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Municipal Stormwater Management Spending in California: Data Extraction, Compilation, and Analysis

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Abstract

Communities in the U.S. fund stormwater management programs to reduce flooding and improve and protect water quality. Few studies have attempted to quantify municipal stormwater management expenditures. This task is important given efforts to meet increasing water quality standards and develop new revenue sources. The purpose of this study was to evaluate trends in municipal stormwater management expenditures across the state of California. The study identified and compiled publicly-available data on reported stormwater expenditures (spending) and budgets for local governments in California. Data were extracted from annual reports for over 160 public agencies. A standardized rubric of activities was developed and used to create a first-of-its-kind database of municipal stormwater budgets and expenditures. The results indicated that there is over $700 million in annual municipal stormwater spending, but this total does not represent all spending due to gaps in publicly-available data. Counties and flood control districts often have the largest total expenditures in a region, but in aggregate cities reported more spending statewide. Available data are not sufficient to adequately evaluate whether current spending meets regulatory requirements. Additionally, publicly-available data are inconsistent across geographic regions regulated by different agencies. The analysis offers a template for improved cost reporting of stormwater programs in U.S. municipalities, which can help answer key questions such as the sufficiency of current funding. Future research can use the method to evaluate spending in other states and regions, evaluate trends over time to improve outcomes, and refine the spending categories based on examples from other states.

Keywords Municipal Finance, Urban drainage, Runoff, California, Costs

Introduction

Municipal stormwater infrastructure was built to control flooding by conveying runoff away from urban streets quickly. Urban drainage infrastructure also collects dry weather runoff from sources such as over-irrigation. In the U.S., amendments to the Clean Water Act (CWA) in 1987 required municipalities to reduce pollution from stormwater, such as sediment, oil and greases, bacteria, and others (33 U.S.C. 1251–1376; Chapter 758; Amended February 4 1987). Through the CWA amendments, regulatory agencies devise pollutant load reduction targets for communities, which are codified based on local conditions or monitoring data. Municipalities must meet contaminant reduction targets as part of obtaining a discharge permit through the National Pollutant Discharge and Elimination System (NPDES).

Controlling floods and protecting and improving water quality are key goals for contemporary stormwater management. To achieve these goals, municipalities must fund maintenance of existing infrastructure, investments in new infrastructure or programs, and reporting efforts. While many communities throughout the U.S. have dedicated stormwater funding such as from a stormwater utility fee, many more do not (Kea et al. 2016, Campbell et al. 2018). Moreover, the adequacy of such funding is unclear. Without dedicated funding streams for stormwater programs,

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municipalities rely on general funds from tax revenues, which means that stormwater management competes against other municipal services. To address funding gaps, some municipalities develop diversified funding for stormwater that includes general funds, dedicated utility revenues, credits, fees, and grants (Fedorchak et al. 2017, Zhao et al. 2019, EPA 2020). Some stormwater programs also leverage other municipal spending by designing projects that not only meet water quality goals, but also support other beneficial outcomes, including urban beautification, ecosystem protection and restoration, reduced water and energy consumption, climate change adaptation, and improved land management (Grigg 2013, Li et al. 2013, Prudencio and Null 2018, Meerow 2019).

Accurate estimates of current spending on stormwater management are necessary to justify financial support at local, regional, and federal levels. Few studies, however, have systematically gathered data on the costs of activities related to stormwater permit compliance or new infrastructure across communities of varying sizes and locations (EFAB 2020). Efforts to identify funding gaps have been inconsistent. America's Infrastructure Report Card, a national benchmark of infrastructure spending, addressed stormwater for the first time in 2019 and estimated a national funding gap of at least $7.5 billion (ASCE 2021). In California, a 2005 study surveyed six municipalities to estimate costs for compliance with permit requirements, finding that communities spent between $18 and $46 per household on permit compliance activities (Currier et al. 2005). Estimated one-time capital funding needs for structural Best Management Practices (BMPs) for a single square mile of urban area subject to the regulatory targets in Los Angeles County ranged from $420,000 for areas of low population density to $33 million for areas of extremely high population density (Devinny et al. 2004). In another California study, the Public Policy Institute of California estimated statewide annual stormwater funding needs in the range of $1–$1.5 billion across the state, while current funding was approximated to be no more than $500–$800 million based on extrapolations from a few case study communities (Hanak et al. 2014). These examples demonstrate the variability in reported and estimated costs for stormwater management. Much of the variability likely results from the absence of standardized or audited financial reports for stormwater management programs, which makes it difficult to evaluate current expenditures and projected funding needs across many areas.

This paper presents a novel analysis of reported local government expenditures on municipal stormwater management in California. Reported expenditures (spending) and budgets across cities, counties, and special districts were collected, standardized, and analyzed based on available reporting for over 160 local governments. The analysis addresses three key questions. First, what budget and expenditure data exist in current reporting that municipalities provide as part of local Municipal Separate Storm Sewer System (MS4) program documentation? Second, what trends exist in spending based on analysis from aggregated and standardized available data? Finally, are the data representative of municipal stormwater spending in California? The analysis involved accumulating and extracting data from semi-structured sources, standardizing the data, and assessing large-scale trends. The study demonstrates the need for electronic (i.e., extractable) and publicly-available data to support decision-making.

Methods

Existing data on stormwater program funding were analyzed through a multi-step approach that included: (1) identifying, collecting, and extracting data from existing sources, (2) synthesizing and standardizing data, (3) creating a typology of stormwater program activities and spending, and (4) analyzing data to summarize trends. The method, which is illustrated in Fig. 1, is applied to the case study of local governments (cities, counties, flood control districts, and others) in California.

Understanding typical municipal stormwater program structures is necessary to collect and standardize data on municipal stormwater spending. Urban stormwater programs can be authorized and organized in several ways. Stormwater management activities may be funded as part of general municipal duties. In these cases, a municipality would support stormwater management from the same accounts that fund other municipal activities, such as trash collection, park management, and others. Alternatively, some jurisdictions form dedicated stormwater utilities. These are enterprises set up within a city that have a dedicated funding stream, such as a parcel charge or tax. The entities are responsible for undertaking a specific set of

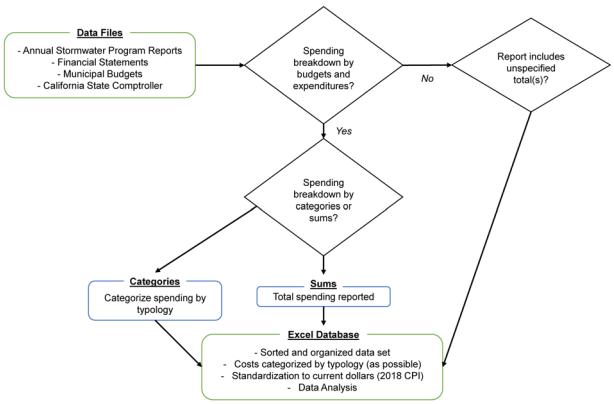

Fig. 1 Method for collecting and synthesizing data

duties. The collection of stormwater-related activities in a city, county, or other jurisdiction comprises a stormwater program. A utility could undertake most or all of a city's stormwater management duties under a program, which include operations, maintenance, compliance, water quality testing, education, and others. Capital spending on stormwater infrastructure may occur through municipal revenues or through financing such as bonds and loans.

Identifying Data Sources and Compiling Data

No single authoritative data source exists for municipal stormwater-related expenditures in California. For many types of municipal expenses, standardized reporting allows for comparing and tracking changes over time. Standardized reports adhere to guidelines of the Government Accounting Standards Board and are published through annual audited financial statements. For stormwater management, however, line item values often do not exist in publicly-available spending data. Many communities do not have dedicated accounts, termed enterprise accounts, for stormwater programs, meaning that spending may be lumped with other municipal duties depending on the administrative organization of departments.

As an alternative, it was hypothesized that sufficient data were available through other existing publicly-available reporting, which could be compiled and standardized to develop a snapshot of municipal spending and examine trends by cities, counties, and other public entities in California. Several potential sources of data were investigated, including annual stormwater program reports submitted to comply with NPDES requirements, audited financial statements, municipal budgeting documents, and financial reporting from the California State Controller.

Several evaluation criteria were developed to assess the sufficiency of information in available sources. First, did reporting break down municipal program spending into budgets and expenditures? Second, did reporting provide sufficient detail on budgets and spending across categories and activities, or were totals lumped together into summary values? Third, was reporting available for multiple years? Examining data over time can help understand fluctuations due to exogenous factors such as economic trends that influence municipal revenue or influxes of grant funding. In addition, it can provide opportunities for future analyses with statistical modeling capable of controlling for multiple explanatory variables.

Based on the evaluation criteria, several data sources were eliminated due to insufficient detail. Ultimately, the best source of potential available information was found in sections of annual stormwater program reports submitted by local governments to state and regional water quality monitoring agencies, known in California as the State Water Resources Control Board (State Water Board) and the Regional Water Boards (Fig. 2).

Fig. 2 Regions of the California State Water Resources Control Board

Financial data was initially collected from the State Water Board's Stormwater Multiple Application and Report Tracking System database. While useful, this statewide database provided annual program reports for only some regions in California and included a disproportionate number of submissions from one region within coastal Southern California (Santa Ana Regional Water Board). To increase the representativeness of surveyed reports, additional reports were identified through keyword searches using web search engines to manually locate additional publicly-available documents, such as annual stormwater reports, Water Quality Improvement Plans, Capital Improvement Plans, and other documents with potential financial information on stormwater spending. In some cases, documents were easily found on state or municipal websites. In other cases, they were found in search engine results as PDF files or in site directories.

The files included a variety of audited and self-reported financial information. In some regions, summary data included multiple municipal permittees within an area. Ultimately, data was identified for 186 entities, including 171 cities, nine counties, four special districts, an airport, and a port authority. The reports spanned multiple years, though continuous records were not available for all entities. Many entities only published reports containing known expenditures for past years and did not provide projected budgets for future needs. Files were stored in a folder

Table 1 Data sources used in the analysis

Variable(s)	Description	Source
Stormwater management budget and expenses data	Identified publicly available budget and spending data as reported by cities, counties, and public districts	Various, compiled from storwmater program annual reports. Full list of entities is included in Supplemental Data
Population	Population size of jurisdiction	U.S. Census, 2017 American Community Survey 5-Year Estimates
Stormwater permit categorizations	Permittee designations based on community size (Phase 1 vs. Phase 2)	California State Water Resources Control Board
City and county polygon boundaries	Boundaries of cities and counites	U.S. Census TIGER shapefiles (California Places)

hierarchy, organized by jurisdictions of the Regional Water Boards. At the time of data collection (2018-2019), no centralized repository of annual stormwater reports with costs existed for the state.

Financial data from program reporting was combined with data from several other sources, including population data from the U.S. Census Bureau, geospatial information from the US Census TIGER GIS file for California Places, and information on stormwater permit categorizations from the (California) State Water Board. Table 1 summarizes the data sources, while the Supplemental Data includes a list of all entities used in the analysis.

Standardizing Data

More data was available for spending than for budgets. The total number of entities with reported annual budget and expenditure data for at least a single year was 178 and 186, respectively. Entities were located in fifteen of California's fifty-eight counties. Areas of the state with more reporting entities were generally within jurisdictions where regional regulatory institutions required cost reporting in sources that are made public. A lack of data for an area does not necessarily represent a lack of stormwater expenses and programs.

Budgets were available for 1999 through 2021 (future years are projections as reported by entities). Expenditures were available for 2000 through 2018. Notably, most entities had data for only a few recent years and very few entities had a record of data spanning more than two decades. Overall, there were 602 total annual budget values and 550 total annual expense values identified. On average, an entity had five years of available data (mean = 4.51, SD = 2.73). In total, the database of annual budgets and expenditures included 1152 distinct records. Figure 3 breaks down available budget and spending data by fiscal year (July 1–June 30).

Some documents reported multiple prior years of spending or budgeting, while others were limited to only 1 year of cost data. Reports with multiple years of data allowed for error-checking the procedures. For instance, some annual reports detailed the previous five years of spending, which revealed how, over time, municipalities may revise prior year totals based on end-of-year audits or budget updates. It was assumed that the most recent report included the most accurate reported data for standardization. When multiple years of data were available, values were compared across years to identify any years with significant

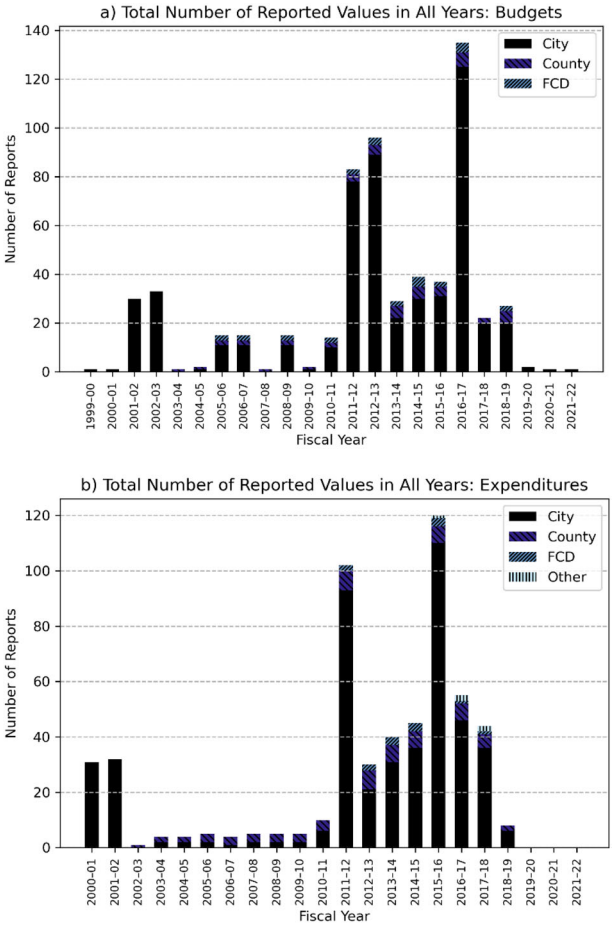

Fig. 3 Total number of: **a** reported budgets and **b** expenditures across all years. ("FCD" = Flood Control Distrct). The "Other" category represents one airport and one port authority, neither of which reported budgets

changes in reported budget or expenditure totals. This served to detect errors and inconsistencies in self-reporting, since the values in annual reports may not have been subject to third-party auditing. Inconsistent values were flagged. In some instances, large inconsistencies between years were present due to an influx of capital or grant funding that was included within a line item. In these cases, associated text and documentation were used in the reports to make decisions to keep the reported data as-is, reclassify totals, or instead rely on a different year of data with more representative values of annual expenditures.

Several entities only reported budgets. Of those, some reported detailed budgeting with line item totals. When detailed budgets were available but corresponding line-item expenditures were not provided, it was assumed that expenditures were equal to the reported budget for a given year.

A database was created that included data for each entity by annual total, and when available, by type of expense (program activity, capital investment). The database includes separate tables for budgets and expenditures. Each table contains records (monetary values), with each record having associated attributes for the jurisdiction name, jurisdiction type (city, county, flood control district, or "other" for airports and port authorities), county, Regional Water Board jurisdiction, NPDES permit type (i.e., Phase I or Phase II), fiscal year the data were reported for, reference year (for categorizing reporting into a single year and adjusting for inflation), and the dollar value reported. Reported activities were maintained, even if they were not ultimately used in standardized categories of the reported spending or budgeting.

Reported budgets and expenditures were standardized across all these organizational types based on geographic area and population for each jurisdiction. GIS was used to estimate geographic area, and U.S. Census data was used to estimate populations (US Census 2014). Then, spending per capita (dollars per person) and spending per unit area (dollars per square mile) were estimated for each entity to normalize and compare values. Unit area analysis was based on jurisdictional area and not contributing watershed area. Future assessments may consider evaluations that include costs based on contributing watershed area under management by a stormwater program.

To create a summary snapshot across all entities with reporting, it was necessary to standardize data for many years. A single year's budget and/or expenditure value was used, depending on data availability, from a recent year for each reporting jurisdiction, referred to as a representative year. For most instances, this was the most recent year of reported budget or expenditures. In instances with a large increase or decrease of the most recent year (as compared to prior years), perhaps due to budget reclassifications or onetime grant or bond revenues, another recent year with spending that more closely resembled trends over time was used. Values were normalized to 2018 dollars using the Consumer Price Index (CPI) inflation indicators (USBLS 2019).

Creating a Typology of Stormwater Activities

Some reporting entities, such as those in Los Angeles and San Diego counties, had standardized reporting categories for recent years, where all permittees within those counties used the same reporting format. This was not the case for all reporting entities. To facilitate a statewide analysis, spending activities were categorized according to a typology, which was developed through an incremental process of additions and revisions. First, spending was classified according to categories included in the EPA's National Menu of Best Management Practices (BMPs) for Stormwater, also referred to as minimum control measures (EPA 2000). As municipal reports were reviewed and additional reported categories were identified, categories were added to the typology to best represent the data. The final typology includes twelve categories, with specific types of activities associated with each category. Table 2 summarizes the categories, while the full table of reported activities and their assigned categories is provided in the Supplemental Data section.

Analyzing Data and Summarizing Results

Values were calculated to summarize results for:

1. Availability of reported data across local government types and spending categories
2. Statistics for reported budgets and spending by entity type
3. Statistics for reported budgets and spending by region
4. Trends over time for selected communities with sufficient data
5. Spending normalized by population (per capita) and area (per square mile) for cities
6. Spending trends by category of program activities

The normalized results for spending per capita and per unit area were only calculated for cities because cities were the only jurisdictions with well-defined boundaries where stormwater spending is implemented. In counties and FCDs, the nested nature of local government structures means that county or FCD programs could include spending across the entire area that includes city jurisdictions or instead focus only on some incorporated areas.

The Supplemental Data section provides additional results that examine trends in total and average spending in cities by region, as well as trends in total spending across land area and total population. Simple univariate linear regression models were fitted to examine overall trends across cities of varying

Table 2 Typology of stormwater cost categories used in this analysis

Expense Category	Typical Activities
Capital costs	• Invest in new green and gray infrastructure or other structural measures, which may be referred to as Stormwater Control Measures (SCMs), Best Management Practices (BMPs), or other names.
Public education and involvement	• Develop programs, brochures, billboards, videos, web pages
	• Encourage volunteerism, public commentary, input on policy, and activism in the community
	• Conduct public engagement activities including education, outreach, involvement, and participation
Illicit discharge detection and elimination	• Investigate calls reporting potential illicit discharge
	• Issue enforcement actions
Construction site stormwater runoff control	• Develop and update best management practices handbooks and resources
	• Issue grading permits
	• Review stormwater pollution prevention plans
	• Issue enforcement actions
	• Send winterization letters
	• Develop and maintain database to track inspections and enforcement actions
Pollution prevention and good housekeeping for municipal operations	• Sweep streets
	• Manage pesticide and fertilizer use
	• Clean ditches
	• Manage used oil recycling
	• Implement secondary containment, including spill response kits and procedures
	• Map facilities
Operations and maintenance	• Inspect BMPs
	• Maintain facility drains
	• Maintain green infrastructure (GI)
	• Inspect municipal facilities
Post-construction stormwater management for new and re-development	• Develop and update handbooks and resources
	• Review plans and issue permits
	• Issue enforcement actions
	• Develop and maintain database to track new infrastructure
Water quality monitoring	• Prepare quality assurance plans and sampling plans
	• Collect samples
	• Conduct sample laboratory analysis
	• Perform data analysis and reporting
Industrial and commercial management	• Conduct inspections
	• Develop and update handbooks and resources
	• Issue enforcement actions
	• Manage permitting and oversight
	• Conduct reporting
Watershed/TMDL collaboration	• Manage regional programs for TMDL compliance and/or watershed planning for multiple benefits
Overall stormwater program management	• Assess program effectiveness
	• Conduct annual reporting
	• Execute permit compliance administration
	• Achieve budget planning
Unable to decipher	• Reported description is insufficient to place into a single category
	• Reported spending may fall into multiple categories

sizes and populations. These are provided as additional information that can inform future and more robust multivariate models with statistical controls.

Results

The results are described below for availability of reporting, reported budgets and spending by entity type and region, trends over time, spending in cities after normalizing for population and area, and spending across categories of program activities.

Availability of Reporting

Available expenditure and budget data in program reports varied widely by year and geographic region. Based on collected data, the 2015–16 fiscal year (FY) had the most available reports. In Fig. 3, these data coincide with

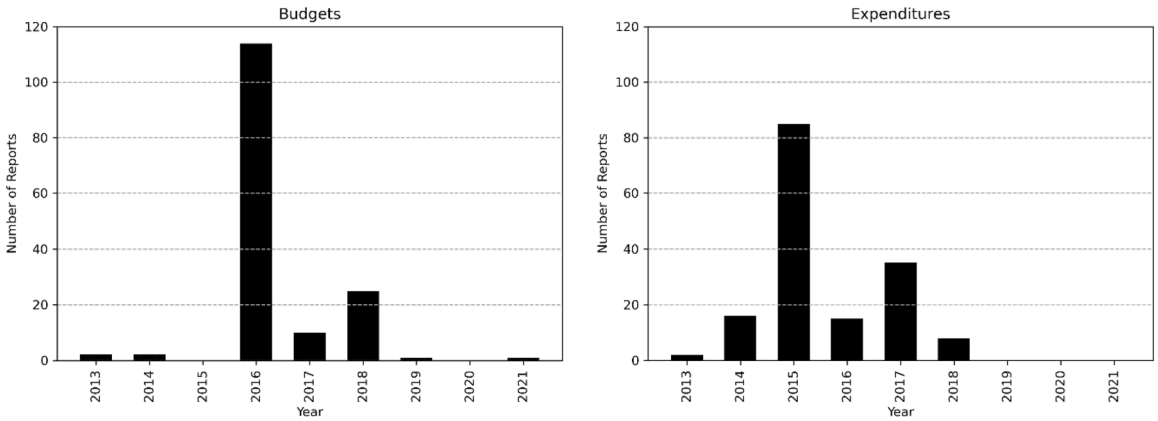

Fig. 4 Number of Entities that reported budgets (left) and expenditures (right). Numbers are based on evaluating the most recent single fiscal year in the jurisdiction's annual reports or another year representative of multi-year spending trends

expenditures that occurred in FY 2015–2016 (2015 in Fig. 3) and budgets expected for FY 2016–2017 (2016 in Fig. 3). This is in part due to an increase in standardized reporting for that year in the Los Angeles region. In addition, the 2011–12 fiscal year was prominent, also due to many reports from the Los Angeles metropolitan region. Only a few entities, such as the City of Berkeley, reported estimated budgets through future years. Figure 4 shows a visual breakdown by year of reported budgets and expenditures selected from a recent, representative year for each entity.

Reported Budgets and Spending by Entity Type and Geography

Results indicated differences in spending across types of municipal entities (Table 3). County budgets were generally larger than city budgets. In a given year, 2018-normalized annual city budgets ranged from $39,000 to $110 million (mean = $2.9 million, median = $1.0 million), while annual county budgets ranged from about $1.3 million to over $93 million (mean = $22 million, median = $9.2 million). Annual expenditures for cities, normalized to 2018 values, ranged from $48,000 to $88 million (mean = $3.1 million, median = $890,000), while county expenditures ranged from $400,000 to $51 million (mean = $18 million, median = $13 million). Complete summary statistics for FCDs, port authorities, and airports were not calculated due to insufficient sample sizes, however, total and average values across all municipal entity types are discussed below. Both city and county spending were right-skewed (Table 3 and Supplementary Fig. S3) due to a small number of MS4s with very large expenditures, indicated by median values lower than the mean.

Counties and FCDs budgeted more per entity than cities. Counties and FCDs budgeted on average $22 and $26 million each, while cities budgeted on average $2.9 million (Fig. 5 and Table 4). There is a similar trend for actual expenditures, with average county and flood control district expenditures of $18 million and $17 million, respectively, and average city expenditures of $3.1 million (Fig. 5 and Table 5). Due to the limited number of MS4s reporting data publicly relative to the total number of MS4s within California, this observation may not hold true statewide, although it is likely when considering the number of regulated cities to counties and other MS4 types.

Table 3 Summary statistics for reported annual budgets and expenditures

Statistic	City Budgets	County Budgets	City Expenditures	County Expenditures
Mean	$2.9 M	$22 M	$3.1 M	$18 M
Median	$1.0 M	$9.2 M	$0.89 M	$13 M
Standard Deviation	$9.5 M	$31 M	$9.5 M	$18 M
Maximum	$110 M	$93 M	$88 M	$51 M
Minimum	$0.039 M	$1.3 M	$0.048 M	$0.40 M
25% Quartile	$0.40 M	$4.0 M	$0.42 M	$5.5 M
75% Quartile	$2.6 M	$24 M	$2.5 M	$28 M
Number of Records	164	8	171	9

Values reported here are only for cities and counties, not flood control districts or others, due to the low sample size for these latter entities. Statistics are for data from the most representative year for each jurisdiction, normalized to 2018 dollars

Average annual expenditures across all entities within each region ranged from $150,000 to $11 million based on as few as one or as many as seventy-eight reporting entities in a Regional Water Board jurisdiction, although data were not reported for all regions (Table 6). Coastal Southern California (Regions 4, 8, and 9) had the highest reported total spending and budgets. These locations also had the preponderance of publicly-available reports. Available data in other regions were more sporadic. Most other regions had

Fig. 5 Average and total annual budgets and expenditures by entity type. All budgets and spending normalized to 2018 dollars

Table 4 Total and average stormwater budgets. Values are reported by entity type, in real dollars (normalized to 2018)

Statistic	City Budgets	County Budgets	Flood Control District Budgets	Others Budgets
Total (Sum)	$480 M	$170 M	$160 M	--
Mean	$2.9 M	$22 M	$26 M	--
Minimum	$0.039 M	$1.3 M	$2.0 M	--
Maximum	$110 M	$93 M	$88 M	--
Sample size	164	8	6	0

The summary statistics are based on the most representative year for each entity, providing a method to estimate statewide budgets

No budget values were available for entities categorized as "Others", as noted by the "--" notation in the table

only a few or no entities with available reporting of expenditures and/or budgets, even though many communities do have stormwater programs in these areas. Given the diversity of reporting entities across regions, summary estimates for total spending are recognized to be underestimated. In total, annual expenditures reported by entities in public sources are $770 million (2018 dollars).

Trends Over Time

While most entities only report expenditures or budgets for a few recent years, several entities have data on spending for a longer period of time. These included several cities in California's Central Valley. To examine trends over time for available communities, real values of expenditures (i.e., normalized to 2018 dollars) were plotted for these selected areas (Fig. 6). In general, many MS4s showed flat or declining levels of expenditures. A few cities (Bakersfield, Folsom, and El Cajon) showed jumps in spending, which may be explained by changes in increased regulations and levels of service, as well as the acquisition of grant funding.

Spending in Cities, Normalized by Population and Area

Per capita and unit area spending vary across cities with reported data. Normalizing spending based on population data for each city indicates that 50% of cities spend $14/person or less on stormwater management. A few small- or medium-sized cities have large reported per capita spending on stormwater of over $300/person. Average and median per capita spending values were $35/person and $14/person, which indicates that per capita spending has a small number of outliers with large unit values (right-skewed). By comparison, these totals are similar to costs reported through a 2005 survey noted previously (Currier et al. 2005). A graph of the spending distribution across cities is shown in the Supplemental Data section (Fig. S5). Average per capita and unit area spending by region is also calculated and shown in the Supplemental Data section, however, the data may not be fully

Table 5 Total and average stormwater expenditures

Statistic	City Expenditures	County Expenditures	Flood Control District Expenditures	Others Expenditures
Total (Sum)	$520 M	$170 M	$69 M	$8.3 M
Mean	$3.1 M	$18 M	$17 M	$4.1 M
Minimum	$0.048 M	$0.40 M	$1.9 M	$3.0 M
Maximum	$88 M	$51 M	$27 M	$5.2 M
Sample size	171	9	4	2

Values are reported by entity type, in real dollars (normalized to 2018). The summary statistics are based on the most representative year for each entity, providing a method to estimate statewide budgets

Table 6 Total and average identified budgets and expenditures (normalized to 2018 dollars) grouped by Regional Water Quality Control Boards in California (M = millions)

Region	Statistic	Budget	Expenditures
Region 1 North Coast	Sum	--	$0.84 M
	Average	--	--
	Sample size	--	1
Region 2 San Francisco Bay	Sum	$9.8 M	$6.6 M
	Average	$4.9 M (± $0.79 M)	--
	Sample size	2	1
Region 3 Central Coast	Sum	$1.1 M	$4.6 M
	Average	--	--
	Sample size	1	1
Region 4 Los Angeles	Sum	$420 M	$300 M
	Average	$4.6 M (± $15 M)	$3.8 M (± $12 M)
	Sample size	90	78
Region 5 Central Valley	Sum	$130 M	$140 M
	Average	$12 M (± $15 M)	$11 M (± $12 M)
	Sample size	11	13
Region 6 Lahontan	Sum	--	--
	Average	--	--
	Sample size	--	--
Region 7 Colorado River Basin	Sum	$0.16 M	$0.15 M
	Average	--	--
	Sample size	1	1
Region 8 Santa Ana	Sum	$220 M	$130 M
	Average	$3.9 M (± $12 M)	$2.3 M (± $4.6 M)
	Sample size	58	58
Region 9 San Diego	Sum	$30 M	$180 M
	Average	$2.0 M (± $1.6 M)	$5.4 M (± $14 M)
	Sample size	15	33
All Regions	Total Spending	$810 M	$770 M

No budget values were available for entities categorized as "Others", as noted by the "--" notation in the table

representative of spending in several regions due to lack of reported data in the public domain at the time of analysis (Fig. S2).

Normalizing city spending per unit area (square-mile) yields a similarly-shaped distribution (Fig. S5). Reported spending ranges from nearly $4000/sq-mile to over $1 million/sq-mile. The average and median values are $152,000/sq-mile and $82,000/sq-mile, again indicating that there exist a small number of outliers with large unit values (right-skewed). Several outliers are coastal cities, especially beach cities of Southern California, which have made significant investments in stormwater infrastructure and programs to support cleanup of beaches, bays, creeks, and oceans.

Spending by Category of Stormwater Program Activity

The average annual expenditures across categories ranged from $120,000 to $990,000 (Table 7). The greatest portion of total annual stormwater expenditures in California went to pollution prevention and good housekeeping activities such as street sweeping and others, totaling $270 million. Conversely, the smallest portions of total expenditures were allocated to industrial and commercial activities, totaling $15 million. Table 7 provides the breakdown of total annual expenditures across all categories (i.e., the sum of spending by all reporting entities for each category for the most representative year, in 2018 dollars). Figure 7 shows the distribution of spending for each cost category. For each category, the distribution was right-skewed, indicating the presence of outliers with high reported spending. This is likely explained by reported values from some larger communities in the Orange County, Los Angeles, and San Diego areas. The capital costs, operations, and maintenance, and pollution prevention categories had the widest variation in spending.

Discussion

The analysis sought to answer three research questions. First, what budget and expenditure data exist in current reporting? Significant information on budgets and expenditures does exist within current reporting. However, it is not easily accessible or readily useful to inform policy-making. Most publicly-available stormwater budget and expenditure data exists in annual reports created by

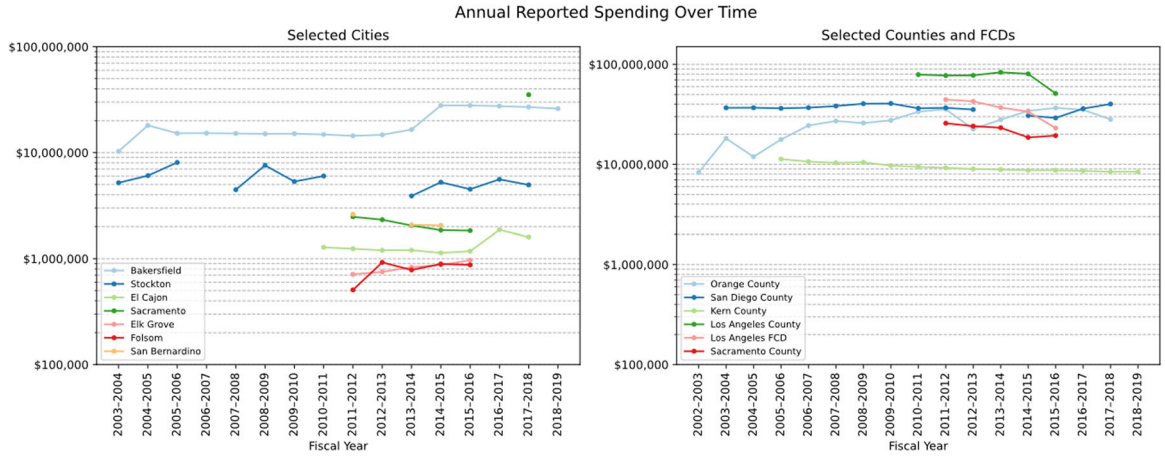

Fig. 6 Annual spending over time (normalized to 2018 dollars) in selected cities and counties in California

Table 7 Average and total annual expenditures by category, normalized to 2018 dollars

Category	Average Annual Expenditures (standard deviation)	Total Annual Expenditures	Sample size
Capital Costs	$1.2 M (±$5.4 M)	$88 M	71
Public Education and Involvement	$0.4 M (±$3.3 M)	$56 M	140
Illicit Discharge	$0.23 M (±$0.98 M)	$26 M	114
Construction Site Controls	$0.25 M (±$0.63 M)	$16 M	62
Pollution Prevention	$1.8 M (±$4.6 M)	$270 M	155
Operations and Maintenance	$1.5 M (±$4.1 M)	$83 M	54
Post-Construction	$0.22 M (±$0.65 M)	$29 M	132
Water Quality Monitoring	$0.19 M (±$0.54 M)	$18 M	92
Industrial and Commercial	$0.13 M (±$0.4 M)	$15 M	114
Watershed/TMDL Collaboration	$0.47 M (±$1.6 M)	$18 M	38
Stormwater Program Management	$0.46 M (±$1.5 M)	$70 M	150
Unable to Decipher	$0.41 M (±$1.3 M)	$48 M	118

individual jurisdictions and is not standardized. Data is not aggregated into a central repository that standardizes all data and reports. The resolution of the data is highly variable. Some entities report lump sum stormwater spending amounts, while others provide a detailed breakdown of stormwater budgets and expenditures. Across reports that do include categorized stormwater cost data, activities are not consistent as each entity tended to formulate its own categorization framework. Some entities report only budgets or only expenditures for a single year, while others include many years of budget and expenditure data in each annual report. In some cases where multiple years of data were included in annual reports, inconsistencies across reports were evident, perhaps as a result of an entity correcting data in later reports. Additionally, many entities may not report capital investments as part of stormwater management programs.

Second, do observable spending trends emerge from aggregating, standardizing, and analyzing the data? Trends across regions and, for some areas, over time are identifiable by aggregating, standardizing, and analyzing existing data. From available data, per capita spending has remained constant over the past decade. Geographic differences were also evident, but trends could not be compared due to a lack of publicly-available reporting in some parts of the state. An efficient approach would centralize data reporting and collection, which could cut down the amount of time needed to aggregate data, identify broad trends in spending, and inform important questions of the sufficiency and effectiveness of expenditures.

Although a central repository would increase efficiency in aggregating and analyzing stormwater cost data, the issue of non-standardized reporting remains. For purposes of comparing trends, a key contribution of the study was to develop a rubric to standardize reported spending, which

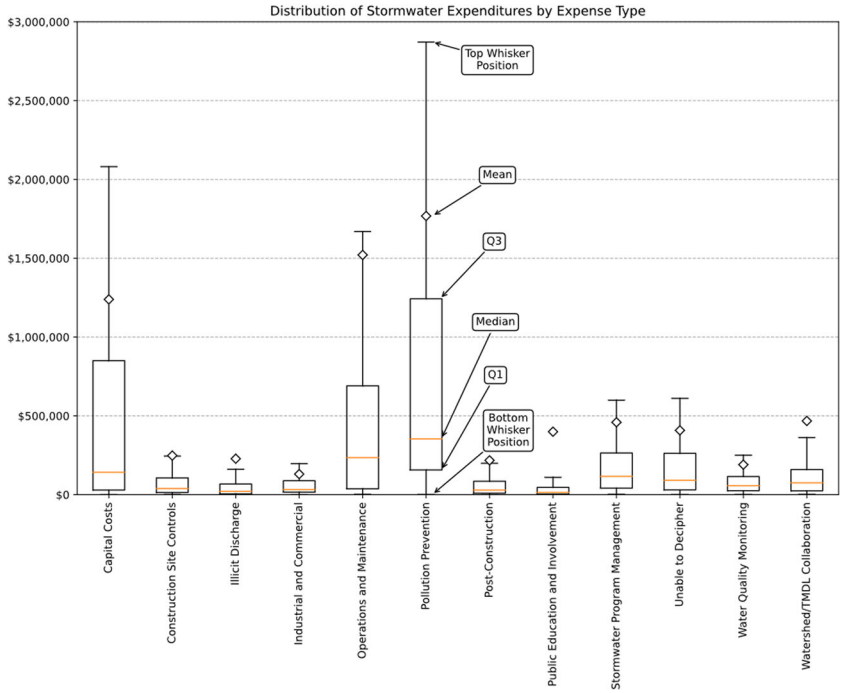

Fig. 7 Stormwater expenditures across reporting entities based on categories of expenses. Median values are represented by horizontal lines. Average values are represented by diamond markers. Outliers are not shown but were included in average value calculations. All values are normalized to 2018 dollars

can be used to compare values across jurisdictions and categories of activities. While this is a time-intensive endeavor, adopting standardized cost categories across agencies would allow for greater ease of tracking stormwater spending trends and potential areas of need. Such standardization may continue to evolve as MS4 permittees adopt guidance issued by regulatory agencies.

Recently in California, a proposed rubric for standardized cost reporting categories was established. In response to the recommendations made by the State Auditor in 2018, state regulators released guidance that intends to: (1) obtain adequate, consistent, and comparable information on stormwater management costs incurred by MS4 permittees so regulators can make informed decisions related to the costs of MS4 permit compliance; and (2) increase consistency and transparency for estimating TMDL implementation costs. Categories of relevant permit and TMDL compliance costs are included in the guidance (SWB 2019b, a). The categories include program management, minimum control measures, project spending (green and gray), monitoring, watershed management planning, alternative compliance plan development, reporting costs, and others. Guidance such as this may inform future reporting by municipalities and encourage use of standardized categorical framework for reporting costs.

Finally, are available data representative of municipal stormwater spending in California? The data can identify the types of activities that municipal stormwater programs undertake, but the approach did not yield sufficient data across all geographic regions to develop accurate statewide totals or compare spending over time and across locations. Instead, sufficient data was only available in some regions. Moreover, discrepancies in annual reported values of budgets and expenditures revealed some inconsistencies within and across reports. For instance, some entities reported categorized expenditures that did not add up to the total reported expenditures. Overall, total discrepancies between data sets are limited to less than 5%. The results of the analysis demonstrate both the usefulness and limitations of using existing reporting through a bottom-up, data accumulation approach.

A key goal of collecting, standardizing, tracking, and analyzing data on public expenditures is to evaluate the sufficiency of funding to meet regulatory requirements, legislative mandates, or social goals. For this task, available data on municipal stormwater spending was not adequate to evaluate the sufficiency of current spending towards meeting regulatory targets. Doing so would require matching program activities with water quality improvements (as indicated by monitoring data) to evaluate the effectiveness of individual program efforts and infrastructure investments.

Conclusions

The analysis validated the approach of collecting and standardizing annual budget and expenditure reporting for municipal stormwater programs as a way to estimate trends. A repeatable methodology was developed for classifying stormwater budget and expenditure data into standardized categories of activities, which can be used to create

replicable data and track trends over time. Based on the available data, total stormwater spending in California is at least $700 million (normalized to 2018 dollars). However, this total does not represent all spending due to limited publicly-reported data from California communities. The analysis identified that publicly-available documentation was not sufficient to estimate total spending through a bottom-up method or assess the level of sufficiency of current spending. Counties and flood control districts spend more per agency and provide significant contributions to stormwater spending, but cities reported more spending in total across the state. Spending by counties and flood control districts was often not differentiated between spending for regional or local needs, which limited the opportunity to compare normalized spending values (per capita and unit area) by cities versus counties. Spending reported by Southern California communities was higher than spending in other regions, possibly due to regional requirements.

The study identified several key areas for future research. First, future research can adapt the categorization rubric to extrapolate spending at larger geographic scales of states and regions. This would require additional analysis to consider population weighting and differences in local regulations.

Second, future research can better evaluate changes in total and per capita spending over time. While regulations continue to emphasize improved water quality, in areas that reported a long-term record of data, total MS4 spending did not change significantly. Recent per capita spending was similar to values reported previously (Currier et al. 2005). The sufficiency of these levels of funding could not be evaluated, but regulated municipalities have an interest in this task. For instance, on the goal of sufficient funding, the California Stormwater Quality Association (CASQA) has identified that the evaluation of approaches and tools for tracking costs is a top priority to support development of financial resources necessary for sustainable stormwater management (CASQA 2020).

Third, future research should help identify ways to connect categories of costs with municipal stormwater management program goals. Across the categories of spending, the largest percentage of spending is devoted to pollution prevention. Some of these costs, however, may include operations and maintenance activities that were not explicitly labeled as such, resulting in elevated representation of pollution prevention efforts and underestimation of O&M costs. Improved categorization of expenditures by municipalities would help to refine the estimates. Cost categories should tie with program objectives, which include permit compliance, drainage and flood control, watershed planning, and multi-benefit outcomes. Linking costs with objectives can help managers to prioritize investments. Overall, better standardization of municipal expenditure data can help answer key policy questions, such as evaluating the sufficiency of current funding to meet water quality, flood control, and multi-benefit goals.

Availability of Data and Material

All data are provided as supplemental data files to the text.

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Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

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