Skogman-Fannie-Elms-Florence Lakes Chain Stormwater Retrofit Analysis

Prepared for the

ISANTI COUNTY SOIL AND WATER CONSERVATION DISTRICT

By

ANOKA CONSERVATION DISTRICT

CLEAN WATER LAND & LEGACY AMENDMENT

Funding provided in part by the Clean Water Fund of the Clean Water, Land, and Legacy Amendment

November 2014

Cover photo: Aerial image of (from left to right) Florence, Elms, Fannie, and Skogman Lakes. Photograph was taken in 2011.

LIST OF FIGURES ..... **III**

LIST OF TABLES ..... **IV**

EXECUTIVE SUMMARY **1**

ABOUT THIS DOCUMENT **8**

Document Organization 8
Background *8*
Analytical Process *8*
Analytical Elements *8*
BMP Descriptions *8*
Catchment Profiles *8*
Retrofit Ranking *9*
References *9*
Appendices *9*
Abbreviations 10

BACKGROUND **11**

ANALYTICAL PROCESS **13**

ANALYTICAL ELEMENTS **14**

Target Pollutants 14
Potential Project Types 15
Project Categories 16
Cost Estimates 17
Location in Watershed 17
Project Selection 18

BMP DESCRIPTIONS **19**

Bioretention 19
Curb-cut Rain Gardens *20*
Boulevard Bioswales *22*
Rain Leader Disconnect Rain Gardens *23*
Lakeshore Restorations 24
New Wet Retention Ponds 26
Iron-Enhanced Sand Filters 28
Retention Pond IESF Bench *28*
IESF Basin *29*
Permeable Check Dams 31
Vegetated Filter Strips & Grassed Waterways 33
Water and Sediment Control Basin (WASCOB) 35
Wetland Restorations 37

CATCHMENT PROFILES **40**

Catchment Profiles Section 1: Urban Catchments 41
Catchment 1 43

Catchment 2 46
Catchment 3 52
Catchment 4 60
Catchment 5 66
Catchment Profiles Section 2: Rural Catchments 79
Catchment 6 81
Catchment 7 87
Catchment 8 96
Catchment 9 104
Catchment Profiles Section 3: Lakeshore Projects 107
Skogman Lake 108
Fannie Lake 112
Elms Lake 116
Florence Lake 119

PROJECT RANKING 126

REFERENCES 130

APPENDIX A – MODELING METHODS 131

Water Quality Models 131
Input Parameters for ArcSWAT 131
ArcSWAT Model Calibration 133
Input Parameters for WinSLAMM 136
Simulating BMPs in SWAT 137
Wetland Restorations 137
Filter Strips 139
Sediment Basins 140
New Ponds 140
Simulating BMPs in WinSLAMM 141
Bioretention Practices 141
IESF Basins and Benches 142
Permeable Check Dams 144
Other BMP Modeling 146
Lakeshore Restorations 146

APPENDIX B – PROJECT BUDGET ESTIMATES 148

IESF Benches 148
IESF Basins 150
Permeable Check Dams 151
New Regional Pond 151

APPENDIX C – ADDITIONAL RANKING TABLES 152

Cost-Benefit for Reducing TSS 152
Cost-Benefit for Reducing Stormwater Volume 156

List of Figures

Figure 1: Proposed stormwater retrofits in the SFEF subwatershed 3
Figure 2: Areas in which projects were proposed, including urban catchments (1-5; colored blue), rural catchments (6-9; colored orange), and along lakeshore properties (colored red). Ranking table color-coding matches this figure. 4
Figure 3: Curb-cut rain gardens before and during rainfall events 21
Figure 4: Right-of-way bioswale installed in New York City (NYC Environmental Protection, 2013) 22
Figure 5: Photographs during (left) and years after (right) a shoreline restoration 24
Figure 6: Typical Cross Section - Simple Design 24
Figure 7: Conceptual images for native plant restorations 25
Figure 8: Schematic of a stormwater retention pond. Figure from the Urban Subwatershed Restoration Manual Series, Chapter 3: Urban Stormwater Retrofit Practices. 26
Figure 9: Iron-Enhanced Sand Filter Concept (Erickson & Gulliver, 2010) 29
Figure 10: Typical IESF basin detail (http://www.minnesotaikes.org/Summit/Summit-2013/Maplewood%20Mall_MEK2.pdf) 30
Figure 11: Rock check dams in a small ditch (www.casfm.org/stormwater_committee/LID-Summary.htm) 31
Figure 12: Check dam schematic (MPCA 2000) 31
Figure 13: Filter Strip (Ohio State University Extension, web) 33
Figure 14: Grassed waterway (US Department of Agriculture, web) 33
Figure 15: Water Control Attached to Drain Tile (illustration courtesy of Illinois NRCS - modified) 35
Figure 16: Box weir around a culvert 37
Figure 17: Channel weir 37
Figure 18: Outlet Control Retrofit 39
Figure 19: Water Control Attached to Drain Tile (illustration courtesy of Illinois NRCS) 39
Figure 20: Map of stormwater catchments referred to in this report. Catchment Profiles on the following pages provide additional detail. 40
Figure 21: WinSLAMM input screen for a curb-cut rain garden 141
Figure 22: WinSLAMM input screen for a boulevard bioswale 142
Figure 23: WinSLAMM input screen for an IESF basin 143
Figure 24: WinSLAMM input screen for an IESF bench 144
Figure 25: WinSLAMM input screen for a permeable check dam (modeled without an underdrain) 145
Figure 26: WinSLAMM input screen for a permeable check dam (modeled with an underdrain) 145
Figure 27: Schematic illustrating lakeshore erosion terms 147

List of Tables

Table 1: Cost-benefit of retrofits with respect to TP reduction. Projects 1-12. TSS and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages. 5
Table 2: Cost-benefit of retrofits with respect to TP reduction. Projects 13-29. TSS and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages. 6
Table 3: Cost-benefits of retrofits with respect to TP reduction. Projects 30-46. TSS and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profiles* pages 7
Table 4: Target pollutants addressed in this report 14
Table 5: Project types identified in the SFEF subwatershed 15
Table 6: Project types considered and not considered throughout this study 16
Table 7: Matrix describing curb-cut rain garden efficacy for pollutant removal based on type 20
Table 8: Matrix describing rain leader disconnect rain garden efficacy for pollutant removal based on type. 23
Table 9: Pollutant removal potential for Project 2-A (numbers presented are for a single rain garden) 50
Table 10: Pollutant removal potential for Project 2-B 51
Table 11: Pollutant removal potential for Project 3-A, a rain garden with a 6" ponding depth and a single curb cut 56
Table 12: Pollutant removal potential for Project 3-A, a rain garden with a 12" ponding depth and a single curb cut 56
Table 13: Pollutant removal potential for Project 3-A, a rain garden with a 6" ponding depth and two curb cuts 57
Table 14: Pollutant removal potential for Project 3-A, a rain garden with a 12" ponding depth and two curb cuts 57
Table 15: Pollutant removal potential for Project 3-B 58
Table 16: Pollutant removal potential for Project 3-C 59
Table 17: Pollutant removal potential for Project 4-A 64
Table 18: Pollutant removal potential for Project 4-B 65
Table 19: Pollutant removal potential for Project 5-A 70
Table 20: Pollutant removal potential for Project 5-B 72
Table 21: Pollutant removal potential for Project 5-C 73
Table 22: Pollutant removal potential for Project 5-D 74
Table 23: Pollutant removal potential for Project 5-E 75
Table 24: Pollutant removal potential for Project 5-F 76
Table 25: Pollutant removal potential for Project 5-G 78
Table 26: Summary of existing pollutant loading from rural catchments 80
Table 27: Pollutant removal potential for Project 6-A 83
Table 28: Pollutant removal potential for Project 6-B, new regional pond only 84
Table 29: Pollutant removal potential for Project 6-B, IESF bench only 85
Table 30: Pollutant removal potential for Project 6-C 86
Table 31: Pollutant removal potential for Project 7-A 89
Table 32: Pollutant removal potential for Project 7-B 90

Table 33: Pollutant removal potential for Project 7-C 91
Table 34: Pollutant removal potential for Project 7-D 92
Table 35: Pollutant removal potential for Project 7-E 93
Table 36: Pollutant removal potential for Project 7-F 94
Table 37: Pollutant removal potential for Project 7-G 95
Table 38: Pollutant removal potential for Project 8-A 98
Table 39: Pollutant removal potential for Project 8-B 99
Table 40: Pollutant removal potential for Project 8-C 100
Table 41: Pollutant removal potential for Project 8-D 101
Table 42: Pollutant removal potential for Project 8-E 102
Table 43: Pollutant removal potential for Project 8-F 103
Table 44: Pollutant removal potential for Project 9-A 106
Table 45: Pollutant removal potential for Project LR-1 109
Table 46: Pollutant removal potential for Project LR-2 110
Table 47: Pollutant removal potential for Project LR-3 111
Table 48: Pollutant removal potential for Project LR-4 113
Table 49: Pollutant removal potential for Project LR-5 114
Table 50: Pollutant removal potential for Project LR-6 115
Table 51: Pollutant removal potential for Project LR-7 117
Table 52: Pollutant removal potential for Project LR-8 118
Table 53: Pollutant removal potential for Project LR-9 120
Table 54: Pollutant removal potential for Project LR-10 121
Table 55: Pollutant removal potential for Project LR-11 122
Table 56: Pollutant removal potential for Project LR-12 123
Table 57: Pollutant removal potential for Project LR-13 124
Table 58: Pollutant removal potential for Project LR-14 125
Table 59: Cost-benefit of retrofits with respect to TP reduction. Projects 1-12. TSS and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages. 127
Table 60: Cost-benefit of retrofits with respect to TP reduction. Projects 13-29. TSS and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages. 128
Table 61: Cost-benefits of retrofits with respect to TP reduction. Projects 30-46. TSS and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profiles* pages 129
Table 62: GIS file sources and use in ArcSWAT modeling and desktop analysis 132
Table 63: ArcSWAT calibration parameters for SFEF catchment models 134
Table 64: WinSLAMM model inputs for catchment and BMP modeling 136
Table 65: ArcSWAT Parameters for the 'Pond' input file (.pnd) 138
Table 66: Lakeshore recession rate classification 147
Table 67: Budget estimate for the IESF pond bench in Catchment 2 148
Table 68: Budget estimate for the IESF pond bench in Catchment 3 148
Table 69: Budget estimate for the 5,000 sq-ft IESF pond bench in Catchment 4 148
Table 70: Budget estimate for the 10,890 sq-ft IESF pond bench in Catchment 4 149
Table 71: Budget estimate for the IESF pond bench in the Parkwood Development of Catchment 5 149

Table 72: Budget estimate for the IESF pond bench along the Highway 95 pond in Catchment 5 149
Table 73: Budget estimate for a 0.25 acre IESF pond bench along the new regional pond in Catchment 6 149
Table 74: Budget estimate for a 0.50 acre IESF pond bench along the new regional pond in Catchment 6 150
Table 75: Budget estimate for a 1.0 acre IESF pond bench along the new regional pond in Catchment 6 150
Table 76: Budget estimate for a 2,000 sq-ft Target parking lot IESF basin in Catchment 5 150
Table 77: Budget estimate for a 4,000 sq-ft Fleet Farm parking lot IESF basin in Catchment 5 151
Table 78: Budget estimate for permeable check dams 151
Table 79: Budget estimate for the regional pond in Catchment 6 151
Table 80: Cost-benefit with respect to TSS reduction. Projects 1-12. TP and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages. 153
Table 81: Cost-benefit with respect to TSS reduction. Projects 13-29. TP and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages. 154
Table 82: Cost-benefit with respect to TSS reduction. Projects 30-46. TP and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages. 155
Table 83: Cost-benefit with respect to stormwater volume reduction. Projects 1-12. TP and TSS reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages. 157
Table 84: Cost-benefit with respect to stormwater volume reduction. Projects 13-29. TP and TSS reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages. 158
Table 85: Cost-benefit with respect to stormwater volume reduction. Projects 30-46. TP and TSS reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages. 159

Executive Summary

This study provides recommendations for cost effectively improving the treatment of stormwater from areas draining to the Skogman-Fannie-Elms-Florence (SFEF) chain of lakes. The lakes chain and its surrounding subwatershed lie within the townships of Cambridge and Isanti in Isanti County and Fish Lake Township in Chisago County. A portion of the subwatershed also lies within the City of Cambridge, which is an EPA Municipal Separate Storm Sewer System (MS4) Phase II community with an approved stormwater management plan.

Improving water quality in these waterbodies is a high priority as both Fannie and Skogman Lakes have been listed as impaired due to nutrient eutrophication. Both lakes, which have been listed as impaired since 2007, witness frequent midsummer algae blooms and low clarity due to high nutrient (particularly phosphorus) concentrations. These concentrations are often above the state water quality standard for phosphorus, 40 µg/L. In addition, Florence Lake can experience winter fish kill due to low oxygen levels caused in part by the dense, nutrient-fed littoral vegetation in the lake.

This report focuses on "stormwater retrofitting" and ranking projects on cost effectiveness following a cost-benefit analysis. Stormwater retrofitting refers to adding stormwater treatment to areas which are already developed or being utilized for production. This process is investigative and creative. Stormwater retrofitting success is sometimes improperly judged by the number of projects installed or by comparing costs alone. Those approaches neglect to consider how much pollution is removed per dollar spent. In this stormwater analysis we estimated both costs and pollutant reductions and used them to calculate cost effectiveness of each possible project.

Areas that drain to the SFEF chain of lakes were delineated using available geographic information systems (GIS) watershed information, maps of stormwater conveyance features (where available), and advanced GIS terrain analysis technologies. Those areas were then divided into nine smaller stormwater drainage areas, or catchments. For each catchment, modeling of stormwater volume and pollutants was completed using water quality software for urban (WinSLAMM) and rural agrarian (ArcSWAT) landscapes. Base (without any stormwater treatment) and existing (with present day stormwater treatment) conditions were modeled. In total, under existing conditions the 7,775 acre subwatershed contributes an estimated 4,249 acre feet (ac-ft) of runoff, 1,362 pounds of phosphorus, and 371 tons of suspended solids each year to the SFEF chain of lakes.

Potential stormwater retrofits identified during this analysis were modeled to estimate reductions in volume, total phosphorus (TP), and total suspended solids (TSS). Finally, cost estimates were developed for each retrofit project, including operations and maintenance costs over the project lifetime. Projects were ranked by cost effectiveness with respect to their reduction of TP.

A variety of stormwater retrofit approaches were identified. They include:

- Maintenance of, or alterations to, existing stormwater treatment practices,
- Residential bioretention including curb-cut rain gardens and boulevard bioswales,
- Iron-enhanced sand filter (IESF) basins and retention pond benches,
- Permeable check dams,
- Lakeshore restorations,
- Filter strips on agricultural land,
- Water and sediment control basins,
- Wetland restorations, and
- New wet retention ponds.

This report provides conceptual sketches or photos of recommended stormwater retrofitting projects. The intent is to provide an understanding of the approach. If a project is selected, site-specific designs must be prepared. In addition, many of the proposed retrofits will require engineered plan sets if selected. This typically occurs after committed partnerships are formed to install the project. Committed partnerships must include willing landowners when installed on private property.

The tables on the next pages summarize 46 potential projects organized from most cost-effective to least, based on cost per pound of TP removed. If all of these practices were installed, pollutant loading to the SFEF lakes chain could be reduced by 260 lbs of TP and 136 tons of TSS. The 260 lbs-TP reduction could potentially reduce algal growth in the lake by 65 tons (assuming 1 lb phosphorus = 500 lbs algae). Reported treatment levels are dependent upon optimal site selection and sizing. More detail about each project can be found in the *Catchment Profile* pages of this report. Projects that were deemed unfeasible due to prohibitive size, number, or were too expensive to justify installation are not included in this report.

Installing all of these projects is unlikely due to funding limitations and landowner interest. Instead, it is recommended that projects be installed in order of cost-effectiveness (pounds of pollution reduced per dollar spent). Other factors, including a project's educational value, visibility, construction timing, total cost, focusing on upstream projects that benefit all lakes, or non-target pollutant reduction also affect project installation decisions and will need to be weighed by resource managers when selecting projects to pursue.

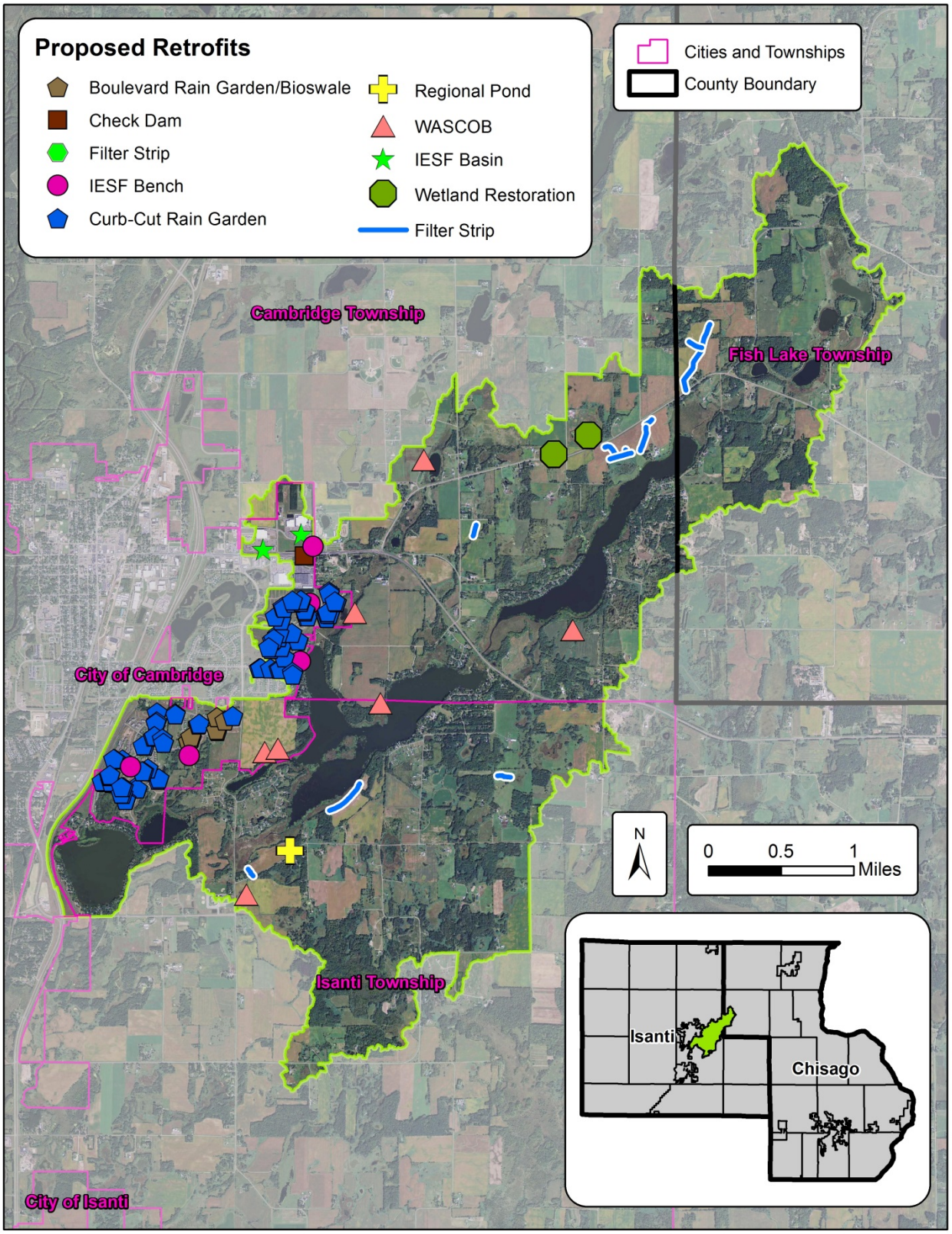

Figure 1: Proposed stormwater retrofits in the SFEF subwatershed

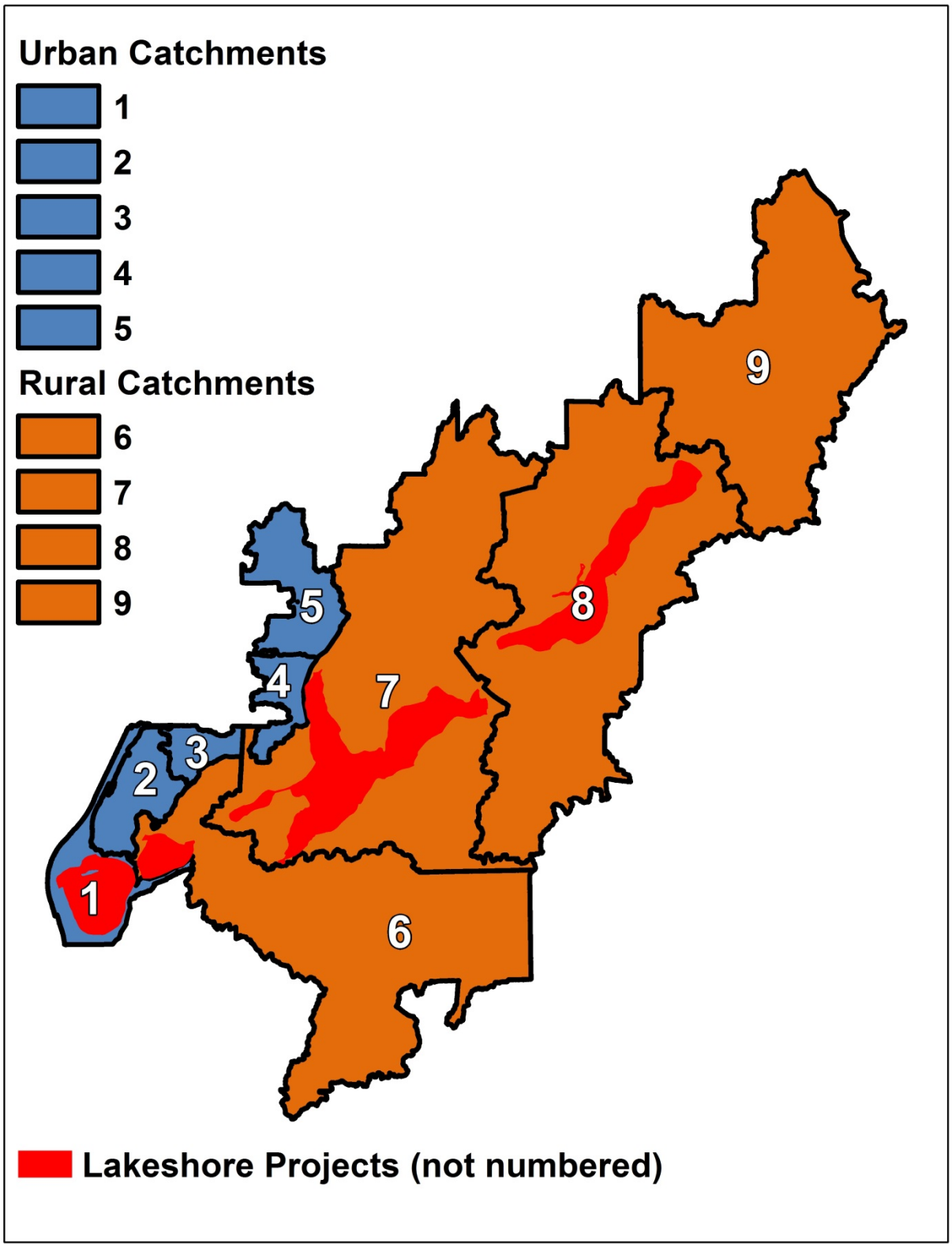

Figure 2: Areas in which projects were proposed, including urban catchments (1-5; colored blue), rural catchments (6-9; colored orange), and along lakeshore properties (colored red). Ranking table color-coding matches this figure.

Table 1: Cost-benefit of retrofits with respect to TP reduction. Projects 1-12. TSS and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages.

Project Rank	Project ID	Page Number	Retrofit Name/Type	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Additional Annual Costs Over Project Life (2014 Dollars)[1]	Cost-Benefit ($/lb-TP/yr)[1]	TP PDR	TP Reduction w/ PDR (lb-TP/yr)	Cost-Benefit w/ PDR ($/lb-TP/yr)
1	9-A	106	Vegetated Filter Strip/Grassed Waterway	15.0-15.7	17,068-17,978	0.0	$10,910-$11,241	$961-$2,283	$100-$181	0.90	13.5-14.1	$111-$201
2	6-A	83	Vegetated Filter Strip	6.8-7.3	6,753-7,281	0.0	$10,809-$10,938	$557-$1,071	$163-$222	0.80	6.8-7.3	$204-$278
3	8-E	102	Vegetated Filter Strip/Grassed Waterway	3.4-3.5	4,805-4,896	0.0	$10,809-$10938	$557-$1,071	$318-$460	0.90	3.1-3.2	$353-$511
4	8-D	101	Vegetated Filter Strip/Grassed Waterway	3.2-3.4	4,247-4,646	0.0	$10,805-$10,924	$539-$1,016	$341-$457	0.90	2.9-3.1	$379-$508
5	7-B	90	WASCOB	3.4-4.9	5,205-8,079	0.0	$21,094-$23,938	$517-$538	$355-$457	0.90	3.1-4.4	$394-$507
6	5-C	73	IESF Bench in the Parkwood Development	7.2	0.0	0.0	$92,327	$459	$491	1.00	7.2	$491
7	6-B	84	IESF Bench for Regional Pond	25.0-50.8	0.0	0.0	$240,933-$779,983	$2,500-$10,000	$396-$647	0.80	20-40.7	$495-$809
8	7-D	92	WASCOB	2.5-3.9	3,510-6,521	0.0	$20,649-$31,138	$508-$550	$511-$614	1.00	2.5-3.9	$511-$614
9	8-A	98	Wetland Restoration	9.8-31.2	701-5,955	1.3-6.7	$260,383-$405,005	$500	$665-$1380	0.80	7.8-25.0	$532-$1,104
10	4-B	65	Catchment 4 IESF Bench	11.5-15.8	0.0	0.0	$152,605-$246,408	$1,148-$2,500	$542-$625	1.00	11.5-15.8	$542-$625
11	2-B	51	Catchment 2 IESF Pond Bench	9.8	0.0	0.0	$136,729	$918	$559	1.00	9.8	$559
12	7-G	95	Vegetated Filter Strip	2.0-2.0	2,598-2.668	0.0	$10,814-$10,883	$575-$851	$567-$694	1.00	2.0-2.0	$567-$694

[1]Includes annual costs for operation and maintenance as well as any production loss payments for projects on agricultural land

Urban Catchments

Rural Catchments

Lakeshore Projects

Table 2: Cost-benefit of retrofits with respect to TP reduction. Projects 13-29. TSS and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profile* pages.

Project Rank	Project ID	Page Number	Retrofit Name/Type	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Additional Annual Costs Over Project Life (2014 Dollars)[1]	Cost-Benefit ($/lb-TP/yr)[1]	TP PDR	TP Reduction w/ PDR (lb-TP/yr)	Cost-Benefit w/ PDR ($/lb-TP/yr)
13	5-F	76	Highway 95 Pond Bench	5.0	0.0	0.0	$92,327	$459	$707	1.00	5.0	$707
14	7-E	93	WASCOB	1.8-2.5	2,268-3,496	0.0	$21,049-$27,938	$516-$538	$774-$871	1.00	1.8-2.5	$774-$871
15	8-B	99	Wetland Restoration	2.1-5.2	2,825-8,673	0.7-1.3	$38,205-$56,205	$500	$640-$1,142	0.80	1.7-4.2	$800-$1,428
16	3-C	59	Catchment 3 IESF Bench	10.7	0.0	0.0	$232,475	$2,479	$956	1.00	10.7	$956
17	7-C	91	WASCOB	0.3-2.0	278-2,560	0.0	$20,827-$32,205	$525-$558	$1,112-$4,746	1.00	0.3-2.0	$1,112-$4,746
18	5-G	78	Highway 95 Permeable Check Dams	1.0	1,347	0.0	$12,753	$730	$1,368	1.00	1.0	$1,368
T19	LR-7	117	LR-7	2.5	3,075.0	0.0	$34,805	$308	$1,540	1.00	2.5	$1,540
T19	LR-8	118	LR-8	2.5	3,075	0.0	$34,805	$308	$1,540	1.00	2.5	$1,540
T19	8-F	103	Vegetated Filter Strip/Grassed Waterway	1.5-1.6	1,108-1,165	0.0	$10,768-$10,791	$392-$484	$616-$660	0.40	0.6-0.6	$1,540-$1,650
T19	7-F	94	Vegetated Filter Strip	1.0-1.0	1,077-1,147	0.0	$10,768-$10,791	$392-$484	$930-$993	0.60	0.6-0.6	$1,550-$1,655
23	6-B	84	Regional Pond	57.8	177,212	1.2	$2,426,023	$1,200	$1,419	0.80	46.2	$1,774
24	LR-11	122	LR-11	0.9	1,125	0.0	$15,305	$113	$1,826	1.00	0.9	$1,826
25	8-C	100	WASCOB	0.6-1.0	587-1,042	0.0	$20,383-$25,005	$503-$508	$1,851-$2,537	1.00	0.6-1.0	$1,851-$2,537
26	LR-10	121	LR-10	0.8	975	0.0	$13,805	$98	$1,895	1.00	0.8	$1,895
27	2-A	49	Catchment 2 Curb-Cut Rain Gardens	0.2-0.3	25-43	0.4-0.5	$11,610	$225	$2,369-$3,356	1.00	0.2-0.3	$2,369-$3,356
28	LR-14	125	LR-14	0.9	1,170	0.0	$23,555	$390	$2,921	1.00	0.9	$2,921
29	7-A	89	WASCOB	0.3-1.0	278-1,153	0.0	$20,472-$21,538	$505-$514	$1,544-$4,632	0.50	0.2-0.5	$3,088-$9,264

[1]Includes annual costs for operation and maintenance as well as any production loss payments for projects on agricultural land

Table 3: Cost-benefits of retrofits with respect to TP reduction. Projects 30-46. TSS and volume reductions also shown. Projects ranked by cost-benefit with the pollutant delivery ratio (PDR; see *Location in Watershed* section for definition). For more information on each project refer to the *Catchment Profiles* pages

Project Rank	Project ID	Page Number	Retrofit Name/Type	TP Reduction (lb/yr)	TSS Reduction (lb/yr)	Volume Reduction (ac-ft/yr)	Probable Project Cost (2014 Dollars)	Additional Annual Costs Over Project Life (2014 Dollars)[1]	Cost-Benefit ($/lb-TP/yr)[1]	TP PDR	TP Reduction w/ PDR (lb-TP/yr)	Cost-Benefit w/ PDR ($/lb-TP/yr)
30	6-C	86	WASCOB	0.3-0.8	236-788	0.0	$20,383-$26,205	$503-$521	$2,409-$5,249	0.70	0.2-0.6	$3,442-$7,500
31	5-D	74	Target Parking Lot IESF Basin	1.0-1.5	252-571	0.6-1.0	$109,088-$159,243	$459-$918	$4,000-$4,150	1.00	1.0-1.5	$4,000-$4,150
32	LR-1	109	LR-1	1.4	1,740	0.0	$47,555	$570	$4,047	1.00	1.4	$4,047
33	LR-5	114	LR-5	1.2	1,530	0.0	$42,305	$765	$4,095	1.00	1.2	$4,095
34	3-A	55	Catchment 3 Curb-Cut Rain Gardens	0.0-0.2	3-34	0.1-0.3	$6,950-$15,710	$225	$5,053-$57,250	1.00	0.0-0.2	$5,053-$57,250
35	5-E	75	Fleet Farm Parking Lot IESF Basin	0.8-0.9	270-511	0.5-0.8	$109,088-$159,243	$459-$918	$5,054-$6,506	1.00	0.8-0.9	$5,054-$6,506
36	LR-9	120	LR-9	0.2	203	0.0	$7,430	$68	$5,066	1.00	0.2	$5,066
T37	LR-2	110	LR-2	0.3	390	0.0	$13,805	$195	$5,082	1.00	0.3	$5,082
T37	LR-4	113	LR-4	0.3	390	0.0	$13,805	$195	$5,082	1.00	0.3	$5,082
39	LR-3	111	LR-3	0.3	345	0.0	$12,680	$173	$5,145	1.00	0.3	$5,145
40	LR-13	124	LR-13	0.2	300	0.0	$11,555	$150	$5,440	1.00	0.2	$5,440
41	LR-6	115	LR-6	0.2	225	0.0	$9,680	$113	$6,003	1.00	0.2	$6,003
T42	4-A	63	Catchment 4 Curb-Cut Rain Gardens	0.1-0.1	7-21	0.1-0.2	$11,610	$225	$6,196-$13,425	1.00	0.0-0.1	$6,196-$13,425
T42	5-A	69	Curb-Cut Rain Gardens in the Parkwood Development	0.1-0.1	7-21	0.1-0.2	$11,610	$225	$6,196-$13,425	1.00	0.1-0.1	$6,196-$13,425
44	3-B	58	Catchment 3 Curb-Cut Boulevard Bioswales	0.0-0.1	4-14	0.0-0.1	$8,310	$225	$6,405-$32,025	1.00	0.0-0.1	$6,405-$32,025
45	5-B	71	Curb-Cut Rain Gardens in the Preserve Development	0.1-0.2	6-17	0.1-0.2	$9,730-$15,710	$225	$6,737-$10,164	1.00	0.1-0.2	$6,737-$10,164
46	LR-12	123	LR-12	0.1	150	0.0	$7,805	$75	$7,129	1.00	0.1	$7,129

[1]Includes annual costs for operation and maintenance as well as any production loss payments for projects on agricultural land