Catchment Scale Stormwater Volume and Pollutant Loading Analyses

Guidance for Municipal Stormwater Program Assessment and Prioritization

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Municipal stormwater programs include a variety of components that are intended to address the range of landscape conditions and water quality concerns existing in the urban environment. Cost-effective programs focus on water quality priorities; assess the ability of program actions to achieve water quality benefits; and, implement program modifications based on new information. A municipal stormwater volume and pollutant loading analysis, conducted at the catchment scale, is a powerful tool to identify which geographic areas within the municipality should be prioritized for program actions and, when used as part of an on-going information management system, allows program managers to assess program effectiveness over time. The geographic perspective provided by a catchment scale analysis also improves the ability to identify multi-benefit stormwater management opportunities related to water supply, flooding, and habitat objectives. This document outlines the necessary analytic components needed to develop and implement a technically credible catchment scale stormwater volume and pollutant loading analysis to support municipal stormwater program development and implementation. To help illustrate concepts, examples and references from the Central Coast Tool to Estimate Load Reductions (TELR) and the Central Coast Best Management Practice Rapid Assessment Methodology (BMP RAM) tools are provided in Attachment A.[1]

Municipal Catchment Scale Stormwater Volume and Pollutant Loading Analyses: Key Outputs

Catchment scale stormwater volume and pollutant loading analyses allow stormwater program managers to focus on water quality actions that are directly relevant to their municipality. While perhaps not the sole information used to prioritize all program actions, the catchment scale stormwater volume and pollutant loading analysis readily informs <u>where</u> actions, if implemented, are likely to provide the greatest water quality return on investment. To be effective, the analysis should, at a minimum, generate the following three outputs:

1. **Stormwater volume and pollutant load estimates for each catchment under an unmitigated scenario**. The "Unmitigated Catchment" scenario provides stormwater volume and pollutant load estimates to the receiving water assuming no structural or non-structural Best Management Practices (BMPs) exist within each catchment. When the analysis is implemented across all catchments within the municipality, the results show the potential water quality risk to the receiving water of any one catchment in relation to all of the other catchments. Knowledge as to which catchments have the greatest potential to adversely impact receiving waters can guide where BMP inventories and assessments should be prioritized and where program actions should be focused. The Unmitigated Catchment scenario also represents the initial load estimates to which subsequent load estimates will be compared.

2. **Stormwater volume and pollutant load estimates for each catchment based on municipal stormwater management actions (i.e., estimates of stormwater volume and pollutant load reductions).** A catchment scale approach can also be used to conduct a "Load Reduction" scenario that accounts for stormwater volume and/or pollutant load reductions resulting from functioning BMPs. Specific load reduction actions that can be reasonably

[1] The Central Coast Water Board, Central Coast Low Impact Development Initiative, and regional municipalities are developing the TELR and BMP RAM tools as part of a collaborative effort funded by the Central Coast Water Board.

quantified include most structural BMPs (e.g., retention ponds, bioretention, catch basins); some operations and maintenance activities (e.g., street sweeping); and, some site design measures (e.g., reduction of impervious surfaces). The year to year difference in stormwater volume and pollutant load for a catchment is the cumulative load reduction or water quality benefit resulting from BMP implementation. Quantification of water quality benefit requires information regarding existing BMPs within each catchment including an estimate of actual BMP performance based on field observations.

3. **Relative ranking of municipal catchments based on pollutant load estimates.** Estimates of stormwater volume and pollutant loading for all catchments within a municipality allow direct comparison and prioritization based on their relative loading to receiving waters. When these relative loading results are illustrated on a map of catchments, it creates a simple and powerful tool to identify and communicate where program actions are expected to have the greatest water quality return on investment. The relative ranking is first conducted after the Unmitigated stormwater volume and pollutant loading scenarios have been completed for all municipal catchments. This first ranking allows municipal staff to prioritize catchments for BMP assessment. Once BMP water quality benefit has been assessed and resulting stormwater volume and pollutant load reductions have been estimated, relative ranking is again employed to iteratively assess priority catchments over time.

The ability to generate the information described above requires an analytic approach that uses catchment scale data to generate meaningful and credible outputs. The following section outlines the fundamental components of a successful catchment scale stormwater and pollutant loading analysis.

Municipal Catchment Scale Stormwater Volume and Pollutant Loading Analyses: Fundamental Components

The analytic approach used to estimate stormwater volume and pollutant loads should simulate actual catchment conditions in a manner that is technically defensible, relatively simple, and cost-effective for the intended use. The application of the method must be consistent such that the quantification of load reductions is due to BMP implementation and performance and not different precipitation inputs, changes in hydrologic routines, or other parameter changes between the Unmitigated Catchment and Load Reduction scenario estimates. Catchment delineation, land use mapping, and BMP inventory and assessment are crucial components for calculating catchment scale stormwater volume and pollutant load estimates. Additionally, selection of appropriate and relevant runoff characteristics; use of an appropriate model; and, implementation of standardized analysis protocols will increase the credibility and value of the results. Table 1 outlines fundamental components of a stormwater volume and pollutant loading analysis.

Table 1. Fundamental Components of a Municipal Catchment Scale Stormwater Volume and Pollutant Loading Analysis.

1. The Spatial Framework	*Catchment delineations and relevant catchment attributes create the spatial framework for estimating stormwater volume and pollutant loads.*
	a. Catchment delineations and associated areas (e.g., acres). To conduct catchment scale pollutant loading analyses, the municipality needs to be divided into spatially explicit units defined by municipal drainage catchments. The catchments are reasonable representations of actual drainage areas where stormwater discharges through an identified outfall. In the instance where many outfalls exist within a small area, drainage areas can be combined to minimize the total number of catchments mapped within the municipality. Delineating catchments of relatively similar size will be helpful when ranking and comparing catchments. A good target size for a catchment is approximately 100 acres. A catchment can possess either a single discrete discharge point (i.e., discharges either to another catchment or to a receiving water via a single outfall), or distributed discharge points to the receiving water (e.g., several small outfalls and/or sheet flow). The municipality should assign identifiers (e.g., name/label) to each catchment. Field verification of delineated catchments is encouraged.
	b. Catchment outfalls and determination of receiving waters to which each catchment discharges. The United State Geological Survey's National Hydrography Dataset (USGS NHD) contains publically available surface water designations and should be used to identify receiving waters accepting stormwater from the municipal outfall. (http://nhd.usgs.gov/). The municipality should assign identifiers (e.g., name/label) to each catchment outfall. Use of more accurate information and field verification is encouraged.
	c. Hydrologic connectivity for each catchment. For purposes of stormwater volume and pollutant load estimates, hydrologic connectivity is the percentage of stormwater runoff generated within the catchment that is delivered to the receiving water. Catchments with high hydrologic connectivity are those where most of the stormwater generated within the catchment reaches the receiving water as opposed to catchments with low hydrologic connectivity where much of the stormwater runoff generated in the catchment does not reach the receiving water. Two aspects of hydrologic connectivity are used to understand the overall connectivity of the catchment to the receiving water: 1) hydrologic connectivity within the catchment to the catchment discharge point (e.g., outfall), and 2) hydrologic connectivity from the catchment discharge point to the actual receiving water. Clear guidance on how to determine hydrologic connectivity is a critical element in providing reasonable estimates of pollutant loads delivered to the receiving water from each catchment.

Table 1. Fundamental Components of a Municipal Catchment Scale Stormwater Volume and Pollutant Loading Analysis. (*continued*)

	d. Land use designations should include the following categories within each catchment and the associated impervious area (in acres): -Single family residential -Multi-family residential -Industrial -Commercial -Cultivated -Paved roads High traffic density Moderate traffic density Low traffic density -Unpaved Roads -Other (typically open space)
2. Runoff Characteristics	*Runoff characteristics of each catchment are used with the spatial framework to calculate stormwater volume and associated pollutant loading.*
	Catchment precipitation, imperviousness, and soil permeability are all critical elements in estimating stormwater volume and pollutant loads. a. Precipitation. Precipitation characterization should be based on a reasonable representation of the historic range of precipitation conditions for the catchment that includes both small (common) and very large (infrequent) precipitation events to generate average annual runoff estimates. b. Imperviousness and soil permeability. The National Land Cover Database (2011; http://www.mrlc.gov/nlcd2011.php) can be used to estimate the percent of imperviousness of each land use (e.g., commercial, residential) within each catchment. Use of generic runoff coefficients based on land use type, is generally insufficient to adequately estimate stormwater runoff volumes. In addition to impervious coverage by land use, incorporation of the relative permeability and native soil retention coefficients should be used to adjust runoff generation from each land use type.
	c. Pollutant types for evaluation. Pollutant types selected for the loading analyses should be relevant and serve as a reasonable proxy for the range of urban pollutants. The effort should be made to base pollutant selection on characteristics including, but not limited to, primary land uses, source of pollutants, fate and transport of pollutants in stormwater, and data availability. Pollutants such as Total Suspended Solids (TSS) and stormwater volume are examples of proxies for the broader suite of pollutants in urban runoff. Alternatively, a suite of representative urban pollutants of concern (e.g., trace metals, nutrients, hydrocarbons, etc.) may be modeled.

Table 1. Fundamental Components of a Municipal Catchment Scale Stormwater Volume and Pollutant Loading Analysis. (*continued*)

	d. Urban runoff pollutant data. Pollutant concentrations associated with various land use types are often used to calculate pollutant loads. Existing urban pollutant models employ a wide array of approaches to generate these pollutant concentrations. The objective in selecting land use pollutant concentrations is to choose values that adequately reflect the conditions being modeled without being overly concerned with the need for absolute accuracy. There is an abundance of credible urban stormwater quality data available online that can be used to estimate pollutant concentrations by urban land use type. The analysis should consistently apply the selected data to all catchments and BMP performance estimates to ensure results are directly comparable among catchments.
	e. Pollutant reduction estimates resulting from stormwater program actions. Pollutant reduction estimates should be based on BMPs whose pollutant reduction capacity can be reasonably quantified. Additionally, reduction estimates should be based on an assessment of actual BMP performance. Methods to assess and quantify actual BMP performance include direct measurements of pollutant removal such as conventional water quality input/output monitoring of a BMP or weighing of sediment collected from street sweeping activities; and, indirect measurements such as field observations that serve as credible proxies for BMP performance and pollutant load reduction effectiveness. "Desktop" quantification of pollutant reduction that assumes structural BMPs are performing as designed may not be accurate since the actual constructed project and/or the maintenance condition of the BMP affects actual water quality performance.
3. Computational requirements	*The computational tool (i.e., model) provides the ability to generate loading estimates and other required outputs. Selection or development of the model requires consideration of all desired outputs including data, tables, figures, and reports.*
	a. Ability to estimate average annual stormwater volume and pollutant loads delivered from each catchment to the receiving water in a manner that is reliable, repeatable, and allows for comparison of results among catchments and over time.
	b. Ability to estimate average annual stormwater volume and pollutant load reductions as a result of BMP implementation and performance by catchment in a manner that is reliable, repeatable and comparable among catchments and over time.
	c. Ability to track and compare data on a spatial (single or multiple catchments) and temporal (year to year) basis.
	d. Ability to generate output in the desired reporting format(s).

Table 1. Fundamental Components of a Municipal Catchment Scale Stormwater Volume and Pollutant Loading Analysis. (*continued*)

4. Standardized Protocols	*Development and implementation of standardized protocols is, in some respects, one of the most import elements of the analytic approach as these protocols lend credibility to the overall analyses.*
	a. Consistent methodology within and across each catchment. Use of a consistent methodology to estimate annual volume and pollutant load reductions should be employed to ensure the results are indicative of structural and non-structural BMP performance and not due to variation in methodology. For example, precipitation inputs driving the hydrologic analysis must be held constant between the Unmitigated Catchment scenario and any subsequent scenarios based on load reduction estimates.
	b. Normalization to allow comparisons among catchments. Converting stormwater volume and pollutant load into volume and load per unit area per time allows for comparison among catchments. By ranking catchments within the municipality by loading rates, (e.g., high to low), catchments with the greatest risk to receiving waters can be identified.

Municipal Catchment Scale Stormwater Volume and Pollutant Loading Analyses: Data Management

The long-term value of a stormwater volume and pollutant loading analysis is the ability to periodically track progress within one or many catchments to inform program priorities and direction. A well-designed data management system can be used to 1) manage input data and results from the various catchment scale stormwater volume and pollutant loading analyses, 2) compare results across space (e.g., catchments) and time, and 3) facilitate communication, information, and data sharing for identified stakeholders. When selecting the analysis approach for estimating municipal catchment stormwater volume and pollutant loads to receiving waters, consideration should also be given to the development and implementation of a data management system regarding efficient data storage; access to previous analysis assumptions and results; and, ability to manage and evaluate data to meet user needs.

Attachment A: Examples of Catchment Scale Pollutant Loading Analysis Tools Developed with Funding from the Central Coast Water Board

A.1 Description of TELR and BMP RAM

The Central Coast Water Board is funding the development of two tools intended to support compliance with municipal stormwater quality requirements. The "Tool to Estimate Load Reductions" (TELR) and the "Best Management Practice Rapid Assessment Methodology" (BMP RAM) tools enable municipalities to conduct stormwater volume and pollutant load analyses to evaluate program effectiveness, prioritize program actions, and track performance and maintenance requirements for structural BMPs. The tools are designed to work together but can be used separately. A brief description of each tool is included in this section.

Tool to Estimate Load Reductions (TELR)

TELR is an event-based stormwater volume and pollutant loading analysis approach and tool that is designed to estimate average annual loading (e.g., acre-ft/yr, lbs/yr) from a municipal catchment to the receiving water. TELR can estimate load reductions based on an assessment of the observed condition of structural stormwater BMPs (e.g. detention ponds, bioretention facilities, catch basins). TELR can also be used to estimate load reductions resulting from certain non-structural BMPs (e.g., street sweeping, LID site design) using methods appropriate to the BMP.

TELR functions from an online data management platform that allows bulk uploads of municipal catchment mapping data including land use type and coverage, estimated impervious surface area, soil data, and other data needed to estimate stormwater volume and pollutant loads. Once municipalities have completed the necessary mapping and related spatial analyses, TELR can be used to generate two pollutant load scenarios for a municipal catchment: an "Unmitigated" and a "Current Load[2]" where the Unmitigated scenario assumes no BMPs are in place and the Current Load scenario takes into account stormwater and pollutant load reductions based on stormwater program actions. For a given evaluation period (e.g., annually), the Current Load estimate for each catchment can be ranked in comparison to all catchments within the municipality. The catchments with the highest loading rate per unit area are the catchments with the greatest potential risk to receiving water quality for the evaluation period. The results of this prioritization are mapped to simplify communication of priority catchments where stormwater program actions are expected to have the greatest benefit.

The TELR user interface is designed to accommodate a broad range of user types (e.g., stormwater program staff, trained interns, consultants). All the required inputs are readily available to stormwater managers through a variety of guidance resources to complete municipal mapping products and BMP inventories and assessments. Rather than attempting to model, track and evaluate multiple pollutants, TELR uses credible proxies to represent the range of urban stormwater runoff pollutants [i.e., stormwater volumes and total suspended solids (TSS)] to estimate pollutant

[2] Current Load reflects load estimates based on the most recent available data, and is calculated as [Unmitigated scenario load estimate] – [load reduction estimate due to BMP implementation].

loads and associated receiving water risk. TELR uses regionally relevant precipitation data, local soils, and catchment hydrologic connectivity to inform a probability distribution approach to estimate average annual catchment volumes.

Analysis results are stored within TELR and users can evaluate load reductions over time by catchment, receiving water, or municipality. Users have the ability to use automated features for key analyses, and map and report generation. Additionally, users can download data from TELR to conduct additional data analyses that may be of interest (e.g., total stormwater volume and pollutant load by outfall). Users can also create and save planning scenarios to estimate potential load reductions from future BMPs for each catchment. TELR users can produce maps, figures, and tables that communicate individual catchment information as well as the relative potential risk of all catchments to receiving water quality. The initial TELR set up requires the user to populate TELR with the required mapping data for all municipal catchments. Once TELR is populated with BMP data, on-going use includes periodic addition of new BMPs, performance assessments for existing BMPs, and any increases to stormwater volume and pollutant loading.

Best Management Practice Rapid Assessment Methodology (BMP RAM)

BMP RAM is an approach and tool that supports municipal stormwater program requirements to inventory, assess, and prioritize structural BMPs for maintenance; and, evaluate and quantify BMP performance as part of an overall assessment of a municipality’s efforts to reduce stormwater pollutant loads. The “rapid” assessment protocols involve use of indirect methods (i.e., field based observations) to assess the relative condition of the BMP. When used in conjunction with TELR, the BMP performance condition is translated into an estimate of stormwater volume and/or pollutant reduction.

As part of BMP RAM, municipalities inventory their existing structural BMPs, assign each BMP to a functional type, and locate the BMPs within a spatial data framework of catchments. Table 2 lists the types of BMPs that can be inventoried and evaluated as part of BMP RAM. Using standardized field protocols that are unique to each BMP type, BMP maintenance condition is assessed and documented on a standardized 0-5 scale, communicating relative performance based on BMP condition to inform and prioritize maintenance actions. A score of 5 is the condition of the BMP following construction or recent effective maintenance and assumes the full potential volume and/or pollutant reduction benefit. Conversely, a score of 0 represents a severely degraded BMP in need of immediate maintenance, providing no stormwater quality benefit. Once inventoried, each BMP can be periodically assessed in the field using the BMP RAM field protocols to document and track BMP condition over time.

The BMP RAM field protocols can be effectively implemented by anyone with approximately a half-day of training. The automated online data management platform translates the field assessment 0-5 scores into mapped red, orange, yellow, and green ranking points for each BMP to easily compare relative condition and associated maintenance urgency. Output from BMP RAM including data, graphs, reporting elements allows assessment, prioritization and communication of BMP performance for a single BMP, all the BMPs within a catchment, and all of the BMPs within the municipality. If used with TELR, BMP RAM condition scores are exported to TELR where stormwater volume and pollutant load reductions from the municipalities’ structural BMPs are estimated as part of the catchment-based loading analyses. Use of TELR without BMP RAM is also possible and will require users to determine a BMP assessment approach equivalent to the BMP RAM approach to support a consistent and credible BMP tracking and evaluation process.

The Central Coast BMP RAM can be accessed at the BMP RAM website (www.bmpram.com).

Table A.1. Examples of structural BMP types that can be inventoried and assessed using BMP RAM.

Structural Stormwater Water Quality and/or Volume Control BMPs
• Basins (e.g., detention, dry, wet, retention, infiltration)
• Media filtration (e.g., bed filters, biofiltration; proprietary devices such as tree boxes, cartridge filters)
• Treatment vaults (hydrodynamic separators, detention vaults, wet vaults)
• Vegetated filtration (Water quality treatment grass swales, vegetated buffer and filter strips)
• Bioretention
• Subsurface infiltration systems (e.g., infiltration trenches, infiltration galleries, dry wells, soak holes)
• Porous pavement
• Settling basins (e.g., sediment chambers, forebays, decant ponds)
• Catch basins
• Trash capture

A.2 Stormwater Volume and Pollutant Load Analysis: Examples of Output Maps and Graphs

Examples of municipal catchment delineation and output from TELR and BMP RAM are included in this section to help illustrate concepts provided in the main portion of this document.

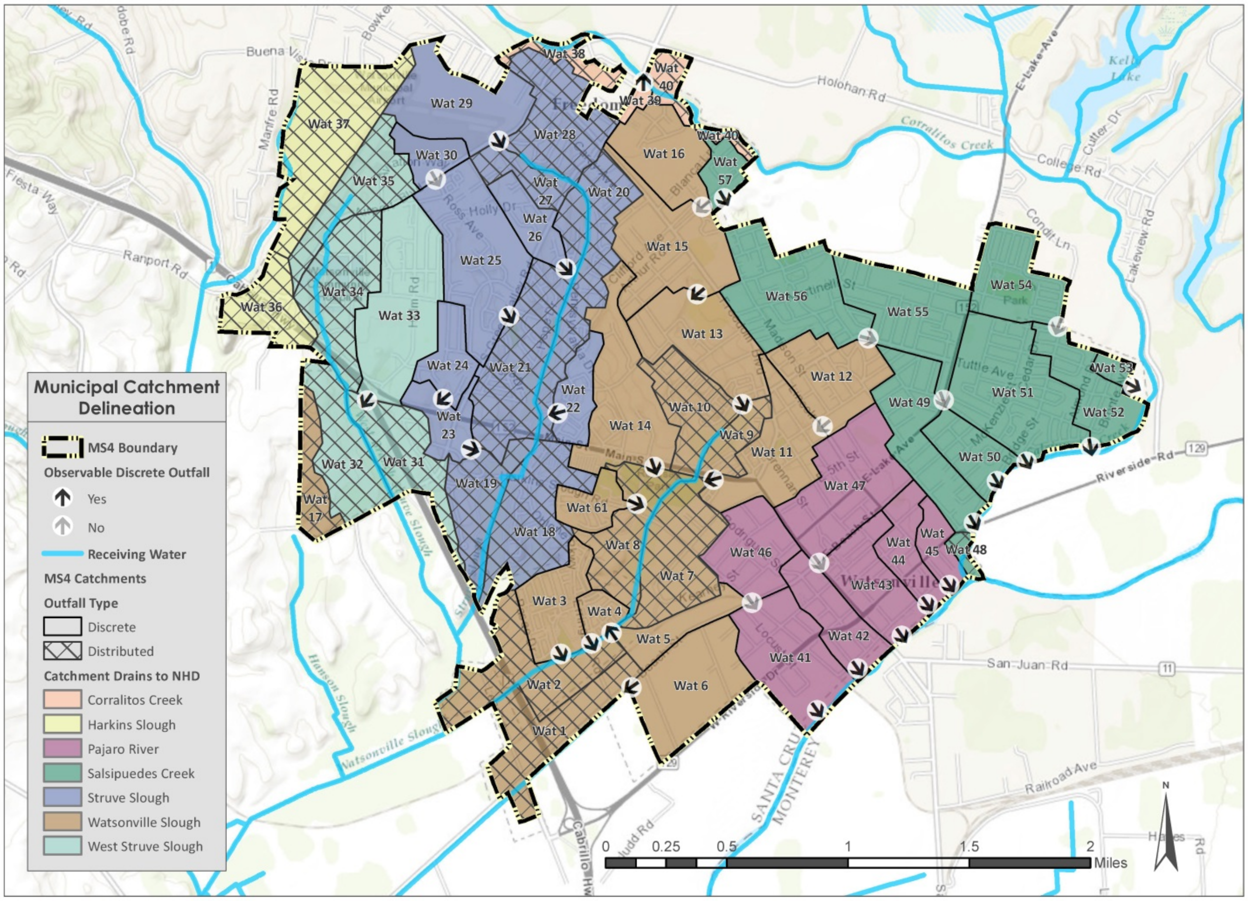


Figure A.2.1. Municipal Catchment Delineation Example. Individual municipal catchments are delineated and provided with a unique catchment identifier (Wat 6, Wat 13, etc.). Each catchment can be described as either having a discrete or distributed outfall type. In catchments with discrete outfalls, the outfall from each catchment is identified as either an observable discrete outfall such as a visible pipe that discharges to a stream (e.g., Wat 11) or, a non-observable discrete outfall such as an underground pipe that conveys water from one catchment to the next (e.g., Wat 12). In catchments with the distributed outfall type, stormwater discharges to the receiving water via multiple pipes and/or surface flow. In this example, catchments are color coded to indicate their respective receiving waters. Pertinent catchment attribute data (e.g., land use type and acreage per catchment) can be managed and presented in table format using software programs such as Excel. However, the mapped depiction helps to visualize and communicate the spatial context and creates the foundation for the catchment scale stormwater volume and pollutant loading analyses.

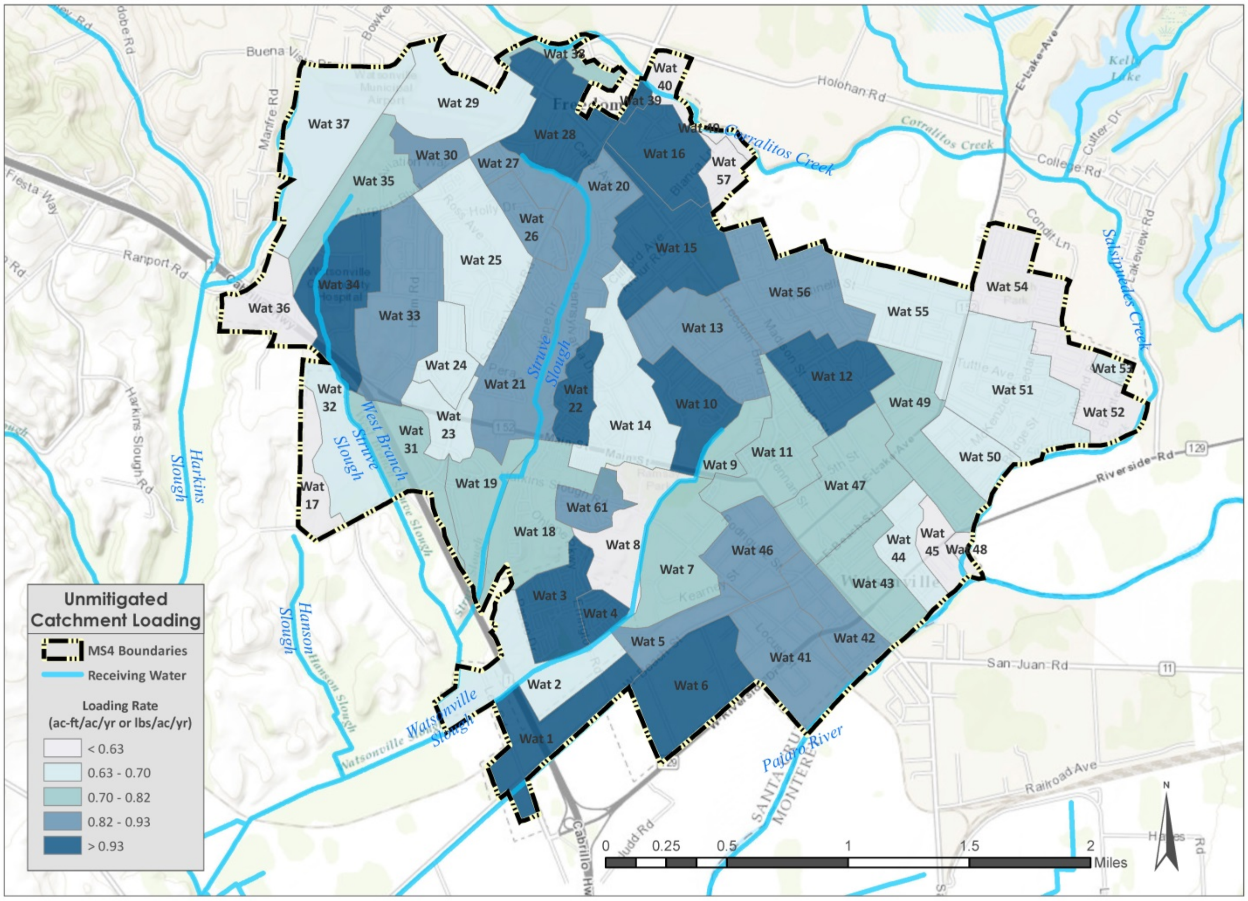


Figure A.2.2. Unmitigated Catchment Loading Scenario and Relative Ranking Example. This hypothetical example shows the stormwater volume and pollutant loading estimates, expressed as loading per unit area per time, for each municipal catchment under the Unmitigated scenario (i.e., no BMPs in place). Color coding is used to indicate the relative ranking of catchments in terms of their potential risk to receiving water quality and therefore, where program actions should be focused.

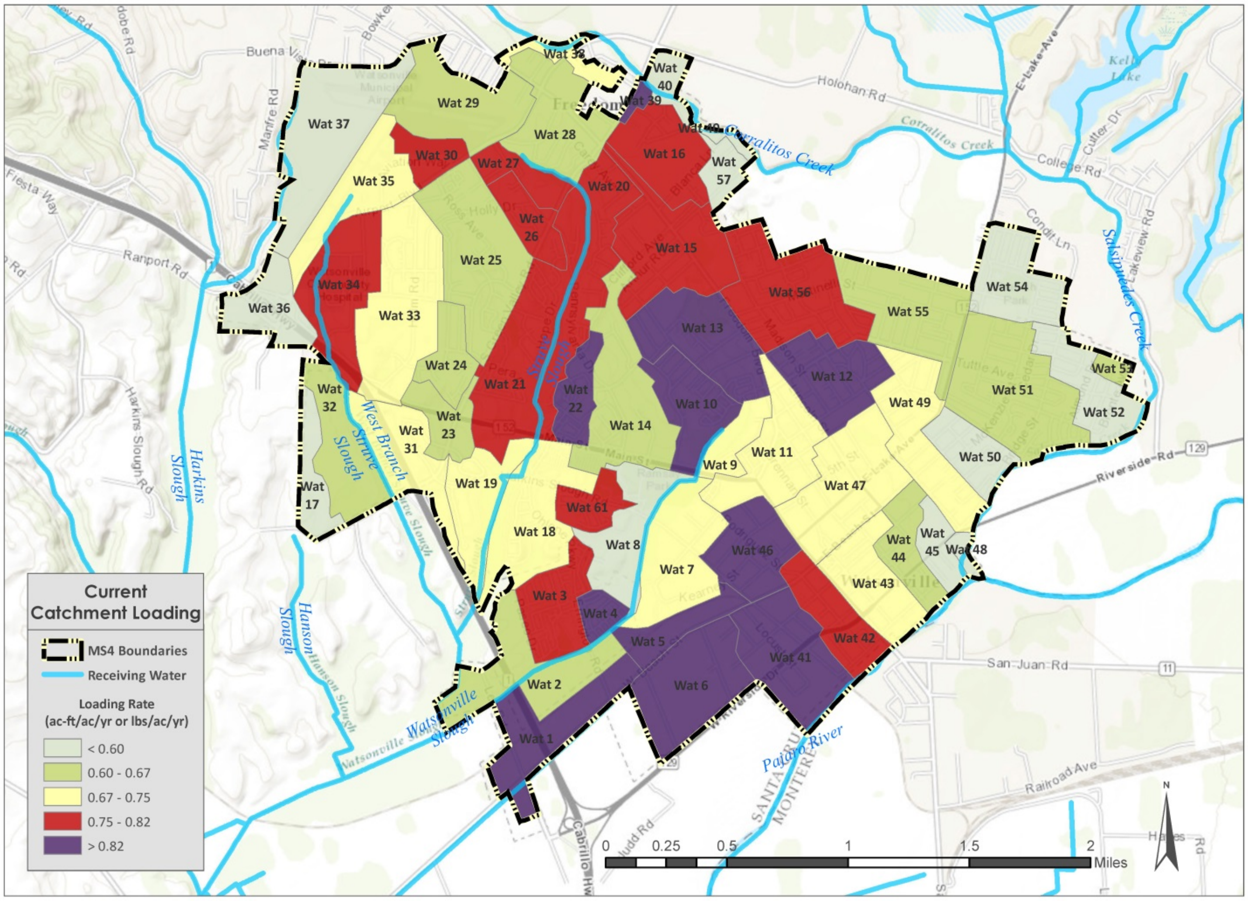
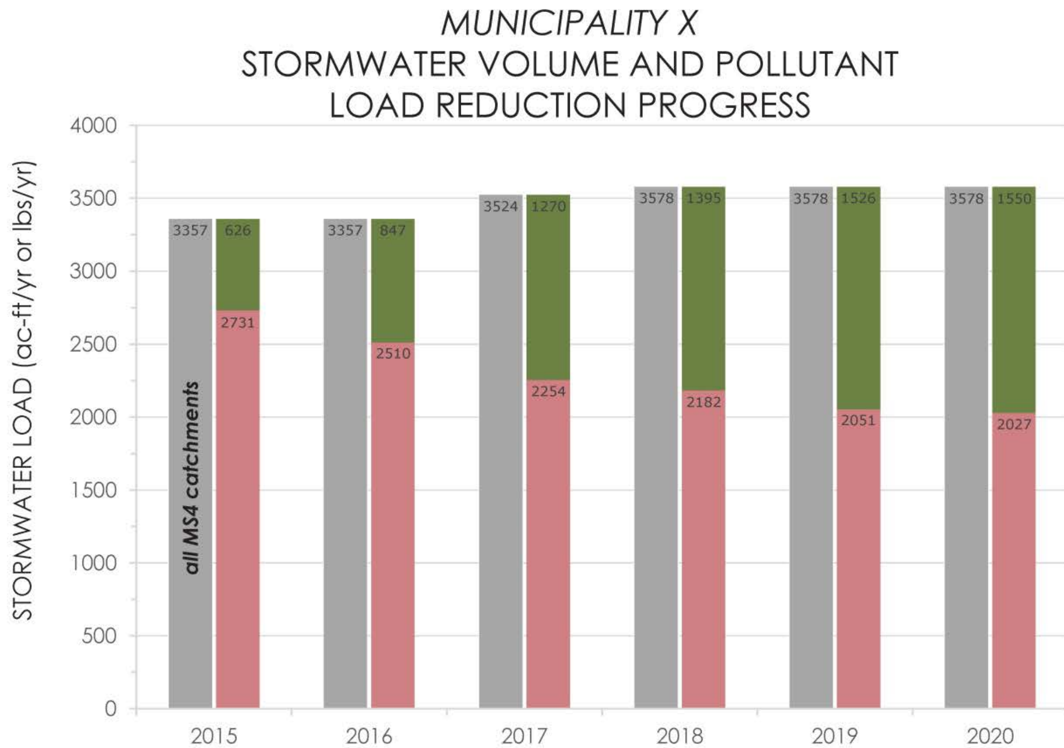


Figure A.2.3. Current Catchment Loading Scenario and Relative Ranking Example. This hypothetical example shows the results of the stormwater volume and pollutant load analyses taking into account program actions and resulting load reductions. Similar to the Unmitigated scenario, catchments are ranked based on their loading rate (e.g., lbs/acre/year) to identify catchments that pose the greatest risk to receiving water quality. Program actions, focused on high risk catchments, should result in reduction in stormwater volume and pollutant loads such that the ranking for high risk catchments should change to a lesser ranking over time (e.g., purple ranked catchments become yellow ranked catchments).



	2015	2016	2017	2018	2019	2020
unmitigated load	3357	3357	3524	3578	3578	3578
current load	2731	2510	2254	2182	2051	2027
load reduction	626	847	1270	1395	1526	1550

Figure A.2.4. Municipal Stormwater Volume and Pollutant Load Reduction Tracking. As part of a stormwater program effectiveness assessment, the reduction in stormwater volumes and pollutant loads can be tracked over time and compared to the Unmitigated scenario and any previous year's load estimates. Load reduction estimates can be tracked by catchment, receiving water, and municipality. This figure shows a hypothetical example of the cumulative load for all municipal catchments for the Unmitigated (i.e., no BMPs) and Current Load scenarios (i.e. load estimates at the time of analysis) as well as the total load reduction. Increases in the Unmitigated load may reflect new development or other new sources of stormwater volume and/or pollutants.

STRUCTURAL BMP CONDITION CHRONOLOGY

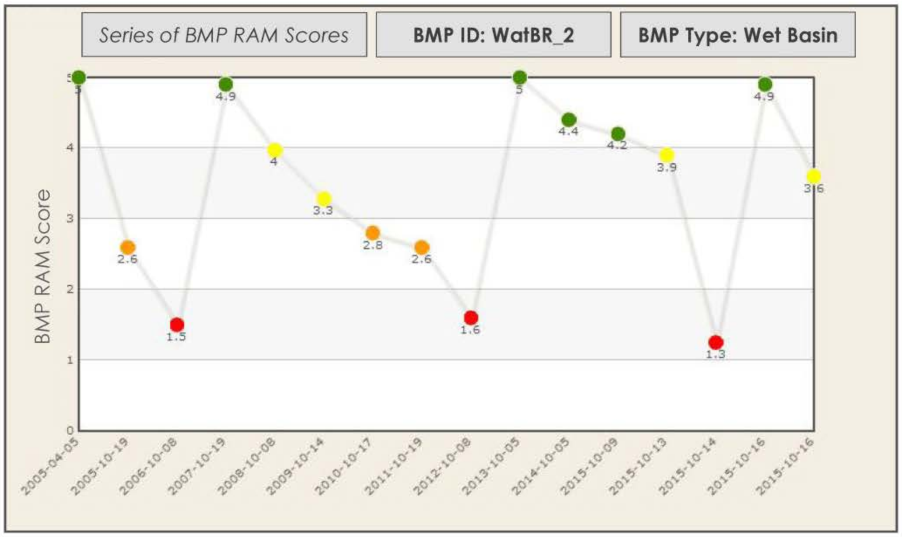


Figure A.2.5. BMP Condition Score Tracking for a Single BMP. This figure shows a hypothetical example of the BMP RAM condition scores assigned to a single BMP (wet basin) where higher scores indicate relatively good water quality performance and lower scores indicate low performance (or possibly no performance). Assessing and tracking BMP performance condition allows program managers to assess BMP maintenance requirements including frequency needed to keep the BMP at a satisfactory performance function for stormwater volume and/or pollutant reduction.

SPATIAL COMPARISON OF STRUCTURAL BMP CONDITION

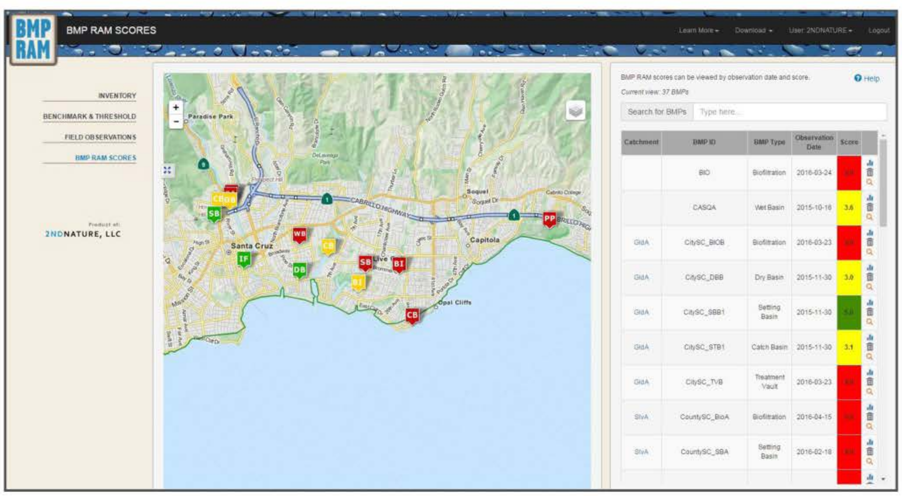


Figure A.2.6. BMP Condition Score for Multiple BMPs. This figure shows a hypothetical example of BMP RAM condition scores assigned to multiple BMPs. Assessing and tracking BMP condition allows program managers to assess BMP maintenance requirements and prioritize which BMPs will receive maintenance based on their condition. When used with TELR, program managers can also prioritize maintenance in catchments that represent high risk to the receiving water.

A.3 Municipal Catchment Mapping Resources

Municipal catchment scale mapping and delineation of associated attributes is a fundamental first step to estimating stormwater volume and pollutant loads, relative risk to receiving waters, and program prioritization. 2NDNATURE developed a document entitled "MS4 Catchment Delineation and Attribute Generation Guidance" for the Central Coast Water Board to support municipal mapping efforts. The document can be found at centralcoastlidi.org.