS	M3	Wod	MSB	P	M4	Sat	OK	BM	CR	See	TrtB
Water Temperature (degree C)	13.47	13.51	13.81	13.53	12.44	11.72	12.42	13.80	12.85	14.29	13.96	13.19	13.16	12.02
[95% Lower Bound]	13.08	13.12	13.32	13.14	11.91	11.01	11.89	13.38	12.41	13.79	13.52	12.78	12.75	11.38
[95% Upper Bound]	13.86	13.90	14.30	13.93	12.97	12.44	12.95	14.22	13.30	14.79	14.40	13.60	13.57	12.65
Specific Conductance (micro-S/cm)	546.19	557.09	636.70	559.96	358.57	171.82	293.43	610.57	411.74	714.30	510.41	489.00	481.15	267.12
[95% Lower Bound]	460.93	468.84	542.68	470.67	306.93	151.79	261.97	510.92	353.93	593.26	451.35	412.60	407.35	229.11
[95% Upper Bound]	631.46	645.35	730.72	649.25	410.22	191.84	324.88	710.23	469.55	835.35	569.47	565.40	554.95	305.13
Dissolved Oxygen (mg/L)	10.40	10.37	10.44	10.35	10.86	11.09	10.84	10.23	10.66	10.01	10.16	10.48	10.51	10.98
[95% Lower Bound]	10.28	10.25	10.28	10.23	10.70	10.87	10.68	10.09	10.53	9.85	10.02	10.36	10.38	10.79
[95% Upper Bound]	10.52	10.50	10.60	10.48	11.02	11.31	11.00	10.36	10.80	10.17	10.30	10.61	10.63	11.17
pH	7.59	7.59	7.61	7.60	7.45	7.36	7.45	7.63	7.50	7.70	7.65	7.55	7.55	7.40
[95% Lower Bound]	7.56	7.56	7.57	7.57	7.41	7.31	7.41	7.60	7.47	7.66	7.62	7.52	7.52	7.35
[95% Upper Bound]	7.61	7.62	7.64	7.62	7.48	7.41	7.48	7.66	7.53	7.73	7.68	7.58	7.58	7.44
Dissolved Ca (mg/L)	61.78	63.26	67.89	63.91	37.73	17.11	31.11	70.62	45.24	83.55	60.12	55.56	54.35	27.92
[95% Lower Bound]	48.68	49.70	53.42	50.19	29.79	14.05	26.30	55.31	36.37	64.95	51.07	43.83	43.02	22.09
[95% Upper	74.88	76.82	82.37	77.62	45.66	20.17	35.93	85.93	54.11	102.1	69.17	67.29	65.68	33.74

Bound]										5				
Dissolved Mg (mg/L)	8.33	8.51	8.90	8.63	4.47	2.11	4.48	9.66	6.06	11.49	10.24	7.43	7.29	3.12
[95% Lower Bound]	8.01	8.19	8.51	8.30	4.04	1.53	4.05	9.31	5.70	11.07	9.87	7.09	6.95	2.61
[95% Upper Bound]	8.65	8.83	9.29	8.95	4.90	2.69	4.91	10.01	6.42	11.91	10.60	7.76	7.62	3.63
Dissolved Na (mg/L)	34.17	34.68	45.31	34.49	24.67	10.73	18.60	36.83	26.28	42.68	27.40	29.94	29.73	17.70
[95% Lower Bound]	21.53	21.60	31.35	21.26	17.02	7.78	13.96	22.06	17.73	24.74	18.67	18.63	18.80	12.08
[95% Upper Bound]	46.80	47.76	59.26	47.72	32.33	13.68	23.24	51.59	34.84	60.62	36.13	41.26	40.66	23.32
Dissolved K (mg/L)	1.26	1.25	1.47	1.25	0.96	0.93	1.25	1.30	1.19	1.38	2.03	1.16	1.18	0.83
[95% Lower Bound]	0.35	0.30	0.46	0.29	0.41	0.72	0.92	0.23	0.57	0.07	1.40	0.34	0.39	0.42
[95% Upper Bound]	2.18	2.20	2.48	2.21	1.52	1.15	1.59	2.37	1.81	2.68	2.67	1.98	1.98	1.24
Alkalinity (mg/L)	22.84	21.84	25.45	21.79	17.89	25.52	33.26	22.07	25.33	20.78	57.40	21.41	22.49	16.82
[95% Lower Bound]	0.00	0.00	0.00	0.00	2.14	19.42	23.68	0.00	7.74	0.00	39.50	0.00	0.05	5.23
[95% Upper Bound]	48.76	48.67	54.06	48.92	33.63	31.63	42.84	52.34	42.92	57.54	75.31	44.64	44.93	28.42
Dissolved Cl (mg/L)	50.62	51.18	70.90	50.69	36.81	15.22	28.26	53.82	39.19	62.24	41.86	43.66	43.61	25.37
[95% Lower Bound]	26.71	26.43	44.49	25.65	22.33	9.64	19.48	25.88	23.00	28.29	25.35	22.25	22.93	14.74
[95% Upper Bound]	74.53	75.93	97.31	75.72	51.29	20.80	37.04	81.77	55.38	96.18	58.38	65.07	64.30	36.01

Table #: Results from Integrated Watershed Condition Model, Current Land Use Scenario.

Variable	M0	M2	SS	M3	Wod	MSB	P	M4	Sat	OK	BM	CR	See	TrtB
Dissolved SO4 (mg/L)	165.60	171.11	177.70	173.34	97.31	29.75	63.68	193.62	113.47	233.88	129.42	148.88	144.05	69.92
[95% Lower Bound]	137.16	141.67	146.25	143.56	80.16	23.17	53.30	160.36	94.25	193.44	109.77	123.44	119.47	57.36
[95% Upper Bound]	194.04	200.56	209.16	203.13	114.47	36.32	74.05	226.88	132.69	274.32	149.07	174.33	168.63	82.48
Dissolved F (mg/L)	0.19	0.19	0.20	0.19	0.16	0.13	0.15	0.20	0.17	0.21	0.17	0.18	0.18	0.15
[95% Lower Bound]	0.16	0.16	0.16	0.16	0.14	0.12	0.13	0.16	0.14	0.17	0.14	0.15	0.15	0.14
[95% Upper Bound]	0.22	0.22	0.23	0.22	0.18	0.14	0.16	0.23	0.19	0.26	0.19	0.21	0.20	0.16
Dissolved SiO2 (mg/L)	5.97	5.96	7.07	5.92	5.48	4.72	5.38	6.00	5.63	6.25	6.11	5.65	5.68	4.97
[95% Lower Bound]	5.84	5.83	6.91	5.78	5.30	4.47	5.19	5.85	5.48	6.07	5.96	5.51	5.54	4.75
[95% Upper Bound]	6.11	6.10	7.24	6.06	5.67	4.97	5.56	6.15	5.78	6.42	6.27	5.79	5.83	5.19
Dissolved Fe (micro-g/L)	128.88	130.48	159.06	129.98	103.69	63.78	83.95	136.36	106.67	152.73	103.47	117.52	116.72	84.69
[95% Lower Bound]	93.73	94.08	120.21	93.16	82.41	55.57	71.04	95.27	82.86	102.81	79.18	86.04	86.31	69.05
[95% Upper Bound]	164.04	166.87	197.90	166.79	124.98	71.99	96.86	177.45	130.48	202.66	127.75	149.00	147.14	100.32
Dissolved Mn (micro-g/L)	162.17	166.42	189.85	167.29	107.69	41.63	73.48	182.83	117.70	216.54	120.22	145.17	141.84	79.41
[95% Lower Bound]	140.24	143.73	165.62	144.33	94.41	36.51	65.43	157.20	102.85	185.40	105.08	125.54	122.87	69.66
[95% Upper Bound]	184.09	189.11	214.07	190.24	120.96	46.75	81.54	208.45	132.55	247.67	135.36	164.80	160.80	89.16
Dissolved Residue	373.4	381.9	429.4	384.5	235.8	102.1	187.3	422.3	274.7	498.6	344.2	333.5	327.1	172.0

(mg/L)	6	1	8	7	7	8	0	6	3	9	8	8	5	8
[95% Lower Bound]	303.89	309.90	352.63	311.73	193.73	85.91	161.73	341.06	227.60	399.92	296.23	271.28	266.96	141.11
[95% Upper Bound]	443.03	453.92	506.32	457.42	278.01	118.44	212.87	503.66	321.86	597.47	392.34	395.88	387.34	203.04
Dissolved NH4 (mg-N/L)	0.33	0.34	0.37	0.34	0.22	0.10	0.16	0.38	0.25	0.44	0.26	0.30	0.29	0.17
[95% Lower Bound]	0.23	0.24	0.26	0.24	0.16	0.08	0.12	0.26	0.18	0.30	0.19	0.21	0.21	0.13
[95% Upper Bound]	0.43	0.45	0.49	0.45	0.28	0.12	0.20	0.49	0.31	0.59	0.33	0.39	0.38	0.22
Dissolved NO2 (mg-N/L)	0.08	0.08	0.09	0.08	0.06	0.03	0.04	0.09	0.06	0.10	0.06	0.07	0.07	0.04
[95% Lower Bound]	0.04	0.04	0.05	0.04	0.03	0.02	0.03	0.05	0.04	0.05	0.04	0.04	0.04	0.03
[95% Upper Bound]	0.12	0.12	0.13	0.12	0.08	0.04	0.06	0.13	0.09	0.16	0.09	0.11	0.10	0.06
Dissolved NO2 + NO3 (mg-N/L)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00
[95% Lower Bound]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00
[95% Upper Bound]	0.83	0.85	0.86	0.87	0.01	0.00	0.29	1.08	0.44	1.41	1.77	0.65	0.64	0.00
Dissolved NH4 + Organic N (mg-N/L)	0.53	0.54	0.55	0.54	0.37	0.24	0.33	0.59	0.42	0.68	0.53	0.49	0.48	0.31
[95% Lower Bound]	0.33	0.33	0.34	0.34	0.25	0.19	0.26	0.36	0.29	0.39	0.39	0.31	0.31	0.22
[95% Upper Bound]	0.73	0.74	0.77	0.75	0.49	0.28	0.40	0.82	0.55	0.96	0.67	0.67	0.65	0.39

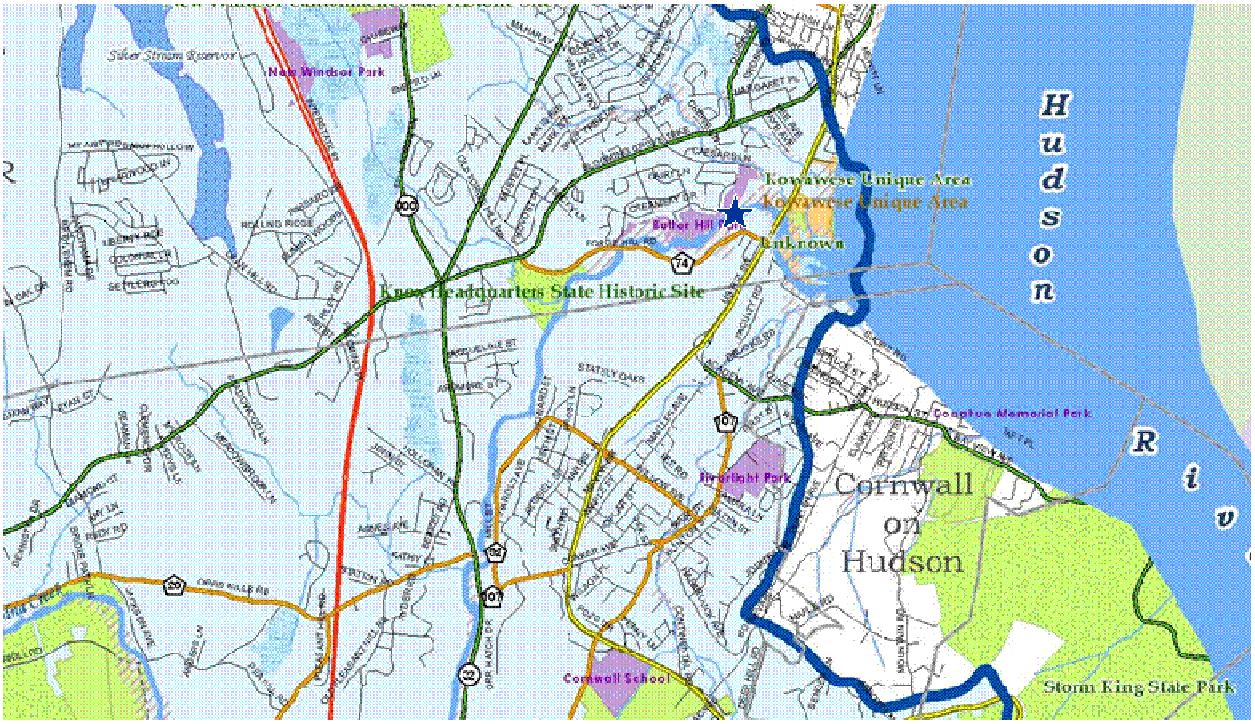
Table # 4: Results from Integrated Watershed Condition Model, Current Land Use Scenario.

Variable	M0	M2	SS	M3	Wod	MSB	P	M4	Sat	OK	BM	CR	See	TrtB
Total NH4 + Organic N (mg-N/L)	0.48	0.48	0.48	0.49	0.34	0.28	0.36	0.53	0.41	0.59	0.58	0.45	0.45	0.30
[95% Lower Bound]	0.44	0.45	0.43	0.46	0.30	0.22	0.32	0.50	0.37	0.55	0.55	0.42	0.41	0.25
[95% Upper Bound]	0.51	0.52	0.53	0.52	0.39	0.34	0.41	0.56	0.45	0.62	0.61	0.49	0.48	0.36
Dissolved PO4 (mg-P/L)	0.15	0.16	0.17	0.16	0.10	0.05	0.08	0.17	0.12	0.20	0.13	0.14	0.14	0.08
[95% Lower Bound]	0.09	0.09	0.10	0.09	0.06	0.03	0.06	0.10	0.07	0.11	0.09	0.08	0.08	0.05
[95% Upper Bound]	0.22	0.23	0.25	0.23	0.14	0.07	0.10	0.25	0.16	0.30	0.18	0.20	0.20	0.11
Dissolved P (mg-P/L)	0.19	0.19	0.21	0.19	0.12	0.06	0.10	0.21	0.14	0.25	0.16	0.17	0.17	0.10
[95% Lower Bound]	0.11	0.11	0.13	0.11	0.08	0.04	0.07	0.12	0.09	0.14	0.11	0.10	0.10	0.06
[95% Upper Bound]	0.26	0.27	0.29	0.27	0.17	0.08	0.12	0.30	0.19	0.35	0.21	0.24	0.23	0.13
Total P (mg-P/L)	0.14	0.14	0.14	0.14	0.09	0.06	0.09	0.15	0.11	0.17	0.16	0.12	0.12	0.07
[95% Lower Bound]	0.12	0.13	0.13	0.13	0.07	0.04	0.07	0.14	0.09	0.16	0.15	0.11	0.11	0.05
[95% Upper Bound]	0.15	0.15	0.15	0.15	0.10	0.08	0.10	0.16	0.12	0.19	0.17	0.14	0.13	0.09
Fish Diversity	1.58	1.58	1.45	1.59	1.59	1.68	1.64	1.59	1.61	1.58	1.66	1.61	1.61	1.64
[95% Lower Bound]	1.53	1.54	1.38	1.54	1.52	1.59	1.57	1.55	1.55	1.53	1.61	1.56	1.55	1.56
[95% Upper Bound]	1.63	1.63	1.52	1.64	1.66	1.77	1.71	1.64	1.66	1.62	1.70	1.66	1.66	1.72

Invertebrate Diversity	2.62	2.62	2.44	2.63	2.74	2.90	2.78	2.60	2.71	2.54	2.61	2.69	2.68	2.84
[95% Lower Bound]	2.56	2.56	2.36	2.57	2.66	2.80	2.69	2.55	2.64	2.49	2.56	2.62	2.62	2.75
[95% Upper Bound]	2.69	2.68	2.53	2.69	2.83	3.01	2.86	2.66	2.78	2.60	2.66	2.75	2.75	2.94
Fish IBI	38.66	38.69	37.49	38.76	38.62	39.12	38.74	38.83	38.69	38.83	38.78	38.88	38.82	38.99
[95% Lower Bound]	37.45	37.48	36.12	37.53	37.42	37.79	37.52	37.59	37.48	37.59	37.55	37.63	37.58	37.70
[95% Upper Bound]	39.86	39.91	38.86	39.98	39.82	40.45	39.96	40.07	39.91	40.07	40.02	40.14	40.06	40.28
Bird IBI	35.63	35.65	32.59	35.71	38.22	40.51	37.84	35.20	37.06	34.09	33.26	36.77	36.68	39.95
[95% Lower Bound]	34.48	34.52	29.54	34.62	36.30	38.29	36.28	34.05	35.69	32.63	31.54	35.65	35.54	37.84
[95% Upper Bound]	36.79	36.78	35.64	36.81	40.13	42.74	39.40	36.35	38.43	35.54	34.98	37.89	37.82	42.05

Stream Gage

Figure # 26: Map showing proposed location of stream gage along the Moodna Creek Outlet, ahead of tide within Butter Hill Park. Results from the gage will be used to calibrate and validate watershed models.



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