Development of a User-Friendly Stormwater Pollution Model

Prediction of Nitrate, Phosphate, and TSS Pollutant Loading using ArcGIS 9

Brandon Luzar ‘05
Swarthmore College – Department of Engineering
Engineering 90 – Prof. Arthur E. McGarity

Abstract

The goal of this project is to develop and test a user-friendly, GIS based stormwater nonpoint pollution model. The model will be written in Visual Basic using the function building capabilities of ArcGIS 9. This model will calculate monthly loading of Total Suspended Solids, nitrate, and phosphate pollutants and will be intended for use in the public domain after completion. Work will be fulfilled at Swarthmore College in the Environmental Engineering and GIS Laboratories with the supervision and funding of research by Prof. Arthur E. McGarity and his ongoing stormwater pollution research project.

Introduction

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The Swarthmore College Environmental Engineering Program, under the guidance of Prof. Arthur E. McGarity, has been involved with nonpoint stormwater pollution research for the past decade. Currently, the program is working on a multiphase stormwater pollution prediction and BMP (Best Management Practice) allocation model. This program will use GIS (Geographic Information Systems) software to predict and model both stormwater pollutant loading and possible corrective solutions to problems caused by pollutants. I will be working on the portion of the model that predicts nitrate, phosphate, and TSS (Total Suspended Solids) pollutant loadings using GIS software and data. The program will be made for the public domain and to be as user-friendly as allowable.

Technical Discussion

The phosphate ion is one pollutant found in nonpoint stormwater runoff. Soaps, fertilizers, and organic wastes (fallen leaves, grass clippings, animal waste, suspended soil particles, etc.) are all major sources of the phosphate ion in stormwater runoff and can lead to eutrophication in bodies of water.

Eutrophication is the presence of excess nutrients in a waterway such that the over-stimulation of organic matter (algal growth) can be considered a hazard to the aquatic ecosystem. More specifically, phosphate pollution leads to the depletion of dissolved oxygen concentrations, decreased light transmittance, the killing of aquatic and marine life, and the aesthetic degradation of affected waterways.

Another common pollutant found in nonpoint stormwater runoff is the nitrate ion. Primarily, nitrate found in runoff is a product of agricultural fertilizers. As is the case with the phosphate ion, excess nitrate leads to eutrophication in waterways but various human health risks, blue baby syndrome and non-Hodgkins lymphoma, connected with excess nitrate in drinking water are growing concerns as well.

A third pollutant resulting from nonpoint stormwater pollution is Total Suspended Solids. Stormwater runoff picks up TSS from agricultural land and stream banks in situations of abnormally high runoff and stream flows. This pollutant is visibly apparent in stormwater because it greatly decreases the depth of light transmittance on the water surface. TSS adversely affects the geomorphology of the environment by redistributing soil particles from stream banks and agricultural areas to fluvial sediment deposits and, thus, altering the habitats of downstream aquatic life and stream side vegetation. Lastly, various heavy metals and pathogenic compounds are present in TSS and can infiltrate drinking water and recreational sites causing health risks to humans and other animals.

GIS software allows a user to integrate the information storage and alteration capabilities of databases with the visual and practical aspects of maps. Over the past two decades, public research projects and developments in GIS Software have expanded the capabilities of geographic modeling and, more specifically, nonpoint stormwater pollution modeling. Models have been created using the data storage and function building capabilities ArcGIS software to calculate

pollutant loading based on verified scientific methods and regionally assigned parameters. Most of this software and data can be easily accessed in the public domain, but a recent, up to date GIS based model is not readily available.

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After development, the model will be tested against field verified, nonpoint stormwater pollution loadings. Data for these loadings will be gathered, processed, and analyzed around Swarthmore College and Springfield Township in Pennsylvania. The Swarthmore College Environmental Laboratory is equipped with a certified chemical analysis facility, multiple ISCO autosamplers, portable and non-portable rain gauges, and a portable sonar flow meter that will be used over the course of this project to allow for accurate measurements of pollutant concentrations during storm events.

ESRI recently released their latest version of GIS software, ArcView 9, in 2004. The new software has increased function building and script writing capabilities along with increase overall user-friendliness. This software provides a strong groundwork for building the most user-friendly and up to date GIS based stormwater pollution model.

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5. Learn ArcGIS 9	4	8	3	24
6. Learn VisualBasic Language	4	8	3	24
7. Gather Needed Information Layers and Select Parameters	3,5,6	8	2	32
8. Create Program	7	9	6	56
9. Obtain Field Data	1	10	14	8
10. Test Model Using Available, Lab Verified Data	9	11,12,13	3	21
11. Written Report	10	--	2	10
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	13	2, 3, 4, 9	3, 1.5, 1, 0-4	5.5-9.5	30.5-38.5
	20	3	0-4	0-4	31-39
	27	3	0-4	0-4	31-39
January	3	3	0-4	0-4	31-39
	10	5, 6, 9	6-10, 6-10, 0-4	12-24	43-59
	17	5, 6, 9	6-10, 6-10, 0-4	12-24	55-79
	24	5, 6, 9	6-10, 6-10, 0-4	12-24	71-79
	31	7, 9	12-18, 0-4	12-22	83-97
February	7	7, 9	12-18, 0-4	12-22	111-119
	14	8, 9	8-10, 0-4	8-14	119-129
	21	8, 9	8-10, 0-4	8-14	127-139
	28	8, 9	8-10, 0-4	8-14	135-149
March	7	8, 9	8-10, 0-4	8-14	143-159
	14	8, 9	8-10, 0-4	8-14	151-169
	21	8, 9	8-10, 0-4	8-14	175
	28	10	5-10	5-10	180-185
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Figure 2 – CPM Network Diagram

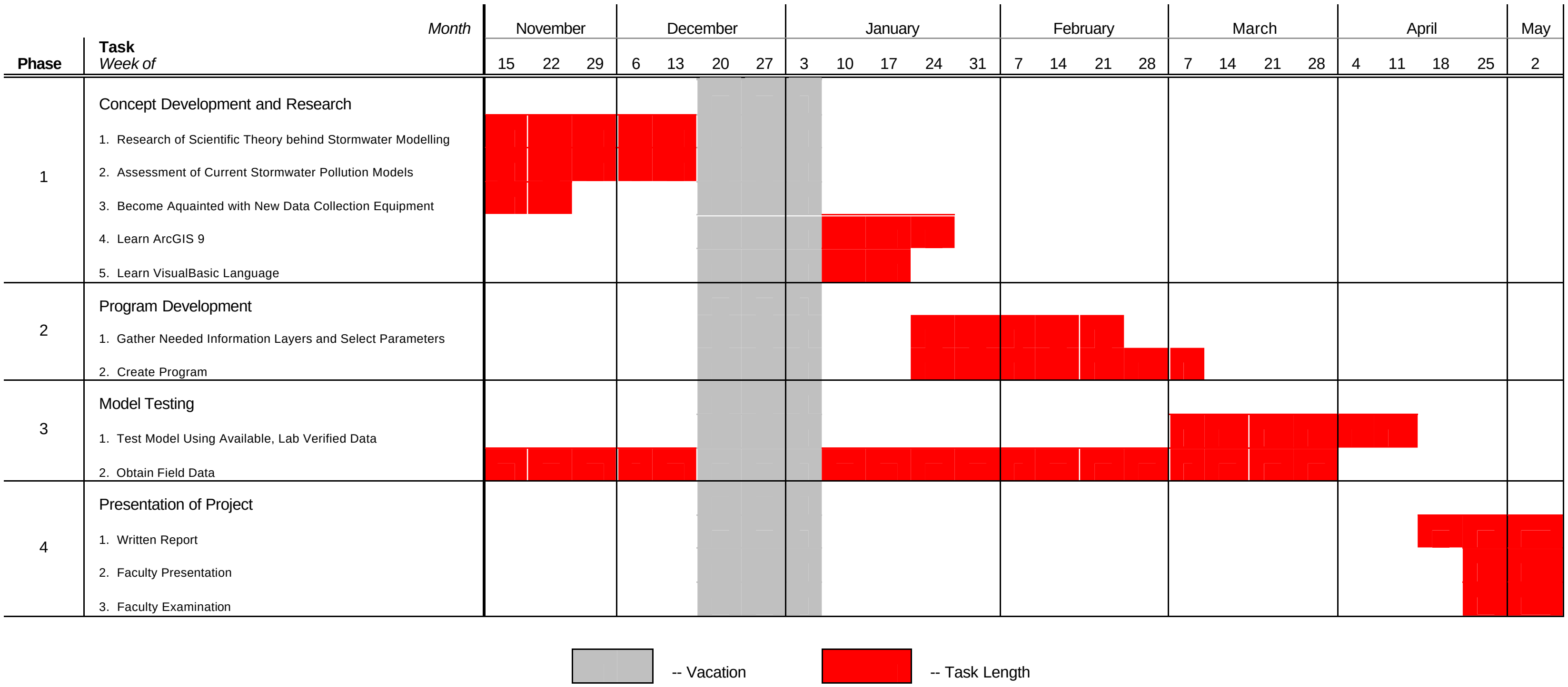

Figure 3 – Gantt Chart of Tasks

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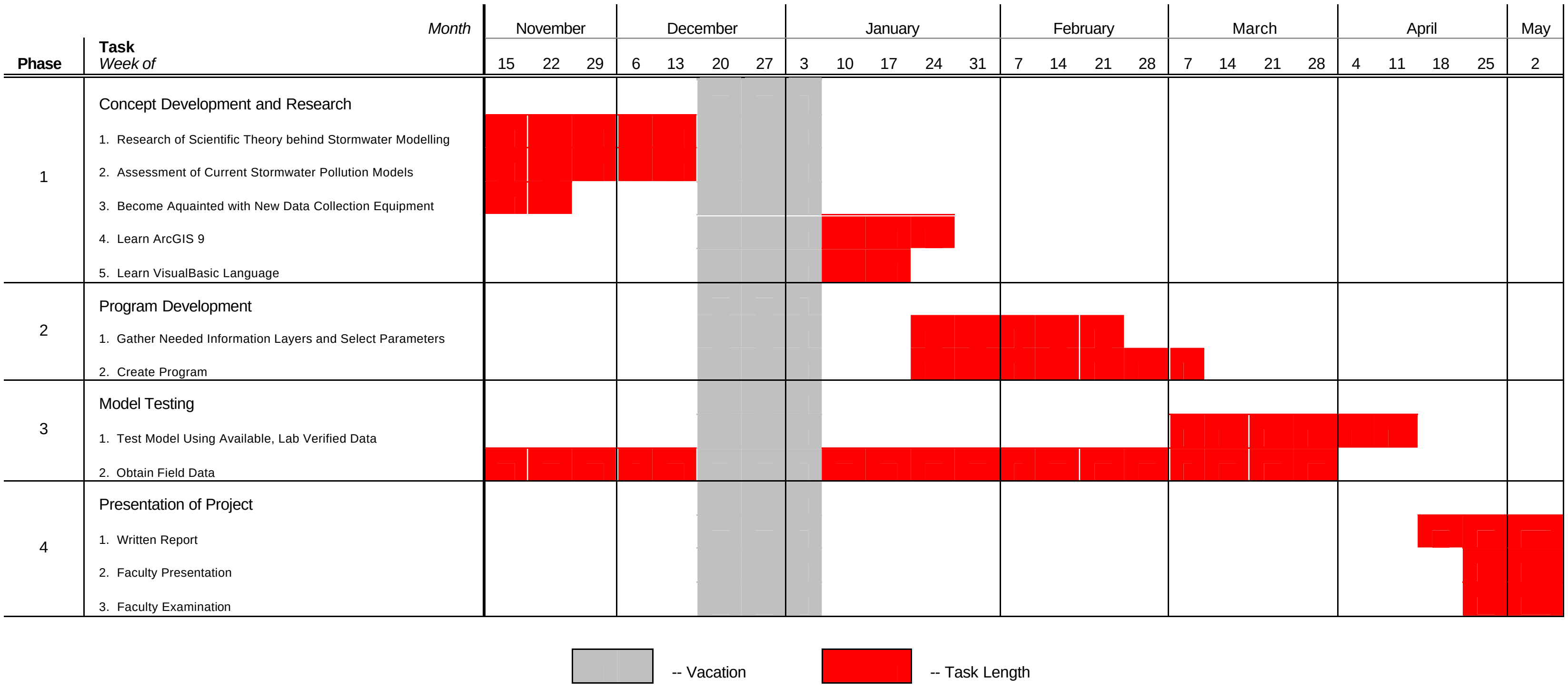

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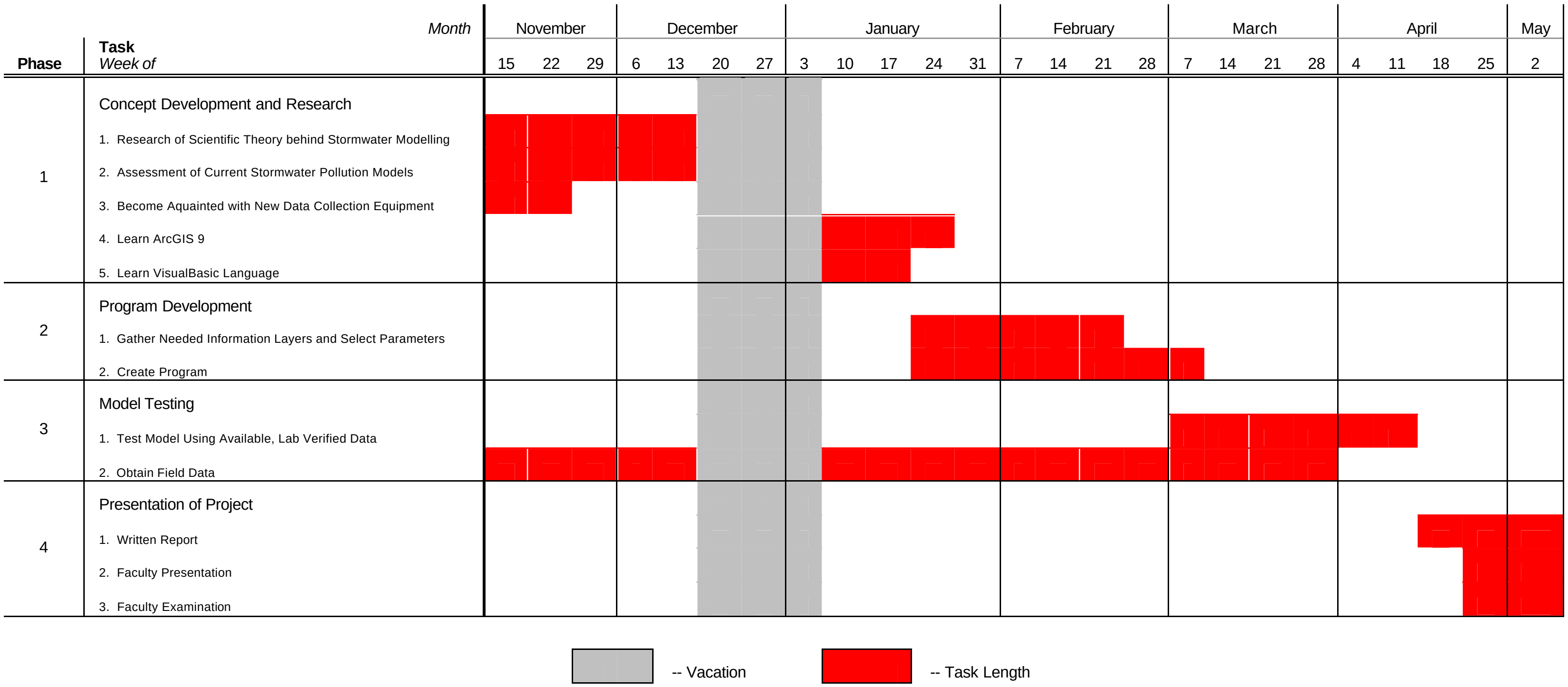

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Swarthmore College – Department of Engineering
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Abstract

The goal of this project is to develop and test a user-friendly, GIS based stormwater nonpoint pollution model. The model will be written in Visual Basic using the function building capabilities of ArcGIS 9. This model will calculate monthly loading of Total Suspended Solids, nitrate, and phosphate pollutants and will be intended for use in the public domain after completion. Work will be fulfilled at Swarthmore College in the Environmental Engineering and GIS Laboratories with the supervision and funding of research by Prof. Arthur E. McGarity and his ongoing stormwater pollution research project.

Introduction

The human race is a continuously growing species that has inhabited every corner of the Earth. To support the basic needs of its constituents society has changed the Earth's surface in many ways; including the construction of cities, roads, power lines and the destruction of forests, wetlands, and other natural ecosystems. As a result of a general increase of impervious surface area and decrease of natural water processing systems, nonpoint pollution from stormwater runoff now threatens the well being and beauty of the Earth and its inhabitants. Nonpoint stormwater pollution has been a growing concern among the environmentally active community over the past half-century, starting with the Clean Water Act of 1972 and the subsequent creation of the Environmental Protection Agency. Since then federal money has been allocated to help regulate nonpoint stormwater pollution and increase research of the problem.

The Swarthmore College Environmental Engineering Program, under the guidance of Prof. Arthur E. McGarity, has been involved with nonpoint stormwater pollution research for the past decade. Currently, the program is working on a multiphase stormwater pollution prediction and BMP (Best Management Practice) allocation model. This program will use GIS (Geographic Information Systems) software to predict and model both stormwater pollutant loading and possible corrective solutions to problems caused by pollutants. I will be working on the portion of the model that predicts nitrate, phosphate, and TSS (Total Suspended Solids) pollutant loadings using GIS software and data. The program will be made for the public domain and to be as user-friendly as allowable.

Technical Discussion

The phosphate ion is one pollutant found in nonpoint stormwater runoff. Soaps, fertilizers, and organic wastes (fallen leaves, grass clippings, animal waste, suspended soil particles, etc.) are all major sources of the phosphate ion in stormwater runoff and can lead to eutrophication in bodies of water.

Eutrophication is the presence of excess nutrients in a waterway such that the over-stimulation of organic matter (algal growth) can be considered a hazard to the aquatic ecosystem. More specifically, phosphate pollution leads to the depletion of dissolved oxygen concentrations, decreased light transmittance, the killing of aquatic and marine life, and the aesthetic degradation of affected waterways.

Another common pollutant found in nonpoint stormwater runoff is the nitrate ion. Primarily, nitrate found in runoff is a product of agricultural fertilizers. As is the case with the phosphate ion, excess nitrate leads to eutrophication in waterways but various human health risks, blue baby syndrome and non-Hodgkins lymphoma, connected with excess nitrate in drinking water are growing concerns as well.

A third pollutant resulting from nonpoint stormwater pollution is Total Suspended Solids. Stormwater runoff picks up TSS from agricultural land and stream banks in situations of abnormally high runoff and stream flows. This pollutant is visibly apparent in stormwater because it greatly decreases the depth of light transmittance on the water surface. TSS adversely affects the geomorphology of the environment by redistributing soil particles from stream banks and agricultural areas to fluvial sediment deposits and, thus, altering the habitats of downstream aquatic life and stream side vegetation. Lastly, various heavy metals and pathogenic compounds are present in TSS and can infiltrate drinking water and recreational sites causing health risks to humans and other animals.

GIS software allows a user to integrate the information storage and alteration capabilities of databases with the visual and practical aspects of maps. Over the past two decades, public research projects and developments in GIS Software have expanded the capabilities of geographic modeling and, more specifically, nonpoint stormwater pollution modeling. Models have been created using the data storage and function building capabilities ArcGIS software to calculate

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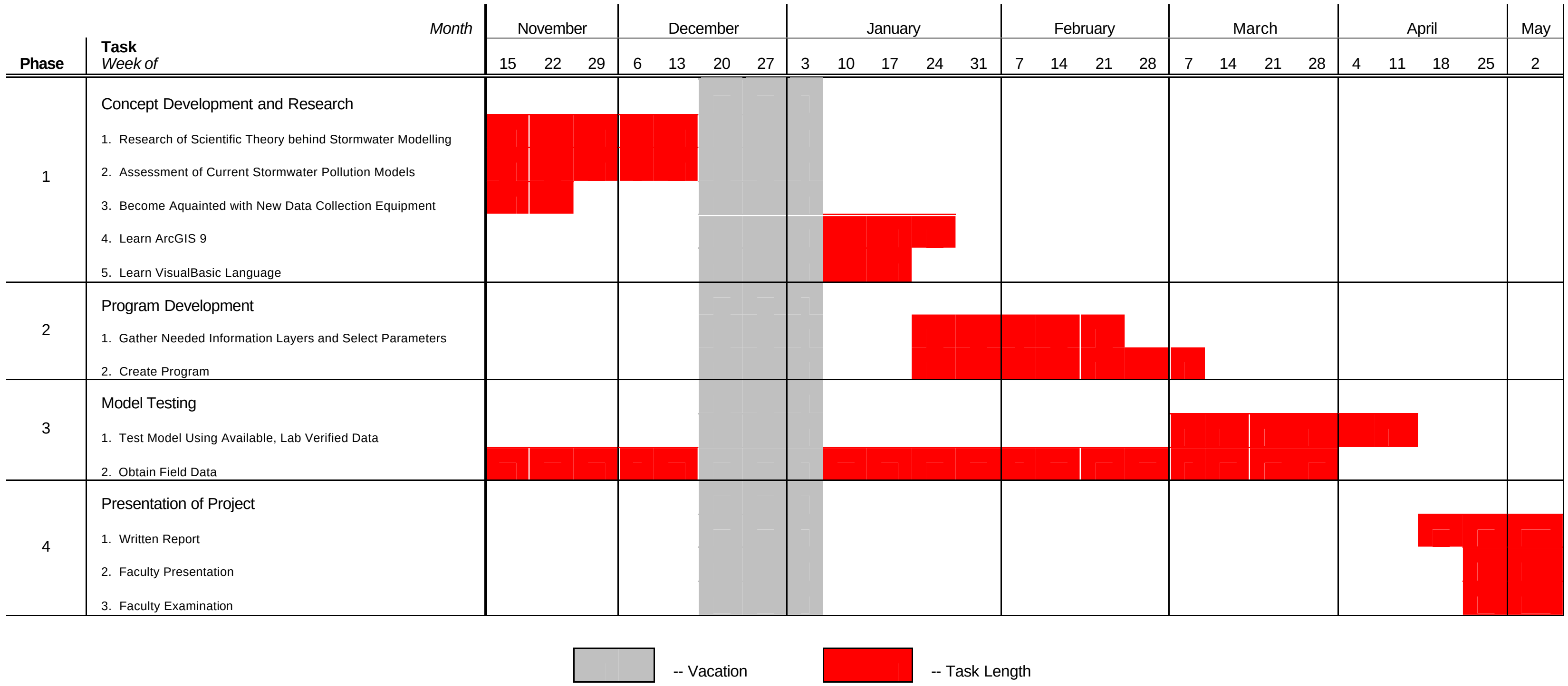

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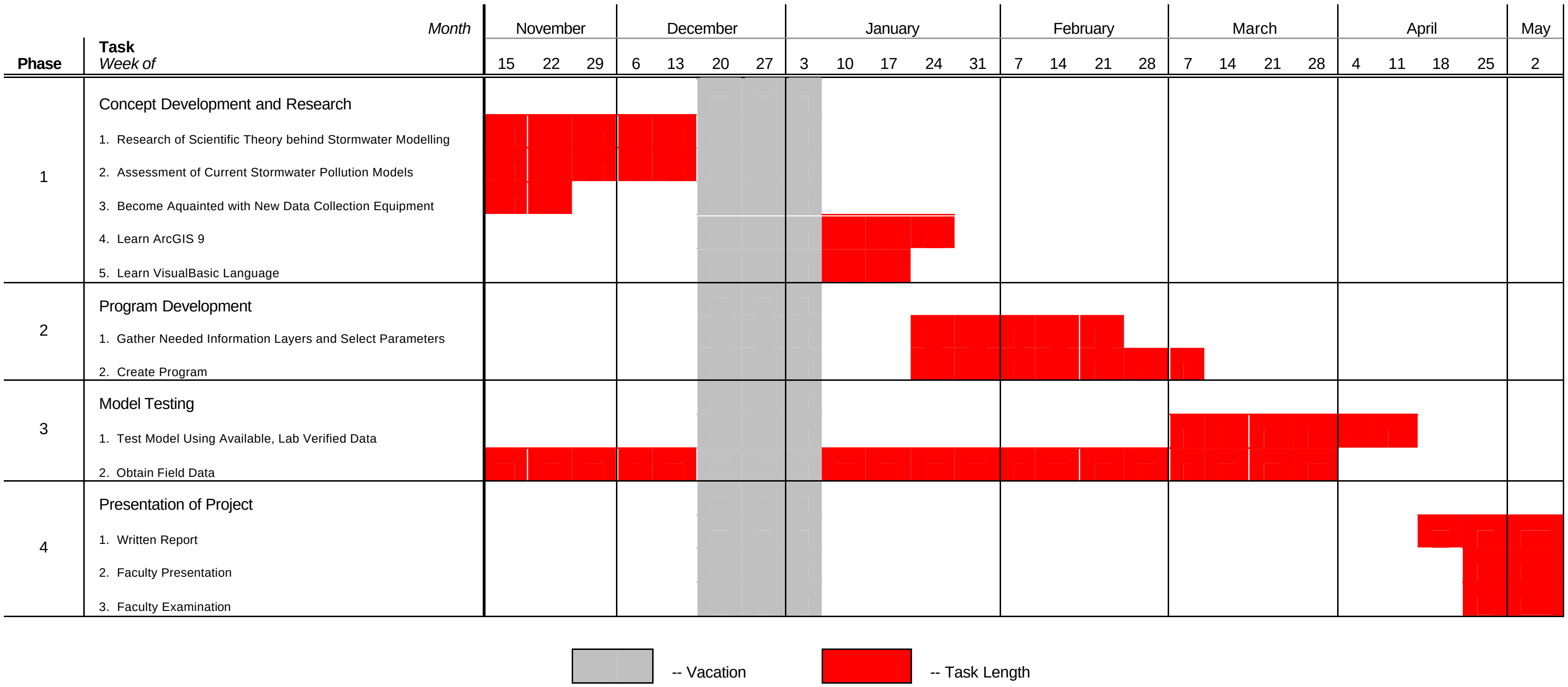

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Introduction

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The Swarthmore College Environmental Engineering Program, under the guidance of Prof. Arthur E. McGarity, has been involved with nonpoint stormwater pollution research for the past decade. Currently, the program is working on a multiphase stormwater pollution prediction and BMP (Best Management Practice) allocation model. This program will use GIS (Geographic Information Systems) software to predict and model both stormwater pollutant loading and possible corrective solutions to problems caused by pollutants. I will be working on the portion of the model that predicts nitrate, phosphate, and TSS (Total Suspended Solids) pollutant loadings using GIS software and data. The program will be made for the public domain and to be as user-friendly as allowable.

Technical Discussion

The phosphate ion is one pollutant found in nonpoint stormwater runoff. Soaps, fertilizers, and organic wastes (fallen leaves, grass clippings, animal waste, suspended soil particles, etc.) are all major sources of the phosphate ion in stormwater runoff and can lead to eutrophication in bodies of water.

Eutrophication is the presence of excess nutrients in a waterway such that the over-stimulation of organic matter (algal growth) can be considered a hazard to the aquatic ecosystem. More specifically, phosphate pollution leads to the depletion of dissolved oxygen concentrations, decreased light transmittance, the killing of aquatic and marine life, and the aesthetic degradation of affected waterways.

Another common pollutant found in nonpoint stormwater runoff is the nitrate ion. Primarily, nitrate found in runoff is a product of agricultural fertilizers. As is the case with the phosphate ion, excess nitrate leads to eutrophication in waterways but various human health risks, blue baby syndrome and non-Hodgkins lymphoma, connected with excess nitrate in drinking water are growing concerns as well.

A third pollutant resulting from nonpoint stormwater pollution is Total Suspended Solids. Stormwater runoff picks up TSS from agricultural land and stream banks in situations of abnormally high runoff and stream flows. This pollutant is visibly apparent in stormwater because it greatly decreases the depth of light transmittance on the water surface. TSS adversely affects the geomorphology of the environment by redistributing soil particles from stream banks and agricultural areas to fluvial sediment deposits and, thus, altering the habitats of downstream aquatic life and stream side vegetation. Lastly, various heavy metals and pathogenic compounds are present in TSS and can infiltrate drinking water and recreational sites causing health risks to humans and other animals.

GIS software allows a user to integrate the information storage and alteration capabilities of databases with the visual and practical aspects of maps. Over the past two decades, public research projects and developments in GIS Software have expanded the capabilities of geographic modeling and, more specifically, nonpoint stormwater pollution modeling. Models have been created using the data storage and function building capabilities ArcGIS software to calculate

pollutant loading based on verified scientific methods and regionally assigned parameters. Most of this software and data can be easily accessed in the public domain, but a recent, up to date GIS based model is not readily available.

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In the "Assessment of Current Stormwater Pollution Models" stage of this project, current nonpoint stormwater pollution models will be researched to gain a better understanding of the optimal complexity required for a user-friendly GIS model. GWLF is one of many stormwater pollution models currently available which uses moderately complex scientific theory. Simpler models, such as the PLOAD model created by the EPA, utilize flow average concentrations or export coefficients to calculate pollutant concentration in streams and stormwater runoff. These models are theoretically less complex than a GWLF, which uses a combination of a mass balances, the universal soil loss equation, and buildup coefficients to calculate pollutant loadings. Conversely, HSPF (also developed by the EPA) and other more complicated models than GWLF are available in the public domain. Currently, the optimal level of theoretical complexity for a user-friendly nonpoint stormwater pollution model is unresolved. Therefore, research

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After development, the model will be tested against field verified, nonpoint stormwater pollution loadings. Data for these loadings will be gathered, processed, and analyzed around Swarthmore College and Springfield Township in Pennsylvania. The Swarthmore College Environmental Laboratory is equipped with a certified chemical analysis facility, multiple ISCO autosamplers, portable and non-portable rain gauges, and a portable sonar flow meter that will be used over the course of this project to allow for accurate measurements of pollutant concentrations during storm events.

ESRI recently released their latest version of GIS software, ArcView 9, in 2004. The new software has increased function building and script writing capabilities along with increase overall user-friendliness. This software provides a strong groundwork for building the most user-friendly and up to date GIS based stormwater pollution model.

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The inherent goals of this project are to help improve the environment through a nonpoint stormwater pollution model. This model will allow professionals to predict pollutant loadings in smaller watersheds and identify possible locations of excessive pollution. During the development of this model, some environmental hazards will be encountered. The process of storm water sampling applies environmental stresses on the environment due to human presence and sampling waste. When collecting samples, human presence causes erosion and other adverse affects to native species. Careful sampling procedures will be used to minimize harmful practices during sample collection. Second, laboratory waste from chemical analyses of stormwater samples can harm the environment if it is not disposed of correctly. In particular, the nitrate-nitrogen test used in the Swarthmore College Environmental Engineering Laboratory produces cadmium waste which must be disposed of as a hazardous material. In response, chemical

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3. Research of Scientific Theory behind Stormwater Modeling	--	7	8	12
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6. Learn VisualBasic Language	4	8	3	24
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8. Create Program	7	9	6	56
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	20	3	0-4	0-4	31-39
	27	3	0-4	0-4	31-39
January	3	3	0-4	0-4	31-39
	10	5, 6, 9	6-10, 6-10, 0-4	12-24	43-59
	17	5, 6, 9	6-10, 6-10, 0-4	12-24	55-79
	24	5, 6, 9	6-10, 6-10, 0-4	12-24	71-79
	31	7, 9	12-18, 0-4	12-22	83-97
February	7	7, 9	12-18, 0-4	12-22	111-119
	14	8, 9	8-10, 0-4	8-14	119-129
	21	8, 9	8-10, 0-4	8-14	127-139
	28	8, 9	8-10, 0-4	8-14	135-149
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	14	8, 9	8-10, 0-4	8-14	151-169
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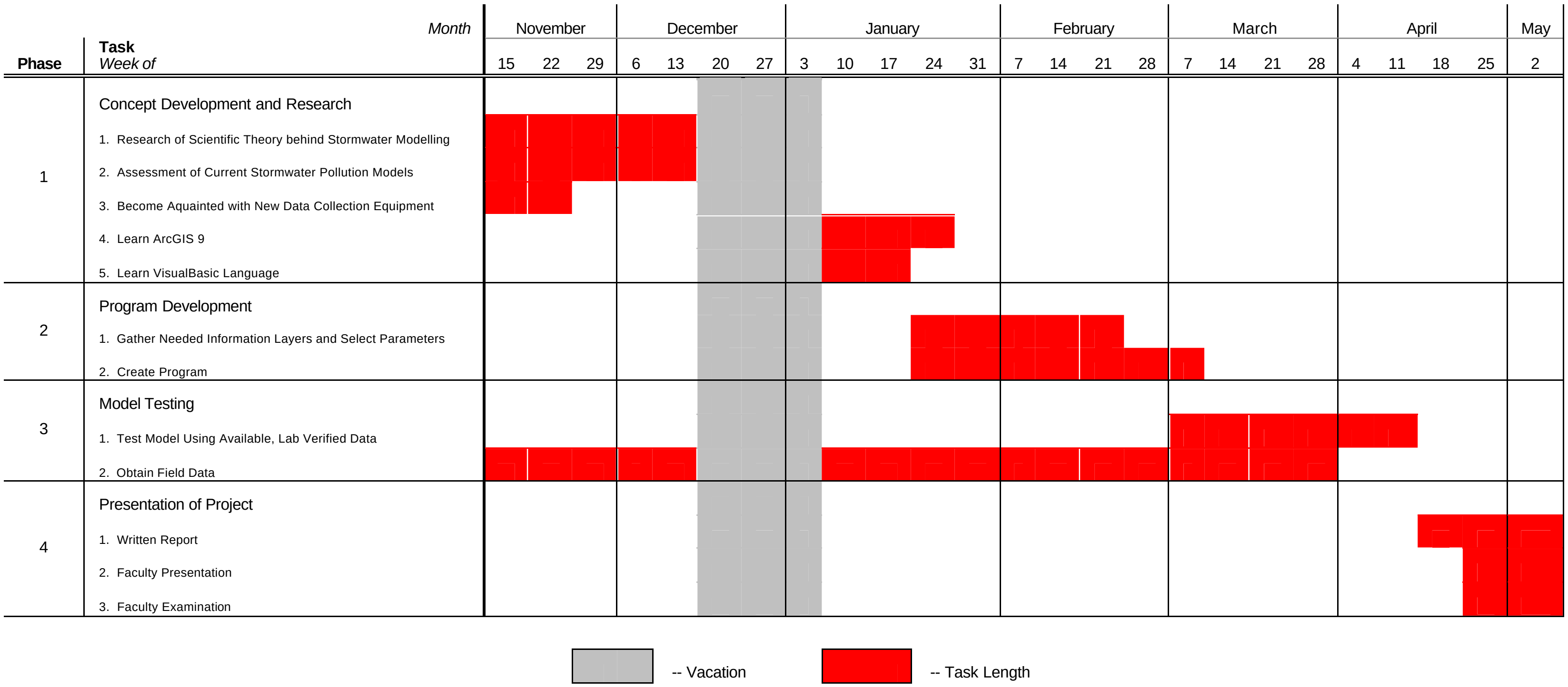

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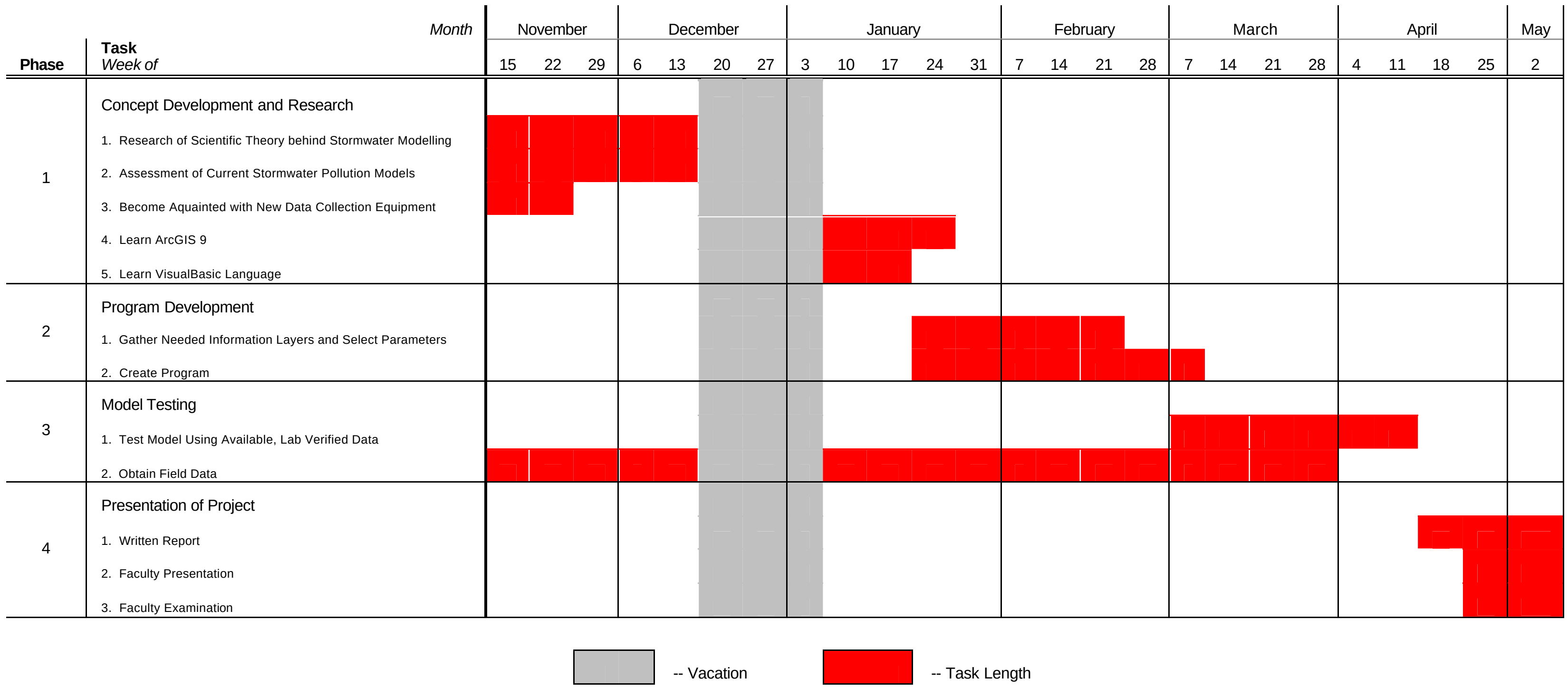

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