Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2014 Work Plan

Date of Report: February 05, 2014

Date of Next Status Update Report: December 31, 2014

Date of Work Plan Approval:

Project Completion Date: June 30, 2017

Does this submission include an amendment request? No

PROJECT TITLE: Watershed Water Budgets for Managing Minnesota's Groundwater

Project Manager: Dave Lorenz

Organization: U.S. Geological Survey

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Location: St. Louis and Goodhue, Rice, and Steele with some additional small areas in neighboring counties.

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$129,000**
	Amount Spent:	**$0**
	Balance:	**$129,000**

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 03i

Appropriation Language:
$129,000 the second year is from the trust fund to the commissioner of natural resources for an agreement with the United States Geological Survey to create a pilot study to calculate complete watershed water budgets for two counties in Minnesota for enhanced groundwater management. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Watershed Water Budgets for Managing Minnesota's Water

II. PROJECT STATEMENT:
Responsible groundwater management requires knowledge the water budget. The water budget is the quantity of water that is flowing through the hydrologic system as well as the amount of groundwater in aquifers (storage). We often have a good idea of groundwater storage (from a county atlas, for example); we have good knowledge of surface-water flow (from USGS and DNR streamflow gages); but we seldom know groundwater flow. This project will tie together those pieces of information.

Problem: The surficial aquifer system is intimately tied to surface-water flow and to flow to and from deeper, buried aquifers. The connection among those systems is poorly understood across much of Minnesota. The lack of understanding of those connections hinders the state's efforts to define the sustainability of water use from surficial aquifers as well as streams and rivers through the state.

Benefits: The water budget information obtained from this study will assist the state in planning for long-term water-use sustainability. The proposed study will provide the Minnesota Department of Natural Resources with information necessary to protect wetlands and ensure streamflows for ecological needs. It should also provide information to the Minnesota Pollution Control Agency information necessary to better understand the interaction between surface- and groundwater.

Scope and Objective: The objective of the proposed pilot study is to calculate the water budgets, including the groundwater flow component, for selected watersheds in St. Louis and Goodhue counties. The goal of the proposed project is to provide information for proactive water management in two areas undergoing mining exploration.

Water budgets would be computed primarily using soil-water-balance (SWB). A current USGS project that uses SWB calculates only recharge for the state; the proposed project would extend those computations to include calibrated evapotranspiration and runoff, giving the water balance. Other data inputs into the watershed water budgets would include data from the USGS synthetic hydrograph project to help understand and map general flowpaths from surficial aquifers to streams.

III. PROJECT STATUS UPDATES:

Project Status as of 12/31/2014:
Project Status as of 06/30/2015:

Project Status as of 12/31/2015:

Project Status as of 06/30/2016**:**

Project Status as of 12/31/2016:

Project Status as of 06/30/2017**:**

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Estimate groundwater contribution to streamflow
Description:

The groundwater contribution to streamflow throughout each area will be estimated from the relations among low streamflows, landscape characteristics, and climate identified in the synthetic hydrograph project. Multiple linear regressions will be used to fit selected points of the flow-duration curve to physical characteristics that can be mapped as part of the synthetic hydrograph project. The overall contribution will be computed from those regression analyses to construct a series that cover a range of base-flow conditions, corresponding to the points on the flow-duration curve.

The product will be a series of maps, and corresponding GIS data, that cover a range of base-flow conditions. The maps will represent the relative contribution from the surficial aquifer system to streamflow under various flow conditions. They will be similar to the specific yield map in Lorenz and Delin (2007) shown in figure 1 (section IX), but will cover only the area of the watershed and be relative contribution rather than the actual value of the variable.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 33,500
Amount Spent: $ 0
Balance: $ 33,500

Activity Completion Date: 06/30/2015

Outcome	Completion Date	Budget
1. Spatial distribution of the average amount of groundwater discharge to rivers.	06/30/2015	$28,500
2. Identify landscape characteristics that explain the spatial distribution of groundwater discharge to streams.	06/30/2015	$5,000

Activity Status as of 12/31/2014:

Activity Status as of 06/30/2015:

Activity Status as of 12/31/2015:

Activity Status as of 06/30/2016**:**

Activity Status as of 12/31/2016:

Final Report Summary:

ACTIVITY 2: Estimate groundwater recharge for each area
Description:
Recharge will be calculated across two selected watersheds in St. Louis and Goodhue counties utilizing the SWB – Soil-Water-Balance Code (Westenbroek and others, 2010). The SWB application will incorporate spatial and temporal variability by using commonly available geographic information system (GIS) data layers and daily, gridded climatological data. As components of the soil-water-balance approach are calculated at daily time steps, recharge estimates can be output as daily, monthly, and/or annual estimates.
Within the SWB approach, recharge is calculated within each grid cell of the model domain based on the difference between soil moisture and the sources (precipitation, snowmelt, inflow) and sinks (interception, outflow, evapotranspiration (ET)) (eq. 1):

$$\text{Recharge} = (\text{precip} + \text{snowmelt} + \text{inflow}) - (\text{interception} + \text{outflow} + \text{ET}) - \Delta\text{soil moisture} \quad (1)$$

Input for the sources and sinks is provided by climate data and landscape characteristics. Output is only limited by the resolution of the climatological data and available land use, land cover, and soil cover data layers. The first step in the approach is to assemble all the required gridded data sets for the state, including the following:

1. Land use / land cover
2. Surface water flow direction
3. Hydrologic soil group
4. Available soil-water capacity

Several data sources will be key for building these statewide grids. The National Land Cover Data (NLCD) will be used as the source for land use/land cover data. A 30-meter Digital Elevation Model (DEM) will be used to determine cell-by-cell flow direction. The Soil Survey Geographic (SSURGO) database will be used to determine the hydrologic soil group and available soil-water capacity.

The daily, gridded climate datasets available from DAYMET (Oak Ridge National Laboratory, 2014) will be the primary sources of information for populating the climate data tables for the model. The minimum data requirements for SWB include daily precipitation, daily minimum air temperature, and daily maximum air temperature. The final required data set, the matrix of soil-water retention for given accumulated potential water loss, is an included part of the SWB code and is derived from Thornthwaite and Mather (1957).

After all the required data sources have been collected, the next step is to build and format the input files (i.e., control files) for running the SWB code. Also, all the initial conditions need to be set in addition to setting options, such as the surface water routing method and the evapotranspiration method. Upon completion of these steps, the SWB will be run for a period of at least 10 years to incorporate climatic variability. Results from the SWB method will be used to create daily, monthly, and/or annual recharge estimates for the two selected watersheds.

Output for the selected watersheds will be similar to Figure 2, except a summary of recharge across the two selected watersheds in St. Louis and Goodhue counties.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 28,500
Amount Spent: $ 0
Balance: $ 28,500

Activity Completion Date: 12/31/2015

Outcome	Completion Date	Budget
1. Compile and produce GIS and climatological datasets.	12/31/2014	$5,000
2. Calculate groundwater recharge and produce preliminary distribution maps.	12/31/2015	$23,500

Activity Status as of 12/31/2014:

Activity Status as of 06/30/2015:

Activity Status as of 12/31/2015:

Activity Status as of 06/30/2016**:**

Activity Status as of 12/31/2016:

Final Report Summary:

ACTIVITY 3: Analysis and map production

Description:

Integrate the results from activities 1 and 2 to reconcile differences and calculate all components of the surface- and groundwater budgets in the watersheds. The integration process takes the recharge data and applies it to the relative contribution information from activity 1 to produce the actual contribution to streamflow at selected flow regimes. The integration also incorporates surface runoff, estimated by the recharge estimates in activity 2, to estimate the contribution to flow at higher flow regimes, floods for example. The resulting products represent the contribution for typical conditions, not necessarily the contribution for any particular time.

Figure 3 shows the current watershed budget for the Cannon River watershed, which covers part of Goodhue County. It is a very crude representation of the watershed budget, showing only average flow. The updated product will show the streamflow for selected flow regimes, like average, drought, and severe drought; and the aquifers that contribute to the streamflow at those flow regimes. The data can be extracted from the GIS products, which will be useful to watershed planners and mangers.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 67,000
Amount Spent: $ 0
Balance: $ 67,000

Activity Completion Date: 06/30/2017

Outcome	Completion Date	Budget
1. Compile water-use data.	12/31/2014	$5,000
2. Produce final distribution maps.	12/31/2016	$31,000
2. Produce map reports.	06/30/2017	$31,000

Activity Status as of 12/31/2014:

Activity Status as of 06/30/2015:

Activity Status as of 12/31/2015:

Activity Status as of 06/30/2016**:**

Activity Status as of 12/31/2016:

Final Report Summary:

V. DISSEMINATION:

Description: A USGS Scientific Investigations Map and the corresponding GIS data will be published by August 15, 2017. The report and supporting data will be hosted on the USGS publications website: http://pubs.er.usgs.gov/. In addition to the report, a group composed of staff of the USGS and the MDNR will monitor the progress and help direct the final product to improve its usefulness. That group will also be instrumental in keeping other interested parties informed of the progress and the final product.

Status as of 12/31/2014:

Status as of 06/30/2015:

Status as of 12/31/2015:

Status as of 06/30/2016**:**

Status as of 12/31/2016:

Status as of 06/30/2017**:**

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Explanation
Personnel:	$129,000	
TOTAL ENRTF BUDGET:	**$129,000**	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: N/A

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 1.0

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: N/A

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
USGS	$63,700	$0	All activities—USGS administrative and indirect costs
TOTAL OTHER FUNDS:	**$63,700**	**$0**	

VII. PROJECT STRATEGY:

A. Project Partners:

Minnesota Department of Natural Resources and Minnesota Pollution Control Agency. Both are interested in the project and a project guiding task force will be formed by representatives from both agencies and the U.S. Geological Survey so that the final product will be most useful to the state agencies.

B. Project Impact and Long-term Strategy:

The water budget information obtained from this study will assist the state in planning for long-term water-use sustainability. The proposed study will provide the Minnesota Department of Natural Resources with information necessary to protect wetlands and ensure streamflows for ecological needs. It should also provide information to the Minnesota Pollution Control Agency information necessary to better understand the interaction between surface- and groundwater.

This project is a proof-of-concept study in two watersheds in Minnesota. It is intended to research and find the most practical methods to produce the GIS products. The long-term goal would be to extend the results to all watersheds in Minnesota.

C. Spending History:

Funding Source	M.L. 2008 or FY09	M.L. 2009 or FY10	M.L. 2010 or FY11	M.L. 2011 or FY12-13	M.L. 2013 or FY14
LCCMR-ENRTF	NA	NA	NA	NA	NA
USGS Cooperative Water Program	NA	NA	NA	NA	NA

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. VISUAL ELEMENT or MAP(S):

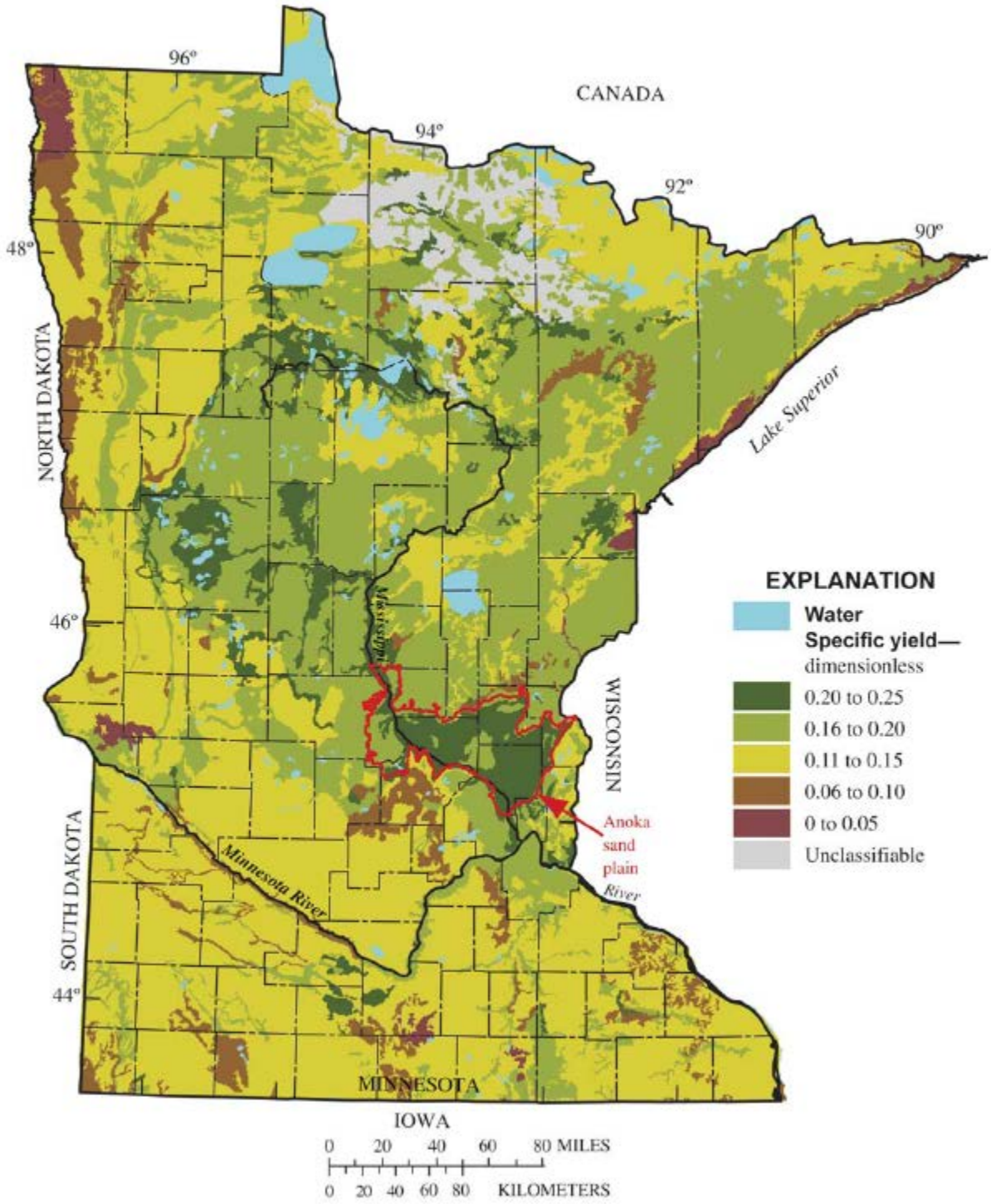

Figure 1. Specific yield of surficial materials in Minnesota.

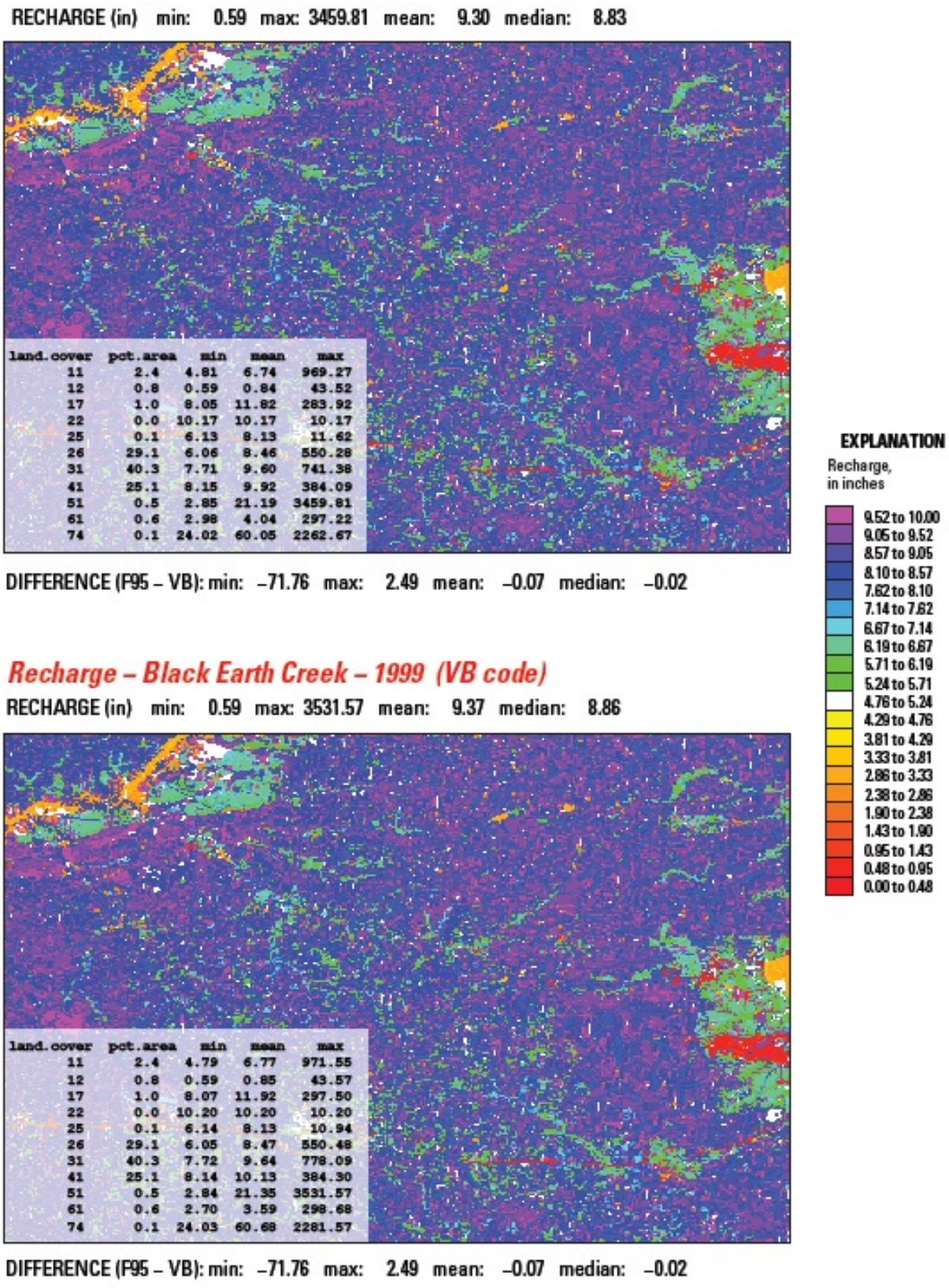

Figure 2. Recharge across an example watershed, Black Earth Creek, WI (copied from Westenbroek and others, 2010).

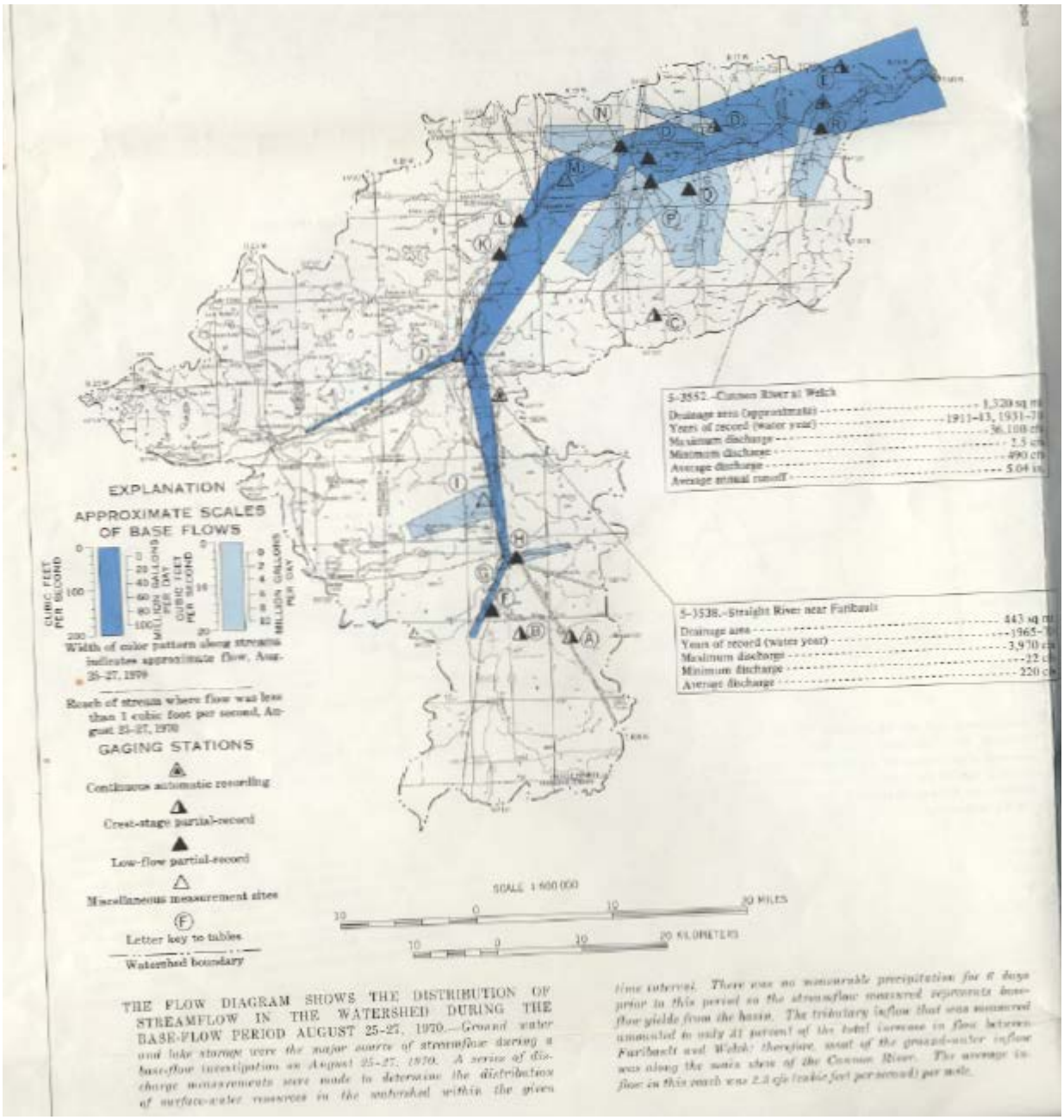

Figure 3. Water budget from Anderson and others, 1974.

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: N/A

XI. RESEARCH ADDENDUM:

The U.S. Geological Survey will conduct internal peer reviews of this detailed proposal and will be revised based on those USGS peer review comments. The proposal will then be approved by the USGS and added to this document. The expected date of proposal approval is April 30, 2014.

XII. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than June 30, 2015; June 30, 2016; and June 30, 2017. A final report and associated products will be submitted between June 30 and August 15, 2017.

XIII REFERENCES:

Anderson, H.W., Jr., Farrell, D.F., Broussard, W.L., and Felsheim, P.E., 1974, Water resources of the Cannon River watershed, southeastern Minnesota: U.S. Geological Survey Hydrologic Atlas HA-522, 3 sheets, scales 1:250,000 and 1:500,000.

Lorenz, D.L., and Delin, G.N., 2007, A regression model to estimate regional ground-water recharge in Minnesota: Ground Water, v. 45, no. 2, 10.1111/j.1745-6584.2006.00273.x.

Oak Ridge National Laboratory, 2014, Daily Surface Weather and Climatological Summaries: accessed January 9, 2014, at http://daymet.ornl.gov/gridded.

Thornthwaite, C.W. and Mather, J.R., 1957, Instructions and tables for computing potential evapotranspiration and the water balance: Centerton, N.J., Laboratory of Climatology, Publications in Climatology, v. 10, no. 3, p. 185-311.

Westenbroek, S.M., Kelson, V.A., Dripps, W.R., Hunt, R.J., and Bradbury, K.R., 2010, SWB – A modified Thornthwaite-Mather Soil-Water-Balance code for estimating groundwater recharge: U.S. Geological Survey Techniques and Methods 6-A31, 60 p.

Environment and Natural Resources Trust Fund

M.L. 2014 Project Budget

Project Title: Watershed Water Budgets for Managing Minnesota's Groundwater

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 03i

Project Manager: Dave Lorenz

Organization: U.S. Geolgical Survey

M.L. 2014 ENRTF Appropriation: $ 129,000

Project Length and Completion Date: 3 Years, June 30, 2017

Date of Report: May 12, 2014

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	**Estimate groundwater contribution to streamflow**			**Estimate groundwater recharge for each area**			**Analysis and map production**				
Personnel (Wages and Benefits)	$33,500	$0	$33,500	$28,500	$0	$28,500	$67,000	$0	$67,000	$129,000	$129,000
USGS Project Chief (Lorenz) 267 hours, 78%salary, 22%benefits ($17,800)											
USGS Hydrologist (Smith) 425 hours, 73% salary, 27% benefits ($26,000)											
USGS Hydrologist (Czuba) 828 hours, 73% salary, 27% benefits ($53,500)											
USGS Water-Use Specialists(Sanocki) 160 hours, 73% salary, 27% benefits ($10,000)											
USGS Technical Administration(2 staff) 180 total hours, 69% salary, 31% benefits ($7,000)											
USGS Project Administration and Oversight (2 staff) 50 total hours, 69% salary, 31% benefits ($4,200)											
USGS Technical Specialists(Erickson and Sanocki) (2staff) 150 hours total, 73% salary, 27% benefits ($10,500)											
COLUMN TOTAL	$33,500	$0	$33,500	$28,500	$0	$28,500	$67,000	$0	$67,000	$129,000	$129,000

Water Budgets for Managing Minnesota's Water—Supplemental Graphics

The image below presents the basic concepts of the water budget for any particular area within a watershed. The overall water budget consists of inputs; precipitation and inflow, which is zero for headwaters; and outputs, losses from evaporation and outflow. The critical components for managing water use are the internal flows, surface runoff and recharge that eventually discharges to the stream. Landscape differences are highlighted in the graphics below—the recharge is larger and the surface runoff is smaller in the more permeable material than in the less permeable material. This pilot study would help to quantify the internal flow so that water use could be more sustainably and proactively managed than knowing only that we can extract more water from more permeable material than from less permeable material.