2008 Project Abstract
For the Period Ending June 30, 2010

PROJECT TITLE: The Future of Energy and Minnesota's Water Resources
PROJECT MANAGER: Sangwon Suh
AFFILIATION: University of California, Santa Barbara
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CITY/STATE/ZIP: Santa Barbara, CA 93106-5131
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WEBSITE: [If applicable]
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: ML 2008, Chap. 367, Sec. 2, Subd. 4.

APPROPRIATION AMOUNT: $270,000

Overall Project Outcome and Results

Minnesota's water resources are poised to undergo significant changes in the coming decades. For example, with new bioenergy policies aiming to reduce fossil fuel dependency, Minnesota has become one of the top five bioethanol producers in the United States in the past two decades. Bio-energy production, together with increasing population, energy demand, and climate uncertainties present a great challenge for water authorities seeking to sustainable future water supply. There is an urgent need to integrate an analysis of demands on Minnesota's water resources with scenarios of future energy production. This project aimed to envision Minnesota's temporal and spatial water schemes by 2030 in response to population, energy, and climate scenarios, by integrating a system dynamics model with geographic information system (GIS) data. We developed an integrated spatial model that analyzes the future of MN's water budget with particular attention to changes in water demand under different scenarios. Key trends incorporated into the scenarios include (1) biofuel production (considering water needs for irrigation of the biofuel feedstock as well as for processing); (2) changes in the electricity grid mix considering Minnesota's Renewable Energy Standards; (3) demographic changes; and (4) climate change. Scenarios of water demand was combined with GIS mapping and water balance techniques, which can deliver spatially and temporally explicit water budget projections for each scenario.

The results indicate that population growth and increasing demand on electric power generation are two primary factors driving increasing future water demand in Minnesota. Water management should be coupled with urban development and planning to reduce water stress induced by population growth and electric power generation. Late summer and winter are two periods of time in which it is particularly challenging to support human demand of water without the potential of drawing down the water resources. This report produced by this project presents maps and regional monthly water availability graphs for various scenarios tested in this study. These system characteristics shown in the current scenario analysis can play an important part of future water conservation and management planning.

Project Results Use and Dissemination

The study results were presented in more than four national and international conferences hosted in the US and Portugal, in which a poster summarizing the findings of this study won the poster contest in the prestigious Gordon Research Conference in 2010. One paper was published in a high-impact journal, Environmental Science and Technology (ES&T) in 2009; the paper was one of the top-three most-cited and downloaded articles in September, 2009.

Another, follow-up article has been submitted to the same journal and is currently under reviewed. In 2008, a round-table forum was hosted at the University of Minnesota to discus water sustainability modeling and its application. Scholars from state agencies, research institutes, and NGOs attended the forum to brainstorm feasible frameworks for assessing Minnesota's water future under different uncertainties. Detailed information of the presentations in this forum and relevant supporting information can be found at http://www.iel.umn.edu/forum/waterforum.htm PI. Suh is participating in a publication by the United Nations Environmental Programme (UNEP) on biofuel's water implication as an author based on the knowledge and findings gathered from this project. The publication is expected to be released in early 2010.

Trust Fund 2008 Work Program Final Report

Date of Report: 11/28/2010
Date of Next Status Report: Final report
Date of Work program Approval: 6/10/08
Project Completion Date: 6/30/10

I. PROJECT TITLE: The Future of Energy and Minnesota's Water Resources

Project Manager: Dr. Sangwon Suh
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http://www.bren.ucsb.edu/people/Faculty/sangwon_suh.htm

Location: *Santa Barbara, CA*

Total Trust Fund Project Budget:	**Trust Fund Appropriation:**	**$ 270,000**
	Minus Amount Spent:	**$ 270,000**
	Equal Balance:	**$ 0**

Legal Citation: ML 2008, Chap. 367, Sec. 2, Subd. 4.

Appropriation Language: $270,000 is from the trust fund to the Board of Regents of the University of Minnesota to spatially model water demand in Minnesota under differing energy production scenarios and develop a Web-based tool for comparing policy scenarios impacts on water resources in the state.

II. and III. FINAL PROJECT SUMMARY AND RESULTS:

Minnesota's water resources are poised to undergo significant changes in the coming decades. For example, with new bioenergy policies aiming to reduce fossil fuel dependency, Minnesota has become one of the top five bioethanol producers in the United States in the past two decades. Bio-energy production, together with increasing population, energy demand, and climate uncertainties present a great challenge for water authorities seeking to sustainable future water supply. There is an urgent need to integrate an analysis of demands on Minnesota's water resources with scenarios of future energy production. This project aimed to envision Minnesota's temporal and spatial water schemes by 2030 in response to population, energy, and climate scenarios, by integrating a system dynamics model with

geographic information system (GIS) data. We developed an integrated spatial model that analyzes the future of MN's water budget with particular attention to changes in water demand under different scenarios. Key trends incorporated into the scenarios include (1) biofuel production (considering water needs for irrigation of the biofuel feedstock as well as for processing); (2) changes in the electricity grid mix considering Minnesota's Renewable Energy Standards; (3) demographic changes; and (4) climate change. Scenarios of water demand was combined with GIS mapping and water balance techniques, which can deliver spatially and temporally explicit water budget projections for each scenario.

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IV. OUTLINE OF PROJECT RESULTS*:*

Result 1: Current spatial water budget in map form

Description: *We produced GIS map layers of current water demand and water supply in Minnesota. These maps were combined to generate a map of Minnesota's water budget, and to identify potentially water-scarce regions and the supply and withdrawal factors that contribute to this water scarcity.*

Summary Budget Information for Result 1:	**Trust Fund Budget:**	**$ 76,714**
	Amount Spent:	**$ 76,714**
	Balance:	**$ 0**

Deliverable	**Completion Date**	**Budget**	**Status**
1. *Background document summarizing current knowledge on groundwater resources and withdrawals*	*9/30/08*	*$ 12,679*	*complete*
2. *List of key factors regulating water supply And demand*	*1/31/09*	*$ 35,737*	*complete*
3. *GIS layers of current water demand and supply, and map of current state water budget*	*6/30/09*	*$ 28,298*	*complete*

Completion Date: *6/30/09*

Final Report Summary: We grouped individual watersheds into 9 zones based on Minnesota's climate divisions defined by NOAA. On the temporal scale, study results were presented per monthly spans in order to highlight seasonal variations. The results show that water availability is governed mainly by climate in all regions, except for the Mississippi River watershed, where its anthropogenic withdrawals could already be influential enough to alter the local water hydrograph. In general, water availability ranks significantly differently from 84 mm/yr (north-west MN) to 280 mm/yr (north-east MN).

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Result 2: Maps of future state water budgets under different scenarios

Description: *We modeled various scenarios of water demand and water supply under dynamic combinations of ethanol production trends, , demographic growth, and climate change. By overlaying a map of water demand under different scenarios with a map of water supply under these scenarios, we generated a spatial water budget for the state, which can reveal areas of potential water scarcity.*

Summary Budget Information for Result 2:	**Trust Fund Budget:**	**$ 108,891**
	Amount Spent:	**$ 108,891**
	Balance:	**$ 0**

Deliverable	**Completion Date**	**Budget**	**Status**
1. *Description of modeled scenarios and GIS layers for water supply and demand in all scenarios*	*6/30/09*	*$ 59,735*	*complete*
2. *Maps for each scenario depicting future water budget*	*12/31/09*	*$ 49,156*	*complete*

Completion Date: *12/31/09*

Final Report Summary: As a result of climate change, western Minnesota continues to be more arid than the eastern part of the state. However, the amount of water available, which is defined as precipitation minus run-off, is expected to increase more significantly in the west (34%~70%) than in the east (-2%~18%) under climate change effects by year 2030. Population change is expected to increase water withdrawal in almost every category, except for the irrigated water

category that responds primarily to climate change. In general, water withdrawal increases significantly under the extreme scenario (Extreme) as expected, in which population change played the most important role in driving future water withdrawals. Electricity demand could also considerably amplify water withdrawal in the locations where power plants are currently located. The effects caused by increasing ethanol production became marginal as compared with the changes induced by population and power generation increase. Climate change, on the other hand, contributed trivial impacts on water withdrawal compared with the forces of population and energy in the short term. However, water withdrawal would still peak during summer in every region while the relative magnitude of increase in withdrawals compared to water availability would be more significant during the winter. In contrast, available water would increase notably in spring but decrease in summer. Using water stress index (WSI, total water withdrawal/total available water) as an indicator, there were eight watersheds classified as high water stress (WSI>0.2) during 2000 to 2009, which would increase to 12 watersheds under the extreme scenario by 2030. If each driver of change is tested separately, population change and change in electric power grid-mix can elevate state average WSI from 0.14 up to 0.18 and 0.19, respectively. On the other hand, climate can slightly lower WSI down to 0.11. For detailed results, please refer to the Chapter 6 of the final report.

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Result 3: Interpretation and dissemination of research results

Description: *We derived policy implications from the analysis, which can be released in a format useful to planners and local citizens. To disseminate this information around the state, we created an online tool that embeds the modeling results in an interactive website, searchable by future scenario and by location. We also conducted seminars at various locations around the state to inform local citizens and policymakers about the results of our analysis.*

Summary Budget Information for Result 3:	**Trust Fund Budget:**	**$ 84,394**
	Amount Spent:	**$ 84,394**
	Balance:	**$ 0**

Deliverable	**Completion Date**	**Budget**	**Status**
1. *Policy recommendations Informed by research results*	*3/31/10*	*$ 33,538*	*complete*
2. *Seminars and online Information tool*	*6/30/10*	*$ 50,856*	*complete*

Completion Date: *6/30/10*

Final Report Summary: The study results were presented in more than four national and international conferences hosted in the US and Portugal, in which a poster summarizing the findings of this study won the poster contest in the prestigious Gordon Research Conference in 2010. One paper was published in a high-impact journal, Environmental Science and Technology (ES&T) in 2009; the paper was one of the top-three most-cited and downloaded articles in September, 2009. Another, follow-up article has been submitted to the same journal and is currently under reviewed. In 2008, a round-table forum was hosted at the University of Minnesota to discus water sustainability modeling and its application. Scholars from state agencies, research institutes, and NGOs attended the forum to brainstorm feasible frameworks for assessing Minnesota's water future under different uncertainties. Detailed information of the presentations in this forum and relevant supporting information can be found at http://www.iel.umn.edu/forum/waterforum.htm PI. Suh is participating in a publication by the United Nations Environmental Programme (UNEP) on biofuel's water implication as an author based on the knowledge and findings gathered from this project. The publication is expected to be released in early 2010.

V. TOTAL TRUST FUND PROJECT BUDGET:

Staff or Contract Services: $266,700
Equipment: $3,300
Other: $ 0

TOTAL TRUST FUND PROJECT BUDGET: $ 270,000

Explanation of Capital Expenditures Greater Than $3,500: *N/A*

VI. OTHER FUNDS & PARTNERS:

A. Project Partners: Anne Kapuscinski, Peter Reich (both faculty, co-PI's of University of Minnesota Ecosystem Science and Sustainability Initiative)

B. Other Funds Proposed to be Spent during the Project Period: *The faculty P.I.'s will spend time on this project that is not paid for by LCCMR.*

C. Past Spending: *The Sustainability Initiative has been funded through a $900,000 Bush Foundation grant that expires in the fall of 2008. This grant is being used to conduct a participant scenario development process, which will provide critical input to our water model. The water balance modeling will also receive input from a project under P.I. Suh to explore the impacts of climate change on state water resources, with funding from the University of Minnesota Agricultural Experiment Station.*

D. Time: 7/1/08 – 6/30/10

VII. DISSEMINATION: *The dissemination of research results is built into the project timeline and budget, as described above.*

VIII. REPORTING REQUIREMENTS:

Periodic work program progress reports will be submitted not later than 1/15/09, 6/30/09, 1/15/10, and 6/30/10. A final work program report and associated products will be submitted between June 30 and August 1, 2010 as requested by the LCCMR.

IX. RESEARCH PROJECTS: n/a

Attachment A: Budget Detail for 2010 Projects - Summary and a Budget page for each partner (if applicable)

Project Title: *Future of energy and Minnesota's Water Resources*

Project Manager Name: *Sangwon Suh*

Trust Fund Appropriation: $ *270,000*

1) See list of non-eligible expenses, do not include any of these items in your budget sheet

2) Remove any budget item lines not applicable

2010 Trust Fund Budget	**Result 1 Budget:**	**Amount Spent** *(date)*	**Balance** *(date)*	**Result 2 Budget:**	**Amount Spent (date)**	**Balance** *(date)*	**Result 3 Budget:**	**Amount Spent** *(date)*	**Balance** *(date)*	**TOTAL BUDGET**	**TOTAL BALANCE**
	Current Spatial Water Budget in Map Form			*Maps of Future State Water Budgets under Different Scenarios*			*Interpretatin and Dissemination of Research Results*				
BUDGET ITEM											
PERSONNEL: wages and benefits *(List individual names, amount budgeted and %FTE; add rows as needed)*	76,714		0	100,519		-3	81,094		-1,040	258,327	-1,043
Schmitt, Laura, Research Associate, .3 FTE		11,826									
Suh, Kyo, Post-doctoral Associate, .4 FTE		18,172						24,099			
Suh, Sangwon, Asst Prof - Summer, .03 FTE		5,261			$ 2,075.25						
Walseth, Brian, Research Specialist, .06 FTE		4,962									
Walseth, Brian, Research Assistant, .4 FTE		19,519						18,292			
Yang, Yi, Research Assistant, .5 FTE		16,974			$ 31,862.65						
Kim, Jae Youn, Visiting Professor, .02 FTE					$ 51.34			4,385			
Kim, Junbeum, Research Assistant, .6 FTE					$ 42,100.18			14,612			
Bae, Jung Han, Research Assistant, .1 FTE					$ 1,171.99			7,048			
Yee, Scott, Research Assistant, .1 FTE					$ 7,246.07						
Chiu, Yi-Wen, Research Assistant, .3 FTE					$ 16,014.25			13,698			
Contracts											
Professional/technical *Michigan State University - Co-PI Schmitt-Olabisi, Laura*				8,373	$ 8,370.28	3				8,373	3
Non-capital Equipment / Tools - Stella Software used for data analysis exclusively for this project							2,300	2,056	244	2,300	244
Travel expenses in Minnesota							1,000	204	796	1,000	796
COLUMN TOTAL	**$76,714**	**$76,714**	**$0**	**$108,892**	**$ 108,892.01**	**$0**	**$84,394**	**$84,394**	**$0**	**$270,000**	**$0**