

NOTE TO USERS

Page(s) missing in number only; text follows. Page(s) were scanned as received.

4,33 and 67.

This reproduction is the best copy available.

UMI[®]



Université d'Ottawa - University of Ottawa



Université d'Ottawa - University of Ottawa

FACULTÉ DES ÉTUDES SUPÉRIEURES
ET POSTDOCTORALES

FACULTY OF GRADUATE AND
POSTDOCTORAL STUDIES

Geoffrey PARKER

AUTEUR DE LA THÈSE - AUTHOR OF THESIS

M. A. Sc. (Civil Engineering)

GRADE - DEGREE

Department of Civil Engineering

FACULTÉ, ÉCOLE, DÉPARTEMENT - FACULTY, SCHOOL, DEPARTMENT

TITRE DE LA THÈSE - TITLE OF THE THESIS

Modelling Best cement Practices in the South Nation watershed

R. Droste

DIRECTEUR DE LA THÈSE - THESIS SUPERVISOR

K. Kenny

CO-DIRECTEUR DE LA THÈSE - THESIS CO-SUPERVISOR

EXAMINATEURS DE LA THÈSE - THESIS EXAMINERS

R. Narbaitz

C. Rennie

P. Van Geel

J.-M. De Koninck, Ph.D.

LE DOYEN DE LA FACULTÉ DES ÉTUDES
SUPÉRIEURES ET POSTDOCTORALES

DEAN OF THE FACULTY OF GRADUATE
AND POSTDOCTORAL STUDIES

MODELING AGRICULTURAL BEST MANAGEMENT
PRACTICES IN THE SOUTH NATION WATERSHED

by

Geoff Parker

A thesis

submitted under the supervision of

Dr. Ronald L. Droste

and

Dr. Kevin J. Kennedy

in partial fulfillment of the
requirements for the degree of
Master of Applied Science
in
Civil Engineering

Department of Civil Engineering

University of Ottawa

Ottawa, Canada

K1N 6N5

May, 2004

© Geoff Parker, Ottawa, Canada, 2004



Library and
Archives Canada

Bibliothèque et
Archives Canada

Published Heritage
Branch

Direction du
Patrimoine de l'édition

395 Wellington Street
Ottawa ON K1A 0N4
Canada

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file *Votre référence*

ISBN: 0-494-01575-6

Our file *Notre référence*

ISBN: 0-494-01575-6

NOTICE:

The author has granted a non-exclusive license allowing Library and Archives Canada to reproduce, publish, archive, preserve, conserve, communicate to the public by telecommunication or on the Internet, loan, distribute and sell theses worldwide, for commercial or non-commercial purposes, in microform, paper, electronic and/or any other formats.

The author retains copyright ownership and moral rights in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

AVIS:

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque et Archives Canada de reproduire, publier, archiver, sauvegarder, conserver, transmettre au public par télécommunication ou par l'Internet, prêter, distribuer et vendre des thèses partout dans le monde, à des fins commerciales ou autres, sur support microforme, papier, électronique et/ou autres formats.

L'auteur conserve la propriété du droit d'auteur et des droits moraux qui protègent cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

In compliance with the Canadian Privacy Act some supporting forms may have been removed from this thesis.

Conformément à la loi canadienne sur la protection de la vie privée, quelques formulaires secondaires ont été enlevés de cette thèse.

While these forms may be included in the document page count, their removal does not represent any loss of content from the thesis.

Bien que ces formulaires aient inclus dans la pagination, il n'y aura aucun contenu manquant.


Canada

THE UNIVERSITY OF OTTAWA-FACULTY OF GRADUATE STUDIES

CERTIFICATE OF EXAMINATION

Examining Board

Advisor

The thesis by

Geoff Parker

entitled

Modeling Best Management Practices in the South Nation Watershed

is accepted in partial fulfillment

of the requirements of the degree of

Master of Applied Science (Environmental Engineering)

in the

Department of Civil Engineering

Date: _____

Chairperson of Examining Board

ACKNOWLEDGEMENTS

I would like to thank Dr Droste, for his efforts and advice in matters technical and otherwise, always delivered with tremendous patience, as well as Dr. Kennedy for his help and suggestions in reviewing the work. I would also like to thank my colleagues at the University of Ottawa, for their invaluable contributions, be it over coffee or email, at all hours of the day.

I am indebted to the friends and family members who inspired me with their own accomplishments, and were perceptive enough to drag me away from the modeling tasks whenever I began to lose touch with reality.

I would especially like to thank my family for their support over the years: my brother, who never takes me too seriously and whose sibling rivalry drives me to this day; my father, whose output as an author and an academic I can only hope to one day match, and my mother, who formed my perception in my youth, my mind as an adolescent and my consciousness as an adult.

ABSTRACT

The South Nation watershed consists of an area of roughly 3900 km² in Eastern Ontario which drains into the South Nation River. The South Nation River in turn drains into the Ottawa River at the watershed outlet. The watershed is vast and encompasses a wide variety of land uses, particularly with respect to agriculture and forestry. Previous studies indicate that the contribution of non-point sources (NPS) to nutrient loadings is both significant and poorly defined in the region. A recent multi-million dollar study of the water resources within Eastern Ontario illustrates the need for better models and decision support tools for watersheds of this nature.

The work presented here included the use of the continuous-simulation Annualized Agricultural Non Point Source (AnnAGNPS) 5.0 dynamic pollutant loading model, which was developed by the U.S Department of Agriculture (USDA).

In-stream water chemistry was also an important element of a meaningful analysis. The dynamic water-quality model CE-QUAL-RIV1 was selected due to its riverine nature, which is closely linked with the AnnAGNPS concept of a channel network.

Utilities were developed to enhance the input and output capabilities of both codes. The linked models were then calibrated to the available data, and a case matrix focused on predicting feasibility of best management practices (BMPs) within the context of climate change was constructed and simulated. The calibration process was done manually at first, based on the results of a sensitivity analysis conducted on the AnnAGNPS package as part of the work. Subsequently, the use of an automatic genetic-algorithm based approach (also developed as part of this work) was explored, which yielded an improvement in the calibrated model and was therefore used as a base case of the model.

The case matrix examined 4 individual BMPs, along with 4 combined BMP scenarios. The intensity of BMP usage in the watershed was considered, resulting in several runs for each of these 8 major management scenarios. The resulting case matrix consisted of 18 runs for a given climate scenario, and 6 individual climate scenarios were examined, resulting in a total of 108 runs.

The results of the work were then further analyzed through use of several ecological indices to determine the intensity (severity), duration and frequency (IDF) of violations to

species survivability which occurred within the stream network. In addition to these biologically based criteria, provincial standards were considered.

The results of the work suggest that BMPs alone are insufficient to reduce nutrient levels in the South Nation watershed to acceptable biological or legislative levels. The model results suggest that several BMPs, notably fertilizer management and filter strips, are quite effective at reducing nutrients entering the river system; however, the reductions do not suffice to bring the South Nation River in line with desired values as defined by the biological and provincial criteria.

TABLE OF CONTENTS

	PAGE
ACKNOWLEDGEMENTS	iii
ABSTRACT	iv
TABLE OF CONTENTS	vi
LIST OF TABLES	viii
LIST OF FIGURES	x
GLOSSARY	xii
CHAPTER 1 INTRODUCTION	1
1.1 PROBLEM DEFINITION	1
1.2 THESIS STRUCTURE	1
1.3 GOALS	2
CHAPTER 2 BACKGROUND KNOWLEDGE	3
2.1 SOUTH NATION WATERSHED	3
2.2 PRIOR WATERSHED-LEVEL STUDIES	4
2.3 MODEL REQUIREMENTS AND SELECTION	4
2.4 AGRICULTURAL PRACTICES	8
2.5 ECOLOGICAL INDICES AND WATER QUALITY	9
CHAPTER 3 REVIEW AND CONFIGURATION OF THE ANNAGNPS MODEL	9
3.1 ANNAGNPS MODEL REVIEW	9
3.2 ANNAGNPS STRUCTURE	10
3.3 ANNAGNPS: THEORY	11
3.4 RUN ANALYSIS AND CONFIGURATION TOOLS	16
3.5 ANNAGNPS SENSITIVITY ANALYSIS	17
CHAPTER 4 MODEL DEVELOPMENT	22
4.1 DATA SOURCES AND MODEL CONFIGURATION	22
4.2 MODEL CALIBRATION	30
4.3 MANAGEMENT PRACTICES SELECTION & SIMULATION	31
4.4 WATER QUALITY MODEL DATA	33
4.5 BIOLOGICAL STRESS INDICES	34
CHAPTER 5 SIMULATION	36
5.1 CASE MATRIX	36

5.2	PROCESSING REQUIREMENTS	37
5.3	RESULTS	37
CHAPTER 6 ANALYSIS OF RESULTS AND DISCUSSION		57
6.1	OVERVIEW	57
6.2	FEASIBILITY OF BMP IMPLEMENTATION	57
6.3	ECONOMICS	59
6.4	WATER QUALITY ANALYSIS	66
6.5	BIOLOGICAL INDICES	66
CHAPTER 7 CONCLUSIONS		70
7.1	GENERAL	70
7.2	RELATIVE EFFECTIVENESS OF BMPS	70
7.3	RECOMMENDATIONS	71
REFERENCES		73
APPENDIX A		77
APPENDIX B		79
APPENDIX C		98
APPENDIX D		144
APPENDIX E		157
APPENDIX F		162

LIST OF TABLES

TABLE	PAGE
3.1 PARAMETER CATEGORIES IN SIMPLE SENSITIVITY ANALYSIS	19
4.1 WEATHER SCENARIOS CONSIDERED	23
4.2 EFFECT OF CSA AND MSCL SELECTION ON WATERSHED DELINEATION	25
4.3 VEGETATIVE FILTER STRIP SEDIMENT REDUCTION RATES	32
4.4 WATER QUALITY CRITERIA USED DURING SIMULATION	33
4.5 HABITAT SUITABILITY STATES FOR FISH SPECIES IN THE SOUTH NATION WATERSHED	34
4.6 CRITERIA FOR GENERATING “STRESS CONDITION” SCORES	35
5.1 MANAGEMENT SCENARIOS MATRIX	36
5.2 GROUPED MANAGEMENT SCENARIO MATRIX	36
5.3 COMPARISON OF CLIMATE SCENARIO EFFECT ON FLOW AT OUTLET FOR BASE CASE	37
5.4 COMPARISON OF CLIMATE SCENARIO EFFECT ON NUTRIENTS AT OUTLET FOR BASE CASE	38
5.5 COMPARISON OF BMP EFFECTIVENESS FOR CLIMATE SCENARIO 1	39
5.6 COMPARISON OF BMP EFFECTIVENESS FOR CLIMATE SCENARIO 2	40
5.7 COMPARISON OF BMP EFFECTIVENESS FOR CLIMATE SCENARIO 3	40
5.8 COMPARISON OF BMP EFFECTIVENESS FOR CLIMATE SCENARIO 4	41
5.9 COMPARISON OF BMP EFFECTIVENESS FOR CLIMATE SCENARIO 5	41
5.10 COMPARISON OF BMP EFFECTIVENESS FOR CLIMATE SCENARIO 6	42
5.11 COMPARISON OF COMPOUND BMP EFFECTIVENESS FOR CLIMATE SCENARIO 1	43
5.12 COMPARISON OF COMPOUND BMP EFFECTIVENESS FOR CLIMATE SCENARIO 2	44
5.13 COMPARISON OF COMPOUND BMP EFFECTIVENESS FOR CLIMATE SCENARIO 3	44
5.14 COMPARISON OF COMPOUND BMP EFFECTIVENESS FOR CLIMATE SCENARIO 4	45
5.15 COMPARISON OF COMPOUND BMP EFFECTIVENESS FOR CLIMATE SCENARIO 5	45
5.16 COMPARISON OF COMPOUND BMP EFFECTIVENESS FOR CLIMATE SCENARIO 6	46
5.17 AVERAGED OVERALL BMP EFFECTIVENESS	49

5.18	AVERAGED OVERALL COMPOUND BMP EFFECTIVENESS	50
5.19	WATER QUALITY IMPROVEMENT WITH BMP IMPLEMENTATION FOR CLIMATE SCENARIO 1	51
5.20	WATER QUALITY IMPROVEMENT WITH BMP IMPLEMENTATION FOR CLIMATE SCENARIO 2	52
5.21	WATER QUALITY IMPROVEMENT WITH BMP IMPLEMENTATION FOR CLIMATE SCENARIO 3	52
5.22	WATER QUALITY IMPROVEMENT WITH BMP IMPLEMENTATION FOR CLIMATE SCENARIO 4	52
5.23	WATER QUALITY IMPROVEMENT WITH BMP IMPLEMENTATION FOR CLIMATE SCENARIO 5	53
5.24	WATER QUALITY IMPROVEMENT WITH BMP IMPLEMENTATION FOR CLIMATE SCENARIO 6	53
5.25	STRESS RATINGS FOR CLIMATE SCENARIO BASES CASES	54
5.26	EFFECT OF BMPS ON STRESSED STATES FOR CLIMATE SCENARIO 1	54
5.27	EFFECT OF BMPS ON STRESSED STATES FOR CLIMATE SCENARIO 2	54
5.28	EFFECT OF BMPS ON STRESSED STATES FOR CLIMATE SCENARIO 3	55
5.29	EFFECT OF BMPS ON STRESSED STATES FOR CLIMATE SCENARIO 4	55
5.30	EFFECT OF BMPS ON STRESSED STATES FOR CLIMATE SCENARIO 5	55
5.31	EFFECT OF BMPS ON STRESSED STATES FOR CLIMATE SCENARIO 6	56
5.32	AVERAGE EFFECTIVENESS OF BMPS ON STRESSED STATES FOR ALL CLIMATE SCENARIOS	56
6.1	ESTIMATED FEASIBILITY OF WATERSHED-LEVEL IMPLEMENTATION OF SIMULATED MANAGEMENT SCENARIOS	59
6.2	WATERSHED-LEVEL ECONOMICS OF FERTILIZER REDUCTION	61
6.3	TYPICAL EXPENSES IN FILTER STRIP IMPLEMENTATION	61
6.4	WATERSHED-LEVEL ECONOMICS OF A GRASS VFS SYSTEM	62
6.5	WATERSHED-LEVEL ECONOMICS OF A HAY VFS SYSTEM	62
6.6	WATERSHED-LEVEL ECONOMICS OF REDUCED STREAM ACCESS	63
6.7	COST OF CONVENTIONAL VS. NO TILLAGE MANAGEMENT SCENARIOS	64
6.8	WATERSHED-LEVEL ECONOMICS OF REDUCED TILLAGE	64
6.9	WATERSHED-LEVEL ECONOMICS OF SIMULATED SCENARIOS	65

LIST OF FIGURES

FIGURE	PAGE
1.1 MAP OF THE SOUTH NATION WATERSHED	3
3.1 INPUT-OUTPUT STRUCTURE OF THE ANNAGNPS COMPUTER CODE	10
3.2 ANNAGNPS WATERSHED CONCEPT	12
3.3 A TYPICAL ANNAGNPS WATERSHED DELINEATION	12
3.4 SCHEMATIC OF SIMPLE SCENARIO SETUP	18
4.1 TOTAL MONTHLY PRECIPITATION FOR CLIMATE SCENARIOS	23
4.2 AVERAGE MONTHLY TEMPERATURE FOR CLIMATE SCENARIOS	24
4.3 COMPUTED CELL SYSTEM FOR THE SOUTH NATION WATERSHED	25
4.4 COMPUTED REACH SYSTEM FOR THE SOUTH NATION WATERSHED	25
4.5 EOWRMS LAND USE DATA	26
4.6 MODEL LAND USE ALLOCATION	26
4.7 EOWRMS SOIL DATA	27
4.8 MODEL SOIL TYPE ALLOCATION	27
4.9 STREAM DATA STATIONS ON THE SOUTH NATION RIVER	29
4.10 EVOLUTIONARY PROCESSES OF A GENETIC ALGORITHM	31
5.1 RELATIVE LOADINGS WHEN COMPARED TO BASE FOR FAR	47
5.2 RELATIVE LOADINGS WHEN COMPARED TO BASE FOR VFS	47
5.3 RELATIVE LOADINGS WHEN COMPARED TO BASE FOR STREAM ACCESS	48
5.4 RELATIVE LOADINGS WHEN COMPARED TO BASE FOR REDUCED TILLAGE	48
5.5 AVERAGE OVERALL BMP EFFECTIVENESS VS. ESTIMATED COST	50
6.1 PERCENTILE DISTRIBUTION OF STRESS CONDITIONS FOR CLIMATE SCENARIO 1	67
6.2 PERCENTILE DISTRIBUTION OF STRESS CONDITIONS FOR CLIMATE SCENARIO 2	67
6.3 PERCENTILE DISTRIBUTION OF STRESS CONDITIONS FOR CLIMATE SCENARIO 3	68
6.4 PERCENTILE DISTRIBUTION OF STRESS CONDITIONS FOR CLIMATE SCENARIO 4	68
6.5 PERCENTILE DISTRIBUTION OF STRESS CONDITIONS FOR CLIMATE SCENARIO 5	69

6.6 PERCENTILE DISTRIBUTION OF STRESS CONDITIONS FOR CLIMATE
SCENARIO 6

GLOSSARY

Abbreviations:

AGNPS	Agricultural Non-Point Source model
ANNAGNPS	Annualized Agricultural Non-Point Source model
ANSWERS	Areal Non-point Source Watershed Environment Response Simulation model
BASINS	Better Assessment Science Integrating Point and Non-Point Sources model
BMPs	Best management practices
CCME	Canadian Council of Ministers of the Environment
CSA	Critical source area
CURA	Community-University Research Alliance
EI	Energy Intensity
EPA	United States Environmental Protection Agency
EOWRMS	Eastern Ontario Water Resources Management Study
FAR	Fertilizer application rate
HIS	Habitat Suitability Index
HSPF	Hydrologic Simulation Program-Fortran
MSCL	Minimum source channel length
NPS	Non-point sources
PL	Pollutant loading
RUSLE	Revised universal soil loss equation
SCS	Soil Conservation Service
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USGS	United States Geological Service
USLE	Universal soil loss equation
VFS	Vegetative filter strips
WASP	Water Quality Analysis Simulation Program

Symbols:

A	EI coefficient (-)
A_{NT}	Area to which reduced tillage is applied (km^2)
A_{vfs}	Total area of VFS (km^2)
B	EI exponent (-)
C	RUSLE C coefficient (-)
C_N	Cost per unit mass of N-fertilizer (\$/kg)
C_P	Cost per unit mass of P-fertilizer (\$/kg)
C_{sa}	Cost of reducing stream access (\$)
C_{vfs}	Total cost of VFS (\$)
CN	SCS curve number
D_a	Total drainage area (ha)
DEM	Digital Elevation Model
DO	Dissolved oxygen concentration (mg/L)
EI	Energy intensity (-)
FAR_N	Fertilizer application rate for nitrogen (kg/km^2)
FAR_P	Fertilizer application rate for phosphorus (kg/km^2)
I_a	Initial abstraction (mm)
K	RUSLE K coefficient (-)
K_d	Partition coefficient of chemical (Mg)
LS	RUSLE LS coefficient (-)
M_c	Total mass of chemical both attached and in solution (Mg)
M_s	Total mass of chemical in solution (Mg)
MSCL	Minimum Source Channel Length
$Num_{NoStress}$	Number of criteria in 'No Stress' condition
Num_{Severe}	Number of criteria in 'Severe' condition
$Num_{Stressed}$	Number of criteria in 'Stressed' condition
P	RUSLE P coefficient (-)
P_{24}	24-hour depth of precipitation (mm)
P_{FAR}	Percent reduction of fertilizer application rate
P_{sar}	Percent of stream access reduced
Q	Depth of runoff (mm)
Q_{24}	24-hour depth of runoff (mm)
QA	quality assurance (-)

Q_p	Peak discharge (m^3/s)
R	Precipitation or snowmelt depth (in.)
R_Q	Surface runoff depth from upstream drainage area (mm)
S	SCS retention variable (mm)
S_{FAR}	Total savings from reduced fertilizer application (\$)
S_{reach}	Stress score for a reach
Sav_{NT}	Net saving of reduced tillage per year (\$)
SDR	Sediment delivery ratio
t_b	Time to base (s)
T_c	Time of concentration (h)
$T_{c,cell}$	In-cell time of concentration (h)
$T_{cf,cell}$	Travel time of concentrated flow (h)
$T_{ov,cell}$	Travel time of overland flow (h)
$T_{scf,cell}$	Travel time of shallow concentrated flow (h)
TC_{fa}	Total cost of fertilizer application (\$/yr)
TN	Total nitrogen
TOC	Total organic carbon
$TP_{Erosion}$	Total potential erosion
TP	Total phosphorus
UC_{vfs}	Cost per unit area of VFS (\$/km ²)
WI	Water input to soil (mm)

CHAPTER 1

INTRODUCTION

1.1 PROBLEM DEFINITION

The South Nation watershed located in eastern Ontario is a vast agricultural watershed where surface river water quality is below environmental norms.

Runoff from agricultural land is major source of Non-Point Source (NPS) pollution, particularly in watersheds as extensively agricultural as the South Nation. Agricultural runoff carries sediment, nutrients, pesticides and organic carbon to the water channels, which accumulates in the river system and impairs water quality throughout the watershed. Nutrient loadings in particular are of concern, as the non-point source component of these pollutants is by far the largest contributor.

The Community-University Research Alliance (CURA) research group of the University of Ottawa was interested in developing a modeling toolset for the effect of varying management practices in the South Nation watershed, particularly with respect to agricultural runoff and NPSs. The group was investigating the effect on environmental system of climate change in Eastern Ontario and was interested in potential mitigation measures.

The problem posed by the CURA group can be paraphrased as follows: “What are the potential benefits of implementing agricultural best management practices (BMPs) throughout the South Nation watershed, and will they continue to be effective under changing climate conditions?”

This thesis attempts to address these issues, by assessing the relative effectiveness of a variety of management scenarios in the South Nation watershed for reduction of nutrient loadings and improvement of water quality.

1.2 THESIS ORGANIZATION

This thesis is organized into a presentation of the key tasks required for the study. The major steps can be outlined as follows:

- 1) Review literature on topics relevant to the study

A literature review was conducted on topics ranging from information specific to the South Nation watershed to computer model selection and BMPs.

- 2) Develop an understanding and appreciation of the Annualized Agricultural Non-Point Source (AnnAGNPS) model characteristics

The next task was to develop a familiarity with the AnnAGNPS modeling system, as well as a series of utilities and additions to aid in the execution of the modeling phase.

- 3) Develop a computer-based model to represent the South Nation watershed

A model, based on data from all pertinent data sources, was constructed to represent the physical characteristics of the watershed as well as the way in which resources are managed.

- 4) Conduct the simulations for a variety of scenarios

The model developed in step 3 was then adjusted to reflect potential modifications to the current management and or physical parameters of the watershed. The results were collected and summarized.

- 5) Review and analyze the results from the simulations

The results from step 4 were then subjected to a multi-faceted analysis to judge the significance of the simulation outcomes.

- 6) Recommend further action

Recommendations were then constructed based on the results and analyses from prior steps. The recommendations focused on consequences of the work, as well as areas where potential improvements may be made.

1.3 GOALS

The primary goal of this work is to provide a quantitative analysis of potential benefits of BMPs in the South Nation watershed, under varied climate scenarios.

This study provides a stepping stone towards a better understanding of management options and integrated planning strategies for pollutant loading of large agricultural watersheds in general, and the South Nation river system in particular.

CHAPTER 2

BACKGROUND KNOWLEDGE

2.1 SOUTH NATION WATERSHED

The South Nation watershed consists of an area of roughly 3900 km² in Eastern Ontario which drains into the South Nation River. The South Nation River in turn drains into the Ottawa River at the watershed outlet. The watershed has a population of roughly 125,000, is vast and encompasses a wide variety of land uses, particularly with respect to agriculture and forestry.

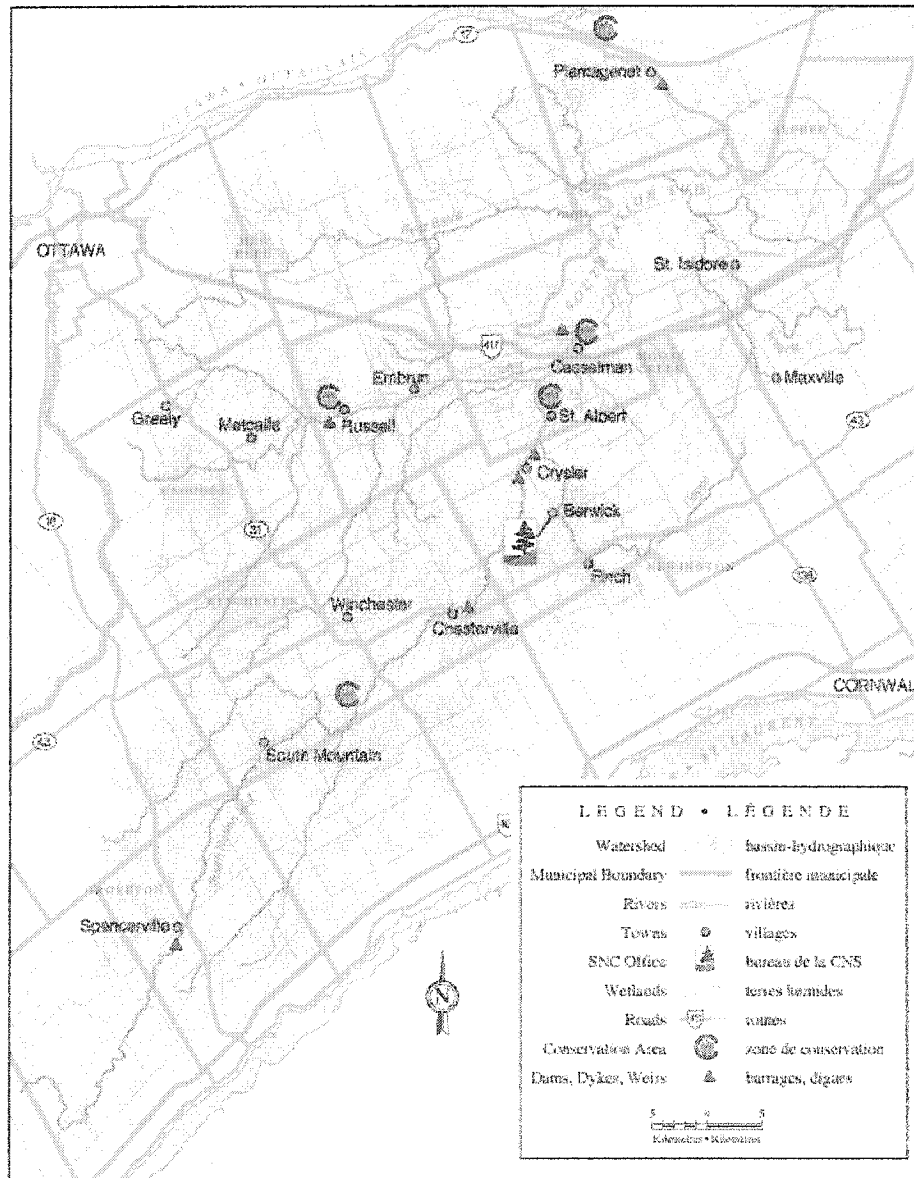


Figure 1.1: Map of the South Nation Watershed

Background research on the South Nation watershed and surrounding region was conducted on many levels, ranging from relatively technical matters such as soil surveys and stream station history, to broader socio-economic considerations as discussed in public consultation and action plans for the region.

Previous studies indicate that the contribution of NPS to nutrient loadings is both significant and poorly defined in the region (Gore and Storrie, 1993; Wilson, 2000). A recent multi-million dollar study of the water resources within Eastern Ontario illustrates the need for better models and decision support tools for watersheds of this nature (CH2M Hill, 2001). The work being conducted by the CURA workgroup at the University of Ottawa further supported the previous assertions.

2.2 PRIOR WATERSHED-LEVEL STUDIES

A review of previous watershed-levels studies, both within and outside the South Nation watershed, was also compiled, with a focus on BMPs and NPS management. This work was deemed necessary to provide an informed assessment of modeling and management decisions, as well as uncovering strengths and limitations of prior work. The selection of the AnnAGNPS model and CE-QUAL-RIV1 was closely linked to this portion of the work.

2.3 MODEL REQUIREMENTS AND SELECTION

2.3.1 WATERSHED-LEVEL MODEL REVIEW

Modeling the NPS pollutant loading in a watershed is not a simple matter, and requires a model of sufficient complexity to simulate an extensive variety of both local and wide-ranging processes (EPA, 2000).

Several computer codes possess the abilities sought for this work, although their relative strengths in specific components vary substantially (EPA, 1997; MPCA, 2000). SWAT, HSPF, ANSWERS and AnnAGNPS were all considered for the work at hand, but ultimately the AnnAGNPS model was selected for this study. The advantages and limitations of various models are discussed below.

2.3.1.1 HSPF

The Hydrologic Simulation Program-Fortran (HSPF) is a package developed by the U.S. Environmental Protection Agency (EPA) that simulates the hydrologic and pollutant loading processes on pervious and impervious land surfaces. It has many of the same capabilities as

AnnAGNPS, and is often used for similar land use-type analyses (Bicknell et al., 1997). The model has been incorporated into the EPA BASINS project (EPA, 2001).

HSPF has its origins as a water quality model. It is primarily designed to compute transport and fate of contaminants in concentrated flows in water bodies. Due to its inclusion in the BASINS project, it has a wide following; however, it is reported that HSPF may be less ideal for computing overland pollutant transport from non-point and upland areas than NPS-specific models. This is due to the 'lumped' nature of the model, which is considered less appropriate for overland flow than a 'distributed parameter' approach (Dilhala, 2001; SAP, 1998). Furthermore, the HSPF model is somewhat less capable than AnnAGNPS in simulating important agricultural components, such as crop management and growth, and does not include the agricultural practices database of the AGNPS packages (SAP, 1998). Finally, the BASINS project relies heavily on specialized data sets not readily available for regions outside the United States. HSPF was not selected for this study due to these reasons.

2.3.1.2 ANSWERS

ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation) is a continuous-simulation model that was developed in the late 1970s as a planning model to evaluate the effects of BMPs on surface runoff and sediment loss from agricultural watersheds (Dillaha et al., 2001).

The ANSWERS model is designed to simulate processes for watersheds between about 5 and 30 km², and relies on a cell size of 0.01 km² for computational accuracy (Dillaha et al., 2001). The model is therefore not suitable for the present study, as the South Nation watershed has an area of approximately 3900 km².

2.3.1.3 SWAT

SWAT is the Soil and Water Assessment Tool, also developed by the USDA-ARS. It has many of the same capabilities as the AnnAGNPS model, and shares the model's history with the the Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS) code which dates back to the late 1970s (Neitsch et al., 2002). The model is meant to be calibrated with stream gauge, sediment and nutrient samples for numerous sites throughout the watershed of interest.

The SWAT model was an attractive option; however, several factors shifted the selection towards the AnnAGNPS model. Firstly, the erosion processes and sediment types are not

handled as well in SWAT as they are in AnnAGNPS, nor is the model designed to handle branched systems (EPA, 1998). Secondly, the SWAT model is a not well suited logistically to a substantial case matrix, as individual runs require approximately 30 input files. Finally, the SWAT data requirements are far in excess of those available for a typical Canadian watershed.

2.3.1.4 AnnAGNPS

The Annualized Agricultural Non-Point Source pollutant loading model was developed by the U.S. Department of Agriculture, and is the successor to AGNPS 5.0 (USDA, 2001). The AGNPS model family is continuously undergoing revisions, with each module bringing new capabilities to the package (Bosh et al., 1998). The AnnAGNPS incarnation has several important additions, notably the ability to run continuous-simulation scenarios over extended periods of time. The model also includes a substantial database with values of parameters for agricultural applications and management scenarios.

AnnAGNPS is a comprehensive package with many desirable capabilities and assets, particularly when analyzing primarily agricultural watersheds, as is the case in this study. The watershed is divided into homogeneous drainage areas which are in turn connected by a dendritic reach system. Water and pollutant loadings from individual fields are simulated as runoff events from rainfall, snowmelt, and irrigation data. Soil loss is calculated based on the Revised Universal Soil Loss Equation (RUSLE). The model was selected as the pollutant loading model. The AnnAGNPS model unfortunately does not model groundwater flows, although a linkage to the Modular three-dimensional finite-difference ground-water Flow (MODFLOW) model is currently underway. Use of the code therefore required the addition of a 'baseflow' component in the model so as to approximate historical stream flows for input into the water chemistry model. The approach is described in more detail in Section 4.1.8 and Appendix C.

2.3.2. WATER CHEMISTRY MODEL REVIEW

The ability to model the surface water chemistry in a dynamic fashion was also a necessary feature of the work. Three freely available models were considered for the work: WASP, CE-QUAL-ICM, and CE-QUAL-RIV1. WASP and CE-QUAL-ICM are both dynamic water quality models with extensive simulation capabilities, but are not well suited to a high resolution study of a stream system as large as the South Nation. The riverine nature of CE-QUAL-RIV1 ultimately led to its selection for the in-stream water quality modeling.

2.3.2.1 WASP

The Water Quality Analysis Simulation Program (WASP) is a package developed by the U.S. EPA that can dynamically model contaminant fate and transport in surface waters. WASP is based on compartment modeling, and can be applied in one, two, or three dimensions. The size of the compartments is dependent on the spatial and temporal scale of the problem being analyzed. The eutrophication sub-model of the WASP package, EUTRO, can be operated at several levels of complexity and can simulate about 16 key water quality variables. The package includes a hydrodynamic code, DYNHYD, which can be used to drive the water quality simulation.

WASP6 was originally chosen as the water quality model to be used in the analysis. However, the input interface in the version tested was prone to software crashes and lost data, as well as being inconsistent. Additionally, the compartment modeling approach does not mesh particularly well with the stream network delineation as generated by AnnAGNPS. In light of these problems the WASP package was abandoned in favor of the CE-QUAL-RIV1 code.

2.3.2.2 CE-QUAL-ICM

CE-QUAL-ICM is a finite volume eutrophication model that can be used to simulate water quality processes in 1, 2 or 3 dimensions. The model, developed by the U.S. Army Corps of Engineers (USACE), is quite versatile and can be applied to a wide variety of surface water systems (Hall and Dortch, 1994).

The model tracks 22 state variables, including various forms of algae, nutrients, and sediment. However, the model does not compute hydrodynamics and is dependent on an external computer code to generate flows, volumes, and diffusion coefficients. Typically CH3D-WES is used (Cercio et al., 1994), which is not readily available to users outside the USACE.

Although the capabilities of the CE-QUAL-ICM model are impressive, they were deemed to exceed the requirements of the present study. Furthermore, given the absence of a readily available hydrodynamics model easily coupled with the CE-QUAL-ICM model, an additional coupling process would have been required.

2.3.2.3 CE-QUAL-RIV1

CE-QUAL-RIV1 is a computer model developed by the USACE that dynamically simulates flow and water quality in rivers. It is ideally suited to branched systems in which

variation along the axis of flow is important, but variation with depth and across the channel can be neglected, and it is suitable for highly unsteady flows (USAEWES, 1995).

The CE-QUAL-RIV1 river concept is an excellent match with the dendritic representation of the channel network in the AnnAGNPS model. The program simulates up to 12 constituents, and although the extent of variables simulated is not as extensive as the previously mentioned codes, model development is much simpler and the code can simulate all of the attributes required. The model was ultimately selected for its ease of use and compatibility with the AnnAGNPS watershed concept.

The model allows for variations in twelve state variables: temperature, carbonaceous biochemical oxygen demand (CBOD), organic nitrogen, ammonia nitrogen, nitrate + nitrite nitrogen, dissolved oxygen, organic phosphorus, dissolved phosphates, algae, dissolved iron, dissolved manganese, and coliform bacteria. Rate constants for the key processes considered in the model are presented in Table C.4 of Appendix C. A timestep of 10 seconds was used to calculate species in the river system.

2.4 AGRICULTURAL PRACTICES

A literature review on guidelines for agriculture and forestry management practices was also conducted, and included the consultation of various state, provincial and national-level manuals and recommendations.

The first part of the review focused on developing an understanding of agricultural systems and practices, as well as collecting information on BMPs and their applications to date. The second part of the examination focused extensively on the state of the knowledge surrounding the specific management practices considered in the current study, and on some of the performance, economic and management issues which are discussed in subsequent sections of this paper.

Management practices designed to minimize soil and nutrient loss from agricultural fields have been studied for quite some time. While originally these practices were considered primarily to prevent loss of agricultural productivity due to reduced soil and nutrient levels, the focus in recent years has been to reduce agricultural runoff and NPS pollutant loading of water bodies. There is a large group of BMPs available, but they are not applicable to all systems. The most commonly in use for crops are conservation tillage, contouring, terracing, vegetative strips along waterways, fertilizer management, impoundments and sedimentation basins. Reducing

livestock access to streams and feedlot runoff management are also important management practices.

Agriculture BMPs are often divided into two categories: 'reactive' and 'proactive' measures. Reactive measures are those that attempt to prevent transport of the nutrients and soil particles to the water body, while proactive methods attempt to reduce the amount of available nutrients. Filter strips, conservation tillage and stream access controls are therefore reactive measures while nutrient management plans are considered to be a proactive approach. Reactive measures have historically been much more widely used, but are generally considered less sound than proactive approaches which limit nutrient buildup on the field and in the system. A brief listing of the relative effectiveness of common agricultural BMPs for typical applications is presented in Table E-1 of Appendix E.

2.5 ECOLOGICAL INDICES AND SPECIES SURVIVABILITY

A review of approaches for defining ecological and species-based water quality criteria was also conducted, with the aim of providing a more meaningful analysis of stream conditions than could be attained using existing surface water quality criteria.

Studies addressing the survivability and habitat suitability of fish species native to the South Nation watershed were gathered as well as recommendations on deriving biologically driven site-specific criteria (McMahon et al., 1984; Edwards et al., 1982; Trial et al., 1983; and others).

CHAPTER 3

REVIEW AND CONFIGURATION OF THE ANNAGNPS MODEL

3.1 ANNAGNPS MODEL REVIEW

During the model-specific literature review phase, certain deficiencies in the AnnAGNPS literature were evident. While some technical documentation is distributed with the model, it is by no means all-encompassing, and no substantial sensitivity analysis or calibration protocol was found in the existing literature, despite previous requests for such work (Bosh et al., 1998). The nature of the AnnAGNPS code is inherently complex (Binger and Theurer, 2001), and intelligent use and interpretation of the model requires these types of tools.

3.2 ANNAGNPS STRUCTURE

3.2.1 MODEL STRUCTURE

The input-output structure of the AnnAGNPS system is shown in Figure 3.1. The package consists of several helper and preprocessing programs.

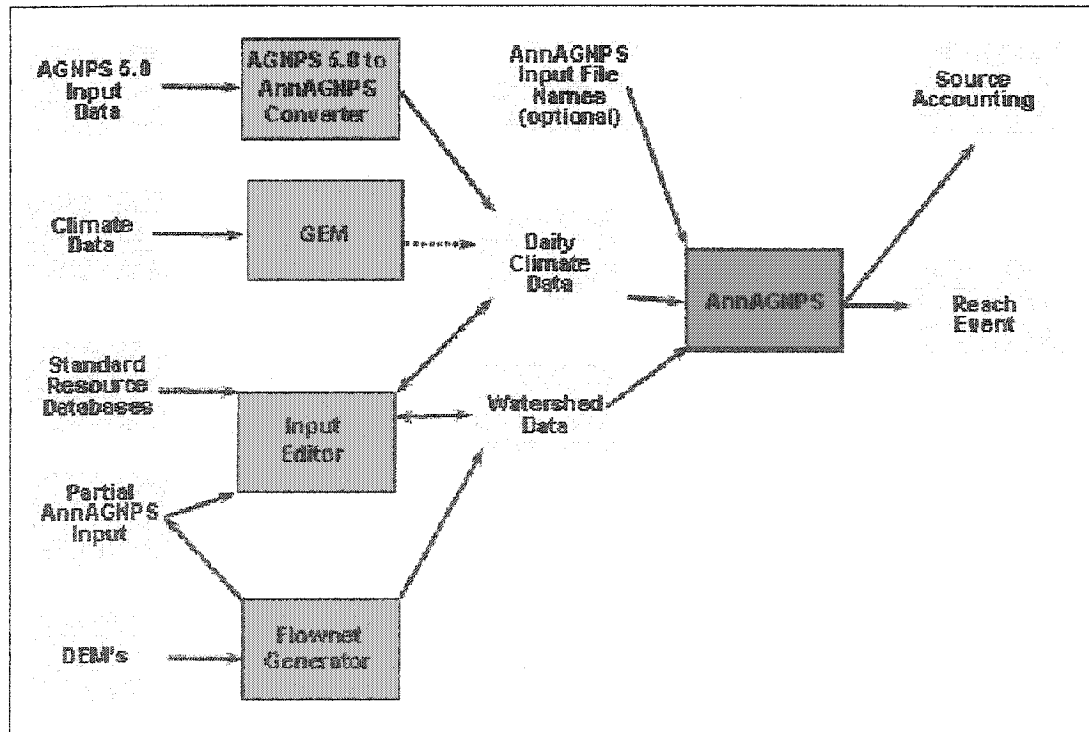


Figure 3.1: Input-Output Structure of the AnnAGNPS Computer Code (adapted from Binger and Theurer, 2001)

The core of the package is the AnnAGNPS program, which is the pollutant loading model. The model requires climate data, physical watershed parameters, as well as land use, soil and management data.

The climate data can either be simulated using the GEM utility, or can be generated manually using historical data. The climate file consists of a series of temperatures, precipitation and similar data listed for each day to be simulated. The climate data varies on a daily basis throughout the simulation period.

The physical watershed parameters delineate the watershed and define cell boundaries, the reach network, slope direction and other information regarding the physical characteristics of the watershed area required by the pollutant loading model. The TOPAGNPS/AGFLOW (also referred to as TOPAZ) preprocessor tools typically generate this information from topographic data files. These parameters are held constant throughout the simulation period.

Land use, soil and management data are typically specified manually for each cell in the AnnAGNPS input editor, or can be edited manually in the raw AnnAGNPS input file. The information includes crop characteristics, soil types, management practices, and so is specific to each location; however, the AnnAGNPS package includes some data which aid in setting initial values.

3.2.2 RESULTS

The output files generated by the pollutant loading model include the loading of water, sediment, nutrients (nitrogen, organic carbon and phosphorus), on a daily event basis at specified locations throughout the watershed. Event days are those days in which runoff from precipitation, snowmelt, irrigation or any combination of the three occurs in the watershed. Monthly and yearly summaries of component loadings may also be generated.

3.3 ANNAGNPS: THEORY

3.3.1 ANNAGNPS WATERSHED CONCEPT

AnnAGNPS represents a watershed as amorphous areas, referred to as "cells" which are homogeneous in soil type, land use and land management. In addition to these 3 basic properties, feedlots, point sources and gullies can also be allocated to each cell.

AnnAGNPS computes the runoff, sediment, and chemicals leaving the cells and routes them through a network of "reaches" which collectively represent the river system in the

watershed. A representation of the basic concepts is illustrated in Figure 3.2. Figure 3.3 shows a typical application of the AnnAGNPS model, where dozens of cells and reaches come together to represent the land area and river system of a real-world watershed.

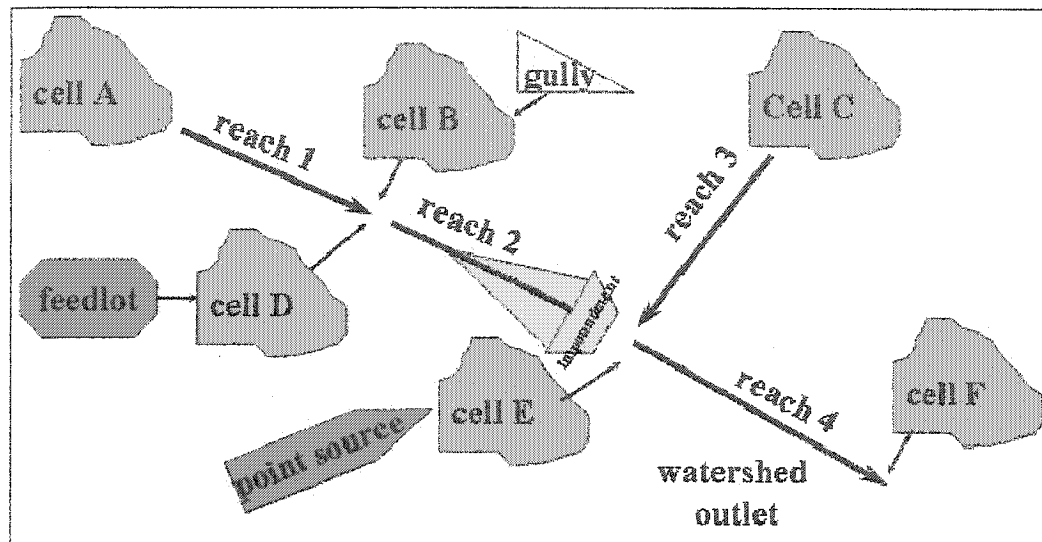


Figure 3.2: AnnAGNPS watershed concept (adapted from Binger and Theurer, 2001)

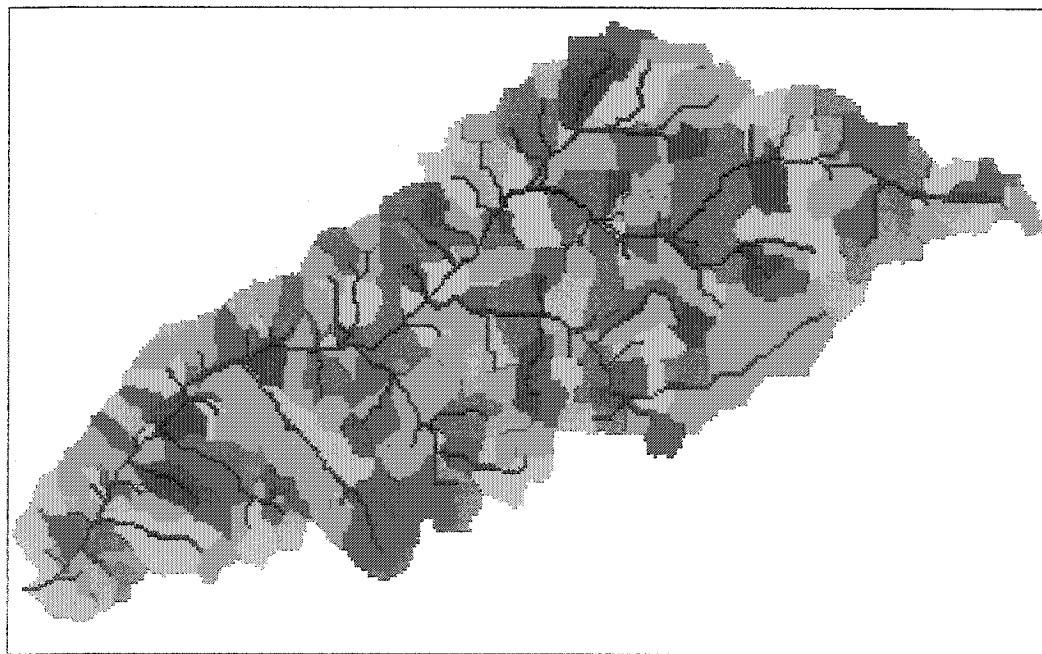


Figure 3.3: A typical AnnAGNPS watershed delineation (adapted from Bosch et al., 1998)

3.3.2 MAJOR PROCESSES

Surface runoff

The Soil Conservation Service (SCS) curve number technique is used within AnnAGNPS to determine the surface runoff from a cell. The model first calculates parameters that will remain constant over the simulation period, such as soil porosity and hydraulic properties.

The average curve number, ($CN_{avg,cell}$) can change both gradually over the course of a simulation (during a crop growth phase for instance), but also suddenly (after a crop harvest or similar operations). SCS curve numbers for each field are also calculated for wet ($CN_{wet,cell}$) and dry ($CN_{dry,cell}$) conditions as a function of the current curve number for average conditions. The actual curve number (CN_{cell}) for each area then is allowed to vary throughout the simulation depending on soil water content.

Surface runoff for each cell is calculated at each time step through use of the retention variable, S:

$$S = 254 \cdot \left(\frac{100}{CN} - 1 \right) \quad (3-1)$$

where S = SCS retention variable (mm)

CN = SCS curve number (-)

Once S has been determined, the surface runoff is then computed by:

$$Q = \frac{(WI - 0.2 \cdot S)^2}{(WI + 0.8 \cdot S)} \quad (3-2)$$

where Q = runoff (mm)

WI = Water input to soil (mm)

Equation 3-2 applies so long as WI is larger than 0.2S; otherwise, Q is simply set to a value of 0.

Channel Hydrology

The in-cell time of concentration, along with the travel time for each reach, are used to calculate the channel hydrology. The time of concentration for each cell is calculated in AnnAGNPS according to Equation 3-3:

$$T_{c,cell} = T_{ov,cell} + T_{scf,cell} + T_{cf,cell} \quad (3-3)$$

where $T_{c,cell}$ = In-cell time of concentration
 $T_{ov,cell}$ = Travel time of overland flow
 $T_{scf,cell}$ = Travel time of shallow concentrated flow
 $T_{cf,cell}$ = Travel time of concentrated flow

AnnAGNPS assumes a triangular shaped hydrograph over the course of each day. The peak discharge for each cell is calculated with the TR-55 approach. First, the initial abstraction is calculated according to Equation 3-4,

$$I_a = (P_{24} + 2 \cdot Q_{24}) - \sqrt{(5 \cdot Q_{24} \cdot P_{24} + 4 \cdot Q_{24}^2)} \quad (3-4)$$

where I_a = Initial abstraction (mm)
 P_{24} = 24-hour precipitation (mm)
 Q_{24} = 24-hour runoff (mm)

Once I_a has been determined, the I_a/P_{24} ratio is computed and peak discharge for runoff event is calculated according to:

$$Q_p = 2.7778 \cdot 10^{-3} \cdot P_{24} \cdot D_a \cdot \left[\frac{a + (c \cdot T_c) + (e \cdot T_c^2)}{1 + (b \cdot T_c) + (d \cdot T_c^2) + (f \cdot T_c^3)} \right] \quad (3-5)$$

where Q_p = Peak discharge (m^3/s)
 P_{24} = 24-hour precipitation (mm)
 D_a = Total drainage area (ha)
 T_c = Time of concentration of drainage area (h)

a, b, c, d, e and f are the unit peak discharge regression coefficients for a given I_a/P_{24} and rainfall distribution.

The duration of a surface runoff event, or the time to base, is calculated according to Equation 3-6,

$$t_b = 20 \cdot (R_Q \cdot \frac{D_a}{Q_p}) \quad (3-6)$$

where Q_p = Peak discharge (m^3/s)
 D_a = Total drainage area (ha)
 R_Q = Surface runoff depth from upstream drainage area (mm)
 t_b = Time to base (s)

Sediment

AnnAGNPS uses the RUSLE (Renard et al., 1997) to predict soil erosion from storm events throughout the watershed. The RUSLE code is incorporated from version 1.5 of the RUSLE program, and has been implemented in a somewhat modified manner to improve its integration in the AnnAGNPS model (Binger et al., 2001).

Erosion within a cell is calculated using the energy-intensity (EI) concept, calculated according to:

$$EI = \frac{A \cdot e^{(2.119 \cdot \log(R) \cdot e^{(0.0086 \cdot \log(24))})}}{e^{(B \cdot \log(24))}} \quad (3-7)$$

where EI = Energy Intensity (-)
 R = Precipitation or Snowmelt (in)
 A = EI coefficient (-)
 B = EI exponent (-)

The values of A and B in Equation 3-7 are looked up from a table based on the rainfall distribution simulated.

The total potential erosion is then calculated for each cell as

$$TP_{Erosion} = EI \cdot LS \cdot K \cdot C \cdot P \cdot SDR \quad (3-8)$$

where $TP_{Erosion}$ = Total Potential Erosion (g)
 EI = Energy Intensity coefficient (-)
 LS = RUSLE LS coefficient (-)
 K = RUSLE K coefficient (-)
 C = RUSLE C coefficient (-)
 P = RUSLE P coefficient (-)
 SDR = Sediment delivery ratio (-)

The LS, K, C and P factors are calculated using a variety of methods, depending on the land use and management type scenario, as outlined in Binger et al. (2001). The sediment delivery ratio for the cell is then calculated and the sediment load exiting the cell computed.

Chemical Routing

AnnAGNPS considers the transport of three nutrients (nitrogen, phosphorus and organic carbon) in two forms: dissolved, and attached. Partitioning between chemical forms is calculated according to

$$M_s = \frac{M_c}{1 + K_d} \quad (3-9)$$

where M_s = Total mass of chemical in solution (Mg)
 M_c = Total mass of chemical both attached and in solution (Mg)
 K_d = partition coefficient of chemical (Mg)

3.4 RUN ANALYSIS AND CONFIGURATION TOOLS

As the study progressed and familiarity with the AnnAGNPS model grew, it became clear that the AnnAGNPS package as supplied was insufficiently automated for the type of analysis desired for this study. A sequence of helper tools and protocols were assembled to aid in the logistics of managing hundreds of runs. These tools ranged from simple batch files and Excel macros to involved Visual Basic programs and run management systems.

One of the more important tools developed was an automated cell-property allocation tool, that uses management and soil type information from a variety of sources and formats. Without this tool it would have been impractical to run a scenario with thousands of cells to be defined using the existing AnnAGNPS utilities. The tool was written in Visual Basic and interfaces directly to native AnnAGNPS file types. At its simplest, the developed program reads spatial soil type and land use data from geospatial data in bitmap or similar format, and decides which are most characteristic of a given watershed subdivision, based on relative area. In the event of a tie between two or more land or soil types, several options are available. The first is for the program to allow for composite land use and soil types for situations where a cell is not clearly of one land use type or another.

The second option is for the program to record all ties, along with the total soil and land use fractions throughout the watershed and then decide which of the tied parameters should win so as to most closely match the watershed makeup. However, given cell size of sufficient resolution, these conflicts can be largely averted, as was the case in this study. The latter approach was therefore used, and land use for each cell was defined as being the land use type which occupied the largest fraction of the cell according to the geospatial data. The validity of

this assumption was tested by setting a condition in the land use allocation parser to flag situations that may be problematic. A small number of cells (around 50, or roughly 2% of the cells) presented a situation where the dominant land type comprised slightly less than 50% of the total cell area. These cells were nonetheless considered to be of the dominant soil or land use type. The inclusion of database values specific to a given watershed is a capability of some value which has further been built into the design.

Also important for purposes of understanding and verifying results quickly and consistently was the creation of standard post-processing and summary data tools. This step was done using a combination of Visual Basic and Excel systems to parse, verify and display the results from each scenario or group of scenarios. The results were first compiled and summarized into daily, monthly and yearly loadings for each run, and then further grouped by both climate and management scenarios. The resulting sheets allowed for side-by-side comparisons of the results, ranging from very similar runs to largely unrelated scenarios.

A second, higher level of management utilities was also generated to aid in the configuration and control of the overall study. Standard practices were laid out and followed for each major step, and quality control phases followed the completion of each step. The quality assurance and control process is described in greater detail in Appendix A.

Additional significant tools were devised during the process of this study. Sections 3.5 and 4.2 detail two additional systems created to aid in the model setup and calibration stages, respectively.

3.5 ANNAGNPS SENSITIVITY ANALYSIS

An extensive sensitivity analysis was conducted as part of the model preparation phase of the study. This work was deemed necessary in order to fill gaps in the model documentation on the code behavior under varying conditions. An artificially simplified scenario was first examined to determine the effect and relative importance of a wide range of input parameters. A much more complex "real-world" scenario with multiple land use and soil types was then constructed, and again subjected to a sensitivity analysis, building on the previous work. The combined body of work produced a more detailed understanding of the AnnAGNPS model behavior, and revealed trends, anomalies, and threshold effects amongst others. Another important result of this work was the development of a protocol for model calibration and calibration heuristics useful to anyone employing the AnnAGNPS model.

3.5.1 SIMPLE SCENARIO

The base case was constructed to provide a scenario based on reasonable values from which a sensitivity analysis could be based. Although inspired from an example scenario included with the AnnAGNPS package, the scenario was somewhat modified to facilitate analysis of the effect of individual changes on the system behavior. A schematic illustrating the synthetic cell-reach system is shown in Figure 3.4.

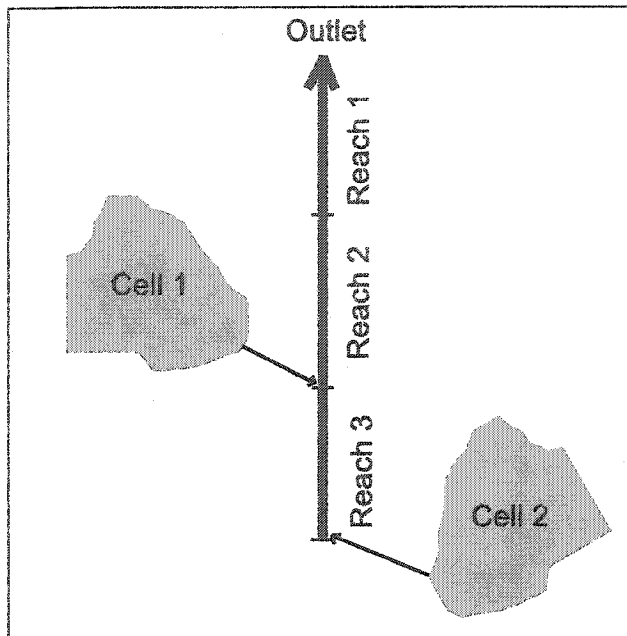


Figure 3.4: Schematic of simple scenario setup

The insertion point of the cell runoffs into distinct reaches allows for separate analysis of individual effects, as well as a net analysis at the outlet. In the base case, Cell 1 covers an area of 0.1335 km² of pasture, while Cell 2 covers an area of 0.1072 km² of cropland.

The base case climate scenario was generated using the GEM program as recommended by the user manual (USDA, 2001a), at a latitude of 45.0 and a longitude of -75.0, corresponding to Eastern Ontario. Additionally, climate scenarios considered for this study (see Section 4.1.1) were all simulated across the simple analysis case matrix.

A case matrix was constructed based on more than 16 categories of parameters and over a hundred individual parameters. Each parameter was adjusted to low values (typically 25% of the base case value) as well as high values (typically 175% of base), within the range of acceptable

values for the model input. A list of the main parameter categories is presented in Table 3.1. The case matrix examined under the model sensitivity analysis is presented in Appendix D.

Table 3.1: Parameter Categories in Simple Sensitivity Analysis

Parameters Category	Runs	Number of Runs	Representative parameter types tested
BASE CASE	Run001	1	Not applicable
Weather Scenarios	Run002-Run008	7	Daily Precipitation, Temperature
Cell Data	Run009-Run038	30	Cell Area, Elevation, Time of concentration
Reach Data	Run039-Run055	17	Reach length, slope, Manning's n
Field Data	Run056-Run062	7	Percent Rock Cover, Interill Erosion code
Reach Nutrient Half-Life Data	Run063-Run068	6	Nitrogen half-life, Phosphorus half-life
Soil Data	Run069-Run117	49	Clay Ratio, pH, Base saturation Field capacity
Runoff Curve Number	Run118-Run122	5	Runoff Curve Number
Land use Reference Data	Run123-Run130	8	Annual Root Mass, Surface Residue Cover
Operations Data	Run131-Run132	2	Operations Date
Operations Reference Data	Run133-Run144	12	Initial Random Roughness, Final Random Roughness, Tillage Depth
Crop Data	Run145-Run171	27	Units Harvested, N Uptake, P Uptake
Simulation Period Data	Run172-Run193	22	Rainfall Dist. Code, 10 yr EI
Fertilizer Application Data	Run194-Run197	4	Fertilizer Rate, Fertilizer Mixing Code
Fertilizer Reference Data	Run198-Run203	6	Inorganic N, Inorganic P, Organic Matter
Feedlot Data	Run204-Run242	39	Open Area, Feedlot Max N, Feedlot Max P
Feedlot Management Data	Run243-Run244	2	Pack Remove Ratio

3.5.2 COMPLEX SCENARIO

The complex scenario sensitivity analysis was conducted on an early version of the South Nation watershed model. The model tested had not yet been highly calibrated and was for the most part based on default values of the model, and management was greatly simplified (one operation per cell) however the physical delineation and characteristics of the simulated watershed were identical to those used in the later versions. Key parameters from the simple analysis were again simulated on the more complex model and examined for sensitivity, as well

as for additional emergent behaviors at the new scale. The conclusions from this stage supplemented the prior work.

3.5.3 RESULTS

The sensitivity analysis conducted on both the simple and complex scenarios yielded several results which were valuable during the model setup and configuration phase.

The first result was a substantiation of the actual behavior of the AnnAGNPS model, as opposed to the theoretical behavior. The AnnAGNPS model exhibited several unintuitive behaviors at both the 'simple' and 'complex' scales under these analyses, and this information is always valuable to modelers, particularly when documentation fails and the source of the model being used is not readily available. Tables D.14 and D.15 in Section D.2 of Appendix D list 'primary' and 'secondary' sensitive parameters. The 'primary' values are those that were very sensitive (a change of 50% in the inputs resulted in a change of approximately the same magnitude in the results) in both the simple and complex scenarios, while the 'secondary' parameters were somewhat less sensitive (a change of 50% in the inputs resulted in a change of approximately half of that magnitude in the results), and more significant in the 'simple' (single-land use) scenario.

Some of the key points from the work were:

- The model allows for four hydrologic soil groups, and all categories of results are quite sensitive to the curve number, so the runoff curve numbers must be set appropriately.
- Field data parameters are sensitive, and affect primarily the attached forms of nitrogen and organic carbon, in a roughly equivalent manner.
- Some of the soil parameters (e.g., runoff curve number, soil group) are sensitive, and affect broad categories of constituent loadings.
- Some of the crop parameters (e.g., senescence, crop residue) are sensitive, and generally affect nutrient loadings only, particularly of the attached forms.
- Some of the operation parameters (e.g., residue, dates) are sensitive, and affect mostly attached forms of nutrients.
- Setting the appropriate SCS storm type is the most important consideration under the Simulation Data category.

-Fertilizer parameter settings are important, and primarily affect loadings of the soluble form of nitrogen.

-Soluble organic carbon loading rates are primarily related to feedlot cells and the parameters pertaining to those cells.

-Attached organic carbon is linked to the organic matter ratio in the soil.

-Attached forms of organic carbon and nitrogen behave very similarly in several categories of parameters and are generally the nutrients most sensitive to changes.

-Attached and soluble forms of phosphorus often mimic the sensitivity of the attached and soluble forms of nitrogen, but they are generally an order of magnitude less sensitive.

The second result generated from this work was a system of calibration heuristics based on the observed sensitivities and correlations between variables, shown in Section D.3 of Appendix D. This result is of substantial use to those attempting to calibrate a model to physical data manually, and was also important in the development of the calibration tool presented in Section 4.2. To calibrate the water loadings requires adjustments of the hydrologic soil groups, runoff curve numbers and similar parameters. Since the phosphorus loadings are generally much less sensitive than the organic carbon or nitrogen loadings, it may be advantageous to first calibrate the P results alone. If the loadings of the soluble form of organic carbon are not adequate, this would indicate that a change in feedlot parameters or cell parameters for feedlot cells is required. Additionally, the threshold behavior of some data, for instance canopy cover, nutrient production, and degree of consolidation can at times simplify the task of parameter adjustment.

CHAPTER 4

MODEL DEVELOPMENT

4.1 DATA SOURCES AND MODEL CONFIGURATION

The South Nation watershed consists of an area of roughly 3900 km² in Eastern Ontario which drains into the South Nation River. The South Nation River in turn drains into the Ottawa River at the watershed outlet.

In 2001, the Eastern Ontario Water Resources Management Study (EOWRMS) was completed. The report covered a large portion of Eastern Ontario, and the study area included the South Nation watershed. One of the main objectives of the study was to develop a database on parameters of interest to water resource planners (CH2M Hill, 2001). The study was therefore an important source of information for the present paper, and was used as extensively as possible.

Additional sources of information were gathered from previous studies (e.g., Matthews et al., 1954; Wicklund et al., 1962; Wilson 2000) of the watershed area and from the literature. A detailed listing of metadata and sources is in Appendix B.

4.1.1 CLIMATE SCENARIOS

It is desirable, when conducting a watershed study of this nature, to examine the behavior of the system when subjected to various weather patterns. Climate data were assembled and selected, with aid from the University of Ottawa CURA Climate Change workgroup.

The AnnAGNPS package includes a synthetic weather generator, GEM that generates data based on historical values for nearby weather stations (USDA, 2001a). A synthetic 'typical' year generated by GEM for the site coordinates was included in the analysis for further comparison. The data used were all available in daily time steps, as required by the AnnAGNPS code. Table 4.1 contains a monthly summary of the scenarios considered, while Figures 4.2 and 4.3 show summaries of the precipitation and temperature conditions over the course of a year for each scenario.

Table 4.1: Weather Scenarios Considered

Weather Scenario	Description	Data Type
1	Average (Synthetic)	GEM
2	Average	Historical (1909)
3	Warm Wet Year	Historical (1966)
4	Warm Dry Year	Historical (1973)
5	Cold Wet Year	Historical ¹
6	Cold Dry Year	Historical ¹

¹ These scenarios are based on an amalgamation of historical data.

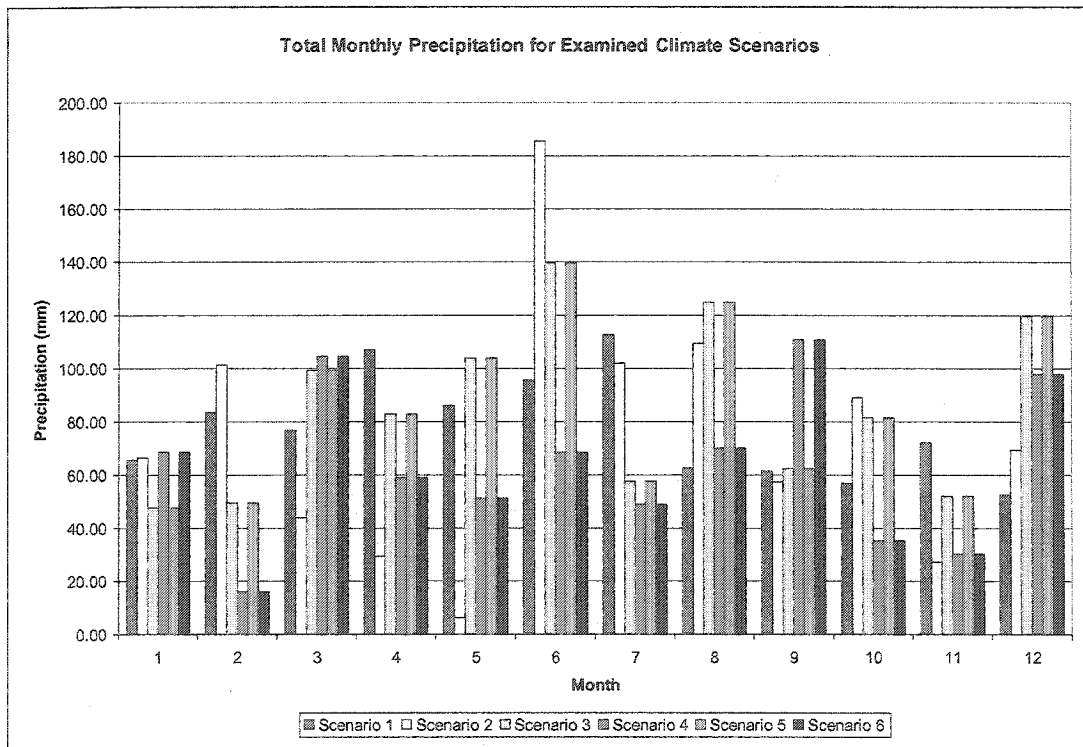


Figure 4.1: Total Monthly Precipitation for Climate Scenarios

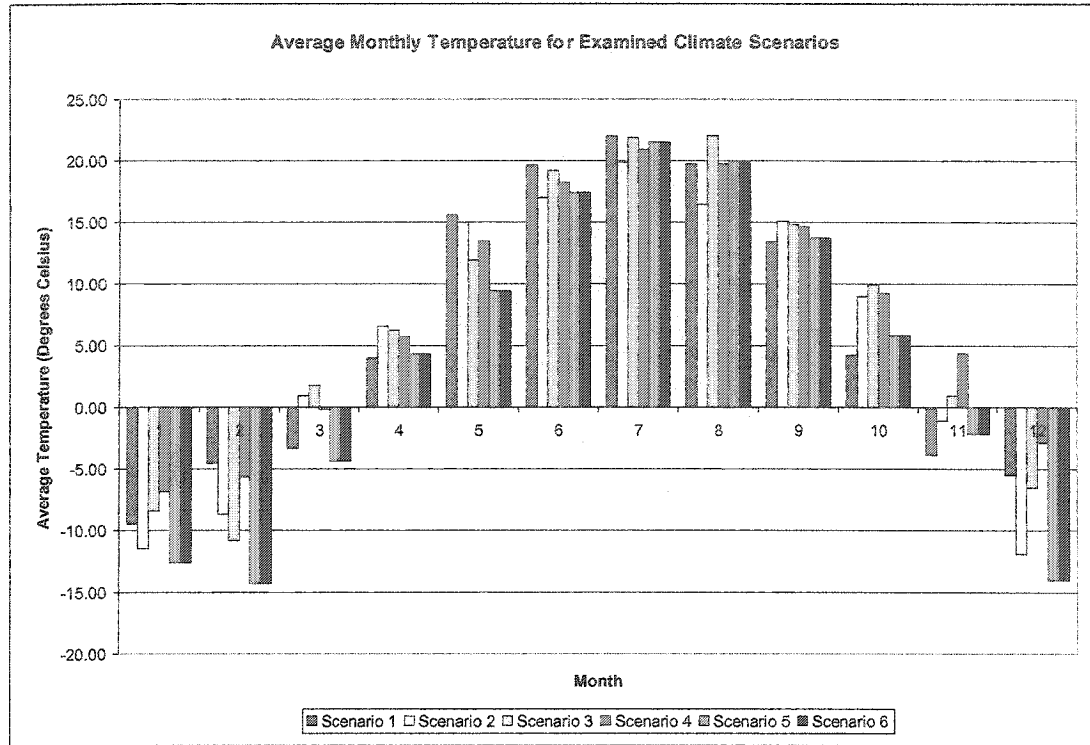


Figure 4.2: Average Monthly Temperature for Climate Scenarios

4.1.2 TOPOGRAPHY DATA

The topography data used as input for the watershed delineation and physical parameter derivation were taken from the 25 m Digital Elevation Model (DEM) used for the EOWRMS study. The DEM file was resampled to a resolution of 50 m to limit the TOPAZ processing requirements to reasonable levels and still provide sufficient accuracy for the task.

The critical source area (CSA) and minimum source channel length (MSCL) are key parameters in the watershed delineation. The CSA is the minimum drainage area to be defined as a cell, below which a source channel is defined. The MSCL is the minimum acceptable length for a source channel to be recognized by the program. A source channel is a reach with a Strahler stream order of 1 (Garbrecht et al., 2000).

Several ranges for each value were tested, as presented in Table 4.2. Ultimately a CSA of 1 km² and an MSCL of 1000 m were selected as they generated the highest resolution useable by subsequent processing stages.

Table 4.2: Effect of CSA and MSCL Selection on Watershed Delineation¹

CSA (km ²)	Number of Cells in Watershed (-)			Max Cell Area (km ²)			Total Drainage Area (km ²)		
	MSCL (m)			MSCL (m)			MSCL (m)		
	250	500	1000	250	500	1000	250	500	1000
1			3030			10.96			3910.49
2.5	2062	1906	1482	17.68	17.68	21.04	3910.52	3910.52	3910.52
5	1001	949	849	27.59	27.59	27.59	3910.54	3910.54	3910.54
7.5	710	684	619	35.37	35.37	38.54	3910.57	3910.57	3910.57
10	509	501	466	53.59	53.59	55.41	3910.57	3910.57	3910.57

¹ The values presented were calculated on a 100 m resolution topography dataset in order to limit processing time

* TOPAGNPS could not compute results for these cases due to extremely high resolution

The resulting watershed delineation consisted of 3077 cells, with an average area of 1.24 km², as well as 1238 reaches, reaching a Strahler stream order of 6. Figures 4.3 and 4.4 show the watershed subdivision. A detailed listing of the cell and reach system as generated is available in Appendix C.

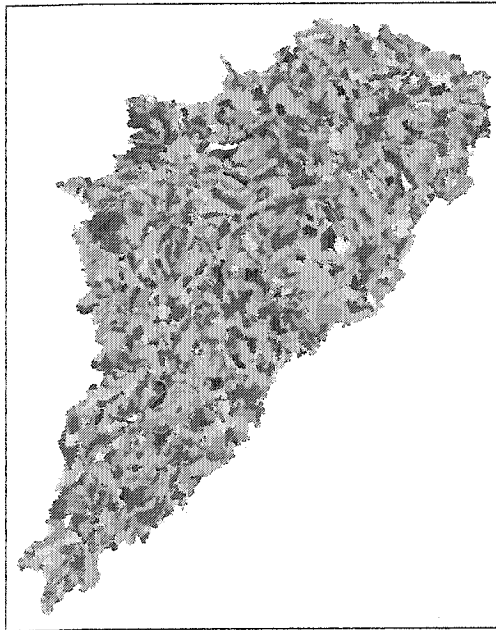


Figure 4.3: Computed cell system for the South Nation watershed

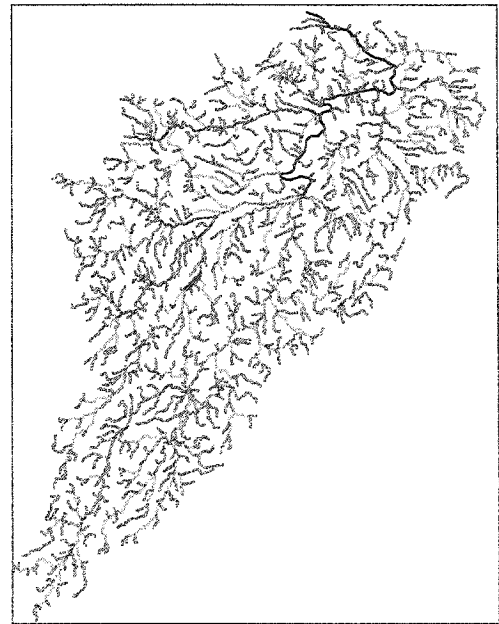


Figure 4.4: Computed reach system for the South Nation watershed

4.1.3 LAND USE DATA

The land use data were gathered from sources contained within the EOWRMS report (CH2M Hill, 2001; see Appendix B for a detailed breakdown of spatial data sources). A 'forestry' and an 'agricultural crop' layer were overlaid to generate an overall model of land use in the watershed. A substantial advantage of using the EOWRMS report was the self-consistency

of the information, so no conflicts appeared between the forestry and agricultural land use data. The forestry and agricultural crop types were defined as land management categories for use in AnnAGNPS, and processed using the utility described in Section 3.4. The results of the allocation routine can be seen in Figures 4.5 and 4.6. The spatial correlation appears to be generally high, which is highly desirable in a study of this nature.

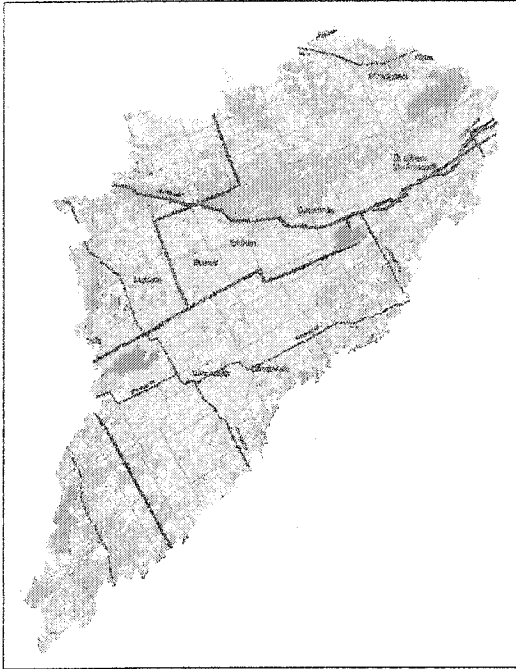


Figure 4.5: EOWRMS land use data

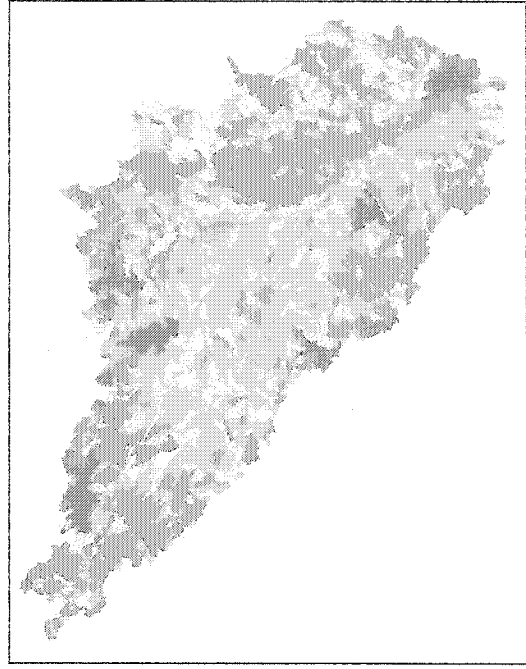


Figure 4.6: Model land use allocation

4.1.4 SOIL DATA

The soil data were allocated in a manner very similar to the land use data, using the same tool adapted for the present purpose. The EOWRMS data however did not subdivide the soil information beyond allocating each grid element with one of 11 textures (although AnnAGNPS could allow in theory for individual soil types for each cell, or more than 3000 soils), which is a gross simplification of the actual soil configuration in the South Nation watershed and omits information on matters such as typical soil horizons and properties, which can be used by AnnAGNPS. This information is typically contained in regional soil surveys, although the agreement between adjacent regions in soil types and datasets is often strikingly poor.

The approach taken was therefore to delineate the study area in agreement with the broad soil texture types identified in the EOWRMS report as seen in Figures 4.7 and 4.8, and then supplement the information from the soil surveys on typical soil properties for the predominant

texture types. The surveys covered the counties of Stormont (Matthews and Richards, 1954), Dundas (Matthews and Richards, 1952), Glengarry (Matthews et al., 1957) and Prescott and Russell (Wicklund and Richards, 1962). The reports used are somewhat dated, but were quite comprehensive and listed more than 32 soil series for the South Nation watershed. The quality and data from each report varied; however, the reports generally listed 4 or more soil horizons, along with information on the soil composition (percentages of sand, silt and clay), pH and organic matter. The 8 predominant soil series were mapped to the more recent EOWRMS data. The series identified in the reports and those selected for the model are summarized in Table D1 of Appendix D.

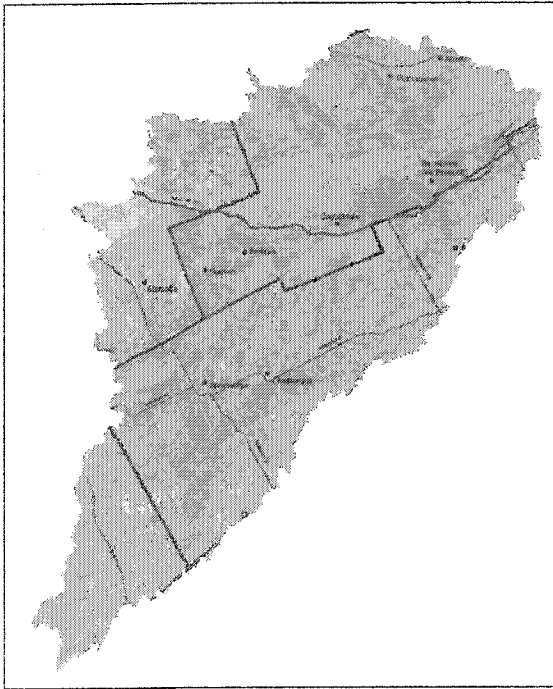


Figure 4.7: EOWRMS soil data

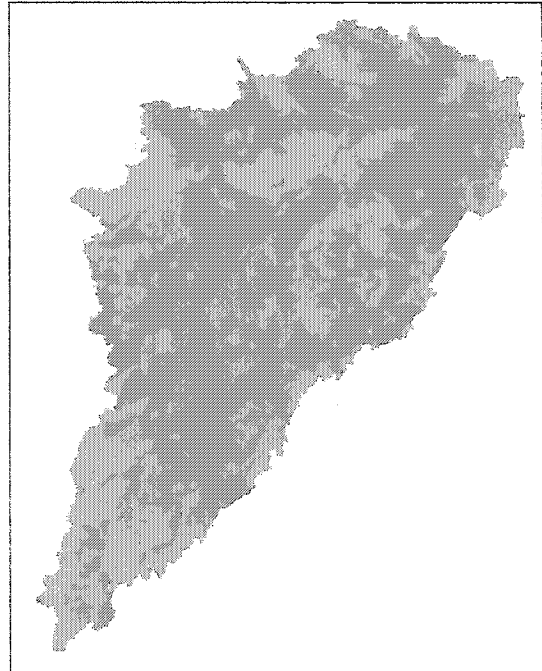


Figure 4.8: Model soil data allocation

4.1.5 MANAGEMENT DATA

Management data in general for the South Nation watershed were difficult to obtain. The USDA recognizes that the data AnnAGNPS would like to use are often not available at all, and rarely available with spatial correlation for most watersheds. Therefore, the package includes reference values which, in conjunction with other sources, were very useful in estimating plausible values for missing information.

Crop management data were compiled from a wide variety of sources, and a range of plausible values were established for each crop type and management scenario (see Section 6 in

Appendix B). These include such factors as fertilizer application amounts and schedules, and crop yields per acre. Sources included other watershed studies (Suttles et al., 2001), Ontario Ministry of Agriculture and Food (OMAF) data, behavioral studies for farmers (Shepard, 2002), and many state and federal surveys and fact sheets (e.g., NRCS 2000, Rauniyar and Parker, 1998).

Fertilizer and Irrigation data were similarly collected from many sources, and the fertilizer industry documentation here was a particularly good source of information on fertilizer composition (see Appendix B, Sections 6 and 7).

4.1.6 LIVESTOCK DATA

Livestock data were available to some degree in the EOWRMS report; however, the data yielded by OMAF-Rural Affairs and Statistics Canada surveys were also very important sources for this information. The data were generally grouped by census area so point-specific values may be somewhat inaccurate for certain cells; however, the overall trend appears to be consistent across data sources. Section 7 of Appendix B lists the census area data which were distributed in the construction of the model.

4.1.7 POINT SOURCES

A list of major point sources was assembled from the recent EOWRMS report and checked against previous studies (Gore and Storrie, 1991; Wilson, 2000). AnnAGNPS does allow for the inclusion of point sources in the input file, but after a few trial runs it became clear that manually including these along with the baseflow into water quality model step would be just as simple and considerably more reliable. The approach used was therefore to model the non-point water and nutrient flows independently and to subsequently add the point source components along each reach prior to linking the results to the CE-QUAL-RIV1. The unified components are presented to the water quality model, and the calculation is conducted accordingly.

4.1.8 HISTORICAL STREAM DATA

Historical stream data were present for certain of reaches of the South Nation watershed in the EOWRMS datasets; however, the data were highly variable in quantity and quality. The locations of stations considered during the run calibration and baseflow separation are presented in Figure 4.9.

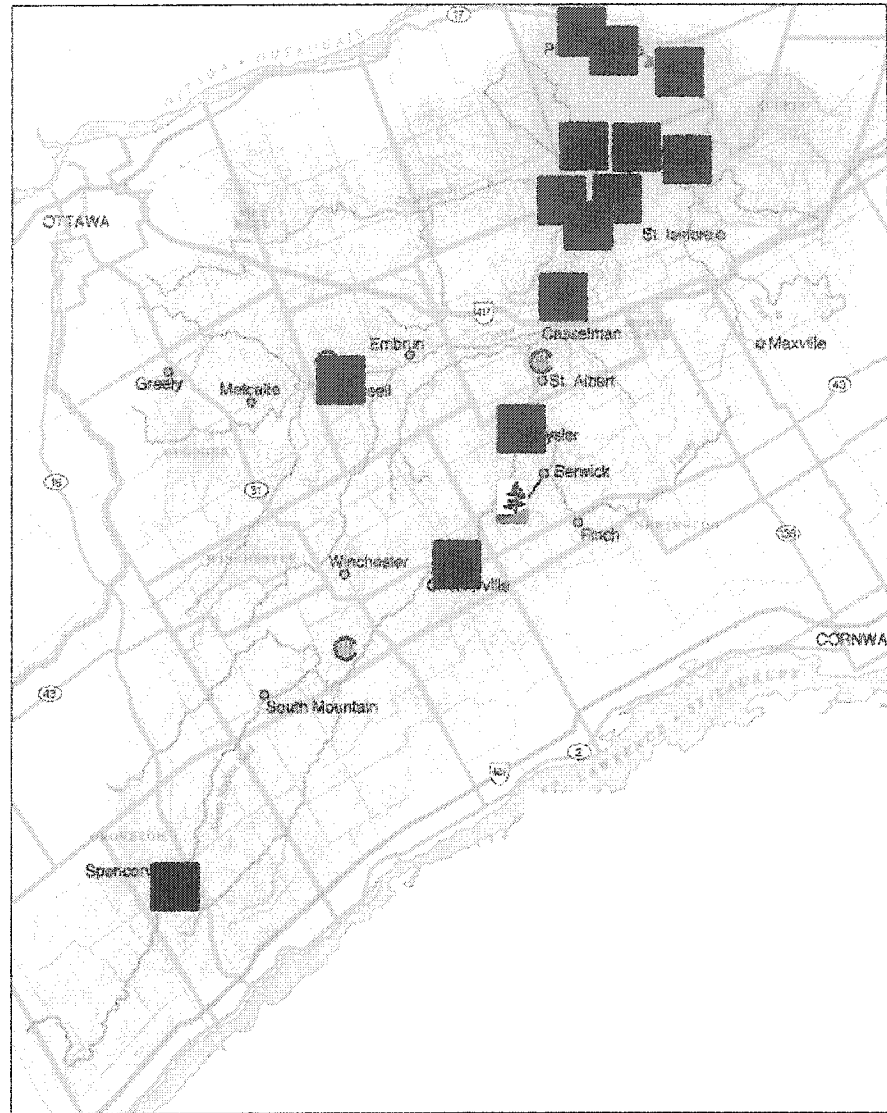


Figure 4.9: Stream data stations on the South Nation River

Baseflow was calculated using available stream flow data and a standard manual hydrograph separation technique (WSDOE, 1999). The trial-and-error method was repeated until a reasonable correlation between baseflow and stream flow was found for the majority of the study area for both of the ‘average’ climate scenarios examined. Automated baseflow separation methods do exist but there is debate as to whether they provide a substantial improvement in model accuracy over manual methods (NDEQ, 2002). The hydrograph separation approach used is described in more detail in Appendix C.

4.2 CALIBRATION

After having assembled the best available data from the sources stated in the preceding sections, the model was calibrated using a limited genetic algorithm to search for solutions with desirable traits.

The lower-confidence data were examined, and subjected to an evolutionary search for an optimal calibration. Crop management and soil data were allowed to vary within ranges deemed acceptable from the management literature. Fertilizer application rates (FARs) for grains for instance, are highly variable and were permitted to vary by as much as 25% from the 'best available data' as presented in Appendix B. Operations data were generally allowed to vary by a few days up to a month from the defaults listed in Appendix B, but were not allowed to change order. Soil data were allowed to vary so as to provide a 'search space' comprising all of the soil types presented in Table B1 of Appendix B. Selection was made based on a fitness criterion, in this case the proximity of predicted nutrient loadings and flow rates at the watershed outlet to historical averages. More advanced spatially and temporally variable criteria was considered; however, it was judged that the data available for calibration did not warrant the increased processing overhead of the more complex fitness evaluation stage.

The individuals (calibration solutions) with a high degree of correlation to observed data score high on the fitness scale and are thus allowed to survive and procreate, while individuals with lower scores are extinguished. The major evolutionary processes simulated in the search algorithm are illustrated in Figure 4.10.

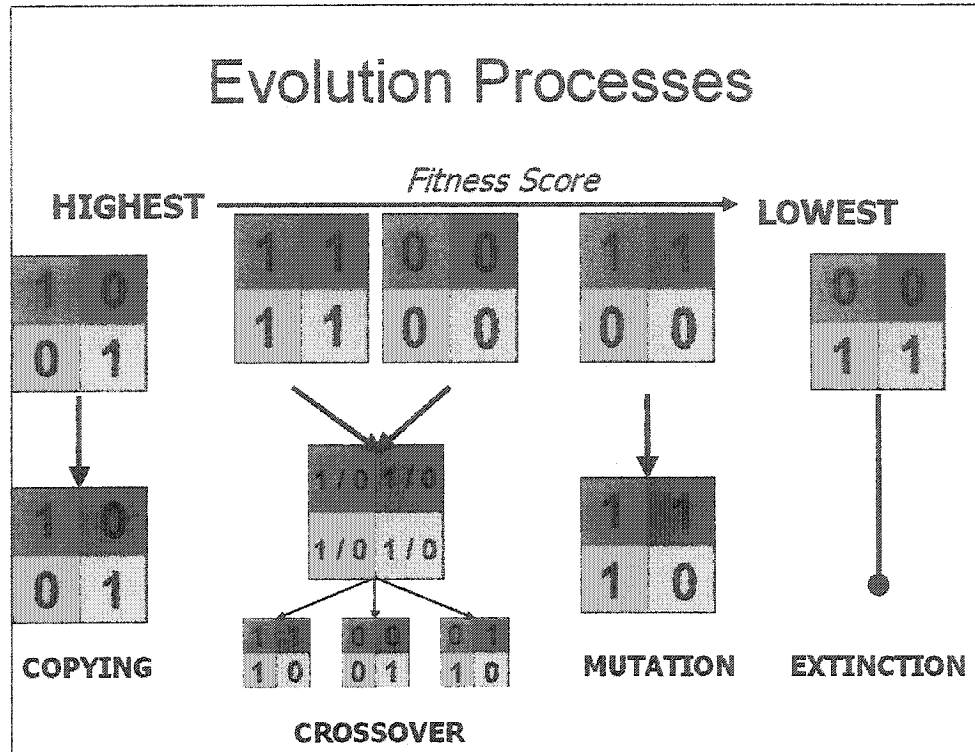


Figure 4.10: Evolutionary processes of a Genetic Algorithm

The evolutionary simulation is repeated for many generations and many individuals, in the hopes of fostering diversity and creativity in solving the problem. Although an optimum solution is perhaps unlikely, a variety of very good solutions can typically be found (Goldberg, 1989).

The search was computer intensive and required hundreds of runs; however, the final solution attained by the algorithm was far superior to the original 'standby' manual calibration. The final solution was then completely revisited for plausibility and physical meaning. Any extreme values were removed and replaced with more plausible ones, typically in the case of soil composition data.

4.3 MANAGEMENT PRACTICES SELECTION AND SIMULATION.

4.3.1 FERTILIZER APPLICATION RATES

The effect of high FARs as a major determinant of agricultural NPS loading has long been known and documented in many studies (NRCS, 2000). Data show that even in watersheds with extensive promotion of nutrient management programs, farmers typically over apply fertilizer by substantial amounts (Shepard, 2002).

It seems likely, therefore, that the current FARs in the South Nation watershed are high. The analysis simulated reductions in fertilizer application of 10 to 50% of base as a potential management practice.

4.3.2 VEGETATIVE FILTER STRIPS

Vegetative filter strips (VFS) are areas placed next to cropland that are designed to remove sediment from runoff. VFS are planted along streams, ponds, and lakes, and can substantially decrease the amount of sediment reaching the waterways. A simplifying assumption for the model was that the VFS would be applied uniformly throughout the watershed. Therefore, the VFS were applied to loadings in all channels shown in Figure 4.4.

VFS implementation throughout the watershed was simulated by reducing the sediment loading reaching the river system. The reduction is dependent on the width of the VFS; therefore, several implementations of these systems were simulated. Table 4.3 shows the widths and simulated sediment reduction considered, based on literature values (Smith et al., 1992; Dillaha et al., 1989). The overall area affected by the BMP is presented in Section 6.3.2 of this thesis.

Table 4.3: Vegetative Filter Strip sediment reduction rates

VFS Width (m)	Sediment removal rates (%)	Factor used to reduce sediment
3	72-88	0.28
6	83-91	0.17
9	96-97	0.04
12	97-98	0.03

4.3.3 STREAM ACCESS

Stream access is controlled through use of topography, natural barriers, and fencing. A reduction in stream access was simulated through reducing the load of livestock waste going directly into the stream. A budget per animal per day of waste was derived for the initial model setup, and modified based on the stream access reductions scenarios. Waste not going directly into the stream is still considered; however, it is given typical treatment for the animal type and the loads were correspondingly reduced. The values for raw and treated animal waste are presented in Tables B3 and B11 of Appendix B.

4.3.4 REDUCED TILLAGE

A variety of tillage reduction methods are in operation throughout North America. Reduced tillage, conservation and no tillage techniques exist in a fairly wide variety of configurations depending on crop type, area to be managed, and so on.

To avoid considering one method exclusively, it was decided that the simulation should focus on the actual reduction in tillage extent throughout the watershed. Accordingly, reduced tillage values were specified in the management options for cells with agricultural land uses.

4.4 WATER QUALITY MODEL DATA

The water quality model was constructed based on the existing data from the EOWRMS study and the data generated during each simulated scenario. The data were combined in a network comprising the major reaches of the South Nation river system, and input into the water quality model.

The additional preparation and processing time for the water quality model was substantial, and hence these additional analysis runs were restricted to the compound scenarios and base cases for each climate condition.

The CE-QUAL-RIV1 network was constructed to mirror the AnnAGNPS outputs and loadings for each reach at each timestep were inputted from the AnnAGNPS simulation results and outputted into the CE-QUAL-RIV1 setup files. Once constructed, the CE-QUAL-RIV1 in-stream simulation files were run, and the water quality components for each reach generated for each timestep. Governing equations for the water quality model are presented in Appendix F.

Water quality criteria were taken from the Canadian Council of Ministers of the Environment guidelines and used to quantify the results (AES, 1999). The criteria used are summarized in Table 4.4.

Table 4.4: Water quality criteria used during simulation

	CCME-based criteria				
Criteria Type	DO	NH3	NO2	TN	TP
Minimum	5.5 mg/L	-	-	-	-
Maximum	-	1.09 mg/L	0.06 mg/L	1.0 mg/L as N	0.05 mg/L as P

Additionally, the total nutrient concentration exiting the watershed over the course of the year was compared with levels known to cause eutrophication problems in lake systems (Vollenweider, 1970). Average nitrogen and phosphorus concentrations exceeding 0.20 and 0.014 mg/L, respectively, over the course of a year were considered to be in violation of the eutrophication criteria.

4.5 BIOLOGICAL STRESS INDICES

Using the Habitat Suitability Indices reports (McMahon et al., 1984; Edwards et al., 1982; Trial et al., 1983; and others), nutrient-based criteria for species in the South Nation watershed were compiled (Table 4.5). The table focuses on the nutrient-related water quality standards (as opposed to features such as cover, stream width, etc.) as these are the variables that are the most directly related to agricultural management practices.

Table 4.5: Habitat suitability states for fish species in the South Nation watershed

Species Name	Min. DO (mg/L)	Large Stress (HSI<0.5)		Stressed (HSI<1)		
		Max. Turbidity (NTU)	Max NH ₃ (mg/L)	Min. DO (mg/L)	Max Turbidity (NTU)	Max NH ₃ (mg/L)
Black Crappie	4.8	100	0.11	5	50	0.07
Blacknose Dace	3	50	0.11	5	40	0.07
Blue Gill	3	150	0.11	5	50	0.07
Carp	4	150	0.11	6	75	0.07
Channel Catfish	4	200	0.11	7	100	0.07
Shiner	3	60	0.11	5	40	0.07
Creek Chub	3	80	0.11	5	40	0.07
Fallfish	3	60	0.11	5	40	0.07
Muskellunge	3	60	0.11	5	40	0.07
Northern Pike	3	60	0.11	5	40	0.07
Smallmouth Bass	5	60	0.11	6	25	0.07
Walleye	4	60	0.11	5	25	0.07
White Sucker	3	150	0.11	6	50	0.07
Yellow Perch	3.2	60	0.11	5	40	0.07

The criteria presented in Table 4.5 were then summarized into broader stress criteria (Table 4.6) for parameters simulated in South Nation River system. "Poor" conditions in each row are allocated a stress factor of 4, while "Stressed" conditions are allocated a stress factor of 2. Non-stressed conditions are scored as nil. The scoring system is somewhat arbitrary, but does provide some measure of overall stress conditions in the river system over the course of a year.

Table 4.6: Criteria for generating "Stress Condition" scores

Stress State	Stress Score	Dissolved Oxygen Concentration Range	Ammonia Concentration Range	Turbidity Range
--------------	--------------	--------------------------------------	-----------------------------	-----------------

Poor	4	< 3 mg/L	> 0.11 mg/L	>110 NTU
Stressed	2	3-5 mg/L	0.07-0.11 mg/L	75-110 NTU
Not Stressed	0	≥ 5 mg/L	≤ 0.07 mg/L	≤ 75 NTU

The stress score for each reach can then be calculated as

$$S_{reach} = 4 \cdot Num_{Severe} + 2 \cdot Num_{Stressed} + 0 \cdot Num_{NoStress} \quad (4-1)$$

- where S_{reach} = Stress Score for the reach (-)
 Num_{Severe} = Number of criteria in "Severe" condition (-)
 $Num_{Stressed}$ = Number of criteria in "Stressed" condition (-)
 $Num_{NoStress}$ = Number of criteria in "No stress" condition (-)

The amalgam stress score for the entire South Nation watershed is then summed over all reaches, and the score recorded for each day of the year. Although an intensity-duration-frequency curve could in theory be derived, and such a derivation was indeed attempted, the number of events in a one-year time frame is not sufficient to permit a meaningful correlation.

CHAPTER 5

SIMULATION

5.1 CASE MATRIX

The 18 management practices shown in Table 5.1 were simulated for each weather scenario.

Table 5.1: Management scenarios matrix

Scenario	BMP implemented
1	BASE CASE
2	FAR = 50%
3	FAR = 60%
4	FAR = 70%
5	FAR = 80%
6	FAR = 90%
7	VFS = 3 m
8	VFS = 6 m
9	VFS = 9 m
10	VFS = 12 m
11	No Stream Access
12	1/3 Stream Access
13	1/2 Stream Access
14	2/3 Stream Access
15	3/4 Stream Access
16	75% Reduced Tillage
17	50% Reduced Tillage
18	25% Reduced Tillage

Additionally, grouped management scenarios were also simulated across the climate scenarios, as shown in Table 5.2.

Table 5.2: Grouped management scenario matrix

Scenario	BMP Implemented
19	Best of all BMPs
20	Moderate BMPs
21	Best of FAR and VFS
22	Moderate FAR and VFS

'Best' implementation of BMPs are the cases where they are applied to the greatest extent simulated, corresponding, to FAR at 50% of base, VFS width of 12 m, no stream access allowed, and tillage is reduced by 75%. 'Moderate' BMP implementations are cases at neither extreme of the simulated application extents. This corresponds to FAR at 70% of base, VFS width of 6 m, stream access reduced by half, and 50% reduced tillage.

5.2 PROCESSING REQUIREMENTS

The simulation was conducted on an IBM PC with an Intel Pentium 4 processor operating at 2.0 GHz machine with 512 MB of RAM. The simulation time varied for each scenario, but typically required approximately 15 minutes for each AnnAGNPS simulation, plus an additional 30 minutes for the automated analysis tools. Total processing time was therefore about 99 hours of dedicated computer time for the entire case matrix. Simulation results required roughly 10 GB of storage excluding external analysis tools.

5.3 RESULTS

This section contains a summary of the 132 cases examined. The data have been greatly summarized for the convenience of the reader.

5.3.1 BASE CASE RESULTS FOR ALL CLIMATE SCENARIOS

Table 5.3 and 5.4 are summaries of the simulation results for the base management case (no BMPs implemented) for each of the weather scenarios examined. Table 5.3 presents monthly and annual flow averages at the watershed outlet for each scenario, while Table 5.4 presents the analogous nutrient loadings at the outlet.

As expected, the wet scenario years generate a larger amount of runoff than the average years, while the dry years generate lower flows. An additional observation is that the cold years, with approximately the same precipitation conditions as warm years, generate higher runoff, particularly in the case of wet years, due primarily to the higher spring melt volumes in April. For instance, the cold-wet conditions of Scenario 5 generates 25% runoff in April than the warm wet conditions of Scenario 3, but the difference is reduced to a mere 5% when compared on an annual basis. The nutrient loadings, of course, are clearly linked with the runoff volumes; however, the scheduling and temperature of the events do have a noticeable impact on the results and the delivery schedule of the nutrients to the channel system. As an example, consider again Scenarios 5 (cold-wet) and 3 (warm-wet). Although the nutrient concentration loading is slightly lower in Scenario 5, with for instance annual TN loadings at 97% of those in Scenario 3 on a mg/l basis, the increased runoff volume must also be considered. Thus, the actual

TN load reaching the outlet on a yearly mass basis is approximately 5% higher than that of Scenario 3.

Table 5.3: Comparison of climate scenario effect on flow at outlet for base case

Month	Synthetic Average Case	Historical Average Case	Warm Wet Case	Warm Dry Case	Cold Wet Case	Cold Dry Case
	Flow (m ³ /s)	Flow (m ³ /s)	Flow (m ³ /s)	Flow (m ³ /s)	Flow (m ³ /s)	Flow (m ³ /s)
Jan	27.2	27.3	27.1	27.3	27.1	27.3
Feb	30.8	25.1	24.7	27.1	24.7	24.4
Mar	77.2	85.8	80.4	70.7	66.3	74.6
Apr	167.5	135.5	142.1	133.8	179.0	145.6
May	47.0	39.7	44.1	40.1	44.6	40.1
Jun	20.4	38.1	45.0	18.3	47.0	18.3
Jul	19.2	20.6	14.1	11.6	14.8	11.6
Aug	11.0	19.3	36.6	13.8	37.5	14.3
Sep	11.5	16.9	11.1	13.1	11.1	13.4
Oct	23.7	27.8	24.9	23.5	25.2	23.5
Nov	47.8	47.5	47.7	47.5	47.7	47.5
Dec	45.9	37.7	40.9	42.5	44.7	38.8
Annual	44.1	43.5	44.9	39.1	47.5	40.0

Table 5.4: Comparison of climate scenario effect on nutrients at outlet for base case

Month	Synthetic Average Case			Historical Average Case			Warm Wet Case			Warm Dry Case			Cold Wet Case			Cold Dry Case		
	Nutrient in mg/L			Nutrient in mg/L			Nutrient in mg/L			Nutrient in mg/L			Nutrient in mg/L			Nutrient in mg/L		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	1.22	0.47	0.08	1.21	0.47	0.08	1.22	0.47	0.08	1.21	0.47	0.08	1.22	0.47	0.08	1.21	0.47	0.08
Feb	1.03	1.94	0.07	1.26	0.59	0.08	1.28	0.60	0.08	1.17	1.45	0.08	1.28	0.60	0.08	1.30	0.60	0.08
Mar	3.82	0.87	3.56	1.04	1.18	0.27	0.90	0.91	0.08	1.24	0.69	0.30	1.15	0.35	0.12	1.05	1.08	0.13
Apr	0.86	0.80	0.10	1.04	0.23	0.09	1.01	0.39	0.10	1.04	0.11	0.08	0.84	1.24	0.11	1.02	0.56	0.12
May	4.15	0.58	0.09	1.16	0.32	0.08	1.18	0.49	0.10	1.15	0.32	0.08	1.19	0.49	0.10	1.15	0.32	0.08
Jun	1.50	0.84	0.09	1.40	1.96	0.11	1.07	1.57	0.09	1.33	0.72	0.07	1.04	1.63	0.09	1.33	0.72	0.07
Jul	1.48	1.65	0.08	1.28	1.53	0.45	1.70	1.58	0.10	1.53	1.11	0.07	1.68	1.57	0.10	1.53	1.14	0.07
Aug	1.81	2.03	0.09	1.51	2.21	0.09	0.80	4.14	0.08	1.73	2.31	0.11	0.79	4.08	0.08	1.69	2.22	0.11
Sep	1.68	2.0	0.09	1.43	2.69	0.08	1.56	1.20	0.07	1.89	2.95	0.12	1.56	1.20	0.07	1.87	2.98	0.12
Oct	1.25	0.54	0.08	1.31	1.19	0.09	1.41	1.03	0.09	1.26	0.55	0.08	1.45	1.13	0.10	1.26	0.55	0.08
Nov	1.12	0.28	0.08	1.13	0.28	0.08	1.13	0.28	0.08	1.13	0.28	0.08	1.13	0.28	0.08	1.13	0.28	0.08
Dec	1.21	1.02	0.10	1.15	0.34	0.08	1.23	0.55	0.09	1.34	1.07	0.10	1.17	0.68	0.10	1.26	0.58	0.09
Annual	1.78	0.88	0.61	1.17	0.82	0.13	1.10	0.93	0.09	1.21	0.63	0.12	1.07	1.12	0.10	1.17	0.73	0.10

5.3.2 BMP SCENARIO EFFECTIVENESS

Tables 5.5 to 5.10 present a comparison of the BMP effectiveness of individual management practices, heavily applied, for individual Climate Scenarios. These tables allow for a direct assessment of relative effectiveness of various management practices for a variety of fixed climate conditions.

Table 5.5: Comparison of BMP Effectiveness¹ (in %) for Climate Scenario 1
(synthetic average case)

Month	FAR = 50% of Base			VFS of 12 m			No Stream Access			75% Reduced Tillage			
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Feb	0.0	0.0	0.0	0.0	73.14	2.16	0.0	0.0	0.0	0.0	0.0	-43.28	0.54
Mar	37.94	0.0	49.03	0.01	78.45	14.18	0.01	0.39	0.0	0.0	0.0	-16.68	0.28
Apr	3.0	0.0	20.84	0.04	87.42	5.33	0.03	0.56	0.08	0.0	0.0	-11.01	0.11
May	38.58	0.0	17.59	0.0	51.17	3.46	0.0	0.0	0.0	0.0	0.0	-4.44	0.28
Jun	11.69	0.0	18.82	0.0	21.65	3.41	0.0	0.0	0.0	0.0	0.0	-3.73	0.0
Jul	27.03	0.0	26.50	0.0	57.84	6.80	0.0	0.0	0.0	0.0	0.0	-11.96	0.09
Aug	16.51	0.0	18.20	0.0	41.13	4.56	0.0	0.0	0.0	0.0	0.0	-11.37	0.64
Sep	10.76	0.0	16.34	0.0	41.09	3.37	0.0	0.0	0.0	0.0	0.0	-6.85	1.38
Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	16.27	0.0	27.29	0.33	70.31	6.65	5.05	5.20	24.36	0.01	0.01	-32.46	0.65
Annual	23.46	0.0	44.90	0.03	64.12	12.90	0.31	0.75	0.38	0.0	0.0	-16.04	0.28

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Table 5.5 shows a clear distinction between two highly effective BMPS, the FAR and VFS scenarios, and two largely ineffective BMPs, the stream access and reduced tillage scenarios. The difference is certainly pronounced on a yearly basis. Compare for instance, the TP reduction of 45% in the FAR management practice scenarios with the negligible reductions (0.3%) in both the stream access and reduced tillage cases. The difference does not seem to lie in particular events or conditions since this pattern is consistent over the months of the year, although the effective BMPs do appear to be particularly effective in the late winter and spring months.

Table 5.6: Comparison of BMP Effectiveness¹ (in %) for Climate Scenario 2 (historical average)

Month	FAR = 50% of Base			VFS of 12 m			No Stream Access			75% Reduced Tillage		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	10.40	0.0	38.21	0.02	84.74	11.31	0.02	0.26	0.02	0.0	-25.28	1.92
Apr	1.14	0.0	7.24	0.0	55.06	1.94	0.0	0.0	0.0	0.0	-5.27	0.12
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun	34.51	0.0	48.25	0.39	79.76	11.13	5.75	3.74	14.14	0.0	-5.19	0.31
Jul	22.68	0.0	47.88	0.33	57.63	13.38	4.19	3.67	4.0	0.01	-5.47	0.56
Aug	33.45	0.0	41.37	0.0	67.78	9.03	0.0	0.0	0.0	0.0	-32.97	0.58
Sep	20.68	0.0	27.35	0.0	68.74	6.05	0.0	0.0	0.0	0.0	-48.39	-0.14
Oct	13.26	0.0	15.31	0.0	59.54	3.43	0.0	0.0	0.0	0.0	-40.43	0.28
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Annual	9.08	0.0	26.21	0.05	61.35	7.26	0.69	0.98	1.42	0.0	-19.45	0.81

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Table 5.7: Comparison of BMP Effectiveness¹ (in %) for Climate Scenario 3 (warm wet case)

Month	FAR = 50% of Base			VFS of 12 m			No Stream Access			75% Reduced Tillage		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	1.13	0.0	7.32	0.0	80.04	3.39	0.0	0.0	0.0	0.0	-41.97	0.29
Apr	2.18	0.0	14.14	0.03	73.82	3.93	0.04	1.02	0.07	0.0	-6.95	0.23
May	7.24	0.0	18.78	0.0	39.60	4.07	0.0	0.0	0.0	0.0	-1.32	0.53
Jun	33.24	0.0	44.67	0.42	78.79	11.07	9.29	3.82	27.22	0.0	-6.10	0.14
Jul	18.76	0.0	31.47	0.0	41.15	5.92	0.0	0.0	0.0	0.0	-7.22	0.31
Aug	33.44	0.0	52.40	2.92	88.78	19.12	4.26	7.57	30.14	0.02	-16.37	0.24
Sep	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct	11.87	0.0	16.04	0.0	48.20	3.18	0.0	0.0	0.0	0.0	-16.32	1.11
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	9.82	0.0	11.01	0.0	41.55	2.51	0.0	0.0	0.0	0.0	-31.17	0.37
Annual	8.05	0.0	16.46	0.19	66.52	4.62	0.97	2.98	4.16	0.0	-15.62	0.27

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Table 5.8: Comparison of BMP Effectiveness¹ (in %) for Climate Scenario 4 (warm dry case)

Month	FAR = 50% of Base			VFS of 12 m			No Stream Access			75% Reduced Tillage		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	60.65	1.21	0.0	0.0	0.0	0.0	-35.61	0.29
Mar	9.59	0.0	37.46	0.0	71.55	10.97	0.0	0.0	0.0	0.0	-12.27	4.68
Apr	0.31	0.0	3.02	0.0	9.42	0.67	0.0	0.0	0.0	0.0	-1.10	0.0
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug	26.85	0.0	39.49	0.0	58.03	7.90	0.0	0.0	0.0	0.0	-19.44	0.62
Sep	24.39	0.0	36.08	0.0	63.79	7.09	0.0	0.0	0.0	0.0	-25.23	2.09
Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	17.50	0.0	18.49	0.0	69.75	4.23	0.0	0.0	0.0	0.0	-44.15	0.80
Annual	5.58	0.0	18.98	0.0	45.40	5.26	0.0	0.0	0.0	0.0	-18.72	2.0

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Table 5.9: Comparison of BMP Effectiveness¹ (in %) for Climate Scenario 5 (cold wet case)

Month	FAR = 50% of Base			VFS of 12 m			No Stream Access			75% Reduced Tillage		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	3.76	0.0	18.28	0.0	44.05	5.24	0.0	0.0	0.0	0.0	-1.26	1.07
Apr	4.90	0.0	23.12	0.09	91.22	6.77	0.08	0.82	0.17	0.0	-11.72	0.17
May	8.42	0.0	19.60	0.0	39.58	4.33	0.0	0.0	0.0	0.0	-3.15	0.40
Jun	33.90	0.0	45.56	0.48	80.23	11.39	9.92	4.07	28.41	0.0	-5.98	0.12
Jul	20.35	0.0	30.23	0.0	43.54	6.18	0.0	0.0	0.0	0.0	-7.63	0.28
Aug	33.83	0.0	52.67	2.83	88.86	18.78	4.22	7.28	29.24	0.01	-17.37	0.17
Sep	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct	15.41	0.0	22.30	0.0	53.05	4.29	0.0	0.0	0.0	0.0	-18.02	1.74
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	13.16	0.0	28.39	0.14	56.04	5.74	4.17	3.28	23.38	0.01	-35.03	0.40
Annual	9.75	0.0	22.59	0.21	72.95	6.12	1.38	2.72	5.72	0.0	-12.04	0.39

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Table 5.10: Comparison of BMP Effectiveness¹ (in %) for Climate Scenario 6 (cold dry case)

Month	FAR = 50% of Base			VFS of 12 m			No Stream Access			75% Reduced Tillage		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	4.84	0.0	22.76	0.0	81.55	6.86	0.0	0.0	0.0	0.0	-14.29	0.45
Apr	4.18	0.0	20.63	0.01	81.12	5.90	0.01	0.18	0.02	0.0	-8.57	0.33
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul	0.0	0.0	1.29	0.0	2.80	0.38	0.0	0.0	0.0	0.0	-0.30	0.0
Aug	27.45	0.0	40.93	0.0	57.83	8.05	0.0	0.0	0.0	0.0	-20.27	0.51
Sep	24.99	0.0	37.39	0.0	64.86	7.26	0.0	0.0	0.0	0.0	-27.64	2.01
Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	8.78	0.0	10.94	0.0	41.70	2.22	0.0	0.0	0.0	0.0	-14.66	0.88
Annual	4.88	0.0	15.38	0.0	53.35	4.18	0.0	0.04	0.01	0.0	-11.32	0.35

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Although the relative effects are substantially different from scenario to scenario in Tables 5.5 to 5.10, certain common traits are apparent. The reduction in FAR, for example, is quite effective across all weather conditions in reducing TP (varying from about 15-40%), sometimes effective at removing TN (from about 5-20%), and ineffective for TOC reduction (negligible in all cases). Conversely, the VFS is very effective at TOC removal with reductions of about 45 to 70%, somewhat effective at TP removal (but by no more than approximately 10%), and generally ineffective at reducing TN loadings.

The stream access and reduced tillage are generally ineffective at nutrient removal when compared with the previous two management practices. The tillage management practice in particular is problematic since, depending on the extent of tillage reduction and the crop management schedule, it can actually lead to a small increase in TOC loadings (this effect only occurs in the extreme tillage reduction scenario). There is some controversy in the literature as to whether tillage reduction can be broadly recommended for nutrient reduction purposes (see, for instance Peet, 1995), so this result is quite interesting.

Another noticeable feature of the results is the relationship of the November and December results. An overview of the tables shows that BMPs implemented in the month of December are typically much more effective than the adjacent winter months of November-February. This result is explained when comparing the relative runoff volumes in these months. Indeed, the runoff contribution to total outlet flow in December months is roughly an order of magnitude higher than those in the adjacent months of November and January, and hence BMPs controlling

runoff pollutant loadings will be far more effective in this month. This is most likely due to the higher precipitation and more moderate temperatures in the early month of December across the Climate Scenarios examined. An additional contributing effect is likely the low precipitation in the November months, which may lead to nutrients not being mobilized to the channel throughout much of that month.

5.3.3 AGGREGATE BMP SCENARIO EFFECTIVENESS

In addition to individual implementation of BMPs, aggregate management scenarios were also simulated for each climate condition. These scenarios consist of conjugate use of two or more BMPs simultaneously throughout the watershed. Section 5.1 and Table 5.2 outline the terminology used and the how the aggregate scenarios were configured in additional detail.

Table 5.11: Comparison of Compound BMP Effectiveness¹ (in %) for Climate Scenario 1
(synthetic average case)

Month	All BMPs Applied Heavily			All BMPs Applied Moderately			F.A.R and VFS Applied Heavily			FAR and VFS Applied Moderately		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	71.84	2.62	0.0	56.02	2.28	0.0	73.14	2.16	0.0	62.58	1.84
Mar	37.95	77.96	56.25	22.77	65.21	38.05	37.95	78.45	56.13	22.77	67.13	37.92
Apr	3.04	87.11	23.20	2.02	73.80	15.60	3.04	87.42	23.16	2.01	74.80	15.56
May	38.58	51.03	18.60	23.15	43.45	12.33	38.58	51.17	18.52	23.15	43.78	12.20
Jun	11.69	21.54	19.51	7.01	18.16	13.19	11.69	21.65	19.51	7.01	18.52	13.19
Jul	27.03	57.48	29.50	16.23	48.10	25.91	27.03	57.84	29.48	16.23	49.49	25.88
Aug	16.51	40.79	20.36	10.26	33.60	17.88	16.51	41.13	20.13	10.26	35.20	17.68
Sep	10.76	40.89	17.70	6.83	34.13	15.14	10.76	41.09	17.36	6.83	35.16	14.71
Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	17.65	69.48	33.40	10.98	55.68	25.44	16.60	70.31	30.0	10.46	60.16	22.23
Annual	23.56	63.66	51.47	14.20	52.82	34.91	23.49	64.12	51.31	14.17	54.87	34.73

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Table 5.11 effectively shows the viability of BMP implementation for purposes of reducing nutrient loadings reaching the outlet, both an annual and a month-by-month basis. Every implementation presented in this table reduces the annual nutrient loadings by at least 15%, and in some cases the reduction is as high as 70% of the base case results. The relative ineffectiveness of the stream access and reduced tillage management practices is again visible in this table by noting the lack of significant effectiveness of “All BMPs” implementations over “FAR and VFS” management practices.

Table 5.12: Comparison of Compound BMP Effectiveness¹ (in %) for Climate Scenario 2
(historical average case)

Month	All BMPs Applied Heavily			All BMPs Applied Moderately			FAR and VFS Applied Heavily			FAR and VFS Applied Moderately		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	10.43	83.98	44.82	6.26	69.28	30.56	10.42	84.74	43.99	6.26	72.51	29.77
Apr	1.14	54.90	8.18	0.68	46.60	5.52	1.14	55.06	8.14	0.68	47.12	5.48
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun	36.75	79.71	56.08	22.46	68.07	35.77	34.90	79.76	52.42	21.87	68.25	34.43
Jul	23.08	57.57	55.04	15.96	48.98	37.18	23.01	57.63	54.35	15.91	49.31	36.50
Aug	33.45	66.79	44.58	20.91	53.23	30.78	33.45	67.78	44.41	20.91	57.99	30.50
Sep	20.68	67.28	29.46	12.92	51.65	19.97	20.68	68.74	29.43	12.92	58.82	19.97
Oct	13.26	58.33	16.64	8.29	44.88	11.28	13.26	59.54	16.53	8.29	50.95	11.14
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Annual	9.30	60.80	30.31	5.79	49.90	20.46	9.14	61.35	29.68	5.74	52.50	19.99

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Table 5.13: Comparison of Compound BMP Effectiveness¹ (in %) for Climate Scenario 3
(warm wet case)

Month	All BMPs Applied Heavily			All BMPs Applied Moderately			FAR and VFS Applied Heavily			FAR and VFS Applied Moderately		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	1.13	78.78	9.85	0.68	62.28	6.94	1.13	80.04	9.65	0.68	68.48	6.74
Apr	2.23	73.64	16.12	1.52	62.59	10.91	2.21	73.82	16.02	1.51	63.17	10.83
May	7.24	39.56	20.30	4.88	33.68	13.56	7.24	39.60	20.15	4.88	33.89	13.36
Jun	34.56	78.72	56.53	23.14	67.17	35.13	33.66	78.79	49.28	21.59	67.41	32.72
Jul	18.76	40.93	32.90	12.01	34.35	21.60	18.76	41.15	32.85	12.01	35.21	21.49
Aug	36.53	88.51	64.49	24.80	74.34	48.63	36.37	88.78	63.95	24.56	75.97	44.89
Sep	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct	11.87	47.71	17.17	7.63	38.76	11.69	11.87	48.20	16.92	7.63	41.24	11.21
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	9.82	40.61	12.04	6.25	30.83	8.06	9.82	41.55	11.93	6.25	35.55	7.87
Annual	8.32	66.14	19.46	5.52	55.0	13.19	8.24	66.52	18.71	5.38	56.92	12.65

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Table 5.14: Comparison of Compound BMP Effectiveness¹ (in %) for Climate Scenario 4
(warm dry case)

Month	All BMPs Applied Heavily			All BMPs Applied Moderately			FAR and VFS Applied Heavily			FAR and VFS Applied Moderately		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	59.58	1.46	0.0	46.48	1.27	0.0	60.65	1.21	0.0	51.90	1.04
Mar	9.59	71.19	45.03	5.76	59.67	31.68	9.59	71.55	43.02	5.76	61.23	29.08
Apr	0.31	9.39	3.25	0.29	7.98	2.16	0.31	9.42	3.25	0.29	8.06	2.16
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug	26.85	57.45	41.80	17.11	46.90	29.14	26.85	58.03	41.70	17.11	49.65	28.93
Sep	24.39	63.03	38.42	15.62	50.84	26.44	24.39	63.79	37.96	15.62	54.58	25.54
Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	17.50	68.43	20.30	11.08	52.96	13.70	17.50	69.75	20.04	11.08	59.68	13.29
Annual	5.58	44.84	22.35	3.52	36.09	15.63	5.58	45.40	21.50	3.52	38.85	14.54

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Table 5.15: Comparison of Compound BMP Effectiveness¹ (in %) for Climate Scenario 5
(cold wet case)

Month	All BMPs Applied Heavily			All BMPs Applied Moderately			FAR and VFS Applied Heavily			FAR and VFS Applied Moderately		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	3.76	44.01	21.33	2.25	37.55	14.54	3.76	44.05	20.88	2.25	37.69	14.10
Apr	5.0	90.89	26.62	3.22	77.02	18.06	4.99	91.22	26.55	3.21	78.06	17.98
May	8.42	39.48	21.23	5.66	33.38	14.14	8.42	39.58	21.10	5.66	33.86	14.01
Jun	35.29	80.18	57.38	23.83	68.45	35.89	34.38	80.23	50.36	22.26	68.65	33.32
Jul	20.35	43.31	32.10	13.04	36.34	21.21	20.35	43.54	32.03	13.04	37.26	21.13
Aug	36.80	88.56	64.47	25.15	74.26	48.26	36.66	88.86	63.85	24.92	76.04	44.62
Sep	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oct	15.41	52.51	23.69	10.08	42.65	16.05	15.41	53.05	23.35	10.08	45.39	15.28
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	13.81	55.08	32.30	8.96	42.93	23.58	13.30	56.04	30.02	8.41	47.95	20.52
Annual	10.09	72.67	26.33	6.67	61.18	17.97	9.96	72.95	25.44	6.48	62.42	17.19

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

Table 5.16: Comparison of Compound BMP effectiveness¹ (in %) for Climate Scenario 6
(cold dry case)

Month	All BMPs Applied Heavily			All BMPs Applied Moderately			FAR and VFS Applied Heavily			FAR and VFS Applied Moderately		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	4.8	81.1	26.5	2.90	68.08	18.05	4.84	81.55	26.33	2.90	69.78	17.84
Apr	4.2	80.9	23.7	2.60	68.60	16.02	4.19	81.12	23.55	2.60	69.41	15.90
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jul	0.0	2.8	1.5	0.0	2.37	1.03	0.0	2.80	1.50	0.0	2.39	1.03
Aug	27.5	57.2	43.2	17.78	46.62	29.09	27.45	57.83	43.08	17.78	49.49	28.92
Sep	25.0	64.0	39.7	16.29	51.39	26.70	24.99	64.86	39.25	16.29	55.50	25.82
Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	8.8	41.3	11.8	5.70	33.42	7.97	8.78	41.70	11.58	5.70	35.68	7.57
Annual	4.9	53.0	17.5	3.10	44.18	11.82	4.88	53.35	17.33	3.10	45.65	11.67

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case.

The results from Tables 5.11-5.16 lead to some observations predicted from the observations in Section 5.3.2. The reduction of FARs and implementation of VFSs alone lead to essentially the same reductions in nutrient loading as the implementation of all the BMPs examined. That is to say, the other two management practices, which are reduced stream access and tillage, have little effect in isolation or in conjunction with other strategies.

The other interesting result apparent in these tables is the relative susceptibility of different nutrient types to the BMPs. The TOC loadings can be reduced by a factor of approximately 2 with either moderate or extensive application of the management practices. The TP loadings can also be substantially reduced, by up to about 20%, although the extent of BMP implementation is an important factor in obtaining a reasonable decrease. The reductions in TN loadings are difficult to predict, and range from a few percent to roughly 25%. The extent of application is again quite important for TN reduction, and the BMP effectiveness appears to be substantially higher in scenarios with high spring runoff volumes.

An additional way of looking at the results of the study is presented in Figures 5.1 to 5.4. These figures are designed to show graphically the relative effectiveness of each BMP at reducing nutrient loadings across varied climate conditions.

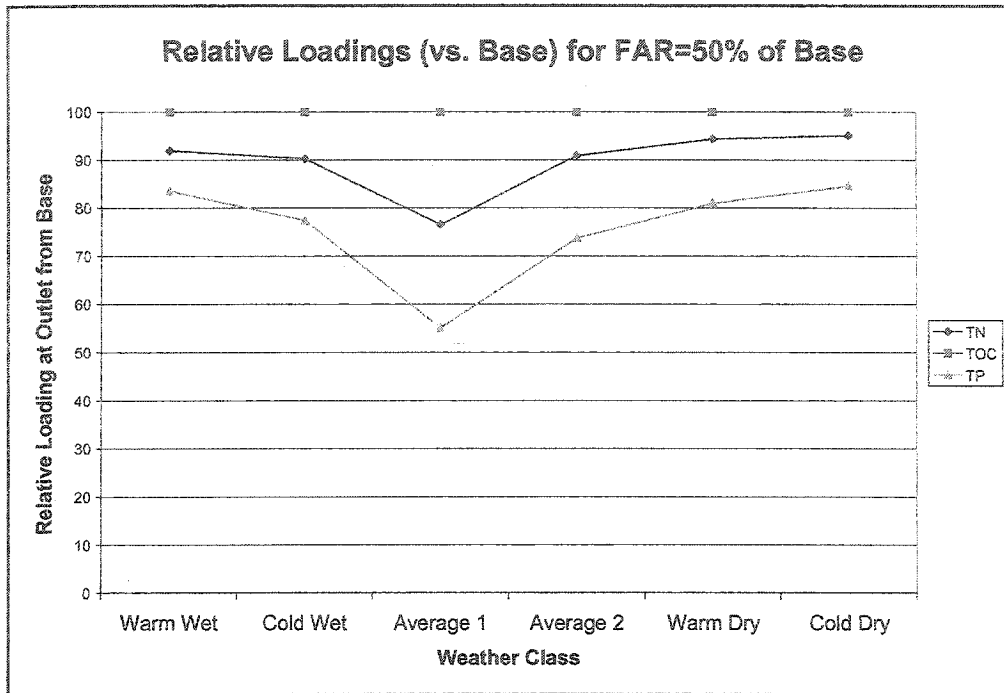


Figure 5.1 Relative loadings when compared to base for FAR BMP across all weather conditions

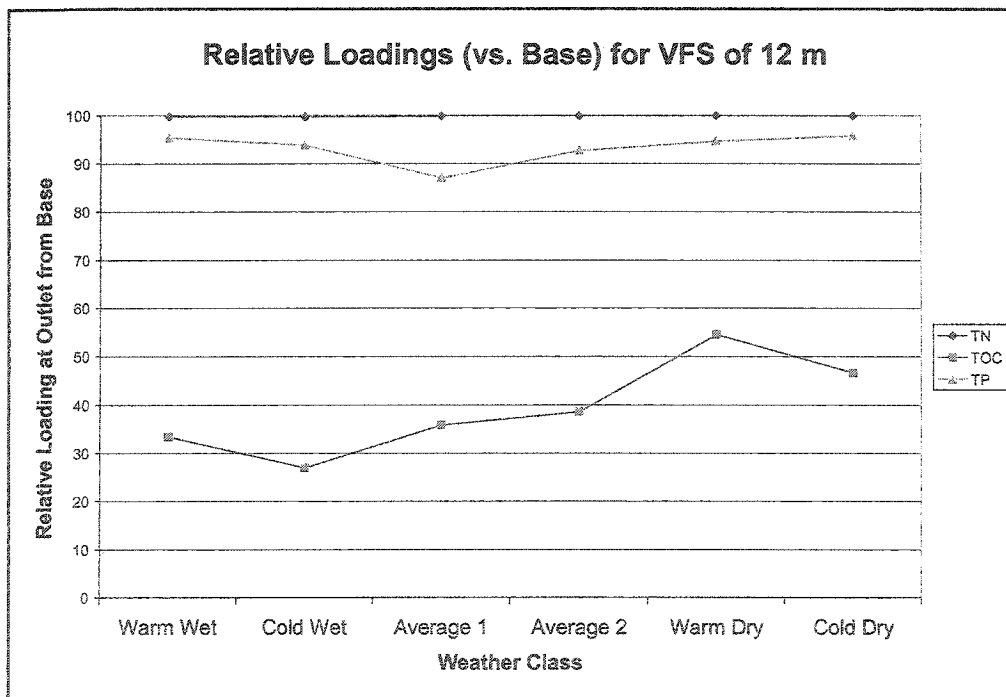


Figure 5.2: Relative loadings when compared to base for VFS BMP across all weather conditions

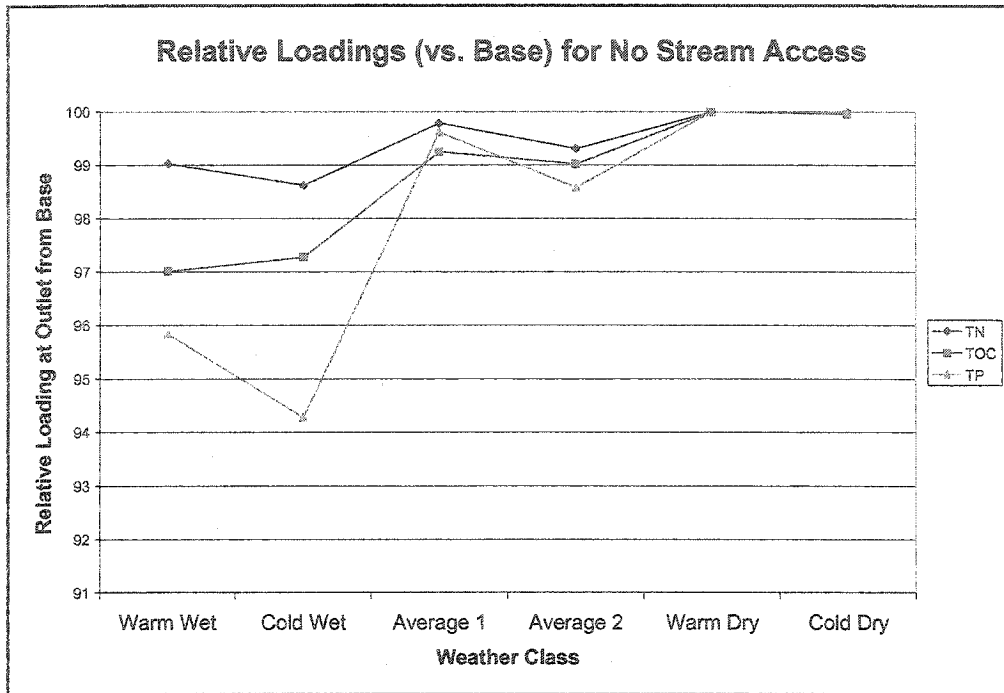


Figure 5.3 Relative loadings when compared to base for reduced stream access BMP across all weather conditions

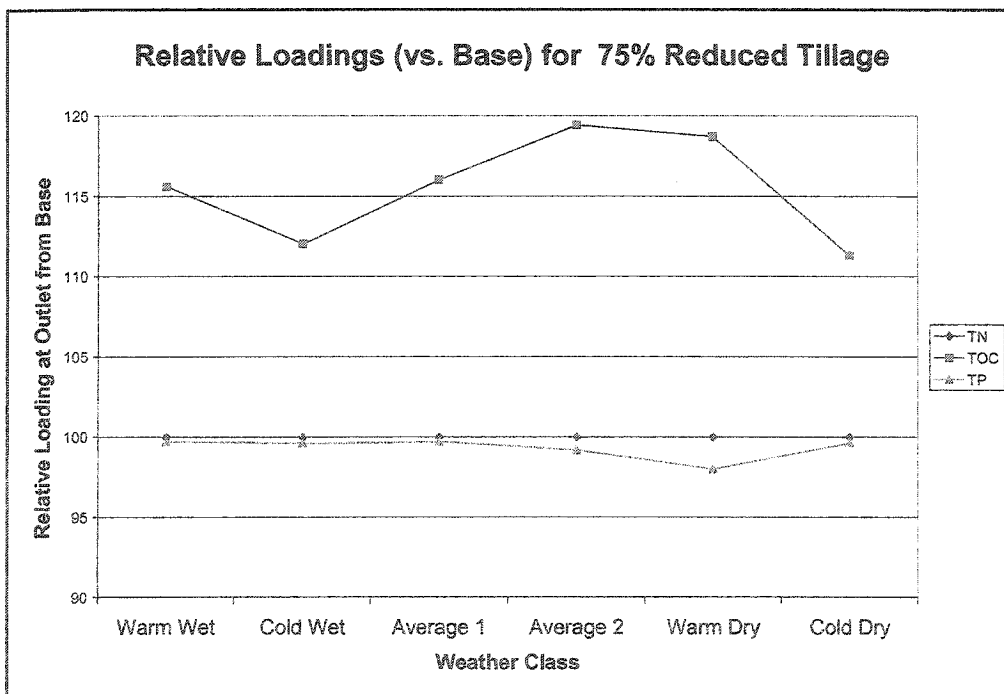


Figure 5.4: Relative loadings when compared to base for reduced tillage BMP across all weather conditions

5.3.4 OVERALL BMP SCENARIO EFFECTIVENESS

In addition to the individual runs considered as separate entities, an average overall BMP effectiveness was deemed to be of some value in assessing the BMP implementations. Therefore, the effectiveness of representative BMPs at reducing nutrient loadings in the watershed was averaged over all climate scenarios and is presented in this section.

Table 5.17: Averaged Overall BMP Effectiveness¹ (in %)

	FAR = 50% of Base			VFS of 12 m			No Stream Access			75% Reduced Tillage		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)
Feb	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	22 (0/73)	1 (0/2)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	-13 (-43/0)	0 (0/1)
Mar	11 (1/38)	0 (0/0)	29 (7/49)	0 (0/0)	73 (44/85)	9 (3/14)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	-19 (-42/-1)	1 (0/5)
Apr	3 (0/5)	0 (0/0)	15 (3/23)	0 (0/0)	66 (9/91)	4 (1/7)	0 (0/0)	0 (0/1)	0 (0/0)	0 (0/0)	-7 (-12/-1)	0 (0/0)
May	9 (0/39)	0 (0/0)	9 (0/20)	0 (0/0)	22 (0/51)	2 (0/4)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	-1 (-4/0)	0 (0/1)
Jun	19 (0/35)	0 (0/0)	26 (0/48)	0 (0/0)	43 (0/80)	6 (0/11)	4 (0/10)	2 (0/4)	12 (0/28)	0 (0/0)	-4 (-6/0)	0 (0/0)
Jul	15 (0/27)	0 (0/0)	23 (0/48)	0 (0/0)	34 (0/58)	5 (0/13)	1 (0/4)	1 (0/4)	1 (0/4)	0 (0/0)	-5 (-12/0)	0 (0/1)
Aug	29 (17/34)	0 (0/0)	41 (18/53)	1 (0/3)	67 (41/89)	11 (5/19)	1 (0/4)	2 (0/8)	10 (0/30)	0 (0/0)	-20 (-33/-11)	0 (0/1)
Sep	13 (0/25)	0 (0/0)	20 (0/37)	0 (0/0)	40 (0/69)	4 (0/7)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	-18 (-48/0)	1 (0/2)
Oct	7 (0/15)	0 (0/0)	9 (0/22)	0 (0/0)	27 (0/60)	2 (0/4)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	-12 (-40/0)	1 (0/2)
Nov	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)	0 (0/0)
Dec	11 (0/18)	0 (0/0)	16 (0/28)	0 (0/0)	47 (0/70)	4 (0/7)	2 (0/5)	1 (0/5)	8 (0/24)	0 (0/0)	-26 (-19/0)	1 (0/1)
Annual	10 (5/23)	0 (0/0)	24 (15/45)	0 (0/0)	61 (45/73)	7 (4/13)	1 (0/1)	1 (0/3)	2 (0/6)	0 (0/0)	-16 (-19/-11)	1 (0/2)

¹The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case. The effectiveness in this table has then been averaged over all 6 climate scenarios. Min and max values are indicated in parentheses beneath the averaged figure.

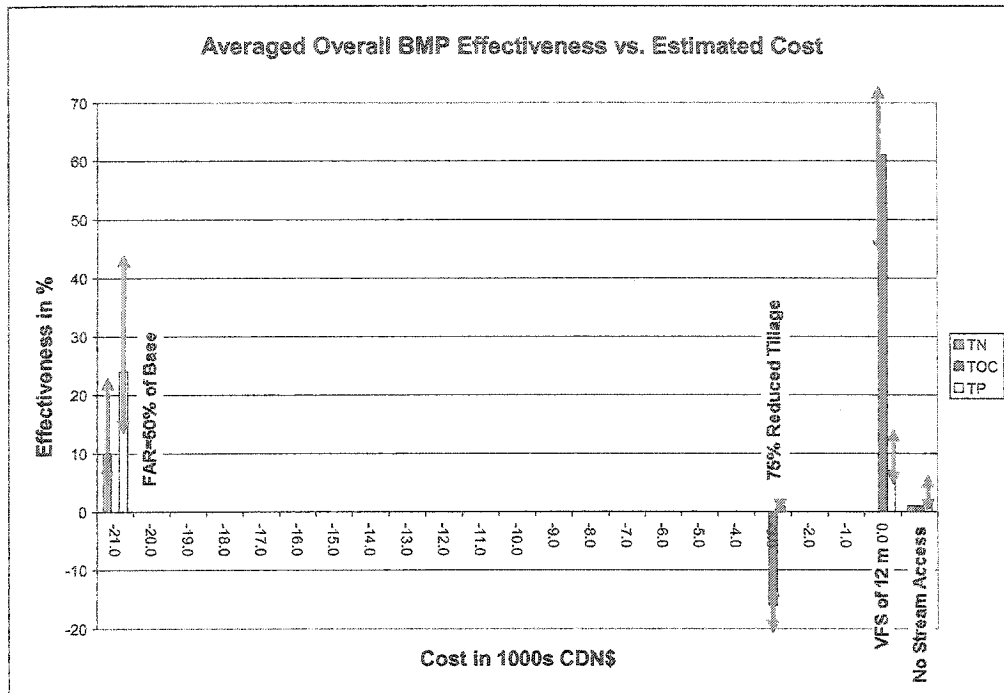


Figure 5.5: Average Overall BMP Effectiveness vs. Estimated Cost (as outlined in Section 6.3.6)

Table 5.18: Averaged Overall Compound BMP Effectiveness¹ (in %)

Month	All BMPs Applied Heavily			All BMPs Applied Moderately			FAR, VFS Applied Heavily			FAR, VFS Applied Moderately		
	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP	TN	TOC	TP
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	22	1	0	17	1	0	22	1	0	0	0
Mar	11	73	34	7	60	23	11	73	33	7	63	23
Apr	3	66	17	2	56	11	3	66	17	2	57	11
May	9	22	10	6	18	7	9	22	10	6	19	7
Jun	20	43	32	13	37	20	19	43	29	12	37	19
Jul	15	34	25	10	28	18	15	34	25	10	29	18
Aug	30	67	46	19	55	34	30	67	46	19	57	33
Sep	7	26	10	4	21	7	7	27	9	4	23	6
Oct	0	0	0	0	0	0	0	0	0	0	0	0
Nov	11	46	18	7	36	13	11	47	17	7	40	12
Dec	10	60	28	6	50	19	10	61	27	6	52	18
Annual	(5/24)	(45/73)	(17/51)	(3/14)	(36/61)	(12/35)	(5/23)	(45/73)	(17/51)	(3/14)	(39/62)	(12/35)

¹ The effectiveness is calculated as the percentage reduction in nutrient concentration reaching the watershed outlet when compared with the base case. The effectiveness in this table has then been averaged over all 6 climate scenarios. Min and max values are indicated in parentheses beneath the averaged figure.

Tables 5.17 and 5.18 confirm some observations from Section 5.3.3., and allow for an overall comparison of BMP effectiveness independently of climate conditions. The efficiency of the FAR and VFS BMPs is again greater than that of the stream access and tillage controls. Additionally, the relative removal potential of the nutrient types is roughly 10% for TN, 30% for TP, and in excess of 50% for TOC when averaged over all the climate scenarios examined.

Figure 5.5 presents a visual comparison of the relative cost and effectiveness of each management practice in nutrient reduction at the outlet. The BMPs to the right of the figure are less costly (a potential profit is displayed as a negative cost value) and those to the left are the most costly. Costs are based on the calculations presented in Section 6.3.

5.3.5 WATER QUALITY MODEL RESULTS

The water quality criteria used, as mentioned in Section 4.4, are based upon the CCME (Environmental Service, 1999) criteria for freshwater-aquatic life as well as eutrophication criteria.

Tables 5.19 to 5.24 reflect the degree of improvement, from a standards point-of-view, of the nutrient-related parameters that were generated by the simulations. It should be noted that for clarity these tables omit violations relating to daily phosphorus and dissolved oxygen (DO) criteria, since these were extremely frequent and nearly identical among all the runs for a given climate scenario.

Table 5.19: Water Quality Improvement with BMP Implementation for Climate Scenario 1
(synthetic average case)

Scenario	Violations of Water Quality Criteria		Meets Permissible Loading for Eutrophication?	
	Yearly sum	(% Improvement)	TN	TP
Base	48	0	N	N
All BMPs applied heavily	42	13	N	N
All BMPs applied moderately	43	10	N	N
FAR, VFS applied heavily	42	13	N	N
FAR, VFS applied moderately	43	10	N	N

Table 5.20: Water Quality Improvement with BMP Implementation for Climate Scenario 2
(historical average case)

Scenario	Violations of Water Quality Criteria		Meets Permissible Loading for Eutrophication?	
	Yearly sum	(% Improvement)	TN	TP
Base	80	0	Y	N
All BMPs applied heavily	69	14	Y	N
All BMPs applied moderately	73	9	Y	N
FAR, VFS applied heavily	69	14	Y	N
FAR, VFS applied moderately	73	9	Y	N

Table 5.21: Water Quality Improvement with BMP Implementation for Climate Scenario 3 (warm wet case)

Scenario	Violations of Water Quality Criteria		Meets Permissible Loading for Eutrophication?	
	Yearly sum	(% Improvement)	TN	TP
Base	77	0	Y	N
All BMPs applied heavily	70	9	Y	N
All BMPs applied moderately	72	6	Y	N
FAR, VFS applied heavily	70	9	Y	N
FAR, VFS applied moderately	72	6	Y	N

Table 5.22: Water Quality Improvement with BMP Implementation for Climate Scenario 4 (warm dry case)

Scenario	Violations of Water Quality Criteria		Meets Permissible Loading for Eutrophication?	
	Yearly sum	(% Improvement)	TN	TP
Base	71	0	Y	N
All BMPs applied heavily	65	8	Y	N
All BMPs applied moderately	66	7	Y	N
FAR, VFS applied heavily	65	8	Y	N

FAR, VFS applied moderately	66	7	Y	N
-----------------------------	----	---	---	---

Table 5.23: Water Quality Improvement with BMP Implementation for Climate Scenario 5 (cold wet case)

Scenario	Violations of Water Quality Criteria		Meets Permissible Loading for Eutrophication?	
	Yearly sum	(% Improvement)	TN	TP
Base	71	0	Y	N
All BMPs applied heavily	65	8	Y	N
All BMPs applied moderately	66	7	Y	N
FAR, VFS applied heavily	65	8	Y	N
FAR, VFS applied moderately	66	7	Y	N

Table 5.24: Water Quality Improvement with BMP Implementation for Climate Scenario 6 (cold dry case)

Scenario	Violations of Water Quality Criteria		Meets Permissible Loading for Eutrophication?	
	Yearly sum	(% Improvement)	TN	TP
Base	68	0	Y	N
All BMPs applied heavily	64	6	Y	N
All BMPs applied moderately	64	6	Y	N
FAR, VFS applied heavily	64	6	Y	N
FAR, VFS applied moderately	64	6	Y	N

The results presented in Tables 5.19-5.24 show that number of CCME standard violations may be reduced by between 5 and 15% depending on the extent of BMP implementation and the climate conditions, although the reduction is typically less than 10% which is little improvement. In addition, there does not appear to be an increased compliance with the eutrophication loading standards regardless of BMP or climate scenario.

5.3.6 BIOLOGICAL INDICES RESULTS

As discussed in Section 4.5, a biological stressing equation was developed for the species present in the South Nation watershed. The water quality results as generated by CE-QUAL-

RIV1 were then input into Equation 4-1 and corresponding stress values were obtained on a daily basis for the watershed. These results are presented in the following tables.

Table 5.25: Stress Ratings for Climate Scenario Bases Cases

	Synthetic Average Case	Historical Average Case	Warm Wet Case	Warm Dry Case	Cold Wet Case	Cold Dry Case
Number of Stress Events	171.0	198.0	189.0	187.0	176.0	173.0
Number of Stress Days	364.0	364.0	364.0	364.0	364.0	364.0
Max Stress Intensity	232.0	244.0	240.0	196.0	252.0	202.0
Avg Stress	81.1	70.2	73.9	68.5	70.9	67.6
Median Stress	90.0	72.0	72.0	72.0	74.0	72.0
95th Percentile	146.0	134.9	138.0	134.0	140.9	134.0
90th Percentile	136.0	112.0	132.0	122.0	119.6	112.0
50th Percentile	90.0	76.0	75.0	73.0	74.0	73.0
10th Percentile	20.0	22.0	16.0	12.2	4.0	4.0
Max Duration	42.0	68.0	65.0	51.0	83.0	82.0
Avg. Duration	2.1	1.8	1.9	1.9	2.1	2.1
Median Duration	1.0	1.0	1.0	1.0	1.0	1.0
95th Percentile	3.5	2.0	2.0	3.0	2.4	3.0
90th Percentile	2.0	1.0	2.0	2.0	1.0	2.0
50th Percentile	1.0	1.0	1.0	1.0	1.0	1.0
10th Percentile	1.0	1.0	1.0	1.0	1.0	1.0

Table 5.26: Effect of BMPs on Stressed States for Climate Scenario 1 (synthetic average case)

	Base Case	All BMPs Applied Heavily	All BMPs Applied Moderately	FAR, VFS Applied Heavily	FAR, VFS Applied Moderately
Number of Stress Events	171.0	161.0	170.0	160.0	170.0
Number of Stress Days	364.0	364.0	364.0	364.0	364.0
Max Stress Intensity	232.0	212.0	222.0	212.0	222.0
Avg. Stress	81.1	77.5	76.3	77.7	75.5
Median Stress	90.0	90.0	78.0	87.0	77.0

Table 5.27: Effect of BMPs on Stressed States for Climate Scenario 2 (historical average case)

	Base Case	All BMPs Applied Heavily	All BMPs Applied Moderately	FAR, VFS Applied Heavily	FAR, VFS Applied Moderately
Number of Stress Events	198.0	193.0	198.0	193.0	196.0
Number of Stress Days	364.0	364.0	364.0	364.0	364.0
Max Stress Intensity	244.0	140.0	188.0	140.0	190.0
Avg. Stress	70.2	65.5	66.6	65.5	67.1
Median Stress	72.0	72.0	72.0	72.0	72.0

Table 5.28: Effect of BMPs on Stressed States for Climate Scenario 3 (warm wet case)

	Base Case	All BMPs Applied Heavily	All BMPs Applied Moderately	FAR, VFS Applied Heavily	FAR, VFS Applied Moderately
Number of Stress Events	189.0	180.0	189.0	180.0	186.0
Number of Stress Days	364.0	364.0	364.0	364.0	364.0
Max Stress Intensity	240.0	146.0	178.0	146.0	194.0
Avg. Stress	73.9	70.1	69.3	70.0	69.8
Median Stress	72.0	70.0	70.0	70.0	70.0

Table 5.29: Effect of BMPs on Stressed States for Climate Scenario 4 (warm dry case)

	Base Case	All BMPs Applied Heavily	All BMPs Applied Moderately	FAR, VFS Applied Heavily	FAR, VFS Applied Moderately
Number of Stress Events	187.0	186.0	187.0	184.0	187.0
Number of Stress Days	364.0	364.0	364.0	364.0	364.0
Max Stress Intensity	196.0	142.0	142.0	142.0	142.0
Avg. Stress	68.5	63.3	65.7	64.3	65.1
Median Stress	72.0	69.0	72.0	71.0	70.0

Table 5.30: Effect of BMPs on Stressed States for Climate Scenario 5 (cold wet case)

	Base Case	All BMPs Applied Heavily	All BMPs Applied Moderately	FAR, VFS Applied Heavily	FAR, VFS Applied Moderately
Number of Stress Events	176.0	172.0	175.0	171.0	175.0
Number of Stress Days	364.0	364.0	364.0	364.0	364.0
Max Stress Intensity	252.0	144.0	176.0	144.0	202.0
Avg. Stress	70.9	63.5	66.0	63.8	65.7
Median Stress	74.0	71.0	72.0	72.0	72.0

Table 5.31: Effect of BMPs on Stressed States for Climate Scenario 6 (cold dry case)

	Run091	Run129	Run130	Run131	Run132
Number of Stress Events	173.0	169.0	172.0	169.0	172.0
Number of Stress Days	364.0	364.0	364.0	364.0	364.0
Max Stress Intensity	202.0	144.0	150.0	144.0	148.0
Avg. Stress	67.6	62.8	64.1	62.7	63.9
Median Stress	72.0	70.0	72.0	70.0	71.0

Table 5.32: Average Effectiveness of BMPs on Stressed States for all Climate Scenarios

	Run109	Run110	Run111	Run112
Number of Stress Events	3.0%	0.3%	3.4%	0.7%
Number of Stress Days	0.0%	0.0%	0.0%	0.0%

Max Stress Intensity	31.6%	22.8%	31.6%	20.0%
Avg. Stress	6.9%	5.6%	6.6%	5.8%
Median Stress	2.3%	3.1%	2.2%	4.0%

Tables 5.25 to 5.32 present a somewhat bleak picture. The South Nation River is essentially in a continually stressed state, regardless of BMP implementation or climate scenario. Additionally, even extensive use of BMPs led to less than a 10% reduction in average stress levels in the system. The BMPs do however, lead to a substantial decrease in maximum stress intensity, with an effectiveness as high as 30% or so, as shown in Table 5.32. These results should certainly somewhat disappoint managers of the watershed; however, the reduction in maximum stress levels does seem to be an attainable and perhaps worthwhile goal.

CHAPTER 6

ANALYSIS

6.1 OVERVIEW

The results summarized in Chapter 5 were subjected to analyses from a series of approaches. The overall feasibility, as well as the economic viability of individual scenarios was first examined, to provide an estimate of the effectiveness of factors not considered directly within the AnnAGNPS package. A review of the raw pollutant loading and parameter results was then conducted, to judge the relative effectiveness and behavior of individual and aggregate BMPs.

Finally, the post-processing results pertaining to water quality and biological suitability were examined, to identify trends and usefulness of management scenarios from an in-stream surface water perspective.

6.2 FEASIBILITY OF BMP IMPLEMENTATION

In this section the feasibility of successfully employing each of the management practices under the case matrix presented in Chapter 5 is considered. This section is not concerned with the degree of effectiveness or the economics of the management practices, which are addressed under other sections, but rather with the logistics and probability of deploying these practices on a watershed scale.

6.2.1 FERTILIZER APPLICATION RATES

Fertilizer appears to almost universally be over applied throughout most watersheds (AAFRD, 2001; Shepard, 2002). Indeed, even farmers with nutrient management plans typically over apply fertilizer, although to a lesser extent than farmers not participating in these plans. Reasons listed for not participating range from lack of time or trust to concern over yields and profits (Shepard, 2002).

Providing farmers with the opportunity to participate in clearly designed nutrient management plans with attainable goals appears to be an effective strategy in improving farmer education and reducing fertilizer application on a watershed level (NRCS, 2000; Shepard, 2002).

6.2.2 VEGETATIVE FILTER STRIPS

Many farmers are currently employing some type of buffer around major waterways (AAFRD, 2001). Unfortunately, for a buffer zone to act as a VFS, it needs to be properly designed. Additionally, buffer zones are often poorly placed and maintained (Smith et al., 1992; Rauniyar and Parker, 1998).

It appears from the literature that there is certainly interest in employing filter strips around waterways in most watersheds. Improved farmer education on the design and operation of these systems appears to be a promising approach for adapting existing esthetic buffer zones into functional filter strips.

6.2.2 STREAM ACCESS

The farmer adoption rate of fencing off waterways and water access to livestock is low in many watersheds, and support for such action is typically low (Rauniyar, 1998; AAFRD, 2001). Although farmers typically understand the potential benefits of managing livestock access to water, there is unwillingness to accept fencing costs. There is also some dispute as to what constitutes a viable fence and to whom responsibility for fencing particular sites should fall (Rauniyar and Parker, 1998; Mayer and Edwards, 1999).

6.2.2 REDUCED TILLAGE

The adoption of no-tillage systems does not appear to currently be an attractive option to many farmers. IWRP (2000) found that while 57% of farmers in a surveyed watershed had some interest in no-till or reduced till, more than 40% had never tried reduced tillage system, and more than a third of those who tried low-till systems had since abandoned it. Major reasons cited for lack of adoption of reduced-till systems were a perceived lower yield, machinery costs, weed problems, and the reluctance to learn a new system.

Despite these setbacks, it seems that some reduction in tillage on the watershed level can be achieved, although adoption rates may vary between groups of farmers considerably (IWRP, 2000). Increased farmer education and aid in transitioning to a reduced-till system may perhaps further improve adoption rates amongst reluctant farmers.

6.2.3 FEASIBILITY OF EXAMINED SCENARIOS

Table 6.1 presents a brief summary of the feasibility of implementing management scenarios in the South Nation watershed, based on the analysis conducted under the preceding

sections. The feasibility score indicated is intended to represent the likelihood of obtaining a net result over the entire watershed when compared with the current condition, represented by the base case scenario.

Table 6.1: Speculated Feasibility of Watershed-Level Implementation of Simulated Management Scenarios

Scenario	Management Practice	Speculated Feasibility
1	BASE CASE	-
2	FAR = 50%	Low
3	FAR = 60%	Low
4	FAR = 70%	Medium
5	FAR = 80%	High
6	FAR = 90%	High
7	VFS = 3 m	High
8	VFS = 6 m	High
9	VFS = 9 m	Medium
10	VFS = 12 m	Medium
11	No Stream Access	Low
12	1/3 Stream Access	Low
13	1/2 Stream Access	Low
14	2/3 Stream Access	Medium
15	3/4 Stream Access	High
16	75% Reduced Tillage	Low
17	50% Reduced Tillage	Low
18	25% Reduced Tillage	Medium
109	Best of all BMPS	Low
110	Typical BMPs	Medium
111	Best of FAR and VFS	Low
112	Typical FAR and VFS	High

6.3 ECONOMICS

This section examines the economics of employing BMPs in the South Nation watershed. The analysis presented here is by no means comprehensive, and does not consider the social and economic benefits of improving water quality throughout the watershed. Nevertheless, the figures do provide some additional insight into the potential economic viability of each management practice.

6.3.1 FERTILIZER APPLICATION RATES

The economics of fertilizer application are difficult to estimate, since below a certain threshold of fertilizer application, the crop production per unit area will decrease. The analysis presented here assumes that fertilizer is not reduced to the point where it becomes limiting, since

farmers typically substantially over apply fertilizer (Shepard, 2002). The base cost of fertilizer application in the watershed can be calculated according to Equation 6-1,

$$TC_{fa} = Area \times FAR \times Cost \quad (6-1)$$

where

TC_{fa}	=	Total cost of fertilizer application (\$/yr)
Area	=	Area to be enriched (m^2)
FAR	=	Fertilizer application rate ($kg/m^2/yr$)
Cost	=	Cost of the fertilizer (\$/kg)

The equation excludes the costs of fertilizer dispersal and integration, and considers only the cost of the fertilizer itself.

The area to which commercial fertilizer is applied in the South Nation watershed is approximately 1455 km^2 (Statistics Canada, 1997). Typical application rates by farmers are 9600 kg/km^2 of N and 9000 kg/km^2 of P (Shepard, 2002). The cost of fertilizer is approximated in the analysis as \$0.66 CDN/kg of N and \$0.69 CDN/kg of P (Duvick, 1995). The savings by reducing the FAR in the watershed are then calculated according to Equation 6-2.

$$S_{FAR} = P_{FAR} \cdot A_{FAR} \cdot (FAR_N \cdot C_N + FAR_P \cdot C_P) \quad (6-2)$$

where

S_{FAR}	=	Total savings from reduced fertilizer application (\$)
P_{FAR}	=	Percent reduction of application rate (-)
A_{FAR}	=	Total area (km^2)
FAR_N	=	Fertilizer application rate for N (kg/km^2)
C_N	=	Cost per unit mass of N-fertilizer (\$/kg)
FAR_P	=	Fertilizer application rate for P (kg/km^2)
C_P	=	Cost per unit mass of P-fertilizer (\$/kg)

Table 6.2: Watershed-Level Economics of Fertilizer Reduction

FAR	Fertilizer Cost Savings in \$1000s CDN ¹		
	1-yr	5-yr	10-yr
50% of base	9160	43866	83214
60% of base	7330	35092	66571
70% of base	5500	26319	49928
80% of base	3660	17546	33286

90% of base	1830	8773	16643
-------------	------	------	-------

¹ All costs are calculated in 2003 dollars, using an interest rate of 5%/yr and an inflation rate of 3%/yr.

6.3.2 VEGETATIVE FILTER STRIPS

The costs associated with implementing VFSs can be broken down into three major components: land opportunity, initial setup, and yearly maintenance costs. Typical levels for these expenses are presented in Table 6.3, and assume a simple grass or hay-based filter strip. The yearly mowing costs apply to grass systems, while the baling costs apply to hay systems where the vegetation is harvested and marketed.

Table 6.3: Typical Expenses in Filter Strip Implementation

Expense	Cost in \$/km ² of VFS ¹
Land opportunity cost	61040 ²
Seed cost	4297 ³
Labor cost	12678 ²
Yearly mowing cost	23477 ²
Yearly baling cost	66675 ²

¹ All costs have been converted to Canadian dollars using an exchange rate of \$1.5 CDN to \$1 US. All costs have also been adjusted to 2003 levels using an inflation rate of 3%/yr.

² Source: Duvick, 1995

³ Source: Nakao et al., 1999

The cost of such a system can then be calculated using Equation 6-3.

$$C_{vfs} = A_{vfs} \times UC_{vfs} \quad (6-3)$$

where C_{vfs} = Total cost of VFS (\$)
 A_{vfs} = Total area of VFS (km²)
 UC_{vfs} = Cost per unit area of filter strip (\$/km²)

In the South Nation watershed, the channel length as defined by the TOPAZ program for the highest 6 Strahler stream orders is approximately 1460 km. Assuming VFS are implemented equally on each side of the stream, the area can be approximated as shown in Equation 6-4.

$$A_{vfs} = 2920km \frac{L_{vfs}}{1000} \quad (6-4)$$

where A_{vfs} = Total area of VFS (km²)
 L_{vfs} = Length of VFS (m)

It is now possible to consider the approximate cost of VFS implementations in the South Nation watershed under several scenarios. Tables 6.4 and 6.5 contain cost calculations using the above data.

Table 6.4: Watershed-Level Economics of a Grass VFS system

VFS Length (m)	Total Area (km ²)	Cumulative Cost in \$1000s CDN ¹		
		1-yr cost	5-yr cost	10-yr cost
3	9	889	3695	6876
6	18	1778	7390	13751
9	26	2667	11084	20627
12	35	3556	14779	27503

¹All costs are calculated in 2003 dollars, using an interest rate of 5%/yr and an inflation rate of 3%/yr.

Table 6.5: Watershed-Level Economics of a Hay VFS system

VFS Width (m)	Total Area (km ²)	Cumulative Cost (Profit) in \$1000s CDN ¹		
		1-yr cost	5-yr cost	10-yr cost
3	9	889	247	(248)
6	18	1778	493	(497)
9	26	2667	740	(745)
12	35	3556	987	(994)

¹All costs are calculated in 2003 dollars, using an interest rate of 5%/yr and an inflation rate of 3%/yr.

Naturally, the hay system, in which a marketable product is harvested each year, costs substantially less over an extended period than the grass system. Indeed, as can be seen in Table 6.5, the hay system can potentially generate income within a 10-year period.

6.3.3 STREAM ACCESS

Estimating the cost of reducing livestock access to streams is a difficult process on a watershed level. In some areas, natural barriers and riparian zones may be sufficient; while in others extensive fencing may be required. This analysis assumes that livestock currently has access to 25% of the South Nation river system (2920 km, as approximated under Section 6.3.2), or 730 km. This estimation is very rough, but in line with indicators from other reports (CH2M Hill, 2001; AAFRD, 2001). The total cost for installation of barbed wire fence, adjusted to 2003 Canadian dollars, is estimated as \$ 3.0 CDN/meter, with an average annual maintenance cost of \$ 0.24 CDN/meter over a useful lifetime of 20-years (Mayer and Edwards, 1999). The cost of

reducing stream access can thus be estimated as Equation 6-5, with an additional maintenance cost calculated from the same equation on a yearly basis. Estimated costs for the scenarios considered in the simulation are presented in Table 6.6.

$$C_{rsa} = \frac{P_{sar}}{100} \cdot L_{sa} \cdot C_{fence} \quad (6-5)$$

where C_{rsa} = Cost of reducing stream access (\$)
 P_{sar} = Percent of stream access reduction (-)
 L_{sa} = Length of stream access in watershed (km)
 C_{fence} = Cost per unit length of fence (\$/km)

Table 6.6: Watershed-Level Economics of Reduced Stream Access

Stream Access (Relative to Base)	Fenced Length (km)	Cumulative Cost in \$1000s CDN ¹		
		1-yr	5-yr	10-yr
0%	730	2190	2850	3603
33%	487	1460	1900	2402
50%	365	1095	1425	1802
67%	243	730	950	1201
75%	183	548	713	901

¹ All costs are calculated in 2003 dollars, using an interest rate of 5%/yr and an inflation rate of 3%/yr.

6.3.4 REDUCED TILLAGE

The cost structure of no till management for crop production is somewhat different from that of conventional tillage systems. Costs associated with the fertilizer incorporation and tillage steps are eliminated from no till schemes. However, supplemental seed drilling costs are usually required. Typical costs for both management scenarios are presented in Table 6.7.

Table 6.7: Cost of Conventional vs. No Tillage Management Scenarios

Expense	Costs per km ² in \$CDN ¹	
	Conventional Till ²	No Till ²
Lime Application	2817	2817
Broadcast Fertilizer	1643	1643
Incorporate Fertilizer	3287	0
Finn Seedbed	2817	0
Drill Seed	4695	5634
Total Equipment and Labor Costs	15260	10095

¹ All costs have been converted to Canadian dollars using an exchange rate of \$1.5 CDN to \$1 US. All costs have also been adjusted to 2003 levels using an inflation rate of 3%/yr.

² Source: Duvick, 1995

However, changing the degree of tillage will also affect the opportunity cost of the land. Duvick (1995) suggests that the opportunity cost associated with crop production under a no till management system is roughly \$4080 CDN/km² (adjusted to 2003 levels). The net savings of reduced tillage per year is then Equation 6-6:

$$Sav_{NT} = C_{NT} \cdot A_{NT} \quad (6-6)$$

where Sav_{NT} = Net savings of reduced tillage per year (\$)
 C_{NT} = Total savings per unit area of reduced tillage (\$/km²) = \$1088
 CDN/km²
 A_{NT} = Area to which the reduced tillage management is applied (km²)

The approximate area used for crops in the South Nation watershed is roughly 1500 km² (CH2M Hill, 2001; Statistics Canada, 1997). Table 6.8 considers the potential savings of the reduced tillage scenarios examined in the case matrix.

Table 6.8: Watershed-Level Economics of Reduced Tillage

Reduction in Tillage Area (%)	No-Till Area (km ²)	Cumulative Savings in \$1000s CDN ¹		
		1-yr	5-yr	10-yr
75%	1125	1224	6015	12003
50%	750	816	4010	8002
25%	375	408	2005	4001

¹ All costs are calculated in 2003 dollars, using an interest rate of 5%/yr and an inflation rate of 3%/yr.

6.3.5 REDUCED WATER POLLUTION

The effects of reduced nutrient and sediment loading, along with improved water quality, clearly lead to social benefits. Estimating the economic benefit of these improvements, however, is more difficult. Estimates of value per kg of pollutant vary greatly in the literature (IRMP, 2000; Schultz et al., 1997).

6.3.6 COSTS OF EXAMINED SCENARIOS

The costs for each scenario examined in the case matrix, calculated according to the methods presented in Sections 6.3.1 to 6.3.4., are presented in Table 6.9. Savings and costs for a theoretical 10 km² farm are presented in the last common of the table for comparison purposes.

Table 6.9: Watershed-Level Economics of Simulated Scenarios

Scenario	Management Practice	10-yr Return (Cost) in \$1000s CDN ¹	Avg. Return (Cost) per Year in \$1000s CDN ¹	Equivalent Return (Cost) for a 10km ² farm in \$1000s CDN ¹
1	BASE CASE	-	-	-
2	FAR = 50%	83214	8321	21
3	FAR = 60%	66571	6657	17
4	FAR = 70%	49928	4993	13
5	FAR = 80%	33286	3329	9
6	FAR = 90%	16643	1664	4
7	VFS = 3 m	248	25	0
8	VFS = 6 m	497	50	0
9	VFS = 9 m	745	75	0
10	VFS = 12 m	994	99	0
11	No Stream Access	(3603)	(360)	(1)
12	1/3 Stream Access	(2402)	(240)	(1)
13	1/2 Stream Access	(1802)	(180)	0
14	2/3 Stream Access	(1201)	(120)	0
15	3/4 Stream Access	(901)	(90)	0
16	75% Reduced Tillage	12003	1224	3
17	50% Reduced Tillage	8002	816	2
18	25% Reduced Tillage	4001	408	1
109	Best of all BMPS	183647	18365	47
110	Typical BMPs	66328	6633	17
111	Best of FAR and VFS	84208	8421	22
112	Typical FAR and VFS	33783	3378	9

¹ All costs are calculated in 2003 dollars, using an interest rate of 5%/yr and an inflation rate of 3%/yr.

The values presented in Table 6.9 do not consider the socio-economic benefits of improved water quality. They illustrate however that, given the correct circumstances, the implementation of better management practices can be profitable even before considering social benefits and downstream economic gains.

6.4 WATER QUALITY ANALYSIS

The water quality simulation, for all scenarios that were run, yielded results that were in frequent violation of the CCME criteria. Indeed, the total phosphorus criteria were violated on a near-daily basis, and the DO levels fell outside the recommended levels on several occasions as well, although never severely nor as frequently as in the case of the phosphorus. These problems were not generally well addressed by the BMP implementation scenarios, although there are notable exceptions such as the high reduction in carbon loadings under VFS scenarios.

However, there was a change in the frequency of violations of the other water quality criteria considered, due mostly to the reduced nitrogen loadings. The maximum improvement

was only a reduction in breaches over the simulation period of about 15%, which is fairly small, and of course does not address the issue of severity of each individual breach.

The simulation data indicate that nitrogen and phosphorus are the limiting stressors in the South Nation watershed, as they are frequently in severe violation of recommended levels and dominate the 'stressed' days. It is clear that the BMPs can potentially offer some improvement of water quality levels through the substantial reductions in loadings as observed in Section 6.4, however these improvements do not appear to be sufficient to meet typical provincial standards by themselves.

6.5 BIOLOGICAL INDICES

The biological stress levels permit an examination of tangible assets in the watershed as opposed to criteria that have not been geared specifically for the South Nation watershed. By considering the frequency, duration and relative severity of conditions in the river system from a biological perspective, it was hoped to achieve a more substantial evaluation of the real potential for BMPs in the South Nation region.

The results of employing the BMPs from a biological perspective are interesting. The reduction of stress days is essentially nil, since the South Nation system seems to be, from a biological perspective, constantly a stressful environment.

The major potential benefits observable from the results were decreased severity of major stress states, as well as slightly increased stability of stress conditions from day to day. The BMPs, it appears, can have a softening effect on the stress levels and variations over the course of the year. However, as can be seen from the percentile distributions in Figures 6.1-6.4, the BMPs do not substantially shift typical conditions to more comfortable levels for the biological conditions examined.

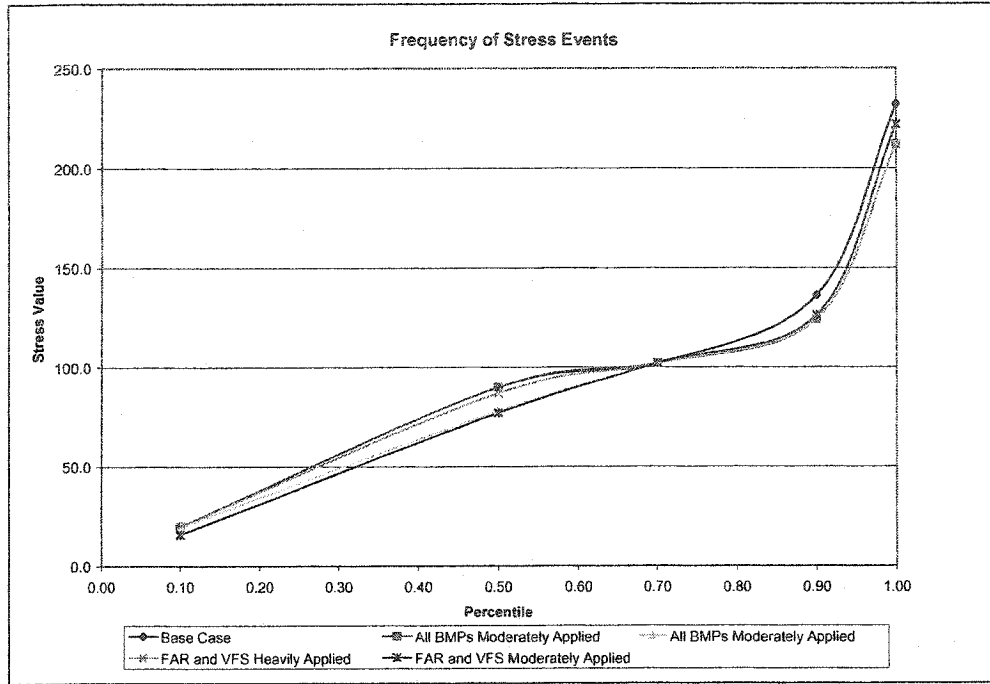


Figure 6.1: Percentile distribution of stress conditions for Climate Scenario 1 (synthetic average case)

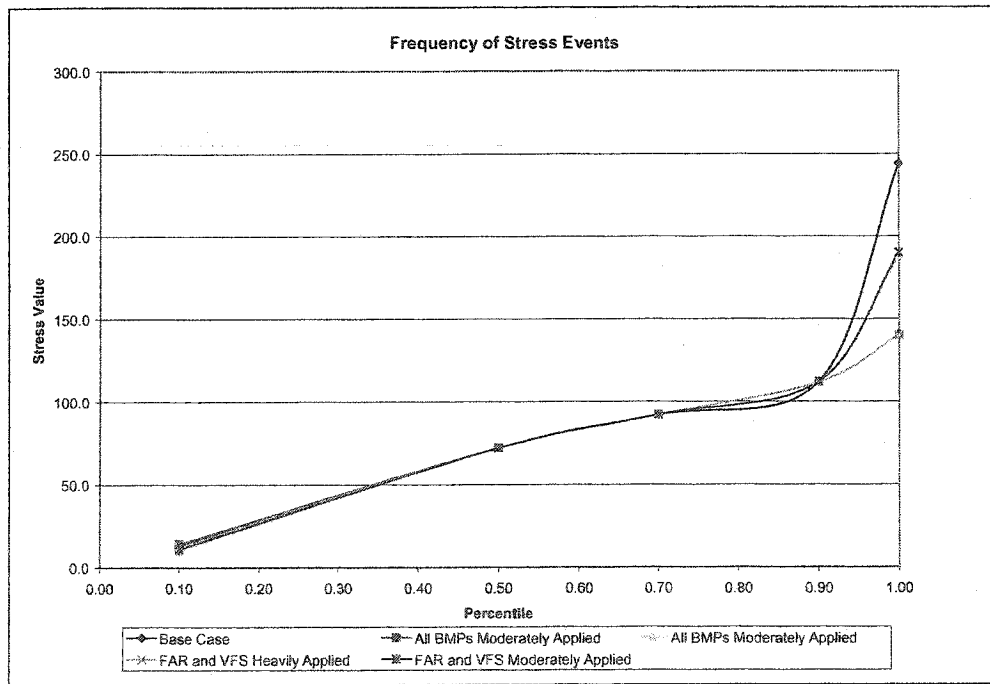


Figure 6.2: Percentile distribution of stress conditions for Climate Scenario 2 (historical average case)

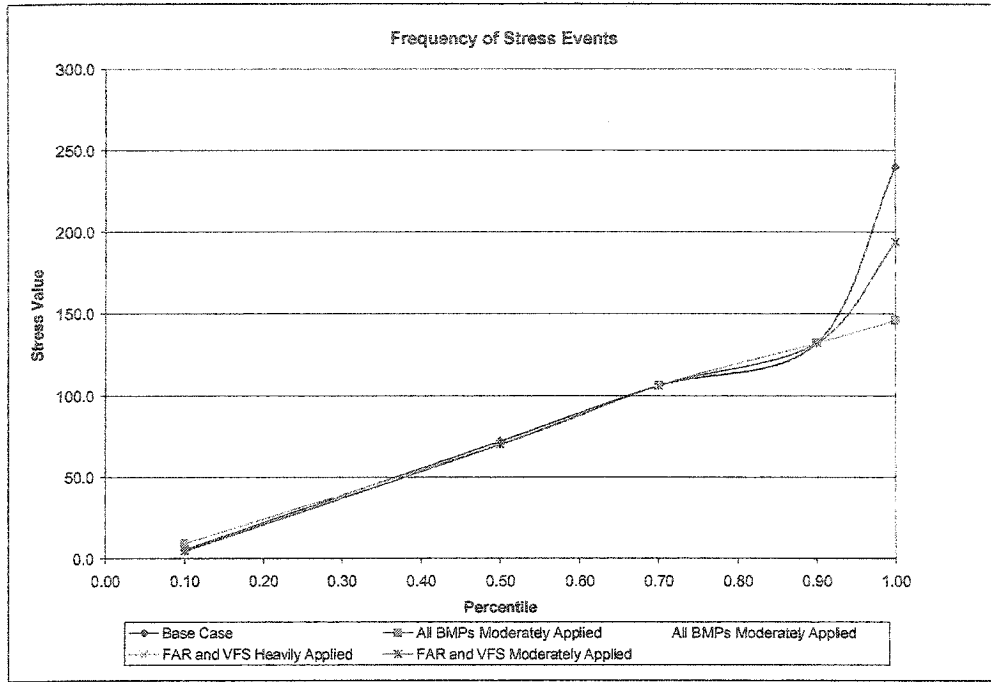


Figure 6.3: Percentile distribution of stress conditions for Climate Scenario 3 (warm wet case)

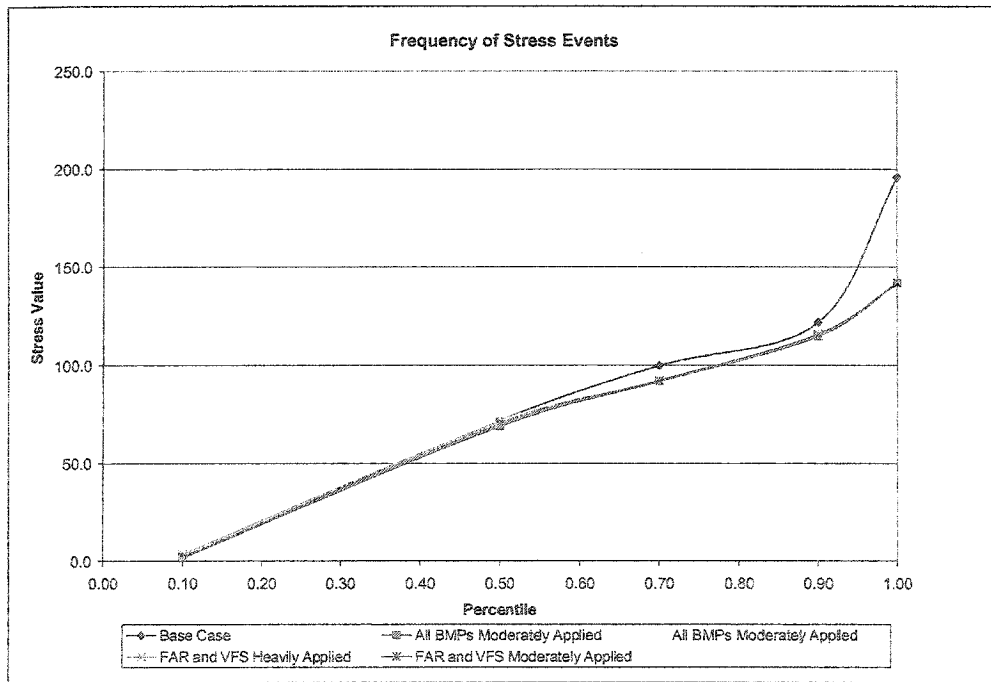


Figure 6.4: Percentile distribution of stress conditions for Climate Scenario 4 (warm dry case)

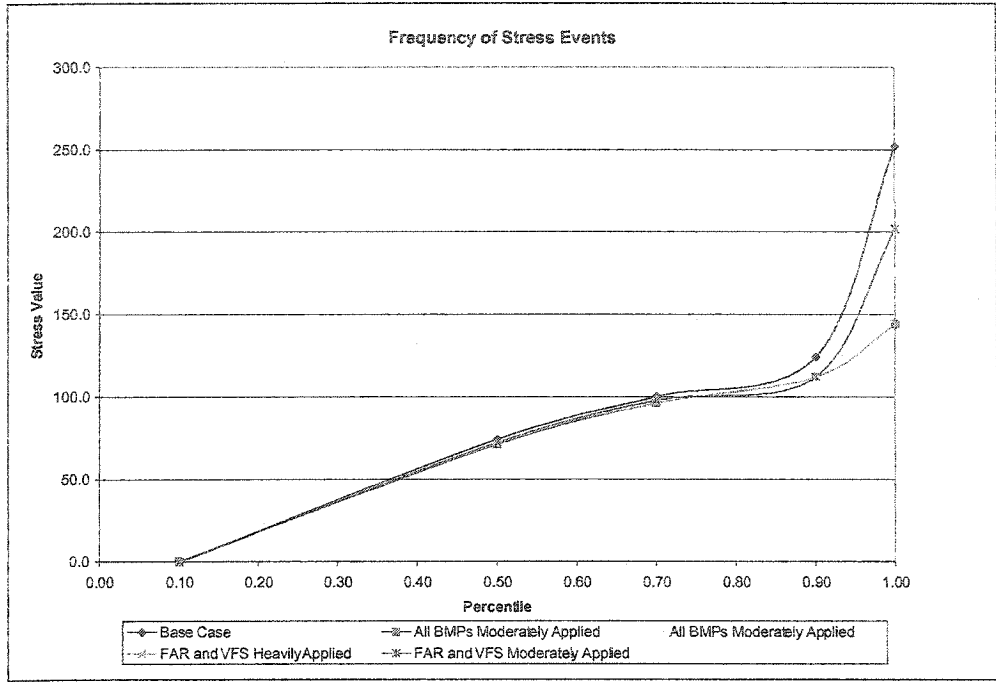


Figure 6.5: Percentile distribution of stress conditions for Climate Scenario 5 (cold wet case)

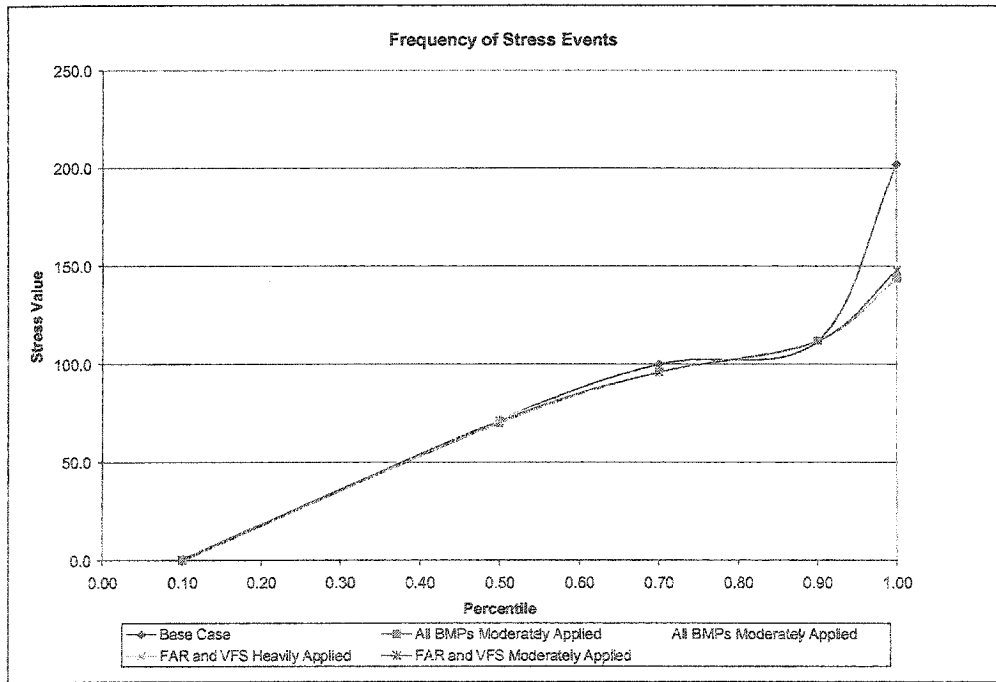


Figure 6.6: Percentile distribution of stress conditions for Climate Scenario 6 (cold dry case)

CHAPTER 7

CONCLUSIONS

7.1 GENERAL COMMENTS

The investigation conducted yielded useful results given the available data; however, several important implications of this analysis must be underlined. It was beyond the scope of the present study to extensively simulate subsurface flow phenomena and nutrient transport, which can be important factors locally in agricultural watersheds. The baseflow method used in lieu of a comprehensive groundwater model was adequate for the task at hand, but certainly not ideal. Nevertheless, it is considered a substantial improvement over studies that ignore this loading component (see, for instance, Suttles et al., 2001), and allows for some correlation and calibration to existing data.

The underlying assumptions of accuracy, from the modeling perspective, of this study, are as follows. While specific local trends may vary considerably from the simulated parameters, the overall watershed nutrient loading behavior is adequately simulated for the purposes of evaluating relative effectiveness of BMPs. This assumption had implications on the calibration, results generation, and analyses presented here. These tasks were conducted to maximize the use of and correlation to available data sources, as was outlined in prior sections. The recommendations and results in this thesis are valid within the given context, and may not be appropriate in other frameworks.

7.2 EFFECTIVENESS OF BEST MANAGEMENT PRACTICES

The relative effectiveness of individual BMPs matched fairly well with observed values from other studies. The FAR and VFS management practices were far more effective than the reduced tillage and stream access approaches, and the potential benefits predicted from the aggregate scenarios including only the top two management practices were essentially identical to those obtained using all four management practices in conjunction.

A further benefit of the FAR and VFS management practices is that they address different areas and complement each other well, providing together a broad reduction of nutrient loading classes. Additionally these management practices are quite feasible, both logistically and economically, and can probably be deployed to a reasonable extent throughout the South Nation watershed.

Unfortunately however, none of the individual or aggregate management practices provide a major improvement in measurable water quality over the course of the year. While it is true that many of the scenarios do substantially reduce annual loadings, the degree of stress states and water standard violations predicted under the new management scenarios do improve only slightly throughout the year. The enhancement in quality conditions is generally small overall and not sufficient to upgrade the water quality class by any measurable amount.

It is therefore the conclusion of this thesis that these best management tools should be made available and encouraged throughout the watershed, due to the relatively low cost and substantial reductions in pollutant loadings they can provide. However they must not be seen as a panacea, and must be considered only partial solutions to integrated watershed management issues. To attain stream provincial standards reduction of agricultural activity is implied.

7.3 RECOMMENDATIONS FOR FUTURE WORK

7.3.1 TECHNICAL

As mentioned previously, a major limitation of the modeling presented in this thesis was the greatly simplified manner in which subsurface flow regimes were handled. A substantial improvement in prediction of local water resource behavior throughout the watershed could likely be attained through use of a subsurface transport package such as MODFLOW.

An additional improvement on this work would be to consider a variety of spatial configurations for management practice implementations. The source accounting capabilities of AnnAGNPS could be coupled with a genetic algorithm similar to that used in the calibration phase to examine optimal cost-benefit allocation for a variety of BMP implementation scenarios.

7.3.2 DATA REQUIREMENTS

As for all but the most fortunate watershed studies, the available data sources were less than ideal. The 'soft' data sources included, in particular, specific information regarding farmer behavior throughout regions of the watershed. Additionally, standardized measurements and practices at locations throughout the watershed would eliminate some of the variation and uncertainty encountered in the model creation phase, and provide a better understanding of local and overall phenomena.

7.3.3 BMP INVESTIGATION AND IMPLEMENTATION

As noted in the study conclusions, BMPs in general, and certain key ones in particular, are a viable component of integrated watershed management plans. Providing educational and decision support tools to encourage and simplify the use of these tools by shareholders throughout the watershed would conceivably present several major benefits. Consider, for instance, the likely benefits of the widespread encouragement and implementation of nutrient management plans would provide, in addition to the social benefit of improved water quality. Firstly, participant farmers would provide commitment to improving their understanding and appreciation of issues relevant to themselves and the entire watershed, thereby increasing the sense of interaction and cooperation in the South Nation. Participants would also present a valuable source of the very data types sought after in Section 7.3.2, through the use of communication tools such as surveys. The rewards for participants are equally attractive, as access to current information and recommendations for management practices could enable farmers to intelligently assess potential costs and benefits of a variety of administration scenarios.

REFERENCES

- Alberta Agriculture Food and Rural Development (2001), "AESA 2001 Farm Survey," Alberta Agriculture Food and Rural Development, Edmonton, AB.
- Alberta Environmental Service (1999), "Surface Water Quality Guidelines for Use in Alberta: 1999," Alberta Environment, Edmonton, AB.
- Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jr., Donigian, A.S., Jr., and Johanson, R.C. (1997), "Hydrological Simulation Program--Fortran, User's Manual for Version 11," U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, Ga.
- Binger, R. and, Theurer, F. (2001), "AnnAGNPS Technical Processes Documentation Version 2," USDA-ARS, Oxford, MS.
- Bosh, D., Theurer, F., Binger, R., Felton, G., and Chaubey, I. (1998), "Evaluation of the AnnAGNPS Water Quality Model," ASAE Paper No. 98-2195, St. Joseph, MI.
- Brown, L., Boone, K., Nokes, S., and Ward, A. (1991), "Agricultural Best Management Practices," AEX-464-91, Ohio State University Extension, Columbus, OH.
- Cerco, C., Bunch, B., Cialone, M. and Wang, H. (1994), "Hydrodynamic and Eutrophication Model Study of Indian River and Rehoboth Bay, Delaware," Technical Report EL-94-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- CH2M Hill (2001), "Eastern Ontario Water Resources Management Study," Ottawa, ON.
- Cook, M.F. and Solomon, R.C. (1987), "Habitat Suitability Index Models: Muskellunge," Biol. Rep. 82 (10.148), US Fish and Wildlife Service, Fort Collins, CO.
- Cumming, J. (2002), "Livestock Statistics," Statistical Services, OMAF and Statistics Canada. Available on the world wide web at <http://www.gov.on.ca/OMAFRA/english/stats/livestock/ctysheep01.html>.
- Dardem, R. and Binger, R. (2001), "AGNPS 2001 Input Data Preparation Model: Technical Reference," v. 2, USDA-ARS, Oxford, MS.
- Deliman, P. N., Glick, R. H., and Ruiz, C. E. (1999), "Review of Watershed Water Quality Models," USACE Technical Report W-99-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Dillaha, T. A., Reneau, R.B., Mostaghimi, S., and Lee, D. (1989), "Vegetative Filter Strips for Agricultural Nonpoint Source Pollution Control," *Trans. A.S.A.E.*, 32: 513-519.
- Dillaha, T. A., Wolfe, M.L., Shirmohammadi, A., and Byne, F.W. (2001), "ANSWERS-2001," Environmental and Water Resources Institute, Washington, DC.
- Duvick, Richard D. (1995), "Farm Custom Rates Paid in Ohio, 1995," Ohio Agricultural Research and Development Center. Ohio State University Extension, Columbus, OH.
- Edwards, E.A., and Twomey, K.A. (1982), "Habitat Suitability Index Models: Common Carp," USDI Fish and Wildlife Service, FWS/OBS-82/10.12, Fort Collins, CO.
- Edwards, E.A., Gebhart, G., and Maughan, O.E. (1983), "Habitat Suitability Information: Smallmouth Bass," USDI Fish and Wildlife Service, FWS/OBS-82/10.36, Fort Collins, CO.

- Edwards, E.D., Krieger, D.A., Bacteller, M., and Maughan, O.E. (1982), "Habitat Suitability Index Models: Black Crappie," USDI Fish and Wildlife Service, FWS/OBS-82/10.6, Fort Collins, CO.
- Garbrecht, J., Martz, L.W., and Binger, R.L. (2000), "TOPAZ Version 3.1: TOPAZ User Manual," USDA-Agricultural Research Service, Washington, DC.
- Goldberg, D.E. (1989), "Genetic Algorithms in Search, Optimization, and Machine Learning," Addison Wesley Publishing Company, New York.
- Gore and Storie (1991), "Final report for the wastewater allocation study South Nation River," South Nation River Conservation Authority, Berwick, ON.
- Hall, R.W. and Dortch, M.S. (1994), "New York Bight Study; Report 2; Development and Application of a Eutrophication/General Water Quality Model," Technical Report CERC-94-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Inskip, P.D. (1982), "Habitat Suitability Index Models: Northern Pike," FWS/OBS-82/10.17, USDI Fish and Wildlife Service, Fort Collins, CO.
- Iowa Residue Management Partnership, (2000), "IRMP Tillage Survey Summary, 1999-2000," USDA-Natural Resources Conservation Service, Des Moines, IA.
- Krieger, D.A., Terrell, J.W., and Nelson, P.E. (1983), "Habitat Suitability Information: Yellow Perch," FWS/OBS-83/10.55, USDI Fish and Wildlife Service, Fort Collins, CO.
- Lowrance, R., Todd, R., Fail, J., Hendrickson, O., Leonard, R., and Asmussen, L. (1984) "Riparian Forests as Nutrient Filters in Agricultural Watersheds," *BioScience*, Vol. 34, No. 6, Athens, GA.
- Matthews, B.C. and Richards, N.R. (1952), "Soil Survey of Dunda County", Report No. 14 of the Ontario Soil Survey, Canada Department of Agriculture, Guelph, ON.
- Matthews, B.C. and Richards, N.R. (1954), "Soil Survey of Stormont County", Report No. 20 of the Ontario Soil Survey, Canada Department of Agriculture, Guelph, ON.
- Matthews, B.C., Richards, N.R., and Wicklund, R.E. (1957), "Soil Survey of Glengarry County", Report No. 24 of the Ontario Soil Survey, Canada Department of Agriculture, Guelph, ON.
- Mayer, R. and Edwards, W. (1999), "Estimated Costs for Livestock Fencing," Report FM-1855, Iowa State University Extension, Ames, IA.
- McMahon, T.E. (1982), "Habitat Suitability Index Models: Creek Chub," FWS/OBS-82/10.4, USDI Fish and Wildlife Service, Fort Collins, CO.
- McMahon, T.E. and Terrell, J.W. (1982), "Habitat Suitability Information: Channel Catfish," U.S. Fish and Wildlife Service, FWS/OBS-82/10.2, Fort Collins, CO.
- McMahon, T.E., Terrell, J.W., and Nelson, P.C. (1984), "Habitat Suitability Information: Walleye," U.S. Fish and Wildlife Service. FWS/OBS-82/10.56m. Fort Collins, CO.
- Minnesota Department of Agriculture (1999), "Useful Nutrient Management Data Factsheet," Saint-Paul, MN.
- Minnesota Pollution Control Agency (2000), "Protecting Water Quality in Urban Areas: Best Management Practices for Urban, Suburban and Developing Areas of Minnesota," Saint-Paul, MN.

- Nakao, M., Sohngne, B., Brown, L., and Leeds, R. (1999), "The Economics of Vegetative Filter Strips," Report No. AE-0006-99, Ohio State University Extension, Columbus, OH.
- Natural Resources Conservation Service, (1986), "Urban Hydrology for Small Watersheds: TR-55," Technical Release 55, USDA-Natural Resources Conservation Service, Washington, DC.
- Natural Resources Conservation Service (2000), "Nutrient Management Planning, Technical Guidance," USDA-Natural Resources Conservation Service, Washington, DC.
- Nebraska Department of Environmental Quality (2002), "2002 Nebraska Groundwater Quality Monitoring Report," Water Quality Assessment Section, Lincoln, NE.
- Neitsch, S.L., Arnold, J.G., Kinikry, J.R., Williams, J.R., and King, K.W. (2002), "Soil and Water Assessment Tool Theoretical Documentation – Version 2000," TWRI Report TR-191, Texas Water River Institute, Temple, TX.
- Park, R.A. (1990), "AQUATOX, a Modular Toxic Effects Model for Aquatic Ecosystems. Final Report," EPA, EPA-026-87, Corvallis, OR.
- Peet, M. (1995), "Sustainable Practices for Vegetable Production in the South," Focus Publishing, Newburyport MA.
- Rauniyar, G.P. and Parker, W.J. (1998), "Constraints to Farm Level Adoption of New Sustainable Technologies and Management Practices in New Zealand Pastoral Agriculture," MAF Policy Technical Paper 98/3, Massey University, Palmerston North, New Zealand.
- Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder (coordinators). "Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)," U.S. Department of Agriculture, Agr. Handb. No 703, 1997.
- Schultz, R.C., Wray, P.H., Colletti, J.P., Isenhardt, T.M., Rodrigues, C.A. and Kuehl, A. (1997), "Stewards of Our Streams: Buffer Strip Design, Establishment and Maintenance," Report PM-1626b, Iowa State University Extension, Ames, IA.
- Scientific Advisory Panel (1998), "Scientific Advisory Panel July 1998 Meeting Final Report," U.S. Environmental Protection Agency, Arlington, VA.
- Shepard, R. (2002), "Measuring Farmer Behavior in Nutrient Management Planning," 2002 Wisconsin Fertilizer, Agrilime and Pest Management Conference, Madison, WI.
- Smith, M., Melvin, S., Pope, R., Miller, G., and Cruse, R. (1992), "Vegetative Filter Strips for Improved Surface Water Quality," Report PM-1507, Iowa State University Extension, Ames, IA
- Suttles, J., Vellidis, G., Bosch, D., Lowrance, R., Usery, E.L., and Sheridan, J.M. (2001), "Use of the AnnAGNPS Model for a Watershed in the Coastal Plain of Georgia," 9th National Nonpoint Source Monitoring Workshop, Indianapolis, IN.
- Statistics Canada (1997), "1996 Census of Agriculture," Publication 93F0033XIE, Statistics Canada.
- Stuber R.J., Gebhart, G., and Maughan, O.E. (1982), "Habitat Suitability Index Models: Bluegill," USDI Fish and Wildlife Service, FWS/OBS-82/10.8, Fort Collins, CO.
- Trial, J.G., Wade, C.S., Stanley, J.G., and Nelson, P.C. (1983a), "Habitat Suitability Information: Common Shiner," USDI Fish and Wildlife Service, FWS/OBS-82/10.40, Fort Collins, CO.

- Trial, J.G., Wade, C.S., Stanley, J.G., and Nelson, P.C. (1983b), "Habitat Suitability Information: Fallfish," USDI Fish and Wildlife Service, FWS/OBS-82/10.48, Fort Collins, CO.
- Trial, J.G., Stanley, J.G., Batcheller, M., Gebhart, G., Maughan, O.E., and Nelson, P.E. (1983c), "Habitat Suitability Information: Blacknose Dace," USDI Fish and Wildlife Service, FWS/OBS-82/10.41, Fort Collins, CO.
- Twomey, K.A., Williamson, K.L., and Nelson, P.E. (1984), "Habitat Suitability Index Model and Instream Flow Suitability Curves: White Sucker," USDI Fish and Wildlife Service, FWS/OBS-82/10.64, Fort Collins, CO.
- U.S. Army Engineer Waterways Experiment Station (1995), "CE-QUAL-RIV1: A Dynamic, One Dimensional (Longitudinal) Water Quality Model for Streams: Users Manual," Report EL-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- United States Department of Agriculture (2001), "AnnAGNPS Version 2: User Documentation," USDA-ARS, Oxford, MS.
- U.S. Environmental Protection Agency (1997), "Compendium of tools for watershed assessment and TMDL development," EPA, EPA-841-B-97-006, Washington, DC.
- U.S. Environmental Protection Agency (2000), "Watershed Analysis and Management (WAM) Guide for Tribes," EPA, Monroe, WA.
- U.S. Environmental Protection Agency (2001), "Better Assessment Science Integrating Point and Nonpoint Sources-BASIN version 3.0 User Manual," EPA-823-B-01-001, Washington, DC.
- U.S. Environmental Protection Agency (2003), "National Management Measure for the Control of Nonpoint Pollution from Agriculture," EPA, EPA-841-B-03-004, Washington, DC
- Vollenweider, R.A. (1970), "Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication," Organization for Economic Co-Operation and Development, Paris, France.
- Washington State Department of Ecology (1999), "Estimated Baseflow Characteristics of Selected Washington Rivers and Streams," Pub. 99-327, Olympia, WA.
- Wicklund, R.E. and Richards, N.R. (1962), "Soil Survey of Russell and Prescott Counties", Report No. 33 of the Ontario Soil Survey, Canada Department of Agriculture, Guelph, ON.
- Wilson, D.J. (2000), "Systems Analysis of Decision Support Systems for Water Resource Users and Planners in Eastern Ontario," MASc Thesis, University of Ottawa, Ottawa, ON.

APPENDIX A: QUALITY ASSURANCE & CONFIGURATION CONTROL PROCEDURES

A.1. PURPOSE

The policies and practice listed here are designed to minimize the risks of errors in calculation and data manipulation tasks, to ensure that the solution and results are of the highest quality and that the methodologies are consistent.

Analyses performed by hand or with custom tools are not exempt from the quality requirements specified here. However, for those cases, the analyst often has a better grasp and control over the limitations, assumptions and methodology than when using complex computer codes. Calculations and tasks routinely performed with well established or previously developed computer codes present a particular challenge because these codes are highly complex, may be supplied by an external source, and are designed to work for a specific range of problems. Complacency and over-confidence in the codes may lead to erroneous results. The policies and practices here should help to ensure that the results are consistently of the highest quality.

A.2. SOURCE CODE QUALITY ASSURANCE REQUIREMENTS

A configuration control system must be in place to track version changes in the source code. Each version of the source code must be assigned a unique version number. Previously tested and "known-good" versions of source are to be archived and retrievable. The changes between two versions of the code must be documented.

If the source of the program, the compiler, or the operating system is modified or upgraded, the quality assurance (QA) qualification process must be repeated to verify the validity of the program. Additionally, programs acquired through third parties must be verified 'in-house' before being QA qualified.

A.3. PROGRAM TESTING

In order for a program to pass the QA qualification process, it must pass a series of test problems. The test problems are conducted, and must be run to completion without crashing. The results of the test problems are then extensively compared to a previously known good solution. Any discrepancies or anomalies (precision or round-off errors, for example) must be documented

and explained. Upon passing qualification, the date, size and version of the source code and executable files must be recorded.

The AnnAGNPS 2.01c package used was obtained from the USDA website at <http://www.sedlab.olemiss.edu/agnps.html>. The code was then verified by running the example cases provided, the “Beaver Creek” and “Mission Creek” data files, and comparing the outputs with the shipped results. The output files were identical to the reference results for both cases, and so the system was deemed tested and known-good.

The utilities constructed were tested extensively against data entered and processed manually, so as to ensure proper behavior. Additionally, diagnostic runs were conducted with variable tracking (‘debugging’) tools to ensure that data were being loaded, handled, and outputted as desired. Backups of all ‘good’ versions were made, and any new features or modifications from a tested version were handled according to the configuration control procedure (described under Section A.4).

A.4. CONFIGURATION CONTROL

The latest QA qualified version of a given program should be under the “\ProgramName\current\” directory. Previously known good versions are archived under “\ProgramName\Old versions\” as zip files bearing the version name. Versions pending QA qualification are placed under the “\ProgramName\pending\versionname\” folder. All files should be regularly backed up to a writable CD or similar “read-only” storage.

APPENDIX B: METADATA AND DATA SOURCES

B.1. INTRODUCTION

Metadata records are listed in this appendix for all of the geospatial data used in this study. As previously mentioned, the work relies heavily on the prior EOWRMS report listed under the references. Additional information on many of these data layers is available from the EOWRMS report and its authors.

B.2. METADATA RECORDS

Dataset name: ca_watershed
Type of data: major watersheds
Metadata record: D. Branson
Pubdate: 20010331
Publish: GeoSolutions Consulting Inc.
Abstract: This cover displays the extents of the watersheds used to define the extents of the South Nation, Raisin Region, and Rideau Valley Conservation Authorities. It was digitized from linework drawn onto 1:50k NTS maps by Conservation Authority staff.
Supplinf: This data set is compiled from 1:50,000 NTS
Scale: 1:50,000
Begdate: 19991201
Enddate: 20010330
Westbc: 420000
Eastbc: 550000
Northbc: 5055000
Southbc: 4940000
Native: -
Procdesc: -
Procdat: -
Direct: polygon
Gridsysn: Universal Transverse Mercator
Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 20010327

Dataset name: study area
Type of data: Boundary
Metadata record: DB Gleig May 24, 2000
Pubdate: ??????????
Publish: MNR
Abstract: This cover marks the outside boundary of the study area. It is based on the county and township boundaries.

Supplinf: This cover was created by dissolving the counties of a clipped OBM county coverage.
Scale: 1:10000
Begdate: ?
Enddate: present
Westbc: 421337
Eastbc: 551535
Northbc: 5054180
Southbc: 4940274
Native: ARC/INFO v7 for HP UNIX. On the hp260 at /home/guelph/gis-data/cadastral/boundary
Procdesc: Original tolerances are unknown, however this coverage was clipped and built with no adjustment of the originals.
Procdat: 19990201
Direct: Polygon
Gridsysn: Universal Transverse Mercator
Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 19990305

Dataset name: landcover_aug98
Type of data: Land Cover
Metadata record: D. Sherman 07/02/01
Pubdate: 19991223
Publish: AAFC
Abstract: The dataset is a landcover classification of eastern Ontario from August 1998 Landsat imagery.
Supplinf: Classification accuracy is ~87%. Individual field crops were not classified due to accuracy and concerns with the training sites. Urban areas were digitized on screen, forests and wetlands were identified by on screen digitizing of training sites and a MLC. Agricultural areas were classified using an unsupervised classification and an iterative process to break the clusters. The classification results were then combined and exported to a vector format. This cover is also available in a generalized format at the scale of 1:50k.
Scale: ???
Begdate: 19990501
Enddate: 19991223
Westbc: 379439
Eastbc: 551520
Northbc: 5054180
Southbc: 4906127
Native: ARC/INFO v7 for HP UNIX. On the hp260 at /home/guelph/gis-data/Landcov/landcover_aur98
Procdesc: The data was georeferenced and orthorectified. Then it was classified using a combination of supervised and unsupervised MLC and ISOCLUS techniques. Classification was done in PCI, then the data was exported to GRID and then was converted to a polygon coverage in ArcInfo. The original Landsat imagery excluded Leeds. A separate classification was performed on Leeds with the

same aforementioned methodology but with 1999 imagery. This classification was then merged with the rest of the study area.

Procdate: 19991223
Direct: polygon
Gridsysn: Universal Transverse Mercator
Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 20000312

Dataset name: forests
Type of data: MNR Forestry

Dataset name: soils
Type of data: Soils maps
Metadata record: D. Sherman 07/02/01
Pubdate: 20000929
Publish: AAFC
Abstract: This cover details the soils of the study area.
Supplinf: Boundary correlations were made between PR and SD&G. Vital attribute information consists of items Soilsym, Slpsym, slp-st, and Clisym. The CLI system is explained online at "http://res.agr.ca/CANSIS/NSDB/CLI/_overview.html". The other fields will be described online soon at "<http://res.agr.ca/CANSIS/ontario>".

Scale: 1:50000
Begdate: ?
Enddate: present
Westbc: 424967
Eastbc: 551488
Northbc: 5054185
Southbc: 4960788
Native: ARC/INFO v7 for HP UNIX. On the hp260 at /home/guelph/gis-data/slc/slc
Procdesc: Original tolerances are unknown and modifications are still in progress.
Procdate: Not complete
Direct: polygon
Gridsysn: Universal Transverse Mercator
Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 20000929

Dataset name: OntSNF, Ont SLF
Type of data: Soil Characteristics

Dataset name: waterlines
Type of data: surface drainage network
Metadata record: D. Sherman 07/02/01
Pubdate: ????????

Publish: MNR
Abstract: This cover details rivers and streams throughout the study area.
Supplinf: MNR-codes 104-105 specify river/streams.
Scale: 1:10000
Begdate: ?
Enddate: present
Westbc: 422900
Eastbc: 551488
Northbc: 5053937
Southbc: 4940299
Native: ARC/INFO v7 for HP UNIX. On the hp260 at /home/guelph/gis-data/hydro/waterline
Procdesc: Original tolerances are unknown, however this coverage was clipped and built with no adjustment of the originals.
Procdat: 19990201
Direct: vector
Gridsysn: Universal Transverse Mercator
Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 19991012

Dataset name: waterpoly
Type of data: surface drainage network
Metadata record: D. Sherman 07/02/01
Pubdate: ????????
Publish: MNR
Abstract: This cover details bodies of water throughout the study area.
Supplinf: Contains "pinched" river polygons. MNR-code 64 specifies lakes.
Scale: 1:10000
Begdate: ?
Enddate: present
Westbc: 423028
Eastbc: 551289
Northbc: 5054123
Southbc: 4940584
Native: ARC/INFO v7 for HP UNIX. On the hp260 at /home/guelph/gis-data/hydro/waterpoly
Procdesc: Original tolerances are unknown, however this coverage was clipped and built with no adjustment of the originals.
Procdat: 19990201
Direct: polygon
Gridsysn: Universal Transverse Mercator
Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 19991012

Dataset name: DEM25
Type of data: DEM

Metadata record: DB Gleig May 24 2000
Pubdate: 19990805
Publish: MNR
Abstract: This cover shows elevation for the study area. It is missing Ottawa-Carleton
Supplinf: This cover was created by clipping a coverage which included leads and excluded Ottawa-Carleton .
Scale: 1:10000
Begdate: 199908??
Enddate: present
Westbc: 421337
Eastbc: 551537
Northbc: 4940262
Southbc: 5054162
Native: ARC/INFO v7 for HP UNIX. On the hp260 at /home/guelph/gis-data/dem/dem25
Procdesc: Original tolerances are unknown; however, this coverage was clipped and built with no adjustment of the originals.
Procdate: not complete
Direct: DEM
Gridsysn:
Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 19991012

Dataset name: subwatershed
Type of data: surface subwatersheds
Metadata record: D. Branson
Pubdate: 20010331
Publish: GeoSolutions Consulting Inc.
Abstract: This cover depicts the subwatersheds of eastern Ontario. It was derived using the hydro extension for ArcView Spatial Analyst. The parameters for the minimum watershed size were set to obtain a level of detail suitable for regional analysis. This resulted in a total of approximately 200 subwatershed for the study area. This number was reduced to 180 through aggregating very small subwatersheds with larger upstream neighbours and aggregating subwatershed along the shoreline of the Ottawa and St. Lawrence Rivers.
Supplinf: The DEM used to compile this data was derived from OBM data.
Scale: 1:10,000
Begdate: 19991201
Enddate: 20010330
Westbc: 420000
Eastbc: 550000
Northbc: 5055000
Southbc: 4940000
Native:
Procdesc:
Procdate:
Direct: DEM
Gridsysn: Universal Transverse Mercator

Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 20010327

Dataset name: log_netgwflux_discharge2
Type of data: groundwater discharge areas
Metadata record: CH2M Hill metadata v2
Pubdate: 20010331
Publish: CH2MHill
Abstract: This cover shows areas of groundwater discharge. Uses DEM and Water Well Records. Areas of groundwater discharge occur where the water levels in the lower overburden aquifer are greater than the ground surface. The magnitude of the discharge is presented as logarithm of the Darcy Flux (q) in metres/second. Where log q is < -10.5 recharge from in the water budget is reduced by 0%. where log q > -10.5 and < -9.76 recharge is reduced by 25%. Where log q > -9.76 and < -8.54 recharged is reduced by 50%. Where log q > -8.54 and < -7.71 recharge is reduced by 75%. Where log q > -7.71 recharge is reduced by 100%.
Supplinf: Please see EOWRMS report for description of how components of Darcy Flux q were estimated and calculated
Scale: n/a
Begdate: 20000101
Enddate: 20010331
Westbc: 420000
Eastbc: 550000
Northbc: 5055000
Southbc: 4940000
Native: MapInfo6.0 TAB
Procdesc:
Procdat:
Direct:
Gridsysn: Universal Transverse Mercator
Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 20010329

Dataset name: Stream Gauges
Type of data: streamflow
Metadata record: CG&S metadata v1
Pubdate: 1999
Publish: Various consultants
Abstract: Data from stream gauges presently in use within the South Nation Watershed monitoring water levels and flow. Rainfall gauges are monitored at selected stream gauge stations.
Supplinf: Stations are located on the South Nation River, Castor River, Bear Brook, North Branch of SNR, West Branch Scotch River, and South Branch SNR.
Scale: n/a
Begdate: 1905

Enddate: 1999
Westbc: 420000
Eastbc: 550000
Northbc: 5055000
Southbc: 4940000
Native: Access 97
Procdesc: Data entered as collected/uploaded
Procdate: Not Complete
Direct: Point
Gridsysn: Universal Transverse Mercator
Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 1999

Dataset name: WSC Streamflow Data
Type of data: Water survey of Canada
Metadata record: CH2MHILL
Pubdate: 2000
Publish: Environment Canada, Water Survey Division
Abstract:
Supplinf: These data include monthly mean flows, daily mean flows, as well as daily mean and instantaneous extreme flows for the historical record

Scale:
Begdate: various
Enddate: various
Westbc: 420000
Eastbc: 550000
Northbc: 5055000
Southbc: 4940000
Native: Excel
Procdesc: Data used as provided from source, unverified
Procdate: Unknown
Direct: Point
Gridsysn:
Utmzone: 18
Horizdn:
Metd: 20010231

Dataset name: City of Ottawa water quality data
Type of data: water quality
Metadata record: CH2MHILL
Pubdate: 2001
Publish: City of Ottawa, Water Quality Program
Abstract: The City of Ottawa maintains a series of stations that collect water for ambient water quality analysis. Data in this series are from the portion of the South Nation watershed that is in the City of Ottawa.
Supplinf: Accuracy of the data has not been verified by the consultant.
Scale: n/a

Begdate: 1993
Enddate: 1999
Westbc: 420000
Eastbc: 550000
Northbc: 5055000
Southbc: 4940000
Native: Excel
Procdesc: Data used as provided from source, unverified
Procdate: Unknown
Direct: Point
Gridsysn:
Utmzone: 18
Horizdn:
Metd: 20010231

Dataset name: Summarized TP and Ammonia Data
Type of data: PWQMN
Metadata record: CG&S metadata v1
Pubdate: 1998
Publish: Ontario Ministry of the Environment
Abstract: The Ministry of Environment operates a network of stations to collect ambient water quality data from rivers and streams throughout Ontario. This network has operated since 1964 and water quality information at more than 1900 locations exist. The period of record varies for each site, with some sites have only a few years of historic data while others have substantial data time series spanning many years. Data for Prescott, Russell, Stormont, Glengarry, and Dundas are readily available upon request.

Supplinf: Sampling frequencies vary from 8 to 12 times per year at each location. The data is intended for the sole use of the client and the MOE remains the owner of the data.

Scale: n/a
Begdate: 1964
Enddate: 1998
Westbc: 420000
Eastbc: 550000
Northbc: 5055000
Southbc: 4940000
Native: LIS digital database
Procdesc: Data entered as reported by laboratory
Procdate: 1997
Direct: Point
Gridsysn: Universal Transverse Mercator
Utmzone: 18
Horizdn: North American Datum of 1927
Metd: 1999

Dataset name: Water Use Estimates
Type of data: Groundwater and Surface Demand

Metadata record: CH2MHILL
Pubdate: 20010331
Publish: n/a
Abstract: This spreadsheet provides estimates of water demand (surface and groundwater sources) from municipal, private, industrial and agricultural users.
Supplinf: Data were derived from various sources.
Scale: n/a
Begdate: 2000
Enddate: 2000
Westbc: 420000
Eastbc: 550000
Northbc: 5055000
Southbc: 4940000
Native: MS Excel
Procdesc: Described in project report
Procdat: 20001031
Direct: non-spatial
Gridsyn: n/a
Utmzone: 18
Horizdn: n/a
Metd: 20010306

Dataset name: groundwater_watersheds
Type of data: groundwater subwatersheds
Metadata record: CH2M Hill metadata v2
Pubdate: 20010331
Publish: CH2MHill
Abstract: This cover presents the groundwater watersheds delineated using a map of the piezometric surface of the contact zone aquifer in Eastern Ontario. Uses Water Well Records and piezometric surface derived from reported static water levels. Contact Zone Aquifer consists of the first 10 metres of bedrock and any sand and gravel that directly overlies the bedrock.
Supplinf: Please see EOWRMS report for description of specific criteria used to delineate these areas.
Scale: n/a
Begdate: 20000101
Enddate: 20010331
Westbc: 420000
Eastbc: 550000
Northbc: 5055000
Southbc: 4940000
Native: MapInfo6.0 TAB
Procdesc:
Procdat:
Direct:
Gridsyn: Universal Transverse Mercator
Utmzone: 18
Horizdn: n/a
Metd: 20010329

B.5. SOIL DATA

Figure 4: EOWRMS Soil type data used as spatial delineation of soil types for AnnAGNPS watershed model

B.3. TOPOGRAPHY DATA

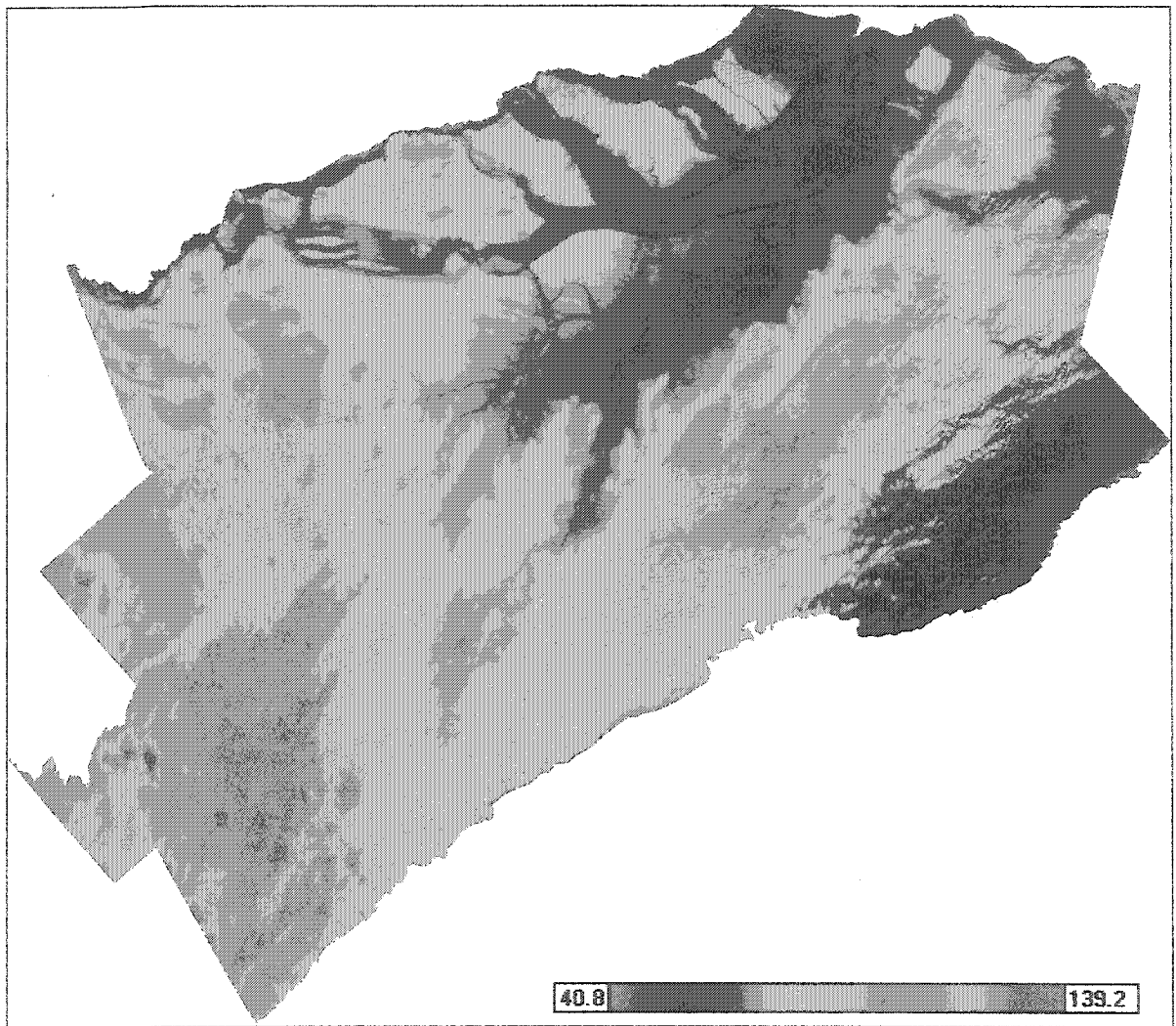


Figure 2: Topographic data used for South Nation watershed delineation

B.4. LANDUSE DATA



Figure 3: EOWRMS Land use data used as input for AnnAGNPS watershed model

Table B1: Soil Series in the South Nation Watershed^{1,2}

Soil Series	Total Area of Soil in South Nation Watershed (ac)	Fraction of Total Area (%)
Allendale	34200	2.5606469
Bainsville	26600	1.991614256
Bearbrook	210300	15.74573226
Belmeade	18700	1.400119796
Bottom Land	19400	1.452530698
Carp	10000	0.748727164
Castor	45800	3.42917041
Eamer	178100	13.33483079
Eroded Channels	21700	1.624737945
Farmington	7000	0.524109015
Granby	15000	1.123090746
Grenville	178400	13.3572926
Kars	33300	2.493261456
L'Achigan	3100	0.232105421
Lyons	4500	0.336927224
Manotick	1400	0.104821803
Marionville	13100	0.980832585
Matilda	28400	2.126385145
Morrisburg	51400	3.848457622
Moutain	13200	0.988319856
Muck	86100	6.446540881
North Gower Series	100300	7.509733453
Osgoode	36600	2.74034142
Osnabruck	12900	0.965858041
Rubicon	62800	4.702006589
Ste. Rosalie	8200	0.613956274
St. Samuel	7400	0.554058101
St. Thomas	100	0.07487272
Uplands	48400	3.623839473
Vars	7300	0.54657083
Wendover	41200	3.084755915
Wolford	10700	0.801138065
	1335600	100

¹ Compiled from Matthews et al., 1954, Matthews et al., 1952; Matthews et al., 1957; and Wicklund et al., 1962.

² Bolded series were selected and allocated to EOWRMS texture types for the model.

B.6. CROP MANAGEMENT DATA

Table B2: Agricultural practices within the South Nation watershed¹

Municipality	Irrigation (ha)	Commercial Fertilizer (ha)	Manure (ha)	
			Solid spreader	Liquid spreader
Williamsburgh	0	4824	974	444
Matilda	17	8388	1507	690
Mountain	262	10005	1448	796
Winchester	0	11899	2172	1212
Finch	0	10532	1313	827
Roxborough	53	6000	870	1140
Caledonia	201	6456	1155	659
Alfred	0	4139	1027	530
South Plantagenet	0	7261	1265	1607
North Plantagenet	376	3437	1007	557
Clarence	88	4665	925	892
Cambridge	122	6893	1029	1193
Russell	136	8442	749	1319
Osgoode	292	10239	1562	689
Cumberland	65	6291	1432	1368
Edwardsburgh	9	3427	1191	401
Augusta	22	2800	1299	99
Cornwall ²	0	2151	539	254
Osnabruck ²	0	2815	1263	127
Kenyon ²	229	4838	1161	808
Lochiel ²	109	6250	1814	754
West Hawkesbury ²	0	2092	606	259
Longueuil ²	0	2403	409	603
Gloucester ²	219	2323	455	0
Elizabethtown ²	13	2934	1624	340
Oxford-on-Rideau ²	29	2746	951	214
South Gower ²	2	1130	288	0

¹ Adapted from Statistics Canada, 1997.

² These townships border or are only partially in the watershed.

Table B3: Nutrient Analysis of Beef, Dairy and Swine Manures¹

Animal	Total N	P2O5	K2O
Dairy			
<i>Solid (kg 1000 kgs)</i>			
Cows	5.5	3.5	4.5
Heifers	6.5	6.0	9.5
<i>Liquid (kg/1000 litres)</i>			
Anaerobic storage	42.9	25.8	46.4
Beef			
<i>Solid (kg 1000 kgs)</i>			
Cows	7.5	5.0	4.5
Steers	7.0	4.5	7.0
Swine			
<i>Solid (kg/1000 kgs)</i>			
Gestation	11.0	13.5	7.0
Finishing	11.0	11.0	8.5
<i>Liquid (kg/1000 L)</i>			
Farrowing	46.4	46.4	25.8
Nursery	58.4	42.9	30.9
Gestation	68.7	72.1	30.9
Finishing	91.0	67.0	49.8

¹ Adapted from Minnesota Department of Agriculture, 1999.

Table B4: Soybean Cultivation Defaults¹

Date	Operation
25-May	Planter; strip till
1-Jul	Fertilize 9.8 kg/ha P
25-Jul	Fertilize 9.8 kg/ha P
22-Sep	Harvest

¹ Adapted from Suttles et al., 2001.

Table B5: Corn Cultivation Defaults¹

Date	Operation
15-Mar	Fertilize 168 kg/ha 10-34-0
18-Mar	Fertilize 176 kg/ha 10-34-0, plant corn w/ conventional tillage
1-May	Fertilize 89.7 kg/ha 20-0-20
19-May	Fertilize 127.9 kg/ha 28-0-0
1-Aug	Harvest

¹ Adapted from Suttles et al., 2001.Table B6: Grain Cultivation Defaults¹

Date	Operation
15-Mar	Fertilize 168 kg/ha 10-34-0
18-Mar	Fertilize 176 kg/ha 10-34-0, plant grains conventional tillage
1-May	Fertilize 89.7 kg/ha 20-0-20
19-May	Fertilize 127.9 kg/ha 28-0-0
1-Aug	Harvest

¹ Adapted from Suttles et al., 2001.Table B7: Pasture Cultivation Defaults¹

Date	Operation
1-Jun	Fertilize 336 kg/ha 10-10-10
8-Jul	Fertilize 336 kg/ha 10-10-10
15-Aug	Fertilize 336 kg/ha 10-10-10
22-Sep	Fertilize 336 kg/ha 10-10-10
29-Oct	Fertilize 336 kg/ha 10-10-10

¹ Adapted from Suttles et al., 2001.

B.7. LIVESTOCK DATATable B8: Number of Sheep by County, July 1, 2001¹

County	Rams (>1 yr)	Ewes & Wethers (>1 yr)	Sheep (>1 yr)	Lambs (<1 yr)	Total Sheep & Lambs
Frontenac County	100	1,650	1,750	1,750	3,500
Lanark County	150	3,150	3,300	3,200	6,550
Leeds and Grenville United Counties	250	5,000	5,250	4,400	9,650
Lennox and Addington County	150	4,200	4,350	2,950	7,300
Ottawa Division	250	2,750	3,000	2,350	5,400
Prescott and Russell United Counties	100	2,200	2,300	2,050	4,350
Renfrew County	100	1,950	2,050	2,100	4,150
Stormont, Dundas and Glengarry Counties	200	4,650	4,850	4,200	9,050
Eastern Ontario Region	1,300	25,600	26,900	23,050	49,900

¹ After Cumming, 2002.

Table B9: Number of Pigs by County, July 1, 2001¹

Counties & Districts	Sows & Bred Gilts (>6 mo.)	Boars (>6 mo.)	All other pigs			Total	Total Pigs
			<45 lbs	45-130 lbs	>130 lbs		
Lanark County	..	..	..	..	..	..	..
Leeds and Grenville United Counties	2,600	50	1,800	1,550	1,400	4,800	7,500
Lennox and Addington County	2,000	150	5,500	3,200	3,300	11,300	13,450
Ottawa Division	800	50	2,350	2,600	2,250	7,150	8,000
Prescott and Russell United Counties	2,400	50	3,300	6,850	6,000	15,450	17,950
Renfrew County	..	..	..	..	..	..	..
Stormont, Dundas and Glengarry Counties	2,900	100	7,150	7,200	6,300	20,700	23,700
Eastern Ontario Region	12,300	450	25,050	24,550	21,500	71,550	84,350

¹ After Cumming, 2002.

Table B10: Number of Cattle by County, July 1, 2001¹

County	Bulls (> 1 yr)	Dairy Cows	Dairy Heifers (> 1 yr)	Beef Cows	Beef Heifers for Breeding (> 1 yr)	Beef Heifers for Slaughter (> 1 yr)	Steers (> 1 yr)	Calves (< 1 yr)	Total Cattle
Frontenac	450	4,450	2,600	8,150	1,550	400	950	8,350	26,550
Lanark	550	3,850	2,450	10,150	2,050	1,000	2,000	9,750	31,650
Leeds and Grenville United	900	11,050	6,450	10,150	2,700	450	1,800	13,300	46,400
Lennox and Addington	350	3,950	2,150	6,900	1,500	500	1,550	8,200	24,950
Ottawa Division	550	13,700	8,600	8,350	2,400	850	2,000	12,850	48,900
Prescott and Russell United	600	26,550	12,650	5,350	1,350	550	900	14,500	61,850
Renfrew	1,200	7,000	3,450	22,900	4,400	2,100	3,900	22,400	66,800
Stormont, Dundas and Glengarry	850	33,250	16,300	9,500	2,750	1,700	2,000	27,250	92,650
Eastern Ontario Region	5,550	103,800	54,650	81,550	18,650	7,550	15,050	116,600	399,700

¹ After CumingTable B11: Per Animal Daily Manure Production and Nutrients¹

Animal	Manure (kg)	N (kg)	P2O5 (kg)	K2O (kg)
Beef (1000 lbs)	27.2	0.15	0.11	0.13
Dairy (1400 lbs)	52.2	0.26	0.11	0.21
Swine (200 lbs)	5.9	0.041	0.032	0.032

¹ Adapted from Minnesota Department of Agriculture, 1999.

APPENDIX C: SIMULATION SETUP

C.1. CASE MATRIX

Table C1: Case Matrix of Watershed Model Runs

Run ID	BMP Implemented	Climate Scenario	Run ID	BMP Implemented	Climate Scenario
1	BASE CASE	1	67	1/2 Stream Access	4
2	FAR = 50%	1	68	2/3 Stream Access	4
3	FAR = 60%	1	69	3/4 Stream Access	4
4	FAR = 70%	1	70	75% Reduced Tillage	4
5	FAR = 80%	1	71	50% Reduced Tillage	4
6	FAR = 90%	1	72	25% Reduced Tillage	4
7	VFS = 3 m	1	73	BASE CASE	5
8	VFS = 6 m	1	74	FAR = 50%	5
9	VFS = 9 m	1	75	FAR = 60%	5
10	VFS = 12 m	1	76	FAR = 70%	5
11	No Stream Access	1	77	FAR = 80%	5
12	1/3 Stream Access	1	78	FAR = 90%	5
13	1/2 Stream Access	1	79	VFS = 3 m	5
14	2/3 Stream Access	1	80	VFS = 6 m	5
15	3/4 Stream Access	1	81	VFS = 9 m	5
16	75% Reduced Tillage	1	82	VFS = 12 m	5
17	50% Reduced Tillage	1	83	No Stream Access	5
18	25% Reduced Tillage	1	84	1/3 Stream Access	5
19	BASE CASE	2	85	1/2 Stream Access	5
20	FAR = 50%	2	86	2/3 Stream Access	5
21	FAR = 60%	2	87	3/4 Stream Access	5
22	FAR = 70%	2	88	75% Reduced Tillage	5
23	FAR = 80%	2	89	50% Reduced Tillage	5
24	FAR = 90%	2	90	25% Reduced Tillage	5
25	VFS = 3 m	2	91	BASE CASE	6
26	VFS = 6 m	2	92	FAR = 50%	6
27	VFS = 9 m	2	93	FAR = 60%	6
28	VFS = 12 m	2	94	FAR = 70%	6
29	No Stream Access	2	95	FAR = 80%	6
30	1/3 Stream Access	2	96	FAR = 90%	6
31	1/2 Stream Access	2	97	VFS = 3 m	6
32	2/3 Stream Access	2	98	VFS = 6 m	6
33	3/4 Stream Access	2	99	VFS = 9 m	6
34	75% Reduced Tillage	2	100	VFS = 12 m	6
35	50% Reduced Tillage	2	101	No Stream Access	6
36	25% Reduced Tillage	2	102	1/3 Stream Access	6
37	BASE CASE	3	103	1/2 Stream Access	6
38	FAR = 50%	3	104	2/3 Stream Access	6
39	FAR = 60%	3	105	3/4 Stream Access	6
40	FAR = 70%	3	106	75% Reduced Tillage	6

41	FAR = 80%	3	107	50% Reduced Tillage	6
42	FAR = 90%	3	108	25% Reduced Tillage	6
43	VFS = 3 m	3	109	Best of all BMPS	1
44	VFS = 6 m	3	110	Typical BMPS	1
45	VFS = 9 m	3	111	Best of FAR and VFS	1
46	VFS = 12 m	3	112	Typical FAR and VFS	1
47	No Stream Access	3	113	Best of all BMPS	2
48	1/3 Stream Access	3	114	Typical BMPS	2
49	1/2 Stream Access	3	115	Best of FAR and VFS	2
50	2/3 Stream Access	3	116	Typical FAR and VFS	2
51	3/4 Stream Access	3	117	Best of all BMPS	3
52	75% Reduced Tillage	3	118	Typical BMPS	3
53	50% Reduced Tillage	3	119	Best of FAR and VFS	3
54	25% Reduced Tillage	3	120	Typical FAR and VFS	3
55	BASE CASE	4	121	Best of all BMPS	4
56	FAR = 50%	4	122	Typical BMPS	4
57	FAR = 60%	4	123	Best of FAR and VFS	4
58	FAR = 70%	4	124	Typical FAR and VFS	4
59	FAR = 80%	4	125	Best of all BMPS	5
60	FAR = 90%	4	126	Typical BMPS	5
61	VFS = 3 m	4	127	Best of FAR and VFS	5
62	VFS = 6 m	4	128	Typical FAR and VFS	5
63	VFS = 9 m	4	129	Best of all BMPS	6
64	VFS = 12 m	4	130	Typical BMPS	6
65	No Stream Access	4	131	Best of FAR and VFS	6
66	1/3 Stream Access	4	132	Typical FAR and VFS	6

C.2. REACH NETWORK PARAMETERS

AgFlow Version 2.02: 09/21/00: AnnAGNPS cell, reach, & subarea data from DEM-related parameters

SOUTH NATION WATERSHED

Code 1: 200 & 500 Code 2: 26 & 200 Code 3: 10 & 100 Code 4: 10 & 50

Using default values for LS-factor parameters

Reach	Rec.	Drain.	Avg.	Channel		Contributing Cell's			Reach
ID	Reach	Area	Elev.	Length	Slope		ID		ID
1238	ID	(ha)	(m)	(m)	(m/m)	Source	Left	Right	
1	1	384331	40.8	0	1E-05	WATER SHED OUTLET			1
2	1	384331	40.8	3639	0.002	none	22	23	2
3	2	383468	41.6	1178	1E-05	none	32	33	3
4	3	382177	41.6	1487	1E-05	none	42	43	4
5	4	381479	41.6	833	1E-05	none	52	53	5
6	5	203	41.6	1207	0.025	61	62	63	6
7	5	381244	41.6	962	1E-05	none	72	73	7
8	7	175	41.6	1345	0.0205	81	82	83	8
9	7	380771	41.6	1490	1E-05	none	92	93	9
10	9	378789	41.6	754	0.013	none	102	103	10
11	10	177.25	42.6	1199	0.021	111	112	113	11
12	10	378574	42.6	2739	0.006	none	122	123	12
13	12	375	44.3	3409	0.0106	131	132	133	13
14	12	377848	44.3	562	1E-05	none	142	143	14
15	14	329	44.3	3397	0.09	151	152	153	15
16	14	377357	44.3	3480	0.002	none	162	163	16
17	16	1793.3	45	2194	0.021	none	172	173	17
18	17	318.25	49.6	1275	0.018	181	182	183	18
19	17	1170.8	49.6	8949	0.037	191	192	193	19
20	16	375136	45	71	1E-05	none	202	none	20
21	20	374274	45	1952	1E-05	none	212	213	21
22	21	373555	45	1004	1E-05	none	222	223	22
23	22	5917.3	45	3159	0.016	none	232	233	23
24	23	444.5	50.1	1711	1E-05	none	242	243	24
25	24	149.75	50.1	1216	0.003	251	252	253	25
26	24	152.25	50.1	1187	1E-05	261	262	263	26
27	23	5071.5	50.1	978	1E-05	none	272	273	27
28	27	741.25	50.1	5629	0.031	281	282	283	28
29	27	4298.3	50.1	1799	1E-05	none	292	293	29
30	29	320.25	50.1	1245	0.01	301	302	303	30
31	29	3595.5	50.1	783	0.001	none	312	313	31
32	31	3228.8	50.2	3032	1E-05	none	322	323	32
33	32	2107.3	50.2	1707	0.007	none	332	333	33
34	33	375.25	51.4	1812	0.02	341	342	343	34
35	33	1541	51.4	3147	0.016	none	352	353	35
36	35	966.25	56.5	3006	0.027	none	362	363	36
37	36	252.25	64.5	2182	0.003	371	372	373	37
38	36	326.75	64.5	2128	0.02	381	382	383	38
39	35	189.5	56.5	1187	8E-05	391	392	393	39
40	32	318.25	50.2	2502	0.027	401	402	403	40
41	31	338.25	50.2	2514	0.015	411	412	413	41
42	22	367581	45	3589	1E-05	none	422	423	42
43	42	13428	45	1187	0.024	none	432	433	43
44	43	1329.8	47.8	2227	0.006	none	442	443	44
45	44	849.5	49.1	2782	0.005	none	452	453	45
46	45	237.5	50.4	1728	0.008	461	462	463	46

47	45	216.25	50.4	2847	0.013	471	472	473	47
48	44	284.75	49.1	2382	0.014	481	482	483	48
49	43	11911	47.8	554	1E-05	none	492	493	49
50	49	5669.8	47.8	4225	0.003	none	502	503	50
51	50	4804.5	49	262	1E-05	none	512	513	51
52	51	261.5	49	1282	1E-05	521	522	523	52
53	51	4521.8	49	7231	0.011	none	532	533	53
54	53	999.25	56.6	625	0.069	none	542	543	54
55	54	530.5	60.9	3756	0.013	551	552	553	55
56	54	449.5	60.9	5637	0.014	561	562	563	56
57	53	2498	56.6	1116	0.025	none	572	573	57
58	57	311.25	59.4	2028	0.03	581	582	583	58
59	57	1801	59.4	1923	0.019	none	592	593	59
60	59	212.25	63.1	1892	0.017	601	602	603	60
61	59	1460	63.1	3028	0.014	none	612	613	61
62	61	254	67.3	1545	0.007	621	622	623	62
63	61	1089.8	67.3	7564	0.02	631	632	633	63
64	50	164.75	49	1395	0.042	641	642	643	64
65	49	6223.3	47.8	9200	0.015	none	652	653	65
66	65	5197.3	61.1	462	1E-05	none	662	663	66
67	66	4878.5	61.1	3577	0.005	none	672	673	67
68	67	3973.8	62.8	562	1E-05	none	682	683	68
69	68	851.25	62.8	1769	0.01	none	692	693	69
70	69	221.25	64.6	1637	0.003	701	702	703	70
71	69	518.75	64.6	3223	0.003	711	712	713	71
72	68	3036	62.8	804	0.024	none	722	723	72
73	72	1460.5	64.7	1092	0.004	none	732	733	73
74	73	346.75	65.1	5046	0.024	741	742	743	74
75	73	1059.8	65.1	2111	0.004	none	752	753	75
76	75	689.5	66	3214	0.039	none	762	763	76
77	76	185.75	78.4	1225	0.057	771	772	773	77
78	76	213.25	78.4	1519	0.027	781	782	783	78
79	75	283	66	1587	0.039	791	792	793	79
80	72	1551.3	64.7	4884	0.029	none	802	803	80
81	80	808.75	79	362	0.022	none	812	813	81
82	81	305	79.8	2923	0.041	821	822	823	82
83	81	488.75	79.8	4404	0.028	831	832	833	83
84	80	163.25	79	1649	0.026	841	842	843	84
85	67	391.75	62.8	2419	0.008	851	852	853	85
86	66	297.25	61.1	1528	0.012	861	862	863	86
87	65	469	61.1	3264	0.009	871	872	873	87
88	42	353542	45	3177	0.006	none	882	883	88
89	88	352614	46.8	804	1E-05	none	892	893	89
90	89	27440	46.8	5187	0.01	none	902	903	90
91	90	26699	51.9	1307	0.011	none	912	913	91
92	91	2641.5	53.3	642	0.019	none	922	923	92
93	92	247.25	54.5	1307	0.078	931	932	933	93
94	92	2373.5	54.5	5517	0.014	none	942	943	94
95	94	270.5	62.3	1157	1E-05	951	952	953	95
96	94	1437.3	62.3	1337	0.007	none	962	963	96
97	96	581.75	63.2	3637	0.003	971	972	973	97
98	96	610.25	63.2	3892	0.005	981	982	983	98
99	91	23894	53.3	1782	0.012	none	992	993	99
100	99	781	55.4	3442	0.014	1001	1002	1003	100
101	99	22912	55.4	1557	1E-05	none	1012	1013	101
102	101	22262	55.4	1911	1E-05	none	1022	1023	102
103	102	21530	55.4	833	1E-05	none	1032	1033	103
104	103	10831	55.4	2535	1E-05	none	1042	1043	104
105	104	3093	55.4	3073	0.029	none	1052	1053	105

106	105	1491	64.4	1911	0.002	none	1062	1063	106
107	106	905.75	64.7	7041	0.015	none	1072	1073	107
108	107	195.5	75.1	1216	0.008	1081	1082	1083	108
109	107	186.5	75.1	1299	0.004	1091	1092	1093	109
110	106	427.25	64.7	4411	0.017	1101	1102	1103	110
111	105	1314.8	64.4	4959	0.009	none	1112	1113	111
112	111	537	68.7	4204	0.045	1121	1122	1123	112
113	111	279.75	68.7	2327	0.043	1131	1132	1133	113
114	104	7260.5	55.4	907	0.012	none	1142	1143	114
115	114	612.25	56.5	6315	0.034	1151	1152	1153	115
116	114	6508.5	56.5	2668	0.029	none	1162	1163	116
117	116	337	64.2	2809	0.028	1171	1172	1173	117
118	116	5929	64.2	2709	0.007	none	1182	1183	118
119	118	5398.5	66	442	0.032	none	1192	1193	119
120	119	4737	67.4	1819	0.062	none	1202	1203	120
121	120	172.25	78.7	1007	0.003	1211	1212	1213	121
122	120	4294.5	78.7	1449	0.006	none	1222	1223	122
123	122	3986.5	79.5	1569	0.003	none	1232	1233	123
124	123	3370.5	80	2856	0.007	none	1242	1243	124
125	124	2864	82.1	1590	0.007	none	1252	1253	125
126	125	2064.3	83.2	1399	0.007	none	1262	1263	126
127	126	1806.8	84.2	1690	1E-05	none	1272	1273	127
128	127	283	84.2	1378	0.012	1281	1282	1283	128
129	127	1326	84.2	10707	0.026	1291	1292	1293	129
130	126	194.25	84.2	1216	0.029	1301	1302	1303	130
131	125	406.25	83.2	3006	0.03	1311	1312	1313	131
132	124	226.75	82.1	1649	0.019	1321	1322	1323	132
133	123	442.25	80	2585	0.0106	1331	1332	1333	133
134	122	126.5	79.5	1157	0.02	1341	1342	1343	134
135	119	603.75	67.4	5887	0.037	1351	1352	1353	135
136	118	181.5	66	1437	0.039	1361	1362	1363	136
137	103	10662	55.4	1166	1E-05	none	1372	1373	137
138	137	10080	55.4	1399	0.024	none	1382	1383	138
139	138	6561.5	58.8	4862	0.013	none	1392	1393	139
140	139	5459.3	64.9	4417	0.015	none	1402	1403	140
141	140	1714	71.5	1016	0.017	none	1412	1413	141
142	141	424.75	73.2	2432	0.057	1421	1422	1423	142
143	141	1196	73.2	1062	0.028	none	1432	1433	143
144	143	323.75	76.2	1245	0.041	1441	1442	1443	144
145	143	805.5	76.2	1107	0.016	none	1452	1453	145
146	145	277.25	78	1719	0.026	1461	1462	1463	146
147	145	322.5	78	3892	0.093	1471	1472	1473	147
148	140	2960.3	71.5	5454	0.015	none	1482	1483	148
149	148	1881.5	79.8	2302	0.009	none	1492	1493	149
150	149	142.5	81.8	1245	0.062	1501	1502	1503	150
151	149	1122.8	81.8	1345	0.015	none	1512	1513	151
152	151	576.5	83.8	2377	0.038	1521	1522	1523	152
153	151	287.75	83.8	1278	0.036	1531	1532	1533	153
154	148	308.25	79.8	2502	0.055	1541	1542	1543	154
155	139	491.25	64.9	5458	0.036	1551	1552	1553	155
156	138	3407	58.8	1187	0.015	none	1562	1563	156
157	156	1715.3	60.6	4096	0.01	none	1572	1573	157
158	157	742.25	64.7	6982	0.036	1581	1582	1583	158
159	157	307.75	64.7	1425	0.059	1591	1592	1593	159
160	156	1606.8	60.6	1844	0.008	none	1602	1603	160
161	160	1079.5	62.1	1607	0.009	none	1612	1613	161
162	161	398	63.6	2402	0.011	1621	1622	1623	162
163	161	547	63.6	4259	0.013	1631	1632	1633	163
164	160	304	62.1	2082	0.005	1641	1642	1643	164

165	137	443.75	55.4	1790	0.034	1651	1652	1653	165
166	102	494.5	55.4	2594	0.034	1661	1662	1663	166
167	101	514.75	55.4	4539	0.025	1671	1672	1673	167
168	90	232.25	51.9	1540	0.079	1681	1682	1683	168
169	89	325076	46.8	292	1E-05	none	1692	1693	169
170	169	324662	46.8	2328	1E-05	none	1702	1703	170
171	170	322951	46.8	221	1E-05	none	1712	none	171
172	171	322494	46.8	962	1E-05	none	1722	1723	172
173	172	808.75	46.8	412	1E-05	none	1732	1733	173
174	173	383.5	46.8	2502	0.006	1741	1742	1743	174
175	173	413	46.8	4559	0.035	1751	1752	1753	175
176	172	321563	46.8	1275	1E-05	none	1762	1763	176
177	176	294	46.8	2190	0.006	1771	1772	1773	177
178	176	321195	46.8	100	1E-05	none	none	1783	178
179	178	320739	46.8	583	1E-05	none	1792	1793	179
180	179	661.5	46.8	3759	0.054	1801	1802	1803	180
181	179	319998	46.8	492	1E-05	none	1812	1813	181
182	181	319446	46.8	2028	1E-05	none	1822	1823	182
183	182	319043	46.8	825	1E-05	none	1832	1833	183
184	183	318571	46.8	1887	1E-05	none	1842	1843	184
185	184	307094	46.8	1949	1E-05	none	1852	1853	185
186	185	873.25	46.8	100	1E-05	none	1862	none	186
187	186	495	46.8	2768	0.02	1871	1872	1873	187
188	186	377.25	46.8	2257	0.097	1881	1882	1883	188
189	185	306163	46.8	2182	1E-05	none	1892	1893	189
190	189	265257	46.8	3085	1E-05	none	1902	1903	190
191	190	14856	46.8	4754	0.015	none	1912	1913	191
192	191	737	54.1	3772	0.035	1921	1922	1923	192
193	191	13423	54.1	142	1E-05	none	1932	1933	193
194	193	1894.3	54.1	1478	0.007	none	1942	1943	194
195	194	1510.5	55.1	875	0.078	none	1952	1953	195
196	195	786	61.9	2332	0.011	none	1962	1963	196
197	196	277	64.4	1678	0.007	1971	1972	1973	197
198	196	199.25	64.4	1533	0.008	1981	1982	1983	198
199	195	619.25	61.9	2818	0.004	1991	1992	1993	199
200	194	267.25	55.1	2040	0.035	2001	2002	2003	200
201	193	11526	54.1	512	1E-05	none	2012	2013	201
202	201	8113.5	54.1	4063	0.006	none	2022	2023	202
203	202	1233.3	56.5	10016	0.029	2031	2032	2033	203
204	202	6336	56.5	1225	0.025	none	2042	2043	204
205	204	1133.3	59.5	11168	0.026	2051	2052	2053	205
206	204	5012	59.5	2444	0.016	none	2062	2063	206
207	206	284.5	63.5	2685	0.016	2071	2072	2073	207
208	206	4506	63.5	612	0.01	none	2082	2083	208
209	208	4053.8	64.1	3859	0.015	none	2092	2093	209
210	209	351.75	69.8	2947	0.025	2101	2102	2103	210
211	209	3297.3	69.8	4749	0.032	none	2112	2113	211
212	211	190.75	85	1732	0.054	2121	2122	2123	212
213	211	2583.5	85	1752	0.003	none	2132	2133	213
214	213	2016	85.5	2057	0.003	none	2142	2143	214
215	214	320.5	86.1	2211	0.057	2151	2152	2153	215
216	214	1475.3	86.1	6936	0.024	2161	2162	2163	216
217	213	205	85.5	1478	0.01	2171	2172	2173	217
218	208	267.75	64.1	1840	0.019	2181	2182	2183	218
219	201	3395	54.1	1037	1E-05	none	2192	2193	219
220	219	3098.5	54.1	995	1E-05	none	2202	2203	220
221	220	2836.8	54.1	242	1E-05	none	2212	2213	221
222	221	2042.3	54.1	4008	0.017	none	2222	2223	222
223	222	952	60.9	3006	0.011	none	2232	2233	223

224	223	245.75	64.2	1537	0.008	2241	2242	2243	224
225	223	422.25	64.2	3439	0.004	2251	2252	2253	225
226	222	482	60.9	3197	0.011	2261	2262	2263	226
227	221	774.25	54.1	725	0.062	none	2272	2273	227
228	227	388.25	58.6	2273	0.022	2281	2282	2283	228
229	227	342	58.6	1911	0.045	2291	2292	2293	229
230	220	166	54.1	1328	0.084	2301	2302	2303	230
231	219	199.5	54.1	2302	0.057	2311	2312	2313	231
232	190	250062	46.8	5929	0.003	none	2322	2323	232
233	232	248856	48.7	716	1E-05	none	2332	2333	233
234	233	248514	48.7	475	1E-05	none	2342	2343	234
235	234	247433	48.7	737	1E-05	none	2352	2353	235
236	235	618.25	48.7	3884	0.047	2361	2362	2363	236
237	235	246756	48.7	4039	1E-05	none	2372	2373	237
238	237	237684	48.7	887	1E-05	none	2382	2383	238
239	238	236762	48.7	4847	1E-05	none	2392	2393	239
240	239	212.5	48.7	1228	0.012	2401	2402	2403	240
241	239	235787	48.7	425	1E-05	none	2412	2413	241
242	241	150.25	48.7	1187	0.0128	2421	2422	2423	242
243	241	235537	48.7	2073	0.04	none	2432	2433	243
244	243	235157	57	1128	1E-05	none	2442	2443	244
245	244	148011	57	50	1E-05	none	2452	2453	245
246	245	7040.3	57	1519	0.01	none	2462	2463	246
247	246	6013.8	58.5	3784	0.019	none	2472	2473	247
248	247	5404	65.7	1219	0.003	none	2482	2483	248
249	248	251.75	66	1669	0.016	2491	2492	2493	249
250	248	5038	66	171	1E-05	none	none	2503	250
251	250	2290.8	66	1699	0.009	none	2512	2513	251
252	251	1930	67.5	492	0.018	none	2522	2523	252
253	252	1551.8	68.4	362	1E-05	none	2532	2533	253
254	253	1036	68.4	1407	0.008	none	2542	2543	254
255	254	424.75	69.5	5662	0.048	2551	2552	2553	255
256	254	424.75	69.5	4479	0.058	2561	2562	2563	256
257	253	506.5	68.4	5167	0.058	2571	2572	2573	257
258	252	313.5	68.4	2032	0.013	2581	2582	2583	258
259	251	289	67.5	2864	0.013	2591	2592	2593	259
260	250	2746	66	3077	0.01	none	2602	2603	260
261	260	1184.8	69	6777	0.029	2611	2612	2613	261
262	260	1296.5	69	7489	0.008	2621	2622	2623	262
263	247	247	65.7	2664	0.01	2631	2632	2633	263
264	246	820.5	58.5	1428	0.032	none	2642	2643	264
265	264	169.5	63.1	1149	0.018	2651	2652	2653	265
266	264	544.5	63.1	1266	0.021	none	2662	2663	266
267	266	192.25	65.7	1328	0.021	2671	2672	2673	267
268	266	196.75	65.7	1087	1E-05	2681	2682	2683	268
269	245	140970	57	666	0.009	none	2692	2693	269
270	269	335.75	57.6	2273	0.033	2701	2702	2703	270
271	269	140616	57.6	1137	1E-05	none	2712	2713	271
272	271	128880	57.6	2164	5E-05	none	2722	2723	272
273	272	127969	57.7	1307	1E-05	none	2732	2733	273
274	273	324.25	57.7	1728	0.042	2741	2742	2743	274
275	273	127575	57.7	1637	0.008	none	2752	2753	275
276	275	379	59	2152	0.04	2761	2762	2763	276
277	275	126986	59	725	0.001	none	2772	2773	277
278	277	126522	59.1	912	1E-05	none	2782	2783	278
279	278	17639	59.1	533	1E-05	none	2792	2793	279
280	279	287.75	59.1	2032	0.04	2801	2802	2803	280
281	279	17330	59.1	5232	0.015	none	2812	2813	281
282	281	1421	67	887	0.053	none	2822	2823	282

283	282	710.75	71.7	975	0.036	none	2832	2833	283
284	283	246.75	75.2	3497	0.063	2841	2842	2843	284
285	283	283.5	75.2	2444	0.044	2851	2852	2853	285
286	282	684.25	71.7	5886	0.032	2861	2862	2863	286
287	281	15020	67	1554	0.023	none	2872	2873	287
288	287	494.75	70.6	5141	0.02	2881	2882	2883	288
289	287	14314	70.6	2073	0.014	none	2892	2893	289
290	289	13443	73.5	4770	0.013	none	2902	2903	290
291	290	3102.5	79.6	2851	0.01	none	2912	2913	291
292	291	361.75	82.5	2261	0.04	2921	2922	2923	292
293	291	2284.3	82.5	683	0.016	none	2932	2933	293
294	293	1728.5	83.6	716	0.013	none	2942	2943	294
295	294	1405.3	84.5	6948	0.023	none	2952	2953	295
296	295	322.75	100.4	2344	0.009	2961	2962	2963	296
297	295	321.75	100.4	1337	0.004	2971	2972	2973	297
298	294	278.75	84.5	1749	0.021	2981	2982	2983	298
299	293	530.25	83.6	3430	0.008	2991	2992	2993	299
300	290	9963.5	79.6	7743	0.01	none	3002	3003	300
301	300	8483	87.4	1240	8E-05	none	3012	3013	301
302	301	8099.3	87.5	454	1E-05	none	3022	3023	302
303	302	6968.5	87.5	2559	1E-05	none	3032	3033	303
304	303	5371	87.5	675	1E-05	none	3042	3043	304
305	304	543.5	87.5	2373	0.011	3051	3052	3053	305
306	304	4751.3	87.5	1911	0.017	none	3062	3063	306
307	306	681.5	90.7	3972	0.007	3071	3072	3073	307
308	306	3912.3	90.7	1749	1E-05	none	3082	3083	308
309	308	2903.8	90.7	3168	0.006	none	3092	3093	309
310	309	129	92.5	1025	0.015	3101	3102	3103	310
311	309	2337.3	92.5	625	0.014	none	3112	3113	311
312	311	1722.3	93.4	2656	0.005	none	3122	3123	312
313	312	288.5	94.7	2111	0.012	3131	3132	3133	313
314	312	1126.5	94.7	845	0.019	none	3142	3143	314
315	314	804.5	96.3	4775	0.034	3151	3152	3153	315
316	314	173	96.3	1037	0.015	3161	3162	3163	316
317	311	565.5	93.4	3759	0.019	3171	3172	3173	317
318	308	805.5	90.7	3909	0.019	3181	3182	3183	318
319	303	1270.3	87.5	887	0.016	none	3192	3193	319
320	319	1005.5	88.9	392	1E-05	none	3202	3203	320
321	320	832.75	88.9	5020	0.02	3211	3212	3213	321
322	320	158.75	88.9	1066	0.024	3221	3222	3223	322
323	319	224	88.9	1540	0.02	3231	3232	3233	323
324	302	1104.3	87.5	7019	0.015	3241	3242	3243	324
325	301	306	87.5	3427	0.025	3251	3252	3253	325
326	300	236.25	87.4	1266	0.022	3261	3262	3263	326
327	289	691.75	73.5	3380	0.004	3271	3272	3273	327
328	278	108832	59.1	2747	1E-05	none	3282	3283	328
329	328	408	59.1	2161	0.035	3291	3292	3293	329
330	328	107911	59.1	1690	0.022	none	3302	3303	330
331	330	105890	62.8	795	1E-05	none	3312	3313	331
332	331	158.75	62.8	1195	0.039	3321	3322	3323	332
333	331	105689	62.8	2732	0.004	none	3332	3333	333
334	333	193.25	63.9	1578	0.046	3341	3342	3343	334
335	333	105172	63.9	1045	1E-05	none	3352	3353	335
336	335	104670	63.9	71	1E-05	none	3362	none	336
337	336	329	63.9	2082	0.032	3371	3372	3373	337
338	336	104340	63.9	1873	1E-05	none	3382	3383	338
339	338	2321	63.9	1819	0.022	none	3392	3393	339
340	339	1919.8	67.9	3822	0.01	none	3402	3403	340
341	340	1391.8	71.8	354	0.017	none	3412	3413	341

342	341	289.25	72.4	2314	0.007	3421	3422	3423	342
343	341	1092.8	72.4	3839	0.02	none	3432	3433	343
344	343	437.5	79.9	2664	0.019	3441	3442	3443	344
345	343	218.75	79.9	2661	0.023	3451	3452	3453	345
346	340	198.25	71.8	1652	0.016	3461	3462	3463	346
347	339	194.25	67.9	1407	0.013	3471	3472	3473	347
348	338	101715	63.9	837	1E-05	none	3482	3483	348
349	348	101442	63.9	212	1E-05	none	3492	3493	349
350	349	101146	63.9	975	1E-05	none	3502	3503	350
351	350	3579.8	63.9	3192	0.015	none	3512	3513	351
352	351	543.75	68.6	3930	0.027	3521	3522	3523	352
353	351	2688	68.6	312	1E-05	none	3532	3533	353
354	353	2086.3	68.6	9978	0.021	none	3542	3543	354
355	354	482	89.2	3497	0.014	3551	3552	3553	355
356	354	166.25	89.2	1107	0.013	3561	3562	3563	356
357	353	503.5	68.6	4746	0.023	3571	3572	3573	357
358	350	97479	63.9	1811	1E-05	none	3582	3583	358
359	358	96159	63.9	2119	0.003	none	3592	3593	359
360	359	586.25	64.6	4154	0.018	3601	3602	3603	360
361	359	95179	64.6	333	1E-05	none	3612	3613	361
362	361	94870	64.6	1282	1E-05	none	3622	3623	362
363	362	94489	64.6	1225	0.011	none	3632	3633	363
364	363	5407.8	66	3430	0.029	none	3642	3643	364
365	364	3092.8	75.8	1137	0.02	none	3652	3653	365
366	365	161.5	78.1	1437	0.025	3661	3662	3663	366
367	365	2797.8	78.1	512	0.02	none	3672	3673	367
368	367	2572.8	79.1	1349	0.017	none	3682	3683	368
369	368	2018.8	81.4	604	1E-05	none	3692	3693	369
370	369	331.25	81.4	2332	1E-05	3701	3702	3703	370
371	369	1585	81.4	2052	0.021	none	3712	3713	371
372	371	736.75	85.6	7798	0.008	3721	3722	3723	372
373	371	674.75	85.6	1137	0.002	none	3732	3733	373
374	373	242.25	85.8	1237	0.028	3741	3742	3743	374
375	373	351	85.8	2240	0.017	3751	3752	3753	375
376	368	327.5	81.4	3047	0.013	3761	3762	3763	376
377	367	169.5	79.1	1540	0.022	3771	3772	3773	377
378	364	2070.8	75.8	2407	0.003	none	3782	3783	378
379	378	1408.8	76.6	1619	0.005	none	3792	3793	379
380	379	977	77.4	783	0.012	none	3802	3803	380
381	380	681	78.3	4125	0.017	3811	3812	3813	381
382	380	238.75	78.3	1919	0.031	3821	3822	3823	382
383	379	218.75	77.4	1257	0.019	3831	3832	3833	383
384	378	374.75	76.6	2414	0.004	3841	3842	3843	384
385	363	88963	66	1778	0.009	none	3852	3853	385
386	385	88384	67.6	1832	1E-05	none	3862	3863	386
387	386	86313	67.6	1016	0.002	none	3872	3873	387
388	387	86008	67.8	1582	1E-05	none	3882	3883	388
389	388	2007.5	67.8	583	0.055	none	3892	3893	389
390	389	886.25	71	312	0.003	none	3902	3903	390
391	390	721	71.1	854	0.027	none	3912	3913	391
392	391	226	73.4	2340	1E-05	3921	3922	3923	392
393	391	454.25	73.4	2364	1E-05	3931	3932	3933	393
394	390	157.25	71.1	1257	0.017	3941	3942	3943	394
395	389	1106	71	2594	0.005	none	3952	3953	395
396	395	302.5	72.4	2314	0.018	3961	3962	3963	396
397	395	430.5	72.4	1907	0.001	3971	3972	3973	397
398	388	83786	67.8	2697	0.005	none	3982	3983	398
399	398	82978	69.2	1028	1E-05	none	3992	3993	399
400	399	2261	69.2	7019	0.007	none	4002	4003	400

401	400	939.75	74.2	6577	0.018	4011	4012	4013	401
402	400	290.75	74.2	1961	0.016	4021	4022	4023	402
403	399	80486	69.2	3709	5E-05	none	4032	4033	403
404	403	79544	69.4	292	1E-05	none	4042	4043	404
405	404	223.25	69.4	1416	0.013	4051	4052	4053	405
406	404	79310	69.4	4458	9E-05	none	4062	4063	406
407	406	9448	69.8	762	1E-05	none	4072	4073	407
408	407	311.25	69.8	1690	0.002	4081	4082	4083	408
409	407	9115.5	69.8	4199	0.005	none	4092	4093	409
410	409	7188.3	71.8	2706	7E-05	none	4102	4103	410
411	410	6624	72	333	1E-05	none	4112	4113	411
412	411	6445.5	72	592	1E-05	none	4122	none	412
413	412	1010.8	72	533	1E-05	none	4132	4133	413
414	413	417.5	72	1882	1E-05	4141	4142	4143	414
415	413	576.75	72	433	1E-05	none	4152	4153	415
416	415	290.5	72	2428	4E-05	4161	4162	4163	416
417	415	254.5	72	3068	0.005	4171	4172	4173	417
418	412	5396.5	72	3147	0.01	none	4182	4183	418
419	418	1381	75	7572	0.012	4191	4192	4193	419
420	418	3894.5	75	2999	0.005	none	4202	4203	420
421	420	3392.5	76.5	2335	0.01	none	4212	4213	421
422	421	1127	78.9	3380	0.015	none	4222	4223	422
423	422	229	83.8	1287	0.008	4231	4232	4233	423
424	422	259.75	83.8	2140	0.008	4241	4242	4243	424
425	421	1993.5	78.9	2594	0.004	none	4252	4253	425
426	425	1531.3	80	2747	0.004	none	4262	4263	426
427	426	586	81.1	2756	0.01	4271	4272	4273	427
428	426	410.25	81.1	3459	0.012	4281	4282	4283	428
429	425	308.75	80	2589	0.007	4291	4292	4293	429
430	420	271.5	76.5	2032	0.009	4301	4302	4303	430
431	411	171.75	72	1295	0.005	4311	4312	4313	431
432	410	180.75	72	1369	0.04	4321	4322	4323	432
433	409	1561.5	71.8	312	1E-05	none	4332	4333	433
434	433	1366.3	71.8	504	1E-05	none	4342	4343	434
435	434	509.25	71.8	3089	0.017	4351	4352	4353	435
436	434	794	71.8	6182	0.014	4361	4362	4363	436
437	433	176	71.8	1819	0.002	4371	4372	4373	437
438	406	69173	69.8	192	1E-05	none	4382	4383	438
439	438	64682	69.8	333	1E-05	none	4392	4393	439
440	439	32353	69.8	371	1E-05	none	4402	4403	440
441	440	30697	69.8	825	1E-05	none	4412	4413	441
442	441	304.25	69.8	3813	0.009	4421	4422	4423	442
443	441	30347	69.8	3284	6E-05	none	4432	4433	443
444	443	624.25	70	5865	0.012	4441	4442	4443	444
445	443	29479	70	71	1E-05	none	none	none	445
446	445	27843	70	1049	1E-05	none	4462	4463	446
447	446	826	70	6198	0.007	4471	4472	4473	447
448	446	26976	70	4746	0.004	none	4482	4483	448
449	448	12266	71.9	2785	4E-05	none	4492	4493	449
450	449	2931.8	72	2423	0.008	none	4502	4503	450
451	450	957.5	73.9	1116	0.022	none	4512	4513	451
452	451	625.5	76.3	4779	0.014	4521	4522	4523	452
453	451	302	76.3	1749	0.009	4531	4532	4533	453
454	450	1728.5	73.9	1902	0.016	none	4542	4543	454
455	454	633.75	77	4708	0.02	4551	4552	4553	455
456	454	885.25	77	6774	0.013	4561	4562	4563	456
457	449	9128.8	72	2697	0.002	none	4572	4573	457
458	457	8544.3	72.4	1228	1E-05	none	4582	4583	458
459	458	442.25	72.4	2556	0.014	4591	4592	4593	459

460	458	8020.8	72.4	1819	0.001	none	4602	4603	460
461	460	7451.5	72.6	1266	0.006	none	4612	4613	461
462	461	2066.3	73.3	907	0.007	none	4622	4623	462
463	462	1039.3	73.9	6994	0.012	4631	4632	4633	463
464	462	920.75	73.9	1940	0.009	none	4642	4643	464
465	464	343.5	75.6	2340	0.013	4651	4652	4653	465
466	464	426.5	75.6	2435	0.016	4661	4662	4663	466
467	461	5292.8	73.3	654	0.011	none	4672	4673	467
468	467	4720	74	804	0.001	none	4682	4683	468
469	468	275.5	74.1	2494	0.01	4691	4692	4693	469
470	468	4373	74.1	3272	0.008	none	4702	4703	470
471	470	774.75	76.8	4858	0.009	4711	4712	4713	471
472	470	3326.3	76.8	1511	0.005	none	4722	4723	472
473	472	3039	77.5	1099	0.004	none	4732	4733	473
474	473	244.25	77.9	1740	0.022	4741	4742	4743	474
475	473	2758.5	77.9	2090	1E-05	none	4752	4753	475
476	475	320	77.9	2827	0.016	4761	4762	4763	476
477	475	2137.8	77.9	5589	0.011	none	4772	4773	477
478	477	443	84.3	1911	0.01	4781	4782	4783	478
479	477	829.25	84.3	1487	1E-05	none	4792	4793	479
480	479	182.75	84.3	1033	0.009	4801	4802	4803	480
481	479	360.5	84.3	1840	0.014	4811	4812	4813	481
482	472	179.5	77.5	1216	0.02	4821	4822	4823	482
483	467	549	74	4999	0.006	4831	4832	4833	483
484	460	224	72.6	2468	0.014	4841	4842	4843	484
485	457	292.5	72.4	1882	0.006	4851	4852	4853	485
486	448	14354	71.9	3801	0.003	none	4862	4863	486
487	486	8702.5	73.2	1416	1E-05	none	4872	4873	487
488	487	8375	73.2	2940	0.003	none	4882	4883	488
489	488	7804.8	74	2244	0.002	none	4892	4893	489
490	489	7362.3	74.5	592	1E-05	none	4902	4903	490
491	490	2399.3	74.5	2599	0.007	none	4912	4913	491
492	491	1720.8	76.2	2814	0.011	none	4922	4923	492
493	492	1135	79.3	8043	0.011	4931	4932	4933	493
494	492	353.25	79.3	2597	0.015	4941	4942	4943	494
495	491	451	76.2	2935	0.011	4951	4952	4953	495
496	490	4920.8	74.5	2285	0.008	none	4962	4963	496
497	496	4278.3	76.3	2652	0.008	none	4972	4973	497
498	497	3757.8	78.5	5291	0.01	none	4982	4983	498
499	498	2603.5	84	412	0.015	none	4992	4993	499
500	499	170.75	84.6	1928	0.021	5001	5002	5003	500
501	499	2423.5	84.6	1994	0.014	none	5012	5013	501
502	501	1827.5	87.3	5646	0.01	none	5022	5023	502
503	502	374.25	93	2044	0.004	5031	5032	5033	503
504	502	501	93	2814	0.014	5041	5042	5043	504
505	501	285.75	87.3	1661	0.025	5051	5052	5053	505
506	498	196.25	84	1228	0.029	5061	5062	5063	506
507	497	392	78.5	3159	0.022	5071	5072	5073	507
508	496	355.25	76.3	1649	0.019	5081	5082	5083	508
509	489	198.5	74.5	1499	0.039	5091	5092	5093	509
510	488	206.5	74	1107	0.032	5101	5102	5103	510
511	487	159.75	73.2	1037	0.014	5111	5112	5113	511
512	486	5360.8	73.2	1345	1E-05	none	5122	5123	512
513	512	3222.8	73.2	4349	0.006	none	5132	5133	513
514	513	2302.5	75.8	3725	0.011	none	5142	5143	514
515	514	735.5	79.8	2406	0.004	none	5152	5153	515
516	515	222.75	80.7	1561	0.012	5161	5162	5163	516
517	515	362	80.7	2723	0.034	5171	5172	5173	517
518	514	926.5	79.8	2918	0.011	none	5182	5183	518

519	518	178.5	82.9	1095	0.017	5191	5192	5193	519
520	518	258	82.9	1328	0.019	5201	5202	5203	520
521	513	295.5	75.8	1769	0.022	5211	5212	5213	521
522	512	2084.5	73.2	1199	0.003	none	5222	5223	522
523	522	1825	73.6	5624	0.015	none	5232	5233	523
524	523	347.25	82.1	3372	0.008	5241	5242	5243	524
525	523	863.75	82.1	2311	0.003	none	5252	5253	525
526	525	224	82.8	1478	0.005	5261	5262	5263	526
527	525	442	82.8	3430	0.002	5271	5272	5273	527
528	522	184	73.6	1440	0.022	5281	5282	5283	528
529	445	1635.3	70	10161	0.01	5291	5292	5293	529
530	440	1630	69.8	1099	1E-05	none	5302	5303	530
531	530	514	69.8	3339	0.004	5311	5312	5313	531
532	530	1082.8	69.8	7239	0.009	5321	5322	5323	532
533	439	32320	69.8	7434	0.003	none	5332	5333	533
534	533	733	72.2	5258	0.014	5341	5342	5343	534
535	533	30987	72.2	221	1E-05	none	5352	5353	535
536	535	30584	72.2	2294	0.003	none	5362	5363	536
537	536	29858	72.9	4932	0.011	none	5372	5373	537
538	537	27739	78.3	3368	0.003	none	5382	5383	538
539	538	26811	79.3	312	1E-05	none	5392	5393	539
540	539	359.75	79.3	2173	0.019	5401	5402	5403	540
541	539	26444	79.3	575	0.016	none	5412	5413	541
542	541	26062	80.2	1157	0.025	none	5422	5423	542
543	542	25103	83.1	3939	1E-05	none	5432	5433	543
544	543	23127	83.1	1957	0.01	none	5442	5443	544
545	544	252.5	85	1590	0.028	5451	5452	5453	545
546	544	22622	85	2285	0.017	none	5462	5463	546
547	546	21054	88.9	1545	1E-05	none	5472	5473	547
548	547	240.75	88.9	1228	0.046	5481	5482	5483	548
549	547	20667	88.9	1757	1E-05	none	5492	5493	549
550	549	221.75	88.9	2435	0.029	5501	5502	5503	550
551	549	20274	88.9	212	1E-05	none	5512	5513	551
552	551	460.75	88.9	4542	0.008	5521	5522	5523	552
553	551	19795	88.9	221	1E-05	none	none	5533	553
554	553	19590	88.9	4172	5E-05	none	5542	5543	554
555	554	18920	89.1	1552	0.009	none	5552	5553	555
556	555	16782	90.5	783	0.001	none	5562	5563	556
557	556	12263	90.6	1175	0.007	none	5572	5573	557
558	557	238.25	91.4	1878	0.014	5581	5582	5583	558
559	557	11903	91.4	271	1E-05	none	5592	5593	559
560	559	693.25	91.4	1490	0.005	none	5602	5603	560
561	560	319.5	92.1	2544	0.014	5611	5612	5613	561
562	560	252.25	92.1	1466	0.023	5621	5622	5623	562
563	559	11202	91.4	2490	1E-05	none	5632	5633	563
564	563	1956.5	91.4	3892	0.008	none	5642	5643	564
565	564	175.25	94.6	1054	0.098	5651	5652	5653	565
566	564	1311.8	94.6	8138	0.015	5661	5662	5663	566
567	563	8845.5	91.4	433	1E-05	none	5672	5673	567
568	567	8422.3	91.4	866	1E-05	none	5682	5683	568
569	568	8002.8	91.4	833	0.001	none	5692	5693	569
570	569	680.75	91.5	5312	0.011	5701	5702	5703	570
571	569	7280.3	91.5	675	1E-05	none	5712	5713	571
572	571	6770	91.5	1469	0.001	none	5722	5723	572
573	572	3856	91.7	2902	0.002	none	5732	5733	573
574	573	950.25	92.2	1973	0.011	none	5742	5743	574
575	574	333	94.3	1587	0.026	5751	5752	5753	575
576	574	379	94.3	2140	0.013	5761	5762	5763	576
577	573	2523.3	92.2	1799	0.008	none	5772	5773	577

578	577	2162.8	93.6	775	0.005	none	5782	5783	578
579	578	1685.5	94	3746	0.01	none	5792	5793	579
580	579	180	97.7	1087	0.004	5801	5802	5803	580
581	579	911	97.7	2185	5E-05	none	5812	5813	581
582	581	196.75	97.8	1287	0.011	5821	5822	5823	582
583	581	486.25	97.8	3722	0.014	5831	5832	5833	583
584	578	394	94	3189	0.046	5841	5842	5843	584
585	577	177.25	93.6	1340	0.028	5851	5852	5853	585
586	572	2760.5	91.7	1549	7E-05	none	5862	5863	586
587	586	355.75	91.8	2194	0.022	5871	5872	5873	587
588	586	2298.8	91.8	5274	0.027	none	5882	5883	588
589	588	335.25	105.8	2618	0.01	5891	5892	5893	589
590	588	1136	105.8	2035	0.009	none	5902	5903	590
591	590	280	107.6	1307	0.005	5911	5912	5913	591
592	590	757.75	107.6	2023	0.027	none	5922	5923	592
593	592	315	113	2268	0.02	5931	5932	5933	593
594	592	197	113	1349	0.003	5941	5942	5943	594
595	571	469	91.5	3359	0.036	5951	5952	5953	595
596	568	312	91.4	2299	0.014	5961	5962	5963	596
597	567	397	91.4	2856	0.028	5971	5972	5973	597
598	556	4422.5	90.6	3992	0.01	none	5982	5983	598
599	598	383.25	94.7	2885	0.013	5991	5992	5993	599
600	598	3598.8	94.7	121	1E-05	none	6002	6003	600
601	600	3336.5	94.7	895	0.029	none	6012	6013	601
602	601	1959	97.3	2082	0.005	none	6022	6023	602
603	602	1140.5	98.4	9112	0.017	6031	6032	6033	603
604	602	447.75	98.4	2564	0.016	6041	6042	6043	604
605	601	1343.8	97.3	907	0.021	none	6052	6053	605
606	605	994.25	99.2	8351	0.006	6061	6062	6063	606
607	605	280.25	99.2	1940	0.002	6071	6072	6073	607
608	600	257.5	94.7	1732	0.019	6081	6082	6083	608
609	555	2028.5	90.5	2232	0.021	none	6092	6093	609
610	609	669	95.1	2706	0.022	6101	6102	6103	610
611	609	1228	95.1	1004	0.016	none	6112	6113	611
612	611	746.75	96.7	2427	0.012	none	6122	6123	612
613	612	156.25	99.7	1437	0.019	6131	6132	6133	613
614	612	324.75	99.7	1799	0.014	6141	6142	6143	614
615	611	392	96.7	1519	0.005	6151	6152	6153	615
616	554	161	89.1	1104	0.05	6161	6162	6163	616
617	553	194.25	88.9	1432	0.064	6171	6172	6173	617
618	546	1351	88.9	475	1E-05	none	6182	6183	618
619	618	296.75	88.9	1902	0.007	6191	6192	6193	619
620	618	1043.5	88.9	2818	0.025	none	6202	6203	620
621	620	319	95.8	1249	0.002	6211	6212	6213	621
622	620	156	95.8	2132	0.034	6221	6222	6223	622
623	543	1340.8	83.1	1237	0.006	none	6232	6233	623
624	623	446.75	83.8	3009	0.023	6241	6242	6243	624
625	623	669.5	83.8	4287	0.032	6251	6252	6253	625
626	542	841.75	83.1	2090	0.017	none	6262	6263	626
627	626	511.25	86.6	3047	0.016	6271	6272	6273	627
628	626	179.75	86.6	1499	0.025	6281	6282	6283	628
629	541	365.75	80.2	2814	0.022	6291	6292	6293	629
630	538	554.25	79.3	4625	0.021	6301	6302	6303	630
631	537	1605.5	78.3	121	1E-05	none	6312	6313	631
632	631	1273.5	78.3	1057	0.045	none	6322	6323	632
633	632	547	83	4104	0.018	6331	6332	6333	633
634	632	653.5	83	4604	0.014	6341	6342	6343	634
635	631	330.5	78.3	4180	0.024	6351	6352	6353	635
636	536	345.5	72.9	3606	0.045	6361	6362	6363	636

637	535	398.25	72.2	3006	0.018	6371	6372	6373	637
638	438	4488	69.8	816	1E-05	none	6382	6383	638
639	638	183.5	69.8	1007	0.012	6391	6392	6393	639
640	638	4272.3	69.8	692	0.015	none	6402	6403	640
641	640	2542	70.8	4113	0.006	none	6412	6413	641
642	641	1646	73.2	1328	0.013	none	6422	6423	642
643	642	182.5	74.9	1099	0.016	6431	6432	6433	643
644	642	1162.8	74.9	1187	0.004	none	6442	6443	644
645	644	288.25	75.4	1849	0.016	6451	6452	6453	645
646	644	817.5	75.4	404	1E-05	none	6462	6463	646
647	646	380	75.4	2832	0.005	6471	6472	6473	647
648	646	407.75	75.4	2694	0.012	6481	6482	6483	648
649	641	484	73.2	2282	0.005	6491	6492	6493	649
650	640	1704.8	70.8	1378	0.004	none	6502	6503	650
651	650	220.75	71.4	1711	0.001	6511	6512	6513	651
652	650	1397.3	71.4	4063	0.003	none	6522	6523	652
653	652	657.5	72.5	4017	0.003	6531	6532	6533	653
654	652	256.5	72.5	2073	0.011	6541	6542	6543	654
655	403	576	69.4	4475	0.012	6551	6552	6553	655
656	398	355.25	69.2	433	0.083	none	6562	6563	656
657	656	122.25	72.8	1087	0.017	6571	6572	6573	657
658	656	172.5	72.8	1016	0.021	6581	6582	6583	658
659	387	275.25	67.8	1661	0.057	6591	6592	6593	659
660	386	1823.3	67.6	2502	0.032	none	6602	6603	660
661	660	688.5	75.5	212	1E-05	none	6612	6613	661
662	661	175.5	75.5	1157	0.017	6621	6622	6623	662
663	661	467.5	75.5	2506	0.004	6631	6632	6633	663
664	660	818.5	75.5	866	1E-05	none	6642	6643	664
665	664	536.5	75.5	4596	0.004	6651	6652	6653	665
666	664	240.5	75.5	1890	0.006	6661	6662	6663	666
667	385	186.75	67.6	2040	0.044	6671	6672	6673	667
668	362	178.25	64.6	1457	0.042	6681	6682	6683	668
669	361	235.75	64.6	2132	0.031	6691	6692	6693	669
670	358	1080	63.9	1228	0.047	none	6702	6703	670
671	670	579.25	69.7	2806	0.019	6711	6712	6713	671
672	670	408	69.7	3335	0.025	6721	6722	6723	672
673	349	282.75	63.9	1882	0.044	6731	6732	6733	673
674	348	245	63.9	2485	0.019	6741	6742	6743	674
675	335	371.75	63.9	2573	0.021	6751	6752	6753	675
676	330	1760.3	62.8	1125	0.021	none	6762	6763	676
677	676	146.5	65.2	1025	0.024	6771	6772	6773	677
678	676	1540.8	65.2	4034	0.014	none	6782	6783	678
679	678	253.75	70.7	1599	0.021	6791	6792	6793	679
680	678	779.25	70.7	895	0.013	none	6802	6803	680
681	680	517.5	71.9	1116	0.02	none	6812	6813	681
682	681	211.75	74.1	1007	0.013	6821	6822	6823	682
683	681	265.75	74.1	1178	0.003	6831	6832	6833	683
684	680	232.25	71.9	1919	0.016	6841	6842	6843	684
685	277	380	59.1	4059	0.028	6851	6852	6853	685
686	272	768.25	57.7	3835	0.021	6861	6862	6863	686
687	271	11637	57.6	2223	0.023	none	6872	6873	687
688	687	2392.8	62.8	4587	0.007	none	6882	6883	688
689	688	1754	66.2	6112	0.007	none	6892	6893	689
690	689	450.75	70.2	1914	1E-05	6901	6902	6903	690
691	689	400	70.2	1673	0.002	6911	6912	6913	691
692	688	291.25	66.2	2794	0.002	6921	6922	6923	692
693	687	9064.5	62.8	3206	1E-05	none	6932	6933	693
694	693	294.5	62.8	3659	0.01	6941	6942	6943	694
695	693	8500.5	62.8	3763	0.004	none	6952	6953	695

696	695	486.25	64.2	4225	0.013	6961	6962	6963	696
697	695	7557.8	64.2	2685	0.006	none	6972	6973	697
698	697	7033.3	65.9	392	1E-05	none	6982	6983	698
699	698	3006.3	65.9	816	0.003	none	6992	6993	699
700	699	367.25	66.1	3156	0.005	7001	7002	7003	700
701	699	2523	66.1	875	1E-05	none	7012	7013	701
702	701	704.5	66.1	5649	0.024	7021	7022	7023	702
703	701	1775.5	66.1	3214	0.003	none	7032	7033	703
704	703	261.5	67.2	1982	0.005	7041	7042	7043	704
705	703	1260	67.2	575	0.005	none	7052	7053	705
706	705	761.25	67.5	825	0.002	none	7062	7063	706
707	706	518.5	67.7	2897	0.025	7071	7072	7073	707
708	706	207.25	67.7	1166	0.007	7081	7082	7083	708
709	705	399.5	67.5	3559	0.012	7091	7092	7093	709
710	698	4014	65.9	3372	1E-05	none	7102	7103	710
711	710	3154.3	65.9	5792	0.005	none	7112	7113	711
712	711	1708.3	68.7	3309	0.012	none	7122	7123	712
713	712	1076.3	72.5	2573	0.009	none	7132	7133	713
714	713	295.5	74.8	1887	0.013	7141	7142	7143	714
715	713	237.25	74.8	1307	0.006	7151	7152	7153	715
716	712	305	72.5	1187	0.006	7161	7162	7163	716
717	711	645.5	68.7	5682	0.012	7171	7172	7173	717
718	710	325	65.9	2668	0.012	7181	7182	7183	718
719	697	272	65.9	1399	0.008	7191	7192	7193	719
720	244	86914	57	821	0.007	none	7202	7203	720
721	720	86660	57.6	7254	0.001	none	7212	7213	721
722	721	84848	58.6	5172	6E-05	none	7222	7223	722
723	722	81344	58.9	2082	0.012	none	7232	7233	723
724	723	79757	61.4	895	1E-05	none	7242	7243	724
725	724	51628	61.4	2580	0.006	none	7252	7253	725
726	725	50829	62.9	2214	1E-05	none	7262	7263	726
727	726	28278	62.9	3152	0.026	none	7272	7273	727
728	727	187.75	71.1	1133	1E-05	7281	7282	7283	728
729	727	27889	71.1	1245	1E-05	none	7292	7293	729
730	729	177	71.1	1349	1E-05	7301	7302	7303	730
731	729	27496	71.1	100	1E-05	none	7312	7313	731
732	731	26928	71.1	2245	1E-05	none	7322	7323	732
733	732	26349	71.1	221	1E-05	none	7332	7333	733
734	733	24252	71.1	221	1E-05	none	7342	7343	734
735	734	3657.8	71.1	100	1E-05	none	7352	7353	735
736	735	3468.8	71.1	312	1E-05	none	7362	7363	736
737	736	2934	71.1	5815	0.003	none	7372	7373	737
738	737	324.25	73	2909	0.011	7381	7382	7383	738
739	737	1810.5	73	621	1E-05	none	7392	7393	739
740	739	560.75	73	3734	0.005	7401	7402	7403	740
741	739	1132.5	73	1342	1E-05	none	7412	7413	741
742	741	546	73	3489	0.009	7421	7422	7423	742
743	741	470.75	73	3696	0.006	7431	7432	7433	743
744	736	468	71.1	2830	1E-05	7441	7442	7443	744
745	735	180.75	71.1	4186	1E-05	7451	7452	7453	745
746	734	20570	71.1	5801	1E-05	none	7462	7463	746
747	746	1835.8	71.1	2152	1E-05	none	7472	7473	747
748	747	423.75	71.1	2173	0.019	7481	7482	7483	748
749	747	1314.5	71.1	5034	0.007	none	7492	7493	749
750	749	339.25	74.6	1678	1E-05	7501	7502	7503	750
751	749	408.75	74.6	2927	0.004	7511	7512	7513	751
752	746	18252	71.1	2166	1E-05	none	7522	7523	752
753	752	1624	71.1	9990	0.005	7531	7532	7533	753
754	752	16378	71.1	3679	0.011	none	7542	7543	754

755	754	150.25	75	1487	0.014	7551	7552	7553	755
756	754	15922	75	3492	6E-05	none	7562	7563	756
757	756	15214	75.2	775	0.003	none	7572	7573	757
758	757	543.25	75.4	645	0.009	none	7582	7583	758
759	758	224	76	1840	0.019	7591	7592	7593	759
760	758	303.5	76	2806	0.016	7601	7602	7603	760
761	757	14620	75.4	3301	0.002	none	7612	7613	761
762	761	276.75	75.9	2161	0.007	7621	7622	7623	762
763	761	13993	75.9	987	0.015	none	7632	7633	763
764	763	13315	77.4	2844	1E-05	none	7642	7643	764
765	764	953.25	77.4	875	0.001	none	7652	7653	765
766	765	198.25	77.5	1319	0.016	7661	7662	7663	766
767	765	718	77.5	1216	0.006	none	7672	7673	767
768	767	208.75	78.2	1187	0.057	7681	7682	7683	768
769	767	371.5	78.2	3264	0.017	7691	7692	7693	769
770	764	11912	77.4	3330	0.006	none	7702	7703	770
771	770	11162	79.4	975	0.004	none	7712	7713	771
772	771	10330	79.8	4670	0.006	none	7722	7723	772
773	772	9238.5	82.4	604	1E-05	none	7732	7733	773
774	773	7742.3	82.4	4725	0.012	none	7742	7743	774
775	774	4901.8	88.2	3934	0.017	none	7752	7753	775
776	775	264.5	94.8	1199	0.028	7761	7762	7763	776
777	775	4096.5	94.8	4175	0.007	none	7772	7773	777
778	777	2215	97.9	825	1E-05	none	7782	7783	778
779	778	441.25	97.9	3147	0.01	7791	7792	7793	779
780	778	1720.3	97.9	825	1E-05	none	7802	7803	780
781	780	163.25	97.9	1649	0.01	7811	7812	7813	781
782	780	1517	97.9	2273	0.011	none	7822	7823	782
783	782	1074.3	100.4	6996	0.004	7831	7832	7833	783
784	782	303	100.4	2149	0.005	7841	7842	7843	784
785	777	1228	97.9	7056	0.008	7851	7852	7853	785
786	774	1994.8	88.2	2761	0.025	none	7862	7863	786
787	786	221.25	95	2382	0.021	7871	7872	7873	787
788	786	1368.3	95	2956	0.02	none	7882	7883	788
789	788	389.75	101	2094	0.011	7891	7892	7893	789
790	788	307.25	101	2111	0.013	7901	7902	7903	790
791	773	1445.5	82.4	5529	0.027	none	7912	7913	791
792	791	358.75	97.3	2564	0.019	7921	7922	7923	792
793	791	342	97.3	1257	0.022	7931	7932	7933	793
794	772	408.25	82.4	3979	0.032	7941	7942	7943	794
795	771	789.25	79.8	775	0.007	none	7952	7953	795
796	795	366.25	80.3	4162	0.026	7961	7962	7963	796
797	795	370.25	80.3	4663	0.058	7971	7972	7973	797
798	770	411	79.4	2502	0.026	7981	7982	7983	798
799	763	600	77.4	3834	0.007	7991	7992	7993	799
800	756	224.25	75.2	1107	0.003	8001	8002	8003	800
801	733	2010.8	71.1	7219	1E-05	none	8012	8013	801
802	801	1530	71.1	3867	0.006	none	8022	8023	802
803	802	600.75	73.4	3118	0.005	8031	8032	8033	803
804	802	267.75	73.4	2161	0.005	8041	8042	8043	804
805	801	158.25	71.1	1269	0.026	8051	8052	8053	805
806	732	195.25	71.1	4764	8E-05	8061	8062	8063	806
807	731	549	71.1	3703	1E-05	8071	8072	8073	807
808	726	22046	62.9	695	0.05	none	8082	8083	808
809	808	200.5	66.4	1445	0.042	8091	8092	8093	809
810	808	21824	66.4	404	1E-05	none	8102	8103	810
811	810	21585	66.4	1287	0.005	none	8112	8113	811
812	811	355	67.1	2344	0.017	8121	8122	8123	812
813	811	21103	67.1	321	1E-05	none	8132	8133	813

814	813	20921	67.1	333	0.054	none	8142	8143	814
815	814	469	68.9	4784	0.009	8151	8152	8153	815
816	814	20436	68.9	1952	1E-05	none	8162	8163	816
817	816	608.5	68.9	5358	0.006	8171	8172	8173	817
818	816	19632	68.9	4534	0.007	none	8182	8183	818
819	818	161.5	72.2	1307	0.002	8191	8192	8193	819
820	818	18919	72.2	2161	1E-05	none	8202	8203	820
821	820	273	72.2	1719	0.007	8211	8212	8213	821
822	820	18227	72.2	2877	0.004	none	8222	8223	822
823	822	17457	73.3	392	1E-05	none	8232	8233	823
824	823	15538	73.3	1169	1E-05	none	8242	8243	824
825	824	362.75	73.3	2794	0.006	8251	8252	8253	825
826	824	15133	73.3	3068	0.002	none	8262	8263	826
827	826	240.75	73.8	1973	0.01	8271	8272	8273	827
828	826	14334	73.8	1873	1E-05	none	8282	8283	828
829	828	264.5	73.8	2132	0.002	8291	8292	8293	829
830	828	13800	73.8	583	1E-05	none	8302	8303	830
831	830	239.5	73.8	2032	0.005	8311	8312	8313	831
832	830	13444	73.8	71	1E-05	none	none	8323	832
833	832	1252	73.8	4758	0.004	none	8332	8333	833
834	833	361.25	75.9	3551	0.005	8341	8342	8343	834
835	833	413.5	75.9	1869	0.014	8351	8352	8353	835
836	832	12191	73.8	71	1E-05	none	none	8363	836
837	836	180.25	73.8	1744	0.006	8371	8372	8373	837
838	836	11900	73.8	2577	0.003	none	8382	8383	838
839	838	5553	74.5	1219	0.012	none	8392	8393	839
840	839	3651	76	4042	0.006	none	8402	8403	840
841	840	1465.5	78.5	3289	0.008	none	8412	8413	841
842	841	216.5	81.2	1490	0.029	8421	8422	8423	842
843	841	869.25	81.2	562	0.029	none	8432	8433	843
844	843	627	82.8	3842	0.031	8441	8442	8443	844
845	843	207.75	82.8	1832	0.039	8451	8452	8453	845
846	840	1519.3	78.5	6084	0.025	none	8462	8463	846
847	846	373.5	93.6	3023	0.026	8471	8472	8473	847
848	846	364.5	93.6	2468	0.022	8481	8482	8483	848
849	839	1726.5	76	171	0.012	none	8492	8493	849
850	849	1112.8	76.2	2656	0.012	none	8502	8503	850
851	850	731.75	79.3	4712	0.027	8511	8512	8513	851
852	850	217.5	79.3	1299	0.017	8521	8522	8523	852
853	849	608.75	76.2	1299	0.015	none	8532	8533	853
854	853	242	78.1	1669	0.016	8541	8542	8543	854
855	853	308.5	78.1	1890	0.016	8551	8552	8553	855
856	838	6179.8	74.5	766	1E-05	none	8562	8563	856
857	856	5323.3	74.5	2123	0.012	none	8572	8573	857
858	857	4920	77.1	1578	0.015	none	8582	8583	858
859	858	3045	79.4	754	0.016	none	8592	8593	859
860	859	2397.5	80.6	866	0.013	none	8602	8603	860
861	860	957	81.7	1949	0.016	none	8612	8613	861
862	861	512.5	84.9	3068	0.017	8621	8622	8623	862
863	861	312.5	84.9	2527	0.015	8631	8632	8633	863
864	860	1342	81.7	2173	0.017	none	8642	8643	864
865	864	815.25	85.4	4499	0.014	8651	8652	8653	865
866	864	233.5	85.4	2106	0.034	8661	8662	8663	866
867	859	603	80.6	4554	0.009	8671	8672	8673	867
868	858	1742.3	79.4	1166	0.012	none	8682	8683	868
869	868	274.25	80.8	1940	0.003	8691	8692	8693	869
870	868	1385	80.8	1637	0.006	none	8702	8703	870
871	870	770.75	81.7	4692	0.01	8711	8712	8713	871
872	870	500	81.7	2506	0.004	8721	8722	8723	872

873	857	259.25	77.1	2261	0.025	8731	8732	8733	873
874	856	821.75	74.5	5349	0.017	8741	8742	8743	874
875	823	1848.8	73.3	71	1E-05	none	none	8753	875
876	875	1433.3	73.3	595	1E-05	none	8762	8763	876
877	876	216.25	73.3	2123	0.007	8771	8772	8773	877
878	876	1206	73.3	1278	0.003	none	8782	8783	878
879	878	962.75	73.7	583	0.002	none	8792	8793	879
880	879	390.5	73.8	2032	0.016	8801	8802	8803	880
881	879	524.75	73.8	483	0.006	none	8812	8813	881
882	881	247.25	74.1	1961	0.012	8821	8822	8823	882
883	881	266.5	74.1	2732	0.014	8831	8832	8833	883
884	878	161.25	73.7	1449	0.016	8841	8842	8843	884
885	875	415	73.3	5512	0.012	8851	8852	8853	885
886	822	444.25	73.3	3106	0.01	8861	8862	8863	886
887	813	161.75	67.1	1099	0.038	8871	8872	8873	887
888	810	219.25	66.4	1178	0.031	8881	8882	8883	888
889	725	336.5	62.9	2739	0.025	8891	8892	8893	889
890	724	28047	61.4	7087	0.007	none	8902	8903	890
891	890	27014	66.1	954	0.004	none	8912	8913	891
892	891	26541	66.5	916	1E-05	none	8922	8923	892
893	892	524	66.5	3351	0.017	8931	8932	8933	893
894	892	25910	66.5	212	1E-05	none	8942	8943	894
895	894	1814.5	66.5	3027	0.005	none	8952	8953	895
896	895	467.25	68.1	3877	0.019	8961	8962	8963	896
897	895	1050.8	68.1	6949	0.009	8971	8972	8973	897
898	894	24075	66.5	1882	0.012	none	8982	8983	898
899	898	10872	68.8	4891	0.01	none	8992	8993	899
900	899	234	73.8	1707	0.036	9001	9002	9003	900
901	899	10064	73.8	5786	0.01	none	9012	9013	901
902	901	6974	79.5	242	0.008	none	9022	9023	902
903	902	294	79.7	1699	0.02	9031	9032	9033	903
904	902	6675.8	79.7	2461	0.007	none	9042	9043	904
905	904	194.5	81.5	2061	0.022	9051	9052	9053	905
906	904	6198	81.5	725	0.004	none	9062	9063	906
907	906	730.5	81.8	625	1E-05	none	9072	9073	907
908	907	444.75	81.8	3959	0.024	9081	9082	9083	908
909	907	219	81.8	1137	0.007	9091	9092	9093	909
910	906	5390.3	81.8	2099	0.007	none	9102	9103	910
911	910	357.75	83.3	3101	0.004	9111	9112	9113	911
912	910	4746.5	83.3	1345	0.008	none	9122	9123	912
913	912	3301	84.4	1432	0.003	none	9132	9133	913
914	913	823.25	84.8	6886	0.012	9141	9142	9143	914
915	913	2239.3	84.8	2019	0.02	none	9152	9153	915
916	915	214	88.8	1366	0.01	9161	9162	9163	916
917	915	1756.8	88.8	654	1E-05	none	9172	9173	917
918	917	1471.3	88.8	3344	0.014	none	9182	9183	918
919	918	806.75	93.6	421	0.017	none	9192	9193	919
920	919	621.25	94.3	3239	0.01	9201	9202	9203	920
921	919	165.75	94.3	1119	0.03	9211	9212	9213	921
922	918	156.5	93.6	1299	0.019	9221	9222	9223	922
923	917	228.5	88.8	1628	0.015	9231	9232	9233	923
924	912	1177	84.4	342	1E-05	none	9242	9243	924
925	924	469.75	84.4	171	1E-05	none	9252	9253	925
926	925	152.75	84.4	1899	0.036	9261	9262	9263	926
927	925	304.75	84.4	3139	0.025	9271	9272	9273	927
928	924	701.75	84.4	3747	0.015	9281	9282	9283	928
929	901	2199.5	79.5	2490	0.02	none	9292	9293	929
930	929	1616.5	84.4	2668	0.002	none	9302	9303	930
931	930	489.25	85	3492	0.017	9311	9312	9313	931

932	930	380.5	85	1449	0.014	9321	9322	9323	932
933	929	328.5	84.4	2123	0.009	9331	9332	9333	933
934	898	13108	68.8	645	0.016	none	9342	9343	934
935	934	249	69.8	3409	0.045	9351	9352	9353	935
936	934	12778	69.8	483	0.006	none	9362	9363	936
937	936	9797.5	70.1	1519	0.012	none	9372	9373	937
938	937	207.5	71.9	1773	0.042	9381	9382	9383	938
939	937	9475.5	71.9	757	0.011	none	9392	9393	939
940	939	322	72.7	2473	0.045	9401	9402	9403	940
941	939	9108.5	72.7	433	1E-05	none	9412	9413	941
942	941	8922.5	72.7	2577	0.004	none	9422	9423	942
943	942	399	73.7	1944	0.013	9431	9432	9433	943
944	942	8255.3	73.7	2569	0.006	none	9442	9443	944
945	944	3877.5	75.2	1761	0.02	none	9452	9453	945
946	945	220	78.7	1557	0.063	9461	9462	9463	946
947	945	3577.5	78.7	645	1E-05	none	9472	9473	947
948	947	2009.8	78.7	2456	0.01	none	9482	9483	948
949	948	869.5	81.1	5282	0.024	9491	9492	9493	949
950	948	861.5	81.1	6665	0.028	9501	9502	9503	950
951	947	1551	78.7	1278	0.005	none	9512	9513	951
952	951	1103	79.3	454	0.027	none	9522	9523	952
953	952	379.75	80.5	3822	0.015	9531	9532	9533	953
954	952	708.5	80.5	5798	0.047	9541	9542	9543	954
955	951	390.25	79.3	3268	0.012	9551	9552	9553	955
956	944	3734.8	75.2	1249	0.014	none	9562	9563	956
957	956	186.25	77	1387	0.013	9571	9572	9573	957
958	956	3292.5	77	1699	0.014	none	9582	9583	958
959	958	2977.3	79.3	3418	0.01	none	9592	9593	959
960	959	346	82.8	2747	0.075	9601	9602	9603	960
961	959	2297.5	82.8	442	0.014	none	9612	9613	961
962	961	2038.5	83.4	4239	0.019	none	9622	9623	962
963	962	440.75	91.6	2411	0.042	9631	9632	9633	963
964	962	1114.8	91.6	292	0.003	none	9642	9643	964
965	964	389.75	91.7	2144	0.012	9651	9652	9653	965
966	964	701	91.7	1752	0.016	none	9662	9663	966
967	966	147	94.5	1799	0.037	9671	9672	9673	967
968	966	337.75	94.5	3939	0.023	9681	9682	9683	968
969	961	250.5	83.4	1216	0.004	9691	9692	9693	969
970	958	223	79.3	1419	0.012	9701	9702	9703	970
971	941	166	72.7	1066	0.005	9711	9712	9713	971
972	936	2962.5	70.1	883	0.013	none	9722	9723	972
973	972	2011.5	71.2	612	0.008	none	9732	9733	973
974	973	176.5	71.7	1316	0.021	9741	9742	9743	974
975	973	1796	71.7	2599	0.011	none	9752	9753	975
976	975	840.25	74.5	5129	0.005	9761	9762	9763	976
977	975	676.5	74.5	3559	0.004	9771	9772	9773	977
978	972	867	71.2	1740	0.014	none	9782	9783	978
979	978	508.75	73.7	4137	0.012	9791	9792	9793	979
980	978	201	73.7	1540	0.006	9801	9802	9803	980
981	891	367.25	66.5	1861	0.028	9811	9812	9813	981
982	890	381.75	66.1	2909	0.029	9821	9822	9823	982
983	723	1464	61.4	5863	0.017	none	9832	9833	983
984	983	273.25	71.2	2173	0.006	9841	9842	9843	984
985	983	238.25	71.2	2685	0.01	9851	9852	9853	985
986	722	2839	58.9	5774	0.02	none	9862	9863	986
987	986	1540.5	70.7	833	0.001	none	9872	9873	987
988	987	475.25	70.8	2356	0.003	9881	9882	9883	988
989	987	1027.8	70.8	2977	0.003	none	9892	9893	989
990	989	208	71.8	2214	0.016	9901	9902	9903	990

991	989	566.5	71.8	625	0.019	none	9912	9913	991
992	991	266	73	1982	0.013	9921	9922	9923	992
993	991	261.75	73	1799	0.007	9931	9932	9933	993
994	986	237.75	70.7	2277	0.002	9941	9942	9943	994
995	721	945.5	58.6	1045	0.034	none	9952	9953	995
996	995	663.5	62.2	1269	0.032	none	9962	9963	996
997	996	246	66.2	1478	0.005	9971	9972	9973	997
998	996	191.75	66.2	1007	0.007	9981	9982	9983	998
999	995	237.75	62.2	1307	0.032	9991	9992	9993	999
1000	720	211.25	57.6	1761	0.043	10001	10002	10003	1000
1001	243	214	57	2102	0.038	10011	10012	10013	1001
1002	238	816.5	48.7	7264	0.028	10021	10022	10023	1002
1003	237	8459.3	48.7	483	0.017	none	10032	10033	1003
1004	1003	6589	49.5	5363	0.031	none	10042	10043	1004
1005	1004	3330.3	65.9	2223	0.003	none	10052	10053	1005
1006	1005	992.75	66.6	6610	0.007	10061	10062	10063	1006
1007	1005	2182.3	66.6	1569	0.005	none	10072	10073	1007
1008	1007	1567	67.3	9966	0.005	none	10082	10083	1008
1009	1008	163.5	72.4	1466	0.014	10091	10092	10093	1009
1010	1008	176.5	72.4	1337	0.013	10101	10102	10103	1010
1011	1007	539.5	67.3	4679	0.011	10111	10112	10113	1011
1012	1004	2358.8	65.9	1566	1E-05	none	10122	10123	1012
1013	1012	1853.5	65.9	4637	0.009	none	10132	10133	1013
1014	1013	1098.5	70.2	1799	0.008	none	10142	10143	1014
1015	1014	719	71.6	3559	0.01	10151	10152	10153	1015
1016	1014	203.5	71.6	1669	0.016	10161	10162	10163	1016
1017	1013	187.25	70.2	1237	0.013	10171	10172	10173	1017
1018	1012	404.75	65.9	3834	0.015	10181	10182	10183	1018
1019	1003	1842	49.5	1569	0.035	none	10192	10193	1019
1020	1019	1435	55	2094	0.034	none	10202	10203	1020
1021	1020	194	62.1	1407	0.058	10211	10212	10213	1021
1022	1020	904	62.1	7805	0.019	10221	10222	10223	1022
1023	1019	170.5	55	1128	0.0122	10231	10232	10233	1023
1024	234	1032.3	48.7	8721	0.031	10241	10242	10243	1024
1025	233	264.75	48.7	2573	0.076	10251	10252	10253	1025
1026	232	236.25	48.7	2473	0.087	10261	10262	10263	1026
1027	189	40688	46.8	895	0.026	none	10272	10273	1027
1028	1027	188.75	49.1	2169	0.056	10281	10282	10283	1028
1029	1027	40423	49.1	454	0.013	none	10292	10293	1029
1030	1029	1781.3	49.7	3347	0.024	none	10302	10303	1030
1031	1030	1214.8	57.7	2497	0.022	none	10312	10313	1031
1032	1031	189.75	63.3	1219	0.046	10321	10322	10323	1032
1033	1031	699.75	63.3	4987	0.025	10331	10332	10333	1033
1034	1030	310.5	57.7	2219	0.06	10341	10342	10343	1034
1035	1029	38626	49.7	2540	0.002	none	10352	10353	1035
1036	1035	37542	50.1	5915	0.002	none	10362	10363	1036
1037	1036	36450	51.4	937	1E-05	none	10372	10373	1037
1038	1037	256	51.4	1990	0.0117	10381	10382	10383	1038
1039	1037	36141	51.4	1254	0.009	none	10392	10393	1039
1040	1039	30030	52.5	3709	0.005	none	10402	10403	1040
1041	1040	27967	54.4	1087	0.009	none	10412	10413	1041
1042	1041	687	55.4	3701	0.056	10421	10422	10423	1042
1043	1041	27084	55.4	1945	0.006	none	10432	10433	1043
1044	1043	26792	56.6	121	1E-05	none	10442	10443	1044
1045	1044	4165	56.6	2211	0.006	none	10452	10453	1045
1046	1045	139.25	58	1028	0.0185	10461	10462	10463	1046
1047	1045	3765.3	58	1249	0.021	none	10472	10473	1047
1048	1047	2736.8	60.6	2977	0.003	none	10482	10483	1048
1049	1048	218	61.5	2264	0.064	10491	10492	10493	1049

1050	1048	1818.3	61.5	766	1E-05	none	10502	10503	1050
1051	1050	1264.3	61.5	7226	0.02	10511	10512	10513	1051
1052	1050	476.25	61.5	4292	0.035	10521	10522	10523	1052
1053	1047	935.5	60.6	5325	0.022	10531	10532	10533	1053
1054	1044	22625	56.6	1866	1E-05	none	10542	10543	1054
1055	1054	22218	56.6	754	1E-05	none	10552	10553	1055
1056	1055	561.75	56.6	433	1E-05	none	10562	10563	1056
1057	1056	381.5	56.6	242	0.062	none	10572	10573	1057
1058	1057	234.5	58.1	1378	0.03	10581	10582	10583	1058
1059	1057	142.5	58.1	1087	0.051	10591	10592	10593	1059
1060	1056	172	56.6	1225	0.055	10601	10602	10603	1060
1061	1055	21629	56.6	412	1E-05	none	10612	10613	1061
1062	1061	21396	56.6	1490	0.003	none	10622	10623	1062
1063	1062	21015	57.1	2132	0.025	none	10632	10633	1063
1064	1063	18716	62.5	1245	0.003	none	10642	10643	1064
1065	1064	807	62.9	1328	0.014	none	10652	10653	1065
1066	1065	205.25	64.8	1478	0.021	10661	10662	10663	1066
1067	1065	561	64.8	775	1E-05	none	10672	10673	1067
1068	1067	289.5	64.8	1228	0.042	10681	10682	10683	1068
1069	1067	238.25	64.8	1740	0.005	10691	10692	10693	1069
1070	1064	17622	62.9	5806	0.002	none	10702	10703	1070
1071	1070	16571	64.2	404	1E-05	none	10712	10713	1071
1072	1071	16032	64.2	354	1E-05	none	10722	10723	1072
1073	1072	4383	64.2	6074	0.006	none	10732	10733	1073
1074	1073	3421.3	68.1	2302	0.024	none	10742	10743	1074
1075	1074	529.5	73.7	3909	0.002	10751	10752	10753	1075
1076	1074	2497.8	73.7	2856	1E-05	none	10762	10763	1076
1077	1076	650.25	73.7	4001	0.009	10771	10772	10773	1077
1078	1076	1342.3	73.7	1257	0.01	none	10782	10783	1078
1079	1078	300.75	75	2714	0.004	10791	10792	10793	1079
1080	1078	939.75	75	5241	0.002	10801	10802	10803	1080
1081	1073	264.5	68.1	1666	0.023	10811	10812	10813	1081
1082	1072	11618	64.2	878	1E-05	none	10822	10823	1082
1083	1082	10558	64.2	3034	1E-05	none	10832	10833	1083
1084	1083	318.25	64.2	2444	0.03	10841	10842	10843	1084
1085	1083	9893.8	64.2	1004	1E-05	none	10852	10853	1085
1086	1085	7638.3	64.2	242	1E-05	none	10862	10863	1086
1087	1086	4831.3	64.2	1440	0.003	none	10872	10873	1087
1088	1087	311	64.6	2173	0.046	10881	10882	10883	1088
1089	1087	4379.8	64.6	9010	0.008	none	10892	10893	1089
1090	1089	1332.5	71.6	2061	0.001	none	10902	10903	1090
1091	1090	329	71.8	1495	0.027	10911	10912	10913	1091
1092	1090	763.5	71.8	2577	0.018	none	10922	10923	1092
1093	1092	202	76.5	1569	0.011	10931	10932	10933	1093
1094	1092	229	76.5	2282	0.015	10941	10942	10943	1094
1095	1089	1621.8	71.6	875	1E-05	none	10952	10953	1095
1096	1095	248	71.6	1723	0.038	10961	10962	10963	1096
1097	1095	1319	71.6	1054	0.01	none	10972	10973	1097
1098	1097	581	72.7	2880	0.027	10981	10982	10983	1098
1099	1097	648.75	72.7	4009	0.019	10991	10992	10993	1099
1100	1086	2799	64.2	71	1E-05	none	none	11003	1100
1101	1100	501.5	64.2	5392	0.007	11011	11012	11013	1101
1102	1100	2294.5	64.2	454	1E-05	none	11022	11023	1102
1103	1102	642.75	64.2	4447	0.008	11031	11032	11033	1103
1104	1102	1639	64.2	866	1E-05	none	11042	11043	1104
1105	1104	1389.8	64.2	1428	0.006	none	11052	11053	1105
1106	1105	1109.3	65	6065	0.031	11061	11062	11063	1106
1107	1105	193.75	65	1723	0.024	11071	11072	11073	1107
1108	1104	201	64.2	2090	0.015	11081	11082	11083	1108

1109	1085	2218	64.2	8355	0.023	none	11092	11093	1109
1110	1109	853	83.1	787	0.008	none	11102	11103	1110
1111	1110	528.25	83.7	1066	0.013	none	11112	11113	1111
1112	1111	172	85.1	1445	0.014	11121	11122	11123	1112
1113	1111	274.5	85.1	1199	0.021	11131	11132	11133	1113
1114	1110	174	83.7	2132	0.024	11141	11142	11143	1114
1115	1109	494.5	83.1	725	0.03	none	11152	11153	1115
1116	1115	229.75	85.3	1166	0.028	11161	11162	11163	1116
1117	1115	158	85.3	1687	0.017	11171	11172	11173	1117
1118	1082	1012.3	64.2	6348	0.03	none	11182	11183	1118
1119	1118	255	83	1319	0.032	11191	11192	11193	1119
1120	1118	190	83	1387	0.033	11201	11202	11203	1120
1121	1071	522	64.2	454	1E-05	none	11212	11213	1121
1122	1121	177	64.2	1349	0.022	11221	11222	11223	1122
1123	1121	335	64.2	3030	0.067	11231	11232	11233	1123
1124	1070	308	64.2	3289	0.062	11241	11242	11243	1124
1125	1063	2149	62.5	2527	0.037	none	11252	11253	1125
1126	1125	1460	71.8	2914	0.034	none	11262	11263	1126
1127	1126	618	81.8	4013	0.016	11271	11272	11273	1127
1128	1126	511.75	81.8	1175	0.011	none	11282	11283	1128
1129	1128	249.75	83.1	1395	0.017	11291	11292	11293	1129
1130	1128	182.25	83.1	1016	0.013	11301	11302	11303	1130
1131	1125	507.75	71.8	2294	0.043	11311	11312	11313	1131
1132	1062	203.75	57.1	1569	0.0126	11321	11322	11323	1132
1133	1061	221	56.6	1902	0.0106	11331	11332	11333	1133
1134	1054	155.25	56.6	1528	0.092	11341	11342	11343	1134
1135	1043	195.5	56.6	1057	0.048	11351	11352	11353	1135
1136	1040	1597.5	54.4	937	0.069	none	11362	11363	1136
1137	1136	181	60.9	1266	0.016	11371	11372	11373	1137
1138	1136	1362.3	60.9	5520	0.024	none	11382	11383	1138
1139	1138	377.25	74.1	2735	0.029	11391	11392	11393	1139
1140	1138	444.5	74.1	3509	0.031	11401	11402	11403	1140
1141	1039	5658.8	52.5	1257	0.006	none	11412	11413	1141
1142	1141	5369.8	53.3	2385	0.025	none	11422	11423	1142
1143	1142	276.25	59.2	2302	0.023	11431	11432	11433	1143
1144	1142	4895	59.2	725	0.012	none	11442	11443	1144
1145	1144	2842.3	60.1	5727	0.009	none	11452	11453	1145
1146	1145	547.5	65.3	4542	0.043	11461	11462	11463	1146
1147	1145	1224.3	65.3	292	1E-05	none	11472	11473	1147
1148	1147	910.75	65.3	1207	0.009	none	11482	11483	1148
1149	1148	309.25	66.4	1699	0.011	11491	11492	11493	1149
1150	1148	508.75	66.4	5329	0.042	11501	11502	11503	1150
1151	1147	153.5	65.3	1116	0.029	11511	11512	11513	1151
1152	1144	2025.5	60.1	2123	0.05	none	11522	11523	1152
1153	1152	1293.5	70.6	3935	0.017	none	11532	11533	1153
1154	1153	816.5	77.4	442	0.014	none	11542	11543	1154
1155	1154	447.75	78	2582	0.023	11551	11552	11553	1155
1156	1154	330.25	78	2040	0.017	11561	11562	11563	1156
1157	1153	200.25	77.4	1678	0.023	11571	11572	11573	1157
1158	1152	466.25	70.6	1928	0.046	11581	11582	11583	1158
1159	1141	222.25	53.3	2173	0.0116	11591	11592	11593	1159
1160	1036	366.75	51.4	1869	0.078	11601	11602	11603	1160
1161	1035	710	50.1	6272	0.016	11611	11612	11613	1161
1162	184	11345	46.8	262	0.073	none	11622	11623	1162
1163	1162	767	48.7	3801	8E-05	11631	11632	11633	1163
1164	1162	10571	48.7	766	0.004	none	11642	11643	1164
1165	1164	10345	49	1482	1E-05	none	11652	11653	1165
1166	1165	6422	49	142	1E-05	none	11662	11663	1166
1167	1166	6162.3	49	2672	1E-05	none	11672	11673	1167

1168	1167	202.25	49	1961	0.009	11681	11682	11683	1168
1169	1167	5629.3	49	1511	1E-05	none	11692	11693	1169
1170	1169	4472.8	49	1461	1E-05	none	11702	11703	1170
1171	1170	241	49	1037	1E-05	11711	11712	11713	1171
1172	1170	4152	49	121	1E-05	none	none	11723	1172
1173	1172	3781.5	49	200	1E-05	none	11732	11733	1173
1174	1173	715.5	49	842	1E-05	none	11742	11743	1174
1175	1174	374.25	49	2818	0.005	11751	11752	11753	1175
1176	1174	322.5	49	1407	0.009	11761	11762	11763	1176
1177	1173	3062	49	725	1E-05	none	11772	11773	1177
1178	1177	382.25	49	2894	0.034	11781	11782	11783	1178
1179	1177	2653.8	49	525	1E-05	none	11792	11793	1179
1180	1179	2264	49	1885	0.008	none	11802	11803	1180
1181	1180	356	50.5	3772	0.048	11811	11812	11813	1181
1182	1180	1656	50.5	171	1E-05	none	11822	11823	1182
1183	1182	1489.8	50.5	1440	0.017	none	11832	11833	1183
1184	1183	286	52.9	2806	0.062	11841	11842	11843	1184
1185	1183	915.75	52.9	1016	0.027	none	11852	11853	1185
1186	1185	291.5	55.6	1869	0.042	11861	11862	11863	1186
1187	1185	527.5	55.6	3804	0.06	11871	11872	11873	1187
1188	1182	162.5	50.5	1687	0.074	11881	11882	11883	1188
1189	1179	375.5	49	3380	0.058	11891	11892	11893	1189
1190	1172	369.75	49	3668	0.06	11901	11902	11903	1190
1191	1169	1031.3	49	121	1E-05	none	11912	11913	1191
1192	1191	286	49	3501	0.048	11921	11922	11923	1192
1193	1191	739	49	504	1E-05	none	11932	11933	1193
1194	1193	290.5	49	3651	0.073	11941	11942	11943	1194
1195	1193	442	49	2702	0.06	11951	11952	11953	1195
1196	1166	250.5	49	1166	0.008	11961	11962	11963	1196
1197	1165	3735.5	49	6365	0.029	none	11972	11973	1197
1198	1197	2913.5	67.4	312	0.096	none	11982	11983	1198
1199	1198	2563.8	70.4	645	0.012	none	11992	11993	1199
1200	1199	1091	71.2	4472	0.021	none	12002	12003	1200
1201	1200	201	80.5	1249	0.012	12011	12012	12013	1201
1202	1200	593.5	80.5	1519	0.01	none	12022	12023	1202
1203	1202	234.25	82	1540	0.015	12031	12032	12033	1203
1204	1202	227.25	82	1478	0.022	12041	12042	12043	1204
1205	1199	1441.3	71.2	2673	0.021	none	12052	12053	1205
1206	1205	276.75	76.7	2435	0.027	12061	12062	12063	1206
1207	1205	902.5	76.7	121	1E-05	none	none	12073	1207
1208	1207	405.25	76.7	3019	0.009	12081	12082	12083	1208
1209	1207	494.5	76.7	2123	0.007	12091	12092	12093	1209
1210	1198	341.5	70.4	3332	0.037	12101	12102	12103	1210
1211	1197	252.5	67.4	1861	0.063	12111	12112	12113	1211
1212	1164	167.25	49	1169	0.002	12121	12122	12123	1212
1213	183	366.5	46.8	2378	0.085	12131	12132	12133	1213
1214	182	226	46.8	3097	0.062	12141	12142	12143	1214
1215	181	542.5	46.8	4746	0.047	12151	12152	12153	1215
1216	178	455.25	46.8	5554	0.039	12161	12162	12163	1216
1217	171	455.75	46.8	2532	0.006	12171	12172	12173	1217
1218	170	1464.3	46.8	633	0.008	none	12182	12183	1218
1219	1218	1246.3	47.3	7181	0.029	none	12192	12193	1219
1220	1219	380.5	67.8	2140	0.04	12201	12202	12203	1220
1221	1219	225.5	67.8	1816	0.053	12211	12212	12213	1221
1222	1218	184.75	47.3	1390	0.012	12221	12222	12223	1222
1223	169	406	46.8	2972	0.008	12231	12232	12233	1223
1224	88	235.75	46.8	2202	0.011	12241	12242	12243	1224
1225	21	520.75	45	7206	0.024	12251	12252	12253	1225
1226	20	769.5	45	1437	0.04	none	12262	12263	1226

1227	1226	305	50.8	1449	0.008	12271	12272	12273	1227
1228	1226	367	50.8	4030	0.01	12281	12282	12283	1228
1229	9	1703.5	41.6	7593	0.025	none	12292	12293	1229
1230	1229	212.5	60.7	1337	0.054	12301	12302	12303	1230
1231	1229	639.5	60.7	1128	0.018	none	12312	12313	1231
1232	1231	196.25	62.7	1307	0.056	12321	12322	12323	1232
1233	1231	196.25	62.7	1037	0.017	12331	12332	12333	1233
1234	4	571.75	41.6	4422	0.052	12341	12342	12343	1234
1235	3	1174.8	41.6	995	0.043	none	12352	12353	1235
1236	1235	191.5	45.9	2032	0.085	12361	12362	12363	1236
1237	1235	852.5	45.9	6599	0.032	12371	12372	12373	1237
1238	2	359.5	41.6	4418	0.027	12381	12382	12383	1238

Number of cells (source, left, right, & total): 619 1231 1227 3077

C.3. WATERSHED CELL PARAMETERS

AgFlow Version 2.02: 09/21/00: AnnAGNPS cell, reach, & subarea data from DEM-related parameters

SUBAREA REPORT

Run Date: 9/12/2002

Run Time: 20:54:21

SOUTH NATION WATERSHED

Code 1: 200 & 500 Code 2: 26 & 200 Code 3: 10 & 100 Code 4: 10 & 50

Using default values for LS-factor parameters

SubArea ID (ha)	Drainage Area	Number of Rasters within					Land Slope (-)	LS Factor	
		Source '2'	Right '3'	Left '4'	Subarea (m/m)	Channel (-)		Calc.	Read
1	0	0	0	0	0	0	OUTLET		
2	503.25	0	695	1318	2013	62	0.0252	0.439	0
3	116.25	0	120	345	465	19	0.0348	0.56	0
4	127	0	290	218	508	26	0.022	0.376	0
5	31.5	0	78	48	126	15	0.0255	0.45	0
6	203	577	199	36	812	20	0.0327	0.624	0
7	297.75	0	205	986	1191	18	0.0311	0.54	0
8	175	401	168	131	700	24	0.022	0.37	0
9	279	0	388	728	1116	24	0.0281	0.5	0
10	38	0	67	85	152	13	0.0312	0.484	0
11	177.25	618	37	54	709	19	0.0158	0.247	0
12	350.5	0	224	1178	1402	44	0.0305	0.522	0
13	375	440	758	302	1500	57	0.0179	0.285	0
14	162.5	0	600	50	650	10	0.099	0.153	0
15	329	601	270	445	1316	58	0.0157	0.254	0
16	427.25	0	437	1272	1709	58	0.0239	0.411	0
17	304.25	0	478	739	1217	36	0.07	0.114	0
18	318.25	408	356	509	1273	23	0.0211	0.352	0
19	1170.8	400	2395	1888	4683	145	0.0172	0.278	0
20	92.75	0	0	371	371	1	0.072	0.114	0
21	198.5	0	366	428	794	32	0.015	0.227	0
22	56.25	0	136	89	225	18	0.0219	0.337	0
23	401.25	0	701	904	1605	52	0.058	0.098	0
24	142.5	0	208	362	570	28	0.032	0.065	0
25	149.75	419	58	122	599	21	0.0159	0.261	0
26	152.25	456	101	52	609	20	0.0139	0.227	0
27	32	0	75	53	128	15	0.084	0.127	0
28	741.25	423	1864	678	2965	96	0.0136	0.221	0
29	382.5	0	898	632	1530	31	0.056	0.093	0
30	320.25	544	629	108	1281	22	0.042	0.077	0
31	28.5	0	46	68	114	14	0.05	0.083	0
32	803.25	0	1742	1471	3213	54	0.059	0.098	0
33	191	0	443	321	764	30	0.091	0.143	0
34	375.25	511	318	672	1501	35	0.052	0.089	0
35	385.25	0	799	742	1541	53	0.07	0.113	0
36	387.25	0	1051	498	1549	51	0.0101	0.161	0
37	252.25	412	215	382	1009	37	0.0225	0.394	0
38	326.75	404	572	331	1307	38	0.0199	0.317	0
39	189.5	427	62	269	758	20	0.098	0.154	0
40	318.25	400	691	182	1273	43	0.045	0.078	0
41	338.25	405	479	469	1353	42	0.055	0.092	0
42	611.25	0	1351	1094	2445	61	0.094	0.147	0
43	187.25	0	188	561	749	20	0.036	0.068	0
44	195.5	0	580	202	782	35	0.043	0.078	0
45	395.75	0	868	715	1583	49	0.048	0.082	0
46	237.5	463	159	328	950	30	0.048	0.085	0
47	216.25	436	200	229	865	47	0.036	0.069	0

48	284.75	517	270	352	1139	41	0.048	0.084	0
49	18.25	0	19	54	73	9	0.048	0.08	0
50	700.5	0	1549	1253	2802	70	0.0119	0.195	0
51	21.25	0	48	37	85	4	0.067	0.109	0
52	261.5	409	48	589	1046	19	0.074	0.121	0
53	1024.5	0	1756	2342	4098	121	0.0153	0.244	0
54	19.25	0	39	38	77	10	0.0235	0.338	0
55	530.5	405	978	739	2122	66	0.069	0.115	0
56	449.5	525	611	662	1798	97	0.0142	0.236	0
57	385.75	0	1473	70	1543	19	0.0117	0.179	0
58	311.25	408	530	307	1245	36	0.0104	0.166	0
59	128.75	0	389	126	515	31	0.0134	0.21	0
60	212.25	438	121	290	849	37	0.062	0.106	0
61	116.25	0	235	230	465	56	0.081	0.128	0
62	254	504	369	143	1016	28	0.0133	0.212	0
63	1089.8	446	1863	2050	4359	126	0.0165	0.267	0
64	164.75	468	113	78	659	25	0.01	0.158	0
65	557	0	1076	1152	2228	155	0.0179	0.27	0
66	21.5	0	41	45	86	8	0.0131	0.19	0
67	513	0	480	1572	2052	62	0.08	0.125	0
68	86.5	0	39	307	346	10	0.068	0.108	0
69	111.25	0	330	115	445	30	0.052	0.087	0
70	221.25	491	116	278	865	29	0.053	0.095	0
71	518.75	497	920	658	2075	57	0.016	0.265	0
72	24.25	0	58	39	97	14	0.036	0.066	0
73	54	0	185	31	216	21	0.032	0.06	0
74	346.75	405	473	509	1387	86	0.0155	0.257	0
75	87.25	0	203	146	349	36	0.048	0.088	0
76	290.5	0	260	902	1162	56	0.0194	0.315	0
77	185.75	400	85	258	743	22	0.0226	0.357	0
78	213.25	415	219	219	853	25	0.0231	0.376	0
79	283	404	198	530	1132	28	0.0176	0.284	0
80	579.25	0	1042	1275	2317	84	0.0113	0.18	0
81	15	0	5	55	60	6	0.0119	0.176	0
82	305	447	313	460	1220	51	0.0238	0.389	0
83	488.75	409	1097	449	1955	74	0.0197	0.317	0
84	163.25	447	136	70	653	28	0.0198	0.318	0
85	391.75	450	897	220	1567	43	0.074	0.126	0
86	297.25	519	572	98	1189	26	0.055	0.092	0
87	469	425	759	692	1876	57	0.057	0.094	0
88	692	0	709	2059	2768	54	0.0139	0.213	0
89	98.75	0	249	146	395	14	0.09	0.134	0
90	508.75	0	725	1310	2035	88	0.0184	0.307	0
91	162.75	0	487	164	651	22	0.0253	0.444	0
92	20.75	0	16	67	83	12	0.0429	0.713	0
93	247.25	492	80	417	989	22	0.075	0.123	0
94	665.75	0	1374	1289	2663	95	0.0123	0.188	0
95	270.5	640	269	173	1082	19	0.06	0.096	0
96	245.25	0	621	360	981	23	0.05	0.084	0
97	581.75	555	1279	493	2327	69	0.061	0.098	0
98	610.25	447	1501	493	2441	65	0.044	0.08	0
99	201.75	0	226	581	807	29	0.0226	0.374	0
100	781	404	1426	1294	3124	56	0.094	0.15	0
101	134.75	0	359	180	539	27	0.0297	0.488	0
102	237.5	0	393	557	950	32	0.0194	0.308	0
103	37	0	84	64	148	15	0.0319	0.478	0
104	477.75	0	1123	788	1911	42	0.0125	0.198	0
105	287.25	0	583	566	1149	54	0.062	0.103	0
106	158	0	242	390	632	32	0.025	0.058	0

107	523.75	0	1149	946	2095	123	0.067	0.11	0
108	195.5	538	100	144	782	21	0.012	0.184	0
109	186.5	425	195	126	746	21	0.0125	0.187	0
110	427.25	460	461	788	1709	82	0.0117	0.179	0
111	498	0	838	1154	1992	88	0.0126	0.236	0
112	537	547	733	868	2148	70	0.018	0.286	0
113	279.75	512	357	250	1119	37	0.0204	0.329	0
114	139.75	0	490	69	559	14	0.0109	0.168	0
115	612.25	457	994	998	2449	106	0.0123	0.187	0
116	242.5	0	822	148	970	43	0.0112	0.168	0
117	337	409	687	252	1348	45	0.093	0.146	0
118	349	0	916	480	1396	43	0.0113	0.182	0
119	57.75	0	77	154	231	8	0.084	0.13	0
120	270.25	0	115	966	1081	31	0.0129	0.207	0
121	172.25	482	41	166	689	16	0.0141	0.215	0
122	181.5	0	274	452	726	24	0.014	0.217	0
123	173.75	0	595	100	695	26	0.0167	0.255	0
124	279.75	0	442	677	1119	48	0.0161	0.253	0
125	393.5	0	145	1429	1574	26	0.0173	0.265	0
126	63.25	0	96	157	253	23	0.0183	0.301	0
127	197.75	0	231	560	791	28	0.0172	0.284	0
128	283	437	76	619	1132	23	0.0176	0.28	0
129	1326	423	2652	2229	5304	181	0.0156	0.248	0
130	194.25	409	271	97	777	21	0.0239	0.397	0
131	406.25	513	298	814	1625	51	0.0172	0.267	0
132	226.75	403	164	340	907	28	0.0219	0.349	0
133	442.25	464	393	912	1769	43	0.0168	0.26	0
134	126.5	404	55	47	506	19	0.0187	0.298	0
135	603.75	404	905	1106	2415	102	0.0167	0.263	0
136	181.5	424	176	126	726	25	0.098	0.16	0
137	138.5	0	205	349	554	20	0.0129	0.203	0
138	111	0	67	377	444	23	0.013	0.201	0
139	611	0	972	1472	2444	79	0.067	0.108	0
140	785	0	1332	1808	3140	73	0.0119	0.19	0
141	93.25	0	286	87	373	17	0.0185	0.315	0
142	424.75	497	569	633	1699	42	0.0171	0.272	0
143	66.75	0	132	135	267	20	0.0214	0.359	0
144	323.75	439	810	46	1295	22	0.0192	0.284	0
145	205.75	0	210	613	823	18	0.0173	0.266	0
146	277.25	482	62	565	1109	29	0.0219	0.327	0
147	322.5	405	472	413	1290	65	0.0125	0.198	0
148	770.5	0	1939	1143	3082	95	0.0154	0.24	0
149	616.25	0	152	2313	2465	39	0.02	0.304	0
150	142.5	470	57	43	570	22	0.0161	0.243	0
151	258.5	0	725	309	1034	24	0.0101	0.157	0
152	576.5	400	802	1104	2306	38	0.0156	0.241	0
153	287.75	463	440	248	1151	21	0.01	0.151	0
154	308.25	426	481	326	1233	43	0.0114	0.176	0
155	491.25	438	821	706	1965	93	0.0157	0.249	0
156	85	0	195	145	340	20	0.096	0.144	0
157	665.25	0	1540	1121	2661	67	0.056	0.094	0
158	742.25	406	1276	1287	2969	121	0.0112	0.173	0
159	307.75	412	729	90	1231	26	0.0231	0.393	0
160	223.25	0	580	313	893	29	0.055	0.091	0
161	134.5	0	360	178	538	28	0.049	0.084	0
162	398	401	395	796	1592	41	0.0109	0.186	0
163	547	429	935	824	2188	74	0.0134	0.232	0
164	304	454	346	416	1216	35	0.037	0.07	0
165	443.75	490	816	469	1775	30	0.056	0.095	0

166	494.5	419	937	622	1978	44	0.065	0.109	0
167	514.75	403	1022	634	2059	80	0.0101	0.162	0
168	232.25	409	106	414	929	25	0.0109	0.174	0
169	7.25	0	7	22	29	5	0.0159	0.22	0
170	246.75	0	365	622	987	42	0.082	0.122	0
171	2	0	0	8	8	4	0.019	0.231	0
172	121.75	0	30	457	487	18	0.0105	0.15	0
173	12.25	0	25	24	49	7	0.084	0.13	0
174	383.5	515	633	386	1534	43	0.0134	0.221	0
175	413	607	735	310	1652	80	0.0133	0.225	0
176	74	0	178	118	296	23	0.0125	0.181	0
177	294	440	538	198	1176	38	0.0113	0.202	0
178	1	0	4	0	4	2	0.0209	0.27	0
179	79.75	0	280	39	319	10	0.0129	0.183	0
180	661.5	509	1547	590	2646	64	0.085	0.156	0
181	9	0	18	18	36	9	0.0197	0.285	0
182	177.5	0	538	172	710	36	0.0167	0.24	0
183	105.25	0	135	286	421	14	0.0102	0.155	0
184	131.75	0	70	457	527	34	0.011	0.167	0
185	58.25	0	92	141	233	34	0.0178	0.246	0
186	1	0	0	4	4	2	0.0132	0.25	0
187	495	400	1045	535	1980	45	0.092	0.163	0
188	377.25	500	788	221	1509	41	0.0115	0.218	0
189	218	0	256	616	872	37	0.0184	0.303	0
190	339	0	579	777	1356	53	0.036	0.634	0
191	695.75	0	917	1866	2783	81	0.0239	0.425	0
192	737	405	1463	1080	2948	63	0.011	0.183	0
193	3.25	0	6	7	13	2	0.0453	0.813	0
194	116.5	0	220	246	466	25	0.0218	0.344	0
195	105.25	0	249	172	421	15	0.063	0.107	0
196	309.75	0	818	421	1239	40	0.051	0.088	0
197	277	469	489	150	1108	29	0.042	0.073	0
198	199.25	488	252	57	797	29	0.041	0.076	0
199	619.25	487	429	1561	2477	46	0.042	0.076	0
200	267.25	429	267	373	1069	35	0.051	0.087	0
201	17	0	43	25	68	9	0.0449	0.741	0
202	544.25	0	951	1226	2177	68	0.014	0.22	0
203	1233.3	417	2574	1942	4933	168	0.091	0.154	0
204	190.75	0	372	391	763	22	0.099	0.152	0
205	1133.3	421	2335	1777	4533	184	0.0105	0.169	0
206	221.5	0	726	160	886	41	0.084	0.131	0
207	284.5	567	262	309	1138	45	0.041	0.075	0
208	184.5	0	599	139	738	11	0.054	0.092	0
209	404.75	0	1019	600	1619	66	0.053	0.091	0
210	351.75	467	495	445	1407	49	0.0129	0.212	0
211	523	0	1098	994	2092	78	0.016	0.253	0
212	190.75	454	136	173	763	28	0.0128	0.2	0
213	362.5	0	605	845	1450	28	0.0138	0.212	0
214	220.25	0	246	635	881	37	0.0215	0.333	0
215	320.5	504	180	598	1282	38	0.0134	0.205	0
216	1475.3	410	3100	2391	5901	118	0.0174	0.279	0
217	205	423	287	110	820	25	0.0209	0.328	0
218	267.75	439	153	479	1071	31	0.043	0.076	0
219	97	0	282	106	388	17	0.0229	0.371	0
220	95.75	0	68	315	383	17	0.0175	0.287	0
221	20.25	0	7	74	81	4	0.0201	0.312	0
222	608.25	0	1466	967	2433	64	0.0126	0.197	0
223	284	0	429	707	1136	51	0.07	0.112	0
224	245.75	400	300	283	983	27	0.056	0.092	0

225	422.25	480	839	370	1689	58	0.046	0.082	0
226	482	466	776	686	1928	54	0.081	0.131	0
227	44	0	128	48	176	12	0.0177	0.28	0
228	388.25	417	801	335	1553	38	0.068	0.11	0
229	342	403	841	124	1368	32	0.054	0.09	0
230	166	400	140	124	664	22	0.073	0.117	0
231	199.5	407	128	263	798	39	0.082	0.136	0
232	969.5	0	1684	2194	3878	102	0.0329	0.613	0
233	77.25	0	59	250	309	11	0.0358	0.641	0
234	48.75	0	111	84	195	7	0.0334	0.614	0
235	59.5	0	163	75	238	11	0.0511	0.963	0
236	618.25	435	1163	875	2473	64	0.099	0.171	0
237	612	0	1764	684	2448	70	0.0288	0.525	0
238	106	0	352	72	424	14	0.0336	0.625	0
239	762.75	0	1455	1596	3051	87	0.0279	0.519	0
240	212.5	509	71	270	850	20	0.0101	0.181	0
241	99.75	0	130	269	399	6	0.0225	0.411	0
242	150.25	400	118	83	601	20	0.0125	0.198	0
243	165.25	0	345	316	661	34	0.0234	0.356	0
244	231.75	0	154	773	927	18	0.014	0.21	0
245	0.75	0	1	2	3	1	0.0152	0.209	0
246	206	0	708	116	824	25	0.0126	0.187	0
247	362.75	0	459	992	1451	62	0.0101	0.159	0
248	114.25	0	107	350	457	19	0.069	0.11	0
249	251.75	571	379	57	1007	28	0.04	0.072	0
250	1.25	0	5	0	5	3	0.095	0.117	0
251	71.75	0	156	131	287	29	0.071	0.111	0
252	64.75	0	150	109	259	9	0.053	0.089	0
253	9.25	0	10	27	37	6	0.047	0.08	0
254	186.5	0	449	297	746	24	0.049	0.085	0
255	424.75	406	516	777	1699	95	0.0122	0.196	0
256	424.75	418	771	510	1699	73	0.0129	0.205	0
257	506.5	403	681	942	2026	88	0.0161	0.26	0
258	313.5	411	128	715	1254	34	0.0119	0.207	0
259	289	408	317	431	1156	49	0.095	0.155	0
260	264.75	0	331	728	1059	52	0.058	0.096	0
261	1184.8	438	1667	2634	4739	114	0.0122	0.184	0
262	1296.5	457	3054	1675	5186	127	0.01	0.159	0
263	247	410	429	149	988	45	0.0137	0.214	0
264	106.5	0	313	113	426	24	0.0103	0.164	0
265	169.5	427	116	135	678	18	0.0108	0.171	0
266	155.5	0	116	506	622	22	0.094	0.152	0
267	192.25	569	153	47	769	22	0.0134	0.21	0
268	196.75	435	114	238	787	18	0.0104	0.163	0
269	19	0	51	25	76	10	0.0305	0.455	0
270	335.75	412	481	450	1343	38	0.054	0.092	0
271	98.5	0	206	188	394	19	0.0173	0.274	0
272	142.75	0	97	474	571	35	0.0182	0.283	0
273	70.5	0	123	159	282	22	0.0197	0.304	0
274	324.25	434	405	458	1297	30	0.062	0.103	0
275	209.75	0	289	550	839	29	0.0134	0.207	0
276	379	412	963	141	1516	36	0.074	0.115	0
277	83.5	0	65	269	334	12	0.0164	0.259	0
278	51	0	68	136	204	17	0.0234	0.364	0
279	21.5	0	21	65	86	9	0.0281	0.424	0
280	287.75	436	550	165	1151	34	0.067	0.106	0
281	889	0	1183	2373	3556	86	0.0132	0.2	0
282	26	0	45	59	104	14	0.0186	0.28	0
283	180.5	0	139	583	722	17	0.0114	0.182	0

284	246.75	402	350	235	987	60	0.0125	0.193	0
285	283.5	402	534	198	1134	41	0.0155	0.24	0
286	684.25	441	1036	1260	2737	97	0.0162	0.26	0
287	211	0	706	138	844	29	0.0144	0.222	0
288	494.75	585	467	927	1979	85	0.0111	0.181	0
289	179.5	0	390	328	718	34	0.0113	0.171	0
290	377	0	602	906	1508	78	0.0135	0.209	0
291	456.5	0	1470	356	1826	45	0.014	0.223	0
292	361.75	449	185	813	1447	39	0.0132	0.208	0
293	25.5	0	60	42	102	12	0.0129	0.194	0
294	44.5	0	107	71	178	11	0.0101	0.152	0
295	760.75	0	1484	1559	3043	117	0.0135	0.21	0
296	322.75	425	566	300	1291	39	0.01	0.16	0
297	321.75	625	361	301	1287	23	0.087	0.138	0
298	278.75	629	174	312	1115	30	0.0147	0.225	0
299	530.25	463	465	1193	2121	57	0.0146	0.23	0
300	1244.3	0	3731	1246	4977	130	0.0107	0.168	0
301	77.75	0	94	217	311	19	0.0118	0.179	0
302	26.5	0	41	65	106	7	0.0143	0.236	0
303	327.25	0	518	791	1309	40	0.0189	0.307	0
304	76.25	0	122	183	305	11	0.0201	0.332	0
305	543.5	419	633	1122	2174	40	0.0157	0.241	0
306	157.5	0	461	169	630	32	0.012	0.188	0
307	681.5	514	1022	1190	2726	67	0.0167	0.265	0
308	203	0	502	310	812	30	0.0169	0.292	0
309	437.5	0	1216	534	1750	53	0.0158	0.247	0
310	129	402	39	75	516	18	0.0137	0.203	0
311	49.5	0	29	169	198	10	0.0118	0.176	0
312	307.25	0	917	312	1229	44	0.0118	0.18	0
313	288.5	423	448	283	1154	36	0.0121	0.191	0
314	149	0	205	391	596	14	0.086	0.133	0
315	804.5	432	1235	1551	3218	81	0.0128	0.195	0
316	173	486	43	163	692	17	0.0122	0.185	0
317	565.5	403	436	1423	2262	64	0.0108	0.166	0
318	805.5	408	1870	944	3222	67	0.0165	0.258	0
319	40.75	0	102	61	163	14	0.014	0.231	0
320	14	0	34	22	56	7	0.0116	0.206	0
321	832.75	438	1246	1647	3331	83	0.015	0.25	0
322	158.75	428	84	123	635	18	0.0216	0.375	0
323	224	443	108	345	896	25	0.02	0.318	0
324	1104.3	512	2360	1545	4417	118	0.0113	0.181	0
325	306	400	324	500	1224	59	0.0146	0.24	0
326	236.25	413	416	116	945	22	0.0135	0.212	0
327	691.75	411	1678	678	2767	56	0.067	0.111	0
328	513.25	0	1280	773	2053	45	0.014	0.216	0
329	408	403	438	791	1632	37	0.083	0.13	0
330	260.25	0	886	155	1041	28	0.0155	0.231	0
331	43	0	34	138	172	13	0.0121	0.189	0
332	158.75	417	59	159	635	21	0.089	0.138	0
333	323.75	0	219	1076	1295	48	0.0134	0.212	0
334	193.25	462	260	51	773	27	0.085	0.132	0
335	129.75	0	214	305	519	18	0.011	0.166	0
336	0.75	0	0	3	3	1	0.01	0.178	0
337	329	426	356	534	1316	35	0.0105	0.16	0
338	304.75	0	365	854	1219	30	0.0104	0.164	0
339	207	0	239	589	828	31	0.01	0.152	0
340	329.75	0	465	854	1319	64	0.067	0.109	0
341	9.75	0	11	28	39	5	0.082	0.129	0
342	289.25	508	326	323	1157	38	0.056	0.093	0

343	436.5	0	493	1253	1746	66	0.01	0.159	0
344	437.5	447	832	471	1750	45	0.0121	0.185	0
345	218.75	444	285	146	875	47	0.0111	0.172	0
346	198.25	409	147	237	793	26	0.0131	0.209	0
347	194.25	415	254	108	777	24	0.068	0.11	0
348	28	0	55	57	112	13	0.0199	0.29	0
349	13	0	10	42	52	3	0.0113	0.156	0
350	87.5	0	122	228	350	17	0.0121	0.184	0
351	348	0	658	734	1392	51	0.049	0.085	0
352	543.75	401	701	1073	2175	67	0.096	0.152	0
353	98.25	0	55	338	393	5	0.059	0.097	0
354	1438	0	2953	2799	5752	166	0.0103	0.16	0
355	482	407	863	658	1928	60	0.0102	0.16	0
356	166.25	400	115	150	665	18	0.0108	0.169	0
357	503.5	415	886	713	2014	80	0.0113	0.171	0
358	239.25	0	731	226	957	30	0.0129	0.195	0
359	393.75	0	321	1254	1575	37	0.089	0.139	0
360	586.25	463	596	1286	2345	69	0.0102	0.154	0
361	73.25	0	277	16	293	5	0.0107	0.159	0
362	203.25	0	561	252	813	19	0.0109	0.164	0
363	118.5	0	155	319	474	22	0.0138	0.206	0
364	244.25	0	260	717	977	57	0.0101	0.154	0
365	133.5	0	140	394	534	19	0.087	0.135	0
366	161.5	402	161	83	646	25	0.079	0.125	0
367	55.5	0	205	17	222	9	0.087	0.136	0
368	226.5	0	722	184	906	22	0.073	0.115	0
369	102.5	0	378	32	410	10	0.0105	0.163	0
370	331.25	416	459	450	1325	40	0.0104	0.16	0
371	173.5	0	437	257	694	34	0.0108	0.16	0
372	736.75	400	1297	1250	2947	134	0.074	0.119	0
373	81.5	0	159	167	326	19	0.072	0.113	0
374	242.25	401	183	385	969	21	0.079	0.123	0
375	351	427	758	219	1404	39	0.073	0.117	0
376	327.5	486	526	298	1310	51	0.095	0.145	0
377	169.5	400	155	123	678	25	0.08	0.124	0
378	287.25	0	610	539	1149	44	0.091	0.137	0
379	213	0	180	672	852	27	0.01	0.151	0
380	57.25	0	63	166	229	14	0.0102	0.157	0
381	681	442	580	1702	2724	68	0.091	0.143	0
382	238.75	423	250	282	955	33	0.0107	0.163	0
383	218.75	417	139	319	875	21	0.0127	0.196	0
384	374.75	422	623	454	1499	40	0.094	0.146	0
385	392	0	317	1251	1568	31	0.096	0.147	0
386	247.5	0	404	586	990	30	0.0145	0.219	0
387	30	0	60	60	120	17	0.0322	0.522	0
388	214	0	515	341	856	25	0.0157	0.232	0
389	15.25	0	38	23	61	10	0.0128	0.188	0
390	8	0	8	24	32	5	0.0104	0.154	0
391	40.75	0	40	123	163	15	0.065	0.109	0
392	226	426	90	388	904	41	0.085	0.137	0
393	454.25	407	1122	288	1817	39	0.066	0.109	0
394	157.25	431	67	131	629	21	0.078	0.121	0
395	373	0	777	715	1492	44	0.048	0.083	0
396	302.5	406	261	543	1210	38	0.0103	0.166	0
397	430.5	403	1037	282	1722	34	0.073	0.116	0
398	453	0	829	983	1812	44	0.0117	0.183	0
399	231.25	0	851	74	925	16	0.086	0.135	0
400	1030.5	0	1865	2257	4122	118	0.053	0.092	0
401	939.75	432	1507	1820	3759	110	0.096	0.149	0

402	290.75	691	183	289	1163	33	0.0102	0.155	0
403	365.75	0	1038	425	1463	63	0.012	0.184	0
404	10.75	0	34	9	43	5	0.09	0.134	0
405	223.25	539	211	143	893	25	0.06	0.1	0
406	689.25	0	1076	1681	2757	73	0.07	0.113	0
407	21.25	0	46	39	85	14	0.029	0.06	0
408	311.25	402	287	556	1245	28	0.065	0.106	0
409	365.75	0	415	1048	1463	67	0.075	0.119	0
410	383.5	0	911	623	1534	45	0.079	0.126	0
411	6.75	0	6	21	27	5	0.058	0.092	0
412	38.25	0	0	153	153	11	0.033	0.066	0
413	16.5	0	33	33	66	9	0.042	0.074	0
414	417.5	410	1022	238	1670	31	0.055	0.093	0
415	31.75	0	91	36	127	7	0.029	0.06	0
416	290.5	400	196	566	1162	44	0.066	0.105	0
417	254.5	418	246	354	1018	51	0.057	0.097	0
418	121	0	206	278	484	53	0.059	0.097	0
419	1381	408	2686	2430	5524	127	0.0107	0.166	0
420	230.5	0	462	460	922	55	0.0117	0.185	0
421	272	0	607	481	1088	38	0.0121	0.183	0
422	638.25	0	1330	1223	2553	56	0.0121	0.189	0
423	229	424	325	167	916	22	0.079	0.122	0
424	259.75	441	378	220	1039	37	0.089	0.138	0
425	153.5	0	201	413	614	44	0.081	0.125	0
426	535	0	279	1861	2140	45	0.092	0.141	0
427	586	430	431	1483	2344	46	0.077	0.12	0
428	410.25	430	742	469	1641	58	0.074	0.118	0
429	308.75	413	577	245	1235	41	0.085	0.13	0
430	271.5	465	331	290	1086	34	0.0115	0.173	0
431	171.75	401	255	31	687	23	0.0121	0.184	0
432	180.75	440	86	197	723	22	0.0109	0.166	0
433	19.25	0	44	33	77	5	0.046	0.08	0
434	63	0	19	233	252	8	0.067	0.106	0
435	509.25	416	589	1032	2037	51	0.0112	0.17	0
436	794	520	1717	939	3176	105	0.0105	0.16	0
437	176	435	99	170	704	31	0.081	0.127	0
438	3.25	0	6	7	13	3	0.0106	0.162	0
439	8.25	0	22	11	33	5	0.07	0.115	0
440	26.25	0	40	65	105	7	0.029	0.061	0
441	45.5	0	125	57	182	14	0.023	0.052	0
442	304.25	407	445	365	1217	63	0.077	0.119	0
443	244.25	0	501	476	977	52	0.065	0.107	0
444	624.25	441	1321	735	2497	97	0.088	0.135	0
445	0.25	0	0	0	1	1	0.007	0.026	0
446	41.25	0	77	88	165	16	0.048	0.082	0
447	826	401	596	2307	3304	102	0.082	0.129	0
448	355.75	0	860	563	1423	80	0.048	0.083	0
449	205.5	0	200	622	822	47	0.053	0.086	0
450	245.75	0	234	749	983	41	0.083	0.127	0
451	30	0	43	77	120	19	0.0119	0.18	0
452	625.5	494	416	1592	2502	79	0.096	0.149	0
453	302	400	646	162	1208	30	0.093	0.143	0
454	209.5	0	463	375	838	31	0.075	0.119	0
455	633.75	402	1211	922	2535	78	0.0102	0.155	0
456	885.25	525	745	2271	3541	116	0.077	0.12	0
457	292	0	392	776	1168	44	0.072	0.113	0
458	81.25	0	135	190	325	20	0.056	0.094	0
459	442.25	564	565	640	1769	42	0.075	0.118	0
460	345.25	0	631	750	1381	31	0.066	0.108	0

461	92.5	0	129	241	370	22	0.096	0.147	0
462	106.25	0	129	296	425	14	0.061	0.101	0
463	1039.3	401	2408	1348	4157	120	0.082	0.127	0
464	150.75	0	343	260	603	33	0.096	0.148	0
465	343.5	427	548	399	1374	41	0.0113	0.171	0
466	426.5	410	633	663	1706	40	0.0111	0.169	0
467	23.75	0	32	63	95	11	0.0129	0.184	0
468	71.5	0	137	149	286	14	0.083	0.128	0
469	275.5	431	330	341	1102	42	0.0105	0.157	0
470	272	0	676	412	1088	53	0.095	0.148	0
471	774.75	503	1589	1007	3099	81	0.0124	0.19	0
472	107.75	0	149	282	431	24	0.0137	0.203	0
473	36.25	0	50	95	145	17	0.0162	0.242	0
474	244.25	415	387	175	977	29	0.095	0.146	0
475	300.75	0	380	823	1203	36	0.0141	0.218	0
476	320	501	288	491	1280	47	0.0188	0.312	0
477	865.5	0	1917	1545	3462	89	0.0148	0.23	0
478	443	595	510	667	1772	32	0.0103	0.162	0
479	286	0	996	148	1144	26	0.011	0.174	0
480	182.75	401	135	195	731	19	0.0111	0.18	0
481	360.5	516	810	116	1442	31	0.0214	0.357	0
482	179.5	412	186	120	718	21	0.092	0.145	0
483	549	410	1115	671	2196	83	0.077	0.122	0
484	224	409	119	368	896	39	0.083	0.126	0
485	292.5	418	486	266	1170	31	0.074	0.116	0
486	290.75	0	643	520	1163	64	0.074	0.114	0
487	167.75	0	576	95	671	25	0.085	0.13	0
488	363.75	0	703	752	1455	53	0.086	0.132	0
489	244	0	487	489	976	37	0.0112	0.167	0
490	42.25	0	28	141	169	11	0.0132	0.196	0
491	227.5	0	304	606	910	47	0.092	0.141	0
492	232.5	0	229	701	930	48	0.094	0.145	0
493	1135	501	1491	2548	4540	136	0.0118	0.188	0
494	353.25	522	394	497	1413	42	0.083	0.129	0
495	451	428	945	431	1804	50	0.072	0.114	0
496	287.25	0	543	606	1149	37	0.0123	0.188	0
497	128.5	0	273	241	514	46	0.0134	0.207	0
498	958	0	1590	2242	3832	88	0.0105	0.164	0
499	9.25	0	13	24	37	7	0.0161	0.243	0
500	170.75	404	161	118	683	34	0.081	0.129	0
501	310.25	0	430	811	1241	32	0.0134	0.203	0
502	952.25	0	2211	1598	3809	98	0.0152	0.244	0
503	374.25	597	141	759	1497	33	0.013	0.213	0
504	501	414	1296	294	2004	48	0.0181	0.29	0
505	285.75	400	159	584	1143	27	0.0171	0.276	0
506	196.25	432	55	298	785	20	0.0198	0.308	0
507	392	473	807	288	1568	52	0.015	0.23	0
508	355.25	614	564	243	1421	28	0.0108	0.172	0
509	198.5	400	205	189	794	25	0.09	0.138	0
510	206.5	562	74	190	826	18	0.094	0.146	0
511	159.75	549	64	26	639	17	0.071	0.111	0
512	53.5	0	124	90	214	24	0.075	0.116	0
513	624.75	0	1605	894	2499	70	0.091	0.14	0
514	640.5	0	1482	1080	2562	60	0.0107	0.166	0
515	150.75	0	257	346	603	39	0.078	0.126	0
516	222.75	401	267	223	891	25	0.0198	0.319	0
517	362	411	542	495	1448	47	0.0165	0.259	0
518	490	0	1426	534	1960	48	0.0107	0.167	0
519	178.5	430	200	84	714	19	0.0174	0.268	0

520	258	446	90	496	1032	22	0.0148	0.233	0
521	295.5	484	73	625	1182	30	0.086	0.136	0
522	75.5	0	210	92	302	19	0.06	0.102	0
523	614	0	1966	490	2456	93	0.071	0.113	0
524	347.25	494	355	540	1389	55	0.084	0.137	0
525	197.75	0	345	446	791	40	0.063	0.105	0
526	224	423	225	248	896	25	0.081	0.132	0
527	442	594	720	454	1768	57	0.072	0.12	0
528	184	459	112	165	736	23	0.071	0.117	0
529	1635.3	551	1852	4138	6541	168	0.08	0.127	0
530	33.25	0	43	90	133	17	0.029	0.06	0
531	514	435	793	828	2056	56	0.067	0.108	0
532	1082.8	517	2466	1348	4331	122	0.067	0.11	0
533	600.5	0	1164	1238	2402	123	0.098	0.15	0
534	733	698	1123	1111	2932	89	0.07	0.112	0
535	4.5	0	13	5	18	4	0.029	0.471	0
536	380.75	0	823	700	1523	38	0.0104	0.158	0
537	513.25	0	1334	719	2053	80	0.0157	0.237	0
538	374	0	795	701	1496	57	0.013	0.205	0
539	6.75	0	17	10	27	5	0.023	0.342	0
540	359.75	417	262	760	1439	36	0.067	0.109	0
541	16.5	0	32	34	66	9	0.0256	0.403	0
542	117.75	0	273	198	471	19	0.0123	0.191	0
543	634.75	0	1197	1342	2539	68	0.0109	0.178	0
544	252.5	0	266	744	1010	35	0.0165	0.263	0
545	252.5	403	258	349	1010	26	0.0192	0.308	0
546	217	0	597	271	868	37	0.0149	0.243	0
547	146.75	0	247	340	587	28	0.0142	0.262	0
548	240.75	525	381	57	963	20	0.0179	0.294	0
549	170.75	0	261	422	683	31	0.0188	0.329	0
550	221.75	400	233	254	887	40	0.0146	0.231	0
551	18.5	0	68	6	74	3	0.0203	0.344	0
552	460.75	439	386	1018	1843	78	0.013	0.208	0
553	11	0	44	0	44	4	0.081	0.148	0
554	508.25	0	964	1069	2033	71	0.0197	0.31	0
555	110.25	0	276	165	441	24	0.0378	0.609	0
556	96.25	0	300	85	385	14	0.0237	0.389	0
557	121.75	0	123	364	487	21	0.0126	0.192	0
558	238.25	480	283	190	953	33	0.0117	0.189	0
559	7.75	0	7	24	31	5	0.07	0.104	0
560	121.5	0	146	340	486	24	0.095	0.151	0
561	319.5	403	540	335	1278	43	0.0154	0.235	0
562	252.25	410	319	280	1009	26	0.0162	0.249	0
563	399.75	0	1144	455	1599	44	0.0134	0.208	0
564	469.5	0	409	1469	1878	65	0.0158	0.247	0
565	175.25	434	112	155	701	19	0.0188	0.294	0
566	1311.8	405	1920	2922	5247	135	0.0149	0.231	0
567	26.25	0	81	24	105	7	0.015	0.234	0
568	107.5	0	184	246	430	14	0.0116	0.176	0
569	41.75	0	51	116	167	15	0.0125	0.189	0
570	680.75	411	816	1496	2723	88	0.0138	0.21	0
571	41.25	0	113	52	165	11	0.0102	0.162	0
572	153.5	0	104	510	614	24	0.012	0.186	0
573	382.5	0	306	1224	1530	51	0.0118	0.183	0
574	238.25	0	167	786	953	32	0.0108	0.167	0
575	333	409	769	154	1332	28	0.0191	0.292	0
576	379	684	379	453	1516	37	0.0197	0.315	0
577	183.25	0	467	266	733	31	0.0107	0.162	0
578	83.25	0	173	160	333	13	0.013	0.2	0

579	594.5	0	1332	1046	2378	60	0.0103	0.162	0
580	180	531	62	127	720	18	0.0261	0.426	0
581	228	0	493	419	912	35	0.0136	0.21	0
582	196.75	406	70	311	787	22	0.015	0.235	0
583	486.25	402	825	718	1945	62	0.0188	0.297	0
584	394	429	517	630	1576	53	0.0136	0.21	0
585	177.25	452	144	113	709	21	0.0128	0.198	0
586	106	0	251	173	424	26	0.0112	0.176	0
587	355.75	701	258	464	1423	36	0.0128	0.198	0
588	827.5	0	2247	1063	3310	86	0.0117	0.182	0
589	335.25	463	319	559	1341	42	0.0111	0.174	0
590	98.25	0	274	119	393	32	0.0113	0.175	0
591	280	572	264	284	1120	22	0.0139	0.213	0
592	245.75	0	551	432	983	33	0.0159	0.249	0
593	315	402	670	188	1260	35	0.0136	0.21	0
594	197	473	169	146	788	22	0.0134	0.219	0
595	469	608	441	827	1876	56	0.0124	0.191	0
596	312	411	546	291	1248	41	0.011	0.17	0
597	397	465	443	680	1588	48	0.0103	0.158	0
598	440.5	0	740	1022	1762	67	0.0159	0.251	0
599	383.25	463	378	692	1533	49	0.0133	0.211	0
600	4.75	0	8	11	19	2	0.0158	0.219	0
601	33.75	0	71	64	135	15	0.0176	0.263	0
602	370.75	0	663	820	1483	35	0.0104	0.162	0
603	1140.5	461	2033	2068	4562	152	0.0108	0.168	0
604	447.75	400	508	883	1791	43	0.084	0.131	0
605	69.25	0	203	74	277	14	0.01	0.153	0
606	994.25	407	1277	2293	3977	143	0.0117	0.184	0
607	280.25	505	173	443	1121	33	0.0108	0.176	0
608	257.5	428	289	313	1030	28	0.0102	0.163	0
609	131.5	0	358	168	526	38	0.0274	0.478	0
610	669	411	446	1819	2676	45	0.0109	0.177	0
611	89.25	0	176	181	357	18	0.0135	0.24	0
612	265.75	0	531	532	1063	39	0.0164	0.275	0
613	156.25	402	141	82	625	25	0.0116	0.191	0
614	324.75	479	513	307	1299	31	0.054	0.095	0
615	392	446	1008	114	1568	25	0.0182	0.309	0
616	161	402	99	143	644	20	0.0256	0.416	0
617	194.25	441	178	158	777	22	0.0211	0.339	0
618	10.75	0	27	16	43	7	0.069	0.123	0
619	296.75	510	386	291	1187	31	0.0196	0.331	0
620	568.5	0	1641	633	2274	46	0.0168	0.267	0
621	319	501	283	492	1276	20	0.0174	0.268	0
622	156	400	118	106	624	36	0.0158	0.242	0
623	224.5	0	182	716	898	21	0.0156	0.249	0
624	446.75	417	973	397	1787	49	0.0189	0.304	0
625	669.5	448	1479	751	2678	70	0.0169	0.265	0
626	150.75	0	268	335	603	36	0.0118	0.186	0
627	511.25	408	1064	573	2045	51	0.0135	0.208	0
628	179.75	403	108	208	719	25	0.0123	0.185	0
629	365.75	445	637	381	1463	48	0.0109	0.17	0
630	554.25	401	1120	696	2217	78	0.0133	0.203	0
631	1.5	0	2	4	6	2	0.0241	0.356	0
632	73	0	169	123	292	17	0.0151	0.222	0
633	547	424	1283	481	2188	68	0.091	0.141	0
634	653.5	426	1216	972	2614	78	0.089	0.137	0
635	330.5	409	350	563	1322	72	0.093	0.145	0
636	345.5	435	491	456	1382	63	0.0128	0.192	0
637	398.25	545	592	456	1593	51	0.0105	0.165	0

638	32.25	0	74	55	129	13	0.063	0.101	0
639	183.5	417	80	237	734	16	0.045	0.079	0
640	25.5	0	38	64	102	13	0.049	0.083	0
641	412	0	475	1173	1648	69	0.06	0.1	0
642	300.75	0	999	204	1203	22	0.076	0.124	0
643	182.5	426	124	180	730	17	0.0107	0.18	0
644	57	0	106	122	228	20	0.093	0.143	0
645	288.25	401	324	428	1153	32	0.095	0.148	0
646	29.75	0	77	42	119	6	0.075	0.115	0
647	380	480	402	638	1520	50	0.0109	0.163	0
648	407.75	704	385	542	1631	46	0.095	0.149	0
649	484	441	728	767	1936	39	0.092	0.157	0
650	86.75	0	226	121	347	23	0.041	0.076	0
651	220.75	468	97	318	883	28	0.054	0.092	0
652	483.25	0	1209	724	1933	68	0.06	0.099	0
653	657.5	418	569	1643	2630	65	0.0106	0.171	0
654	256.5	431	251	344	1026	34	0.063	0.104	0
655	576	449	619	1236	2304	75	0.076	0.122	0
656	60.5	0	232	10	242	7	0.067	0.11	0
657	122.25	403	22	64	489	18	0.07	0.116	0
658	172.5	401	76	213	690	17	0.096	0.144	0
659	275.25	402	158	541	1101	27	0.0114	0.176	0
660	316.25	0	558	707	1265	43	0.0106	0.161	0
661	45.5	0	75	107	182	3	0.053	0.097	0
662	175.5	409	249	44	702	19	0.089	0.137	0
663	467.5	404	680	786	1870	41	0.069	0.111	0
664	41.5	0	146	20	166	14	0.063	0.107	0
665	536.5	493	1181	472	2146	77	0.089	0.145	0
666	240.5	401	462	99	962	32	0.082	0.131	0
667	186.75	415	160	172	747	35	0.0109	0.17	0
668	178.25	409	222	82	713	25	0.0118	0.179	0
669	235.75	462	351	130	943	36	0.095	0.145	0
670	92.75	0	96	275	371	20	0.082	0.126	0
671	579.25	484	808	1025	2317	47	0.0113	0.171	0
672	408	448	706	478	1632	58	0.0129	0.198	0
673	282.75	568	205	358	1131	31	0.0133	0.195	0
674	245	410	155	415	980	41	0.097	0.148	0
675	371.75	400	550	537	1487	44	0.078	0.123	0
676	73	0	236	56	292	20	0.0126	0.192	0
677	146.5	400	45	141	586	18	0.09	0.146	0
678	507.75	0	1413	618	2031	67	0.077	0.121	0
679	253.75	439	124	452	1015	27	0.0124	0.197	0
680	29.5	0	75	43	118	15	0.082	0.126	0
681	40	0	44	116	160	19	0.095	0.152	0
682	211.75	411	375	61	847	16	0.0113	0.171	0
683	265.75	425	567	71	1063	19	0.0118	0.183	0
684	232.25	404	213	312	929	33	0.0131	0.198	0
685	380	406	568	546	1520	70	0.085	0.132	0
686	768.25	401	1792	880	3073	68	0.087	0.137	0
687	179.5	0	349	369	718	37	0.0106	0.164	0
688	347.5	0	897	493	1390	76	0.056	0.093	0
689	903.25	0	1504	2109	3613	104	0.086	0.139	0
690	450.75	476	182	1145	1803	30	0.088	0.141	0
691	400	400	660	540	1600	26	0.0118	0.193	0
692	291.25	647	213	305	1165	48	0.01	0.16	0
693	269.5	0	425	653	1078	55	0.096	0.145	0
694	294.5	434	416	328	1178	62	0.038	0.07	0
695	456.5	0	457	1369	1826	62	0.081	0.128	0
696	486.25	417	826	702	1945	70	0.09	0.145	0

697	252.5	0	644	366	1010	45	0.067	0.105	0
698	13	0	28	24	52	7	0.085	0.129	0
699	116	0	36	428	464	13	0.056	0.094	0
700	367.25	538	518	413	1469	54	0.083	0.134	0
701	43	0	86	86	172	15	0.064	0.099	0
702	704.5	431	1041	1346	2818	96	0.0107	0.171	0
703	254	0	609	407	1016	56	0.075	0.122	0
704	261.5	422	203	421	1046	33	0.098	0.157	0
705	99.25	0	232	165	397	9	0.047	0.084	0
706	35.5	0	74	68	142	14	0.044	0.078	0
707	518.5	442	1160	472	2074	48	0.0134	0.21	0
708	207.25	400	124	305	829	20	0.0145	0.233	0
709	399.5	413	800	385	1598	60	0.086	0.141	0
710	534.75	0	1282	857	2139	55	0.058	0.099	0
711	800.5	0	1915	1287	3202	103	0.065	0.104	0
712	327	0	798	510	1308	55	0.0117	0.187	0
713	543.5	0	1207	967	2174	44	0.0121	0.192	0
714	295.5	582	451	149	1182	34	0.0104	0.174	0
715	237.25	416	371	162	949	22	0.084	0.135	0
716	305	535	204	481	1220	20	0.0133	0.211	0
717	645.5	400	1261	921	2582	95	0.011	0.176	0
718	325	406	392	502	1300	43	0.056	0.096	0
719	272	612	402	74	1088	23	0.057	0.094	0
720	42.75	0	110	61	171	16	0.0214	0.348	0
721	867.25	0	2462	1007	3469	131	0.0136	0.209	0
722	664.25	0	1079	1578	2657	91	0.0157	0.246	0
723	123.75	0	156	339	495	35	0.0304	0.496	0
724	82	0	80	248	328	15	0.0152	0.235	0
725	462.75	0	401	1450	1851	40	0.095	0.149	0
726	505	0	629	1391	2020	36	0.095	0.147	0
727	201.5	0	377	429	806	56	0.0131	0.191	0
728	187.75	562	56	133	751	21	0.053	0.094	0
729	216	0	657	207	864	22	0.0144	0.232	0
730	177	446	114	148	708	22	0.042	0.084	0
731	18.5	0	4	70	74	2	0.001	0.026	0
732	384.5	0	853	685	1538	42	0.032	0.074	0
733	85.5	0	300	42	342	4	0.005	0.031	0
734	24.75	0	5	94	99	4	0.042	0.105	0
735	8.25	0	3	30	33	2	5E-05	0.025	0
736	66.75	0	6	261	267	5	0.071	0.129	0
737	799.25	0	1415	1782	3197	96	0.098	0.15	0
738	324.25	460	507	330	1297	47	0.0109	0.168	0
739	117.25	0	412	57	469	12	0.0126	0.196	0
740	560.75	406	321	1516	2243	61	0.0101	0.153	0
741	115.75	0	358	105	463	26	0.0104	0.16	0
742	546	404	678	1102	2184	59	0.093	0.145	0
743	470.75	405	906	572	1883	59	0.08	0.128	0
744	468	460	773	639	1872	45	0.033	0.074	0
745	180.75	402	194	127	723	63	0.064	0.124	0
746	482.5	0	695	1235	1930	92	0.007	0.034	0
747	97.5	0	112	278	390	36	0.054	0.095	0
748	423.75	459	1107	129	1695	36	0.0112	0.171	0
749	566.5	0	1274	992	2266	87	0.0121	0.184	0
750	339.25	438	375	544	1357	29	0.075	0.117	0
751	408.75	434	921	280	1635	49	0.092	0.148	0
752	249.75	0	472	527	999	40	0.012	0.038	0
753	1624	426	2895	3175	6496	165	0.091	0.147	0
754	305.25	0	625	596	1221	57	0.096	0.15	0
755	150.25	406	126	69	601	26	0.0147	0.236	0

756	484	0	937	999	1936	57	0.0101	0.156	0
757	50.75	0	175	28	203	13	0.016	0.044	0
758	15.75	0	32	31	63	10	0.036	0.069	0
759	224	532	133	231	896	31	0.0118	0.183	0
760	303.5	409	418	387	1214	47	0.0125	0.196	0
761	350	0	926	474	1400	54	0.054	0.093	0
762	276.75	405	104	598	1107	37	0.091	0.151	0
763	78.5	0	106	208	314	16	0.081	0.131	0
764	449.25	0	913	884	1797	49	0.062	0.103	0
765	37	0	49	99	148	15	0.081	0.123	0
766	198.25	426	107	260	793	21	0.0106	0.167	0
767	137.75	0	461	90	551	21	0.062	0.101	0
768	208.75	410	279	146	835	20	0.0137	0.209	0
769	371.5	415	590	481	1486	57	0.0102	0.16	0
770	339.5	0	928	430	1358	55	0.0101	0.159	0
771	42.5	0	71	99	170	17	0.067	0.107	0
772	683.25	0	1143	1590	2733	76	0.0106	0.161	0
773	50.75	0	90	113	203	10	0.0152	0.228	0
774	845.75	0	1263	2120	3383	80	0.0127	0.199	0
775	540.75	0	799	1364	2163	65	0.0204	0.321	0
776	264.5	660	150	248	1058	19	0.0162	0.266	0
777	653.5	0	1277	1337	2614	69	0.0178	0.297	0
778	53.5	0	126	88	214	14	0.073	0.131	0
779	441.25	433	372	960	1765	53	0.0156	0.253	0
780	40	0	114	46	160	14	0.0126	0.198	0
781	163.25	413	136	104	653	28	0.0106	0.174	0
782	139.75	0	406	153	559	38	0.014	0.237	0
783	1074.3	424	1294	2579	4297	125	0.092	0.148	0
784	303	410	634	168	1212	38	0.0102	0.169	0
785	1228	401	1862	2649	4912	120	0.0149	0.241	0
786	405.25	0	850	771	1621	49	0.0278	0.487	0
787	221.25	448	202	235	885	41	0.0168	0.275	0
788	671.25	0	1685	1000	2685	50	0.0136	0.22	0
789	389.75	406	459	694	1559	34	0.0136	0.221	0
790	307.25	404	406	419	1229	36	0.0114	0.182	0
791	744.75	0	1752	1227	2979	94	0.0128	0.201	0
792	358.75	403	416	616	1435	43	0.0149	0.232	0
793	342	400	557	411	1368	21	0.0109	0.171	0
794	408.25	581	519	533	1633	63	0.013	0.204	0
795	52.75	0	129	82	211	13	0.084	0.127	0
796	366.25	476	379	610	1465	65	0.0133	0.205	0
797	370.25	409	408	664	1481	80	0.0161	0.252	0
798	411	447	615	582	1644	43	0.016	0.251	0
799	600	802	1290	308	2400	63	0.0147	0.226	0
800	224.25	416	208	273	897	18	0.062	0.114	0
801	322.5	0	912	378	1290	110	0.0109	0.177	0
802	661.5	0	726	1920	2646	62	0.089	0.142	0
803	600.75	439	1461	503	2403	52	0.077	0.122	0
804	267.75	400	159	512	1071	37	0.0109	0.172	0
805	158.25	400	98	135	633	20	0.0127	0.199	0
806	195.25	464	82	235	781	70	0.0111	0.182	0
807	549	449	1063	684	2196	55	0.0145	0.232	0
808	20.75	0	36	47	83	11	0.0258	0.383	0
809	200.5	453	155	194	802	26	0.0148	0.233	0
810	20	0	63	17	80	6	0.0118	0.185	0
811	126.75	0	298	209	507	22	0.094	0.146	0
812	355	441	466	513	1420	39	0.0142	0.226	0
813	20.25	0	48	33	81	6	0.0122	0.187	0
814	16.25	0	51	14	65	5	0.0108	0.158	0

815	469	426	474	976	1876	82	0.0141	0.218	0
816	196	0	549	235	784	32	0.0153	0.233	0
817	608.5	485	642	1307	2434	91	0.095	0.147	0
818	551.25	0	1426	779	2205	77	0.0121	0.188	0
819	161.5	408	104	134	646	22	0.078	0.123	0
820	418.75	0	889	786	1675	37	0.0106	0.17	0
821	273	407	217	468	1092	29	0.0125	0.193	0
822	326.25	0	539	766	1305	48	0.0109	0.172	0
823	70.25	0	247	34	281	7	0.075	0.124	0
824	42	0	39	129	168	18	0.036	0.072	0
825	362.75	409	650	392	1451	48	0.0108	0.172	0
826	557.75	0	1452	779	2231	51	0.0113	0.177	0
827	240.75	421	348	194	963	32	0.0134	0.229	0
828	270.25	0	784	297	1081	30	0.067	0.108	0
829	264.5	417	115	526	1058	36	0.074	0.123	0
830	115.75	0	56	407	463	10	0.024	0.055	0
831	239.5	406	200	352	958	34	0.062	0.114	0
832	1.25	0	5	0	5	1	0.037	0.066	0
833	477.25	0	725	1184	1909	79	0.04	0.076	0
834	361.25	408	580	457	1445	59	0.0127	0.203	0
835	413.5	443	780	431	1654	32	0.068	0.117	0
836	111.25	0	445	0	445	1	0.091	0.14	0
837	180.25	494	98	129	721	27	0.045	0.078	0
838	166.75	0	318	349	667	42	0.084	0.134	0
839	175.5	0	518	184	702	19	0.065	0.11	0
840	666.25	0	1440	1225	2665	68	0.04	0.073	0
841	379.75	0	451	1068	1519	55	0.014	0.232	0
842	216.5	418	162	286	866	24	0.0175	0.273	0
843	34.5	0	126	12	138	10	0.067	0.105	0
844	627	411	664	1433	2508	64	0.0172	0.262	0
845	207.75	437	294	100	831	30	0.0123	0.197	0
846	781.25	0	2410	715	3125	96	0.0126	0.198	0
847	373.5	404	225	865	1494	53	0.0141	0.225	0
848	364.5	538	523	397	1458	39	0.0132	0.205	0
849	5	0	6	14	20	3	0.066	0.106	0
850	163.5	0	471	183	654	44	0.064	0.102	0
851	731.75	518	1959	450	2927	76	0.095	0.149	0
852	217.5	439	242	189	870	21	0.08	0.128	0
853	58.25	0	123	110	233	21	0.068	0.109	0
854	242	430	423	115	968	28	0.077	0.122	0
855	308.5	582	372	280	1234	32	0.088	0.141	0
856	34.75	0	97	42	139	12	0.0152	0.224	0
857	144	0	316	260	576	35	0.0116	0.178	0
858	132.75	0	191	340	531	27	0.0123	0.192	0
859	44.5	0	74	104	178	13	0.088	0.133	0
860	98.5	0	147	247	394	14	0.071	0.121	0
861	132	0	280	248	528	34	0.0101	0.167	0
862	512.5	622	443	985	2050	51	0.011	0.177	0
863	312.5	404	528	318	1250	41	0.0115	0.187	0
864	293.25	0	578	595	1173	36	0.092	0.146	0
865	815.25	427	1217	1617	3261	73	0.082	0.133	0
866	233.5	436	113	385	934	33	0.082	0.131	0
867	603	479	927	1006	2412	77	0.0106	0.169	0
868	83	0	169	163	332	20	0.0103	0.152	0
869	274.25	522	355	220	1097	33	0.07	0.114	0
870	114.25	0	334	123	457	29	0.011	0.174	0
871	770.75	422	2125	536	3083	81	0.074	0.12	0
872	500	471	1129	400	2000	41	0.0111	0.182	0
873	259.25	410	462	165	1037	39	0.0122	0.189	0

874	821.75	402	1418	1467	3287	90	0.0123	0.188	0
875	0.5	0	2	0	2	1	1E-05	0.026	0
876	11	0	33	11	44	9	0.004	0.031	0
877	216.25	421	286	158	865	35	0.0143	0.22	0
878	82	0	46	282	328	21	0.044	0.081	0
879	47.5	0	32	158	190	10	0.0107	0.18	0
880	390.5	682	665	215	1562	34	0.015	0.229	0
881	11	0	24	20	44	8	0.085	0.135	0
882	247.25	446	249	294	989	33	0.0157	0.238	0
883	266.5	401	212	453	1066	48	0.0126	0.196	0
884	161.25	403	115	127	645	24	0.0121	0.195	0
885	415	413	563	684	1660	92	0.0144	0.233	0
886	444.25	547	819	411	1777	53	0.0116	0.188	0
887	161.75	483	54	110	647	17	0.077	0.129	0
888	219.25	425	86	366	877	19	0.05	0.087	0
889	336.5	413	430	503	1346	44	0.048	0.083	0
890	650.75	0	1323	1280	2603	126	0.0161	0.252	0
891	105.75	0	111	312	423	17	0.0106	0.171	0
892	107.25	0	53	376	429	15	0.0109	0.175	0
893	524	405	462	1229	2096	55	0.01	0.17	0
894	20.25	0	75	6	81	3	0.0106	0.153	0
895	296.5	0	555	631	1186	51	0.098	0.153	0
896	467.25	407	462	1000	1869	68	0.0126	0.203	0
897	1050.8	400	2254	1549	4203	122	0.0145	0.226	0
898	95.5	0	251	131	382	31	0.0127	0.193	0
899	573.5	0	1450	844	2294	80	0.0151	0.237	0
900	234	414	168	354	936	30	0.0141	0.224	0
901	890.75	0	2117	1446	3563	95	0.0177	0.278	0
902	4.25	0	7	10	17	4	0.0144	0.217	0
903	294	406	542	228	1176	29	0.0165	0.261	0
904	283.25	0	938	195	1133	43	0.0147	0.229	0
905	194.5	425	179	174	778	35	0.0162	0.262	0
906	77.25	0	264	45	309	12	0.0123	0.186	0
907	66.75	0	42	225	267	10	0.079	0.132	0
908	444.75	433	576	770	1779	68	0.098	0.155	0
909	219	418	255	203	876	19	0.087	0.141	0
910	286	0	873	271	1144	37	0.0131	0.201	0
911	357.75	408	450	573	1431	50	0.0122	0.197	0
912	268.5	0	823	251	1074	24	0.0135	0.214	0
913	238.5	0	514	440	954	22	0.088	0.148	0
914	823.25	423	1303	1567	3293	117	0.092	0.145	0
915	268.5	0	781	293	1074	35	0.088	0.146	0
916	214	529	113	214	856	24	0.057	0.098	0
917	57	0	30	198	228	11	0.047	0.083	0
918	508	0	371	1661	2032	59	0.0142	0.226	0
919	19.75	0	19	60	79	8	0.0148	0.248	0
920	621.25	478	1149	858	2485	54	0.0135	0.218	0
921	165.75	431	99	133	663	17	0.091	0.146	0
922	156.5	403	89	134	626	21	0.066	0.106	0
923	228.5	406	353	155	914	28	0.0102	0.162	0
924	5.5	0	8	14	22	6	0.036	0.07	0
925	12.25	0	2	47	49	3	0.025	0.054	0
926	152.75	400	149	62	611	33	0.0104	0.168	0
927	304.75	507	198	514	1219	52	0.094	0.151	0
928	701.75	406	983	1418	2807	65	0.0106	0.167	0
929	254.5	0	480	538	1018	44	0.0179	0.278	0
930	746.75	0	1102	1885	2987	43	0.095	0.152	0
931	489.25	519	946	492	1957	57	0.0104	0.166	0
932	380.5	420	506	596	1522	24	0.0127	0.2	0

933	328.5	418	385	511	1314	35	0.0151	0.237	0
934	81	0	256	68	324	10	0.084	0.133	0
935	249	404	255	337	996	57	0.0134	0.211	0
936	18	0	41	31	72	8	0.0147	0.204	0
937	114.5	0	175	283	458	25	0.0131	0.2	0
938	207.5	446	169	215	830	28	0.0172	0.276	0
939	45	0	74	106	180	11	0.083	0.128	0
940	322	419	300	569	1288	42	0.0162	0.254	0
941	20	0	31	49	80	7	0.083	0.129	0
942	268.25	0	604	469	1073	42	0.0104	0.172	0
943	399	521	242	833	1596	31	0.0145	0.234	0
944	643	0	1202	1370	2572	46	0.0111	0.17	0
945	80	0	126	194	320	29	0.0113	0.174	0
946	220	402	214	264	880	27	0.0175	0.28	0
947	16.75	0	29	38	67	10	0.079	0.12	0
948	278.75	0	453	662	1115	40	0.0113	0.177	0
949	869.5	435	1410	1633	3478	87	0.0108	0.165	0
950	861.5	496	1538	1412	3446	113	0.0102	0.157	0
951	57.75	0	104	127	231	21	0.083	0.127	0
952	14.75	0	34	25	59	7	0.046	0.087	0
953	379.75	579	587	353	1519	64	0.0149	0.243	0
954	708.5	453	1556	825	2834	94	0.0204	0.32	0
955	390.25	432	287	842	1561	55	0.0185	0.305	0
956	256	0	370	654	1024	20	0.077	0.121	0
957	186.25	498	67	180	745	24	0.048	0.084	0
958	92.25	0	217	152	369	29	0.054	0.09	0
959	333.75	0	912	423	1335	58	0.037	0.069	0
960	346	498	510	376	1384	45	0.0247	0.442	0
961	8.5	0	23	11	34	8	0.05	0.079	0
962	483	0	815	1117	1932	74	0.0167	0.262	0
963	440.75	406	754	603	1763	42	0.0162	0.256	0
964	24	0	87	9	96	5	0.0113	0.187	0
965	389.75	698	587	274	1559	35	0.0116	0.178	0
966	216.25	0	714	151	865	28	0.0118	0.181	0
967	147	404	63	121	588	31	0.0108	0.166	0
968	337.75	401	281	669	1351	68	0.097	0.149	0
969	250.5	604	343	55	1002	21	0.058	0.098	0
970	223	663	107	122	892	23	0.055	0.092	0
971	166	437	169	58	664	18	0.063	0.103	0
972	84	0	239	97	336	16	0.088	0.136	0
973	39	0	54	102	156	11	0.096	0.141	0
974	176.5	425	209	72	706	23	0.049	0.083	0
975	279.25	0	766	351	1117	47	0.069	0.109	0
976	840.25	679	1486	1196	3361	86	0.044	0.079	0
977	676.5	621	1061	1024	2706	60	0.047	0.081	0
978	157.25	0	513	116	629	29	0.065	0.106	0
979	508.75	412	666	957	2035	67	0.0107	0.174	0
980	201	441	99	264	804	25	0.0103	0.159	0
981	367.25	471	316	682	1469	31	0.073	0.117	0
982	381.75	414	748	365	1527	47	0.0127	0.199	0
983	952.5	0	2692	1118	3810	104	0.057	0.095	0
984	273.25	407	196	490	1093	36	0.058	0.098	0
985	238.25	420	385	148	953	45	0.07	0.114	0
986	1060.8	0	2680	1563	4243	96	0.044	0.078	0
987	37.5	0	76	74	150	15	0.031	0.061	0
988	475.25	588	399	914	1901	38	0.055	0.094	0
989	253.25	0	611	402	1013	50	0.041	0.077	0
990	208	405	179	248	832	36	0.097	0.151	0
991	38.75	0	113	42	155	10	0.036	0.068	0

992	266	411	401	252	1064	33	0.0108	0.167	0
993	261.75	550	241	256	1047	31	0.087	0.136	0
994	237.75	430	329	192	951	36	0.054	0.09	0
995	44.25	0	48	129	177	18	0.0169	0.246	0
996	225.75	0	565	338	903	20	0.054	0.091	0
997	246	415	154	415	984	25	0.051	0.091	0
998	191.75	403	279	85	767	16	0.072	0.115	0
999	237.75	444	442	65	951	22	0.05	0.086	0
1000	211.25	495	203	147	845	29	0.055	0.091	0
1001	214	401	224	231	856	35	0.046	0.082	0
1002	816.5	402	1639	1225	3266	120	0.093	0.151	0
1003	28.25	0	78	35	113	8	0.0469	0.849	0
1004	900	0	1877	1723	3600	94	0.0124	0.197	0
1005	155.25	0	435	186	621	37	0.01	0.148	0
1006	992.75	470	1502	1999	3971	109	0.049	0.086	0
1007	75.75	0	150	153	303	26	0.0104	0.162	0
1008	1227	0	2543	2365	4908	167	0.067	0.108	0
1009	163.5	417	93	144	654	26	0.0107	0.165	0
1010	176.5	526	72	108	706	23	0.0105	0.157	0
1011	539.5	408	885	865	2158	77	0.07	0.112	0
1012	100.5	0	185	217	402	28	0.0142	0.223	0
1013	567.75	0	1152	1119	2271	77	0.0101	0.154	0
1014	176	0	121	583	704	31	0.062	0.101	0
1015	719	461	1280	1135	2876	60	0.064	0.104	0
1016	203.5	429	203	182	814	28	0.059	0.098	0
1017	187.25	568	102	79	749	21	0.059	0.1	0
1018	404.75	430	480	709	1619	63	0.072	0.115	0
1019	236.5	0	409	537	946	26	0.0212	0.37	0
1020	337	0	990	358	1348	34	0.016	0.255	0
1021	194	401	267	108	776	24	0.069	0.11	0
1022	904	436	1095	2085	3616	130	0.088	0.142	0
1023	170.5	422	100	160	682	18	0.011	0.18	0
1024	1032.3	401	1320	2408	4129	145	0.078	0.131	0
1025	264.75	457	365	237	1059	44	0.0129	0.205	0
1026	236.25	473	238	234	945	42	0.0141	0.234	0
1027	76	0	63	241	304	15	0.0131	0.201	0
1028	188.75	438	149	168	755	38	0.014	0.215	0
1029	16	0	53	11	64	7	0.0138	0.21	0
1030	256	0	465	559	1024	57	0.0229	0.363	0
1031	325.25	0	786	515	1301	40	0.0175	0.268	0
1032	189.75	443	186	130	759	19	0.074	0.121	0
1033	699.75	400	1346	1053	2799	84	0.078	0.126	0
1034	310.5	576	365	301	1242	39	0.01	0.158	0
1035	374	0	240	1256	1496	45	0.0126	0.209	0
1036	725.5	0	869	2033	2902	98	0.0215	0.368	0
1037	52.5	0	66	144	210	15	0.0266	0.411	0
1038	256	437	363	224	1024	34	0.0127	0.21	0
1039	452.5	0	496	1314	1810	23	0.0144	0.248	0
1040	465.5	0	706	1156	1862	63	0.0233	0.421	0
1041	195.75	0	204	579	783	18	0.0211	0.372	0
1042	687	421	1594	733	2748	62	0.088	0.144	0
1043	96.75	0	266	121	387	36	0.0252	0.354	0
1044	2	0	4	4	8	2	0.033	0.596	0
1045	260.5	0	426	616	1042	38	0.0217	0.371	0
1046	139.25	403	115	39	557	16	0.07	0.114	0
1047	93	0	248	124	372	20	0.0253	0.435	0
1048	700.5	0	1160	1642	2802	50	0.0167	0.26	0
1049	218	442	246	184	872	37	0.0111	0.179	0
1050	77.75	0	158	153	311	12	0.018	0.282	0

1051	1264.3	406	2188	2463	5057	118	0.0111	0.176	0
1052	476.25	402	703	800	1905	73	0.075	0.119	0
1053	935.5	422	1923	1397	3742	92	0.0145	0.236	0
1054	251.25	0	745	260	1005	34	0.0205	0.321	0
1055	27.75	0	43	68	111	13	0.0297	0.455	0
1056	8.25	0	14	19	33	7	0.0318	0.528	0
1057	4.5	0	8	10	18	4	0.0224	0.341	0
1058	234.5	444	241	253	938	23	0.084	0.135	0
1059	142.5	401	49	120	570	18	0.0111	0.178	0
1060	172	409	62	217	688	22	0.0107	0.167	0
1061	12	0	26	22	48	7	0.0274	0.427	0
1062	177.5	0	472	238	710	24	0.024	0.39	0
1063	149.25	0	365	232	597	36	0.0195	0.313	0
1064	287.75	0	357	794	1151	22	0.0151	0.237	0
1065	40.75	0	74	89	163	22	0.022	0.354	0
1066	205.25	424	268	129	821	25	0.015	0.228	0
1067	33.25	0	61	72	133	13	0.0152	0.233	0
1068	289.5	452	470	236	1158	20	0.0143	0.212	0
1069	238.25	426	274	253	953	29	0.0166	0.257	0
1070	742.5	0	1742	1228	2970	95	0.0211	0.343	0
1071	17	0	59	9	68	6	0.07	0.113	0
1072	31.25	0	11	114	125	5	0.093	0.163	0
1073	697.25	0	1085	1704	2789	102	0.0107	0.174	0
1074	394	0	298	1278	1576	39	0.0108	0.165	0
1075	529.5	448	887	783	2118	67	0.082	0.131	0
1076	505.25	0	1208	813	2021	48	0.076	0.12	0
1077	650.25	590	483	1528	2601	68	0.098	0.15	0
1078	101.75	0	312	95	407	21	0.052	0.09	0
1079	300.75	408	579	216	1203	46	0.036	0.069	0
1080	939.75	457	1438	1864	3759	87	0.046	0.081	0
1081	264.5	442	298	318	1058	30	0.081	0.131	0
1082	48	0	127	65	192	13	0.0111	0.195	0
1083	345.5	0	934	448	1382	47	0.097	0.161	0
1084	318.25	405	619	249	1273	41	0.086	0.144	0
1085	37.5	0	56	94	150	18	0.041	0.074	0
1086	8	0	8	24	32	4	0.027	0.058	0
1087	140.5	0	195	367	562	23	0.0101	0.168	0
1088	311	425	486	333	1244	36	0.0109	0.161	0
1089	1425.5	0	2278	3424	5702	157	0.0136	0.21	0
1090	240	0	423	537	960	35	0.0126	0.189	0
1091	329	404	759	153	1316	27	0.062	0.101	0
1092	332.5	0	719	611	1330	42	0.087	0.138	0
1093	202	408	193	207	808	26	0.054	0.092	0
1094	229	452	276	188	916	39	0.039	0.072	0
1095	54.75	0	86	133	219	15	0.0175	0.267	0
1096	248	406	357	229	992	27	0.081	0.126	0
1097	89.25	0	168	189	357	19	0.0159	0.235	0
1098	581	466	525	1333	2324	46	0.067	0.109	0
1099	648.75	412	1440	743	2595	69	0.074	0.118	0
1100	3	0	12	0	12	1	0.044	0.086	0
1101	501.5	418	715	873	2006	95	0.0102	0.16	0
1102	12.75	0	40	11	51	7	0.039	0.071	0
1103	642.75	401	902	1268	2571	79	0.041	0.075	0
1104	48.25	0	110	83	193	14	0.061	0.105	0
1105	86.75	0	212	135	347	24	0.048	0.083	0
1106	1109.3	577	1693	2167	4437	101	0.099	0.168	0
1107	193.75	412	137	226	775	27	0.0138	0.236	0
1108	201	406	222	176	804	36	0.0118	0.194	0
1109	870.5	0	2453	1029	3482	141	0.0139	0.223	0

1110	150.75	0	87	516	603	12	0.058	0.095	0
1111	81.75	0	56	271	327	18	0.047	0.081	0
1112	172	401	140	147	688	26	0.044	0.08	0
1113	274.5	445	568	85	1098	19	0.031	0.062	0
1114	174	400	203	93	696	36	0.034	0.066	0
1115	106.75	0	141	286	427	12	0.069	0.112	0
1116	229.75	628	108	183	919	20	0.029	0.06	0
1117	158	407	118	107	632	30	0.06	0.112	0
1118	567.25	0	1313	956	2269	105	0.0165	0.256	0
1119	255	400	150	470	1020	21	0.097	0.167	0
1120	190	529	140	91	760	24	0.0145	0.272	0
1121	10	0	9	31	40	7	0.013	0.044	0
1122	177	485	152	71	708	22	0.0169	0.272	0
1123	335	431	444	465	1340	49	0.0178	0.277	0
1124	308	442	472	318	1232	55	0.0165	0.259	0
1125	181.25	0	515	210	725	41	0.0234	0.413	0
1126	330.25	0	568	753	1321	50	0.0151	0.239	0
1127	618	443	1111	918	2472	67	0.0195	0.412	0
1128	79.75	0	80	239	319	21	0.0104	0.188	0
1129	249.75	543	119	337	999	25	0.048	0.085	0
1130	182.25	403	261	65	729	17	0.0155	0.279	0
1131	507.75	432	339	1260	2031	38	0.0133	0.206	0
1132	203.75	434	79	302	815	26	0.0137	0.222	0
1133	221	436	249	199	884	31	0.0162	0.267	0
1134	155.25	400	104	117	621	26	0.0141	0.22	0
1135	195.5	461	60	261	782	17	0.0172	0.269	0
1136	54.25	0	175	42	217	15	0.01	0.149	0
1137	181	511	132	81	724	22	0.0108	0.176	0
1138	540.5	0	707	1455	2162	93	0.012	0.191	0
1139	377.25	408	605	496	1509	46	0.0173	0.272	0
1140	444.5	400	1084	294	1778	59	0.0271	0.559	0
1141	66.75	0	177	90	267	21	0.0291	0.459	0
1142	198.5	0	353	441	794	39	0.0146	0.223	0
1143	276.25	424	181	500	1105	39	0.011	0.17	0
1144	27.25	0	42	67	109	12	0.0176	0.269	0
1145	1070.5	0	2112	2170	4282	93	0.019	0.307	0
1146	547.5	403	892	895	2190	78	0.0145	0.233	0
1147	160	0	11	629	640	5	0.0183	0.325	0
1148	92.75	0	61	310	371	20	0.0129	0.198	0
1149	309.25	451	445	341	1237	29	0.0191	0.315	0
1150	508.75	410	812	813	2035	90	0.077	0.123	0
1151	153.5	402	69	143	614	19	0.0197	0.345	0
1152	265.75	0	919	144	1063	35	0.0175	0.292	0
1153	276.75	0	569	538	1107	70	0.0174	0.263	0
1154	38.5	0	98	56	154	8	0.091	0.139	0
1155	447.75	425	244	1122	1791	45	0.052	0.087	0
1156	330.25	403	608	310	1321	35	0.078	0.12	0
1157	200.25	506	194	101	801	29	0.063	0.101	0
1158	466.25	434	506	925	1865	34	0.096	0.15	0
1159	222.25	433	178	278	889	36	0.0155	0.246	0
1160	366.75	450	128	889	1467	32	0.013	0.196	0
1161	710	412	1523	905	2840	101	0.0165	0.273	0
1162	6.75	0	19	8	27	4	0.0131	0.181	0
1163	767	408	552	2108	3068	64	0.052	0.095	0
1164	59.5	0	63	175	238	12	0.012	0.04	0
1165	187	0	709	39	748	23	0.0116	0.2	0
1166	9.25	0	28	9	37	2	6E-05	0.025	0
1167	330.75	0	760	563	1323	41	0.066	0.113	0
1168	202.25	407	212	190	809	33	0.064	0.104	0

1169	125.25	0	192	309	501	24	0.045	0.084	0
1170	79.75	0	113	206	319	23	0.061	0.106	0
1171	241	400	505	59	964	17	0.062	0.102	0
1172	0.75	0	3	0	3	2	0.007	0.032	0
1173	4	0	12	4	16	4	0.011	0.04	0
1174	18.75	0	26	49	75	16	0.01	0.039	0
1175	374.25	430	598	469	1497	46	0.0149	0.227	0
1176	322.5	500	271	519	1290	24	0.019	0.31	0
1177	26	0	71	33	104	12	0.034	0.064	0
1178	382.25	415	916	198	1529	50	0.0234	0.407	0
1179	14.25	0	34	23	57	8	0.041	0.082	0
1180	252	0	433	575	1008	29	0.095	0.15	0
1181	356	457	299	668	1424	63	0.0198	0.316	0
1182	3.75	0	10	5	15	3	0.094	0.132	0
1183	288	0	852	300	1152	23	0.0231	0.375	0
1184	286	405	218	521	1144	47	0.0204	0.339	0
1185	96.75	0	167	220	387	17	0.097	0.157	0
1186	291.5	409	175	582	1166	32	0.0211	0.334	0
1187	527.5	505	979	626	2110	62	0.0177	0.28	0
1188	162.5	441	111	98	650	30	0.0208	0.336	0
1189	375.5	439	736	327	1502	56	0.0208	0.328	0
1190	369.75	514	618	347	1479	63	0.0142	0.225	0
1191	6.25	0	22	3	25	2	0.034	0.07	0
1192	286	455	445	244	1144	58	0.0151	0.234	0
1193	6.5	0	11	15	26	8	0.055	0.099	0
1194	290.5	435	293	434	1162	61	0.0163	0.273	0
1195	442	469	685	614	1768	47	0.016	0.268	0
1196	250.5	419	540	43	1002	20	0.0163	0.304	0
1197	569.5	0	994	1284	2278	107	0.0242	0.415	0
1198	8.25	0	23	10	33	5	0.0333	0.488	0
1199	31.5	0	30	96	126	10	0.0222	0.339	0
1200	296.5	0	493	693	1186	77	0.0121	0.186	0
1201	201	408	88	308	804	20	0.046	0.08	0
1202	132	0	458	70	528	25	0.051	0.086	0
1203	234.25	404	211	322	937	25	0.05	0.087	0
1204	227.25	435	65	409	909	25	0.052	0.087	0
1205	262	0	550	498	1048	46	0.0129	0.199	0
1206	276.75	401	243	463	1107	40	0.062	0.101	0
1207	2.75	0	11	0	11	2	0.053	0.079	0
1208	405.25	425	281	915	1621	55	0.092	0.142	0
1209	494.5	403	932	643	1978	35	0.072	0.113	0
1210	341.5	418	741	207	1366	60	0.0105	0.16	0
1211	252.5	493	287	230	1010	31	0.0108	0.172	0
1212	167.25	416	210	43	669	18	0.0127	0.202	0
1213	366.5	417	132	917	1466	43	0.0112	0.174	0
1214	226	411	340	153	904	52	0.086	0.13	0
1215	542.5	481	612	1077	2170	80	0.0128	0.193	0
1216	455.25	413	428	980	1821	97	0.073	0.114	0
1217	455.75	464	1131	228	1823	44	0.0102	0.155	0
1218	33.25	0	79	54	133	11	0.062	0.098	0
1219	640.25	0	1803	758	2561	120	0.0115	0.177	0
1220	380.5	506	367	649	1522	37	0.0108	0.159	0
1221	225.5	405	151	346	902	33	0.0103	0.161	0
1222	184.75	401	215	123	739	22	0.082	0.138	0
1223	406	402	491	731	1624	47	0.07	0.116	0
1224	235.75	401	381	161	943	37	0.04	0.072	0
1225	520.75	412	1021	650	2083	123	0.011	0.169	0
1226	97.5	0	91	299	390	25	0.066	0.108	0
1227	305	761	61	398	1220	24	0.0126	0.195	0

1228	367	552	392	524	1468	69	0.0135	0.21	0
1229	851.5	0	2518	888	3406	127	0.0216	0.386	0
1230	212.5	478	330	42	850	23	0.0174	0.274	0
1231	247	0	368	620	988	18	0.0205	0.338	0
1232	196.25	401	229	155	785	22	0.0161	0.247	0
1233	196.25	400	272	113	785	17	0.0231	0.396	0
1234	571.75	476	945	866	2287	76	0.0336	0.683	0
1235	130.75	0	84	439	523	17	0.0225	0.345	0
1236	191.5	427	146	193	766	34	0.0313	0.586	0
1237	852.5	466	1204	1740	3410	115	0.0274	0.556	0
1238	359.5	435	341	662	1438	78	0.09	0.14	0

1 384331 278744 629815 628764 49974 2E+06 0.189 0

Note: source, left, and right cells include alternate channel rasters.

Table C4: CE-QUAL-RIV1 Simulation Parameter Used

Variable	Value	Description	Units
DOsat	9.092	Saturated DO level	mg/L
K1	0.35	deoxygenation coefficient	d-1
K2	1.1	reaeration coefficient	d-1
K3	0	BOD settling rate	d-1
K4	20	Sediment oxygen demand rate	mg/m2/d
umax	2.5	Maximum algal growth rate	d-1
f(L,N,P)	0.7	algal growth limitation factor	
a3	1.6	mg-O/mg-ABM	
a4	2	mg-O/mg-ABM	
rho	0.1	algal respiration rate	d-1
sig1	0.1	algal settling rate	d-1
sig2	1	benthos source rate for P	mg/m2/d
sig3	4	benthos source rate for N	mg/m2/d
sig4	0.1	N settling rate	d-1
sig5	0.1	P settling rate	d-1
Beta1	0.15	ammonia oxidation rate	d-1
Beta2	1	nitrite oxidation rate	d-1
Beta3	0.25	N hydrolysis rate	d-1
Beta4	0.2	P hydrolysis rate	d-1
fnitr	1	nitrification limitation factor	
Fnh4	0.9	ammonia preference factor	

C.3. BASEFLOW SEPARATION

Baseflow was determined for typical years based on historical streamflow records at the watershed outlet and along the river channel. Data was examined both on a daily and monthly timestep, and a simple manual separation technique was employed to estimate average monthly baseflow conditions.

The method used to separate streamflow into direct runoff and baseflow components is shown in Figure C1.

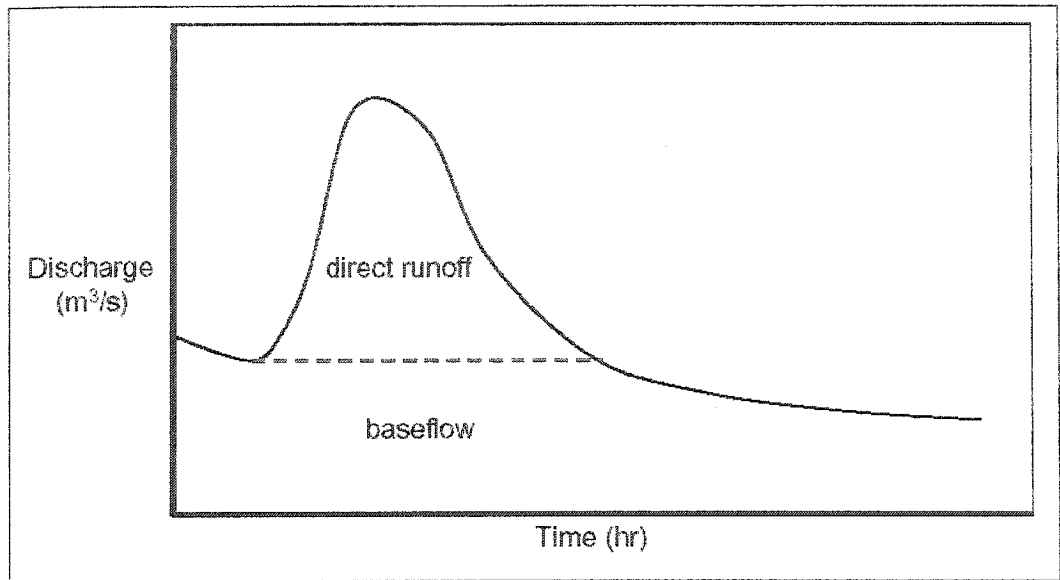


Figure C1: Manual Baseflow Separation Technique

Essentially the separation assumes that flow prior to the beginning of precipitation events is baseflow and that the baseflow component does not change substantially during the runoff event. This method was applied on the daily timestep data to obtain daily direct runoff and baseflow components. The assumption was further made that baseflow changes over a monthly period were negligible, so a monthly baseflow component was then derived from the averages of the daily results. Although strictly speaking this is considered a “manual” technique, a spreadsheet was constructed to aid in the hydrograph separation process. The resulting separation yields a simple model of the base flow component, as shown in Figure C2.

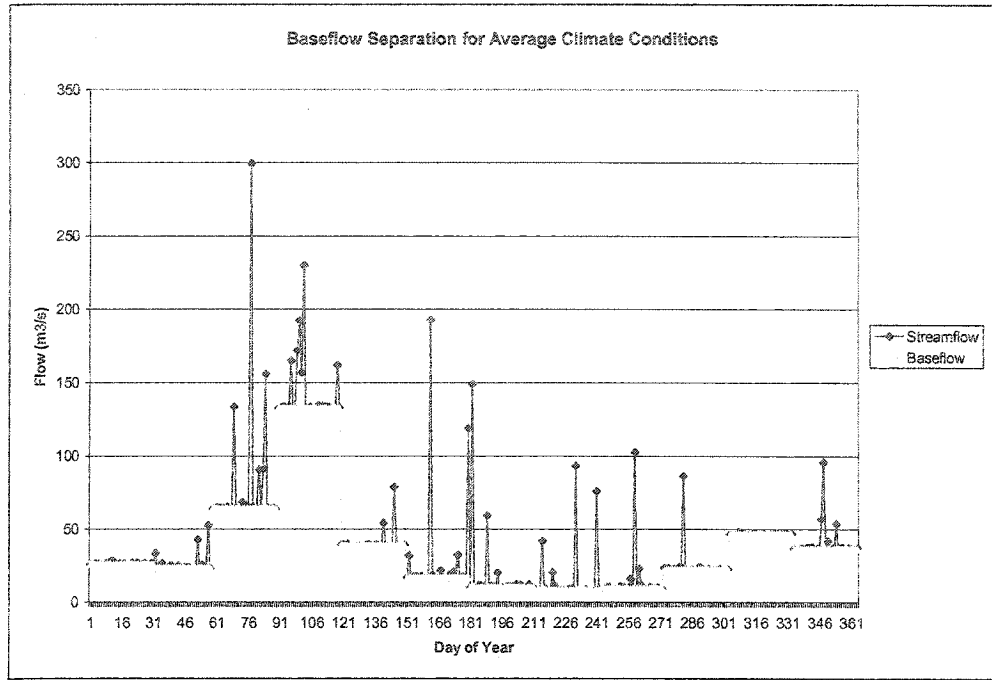


Figure C2: Baseflow Separation Results

It should be noted that this method, like most baseflow separation techniques, is to some degree arbitrary and highly subjective.

APPENDIX D: ANNAGNPS SENSITIVITY ANALYSIS

Table D1: Case Matrix (Weather Scenarios)

Run Name	Climate Description	Data Source
Run001	Base Case (Average)	Synthetic from GEM
Run002	Average	Historical
Run003	Warm, Wet Year	Historical
Run004	Warm, Dry Year	Historical
Run005	Cold, Wet Year	Historical
Run006	Cold, Dry Year	Historical
Run007	25% Precipitation of Base Case	Multiple of Base Case
Run008	175% Precipitation of Base Case	Multiple of Base Case

Table D2: Case Matrix (Cell Data)

Run Number	Adjusted Parameter	Adjusted Value
9	Cell Area	25% Base
10	Cell Area	175% Base
11	Cell Elevation	25% Base
12	Cell Elevation	175% Base
13	Cell avg Land slope	25% Base
14	Cell avg Land slope	175% Base
15	Cell Aspect	25% Base
16	Cell Aspect	175% Base
17	RUSLE/USLE Is factor	25% Base
18	RUSLE/USLE Is factor	175% Base
19	Sheet Flow n	25% Base
20	Sheet Flow n	175% Base
21	Sheet Flow Slope	25% Base
22	Sheet Flow Slope	175% Base
23	Sheet Flow Length	25% Base
24	Sheet Flow Length	50% Base
25	Shallow Conc Flow Slope	25% Base
26	Shallow Conc Flow Slope	175% Base
27	Shallow Conc Flow Length	25% Base
28	Shallow Conc Flow Length	50% Base
29	Conc Flow Slope	25% Base
30	Conc Flow Slope	175% Base
31	Conc Flow Length	25% Base
32	Conc Flow Length	175% Base
33	Conc Flow Hyd. Depth	25% Base
34	Conc Flow Hyd. Depth	175% Base
35	Concentrated Flow n	25% Base
36	Concentrated Flow n	175% Base
37	Time of concentration	25% Base
38	Time of concentration	175% Base

Table D3: Case Matrix (Reach Data)

Run Number	Adjusted Parameter	Adjusted Value
39	Reach Elevation	25% Base
40	Reach Elevation	175% Base
41	Reach Slope	25% Base
42	Reach Slope	175% Base
43	Reach Manning's n	25% Base
44	Reach Manning's n	175% Base
45	Reach Length	25% Base
46	Reach Length	175% Base
47	Reach Top Width	25% Base
48	Reach Top Width	175% Base
49	Reach Flow Depth	25% Base
50	Reach Flow Depth	175% Base
51	Valley Width	25% Base
52	Valley Width	175% Base
53	Valley Manning's n	25% Base
54	Valley Manning's n	175% Base
55	Distance to Outlet	10000% Base

Table D4: Case Matrix (Field Data)

Run Number	Adjusted Parameter	Adjusted Value
56	Percent Rock Cover	25%
57	Percent Rock Cover	75%
58	RUSLE sub-P factor	25%
59	RUSLE sub-P factor	75%
60	Inter-rill Erosion Code	1
61	Inter-rill Erosion Code	2
62	Inter-rill Erosion Code	4

Table D5: Case Matrix (Reach Nutrient Half-Life Data)

Run Number	Adjusted Parameter	Adjusted Value
63	Reach Nitrogen Half-life	25% Base
64	Reach Nitrogen Half-life	175% Base
65	Reach Phosphorus Half-life	25% Base
66	Reach Phosphorus Half-life	175% Base
67	Reach Organic Carbon Half-life	25% Base
68	Reach Organic Carbon Half-life	175% Base

Table D6: Case Matrix (Soil Data)

Run Number	Adjusted Parameter	Adjusted Value
69	Hydrologic Soil Group	A
70	Hydrologic Soil Group	B
71	Hydrologic Soil Group	D
72	K factor	25% Base
73	K factor	175% Base
74	Albedo	25% Base
75	Albedo	175% Base
76	Time to consolidation	25% Base
77	Time to consolidation	175% Base
78	Impervious depth	25% Base
79	Impervious depth	75% Base
80	Specific Gravity	50% Base
81	Specific Gravity	150% Base
82	Clay Ratio	25% Base
83	Clay Ratio	175% Base
84	Silt Ratio	75% Base
85	Silt Ratio	125% Base
86	Sand Ratio	25% Base
87	Sand Ratio	175% Base
88	Rock Ratio	25%
89	Rock Ratio	75%
90	Very Fine Sand Ratio	25% Base

91	Very Fine Sand Ratio	75% Base
92	CaCO3 content	25% Base
93	CaCO3 content	175% Base
94	Saturated Conductivity	25% Base
95	Saturated Conductivity	175% Base
96	Field Capacity	50% Base
97	Field Capacity	150% Base
98	Wilting Point	25% Base
99	Wilting Point	175% Base
100	Volcanic Code	Y
101	Base Saturation	25% Base
102	Base Saturation	175% Base
103	pH	25% Base
104	pH	175% Base
105	Organic Matter Ratio	25% Base
106	Organic Matter Ratio	175% Base
107	Organic N Ratio	25% Base
108	Organic N Ratio	175% Base
109	Inorganic N Ratio	25% Base
110	Inorganic N Ratio	175% Base
111	Organic P Ratio	25% Base
112	Organic P Ratio	175% Base
113	Inorganic P Ratio	25% Base
114	Inorganic P Ratio	175% Base
115	Soil Structure Code	2
116	Soil Structure Code	3
117	Soil Structure Code	4

Table D7: Case Matrix (Runoff Curve Number)

Run Number	Adjusted Parameter	Adjusted Value
118	Curve Number	90% Base (for all)
119	Curve Number	110% Base (for all)
120	Curve Number	C Ident to A

121	Curve Number	C Ident to B
122	Curve Number	C Ident to D

Table D8: Case Matrix (Landuse Reference Data)

Run Number	Adjusted Parameter	Adjusted Value
123	Annual Root Mass	25% Base
124	Annual Root Mass	175% Base
125	Annual Cover Ratio	75% Base
126	Annual Cover Ratio	125% Base
127	Annual Rain Fall Height	25% Base
128	Annual Rain Fall Height	175% Base
129	Surface Residue Cover	25% Base
130	Surface Residue Cover	175% Base

Table D9: Case Matrix (Operations Data)

Run Number	Adjusted Parameter	Adjusted Value
131	Operations Date	+2 months
132	Operations Date	-2 months
133	Residue Cover Remaining	90% Base
134	Residue Cover Remaining	110% Base
135	Residue Weight Remaining	25%
136	Residue Weight Remaining	75%
137	Area Disturbed	25% Base
138	Area Disturbed	175% Base
139	Initial Random Roughness	25% Base
140	Initial Random Roughness	175% Base
141	Final Random Roughness	25% Base
142	Final Random Roughness	175% Base
143	Operation Tillage Depth	25% Base
144	Operation Tillage Depth	175% Base

Table D10: Case Matrix (Crop Data)

Run Number	Adjusted Parameter	Adjusted Value
145	Units Harvested	25% Base
146	Units Harvested	15% Base
147	Residue Weight Ratio	25% Base
148	Residue Weight Ratio	175% Base
149	Crop Residue	25% Base
150	Crop Residue	175% Base
151	Senescence Code	N
152	Yield Unit Weight	25% Base
153	Yield Unit Weight	175% Base
154	Harvest C-N Ratio	25% Base
155	Harvest C-N Ratio	175% Base
156	N Uptake	25% Base
157	N Uptake	175% Base
158	P Uptake	25% Base
159	P Uptake	175% Base
160	Harvest C-P Ratio	75% Base
161	Harvest C-P Ratio	125% Base
162	Growth N Uptake (rate)	25% Uptake Schedule
163	Growth N Uptake (rate)	175% Uptake Schedule
164	Growth P Uptake (rate)	25% Uptake Schedule
165	Growth P Uptake (rate)	175% Uptake Schedule
166	Root Mass	25% Base
167	Root Mass	175% Base
168	Canopy Cover	25% Base
169	Canopy Cover	175% Base
170	Rain Fall Height	25% Base
171	Rain Fall Height	175% Base

Table D11: Case Matrix (Simulation Period Data)

Run Number	Adjusted Parameter	Adjusted Value
172	Rainfall Dist. Code	1
173	Rainfall Dist. Code	2
174	Rainfall Dist. Code	4
175	Rainfall Dist. Code	5
176	Rainfall Dist. Code	6
177	Rainfall Dist. Code	7
178	Rainfall Dist. Code	8
179	Rainfall Dist. Code	9
180	Rainfall Dist. Code	10
181	Rainfall Dist. Code	11
182	Rainfall Factor	25% Base
183	Rainfall Factor	175% Base
184	10 yr EI	25% Base
185	10 yr EI	175% Base
186	EI Distribution	1
187	EI Distribution	50
188	EI Distribution	149
189	Irrigation Climate Code	100%
190	Soil Moisture Steps	25% Base
191	Soil Moisture Steps	175% Base
192	Annual K factor code	N
193	Variable K factor code	N

Table D12: Case Matrix (Fertilizer Application & Reference Data)

Run Number	Adjusted Parameter	Adjusted Value
194	Fertilizer Base Case	0%
195	Fertilizer Rate	25% Base
196	Fertilizer Rate	175% Base
197	Fertilizer Mixing Code	Y
198	Inorganic N	50% Base
199	Inorganic N	25% Base
200	Inorganic P	50% Base
201	Inorganic P	25% Base
202	Organic Matter	42.5%
203	Organic Matter	85%

Table D13: Case Matrix (Feedlot & Feedlot Management Data)

Run Number	Adjusted Parameter	Adjusted Value
204	Feedlot Base Case	0%
205	Open Area	25% Base
206	Open Area	175% Base
207	Paved Ratio	25% Base
208	Paved Ratio	175% Base
209	Roof Area	25% Base
210	Roof Area	175% Base
211	Upslope Area	25% Base
212	Upslope Area	175% Base
213	Feedlot Initial N	25% Base
214	Feedlot Initial N	175% Base
215	Feedlot Initial P	25% Base
216	Feedlot Initial P	175% Base
217	Feedlot Initial OC	25% Base
218	Feedlot Initial OC	175% Base
219	Delta N	10% Initial
220	Delta N	25% Initial
221	Delta P	10% Initial
222	Delta P	25% Initial

224	Delta OC	25% Initial
225	Feedlot Max N	25% Base
226	Feedlot Max N	175% Base
227	Feedlot Max P	25% Base
228	Feedlot Max P	175% Base
229	Feedlot Max OC	25% Base
230	Feedlot Max OC	75% Base
231	Feedlot Pack N	25% Base
232	Feedlot Pack N	175% Base
233	Feedlot Pack P	25% Base
234	Feedlot Pack P	175% Base
235	Feedlot Pack OC	25% Base
236	Feedlot Pack OC	175% Base
237	Cell Open Fract	0%
238	Cell Open Fract	50%
239	Cell Upslope Fract	0%
240	Cell Upslope Fract	50%
241	Cell Buffer Length	75 m
242	Cell Buffer Length	225 m
243	Pack Remove Ratio	0
244	Pack Remove Ratio	100%

D.2. SENSITIVE PARAMETER LIST

Table D14: Primary Parameters

Parameter Category	Parameters
Crop Data	Senescence code, Yield Units Harvested, Crop Residue, Yield Unit Weight
Soil Data	Hydrological Soil Group & Runoff Curve Number, Organic Matter, P & N ratios, Soil Structure code
Simulation Data	SCS Distribution, Rainfall Factor
Field Data	Percent Rock Cover, RUSLE sub-P factor, Inter-rill Erosion code

(Parameters are listed in approximate order of effect.)

Table D15: Secondary Parameters

Parameter Category	Parameters
Crop Data	Root Mass, Canopy Cover
Soil Data	Specific Gravity, Soil Clay/Silt/Sand Ratio.
Operations Data	Dates of implementation, residue weight remaining, random roughness
Fertilizer Data	FAR, Inorganic N
Feedlot Data	Feedlot Max N, P & OC

(Parameters are listed in approximate order of effect.)

D.3 HEURISTIC APPROACH FOR THE CALIBRATION TASK

- 'Primary' parameters will generally impact watershed-wide calibration issues, while secondary parameters may be useful for adjusting behaviour of the model locally without greatly affecting the entire model.
- The volume of water should be calibrated first to known data.
- If the volume of water needs to be adjusted, the hydrologic soil groups, runoff curve numbers and other parameters known to affect water volume may need adjusting.
- Since the phosphorus loadings are generally much less sensitive than the organic carbon or nitrogen loadings, it may be advantageous to first calibrate the P results alone.
- The soluble forms of nitrogen can be calibrated next, and these are especially linked to FARs.
- The attached nitrogen and organic carbon nutrients can then be calibrated. When a reasonably close value for nitrogen and carbon is obtained, the attached organic carbon can be adjusted individually by adjusting the soil parameters.
- If the loadings of the soluble form of organic carbon are inadequate, this may indicate that a change in feedlot parameters or cell parameters for feedlot cells is required.
- Refine the nutrient calibration by going through Steps 3- 6 again.
- Threshold parameters (e.g., 'time to consolidation', 'impervious depth', 'canopy cover') can be used to isolate and simplify calibration tasks.

D.4 GA CALIBRATION

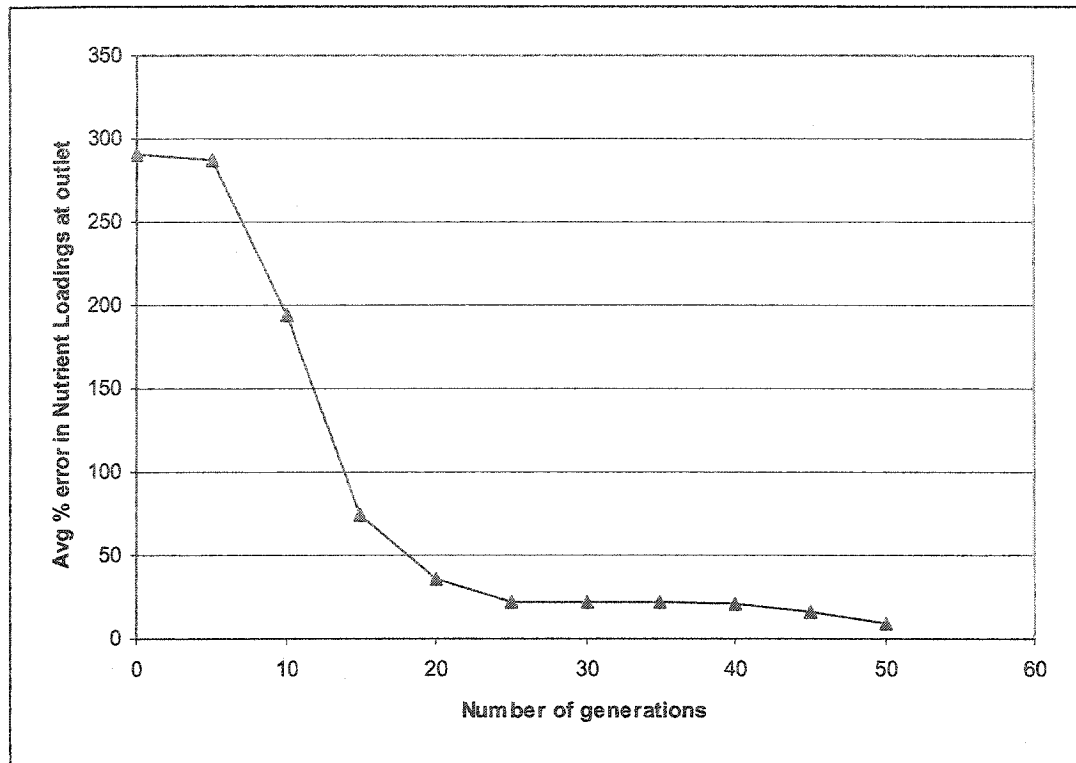


Figure D.1: Progress of GA Calibration at outlet

Figure D.1 shows the progression of calibration 'fitness' at the watershed outlet as the genetic algorithm progressed through several generations. The 'fitness' as considered in this case is the relative error in nutrient loadings at the outlet.

**APPENDIX E: AGRICULTURAL BMP REVIEW
DOCUMENTATION**

Table E.1: Agricultural BMP Summary Guide¹

Resource Concerns													
Best Management Practices	Surface Water Quality										Ground Water Quality		
	Salinity	Temperature	Sediment	Soluble Nutrients	Absorbed Nutrients	Soluble Pesticides	Absorbed Pesticides	Oxygen-Demanding Substances	Pathogens	Nutrients	Pesticide Loss		
Management Practices													
Nutrient Management	C	C	C	A	A	C	C	C	C	A	C		
Pest Management	C	C	C	C	C	A	A	C	C	C	A		
Irrigation System, Tailwater Recovery	A	?	A	A	A	A	A	C	C	?	?		
Irrigation Water Management	A	C	A	A	A	A	A	C	C	B	B		
Regulating Water in Drainage Systems	B	?	C	A	C	A	A	C	C	?	?		
Soil Salinity Management	A	C	B	B	B	B	B	C	C	C	C		
Structure for Water Control	C	C	A	C	A	C	B	A	C	C	C		
Water Table Control	B	?	C	A	C	A	C	C	C	?	?		
Waste Management System ³	C	C	A	A	A	C	C	A	A	A	C		
Runoff Management System ³	C	?	A	A	A	C	C	A	A	A	C		

Vegetative and Tillage Practices												
	C	C	A	C	A	C	A	C	A	C	C	?
Conservation Tillage	C	C	A	A	A	B	A	B	A	C	C	?
Contour Farming	C	C	A	A	A	B	A	B	A	B	B	?
Contour Stripcropping	C	C	A	A	A	B	A	B	A	B	B	C
Filter Strip	C	C	B	B	B	C	B	C	B	B	B	?
Field Border	C	C	B	B	B	C	B	C	B	B	B	C
Cover and Green Manure Crop	C	B	B	B	B	B	B	B	B	C	C	B
Conservation Cropping Sequence	B	C	A	B	A	B	A	B	A	C	C	B
Field Windbreaks	C	C	B	B	B	C	B	C	B	C	C	C
Pasture and Hayland Management	C	B	B	B	B	C	B	C	C	B	B	C
Field Stripcropping	C	C	B	B	B	B	B	B	B	C	C	C
Grasses and Legumes in Rotation	C	B	B	B	B	B	B	B	B	C	C	C

Structural Practices												
	?	?	A	B	A	B	A	B	A	B	B	?
Terrace	?	?	A	B	A	B	A	B	A	B	B	?
Water and Sediment Control Basin	C	?	A	C	A	C	A	B	A	B	C	?
Diversion	C	?	B	C	B	C	B	C	B	C	B	C
Grade Stabilization Structure	C	C	B	C	B	C	B	C	C	C	C	C
Grassed Waterway	C	C	B	C	B	C	B	C	B	C	C	C
Streambank and Shoreline Protection	C	A	A	C	A	C	A	C	C	B	C	C
Wetland Development or Restoration	C	B	A	B	A	B	A	B	A	A	B	?

Key

- A Medium to high effectiveness
- B Low to medium effectiveness
- C No control to low effectiveness

? May increase or decrease impact²

¹ Abstracted from USDA Agriculture Information Bulletin No. 598, after Brown et al. (1991). NOTE: Because of the general nature of this chart, there may be situations and sites where practices will not perform as indicated.

² Depends on soil, crop, practice design, and management characteristics.

³ Includes all appropriate structural, vegetative, and management characteristics.

APPENDIX F:

Governing Equations of CE-QUAL-RIV1 Model

(as extracted from USAWES (1995))

PART II: THE GOVERNING EQUATIONS

General Considerations

11. The transport of momentum and water quality constituents during unsteady flows can be marked by sharp gradients in flow, elevation, and water quality concentrations. These gradients can be propagated by the flow wave through regions of highly variable cross sections intermittently joined by major inflow tributaries, with the magnitudes of concentrations often being augmented by both point and nonpoint source contributions.

12. Since the speed of flow waves is often quite high, water quality concentrations can be dominated by advective transport rather than biogeochemical interactions and diffusion. Therefore, the water quality model must be dynamic and have the following minimum attributes. The model must:

- a. Account for time-varying flow, elevation, and water quality constituent changes resulting from highly unsteady flows.
- b. Include the direct explicit interaction of flow and elevation on the constituent distributions.
- c. Be applicable for a river channel of arbitrary cross section and specified bottom slope.
- d. Allow for a number of water quality constituents and the proper mathematical specification of their mathematical interrelationship.
- e. Account for the effects of lateral inputs of water and associated pollutant concentrations.
- f. Allow simulation of multiple hydraulic control structures.

13. The assumptions that the above attributes require for the development of the basic governing transport equations are listed below. For a river that is much longer than wide or deep, the following assumptions apply:

- a. Hydrostatic pressure exists.
- b. Lateral and vertical gradients are small and neglected; thus the equations are cross-sectionally averaged for flow and constituent variables (1-D assumption).
- c. All cross sections and bottom configurations are known.
- d. All lateral point and nonpoint source flows and input concentrations are known.

14. When solved, the hydraulic transport equations permit the calculation of downstream histories of flow and water surface elevation. These equations are well known, and their derivations are quite routine. There are two different approaches to the derivation of flow wave equations. The first

starts with the basic three-dimensional (3-D) equations of continuity and Navier Stokes (Bird, Stewart, and Lightfoot 1964) and by cross-sectional averaging reduces the four equations to a coupled pair of dynamic cross-sectionally averaged equations for longitudinal space and time patterns of flow and elevation. This procedure, however, always results in the necessity of specifying a very ambiguous eddy viscosity to account for the ever-present correlations between fluctuating components resulting from the averaging. Longitudinal eddy viscosities are very small, particularly during elevated flows (Fischer et al. 1979), and are quite frequently used improperly to tune the correct answer into existence rather than to represent actual problem physics. A second approach, which assumes inviscid flow, is the control volume method (Liggett 1973) used to derive the equations herein.

15. The notation and coordinate system are defined as in Figure 1. It is assumed that the coordinate system is placed in the river bottom with the bed slope relative to a gravity-based coordinate system being such that $\tan \theta \approx \theta$, and, therefore, θ is very small. It is further assumed that x is directed positive downstream and that because the bed slope is very small, the water elevation $h(x,t)$, directed parallel to the gravitational direction, is perpendicular to x . $A(x,t)$ is the cross-sectional area of flow, and $B(x,t)$ is the top width of flow. If the relationship among area of

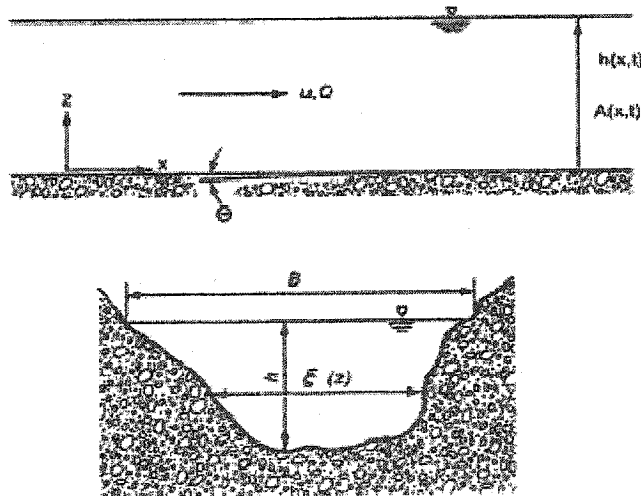


Figure 1. Coordinate system and notation

flow, top width, and flow depth is represented by the shape factor $\xi(z)$, A and B can be related to $h(x,t)$.

16. Assume as in Figure 2 that a discrete length Δx of river channel is isolated. If the flow is from left to right, then unit normals n_x and n_y are defined as being positive away from each face through which flow is entering and exiting. Total mass, momentum, and species mass will be conserved within this control volume. Streeter and Wylie (1979) present the general form of the control volume conservation law in a continuum with mass concentration b as

$$\frac{dB}{dt} = \iiint_{CV} \frac{\partial b}{\partial t} dV + \iint_{CS} b(\vec{v} \cdot \vec{n}) dA \quad (1)$$

Equation 1 states that the total time rate of change of mass in the control volume, B , ($\dot{B} = b\dot{V}$) equals the time rate of accumulation of b within the control volume (cv) plus the net rate at which b is being carried into the control volume through the control surface (cs). The cv conservations of water mass, momentum, and species mass are, respectively, written for an arbitrary cv in a 3-D flow field \vec{v} as

$$\text{Mass: } \iiint_{CV} \frac{\partial \rho}{\partial t} dV + \iint_{CS} (\rho \vec{v} \cdot \vec{n}) dA = 0 \quad (2)$$

$$\text{Momentum: } \iiint_{CV} \frac{\partial \vec{v} \rho}{\partial t} dV + \iint_{CS} \vec{v}(\rho \vec{v} \cdot \vec{n}) dA = \vec{F} \quad (3)$$

$$\begin{array}{l} \text{Mass} \\ \text{species:} \end{array} \iiint_{CV} \frac{\partial \alpha}{\partial t} dV + \iint_{CS} \alpha(\vec{v} \cdot \vec{n}) dA = S_s \quad (4)$$

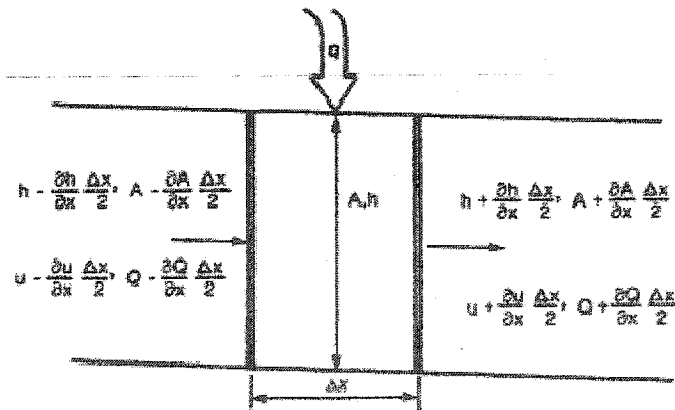
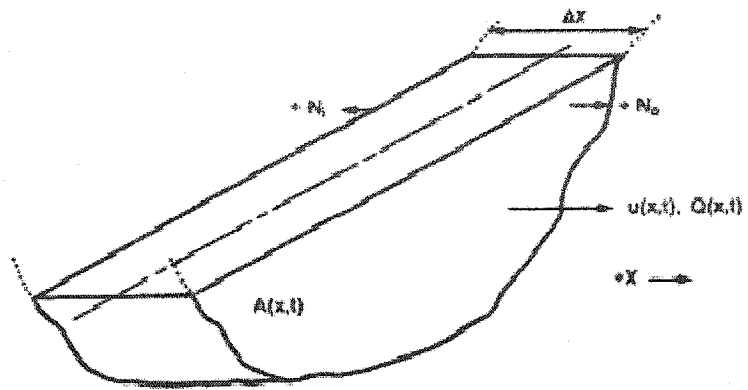


Figure 2. Control volume definitions

where

ρ = fluid density, M/L^3

t = time

dV = differential volume, L^3

\vec{v} = velocity vector ($u\vec{i} + v\vec{j} + w\vec{k}$), L/t

dA = differential area, L^2

\vec{F} = vector sum of the real applied external forces on the cv, ML/t^2

α = species mass concentration, M/L^3

S^* = net source term for biochemical changes in α , M/t

The variables M , L , and t are general units of mass, length, and time, respectively.

Derivation of Equations

17. As in Liggert (1975), a much simpler derivation is obtained for the river problem by assuming that the average velocity U (or average species concentration α) is known at a cross section. A Taylor series expansion across inlet and outlet permits much simpler expressions to be identified.

Conservation of Mass

18. The conservation of water mass equation shows that the time rate of change of storage equals net mass afflux through the cv surface. By a Taylor series expansion, therefore

$$\frac{\partial(\rho A \Delta x)}{\partial t} = \rho \left[\left(U - \frac{\partial U}{\partial x} \frac{\Delta x}{2} \right) \left(A - \frac{\partial A}{\partial x} \frac{\Delta x}{2} \right) - \left(U + \frac{\partial U}{\partial x} \frac{\Delta x}{2} \right) \left(A + \frac{\partial A}{\partial x} \frac{\Delta x}{2} \right) \right] \quad (5)$$

For an incompressible fluid such as water, ρ = constant; multiplying out and dividing by $\rho \Delta x$ gives for small Δx

$$\frac{\partial A}{\partial t} + \frac{\partial(UA)}{\partial x} = 0 \text{ or } \frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0 \quad (6)$$

where Q is the volumetric flow rate.

Momentum conservation

19. The momentum equation is a bit more difficult. It states that the net force acting on the cv equals the time rate of change of momentum in the cv plus the net rate of efflux of momentum through the cv. Therefore

$$\frac{\partial(QAx)}{\partial t} + \rho \left\{ [U(UA)] + \frac{\partial}{\partial x} \left[U(UA) \frac{\Delta x}{2} \right] \right\} \\ = \rho \left\{ [U(UA)] - \frac{\partial}{\partial x} \left[U(UA) \frac{\Delta x}{2} \right] \right\} = \bar{F} \quad (7)$$

The force vector \bar{F} requires further expansion into three subcategories: gravity, shear, and pressure forces.

20. Gravity force f_g . The total gravity force is nothing more than the component of the weight of water in the cv ($\rho g A \Delta x$) directed in the x-direction or $\rho g A \Delta x \sin \theta$. Therefore

$$f_g = \rho g A \Delta x S_g \quad (8)$$

where $S_g = \sin \theta = \theta$ is the slope.

21. Shear force f_s . The channel sides and bottoms deplete momentum by the action of bottom friction or shear. This depletion is made mathematically analogous to the gravity slope term by setting

$$f_s = \rho g A \Delta x S_f \quad (9)$$

where S_f is the friction slope. Several forms for the friction slope exist, but either Chezy or Manning forms predominate, i.e.

$$S_f = \frac{V^2 n^2}{(1.486 R^{2/3})^2} \quad (10)$$

where

n = Manning's friction factor

R = hydraulic radius which is approximately equal to A/B , where B is the top width

Therefore,

$$f_s = \rho g A \Delta x \frac{U^2 n^2}{(1.486 R^{2/3})^2}$$

or

$$f_s = \rho g A \Delta x \frac{n^2 |Q| Q}{2.2 A^2 R^{4/3}} \quad (11)$$

where the absolute value has been retained to ensure that no matter which way the wave propagates, shear always dissipates momentum.

22. Pressure force f_p . The total pressure force on the face of the cv is the integral of the irregular trace of the cv, i.e.

$$f_p = \int_0^h \rho g (h - z) \xi(z) dz \quad (12)$$

where $\xi(z)$ is the channel width at height z above the bottom. A Taylor series expansion gives the net pressure in the downstream direction

$$\begin{aligned} f_p &= - \frac{\partial}{\partial x} \int_0^h \rho g (h - z) \xi(z) dz \Delta x \\ &= - \rho g \int_0^h \frac{\partial}{\partial x} [(h - z) \xi(z)] dz \Delta x \end{aligned} \quad (13)$$

and by chain rule differentiation

$$F_p = - \rho g \left[\frac{\partial h}{\partial x} \int_0^h \tau(z) dz + \int_0^h (h-z) \frac{\partial \tau(z)}{\partial x} dz \right] \Delta x \quad (14)$$

The first term represents the pressure force at that particular cross section. The second term represents the net pressure force caused by rapid area changes over the length Δx . If the channels are considered prismatic and regular, then the last term has little significance. Therefore

$$F_p = - \rho g A \frac{\partial h}{\partial x} \Delta x \quad (15)$$

The final equation for momentum is then

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x} (QU) + gA \frac{\partial h}{\partial x} = gA(S_0 - S_f) \quad (16)$$

Modifications to momentum and continuity

23. Lateral and tributary inflow. Runoff from lands adjacent to the channel or tributary inflow can cause increased levels of total mass and momentum in the river. If q is the flow per unit channel length entering the river with velocity U_q , then Equations 6 and 16 become, respectively,

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \quad (17)$$

and

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x} (QU) + gA \frac{\partial h}{\partial x} = gA(S_0 - S_f) + qU_q \quad (18)$$

However, the model code does not include the last term in Equation 18 because it is relatively insignificant compared with other terms of the momentum equation.

24. Floodplain storage. As sometimes occurs, excess quantities of non-moving water are often stored in the floodplain. Since the water is not moving, the momentum equation remains unaffected by this feature. The continuity equation must, however, account for the excess mass. If, as in Figure 3, A_c is defined as the cross-sectional area of the floodplain waters, then Equation 17 becomes

$$\frac{\partial(A + A_c)}{\partial x} + \frac{\partial Q}{\partial x} = q \quad (19)$$

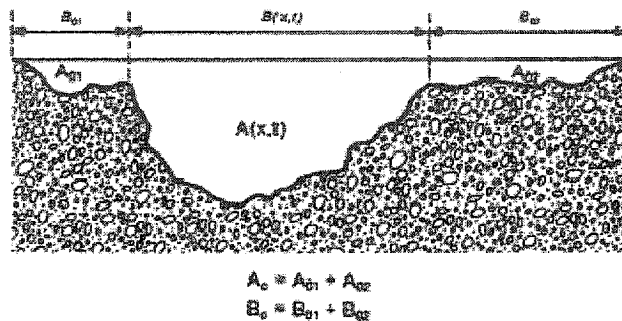


Figure 3. Floodplain geometry and notation

However, the effect of floodplain storage is not presently included in the code.

25. Channel constrictions. Often very intense channel constrictions, due to bridges for example, occur over channel lengths that are far too small to economically resolve in the model. The subgrid scale effect of such constrictions is a momentum loss and backwater effect. This effect is accounted for in the right side of the momentum equation by subtracting the force term, $\rho g h_f$ where h_f is a head loss and K_f is a coefficient to be selected and optimized.

$$h_c = \frac{K_c}{2g} \left(\frac{Q}{A} \right)^2 \quad (20)$$

The default value is zero for no constriction loss. A value for K_c as high as 0.5 may be appropriate for an abrupt constriction.

26. Momentum correction factor. When the velocity across the channel is substantially nonuniform through the model reach, it may be necessary to use a momentum correction factor β in the momentum equation. The momentum correction factor β multiplies the second term on the left side of Equation 18; this correction permits the use of the average velocity, U , in the solution whereas the velocity distribution at each cross section may be quite different from U . For example, for laminar flow in a straight round tube, β is 4/3. It equals 1.0 for uniform flow and cannot be less than 1.0. For RIV1H, a constant value is used throughout the modeled reach. The default value of 1.0 is recommended for rivers and streams.

27. Tributary networks. The momentum and continuity equations above must be applied to each and every tributary entering the main stem. At each junction, the water surfaces in each branch must be equal.

Mass species equation

28. Again, by using the Taylor series approach, the advection and diffusion of a biogeochemically reactive substance of concentration c is

$$\frac{\partial(cA)}{\partial t} + \frac{\partial(Qc)}{\partial x} = \frac{\partial}{\partial x} \left(DA \frac{\partial c}{\partial x} \right) + \gamma q + S^* \quad (21)$$

where

D = turbulent dispersion coefficient

γ = concentration of species type c entering the tributary from lateral flow q

S^* = source/sink term in units of (M/Lt)

Equation 21 must be written for every transported species.

Initial and Boundary ConditionsInitial conditions

29. For continuity, the only initial conditions to be specified at time $t = t_0$ for all the nodes i for $i = 1$ to N are

$$A(t = t_0, x) = A_i(x) \quad (22)$$

or since there is a direct correspondence between A and h , it is permissible to use

$$h(t = t_0, x) = h_i(x) \quad (23)$$

Either Equation 22 or 23 must be used, but not both.

30. For the momentum equation either

$$Q(t = t_0, x) = Q_i(x) \quad (24)$$

or

$$U(t = t_0, x) = U_i(x) \quad (25)$$

is permissible.

31. For the species transport equation, the following is used:

$$c(t = t_0, x) = c_i(x) \quad (26)$$

Boundary conditions for continuity and momentum

32. For the upstream boundary at $x = 0$ and the downstream boundary at $x = L$, the following sets of boundary conditions may be used for the combined set of continuity and momentum equations. Please note that two first-order

equations require only a total of two boundary conditions. Therefore, only one set may be used for each simulation.

$$h(t, x = 0) = h_u(t) \text{ and } h(t, x = L) = h_d(t) \quad (27)$$

$$Q(t, x = 0) = Q_u(t) \text{ and } Q(t, x = L) = Q_d(t) \quad (28)$$

$$h(t, x = 0) = h_u(t) \text{ and } Q(t, x = L) = Q_d(t) \quad (29)$$

$$Q(t, x = 0) = Q_u(t) \text{ and } h(t, x = L) = h_d(t) \quad (30)$$

$$h(t, x = 0) = h_u(t) \text{ and } f_1(Q, h) = f_{1d}(t) \quad (31)$$

$$Q(t, x = 0) = Q_u(t) \text{ and } f_2(Q, h) = f_{2d}(t) \quad (32)$$

where f_1 and f_2 are rating curves relating h and Q for the downstream boundary conditions. It is permissible to properly substitute A and U for Q in these expressions.

33. It should be noted that the upstream boundary condition for a tributary can be selected by specifying either the elevation or the flow. At the downstream tributary boundary, i.e. the confluence with the main stem, only the elevation is allowed as a "boundary" condition to ensure that continuity is preserved at the junction.

Boundary conditions
for species transport

34. The boundary conditions for species transport are

$$\begin{aligned} a(t, x = 0) &= a_u(t) \\ a(t, x = L) &= a_d(t) \end{aligned} \quad (33)$$

However, the condition $a_d(t)$ is presently not specified as input data for riverine simulations. This must be included as input if the model is modified for inflow at the downstream end, such as occurs with estuarine boundary conditions.

Equation Summary

35. The following equations govern the unsteady, 1-D (longitudinal) hydrodynamics and transport:

Continuity

$$\frac{\partial(A + A_s)}{\partial t} + \frac{\partial Q}{\partial x} = q \quad (34)$$

Momentum

$$\frac{\partial Q}{\partial t} + \frac{\partial(UQ)}{\partial x} + gA \frac{\partial h}{\partial x} = gA \left(S_o - S_f - \frac{h_s}{\Delta x} \right) + qU_q \quad (35)$$

Equations 34 and 35 are commonly referred to as the St. Venant equations.

Constituent transport

$$\frac{\partial(\alpha A)}{\partial t} + \frac{\partial(Q\alpha)}{\partial x} = \frac{\partial}{\partial x} \left(DA \frac{\partial \alpha}{\partial x} \right) + \gamma q + S_s \quad (36)$$

Equation 36 is often referred to as the "advection-dispersion equation with source/sink terms." The initial conditions are Equations 22 (or 23), 24 (or 25), and 26 for the continuity, momentum, and mass species equations, respectively. Boundary conditions are one set selected from Equations 27 through 32 for the momentum and continuity equation and Equation 33 for the mass species equation.