

Long Term Hydrologic Effects on Stream Health from Residential Development Patterns

Brendan C. Lockard

Thesis submitted to the Faculty of
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of:

Master of Science
In
Civil and Environmental Engineering

Thesis Committee:

Dr. David F. Kibler, Co-Chair
Dr. Vinod Lohani, Co-Chair
Dr. Tammy Newcomb

July 8, 2002
Blacksburg, Virginia

Long Term Hydrologic Effects on Stream Health from Residential Development Patterns

Brendan C. Lockard
(Abstract)

In this study eight residential development scenarios are created for the mostly undeveloped Back Creek Watershed outside Roanoke, Virginia. The development scenarios include low, medium (cluster), medium (conventional), and high density development with and without development restrictions. These scenarios represent a large range of development as the land use imperviousness varies from 1% for the baseline condition to 34% for the most developed scenario. The hydrologic model HSPF is used to generate overland and channel flows from 43 years of rainfall.

Hydrologic output from HSPF of the various landuse patterns from the eight scenarios are evaluated using Post Processor, a Visual Basic program. The results show that increased development causes a reduction in Back Creek's baseflow and an increase in the occurrence of both high and low flow extreme events. Overall, these results indicate that increased development will increase the variability of flowrate in Back Creek.

Stream health impacts from flow variability were also analyzed with the Post Processor. First, hydrologic statistical variables with ecological relationships were used to gage the level of stream health impacts from flow variability. The averaged stream health index for the development scenarios was found to closely follow the amount of development, represented by the percent of impervious landuse. Second, the amount of velocity, depth, and both depth and velocity habitat available for three habitat guild representative species was evaluated for each scenario. The results indicated that increased development would lead to a substantial reduction in available riffle species habitat (represented by the fantail darter) and a moderate reduction in run and pool species habitat (represented by the central stoneroller and smallmouth bass, respectively).

Overall, increased development has been found to have a negative impact on stream health. This impact should be considered in any future expansion of the Roanoke suburbs into this watershed.

Acknowledgements

I would like to thank my co-advisors, Drs. David Kibler and Vinod Lohani, and committee member Dr. Tammy Newcomb who have guided and encouraged me throughout the thesis process. I appreciate the insight, humor, and companionship of my fellow graduate students in the hydrosystems department.

I would also like to thank my fiancé, Helen Smartt, and my best friend Archie Freeman who have stood by me and encouraged me throughout my college career. I also owe a great debt of gratitude to my parents who have given me so much financial and emotional support that I could never repay them. Finally, I would like to thank God for his unfailing love and support for me.

Table of Contents

Abstract.....	ii
Acknowledgements.....	iii
Table of Contents.....	iv
List of Tables.....	vi
List of Figures.....	vii
Chapter 1. Introduction	1
1.1 Problem Statement.....	1
1.2 Objectives.....	2
Chapter 2. Literature Review	3
2.1 Introduction.....	3
2.2 Direct Linkages of Land Cover to Stream Health.....	3
2.3 Linkages of Land Cover to Hydrology.....	5
2.4 Linkages of Hydrology to Stream Health.....	5
2.5 Summary and Conclusions.....	11
Chapter 3. Hydrologic Effects of Residential Development Patterns	16
3.1 Introduction.....	16
3.2 Site and Model Selection.....	16
3.3 Model Data Calibration and Validation.....	17
3.4 Scenario Development.....	20
3.5 Extension of the Calibrated Model to 43 Years.....	22
3.6 Results and Discussion.....	27
3.7 Summary and Conclusions.....	32
Chapter 4. Linking Stream Health with Hydrologic Measures	34
4.1 Introduction.....	34
4.2 Methods.....	35
4.2.1 Flow Variability Metrics.....	35
4.2.2 Habitat Suitability Parameters.....	39
4.3 Results and Discussion.....	45

4.4 Summary and Conclusions.....	64
Chapter 5. Summary, Conclusions, and Recommendations.....	65
5.1 Summary.....	65
5.2 Contributions and Conclusions.....	67
5.3 Limitations and Recommendations.....	68
References.....	69
Vita.....	73
Appendix A UCI Files For HSPF.....	74
Appendix B Additional Calculation Methods.....	228
Appendix C Visual Basic Code for HSPF Post Processor.....	230
Appendix D Post Processor Inputs.....	354
Appendix E Graphical Post Processor Output.....	360
Appendix F Post Processor Scenario Output Files.....	418
Appendix G Additional Summary Output Plots.....	803
Appendix H Post Processor Tutorial.....	830

List of Tables

Table 2.1 List of hydrologic variables with linkages to stream health.....	12
Table 3.1 Descriptions and distribution of scenarios with restricted development.....	21
Table 3.2 Descriptions and distribution of scenarios with no restrictions on development.....	21
Table 3.3 Number of flood events in each baseline flood class for the various scenarios.....	28
Table 3.4 Summary of low flow values (cfs) for the scenarios.....	31
Table 4.1 Flow variability statistics and groupings.....	37
Table 4.2 Flow variables and index ranges of perceived stream health impact.....	38
Table 4.3 Habitat guild representative species and habitat ranges from Vadas (1994).....	42
Table 4.4 Flow variability measures for the base condition and eight scenarios near the outlet of Back Creek.....	46
Table 4.5 Flow variability indices for the base condition and eight scenarios near the outlet of Back Creek.....	47
Table 4.6 Flow variability indices by statistical group and impervious land use percent for the base condition and eight scenarios.....	47
Table 4.7 Acronyms and abbreviations for the scenarios used in this chapter.....	49
Table 4.8 Selected fish species and occurrence from fish sampling of Back Creek in 1998 and 1999 by Stancil (2000).....	54

List of Figures

Figure 3.1 Back Creek Watershed, Roanoke County, Virginia.....	17
Figure 3.2 Back Creek Watershed with gage, stream, subarea, and Theissen polygon locations.....	18
Figure 3.3 Example of calibration results for Water Year 1997 from Lohani et al., 2002.....	19
Figure 3.4 Validation results for Water Year 1998 from Lohani et al., 2002.....	19
Figure 3.5 Scenario Generator input screen for SubArea 1.....	22
Figure 3.6 Double mass curve of Roanoke long term precipitation (43 years) and MAP (4 years).....	23
Figure 3.7 Annual precipitation of the adjusted Roanoke Airport data.....	24
Figure 3.8 Method to separate storm events from baseflow.....	25
Figure 3.9 Sample numerical output from HSPF Post Processor for the high density full build out without restrictions scenario.....	26
Figure 3.10 Sample graphical output from HSPF Post Processor corresponding to Figure 3.9.....	27
Figure 3.11 Flood Frequency curves for the scenarios.....	28
Figure 3.12 Log base 10 of the number of flood events in each baseline flood class for the various scenarios.....	29
Figure 3.13 Log Pearson Type 3 density curves for the scenarios.....	30
Figure 3.14 Low flow values for 50 year return period for the scenarios.....	32
Figure 4.1 Sample graphical output from the Post Processor program showing flow variability for the high density with restrictions full build out scenario.....	39
Figure 4.2 General steps in velocity disaggregation method used in the Post Processor program.....	41
Figure 4.3 Sample HSI input file for the central stoneroller.....	43

Figure 4.4 Sample graphical area-velocity output for the high density without restrictions full build out scenario from the Post Processor program . The amount of area available (fraction of Available) and the amount of time each area is available (1 – Quantile) are shown for each reach and for the entire stream.....	44
Figure 4.5 Comparison of Averaged Variability Index and % Imperviousness.....	48
Figure 4.6 Central stoneroller plots showing amount of time habitat parameters are present at channel cross sections.....	51
Figure 4.7 Fantail darter plots showing amount of time habitat parameters are present at channel cross sections.....	52
Figure 4.8 Smallmouth bass plots showing amount of time habitat parameters are present at channel cross sections.....	53
Figure 4.9 Plots showing amount of time habitat parameters are present within the channel.....	58
Figure 4.10 Method for arriving at the fraction of time that fractional area occurs.....	59
Figure 4.11 Central stoneroller plots showing amount of time and area that habitat parameters are present within the channel.....	60
Figure 4.12 Fantail darter plots showing amount of time and area that habitat parameters are present within the channel.....	61
Figure 4.13 Smallmouth bass plots showing amount of time and area that habitat parameters are present within the channel.....	62