USING INDICATORS TO IMPROVE YOUR STORMWATER PROGRAM

Dan Cloak
Dan Cloak Environmental Consulting
Berkeley, CA
www.dancloak.com

ABSTRACT

Indicators are a useful tool for evaluating stormwater pollution prevention programs if they are applied in the context of continuous improvement and are framed by a conceptual model that illustrates causal relationships between stormwater pollution, the prevention program, and other factors affecting beneficial uses of water.

INTRODUCTION

Applications for NPDES Phase I stormwater permits require that the storm water management program include monitoring to estimate the reduction in pollutant loadings achieved[1]. NPDES Phase II permits allow a more general evaluation of progress toward program goals.

Leading up to and following promulgation of Phase I program requirements in 1990, stormwater programs focused on estimating pollutant loads. Typical estimates involved composite sampling of stormwater flows, analysis of pollutant concentrations, and hydrographic modeling of total volumes of flow, often on an annual basis. This methodology can provide a rough approximation of annual average pollutant loadings, but lacks the precision and statistical power to detect changes in concentration or loadings at the watershed scale. Therefore, although water-quality monitoring may be useful to assess the effectiveness of individual BMPs, or the application of BMPs at a specific site or within a small catchment, it is of less utility in evaluating the effectiveness of a municipal stormwater program as a whole.

Stormwater programs typically encounter, and may take responsibility for, the collection of water-quality and environmental data for other purposes. These purposes may include water-quality surveys for preparation of 305(b) reports, identification of site-specific pollutant problems, preparation of TMDLs, general assessments of stream ecosystem health, and stream restoration planning. Each of these purposes raises its own questions and hypotheses; successful application of the scientific method requires a separate experimental design tailored to each type of study.

A successful strategy to evaluate stormwater program effectiveness requires application of two principles. The first is a commitment to continuous improvement of the program. The second is a clearly stated understanding of the causes and effects the stormwater program is expected to address.

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[1] 40 CFR 122.26(d)(2)(v)

CONTINUOUS IMPROVEMENT

The National Research Council (1990) critically reviewed marine environmental monitoring programs. The resulting report emphasized, as its first recommendation, that environmental monitoring should be envisioned as a component of an environmental management system. Monitoring programs should be designed to assist decisions and facilitate remediation and restoration. Program designs should incorporate the synthesis, interpretation and reporting of environmental data.

The role of monitoring in environmental management is to “close the loop” of an iterative process. Continuous improvement, adaptive management, and environmental results management are variations on this same mechanism. The “loop” includes program planning, implementation, checking of results (monitoring), and changes to the program plan based on results. The environmental results management system loop (ERMS Initiative 2000) is illustrated in Figure 1.

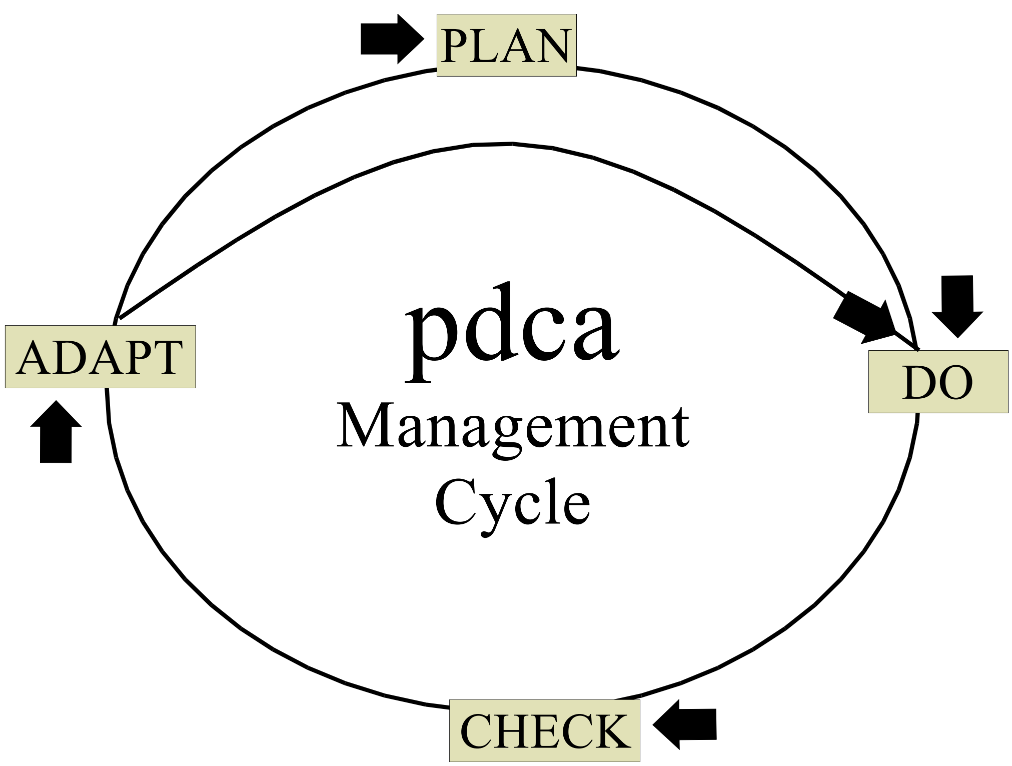

Figure 1. Environmental Results Management System pdca cycle.

The concept extends principles of quality assurance and quality control into the environmental arena. Continuous improvement is incorporated into the ISO 14000 series of standards for environmental management, similar to the ISO 9000 series of quality control standards.

CONCEPTUAL MODELS

Continuous improvement of a program is impossible, of course, without a clear fix on program objectives. The larger goal of the Clean Water Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters.[2] Section 402 (p) of the Clean Water Act amendments of 1987 mandates that permits for municipal separate storm sewer discharges (1) effectively prohibit non-stormwater discharges into the storm sewers; and (2) shall require controls to reduce the discharge of pollutants to the maximum extent practicable. 40 CFR 122.26 requires a management program that incorporates municipal activities, illicit discharge elimination, industrial inspections, planning procedures, and educational activities. Stormwater NPDES permits may specify best management practices (BMPs) and may also describe the extent of implementation that corresponds to "maximum extent practicable."

This creates a wide range of relevant outcomes that are candidate measures of "effectiveness." Should we measure the effectiveness of individual BMPs? The consistency or thoroughness with which BMPs are implemented? Whether a program has advanced all of the required components of its management program? Whether it complies with each provision of its NPDES permit?

Or should we measure reduction in the discharge of pollutants (which is difficult enough, and how can this be compared to "maximum extent practicable?"). Or whether the "chemical, physical, and biological integrity" of the receiving stream, lake, or estuary has actually been restored?

To clarify these questions – and to place the various measurements of program performance in context – it is useful to sketch a simple conceptual model of stormwater pollution (Figure 2). This conceptual model illustrates the assumptions implicit in the law and regulation:

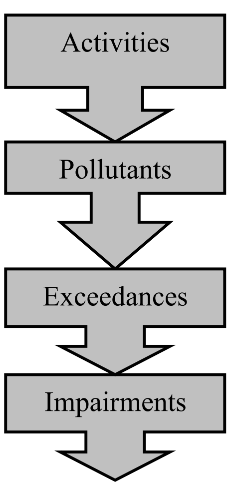

Figure 2. Conceptual Model of Stormwater Pollution

[2] USC Title 33, Chapter 26, Subchapter 1, Section 1251

In narrative form, this states that human activities in a watershed (e.g. a city) generate pollutants in runoff. These pollutants cause one or more water-quality criteria in the receiving water to be exceeded, thereby impairing the beneficial uses of that water.

Laws and regulations mandating stormwater pollution control imply the conceptual model of pollution prevention and control shown in Figure 3:

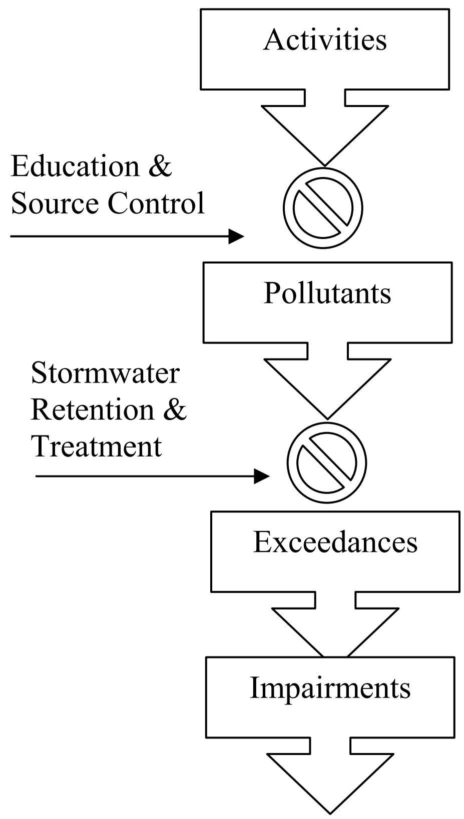

Figure 3. Conceptual Model of Stormwater Pollution Prevention

This expresses the idea that education and pollution prevention can reduce the quantity of pollutants produced by human activities in the watershed that reach runoff, and that treatment can remove some of the pollutants before they reach the receiving water and cause water-quality criteria to be exceeded.

This simple conceptual model helps us in two ways: First, by illustrating assumed causal links between activities, pollutants, pollution-prevention programs, and water quality, it suggests experiments and investigations might be needed to test those assumptions. Do education and BMPs really reduce the quantity of pollutants in runoff? Are stormwater pollutants really causing water quality criteria to be exceeded? If so, are the exceedances impairing beneficial uses? Are there other factors, such as flow diversions, "legacy" pollutants, loss of in-stream structure, or loss of riparian habitat, that may be at work?

Second, it suggests that there are many points at which a stormwater program can be monitored – some programmatically and directly (e.g., percentage of industrial facilities inspected last year) and some indirectly (e.g., what is the status of beneficial uses compared to three years ago?). The relevance of the measurement is related both to its comprehensiveness (i.e., how much of the "big picture" is captured in one measurement) and by the strength of the causal links.

OUTPUTS AND OUTCOMES

Each program component can be assessed by measuring outputs, outcomes, or both. An output indicates a level of investment or effort and is the most direct way to insure program accountability. An outcome measures the results of the program component, and can be affected by factors internal to the program (e.g., level of effort, degree of expertise or organization) and external factors (e.g., economic conditions, seasons, other programs that may complement or compete with stormwater programs). For example, the industrial inspection component of a stormwater program could be monitored for the number of inspections completed in a year, or the percentage of facilities in compliance, or both. An educational program could be monitored by expenditure on media buys, or by surveys that measure awareness, or both.

Using a conceptual model, and paying attention to whether outputs or outcomes are being measured, helps us interpret the results so that we can "close the loop" in our continuous improvement. Changes in outputs tell us the most about how the program is performing, and should be tied most closely to permit compliance. Changes in outcomes, on the other hand, may indicate changes in program performance – or may indicate changes in external conditions.

SELECTING INDICATORS

As we select indicators, we can anticipate two useful applications of indicator results: results may help us identify ways to improve our programs, and they may help us improve our understanding (our conceptual model) of the relationships between activities, pollutants, water quality, and beneficial uses.

Both applications are ultimately necessary for continuous improvement to work. Demonstrating that the program is being implemented (outputs) and that it is having a measurable effect (outcomes) isn't enough; it is also necessary to demonstrate that the outcomes are relevant to the beneficial uses that people care about.

For this latter purpose, it is helpful to think of indicators as building blocks toward a narrative that explains the stormwater program's purpose and relevance, builds support for its aims, and catalyzes action. For example, linking litter control and enforcement against illegal dumping (measured by litter picked up and citations issued) to clean up and restoration of a local recreational lake (measured by use, or by a survey of users) – can generate support for the program and (perhaps) result in a change in behaviors (measured by longer-term changes in litter picked up and citations issued).

STORMWATER INDICATOR RESOURCES

Under Clean Water Act Section 104(B)(3), USEPA funded a literature review and bibliography of resources for stormwater indicators. In a second phase of the project, the Center for Watershed Protection published *Environmental Indicators to Assess Stormwater Control Programs and Practices* (Claytor and Brown, 1996). That report includes "indicator profiles", or fact sheets, describing 26 stormwater environmental indicators.[3] The authors also outlined a methodology, and illustrated scenarios, for applying the indicators.

In a third phase, funded through the Water Environment Research Foundation and the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), twenty of the 26 indicators (Table 1) were tested at two scales: the 310-square-mile watershed of Coyote Creek (which includes the eastern portion of the City of San Jose) and a 28-acre industrial catchment along Walsh Avenue in the City of Santa Clara (Figure 4). The semi-arid climate is typical of California's coast from the San Francisco Bay area southward.

The results of this study (Cloak, et al., 2000, Cloak and Buchan 2001) illustrate the need to choose and apply indicators based on an understanding of the complex environmental factors at work – and the role of the stormwater program and other entities in addressing those factors. In the Coyote Creek watershed, the baseline was a 1979-1981 EPA-sponsored study that sought to identify the effects of urban runoff on water quality, sediment, fish, macroinvertebrates, attached algae, and rooted aquatic vegetation. In addition, SCVURPPP monitored stormwater constituents and toxicity in the creek 1987-1996. In 1999, investigators sampled fish and assessed physical habitat at 18 locations in Coyote Creek, sampled surficial sediment at six locations, and sampled benthic macroinvertebrates at nine locations. The project team analyzed flooding, changes to stream morphology, and sources of imperviousness in the surrounding watershed. The team also georeferenced reports of illegal dumping and known industrial and construction sites.

Eighteen of the Walsh Avenue catchment's 32 businesses participated in a 1992 pilot industrial stormwater pollution control study. Drainage from the catchment was sampled and analyzed for pollutants 1989-1996 and again in 1999. Investigators reviewed the City of Santa Clara's inspection records and conducted on-site interviews with managers of 29 of the 32 businesses.

Coyote Creek's physical habitat, stream geomorphology, and biological indicators are affected by reservoir releases, stream channel alterations, diverted flows, and a history of mining and grazing — all of which are typical for California streams, particularly those in urbanized areas. These factors have irreversibly altered the stream ecology.

[3] The indicator profiles can be viewed at www.stormwatercenter.net.

Fish assemblages in Coyote Creek were much the same as they had been since the construction of a major dam in 1950. However, analysis of fish and macroinvertebrate indices showed changes in reaches that have urbanized since the 1979-81 study. A 70-fold decrease in illicit connections reported 1993-1998 suggests the cities' surveys and monitoring have effectively

Table 1. Center for Watershed Protection Indicators Tested

Claytor and Brown Categories	#	Indicator Name	Walsh	Coyote	Program Area
Water Quality Indicators	1	Water quality pollutant constituent monitoring		√	
	2	Toxicity testing	√		
	3	Non-point source loadings	√		
	4	Exceedance frequencies of water quality standards		√	
	5	Sediment contamination		√	
	*6**	*Human health criteria*			
Physical and Hydrological Indicators	7	Stream widening/downcutting		√	
	8	Physical habitat monitoring		√	
	*9**	*Impacted dry weather flows*			
	10	Increased flooding frequency		√	
	11	Stream temperature monitoring		√	
Biological Indicators	12	Fish assemblage		√	
	13	Macro-invertebrate assemblage		√	
	*14**	*Single species indicator*			
	*15**	*Composite indicators*			
	*16**	*Other biological indicators*			
Social Indicators	17	Public attitude surveys			√
	18	Industrial/commercial pollution prevention	√		
	19	Public involvement and monitoring			√
	20	User perception			√
Programmatic Indicators	21	Number of illicit connections identified/corrected		√	
	22	Number of BMP's installed, inspected, and maintained	√		
	23	Permitting and compliance	√	√	
	24	Growth and development		√	
Site Indicators	*25**	*BMP performance monitoring*			
	26	Industrial site compliance monitoring	√		

** Claytor and Brown indicators which were not implemented as part of the Stormwater Environmental Indicators Demonstration Project.*

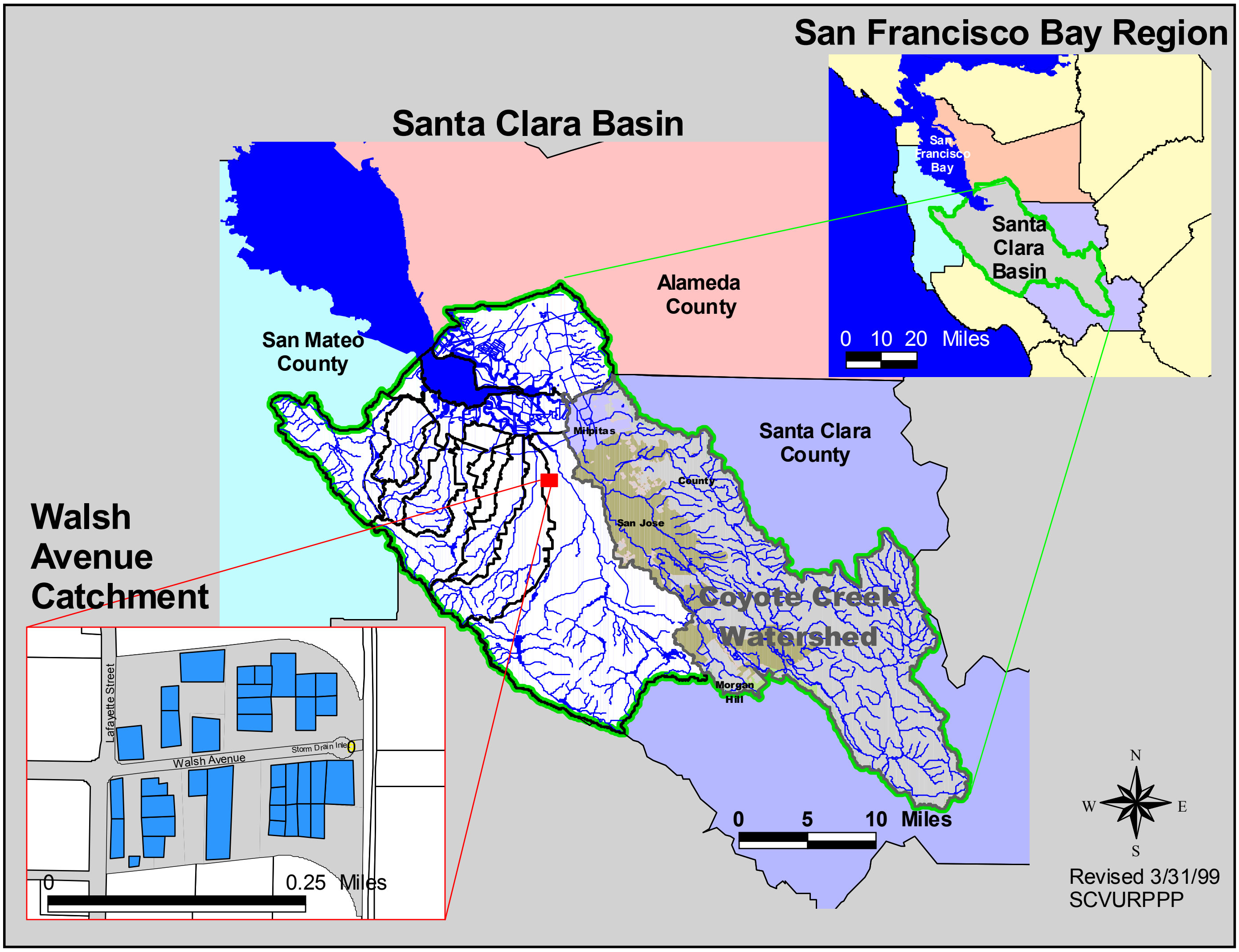

Figure 4. Stormwater Environmental Indicators Demonstration Project Area

eliminated illicit connections to storm drains. A 1993-1998 trend toward fewer illegal dumping reports (for most incident categories) suggest that the Co-permittees' outreach, industrial/commercial inspections, response to dumping incidents, and enforcement have had an effect. Increased staff and public awareness, and a construction boom, may have contributed to the rising number of reports for other categories.

Businesses in the Walsh Avenue catchment were implementing more BMPs in 1999 than in 1992, but investigators attributed this to the existence of other regulatory programs and generally heightened awareness, rather than the local urban runoff pollution prevention program's efforts. Nickel and lead concentrations apparently decreased, but toxicity due to high zinc concentrations was unchanged.

ROLE FOR INDICATORS

The Santa Clara Valley experience illustrates the need to apply indicators in the context of a comprehensive understanding of factors affecting streams and other water bodies and consensus on the role of the stormwater program.

To apply indicator results to continuous improvement, programs should have already documented the extent and means of their maintenance BMPs, industrial inspections, surveillance, and other activities and committed to a structured process for continuous improvement.

Indicators can also build, among watershed stakeholders, a common understanding of the interrelationships of urbanization, imperviousness, floodplain management, stream geomorphology, habitat functions, and water quality. This understanding requires that indicators be applied and interpreted in the context of conceptual models that describe the interrelationships and help guide further study and remedial action. Adaptive management, used increasingly to direct stream restoration projects, is a useful model for using conceptual models and indicators in a stakeholder-driven watershed management process.

SUMMARY

To successfully apply indicators to improve a stormwater pollution prevention program:

- Envision monitoring and assessment as a component of an environmental management system.
- Adopt and practice the principle of continuous improvement of the stormwater program.
- Document program BMPs and standard operating procedures as baseline for interpreting indicator results and identifying potential improvements.
- Diagram a conceptual model to facilitate understanding of causal relationships (and uncertainties in those relationships) among program activities, outcomes, and environmental variables.
- Measure both outputs and outcomes and interpret results accordingly.
- Strive to improve both the program and your understanding of its role among complex variables affecting the watershed.
- Select indicators that tell a story about the program and its role in the watershed.

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