Appendix A: Study Methods

IDENTIFYING STORMWATER-RELATED CLIMATE IMPACTS AND ASSESSING RISK BY REGION AND STATE

The potential impacts of climate change are wide ranging, from more frequent extreme flood events in some regions to increased period of drought in others. In addition, some regions may experience a combination of extended drought periods along with more intense storms.

For this study, we focused more narrowly on effects of climate change that 1) directly impact the function of stormwater BMPs or 2) can be directly or indirectly mitigated by changes to stormwater BMP design. The climate change impacts that can affect stormwater management were identified using the Fourth National Climate Assessment (later updated with data from the Fifth National Climate Assessment). Some climate impacts that affect stormwater management or water quality were not included for other specific reasons. For example, while wildfires can cause major water quality issues for stormwater managers, there are limited ways to manage these impacts through site-specific stormwater BMP design. Another example is changes in snowmelt which has implications for watershed-scale water supply and flood management but limited solutions at the development site scale. The resulting climate impacts of interest were grouped into four major categories, including:

- High Precipitation
- Drought
- High Temperature
- Sea Level Rise

For each U.S. climate region in the National Climate Assessment, a value of High, Moderate, or Low was assigned to illustrate the extent to which these major climate impacts are occurring or expected within each U.S region and state. The section below explains how these High, Moderate, and Low categories were assigned.

The High Precipitation impact classification was based on Figure 2.6 of the Fourth National Climate Assessment, which summarized both observed changes in heavy precipitation, defined as annual precipitation falling in the heaviest 1% of events. We used two pieces of information from this figure: 1) the observed change from 1958-2016 and 2) projected changes by the late 21st century using the Higher Scenario modeling results.

- Regions where the projected modeling scenario had no areas with at least 40% projected change were assigned a "Low" vulnerability.
- Regions that experienced both areas with a projected and observed change of at least 40% were assigned a "High" vulnerability.
- All other regions were assigned a "Moderate" vulnerability.

Drought was classified using Figure 2.5 of the Fourth National Climate Assessment, which summarized projected changes in seasonal rainfall depths by the late 21st century for the Higher Scenario modeling results:

- Regions where all four seasons are projected to experience at least 10% reduction in precipitation were classified as "High" vulnerability.
- Regions where no seasons experience a decrease in rainfall were classified as "Low" Vulnerability.
- All other regions were classified as "Moderate" Vulnerability.

Temperature was impacts were based on Figure 2.4 of the Fourth National Climate Assessment, which summarizes projected changes in the annual average temperature, and with classifications based on the Late 21st Century Higher Scenario:

- Regions dominated by temperature increases of 8 ºF were classified as "High" vulnerability.
- Regions dominated by increases less than 8 ºF in the southern U.S. were classified as "Moderate" vulnerability.
- Hawaii and the Northwest were classified as "Low" vulnerability since both regions are dominated by temperature increases less than 8 ºF and currently have relatively cool summers.

Sea Level Rise was assessed at the state level, since regions include states with and without coastlines. Sea Level Rise was categorized based on the level of sea level rise projected by 2050 using an Intermediate Sea Level Rise Scenario (Figure 9.2 of the Fifth National Climate Assessment) as follows:

- States with no coastline were assessed as "Low" vulnerability.
- Coastal states with less than 1' of sea level rise compared to 2000 were assessed as "Moderate" vulnerability.
- Coastal states with at least 1' of sea level rise were characterized as "High" vulnerability.

DEVELOPED LAND PROJECTIONS

Several data sources were explored to characterize the projected increase in developed land at the state level (Table A-1). Two general types of urban growth projections were identified: 1) projections of the additional urban land needed to accommodate the projected population change and associated urban growth, and 2) analysis of historic changes in land use/land cover and relationship with explanatory variables (e.g., distance to roads, slope, protected lands).

Table A-1. Data Sources Reviewed

Data Source	Years	Resolution/Extent	Projection Type and Notes
Nowak and Walton 2005 Projected Urban Growth (2000-2050) and Its Estimated Impact on the US Forest Resource	2000 - 2050	Census Blocks/ Conterminous U.S.	Historic changes in land use/land cover; County-level analysis using Census population data.
The Clark Labs 2050 Conterminous US Land Cover Prediction	2011 - 2050	30-meter/ Conterminous U.S.	Historic changes in land use/land cover; Data access requires a subscription.
ESRI Land Cover 2050	2018 - 2050	300-meter/Global	Historic changes in land use/land cover
Gao and O'Neill 2020 Mapping Global Urban Land for the 21st Century with Data-Driven Simulations and Shared Socioeconomic Pathways	2000 - 2100	1-kilometer/Global	Population changes
EPA's Integrated Climate and Land-Use Scenarios	2000 - 2100	90-meter/ Conterminous U.S.	Population changes

The EPA Integrated Climate and Land Use Scenario (ICLUS) data was chosen for the developed land analysis due to data availability, focus within the U.S. as opposed to a global model, and reasonable data resolution of 90-meters. ICLUS data is based on population projections and migration using social, economic, demographic and climate factors. A middle of the road scenario of the data was chosen for the state urban growth analysis

based on Shared Socioeconomic Pathway 2 (SSP2) where social, economic, and technological trends do not shift markedly from historical patterns, and Representative Concentration Pathway 4.5 (RCP4.5) which assumes that global greenhouse gas emissions increase into the latter part of the century, before leveling off and eventually stabilizing by 2100 as a result of various climate change policies[1].

Land use is represented by 19 discrete categories delineated in the U.S. National Land Use Dataset (US-NLUD; US EPA, 2017). The developed land use group consists of parks, golf courses, exurban, suburban, urban, commercial, industrial, institutional, and transportation. For the developed land analysis, the absolute change in the percent of developed land for each state from 2020-2050 was calculated. The data was classified by Jenks natural breaks into 3 classes representing low, medium, and high change in developed land. Alaska and Hawaii were not included because the data extent is for the conterminous United States.

For Alaska and Hawaii, a global land cover map that was modeled by country for the year 2050 at a pixel resolution of 300m was used to categorize the expected increase in developed land. This map predicts land cover changes based upon patterns observed in the period 2010-2018 using a ten-class land cover generated from ESA Climate Change Initiative Land Cover. These data are made available by Clark Labs at the following link: Land Cover 2050 - Country - Overview (arcgis.com). Figure A-1 shows the absolute change in the percent of developed land for each state and Figure A-2 shows the extent of developed land in 2020 and projections for 2050. The greatest increases in land development are projected for the Southeast climate region, as well as portions of the Northeast and Southern Great Plains.

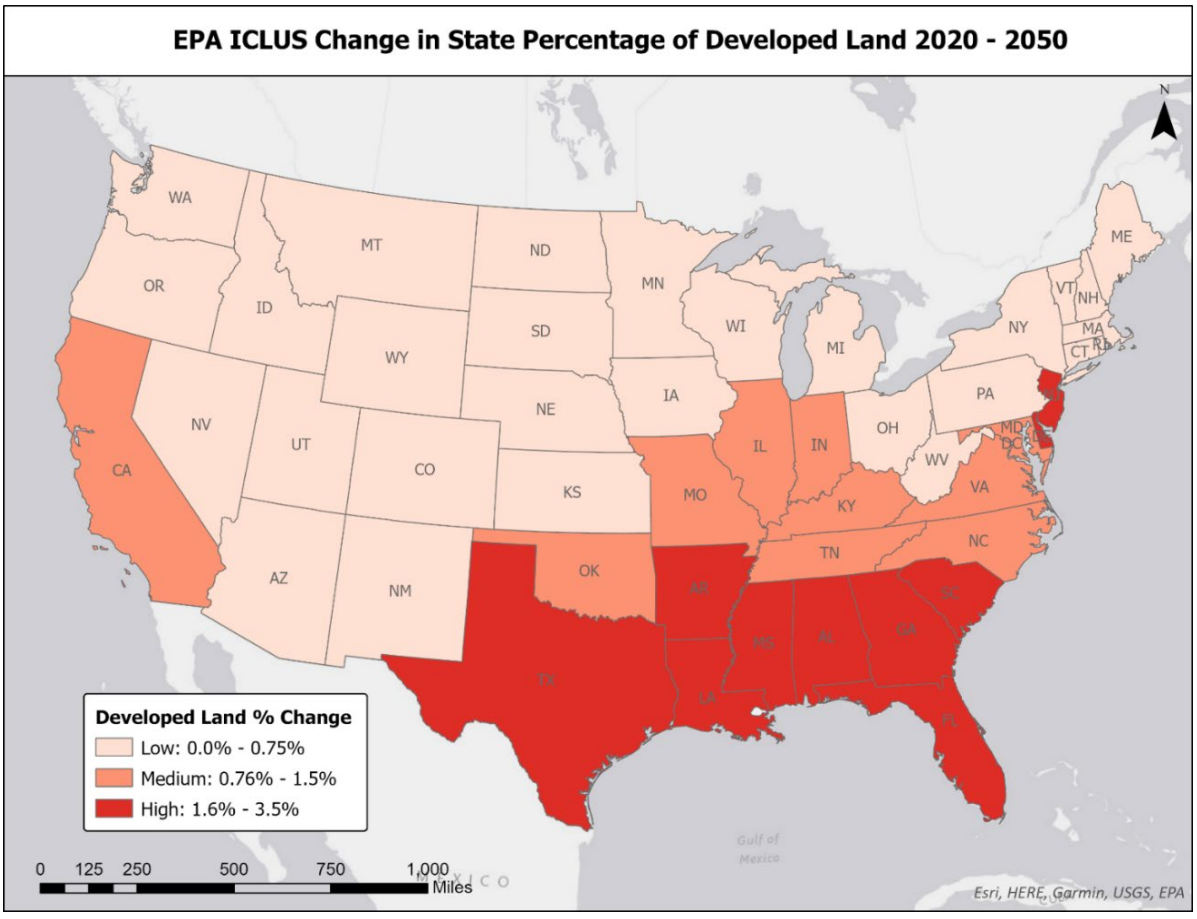

Figure A-1. Absolute Change in Percent of Developed Land by State, 2020-2050

[1] https://catalog.data.gov/dataset/iclus-v2-1-1-land-use-projections-for-ssp2-and-rcp4-5-pathways2

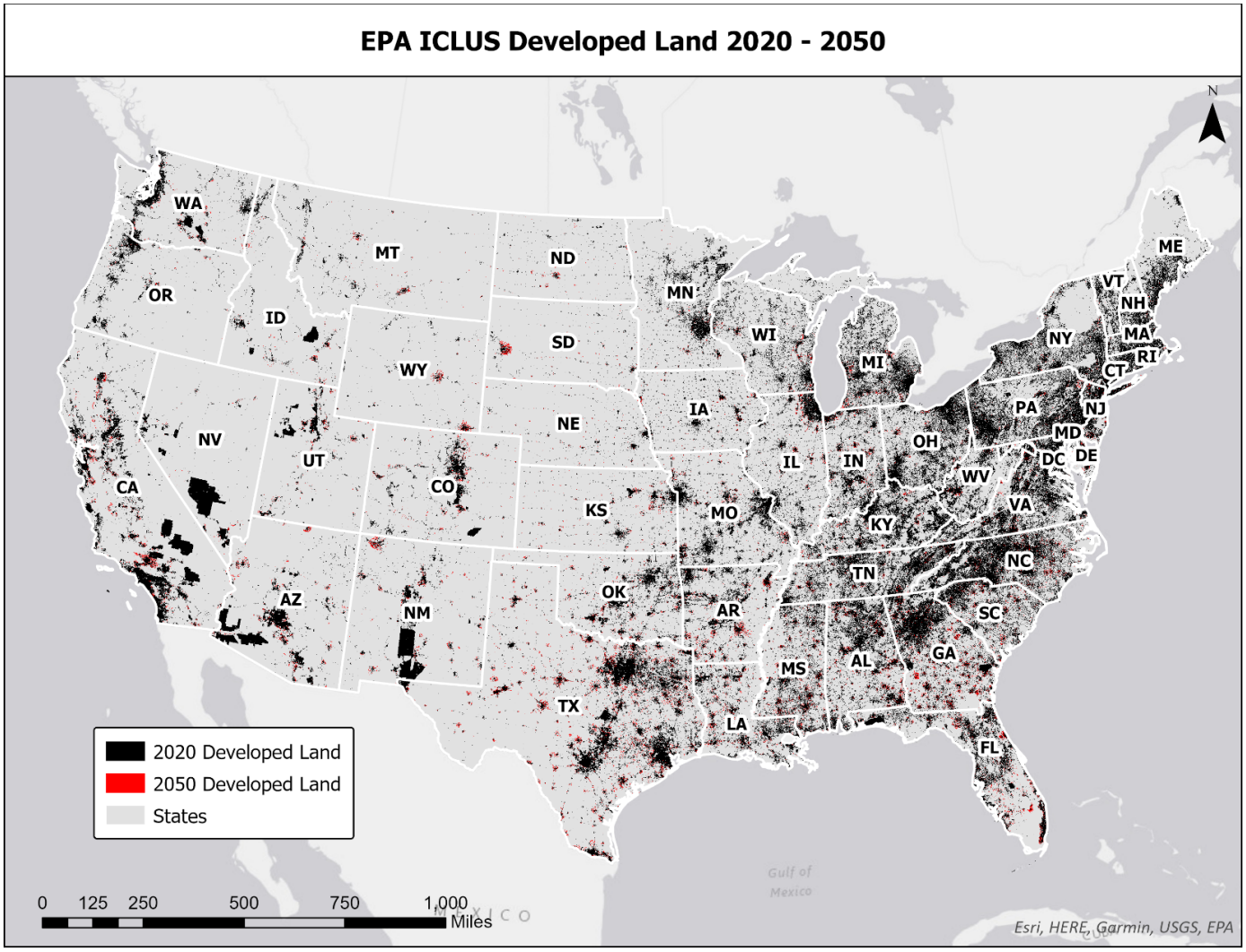

Figure A-2. Extent of Developed Land in 2020 and Projections for 2050

LITERATURE REVIEW TO IDENTIFY BEST STORMWATER DESIGN PRACTICES TO MANAGE CLIMATE VULNERABILITY

CWP searched primarily for synthesis papers that present strategies for adapting stormwater management to climate change, but also included relevant BMP modeling studies. The search was conducted using Google, Google Scholar, ChatGPT, and the North Carolina State University library system. Keyword searches were conducted with general terms, including 'climate change,' 'BMPs' or 'best management practices,' 'adaptation,' 'resiliency,' 'design,' and searches on individual practice types, such as 'rainwater harvesting.' Papers recommended from the steering committee were also reviewed. Sources included academic journals and gray literature such as government reports.

The majority of papers were national in scale, or from the southwest, northeast or Chesapeake Bay regions. No papers were found from the northern or southern great plains regions, Alaska, Hawaii, or Caribbean. Table A-2 provides a summary of the papers reviewed by climate region and Figure A-3 shows the papers reviewed based on the type of publishing organization. Note that this was a systematic review as opposed to a meta-analysis, and therefore a statistical analysis to synthesize the result was not conducted.

For each paper reviewed, CWP set up a spreadsheet to record the following information: full citation, region of study, major climate impact(s) addressed, specific climate impact(s) addressed (taken from the sources identified in the National Climate Assessments and EPA's Climate Indicators website), BMP adaptation(s)

identified, and specific notes regarding design adaptations. Table A-3 provides the list of climate regions, impacts, and BMP adaptations included in the review matrix. The completed review matrix is provided at the end of this appendix.

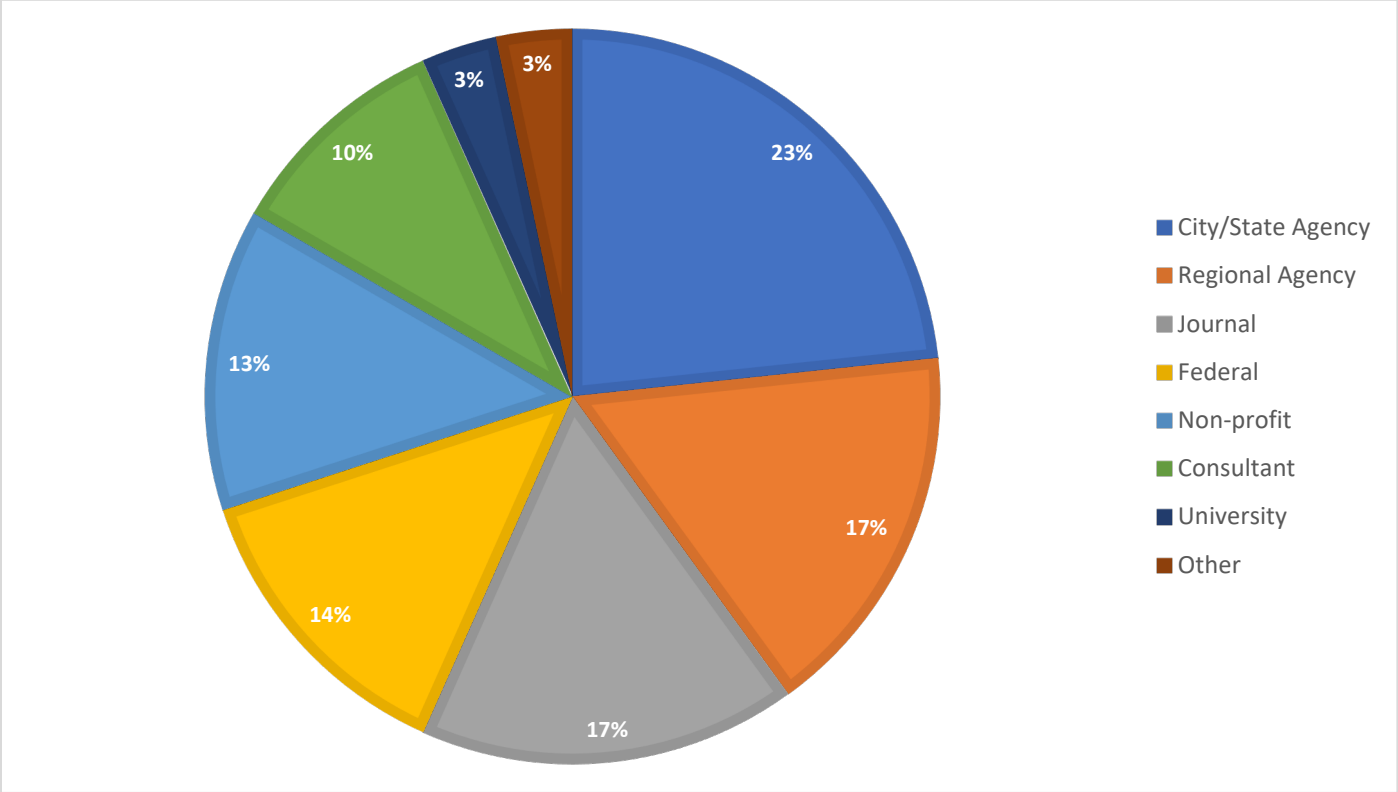

Figure A-2. Papers Reviewed by Publishing Organization

Table A-2. Number of Papers Reviewed by Climate Region	
Region	**Number of Papers Reviewed**
National	10
Southwest	6
Northeast	6
Chesapeake Bay	3
Midwest	1
Southeast	1
Western	1
Chesapeake Bay and Great Lakes	1
Northwest	1
TOTAL	**30**

Table A-3. Climate Regions, Impacts, and BMP Adaptations Included in the Literature Review Matrix			
Regions	**Major Climate Impacts**	**Specific Climate Impacts**	**BMP Adaptations**
• Northeast • Southeast • Midwest • Great Plains • Southwest • Northwest • Alaska • Hawaii Pacific • National	High Precipitation	Extreme_Storm Frequent_Storms Wet_Soils Erosion River_Flooding Local_Flooding Plants_Inundation Sediment_Pollutant_Load_Increase	• BMP Sizing • Design Storm Data • BMP Selection • BMP Siting • Design Modification - Storage • Design Modification - Resiliency • Modeling • Plant Selection • Material Selection • Modify Maintenance Requirements • Stormwater Harvesting
	Drought	Drought_Regional Drought_Plants Soils_Effects In_Stream Seasonal_Snow	
	Temperature	Human_Health Plants Seasonal_Snow In_Stream Materials	
	Sea Level Rise	Salt_Water Tail_Water Ground_Water Plants_Salt	

A list of papers reviewed is provided below.

Brand, M., Guo, L., Stein, E., and B. Sanders. Multi-decadal Simulation of Estuarine Sedimentation under Sea Level Rise with a Response-Surface Surrogate Model. Advances in Water Resources. 2021. Link.

Burkey, J., and J. Pray. Evaluation of Potential Climate Change Impacts on Stormwater Facility Size and Cost. King County, WA. 2019. PDF.

Butcher, J., Job, S., Roth, N., Groza, B., Pickard, B., and P. Kwon. Climate Impacts to Restoration Practices - Project Report. Tetra Tech. 2020. PDF.

California Natural Resources Agency, California Dept of Food and Agriculture, and California Environmental Protection Agency. California Water Action Plan 2016 Update. California Natural Resources Agency. 2016. PDF.

Chesapeake Stormwater Network. Menu of Options to Promote Urban Watershed Resilience in Chesapeake Bay Communities. 2021. PDF.

Chesapeake Stormwater Network. Vulnerability Analysis and Resilient Design Considerations for Stormwater Best Management Practices. 2021. PDF.

Finzi Hart, J., May, C.L., Mak, M., Ramirez Lopez, D., Badet, Y., Cohn, A., Rockwell J., and T. Anbessie. Scaling and Application of Climate Projections to Stormwater and Wastewater Resilience Planning. Water Utility Climate Alliance. 2022. PDF.

Geosyntec Consultants. Climate Resilience Resources Guide: Part 1. 2022. PDF.

Hirschman, D., Caraco, D., and S. Drescher. Linking Stormwater and Climate Change: Retooling for Adaptation. Center for Watershed Protection. 2011. Link.

Horsley Witten Group, Inc. Assessment of Climate Change Impacts on Stormwater BMPs and Recommended BMP Design Considerations in Coastal Communities. 2015. Link.

Job, S.C., Harris, M., Julius, S.H., Butcher, J.B., and J.T. Kennedy. Improving the Resilience of Best Management Practices in a Changing Environment: Urban Stormwater Modeling Studies. EPA. 2018. PDF.

Johnson, T., Butcher, J., Santell, S., Schwartz, S., Julius, S., and S. LeDuc. A Review of Climate Change Effects on Practices for Mitigating Water Quality Impacts. Journal of Water and Climate Change. 2022. Link.

Khan, M.P., Hubacek, K., Brubaker, K.L., Sun, L., and G.E. Moglen. Stormwater Management Adaptation Pathways under Climate Change and Urbanization. Journal of Sustainable Water in the Built Environment. 2022. PDF.

Minnesota Pollution Control Agency. Minnesota Stormwater Manual – Climate Benefits of Green Stormwater Infrastructure. 2013. Link.

NYC Mayor's Office of Resiliency. Climate Resiliency Design Guidelines. NYC Mayor's Office of Resiliency. 2020.

Philadelphia Water Department. Climate-Resilient Planning and Design Guidelines. 2022. PDF.

Weathers, M., Hathaway, J.M., Tirpak, A., and A. Khojandi. Evaluating the impact of climate change on future bioretention performance across the contiguous United States. Journal of Hydrology. 2023. Link.

IDENTIFYING RECOMMENDED STORMWATER DESIGN ADAPTATIONS

Recommended stormwater design adaptations for each climate impact category were derived from the literature review database, along with recommendations from CWP's National Watershed Research Network Steering Committee and external reviewers. The process was as follows:

- Filter the database by climate category, and then by stormwater adaptation method.
- Enumerate and summarize the adaptation measures identified in the literature reviewed to develop a bullet list of recommendations.
- Supplement this list with recommendations from the review committee.

One running theme was that strong basic stormwater criteria (referred to in this report as "Modern Manual" criteria) are often useful for adapting to climate change. For example, many articles reviewed suggested using Green Infrastructure practices to adapt to climate change, but these are also considered generally sound stormwater practices. The "Modern Manual" criteria include measures identified through the literature review as possible climate adaptations, along with other baseline elements of sound stormwater criteria.

STORMWATER STANDARDS REVIEW AND SCORING

Starting with the list of BMP adaptations from the literature review, CWP developed a questionnaire for use in reviewing state stormwater standards to determine whether these adaptations are incorporated. Best professional judgment and experience of engineering staff with updating state and local stormwater standards was also employed to develop the questionnaire. External reviewers provided review of the questions and proposed scoring system. The scoring system was designed to take into account the extent to which major climate impacts are expected in each region and also included a section that evaluated whether the standards include a baseline set of elements (Modern Manual criteria) considered to be important for modern stormwater management. The scoring system was vetted with CWP's National Watershed Research Network Steering Committee.

CWP put the questionnaire into a Google Form so that results from all states could be easily compiled into spreadsheet format. Next, a spreadsheet was created with links to the sources of stormwater standards in each state (e.g. MS4 permit, state regulation, stormwater manual, construction permit). Reviews were split between two staff, who completed the Google Form while reviewing the relevant documents. Both regulatory requirements and guidance documents were considered in the review. For example, a state whose BMP manual is not regulatory but that includes climate adaptations would receive points for those relevant questions. Draft policies and permits were not reviewed but a handful of draft stormwater manuals were included in the review because they outline specific standards. A list of the primary documents reviewed for each state is provided in Table A-4.

Table A-4. State Documents Reviewed

State	Documents Reviewed
Alabama	• Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas (Volume 1, 2) • Low Impact Development for the State of Alabama • National Pollutant Discharge Elimination System General Permit
Alaska	• Alaska Storm Water Guide • Anchorage Municipal Separate Storm Sewer System - Individual Permit No. ASK052558 • Permit for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems Permit No. AKS053406
Arizona	• Arizona Pollutant Discharge Elimination System General Permit for Stormwater Discharges Associated with Construction Activity to Protected Surface Waters
Arkansas	• Authorization to Discharge Stormwater Under the NPDES and the Arkansas Water and Air Pollution Control Act • Fact Sheet and Supplementary Info for General Permit ARR150000
California	• Stormwater Best Management Practice Online Handbook: Development • National Pollutant Discharge Elimination System (NPDES) General Permit for Waste Discharge Requirements (WDRs) for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) • Construction Stormwater General Permit
Colorado	• Colorado's Stormwater Program Fact Sheet • Floodplain Stormwater & Criteria Manual 2008

Table A-4. State Documents Reviewed	
State	**Documents Reviewed**
	• CDPS General Permit COR090000 Stormwater Discharges Associated with Municipal Separate Storm Sewer Systems (MS4s) Authorization to Discharge Under the Colorado Discharge Permit System
Connecticut	• Connecticut Stormwater Quality Manual • General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities
Delaware	• Delaware Post Construction Stormwater BMP (2019) Standards & Specifications • 5101 Sediment and Stormwater Regulations
District of Columbia	• Stormwater Management Guidebook • Authorization to Discharge Under the National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System Permit
Florida	• Environmental Resource Permit Applicants Handbook, Volume II • Chapter 62-330 Environmental Resource Permitting • Clean Waterways Act Stormwater TAC Updates
Georgia	• Georgia Stormwater Management Manual • Authorization to Discharge Under the National Pollutant Discharge Elimination System Stormwater Discharges Associated with Small Municipal Separate Storm Sewer Systems
Hawaii	• A Handbook for Stormwater Reclamation and Reuse Best Management Practices in Hawaii • NPDES General Permit Authorizing Discharges of Storm Water and Certain Non-Storm Water Discharges from Small Municipal Separate Storm Sewer Systems
Idaho	• Idaho Catalog of Stormwater Best Management Practices (2020) • Idaho MS4 Permits
Illinois	• Illinois Urban Manual, Practice Standards, Construction Specifications, Material Specifications • General NPDES Permit ILR40 for Discharges from Small Municipal Separate Storm Sewer Systems
Indiana	• Planning and Specification Guide for Effective Erosion and Sediment Control and Post Construction Water Quality • Municipal Separate Storm Sewer System General Permit (INR0400000)
Iowa	• Iowa Stormwater Management Manual • Iowa Administrative Code 567—64.13(2). This rule is intended to implement Iowa Code chapter 455B, division III, part 1 (455B.171 to 455B.187
Kansas	• Kansas Water Pollution Control General Permit and Authorization to Discharge Stormwater Runoff from Construction Activities Under the National Pollutant Discharge Elimination System (Federal Permit No. KSR100000)
Kentucky	• Planning and Technical Specs Manual for Stormwater Pollution Prevention Plans (2009) • Kentucky Erosion Prevention and Sediment Control Field Guide (2009)

Table A-4. State Documents Reviewed	
State	**Documents Reviewed**
Louisiana	• Urban Storm Water Runoff: Roads, Highways Bridges- BMPs For Coastal Louisiana Nonpoint Source Pollution • General Permit for Discharges from Small MS4s
Maine	• Maine Stormwater Management Design Manual, 3 Volumes • Chapter 500. Stormwater Management
Maryland	• 2009 Maryland Stormwater Design Manual • Maryland Stormwater Management Act • National Pollutant Discharge Elimination System General Permit for Discharges from Small Municipal Separate Storm Sewer Systems (General Discharge Permit No. 13-IM-5500. General NPDES No. MDR055500)
Massachusetts	• Massachusetts Stormwater Handbook • Massachusetts Stormwater Handbook: Documenting Compliance • General Permits for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems in Massachusetts
Michigan	• Nonpoint Source Best Management Practices Manual • Stormwater Management Guidebook • Michigan Department of Environmental Quality National Pollutant Discharge Elimination System Wastewater Discharge General Permit: Storm Water Discharges from Municipal Separate Storm Sewer Systems (MS4s) With Controls Based on Six Minimum Measures (Permit No. MIS040000)
Minnesota	• The Minnesota Stormwater Manual • Authorization to Discharge Stormwater Associated with Small Municipal Separate Storm Sewer Systems Under the National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) Program (Permit No. MNR040000)
Mississippi	• Stormwater Runoff Management Manual Volume 2 • Small Municipal Separate Storm Sewer System (MS4) General Permit (Permit No. MSRMS4)
Missouri	• Missouri State Operating Permit • Discharges from Regulated Phase II Municipal Separate Storm Sewer Systems Comprehensive General Permit (Permit No. MO-R04Cxxx)
Montana	• Montana Post-Construction Stormwater BMP Design Guidance Manual • General Permit for Storm Water Discharges Associated with Small Municipal Separate Storm Sewer Systems (MS4s): Permit Number MTR0400000
Nebraska	• NPDES MS4 Stormwater Management Plan
Nevada	• Best Management Practices Handbook
New Hampshire	• New Hampshire Stormwater Manual • NH Code of Administrative Rules, Chapter Env-WG 1500, Alteration of Terrain • General Permits for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems in New Hampshire

Table A-4. State Documents Reviewed	
State	**Documents Reviewed**
New Jersey	• NJ Stormwater Best Management Practices Manual 2016 • NJAC 7:8 Stormwater Management Rule 2023
New Mexico	• Comprehensive Assessment and Listing Methodology Procedures for Assessing Water Quality Standards Attainment (2023) • Statewide Water Quality Management Plan (2020) • NPDES Stormwater General Permit for Small MS4s in New Mexico
New York	• New York State Stormwater Management Design Manual (Draft) • SPDES General Permit for Stormwater Discharges from Construction Activity • SPDES General Permit for Stormwater Discharges from Municipal Separate Storm Sewer Systems (Permit No. GP-0-15-003)
North Carolina	• NCDEQ Stormwater Design Manual • Stormwater Rules and Regulations, Administrative Code
North Dakota	• North Dakota Pollutant Discharge Elimination System
Ohio	• Rainwater And Land Development Ohio's Standards for Stormwater Management Land Development and Urban Stream Protection • Stormwater Discharges from Small and Large Construction Activities - General Permit • Authorization for Small Municipal Separate Storm Sewer Systems to Discharge Storm Water Under the National Pollutant Discharge Elimination System (Permit No. OHQ000004)
Oklahoma	• General Permit OKR04 For Stormwater Discharges from Construction Activities Within the State of Oklahoma
Oregon	• Central Oregon Stormwater Manual, Guide 3: Stormwater Management Standards • National Pollutant Discharge Elimination System Municipal Separate Storm Sewer Systems Phase II General Permit
Pennsylvania	• Pennsylvania Post-Construction Stormwater Management (Draft) Manual • Act 167, Stormwater Management Act • PAG-13 Authorization to Discharge Under the National Pollutant Discharge Elimination System (NPDES) General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) Approval of Coverage
Rhode Island	• Rhode Island Stormwater Design and Installation Standards Manual • General Permit Rhode Island Pollutant Discharge Elimination System Storm Water Discharge from Small Municipal Separate Storm Sewer Systems and from Industrial Activity at Eligible Facilities Operated by Regulated Small MS4s (Permit No. RIR040000)

Table A-4. State Documents Reviewed	
State	**Documents Reviewed**
South Carolina	• South Carolina BMP Handbook • State of South Carolina NPDES General Permit for Storm Water Discharges from Regulated Small Municipal Separate Storm Sewer Systems (SMS4) • Regulation 72-300 through 72-316 Standards for Stormwater Management and Sediment Reduction • Policies and Procedures of the South Carolina Coastal Management Program
South Dakota	• General Permit Authorizing Stormwater Discharges Associated with Construction Activities
Tennessee	• Tennessee Permanent Stormwater Management and Design Guidance Manual • Small MS4 General Permit
Texas	• General Permit to Discharge Under the Texas Pollutant Discharge Elimination System (Permit No. TXR040000)
Utah	• A Guide to Low Impact Development Within Utah (Aug. 2020) • Authorization to Discharge Under the Utah Pollutant Discharge Elimination System (UPDES) - General Permit for Discharges from Small Municipal Separate Storm Sewer Systems (MS4s). UPDES Permit Number UTR090000
Vermont	• 2017 Vermont Stormwater Management Manual Rule and Design Guidance • Title 10: Conservation and Development. Chapter 047: Water Pollution Control. § 1264. Stormwater management
Virginia	• DEQ Stormwater Management Handbook (2013 Draft Handbook) • Article 2.3. Stormwater Management Act
Washington	• 2019 Stormwater Management Manual for Western Washington • SWMMWW Preliminary Draft Package • Phase I Municipal Stormwater Permit. National Pollutant Discharge Elimination System and State Waste Discharge General Permit for Discharges from Large and Medium Municipal Separate Storm Sewer Systems • Western Washington Phase II Municipal Stormwater Permit. National Pollutant Discharge Elimination System and State Waste Discharge General Permit for Discharges from Small Municipal Separate Storm Sewers in Western Washington • Eastern Washington Phase II Municipal Stormwater Permit. National Pollutant Discharge Elimination System and State Waste Discharge General Permit for Discharges from Small Municipal Separate Storm Sewers in Eastern Washington • Appendix 1 - Minimum Technical Requirements for New Development and Redevelopment (Phase I Municipal Stormwater Permit)
West Virginia	• West Virginia Stormwater Management and Design Guidance Manual • General National Pollution Discharge Elimination System Water Pollution Control Permit
Wisconsin	• Storm Water Post-Construction Technical Standards • NR 151.121 Post-Construction Performance Standards

Table A-4. State Documents Reviewed	
State	**Documents Reviewed**
Wyoming	• General Permit to Discharge Storm Water Associated with Municipal Separate Storm Sewer Systems (MS4s) under the Wyoming Pollutant Discharge Elimination System (WYPDES)

While designed to be repeatable, the review is somewhat subjective, so CWP reviewers coordinated closely during the review process. Several meetings were held during the review process to discuss questions that arose and ensure consistency in scoring. A Senior Water Resources Engineer reviewed the results for quality control. The summary spreadsheet of scores was modified to automatically calculate separate scores for each state for the five major sections of the questionnaire: Modern Manual (maximum 40 points), High Precipitation (maximum 54 points), Drought (maximum 20 points), High Temperature (Maximum 18 points), and Sea Level Rise (Maximum 31 points). The scoring sheet is included in Appendix B.

The standards review was also used to identify two sets of recommendations: 1) a complete list of recommendations derived from responses to individual questions (see Appendix D) and 2) a "Top5" list of recommendations which are included in the state profile sheets in Appendix C. The Top 5 were derived from a consolidated list of potential recommendations for the Modern Manual, High Precipitation and Drought categories (Table A-5). These recommendations were first filtered based on responses to the survey. For example, states with recently updated standards that include water quality and quantity sizing and provide specific guidance for BMPs and their selection did not receive that recommendation.

Table A-5. Potential Consolidated Recommendations	
Category	**Potential List of Recommendations**
Modern Manual	• Revise or update design standards to include water quality and quantity sizing, selection and specifications of BMPs. • Update design storms to reference the most recent available storm data. • Incorporate maintenance requirements, evaluation methods and schedule into the design standards. • Standards should include a recharge or runoff reduction volume requirement, and Green Infrastructure practices should be given credit toward meeting this requirement. • Establish a process and credit system that promotes redevelopment, impervious cover reduction, natural area conservation and tree protection and planting. • Incorporate quantity criteria to address stream channel protection and flooding. • Enhance ponding depth, storage design and filter media specifications in filtering/ bioretention systems to provide effective storage, prevent bypass of high intensity storm events and avoid clogging. • Include a plant list that identifies plant tolerances to drought, differing soil conditions, salt tolerance and inundation. • Expand permit coverage by applying standards to redevelopment or to smaller sites.

Table A-5. Potential Consolidated Recommendations	
Category	**Potential List of Recommendations**
High Precipitation	• Add a section that discusses state's climate change priorities and incorporates specific adaptation measures into the existing standards. • For water quantity sizing, consider incorporating projected storm data or other options that account for increased storms. Ensure the precipitation data are referenced to their source. • Revise stormwater quantity sizing to either over-control the storm event or match a historical peak discharge or incorporate modeling. • To provide BMP resilience, consider enhancing conveyance, pretreatment and storage capacity for water quality or runoff reduction using techniques such as modeling shorter-duration, intense storm events.
Drought	• Add a section that discusses state's climate change priorities and incorporates specific adaptation measures into the existing standards. • Set specific goals for rainwater harvesting and incorporate design details for sizing of the systems. • Prohibit or restrict the use of practices that consume water (e.g., practices with a permanent pool of water. • The landscaping section should suggest methods to modify plant selections based on changing climate conditions and provide a plant list that includes species that are fire-resistant and tolerant to periods of prolonged drought. • Bioretention designs should incorporate methods to retain soil moisture such as internal water storage or incorporating adding polymers or biochar to the media to retain soil moisture.
Sea Level Rise	• Add a section in the standards to include approaches and techniques that reduce the impact of sea level rise on stormwater practices, such as increasing conveyance capacity and elevating outfall inverts.

After the list of recommendations for each category was filtered, the final list was selected based on the Modern Manual score and the Vulnerability to climate change impacts as follows:

- In states with low Modern Manual scores, or medium Modern Manual scores and Low/Moderate climate impacts, Modern Manual recommendations are prioritized, followed by recommendations for the climate impact with the higher Vulnerability between High Precipitation or Drought.
- In states with high Modern Manual scores, Drought or High Precipitation adaptations are prioritized, followed by Modern Manual recommendations.
- In states with medium Modern Manual scores, Modern Manual recommendations are prioritized if the region is not highly vulnerable to Drought and High Precipitation, and High Precipitation/Drought recommendations are prioritized when the region's vulnerability to these impacts is High.
- In states with High Vulnerability to Sea Level Rise, the Sea Level Rise recommendations are included.
- In states with Moderate Vulnerability to Sea Level Rise, the Sea Level Rise recommendations are included if less than five other priority recommendations have already been identified.