Minnesota Pollution Control Agency
520 Lafayette Road
St. Paul, MN 55155-4194

319/Clean Water Partnership/ Total Maximum Daily Loads

Semi-Annual Report for Reporting Year 2009

Reporting Period: ☐ January 1 through June 30, 2009 (Due August 1, 2009)
☒ July 1 through December 31, 2009 (Due February 1, 2010)

All information is required by U.S. Environmental Protection Agency (EPA). Do not leave blanks. This report form can be typed using your computer. Use the "**tab**" key to move through the fields of this form. Enter responses using text and check boxes as indicated. Keep a copy for your records.

I. General Report Information

1.	Project Title:	Duluth Residential Stormwater Reduction Demonstration Project for Lake Superior Tributaries		
2.	Project Sponsor:	City of Duluth/Utility Operations		
3.	Project Representative:	Chris Kleist		
4.	Email Address:	ckleist@duluthmn.gov		
5.	Loan Sponsor (if applicable):			
6.	Contract Number:	B10575	Loan Number:	
7.	MPCA Project Manager:	Karen Evens		
8.	Contract Start Date:	2-27-2008	Contract End Date:	6-30-2011
9.	Best Management Practice (BMP) Name (Refer to BMP List):	570, 912		

10. **319/Clean Water Partnership (CWP) only** - Nonpoint Source (NPS) Category (Refer to NPS Definition of Categories):

	Primary	Secondary	Others
Category			

11. **319/CWP only** - NPS Functional Category (Refer to NPS Definition of Categories):

	Primary	Secondary	Others
Category	**20**	**600**	

12.	Waterbody type (refer to NPS Waterbody Type):		**ST**	
13.	Hydrologic unit code (8 digits):	04010102	Latitude-longitude:	**46'50''11''' x -92'00''22'''**
14.	**319/ CWP only:** Type of pollutant(s) addressed (refer to NPS Pollutants):	**1500**		
15.	Ecoregion (refer to NPS Ecoregion):	**5000**		

16. Basin name (check all that apply): Statewide

- ☒ Lake Superior
- ☐ Lower Mississippi/Cedar
- ☐ Upper Mississippi
- ☐ Minnesota
- ☐ Rainy
- ☐ Red River
- ☐ Des Moines
- ☐ Missouri
- ☐ St. Croix

II. Project Description

1. Project Description Summary (taken from work plan summary) – Include at least two paragraphs that briefly summarize the project scope, the processes and the events that occurred **before** this reporting period.

We propose to demonstrate the effectiveness of residential Best Management Practices (BMPs) at reducing stormwater runoff problems for Lake Superior tributaries. We will install residential BMPs in a subwatershed in an older residential neighborhood and compare the runoff to that of similar control subwatersheds without stormwater BMPs. The neighborhoods identified for the program are located in the Lester-Amity stream system that is on the Minnesota 303(d) list for turbidity. Tributaries receiving the runoff from the targeted neighborhoods/subwatersheds are being severely eroded by high peak flows and deliver highly turbid water to the stream. Water flow, temperature, and turbidity measurements will be taken within storm sewers in both subwatersheds before and after BMP installation, requiring *three* full field seasons of work. Flow, temperature, and turbidity data from storm sewer flow will be posted and interpreted on the educational Lake Superior Streams website, as will final results. Residents' knowledge of runoff issues, solutions, and responsibilities will be evaluated at the beginning and end of the project. Results from this demonstration project should be applicable throughout the Great Lakes.

Both Lester River and Amity Creek are on the Minnesota 303(d) list for excessive turbidity. Other Lake Superior North Shore and South Shore streams, and streams elsewhere around the Great Lakes, face similar problems. In the western arm of Lake Superior, streams nearing the lake often cut through clay or clay loam soils. These highly erodable soils are particularly vulnerable to excessive stream power caused by high levels of runoff during heavy rainstorms and snowmelt (Anderson et al. 2003). Runoff from residential neighborhoods helps to create these high peak flows, leading to the erosion that creates turbidity in Amity Creek and similar stream systems. City staff report many complaints from residents about wet yards and winter icing from sump pump activity. The City is seeking an effective program for addressing this nuisance ponding at the source, as well as reducing flows to the storm water system and reducing winter icing problems.

The Amity Creek tributary under consideration for the proposed project runs turbid during storm events, and has severely eroding banks and gullying due to excessive runoff received from adjoining neighborhoods' storm sewers. Excessive runoff, and the associated sediment caused by the increased erosion, often carries greater loads of nutrients and chloride into streams (Anderson et al. 2003). In Duluth, total runoff infiltration is not feasible, so this project is directed at reducing high intensity flows, primarily by retention with some increased infiltration. We will demonstrate that runoff retention BMPs implemented at the residential level can reduce storm sewer peak flows. The project will also document the challenges and solutions to retrofitting older residential areas (30-50 yrs old) with runoff BMPs. The end result will reduce runoff/footing drain discharge within a problem subwatershed and create a demonstration project for other Lake Superior and Great Lakes communities.

The project began Feb. 27, 2008. Prior to this, the project leaders met with the Minnesota leaders of the 319 SIDMA Social Indicators Evaluation project. These researchers are assisting EPA in developing an evaluation survey tool to help document improvements in knowledge and awareness by the public in areas where 319 programs are active. Our project was selected as a test case; several of us helped beta-test the SIDMA software and survey system; later, two different survey types were developed and administered as pre-BMP installation surveys: the KAP survey given door-to-door by a Minnesota Conservation Corps college crew and the EPA SIDMA survey at a neighborhood meeting. The door-to-door survey was very successful, with a 72% response rate.

Monitoring equipment (flow, temperature, conductivity, and turbidity) was installed in the neighborhood storm sewer systems from April –November, 2008. Collection of the pre-BMP storm sewer flow and temperature data was quite successful, and the high number of rainstorms in 2008 provided an interesting pre-BMP dataset. The two control streets are fairly well matched in terms of runoff amounts, with the study street being somewhat more difficult to figure out. However, season and apparently the amount of soil saturation make a large difference in the amount of runoff coming through storm sewers. For example, rainfall events in the spring and early summer, or following another rainstorm, result in high amounts of runoff, while similar amounts of rain in mid-to-late summer and after a dry spell result in much lower runoff amounts. Two volunteers willing to read rain gauges were found near the target neighborhoods and provided with rain gauges, monitoring instructions, and data collection spreadsheets. They have been providing data from April – October on rain amounts to help determine the exact amount of rain falling on the neighborhoods. This helps us check the numbers coming from the city's recording rain gauges, which are several miles from the study site.

All residents of the three streets in the target area were invited to a neighborhood meeting in early September. At this meeting, we had the residents take and provide feedback on the SIDMA survey. The SIDMA survey, with its locked choice of questions, was not a good fit for our small project, taking a long time for folks to fill out and providing our research team with little of the information that we really wanted to get from residents. The main goal of the meeting, however, was to provide the residents with a description of the project and information about the potential BMPs that we will be offering to the street that is chosen as the treatment street. Surprisingly, the street showing the most interest was the one we had not considered because its storm sewer pipes are a slightly different configuration than the other two streets. The meeting went well, although it was attended by only about a dozen residents (out of more than 70 households invited).

After consideration of a number of factors, we elected to install BMPs on the street whose residents showed the greatest amount of interest in participating in the project because they truly had runoff problems. Although this means that we will not be installing BMPs at the school, the school is scheduled for closure within the next year or so and we had doubts about using the school as a site because of this. Approximately 20 households initially indicated willingness to consider accepting BMPs. Engineers from South Saint Louis Soil and Water Conservation District and Barr Engineering along with Sea Grant and NRRI personnel immediately started working on potential BMPs for each property. These included: work on a stormwater ditch that drains runoff in the backyards between the streets, locations for rain gardens, areas in which tree and shrub plantings would be beneficial, driveways in need of trench drains that lead to rain gardens, and rain barrels. Each property owner was visited individually to discuss their runoff/water problems and the potential solutions the team had generated. Only BMPs that the landowners approved of and thought that they could care for were selected for inclusion. Landowner acceptance and "ownership" of the BMPs is considered crucial to the long-term success of the BMPs. Most stormwater BMPs require some maintenance, at least initially, and many require a long-term commitment. All residents willing agreed to provide at least 10 hrs of assistance with the project, most of which will consist of caring for the BMPs that they receive.

The MCC College Program provided us with a 4 person crew to assist with the planting trees and shrubs in late May. In two days, the MCC, assisted by 4 other Sea Grant and NRRI personnel and our project intern, planted and fenced (against deer) over 250 trees and shrubs on 18 properties. City of Duluth personnel were instrumental in assisting with marking planting locations, getting utilities located for the digging, and helping purchase and move the fencing materials. Over the next few years as these trees and shrubs grow, their roots should greatly increase the amount of stormwater infiltration in these areas that were formerly turfgrass lawn.

2. Specific Project Goals – Include numeric, quantifiable goals for environmental improvement, the number of Best Management Practices to be installed, **pollutant reductions** as well as programmatic and social goals.

We are using paired subwatersheds (neighborhoods) of Amity Creek to demonstrate the effectiveness of homeowner BMPs to reduce residential stormwater and footing drain water to storm sewers. The resulting data will be interpreted on an existing stream education website and used to educate neighborhood, city of Duluth, and regional residents on stormwater issues, individual responsibility, and BMP options. Flyers and training materials developed in the course of this project will be used by the City, Minnesota Sea Grant, and other local agencies and groups to inform area residents about stormwater issues and BMP choices that individuals can implement. All of these activities will result in reduced stormwater inflow to storm sewers.

- We will install as many residential stormwater runoff reduction BMPs as the grant can afford and homeowners in the target neighborhood will accept – the target is at least a dozen homes accepting a BMP.
- The project will result in a measurable increase in the knowledge and understanding of neighborhood residents about stormwater runoff issues, environmental problems, and ways that they can help solve the problem (i.e., increase in individual responsibility).
- We expect that the stormwater flow will be measurably reduced in the storm sewers of the target neighborhood. These storm sewers flow into a local 303d-listed stream, Amity Creek.
- The ability of the Regional Stormwater Protection Team members to cooperate and collaborate on stormwater runoff reduction issues will be substantially increased by their collaboration on this project, making future projects both more likely and easier to initiate.

III. Semi-annual Report Information

1. Project activities completed during last six (6) months according to the program elements or tasks:

Program Element 1: Pre-installation analysis of paired watersheds

Objectives A and B: Installation of Monitoring Equipment and Collection of Baseline Stormwater Data:

Flow monitors and Hydrolab units that record flow volume, temperature, turbidity, and conductivity were installed in the two storm sewers draining the control and target neighborhoods from April through early November, 2008, and were reinstalled from late March to late November 2009 to get more pre-construction storm flow data, and to see how things start to change as BMPs are installed (Figure 2, Table 1). Unfortunately there were few spring rainstorms this year, with May, June, and early July very dry. The two volunteer rain gauge readers continued providing rainfall data the whole ice-free season (April-Oct. 2009). These objectives are now complete.

Objectives C&D were previously completed.

Program Element 2: Stormwater BMP installation

Objective E: Design property-specific BMPs.

During the spring, engineers from South Saint Louis Soil and Water Conservation District and Barr Engineering visited all of the participating properties (20), talked with property owners, and developed site-specific BMPs for each property. This objective is now complete.

Objective F: BMP installation training

After discussion with MCC staff, we determined that our plans to hold formal BMP installation classes open to both landscapers and to train the MCC crews were not the ideal method for crew training. Instead, MCC youth crews were given an overview of the project and its goals and then provided with specific, detailed, on-the-job training for each task as it was encountered, with continual oversight by project leaders. The youth crews and their leaders learned quickly and over the two weeks became very good at tasks they got to do several times. For example, several MCC youth became very interested in the rain garden plants and helped sort and lay out the hundreds of plants used in the rain gardens. This involved looking up information about each species to determine whether it should be planted in shade, part-shade, or sun, and then what wetness level each species could tolerate, then matching these characteristics to garden design schematics and delivering the proper plants to the proper locations in each garden. Other MCC youth became good at building ditch checks to slow and filter water in the stormwater ditch. This method of training worked well for MCC. Now that the BMPs are in place we will hold rain garden classes during summer 2010 for local gardeners and landscapers and use the rain gardens built by us and MCC as examples for the classes.

Objective G: Install stormwater BMPs

During July, city of Duluth, NRRI, and Sea Grant personnel worked with MCC youth corps crews to install the BMPs designed under Objective E. In all, 22 homes in the general drainage area for the treatment street agreed to some type of BMP (see Figure 1). For each specific task, MCC crews were given specific on-the-job training, including safety training, and then supervised closely. Erosion control measures were installed for each project as needed before construction began. The crews re-dug 200 feet of stormwater runoff ditch in the unbuilt alley between two of the streets. This will increase the capacity of the ditch to store stormwater. Stormwater storage was further

increase by installing 5 ditch checks (these look like rock dams) along the ditch to slow and hold back some of the stormwater and make sure that it drops any sediment it is carrying. Five rain gardens were created on 4 properties, ranging in size from about 50 sq ft. to about 100 sq ft. These were planted with a variety of flowers and other plants. Two of the gardens have underdrains leading to rock-filled sumps for additional water storage. Drain tile was installed in two properties beneath swales to improve conditions for the property owners and reduce water runoff onto the street, which was creating a large ice problem in winter and resulting in large amounts of salt being applied. If this fix works, chloride entering the stream from this section of street should be greatly reduced. Rock sumps along the curb were dug in a number of places where water is flowing from sump and foundation drains. These sumps provide additional water storage and will help reduce peak flow during rainstorms. Twenty rain barrels were installed; most were 50 gallon, but one was 100 gallon. These will hold back over 1000 gal of water during each rainstorm if the residents remember to empty them between storms. A few additional trees and shrubs were obtained and planted, including fencing to decrease damage from deer. All lawns on the treatment street and a few of the back yards of the uphill street were aerated. This should help increase rainwater infiltration in these heavy clay soils. Finally, in an effort to continue to get homeowners to mow less lawn, wildflower plants and seeds were planted amongst the trees and shrubs that we planted in May. We are hoping that if these areas of lawn have pretty flowers, the residents will quit mowing them. In a few years, the trees and shrubs will be large enough on their own to discourage mowing. Wildflower seeding was done by college students involved in the Green Duluth program (a program paid for by Duluth that pays college students to canvas everyone in the city to get homeowners to make their homes more efficient through free or subsidized programs). Green Duluth's 10 students spent an afternoon planting wildflower seeds on a completely volunteer basis after hearing about the project and wanting to be involved. They planted wildflower seeds on 10 properties. This objective is now complete.

2. Challenges faced (optional):

- Neither of the two streets originally targeted for potential BMP installation proved to be ideal. Instead, the intervening street was deemed to both have more interested residents and to have more potential for stormwater runoff reduction BMPs to have a significant effect. Therefore, we installed monitoring equipment in the intervening street in September 2008 to catch the fall storms for pre-installation data. Monitoring equipment was reinstalled in late March 2009 to catch the spring runoff and storms to add to the pre-installation data. Unfortunately, spring and early summer rainstorms were sparse, leaving us with less pre-construction data than we would like.
- A beaver took up residence in the storm sewer of the targeted BMP street. Before he could be removed he cut down eighteen 10-20 yr old aspen trees and filled a stormwater catch basin about 2/3 full of sticks. Fortunately, there was no damage to monitoring equipment and there were no major rain events during this period.
- Few rain events during fall 2008 and spring 2009 means that we have less pre-installation data from the study street than we would like. The BMP street's runoff also seems to be somewhat less predictable in relationship to the control streets than we had anticipated. This will make data analysis more difficult and we are exploring ways to deal with these issues.
- In discussing plans for the BMP installation training workshop (Objective F), we discovered that our classroom-based plans were inappropriate for training the MCC youth who would be working with us on BMP construction. Thus we provided hands-on training with intensive supervision for the installation work with the MCC crew. We are planning spring 2010 rain garden workshops and study-site tours for local landscape professionals and interested gardeners.
- More sand, sediment, and debris are moving through the storm sewer pipes than we expected, burying the monitoring probes at times. This has resulted in a need for more frequent equipment care than was anticipated, causing higher personnel costs for monitoring than we projected. This has also caused the chloride and turbidity data to be quite compromised. On the other hand, it provides a good teaching opportunity for us to talk to the residents about keeping the storm sewers clean.
- Construction of BMPs, particularly the ditch and trench digging by hand, were more difficult than anticipated. We compensated by renting small walk-behind power digging equipment, and the MCC youth crews and our UMD summer intern proved that they were very tough and could work very hard. We also discovered that curb drain pipes were not in the locations indicated on city street maps. We compensated by creating rock and gravel deep sumps for water storage.
- Administratively, the Expenditure Report is in a form that is very difficult for the University and the Project Manager to complete, and it may be impossible to make the amounts exactly match those that are invoiced. However, detailed monthly invoices are submitted by the University of Minnesota's Sponsored Projects Administration office and detailed personnel effort records are maintained by the University and NRRI based on bi-monthly (2 week) reporting intervals.

3. Summary of monitoring data collected:

Table 1. Storm sewer flow data for March-November 2009 for streets in the project area. Note that flow measurements from the treatment street (Idlewild) may be inaccurate after July due to erosion control measures in place for BMP installation.

Date	Rain (inches)	Ivanhoe (control)	Idlewild (trt)	Kingston (control)
3/22-3/25/09	1.4	611560	184834	131605
5/5/2009	0.42	18990	10506	5692
5/15-5/16/09	0.4	11790	4553	6386
6/8-6/9/09	1.22	63355	22812	22518
7/14-7/15/09	0.82	1860	1337	7708
7/21-7/26/09	1.09	81575	6615	35086
8/9/2009	0.4	3440	1724	2820

8/19-8/20/09	1.99	90045	23245	39076
8/28/2009	0.43	10260	497	4674
10/6-10/7/09	0.64	8740	1300	8126
10/29-11/3/09	1.62	46180	10985	55118
11/13-11/17/09	0.58	63770	17728	21584
Totals	**11.01**	**1011565**	**286136**	**340393**

Table 1 shows storm sewer flow data for March – November 2010 for the two-block area of all three streets in the neighborhood. The older control street (Ivanhoe) contributes more stormwater than the newer control street (Kingston), in general, during rainstorms, but these data have not yet been weighted by drainage area. The stormwater flow from the BMP street (Idlewild) is highly variable. As expected, the amount of water entering storm sewers depends on the dryness of the soil, so that rain events shortly after snowmelt result in greater storm sewer flows than rain events that occur later in the spring and summer after the soils have dried. See Figure 1 for a visual representation of these data.

Note: Data are collected in residential stormwater sewers and thus are not appropriate for the STORET system. Therefore these data are not being submitted to STORET, but will be made available on request to interested parties.

4. Have all monitoring stations been established in STORET? ☐ Yes ☒ No

5. Are the data being routinely submitted for storage into STORET? ☐ Yes ☒ No Last submittal date:

6. Are the data being annually entered into E-Link? ☐ Yes ☒ No Date last entered:

7. Identify any significant **findings** and **results** of the project to date, as well as any unanticipated findings:

Flow data were collected with reasonable ease during the ice-free season of both years. The streets are generating reasonably comparable amounts of runoff and the runoff pattern is quite similar for two streets. However, the amount of runoff is greatly influenced by season and time since the last significant rain event. We interpret this as a soil moisture effect, with much greater runoff occurring when soil moisture levels are high and the ground cannot hold much water. This is good news, indicating that there may be more potential for infiltration than we had first thought. However, it will make data analysis more difficult because it means that the amount of runoff from a one-inch rainstorm may vary by 4 or more times depending on soil moisture levels. We are investigating statistical and modeling ways to deal with this analysis issue.

Temperature data were also reliably collected from the storm sewers during runoff events in 2008. Unlike the flow data, there was sometimes a large temperature difference in the summer between the streets, with the runoff from the oldest and most shaded street being more than 5 ºC cooler than the runoff from the newest and almost completely unshaded street (figure in previous report). We will be able to use these data to demonstrate the benefits of street shading in helping to keep runoff cool, and thus helping to keep our local streams cooler during summer rainstorms.

8. Describe specific (quantifiable, if possible) results achieved during this period:

Flow, temperature, turbidity, and conductivity monitoring devices were successfully installed in two storm sewer pipes and quantitative stormwater runoff and stormwater temperature data were collected from April to November, 2008, and 2009.

Twenty rain barrels capable of holding back over 1000 gal were installed. Five rain gardens capable of holding back several hundred gallons of water each were installed. The stormwater ditch in which ditch checks were installed should be able to store several hundred more gallons of water. Each of the rock sumps can hold 100-200 gal of water. More than 250 trees and shrubs were planted and fenced on 18 properties to increase infiltration and encourage smaller lawn sizes.

9. Summarize any work plan changes:

After the work plan was written, but prior to the start of the contract, the project team realized that one of the two proposed locations was not as appropriate for this work as previously thought. Since only one location was to be selected, the inappropriate location was dropped from consideration at that time and all efforts have since focused on the Lakeside neighborhoods.

During the organizational meeting, the project team expressed doubt about installing BMPs at the neighborhood school because that school is now on a list for closure and much of the school grounds do not drain into the storm sewers that are being monitored. Instead, we installed all the BMPs in the target neighborhood, which are those properties that drain to the storm sewers on the middle street (Idlewild St.).

We discovered that our BMP installation training workshop, planned as largely a classroom exercise, would be inappropriate to adequately train the MCC youth who will be providing the labor for most of our BMP installation. Thus we held on-site hands-on training with high levels of project personnel supervision. A BMP workshop for area landscape professionals will be held spring or summer 2010 so that it can include lessons-learned from the BMPs installed in Lakeside. It will also include a visit to the Lakeside study area to view the BMPs.

10. List anticipated activities for next six (6) months:

Objective F: Conduct BMP Training Workshop

We will host at least one, possibly two, rain garden workshops for gardeners and landscape professionals this summer.

Objective H: Collect post-installation stormwater data

Starting in March or April, monitoring equipment will again be placed in the storm sewers of all 3 streets to collect post-installation ("after") data for comparison with the pre-installation ("before") data.

Objective J: Education, outreach, and evaluation

We are designing web pages for the Lake Superior Streams website that will inform the public about the project and will allow us to more easily keep neighborhood residents up-to-date on it. We will post data from the project on this website, as well as sample and summary results that are explained for the general public. We are also developing some of the storm runoff data into "vignettes" that feature animated graphs to illustrate the flow through the storm sewer from the neighborhoods.

11. List all products (documents, pamphlets, videos, maps, etc.) produced in this reporting period.

We have created a number of presentations about this project, the BMPs, and our results thus far. We have also created a couple of handouts about the project and BMP options as well as collecting handouts on BMPs from a number of other organizations around the state and nation. Maps of the neighborhood area showing storm sewer flow direction have been created.

IV. Expenditure Information for this Period

CWP: Provide a copy of the Expenditure Report with cumulative expenditures and this period's expenditures budget balances by work plan program element. The format for the Semi-Annual Expenditure Report is available on the Web at: http://www.pca.state.mn.us/publications/wq-cwp7-09.xls.

☒ Expenditure Report attached

Note *- the Expenditure Report requires a level of detail that cannot be matched by University research managers, and is probably impossible for the project manager to complete accurately. Detailed monthly invoices are submitted by the University of Minnesota's Sponsored Projects Administration office to the City (forwarded to MPCA), just as they are for other MPCA and EPA grants. Detailed personnel effort records, including match, are maintained by the University and NRRI based on bi-monthly (2 week) reporting intervals. The matter should be discussed with Naisan Madson, Senior Accountant, Sponsored Financial Reporting 200 Oak Street SE Suite, Suite 450, Minneapolis, MN 554455 Phone: 612-624-8262 Fax: 612-626-0321 Madso067@umn.edu. We will submit a summary of Match contributions as soon as possible with the same level of detail as per the University Invoice. Match amounts from the University typically are running about 3 months behind the MPCA reporting periods.*

CWP, 319, and TMDL - Complete the table below:	**Amount**
Total Grant Amount:	**167,383**
Total Match Amount (if applicable)	**167,384**
Total Project Amount:	**334,767**
Cumulative Grant Expenditures through this period:	**79,689**
Cumulative Match Expenditures through this period:	**141,191**
Total Cumulative Expenditures through this period:	**220,880**

Date form completed:	2/07/2010
Please submit to:	Karen Evens, MPCA

Figure 1. Aerial photograph of study neighborhoods near Amity Creek and its tributaries (6 blocks to the west). Gold rectangle indicates approximate drainage area for storm sewers on treatment street. Monitoring locations on the treatment street and control streets are marked with an M (equipment down in the storm sewers). Beaver damage location is noted. Other codes indicate BMPs installed on each property: B = rain barrel in 50 gal equivalents (2 = 100 gal or 2 at 50 gal, etc); S = sump (rock-filled hole in the ground, approx 3 ft long, 2.5 ft wide, and 3.5 ft deep); D = ditch or trench to drain/store water; G = rain garden (number indicates how many if more than 1); A = lawn aeration; TS = trees, shrubs, and wildflowers planted; N = no treatment

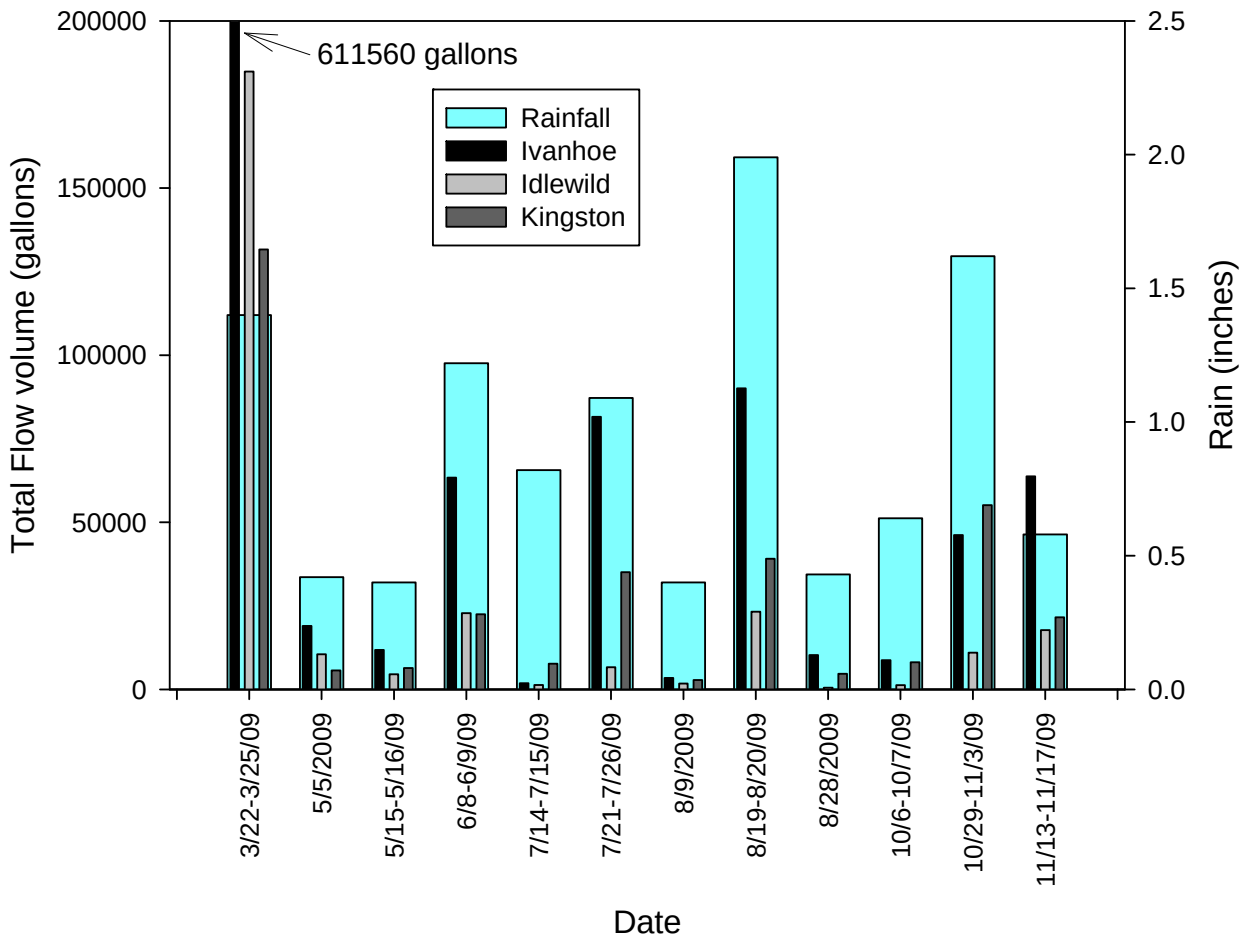

Figure 2. Rainfall and storm sewer flow data for the three study streets for rainfall events in 2009. Note that the relative amounts of flow from the 3 streets are not at all consistent over time, with each street sometimes generating much more runoff than the neighboring two streets. 2009 was quite a dry year, with few large rainfall events. Note the high runoff for a rainstorm that occurred during or just after snowmelt in March.