

Introduction

The purpose of this Research Road Map is to present research directions for the Standing Committee on the Environment (SCOE) Subcommittee on Natural Resources (NR) Subcommittee, which is focused on specific topics of interest to state Departments of Transportation, herein referred to as “members”, specific to stormwater. This Stormwater Research Road Map may include other issues of concern to SCOE and also includes issues of concern to other AASHTO committees and subcommittees. As such, it is anticipated that the Stormwater Research Road Map will overlap with other SCOE subcommittees’ research roadmaps, including the Extreme Weather Events Research Road Map and the separate research road map for other natural resource issues of concern. This overlap was expected due to the complex relationship between natural cycles (which include stormwater events); human activity; air, biotic, and aquatic ecosystem quality; water quality and quantity; and, human health.

The research directions outlined are based on the results of discussions with certain NR Subcommittee members; a survey conducted of all SCOE Subcommittee members; an assessment of existing and ongoing stormwater-related research; and a review of information that was reviewed from the Center for Environmental Excellence by AASHTO (Center) Stormwater Management Community of Practice (CoP). Stormwater has received considerable attention from members, the NR Subcommittee, TRB and the research community for many years. Future SCOE-sponsored research should address gaps, reflect, complement, and build-on preceding research, as well as the work that is currently being conducted by others.

Research Road Map

The Research Road Map includes potential topic areas, grouped around seven subject areas or research categories that are depicted in **Figure 1**.

Figure 1: Key Topic Categories for Subcommittee Research

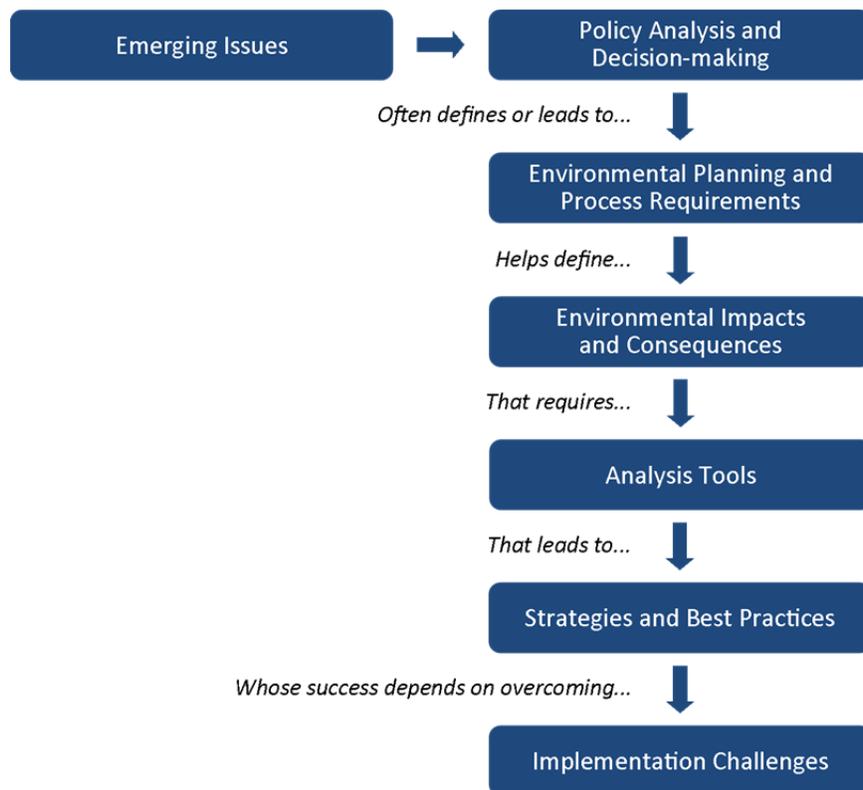


Figure 1 shows how the seven topic areas are connected to different phases of each topic area. For example, emerging issues might focus on those topic areas where very little thought has been given to the implications of a particular issue and its effect on the transportation community. Or, members may have faced a particular issue for some time but one of the key challenges is inadequate tools or databases to analyze the impacts of that issue. Or, members might have appropriate analysis tools and data, but the key challenges are found in overcoming critical barriers to implementing the recommended strategies. A key observation from **Figure 1** as it relates to stormwater issues and the NR Subcommittee’s and Stormwater Management CoP research agendas is that stormwater is fraught with embedded emerging issues that affect member’s “mature” stormwater practices. As such, stormwater management and related research will need to respond quickly to changing requirements and other issues.

Updates to the Research Road Map

To remain relevant, this Research Road Map requires regular updates. The process is as follows:

1. An annual update will occur in conjunction with the NR Subcommittee chair’s notice for the annual “Call for Research” Transportation and Environmental Research Ideas (TERI database).
2. Other updates may be requested by any SCOE or NR Subcommittee member.
3. All updates will be coordinated by the NR Subcommittee Research Coordinator.
4. NR Subcommittee members will have the opportunity to review and comment on updates.
5. The consensus Research Road Map will be posted on the TERI database.
6. NR Subcommittee members and others will be invited to develop research proposals linked to the Research Road Map entries.
7. The NR Subcommittee will consult the Research Road Map during development of the annual NCHRP research program and response to calls for research suggestions from FHWA and others.

Potential Research Topics

The identification of research topics for Subcommittee sponsorship should reflect the importance of a topic to members, the level to which the research will add understanding or capability to members’ technical analysis, the degree to which the research will not overlap with what others are doing on that topic, and additional input, improvements to streamlining and/or cost-effectiveness of technical analyses, or environmental clearance processes, and other considerations (e.g. regulatory) as appropriate.

With respect to the importance of stormwater research, a survey of the full SCOE membership ranked the water quality and total maximum daily loads (TMDLs) topics as the second and third (respectively) most important topics out of 30 potential research topics. There is clearly a great deal of interest in supporting more research attention on those issues surrounding stormwater.

The stormwater research topic areas presented below provide examples of specific topics of interest to the NR Subcommittee for each subject or research category. They are not intended to be the only ideas that may be funded, or in any way exclude new ideas received in the annual TERI database update process from being considered for funding. Rather, the topics are provided to serve as a framework of ideas of interest to SCOE and the NR Subcommittee that can be revised as needed.

The topics identified by the survey as well as other research topics that were identified through discussions with member officials are summarized below under each of the topic categories (a topic was listed from the survey if it received votes of “medium” or “high” priority). Information developed as part of the Stormwater

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Management CoP was also reviewed. This review included the information posted on the Center website regarding the Stormwater Management CoP and reports including:

- *Stormwater State-of-the-Practice Report: Source Control, May 2011*
- *EPA Post-Construction Stormwater Control Rulemaking CoP State-of-the-Practice Report, March 2010*
- *TMDL CoP State-of-the-Practice Report, March 2010*
- *Effluent Limitation's Guidelines CoP State-of-the-Practice Report, March 2010*
- *Stormwater Management CoP State-of-the-Practice Report, June 2009.*

A review of the proceedings from the July 2014 National Stormwater Practitioners Meeting highlighted discussion topics, concerns and information associated with:

- Audits by federal and state regulators;
- Construction contract administration;
- Asset/data management and tracking;
- Research findings and tools;
- Maintenance; and
- TMDL implementation and the watershed approach.

The key findings from the proceedings played a critical role in helping to identify and refine research areas. The following is a summary of the key factors that influenced the Stormwater Research Road Map:

- The survey of the NR Subcommittee members showed strong support for a Subcommittee goal of “identifying and prioritizing research priorities and supporting their selection and funding” (average rating of 4.73 out of 5.0);
- The research-oriented questions on the survey focused on both existing and new areas of research interests;
- The research topics identified by the survey that either directly or indirectly pertained to stormwater;
- Research topics that were identified through the review of information reflected in the Stormwater Management CoP; and
- Review of past stormwater related research.

The NR Subcommittee identified areas to research that overlap and either directly address or can be used to address stormwater issues. Topics may be presented as a research question, though they might also represent topics for discussion, guide book development, workshops, agenda items, etc. The current topics of interest to the NR Subcommittee reflect its ongoing interest in: stormwater.

Policy Analysis and Decision-making

This category includes research to better understand the underlying factors associated with specific environmental policies. It also includes emphasis on how these factors can be considered within the state DOT decision-making processes.

- What are the potential implications to state DOTs as MS4 operators, as a result of EPA rulemaking in the area of NPDES and Waters of the United States? (“Definition of ‘Waters of the United States’ Under the Clean Water Act,” published at 79 Federal Register 22,188 (April 21, 2014) (“Proposed Rule”). There are past court decisions and existing guidance on Waters of the U.S. It seems that the MS4 community needs more certainty regarding the interplay between Sections 402 and 404 of the Clean Water Act, i.e., NPDES and 404 permits. What would be the impact to state DOTs if MS4 (including component parts such as ditches, etc.) are somehow considered jurisdictional Waters of the U. S.? A 25-25(52) study completed in 2009 gave the perspective that ditches should not be considered jurisdictional.)
- What are the potential implications to state DOTs as a result of trends in stormwater management regulatory practices (regulating and reducing flow; performance requirements in permits; second generation permits regulating discharges into waters under a TMDL, which includes tighter water quality limits or may have impervious surface retrofit requirements; and, development of standards incorporating on-site retention requirements)?
- What information does FHWA need in developing a nationwide performance measure(s) for stormwater?
- What are the implications for state DOT stormwater management programs when EPA is considering that highway runoff discharges constitute a release of hazardous substances and a source of contaminated water body sediments, per CERCLA?
- What are the information needs for decision-makers, policy-makers and regulators that need to be addressed regarding the application of road salts and the realities of needing its use, but considering its effect on MS4 permit requirements, water quality and quantity, aquatic species, etc.? (In the Northeast, it is not unusual for highway runoff to cause exceedances of chloride water quality standards (e.g., where an intermittent stream (receiving water) runs next to a multi-lane highway). DOTs/regulators need practical measures in terms of policies and design options to address these occasional impairments. Considerable research has been done on winter operations, salt, sand and chemical management. (Included in other portions of this research road map are further research questions that need to be addressed.)
- What are some local and state DOT existing policies and realistic future policy options in managing and regulating volume and discharge into state DOT right-of-way? Would monitoring inflow and outflow of off-site stormwater into the right-of-way be cost-effective and provide the needed information to influence policy and regulatory changes?
- What information needs to be supplied to EPA and State Departments of Environmental Quality for the assignment of TMDLs to the original discharger of polluted off-site source stormwater rather than to the state DOT as the MS4 permit holder?
- What are some mechanisms available to state DOTs, to influence policies and decision-making regarding TMDL development?
- What are the best practices and challenges in documenting emergencies resulting from extreme weather events that may lead to issues with BMPs (e.g., BMP (re)design approach, revised design standards, BMP failure, non-compliance, enforcement, etc.)?

- What policy decisions (internal and external to state DOTs), if any, need to be modified to allow for in-lieu fee, banking, restoration, regional BMPs (i.e., off-site and out-of-kind mitigation) and other types of regional mitigation for more effective stormwater management?
- What information is needed by state DOT policy and decision-makers to resolve problems regarding resources (human) needed to collect surface water samples to satisfy TMDLs for *E. coli*, other assigned TMDLs and for overall MS4 compliance?

Environmental Planning and Process Requirements

This category includes research on how the process of considering transportation-related impacts can better consider environmental concerns. It also covers understanding of how existing or new process requirements can fit into state transportation and environmental planning efforts and improving collaborative efforts in environmental analysis.

- What practical processes are needed to identify effective BMPs, reduce long-term operation and maintenance costs, increase project life span, reduce capital costs for retrofit projects, and to assess if the overall process is working?
- Are there situations where the same amount of effort/funds used by state DOTs to meet TMDL requirements could be used for greater benefit elsewhere in a watershed?
- What should be the process framework for selecting effective BMPs to address assigned TMDLs?
- What laws, rules, regulations, processes, procedures and agreements are needed to more efficiently and effectively regulate stormwater, water quality and quantity, and endangered species? (The intent is to eliminate duplication and conflicts in regulatory approaches and to achieve added value through efficiencies and coordinated efforts.)
- What are the long-term advantages and disadvantages from current partnerships and how can these current or new partnerships be used to improve and positively advance state DOT stormwater programs?
- What is the current status and what is the needed framework for stormwater quality banking (e.g., stream restoration, leveraging wetlands for hydromodification, other flow control activities, etc.) and trading?
- What are the appropriate application rates for anti-icing and deicing, effectiveness of incentive programs, effective use of hot water, and innovative use of roadside vegetation and efficiency of reactive strategies in cold regions?
- What credit programs are available for source control and what are the requirements for being included and trading?

Environmental Impacts and Consequences

This category focuses on research on the community and transportation system consequences of environmental impacts. Focus could be on sole impacts or cumulative impacts over time.

- How effective are the six minimum control measures as implemented by the state DOTs? How appropriate are the six measures for state DOTs (as opposed to municipalities)?
- How have state DOT stormwater management programs positively affected NR?
- How effective is off-site mitigation (in-lieu fee, banking, regional BMPs, etc.) versus on-site strategies under watershed – and entity – based permitting for MS4 permits and what combination results in overall better outcomes?

- What model and tools can be used to evaluate impacts and mitigation for water quality, stormwater and endangered species that could be used to inform better outcomes and a coordinated and effective decision-making and permitting by the regulatory agencies?
- What factors need to be considered in BMP evaluation, selection, design, performance and maintenance as related to impacts and mitigation for endangered species, habitat connectivity, temperature, water quality, and water quantity?
- What are the environmental costs/benefits for state DOT implementation of plans to comply with TMDLs?
- What are the benefits and risks of using liquids for anti-icing and deicing, impacts and implications of removing impaired roadside vegetation, cost-effectiveness and environmental impacts of agro-based deicers, fate and transport of pollutants?
- What do field investigations reflect regarding the use of mobile salinity sensors, salt-tolerant vegetation, and the correlation of the chloride loading in adjacent soils with deicer usage and the effectiveness of salt management plans?
- What do water quality monitoring results indicate regarding the effectiveness of roadway BMPs not traditionally credited (e.g., vegetated filter strips, open graded friction course, tree buffers, etc.)?
- How effective are the different vegetation types within existing rights-of-way as BMPs for pollutant reduction; and, what specific vegetation types are needed for pollutant reduction by climate region?

Analysis Tools

This category covers research on models and tools that can be used to analyze and assess environmental impacts. It also includes examining the sources and use of data as part of the analysis process.

- What are best practices in stormwater monitoring programs (evaluate pollution in stormwater runoff and evaluate effectiveness of controls) and what are the recommended models for state DOT stormwater monitoring programs to successfully meet their individual existing and evolving MS4 requirements? (The intent is to design and implement effective, realistic and reasonable stormwater monitoring programs that provide actionable information and support compliance with MS4 requirements. The research should also consider that the resulting information will be used to guide conversations with regulators regarding monitoring.)
- Is there a need to develop a flexible tool/decision support system that considers climatic and other region and site specific considerations for evaluating and selecting mitigation (banking, etc.) and BMPs (e.g. performance; location; single, train or regional BMP; construction; maintenance; life-cycle cost; etc. and organized by climatic regions)? What modeling and/or tools are needed to analyze TMDLs and establish proper Waste Load Allocation (WLA) to state DOTs and others and to determine the extent of that WLA? (The goal is to assign responsibility to the original dischargers rather than to MS4 owners/operators.)
- What models and/or tools are needed for watershed planning and TMDL implementation?
- What modeling and/or other tools are needed to evaluate regional BMPs/mitigation and on-site BMPs/mitigation approaches?
- What models, tools and technologies need to be identified, developed and implemented or better integrated into state DOT stormwater programs? (GIS, drones, smart systems, etc.)
- Are there consistent and scientifically supportable criteria for determining when hydrologic mitigation is appropriate and necessary, as well as guidance for designing hydromodification controls? (Research could include evaluating existing criteria and rationale, methods [e.g., stream restoration, leveraging

wetlands, etc.], recommending criteria by climatic region and geomorphology and developing design guidance.)

- What is the status of technology performance such as anti-icing pavement, better chemical products and improved thermal road mapping?
- Would contract administration templates to evaluate contractors and to communicate performance requirements in contracts involved in stormwater monitoring and/or maintenance be useful?
- Would contract administration templates for transferring responsibilities associated with stormwater, to design-bid-build, design-build and Public/Private Partnerships (P3s) be useful?
- Would a handbook based on lessons learned be useful to guide conversations for establishing or revising a Transportation Separate Storm Sewer System (TS4) program? What tools exist for identifying and prioritizing retrofit projects?
- What is the recommended monitoring program (protocols, procedures, locations, schedule, training, implementation, etc.) for state DOTs for illicit discharge detection and elimination?

Strategies and Best Practices

This category covers research on the effectiveness of different strategies to mitigate or adapt community and transportation system impacts. It also includes examining best practices of state DOTs.

- What are best practices in TMDL assignment, TMDL partnerships for management and BMP approaches for addressing assigned TMDLs?
- What are best practices in preparing for audits (understanding MS4 permit requirements, preparations, and lessons learned?)
- What are best practices to integrate funding constraints into state DOT stormwater management programs?
- What are best practices in funding projects regionally – regional BMPs and associated new development, redevelopment and retrofit projects or programs?
- What are best practices and strategies for improving construction and maintenance contract administration as related to stormwater?
- What are best practices and strategies for contract provisions in P3 agreements as related to stormwater?
- What are best practices in assigning roles and responsibilities to internal and external parties in monitoring programs and BMP maintenance to maintain effectiveness under state DOT stormwater programs?
- What are best practices and strategies for state DOT good housekeeping and other activities (of concern to stormwater, state DOT MS4 permit and other compliance) occurring on state DOT owned facilities such as Headquarters, district and maintenance offices and other buildings and yards and right-of-way?
- What are best practices and strategies to improve stormwater permit compliance with respect to maintenance practices and activities, including best management practice (BMP) inspection, tracking, and reporting concepts, winter storm management-related procedures with considerations to the region's environment? (guidance, training, etc.)
- What are best practices and strategies to incorporate stormwater features inventories into (and be components of) corporate asset management databases and systems?
- What are best practices in improving and/or implementing asset/data management, tracking and response as related to state DOT stormwater programs? (Reason for collecting data; type and quantity

of data to collect; use of funding systems; use of technological tools; the need for actionable, meaningful data that the state DOT can actually use; how to determine what an asset consists of; and, the level of data to collect).

- What are best management practices for porous pavements considering long-term performance, life-cycle costs, pavement longevity, routine maintenance requirements and maintaining environmental benefits (mostly to purify stormwater)?
- What are the best practices and recommended strategies for BMP maintenance techniques and schedules to achieve stormwater BMP performance requirements, based on certain parameters (e.g., road type, sanding practices, climate areas, etc.)?
- What are realistic and best practices in managing stormwater volume by state DOTs?
- What are innovative practices in mitigating (banking, BMPs, etc.) for stormwater impacts, with and without other environmental impacts? What are best practices in stream restoration in lieu of more traditional stormwater management practices to meet regulatory requirements and to achieve pollutant reduction requirements?
- What stream restoration and leveraging of wetlands (for hydromodification) practices can be used to meet regulatory pollutant reduction and volume requirements?
- What are strategies to get stream restoration and leveraging of wetlands practices accepted by regulatory agencies as a mitigation for stormwater impacts?
- What are best practices in using social media and technologies as part of the Public Education and Outreach/Public Participation/Public Involvement minimum control measures?
- Have the results for BMPs in roadway settings been consolidated and reflected in the International BMP database?

Implementation Challenges

This category focuses on research on the barriers and opportunities to implement environmental policy, planning requirements and mitigation strategies.

- What is the status of TS4 permit development?
- What have been the challenges and strategies used by state DOTs to implement their MS4 permit, and what needs have been identified?
- What are the models or data or both that will help prioritize and allocate limited funding for retrofits?
- What are source control options that may be appropriate for some traditional pollutants of concern specific to state DOT activities and third party activities? (Third party information will inform state DOT outreach, communication, coordination, collaboration and cooperation.)
- What is needed for a more rigorous science-based TMDL development process and to demonstrate the fact that state DOTs are often minimal contributors to many TMDLs?
- What are the best practices, strategies, challenges and needs for TMDL implementation and watershed permitting?
- What are the options, challenges and opportunities for mitigation (in-lieu fees, banking, regional BMPs, etc.) under watershed based permitting?
- What are the opportunities and challenges for new development; redevelopment and retrofit projects under watershed based permitting?

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- What partnerships exist or need to be formed to develop stormwater management success for existing and evolving MS4 permits and for the watershed scale level?
- What are the best practices and challenges for incorporating BMPs in the state DOT right-of-way?
- What are the geographic factors that negatively affect BMP effectiveness?
- What challenges and opportunities exist in current state DOT stormwater monitoring programs for adaptive management considering the six minimum control measures, Construction General Permit (CGP), endangered species and Section 404 requirements?
- What is being reported in MS4 Annual Reports and how are the regulators and state DOTs responding?
- What are best practices and opportunities in addressing construction and maintenance activity compliance (erosion and sediment control, good housekeeping, etc.) in response to State DOT or regulatory audits?
- What are the challenges, future opportunities and current realistic opportunities for volume reduction by state DOTs?
- What are the challenges and opportunities to state DOTs in not allowing bats to roost under bridges or in culverts due to water quality concerns?
- What are best practices in addressing the Migratory Bird Convention Action (Canada)/Migratory Bird Treaty Act (U.S.) as it relates to state DOT stormwater programs?
- What are the issues and methods of disposing or reusing BMP and drainage system (e.g., catch basin) generated waste?
- Why and how can compost be used in stormwater management as a permanent BMP?
- What are the best practices and challenges in capturing emergencies that may lead to issues with BMPs? (Emergencies resulting from extreme weather events, etc.)
- What are the key organizational resources and structures needed to provide a strong capability for stormwater program development, implementation and management—staff, agency structure, funding, tools, partnering and technical guidance?
- How can a business case be made to address implementation challenges?
- What are the opportunities for better capturing research gaps routinely identified in existing and ongoing stormwater related research?
- What are the gaps in training, practical guidance documents and tools to better position state DOTs to respond to changes and incorporate necessary changes into their stormwater management programs.
- What completed stormwater research would benefit from further research for conversion into practical user’s guidance documents?
- What are the best mechanisms for keeping any developed stormwater training, practical guidance documents and tools updated?
- What are the opportunities and challenges in providing the human resources needed for the growing industry of water resources, environmental planning and design?
- What are the best practices and opportunities in the use of devices and technology for all areas of stormwater management? (drones, GIS, smart systems, etc.)
- What are the opportunities and challenges in implementing source controls external to the control of state DOTs?

- What are the opportunities and challenges in implementing the Watershed Resource Registry? What is needed to implement the Watershed Resource Registry for use in watershed planning and permitting and ultimately as part of stormwater management programs?

Emerging Issues

This category covers research on new and emerging environmental issues that will affect state DOTs in the near future.

- What are the potential implications to state DOT MS4 permits and stormwater programs as a result of national and state proposed laws, rules, etc.?
- What are the potential implications to state DOTs as a result of trends in stormwater management regulatory practices (regulating and reducing flow; performance requirements in permits; use of surrogates in TMDL development, second generation permits regulating discharges into waters with a TMDL, which includes tighter water quality limits or may have impervious surface retrofit requirements; and, development of standards incorporating on-site retention requirements)?
- What are the implications to state DOTs as a result of lawsuits filed against EPA, other regulators and MS4 operators?
- What are the opportunities and challenges in new technology for stormwater management?
- What adaptations for stormwater BMP evaluation, location, selection and design are needed to address extreme weather events?
- What is needed to evaluate stormwater investments by state DOTs being overwhelmed by precipitation impacts that are beyond those anticipated by past stormwater management programs?
- What data and modeling tools are needed to assist state DOTs in supporting their future stormwater programs and approaches considering extreme weather events?
- What are examples, opportunities and challenges for P3 involvement in stormwater management?
- What are examples of collaborative project development teams in the area of stormwater to include project planning, BMP evaluation, selection and design, that factor in construction and maintenance considerations?
- What are the evolving threats and risks to state DOTs as MS4 owners/operators and to their stormwater management programs?