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Minnesota Stormwater Research and Technology Transfer Program - A Comprehensive Approach to Collaborative Research

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Abstract: The University of Minnesota Water Resources Center (UMN WRC) in collaboration with the Minnesota Stormwater Research Council (MSRC) has developed a robust program to advance urban stormwater management and policy through the completion of research. Through this unique collaboration, stormwater professionals and researchers across Minnesota are engaged in multi-sector research to prevent, minimize, and mitigate urban stormwater impacts by studying existing and innovative structural and non-structural practices, policies, and management techniques. The center and the council have evolved a comprehensive approach by:

- Obtaining diversified funding resulting in an annual average $1M budget.
- Coordinating and building partnerships at local, regional, state, and federal levels to leverage stormwater research resources.
- Using the council to engage with stormwater researchers, professionals, policymakers, and stakeholders.
- Identifying strategic priorities through assessments of needed research (i.e., the Minnesota Stormwater Research Roadmap).
- Providing a process for prioritizing, soliciting, submitting, approving, and implementing stormwater-related research proposals.

The program also invests in technology transfer seeking the effective and efficient dissemination of research results to those who can best benefit from it. The council is an organization of stormwater professionals, practitioners, managers, engineers, researchers, and others established in 2016 to work with the center to facilitate relevant, applied research and support education and technology transfer. This paper summarizes the efforts of the program, the future outlook, and highlights the collaboration and the connection of the University and the center to agencies, local units of government, and private engineering consulting businesses, who all were integral to the success of the program.

Keywords: *practices, policies, management, urban, water, pollution*

Urban stormwater, runoff from largely impervious surfaces including streets, sidewalks, parking lots, roofs, and in some cases, turf grass, is a major source of nonpoint source pollution. As runoff flows across and down the landscape, it collects and transports sediment, nutrients, chlorides, pathogens, toxic contaminants, and debris. In excess, these pollute our communities' lakes, rivers, streams, wetlands, and groundwater resources (UMN WRC 2011; Subramanian 2016; Baker et al. 2018). Stormwater runoff can also lead to flooding concerns as both the quantity and rate of runoff flow is increased from urban landscapes.

Urban stormwater requires specialized study and control technologies because of the vastly altered hydrology in developed landscapes as well as the numerous contaminants from different land uses that can be carried with urban runoff. While research has advanced our understanding of

Research Implications

- The Minnesota Stormwater Research and Technology Transfer Program (MSRTTP) results in discoveries that will help researchers, stormwater practitioners, professionals, and policymakers: 1) evaluate and design more effective stormwater practices; 2) revise stormwater policies and guidance materials; 3) manage urban runoff to prevent, reduce, and mitigate impacts to lakes, rivers, streams, and groundwater; and 4) maintain investments in stormwater infrastructure for efficient, effective, and continued operation.
- The research program can serve as a model of stormwater research collaboration and grow to address local, regional, and national needs.

stormwater processes and treatment technologies, much remains unknown about the sources and fate of contaminants in urban watersheds and the most effective forms of treatment. Treatment technologies for emerging contaminants such as hydrocarbons remain in an exploratory stage.

Managing urban stormwater is a continuing challenge in Minnesota, around the nation, and throughout the world. Developed areas have a disproportionate impact on water resources, leading to an estimated 22% of the nation's impairments in lakes and 14% of impairments in streams, while accounting for only 3.1% of land area (Strassler et al. 1999; Bigelow and Borchers 2017). A body of water is considered impaired if it fails to meet one or more water quality standards. These standards are set to maintain beneficial uses such as drinking water, recreation activities such as swimming and fishing, and healthy wildlife and biota. Impairments from urban stormwater are locally concentrated in urbanized watersheds, which have become the source of water for a majority of public drinking water systems (Robbins et al. 1991).

Approximately 40% of the nation's waters do not meet water quality standards. Minnesota fares no better (UMN WRC 2011). The Proposed 2020 Impaired Waters List for Minnesota has 5775 impairments. Twenty-five percent of lakes in the state do not meet water quality standards and more than 17,000 stream miles are impaired for one or more designated uses (Minnesota Pollution Control Agency 2020a; 2020b). Long-term trends from climate change and land-use development in cities, towns, and municipalities will increase the threat from urban stormwater impacts (National Research Council 2009). Moreover, Minnesota faces additional challenges in stormwater management due to its seasonal cold climate with continuous winter snow cover and water quality concerns related to deicing agents.

The Minnesota Water Sustainability Framework (referred to as framework hereafter) and the 2020 State of Water Plan highlight the extent to which Minnesota's residents highly value water resources and recognize these pollutants as a threat to the quality of water for drinking, recreation, wildlife and biota, and aesthetics. The framework was a legislative-directed activity to describe the needs and goals that would need to be accomplished to achieve a sustainable water future for Minnesota. At the time it was published, it was the nation's first state-level plan for ensuring that waters would be preserved, protected, and available for generations to come. As part of the development of the framework, Minnesotan's attitudes and beliefs about water were evaluated. Using the results from more than 4,500 surveys and nine listening sessions across the state, the Framework team concluded, in part, that Minnesotans want to address water pollution concerns (UMN WRC 2011). The Minnesota Legislature, through state statutes, also directed the Environmental Quality Board to establish a plan for aligning state agencies, legislative priorities, and local government policy, programs, and actions to protect and improve water resources, and to update that plan every ten years. The 2020 update to this plan (2020 State Water Plan: Water and Climate) also provided evidence that Minnesotans valued clean water. In a 2018 survey of more than 1,400 residents, more than 90% believed clean and safe drinking water was extremely important and more than 80% supported multiple actions to protect and restore water resources (Minnesota Environmental Quality Board 2020).

Urban stormwater runoff challenges are further complicated by the increased intensity of rain events associated with climate change (National Research Council 2009). Recent monitoring

indicates changes in climate and precipitation are already occurring. For example, Minnesota has experienced 11 mega-rain events since 2000, events in which six inches of rain covers more than 1000 square miles and the core of the event tops eight inches of rainfall. Furthermore, scientific evidence projects Minnesota will see significant future changes including warmer winters, more frequent, larger rainfall events, and the potential for longer dry spells (Minnesota Environmental Quality Board 2020). This same trend is reflected in forecasts for other parts of the country. Modeled future high and low emission scenarios both forecast more frequent extreme events for certain parts of the country. The Northeast, Great Lakes, and North Central regions are projected to have the greatest possible impacts. For example, the Northeast region is projected to experience a 40% increase in heavy rain events by the end of the century (Scott 2019).

The impacts of urban stormwater runoff reflect challenges in both water quality and quantity. These coupled with expressed support from citizens, professionals, policymakers, and agencies suggest we need effective and efficient urban stormwater management and we must do more to prevent, minimize, and mitigate the impacts of urban stormwater runoff.

The University of Minnesota Water Resources Center (UMN WRC; referred to as center hereafter) is well suited to address these needs. The center is one of the nation's 54 water resources research institutes authorized by Congress. The center provides leadership in freshwater management by 1) conducting, facilitating, and funding cutting-edge research, 2) providing graduate and undergraduate education, including masters and doctoral programs in water resource science, and 3) engaging with community stakeholders, citizens, policy leaders, and professionals. An example of the critical role of the center in regional water management includes the development of the Minnesota Water Sustainability Framework previously mentioned. Based upon its mission, multiple past successes, and effective partnerships, in 2015 the center began more formal collaboration efforts with stormwater practitioners, professionals, and researchers to assess urban stormwater challenges in Minnesota and strategies to address them. In particular, the group explored the impact urban stormwater runoff has on the state's water resources, the gaps in information needed to address those impacts, and how a state-led comprehensive approach to research would help increase the effectiveness and efficiency of urban stormwater management practices and policies.

One of the components of those efforts, the Minnesota Stormwater Research Roadmap (Baker et al. 2018), articulated five key reasons why developing a coordinated stormwater research strategy could reduce urban stormwater pollution.

1. There are many impaired urban waters in Minnesota that receive much of their pollution from stormwater.
2. The cost of meeting Clean Water goals is very high − estimated to be $317 million per year.
3. There is a perception among stormwater professionals that current stormwater management is not as efficacious as it could be.
4. Past research in Minnesota to improve urban stormwater management has resulted in the implementation of improved stormwater management practices.
5. Future research would likely be even more productive because it would be informed by our constantly improving capacity to acquire, store, and process information and because it will build upon lessons learned from previous research and implementation.

Gathering more information on current stormwater practices and management schemes and developing new mechanisms to prevent, minimize, and mitigate the impacts from urban stormwater runoff would require a robust, comprehensive approach to collaborative research.

The Minnesota Stormwater Research and Technology Transfer Program

In 2017, in response to these needs for more information, the center established the Minnesota Stormwater Research and Technology Transfer Program (program) to lead a comprehensive approach to urban stormwater research and facilitate the transfer of science to practitioners, professionals, and policymakers. Establishing the

program did not happen overnight. It was built on a foundation of past and current partnerships, collaborations, and committees. Minnesota is fortunate to have diverse state agencies, local units of government, academic units, and private industry environmental engineers that collaborate to address urban stormwater management. For many years, partnerships and collaborations of professionals, researchers, and practitioners worked together formally and informally on research projects, revising policy, and on stormwater related implementation projects.

Two such examples include the Minnesota Stormwater Steering Committee and the Minnesota Minimal Impacts Design (MIDS) Committee. The steering committee was a collective of professionals, researchers, practitioners, and policymakers brought together by the Minnesota Pollution Control Agency that provided input to the agency and, more importantly, worked together to discuss critical stormwater management needs and seek collective solutions. The steering committee was instrumental in the first version of the Minnesota Stormwater Manual, published in 2005, and provided insights for the Assessment of Stormwater Best Management Practices published by the University of Minnesota in 2008. The MIDS Committee was established as a result of Minnesota legislative action in 2008 requiring the agency to develop new stormwater performance standards. As a result, the MIDS Committee was formed to guide the agency and operated for three years.

These efforts are two prominent examples of how Minnesota experts collaborated and influenced the establishment of a research program by providing insights on research needs, options, and alternatives to the formation of the program, and by serving as links to active engagement with stakeholders. A partial list of these influencers includes representatives from:

- UMN Water Resources Center
- UMN St. Anthony Falls Laboratory
- UMN Sea Grant Program
- UMN Natural Resources and Research Institute
- Minnesota Pollution Control Agency
- Minnesota Department of Natural Resources
- Minnesota Board of Water and Soil Resources
- Minnesota Department of Health
- Minnesota Department of Transportation
- Local units of government including cities and counties
- Watershed districts and organizations
- Minnesota Cities Stormwater Coalition
- The Watershed Partners
- Many engineers, designers, and professionals from private consulting firms

Over the several years pre-dating the creation of the program in 2017, individuals and groups representing professionals, practitioners, and policymakers gathered informally to discuss the need to form an urban stormwater research council, to support additional research increasing the efficacy of current stormwater practices, and to develop new, innovative practices. Two simultaneous and significant events followed that eventually became the cornerstones of the program.

One of the initial events instrumental to establishment of the program was to recognize and establish urban stormwater as one of the five focus areas in the new Center Strategic Plan (UMN WRC 2018; Figure 1). The center developed its strategic plan by gathering input from a broad group of researchers, stakeholders, center staff, and university leadership. All of this information was analyzed to identify areas where the center and its surrounding community were well positioned to advance water science to address state needs. Stormwater emerged from this process as a clear priority, reflecting an alignment of research needs with scientific expertise and established relationships. Having named stormwater as a strategic priority, the center committed to working with its partners to propel urban stormwater research and technology transfer forward.

Simultaneously, the Minnesota Stormwater Research Council (MSRC; hereafter referred to

Figure 1. Urban Stormwater is one of the five focus areas of the center's strategic plan adopted in 2018 (UMN WRC 2018).

as council) was established in recognition that partner collaboration and stormwater stakeholder engagement with the center were essential. Following years of discussion, and after considering alternative models for a research program such as forming a not-for-profit organization, stormwater practitioners, professionals, and policymakers asked the center to form, lead, and administer a council.

The council is an organization of stormwater professionals, practitioners, managers, engineers, researchers, and others established to:

- Facilitate the completion of needed applied research that enables more informed decisions about the use, management, and protection of our water resources in urbanized areas.
- Periodically assess the status of research, identify consensus research priorities, and communicate these to Minnesota's public and private research agencies and organizations.
- Promote coordination of research goals, objectives, and funding among the research agencies and organizations.
- Facilitate technology transfer of stormwater research to practitioners, agencies, organizations, and others. For the council, technology transfer includes support for and facilitation of education, outreach, and training, as well as translation of research results into related manuals and policies.

One of the first steps in forming the council was developing the Guiding Framework to establish the purpose and objectives of the council and articulate the roles and responsibilities of an advisory board (UMN 2021). The framework was developed over a period of more than twelve months by the advisory board, with robust input from stakeholders.

The advisory board, the decision-making body of the council, sets research priorities, acquires funds to support research, and chooses projects to award and complete. The board consists of a diverse set of twenty individual stakeholders representing cities, watershed districts or organizations, private industry, research institutions, and state agencies (UMN 2021). Board members provide representation and continual engagement of stakeholders critical to completion of the work and continuation of funding and ensure the relevance of research results for end-users. Additional detail about the role of the council in obtaining funding is discussed later in this paper. The Council Framework is subject to annual review and moderate changes have been made over the years, but the objectives and mission of the council remain fixed. More information about the council is available online at www.wrc.umn.edu/msrc.

The program situated at the center works in unison with the council. This cooperative and comprehensive approach, combining a formal research program at the University and a robust external stakeholder council, provides a unique foundation that has led to successful endeavors addressing critical urban stormwater issues. This partnership requires dedicated leadership, transparent communication, and efficacious administration. Therefore, in 2019 the center established a full-time director to administer the program.

Research Priorities

One of the first efforts of the council was to examine urban stormwater research needs. An interim report of needs was completed in 2017 (Erickson et al. 2017). The 2017 report included a literature review and compilation of research needs identified in previous reports, past surveys, and stakeholder discussions. In addition, the 2017 report presented a list of stormwater knowledge gaps and research needs, and documented challenges to meeting those research needs. With the program newly created and situated in the center, funding and capacity were dedicated toward development of a next generation report that would expand and further describe research needs and establish methods to prioritize those for Minnesota. This endeavor was much more comprehensive than the previous effort. It included literature reviews, surveys, focus groups, and interviews of stormwater professionals, practitioners, researchers, and policymakers across the state. The result was the Minnesota Stormwater Research Roadmap (Baker et al. 2018).

The Roadmap identifies research priorities that serve as the main pillars of the program. The Roadmap was developed by examining gaps

in knowledge about urban stormwater − gaps that if filled, could help practices, policies, and management schemes become more effective and efficient to prevent, minimize, and mitigate the impacts from urban stormwater runoff. In short, it described Minnesota's urban stormwater research needs. Given the extensive list of research needs and the limited funding and capacity existing to address all of them, the Roadmap also identified prioritization indices. The Roadmap employed multiple strategies including focus groups, surveys, interviews, and reviews of past published research, reports, and projects to distill eight major research priorities (Figure 2).

Additional details under each of the eight major priorities identify specific information needs or research advancements that could benefit practitioners, professionals, and policymakers. For example, under the *Improve performance and reduce maintenance on structural BMPs* category, specific research on stormwater ponds such as the fate of dissolved phosphorus, the extent of polycyclic aromatic hydrocarbon (PAHs) pollution, and effective pretreatment practices for bioretention are identified as very high priorities. These eight major priorities and the specific needs for each of them provide focus for organizing research activities and allocating investment in the program.

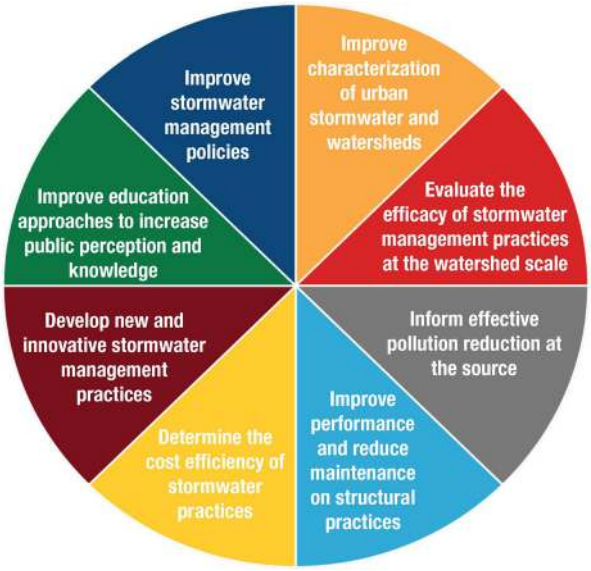

Figure 2. The eight major categories of Minnesota's urban stormwater research priorities (UMN WRC 2018).

The Roadmap provides an overall structure to address dynamic research priorities. New individual research needs emerge as research is completed, problems surface in communities, or new challenges are encountered. The center and the council will embark on an update to the Roadmap in 2022. In the upcoming research portfolio section of this manuscript, the connection of these eight categories emerges in the descriptions of the projects that have been funded and implemented.

Research Portfolio

Since the program's inception in 2016, 19 research projects have been funded, completed, or are in progress (Table 1). The portfolio consists of two categories: rapid response projects and discovery projects. Rapid response projects address specific questions that can be answered with applied research in one to two years, whereas discovery projects have longer durations involving multiple years of data collection and often larger interdisciplinary teams. This categorization allows for timely response to specific questions and challenges, and also recognizes the need for in-depth observations or trends that require more time and broader expertise.

Rapid Response Project Example:

Effectiveness of Sump Manholes for Pretreatment Particulate Removal (Chapman 2020). Initiated January 2019 and completed in March 2020. This project evaluated sediment characteristics in urban stormwater runoff and recommended sediment concentrations for use in the SHSAM model. It went on to recommend inspection and maintenance frequency to ensure the practice functions as designed.

Discovery Project Example:

Detecting Phosphorus Release from Stormwater Ponds to Guide Management and Design (Janke et al. 2021). Initiated in 2019 and completed in 2021. This project evaluated the factors that influence phosphorus release in urban stormwater ponds. Results showed that dissolved oxygen levels, stratification and mixing, and vegetation within and adjacent to the pond all play critical roles in

Table 1. Research program portfolio 2017-2021.

Title	Start - End Date
2020 Research Cycle Projects	
Biofiltration Media Optimization – Phase II: Multi-Year Performance, Impacts of Road Salt, and Optimized Organic Ratio	2020 - 2022
Equipping Municipalities with Climate Change Data to Inform Stormwater Management	2020 - 2021
Evaluation of Microbial and Chemical Contaminant Removals in Different Stormwater Reuse Systems	2020 - 2021
Field Evaluation of Stormwater Best Management Practices to Characterize the Comprehensive Contaminant Removal Performance of Biochar-Augmented Filter Media	2020 - 2022
Leveraging Minnesota's Stormwater Data for Improved Modeling and Management of Water Quality in Cities	2020 - 2022
Monitoring Methods for Prioritization and Assessment of Stormwater Practices	2020 - 2021
Pollutant Removal and Maintenance Assessment of Underground Filtration Systems	2020 - 2021
Understanding Solids Loading in Minnesota Stormwater	2020 - 2022
2019 Research Cycle Projects	
Biofiltration Media Optimization - Phase I	2019 - 2020
Detecting Phosphorus Release from Stormwater Ponds to Guide Management and Design	2019 - 2021
Developing a Street Sweeping Credit for Stormwater Phosphorus Source Reduction	2019 - 2020
Draft Stormwater Geospatial Data Standard: Pilot and Proof-of-Concept	2019 - 2020
Effectiveness of Sump Manholes for Pretreatment Particulate Removal	2019 - 2020
Identifying Sources of Contaminants in Urban Stormwater and Evaluation of Their Removal Efficacy Across a Continuum of Urban Best Management Practices	2019 - 2021
Inspiring Community Action for Stormwater Management	2019 - 2021
Pond Treatment with Spent Lime to Control Phosphorus Release from Sediments	2019 - 2021
Temporal Dynamics of Pathogens and Antibiotic Resistance in Raw and Treated Stormwater	2019 - 2020
2017 Research Cycle Projects	
Capture of Gross Solids and Sediment by Pretreatment Practices for Bioretention	2017 - 2019
Determining which Iron Minerals in Iron-enhanced Sand Filters	2017 - 2019

the release of phosphorus, and management and design should take these into account.

Proposal Solicitation, Review, Selection, and Management

Research needs exceeded the available funding for the past three research proposal cycles (Figure 3). Acknowledging this early on, the program leaned heavily on the stormwater research priorities in the Roadmap and established criteria to solicit and evaluate proposals. Priorities evolved from one research cycle to the next by referencing the Roadmap in discussions with the council's advisory board. Acknowledging immediate and higher priority needs allowed for requests for proposals (RFP) to be balanced between rapid response and discovery projects, and these were clearly identified in the RFP.

Following the first RFP cycle in 2017, one of the adaptations required researchers to identify a primary and secondary research priority during the application process. This allowed the center and council to evaluate the distribution of proposals across needs and topics. It also allowed for various ways of grouping proposed work, such as pollution prevention compared to pollution mitigation, or quantitative stormwater sampling research compared to social and policy related sciences. Funding decisions then could be based upon the specific topics projects would address as well as

the balance across larger categories of research and management needs, such as science in water chemistry, monitoring, social studies, and behavior and policy.

Criteria for Review and Ranking

The criteria used to evaluate proposals evolved over time. Clearly-stated criteria in the RFP offered researchers the opportunity to focus their proposals and provided the reviewers the benchmarks by which they could evaluate them. The individual criteria are weighted equally. These are the criteria that were used for the 2020 research cycle:

- **Relevance** - Does the proposed project relate to urban stormwater management or concerns in Minnesota? Does it benefit Minnesota waters? Is it applicable and does it have high value to Minnesota stormwater professionals, managers, engineers, and policy leaders? Does this project evaluate, improve, or innovate the performance and effectiveness of stormwater BMPs? Does the project evaluate or innovate standards and guidance? Does the work avoid duplicating previous efforts?
- **Priority Research** - Does the research examine specific ideas or concepts well-suited under the research need? Does the proposal address one of the more specific 2020 priority focus areas? Does the research and do the deliverables sufficiently address the priority research need identified?
- **Scientific Merit** - What is the quality of the research plan? Is the approach scientifically valid? Are the objectives and activities clearly explained? Will proposed activities achieve objectives? Will the research activities result in a significant advance in knowledge? Will this research provide us with new information needed by managers or stakeholders?
- **Technology Transfer** - How strong is the technology transfer plan? Are audiences and objectives of education and outreach identified? Will the education and technology proposed lead to changes in learning or actions for an identified audience?
- **Capacity and Collaboration** - Do the personnel and institutions have the capacity and expertise to effectively complete proposed work? Are the budget and timeframe realistic and reasonable for completing activities and objectives? Does the proposal identify collaborations that strengthen the work? Does the proposal identify and discuss connections or communication with any of the major agencies involved in urban stormwater management in Minnesota?

Figure 3. Total requested research funding compared to total actual funding awarded, by research cycle year. For each of the three competitive research cycles conducted since the program's inception, total stormwater research financial support requested exceeds the funds available and number of projects that can be chosen for funding and completed.

- **Cost** - How does the proposed budget compare to the work proposed? Is the budget within the specifications of rapid response and discovery projects? Is there specification of how the project could be phased?
- **Project Timeline** - Is the proposed timeline appropriate, with time allowed for completion of final reports? Are project benchmarks identified? Is there an indication of how the project could be phased?

Multi-tiered Review Process

A three-tiered approach is used to evaluate proposals. First, center staff evaluate proposals to ensure they meet eligibility criteria and are complete. This includes reviewing specific components such as the budget and budget justification. Budget review includes evaluation of whether the budget is fair and reasonable and whether the expenses can be justified and are allowable from the perspective of the funding sources and University policy. Staff also review and summarize the topics and concerns addressed by the entire suite of proposals.

In the second tier, the council's advisory board completes a thorough review and scoring of each proposal. Numerical scores are assigned for each criterion and review comments are submitted. Simultaneously, a third-tier review by external peers is completed for all discovery proposals. External peer reviews are not sought for rapid response projects. The expertise of the advisory board is sufficient to evaluate these smaller, less intensive projects. External peer reviewers are most often from experts in the specific area of content from other research institutions and agencies. Three external peer reviews are sought for each proposal, with the number of reviews sometimes adjusted for the level of depth and specialization of the proposed work. While external peer reviewers do evaluate all the criteria, they are asked to focus on the science, methodology, data collection, and analysis components. External peer reviewers also assign numerical scores and submit review comments.

This information is not the sole selection method. With the summarized review scores and comments in hand, the advisory board meets to discuss all the projects, assessing their merit, methodology, and priority. The broad diversity of the board ensures substantial stakeholder input from cities, watersheds, local units of government, and agencies that will ultimately most benefit from the work. Using the available funding for the research cycle, the board also considers the cost-benefit as it prioritizes the projects, ultimately choosing a balance of rapid response and discovery projects. In some instances, the center and board have asked for proposal revisions and clarifications before a project can go forward.

Employing a Proposal and Project Management System

This three-tiered review approach generates substantial information on each proposal. During the first two proposal periods (2017 & 2018), a combination of emails, document exchanges, and online survey tools such as Survey Monkey and Qualtrics were used to gather information. The center team was immediately challenged by the growing amounts of data resulting from the review of the proposals, the inefficiencies in review collection, and less-than-ideal processes to compile, analyze, and review the growing number of proposals and their reviews.

After research of their own, over the course of more than six months, the center invested in a proposal and project management system to aid in these processes. The chosen online software package, WizeHive, brings a full lifecycle management system for grant proposals and projects. For the program, such a system has provided benefits and has added value for applicants, reviewers, and program staff. Applicants have found the system user friendly, as they can construct their proposal in routinely used software (Microsoft Word and Excel) and copy and paste (or upload) those contents into well-identified sections in an online application portal. Features include the capacity for applicants to adjust a submission up to the application deadline, and for center staff to easily request revisions to one or more sections of the proposal.

Perhaps the greatest advantages of such systems are found in the review process. Reviewers, including the advisory board, can repeatedly log in and out to complete reviews as they have time. Well-designed systems also make it easier

for reviewers to work with electronic documents, avoiding the need to print sometimes lengthy proposals. WizeHive provides a split-screen approach in the review stage, allowing reviewers to see a specific section of the proposal with the scoring selection immediately adjacent to it. For example, when reviewing and scoring the budget, the left side of the computer screen displays the budget and budget justification (or links to the PDF) and the budget scoring matrix appears on the right side of the screen. The reviewer can continually reference the budget while entering their scores and comments on the same screen.

The proposal management system also increases the efficiency of program staff. WizeHive allows program staff to quickly assign submitted proposals to reviewers. Reviews then can be conducted simultaneously by all twenty advisory board members and external peer reviewers. Meanwhile, program staff can access the system and see which reviews are complete and which reviewers might need reminders. Reminders can be pre-programmed to be sent to any of the reviewers. Once reviews are complete, review scores and comments can be summarized and analyzed quickly and easily (Figure 4). The various graphic and text summary outputs from the system provide program staff the necessary information for the advisory board meetings where discussion results in selections for project funding or potential revision. The system can quickly summarize proposals by title, principal investigator, submitting organization or department, research track, total of funds requested, or any of the submission entries.

PI	Short Title	Criteria Total Avg Score*	Relevance	Priority Research	Scientific Merit	Technology Transfer	Capacity And Collaboration	Cost	Project Timeline	Overall Avg Score	Track	Total Budget
Name	*Title*	25.8	4.2	4.0	3.6	3.8	3.7	3.4	3.4	3.8	Discovery	$300,000
Name	*Title*	19.8	3.2	2.7	3.2	2.4	3.1	2.4	3.0	2.5	Discovery	$259,000

**Numbers are averages of twenty advisory board member scores.*

Criteria scoring rubric. *Maximum total score is 35		
0	Unacceptable	Does not meet the criteria or elements in this category.
1	Poor	Weakly satisfies a few elements, does not satisfy others.
2	Fair	Satisfies most elements to a minimum standard.
3	Good	Adequately satisfies all elements.
4	Very Good	All elements satisfied, some exceeding expected standards.
5	Excellent	Exceptional. All elements satisfied beyond expected standards.

Overall score rubric	
0	Unacceptable. We absolutely should not fund this.
1	Poor. Proposal has serious deficiencies in one or more areas and should not be funded.
2	Fair. Marginal approach but does not address topics in the RFP. Major deficiencies.
3	Good. This is a good candidate for funding. Acceptable quality. May have some revisions.
4	Very Good. This is a great proposal to consider supporting with funds.
5	Excellent. We should definitely fund this proposal.

Figure 4. Example of how the proposal and project management system can generate reports of review scores for program staff and the advisory board.

Finally, WizeHive also provides for overall project management. Once a project is selected, the system can notify applicants, request revisions to a particular component, request mid-project updates, and other staff directed inquiries.

Financing Urban Stormwater Research

The annual budget of the program is approximately $1 million. The majority of the budget (80%) funds research projects, most of which are chosen on a competitive basis. The remaining 20% funds technology transfer, including education, training, and outreach, and supports administrative costs for the program. Legislative language and the goals of the MSRC require the majority of the budget to be spent on research to fulfill the program's primary mission; to discover new science and revise technologies and practices that will prevent, minimize, and mitigate the impacts from urban stormwater runoff. A diversified approach to funding the program helps deliver stability, builds stakeholder support and buy-in, and creates momentum.

Over the past three biennia, the Minnesota Legislature has made a multimillion-dollar investment into the program (Figure 5). These funds are sourced from the Minnesota Clean Water, Land and Legacy Amendment, which was enacted to protect drinking water sources; to protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat; to preserve arts and cultural heritage; to support parks and trails; and to protect, enhance, and restore lakes, rivers, streams, and groundwater. The Legacy Amendment increased the state sales tax by three-eighths of one percent beginning July 1, 2009 and continuing until 2034. Funds for the stormwater research program are specifically provided by the Clean Water Fund, which is one of the areas the Legacy Amendment supports. The budget and investments of the Clean Water Fund are recommended by the Clean Water Council. The Clean Water Council consists of seventeen governor appointed legislators, agency representatives and other local units of government, and community organization representatives and was established to advise the Legislature and the Governor on the administration and implementation of the Clean Water Fund. The stormwater research program makes a biennial request to the Clean Water Council for funding and provides regular updates on research funded and accomplished. More importantly, the program communicates the implications and usefulness of its research for Minnesota communities, professionals, and policy leaders.

Additional funds to support the program are sought from and contributed by local units of government, including cities, watershed districts, organizations, and by private industry (Figure 5). These relatively small, individual amounts (compared to the total cost of a research project), add up quickly when pooled together. On average, pooled funds from cities, watersheds, and private industry have totaled $150,000 per year and are steadily increasing. In Minnesota, watershed districts and watershed organizations are special-purpose local units of government, authorized by the Legislature in 1955. Many of these local watershed units have funds available for investment into the program through taxing authority or other revenue sources. Many cities that meet the qualification of owning, operating, or maintaining a municipal separate storm sewer system (MS4), have stormwater utility fees or other financial resources which they may use to support the program. Minnesota is also fortunate to have talented and highly engaged private environmental consulting businesses that support the program. These local units of government, and the professionals, practitioners, and policymakers that work within them, find high value in applied urban stormwater research. Contributors see the benefits of large-scale, coordinated research that they could not afford to support and conduct alone. The information and recommendations resulting from the program's research ultimately help everyone to manage urban stormwater more effectively and efficiently.

Administering the program through the center provides the ability to leverage additional university, state, and federal programs. As part of the National Institutes for Water Resources, the center receives base support from the U.S. Geological Survey (USGS) and manages a number of USGS-sponsored grants for Minnesota researchers. Additional base support for the

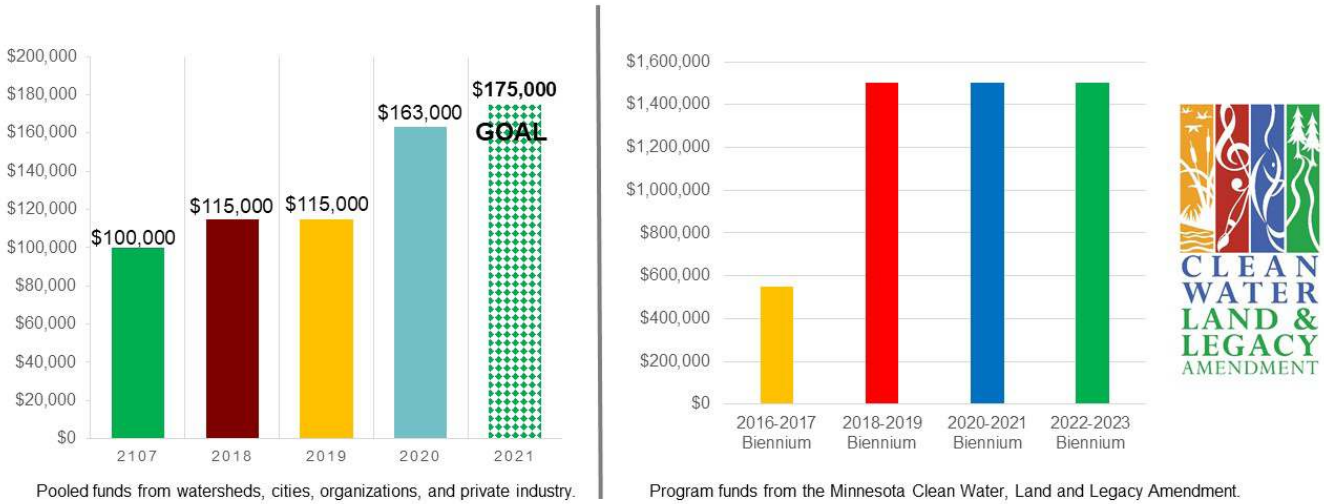

Figure 5. Annual totals of pooled funds from cities, watersheds, and private businesses, 2017-2021 (left side) and biennial financial support from the Minnesota Clean Water, Land, and Legacy Amendment, 2016-2023 (right side). The center provides additional in-kind support for administrative functions.

center comes from university sources, including University of Minnesota Extension, the College of Food, Agricultural, and Natural Resource Sciences, and the Minnesota Agricultural Experiment Station. Base support from all these sources sustains the center's capabilities for office activities and financial functions, providing a core of administrative support that can be leveraged for individual programs such as the MSRTTP. The center's multiple affiliations also provide access to overlapping networks of expertise and stakeholders.

The fulltime administrative leader for the program and the advisory board members are responsible for soliciting and securing financial resources. Board members often provide testimony to the Clean Water Council about the value of the program and also participate in presentations to watershed governing boards, cities, and groups of private industry professionals. Overall financial budget management is provided through the center.

This diversified funding approach provides a substantial budget on an annual basis, while maximizing the share of sponsored funding for research and technology transfer. Of equal importance, the diversified funding approach increases stability and creates ownership and buy-in across the very units of practitioners, professionals, and policymakers that will use and benefit from the research.

Project Reporting

Principal investigators and research teams are required to provide annual mid-project reports and a final report. The annual mid-project reports consist of a short summary of progress in reflection of the activities and deliverables designated in the research plan. It also includes an update on the budget, expenses incurred to date, and adjustments that may need to be considered. In 2020 and 2021, mid-project reports helped both the center and the research teams adjust for impacts due to the Covid 19 pandemic. For example, some research activities were unable to be completed or were significantly delayed as researchers navigated social distancing requirements.

Mid-project reporting is not merely an administrative exercise. The MSRC holds an annual meeting for its advisory board and members. Research teams funded by the MSRTTP are required to present mid-project reports at this event. While the reporting provides communication to stakeholders about the work, it also provides a valuable opportunity for the research teams to gather feedback or solicit additional field sites. Furthermore, information from the mid-project reports is used in a feedback loop to the financial providers, helping the program solicit and secure future funding.

A final research report is required for all projects. This includes the traditional literature

review, abstract, methodology, results, and conclusions. It also requires data and other information to be included as appendices. Teams are required to present their findings to the council, often scheduled as part of the Minnesota Stormwater Seminar Series, discussed in the Technology Transfer section that follows. Principal investigators are required to enter their final report into the University of Minnesota Digital Conservancy Library and/or the Minnesota Water Research Digital Library. This ensures the results and data are publicly available.

The administrator of the research program manages the reporting process and is in frequent communication with all principal investigators and their team members. We believe we have designed a reporting process that helps us know the status of projects and communicate the impacts, all while not being laborious for investigators. Reports are most often submitted through a program-administered email account, although the project management software WizeHive also provides for this activity. Final reports are not the end of this program's story.

Technology Transfer

Technology transfer has been recognized as being a critical component of the program since its inception. While completing priority research is an essential first step, implementation of research results by practitioners, professionals, and policymakers is equally essential for the program to have its intended impact. This takes a commitment to education, training, and outreach, as well as integration into design manuals and policies. The program accomplishes this by:

1. Requiring all funded research projects to have a technology transfer component.
2. Designing and delivering a variety of research transfer events.
3. Establishing a full time Extension Educator position jointly funded by the center and the Minnesota Sea Grant College Program.

Research project investigators must have a defined approach to deliver their results to the practitioners, professionals, and policymakers who will most benefit from the work. Research teams must describe an approach to transfer the science and results including methods for education, outreach and training, desired outcomes, and the intended audiences. Their technology transfer plan is reviewed and taken into consideration when choosing projects for funding. Adopting this strategy places some responsibility on the research teams rather than solely on the center and its Land-Grant and Sea-Grant Extension programs to help achieve dissemination of results. A portion of the project's overall budget can be and often is used to support researchers' technology transfer efforts. One such example is financially supporting the researchers and often their graduate students to present their work at the annual Minnesota Water Resources Conference led by the center. This event draws more than 800 water professionals from across the state and provides a perfect opportunity to discuss the results of these stormwater projects.

Research teams are not on their own in regard to technology transfer. The program in cooperation with the center, Land-Grant and Sea-Grant Extension, and other units and organizations, designs and delivers a variety of research transfer events. One example is the partnership with the St. Anthony Falls Laboratory that has led and offered the Minnesota Stormwater Seminar Series and Minnesota Research Spotlights on a monthly basis for more than two years. Alternating by month, one month features a national expert coupled with a local panel, and the next month features the program's funded research projects in Minnesota. The seminars have been well attended and well received. In 2020, there were more than 1700 participants in these events. The breadth and depth of the topics presented appeal to a wide audience of stormwater practitioners, researchers, and professionals (Figure 6).

As research is completed and where applicable, results are also incorporated into professional training. One such example includes the Inspection and Maintenance of Permanent Stormwater Treatment Practices Certification Course led by the Erosion and Stormwater Certification Program through the Department of Bioproducts and Biosystems Engineering.

Urban stormwater concurrent sessions are also featured during the annual Minnesota Water Resources Conference, which is attended by more than 800 Minnesota water resource professionals,

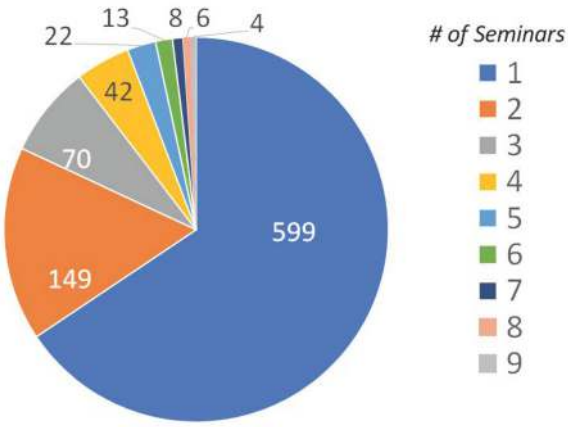

Figure 6. Participation in the Minnesota Stormwater Seminar Series by the number of seminars attended. While most participants join for one specific seminar, likely for a presentation on a unique and specialized topic, many others join repeatedly.

experts, researchers, and managers. The conference has served historically as a gathering forum for the stormwater community, building momentum toward formation of the MSRC. More recently, advances in stormwater have been featured at the conference in plenary talks and special sessions, as well as in regular technical sessions. The Covid pandemic of 2020 provided an opportunity to deliver both the seminar series and the conference virtually, with more participants in attendance than when held in person.

The council has an annual meeting, which was held in person in 2018 and 2019 and was adapted to a virtual format in 2020 and 2021. Funded research teams are required to provide updates on their projects to the full council. This also allows for researchers to solicit input on methods, project field sites, or present draft findings and gather stakeholder feedback. The program also provides frequent presentations and email communication about the status of projects and maintains an individual webpage for each project.

To further help fulfill the goals of technology transfer, the program established a full time Extension Educator position jointly funded by the center and the Minnesota Sea Grant College Program. The educator was brought on board in August 2021 and will develop, lead, teach, and evaluate Extension programs, education, and outreach on urban stormwater practices and policies. The educator will work closely with researchers who have recently completed their projects. This uniquely collaborative position also allows for the educator to network with other Extension Educators in both the Minnesota Land Grant and Sea Grant Extension programs, expanding the delivery team and its reach across the state and region.

Conclusions

Program Future

The program is having impact in Minnesota and in the field of urban stormwater management. Although the program is only a few years old and only the initial wave of research has been completed, there is evidence that practitioners, professionals, and policymakers are beginning to integrate research findings into their work. One example is research that the program supported on urban street sweeping. Cities are now adopting targeted street sweeping strategies to increase efficiency and effectiveness of this common pollution prevention practice. At the same time, the Minnesota Pollution Control Agency and researchers are continuing their work to develop pollution reduction credits for cities that have TMDL reduction goals and that adopt and implement robust enhanced street sweeping programs (Hobbie et al. 2021).

The program has established a base of support for future sustainability, and it also has opportunities to grow. The impacts and relevance of existing projects are leading to growing capital investments and support for the program. As the program emerges from its infancy, explorations are underway to collaborate with and leverage in-state programs and resources working within the stormwater arena. At the same time, the research outcomes have regional and national implications. Ample opportunity exists to collaborate with and leverage resources from the National Institutes for Water Resources, the National Sea Grant Programs and Land Grant Extension Programs across the region and country, the U.S. Environmental Protection Agency, and the National Oceanic and Atmospheric Administration, as well as other like-minded stormwater programs, centers, and groups such as the Water Environment Federation Stormwater Institute. The program has the potential to serve as a model of stormwater research

collaboration and grow to address local, regional, and national needs.

Program Changes

Given both the successes and lessons learned since the program's inception, we anticipate exploration of changes and enhancements to the program in the future. Some of these are related to administrative functions and others are related to providing greater focus on future research priorities and project investments.

- Process changes under consideration include adoption of a pre-proposal stage and applicant presentations, both of which would assist in improving and enhancing proposals and in focusing research investments.
- Proposal review enhancements under consideration include weighting review and selection criteria, adding some type of cost-benefit criteria during review, and lengthening overall project timelines for future work, especially given the lessons learned from the Covid pandemic.
- Future allocation of funds may include a directed research pool to study specific stormwater practices that are long-term priorities. For example, in 2021 the council and center established a research pool specifically for advanced research on needs relating to stormwater ponds. This creates an avenue to work directly with experts to address very high, critical needs without an extensive competitive process.

For more information about the Minnesota Stormwater Research and Technology Transfer Program and the Minnesota Stormwater Research Council, visit https://www.wrc.umn.edu/projects/stormwater.

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