ML 2013 Project Abstract

For the Period Ending June 30, 2017

PROJECT TITLE: Measuring Hydrologic Benefits from Glacial Ridge Habitat Restoration
PROJECT MANAGER: Myron Jesme
AFFILIATION: Red Lake Watershed District
MAILING ADDRESS: 1000 Pennington Avenue South
CITY/STATE/ZIP: Thief River Falls, MN 56701
PHONE: (218) 681-5800
E-MAIL: jesme@wiktel.com
WEBSITE: http://www.redlakewatershed.org
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2013, Chp. 52, Sec. 2, Subd. 05e and M.L. 2015, Chp. 76, Sec. 2, Subd. 19

APPROPRIATION AMOUNT: $400,000.00
AMOUNT SPENT: $400,000.00
AMOUNT REMAINING: $0.00

Note: M.L. 2013, Chp. 52, Sec. 2, Subd. 05e and M.L. 2014, Chp. 226, Sec. 2, Subd 03m are an identical project, funded through two separate appropriations.

M.L. 2014 APPROPRIATION AMOUNT: $168,000
M.L. 2014 AMOUNT SPENT: $168,000
M.L. 2014 AMOUNT REMAINING: $0.00

<u>**Overall Project Outcomes and Results**</u>

A comparison between the hydrology of the Glacial Ridge National Wildlife Refuge before and after wetland and prairie restoration shows substantial changes in flows of water through the hydrologic cycle, in behavior of overland runoff and ditch flow during storms, and in water quality. Within the 6 basins measured for this study, the area of cropland decreased by 14 percent, the area of wetlands increased by 6 percent, and the area of native prairie increase by 19 percent between 2002 and 2015 due to restorations. During the same period, hydrologic changes had the benefits of decreasing runoff rate (-33 percent, as a proportion of precipitation) and ditch flow rate (-23 percent) and improving water quality as measured by nitrate concentration (surficial groundwater median: -79 percent, ditchwater median: -53 percent) and suspended sediment in ditchwater (-64 percent) within the study area. Peak ditch flow from storms decreased, ditch flow recessions lengthened, and base flow from groundwater discharge increased, though only a small amount. These changes reduce the amount of water leaving the study area through ditches, reducing flows that contribute to flooding.

Neither the density of restorations nor the beneficial changes in hydrology were evenly distributed throughout the study area. Amount of hydrologic benefits within an individual ditch basin did not correlate directly with amount of restoration in that basin. This is likely because of complicating factors within each basin like the kind of land restored, the amount of surficial aquifer, the amount of remaining ditches, and the density of closed wetland and lake basins.

An analysis of landscape characteristics that correlated with hydrologic benefits in the study area showed that area of surficial aquifer and area of drained wetlands are most important. Surficial aquifers provide a groundwater reservoir that can reduce runoff and slowly release water as base flow to streams. Drained wetlands simply provide the opportunity for restoration of closed basins, which reduces streamflow. Areas with the highest density of surficial aquifers and drained wetlands have the highest potential for hydrologic benefits from prairie and wetland restoration. In western Minnesota, these areas are the uplands the Alexandria Moraine Complex and the beaches of Glacial Lake Agassiz on the eastern side of the western third of Minnesota, north of Wilmar, MN (Cowdery and others, 2017)

Cowdery, T.K., Christenson, C.A., and Zeigwied, J.R., 2017, The hydrologic benefits of wetland and prairie restoration in western Minnesota: lessons learned at the Glacial Ridge National Wildlife Refuge, 2002–15: U.S. Geological Survey Scientific Investigations Report 2017-xxxx, in preparation.

Project Results Use and Dissemination

The information generated by this grant will be documented in a U.S. Geological Survey Scientific Investigations Report that is in preparation. A draft of the report is attached to the project work plan. We expect the final draft of the report will be completed by 15 August. 2017. The report must be reviewed and approved, which we expect will occur by 31 October 2017. Once published, we will issue press announcements of the project results regionally and nationally. Additionally, the information in this report will be presented at several scientific meetings including that of the Minnesota Groundwater Association, the Minnesota Water-Resources Conference, and at annual conference of either the Geological Society of America or the American Geophysical Union. Presentations of interim result from this project have already been presented at meetings of the Minnesota Groundwater Association, the past Minnesota Water-Resources Conferences.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2013 Work Plan

Date of Status Update Report: 29 June 2017
Date of Next Status Update Report: None
Date of Work Plan Approval: 11 June 2013
Project Completion Date: 30 June 2017 **Is this an amendment request?** Yes

PROJECT TITLE: Measuring Hydrologic Benefits from Glacial Ridge Habitat Restoration

Project Manager: Myron Jesme
Affiliation: Red Lake Watershed District

Mailing Address: 1000 Pennington Avenue South
City/State/Zip Code: Thief River Falls, MN 56701
Telephone Number: (218) 681-5800
Email Address: jesme@wiktel.com
Web Address: http://www.redlakewatershed.org/default.html

Project Cooperator: Tim Cowdery
Affiliation: U.S. Geological Survey, Minnesota Water-Science Center
Mailing Address: 2280 Woodale Drive
City/State/Zip Code: Mounds View, MN 55112-4900
Telephone Number: (763) 783-3273
Email Address: cowdery@usgs.gov
Web Address: http://mn.water.usgs.gov/index.html

Location: The work will occur in and around the Glacial Ridge National Wildlife Refuge, Polk and Red Lake Counties. The results of the study will be applied statewide.

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$400,000.00**
	Amount Spent:	**$400,000.00**
	Balance:	**$0.00**

Legal Citation: M.L. 2013, Chp. 52, Sec. 2, Subd. 05e and M.L. 2015, Chp. 76, Sec. 2, Subd. 19

Appropriation Language:

$400,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with the Red Lake Watershed District in cooperation with the United States Geological Survey to compare the hydrology of habitats before and after restorations to evaluate and quantify the impacts on flood reduction and water quality in order to inform improvements to restoration techniques. The United States Geologic Survey is not subject to the requirements in Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2016, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Measuring hydrologic benefits from Glacial Ridge habitat restoration

II. PROJECT STATEMENT: Flooding, degraded water quality and habitat loss are among the greatest natural resource challenges faced by Minnesotans. Starting in the year 2000, a diverse group of more than thirty partners set out to demonstrate that large-scale habitat restoration is a viable way to reduce flooding and improve water quality. Among the largest prairie-wetland restorations in the world, the Glacial Ridge Project spans more than 22,000 acres, and is adjacent to an additional 16,000 acres of private and public conservation land. **How significant are the benefits of large-scale habitat restoration to flood reduction and water quality**? This project is an historic opportunity to provide real numbers that measure these improvements. The overall goal of the project is to characterize and measure the amount of flood reduction, water-quality improvement, and ecosystem-function change of the hydrologic system resulting from wetland and prairie restoration at Glacial Ridge. In so doing, the project will measure the success of restoration techniques employed on this land. The project will use these results to identify other parts of Minnesota that could benefit from similar restorations and quantify the resulting potential water and habitat improvements.

Glacial Ridge presents a unique opportunity to measure restoration benefits because of its size and a $1.8-million comprehensive hydrologic characterization of the area prior to restoration. This study was conducted by the U.S. Geological Survey (USGS) during 2002–5. The resulting hydrologic baseline makes it possible to quantify to what degree the restorations contributed to flood reduction and water quality improvements. The USGS began the post-restoration characterization in 2011 with initial funds provided by the U.S. Fish and Wildlife Service's (USFWS) Plains and Prairie Potholes Landscape Conservation Cooperative, USFWS Region 3, Glacial Ridge Wildlife Refuge, and the City of Crookston. This initial $562,000 investment funded data collection needed to determine hydrologic benefits through 2012. LCCMR funding will complete this project and produce the definitive evidence that habitat restoration generates big benefits for flood reduction and water-quality improvement.

The project is divided into 3 main activities:

Water flows—the amount and directions of water flowing through the groundwater and surface-water system of the restored wetland and prairies will be characterized and measured. This activity will produce surface-water and groundwater balances in four ditch basins to quantify water flows after wetland and prairie restorations. Two basins have small restored areas and will act as controls. Two other basins have extensive restored areas and will be treatments basins. The water balances will be calculated from measurements of groundwater and surface-water levels, from ditch flows, and from weather data, including rainfall, temperature, humidity, and wind speed. The flows in each part of the water cycle will characterize the pattern of water movement now that the wetland and prairie restorations have been completed.

Water quality—the restored area will be characterized and analyzed for variability and trends. Groundwater samples will be collected 5 times per year for two years at 9 wells and analyzed for nutrients. Surface water will be collected at 5 ditches and analyzed for nutrients and suspended sediment concentration. All water samples will be measured for field characteristics including alkalinity concentrations. At least 10 percent of water samples collected will be sample replicates or blank samples to assure the quality of all samples collected. The samples will document the state of post-restoration water quality and will be analyzed with samples collected during the previous 10 years to define water-quality trends in the study area.

Pre-and post-restoration changes in water flow and quality at Glacial Ridge will be analyzed and attributed to the restorations, or other factors (e.g. weather variability or climate change). The effects of the restoration changes would then be extended to other parts of Minnesota where such restorations could be implemented to provide similar benefits. This analysis will identify areas of Minnesota where restorations will have the most benefit and quantify the size of those benefits. This knowledge is crucial to an accurate restoration cost/benefit analysis. Landscape characteristics like soil type, slope, percent of land restored, previous land use, and existing reservoirs of native plant materials may be important factors that explain the success of restorations to reduce flooding and improve water quality.

Through these activities, this project will document the post-restoration state of the water at Glacial Ridge and identify those landscape characteristics that are most important to successful wetland and prairie restorations. We will then analyze the Minnesota landscape using geographical information to identify areas where these characteristics exist. These will be the areas that hold the most promise for decreased flooding and improved water quality from wetland and prairie restorations. Further, an estimate of the degree of improvement could be made based on the degree of improvements documented in this study at the Glacial Ridge National Wildlife Refuge.

III. PROJECT STATUS UPDATES:

Project Status as of October 2013:

Water level, water temperature (wells only) and shelter temperature were recorded hourly at 12 wells and every 15 minutes at 6 ditch gages. Rating curves are now maintained to convert stage into flow. Fifteen-minute rainfall sums were recorded at the 10 wells. Continuous hydrograph data are available in real time on the world-wide-web at: http://waterdata.usgs.gov/mn/nwis/current/?type=gw

for the following wells:

USGS Well No.	USGS well name (short name, Public Land Survey location, MN Unique Well No.)
474135096203001	G01-R 149N44W30CAAD 0000620661
474346096185501	G08-R 149N44W17ABAD 0000620668
474126096165301	G12-R 149N44W27CDBB 0000620672
473841096153101	G15-R 148N44W10CCCC 0000620675
474310096121801	G20S-R 149N43W18DDBA 0000620680
474125096120602	G22S-R 149N43W29CCBB 0000620682
473933096243701	G25-R 148N45W05DDDD 0000620685
473945096202401	E01D-R 148N45W01CBDD L107 0000516287
473945096202402	E01S-R 148N45W01CBDD L000 0000249810
474436096140801	E03-R 149N44W12BADA S12 Ob. Well 1 0000654754
474309096122001	E04D-R 149N43W18DDBA Ob. Well 4, NWF 0000654760
474719096163100	E05-R 150N44W27ABBAA L058

and for the following ditch gages:

USGS Gage	USGS Gage name (Ditch name and location, short name)
05079250	COUNTY DITCH 65 NEAR MAPLE BAY, MN (SW2)
05079200	COUNTY DITCH 72 (BURNHAM CK) NR. MAPLE BAY (SW3)
05078470	JUDICIAL DITCH 64 NEAR MENTOR, MN (SW4)
05078520	CYR CREEK NEAR MARCOUX CORNERS, MN (SW5)
05078770	JUDICIAL DITCH 66 NEAR MARCOUX CORNERS, MN (SW6)
05078720	CO DITCH 140 ABV BR-6 IMP NR TILDEN JCT, MN (SW8)

All surface-water (SW) and wetland gage measuring points were optically surveyed in September. One synoptic water-level measurement consisting of 72 wells, 11 wetlands, and 7 ditches was completed. One sampling trip was completed. During the trip, 12 groundwater (GW) and 6 SW samples were collected and analyzed for field parameters and nutrient and suspended sediment (SW sites only) concentrations.

Two SW gages and 3 GW gages will be decommissioned beginning in FY 2014 unless further funding is secured. The seasonal analysis of water flows and the water-quality synoptic are also not yet funded. Another LCCMR proposal was prepared and submitted to continue all project gaging and analyses.

The new owner of the grain elevator that hosted our telemetry radio removed our equipment thereby eliminating our GW gage telemetry.

Project Status as of March 2014:

Water level, water temperature (wells only) and shelter temperature continue to be recorded hourly at 12 wells and every 15 minutes at 6 ditch gages. Rating curves are maintained to convert stage into flow. Fifteen-minute rainfall sums were recorded at the 10 wells. Continuous hydrograph data are available in real time on the world-wide-web at: http://waterdata.usgs.gov/mn/nwis/current/?type=gw See the Project Status as of October 2013 section for links to the individual sites.

The 5 gages in danger of decommissioning continue to run because a grant to continue their operation was secured from the LCCMR.

Gage telemetry was partially reestablished at some sites using a small tower at the University of North Dakota's Glacial Ridge Atmospheric Laboratory.

All groundwater and rainfall continuous data records were checked for gaps during the entire period of record. Missing data were estimated based on data trends and data from surrounding gages.

Amendment Request (07/28/2014):

In order to comply with the State of Minnesota limits on travel per diem limits, we request that the amount budgeted and charged for meals (Line 28 of the budget spreadsheet) be reduced from a total of $8,421 to $6,300. We request that the difference ($2,121) be moved to project management and groundwater specialist salary of Activity 1(Line16). The amount spent on Meals for Activity 1 (cell C28) should be reduced by $121.79 to comply with the State per diem limits.

Amendment Approved: 08/11/2014

Project Status as of October 2014:

Water level, water temperature (wells only) and shelter temperature continue to be recorded hourly at 9 wells and every 15 minutes at 4 ditch gages. Rating curves are maintained to convert stage into flow. Fifteen-minute rainfall sums were recorded at the 8 wells. Continuous hydrograph data are available in real time on the world-wide-web at: http://waterdata.usgs.gov/mn/nwis/current/?type=gw See the Project Status as of October 2013 section for links to the individual sites.

The four GW and five SW sampling trips were completed. During each trip, 12 GW and/or 6 SW samples were collected and analyzed for nutrient and suspended sediment (SW sites only)

Six synoptic water-level measurements were completed. The synoptic measurement consists of 72 wells, 11 wetlands, and 6 ditches. All synoptic water-level measurements for the past 12 years were quality-assured by plotting hydrographs at each site and producing contour maps for each synoptic. All errors identified were corrected.

Amendment Request (12/15/2014):

In order to have time to incorporate the last data collected for this project in late 2015, we request that the final date for this project be extended from 30 June 2016 to 31 December 2016.

Project Status as of March 2015:

Water level, water temperature (wells only) and shelter temperature continue to be recorded hourly at 9 wells and every 15 minutes at 4 ditch gages. Rating curves are maintained to convert stage into flow. Fifteen-minute rainfall sums were recorded at the 8 wells. Continuous hydrograph data are available in real time on the world-wide-web at: http://waterdata.usgs.gov/mn/nwis/current/?type=gw See the Project Status as of October 2013 section for links to the individual sites. Water level and flow monitoring were discontinued with the end of federal fiscal year 2015 on 1 October.

One GW and SW sampling trip was completed. During the trip, 9 GW and 4 SW samples were collected and analyzed for nutrient and suspended sediment (SW sites only)

One synoptic water-level measurement was completed. The synoptic measurement consists of 72 wells, 11 wetlands, and 6 ditches. All synoptic water-level measurements for the past 6 months were quality-assured by plotting hydrographs at each site and producing contour maps for each synoptic. All errors identified were corrected.

New or destroyed elevation reference marks were surveyed and water level elevations were corrected. These corrected water levels were incorporated into temporal data sets and a water table map was produced for each synoptic water level measurement. Difference maps were also produced between subsequent measurements and the change in groundwater storage was calculated for each basin in the study.

Land-use data were compiled from NRCS Wetland Reserve Programs records and remote sensing crop estimates (USDA Cropland Data Layer) to produce a time series of land use during the period 2006-13. These data will be used as input to the SWB model to estimate evapotranspiration for water mass balances. The data will also be used to quantify land-use change in the study area before and after restoration. Compilation of rainfall data has begun.

Project Status as of October 2015:

Water level, water temperature (wells only) and shelter temperature continue to be recorded hourly at 9 wells and every 15 minutes at 4 ditch gages. Rating curves are maintained to convert stage into flow. Fifteen-minute rainfall sums were recorded at the 8 wells. Continuous hydrograph data are available in real time on the world-wide-web at: http://waterdata.usgs.gov/mn/nwis/current/?type=gw See the Project Status as of October 2013 section for links to the individual sites. Dataloggers will continue to operate as long as they are able through the end of the project and calibration groundwater levels will be measured when other work in the area permits it. No further records will be corrected.

Four GW and five SW sampling trip was completed. During the trip, 9 GW and 4 SW samples were collected and analyzed for nutrient and suspended sediment (SW sites only)

Three synoptic water-level measurements were completed. The synoptic measurement consists of 72 wells, 11 wetlands, and 6 ditches. All synoptic water-level measurements for the past 6 months were quality-assured by plotting hydrographs at each site and producing contour maps for each synoptic. All errors identified were corrected. Difference maps between subsequent synoptic measurements were produced. All synoptic water-level measurements were interpolated to a 50-m grid to be used in soil-water balance (SWB) model. This model is used to estimate flows through all components of the water cycle.

Rainfall data were compiled, gaps filled in, and aggregated to seasonal and annual totals at 9 of the 10 study sites and the SCAN climate station. Gaps were filled in by data from the nearest 4 other sites. If data were missing at all 5 of these sites, DayMet data from the cell containing the site was used. Recorded winter precipitation data at all sites were retained and used in the compilation. Compiled rainfall data were interpolated to a 50-m grid of the study area for each day during 1 October 2002-31 December 2014. Analysis of precipitation between recorder sites and DayMet interpolations at the same locations showed that unheated raingage data recorded about 25% of winter precipitation. To adjust for this, all recorded precipitation was increased by 4-times before interpolation. Because timing of winter precipitation is not accurate, these data can only be used in winter aggregations.

Recharge based on water-level rise was calculated for all 10 continuous WL wells and aggregated seasonally and annually. An automated method to estimate recharge was developed using individual groundwater recession curves. This method will be used to more accurately estimate recharge at continuous water-level wells.

Initial work began on unit-hydrograph modeling of ditch-gage flow hydrographs.

Project Status as of March 2016:

Water level, water temperature (wells only) and shelter temperature continue to be recorded hourly at 7 wells and every 15 minutes. Fifteen-minute rainfall sums were recorded at the 8 wells. Continuous hydrograph data are available in real time on the world-wide-web at: http://waterdata.usgs.gov/mn/nwis/current/?type=gw See the Project Status as of October 2013 section for links to the individual sites. Dataloggers will continue to operate as long as they are able through the end of the project and calibration groundwater levels will be measured when other work in the area permits it. No further records will be corrected.

One GW and SW sampling trip was completed. During the trip, 9 GW and 4 SW samples were collected and analyzed for nutrient and suspended sediment (SW sites only)

One synoptic water-level measurements were completed. The synoptic measurement consists of 72 wells, 11 wetlands, and 6 ditches. The synoptic water-level measurement was quality-assured by plotting hydrographs at each site and producing contour map. All errors identified were corrected. A difference map between subsequent synoptic measurements was produced. The synoptic water-level measurement was interpolated to a 60-m grid to be used in mass-balance calculations

Rainfall data were compiled, gaps filled in, and aggregated to seasonal and annual totals at 9 of the 10 study sites and the SCAN climate station through 30 September 2015. Gaps were filled in by data from the nearest 4 other sites. If data were missing at all 5 of these sites, DayMet data from the cell containing the site was used. Recorded winter precipitation data at all sites were retained and used in the compilation. All rainfall data were re-interpolated to a 60-m grid of the study area for each day during 1 October 2002-30 September 2015. The new grid was chosen to be a multiple of the 30-m landuse data that will be used in mass-balance and landscape factor analyses.

Recharge based on water-level rise was calculated for all 8 of 10 continuous WL wells and aggregated seasonally and annually during 1 October 2002-30 September 2015.

Unit-hydrograph modeling of ditch-gage flow hydrographs was completed. Ditch flow was aggregated seasonally and annually during 1 October 2002-30 September 2015.

Problems were identified with the use of the Soil-Water Balance (SWB) model to estimate evapotranspiration for the mass-balance calculations. After evaluating several other options, we have decided to use the University of Wisconsin Extension's ET model and the WEPP model.

The final report outline was completed.

Amendment Request (03/25/2016):

Because of staff conflicts with other work, we request that the final date for this project be extended from 31 December 2016 to 31 March 2017.

Project Status as of October 2016:

Water level, water temperature (wells only) and shelter temperature continue to be recorded hourly at 8 wells and every 15 minutes. Fifteen-minute rainfall sums were recorded at the 8 wells. Continuous hydrograph data from 3 wells are available in real time on the world-wide-web at: http://maps.waterdata.usgs.gov/mapper/index.html?state=mn. See the Project Status as of October 2013 section for links to wells G08, G12, and E05. Dataloggers will continue to operate as long as they are able through the end of the project and calibration groundwater levels will be measured when other work in the area permits it. No further records will be corrected. The transducer at well G08 failed in August 2015 but was replaced in May 2016.

Precipitation data were re-interpolated to a common 60m grid after errors were found. Groundwater recharge, groundwater discharge to ditches and total ditch runoff were re-calculated at all stations and were distributed among the mass-balance basins using Thiessen polygons and aggregated annually and seasonally. Annual change in groundwater storage was calculated by basin using a newly developed ArcGIS-based water-table interpolation tool. Evapotranspiration was calculated from 2002 through 2014 using a published Statewide SWB model and using a new, much more detailed, uncalibrated study-scale SWB model. All synoptic water-levels were contoured and maps subtracted to produce changes in groundwater storage. All components of the water budget are now calculated.

Land-use change summaries were calculated by basin seasonally. 60-m grids of landscape characteristic were produced that may explain changes between pre- and post-restoration hydrologic changes. Two abstracts were submitted and accepted to 2 conferences. Unfortunately, no funds are available to attend one of these conferences and we have withdrawn the abstracts.

Mass balances show that Rainfall in the study area was 14% less during the post-restoration period (post-RP, 2012-5) than during the pre-restoration period (pre-RP, 2003–6). During the periods, Streamflow rate decreased 34% to 14% of precipitation, and overland runoff decreased 33% to 9 % of precipitation. These decreases were offset primarily by increased evapotranspiration rate, which increased 6% to nearly 89% of precipitation. In addition, a larger portion of streamflow comes from groundwater discharge, which increased from 26% to 35% of total streamflow. Therefore, restorations not only cause a decrease of 34% in streamflow rate (streamflow/precipitation), but more of it comes from groundwater discharge leading to lower flood peaks and more sustained low flows.

Retroactive Amendment Request (06/28/2017):

We request that the final date for this project be extended from 31 March 2017 to 30 June 2017.

We request that funds be moved among the following budget categories:

Travel expenses in Minnesota, Lodging: Activity 1:-$2240.76, Activity 2: -$1767.03, total: -$4007.79

Travel expenses in Minnesota, Meals: Activity 1:-$621.62, Activity 2: -$811.78, total: -$1433.40

Travel expenses in Minnesota, Vehicles: Activity 2: -$799.75, total: -$799.75

The three budget items above had surpluses because we were able to accomplish the field work more efficiently. This was partially because we were able to use a crew that was familiar with the field area and with measuring techniques. We also had better weather than we planned for. Finally, we worked long weeks to avoid paying the extra travel expenses of returning to the field area finish work that otherwise would have lasted more than 5 days.

Personnel Overall (Wages and Benefits): Activity 1: $4250.00, Activity 3: $1990.94, total: $6240.94

We spent more time than budgeted analyzing the flow data collected for the project. With these funds we were able to look in detail at differences in water flows among 3 basins and try to understand why basins with similar restoration areas had varying water-budget changes. We were also able to interpolate precipitation recorded at rain gages much more accurately by including existing National Weather Service raingage data and interpolating to a 60-m grid rather than using cruder Theissen polygons (Activity 1). We also spent more time than budgeted searching for relations between landscape characteristics and hydrologic benefits. Specifically, we looked at how both the slope of ditches and the average slope of in each of 3 basins related to hydrologic benefits. Unfortunately, these landscape characteristics did not help explain the benefits (Activity 3).

Project Status as of June 2017:

All funds for the project have been spent and the project is complete. A rough draft of the USGS Scientific Investigations Report is complete and attached as an addendum. We expect the final draft of the report will be completed by 15 August. 2017. The report must be reviewed and approved, which we expect will occur by 31 October 2017. The overall results of the study are presented immediately below.

Overall Project Outcomes and Results

A comparison between the hydrology of the Glacial Ridge National Wildlife Refuge before and after wetland and prairie restoration shows substantial changes in flows of water through the hydrologic cycle, in behavior of overland runoff and ditchflow during storms, and in water quality. Within the 6 basins measured for this study, the area of cropland decreased by 14 percent, the area of wetlands increased by 6 percent, and the area of native prairie increase by 19 percent between 2002 and 2015 due to restorations. During the same period, hydrologic changes had the benefits of decreasing runoff rate (-33 percent, as a proportion of precipitation) and ditchflow rate(-23 percent) and improving water quality as measured by nitrate concentration (surficial groundwater median: -79 percent, ditchwater median: -53 percent) and suspended sediment in ditchwater (-64 percent) within the study area. Peak ditchflow from storms decreased, ditchflow recessions lengthened, and baseflow from groundwater discharge increased, though only a small amount. These changes reduce the amount of water leaving the study area through ditches, reducing flows that contribute to flooding.

Neither the density of restorations nor the beneficial changes in hydrology were evenly distributed throughout the study area. Amount of hydrologic benefits within an individual ditch basin did not correlate directly with amount of restoration in that basin. This is likely because of complicating factors within each basin like the kind of land restored, the amount of surficial aquifer, the amount of remaining ditches, and the density of closed wetland and lake basins.

An analysis of landscape characteristics that correlated with hydrologic benefits in the study area showed that area of surficial aquifer and area of drained wetlands are most important. Surficial aquifers provide a groundwater reservoir that can reduce runoff and slowly release water as baseflow to streams. Drained wetlands simply provide the opportunity for restoration of closed basins, which reduces streamflow. Areas with the highest density of surficial aquifers and drained wetlands have the highest potential for hydrologic benefits from prairie and wetland restoration. In western Minnesota, these areas are the uplands the Alexandria Moraine Complex and the beaches of Glacial Lake Agassiz on the eastern side of the western one-third of Minnesota, north of Wilmar, MN.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1:

Description: Measure and characterize water flows through all parts of the water cycle in 4 surface (SW) and groundwater (GW) basins covering 28,754 acres. The parts of the water cycle through which flow will be measured are:

- **Precipitation:** measured every 15 minutes at a network of 10 rain gages, nine of which are funded by this project.
- **Net surface run off:** measured every 15 minutes at 4 ditch gages located at the edge of the study area
- **Groundwater discharge to ditches:** calculated from base-flow separations of hydrographs from the 4 gaged ditches
- **Net infiltration:** the amount of water that gets to the water table (**net groundwater recharge**), calculated from water level and temperature measured every hour at 9 wells in the four gaged ditch basins
- **Evapotranspiration:** calculated using publicly available weather and satellite data
- **Changes in groundwater storage:** calculated from bimonthly synoptic water-level measurement at about 100 sites.

These data will be combined into water-balance equations to account for all water moving through the four ditch basins in the study area. The variability in flow among basins and through time will be explained by atmospheric factors like precipitation, and by landscape factors like percent restored land. These measurements will document the post-restoration state of the water flow through the study area. Differences among basins in water flow among the components of the water cycle will be documented and explained on the basis of land use, weather, and climate differences and changes in space and time.

Summary Budget Information for Activity 1:	**ENRTF Budget:**	**$~~230,163.00~~** **$231,550.62**
	Amount Spent:	**$231,550.62**
	Balance:	**$ 0.00**

Activity Completion Date:

Outcome	Completion Date	Budget
1. Flows are measured in all components of the water cycle in 4 SW basins	October 2015	$132,404
2. Flow variability is explained by relevant atmospheric and landscape factors	June 2016	$~~97,759~~ $ 99,147

Activity Status as of October 2013:

Water level, water temperature (wells only) and shelter temperature were recorded hourly at 12 wells and every 15 minutes at 6 ditch gages. Changes in GW levels were analyzed and converted to GW recharge. Rating curves are now maintained to convert stage into flow at SW gages. Fifteen-minute rainfall sums were recorded at the 10 wells. These gages measured basic water flows in 6 SW basins during July–September 2013.

Activity Status as of March 2014:

Water level, water temperature (wells only) and shelter temperature were recorded hourly at 12 wells and every 15 minutes at 6 ditch gages. Changes in GW levels were analyzed and converted to GW recharge. Rating curves were maintained to convert stage into flow at SW gages. Fifteen-minute rainfall sums were recorded at the 10 wells. These gages measured basic water flows in 6 SW basins during October 2013–March 2014.

Activity Status as of October 2014:

Water level, water temperature (wells only) and shelter temperature were recorded hourly at 9 wells and every 15 minutes at 4 ditch gages. Changes in GW levels were analyzed and converted to GW recharge. Rating curves were maintained to convert stage into flow at SW gages. Fifteen-minute rainfall sums were recorded at the 8 wells. These gages measured basic water flows in 4 SW basins during April 2014–October 2014.

Activity Status as of March 2015:

Water level, water temperature (wells only) and shelter temperature were recorded hourly at 9 wells and every 15 minutes at 4 ditch gages. Changes in GW levels were analyzed and converted to GW recharge. Rating curves were maintained to convert stage into flow at SW gages. Fifteen-minute rainfall sums were recorded at the 8 wells. These gages measured basic water flows in 4 SW basins during November 2014–March 2015.

New or destroyed elevation reference marks were surveyed and water level elevations were corrected. These corrected water levels were incorporated into temporal data sets and a water table map was produced for each synoptic water level measurement. Difference maps were also produced between subsequent measurements and the change in groundwater storage was calculated for each basin in the study. The overall results mostly follow initial expectations correlating groundwater storage change with annual and seasonal weather patterns; historically dry and wet years are represented, and groundwater storage increases during spring/early summer and again in the fall. The six basins do not always follow the same trend between synoptic water-level measurements, so further analysis will be essential to understand the patterns of individual basins.

Activity Status as of October 2015:

Water level, water temperature (wells only) and shelter temperature were recorded hourly at 9 wells and every 15 minutes at 4 ditch gages. Changes in GW levels were analyzed and converted to GW recharge. Rating curves were maintained to convert stage into flow at SW gages. These gages measured basic water flows in 4 SW basins during November 2014–September 2015. Fifteen-minute rainfall sums were recorded at the 8 wells.

Difference maps were also produced between subsequent measurements and the change in groundwater storage was calculated for each basin in the study. The overall results mostly follow initial expectations correlating groundwater storage change with annual and seasonal weather patterns; historically dry and wet years are represented, and groundwater storage increases during spring/early summer and again in the fall. Summer 2015 received fairly average rainfall, but was evenly distributed across the season. September was dry.

Analysis of all precipitation data show that study data are about 20% lower than national spatially interpolated DayMet data. The range is 62%-92% among sites and 63%-94% among years (2002-14). Seasonal analysis shows that the study gages are low in the winter because snow blows out of the unheated raingage before it melts through. Winter precipitation was increased 4 times to match the DayMet winter precipitation. Variability analysis shows that DayMet data are substantially smoothed across the study area. Equivalent DayMet data are 5 times less variable than study precipitation data.

Average annual rainfall between the DayMet and study sites was quite different. For example, 2008 was the wettest year in the DayMet data but was slightly above average in the study data. These data show that local variability is very important in precipitation, especially in the summer when individual storms may be very local.

During 2002-2014, area-wide average precipitation was 20.68 in., ranging from 19.99 in. in basin SW8 to 21.66 in. in basin SW2. Basins did not show consistent ranking for precipitation, either annually or seasonally. The standard deviation of annual area-wide precipitation was 4.12 in. 2010 was the wettest year with 28.95 in. and 2011 was the driest year with about one-half that amount (14.62 in.). Seasonally, summer is the wettest, receiving about half of the precipitation (45.6% on average). Winter receives only an average of 2% of annual precipitation. Spring and fall receive about one-quarter of the annual average precipitation each. Although summer and fall are the most variable months for precipitation (standard deviation (SD) is 2.77 in. and 2.66 in. respectively), when normalized for total seasonal precipitation, winter is the most variable (SD: 0.752 in./in.) and fall is 50% more variable than summer (0.47 in./in. and 0.29 in./in., respectively).

Activity Status as of March 2016:

Water level, water temperature (wells only) and shelter temperature were recorded hourly at 7 wells. Transducers have failed at 2 wells and are no longer producing water levels. Changes in GW levels were analyzed and converted to GW recharge. Fifteen-minute rainfall sums were recorded at the 8 wells. A difference map was produced between subsequent synoptic water-level measurements and the change in groundwater storage was calculated for each basin in the study. All mass-balance data were re-interpolated to the new 60-m grid, which was chosen to be a multiple of the land-use 30-m grid data. Year 2015 received slightly lower-than-average precipitation.

Activity Status as of October 2016:

One failed transducer was replaced so water level, water temperature (wells only) and shelter temperature were recorded hourly at 8 wells. Fifteen-minute rainfall sums were recorded at the 8 wells. Evapotranspiration (ET) was calculated using a study-are-specific SWB model. The model produced ET estimates that were in good agreement with a previously produced State-wide SWB model and accounted for nearly all the unmeasured losses in the water mass-balance during the two 4-year pre-restoration and post-restoration balances.

Precipitation data were re-interpolated to a common 60m grid after errors were found. Groundwater recharge, groundwater discharge to ditches and total ditch runoff were re-calculated at all stations and were distributed among the mass-balance basins using Thiessen polygons and aggregated annually and seasonally. Annual change in groundwater storage was calculated by basin using a newly developed ArcGIS-based water-table interpolation tool. Evapotranspiration was calculated from 2002 through 2014 using a published Statewide SWB model and using a new, much more detailed, uncalibrated study-scale SWB model. All synoptic water-levels were contoured and maps subtracted to produce changes in groundwater storage. All components of the water budget are now calculated.

Land-use change summaries were calculated by basin seasonally. 60-m grids of landscape characteristic were produced that may explain changes between pre- and post-restoration hydrologic changes. Two abstracts were submitted and accepted to 2 conferences. Unfortunately, no funds are available to attend one of these conferences and we have withdrawn the abstracts.

Mass balances show that Rainfall in the study area was 14% less during the post-restoration period (post-RP, 2012-5) than during the pre-restoration period (pre-RP, 2003–6). During the periods, Streamflow rate decreased 34% to 14% of precipitation, and overland runoff decreased 33% to 9 % of precipitation. These decreases were offset primarily by increased evapotranspiration rate, which increased 6% to nearly 89% of precipitation. In addition, a larger portion of streamflow comes from groundwater discharge, which increased from 26% to 35% of total streamflow. Therefore, restorations not only cause a decrease of 34% in streamflow rate (streamflow/precipitation), but more of it comes from groundwater discharge leading to lower flood peaks and more sustained low flows.

Activity Status as of June 2017:

All water flows in 4 ditch basins were measured, compiled, quality assured, and analyzed in 4 ditch basins. Water flows in the groundwater and surface water systems changed as wetland and prairie restorations occurred in the basins. A draft USGS Scientific-Investigations report draft was prepared and is being finalized for colleague review and approval. This report will document the work done for activity 1 and present the details of the results of this activity.

Final Report Summary:

A comparison between the hydrology of the Glacial Ridge National Wildlife Refuge before and after wetland and prairie restoration shows substantial changes in flows of water through the hydrologic cycle and in the behavior of overland runoff and ditchflow during storms. Within the 6 basins measured for this study, the area of cropland decreased by 14 percent, the area of wetlands increased by 6 percent, and the area of native prairie increase by 19 percent between 2002 and 2015 due to restorations. During the same period, hydrologic changes had the benefits of decreasing runoff rate (-33 percent, as a proportion of precipitation) and ditchflow rate(-23 percent) within the study area. Peak ditchflow from storms decreased, ditchflow recessions lengthened, and baseflow from groundwater discharge increased, though only a small amount. These changes reduce the amount of water leaving the study area through ditches, reducing flows that contribute to flooding.

ACTIVITY 2:

Description: Measure and characterize water quality in four groundwater and surface-water basins for comparison with pre-restoration water quality.

Water samples will be collected at 9 wells and 5 streams during the two-year period of October 2013 through September 2015. Groundwater samples will be collected bi-monthly (except February), measured for field characteristics including alkalinity concentrations, and analyzed for nutrient concentrations. Surface-water samples will be collected bi-monthly, and measured and analyzed for the same characteristics and concentrations as groundwater, plus suspended sediment concentration. Six replicate and six blank samples will be collected from groundwater and surface-water samples to ensure that the analytical results represent the quality of the sampled waters.

The post-restoration state of water at Glacial Ridge will be characterized by the results of the analyses of these samples. The results of these samples will be combined with the results of samples collected during the previous 10 year and analyzed for temporal variability and trends in concentration. Water-quality differences among basins and through time will be documented and observed differences will explained on the basis of land use, weather, and climate differences and changes.

Summary Budget Information for Activity 2:	**ENRTF Budget:**	**$~~88,302.00~~**
		<u>$84,923.44</u>
	Amount Spent:	**$84,923.44**
	Balance:	**$ 0.00**

Activity Completion Date:

Outcome	Completion Date	Budget
1. GW and SW post-restoration status and trend sampling for nutrients and suspended sediment	October 2015	$~~70,522~~ <u>$67,143</u>
2. Water-quality trend and variability analysis	June 2016	$17,780

Activity Status as of October 2013:

One set of outcome 1 samples were collected 12 wells and 6 streams and analyzed for physical characteristics, nutrient concentrations, and sediment concentrations (SW samples only). Results were compared to historical concentrations to put them into context and identify water-quality trends.

Activity Status as of March 2014:

All water-quality data collected during October 2012–September 2013 were reviewed for accuracy and approved. Preparations were made for the April 2014 sampling trip.

Activity Status as of October 2014:

Five set of outcome 1 GW samples and 6 sets of outcome 1 SW samples were collected 9 wells and 4 streams and analyzed for physical characteristics, nutrient concentrations, and sediment concentrations (SW samples only). Results were compared to historical concentrations to put them into context and identify water-quality trends.

Activity Status as of March 2015:

One set of outcome 1 GW and SW samples were collected 9 wells and 4 streams and analyzed for physical characteristics, nutrient concentrations, and sediment concentrations (SW samples only). Results were compared to historical concentrations to put them into context and identify water-quality trends.

Nutrient concentrations continue to fall or remain low in samples from most wells. Nitrate concentrations are less than 5 mg/L as N in samples from all wells except G22S and E03. However, samples from about one-half of the wells now have increasing trends in nitrate, rising from a low in about 2010. Samples from well E03 are variable between 10 and 20 mg/L as N, compared with about 7 mg/L as N in 2004. The reason for these rises is unknown. Ammonia and phosphorus concentration are highest samples from wells in buried aquifers.

Nitrate, ammonia, and organic nitrogen continue to be the major nutrient in ditch water, all generally below about 1.5 mg/L as N. Ammonia is generally about an order of magnitude less than the other nitrogen compounds. Phosphorus concentrations also are generally low (generally less than 0.1 mg/L as P).

Activity Status as of October 2015:

Four sets of outcome 1 GW and and 5 sets of outcome 1 SW samples were collected 9 wells and 4 streams and analyzed for physical characteristics, nutrient concentrations, and sediment concentrations (SW samples only). Results were compared to historical concentrations to put them into context and identify water-quality trends.

Nutrient concentrations continue to fall or remain low in samples from most wells. Nitrate concentrations are less than 5 mg/L as N in samples from all wells except G16, G22S and E03. However, samples from about one-half of the wells now have increasing trends in nitrate, rising from a low in about 2010. Samples from well G16 continue to rise and are now approaching the drinking-water standard of 10 mg/L as nitrogen. This well is across the road from a farm field growing row crops. Groundwater flow directions should be analyzed to determine if it is a likely source for this nitrate.

Nitrate, ammonia, and organic nitrogen continue to be the major nutrients in ditch water, all generally below about 1.5 mg/L as N. Ammonia is generally about an order of magnitude less than the other nitrogen compounds. Phosphorus concentrations also are generally low (generally less than 0.1 mg/L as P).

Activity Status as of March 2016:

One set of outcome 1 GW and SW samples were collected 9 wells and 4 streams and analyzed for physical characteristics, nutrient concentrations, and sediment concentrations (SW samples only). Results were compared to historical concentrations to put them into context and identify water-quality trends.

Activity Status as of October 2016:

Nothing to report.

Activity Status as of ~~March~~ June 2017:

Groundwater and surface-water quality in 4 ditch basins were measured, compiled, quality assured, and analyzed in 4 ditch basins. Groundwater and surface-water quality generally improved as wetland and prairie restorations occurred in the basins. A draft USGS Scientific-Investigations report draft was prepared and is being finalized for colleague review and approval. This report will document the work done for activity 2 and present the details of the results of this activity.

Final Report Summary:

A comparison between the hydrology of the Glacial Ridge National Wildlife Refuge before and after wetland and prairie restoration shows substantial changes in water quality. Within the 6 basins measured for this study, the area of cropland decreased by 14 percent, the area of wetlands increased by 6 percent, and the area of native prairie increase by 19 percent between 2002 and 2015 due to restorations. During the same period, hydrologic changes had the benefits of improving water quality as measured by nitrate concentration (surficial groundwater median: -79 percent, ditchwater median: -53 percent) and suspended sediment in ditchwater (-64 percent) within the study area.

ACTIVITY 3:

Description: Attribute water-flow and -quality changes to wetland and prairie restorations and extend results to the rest of Minnesota, where appropriate.

- Compare changes in flows and water quality between pre- and post-restoration waters

When compared with the results of the pre-restoration study results, the water-flow and -quality measurements and analyses produced by this study will show how much flood reduction and water-quality improvement has occurred in the Glacial Ridge area as a result of wetland and prairie restoration.

- Attribute any changes to restorations or other factors such as weather variability and climate change.

Attributing flood reduction and water-quality improvements to restorations can be complicated by the vagaries of weather and by changing climate conditions, however. By comparing the amount of flood reduction among the four studied basins with the amount of restoration in the basins, we can identify and quantify the flood reduction produced by the restored wetlands and prairies. Likewise, by comparing the amount of water-quality improvement among the four studied basins with the amount of restoration in the basins, we can identify and quantify the water-quality improvement produced by the restored wetlands and prairies.

- Identify other parts of Minnesota that show promise for restoration and quantify benefits.

Once the amount of improvement that came from restorations has been quantified, we can look for landscape characteristics like soil type, land slope, percentage of remaining wetlands, original land cover and current land use to explain differences in improvements observed among the four basins studied. After identifying the landscape characteristics that maximize restoration benefits, we can identify other part of Minnesota that share these characteristics and would benefit most from wetland and prairie restorations in terms of flood reductions and water-quality improvements. Using the data from Glacial Ridge as a guide, we can estimate the amount of benefit one could expect from such restorations.

Summary Budget Information for Activity 3:	**ENRTF Budget:**	**$~~81,535.00~~**
		<u>$83,611.44</u>
	Amount Spent:	**$83,611.44**
	Balance:	**$0.00**

Activity Completion Date:

Outcome	**Completion Date**	**Budget**
1. Pre- and post-restoration hydrologic comparison	June 2016	$15,000
2 Extend restoration hydrologic implications to other areas of Minnesota	June 2016	$~~20,000~~ <u>$21,991</u>
3. Final project report	June 2016	$46,535

Activity Status as of October 2013:

Nothing to report.

Activity Status as of March 2014:

Nothing to report.

Activity Status as of October 2014:

Nothing to report.

Activity Status as of March 2015:

Land-use data were compiled from NRCS Wetland Reserve Programs records and remote sensing crop estimates (USDA Cropland Data Layer) to produce a time series of land use during the period 2006-13. These data will be used as input to the SWB model to estimate evapotranspiration for water mass balances. The data will also be used to quantify land-use change in the study area before and after restoration. Compilation of rainfall data has begun. Land-use analysis shows that restoration gradually increased after 2002 and was completed in 2011, primarily restoring cropland to native prairie and wetland. Much of the area immediately surrounding Glacial Ridge saw a shift from either fallow or uncultivated grassland to productive cropland during 2011-2013.

Activity Status as of October 2015:

Rainfall data were compiled, gaps filled in, and aggregated to seasonal and annual totals at 9 of the 10 study sites and the SCAN climate station. Gaps were filled in by data from the nearest 4 other sites. If data were missing at all 5 of these sites, DayMet data from the cell containing the site was used. Recorded winter precipitation data at all sites were retained and used in the compilation. Compiled rainfall data were interpolated to a 50-m grid of the study area for each day during 1 October 2002-31 December 2014. Analysis of precipitation between recorder sites and DayMet interpolations at the same locations showed that unheated raingage data recorded about 25% of winter precipitation. To adjust for this, all recorded precipitation was increased by 4-times before interpolation. Because timing of winter precipitation is not accurate, these data can only be used in winter aggregations.

Recharge based on water-level rise was calculated for all 10 continuous WL wells and aggregated seasonally and annually. An automated method to estimate recharge was developed using individual groundwater recession curves. This method will be used to more accurately estimate recharge at continuous water-level wells.

Initial work began on unit-hydrograph modeling of ditch-gage flow hydrographs.

Activity Status as of March 2016:

Rainfall data were compiled, gaps filled in, and aggregated to seasonal and annual totals at 9 of the 10 study sites and the SCAN climate station through 30 September 2015. Gaps were filled in by data from the nearest 4 other sites. If data were missing at all 5 of these sites, DayMet data from the cell containing the site was used. Recorded winter precipitation data at all sites were retained and used in the compilation. All rainfall data were re-interpolated to a 60-m grid of the study area for each day during 1 October 2002-30 September 2015. The new grid was chosen to be a multiple of the 30-m landuse data that will be used in mass-balance and landscape factor analyses.

Recharge based on water-level rise was calculated for all 10 continuous WL wells and aggregated seasonally and annually during 1 October 2002-30 September 2015.

Unit-hydrograph modeling of ditch-gage flow hydrographs was completed. Ditch flow was aggregated seasonally and annually during 1 October 2002-30 September 2015.

Problems were identified with the use of the Soil-Water Balance (SWB) model to estimate evapotranspiration for the mass-balance calculations. After evaluating several other options, we have decided to use the University of Wisconsin Extension's ET model and the WEPP model.

Activity Status as of October 2016:

Problems with the SWB model were overcome and ET was computed in all basins. All annual land use grids were finalized and summarized.

Activity Status as of ~~March~~ June 2017:

Landscape characteristics were analyzed to look for correlations with hydrologic improvements with wetland and prairie restorations in 4 ditch basins. Area of surficial aquifer and area of drained wetlands were most important. A map of the western one-third of Minnesota was prepared delineating areas where these conditions exist. These are the areas where the hydrologic benefits of prairie and wetland restoration will be most likely. A draft USGS Scientific-Investigations report draft was prepared and is being finalized for colleague review and approval. This report will document the work done for activity 1 and present the details of the results of this activity.

Final Report Summary:

Neither the density of restorations nor the beneficial changes in hydrology were evenly distributed throughout the study area. Amount of hydrologic benefits within an individual ditch basin did not correlate directly with amount of restoration in that basin. This is likely because of complicating factors within each basin like the kind of land restored, the amount of surficial aquifer, the amount of remaining ditches, and the density of closed wetland and lake basins.

An analysis of landscape characteristics that correlated with hydrologic benefits in the study area showed that area of surficial aquifer and area of drained wetlands are most important. Surficial aquifers provide a groundwater reservoir that can reduce runoff and slowly release water as baseflow to streams. Drained wetlands simply provide the opportunity for restoration of closed basins, which reduces streamflow. Areas with the highest density of surficial aquifers and drained wetlands have the highest potential for hydrologic benefits from prairie and wetland restoration. In western Minnesota, these areas are the uplands the Alexandria Moraine Complex and the beaches of Glacial Lake Agassiz on the eastern side of the western one-third of Minnesota, north of Wilmar, MN.

V. DISSEMINATION:

Description: The results of this study will be reported in a U.S. Geological Survey Science-Investigations report. This report will parallel USGS SIR 2007-5200, which reports on the hydrology of Glacial Ridge prior to wetland and prairie restoration. Periodic progress reports and the results of all research done at the Glacial Ridge NWR are posted to the following website, which is maintained by The Nature Conservancy, the U.S. Fish and Wildlife Service, and the USGS: https://sites.google.com/site/largescaleresto/. A copy of the USGS pre-restoration study is available at this site. All data collected for this study will be available from the USGS at the following map-based website: http://maps.waterdata.usgs.gov/mapper/. A site-based website will also be available: http://waterdata.usgs.gov/mn/nwis/. Interim and final results from the study will be presented at Minnesota and national scientific conferences. The project manager will also be available to make ad hoc presentations to managers and the public.

Status as of October 2013:

Nothing to report.

Status as of March 2014:

Nothing to report.

Status as of October 2014:

Nothing to report.

Status as of March 2015:

Nothing to report.

Status as of October 2015:

Nothing to report.

Status as of March 2016:

The final report outline was completed.

Status as of October 2016:

Two abstracts were submitted and accepted to 2 conferences. Unfortunately, no funds are available to attend one of these conferences and we have withdrawn the abstracts.

Status as of ~~March~~ June 2017:

A draft USGS Scientific-Investigations report draft was prepared and is being finalized for colleague review and approval. This report will document the work done for activity 1 and present the details of the results of this activity.

Final Report Summary:

The information generated by this grant will be documented in a U.S. Geological Survey Scientific Investigations Report that is in preparation. A draft of the report is attached to the project workplan. We expect the final draft of the report will be completed by 15 August. 2017. The report must be reviewed and approved, which we expect will occur by 31 October 2017. Once published, we will issue press announcements of the project results regionally and nationally. Additionally, the information in this report will be presented at several scientific meetings including that of the Minnesota Groundwater Association, the Minnesota Water-Resources Conference, and at annual conference of either the Geological Society of America or the American Geophysical Union. Presentations of interim result from this project have already been presented at meetings of the Minnesota Groundwater Association, the past Minnesota Water-Resources Conferences.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget:

Budget Category	$ Amount	Explanation

Red Lake Watershed District		
Personnel:	$1,740	• 1 administrator, Red Lake Watershed District, project administration, 1%-time for 3 years, 75% salary, 25% benefits
Professional/Technical/Service Contracts – U.S. Geological Survey		
Personnel:	~~$314,060~~ <u>$320,301</u>	• 1 hydrologist, USGS project management and groundwater specialist, ~~51%~~ <u>52%</u> time for 3 years, 75% salary, 25% benefits • 1 hydrologist, USGS surface-water specialist, 10% time for 3 years, 75% salary, 25% benefits • 1 hydrologic technician, USGS groundwater specialist, 17% time for 2 years, 75% salary, 25% benefits • 1 hydrologic technician, USGS surface-water specialist, 13% time for 2 years, 75% salary, 25% benefits • 1 student intern, USGS, 4% time for 3 years, 75% salary, 25% benefits
Professional/Technical/Service Contracts:	$27,283	6 groundwater hydrograph data collection, processing and analysis
Equipment/Tools/Supplies:	$9,253	Replacement equipment: 3 pressure transducers ($1070 ea.), data logger upgrades, telemetry modems, water-quality meters, probes, pumps sampling tubes, water filters, etc.
Printing:	$6,633	Production of the Final USGS Water-Resources Investigation report
Travel Expenses in MN:	~~$22,957~~ <u>$16,716.06</u>	Lodging, meals, vehicles
Laboratory Analyses	$17,307	96 groundwater nutrient and 66 surface-water nutrient and suspended sediment samples
Other:	$767	Data telemetry phone line, sample shipping
TOTAL ENRTF BUDGET:	**$400,000**	

Explanation of Use of Classified Staff: N/A

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

Number of Full-time Equivalent (FTE) funded with this ENRTF appropriation: 2.55 FTE over 3 years

Number of Full-time Equivalent (FTE) estimated to be funded through contracts with this ENRTF appropriation: 0.2 FTE over 3 years

B. Other Funds:

Source of Funds	**$ Amount Proposed**	**$ Amount Spent**	**Use of Other Funds**

Non-state: U.S. Geological Survey Cooperative Matching Program	$253,093	$43,997	Personnel, equipment, supplies, travel, training, quality assurance, expert support and consultation, office costs, computers and support, report production,
U.S. Fish and Wildlife In-Kind Services	$47,732	$5,304	Personnel
TOTAL OTHER FUNDS:	**$300,825**	**$49,301**	

VII. PROJECT STRATEGY:

A. Project Partners:

- Myron Jesme, Administrator, Red Lake Watershed District. Mr. Jesme will be the administrator of the project. The District will be receiving minimal ENRTF funds for project oversight and reporting.
- Tim Cowdery, Hydrologist, U.S. Geological Survey. Mr. Cowdery will be the principal investigator of the project. The USGS will be contributing 40 % of the non-water analysis project funds. The USGS will be receiving nearly all of the ENRTF funds. Mr. Cowdery is a principal investigator of the related USFWS Land Conservation Cooperative (LCC) project.
- Josh Eash, Hydrologist, U.S. Fish and Wildlife Service. Mr. Eash is a principal investigator of the USFWS LCC project, is a project science advisor and provides field support for data collection. Mr. Eash will be providing support to the project but will not be receiving project funds.

B. Project Impact and Long-term Strategy:

This proposal partially funds the final 3 years of the second part of a 14-year effort to scientifically document the flood-control, water-quality and habitat benefits of wetland and prairie restoration. The results of this second, post-restoration study will be compared to the initial $1.8-million pre-restoration hydrologic characterization to measure restoration success. Analysis of hydrologic and habitat changes resulting from wetland and prairie restoration at Glacial Ridge will identify promising restoration areas across Minnesota and quantify the benefits of restoration in those areas.

Water-quality analyses of agricultural herbicides and their metabolites were included in the 2005 pre-restoration study. Funding such sampling in the future would provide more complete understanding of water-quality benefits of wetland and prairie restorations, but exceed the funding available in this grant.

C. Spending History:

Funding Source	**October 2002-December 2006**	**January 2006-December 2010**	**January 2011 – June 2013**
MN Pollution Control Agency Clean-Water Partnership Grant	$900,000		
U.S. Geological Survey Cooperative Matching Program	$900,000	260,000	$220,667
U.S. Fish and Wildlife Service Ecological Contaminants grant			
U.S. Fish and Wildlife Service Landscape Conservation Cooperative grant		260,000	$200,000

U.S. Fish and Wildlife Service regional funds			$100,000
U.S. Fish and Wildlife Service Glacial Ridge NWR funds			$30,000
City of Crookston			$1,000

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. MAP(S): see Glacial Ridge 2013 maps.pdf

X. RESEARCH ADDENDUM: see Glacial Ridge 2013 Research Addendum.docx. This is the original USGS-approved, colleague-reviewed project proposal. It includes work not funded by the LCCMR. The proposal timeline is also obsolete because adequate funding was not secured for federal fiscal years 2012 and 2013. This proposal can be modified to include only LCCMR-funded work, if necessary.

XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted not later than 15 October, 2013, 15 March 2014, 15 October 2014, , 15 March 2015, 15 October 2015, 15 March 2016, and 15 October 2016. A final report and associated products will be submitted ~~between 31 December 2016 and 15 February 2017~~ on 30 June 2017 as requested by the LCCMR.

Attachment A: Budget Detail for M.L. 2013 Environment and Natural Resources Trust Fund Projects

Project Title: Measuring hydrologic benefits from Glacial Ridge habitat restoration
Legal Citation: M.L. 2013, Chp. 52, Sec. 2, Subd. 05e
Project Manager: Tim Cowdery
M.L. 2013 ENRTF Appropriation: $ 400,000
Project Length and Completion Date: 3 years, March 2017
Date of Update: 13 October 2016

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Revised Activity 1 Budget 28 June 2017	Amount Spent	Balance	Activity 2 Budget	Revised Activity 2 Budget 29 June 2017	Amount Spent	Balance	Activity 3 Budget	Revised Activity 3 Budget 29 June 2017	Amount Spent	Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	*28-Jun-17*				*Measure and characterize water quality*				*Attribute water-flow and -quality changes to wetland and prairie restorations*					
Personnel (Wages and Benefits)														
1 administrator, Red Lake Watershed District, project adminstration, 1%-time for 3 years, 75% salary, 25% benefits ($1,740 total)	$1,740.00		$1,740.00	$0.00									$1,740.00	$0.00
Professional/Technical/Service Contracts - USGS														
Personnel Overall (Wages and Benefits)	~~$175,835.00~~	$180,085.00	$180,085.00	$0.00	$58,692.00		$58,692.00	$0.00	$79,533.00	$81,523.94	$81,523.94	$0.00	$320,300.94	$0.00
1 hydrologist, USGS project management and groundwater specialist, 51% time for 3 years, 75% salary, 25% benefits ($207,567 total)			$109,399.61				$31,397.42				$35,715.67		$207,567.00	$31,054.30
1 hydrologist, USGS surface-water specialist, 10% time for 3 years, 75% salary, 25% benefits ($51,229 total)			$10,779.60				$4,311.83				$6,467.74		$51,229.00	$29,669.83
1 hydrologic technician, USGS groundwater specialist, 17% time for 2 years, 75% salary, 25% benefits ($22,693 total)			$38,137.67				$14,299.35				$10,628.07		$22,693.00	-$40,372.09
1 hydrologic technician, USGS surface-water specialist, 13% time for 2 years, 75% salary, 25% benefits ($27,727 total)			$11,545.62				$4,594.39				$4,115.21		$27,727.00	$7,471.78
1 student intern, USGS, 4% time for 3 years, 75% salary, 25% benefits ($4,844 total)			$10,222.50				$4,089.01				$24,597.25		$4,844.00	-$34,064.76
Professional/Technical/Service Contracts by USGS USGS groundwater hydrograph collection and processing: 9 sites	$27,283.00		$27,283.00	$0.00									$27,283.00	$0.00
Laboratory analyses USGS National Water-Quality Laboratory: 96 groundwater nutrient and 66 surface-water nutrient and suspended sediment samples					$17,307.00		$17,307.00	$0.00					$17,307.00	$0.00
Equipment/Tools/Supplies: Sampling supplies: filters, preserv. acid					$3,053.00		$3,053.00	$0.00			$0.00		$3,053.00	$0.00
Expendable groundwater and surface-water gaging equipment: pressure transducers (3 transducers, $1,070 each), data loggers, telecommunication equipment, etc.	$5,200.00		$5,200.00	$0.00									$5,200.00	$0.00
Water-quality sampling equipment: water-quality meters, probes, pumps, sample tubes, etc.					$1,000.00		$1,000.00	$0.00					$1,000.00	$0.00
Printing USGS Science Investigation Report production	$3,319.00		$3,319.00	$0.00	$1,312.00		$1,312.00	$0.00	$2,002.00		$2,002.00	$0.00	$6,633.00	$0.00
Travel expenses in Minnesota: Lodging: $85 per night, 35 person-weeks	~~$8,510.00~~	$6,269.24	$6,269.24	$0.00	~~$3,361.00~~	$1,593.97	$1,593.97	$0.00					$7,863.21	$0.00
Meals: $36 per day, 35 person-weeks	~~$4,516.00~~	$3,894.38	$3,894.38	$0.00	~~$1,784.00~~	$972.22	$972.22	$0.00					$4,866.60	$0.00
Vehicles: 750 miles/trip, 35 trips	$3,431.00		$3,431.00	$0.00	~~$1,355.00~~	$555.25	$555.25	$0.00					$3,986.25	$0.00
Other Data telemetry phone line	$329.00		$329.00	$0.00									$329.00	$0.00
Sample shipping					$438.00		$438.00	$0.00					$438.00	$0.00
COLUMN TOTAL	**$231,550.62**		**$231,550.62**	**$0.00**	**$84,923.44**		**$84,923.44**	**$0.00**	**$83,525.94**		**$83,525.94**	**$0.00**	$400,000.00	$0.00